Smart Innovation, Systems and Technologies 148

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Agents and Multi-agent Systems: Technologies and Applications 2019

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Preface

This volume contains the proceedings of the 13th KES Conference on Agent and Multi-agent Systems—Technologies and Applications (KES-AMSTA 2019) which will be held in St. Julian's, Malta, between 17 and 19 June 2019. The conference was organized by KES International, its focus group on agent and multi-agent systems and University of Zagreb, Faculty of Electrical Engineering and Computing. The KES-AMSTA conference is a subseries of the KES conference series.

Following the success of previous KES Conferences on Agent and Multi-agent Systems—Technologies and Applications, held in Gold Coast, Vilamoura, Puerto de la Cruz, Sorrento, Chania, Hue, Dubrovnik, Manchester, Gdynia, Uppsala, Incheon and Wroclaw, the conference featured the usual keynote talks, oral presentations and invited sessions closely aligned to its established themes.

KES-AMSTA is an international scientific conference for discussing and publishing innovative research in the field of agent and multi-agent systems and technologies applicable in the digital and knowledge economy. The aim of the conference is to provide an internationally respected forum for both the research and industrial communities on their latest work on innovative technologies and applications that is potentially disruptive to industries. Current topics of research in the field include technologies in the area of decision-making, big data analysis, Internet of things (IoT), business informatics, artificial intelligence, social systems, health, transportation systems and smart environments, etc. Special attention is paid on the feature topics: agent communication and architectures, modelling and simulation agents, agent negotiation and optimization, business informatics, intelligent agents and multi-agent systems.

The conference attracted a substantial number of researchers and practitioners from all over the world who submitted their papers for main track covering the methodologies of agent and multi-agent systems applicable in the smart environments and knowledge economy, and four invited sessions on specific topics within the field. Submissions came from 15 countries. Each paper was peer-reviewed by at least two members of the International Programme Committee and International

Reviewer Board. Thirty-one papers were selected for oral presentation and publication in the volume of the KES-AMSTA 2019 proceedings.

The Programme Committee defined the following main tracks: agent communication and architectures, and multi-agent systems. In addition to the main tracks of the conference, there were the following invited sessions: agents and MAS applied to well-being and health, business informatics, MAS in transportation systems and agent-based modelling and simulation.

Accepted and presented papers highlight new trends and challenges in agent and multi-agent research. We hope that these results will be of value to the research community working in the fields of artificial intelligence, collective computational intelligence, health, robotics, smart systems and, in particular, agent and multi-agent systems, technologies, tools and applications.

The Chairs' special thanks go to the following special session organizers: Dra. Maria del Rosario Baltazar Flores, Instituto Tecnologico de Leon, Mexico; Prof. Arnulfo Alanis Garza, Instituto Tecnológico de Tijuana, Mexico; Prof. Hiroshi Takahashi, Keio University, Japan; Prof. Setsuya Kurahashi, University of Tsukuba, Tokyo, Japan; Prof. Takao Terano, Tokyo Institute of Technology, Japan; and Dr. Mahdi Zargayouna, IFSTTAR, France, for their excellent work.

Thanks are due to the Programme Co-Chairs, all Programme and Reviewer Committee members and all the additional reviewers for their valuable efforts in the review process, which helped us to guarantee the highest quality of selected papers for the conference.

We cordially thank all authors for their valuable contributions and all of the other participants in this conference. The conference would not be possible without their support.

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Part I
Agent Communication and Architectures

Enforcing Social Semantic in FIPA-ACL Using SPIN

Kim Soon Gan, Patricia Anthony, Kim On Chin and Abdul Razak Hamdan

Abstract Agent technology is an emerging software paradigm for developing open, distributed and heterogeneous complex system. There is a need for different software to communicate with one another in order to achieve its task. Therefore, a standard protocol is required. In agent technology, this common protocol is referred to as agent communication language. Agent communication language is a high-level protocol/language that allows agent applications to exchange, parse and understand the meaning of the exchanged content. One of the widely adopted agent communications is FIPA-ACL. An ontology for FIPA-ACL has been developed in previous work. However, the developed ontology does not incorporate any semantic model. Hence, in this paper, SPIN notation is used to model the social semantic of FIPA-ACL as it is able to link the class definition with SPARQL queries to capture rules and constraints to formalize the expected behaviour of classes.

Keywords Agent communication language · FIPA-ACL · Social commitment · Semantic web · OWL · SPIN

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1 Introduction

Agent technology is an emerging software paradigm that provides agent abstraction for developing open, distributed and heterogeneous systems that match with today's Internet application environment [1]. The four main characteristics of agent are autonomy, proactive, reactive and social [2, 3]. Autonomy implies that an agent can execute the program and make decision without or with minimal user intervention. Agent exhibits a proactive behaviour in a goal-directed action based on their design objective. Agent reacts appropriately to environmental changes in a timely fashion. Agent is also able to communicate using high-level information such as mental state and plan instead of a simple low-level message passing [4]. There are other attributes of agent systems such as rational, learning, benevolence and others. However, these attributes are dependent on the application domain. Agent exhibiting these attributes is considered as a weaker notion of agency. Stronger notion of agency states that besides these attributes, an agent should be endowed with mental attitudes such as belief, desire and intention.

In order for the heterogeneous agents to communicate and understand each other, a standard communication medium is required. Agent communication language (ACL) is the standard communication medium that plays a vital role in multi-agent system interaction [5, 6]. There are two popular ACLs that are widely adopted which are the FIPA-ACL and Knowledge and Query Manipulate Language (KQML). KQML is the first ACL developed by DARPA through the knowledge sharing effort [7–9]. KQML adopted KIF as the de facto for content language and ontolingua as the ontology service [10, 11]. One of the unique features of KQML is the implementation of facilitator which acts as an agent mediator. FIPA-ACL is an ACL developed by FIPA which is a non-profit organization established to promote agent technology and increase interoperability between multi-agent system through devising sets of standard specification [12–14]. Although FIPA-ACL is similar to KQML, it is more popular than KQML due to the official body that governs the evolution of FIPA-ACL and the adoption of formal semantic in FIPA-ACL.

There are three main components that contribute to each ACL; these are the syntax, semantic and pragmatic. The syntax is the grammar rule used to parse the ACL for further processing. The semantic is the information processing to achieve the uniform understanding between the communicating agents. There are three semantic models adopted in ACL which are mentalistic approach, conversation policy and social semantic. The mentalistic approach is based on the mental attitudes such as belief, desire and intention. The conversation policy approach is based on the interaction rules list for each interaction to be carried out [15]. The social semantic is based on the social interaction between agents in terms of norm and commitments [16, 17]. The social semantic emphasizes the commitment from a debtor towards a creditor in promising or agreeing to complete on some tasks during the interaction. The social semantic is more popular because it reduces the limitation in mentalistic (unverifiable) and conversation policy model (complexity in combining rules). The third component of ACL is pragmatic, which is the ease of adoption of ACL in real-world environment.

Many techniques and methods have been used in order to achieve the interoperability of ACLs including conceptual structure and object constraint language. Another emerging trend is to use semantic web technologies. Semantic web (SW) encodes the web content as promoted by W3C [18]. The SW is an extension of the current web by encoding the web content with well-defined meaning that is machine processable [19]. A set of standards such as RDF [20], RDFS [21], OWL [22], SWRL [23] and SPIN [24] have been created to realize the semantic web. There is an increasing trend in applying semantic web into multi-agent system to increase automation, computation efficiency and enhance the communication of ACL. SW enables accessibility of the encoded knowledge and increases the utilization of the knowledge for computing. Therefore, representing the ACL with SW technologies enables the encoded knowledge to be exchangeable and processable between agents. In addition, this allows different agent applications to reuse existing knowledgebase in SW (such as DBpedia).

In previous work [25], a FIPA-ACL ontology was developed to enhance the interoperability between MAS. FIPA-ACL ontology encodes the knowledge and vocabulary required to utilize the FIPA-ACL as communication medium in MAS. This work will extend the FIPA-ACL ontology by incorporating SPIN notation in enforcing the FIPA-ACL social semantic integrity constraint. SPIN is an industry standard to represent SPARQL rules and constraints on semantic web models [26]. Therefore, it can be used to represent the rules and constraints to enforce the social semantic integrity constraints. Moreover, SPIN's object-oriented features made it possible to define reusable functions and templates. An example of a social semantic integrity constraint is assigning the different communicative acts to the sender and receiver of the message to take up the roles of debtor and creditor in a conversation. In this case, a debtor is committed to fulfil certain commitment towards the creditor. In this situation, SPIN can be used to represent this kind of rule which will be attached to different communicative act classes.

2 Related Work

In this section, some of the related works in ontology-based FIPA-ACL are reviewed to serve as the foundation and motivation of this research. This review is organized in chronological order to observe how the researches in this area have progressed over time. One of the earlier works by FIPA is on its specification to encode the content of the message in RDF encoding known as the FIPA RDF Content Language Specification [27]. This specification specifies how to represent objects, propositions and actions in RDF and in different RDF versions with different extensions. The motivation for encoding in RDF is to increase the level of interoperability. The advantages of RDF encoding include extensibility, reusability, simplicity and standards for data and schemas exchange. However, RDF is just a data format for encoding and exchange, and so its expressiveness is limited. For example, RDF is unable to specify the OWL constraints such as cardinality and the type of properties.

Another semantic web technology, DAML, has also been proposed to encode the ACL message [28]. The richer expressivity of DAML compared to RDF and RDFS enriched the content expressed in the ACL message. In this work, a DAML ontology is defined for communication between agents. A demo application of ITTalks project was used to illustrate the communication encoding in DAML. Unfortunately, DAML as a cornerstone of OWL did not gain momentum as semantic web technology. Zou continued his research effort in ACL using semantic web language as content language but this time he focused on OWL. Travel Agent Game in Agentcities (TAGA) is a FIPA-compliant framework that extended and enhanced Trading Agent Competition (TAC) scenario in Agentcities as an open MAS environment. OWL was used as the content language in FIPA-ACL messages for agents to communicate with each other and reason about the action and services. By utilizing the benefits of OWL, the content of the message can be more expressive, unambiguous, computer-interpretable, and interoperable, and has automated reasoning techniques, higher level of interoperability between agents and meaningful content can be shared [29, 30].

AgentOWL is another research that incorporated OWL as representation for agent internal model and communication [31]. It is a MAS-distributed framework that is built on top of JADE with a generic knowledge model for agent. Formal description of the model is represented using description logic. There are five main elements in the model including resources, actions, actors, context and events. AgentOWL used Jena semantic reasoner to reason the context, resource, action and knowledge domain of the agent and content of agent communication. CommonKADs is used to model and develop the MAS and the UML, and AUML modelling languages are used for modelling formalism. As a result, the agent knowledge model is more generic and expressive and can be easily adopted and used in other similar applications.

Pu used semantic web representation for negotiation protocol in electronic commerce [32]. Ontology was used to describe the negotiation protocol to increase the efficiency of the negotiation process. The negotiation protocol used in this research was the contract net protocol. The prototype demo was built on top of JADE and the reasoning used Jena API. This work was further extended using OWL for the agent communication process in a layered architecture.

Semantic agent model (SAM) used semantic web technologies in MAS modelling and knowledge base support [33]. In SAM, semantic web rule language (SWRL) was used in modelling the behaviour and constraints of different agents. A three-layered architecture was used to model the agents which was made up of a knowledge base layer, an engine layer and a low-level action layer. The different states of agent actions were modelled using extended FSM concept.

Fornara was one of the important key players in representing ACL social semantic model using obligation and norms [34, 35]. An obligation ontology was developed to model the obligation between debtor and creditor in temporal proposition. An external program was used to keep track of the temporal constraints in the temporal proposition to determine the different states of the obligations. Fornara and her team further extended the research to study the representation of policy and artificial institution [36, 37].

It can be observed that there are some ongoing works in ACLs. However, none of these has used SPIN in the modelling of FIPA-ACL. SPIN's ability to attach the SPARQL rules and constraints to class definition is suitable in enforcing social semantic integrity constraints to different classes of communicative act. Hence, in this research, the SPIN notation is used in the FIPA-ACL modelling.

3 SPIN

SPIN stands for SPARQL Inference Notation. SPARQL is the querying protocol and language used to query the RDF data. RDF is basic data format in the SW stack to encode information to facilitate information exchange and processing. SPIN is a de facto industry standard used to represent business rules and constraints in SPARQL RDF. SPIN is based on combination of object behaviour of object-oriented paradigm, query language and rule-based language. The key idea of SPIN is to link class definition with SPARQL queries to capture rules and constraints to formalize expected behaviour of classes. SPIN architecture is based on layering framework which consists of three layers. The first layer is the SPIN SPARQL syntax which is composed of RDF vocabulary for queries. The second layer is the SPIN Modelling Vocabulary which is composed of rules, constraints, function and templates. The third layer is the SPIN Standard Modules Library which is composed of different reusable modelling constructs of the function and templates mechanism. SPIN provides vocabulary for representing SPARQL queries using RDF triples. It provides a meta-modelling capability to define SPARQL functions and different templates. The main advantage of SPIN is its ability to store SPARQL queries together with the domain ontology model which can be easily shared on semantic web. It also allows referential integrity between ontology concepts and manages namespaces only once. SPIN implements constraints through spin: constraint property to link class with SPARQL queries formalizing invariant for class member. SPIN implements rule through spin: rule property to link class with SPARQL CONSTRUCT queries to define inferences for class member. Further, SPIN allows SPARQL function to be defined using spin: Function where the SPARQL queries are used in spin: Function body. SPIN function can modularize and extend SPARQL in a declarative manner and store it as RDF. The expressiveness of SPARQL is further extended through recursion. SPIN allows all the above queries to be stored in reusable form through spin: Template where it wraps SPARQL queries into reusable building blocks by instantiating them with arguments. This is done through industrial-strength RDF APIs implementation which runs directly on RDF data. SPIN enables the computation of property values from existing properties. It can initialize resource values with either a default value or compute values. It also allows set of rules being isolated to execute in different conditions. SPIN supports incremental reasoning where reasoning can take into account new assert information. These templates allow user to define rules in high-level domain. SPIN can be used to check the validity of data through constraint checking. The constraint checking operates with closed-world reasoning and automatically raise inconsistency flags. The templates for constraint checking are implemented using ASK and CONSTRUCT templates. ASK query can be used to return Boolean query results and CONSTRUCT query can be used to construct new RDF from the query result. SPIN also provides a list of common functions in a library. The different rules and constraints bound to FIPA-ACL ontology are discussed in the next section.

4 SPIN Rules for Agent Communication Languages

In this section, the SPIN rules and constraints are used in combination with FIPA-ACL ontology to enforce the social semantic integrity constraint. Different SPIN rules and constraints are linked to different classes of communicative act in the FIPA-ACL ontology. Besides, SPIN rules and functions are used to automate the social semantic for message exchanges between agents.

One of the rules attached to Message class is a rule to infer debtor and creditor agent of a commitment based on the sender and receiver of a particular communicative act type is shown in Fig. 1. The commitment object is based on the conversations between agents in order to assign the debtor and creditor. The rule will receive the argument of message communicative act. Hence, this rule will infer the commitment debtor and creditor based on the communicative act.

CONSTRUCT can also be used in spin: constraint to raise flag for inconsistency in the ontology. Another constraint that can be applied to Message class is to make sure that the sender and receiver agents of a message are two different agents. The rules in Fig. 1 will establish a commitment object between communicating agents, and the violation rule is used to enforce the constraint where the sender and receiver should not be the same.

SPIN operates on closed-world reasoning assumption; therefore, rules update to superclass will be inherited by the subclasses as well. The temporal proposition class which requires closed-world reasoning is to infer the temporal proposition status of undefined, true or false over temporal value. The rules shown in Fig. 2 are used to update the temporal proposition from undefined to IsTrue or IsFalse based on the event (such as message exchange event).

The commitment class which requires closed-world reasoning is to infer the commitment status of activated, cancelled, fulfilled, pending and violated, and the rules are shown in Fig. 3.

Besides that, rule can be used to infer the action actor as the debtor of the commitment because the debtor is the agent who obliged to bring about some state of affair or action relative to the creditor agent. The rule shown in Fig. 4 is to insert the agent's committed action to bring about some state of the world after the debtor has agreed to commit to certain commitment.

```
Message:
   CONSTRUCT  {?this          :hasCommitment         ?com .
               ?com           :hasCreditor           ?creditor .
               ?com           :hasDebtor             ?debtor . }
   WHERE      {?this          a                      :Message;
                              :hasCA                 ?ca .
               ?ca            a                      ?arg1 .
               ?this          :hasSender             ?creditor ;
                              :hasReceiver           ?debtor . }

   CONSTRUCT {_:violation     a                      spin:ConstraintViolation ;
                              spin:violationRoot     ?this ;
                              spin:violationPath     :hasReceiver ;
                              spin:violationValue    ?receiver ;
                              spin:violationLevel    spin:Error ;
                              rdfs:label             "sender and receiver
                                                      agent should not be the
                                                      same agent" }
   WHERE      {?this          :hasSender             ?sender .
               ?this          :hasReceiver           ?receiver .
               FILTER (?sender = ?receiver) . }
```

Fig. 1 SPIN rules and constraints attached to the Message class

```
IsTrue:
      DELETE        {?this        a               :Undefined . }
      INSERT        {?this        a               :IsTrue . }
      WHERE         {?this        :hasStart       ?tStart ;
                                  :hasEnd         ?tEnd .
                    FILTER (?arg1 > ?tStart and ?arg1 < ?tEnd) }
IsFalse:
      DELETE        {?this        a               :Undefined .
                    ?this         a               :IsTrue . }
      INSERT        {?this        a               :IsFalse . }
      WHERE         {?this        :hasEnd         ?tEnd .
                    FILTER (?arg1 > ?tEnd) }
TemporalProposition:
      spin:rule     {a                      spl:InferDefaultValue ;
                    spl:defaultValue        Undefined ;
                    spl:predicate           rdf:type }
```

Fig. 2 SPIN rules and constraints attached to the TemporalProposition class and its subclasses

Fig. 3 SPIN rules and constraints attached to the Commitment class and its subclasses

time	t=0	t=1	t=2
tpBuyBook	IsTrue		
c(buyer, seller, commitment)	undefined		
tpSellBook		IsTrue	
c(buyer, seller, commitment)		Activated	
tpDeliverBook			IsTrue
c(buyer, seller, commitment)			Fulfilled

```
Commitment:
   spin:rule      {a                          spl:InferDefaultValue ;
                   spl:defaultValue   Pending ;
                   spl:predicate              rdf:type   }
Activated:
   DELETE         {?this    a                           :Pending . }
   INSERT         {?this    a                           :Activated .}
   WHERE          {?msg     :hasCommitment              ?this ;
                            :hasContent                 ?tp1;
                            :hasCondition               ?tp2 .
                  ?tp1      a                           Undefined.
                  ?tp2      a                           IsTrue . }
Fulfilled:
   DELETE         {?this    a                           :Pending .
                    ?this   a                           :Active  }
   INSERT         {?this    a                           :Fulfill . }
   WHERE          {?msg     :hasCommitment              ?this ;
                            :hasContent                 ?tp1;
                            :hasCondition               ?tp2 .
                  ?tp1      a                           IsTrue .
                  ?tp2      a                           IsTrue . }
Violated:
   DELETE         {?this    a                           :Pending .
                   ?this    a                           :Active }
   INSERT         {?this    a                           :Violated . }
   WHERE          {?msg     :hasCommitment              ?this ;
                            :hasContent                 ?tp1;
                            :hasCondition               ?tp2 .
                  ?tp1      a                           IsFalse .
                  ?tp2      a                           IsTrue . }
```

Fig. 4 SPIN rules and constraints attached to the Action class

In the previous work, the FIPA-ACL ontology with required terms and vocabulary for FIPA-ACL communication was developed. However, the ontology does not include the required semantic model. In this work, SPIN is used to model the social semantic and enforce the social semantic through rules and constraints. SPIN is used in this work because of its ability to create rules and constraints that are linked to different OWL classes. Besides, reusable SPARQL functions can be created to automate the computing process of the queries.

A simple simulation of book buying and selling scenario implemented using JADE is used to verify the conformance of FIPA-ACL ontology and SPIN rules for

```
Action
        CONSTRUCT {   ?this     hasActor ?agent1 . }
        WHERE     {   ?tp       hasAction        ?this .
                      ?msg      hasContent       ?tp .
                      ?msg      hasCommitment    ?com
                      ?com      hasDebtor        ?agent1. }
```

Fig. 5 Verification steps for simple book buying and selling scenario

communication exchange. The verification is verified through the inspector agent to capture all the message exchanges between agents. The results showed that the FIPA-ACL ontology and SPIN rules react accordingly based on different contexts. Figure 5 shows a simple verification step.

5 Conclusion and Future Works

This paper illustrates the modelling using OWL and SPIN for FIPA-ACL ontologies which incorporates the notion of social semantic into FIPA-ACL ontologies. Using SPIN to model social semantic, it can automate the enforcement process through the constraints and rules to be applied to particular class due to the object-oriented characteristics of SPIN. Therefore, enforcing semantic constraint through rules, constraints and functions and attaching them to the class definition can prevent from any inconsistencies in the ontology. SPIN is different from SWRL in which it allows object-oriented modelling to link classes with different rules and constraints. It also allows for the creation of reusable functions that can be used in other queries which is difficult to implement in SWRL. Besides that, SPIN closed-world assumption reasoning feature does not require additional operator to reason in the open-world assumption of semantic web technologies. The next step is to test and verify the FIPA-ACL ontology together with the rules modelling in more complex scenario and verify the usability of the model. It is possible that FIPA-ACL ontology can then be further extended to incorporate different interaction protocol models. Besides that, these rules can be further enhanced with an evolved version of SPIN (SHACL) to incorporate newer features provided by SHACL.

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An Agent-Oriented Group Decision Architecture

Liang Xiao

Abstract Group decisions are useful and crucial across socio-technical contexts, but there is a lack of generic, systematic, and comprehensive architecture that can support decision-making practically. In this paper, we propose an agent-oriented group decision architecture. It provides separate but unified representation formalisms for both global interaction protocols and local decision rules. An accompanied runtime coordination mechanism is offered, as well as an engine for agent interpretation of global and local levels of interactions towards decision-making. The architecture is general enough for group decision-making across disciplines.

Keywords Agent · Group decision-making · Protocol · Rule

1 Introduction

Group decision-making has become increasingly important. Its applications ranging from everyday organizational decisions to retailers' sourcing decisions for products provided by alternative vendors or pricing decisions for products selling to potential customers [1, 2], as well as life-critical clinical decisions for patients among a group of specialists [3, 4]. In making a group decision, multiple parties with complementary data, knowledge, capabilities, experience, and preferences are brought together, to solve a complex problem or reach a joint decision that is beyond each individual's power. Due to the increased availability of data and knowledge but decreased time to spend on the investigation, the heightened requirements of accuracy and efficiency but shortened deadlines, the augmented frequency of decisions but limited resources, providing decision support and improving decision quality is vital. Traditionally, group decisions involve social interactions and require everyone to be at the same place and at the same time in the real world. This becomes increasingly unsuitable and inconvenient in modern time due to the nature of distributed sites

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of expertise, distributed resources available to decision-making, and more and more regular decision demands. Even worse, good local decisions together sometimes turn out to be not good enough globally, and coordination among a group can be difficult. It would be much desirable, in various socio-technical contexts, to coordinate geographically spanned decision makers wherever they are, whenever decision needs emerge, and yield the most optimum decision outcomes possible. Better still, they are grouped opportunistically, and decision support is provided in a user-friendly manner. These raise some considerable challenges.

For these reasons, we believe a well-defined software architecture shall be in place to support group decision-making systematically. Here, we are interested in the design of an architecture characterized by supporting *fully distributed and open*, *highly interactive and heterogeneous*, and *semi-intelligent* group decisions. First, geographically distributed decision makers can, at their own wills, be joined together in such an architecture. Wherever necessary, they can be put flexibly into different groups to solve different decision problems. Second, the fact that the decision support architecture runs across multiple sites shall be transparent to human decision makers. Their decision processes can be guided by local interactive interfaces, in a stepwise manner. This is via integration of decision support into their routine working environment, no matter it is a desktop, a web, or a mobile application. Third and finally, as the decision processes unfold, data and knowledge currently relevant to a decision can be available to the decision makers as well as required from them. Decision options can be ranked, and prompted for their consideration at the very point that a decision is to be made. The underlying architecture shall by no means commit decisions in a fully automatic or intelligent manner without human intervention, as decision outcomes often have social impact. Therefore, the aimed group decision architecture shall address three prominent issues:

(1) The **organization of individual decision makers** across geographically distributed sites, **and their dynamic coordination** at group decision runtime.
(2) The **provision of interactive interfaces to decision makers** as automatic as possible.
(3) The **collection and presentation of data and knowledge relevant to each decision**, leading to decision option ranking and user commitment.

We propose an agent-oriented architecture in order to address the above issues. *Agents* are computational entities with general features of autonomy, concurrency, decentralization, proactiveness, social-ability and flexibility [5]. They are also endowed with human-like mental and cognitive characteristics such as belief, goal, plan, commitment, and so on. Among the Agent-Oriented Software Engineering (AOSE) methodologies, BDI [6] is useful for modeling beliefs and goals, Gaia [7] and FIPA AUML modeling agent roles and interactions, Tropos [8] and *i** [9] modeling goals, plans, dependencies, and establishing interdependency among agent actors, and KAOS [10] decomposing goals into responsibilities, capabilities, or constraints for direct assignment to agents. In fact, the autonomy and decentralization features make agents very suitable for distributed computing. The mental and cognitive characteristics make them very suitable for decision-making. The social-ability feature suggests agents are cooperative and best grouped together, often termed as *Multi-Agent Systems* (MASs), rather than run as standalone entities. Moreover, the flexibility feature suggests they can remain useful in a ever-changing environment. Altogether, it would be very promising to apply agents for group decision-making in a distributed environment. In an agent paradigm, participant decision sites can maintain their own decision-logic and autonomy, and agents can be distributed among these places. The agents may, on behalf of their representative decision makers, be responsible for tasks such as receiving decision requests, retrieving required decision data, interpreting available decision knowledge, presenting decision options, requesting decision commitments, and forwarding decision results to other participants. The agents can interact with humans at local sites and with each other across sites, achieving decision goals eventually.

We will present, in this architecture, the use of interaction protocols to govern agent interactions toward global decision goals, and rules govern human–agent interactions towards local decision tasks. A unified language is used to describe interactions at both global and local levels. An engine is designed for agent interpretation of the description and generation of decision interfaces. A Coordinator Agent is responsible for the distribution and coordination of protocols, and monitoring group decision processes to alleviate contingencies at runtime. The remainder of the paper is structured as follows. The background information and related works are described in Sect. 2. The details about the design of the architecture are presented in Sect. 3. The conclusions are drawn in Sect. 4.

2 Background

Group decision support systems (GDSSs) have been first studied in [11, 12] as information exchange platforms to enable groups with joint responsibilities, e.g., committees, review panels, executive boards, to pursue their decision paths. Later, Web-based GDSSs have emerged and some emphases have been given on reaching consensus among group members, even in physically dispersed locations [13]. More recently, agent technology has been applied to GDSSs. A common design is that agents are delegated to decision makers and make decisions on their behalf. For example, a context-aware and emotion-based model [14] has been built for the design of agents. In [15], agents are modeled by a set of behavioral styles and represent decision makers in achieving their own goals or following those of others within a group setting. A decision-making algorithm toward task allocation is suggested in [16] for agents to consider whether or not to take new tasks while they take care of current tasks, aiming at maximizing organizational benefits. Elsewhere, an agent-oriented architecture is proposed for dynamic solving of operational decisions in Home Health Care (HHC) [17], whereas caregiver assignment to patients becomes a centralized decision, and caregiver routings become local decisions with four local decision rules defined for selection.

Many agent-oriented decision support architectures emphasize the design of different agent types and their interactions. MADSS [18] proposes a decision support pyramid, and agents are grouped from below to the top of the pyramid according to the decision-making phases. These are the "intelligent group" that gathers information from all kinds of sources, the "design group" that submit proposals and support analysis, and finally, the "choice group" that critique positive or negative. Relevant data and knowledge passes across agent groups and this indicates the transition of decision phases. In FELINE [5], agents maintain an environment model about the skills and interests of themselves and others. They solve a problem together via performing a recursive descent of an inference network about hypotheses associated with the goal. The leaf nodes of the inference network are either questions of interest to be asked to the user or hypotheses to be requested to the agents, being listed as possessing corresponding skills in the environment model.

MADSS and FELINE, as well as others, represent a kind of approaches that employ many intelligent agents. Difficult problems may be solved in a computationally automatic manner, though the way of communicating tentative results may need to be exploited at runtime. Such approaches often do not model human–agent interaction processes at all or even they do, these are not modeled explicitly as an integrated part of the decision processes that lead to optimum outcomes. An opportunity is missed to combine intelligence from both parties. Also, the omission of this important part of design hinders their architectures from direct application in a wider scope of usage scenarios. Very limited works exist so far in modeling interactions of multiple agents to support multiple humans.

3 The Design of an Agent-Oriented Group Decision Support Architecture

Unlike many previous attempts of applying agents to solve complex but concrete decision problems, we wish to propose a general architecture to support as many kinds of group decision problems as possible. This implies two major concerns of the architecture: (1) the design of a general description for agent interactions and human–agent interactions toward group decision-making, and (2) the design of a general way for their interpretation and coordination. These represent the knowledge and computational perspectives of the design, and will lay the foundation of this architecture. Each perspective of the design has a global and a local level of consideration. A group's organizational structure and its coordination are important, since any group decision must be made in a physical organization or a temporarily arranged organization. Next comes further consideration of the modeling and execution of individual decision tasks via human interactions.

(1) In the knowledge perspective, interaction protocols are used to govern the global organizational structure embodied by agent interactions, and decision rules govern local decisions embodied by human–agent interactions. As our agent-

oriented group decision architecture must comply with human organizational structure, this means that each agent, like a human being, can only be aware of its own portion of an interaction protocol: *what* agents it needs to interact, *what* incoming message it expects, and *what* outcome message it generates. In comparison, decision rules determine *how* these happen for the agent, in dealing with a decision request and generating a decision outcome in the context of human interventions.

(2) In the computational perspective, a dedicated Coordinator Agent is responsible for protocol distribution and runtime coordination among the group. In contrast, participant agents are responsible for executing their protocol parts along with decision rules. The separation of protocol distribution and coordination from the actual execution suits a distributed running environment well. The clear separation of coordination and computation for each participant agent relieves them from coordination burden and enables them to concentrate on the more important decision responsibility, while the overall coordination responsibility is put upon a dedicated one. This also demands the design of two very different kinds of agent engines rather than one, as often seen in a centralized knowledge execution environment.

3.1 The Design Overview

Our agent-oriented group decision architecture includes a number of components as follows. A multi-agent system runs across the group decision sites. A repository holds protocols and rules as well as the latest version of an agent engine. A Coordinator Agent at a dedicated site distributes the protocol parts whereas group decisions are required, and it also coordinates the overall decision processes at runtime. The agents sitting at the participant sites can each download a copy of the engine to interpret protocol parts and rules. This helps them to guide local decision-making via interactive interfaces. Figure 1 shows a high-level overview and how it works in ten steps, and Table 1 lists their details.

At design time, protocols and rules can be specified by domain experts, and stored in a central repository server (C1) as shown in Fig. 1. The latest version of an engine and other elements are also deployed in C1. At runtime, each participant agent downloads an engine (Step 1) to support a local decision maker in her decision process via interaction. A delegated Coordinator Agent is situated within a second central server (C2). It is responsible for downloading protocols and distributing their parts, the coordination of results following local execution, and performance and contingency management for the overall processes (Steps 2, 3, and 10). The Coordinator Agent must be instructed by a human coordinator to initialize a group decision process, but no human intervention is necessary afterward. A single human coordinator is sufficient in the architecture and this can also be the first decision maker. In each running instance of a protocol, she can choose particular Message Data Templates and Constraint Service Templates (Step 4). Across sites, local agents

Table 1 A group decision process in ten steps, marked 1–10 in Fig. 1

Steps of a group decision process	Description
1. Download engine	Local agents download the latest version of an engine from the Engine Server (C1)
2. Download a protocol to run	A Coordinator Agent downloads a protocol, as instructed by a human coordinator, to run across sites
3. Distribute protocol parts	The Coordinator Agent decomposes the protocol into parts, and distributes them to appropriate agents
4. Choose constraint service and message data from available templates	A human coordinator chooses constraint service and message data from available templates for this running instance of the protocol
5. Bind the agreed service & data templates	Local agents bind the agreed service & data templates for use
6. Choose decision rules as currently required	Local decision makers choose decision rules as currently required. Different decision rules may be available for the same protocol but suitable in different conditions
7. Collect and present relevant data and knowledge	The agent's engine parses the received protocol and rules, and interacts with local decision maker toward ***(a)*** *the collection and presentation of data and knowledge relevant to each decision*
8. Execute protocol and rules for local decision-making via interactive interfaces	The agent's engine proceeds to use the collected data and knowledge to rank decision options, make recommendations, and wait for user commitment, together with a process of the ***(b)*** *provision of interactive interfaces to decision makers*
9. Forward decision outcome according to the protocol, under global coordination	Upon the receipt of a decision commitment, the agent forwards it and other useful information to the next agent in the protocol, as well as the Coordinator Agent. This is an iterative process and with previous steps, together with supports the ***(c)*** *organization of individual decision makers and their dynamic coordination*
10. Performance and contingency management	The Coordinator Agent keeps performance records, and this helps with group decision quality improvement via continuous monitoring and intervention

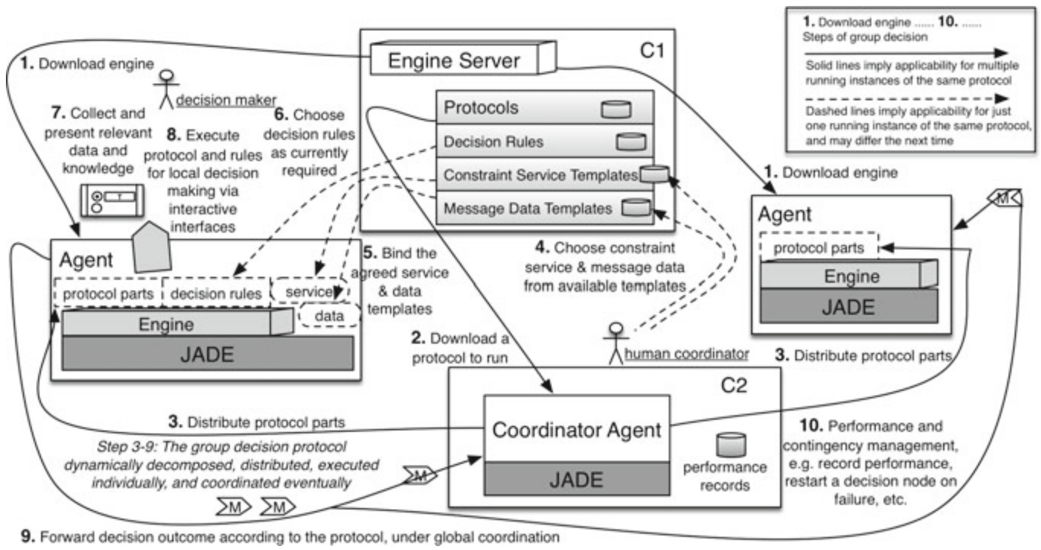

Fig. 1 An overview of the agent-oriented group decision architecture

will bind these application-specific data structures and computational services (Step 5). Each decision maker can choose preferable decision rules (Step 6) to attach locally. In this way, decision needs at both global and local levels can be accommodated.

In above, three issues raised in the Introduction section are addressed in Steps 7, 8, and 9, respectively, marked as (a), (b), and (c). First, our architecture makes use of protocols and rules to describe joint and individual decision behavior among an agent group. Each agent is delegated to a participant decision maker who is willing to join and interprets the decision knowledge to provide decision support at her own site. A Coordinator Agent coordinates them to achieve an ultimate group decision. This helps to address the issue of **organization of individual decision makers and their dynamic coordination**, and offers a *fully distributed and open* feature of the architecture. Second, an agent engine interprets protocol parts and rules to guide local decision-making via human–agent interaction. This helps to address the **provision of interactive interfaces to decision makers**, a *highly interactive and heterogeneous* feature of the architecture. Third and lastly, during local decision-making, the engine determines what information is required to run decision algorithms, the ranking of decision options, and presenting results for human approval. This helps to address the **collection and presentation of data and knowledge relevant to each decision**, a *semi-intelligent* feature of the architecture.

$Agent_i(iRule_i{:}Message(m_i)) \Rightarrow Agent_j\ (dRule_j) \leftarrow constraint\ (m_i.meets(p))$
then
$(Agent_{k1}(dRule_{k1}) \Leftarrow Agent_j\ (dRule_j{:}Message(m_j)) \leftarrow constraint\ (m_j.meets(q))$
or
$Agent_{k2}(dRule_{k2}) \Leftarrow Agent_j\ (dRule_j{:}Message(m_j)) \leftarrow constraint\ (m_j.meets(r)))$
then ……

Fig. 2 An interaction protocol specification for group decisions

3.2 An Interaction Protocol Specification for Describing Group Decisions

We aim at an architecture supporting *fully distributed and open*, *highly interactive and heterogeneous*, and *semi-intelligent* group decisions. The first and foremost component we shall design is a unified language for describing group decision behavior. An **interaction protocol**, or simply a protocol, specifies a group decision with message passing behavior among agents, focusing upon the *distributed and open* nature of group decisions. A **decision rule**, or simply a rule, has a decision-logic and requires certain data and knowledge to run, focusing upon the *intelligent* nature. A decision rule is often an **interactive decision rule**, given it involves a human–agent interaction, focusing upon the *interactive and heterogeneous* nature. Occasionally, a rule can have its decision automated by default user settings without human intervention. In even rare cases, a rule can be defined as an **interactive rule** without a decision part, being used at an initializing point of requesting group decisions or a finalizing point of presenting decision outcomes.

As opposed to being identified by roles or responsibilities as often seen elsewhere, agents in our design are associated with rules in a protocol specification. A protocol includes multiple clauses describing agent interactions and rule-based decision-making. Each clause declares a message passing between an agent pair. These clauses are connected by keywords of "then", "or", and others, determining the sequential, conditional and other relationships between them. The declaration of rules is present in clauses but the details about how such behavior might be achieved are hidden away in the next level of rule specification. Constraints may need to be judged prior to clauses carrying on, sometimes leading to the selection of decision branches.

An example protocol specification is shown in Fig. 2, and its syntax and semantics are as follows.

(1) "$Agent_i\ () \Rightarrow Agent_j\ ()$" or "$Agent_{k1}\ () \Leftarrow Agent_j\ ()$" denotes an agent passing a message to another. A message declaration needs to be specified in the parentheses of the sending agent side, and a rule declaration specified in the parentheses of the recipient agent side. Such a rule is declared to process the message and make a decision.

(2) *"$Agent_i(iRule_i)$"* or *"$Agent_j$ $(dRule_j)$"* denotes an agent applying an interactive rule or a decision rule.
(3) *"$iRule_i$: $Message(m_i)$"* denotes a rule generating a message.
(4) *"then"* denotes that a clause before it must proceed a clause after it.
(5) *"or"* denotes that alternative decision branches are available and only one should be chosen.
(6) *"$\leftarrow$ constraint()"* denotes that a constraint satisfaction function must be resolved as true for its associated clause to carry out.

In the example, the first clause denotes that $Agent_i$ uses an interactive rule of $iRule_i$ to generate a *Message* m_i and send it to $Agent_j$, given a constraint of $m_i.meets(p)$ is resolved as true or say, m_i meets a requirement of p. On receipt of the message, $Agent_j$ uses a decision rule of $dRule_j$ to process it. The messages only need to be specified on the sending sides, but rules on both sides. The first clause is followed by a keyword of "*then*" that determines the sequential order of message passing. What followed next is a composite clause, two subclauses being joined together by a keyword of "*or*". This implies that a decision needs to be made to select one or another to proceed. Between these two subclauses, a common part is that $Agent_j$ applying $dRule_j$ to generate another *Message* m_j, in response to its receipt of m_i. The difference is in the receiving parties and constraints: the message is sent to $Agent_{k1}$ given m_j meets a requirement of q, and sent to $Agent_{k2}$ given m_j meets a requirement of r. At the local level, $iRule_i$ involves human–agent interactions but no decision-making, while $dRule_j$ involves choosing a decision branch (justified by the nature of its generated message) but not necessarily a human interaction part. These are specified separately and independently from the protocol. At the global level, group decision goals can be achieved via a series of such interactions. The example protocol can be adapted, extended, or embedded into other protocols to represent more complex group decisions. The specification language is intuitive (as it focuses on overall decision processes), simple (as it benefits from the separation of global and local representations), but also general (as it can describe many decision scenarios).

In this design, constraint satisfaction functions are of significant importance, as they represent a key part of the solution to distributed group decisions. A distributed group decision or distributed problem-solving is often down to a distributed constraint satisfaction problem. Individual agents attempt to match values (or solutions) against variables (or subproblems) so that constraints between variables are satisfied, and these agents' combined local solutions (or decisions) fit together into a global solution (or group decision). A concrete application of the above example is that, only when Bob is motivated and qualified in his company's upcoming projects (constraint p) he will recommend himself to the general manager Mary so that he can get engaged, and Mary will direct Bob to one or another project manager while she decides where Bob's specialty fits in (constraint q or r). Another example is for the negotiation of the decomposition of a job between a pair of collaborators (the two clauses connected by "or" are merged into one): if you can do this part of the job, then I can do the other part of the job (constraint p and q/r represents the decomposed job parts).

3.3 A Coordination Mechanism for Group Decision-Making

Coordination is a key feature that distinguishes distributed decision-makings from centralized ones. In a distributed group decision process, it is essential to coordinate local decision processes as well as local decision results. As decision rules are chosen under local autonomy and their outcomes generated dynamically, global coordination must be in place so that a given interaction protocol yields meaningful results. Also, we have in our design no dedicated engine for direct protocol execution. Instead, a protocol is distributed among agents for executing their responsible parts. Our main solution to these issues lies in the design of a Coordinator Agent with protocol distribution, global coordination, and runtime monitoring capabilities. Actually, a primary design purpose of describing agent interactions as protocols is to use them as communication protocols. In any protocol specification, the clause joining keywords of "then", "or", and so on naturally serve as the splitting points for their decomposition into different portions. The sending and receiving parties in clauses are the ones to be assigned to and responsible for execution. This enables the Coordinator Agent to decompose and distribute a protocol straightforward. While each clause is executed locally, an agent passes its decision result to another agent, a similar process follows iteratively, and this makes cross-site result aggregation possible. In this process, each agent is responsible for its local decision-making, and the Coordinator Agent responsible for cross-site coordination and monitoring to ensure a protocol progresses smoothly.

It is shown in Fig. 3 a coordination process for our example protocol, as described in Fig. 2. The Coordinator Agent starts with sending an "*activate*" message, which grants a control token to the first active agent $Agent_i$. The message also includes the protocol parts this agent responsible for. Following the execution of the protocol parts (including human interaction), $Agent_i$ sends a m_i message to $Agent_j$, and later a "*complete*" message to release the control token back to the Coordinator Agent. The Coordinator Agent can then send an "activate" message to $Agent_j$, which chooses its interaction with either $Agent_{k1}$ or $Agent_{k1}$. In the above course, only one participant of the protocol can obtain the token during a certain period of time. This does not exclude the situation, however, that multiple agents are in active status simultaneously and execute protocol parts in parallel. Nevertheless, participants never request the control token proactively. It's the Coordinator Agent's responsibility for protocol distribution as well as failure detection. It can continuously check the time period between the "*activate*" message sent out point and the "*complete*" message expecting point, against a given threshold. It may also be necessary for agents to include key decision results in the "*complete*" message. In Fig. 3, it is useful to include in the "*complete*" message sent from $Agent_j$ to the Coordinator Agent the choice of $Agent_{k1}$ or $Agent_{k1}$. This lets the latter know the right one to be activated next and while a problem occurs, e.g., the following progress fails to proceed within a deadline, where it is raised and how to react.

Therefore, the Coordinator Agent's engine shall maintain a number of different protocol-related internal statuses and keep track of their changes. These include:

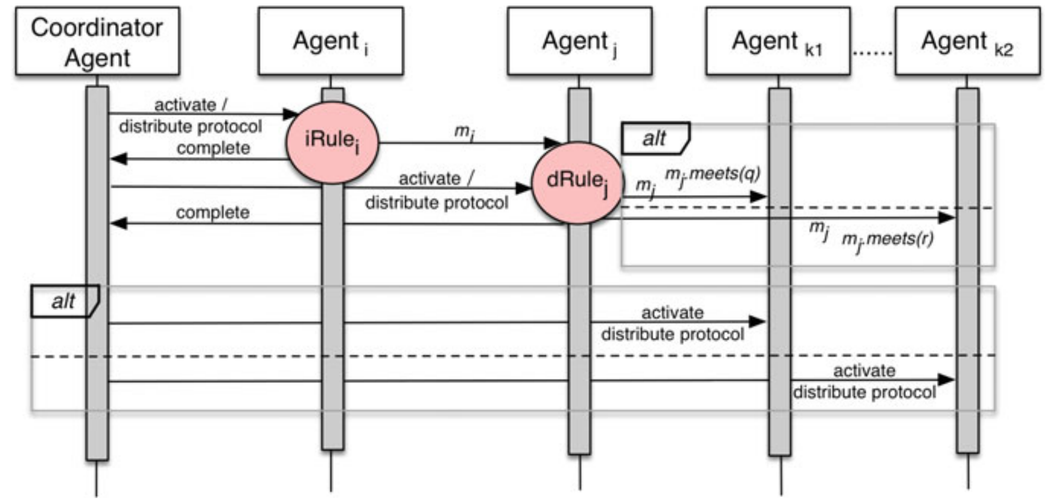

Fig. 3 The Coordinator Agent and its protocol coordination process

currently active agent and rule as well as the activation time point, the next agent to be activated as well as protocol parts to be assigned, the most recent message being sent and its time point, the next message expected to be sent and its deadline, a list of constraint satisfaction results, and finally the committed choices of alternative decision branches associated with the running protocol. At runtime, the Coordinator Agent monitors these global variables, has full knowledge of the progress of a protocol, and responds accordingly. These can help it with agent replacement or protocol recovery to ensure successful group decisions.

Although the Coordinator Agent can help to alleviate potential faults, its own failure is non-tolerable in the architecture. A simple solution is to group a number of replicated and distributed Coordinator Agent instances and interpose a front-end agent between the participant agents and the physical Coordinator Agents. This is transparent to participants and they simply treat the front-end agent as their Coordinator Agent. One or more replica responds to the front-end whereas there is a need for coordination, and each of them keeps replication of protocol-related variables simultaneously.

Further coordination between participant agents is concerned about resolving potential conflicts and generating successful decision results. Elsewhere, this often implies the need to resolve conflict of interests among agents, as they often represent different decision-making individuals, possibly from different organizations. We consider the agents engaged in group decision-making as cooperative and dependent one another. Nevertheless, there are still situations whereas participants progress through the assigned protocol parts but to a dead end, successful group decision outcomes being unavailable. As opposed to the usual need of altering the group decision structure, we may keep the high-level protocol structure intact, and just let local decision makers replace some rules with alternative ones to deal with the contingency. A previously given example is that a general manager Mary needs to decide on the assignment of Bob to one of the project managers. However, if Mary finds Bob's specialty fits in neither of the projects then a failure occurs and no one is happy. Rather than confronted with the failure or abandoned the overall group decision protocol, a new decision rule can be added for Mary that directs Bob to a training department for him to obtain the necessary skills desired by the company.

The example indicates the layered structure of protocols and rules appropriate for group decisions. Indeed, as long as the group decision structure is applicable to a given situation, each individual decision maker shall have the choices about how to achieve their local decisions. A diverse range of decision plans may be predefined for each type of local decisions and made available for dynamic configuration. The failure of one kind of combinations shall not invalidate the whole. This architecture provides an exact way for participants to explore the possibilities to reach the final group decision goal. The rationale is simple: if it is possible to address any contingency that may endanger the whole at a local level (rules), then saves the coordination effort at a global level (protocols). If the runtime environment encourages more intelligent agent design, they may even agree at an abstract level the global decision protocols, while re-plan continuously at a specific level, simply via dynamic rule selection and replacement. Whether it is done automatically by agents at runtime or specified by experts, the combination and recombination of rules supports dynamic agent coordination and guarantees fruitful group decision outcomes.

3.4 A Rule-Driven Local Decision Process and Its Interpretation

A decision rule guides a local decision process via human–agent interactions. Unlike many other approaches whereas human interaction models are either omitted or regarded as a second-class citizen, we consider them as an essential part of real-world decisions and a solution to address decisions in dynamic socio-technical contexts. Indeed, humans and agents have separate responsibilities and through interactions they together achieve decision goals: humans supply decision requirements and agents come up with decision knowledge, humans proceed with decision paths and agents prompt decision options in ranked order, humans commit their preferences and agents forward the results and coordinate towards a final decision. It is advantageous to model both human–agent interactions at local sites and agent interactions across sites in the architecture. This will enable a decision maker to employ an agent as an integrated part of her routine working environment, without any concern about group coordination via backend servers.

As we aim at a unified description language, no distinction is made between human–agent interactions via interfaces and agent–agent interactions via message passing. An agent's interaction behavior is described in a consistent formalism, no matter it is to recommend a decision option at a local site, or collaborate with a follow-up agent in a group. In this way, an engine can be designed with coherent interpretation functions for both kinds of interactions. It is shown in Fig. 4 that a

```
Agent_j (receiveProtocolPart) ⇐ CoordinatorAgent(protocol_parts) then                a)
 Agent_j (initialiseDecision: problem_context_description) ⇒ H_j () then
  Agent_j () ⇐ H_j (proceed_instruction) then
   H_j (decision_rule_choices) ⇒ C1 () then
    H_j () ⇐ C1 (available_decision_rules) then
     H_j (chosen_decision_rule) ⇒ Agent_j (bindRule) then                           b)
      Agent_j (processEventMsg) ⇐ Agent_i (Event_Message) then
       for (m=1, !all_data_prepared, m++)
        {Agent_j (prepareDataItems(ctlLogic):Q[Q_m1, Q_m2,… Q_mn]) ⇒ H_j () then
          Agent_j () ⇐ H_j (A[A_m1, A_m2,… A_mn]) then
           Agent_j (QA_context_description) ⇒ H_j () then
           check(chosen_decision_rule, dataitems, all_data_prepared)
        }                                                                            c)
     decision-logic(chosen_decision_rule, O[O_1, O_2,… O_n])
     processing(chosen_decision_rule, dataitems, O, W[W_1, W_2,… W_n])
     Agent_j (getUserCommitment: (O[O_1, O_2,… O_n], W[W_1, W_2,… W_n])) ⇒ H_j () then
     Agent_j () ⇐ H_j (commit(O_c)) then
     Agent_j (generateActionMsg: Action_Message) ⇒ Agent_k () then                   d)
     Agent_j (completeProtocolPart: completeMsg) ⇒ CoordinatorAgent()
```

Fig. 4 A human–agent interaction process towards local decision-making

series of human–agent interactions are unfolded, regarding $dRule_j$ as referred to in Fig. 2, in a similar structure with a protocol specification. In contrast with a pair of *Agent* symbols defined on both sides of message passing, an *H* symbol is introduced that often coupled with an *Agent* symbol. H_j denotes a human decision maker co-located with $Agent_j$. An engine function can help an agent in message generation: $Agent_j(Function(p1, p2, \ldots): m1, m2, \ldots)$, whereas the function can have parameters and the message have one or more composite parts. An agent may generate a message in a default setting without parameters, or apply a function without generating a message. Generally, "$A_j(Function) \Leftarrow H_j(Msg)$" or "$H_j(Msg) \Rightarrow A_j(Function)$" equally defines that an agent receives a message (or information) from a human decision maker and applies an engine function to deal with it. While a human decision maker receives a message: "$A_j(Msg) \Rightarrow H_j()$" or "$H_j() \Leftarrow A_j(Msg)$", an internal human mental process follows implicitly. A simple human–agent interaction can be represented as "$A_j(Msg1) \Rightarrow H_j()$ *then* $A_j(Function) \Leftarrow H_j(Msg2)$", and such can be combined flexibly. A set of agent engine functions (indicated in bold and italic) supports these interactions.

Although it is almost impossible to generalize a human–computer/agent interaction process towards decision-making, the above one is quite typical and representative. In particular, complex problems have already been decomposed among decision makers in our architecture, the resulting local decisions are often relatively simple, atomic, and focused, and the above process or its adaptation is often applicable in such situations. It includes three main composite parts.

(1) *Setting the context and goal*. The first part (line *a* to *b*) is responsible for receiving protocol parts and choosing a rule. This both sets a context about what problem is to be solved and how. Specifically to the example, the first three lines of the protocol specification in Fig. 2 are received from the Coordinator Agent. Thus, the local agent knows it shall process a message from $Agent_i$, and it needs to generate a message to send to either $Agent_{k1}$ or $Agent_{k2}$, via using a decision rule of $dRule_j$. The key engine functions here are ***receiveProtocolPart***, ***initialiseDecision***, and ***bindRule***.

(2) *Preparing the necessary data*. The second part (line *b* to *c*) is responsible for collecting the prerequisite data to run the decision rule via several rounds of human interactions. The process is triggered by an event message sent by its previous agent of $Agent_i$. The local agent guides the user in a stepwise manner, and in each step, the agent asks a set of context-dependent questions via dynamically generated interfaces. Upon the receipt of the answer set from the user, it has more knowledge about the problem domain and decides an appropriate decision branch. A further set of questions may be asked, until all data items to run the rule are collected. Likewise, one may define similar processes of data collection from third-party sources, if available and helpful. The key engine functions here are ***processEventMsg***, ***prepareDataItems***, and ***check***. In each round of data collection, *prepareDataItems* interprets the rule to understand what is the next group of data items in demand. Their types are mapped to the corresponding interface components for user fulfillment, i.e., a text field is generated for a String, a Calendar for a Date, radio buttons for a Boolean, and radio buttons or checkboxes for a single or multiple choices from a collection, and so on. The interface pages can thus be generated. An internal variable of *all_data_prepared* indicates whether to continue to the next round, its value being set via the *check* function which checks the collected data items against the decision rule.

(3) *Processing the rule and making a decision*. The third and last part (line *c* to *d*) is responsible for determining and ranking the decision options, and helping with human decision-making. Each decision option is assigned with a weight according to the data collected and the decision-logic. The user can then be recommended of these decision options, along with the raking result and possibly their pros and cons indicated by the data. Upon receiving a final user commitment, a message is generated and sent to the following agent in the protocol (line *d*). This completes the internal interaction and accomplishes the received parts of the protocol. The key engine functions here are ***decision-logic***, ***processing***, ***getUserCommitment***, and ***generateActionMsg***.

The last line (the line after *d*) is responsible for notifying the Coordinator Agent to facilitate coordination. The step-by-step interactive process leads to dynamic user interface generation and human–agent interaction. The described interactions are shown in Fig. 5, and the engine functions outlined in Table 2.

The development of an agent engine has two perspectives of concerns with regards to decision rule processing. The first is concerned about agent-side functions as listed

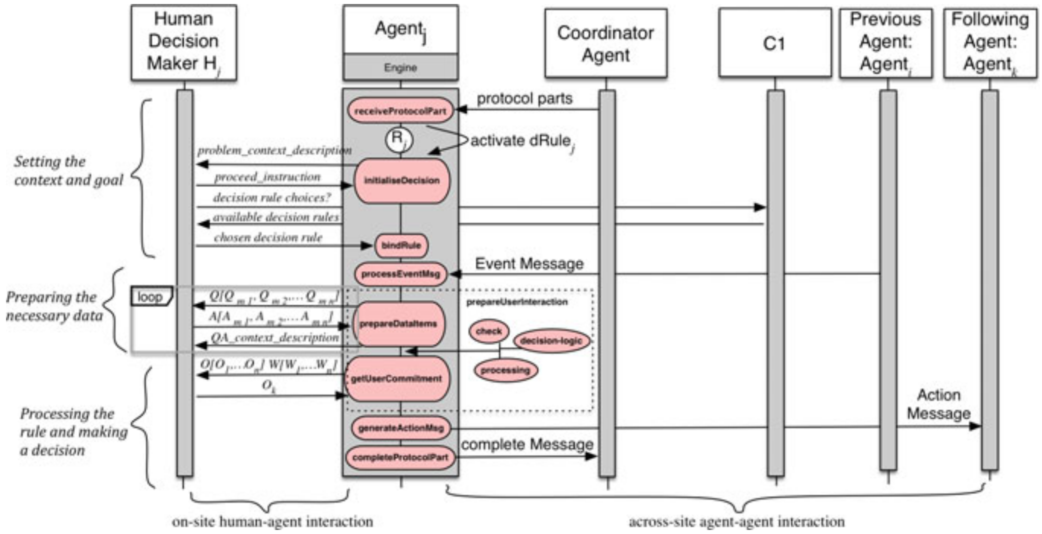

Fig. 5 A rule-driven local decision process and its human–agent interaction, making use of engine functions as outlined in Table 2

in Table 2. For example, the declaration of *check(chosen_decision_rule, dataitems, all_data_prepared)* indicates a function should be in place to help checking whether the acquired data items are the full set required to run the rule and if so, sets a Boolean true value to jump out of the data collection loop. The second is concerned about human interface generation and controlling logic. A number of human-side constructs are declared in Fig. 4, these constructs imply the need for human cognitive thinking and judgment, and some resulting values should be passed to the agent via interfaces. For example, H_j *(chosen_decision_rule)* or H_j *(commit(*O_c*))* implies a particular choice should be selected from several options, possibly via radio buttons, and H_j $(A[A_{m\,1}, A_{m\,2}, \ldots A_{m\,n}])$ implies a set of answers should be supplied, possibly filled in via text fields or chosen from checkboxes, whatsoever. Sometimes the two concerns are intertwined. For example, "$Agent_j$ *(prepareDataItems(ctlLogic):* $Q[Q_{m\,1}, Q_{m\,2}, \ldots Q_{m\,n}]) \Rightarrow H_j$ *() then* $Agent_j$ $() \Leftarrow H_j$ $(A[A_{m\,1}, A_{m\,2}, \ldots A_{m\,n}])$": the clauses in the loop indicates the engine should prepare an appropriate set of questions to present on interfaces in each round of data collection according to the rule, and expect a matching answer set, in an iterative manner.

4 Conclusions

In this paper, we propose an agent-oriented group decision support architecture. It supports distributed group decision-making via separate but unified representations of global interaction protocols and local decision rules, as well as a runtime coordination mechanism. An engine supports agents to interpret agent interactions among groups as well as human–agent interactions so that local decisions can be

Table 2 The engine functions and description (bold and italic items in Fig. 5)

Engine functions	Description of the functions
receiveProtocolPart	Receive a decomposed part of a protocol from the Coordinator Agent
initialiseDecision	Initialize a decision process, generate an interface page and present the contextual information to the user about the problem to solve, and wait for her to be ready
bindRule	Bind a user chosen rule for this session of protocol execution
processEventMsg	Process an incoming message and decode its contents
prepareUserInteraction	Provide a bunch of main user decision support functions, including five specific ones as follows
prepareDataItems	Guide the user in a stepwise manner and collect data items, under certain control logic. One screen of question set is presented following another, as well as acknowledgment about where she is in the decision process. The questions are dynamically generated via parsing the decision rule and determining the prerequisite data to run the rule
check	An agent's internal function: check if all data items are acquired to run the rule, and if so jump out of the loop of data collection
decision-logic	An agent's internal function: parse the decision rule and find out a list of decision options available
processing	An agent's internal function: process the decision rule with all data collected, assign weights to the decision options accordingly
getUserCommitment	Rank decision options by weights and recommend them to the user. A user commitment is expected afterward, which indicates the end of this human–agent interaction
generateActionMsg	Generate an outgoing message on the basis of user commitment, and send it to the following agent according to the protocol
completeProtocolPart	Notify the Coordinator Agent that this part of the protocol has been completed

guided. A Coordinator Agent decomposes and distributes protocols, and coordinates the group behavior at runtime. This architecture represents a top-down approach of formalizing protocols and rules, which need to be globally agreed or locally chosen, to drive group decision-making. This is in contrast with a bottom-up approach, whereas conflict of interests among group members needs to be resolved and plans revised continuously to meet overall decision goals. The art in AI is traded-off for a solid Software Engineering practice.

The architecture joins together an interaction and coordination model of agents, a representation of local decision-making, as well as human–agent interactions. Currently, there is a lack of modeling approach that puts all of them together into an integrated architecture towards group decisions. A wide range of works exists in modeling individual agents as personal assistants or advisers [5]. Also, a large group of works concentrates on modeling decision algorithms, e.g., treatment protocols that can guide prescribing [19], and rules that can encapsulate clinical guidelines and guide diagnosis [20]. Both areas of works are limited in their centralized nature of decision support or user interaction. Multi-agent interaction models exist in the literature largely in association with achieving goals, not necessarily decision goals. A notable one of them is the Lightweight Coordination Calculus (LCC) language, developed in the OpenKnowledge project [21–23]. LCC advocates explicit modeling and sharing of the knowledge about agent interactions. Its major advantage is that its declarative specifications can be transmitted and interpreted by agents dynamically when joining in interactions. The language is designed explicitly to separate the higher level knowledge sharing among an agent group (specified by knowledge engineers) from the lower level operation of individual agents (specified by software engineers). It has been applied, for example, successfully for describing a security protocol in clinical decision support [24], and a regional clinical data sharing protocol across organization or platform boundaries [25]. Although LCC includes no explicit model for user interactions, its extension of Lightweight Social Calculus (LSC) [26] has some complementary features. This language can provide a way to create social machines [27] that built upon existing social networks such as Twitter, and human interactions supported via formal role binding, protocol enactment, and result interpretation back to human society. As a result, existing infrastructures are reused, the cost of joining a formal interaction is gone, but computational intelligence provided to participants in a completely invisible manner. The language is well suited for the current trend of deep embedding of computation into society whereas the social framework also plays a key role, as only within it human efforts and expertise can be augmented by the automated systems [28]. However, in terms of group decision support, we feel strongly that employing a decision rule paradigm is advantageous in that it provides an independent layer of knowledge from global interaction models, and they can be dynamically configured into interactions to fit local decision needs. This can help to separate a designer's concerns, improve knowledge maintainability, and increase runtime flexibility. Nevertheless, this architecture especially protocol specification is closely related to the LCC/LSC languages which inspire some of our design.

As group decisions become useful and crucial across socio-technical contexts, we feel a strong motive for the communities of decision support, software engineering, knowledge engineering, artificial intelligence, among others to together advance the state of the art in designing a useful and practical group decision architecture that fits the modern world. Nowadays, group decision support systems are built in a great number, as knowledge accumulates in every discipline and lays a solid foundation. More than often, these are separated domain from the domain in terms of their underlying architectures. Research works are highly specialized and narrowed to one's own domain, e.g., clinical decision support in its long history is related to disseminating the best practice aligned with evidence-based medicine. A high level of variability exists even in the same area. Some systems are more useful than others in certain situations and for certain users, and things can be very different otherwise. There is, up to date, hardly a generic, systematic, and comprehensive architecture that can support the delivery of reliable decision outcomes across disciplines, and we hope this work contributes a common ground. More investigation may need to be carried out, but works so far indicate this architecture is quite promising.

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Context-Aware Service Orchestration in Smart Environments

Renato Soic, Marin Vukovic, Pavle Skocir and Gordan Jezic

Abstract With rapid technological advancements, smart systems have become an integral part of human environments. Capabilities of such systems are evolving constantly, resulting in broad areas of specific applications, ranging from personal to business and industrial use cases. This has encouraged the development of complex heterogeneous service ecosystems able to perform a wide variety of specific functionalities deployed on diverse physical nodes. Consequently, it has become a greater challenge to both maintain optimal resource utilization and achieve reliable management and orchestration of available services. For this purpose, we propose an agent-based system capable of orchestrating services on system nodes based on current context. This enables simplification of large-scale systems by introducing a generic set of services available to all nodes in the system, while service activation depends on environment state. The proposed solution provides flexibility in versatile environments typically encountered in domains such as smart homes and buildings, smart cities, and Industry 4.0. Additionally, it enables reduced consumption of resources on a given physical node. The described system is evaluated using a case study in the smart building environment, where it is shown how the proposed model can simplify the system and reduce resource utilization.

Keywords Software agents · Smart environments · Industry 4.0 · IoT · RFID · Context-awareness · Human–computer interaction · Service orchestration

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1 Introduction

Smart environments are evolving rapidly, becoming an important factor both in personal life and in the business world. Their domain of operation has become significantly broader, ranging from personal environments (e.g., smart home), buildings, over industrial facilities to entire cities. Goals and purposes of such smart systems have evolved accordingly, resulting in increased complexity. On physical level, they comprised of numerous devices present basically everywhere around us. Various sensors are collecting vast quantities of information, while miniature embedded computers enable execution of specific actions on different kinds of actuators along with efficient data processing and decision-making functionalities. Thus, such systems could be described as complex networks of devices communicating by different protocols in real time. Consequentially, both the quantity and variety of information collected from the physical environments have increased and are growing constantly [1]. Additional challenges can be found in real-time processing of large volumes of data, with the purpose of performing tasks like context resolution and decision-making. This has become more complex in distributed systems, because dislocated system components need to share information between themselves but also rely on global context. Management and orchestration of system functionalities have become a greater challenge due to increased capabilities of system components. Therefore, the goal has become to design systems which could autonomously operate in environments with complex infrastructure while handling numerous types of user requests [2].

In this paper, we propose an agent-based system capable of orchestrating node-level services based on current context of the specific node and the entire system. The purpose of the proposed system is to dynamically orchestrate services running on a specific node to provide automatic adaptation to changes in the environment. Changes can relate to different requirements in terms of node-specific functionalities, different conditions in the industrial or production plant, different user interface adaptation based on specific user preferences or disabilities, etc. This results in a state where specific node is running only the services; it truly needs at the given moment, thus providing better resource utilization. Furthermore, reducing the set of active services results in lower amount of total network traffic. Finally, security is improved due to the reduced attack surface [3].

The next section discusses current state-of-the-art regarding use of agents in industrial applications for service orchestration. Third section proposes a model for agent-based approach to service orchestration in smart environments. In order to present the functionalities of the model in real environment, section four discusses evaluation of the proposed model on an RFID-based presence tracking system in smart building. Finally, the paper is concluded in section five where guidelines for future work are provided.

2 Agent-Based Systems in Smart Environments

The fourth industrial revolution introduced new paradigms in design of manufacturing facilities. Centralized, monolithic approach has been replaced with a distributed one, with autonomous components representing interfaces to the physical world [4]. In industrial environments, this is typically reflected in machine having its virtual counterpart, which can be represented by the embedded computer monitoring and controlling the machine [5].

Modern industrial systems consist of various interconnected devices and systems, establishing transparent communication and data exchange between themselves. Such an approach has enabled recognition of various behavioral patterns. Combined with the ability to understand context, this has resulted in intelligent adaptation and optimization possibilities [6]. Agent-based approach has been proven convenient because it enables modeling of high-level cognitive processes making use of all the available information. This is achieved by employing various techniques inspired by social and biological processes. Integration of concepts like swarm intelligence, emergence, and self-organization has allowed the development of self-adaptive and evolvable complex systems [7]. These characteristics are typically related to cyber-physical systems, an approach which is focused on the integration of software applications with physical devices. In this approach, a system is designed as a network of interacting cyber and physical elements [8]. There have been successful real-life applications of multi-agent systems in industrial environments. The most notable examples in this context are two innovative projects which were applied in real industrial environments: European Innovation Project GRACE [9] and European Innovation Project ARUM [10].

Despite novel approaches, autonomy and intelligence achieved in industrial systems did not make human activities obsolete. Manufacturing processes still rely on human intervention in various terms. In smart environments, interaction between human and a computer system can be achieved using various communication channels. An example of a typical communication channel in industrial environments would be a computer terminal providing access to a graphical user interface. However, other common devices can be used for the same purpose—tablets, smartphones, speakers, lights, etc. Choosing the most convenient communication channel depends on parameters such as user's location and nearby devices, user's activity at the given moment, type of information which should be conveyed. User's context has the most important role in establishing interaction between the system and the user. Interaction capabilities of devices in the system are also a subject to change depending on the context [11].

For human users, the most natural and most efficient method of communication is speech. Capabilities and quality of service enabling spoken interaction between human user and a computer system depend on underlying fundamental components: speech synthesis (i.e., *text-to-speech*), speech recognition (i.e., *speech-to-text*), and natural language understanding. These components need to depend on the available context to provide better results. The interaction process needs to be performed in real time, which requires significant computing resources. Therefore, it is common for smart environments to rely on cloud platforms to provide all required functionalities related to spoken interaction, along with traditional functionalities such as data processing and storage [12]. Speech interfaces have been successfully integrated with smart environments, especially since intelligent personal assistants (IPAs) have been developed and successfully commercialized. IPAs are generally represented as an AI platform in the cloud, providing various advanced functionalities such as speech recognition and speech synthesis, natural language understanding, context resolution, decision-making, etc. Furthermore, they are designed to be quite easily integrated with other devices and systems like IoT platforms. This concept allows voice-driven interaction between human users and numerous interconnected devices and systems [13]. Regarding the smart industrial environments, spoken interaction between human workers and the production system has been recognized as one of the essential interaction methods in scope of intelligent user interfaces [14].

The examined related work shows that software agents are suitable for integration in complex industrial processes, especially with the purpose of orchestrating and monitoring the production processes. Model proposed in this paper aims at agent-based context-aware lifecycle management of node services.

3 Agent-Based Service Orchestration System for Smart Environments

Smart environment can be represented by a network of interconnected physical and virtual nodes, where each node relates to an arbitrary number of sensors and actuators or external systems. Each node represents the source of information collected from the given environment, available to the entire distributed system. This enables construction of rich global context, which is essential for advanced decision-making. Additionally, each node interacts with its environment and human users using various types of actuators.

In the proposed model, we identify two types of software entities present in the system: agents and services. Software agents represent high-level functionalities available in scope of the given smart environment. Services are “tools” used by software agents to shape intended functionalities. They usually perform specific tasks like providing access to physical devices or external systems. Ideally, every physical or virtual node should be able to communicate with all other nodes in the network. However, only a portion of information collected on a single node needs to be shared with other nodes. The main reason is to avoid flooding the system with unnecessary information. Additionally, in heterogeneous networks, not all nodes can process all types of information. Therefore, the flow of information needs to be filtered or constrained according to node capabilities. An example of such heterogeneous network is depicted in Fig. 1, with three physical nodes and one virtual node. Virtual node is a node typically operating in a virtualized environment such as cloud. A

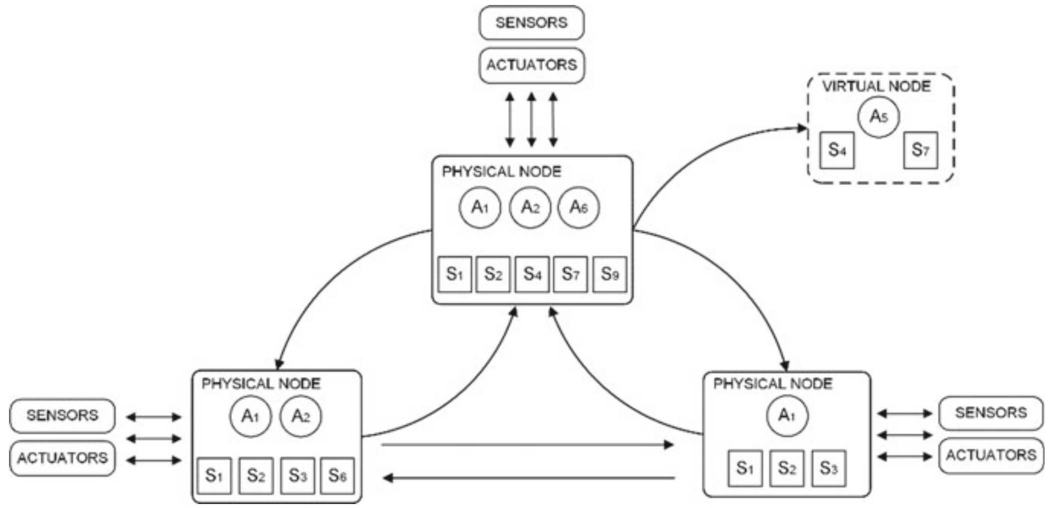

Fig. 1 A network of generic physical and virtual nodes, with different active service sets on each node managed by associated agents

formal description of the system needs to address the physical organization of the nodes in the network and logical decomposition of node capabilities represented by different service sets. N represents a network of physical nodes in the distributed multi-agent system:

$$N = \left\{N_1, N_2, N_{3_2}, \ldots, N_{\mathrm{n}}\right\} \tag{1}$$

C_n is a collection of agents consisting of an arbitrary number of stationary or mobile agents, thus corresponding to a multi-agent system. Associated agents can be distributed; deployed at the physical node or at the virtual node in the cloud that processes the data retrieved from the node and/or system. Each multi-agent system C_n is typically assigned to a single node or group of nodes with the same functionality and context in the network N. Each multi-agent system consists of agents which can be in enabled or disabled state:

$$C_{\mathrm{n}} = A_{\mathrm{e}}\, U\, A_{\mathrm{d}} \tag{2}$$

Here, A_{e} represents the set of enabled software agents which are actively performing their functions on the given node in the network, while A_{d} is a set of disabled, inactive agents:

$$A_{\mathrm{e}} = \{A_1,\ A_2, \ldots, A_{\mathrm{i}}\} \tag{3}$$

$$A_{\mathrm{d}} = \{A_i,\ A_{i+1}, \ldots, A_{\mathrm{j}}\} \tag{4}$$

Node-level functionalities can be represented with a set of services. These services typically perform predefined tasks, like collecting readings from sensors and external systems, or interfacing other physical equipment. They provide functionalities required for interaction with human users, as well. Each node in the network N is associated with a set of services:

$$S_{\mathrm{n}} = \{S_1,\ S_2,\ S_3, \ldots, S_{\mathrm{m}}\} \tag{5}$$

Like the software agents, the set of services on a given node consists of sets of enabled and disabled services, which correspond to enabled or disabled agents consuming them. Based on information collected from the sensors or the events occurring in the environment, services and corresponding agents can be required to change their state from enabled to disabled, and vice versa. This decision is made by the lifecycle management agent, which oversees enabling and disabling of other agents and services within the multi-agent system. The lifecycle management agent is therefore required to permanently be in the enabled state, associated with every node in the system within the corresponding multi-agent system responsible for the node functionalities. The decision whether a certain functionality should be enabled on the given physical node depends on node's input and output capabilities and the ability to perform in the given physical environment.

Input and output capabilities of a given node depend on physical location and presence of peripheral devices which can be used by human users for interaction with the system. These capabilities are enabled by specific services such as graphical user interface, speech recognition, speech synthesis, motion control, etc. Additionally, physical interaction is enabled by a set of simple, atomic services communicating with peripheral devices, thus providing interfaces to the physical environment. In complex interaction scenarios, there must also be a software agent involved, performing required cognitive tasks, such as contextualization. Based on conditions in the environment of a specific node, or certain global conditions, some functionalities may be considered inapplicable. Therefore, services and corresponding agents should not be enabled. Relevant conditions may be noise level, luminosity, temperature, etc. Certain conditions in the physical environment (e.g., noise) may negatively influence sensitive equipment or devices, making some functionalities unavailable.

The transition of a software agent from enabled to disabled state according to previously described criteria is decided by the lifecycle management agent, as shown in Fig. 2. The agent needs to deduce whether a specific service needs to be in enabled or disabled state. To achieve this, it relies on local and global context, and on specific constraints defined in scope of each other software agent. These constraints may be defined as a set of conditions required for the software agent to reliably perform its functionalities. Based on information available, the lifecycle management agent can decide to put another agent to disabled state. The lifecycle management agent can enable an alternative functionality (e.g., graphical user interface) based on the capabilities of the given node. Generic services do not need to provide such conditions or constraints regarding their performance. A generic service will be put to disabled

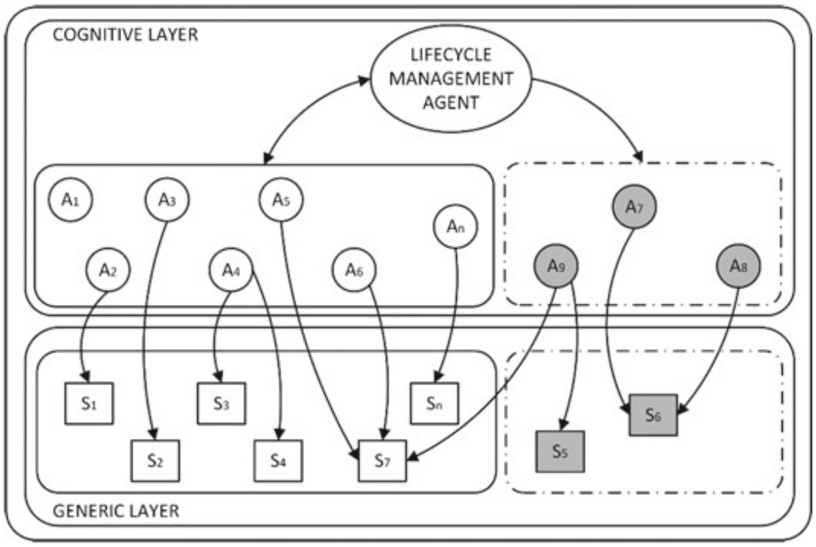

Fig. 2 Organization of the system node, with associations between agents and services

state if all its associated software agents are in disabled state. As stated previously, agent-based approach is convenient for modeling of complex cognitive processes and tasks. On the other hand, generic services are performing specific, predefined tasks. In the proposed model, this distinction is visible in a layered organization consisting of two layers: cognitive layer and generic layer.

As shown in Fig. 2, the cognitive layer consists of software agents which are performing diverse functionalities that typically employ advanced computing techniques. They are relying on services from the generic layer. These services perform generic and straightforward operations. They provide information about the physical environment by communicating with sensors and control physical devices. Additionally, they provide access to different resources available locally or remotely, in external systems such as cloud infrastructure. In the proposed model, each agent from the cognitive layer can be associated with an arbitrary set of services from the generic layer. Agents from the cognitive layer shape and constrain the service functionalities based on the current context.

4 Case Study: Service Orchestration in Smart Building Presence Tracking Environment

The proposed model was implemented and evaluated on a system for person and asset presence tracking. Persons and/or assets are identified by UHF (Ultra-High Frequency) RFID (Radio Frequency Identification) tags. Remote physical nodes in the system are implemented as RFID gates which are placed on every entrance to

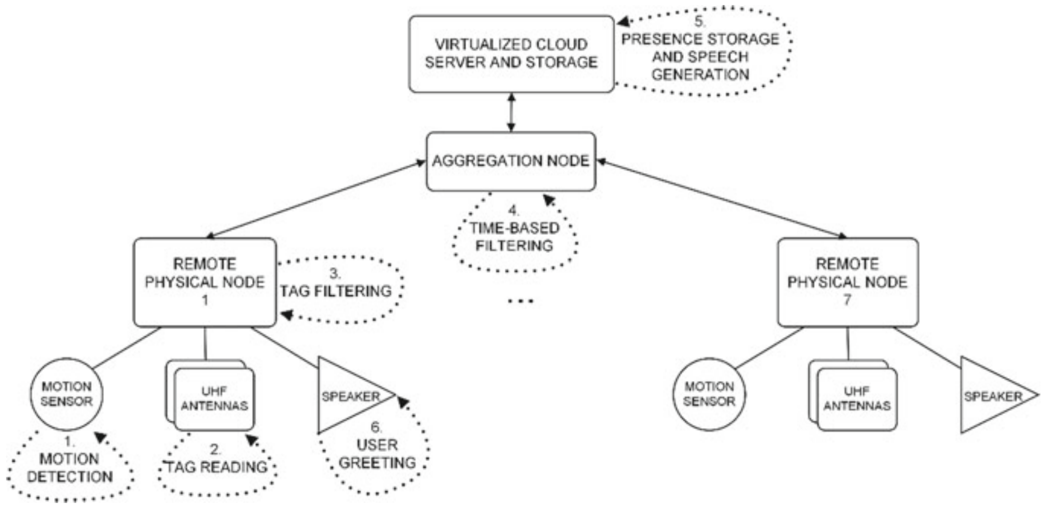

Fig. 3 Architecture of the system for asset and person presence tracking

the building. The system consists of remote physical nodes, aggregation node and a virtualized server in the cloud.

As illustrated in Fig. 3, remote nodes contain a pair of UHF antennas connected with a single RFID reader, a motion sensor, and a speaker for greeting users when necessary. When motion sensor is triggered, antennas are enabled and a tag is read. The reading is then sent to aggregation node, which performs tag filtering and controls the tag reading time interval. Tag filtering is required due to the possibility of registering nonsystem tags that could not be mapped to a person or asset within the system. Such tags are typically a leftover from the production process and can be found on virtually all items (e.g., clothing, bags, etc.). Besides filtering, aggregation node can send commands to remote nodes in order to prolong or stop the tag reading process. Finally, the filtered reading is sent to the cloud virtualized server which stores the received information and calculates whether the asset is moving in or out of the building based on previous tag readings. The cloud server also provides functionalities required for generating speech, which is used experimentally for greeting users if they are identified by corresponding tags.

In scope of the proposed model, it is interesting to perform the analysis of how context-aware service orchestration is applied to the proposed system. The most extreme case is Case 1, where no orchestration is present and services are running all the time. In Case 2, services are optimized using motion sensors and tag filtering. This way, tag reading will be started only if motion is detected on the remote node, thus preventing waste of resources, unnecessary processing, and communication between remote physical nodes and aggregation node. Once started, tag reading process is active for the duration of 10 s, which is a value used for experiments based on observed movement of people through the RFID gates. On the next level in the architecture, tag readings are filtered and only the system-specific tags are forwarded to the cloud server for storage and processing. This significantly reduces cloud server load and communication between aggregation node and cloud server.

Table 1 Comparison of specific service uptime values in described cases

	Case 1	Case 2		Case 3	
	Average uptime (h)	Average uptime (h)	Reduction to Case 1 (%)	Average uptime (h)	Reduction to Case 1 (%)
Remote node services					
Motion detection	8	8	0	8	0
Tag reading	8	2.78	65.3	0.28	96.5
Speaker	8	0.63	92.1	0.63	92.1
Aggregation node services					
Filtering	8	2.78	65.3	0.28	96.5
Reading interval control	0	2.78	/	0	0
Cloud services					
Storage and processing	8	0.53	93.4	0.53	93.4
Speech generation	8	0.72	91	0.72	91

Finally, we examine Case 3, where tag reading is performed in 1 s bursts according to motion sensor activation, rather than for 10 s as in Case 2. Evaluation results are presented in Table 1, where we examine uptime of various services on each system element. The evaluation was done on a sample system log for 8 working hours. The data consists of readings collected from 7 remote nodes, covering 369 persons and 94 assets in 1423 readings, where 1001 readings were filtered as system-specific tags.

The first major reduction in service uptime can be observed in Case 2, when motion sensor is used for activation of tag reading operation. This simple enhancement results in reduction of multiple physical node, aggregation node, and cloud server services' uptime for more than 10 times. Furthermore, using burst tag reading approach, we can obtain even more reduction for specific tag reading and filtering-related services. However, it was observed that using burst readings could also have negative effects on tag reading performance. The possible case is when two tags are traversing through the RFID gates one after another; the first tagged object triggers the motion sensor and tag reading, but the following tag is not read by the system since it is coming into the antenna range right after the initial burst is finished. In the examined dataset, approximately 30% of tag readings in Case 2 were read within 2 s time distance. This might prove to be a problem and will be addressed in future work. Without tag filtering on aggregation node, all 1423 readings would be sent for processing to the cloud server. With filtering, the cloud server received only 1001 requests for processing, which confirms the importance of filtering the readings very low in the system hierarchy in order to reduce load. Additional optimization could be achieved with tag filtering performed on node level, thus furtherly reducing the system load.

5 Conclusion and Future Work

Regardless of the operational domain, context-aware, intelligent systems require real-time insight into their physical environments and the ability to understand the available information. This enables the system to deduce important facts related to its own capabilities and use that knowledge to optimize performance and resource consumption. In distributed systems, those capabilities are arranged across an arbitrary number of autonomous nodes, which makes the decision-making process more challenging.

This paper proposes an agent-based model for dynamic service orchestration using available contextual data in smart distributed environments. It consists of multi-agent systems that correspond to each physical or virtual node or a group of nodes with the same functionalities. Within each system node, there are agents used for managing and limiting the context of node-related services according to the current context of the node or the system. These agents can enable or disable node-related services according to the current needs, which may optimize complex smart environments due to reduced number of services running. This also results in raised security level due to decreased attack surface.

The proposed agent-based service orchestration model is evaluated on a case study in smart building presence tracking. It is shown that the application of the model can significantly reduce the required uptime of running services while sustaining the same level of service functionality. Evaluation also addresses possible topics of further research, which will focus on evaluating the proposed system in various smart environments and on introducing new node-related functionalities into the model. Furthermore, since the process of service orchestration for each node may become rather complex when dealing with various node-level and node-related functionalities, part of the future research will also focus on negotiation and deduction techniques to apply the optimal service composition to each physical node in the examined system.

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A Proposal of Evacuation Support System with Redundancy Using Multiple Mobile Agents

Itsuki Tago, Naoto Suzuki, Tomofumi Matsuzawa, Munehiro Takimoto and Yasushi Kambayashi

Abstract We present a prototype of robust evacuation support systems that use mobile agents to move a database server and to minimize the necessity of redundant configurations. We have conducted a project for evacuation support systems. In order to provide versatility in the system, we have employed Google Maps API to construct evacuation routes. The previous system has two problems. One of them is the existence of a single point of failure. When one of the database servers or application servers of the system breaks down, the whole system stops functioning. In order to solve this problem, we propose a system using mobile agents to remove the single point of failure. In the current system, we not only transfer data to another server but also make the servers move as mobile agents so that we do not need to use any cloud servers such as AWS and GitHub. In this paper, we describe the design and implementation of our server agent, and report experiences and observations we have found during the experiments.

Keywords Mobile agents · Server systems · Fault-tolerant systems

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1 Introduction

Recently in Japan, we have suffered from many natural disasters, including the Great East Japan Earthquake that occurred in Japan in 2011, especially the Hokkaido Iburi Eastern Earthquake in September 2018, the main power station of Hokkaido Electric Power Company (HEPCO) Tomatou Atsuma Power Station stopped, and a blackout occurred in almost all the areas of Hokkaido. According to the Federation of Electric Power Companies of Japan, the blackout occurred for the first time due to the phenomena caused by the earthquake. There is concern that an earthquake on the Tokyo Inland fault line or Nankai Trough will occur in the near future. There is a possibility a large-scale blackout will occur.

Every time a natural disaster occurs, each local government issues information on safe places and shelters for the people in the area and call for the evacuation. We have built an evacuate support system for residents so that they can head to the regional shelters through optimal routes [1]. Simulation results have shown the effectiveness of our evacuation support system. If a failure occurs, in one of the server monitoring systems, or DNS, however, they can be a single point of failure where the entire system will stop functioning. Therefore, it is necessary to configure these parts to be redundant. In this paper, we propose a method to make database servers physically move when detecting the danger, so that even server machines break, the server can survive on another machine.

The structure of this paper is as follows: in Sect. 2, we will explain the background. Section 3 describes the development overview. In Sect. 4, we describe the system configuration. In Sect. 5, we describe the experiments and the results, and lastly, in Sect. 6, we give a summary and outline prospective future study.

2 Backgrounds

2.1 Evacuation Support System

Goto et al. proposed an improved version of the ant colony optimization (ACO) algorithm for constructing evacuation routes. They have improved pheromone control for disaster evacuation guidance [2]. They have studied the advantages and disadvantages of adopting the ACO algorithm for evacuation support. They have observed that ant pheromones derive the shortest distance that does not always guarantee the optimum evacuation route at the time of a disaster, and in the event of an earthquake or fire, a dangerous area could dynamically arise, so they have concluded that the pure ACO algorithm is inadequate [3].

Taga et al. used the GPS information from evacuees' smartphones for collecting information for escape route guidance. They have constructed a simulation system that uses the ACO algorithm [4]. With the algorithm, their system guides people who try to return home or safe places set on the map through the shortest route.

In addition, the smartphone performs ad hoc communication and multiple mobile agents that exchange the location information of evacuees and construct optimal routes to safe areas [5]. Their mobile agent system consists of the following four agents [6].

We have built a client/server-based evacuation support system using Linux server machines such as servers and smartphones as clients [1]. Although the system provides optimal evacuation routes, it has a single point of failure in the servers that constitute the system. Therefore, we propose, in this paper, a system aimed at solving this single point of failure by employing mobile agents.

2.2 *Zabbix Server and Agents*

Figure 1 shows the model of our original evacuation support system [1]. Any of the three servers in the figure can be a single point of failure. In order to mitigate this problem, we have added one more server, namely, Zabbix server, that surveils the DB server. We have made the DB server as a mobile agent so that it can migrate to another server machine through communication network. In order to achieve this surveillance system, the Zabbix server stations one Zabbix agent on each server in our evacuation support system to detect any anomaly. When the Zabbix server senses a trouble on the DB server, it makes the DB server migrate to another machine as well as dispatches an agent to provide troubleshooting.

Zabbix is system monitoring software released as free software in 2001 [7]. Its development started in 1997. Zabbix is currently used in approximately 100,000 devices and 5,000,000 triggers in the retail, finance, aviation, and information industries around the world.

Zabbix installs the Zabbix agents for monitoring. When Zabbix activates its agents, the Zabbix server, which is prepared in advance, can start monitoring easily the target systems where Zabbix agents are installed. The Zabbix server can obtain data such as the CPU temperature and operation rate of the client (the monitoring tar-

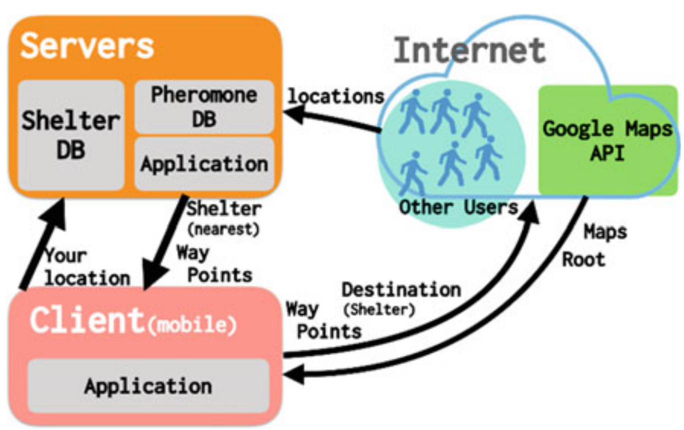


Fig. 1 The original design of the evacuation support system

get system), as long as the installed Zabbix agents are active. In the event of a failure, the agent on the particular client can send mail or SMS to the system administrator and the agent can also run arbitrary programs [8]. Currently, it can be monitored by logging in from browsers such as Internet Explorer, Opera, Google Chrome, and Safari.

2.3 Mobile Agent

A mobile agent is a program that continues processing while moving between computing sites. A mobile agent can autonomously choose the destination to which it migrates. Agent systems have been widely developed in various languages [9]. MobileSpace is the prominent agent system that we have intensively adopt to multi-robot control systems [10, 11]. Most agent systems focus intelligent behaviors as well as continuity of processing; we have developed a simple lightweight mobile agent platform in Python language for our proposed system. The aim of our mobile agent system is to provide simple migration facilities, and not to provide intelligent behaviors. It only conveys the DB server to another server machine, and the server itself has recovery processing from the transaction file sent as a separate file. Another mobile agent dispatched from Zabbix server takes charge of collecting fragment of a transaction and convey them to the newly installed DB server.

3 Development Overview

We have tried to remove the single point of failure of the evacuate support system described in the previous paper and also tried to minimize redundant configurations using mobile agents [1]. A mobile agent is an executable program that can physically move from a device to another device [9]. First, we set up a server, in which Linux was installed, as the base system, and we employ the Zabbix for monitoring the status of the server. Since this system has many subsystems, it is effective to construct a redundant configuration. Figure 2 shows a schematic diagram of the backup system by agent moving between systems.

This system has a redundant configuration of a backup system that consists of four Linux servers. Two of them run Zabbix agents and the other runs as a Zabbix server. The servers on which Zabbix agents run are DB servers. One collects GPS information of evacuating people and the other stores shelter information. The former performs transaction processing and stores a minimal journal [12, 13]. The last server backs up the backup file created by the server. We have employed Apache as the middleware and MariaDB as the RDBMS so that we can easily deploy in different regions with different environments, because it is compatible to the de facto standard, MySQL [14]. When a monitoring target server becomes in a dangerous state due to a disaster, the installed agent obtains the fragment data in the journal from the server

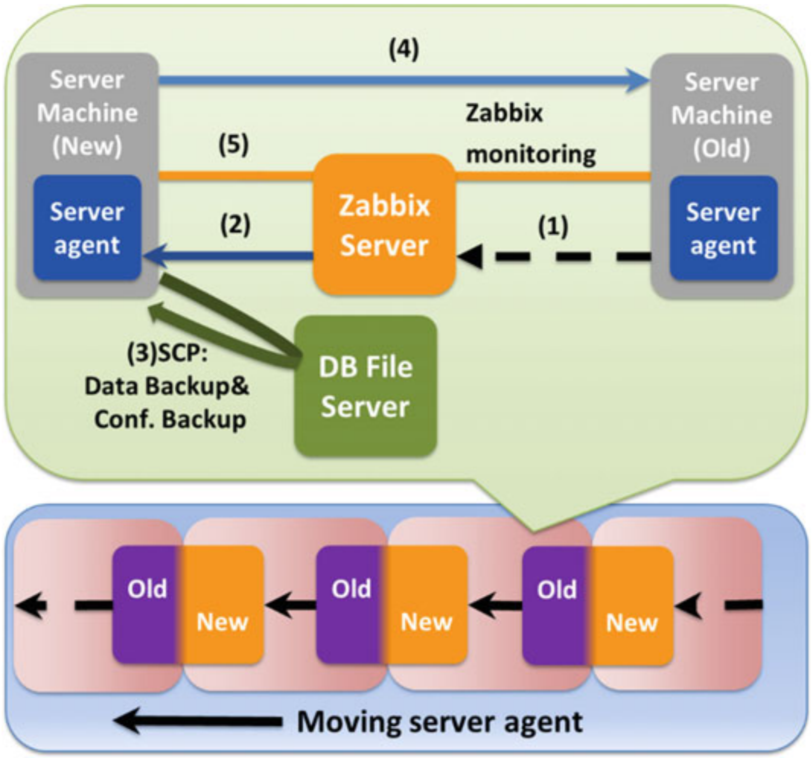


Fig. 2 Schematic diagram of the backup system

and move to a backup server and uploads the data in perfect condition [15]. The system is built with a mutually linked backup system. The backup procedure is as follows.

(1) The Zabbix server detected a server agent fails.
(2) The Zabbix server sends an execution instruction agent of the server agent.
(3) With this agent, data is transmitted from the backup file server to the moved server agent.
(4) Shutdown starts on the troubled machine where the server agent was before moved.
(5) When the moved server retrieves the backup data from the DB file server and receives journal data from another mobile agent, the recovery completes, and the system restarts with recovered data on a new server machine in a safe place.

4 System Configuration

Figure 3 shows the system configuration and the details of the data flow including agents' movements of the upper half in Fig. 2.

Our system is built to accommodate when the original server is not functioning properly. In order to achieve this purpose, we have created a new kind of mobile agents

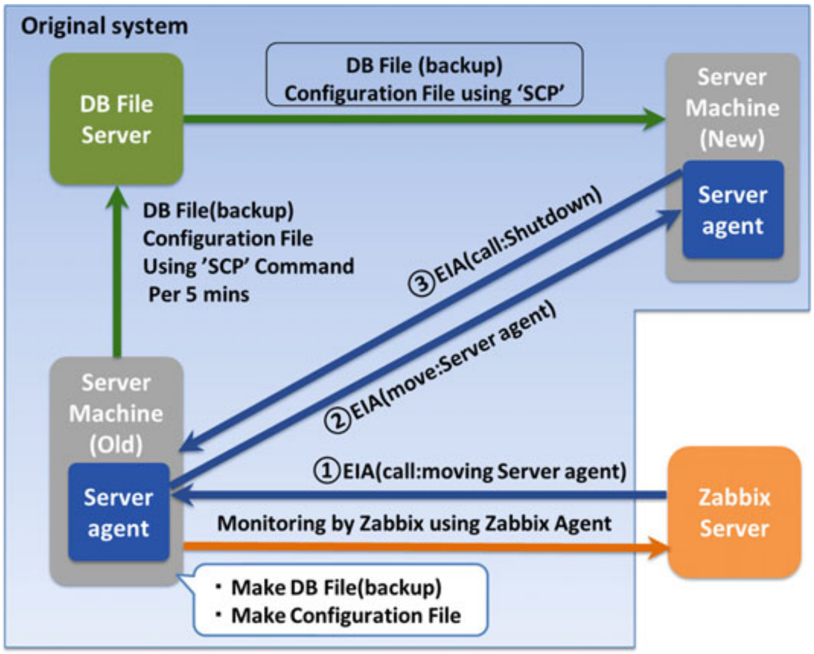


Fig. 3 System configuration

that move to proper server machines and give appropriate instructions in addition to the Zabbix agents. We call this new mobile agent the execution instruction agent (EIA). The system behaves in an emergency algorithm as follows.

1. The server agent, which is monitored by the Zabbix server, performs backup its DB file to another server machine once every 5 min using the SCP command.
2. When the Zabbix server detects a trouble on the server machine, it sends a message to the server agent to move to a safe machine.
3. Since the server agent is implemented as a mobile agent, it moves (escapes) to the new server machine. The Zabbix server sends mobile agents EIA to the troubled server machine to collect journal data and moves to the new server machine and instructs the server agent to recover database from the backup DB file server. Upon recovering the database, EIA sends the old server machine a message to shut down.
4. After the recovery completes and the server agent starts working, the emergency algorithm returns to step 1.

The EIA program is an agent that collects journal data and any incomplete data on the server agent and conveys all those data to the server agent to recover the database. The server agent itself is a mobile agent and move to the new server machine in a safe place when the Zabbix agent detects a failure of the server agent. EIA also instructs the old server machine to shut down gracefully when all the recovery completes.

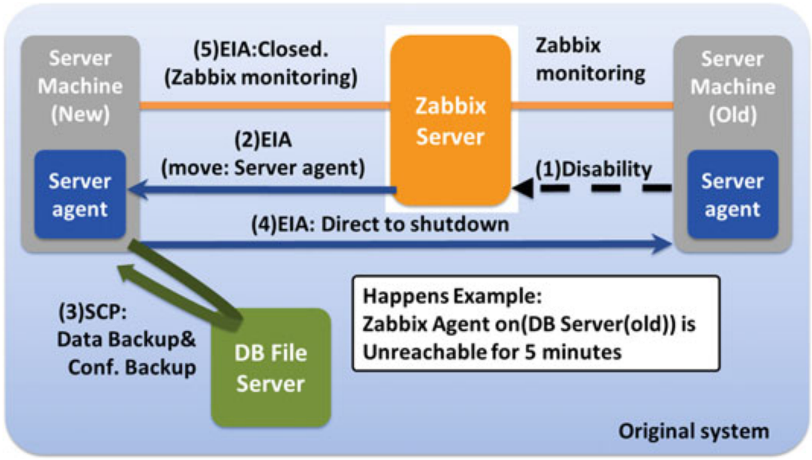


Fig. 4 Transition diagram when abnormality by Zabbix is detected

4.1 *Monitoring System*

In this section, we describe the monitoring system. Figure 4 shows the dataflow including agents' movements at the time when the Zabbix agent detects a failure in the server machine. The behaviors of the agents are as follows.

(1) Zabbix server is monitoring the server agent through Zabbix agents. When the Zabbix server finds the Zabbix agents that fail to send monitoring data five minutes or over, the Zabbix server determines that the monitoring server agent is in trouble.
(2) If the Zabbix server decides it as a failure, e.g., monitoring items ("Zabbix agent on server agent is unreachable for 5 min") happens, Zabbix server dispatches EIA (execution instruct of the backup program) to that server machine.
(3) When EIA arrives at the troubled server machine, it makes the DB server (a mobile agent) moves to a safe server machine. Since the backup file is saved in the DB file server, the server agent can retrieve data from the file server in order to recover the database upon arrival at the safe machine.

4.2 *Agent Programs*

In this section, we describe the EIA. The Zabbix server dispatches EIA to the troubled server machine. Upon arrival, EIA first makes the server agent move to another server machine and then starts collecting journal and other fragments of incomplete transaction. When it collects enough data, it also moves to the new server machine where the server agent (the DB server) has already moved. EIA makes the server agent invoke the following function to move.

```
def rsp():
p =subprocess.run([‘python3’,’/home/user/EIA/c1.py’])
return p
```

In order to invoke the above function, EIA must execute the following code.

```
s2 =xmlrpc_server.SimpleXMLRPCServer((“x.x.x.1”,p2))
s2.register_function(rsp)
```

Since the moved server agent needs backup data, it must retrieve the data from the DB file server. The following code shows how server agent retrieves backup data from the DB file server.

```
p =p +subprocess.run([‘scp’,’-i’,
‘/home/user/.ssh/id_rsa’,’pi@x.x.x.1:/home/user/Desktop/*
.sql.gz’, ’/home/user/Desktop/*.sql.gz’])
```

The server agent must communicate with the DB file server to retrieve the backup data. In general, when two servers establish a communication, SSH authentication is required between the two servers that transmit and receive data. In order to authenticate, a password input required. This is a hindrance for our agents' communication. In order to solve this problem, we make the servers (the server agent and DB file server) perform the Diffie–Hellman key exchange to share the key, and then execute the data retrieval program to transfer data.

Finally, EIA sends a shutdown message to the troubled server machine's agent platform. Upon receiving that message, the agent platform on the old server machine performs the following code to shut down its machine.

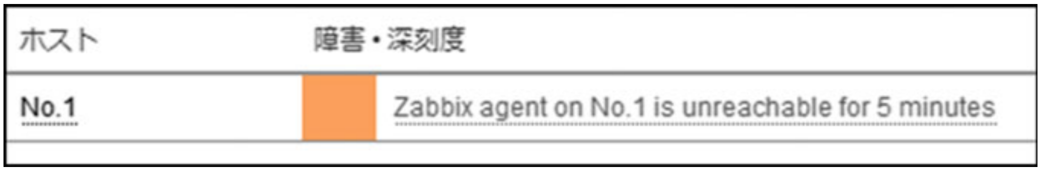
```
P =subprocess.run([‘sudo’,‘shutdown’,’-t’,’0’])
```

5 Demonstration Experiment

In order to demonstrate the feasibility of our mobile server agent system, we have conducted an experiment. The experiment conditions are as follows. We set four Raspberry Pi Zero machines with 1 GHz ARM processor connected with wireless LAN. The database size is 466 KB. It is a toy networked database system that simulates a large-scale powerful server machine.

We make the Zabbix agent running on the DB server stop its execution. Then, the Zabbix server determines that there is a failure about the server agent, because the Zabbix server cannot reach the Zabbix agent who monitors the server agent as shown in Fig. 5. We have repeated this experiment ten times and taken the average out of measured recovery time.

We have observed that the Zabbix server dispatches EIA to the server machine so that the server agent moved to a new machine, and then retrieved the backup data from the DB file server and complete recovery in 5.5 s. Also, we have observed EIA successfully collected the journal file from the old server machine to assist the server agent to complete recovery.



ホスト	障害・深刻度	
No.1		Zabbix agent on No.1 is unreachable for 5 minutes

Fig. 5 Example of Zabbix's reaction when making a quasi-obstacle

6 Conclusion and Future Directions

In this paper, we proposed a mobile server agent system that provides redundancy to a system structure with single point of failure while minimizing physical redundant configuration. This system consists of several Linux servers (minimum four) that are connected through the Internet. Since the server is implemented as a mobile agent, it can move between the Linux server machines installed in a different location. The server agent can recover the DB system on the destination server machine by retrieving the backup data saved in a DB file server which resides on a different machine. Currently, we employ the Zabbix server and Zabbix agents to monitor the server agent, and we have confirmed that they successfully perform monitoring and fault detection of the server agent. Also, the Zabbix server dispatches another agent, i.e., EIA, to make the server agent move to another Linux server machine. We have confirmed the success of recovery of the database.

As we confess in the previous section, our system is a toy networked database system that simulates a large-scale powerful server machine. To pursue practicality, the conventional redundant systems, such as duplex systems, provide more secure and robust server systems. Their advantages, however, solely depend on secure communication network. If network infrastructure is damaged, all the systems are paralyzed. As our future experiment, on the contrary, we currently constructing a mobile agent system based on ad hoc network [3]. Actually, Taga et al. are constructing an evacuation support system based on the ad hoc network system [4]. Since our server systems are based on micro-servers, we expect to adopt the ad hoc network in our system so that we can construct a robust evacuation support system that does not depend on the network infrastructure.

As a future direction, we plan to extend this system so that the server agent can move continuously, while EIA can follow the server agent with collected transaction fragments, and to provide continuous DB service. We also would like to build a more realistic database system with powerful server machines, and then construct a realistic evacuation support system.

Acknowledgements This work is supported in part by Japan Society for Promotion of Science (JSPS), with the basic research program (C) (No. 17K01304 and 17K01342), Grant-in-Aid for Scientific Research (KAKENHI).

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From Thing to Smart Thing: Towards an Architecture for Agent-Based AmI Systems

Carlos Eduardo Pantoja, José Viterbo and Amal El-Fallah Seghrouchni

Abstract This paper presents the Internet of Smart Things, which uses improved things managed by Multi-Agent Systems for providing a network of devices for open environments in Ambient Intelligence systems. The proposed architecture employs a middleware for the Internet of Things as a base for the connectivity and communicability of devices. The Smart Things are deployed using hardware technologies interconnected to provide autonomy and specialized agents for interfacing controllers and to communicate with other devices. Prototypes are built as a proof-of-concept for validating the approach.

Keywords Ubiquitous computing · Multi-agent systems · AmI

1 Introduction

Ubiquitous Computing is the capability of embedding intelligence in everyday objects using computer systems to provide services and information continuously to support users in daily tasks and acting transparently in the environment [1]. One of its subareas is Ambient Intelligence (AmI), which comprises electronic and intelligent environments interconnecting different technologies for assisting in daily tasks autonomously and proactively [2]. In dynamic environments such as AmI based on Internet of Things (IoT), devices can enter or leave anytime, growing or even reducing the hardware infrastructure available. In fact, there will be a fixed part of

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the infrastructure—such as electrical facilities—and a mobile part that can grow depending on upcoming devices.

Intelligent agents are entities that can be constructed in both hardware and software and they are able of performing actions in certain environments autonomously and pro-actively based on some cognitive model of reasoning. A Multi-Agent System (MAS) is composed of intelligent agents capable of communicating and collaborating—or even competing—for using resources in an environment to achieve conflicting or common goals [3]. The use of the agent approach in AmI systems is justified by the autonomous characteristics of agents and their use in complex systems, both found in Ubiquitous Computing [4, 5].

Some works [6–9] apply MAS in IoT domain. However, they use only one agent for each device, which can raise issues such as processing bottlenecks and agents overloading depending on what is executed. In these cases, a MAS could be preferable for controlling devices because agents can be specialized in some functions such as dealing with hardware interfaces and communication. Thus, applying MAS in embedded systems for devices is not a simple task and problems can arise because of the number of perceptions in environments and real-time constraints that agents have to consider in response to a stimulus.

For helping create autonomous embedded MAS, some approaches deal with them [10, 11]. However, these works consider a MAS embedded in a device without the ability to communicate with other devices. Every agent present in the MAS just communicates with agents from its own MAS and controls hardware. Therefore, some communication mechanism must be provided for such kind of devices to enable a horizontal communication between the devices in an IoT or AmI system. If the embedded MAS does not have any kind of mechanism for exchanging information with other devices, it will not be useful in a collective system where decisions have to be made considering distributed information.

The objective of this work is to propose an architecture characterized as an Internet of Smart Things (IoST) for the deployment of AmI Systems in open environments based on IoT technologies comprising devices managed by MAS as Smart Things. So, we consider an open environment as an AmI system running over an IoT network, where devices can enter or leave anytime. Every device is independent and autonomous with enough processing power and memory for hosting an embedded MAS (Smart Thing), which controls sensors and actuators, hardware interface, and tiny computers. For validating the proposed architecture and the Smart Thing, two prototypes are assembled and tests about communicability, connectivity, and autonomy are performed as a proof-of-concept [12].

When the number of devices grows exponentially, the concern with scalability becomes latent. To address these limitations, *ContextNet* middleware [13] treats the communication and connectivity of nodes in a scalable way using data protocols based on OMG [14] standards. Furthermore, we present an extended version of Jason [15] for programming MAS. The outlined contributions of this work are the architecture for interconnecting devices using IoT technologies responsible for the proposed IoST; the Smart Thing definition and design controlled by embedded MAS; and a Jason's customized agent architecture able to exchange messages and connect into the IoST. In Sect. 2, the state of art is presented; Sect. 3 presents the Smart Things; the architecture and a proof-of-concept are presented in Sect. 4, and it is concluded in Sect. 5.

2 State of the Art

With the emergence of IoT technologies, it became possible to enhance and interconnect daily objects in an open environment for communication over the Internet to perform pervasively actions for helping humans being. The IoT, MAS, and AmI deal with autonomous devices capable of communication over a network to enhance an ambient with a degree of automation or even intelligence. There are several works, which uses agents to deal with some details of IoT such as collaboration, autonomy, and sensing in AmI systems. Mobile agents [6] provide collaboration in an IoT and Wireless Sensor Network (WSN) using an architecture for providing integration between heterogeneous devices, platforms, and WSN nodes. The authors affirm that the agency model facilitates the dynamic resource configuration at runtime and the architecture is generic considering the programming language. There is an agent for each device and in a certain period, only one agent can be on the device. The agents are able to move from device to device using the HTTP and from node to node in the WSN using CoAP protocol. The use of different controllers in WSN nodes is interesting since agents are unaware of them. The devices work as a spot where agents can move to perform some operations, then every node and device in this IoT network is not autonomously, depending on agent occupancy.

The Agent of Things [16] is a definition for devices managed by a single agent in dynamic environments. The authors suggest that the approach used in most solutions to provide communication between devices are highly programmable and depends on a previous interaction configuration. It is proposed a conceptual framework, which considers a direct physical interaction between devices using hardware and software layers where every agent represents a device. But in the framework, agents are only situated and centralized in the software layer.

A discussion [7] about using MAS in IoT raises questions about communication and the use of protocols such as CoAP, MQTT, and AMQP, and how to implement functionalities for access control in an agent-based IoT. It uses a server for coordinating the communication using those protocols in a WSN system containing agents and IoT devices. Some agents are responsible for reasoning and communicating with the IoT devices (there is one agent per device). The Agent-based Cooperating So (ACOSO) is used as middleware in an IoT network where agents are devices [8]. It supports the development of MAS in the level of things. So, every smart object can be abstracted to an agent using Jade as Agent-Oriented Programming Language (AOPL). It provides a three-layered architecture: application; transport; and net and physical. The agents manage sensors and actuators, and reason using local and distributed databases.

In a decentralized approach for engineering IoT applications [9], smart objects are data gathers and senders and the data is stored and processed in central servers compromising their autonomy. The smart objects run even if remote technologies are not available and there is one agent for a smart object. Some authors visioned the idea of decentralized MAS responsible for cognitive intelligence in distributed computing for IoT directing the area for the development of truly autonomous smart objects independent of infrastructure technologies [17].

Commonly, these approaches consider centralized reasoning where agents are running at a server representing devices, which is not appropriated in most cases. The system becomes highly dependent on the server and the device autonomy is compromised since it depends on agents situated outside the device's physical structure. The advance of the network and microprocessors technology helped the development of IoT and its use in the AmI domain. Thus, agents started to be effectively embedded in devices providing the necessary autonomy to them. Yet, the approaches deal with one-to-one relations between agents and devices, which overload agents and delays may rise since agents have to deal with many perceptions from sensors. When comparing the performance of using one or more agents per device, it is expected that the later approach to producing better results. Some approaches consider devices as fixed spots where agents can move and stay for a while. However, it is not simple to deal with the configuration of devices since users have to indicate manually their presence.

So, we propose the Smart Thing, a fixed or mobile device with an embedded MAS capable of sensing and acting in an IoT based AmI System. The Smart Thing is autonomous in any environment but when connected to an IoT network it improves its abilities with communication capabilities for context transfer.

3 From "Thing" to "Smart Thing"

A Thing in the IoT is a device that connects to any available network structure to perform actions or transfer data and they should act autonomously to attend an expected functionality. Most of things have an architecture employing sensors and actuators connected to hardware controllers for creating its physical body. Since, most of controllers are limited, an embedded system should be used for helping the device's functionalities. Serial Interfaces are used for transferring information between hardware and the embedded system. The proposed Smart Thing has a similar structure when considering hardware technologies but it uses a MAS on top of devices. We assert that the agent approach can bring several advantages comparing to traditional things including internal decentralized processing, improved context generation, do not work only as data repeaters, and its autonomous because they do not depend on external technologies.

A traditional Thing shares some attributes (functional and non-functional) with our Smart Things. The following functional attributes can be identified to provide real embedded devices that are able of acting in an AmI system:

- **Autonomy**: every Smart Thing hosts a MAS providing autonomy and it should perform independently of any technology that is not part of its architecture. Yet, a Smart Thing should work properly if it has been moved to another environment or AmI system. It should still perform its functionalities even if there is no communication with other systems and devices.
- **Communicability**: since the Smart Thing is an autonomous entity, it should be able to communicate with other devices including Smart Things themselves. Then, a communication infrastructure with different devices should be present in the AmI system.
- **Connectivity**: Smart Things connect to an IoT infrastructure where middleware for IoT plays an important role because they are constructed to deal with several issues regarding connectivity and availability.
- **Context-awareness**: most devices act as data repeaters transmitting raw data from sensors to a central computer where data processing takes place. In Smart Things, this data processing can occur in the device, which can process and use the result for decision making, or send improved context to a third part in the AmI system.
- **Heterogeneity**: Smart Things have hardware components that are responsible for the interaction between the device and the real world. So, the Smart Thing should provide an uncoupled architecture for interfacing hardware components where a MAS is able of controlling these components and it must employ different kinds of hardware controllers. The heterogeneity of controllers increases the range of possibilities for creating Smart Things.

Besides, the following non-functional attributes are also identified in the proposed Smart Things:

- **Adaptability**: The Smart Thing must be applicable in any domain. It means that they cannot be coupled to the deployed solution. Besides, a Smart Thing of any domain could be able of moving to another domain compliant system without any modification in its architecture or programming.
- **Computational Capacity**: since Smart Things are controlled by an embedded MAS they must use platforms with enough storing and processing capability. A Smart Thing can employ any platform hosting an Operational System. In fact, there is not a size limit for Smart Things.
- **Interoperability**: no matter what AOPL is being used for the development of Smart Things, they must communicate properly. Besides, Smart Things are able to communicate with other devices such as smartphones. So, mechanisms for interoperability between systems must exist.
- **Reliability**: The Smart Thing must be reliable. It means that the hardware interfaces, reasoning and all components of a Smart Thing should work properly as long as possible without crashing.
- **Scalability**: The IoST must be scalable, allowing the entrance of new Smart Things without losing performance or crashing the system. So, every Smart Thing should be prepared to enter or leave the IoST in a scalable way.

4 An Architecture for the Internet of Smart Things

Despite the fact of a Smart Thing to be autonomous, it needs an infrastructure to be part of and to put its all attributes in action. As they are extensions of Things from IoT, the infrastructure needs to comply with the IoT bases, considering technological issues such as network facilities and middleware. Based on that, IoST is an IoT network of interconnected Smart Things and devices that use local networks for providing fixed structures where Smart Things should connect to be part of the system. These structures are servers computers running a middleware for IoT to provide scalability, connectivity, communicability, context awareness and openness of the system. Once a Smart Thing enters in the IoST, it is possible to interact with other existing devices of the system. As stated before, Smart Things use embedded MAS where there will be specialized agents dedicated to performing functions for avoiding processing bottlenecks or undesirable delays. Thus, this MAS must have mechanisms to use the IoT as a channel for exchanging information and messages in the AmI system. An agent named *Communicator* will be responsible for the identification and communicability of the Smart Thing, *Interface* agents will be dedicated for interfacing controllers, and *Traditional* agents are responsible for helping in the internal decision-making process. The IoST architecture can be seen in Fig. 1.

This approach leads to a decentralized architecture since every embedded MAS is considered an autonomous and independent device capable of communicating and, eventually, negotiating with other devices. By independent, it means that Smart Things are able to keep running and reasoning even if communication technologies stop. In the architecture, devices can be mobile or fixed, where the former one is composed of all movable devices. The later one is composed of all devices that are fixed in the infrastructure of the environment and cannot be moved without changing physical parts, such as electrical facilities.

The architecture uses the *ContextNet* as IoT middleware where every device should connect to be part of the system and to communicate with other devices.

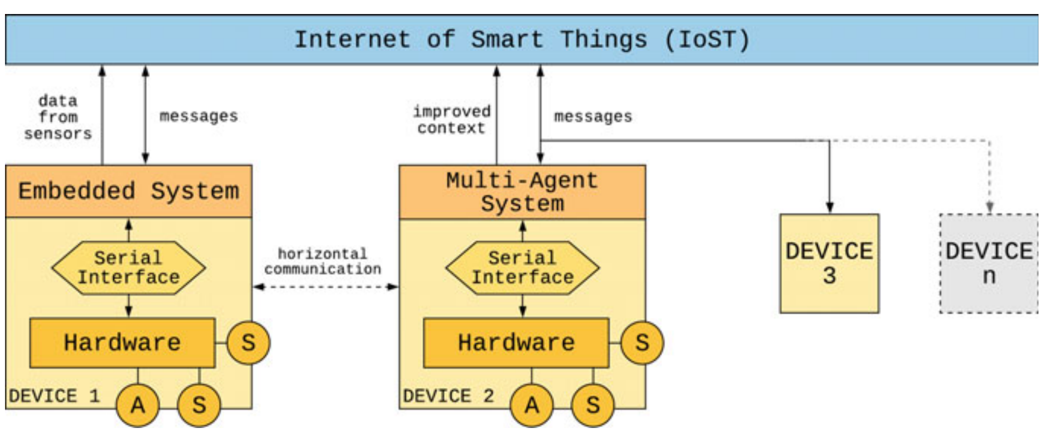

Fig. 1 The IoST architecture with things and smart things

In this approach, we assert that devices can employ embedded MAS for managing sensors and actuators in the AmI systems and work as Smart Things. It is composed of a cognitive layer using Jason framework with agents responsible for interfacing hardware components, and agents responsible for communication in the network using an instance of *ContextNet*. The hardware layer is composed of: the platform for embedding the MAS, which could be any tiny computer such as Raspberry Pi; sensors and actuators; and controllers. Therefore, it is possible to employ three types of agents in a project:

– **Standard**: the basic unit of a MAS. It is able to communicate with other agents of its MAS but not with agents from a different MAS. It is not able to control any kind of hardware. In the IoST, it is the *Traditional* agent.
– **Interface**: it controls hardware independently of its type and the domain applied in the solution. They have all the abilities of a standard agent but they are not able to communicate with agents from a different MAS.
– **Communicator**: it can communicate with agents from a different MAS or any device using *ContextNet*. It has the same abilities of a standard agent but it is not able of controlling hardware.

We propose the use of MAS developed using Jason and *ContextNet* to exploit some advantages of using a robust middleware for IoT applications, which guarantees a great number of devices transmitting data at same time, and a well-known framework for agents solutions. Jason already counts with **Standard** and **Interface** agents. Then, we present a customized architecture for **Communicator** agents with an embedded instance of *ContextNet*.

4.1 Communicability and Connectivity for Smart Things

For the programming of agents that are able to exchange messages with agents from different MAS, a new kind of agent named *Communicator* was proposed. Based on the IoST architecture, the *Communicator* agent must have mechanisms for sending and receiving messages connected to the *ContextNet*. Thus, the reasoning cycle of the *Communicator* agent was extended with the *ContextNet* middleware embedded in its architecture (Fig. 2).

At the beginning of the reasoning cycle, it is capable of receiving messages from other devices using *ContextNet*. All messages received generates events and updates the agent's *Belief Base*. The next modification was inserted at the end of the reasoning cycle after the *sendMsg* step. At this moment, the agent can send a message to agents from a device using *ContextNet*. Every agent must have an identification number provided by *ContextNet* and it uses an internal action named **sendOut** likewise the original **send** from Jason. Both of them send a message to an addressee using an illocutionary force. The major difference between them is that **sendOut** sends a message to a **Communicator** agent in another MAS. In this version, the available illocutionary forces are:

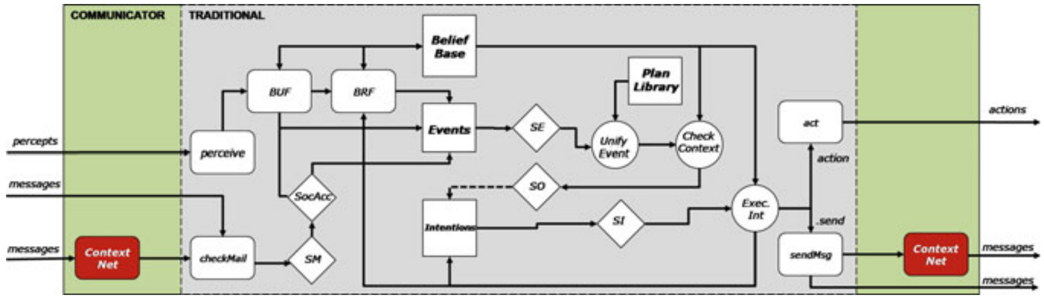

Fig. 2 The reasoning cycle of communicator agents

– **achieve**: sends a goal to be accomplished by the addressee. The content of the message sent will be inserted in the base of intentions of this agent.
– **unachieve**: drops a goal in case it has not been reached yet. The content of the message will be removed from the base of intentions of the addressee.
– **tell**: sends a belief that the addressee believes to be true. The content of the message must be a literal representing a belief. It will be inserted into the belief base of the addressee.
– **untell**: the sender agent informs the addressee agent that the belief is no longer to be believed. The content of the message is removed from the belief base of the addressee.

4.2 Proof-of-Concept

First, the IoST must be provided to allow the connection of devices. For this, a server with an instance of ContextNet middleware was configured as well as all the network requirements needed. ContextNet is responsible for the connectivity, communicability, reliability, and scalability of the IoST. A Smart Thing is equipped with controllers, sensors, and actuators connected to any computational platform with an operational system and sufficient processing power for hosting a MAS. Tiny computers are commonly used since they are small, hold serial ports, and onboard communication technologies. So, we employed in the Smart Things ATMEGA328 controllers connected with temperature and luminosity sensors and power plug where electricity can be turned on or off, and a Raspberry Pi Zero for hosting the MAS (Fig. 3). In the MAS was employed one *Communicator* agent per device, one *Interface* agent per controller, and one *Traditional* agent for aiding the other ones in the communication process.

In order to test the functional attributes of Smart Things, some devices were prepared to attend our proof-of-concept. The autonomy of devices was tested by verifying if sensors values were still being gathered when the server was disconnected. So, we assembled one Smart Thing responsible for gathering data from a temperature sensor and depending on the temperature measured, it should turn on or

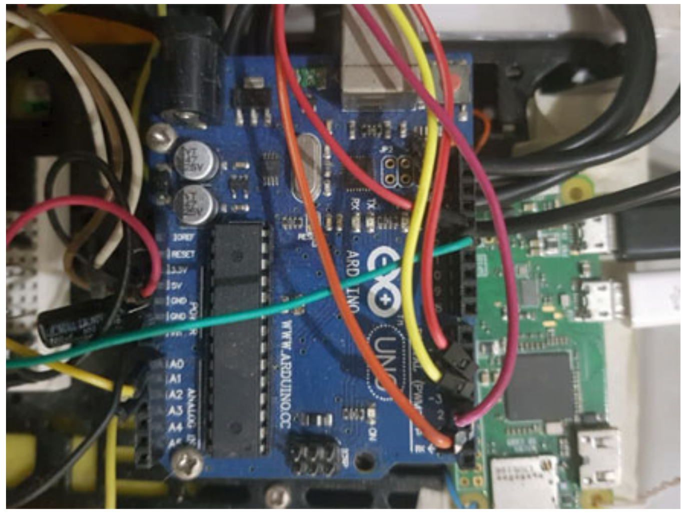

Fig. 3 One of the smart thing prototypes

off the plug where an air-conditioner is connected. The Smart Thing should connect to the ContextNet and after that, the server was disconnected. We repeated this ten times and the Smart Thing was able to perform autonomously in all opportunities. Once the server is available, the connectivity and communicability were possible to be tested. Thus, we tested the behavior of Smart Things by sending messages with data from the luminosity sensor of one Smart Thing to another one. This former one is responsible for executing a turn on action in its light actuator based on the value received. There were no problems in the execution of these tests.

The context-awareness was tested using the former test but changing the information that was sent. Instead of sending just the raw information from luminosity sensor, the Smart Thing was able to gather and process this information as *dark* or *bright* and it sent this context for the second Smart Thing to execute the turn-on action. The heterogeneity was tested by changing the controller from ATMEGA328 to Galileo Gen 2 in the first Smart Thing. Again, it was not identified any problems during the execution and everything went well. The objective of this proof-of-concept is to highlight that it is possible to employ MAS in embedded systems to provide autonomous and pro-active devices that are not dependable on central services to keep reasoning. Besides, the IoST extends the Smart Thing reach, providing a layer with connectivity, scalability, and communication. Although simple, these tests aim to validate the main functionalities and the communication between the layers of the approach. However, formalization and more complex tests using as many devices as possible are necessary.

5 Conclusions

In this paper, it was introduced the IoST, which is an architecture for the deployment of devices enhanced with MAS working as Smart Things. In some cases, the use of

MAS in devices can bring advantages compared to traditional things that only work as data repeaters sending data from sensors to a server for generating context about a situation and they need stimulus from other devices to act upon the environment. Besides, Smart Things communicate with other devices and they also allow improved information or even a previous context generation before sending it to a server application releasing processing power of server applications, for example. Smart Things are also autonomous because agents can make decisions and act without depending on a third part processing.

Smart Things are constructed based on several hardware technologies that act together to provide autonomy without depending on third parts such as IoST's servers. A proof-of-concept example was presented showing some of the proposed behaviors of the IoST such as connectivity, autonomy, and communicability. As future works, the IoST must be tested in a broad scenario involving many devices as possible. Besides, the IoST can be used as a middle layer for the virtualization of devices using web services where interested people can access their information publicly or privately according to their needs. In this way, the devices connected to the IoST can expose their resources as Sensor as a service model.

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Automatic Clustering of User Communities

A System Architecture

Matteo Cristani, Michele Manzato, Simone Scannapieco, Claudio Tomazzoli and Stefano-Francesco Zuliani

Abstract A semantic community is a set of individuals who are interested in the contents that refer to a specific domain, around which they aggregate to perform social activities such as sharing, commenting, possibly editing, those contents. Every producer of contents that is interested in interacting on social networks and in general on digital news platforms is interested in actively collaborating with the semantic communities that exist about the topics she produces. In general, moreover, a content producer is interested in fostering communities, mainly because this will generate a higher interest on her contents. In this paper, we illustrate an architecture of a system able to support and manage semantic communities in the framework of a project for digital news delivering. The architecture is illustrated and its basic concept is presented.

1 Introduction

Providing information tailored to the specific user needs and interests, as well as, building engagement with the audience is an open problem in the digital news industry. Understanding user preferences, given only what is detectable in a digital world

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such as the internet, is the task where the majority of the efforts have been spent, both in recent past and nowadays.

Several newspapers have developed technological solutions to assist readers in browsing the newspaper's website or mobile app in a way such that the proposed material best matches his/her tastes. On the other hand, almost every newspaper is trying out new ways to build stronger relationships with their readers, with highly varying level of success.

A key problem is dealing with users with very different habits and ways of approaching digital news due to their education, occupation, lifestyle and age. In these regards, we recall two noteworthy attempts to tackle the aforementioned issues.

The current New York Times (NYT) approach is essentially structured into a mediated twofold proposal. The 'Reader Center' is a section of the newspaper that allows digital readers to interact, comment and provide feedback to the newsroom. In addition to this section, NYT also provides specific feedback opportunities on the social networks with structured pages that include 'Groups' and 'Community' sections, both moderated by journalists specifically dedicated to the task. The 'Groups' section is at present limited to two categories: one related to Australia, and one dedicated to comment gathering about Podcasts. This classification is a very neat example of well-defined—yet segregated—community. Moreover, there are links to image-centric social networks, video links on the newspaper homepage, a Twitter profile and a Youtube channel set, which comprises a video interview channel called TimesTalk. Conversely, several NYT sections are thematic, such as 'Science', 'Sports' and so on. In these sections, news are published and social sharing functions are provided. Although no direct space for comments exists, the presence of the sharing functions allows readers to provide some sort of feedback.

The second example is the British Guardian, which adopts a different approach. In addition to sectioning and providing social sharing on the newspaper's site, they are also trying out a different and bold idea: the Guardian Professional Networks. These are indeed thematic communities, where members share knowledge within the network itself and provide moderated access to socially produced materials. More generally, the Guardian gathers contributions provided directly by the readers and use them to edit the section on 'Opinions'. Despite the high sophistication of this feedback architecture, everything is still in the hands of the readers.

In the present paper, an innovative approach is proposed that makes extensive use of machine learning and semantics techniques. The main aim is to automatise the process of understanding both what is delivered by the newspaper in terms of articles, images, video clips and what people are talking about in social networks. The comprehension of 'what is going on' takes the form of what we call *topics* so that people can be grouped in clusters based on what they read and they discuss. These clusters are, therefore, considered as communities of persons who share one or more interests so that specific actions may be performed to try and engage them. Having an automated process for topic discovery and people clustering allows the ability to adapt the system to changes over time with little or no effort.

The rest of the paper is organised as follows: Sect. 2 reviews existing studies on the topic, while Sect. 3 frameworks the project within which the architecture, that is proposed in Sect. 4 and illustrated in details in Sect. 5 is developed. Finally, Sect. 6 takes conclusions and sketches further work.

2 Related Work

Majorly, problems of topic segregation and community detection are related to the problem of establishing the meaning of things as intended in a group of individuals, more than by one single individual. This is a rather complex point, that has interested scholars of different subareas of computer science, including some of the authors in [1–5].

There is an ample attention in many research areas of computer science and Information Engineering about the problems of community detection and the relationship between this problem and the topic classification of documents.

In particular, in video analysis, retrieval and markup there is a long stream of studies [6–10].

More generally, we have several important investigations on the theme of community detection that are referential. In particular, [11, 12] are works regarding the usage of machine learning techniques for community detection. The use of classic unsupervised learning techniques, applied to the detection of a set of individuals who interact with each other by observing their social behaviour, has also been studied in relation with social analysis measures, as in [13–15].

Specific topic-oriented communities are the subject of the investigation of Zhao et al. [16], whilst in [17–19] authors deal with the problem of multi-objectivity. Further on, the usage of semantic tools such as semantic networks is explored in [20]. Studies on community segregation based on social network analysis and graph theory is dealt with in [21, 22].

An important matter of the project is the topic analysis in documents that make use of more than one modality, as in the case of video with text, or image with text [23, 24].

3 The Project

This project is meant to define a system that performs searches over editorial contents (intended as newspaper articles, images and videos) using visual criteria. In particular, system capabilities ascribe to three main phases:

- Content Acquisition and Indexing;
- Automatic topic recognition;
- Search.

The working principles of the overall system are based on two separate processes: acquisition and search. In Fig. 1, these processes are represented, with respect to

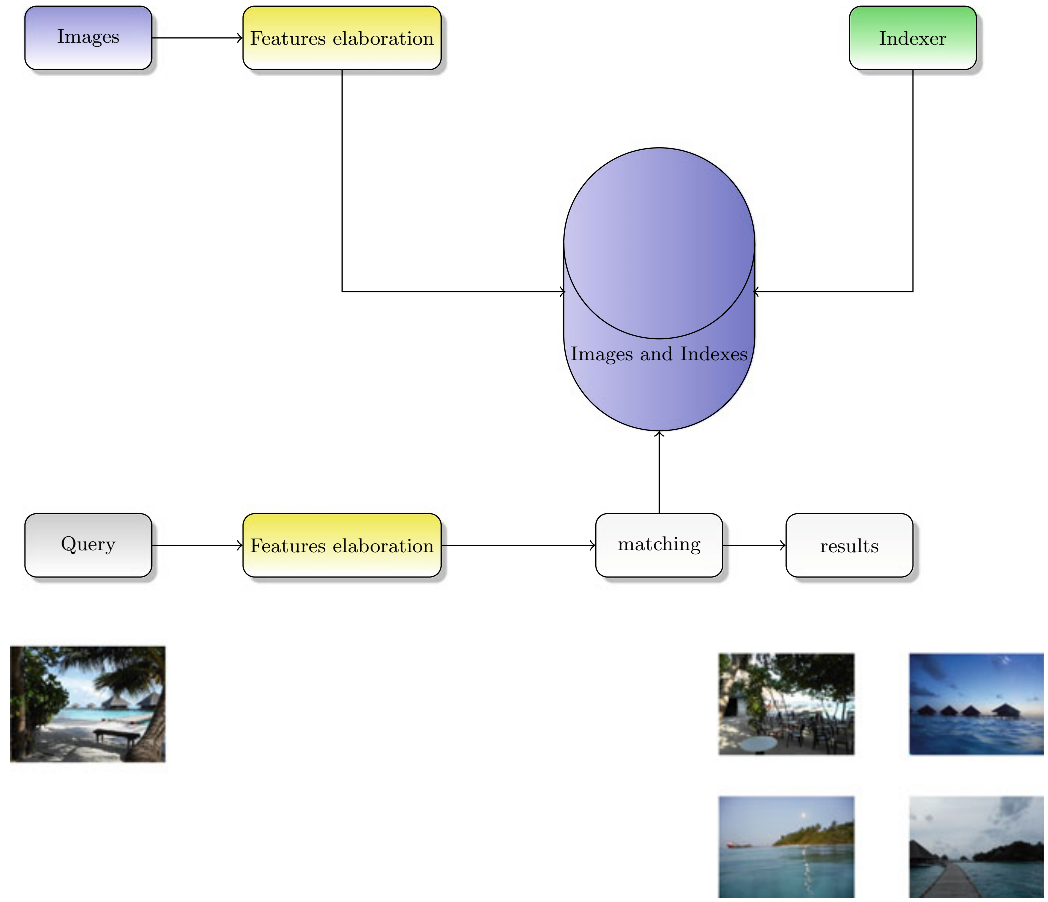

Fig. 1 Image indexing and retrieval

images only for the sake of simplicity: the Acquisition process is described in the upper half of the picture, while the lower half gives an idea of the Search process.

The perceived result is an engine that shall be queried to build thematic web sites. Such websites shall allow people with similar interests to both interact, and read/watch editorial material which likely adjusts to their preferences.

4 Proposed Solution

We propose an innovative multimedia approach involving the semantic analysis of text, image and video in order to build a single *Multimedia Semantic Database* (MSD). MSD is supposed to store connections and relationships between all digital assets.

The MSD shall be constantly updated as new content that is produced for the newspapers becomes available. In addition, *external* content that is produced by users on their social activities shall also be considered, together with access statistics coming from analytics systems such as Google Analytics and Chartbeat.

Contents might be geo-referenced to the relevant geographic area of the event or events described in the content. We shall test semantic analysis of video by implementing novel algorithms based on change-of-frame computer vision. We aim to be able to recognise people, objects and places shown in the video, as well as to weight the importance of each within the content. Semantic information extracted from the video shall be integrated with semantic analysis of the textual content associated to the video.

The knowledge of what we are publishing shall be merged with the understanding of what people talk about so that we can figure out our real placement in terms of how our information offer responds to people interests.

To implement the analysis engine, using the MSD, algorithms shall be designed and implemented to extract relevant information from all the available data, that is, to isolate 'signal' from 'noise'. This Artificial Intelligence analysis shall produce suggestions for

Topics in such a way that popular topics drive the establishment of new communities;

Themes/subjects which shall be provided as an input to the journalists for their day-to-day contributions;

Existing content taken from the newspaper digital archives, which may be (re-)used as additional content for the communities in addition to original content.

The analysis engine shall also take into account the performances from existing communities to detect 'fading' topics and hence suggest shifting efforts to existing or new topics that can gain a higher response from the audience.

The schema in Fig. 2 describes how we plan to implement this system.

4.1 Feature Extraction

Feature extraction shall be performed based on pure visual content on all editorial material available from the newspapers. In the current vision of the Project, such phase is meant to isolate the following characteristics:

- **Similarity score** as a normalised measure denoting how much the content of a text (respectively, an image or a video) is aligned to another text (or another image or video, respectively). Specifically, similarity degree shall be determined:
  - among texts by using *Natural Language Processing* (NLP) techniques such as the *bag of word*;
  - among images by using general and visual criteria, often but not only using the *bag of visual word* technique;
  - among videos (or between a video and an image) by using general and visual criteria, often but not only using the *bag of visual word* technique applied on each frame.

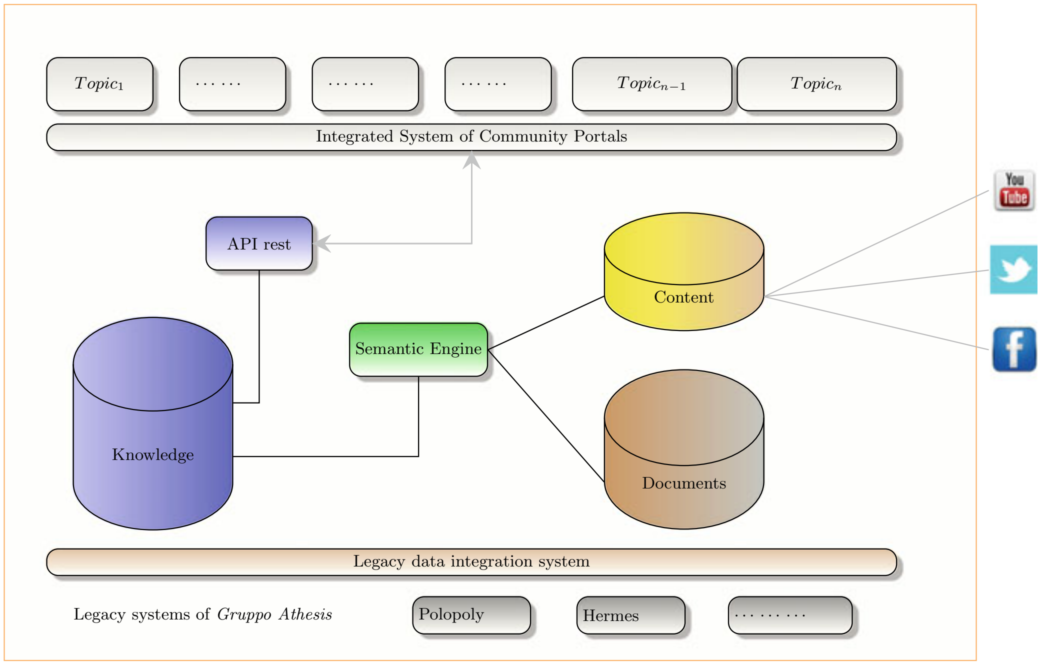

Fig. 2 General schema of the proposed solution

- **Place** that identifies:
  - the geographical areas whose names are present in a text by using syntactic and semantic similarity methodologies with other texts of which the places are known;
  - the geographical areas depicted in the image or video by using visual similarity with other images or videos of which the place is known.
- **Geolocation** intended as geographic coordinates by using either the place feature, or:
  - a query to a proper external service as regards texts;
  - the metadata included in the image or video file.
- **Faces**—applicable to images and videos—to identify people without person association, with the relative bounding box (in the image or in each frame of the video, respectively) and recognisable within a given resolution span.

4.2 *Topic Recognition*

Topic recognition, which enables the so-called *community segregation*, is the main area of scientific research in the Project. Three phases of investigation have been devised at the moment:

- The analysis of the current state-of-the-art solutions;
- The development of an improved algorithm;
- The comparison of the algorithmic solution against real-world datasets.

Several aspects shall be taken under consideration during the evaluation of such phases, in particular:

News aggregation by keywords, which has been tried in several practical cases and is not going to be used as a pure commodity, but investigated in all its evaluation parameters. These include basic (and rather obvious) parameters such as precision, recall and accuracy as well as more refined measures such as sensitivity of the aggregation function, and completeness against a keyword list;
Topic definition by keyword;
Topic labelling of news;
Community aggregation based on topics;
Correspondence of news and readers;
Ad-words and other advertisements aggregation to communities.

The final solution of the algorithmic method test shall be considered acceptable when satisfying levels of accuracy shall be reached comparing to literature milestones.

5 System Architecture

The proposed solution is based on ad hoc software developed using Java language programming and related technologies. The software architecture shall, therefore, be multi-tier and described in detail in the following paragraphs.

5.1 Enabling Technology

The enabling technology for this Project is a software we name *semantic engine*, where the knowledge about images, videos and texts is extracted and stored in compact data structures known as *feature vectors*.

Depending on the complexity of the object to be analysed, the vector might have a huge number of components such as text features, images features, audio or video features, so that the vector might belong to an n-dimensional vector space with n quite big. To optimise search in the n-dimensional feature space, similar feature vectors are clustered together using distance measures with respect to particular cluster representations called *centroids* (which denote their weighted middle points).

The semantic engine exposes several *web services* so that an external system may interact with these services to query the system. Among others, two web services shall be implemented.

- **Indexing web service**. In the indexing phase, an object has to be added to the knowledge base. The service accepts as input:
  - a file;
  - a text containing an identifier (*file id*);
  - a (optional) text with a brief description for the file;
  - a (optional) text containing the file id of a *reference file* (as an example, an image belonging to an article as well as the text shall have the id of the text as reference).

  The answer, formatted using *JSON* syntax, contains a text with an identifier (*protocol number*) of the file itself whose feature vector is now stored in the knowledge base.
- **Search web service**. The query object is analysed and the feature vector of the query object itself is extracted. The vector is then compared to other vectors in the knowledge base and the ones whose distance is below a certain threshold are given as an answer to the query. To speed up the search process, similarity is first computed between the object (*query*) and the centroid of each cluster. The clusters whose centroid is more similar (in other words, closer) to the query object are then used in the full search process using the full feature vector distance comparison.

  The service accepts as input either:
  - a file;
  - a text containing the protocol number of a file which is supposedly indexed in the knowledge base.

  The output of the service, formatted using *JSON* syntax, contains a list of the elements similar to the query object $[id, score]$, ordered by *score*.

5.2 Logic Model

The system is logically modelled as depicted in Fig. 3, and shall interoperate with *legacy systems* for content retrieval, *crawlers* for content retrieval from social networks and the *external world* through exposition of web services (see Sect. 5.1).

The modules reported in the figure have the following meaning.

Knowledge Base. This the database of the whole system, where all parameter data and the knowledge about content, usage, topics, texts, images, videos is stored.

Topic Recognition. This module has the responsibility of the semantic extraction of the correct number and definition of topics, grouping tighter those who are semantically correlated (hyponym, hyperonym and so on). This module shall have as input a document *corpus* and a desired maximum number of topics and give as output a set of topics and their definition. It stores all (partial) results in the **Knowledge Base**.

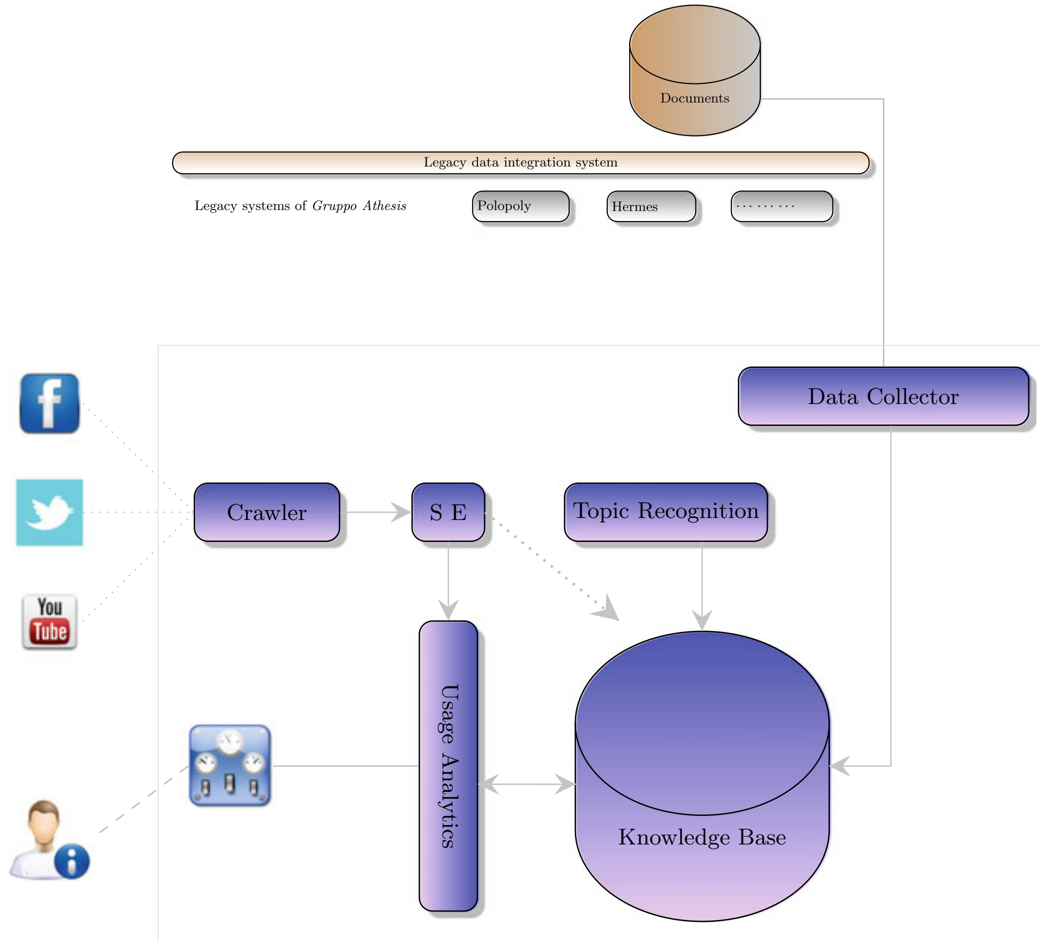

Fig. 3 Logical model of the system

Crawler. This module is responsible for the connection and data retrieval from social networks. It extracts and normalises contents to be delivered to the **SE**.

Data Collector. This component extracts and normalises contents from the database *Documenti*, which in turn collects items from several *legacy* systems. Normalised contents shall then be passed to the **SE**, and are also available to the **Topic Recognition** module.

SE. Acronym for *Semantic Engine*, this module interprets data coming from the **Crawler** and the **Data Collector** and performs all operations in order to extract the correct feature vector for a given content.

Usage Analytics. This module functions as a *business intelligence* module and extracts usage data from the logs so that content which are digitally published can be related to those indexed by the **SE** and the resulting information can be used to integrate the knowledge in the **Knowledge Base**.

6 Conclusions

In this paper, we dealt with the problem of defining a feasible architecture for a systematic detection and management of semantic communities.

The solution we have proposed is discussed and defined in detail. Also, we have dealt with the technicalities of the construction of such a system in the realm of digital news. The project development is active and the deployment of the devised architecture is forecasted. The future development of this study will be threefold:

- The analysis and comparison of the existing solutions in reference literature as discussed briefly in Sect. 2;
- The experimental evaluation of existing an possibly new techniques in the area of semantic community detection and analysis;
- The construction of a prototype solution for the core architectural system able to provide the above-mentioned features.

Several aspects of the project need to be developed, and some of these shall require an intense research effort, especially on the experimental side. In particular, this will challenge the research group on three aspects:

- The *community attribution effort* will be specifically devoted to determining adequate methods to isolate a group of individuals who share the same interests. Known problems related to this aspect are the ones of user profiling and community detection, see [25–28] for some recent results on the first problem and [29] for a survey on the second. This effort will be conducted on an experimental basis of websites and social network data.
- The *topic segregation effort* will aim at determining a group of documents that indeed refer to the same topic, or to a group of topics. Again, this is a research theme that has received some attention in the recent past as in [30, 31]. Again, we shall perform this effort on web documents.
- Finally, the *community shifting* processes, those in which an individual changes its position on a group have received indeed little attention in the artificial intelligence community.

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Part II
Multi-agent Systems

A Optimization Approach for Consensus in Multi-agent Systems

Carlos R. P. dos Santos Junior, José Reginaldo H. Carvalho and Heitor J. Savino

Abstract This work presents a method based on the application of optimization theory to minimize time for consensus in multi-agent systems. More specifically, the Nelder–Mead algorithm, modified for constrained problems, is utilized to compute an optimum matrix gain that minimizes time in an objective function related to consensus time. The paper presents the problem formulation, simulations, and results that prove the efficiency of optimization methods for this class of application.

Keywords Consensus · Multi-agent systems · Nelder–Mead optimization

1 Introduction

Researchers from several areas have increased their interest on multi-agent systems. One has, for instance, the coordinated control of unmanned aerial vehicles [1], flight formation [2], cooperative control of autonomous agents [3], distributed sensors networks [4], and satellite alignment [5]. These multi-agent applications have in common three aspects: (1) the dynamic nature of the system states; (2) the loosed coupling of agent dynamics; (3) the absence of a rigid link between agents and the working environment.

Some multi-agent solutions are, in essence, path planners. They solve combinatorial problems suited for static models [6, 7]. Other approaches model the problem as a MIMO system, with strong coupling among agents' states [8]. These solutions are not scalable, thus unfeasible for a large number of agents. The less obvious is

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the implication of the third aspect. In assuming no rigid link means that the agents cannot readily measure changes in the working environment. The lack of a rigid connection implies a degree of uncertainty of the states in both value and time. This uncertainty compromises the adequacy of the computed solution, when related to the overall stability of the system. For instance, in [9], the reader finds an interesting multi-agent modeling of Universal Mobile Telecommunications System (UMTS) network to optimize antennas alignment. However, the authors did not present a formal demonstration of stability. The solution is suitable for scenarios where changes in the working environment are either restricted or readily measurable, i.e., rigidly linked to the agents.

We can resume the problem of interest as to compute a control law that brings multiple loosed coupled mobile agents to an agreement on their states, and ensuring they will keep the agreement as long as necessary, using only information from their fellow agents. This subject, named as Consensus by the Computer Science community, is a class of distributed algorithm [10], and incorporates all three aspects mentioned in the first paragraph. We have a particular interest in Consensus theory applied to multiple autonomous vehicle systems [1].

The interaction dynamics among neighbors was first introduced in [11], by investigating the ordering of a system of particles that moves in a plane. In this work, the authors presented a discrete-time control law to update the direction of each particle with the value of its own added to the mean of the direction of the neighbors. The approach was able to drive all the agents to one direction without a centralized control. Then, [12] modeled the consensus of [11] by graph theory. The proposal considered the state values of its neighbors as bidirectional connections. Few years later, in [13], the authors addressed the various aspects of the Consensus Protocol, including fixed or variable network topologies, communication delays, and the directed or non-directed networks.

None of these works attempted to find a control law to speed-up time for consensus. In previous work of the authors, for heterogeneous agents, we managed to estimate the rate of consensus, but we did not control it [14]. The implicit assumption in all these works is that the consensus time is not constrained. However, there are scenarios where this assumption does not hold. For instance, the fast recovery of the agents in the occurrence of failure, or their reorganization to pass through obstacles, are examples associated with strong time constraints.

Optimization is a mathematical tool that consists on finding the minimum or maximum of a function of one or several variables, with values within a given region of a space with arbitrary dimension [15, 16]. The authors have a long experience in applying optimization theory to the control of dynamic systems [6, 14, 17–19]. In this work, we propose the use of an optimization method to compute the gain matrix to minimize consensus time of multi-agent systems, more specifically, the modified version of the Nelder–Mead algorithm for constraint problems. It is important to mention that the methodology proposed by this work is perfectly applicable in a real system. It is only necessary to consider the saturation of the actuators of the system agents.

The contribution of this work is twofold: to propose a general formulation for the time-constrained consensus problem, and to present a numeric solution based on the Nelder–Mead algorithm. The results show that the solution is considerably faster, without compromising the stability of the overall control law.

We organized the remaining of this paper as follows. Section 2 presents a description of the main concepts, Nelder–Mead Method and Algebraic Theory of Graphs. Section 3 formulates the problem. Section 4 presents the methodology used to implement the solution and, finally, Sect. 5 presents results that prove the efficiency of using optimization to minimize time for consensus in multi-agent systems.

2 Preliminaries

This work requires knowledge on optimization theory, and graph representation. Due to the limited space, we restrict ourselves to present: the Nelder–Mead optimization method [20] and few basic concepts of graphs [21].

2.1 *The Nelder–Mead Modified Method*

The Nelder–Mead Method modified for constrained problems is given in details in [22]. The method requires the objective function to be continuous, although not differentiable. Nelder–Mead method works with $n + 1$ points (n is the problem dimension) as the vertices of a polytope denominated simplex. Let us now consider the following definitions:

- $f(\cdot)$ is the objective function, evaluated on the vertices of the polytope;
- $\{b, w, s\} \subset \{1, \ldots, n + 1\}$ are the indexes of the vertex with the best, worst, and second worst values of the objective function, respectively;
- x_w is the centroid of the opposite edge, given by

$$\hat{x} = \frac{1}{n} \sum_{i=1, i \neq w}^{n+1} x_i$$

- $x_{op} = \hat{x} + \alpha(\hat{x} - x_w)$ is the basic Nelder–Mead operator.

At each iteration, the current point w is eliminated. The algorithm defines four operators by changing the value of α to create a new point, and the Shrink operator, all given as follows:

- **Reflection**: $x_r = x_{op}$ for $\alpha = 1$. It displaces the current solution by reflecting w in relation to x_w.
- **Expansion**: $x_e = x_{op}$ for $\alpha = 2$. It expands the simplex in the opposite direction of w and beyond the reflection point.

- **Internal Contraction**: $x_{c-} = x_{op}$ for $\alpha = -0.5$. It contracts the simplex in the opposite direction of w. The new vertex is inside the current simplex.
- **External Contraction**: $x_{c+} = x_{op}$ for $\alpha = 0.5$. It reflects and contracts the simplex in the opposite direction of w. The new vertex is outside the current simplex.
- **Shrink**: $x_i = x_b + \beta(x_i - x_b)$, $i = 1, \ldots, n+1, i \neq b$, $\beta = 0.5$. It will shrink the simplex in the direction of x_b.

If $f(x_r)$ is lower than $f(x_b)$, then the simplex moved to a direction that is worth expanding. Thus, x_e is computed. Otherwise, if x_r does not improve the objective function, the simplex may be close to the minimum. In this case, it applies external and internal contractions. When none of the operations find a new vertex better than the x_w, then the minimum point is assumed to be internal. The shrink operation is applied, preserving x_b, bringing the other vertices to its direction. The stopping criterion is generally based on the size of the simplex. For example, one can monitor the larger edge length $f(x_i) = ||x_i - x_b||_\infty$, $i = 1, \ldots, n$. If it is below a tolerance value, the method stops.

Algorithm 1 shows the core of the Nelder–Mead unconstrained method. As pointed out in [22], there are techniques to transform a bounded problem into an unconstrained problem. Please, refer to this reference for further details.

Algorithm 1 Nelder–Mead Algorithm

```
while stopping criterion not reached do
    Reflection;
    if f(x_r) < f(x_b) then
        Expansion;
    if f(x_e < f(x_r) then
        x_new = x_e;
    else
        x_new = x_r;
    if f(x_b) < f(x_r) < f(x_s) then
        x_new = x_r;
    else if f(x_s) < f(x_r) < f(x_w) then
        External Contraction;
    else if f(x_r) > f(x_w) then
        Internal Contraction;
    if f(x_c-) < f(x_w) then
        x_new = x_c-;
    else
        Shrink;
```

2.2 Algebraic Representation of Graphs

A graph is a representation of a set of nodes and edges. It can be directed or non-directed, connected or not connected. In a directed graph, the edges can be unidirectional, while in non-directed graphs they are bidirectional. The graph is connected if there is a path from one node to any other node, otherwise, the graph is not connected [21]. One can represent a graph as $\mathcal{G} = \{\mathcal{V}, \mathcal{E}, \mathcal{A}\}$, where $\mathcal{V}$, is the set of nodes, $\mathcal{E}$ the set of edges and $\mathcal{A}$ the adjacency matrix, defined by $a_{ii} = 0$ and $a_{ij} \geq 0$, with $a_{ij} > 0$ if there is an edge connecting the nodes v_i and v_j. The degree matrix of a graph is a diagonal matrix Δ with δ_{ii} the number of neighbors of i, and $\delta_{ij} = 0$ for $i \neq j$. Another important matrix of a graph is the Laplacian matrix $\mathcal{L}$, defined as $\mathcal{L} = \Delta - \mathcal{A}$ [21].

3 Problem Description

This section summarizes Consensus theory and the Laplacian matrix.

3.1 Multi-agent System Consensus Modeling

The multi-agent system can be written as a graph, with agents as nodes and communication links as edges. Here, the dynamics of each agent is given by

$$\dot{x}_i(t) = u_i(t),\ \ i = 1, 2, \ldots, n, \tag{1}$$

where $x_i(t) \in \mathbb{R}$ is the state and $u_i \in \mathbb{R}$ the control input of agent i, and n is the number of agents. The problem of consensus aims to bring agents' states (or a subset of them) to the same value, as specified by the control designer.

The protocol used to solve the consensus problem of the multi-agent system (1) is the same proposed in [12], presented below:

$$u_i(t) = -\sum_{j=1}^{n} a_{ij}\big(x_i(t) - x_j(t)\big). \tag{2}$$

Given the system dynamics (1) and the consensus protocol (2), with the Laplacian matrix one can write:

$$\dot{X}(t) = U(t) = -\mathcal{L}X(t) \tag{3}$$

as the representation that jointly considers all agents specific dynamics, and their communication protocol. Where $X(t) = [x_1(t) \quad x_2(t) \quad \cdots \quad x_n(t)]^T$, $U(t) = [u_1(t) \quad u_2(t) \quad \cdots \quad u_n(t)]^T$, and $\mathcal{L}$ is the associated Laplacian matrix.

There are several variants of the Consensus problem [23–25]. In this paper we consider homogeneous agents with first-order dynamics, due to its simplicity, without compromising generalization of the results.

As mentioned before, the multi-agent system reaches consensus when the specified states of all agents reach the same desired value. For stable systems, the progress of the states depends on the agents' initial conditions and the weights of communication links described in Laplacian matrix. Those are fixed parameters, thus the designer cannot use them to manipulate consensus time. We, then, define the following gain matrix K to enable consensus time control as a diagonal matrix $K = \mathrm{diag}\{k_1, k_2, \ldots, k_n\}$, where $k_1, k_2, \ldots, k_n$ are, respectively, the individual gain of agent $1, 2, \ldots, n$.

Matrix K allows consensus time control by changing the weights of the information exchange between agents. With the gain matrix in the model, we have:

$$\dot{X}(t) = -K\mathcal{L}X(t) \tag{4}$$

3.2 Optimization Problem Formulation

Lets consider the following first-order discretization of (4):

$$X(z+1) = X(z) - \epsilon K\mathcal{L}X(z) \tag{5}$$

Based on the model in (5), the goal is to find a matrix K that leads the discrete system to reach consensus within the shortest possible time. This is a constrained optimization problem formalized as

$$\min_{K} \quad t_c$$

$$subject\ to \quad K > 0$$

where K is the matrix gain and t_c the consensus time.

4 Consensus Time Minimization Method

The proposed method to optimize consensus time has three steps, detailed in the next subsections.

4.1 Understanding the System

To verify its behavior one need to simulate the system. We used MATLAB in all simulations. Figure 3-top-left presents the simulation for the directed graph of Fig. 1a. The initial conditions were $k_1 = 1$, $k_2 = 1$, $k_3 = 1$ and $k_4 = 1$ (i.e., without the influence of K, since it is unitary) and $X_0 = [1\ 2\ 3\ 4]^T$. The consensus time obtained for these conditions was 7.06 s.

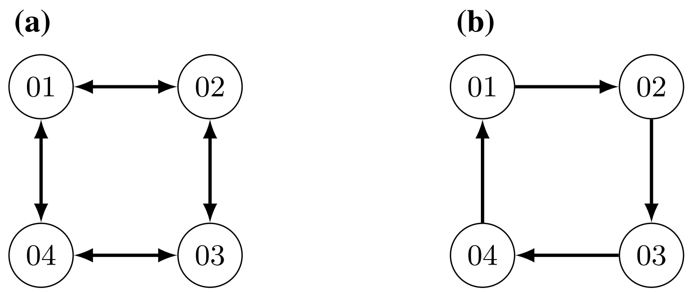

Fig. 1 **a** Non-directed graph; **b** Directed graph

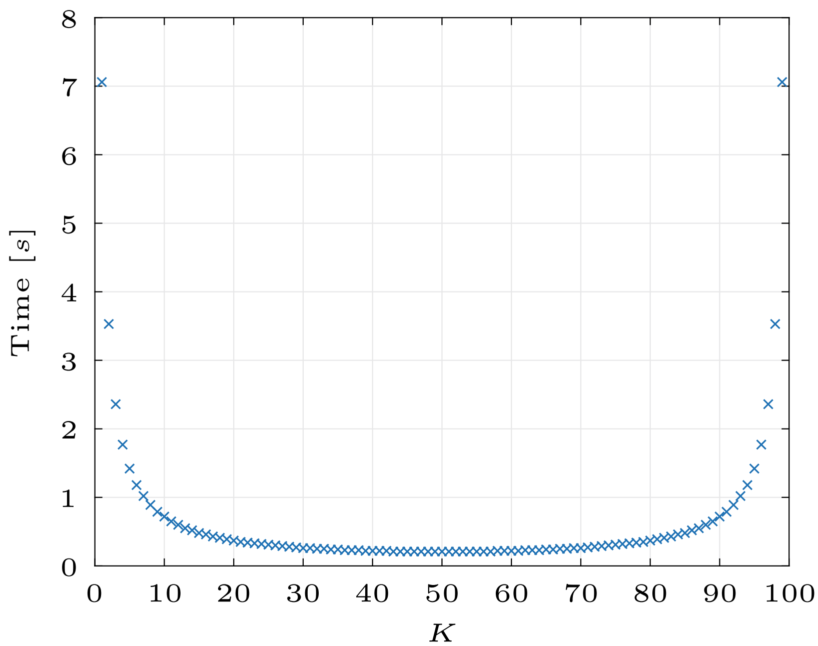

Fig. 2 Consensus time behavior for different values of K

4.2 Matrix K and Consensus Time

Next step is to understand how the gain matrix K influences consensus time. This step is important to define the initial Nelder–Mead simplex. We run one simulation for each $k_1 = k_2 = k_3 = k_4$ from 1 to 99. The simulation was set to stop when consensus was reached within a tolerance of 10^{-6}.

Figure 2 shows the resulting Consensus time for Graph A with the same initial conditions used in the first step for all matrix K. Note that the time for consensus reduces very quickly. The behavior is convex and nonlinear for the case of uniform increase on each gain k_i. The designer can use this information to decide for a simplex that will better fit the agents' input restrictions (i.e., to avoid saturation).

In this work, the objective function is the simulation time t_c. The optimization variable is the matrix K. Constraints are $K > 0$ and the states obey the system's dynamics.

4.3 Minimizing Consensus Time

The objective function has characteristics of a nonlinear and unimodal convex function with bounded variables. We applied the modified version of the Nelder–Mead method for constrained problems [22]. In the present case, matrix K are transformed to not be out of its bounds. As mentioned in Sect. 2, Nelder–Mead algorithm is robust, simple, and applicable to a broad class of problems. It only requires a continuous objective function and initial simplex for the search space. The Nelder–Mead Algorithm 1 is publicly available by Mathworks in the $fminsearchbnd$ function for MATLAB.[1]

4.4 Algorithm for Minimizing Consensus Time

We propose the following algorithm to compute the gain matrix. The input parameters are the system Laplacian matrix, the initial conditions, and the initial gain. The returning value is the optimum K that minimizes consensus time.

5 Results

To verify the efficiency of Algorithm 2, we applied it in a multi-agent system with dynamics as (5) with communication topology described by Graphs A and B (Fig. 1).

Algorithm 2 Minimum Consensus Time

1: Define the Multi-Agent System by $\mathcal{L}$
2: Set the initial conditions (X_0 and K_0)
3: Compute the natural consensus time ($k_1 = k_2 = k_3 = k_4 = 1$)
4: Model the Objective Function
5: Find K that Minimizes Consensus Time (K^*)

Table 1 show the optimal gain matrix and its resulting consensus time. Figure 3-left and right illustrate the behavior of the system for Graphs A and B, respectively,

[1] A detailed explanation of this function may be found at https://www.mathworks.com/matlabcentral/fileexchange/8277-fminsearchbnd-fminsearchcon.

Table 1 Comparing initial and optimal solutions

	Graph A		Graph B	
	Initial K	Optimum K	Initial K	Optimum K
	$k_1 = 1$	$k_1 = 19.9$	$k_1 = 1$	$k_1 = 19.9$
	$k_2 = 1$	$k_2 = 17.7$	$k_2 = 1$	$k_2 = 19.6$
	$k_3 = 1$	$k_3 = 17.3$	$k_3 = 1$	$k_3 = 19.9$
	$k_4 = 1$	$k_4 = 19.6$	$k_4 = 1$	$k_4 = 19.9$
Consensus time (s)	7.06	0.39	3.50	0.14
Initial condition	$X_0 = [1 \quad 2 \quad 3 \quad 4]^T$			

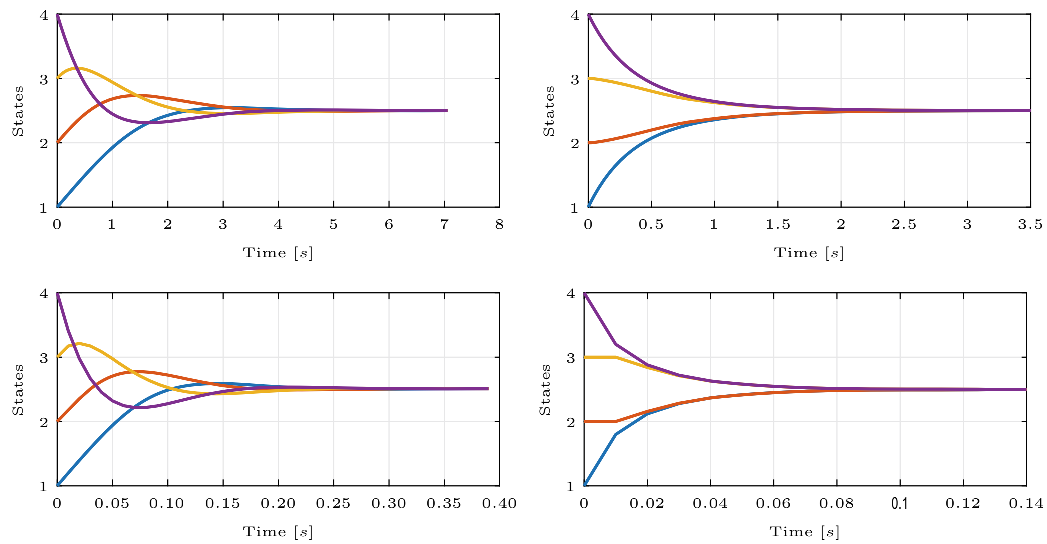

Fig. 3 Natural (top) and Minimized (bottom) consensus time for the multi-agent system of Graph A (left column) and Graph B (right column)

with the initial (top) and optimal gains (bottom). One can readily verify a strong reduction in consensus time.

Concerning system stability (4), $K > 0$ constraint implies that the matrix of gains K will vary in a positive interval. As a consequence, a demonstration presented in [26] ensures the stability of the system for any initial condition.

Final Considerations

This work proposed a method to minimize time for Consensus in multi-agent systems. The Algorithm 2 summarizes the method in a way it can be easily reproduced. The results showed that the gain matrix K found (within the constrained limits) is effectively the one that brings the system to consensus with the shortest possible time.

The modified Nelder–Mead optimization method is very convenient due to its simplicity. One can implement it in any programming language. The results were encouraging in pursuing a faster multi-agent system capable to cope with on-the-fly changes in the topology or dealing with failures.

For future work, we plan to implement and compare other optimization methods. Furthermore, we intend to extend the work to multi-agent systems with heterogeneous dynamics, with different consensus protocols and for systems of higher order. We also intend to implement this method in a real system composed of mobile robots.

By dealing with the time variable, the proposed method promotes the use of consensus theory in actual systems. It is necessary to consider the saturation of the actuators of agents, though. This is also planned as future work.

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A Multi-agent Model for Cell Population

Fernando Arroyo, Victor Mitrana, Andrei Păun and Mihaela Păun

Abstract An intriguing problem in computer science is the formal description of dynamics in cell populations. We propose here a multi-agent-based model that could be used in this respect. The model proposed in this paper consists of biological entities (cells) as agents and a biochemical environment. Both are represented by multisets of symbols. The environment evolution is regulated by multiset Lindenmayer rules depending on the current state of all agents, while the evolution of each agent, which depends on the environment current state, is defined by means of multiset patterns. We discuss some algorithmic problems related to the dynamics of the proposed multi-agent model: infinite and stationary evolution, environment, and agent reachability.

Keywords Multiset · Multiset L-rule · Multiset pattern · Cell population · Multi-agent system

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1 Introduction

A multi-agent system is widely understood as a system consisting of two main parts: different types of entities, called *agents*, and their virtual or physical *environment*. Agents can be fully cognitive (human individuals or teams) or less cognitive (robots, software products, animals, etc.) Actually, there are many real systems of such type in economics, sociology, robotics, etc. We refer to [12] for more motivations and applications in engineering and technology, as well as for different connections with other disciplines. We consider here a multi-agent system with biological entities (cells) as agents and a biochemical environment. Description of the dynamics of evolving cell populations is an intriguing mechanism which has been of interest in current computer science research.

Nowadays, the access to massive, reliable, and less expensive biological data is possible due to the new technologies in the of biological data acquisition. However, there are still some issues regarding the integration of this biological information in databases. The multi-agent paradigm could be useful in this respect. Such an approach is [5], which proposes a multi-agent system for modeling the protein synthesis. The main idea is to model the dynamic behavior and the interactions that characterize the protein synthesis processes. Along the same lines, an attempt to model cell behavior in systems biology that is based on intracellular biochemical pathway is reported in [15]. Agents are representing cells and integrate a fuzzy model for the intracellular biochemical pathway. It is a long-standing debate about the role of environment in multi-agent systems. Some authors assign limited responsibilities to the environment while others consider that both structure and activity of the environment are essential for multi-agent systems, see e.g., [20] for a nice overview. A critical analysis of the use of multi-agent systems for performing simulations of biological processes in amply discussed in [1]. On the one hand, the possibility of associating different elements of a biological process to independent computing entities, called agents, makes multi-agent systems a powerful and flexible tool for simulation from a theoretical point of view. On the other hand, the weak validation of the results obtained makes the simulations based on multi-agent systems hard to trust. However, it is widely accepted that multi-agent systems may provide an interesting way to design and implement simulations of biological systems.

We stick ourselves to the opinion that both structure and activity of the environment are essential for multi-agent systems. Another hypothesis which we support is that both the evolution of environment and agents can be described by strings of symbols or multisets of symbols over a given alphabet. In this paper, we prefer to describe both the environment and the agents by multisets of symbols because the linear order of strings does not bring any further information. Thus, each agent is a cell population, each cell being represented by a symbol. As the population may contain multiple copies of the same cell, we use a multiset of symbols. Each agent evolves in accordance with the current state of the environment, but also depending on the current state of the other agents. On the other hand, the environment components are also represented by symbols over other sets than that for agents. The

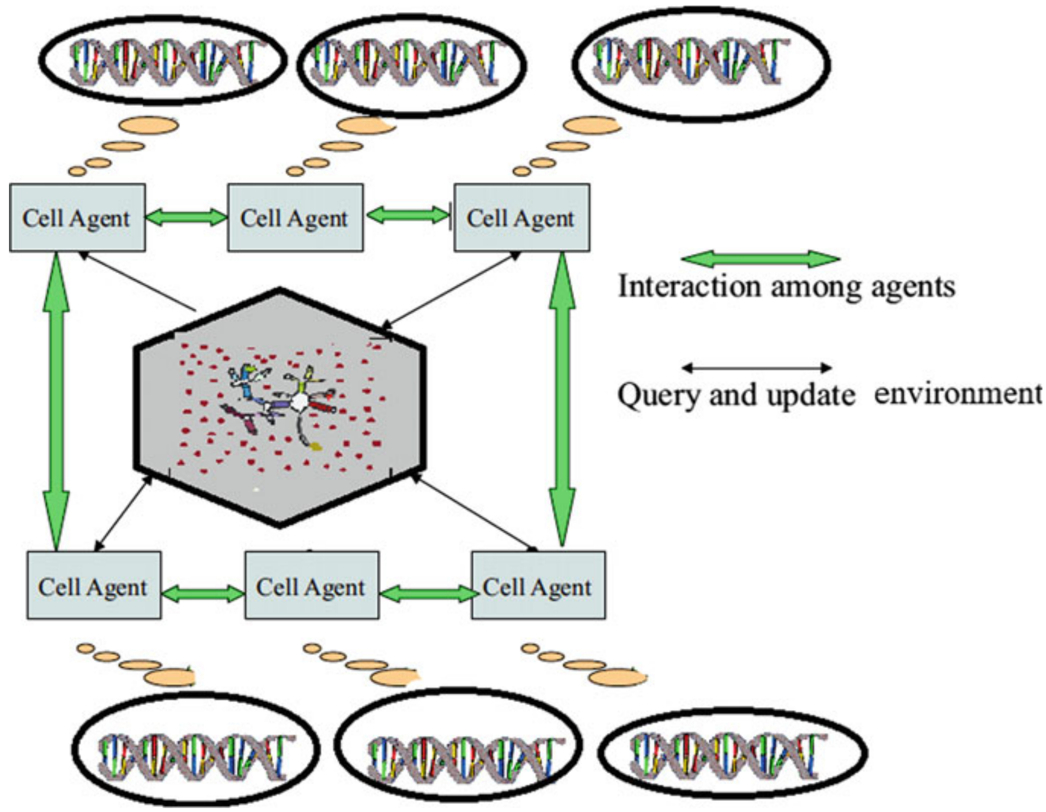

Fig. 1 Multi-agent system with cells as agents

environment evolves by its own rules chosen in accordance with the states of agents. A schematic view of a multi-agent system considered in this paper is illustrated in Fig. 1.

In his book [8], Artificial Life was defined by Chris Langton as "the study of man-made systems that exhibit behaviors characteristic of natural living systems". The primary goal of this field is to create and study artificial organisms that mimic natural organisms. But we cannot settle this problem unless we have a general definition of an alive organism. The first property associated with life in [8] is:

"Life is a *pattern* in spacetime, rather than a specific material object". Most of the cells of a real being are replaced many times during its lifetime. It is the pattern and the set of relationships that are important, rather than a specific identity of the atoms. Starting from such considerations, we define a multi-agent model based on patterns for cell population.

In the next section, we present some basic definitions and notations. We define what a multiset is and which are the operations on multisets. Then we define the Lindenmayer system on multisets. The second section ends with a discussion about patterns on multisets which assures all the preparatives for the introduction of our model. In the third section, after introducing our model, we emphasize some of its main characteristics. In the last section, we present some relevant problems and conclude with some directions for further research.

2 Preliminaries

In [6], a formalism based on multiset rewriting, called *constraint multiset grammar* was introduced with the aim of providing a high-level framework for the definition of visual languages. Constraint multiset grammars were investigated in [10] with a view to the parsing complexity of visual languages. These grammars may be viewed as a bridge between the usual string grammars, dealing with string rewriting, and constraint logic programs, dealing with set rewriting. Other devices based on multiset rewriting have been reported in [18, 19] where *abstract rewriting multiset systems* were used for modeling some features of the population development in artificial cell systems.

For a finite set A, we denote by $card(A)$ the cardinality of A. A finite *multiset* over a finite set A is a mapping $\sigma : A \longrightarrow \mathbb{N}$; $\sigma(a)$ expresses the number of copies of $a \in A$ in the multiset σ. The *empty multiset* over a set A is denoted by ε_A, that is $\varepsilon_A(a) = 0$ for all $a \in A$. We use the same notation for the *empty set* and *empty macroset*, namely $\emptyset$.

In what follows, a multiset containing the elements $b_1, b_2, \ldots, b_r$ any of them possibly with repetitions, will be denoted by $\langle b_1, b_2, \ldots, b_r \rangle$. Each multiset σ over a set A of cardinality n may also be viewed as an array of size n with nonnegative entries.

The set of all multisets over A is denoted by $A^{\#}$. A subset of $A^{\#}$ is called *macroset* over A. The *weight* of a multiset σ as above is $\| \sigma \| = \sum_{a \in A} \sigma(a)$, and $\| \sigma \|_B = \sum_{b \in B} \sigma(b)$ for any subset B of A.

Normally, we use lowercase Greek letters for multisets and capital Greek letters for macrosets. For two multisets σ, τ over the set A, we define

- the addition multiset $\sigma + \tau$ with $(\sigma + \tau)(a) = \sigma(a) + \tau(a)$ for all $a \in A$;
- the difference multiset $\sigma - \tau$ with $(\sigma - \tau)(a) = \max(\sigma(a) - \tau(a), 0)$ for each $a \in A$;
- scalar multiplication multiset $c\sigma$, with $c \in \mathbb{N}$, with $(c\sigma)(a) = c\sigma(a)$ for all $a \in A$.

We now introduce the multiset Lindenmayer system (L-system) as a multiset counterpart of Lindenmayer systems introduced in [9]. String L-systems were introduced and developed in 1968 by Aristid Lindenmayer, see [9], who used these systems to describe the behavior of plant cells and to model the growth processes of plant development. L-systems have received a lot of interest from the computer science community as they have turned out to be very useful in different areas: cell biology modeling [13], image processing [17], fractals generation [14], etc. A nice mathematical theory of L-systems was developed in [16]. A multiset L-system is a triple $\mathcal{L} = (V, P, \sigma)$, where V is a finite set of symbols, σ is a multiset over V, and P is a mapping that associates a finite set of multisets over V with every symbol in V. Given a multiset L-system $\mathcal{L} = (V, P, \sigma)$, an infinite sequence of macrosets can be obtained as follows:

$$\tau^0(\mathcal{L}) = \sigma, \tag{1}$$

$$\tau^{n+1}(\mathcal{L}) = \{\theta \mid \theta(a) = \sum_{b \in V} \mu(b) \times P(b)(a), a \in V, \mu \in \tau^n(\mathcal{L})\}. \tag{2}$$

A *multiset pattern* is understood in this paper as a multiset containing two types of symbols: constants and variables. This definition and the interpretation of a multiset pattern follows the Angluin's work [2], where string patterns have been introduced. Let T and V be two disjoint sets of constants and variables, respectively. Each multiset over $V \cup T$ containing at least one variable is called multiset pattern.

Given a multiset pattern α over $V \cup T$, denote by $H_{V,T}$ the set of mappings $h : V \to T^{\#}$. The interpretation of α is defined, analogously to the string case [7], as the multiset

$$L(\alpha) = \{\alpha - \beta + \gamma \mid \beta(a) = \begin{cases} \alpha(a), & \text{if } a \in V \\ 0, & \text{if } a \in T \end{cases}, \tag{3}$$

$$\gamma(a) = \sum_{X \in V} h(X)(a) \times \alpha(X)\}. \tag{4}$$

We now consider the concept of multiset pattern systems similarly to that introduced in [11]. The idea is to consider a set of multiset patterns and a set of starting constant multisets, associated with each variable. All multiset patterns cooperate in a dynamic manner in the process of generating new multisets. Given a finite set of constant multisets for each variable, we uniformly replace the variables occurring in multiset patterns by constant multisets in the given set, thus obtaining a new sequence of constant multisets, and the process restarts. Only multisets in the previous step participate to produce new multisets. In other words, in a multiset pattern system, not everything can be substituted for variables. Formally,

A *multiset pattern system* is a construct $\mathcal{P} = (V, T, p, t)$, where p and t are mappings that associate with each variable a set of multiset patterns and a set of multisets, respectively.

A multiset pattern system, $\mathcal{P} = (V, T, p, t)$, $V = \{X_1, X_2, \ldots, X_n\}$, generates the following sequence of n-tuples of constant multisets, recursively, as follows:

- $(\sigma_1^{(0)}, \ldots, \sigma_n^{(0)}) \in D^{(0)}(\mathcal{P})$ iff $\sigma_j^{(0)} \in t(X_j)$, $1 \le j \le n$,
- $(\sigma_1^{(i+1)}, \ldots, \sigma_n^{(i+1)}) \in D^{(i+1)}(\mathcal{P})$ iff exists $(\sigma_1^{(i)}, \ldots, \sigma_n^{(i)}) \in D^{(i)}(\mathcal{P})$, $\alpha_j \in p(X_j)$, $1 \le j \le n$, such that $\sigma_j^{(i+1)}$ results from a $\alpha_j \in p(X_j)$, $1 \le j \le n$, by substituting all occurrences of X_1 by $\sigma_1^{(i)}$, X_2 by $\sigma_2^{(i)}$ and so forth.

A pattern system $\mathcal{P} = (V, T, p, t)$ is said to be *deterministic* if for all $X \in V$ we have $card(p(X)) = card(t(X)) = 1$.

3 The Multi-agent Model

In the sequel, we give the formal definition of our model. A *multi-agent system for cell population* (MASCP for short) is a construct

$$\mathcal{G} = (E, R, \sigma_0, V_A, T_A, p, t, F, g), \tag{5}$$

where

- E, V_A, T_A are pairwise disjoint sets of symbols, $\sigma_0 \in E^{\#}$,
- R is a finite set of multiset L-rules of the form $a \to \tau, a \in E, \tau \in E^{\#}$,
- p and t are mappings from V_A into the nonempty finite macrosets of multiset patterns over $V_A \cup T_A$ and multisets over T_A, respectively,
- $F = \{f_X : E^{\#} \to 2^{p(X)} \mid X \in V_A\}$
- $g : (T_A^{\#})^n \to 2^R$, where $n = card(V_A)$, with $\varphi(\sigma_1, \ldots, \sigma_n)$ containing at least one multiset L-rule as above with a in its left-hand side, for all a in E.

These elements may be interpreted as follows:

- E is the set of symbols describing the environment;
- R is the set of all evolution rules of the environment;
- σ_0 is the initial description of the environment;
- V_A is the set of variables denoting the agents;
- T_A is the set of symbols for describing the states of the agents;
- $p(X)$ is the set of all multiset patterns associated to the agent X;
- $t(X)$ is the set of all initial descriptions (states) of X;
- f_X is the mapping for selecting the multiset patterns which describe the actual evolution of X, depending on the environment state;
- g selects the rules for the evolution of the environment, depending on all states of the agents.

A configuration of the MASCP is described by the $n + 1$-tuple

$$C = (\sigma_E, \sigma_1, \sigma_2, \ldots, \sigma_n), \tag{6}$$

where $\sigma_E \in E^{\#}, \sigma_i \in T_A^{\#}, 1 \le i \le n$.

Assume that $V_A = \{X_1, \ldots, X_n\}$, for some $n \ge 0$. A configuration

$$C = (\sigma_E, \sigma_1, \sigma_2, \ldots, \sigma_n) \tag{7}$$

is called initial if

$$\sigma_E = \sigma_0, \sigma_i \in t(X_i), 1 \le i \le n. \tag{8}$$

Now, we are able to define the working mode of this model. Let us consider two configurations $C = (\sigma_E, \sigma_1, \sigma_2, \ldots, \sigma_n)$ and $C' = (\sigma'_E, \sigma'_1, \sigma'_2, \ldots, \sigma'_n)$. We write $C \Rightarrow C'$ if

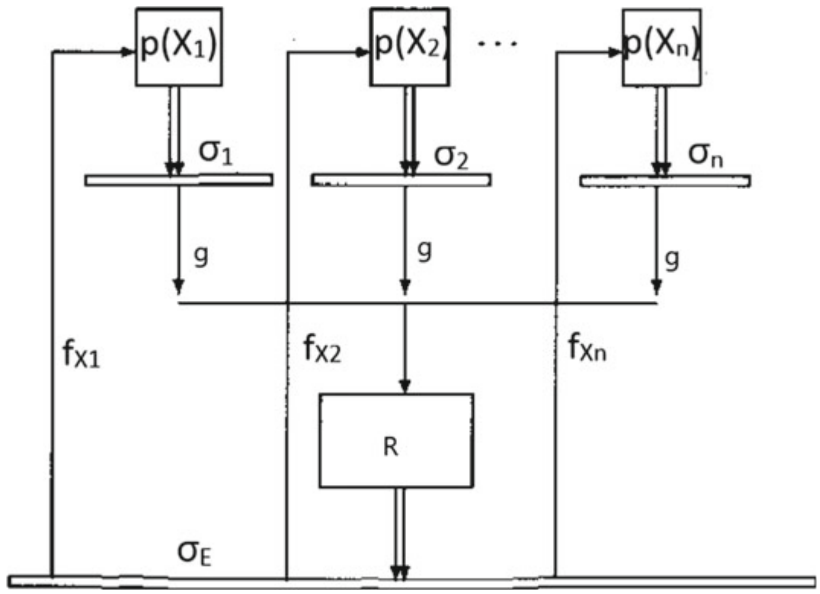

Fig. 2 Multi-agent system for cell population

1. σ'_E is obtained from σ_E, by applying multiset L-rules in the set $g(\sigma_1, \ldots, \sigma_n)$;
2. σ'_i, $1 \leq i \leq n$, is obtained from the interpretation of a multiset pattern $\alpha \in f_{X_i}(\sigma_E)$ by substituting all occurrences of X_j by σ_j, $1 \leq j \leq n$.

Schematically, the model can be represented as in Fig. 2. The arrows indicate the dependence of sets of multiset patterns on the pattern describing the environment as well as the dependence of the multiset L-rules on the multiset patterns describing the current state of agents. The double arrow represents the use of multiset L-rules in the evolution of environment and the interpretations of multiset patterns chosen for the evolution of agents.

At this stage, we want to point out some characteristics of our model.

1. There is assumed a universal clock, which marks uniformly time units, the same for all components of the system. Unfortunately, there is no dependence of the process on different time units.
2. The multiset patterns which characterize the evolution of the agents depend on the environment state (at a given moment, a subset of all multiset patterns associated to an agent is chosen).
3. Every agent can act on the other agents.
4. The evolution of the environment depends on the states of the agents.
5. The evolution rules of the environment are multiset L-rules.
6. We have an asymmetry between evolution and action.
7. The new configurations are obtained due to a derivation-like process owing to the multiset pattern system associated to the agents.
8. In our model the distinction between the environment and the agents is illustrated by the different model of their evolution: multiset L-rules for the environment and multiset patterns for the agents.

9. There is no priority of the actions of agents on the environment or on the other agents or vice versa.
10. In our system the agents cannot act directly on the environment state, they can determine which evolution rules are proper to change the actual state of the environment. This is very different from other models where each agent uses at most one action rule, directly on the environment state, in each time unit.

Let $C_1, C_2, \ldots C_m, \ldots$ be a sequence of configurations such that $C_i \Rightarrow C_{i+1}$, for all $i \geq 1$. If

$$C_i = (\sigma_E^{(i)}, \sigma_1^{(i)}, \ldots \sigma_n^{(i)}), \tag{9}$$

$i \geq 1$, we say that:

– The macroset describing the environment evolution (the set of all environment states) is defined by $\mathcal{M}_E(\mathcal{G}) = \{\sigma_E^{(i)} \mid i \geq 1\}$.
– The macroset describing the evolution of the k-th agent (the set of all states of the k-th agent) is defined by $\mathcal{M}_k(\mathcal{G}) = \{\sigma_k^{(i)} \mid i \geq 1\}$.

We say that a MASCP

$$\mathcal{G} = (E, R, \sigma_0, V_A, T_A, p, t, F, g) \tag{10}$$

is deterministic if

(i) $card(t(X)) = card(f_X(\sigma)) = 1, X \in V_A, \sigma \in E^{\#}$.
(ii) For each $(\sigma_1, \ldots, \sigma_n) \in (T_A^{\#})^n$, $g(\sigma_1, \ldots, \sigma_n)$ contains exactly one multiset rule for each symbol $a \in E$.

It is worth having a brief discussion about the possible ways of enhancing the model in the aim of a more versatile model. As the dynamic of cell population is high, it would be desirable to consider a multi-agent system with a variable number of agents. In such a scenario, one or more agents can disappear (that population dies) or enter into the system (new populations arise). This can be accomplished by allowing the mappings f_{X_i} to select either the option to eliminate the agent X_i or to create a copy of this agent which could evolve differently than the original one. The second situation is a bit more complicated when the next state of the environment is defined. Remember that the environment evolution depends on the current states of all agents. If an agent is missing, one can consider that its state is described by the empty multiset. However, if at a given moment there are more agents than in the initial state, how is it defined the multiset L-rules that change the current state of the environment? A feasible possibility could be that all agents entering the system as a result of division, are associated with the same variable as that of the original agent. We do not give here the formal definition of this variant of our model, but the reader can easily do it.

4 Conclusion and Some Relevant Problems

Although many approaches based on multi-agent system have been proposed simulating the behavior of cells or cell populations, we formulate here a first comprehensive design of a multi- agent system where the data are organized as multisets and the dynamics is distributed: the dynamic of environment is based on multiset Lindenmayer systems while the dynamics of agents is based on multiset pattern interpretation. Due to these computational characteristics, we hope that our system might be implemented using a suitable software. Several algorithmic problems that are relevant and attractive in our opinion are considered below.

1. *Infinite evolution*: Given a MASCP, is it algorithmically decidable whether or not the system evolves indefinitely? More precisely, is it possible to have an infinite sequence of configurations $C_1, C_2, \dots C_m, \dots$ without repetitions?
2. *Stationary evolution*: As a variant of the previous problem, one may ask whether or not a given MASCP system enters eventually a stationary evolution, that is the infinite sequence of configurations $C_1, C_2, \dots C_m, \dots$ contains only identical configurations starting from a given moment?
3. *Environment reachability*: Given a MASCP is it algorithmically decidable whether or not the system reaches a given state of the environment? Formally, given a MASCP with an infinite sequence of configurations C_1, C_2, $\dots$ C_m, $\dots$, and a multiset μ over the set of symbols associated with the environment, is there a configuration C_k such that $\sigma_E^{(k)} = \mu$?
4. *Agent reachability*: A similar problem may be asked for an agent.

Clearly, the answers depend mainly on the complexity of the functions in F as well as that of the function g. It is obvious that none of the above problems is decidable provided that at least one of these functions is not algorithmically computable. On the other hand, an algorithm for solving the third problem in the above enumeration can be constructed based on an idea from [4], provided that the functions in F as well g are defined by the membership of their arguments to the macroset accepted by a multiset finite automaton [3]. This algorithm could be adapted to solve the last problem as well but it is expected to be highly time inefficient.

We finish this note by emphasizing that two completely new concepts have been introduced here: multiset Lindenmayer systems and multiset patterns. We consider that an investigation of the computational properties of them are of interest. We hope to return with formal answers to these problems and other results having relevance from the Artificial Life point of view, in a forthcoming paper.

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Improving Water Allocation Using Multi-agent Negotiation Mechanisms

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Abstract This paper describes a multi-agent irrigation management system that can be used to distribute water efficiently among farmers in a community irrigation scheme during water scarcity. Each farm is represented as an agent that can calculate how much water is needed in the farm and hence estimate the marginal profit for the farm based on how much water is available. During water scarcity such as drought, some farmers would face water shortages and some would have excess water for irrigation. To ensure efficient water distribution, those farmers with excess water should share their water with other farmers needing water. In this study, we used the auction mechanism to distribute water efficiently among the farmers with the objective of maximizing the farmer's expected utility (profit margin). Our preliminary experiments showed that water distribution using an auction mechanism yielded a higher profit margin for all farmers in a community irrigation scheme when compared to direct negotiation strategy with a fixed price.

Keywords Multi-agent negotiation · Water allocation · Auction mechanism · Water scarcity

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1 Introduction

Water demand for irrigation in Canterbury has been increasing in the past 20 years. The New Zealand statistic data shows that irrigated areas in Canterbury have increased by 200,000 ha from 2002 to 2015 [1]. It is expected that water demand will affect the water allocation scheme in this region in the future. Currently, access to water is controlled by the government. However, farmers can apply for water consent to irrigate their areas. Water consent requests are processed and determined in the order they are received (on a first come first serve basis). This policy has worked in the past because the water demand and the total irrigated area were in equilibrium. However, the processing method based on first come first serve is no longer efficient as the demand for water has increased but the water capacity in Canterbury remains unchanged [2]. Moreover, where water availability is not sufficient, this approach cannot ensure water allocation to the most productive use. Therefore, community irrigation scheme is in practice, where farmers get water with high reliability and flexibility. Under this scheme, water is distributed to shareholders through a piped system and water consent is obtained by the community irrigation scheme. Shareholders have to pay for their shares based on the size of the farm and water charges on an annual basis. However, a request for the required irrigation must be done one day in advance. This scheme provides water to the shareholders based on their demand provided that there is enough water to meet the demand. If available water is not sufficient to meet 100% of the demand, then the distribution is reduced proportionally.

Since farmers need to estimate their water usage for farming and pay for it, they need to consider many aspects in the farm such as the size of the farm, the crops to be planted as well as the soil condition. If farmers overestimate, they risk paying more for the water and they will have unused excess water. If they underestimate, then they may run into water shortages which will result in poor crop yields, which in turn affect their profit. This becomes more serious during drought season when water is scarcer. Ideally, if farmers can decide on the irrigation plan that is dependent on the importance of the crops, they can keep their productivity and profit margin during water restriction [3]. In a community irrigation scheme, during water scarcity, there are farmers who have excess water and farmers who have water shortages and it would be beneficial if farmers with excess water can extend this water to their counterparts who are facing water shortages. Unfortunately, these farmers do not have an efficient mechanism for selling or buying water from others when the situation arises.

In our previous work, we have developed an agent-based water management system that can be used by farmers to calculate the water requirement in the farm based on the types of crop, the soil condition, and the size of the farm. However, this application can only be used for a single farm [3]. In this paper, we described the extension of this work to a multi-agent system to improve water allocation and to investigate efficient water distribution mechanisms among the farmers in a community irrigation scheme. Each farm is represented as an intelligent agent that can work out the actual water needed for that farm at any given time. The agent can also work out the water shortage/excess for that farm as well as the marginal profit of that farm at any particular time (in this case, during drought season when water distribution is reduced). Each agent makes a decision on behalf of the farmer whether to buy or sell water and at what cost. These agents negotiate with each other to buy and sell water with the aim of maximizing their profit margins. In this preliminary experiment, we compared two negotiation strategies (the direct negotiation with a fixed price and first-price sealed bid auction) and observed the additional profit obtained by the sellers and the total loss reduction for all the farmers in the community. This work advances the state of the art as it proposes a multi-agent irrigation management system that can allocate water efficiently in a farming community. This system consists of multiple agents that can make a decision on behalf of the farmers whether to buy or sell water and negotiate with each other using negotiation strategies with the objective of maximizing their own profit margin. The remainder of this paper is organized as follows. Section 2 describes the overview of irrigation system and water requirement estimation, auction process and agent irrigation management. The proposed multi-agent for irrigation management is discussed in Sect. 3. The initial experiment and results are discussed in Sect. 4. Finally, Sect. 5 concludes and discusses future works.

2 Related Works

2.1 Irrigation Water Need and Tools

There are three stages in the cycle of crop growth; (1) soil preparation, (2) irrigation process, and (3) after irrigation process. Farmers needs to work out an irrigation plan based on crop evapotranspiration (ET) and crop coefficient (K_c) [4]. ET is the summation of plant transpiration and evaporation from the soil. The K_c value is determined based on the crop's growth stage. Currently, there are computing tools that use ET and K_c factors to estimate irrigation water need and crop planning. The most popular ones are IrriCalc and OVERSEER. The irrigation water need formula is defined by the Food and Agriculture Organization (FAO) [5]. Both OVERSEER and IrriCalc follow the crop water need formula (1) to estimate the crop water need. However, both tools can only be used to calculate for a single crop farm and they do not provide an option for multiple crops water calculation [5, 6]. The crop water need calculation is as follows:

$$ET_{crop} = ET_0 \times K_C \tag{1}$$

In this equation, ET_{crop} is the crop water need, ET_0 is the influence of climate on crop water need, and K_C is the influence of crop type on crop water need. Based on the crop water need, farmers can then estimate the water requirement and the cost of water for their yearly farming schedule. The farmer can also estimate the total profit for their farm. During the water restriction scheme, they make a decision on which crops should have higher irrigation priority (usually based on which crops yield higher profit).

2.2 Margin Value and Crop Value

The profit margin for crop productivity can be calculated using the following formula [7];.

$$V_{profit} = Total\ Revenue - Total\ Cost \tag{2}$$

V_{profit} is total profit on the farm which is calculated by subtracting the farming cost (Total Cost) from the crop revenue (Total Revenue). The crop revenue varies by plot size, the value of crop (price per kilogram), and harvesting season. The farming cost includes the water consent fee, purchases of fertilizers (dollar/hectare), labor charges, etc. The goal is to obtain as much profit as possible.

2.3 Multi-agent Approach and Auction System

Multi-agent agent system has been applied to solve complex problems such as resource allocation problems [8]. The agent can be adapted to many types of modeling with varying agent behaviors [9]. When the environment changes, the agent can learn and adapt itself to the desires of its users [10]. Agent-based model has also been implemented in water resource allocation. For example, agent-based model was used for capturing the collective problems in small and large scale water infrastructure provision. This is done by simulating the different behaviors of water users to learn and understand the complexity of water use at the Maule river basin [11]. Giuliani et al. [12] proposed a multi-agent system to demonstrate a hypothetical water allocation problem. This model involved several active agents and passive agents under the same environment to investigate efficiency-acceptability trade-off. The results were used to support the design of a distributed solution. In terms of water policy analysis, multi-agent can be used to create a simulation model for improved policies. For example, an uncertainty analysis was applied in the agent-based model for optimizing complexity of residential water use in Beijing, China. The multi-agent can evaluate the consumer responses on water and provide insights to seller agency to develop water usage policy [13]. Huang et al. [14] developed a water resource allocation in China using multi-agent and complex adaptive system. In this work, multi-agent was used to verify the rules of internal stage and behavior of the agent based on government policy. The results showed that the typical characteristics from agent changed based on the situation and can be used to improved water management policies. Ding et al. [15] used agent-based modeling to understand the interaction between stakeholders in transboundary Nile River. This work generated farmers and water sharing scheme with the intention to optimize allocated water for each user and finding optimal water allocation method for stockholder's at basin based on crop types and user behaviors [15]. Multi-agent modeling was implemented to optimize the trade policies of inter-basin water restriction in Texas, USA. The multi-agent model and complex adaptive system was developed to simulate consumer agents and were encoded to represent the interaction between consumers and policy maker agents to evaluate the performance of demand-side strategies [16].

An auction is a process of buying and selling goods or services. The most popular auction protocol is the English auction which is an ascending-price auction. The auctioneer begins with the lowest acceptable price and proceeds to find the highest bidder. The auction is considered complete when no one increases their bid price and the item is sold to the bidder with the highest price [16, 17]. Another popular auction protocol is the first-price sealed bid auction, where all bidders simultaneously submit sealed bids within a specified period of time and they have no knowledge of what the others bid. The winner is the one with the highest bid and he pays the price he submitted. There are many applications that apply auction mechanisms such as eBay and TradeMe. Both use intelligent agents to provide the facility for users to make automated bids in auctions. To use the bidding agent, users only need to set up the maximum and minimum bid price for the item they are interested in [18]. Book.com uses continuous double auction that applies the Markov model for agent behavior to create bidding strategies. This auction supports the trading process for users who can freely join and leave the trading market [19]. Sealed bid auction with econometric analysis was used in mussels' market in the Netherlands. The purpose of this analysis was to identify factors that determine the mussels' price and to quantify the performance of individual purchase managers [20]. It can be seen that the auction process is useful for trading goods and is also applicable to water allocation within a community irrigation scheme.

3 Multi-agent Model for Irrigation Management

3.1 Conceptual Design

This study focuses on using multi-agent approach to find an efficient mechanism for water allocation between farmers in a community irrigation scheme during water scarcity. As mentioned, each agent represents a farm that can calculate the total water requirement of the farm, prioritize crops to be irrigated, calculate water reduction for each crop in the farm, make a decision whether to sell or buy water and negotiate with other agents. The multi-agent environment and the pseudocode for multi-agent water management system are shown in Fig. 1. The system can be explained to two parts; (1) Total crop water need on a single farm and (2) the negotiation process using first-price sealed bid auction. The crop water need is calculated using Eq. (1) on each

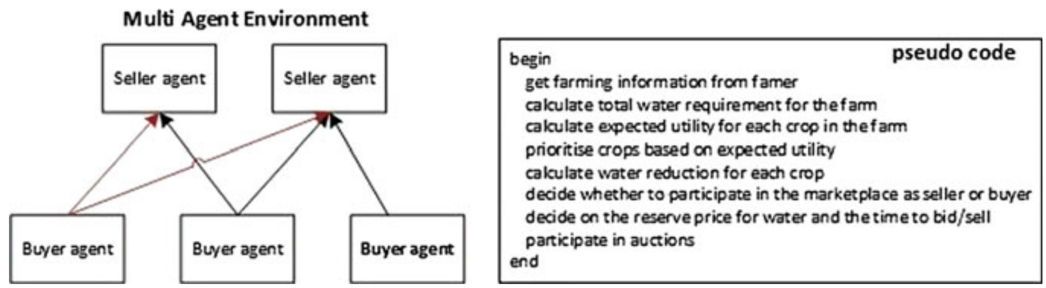


Fig. 1 Pseudocode for multi-agent irrigation management system

crop. The crop water need for a single farm is calculated using the single-agent water management algorithm [21]. The agent is able to estimate the crop water need on a daily basis based on the farming information such as crop types, crop stage, and soil type (more details can be found in [3]).

Agent creates a crops prioritized list which follows the decision rules based on productivity value, drought sensitivity and soil type respectively. The result of the calculation will show the total crop water need in the farm and whether the agent will be participating in the water marketplace as a bidder or a seller. The decision of whether an agent should be a seller or a bidder is based on the farming profit calculation shown below:

$$P = \sum CV_i - \sum FC_j \tag{3}$$

Here, P is the total marginal profit in the farm, CV is the total crop value, FC is the total farming cost, i is the crops planted in the farm and j is the farming cost factors for each crop.

Based on the crop water requirement, the agent can decide to be a seller if it has excess water, or it can be a buyer (bidder) agent if it has a water shortage. The seller agent will work out the reserve price (minimum price it is willing to sell the water) for its water based on price per cubic meter. On the other hand, a buyer agent sets a reserve price (maximum price it is willing to buy water) which is dependent on the expected profit on the farm. The water pricing equations are shown in (4, 5 and 6). The water price for agents varies by farming profit. We can assume that the profit will decrease during water scarcity but the total farm cost is the same. In this situation, the farming profit value will decrease if the farmer does not have enough water for the farm as shown in Eq. (4). On the other hand, if the farmer has more water than required, he can gain more profit by selling water to others as shown in Eq. (5). The expected profit function is shown in Eq. (6) where x is the profit changed value (in dollars), $f(y)$ is the total farm cost function and $f(z)$ is the utility function for water pricing. $f(z)$ is then used as a maximum price for the buyer agent and a minimum price for the seller agent.

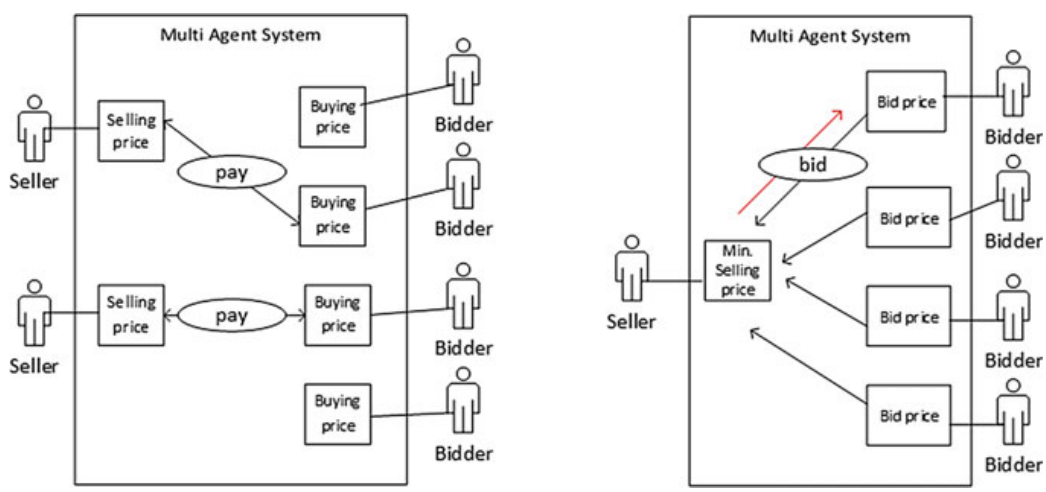
$$P - x = f(x)_{income} - f(y)_{farm\,cost} \tag{4}$$

$$P + x = f(x)_{income} - f(y)_{farm\,cost} \tag{5}$$

$$f(z) = \begin{cases} \sum CV_i - \sum FC_j - x & ;\, seller\ stage \\ \sum CV_i - \sum FC_j + x & ;\, buyer\ stage \end{cases} \tag{6}$$

3.2 Multi-agent Irrigation Management Process

In this scenario, we used two negotiation mechanisms (direct negotiation with a fixed price and first-price sealed bid auction). The direct negotiation with fixed price mechanism is where a seller wishes to sell his excess water with a fixed price. The seller will broadcast this sale to all the agents in the marketplace. Any buyer agents who are willing to buy water at this price will respond with an offer to buy from the seller agent. If there are multiple buyers making the offers, the seller will sell the water at the price he set to the first buyer who offered to buy the water (see Fig. 2a). The second negotiation mechanism is using a first-price sealed bid auction. The seller broadcasts to all the agents in the marketplace with the auction deadline and each buyer agent will then make an offer to the seller agent. When time is up, the seller will select the highest bidder as the winner (see Fig. 2b) as long as the bid is equal to or higher than the seller's reserve price. In this case, the bidders have no knowledge of the reserve price set by the seller. They are also not privy to the bids of the other bidder agents.



(a) Direct negotiation with fixed price mechanism

(b) First-price sealed-bid auction Mechanism

Fig. 2 Negotiation mechanisms

3.3 Experimental Setup

The purpose of this experiment is to determine which negotiation mechanism is more efficient in water allocation within a community irrigation scheme. To test the performance of multi-agent irrigation management system, we conducted the two experiments using 2 seller agents and 20 bidder agents using the two negotiation mechanisms. For each experiment, we randomly generated 20 farms with varying crop properties which are common in New Zealand's farm. Crop properties are randomized based on the growth stage and crop types. The farm size is fixed to 200 hectares and the water capacity to 15,000 m^3. The actual water need is calculated based on FAO's formula for calculating crop water requirement [22]. To simulate water scarcity situation, we run this experiment using three reduction schemes at 5, 10, and 15% (these reduction schemes are set by the community irrigation scheme based on the water availability) and compared the total loss of all the farmers in the community. We also observe the additional profit earned by those sellers with excess water.

4 Results and Analysis

Table 1 shows the total loss for all the farmers (sellers and bidders) in the irrigation scheme. If water is not traded among the agents, the total loss are 10.23% (5% reduction), 11.54% (10% reduction), and 13.11% (15% reduction). Using direct negotiation with fixed price mechanism to trade water, the total loss is reduced to 9.77%, 11.23% and 12.97%, respectively. It can also be seen that all the remaining water are distributed to the farms (shown as 0.00 in the table). This also shows that it is better to trade the excess water as the losses can be reduced. This would mean that the sellers gained additional profit by selling their water to the other farmers who need it which in turn allow the buyers to reduce their losses. Using the first-price sealed bid auction mechanism, the loss is reduced further to 9.12, 10.80, and 12.35% for the three reduction schemes. All excess water were also successfully traded. This indicates that water allocation using first-price sealed bid auction resulted in a lower loss compared to direct negotiation with the fixed price mechanism. This also means that allocating water using an auction mechanism is economically better than using a fixed price mechanism.

Figure 3 shows the percentage of marginal profit based on trading mechanism. It can be seen from Fig. 3 that farmers/agents with excess water cannot gain additional profit if the water is not traded (shown as 0 in Fig. 3). However, it can be seen that using direct negotiation, sellers gain additional profit. (1.97% with 5% reduction, 2.21% with 10% reduction and 3.57% with 15% reduction). This is as expected as trading excess water would lead to additional profit for the sellers. It can also be observed that using a first-price sealed bid auction mechanism, the additional marginal profit is higher than the additional marginal profit gained from direct negotiation with fixed price. The additional marginal profit increases to 2.28%, 2.85%, and 3.89%,

Table 1 The average proposed water management for difference reduction schemes

	Water reduction (m^3)					
	5% of reduction		10% of reduction		15% of reduction	
	Value	%	Value	%	Value	%
Total water left (m^3)	28,080	9.36	37,200.00	12.40	39,210.00	13.07
Total loss ($)	710,371	10.23	801,337.60	11.54	910,358.40	13.11
Fixed price mechanism						
Total water left (m^3)	0.00	0.00	0.00	0.00	0.00	0.00
Total loss ($)	678,428.80	9.77	779,811.20	11.23	900,636.80	12.97
Auction mechanism						
Total water left (m3)	0.00	0.00	0.00	0.00	0.00	0.00
Total loss ($)	633,292.80	9.12	749,952.00	10.80	857,584.00	12.35

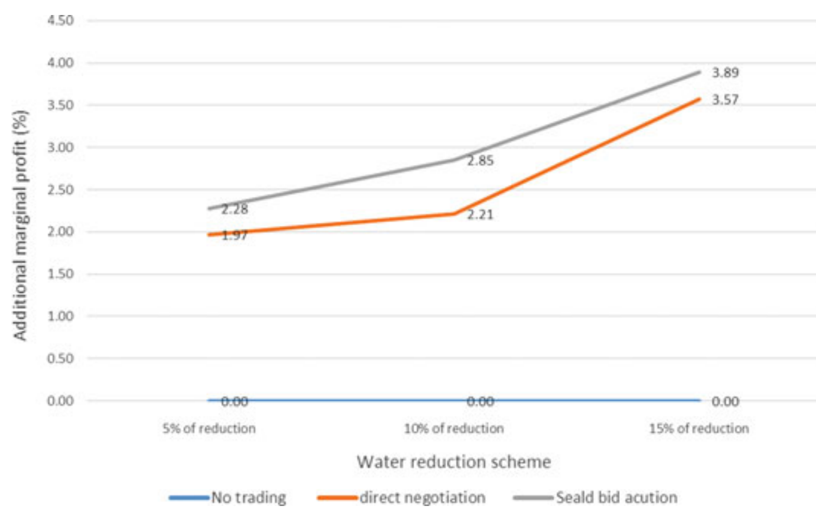


Fig. 3 The percentage of agent's marginal profit

respectively. Both trading mechanisms yielded additional marginal profit, but first-price sealed bid auction would be the preferred mechanism as it generated a higher additional profit margin.

5 Conclusion and Future Work

In this paper, we describe a multi-agent irrigation management system that can be used to distribute water efficiently between farms in a community irrigation scheme. The advantage of this MAS system is in its ability to autonomously decide on behalf of the farmer whether to engage in a negotiation or not depending on the current water situation in the farm. This MAS is especially useful for the farmer who needs to optimize marginal profit in the farm during water scarcity. Based on the preliminary experimental result, it can be seen that the total loss for each farm can be reduced using a first-price sealed bid auction. This loss is much lower when compared to trading water using direct negotiation with fixed price. Moreover, seller agents with excess water were able to obtain additional profit when they traded their excess water. In this experiment, it can also be observed that using the auction mechanism is better than direct negotiation as it resulted in a higher (additional) marginal profit. For future work, we plan to extend this work by implementing combinatorial auction to trade water. In its current design, it is assumed that the farmers sell their excess water as a single unit. In reality, farmers might be more interested in buying parts of the water (purchase certain volume for a certain price) depending on their needs. This means, that if a farmer has a 1000 m^3 in volume, he can choose to sell the water in units with different prices (200 m^3 at \$x, 500 m^3 at \$y, and 300 m^3 at \$z). It is quite possible that farmers will be able to recover their losses further by using this mechanism and may result in a more efficient market. Other types of auction mechanisms will also be explored.

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A Multi-agent System with Self-optimization for Automated Clustering (MASAC)

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Abstract Multi-agent Systems (MAS) offer an alternative to handling large quantities of data with the added advantage that control is not centralized, and consequently, such systems are endowed with robustness and versatility. This paper describes a Multi-agent System for Automated Clustering with self-optimization (MASAC). The framework comprises six categories of agents: information updater agent, document uploader agent, parser agent, convertor agent, clustering agent, and subset extractor agent. A novelty and feature of MASAC is that it supports self-optimization allowing for the enhancement of the initial clusters configuration in real time, and not only after running a cluster validation agent, as in other MAS presented in the literature.

Keywords Clustering · Multi-agent system · Self-optimization

1 Introduction

Clustering is widely recognized as grouping of objects by some similarity criteria, and it is one of the most frequently used techniques in exploratory data mining and statistical data analytics. It is applied in many fields of research such as machine learning, pattern recognition, image analysis, information retrieval, bioinformatics, data compression, and computer graphics. However, there is no uniquely accepted definition and a unique recommended methodology for clustering. Moreover, it can be achieved by various algorithms. The appropriate clustering algorithm and parameter settings depend on the individual data set and the intended applicability of the

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results. A popular approach in clustering analytics is applying distributed and parallel data mining techniques. Some of the disadvantages of such techniques are centralized control, they are suitable for specific data mining applications and they lack generality. Multi-agent Systems (MAS) offer an alternative to handling large quantities of data with the added advantages that control is not centralized and consequently such systems can be much more robust and versatile [1]. Multi-agent Data Mining (MADM) or Agent Assisted Data Mining (AADM) offers notable advantages in terms of robustness.

This paper describes a Multi-Agent System for Automated Clustering with self-optimization (MASAC). The framework comprises six categories of agents: information updater agent, document uploader agent, parser agent, convertor agent, clustering agent, and the subset extractor agent. Agents lifetime is equivalent to the duration of a given task. A feature of the framework is that it supports self-optimization that allows for the enhancement of the initial cluster's configuration in real time and not after running a cluster validation agent.

The reminder of this paper is organized as follows: Sect. 2 describes related background for clustering algorithms, also previous work on MAS clustering and validation techniques, Sect. 3 introduces the methodology designed for the proposed system, Sect. 4 presents experiments and results, and comparing those results with other approaches, while Sect. 5 presents conclusions and future work.

2 Related Work

Cluster analysis is an iterative process of knowledge discovery within a problem of interactive multi-objective optimization. It is often necessary to modify data preprocessing and model parameters until the results serve the objectives of the analysis [2]. The most appropriate clustering algorithm for a problem often needs to be chosen experimentally which might be a tedious work that requires significant computational power.

The earliest architectures of multi-agent-systems for clustering were centralized architectures, namely, a coordinator agent was responsible for the interactions between the mining agents. For example, PADMA [3] has generated hierarchical clusters for document classification. Another distributed clustering system was PAPYRUS [4] in which the results have been communicated between agents on the bases of communication strategies. KDEC [5] used a distributed density-based clustering algorithm. In KDEC, density estimation samples were transmitted instead of actual data values, in order to preserve data privacy and minimize communication between sites [5]. Kiselev and Alhajj [6] proposed a clustering agent-based system dealing with data streams in distributed and dynamic environments whereby input data sets and decision criteria were changed at runtime. Agogino and Tumer [7] proposed an agent-based cluster approach to generate a best cluster configuration by using reinforcement learning to maximize a utility function with respect to the original clustering results. A negotiation-based multi-agent clustering was proposed in [2], where the evaluation of the clustering effectiveness was based on negotiation between agents. An automatic clustering intelligent system that comprised a clustering agent and a cluster performance evaluation agent was proposed in [8]. The clustering agent used self-organization feature map as clustering algorithm. Self-organization feature maps enable very fast clustering and are suitable for the clustering of real-time Internet data. The cluster performance evaluation was performed through the Variance Criterion (VC) [8]. A distributed clustering technique based on agent technology was presented in [9]. This clustering technique was compared with hierarchical agglomerative clustering (HAC). A method of clustering within a fully decentralized multi-agent system is presented in [10]. The goal was to group agents with similar objectives or data. However [10], added the additional constraint that agents must remain in place on a network, instead of first being collected into a centralized database. In order to investigate the feasibility of a decentralized approach, a comparison between the proposed method's clustering ability and that of the k-means clustering algorithm was presented. A digital image clustering algorithm based on Multi-agent Center Optimization (DICA-MCO) has been proposed by [11]. The proposed algorithm established a problem optimization and solving system composed of agents. To achieve fuzzy evaluation, DICA-MCO mapped the digital image clustering problem as a problem of intelligent agent movement in a multidimensional solution space. Results demonstrated that compared with traditional algorithms, DICA-MCO could select the optimal number of categories and value of center points and had high classification accuracy and classification effect [11].

There is little reported work on agent-based clustering system that supports self-optimization in order to re-enhance initial cluster configurations. In the next section, we present a methodology for developing a clustering agent that can choose the optimal distance within a partition-based clustering algorithm in real time.

3 Methodology

3.1 Partition-Based Clustering Algorithm

Cluster analysis uses several different algorithms and methods for grouping objects of similar kind into respective categories. Such algorithms are concerned with organizing observed data into meaningful structures. The algorithms are divided into two categories: partition-based algorithms and hierarchical algorithms [12].

For the clustering agent, the partition-based clustering k-means algorithm [12] has been applied. K-means is a classical partitioning technique that clusters the data set of n objects into k clusters with k known a priori. Clustering methods use distance measures to determine the similarity or dissimilarity between any pair of objects. The distance of p order between two data instances can be calculated using the Minkowski metric [13].

All distances obeying (1) are called Minkowski distances. The Euclidean distance between two points is achieved when p = 2. If p = 1 then the Manhattan distance is obtained.

Distance functions: Let A, B be two points in an n-dimensional space:

$$A = (x_1, x_2, \ldots, x_n), \quad B = (y_1, y_2, \ldots, y_n), \quad A, B \in \mathbb{R}^n$$

Minkowski distance of p order between the two points is given by

$$d_{Mi}(A, B) = \left(\sum_{i=1}^{n} |x_i - y_i|^p \right)^{1/p}. \tag{1}$$

For $p = 1$, Minkowski distance becomes Manhattan distance:

$$d_{Ma}(A, B) = \sum_{i=1}^{n} |x_i - y_1|. \tag{2}$$

For $p = 2$, Minkowski distance becomes Euclidean distance:

$$d_{Eu}(A, B) = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2}. \tag{3}$$

The efficiency of the k-means algorithm is given by the Sum of Squared Errors (SSE) [13]. For K clusters, each cluster C having n instances y and a centroid x, the SSE value is obtained by the following formula:

$$SSE = \sum_{i=1}^{K} \left(\sum_{y=1, y \in C_i}^{n} dist^2(x_i, y) \right). \tag{4}$$

3.2 Multi-agent System for Automated Clustering (MASAC)

Software agents have the speed advantage of tens (and in some cases even hundreds) to humans. While human processing takes seconds, agents manage to outperform these time spans getting to the order of milliseconds [14].

Another advantage of agents consists in the accuracy while setting of parameters and options in clustering algorithms. Agents can optimize the algorithm in an impartial and objective way, while humans tend to be subjective about the values of parameters, e.g., choosing Manhattan distance to Euclidean distance in clustering algorithms. In order to ensure the automation factor, this framework proposes six agents, each with well-defined primary tasks (Table 1).

Table 1 Agents tasks

Agent name	Primary task
InformationUpdaterAgent	Keep the application's history, debugging role
DocumentLoaderAgent	Load document in application (*owl* file)
OntologyParserAgent	Parse and convert owl to *sql* file
ConvertorAgent	Convert *sql* file to *arff* file
ClusteringAgent	Select the optimum clustering algorithm
SubsetExtractorAgent	Extract the optimum feature subset

In addition to primary tasks, each agent communicates with others, requiring collaboration to other agents. Except for the *InformationUpdaterAgent* that receives messages from all agents, each agent creates the next agent in an operation chain and sends a message at the end of its own task in order to make the next agent able to start its behaviors. The whole process is represented in the activity diagram (Fig. 1).

Remark: the messages are sent only to the next agents, and not vice versa, because the agents are destroyed after they have finished their own task and after they create the next agent and sent a message. *InformationUpdaterAgent* represents the only exception to this rule because it runs throughout the whole active state of the application.

Agents collaborate in a complex manner that has been described in a collaboration diagram shown in Fig. 2.

The *ClusteringAgent* has the most complex task with a sequence of seven subtasks shown in the sequence diagram (see Fig. 3). For this reason, it has extended the basic behavior and then it has implemented its own action mode. Before clustering, the algorithm's variables have been initialized. Also, it was necessary to introduce three other variables: a step variable, an *optimalNumClusters* variable and an *optimalMaxIteration* variable that will get *true* value when the optimum number of clusters and the optimum number of maximum iterations are reached. Unlike other agents, the *ClusteringAgent* has to inform the *InformationUpdaterAgent* about all the results returned by the *switch statement*. In the clustering process, the *switch statement* has seven steps:

Step 1. Store time and Sum of Square Error (SSE) in the case of Euclidian distance clustering. In this step, K-means algorithm runs with default options and Euclidian distance. The running time and the SSE (used with four decimals) are stored in order to compare the clustering accuracy (in the third step) values with the ones obtained using Manhattan distance (in the second step). So, the most suitable distance can be discovered in terms of the optimum time and error obtained.

Step 2. Store time and SSE in the case of Manhattan distance clustering.

Step 3. Compare time and SSE in order to choose the optimum distance. To compare the distances a computational formula was needed. The implemented formula

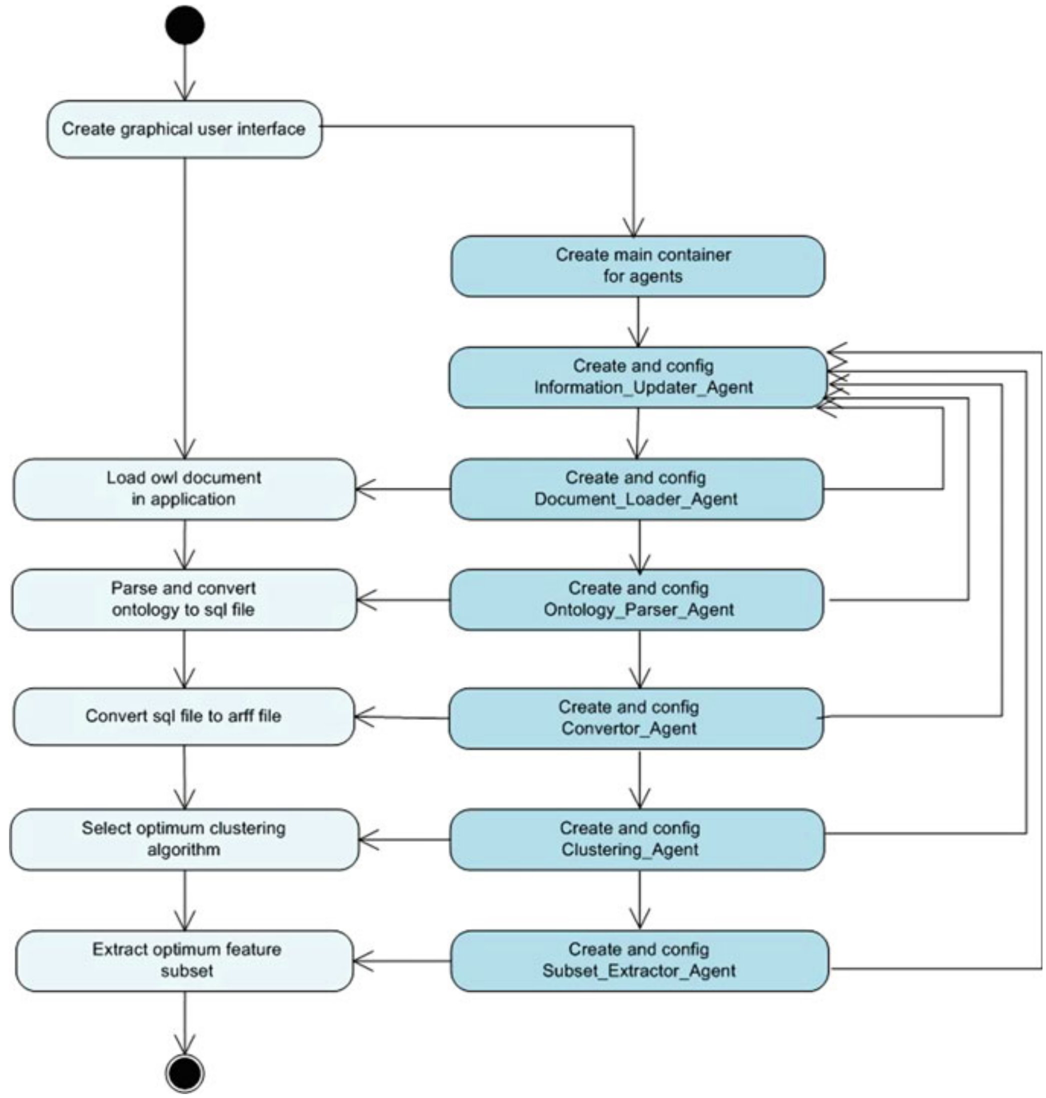

Fig. 1 Activity diagram

calculates a score between 0 (minimum) and 1 (maximum value) for each distance used. The highest score will decide the optimum distance and in case of equality, Euclidean distance is chosen because it is set by default. The time and SSE have 50–50% importance in computing the score. A value equal to 1 is added in the cases when the running time or the SSE is 0. The probability that time will be equal to 0 ms is very low, but SSE becomes 0 when the number of clusters is equal to the number of attributes. For example, if the number of clusters will be set equal to the number of attributes, respectively, equal to 12 and the dataset contains only the first 15 records, clustering would take between 0 and 0.02 s, and SSE will be 0. In order to get the score between 0 and 1, the previous result is divided by 1000.

Step 4. This stage ends with sending a message to *InformationUpdaterAgent* with specified chosen distance, the running time, and the SSE score obtained. After

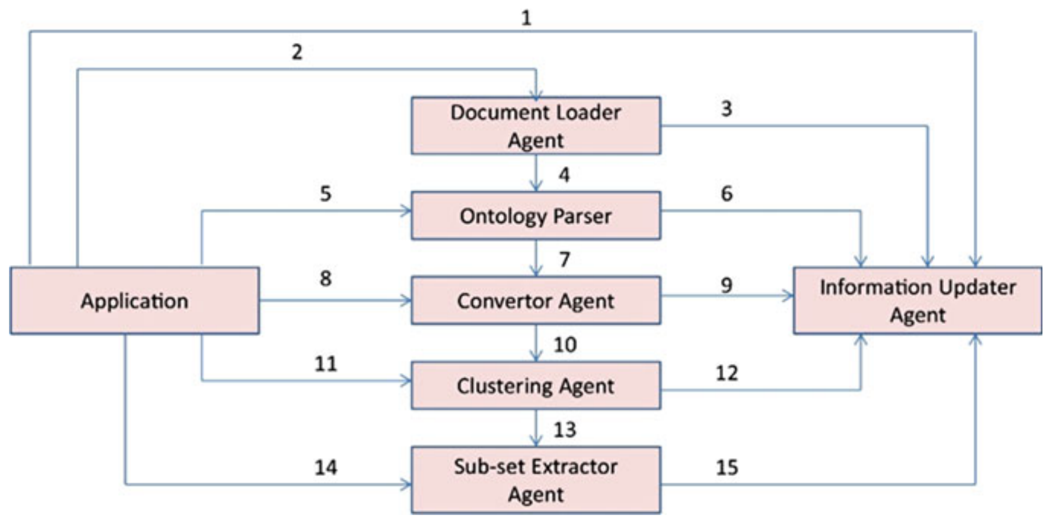

Fig. 2 Collaboration diagram

computing the distance in the third step, the algorithm clusters again the dataset with this distance, incrementing only the number of clusters with a step equal to 1, until the optimum value of this parameter is obtained based on the required runtime. This condition is fulfilled when *optimalNumClusters* variable becomes *true*. The number of clusters starts from three, since the time necessary for two clusters is already known. If the running time decreases when using a new number of clusters, this step should be repeated. The only way to do this is to decrement the step variable with 1, in order to stop proceeding to the fifth step of clustering process. When the runtime no longer decreases, it is considered that the number of clusters is optimal, and its value is given by the previous clustering.

Step 5. Chooses the optimum number of maximum iterations. When time required to cluster the new maximum number of iterations does not decrease, it is considered that the optimal value for the *maxIteration* parameter is the one found in the previous clustering.

Step 6. Saves clustered and labeled data into *.arff* file using found optimum options.

Step 7. Runs the new clustering algorithm with optimal options found. In addition, clustering process is evaluated to determine the cluster membership of each instance.

The seventh step represents the final stage of clustering and creates *SubsetExtractorAgent*. The last agent, *SubsetExtractorAgent*, obtains the optimal subset of attributes from the clustered data. The difference between this agent and the others is that *SubsetExtractorAgent* finally sends the task only to *InformationUpdaterAgent*. Once the optimal subset of attributes is saved, the application completes its execution cycle and there is no need to create other agents.

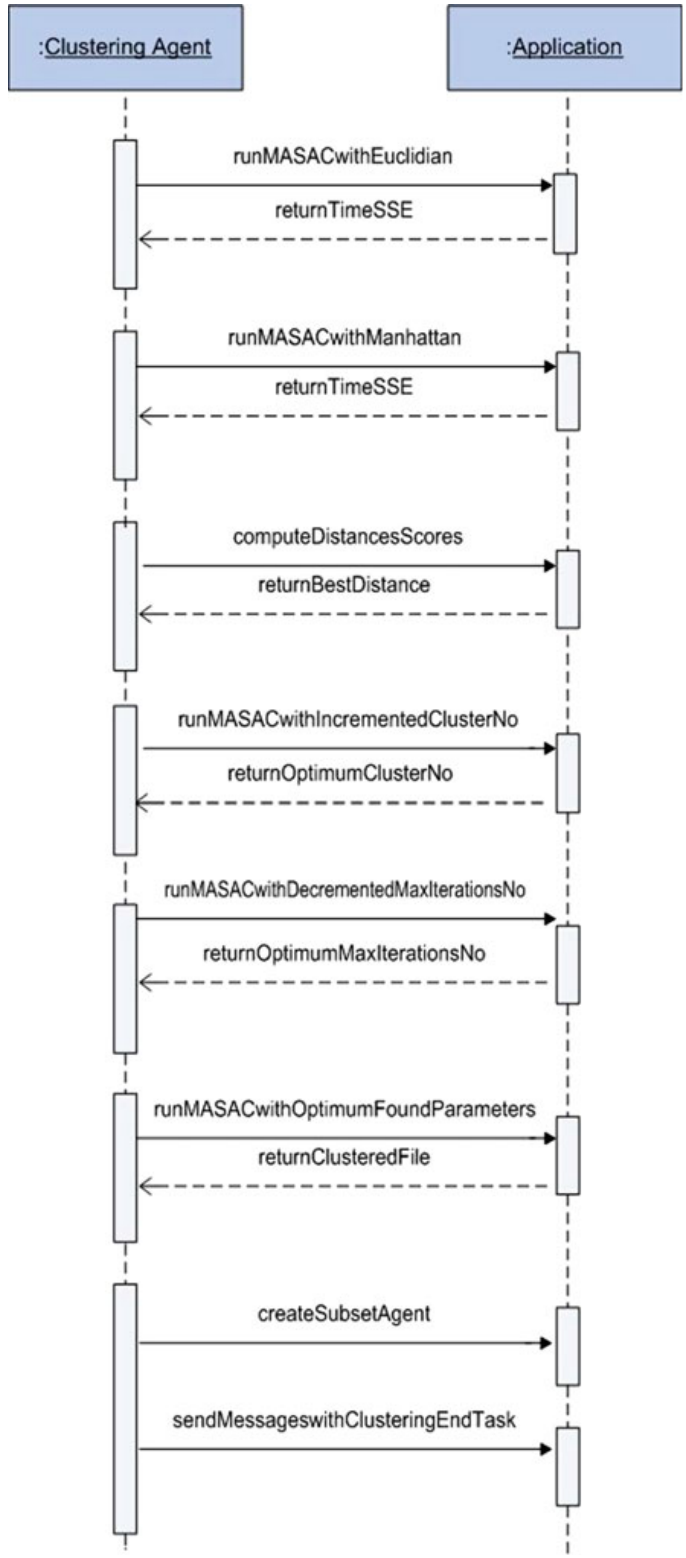

Fig. 3 *Clustering Agent's* sequence diagram

4 Testing and Performance Evaluation

In order to test the implementation and the outcomes of the proposed application, a corpus of documents containing cultural heritage information has been chosen. An ontology has been developed and it was populated as described in [15]. The dataset provided by the populated ontology (*owl* file) was used for the clustering task. Results obtained with MASAC application have been compared to the results obtained by running Weka data mining tool on the same dataset [16]. The comparison has been achieved in terms of cluster centroids, cluster distribution of instances, and runtime of K-means algorithm in the same clustering conditions (see Figs. 4, 5 and 6).

The performed experiments have shown that the number of instances discovered for each cluster was the same by using both applications, the cluster centroids had small differences, but the time needed to build the model was better in the case of the developed application (MASAC) (0.01 s) than the one needed by using Weka data mining software (0.04 s). For larger datasets, this difference will increase, the fact that demonstrates efficiency and robustness of the MASAC application.

From the above experiments, one can notice that Manhattan distance is more suitable for the dataset, and also that maximum 300 iterations were necessary to obtain best performance in less time (See Fig. 7). Both experiments, Weka SimpleKMeans and MASAC were performed using the same values for parameters. MASAC algorithm had also an improved SSE value. If Weka SimpleKMeans clusters the dataset with an SSE equal to 38, the SSE of MASAC is equal to 36, meaning a better cluster assignment.

MASAC results have been also compared with another approach. For this second experiment, Python with Pandas and Scikit-Learn packages [17] were used to cluster the original dataset. After running the script in Python, the results were three clusters with partitioning:

- Cluster 0: 11 instances,
- Cluster 1: 10 instances, and
- Cluster 2: 11 instances (Fig. 8).

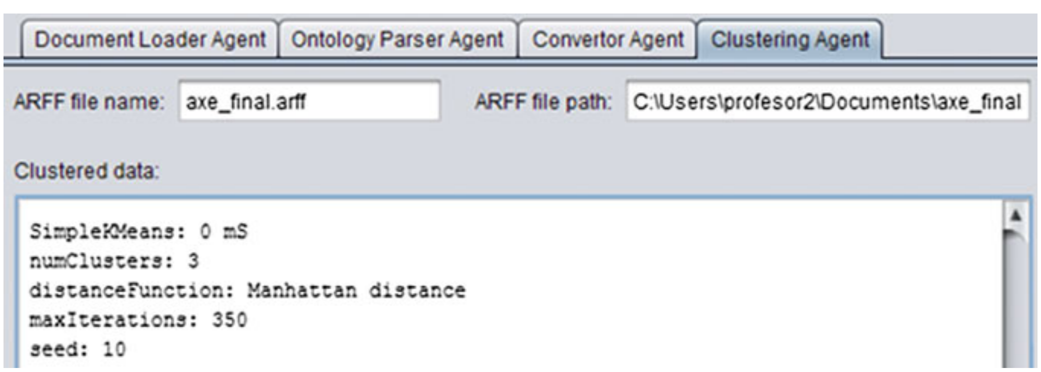

Fig. 4 Clustering options

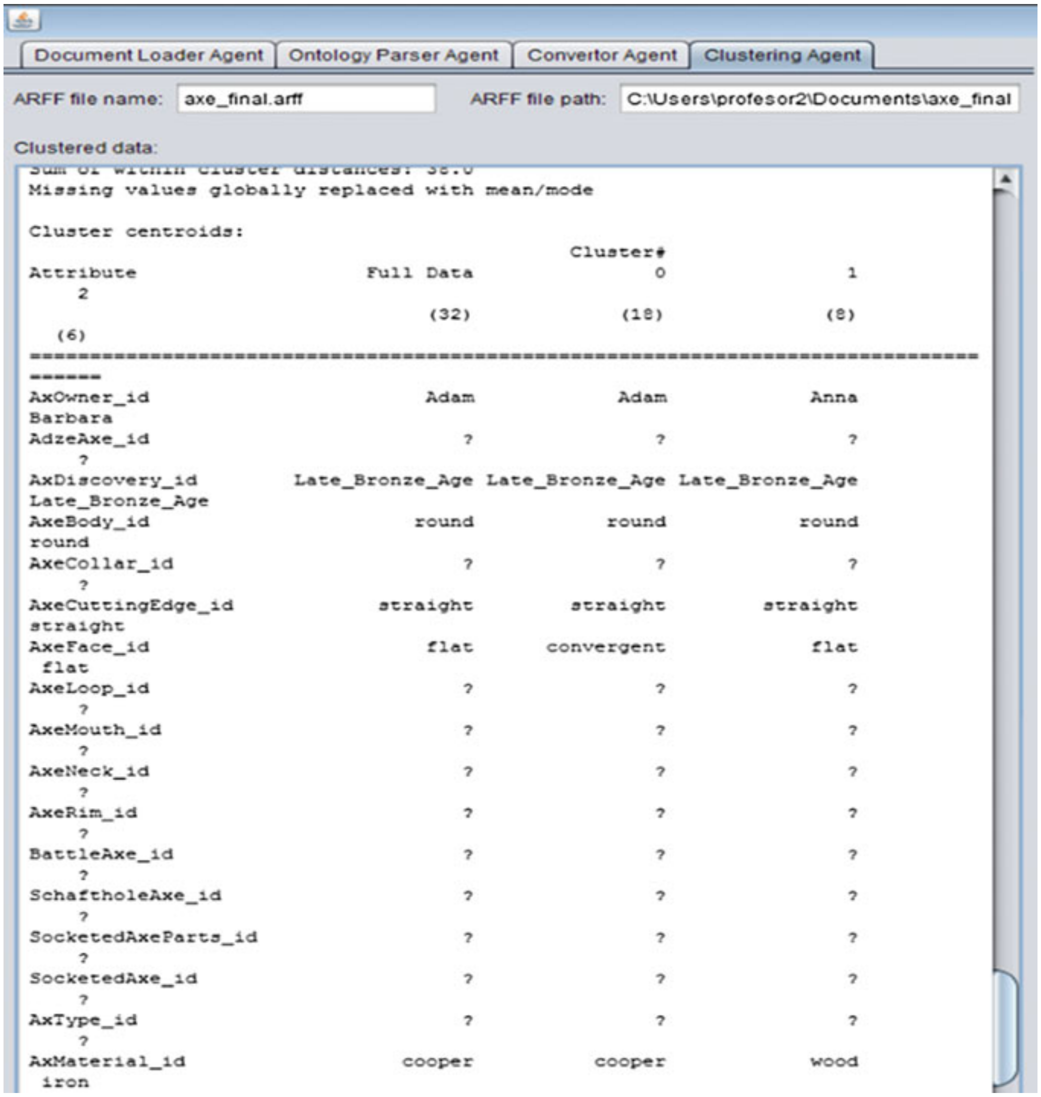

Fig. 5 Cluster centroids in MASAC

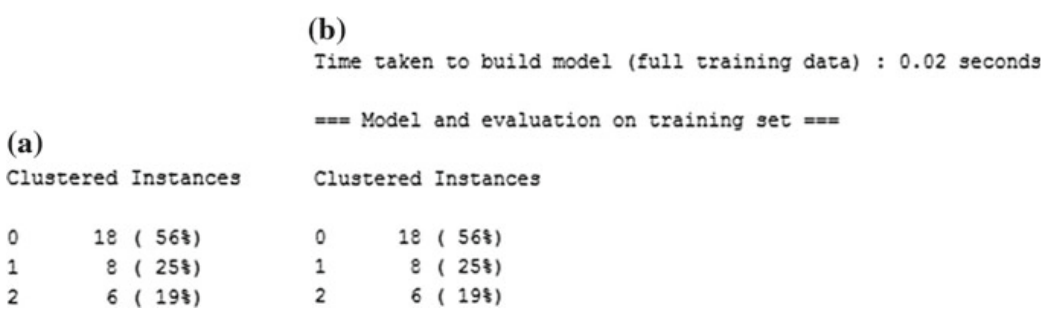

Fig. 6 **a** Number of instances for each cluster—MASAC application. **b** Weka data mining software

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15:25:37: the message 'Set the optimum number of maximum iterations: 300' was sent to Clustering_Agent
15:25:37: the message 'Sum Square Error for Manhattan distance: 36.0' was sent to Clustering_Agent
15:25:37: the message 'Computation formula = 1000.0 / (1 + (1.0/2.0) * time + (1.0/2.0) * SSE)'
was sent to Clustering_Agent
15:25:37: the message 'Euclidean distance score = 4.988' was sent to Clustering_Agent
15:25:37: the message 'Manhattan distance score = 42.56' was sent to Clustering_Agent
15:25:37: the message 'Manhattan distance has been chosen: TIME = 0.1, SSE = 36.0, SCORE = 42.56'
was sent to Clustering_Agent
```

Fig. 7 Sample of MASAC results

```
[32 rows x 16 columns]>
[1 1 0 0 1 2 2 2 2 2 0 1 2 0 0 1 0 2 0 0 1 0 2 1 1 0 1 2 2 2 0 2 1]
Duration run: 0:00:00.068613

Process finished with exit code 0
```

Fig. 8 Results obtained with Pandas and Scikit-Learn in Python

Compared to Weka the results disclosed an increase in run time of ~0.02 and even greater than MASAC with ~0.05. Also, the cluster distribution is different. With Python the dataset records are more equally distributed, fact expected considering it defaults to Euclidean distance.

5 Conclusions and Future Work

Due to the integrated intelligent agents, the application can self-configure in order to optimize the clustering process. During the whole process, there are only three active intelligent agents even if the application consisted of six agents. The effect is an efficient use of hardware resources. Even if the complexity increases in the back end of the application, the graphical user interface is very simple. In the future, other clustering models and algorithms will be tested and another intelligent agent will be introduced to decide on the most suitable algorithm, namely, the *AlgorithmTestingAgent*. This agent will run right before the *ClusteringAgent* that deals with algorithm self-optimization as presented in this paper.

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Web Literature, Authorship Attribution and Editorial Workflow Ontologies

Matteo Cristani, Francesco Olivieri, Claudio Tomazzoli and Margherita Zorzi

Abstract In this paper, we illustrate a combinatorial approach to the problem of defining an ontology used for detecting multiple authorship and roles in weblogs and social network literature production. The investigation aims at providing a model of workflows and therefore traits to be recognised in these documents.

1 Introduction

Authorship attribution is a research theme that received intense attention in recent investigations of Computer Science.

However, although a number of studies carried out interesting results, especially those related with small text authorship (as in social networks context), the problem of *detecting multiple authors along with their roles from a text* remains unchallenged.

A structured analysis of the process of detecting multiple authorship requires at least two macro-phases: the detection of the precise set of atomic steps of the workflow, concerning each role of each author and the detection of the analytical process. This is a tricky task since the interplay between different authors' actions along the versioning of a document clearly generates a complex workflow.

For this reason, even if to consider the general problem of multiple authorship detection in a generic document will be the desirable goal, in this first investigation we start from a restricted domain. A reasonable simplification we made is the following:

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only textual content of documents is taken into account. Of course, an authorship analysis could also include images and other channels, as already discussed in [6–9] by some of the authors. We further comment on these points in Sect. 5.

Coming back to our goal, we can identify three basic phases of a medium-term investigation planning: (i) Determine which features (action, roles...) potentially describe a multiple-author workflow for literature production; (ii) Identify measures on texts that detect these features and (iii) Measure the accuracy in the detection process.

Second and third phases will be dealt with in further investigations.

In this paper, we focus the attention on the first phase, which is preparatory to other ones, and consists of developing an *ontology of literature editorial workflows*. This is a step that is very common in similar situations such as [27].

As a very initial step, we need therefore to identify and conceptually formalise the document types and their editing processes. In fact, the definition of the ontology is subordinate to the document description level that contains not only the final result of the editing process but also additional information about the document production.

Looking to standard regulative models of document, we can observe that the editing presume at least the following three fundamental concepts:

1. **Versioning**. A document exists in a stream of its versions.
2. **Comments and editing notes**. Information on the state of a given version and suggestions/decisions of change at a given revision step.
3. **Partition**. The document is organised in *sections* and the relations among the sections and their structure are provided along with specific privileges.

This consideration suggests us a document-centric approach in the definition of the ontology for the editorial workflows in the context of literature. In fact, we will build the ontology starting exactly from basic editing operation on documents. On this basis, we will define author's roles, related privileges, meta-level classifications such as documents' taxonomy based on different versions and meta-level concepts as versioning rules, hierarchy of roles and metaroles.

Figure 1 summarises the notion of document and editing process we are capturing. The provided schema is not universal but it is quite general for literature. The main idea is that *different editorial workflows can result detectable to some extent even when the workflow itself is provided by no means in form of meta-information.*

We aim at measuring better performances when some meta-information is retained. In particular, when versions are attributed, and possibly revision notes, comments and suggestions are present as additional information. In this case, the largest part of the detection process indeed consists in determining the roles and detecting the privileges, based upon the actions (related to specific roles) that are detected.

Of course, in the majority of the cases that can be exemplified in practice, we shall only have a partial and fragmented information set about the features to detect. Consequently, we might have only a partial description of the version relations, the roles used in the process and other data that could possibly be used to completely process the document and complete the detection of multiple authors and their roles, and also the workflow employed to process the document.

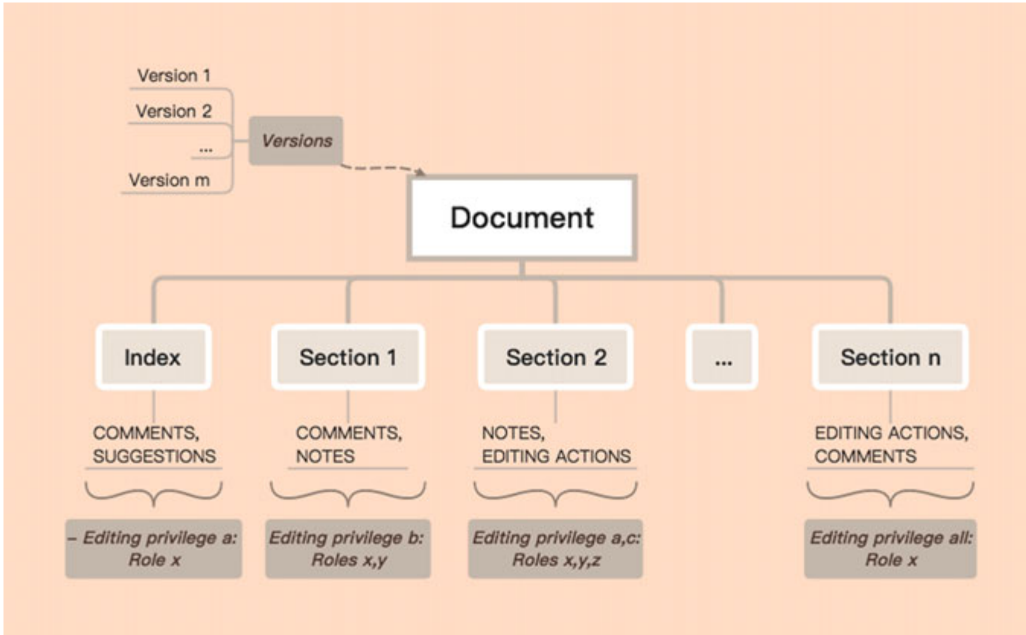

Fig. 1 A schema of document structures in literature

An example is represented by weblogs, where the existence of a single author or multiple authors can be derived only by looking at the document, and by detecting sections of the document that have different styles.

The rest of the paper is organised as follows: Sect. 2 describes the mentioned concepts and devise the base of an abstract notion of workflow class for these purposes, whilst Sect. 3 introduces a classification of workflows based on their types. Section 4 reviews current literature on the topic and discusses some related work, and finally Sect. 5 takes some conclusions and discusses further work.

2 Privileges, Roles and Their Completeness

The notion that we need to start with is the one of *editing action*. Basically, the process of editing a document is determined by two elementary actions: (α_+) **adding** some material and (α_-) **deleting** some material. In many senses, these two actions cover the entire possibilities of modifying a document, however, for the purpose of editing in a multiple-author setting, we might also desire to add an action of modifying the text, usually known by the name of (α_σ) **editing** action.

To understand the meaning of other classical actions that need to be defined, we should consider that a document part may be described not only by its content but also by its *state*. The state of a document part (a section in the denomination we use here) can be classified schematically by the names used in editing processing descriptions: (δ_p) placeholder, (δ_d) draft, (δ_c) completed. The three states introduced above relate the content of the part and the action of the author of the part itself. Clearly, this judgment is not universal, and when someone else, with a privilege of some type, can intervene and modify the state, then her action will be either to approve ($e_{\checkmark}$) or to reject ($e_{\times}$). When an author has added some of the above actions to a document, she can close the action set and create a version of the document itself. To each part of the document you associate the same version, but to every action added on a single part of the document you also add an editing note that constitutes the discussion of the document in that version. Closing a version and adding a note to the closure of the version itself is a specific privilege, as well as adding comments. Suggestions are types of comments that are associated with a backward step in the editing process that delegates an action to the person receiving the suggestion. The suggestions are therefore simply state changes associated with a comment. The privilege to change a state from completed to draft (χ_d) or from completed or draft to placeholder (χ_p) can also include an editing action.

Summarising the model we propose here include the actions listed in Table 1. Table refers to the privileges standardised in UNIX: `x` (execute) is the privilege of creating an object, `w` (writing) is the privilege of writing an object and `r` (reading) is the privilege of reading an object. Clearly, all the members of an authorship team have at least some writing or deleting privilege, whilst every member has the reading privilege.

Table 1 List of actions related to privileges

Name	Role name	Privilege	Structure
Create a document	Master author	`xrw`	-
Create a section	Master author	`xrw`	-
Relate two sections in order	Master author	`xrw`	-
Comment the section names	Master editor	`-r-`	$\alpha_+, \alpha_-, \alpha_\sigma$
Comment the section order	Structure master editor	`-r-`	$\alpha_+, \alpha_-, \alpha_\sigma$
Approve the section names	Master approver	`xr-`	$e_{\checkmark}, e_{\times}$
Approve the section order	Structure master approver	`xr-`	$e_{\checkmark}, e_{\times}$
Edit a section	Author	`-rw`	$\alpha_+, \alpha_-, \alpha_\sigma$
Comment on a section	Commenter	`-r-`	$\alpha_+, \alpha_-, \alpha_\sigma$
Version the document	Editor	`xr-`	-
Back change the state	Master editor	`xrw`	χ_d, χ_p
Make a suggestion on a section	Privileged editor	`xrw`	$\alpha_+, \alpha_-, \alpha_\sigma, \chi_d, \chi_p$

3 Workflow Classification

The workflow classification that we propose here is essentially fourfold. We consider the following:

– Roles activated in the workflow;
– Hierarchy of roles (for the roles to be ordered);
– Versioning rules and
– Metaroles.

The idea of metaroles is essentially to assign to some of the roles the possibility of activating/deactivating roles, and to assign specific privileges to certain members of the team, to add/remove members of the team, to assign tasks to the members of the team, and finally to modify the state of the document in the editing phase.

We consider workflows to have at least one author role associated that we name, as provided in Sect. 1 *master author*. A master author is the sole author who possesses the privilege of metarole assignment.

Basically, we can distinguish two types of editorial workflows, based on the existence of a termination state. A termination state is the state declared by the master author as final, associated with an action that provides a publishing authorization. Once this action has been performed, the document in editing phase cannot be modified thenceforth.

This is the typical activity of producing a post on a weblog, or an article in a digital newspaper or even to produce a scientific document. Differently, when a document has a nature of permanent information document, such as a FAQ document, or the credits of a website, or again rules for a weblog publication, this document is permanently open for editing by the authors, editors, approvers and publishers. Therefore, this document does not have a publishing state, in which the delivery of the document itself is terminal, but a *version* that is **current** and a version that is **future**, and a specific action by the master author consisting in the duplication of the version in current state, and the attribution of the state of current to one of the versions (and obviously the simultaneous downgrade of the corresponding current version to the state of **past version**).

The combinatorics of roles discussed in Sect. 2 generates a large potential set of role combinations, and consequently some forms of role hierarchy and metaroles. First of all, no system like this exists if we miss to have at least one master author role and one master editor, and these roles are assigned to two different individuals. The existence of a third role, namely, the master approver is needed for the mere existence of the workflow, but we do need it to be assigned to a third person. If we fail to have such a distinction, then we cannot process the text, and we fail to make a distinctive assignment of roles onto different individuals, we are not governing a multiple authorship flow.

Generally speaking, we may have a role assignment that is simple as: one master author, one master editor (distinct from the author) and one master approver, who coincide with the editor. This workflow will also comprise the assignment of the roles of Structure Master Editor and Structure Master Approver to the same individual who possesses the roles of Master editor. There is no hierarchy of roles, and no metaroles assigned, and therefore the versioning rules governing this simplified flow determine the possible formats. Versioning rules vary on the hierarchy, and therefore, on a simple hierarchy such as this, we may have either linear approval workflows or forked ones. Linear approvals habilitate author changes to the document until the editor decides that it is worth delivering the document itself, and the cycle ends after a sequence of steps of editing proposals, changes and one single approval. In the forked versioning model, authors can reject editing proposals and withdraw the document from the cycle. A possible basic model is sketched in Fig. 2.

If we limit ourselves to the analysis of possible combinatorics, we notice that, based on just the remainder subsets, we have the combinations of roles described in Table 2.

As a consequence of the above combinatorics, we have corresponding hierarchy possibilities. Indeed, if we have a configuration with three authors, one is the master author and the other two are related directly with the master, as subordinate. However, the presence of more than one author and more than one editor and approver allow to configure editors as related to authors (in the most complex case, we may have one editor for every author, and one author subject to one editor, but we can also have authors edited by more than one single editor), and approvers related to editors. The corresponding hierarchies can be essentially classified in two groups: those in which authors have *pre-assigned* editing activities that correspond also to the partition of the document to be edited in parts, each assigned to *one* single author, and the case in which more than one author edits the parts of the document.

Weblogs where an author writes only one part of the document, and one or more than one editor exist, and one or more than one approver exist and they act on the single partsby publishing final versions, as either approved directly or mandatorily modified by the authors, following one of the basic schemas in Fig. 2.

Wikis where authors are entitled to modify one part collectively (independently of the editors' and approvers' activities).

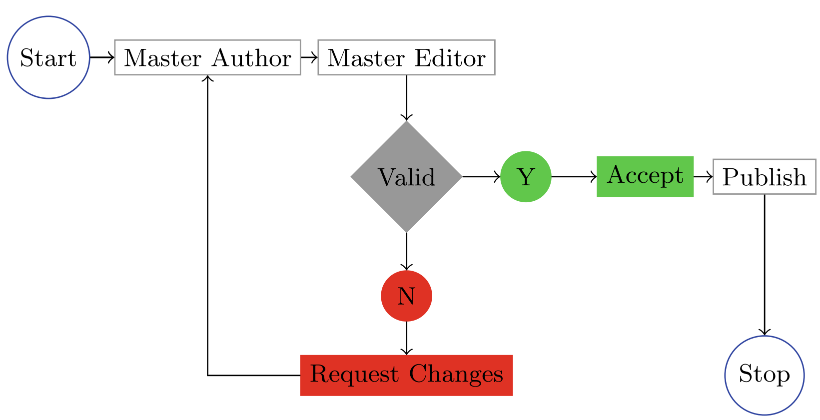

Fig. 2 The basic workflow of linear author literature provision

Table 2 Combinations of roles

Roles	Number	Individuals
Master author, master editor, master approver	1	2
Master author, master editor, master approver, author	2	3
Master author, master editor, master approver, author, editor	4	4
Master author, master editor, master approver, author, editor, approver	5	5
Master author, master editor, master approver, master structure editor, author	4	4
Master author, master editor, master approver, master structure editor, author, editor	5	5
Master author, master editor, master approver, master structure editor, author, editor, approver	6	5
Master author, master editor, master approver, master structure approver, author	4	4
Master author, master editor, master approver, master structure approver, author, editor	5	4
Master author, master editor, master approver, master structure approver, author, editor, approver	6	4
Master author, master editor, master approver, master structure editor, master structure approver, author	7	5
Master author, master editor, master approver, master structure editor, master structure approver, author, editor	7	5
Master author, master editor, master approver, master structure editor, master structure approver, author, editor, approver	7	5

Document formalised workflows where authors act on a website for modifying the documents in a cycle (these tend to use linear workflows).

The complexity and the articulation of the above mentioned workflow categories is large. In particular, given the roles as described in leftmost column of Table 2 as classes, the definition of all possible relationships between these roles is compulsory to obtain a comprehensive formal ontology; however such a task leads to a huge model which is likely to be redundant and difficult to check for completeness and correctness. A non redundant model can be obtained considering relations with regard to specific real word editorial workflows, so that we suggest the existence of a whole family of instance dependent ontologies, based on the roles above specified.

3.1 A Practical Example

We show an example taken from researcher's everyday life: the editorial workflow of even a simple scientific paper. In this process, the roles are known: at least one or more authors and one or more reviewers. We can see the outcome of the editorial

	Version 1.0 (δ_d)		*Version 1.1 (δ_c)*
Snippet 1	Text normalization into medical dictionary is time consuming. Moreover, in the last years narrative web spontaneous reports have grown exponentially, making the encoding task difficult and often unbearable for people responsible for ThisgreviousTask. To support ThisgreviousTask experts' normalization task we designed and implemented ThisLovelyTool , an NLP software that, given a narrative description, automatically extracts an encoding into ThisFamousDictionary terminology.	α_σ, α_-, α_σ, α_σ	Mapping text snippets to terms in a medical dictionary is time consuming. Moreover, in the last years spontaneous reports (principally collected through the web) have grown exponentially, making the encoding task difficult and often unbearable for people responsible for ThisgreviousTask. To support ThisgreviousTask experts' normalisation task we designed and implemented ThisLovelyTool, an NLP software that, given a narrative description, automatically extracts codes from the ThisFamousDictionary terminology.
	.....		.....
Snippet 2	We design some new experiments, evaluating the behaviour of single features on a base version of the software. Features are added and tested individually. This is different from what we done in [5], where we observed the improvement of performance metrics along "incremental" versions of the software.	α_σ	We design some new experiments, evaluating the behaviour of single features on a base version of the software. Features are added and tested individually. This is different from what we did in our prior work [5], where we observed the improvement of performance metrics along "incremental" versions of the software.
	.....		.....
Snippet 3	We test ThisLovelyTool on the WellReknown dataset, a corpus of annotated English ADRs posts from social media. Thus, we move from Italian to English narrative documents. Posts are radically different from spontaneous reports, but represent an interesting setting, since clinical information extraction from social media is one of the most intriguing trends in healthcare natural language processing.	α_σ	We test ThisLovelyTool on the WellReknown dataset, a corpus of annotated English ADRs posts from social media. Thus, we move from Italian to English narrative documents. Posts are radically different from spontaneous reports, but represent an interesting setting, since clinical information extraction from social media is one of the most intriguing trends in health NLP.

Fig. 3 Request for change from version 1.0 (draft) to Version 1.1(final). Snippet 1: normalisation into medical dictionary → mapping text snippets to terms in a medical dictionary; narrative web spontaneous reports is a confusing noun phrase, please change; normalisation → normalisation; extracts an encoding into → extracts codes from the. Snippet 2: what we DONE in [5] → what we DID in [5] Snippet 3: healthcare natural language processing: health or biomedical NLP is fine

process as well as all the versions of the documents; for the sake of space, we will show only two subsequent versions. Figure 3 provides the versions of few snippets from a real article: differences between version 1.0 and version 1.1 are highlighted and we can consider the reviewer as an 'author' even though he does not personally implement the changes.

4 Related Work

Our proposal can be inscribed into the wide context of document analysis that is a crossroad theme along different research areas (including Natural Language Processing, Ontologies development and Text Mining).

In particular, the ontological framework of document processing encompasses different aspects, equally important and strongly correlated to each other. First of these aspects is the *structure of documents*, as discussed in many different setting, both general and specific [10, 11, 26]. Fundamental studies on the nature of documents relate to web research [18]. The second of these aspects is *document retrieval and text classification* [20, 25], research themes particularly lively in technical linguistic domains [4–9, 12, 13, 29, 30]. Another central aspect is of course the document workflow design itself [19, 21].

The matter of workflow ontologies and the compliance of workflows to a set of norms that are crucial to the development of the framework we are referring to received, instead, only an attention related to workflows in general, as discussed, for instance, in [15–17, 22, 23].

Focusing on the specific literature concerning the modelling of publishing reality, there are at least two recent studies particularly relevant to this paper. In [14], authors describe an ontology of publishing workflows. The ontology employs a limited number of concepts (action, step, workflow and workflow execution) to describe the stages in a workflow. The approach chosen by the authors is to extract the minimum requirements from the natural language definition of workflow, as considered for publishing activities,in order to improve the ontology quality during ontology design. This allows not only to applying PWO to publishing domains but also to potentially reuse the ontology in other domains, like legislative or scientific applications. In [14], an example of applying PWO to the publishing domains is shown. The example contains a simple flow of main steps that composes a workflow associated with a document publication. The flow begins with the submission of manuscript and continues with intermediate step such as review, revision phase, etc. and ends with the possible publication or rejection of the document. Each step describes the task to be performed and the actor involved to perform it. In [28], authors present an agent-based workflow ontology model that combines the work process language BPEL4WS [1] and ontology language OWL-S [24] for purpose of semantic workflow building, reasoning and process reconfiguration. The ontology created is on three levels: workflow and abstract task (top level), execution task and abstract services (middle level), and internal and external services (bottom level). Each level is controlled by an agent: the workflow planner agent controls the workflow, broker agent takes care of task coordination, task mediation and task communication with outside services and the service agents are responsible for execution task at the lowest level. When a workflow instance is implemented, this level subdivision dynamically allows to interpret and to decompose the top level into low-level ontology by logic reasoning.

Since the interplay between different agents' roles is complex, the problems also related to meaning negotiation [2, 3].

5 Discussions and Conclusions

The problem of multiple authorship attribution in a complex and heterogeneous process is not only challenging but sometimes it is also hard to understand weather or not it can be solved without superimposing application-dependant boundaries.

This, in our opinion, is due to the lack of necessary information so that it is reasonable to face the problem only when some restrictive conditions are met.

Among the others, versions and the knowledge of the roles involved are of paramount importance, so that when all these information are accessible the editorial workflow might be deduced and known authorship detection techniques can be applied to try and solve the problem.

In this paper, we introduced a framework for a family of ontological structures able to model the workflow of an editorial process. Every workflow is characterised by the notions of editing action, role, privilege, document version, suggestion, comment, editing note, document state and metaroles.

The combinatorics of the privileges on the actions, the comments and the editing notes define roles. The combinatorics of privileges on the assignment of roles and actions to individuals and the assignment of editorial duties to individuals define metaroles. Overall, the above-mentioned combinatorics provide the structure of the classification of workflows that is presented and discussed.

This work is open to several developments. Nowadays, we mainly focus on web literature. This looks like a restriction unless we consider that a web document, without further hypothesis, is non-necessarily simpler than a non-web one. Web text style is more related to spoken language and often avoid linguistic formal rules, even when resulting from an editorial process. Editorial objects (documents) represent the subject of authorship analysis, nevertheless focusing on the investigation of editorial workflow on web literature, we have been able to simplify the temporal aspects of the model.

Finally, as a medium time goal, we are also planning to extend the ontology taking into account not only textual information. As said in Sect. 1, an authorship analysis could also include images and other channels [6–9] that provide a useful amount of information that it will be indubitably useful in multiple authorship detection.

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Part III
Agents and MAS Applied to Well-being and Health

Multi-agent Complex System for Identification of Characteristics and Personality Types and Their Relationship in the Process of Motivation of Students

Margarita Ramírez Ramírez, Felipe Lara Rosano, Ricardo Fernando Rosales Cisneros, Esperanza Manrique Rojas, Hilda Beatriz Ramírez Moreno and Gonzalo Maldonado Guzmán

Abstract This paper presents a proposal design of multi-agent complex system for the identification of the characteristics and the types of personality of university students as well as their relationship in the process of motivation for them. Diagnosis and identification of personality types are based on the analysis of knowledge base and the collected information of students with concrete actions that agents through their communication skills and interaction with the rules and standards defined receive, analyze, and determine the identification of outstanding personality type and the most important motivating factors according to the identified personality.

Keywords Multi-agent systems · Complex systems · Personality

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1 Introduction

Human beings have personality that distinguishes us and differs from others, which is formed by a pattern of thoughts, feelings, and behavior that persist across time and situations as well as the result of the influence of inheritance and the environment, on the other hand, the motivation that a person can have is influenced by personal characteristics, their physical characteristics, their skills, and their attitudes. In the educational environment, it is important to recognize the different personality types, identify the motivation that students have, and that it influences them to carry out their activities and definition of your goals and objectives. Knowledge of student personality traits to who is intended to influence or form allows you to achieve the best results in the process of teaching and learning information technologies are an important support in the development of systems that will assist in the identification of traits and diagnosis of personalities, through the integration and manipulation of large volumes of information.

The use of multi-agent systems favors a correct diagnosis, and through agents it is possible to decompose the classical procedures in tasks that are solved by making use of the capabilities of communication that agents have, and integrate any number of variables when making a differential diagnosis. This paper presents the design of multi-agent complex system for identifying characteristics, the type of personality of students, and its relationship with the motivation.

2 Justification

In the academic environment, the development of a student is influenced by different variants, one dominant is the type of personality and motivation to achieve the goals it pursues or plans to achieve that. The use of a tool that facilitates the diagnosis of the type of personality of a student that can be very useful in the learning environment since it allows to know more specifically the characteristics and possible reactions that this may present in certain situations, including academic development. A tool that can support this process is a social simulator, which allowed to determine the type of dominant personality of the student, as well as obtaining information useful in the teaching–learning factors that have a student. Be able to analyze the characteristics of personality and motivational factors will support the determination of the type of attention required for each student, as well as in the elaboration of plans and actions according to the best academic results.

In the academic environment, the development of a student is influenced by many variants, one dominant is the type of personality, motivations it has, and the goals it pursues or plans to achieve. The use of a tool that facilitates the diagnosis of personality of a student can be very useful, since it allows to know more specifically the characteristics and possible reactions that this may present.

3 General Objective

Design of a Social Simulator that allows to identify the type of personality and the influence of it on the personal motivation of students.

4 Personality

The personality of the human being is composed of the way in how it relates to others, how you react to stimuli from the environment, as well as physical and psychological traits that comprise it. It is possible to consider that the heritage, the environment, and what touches you live play decisive role in the identification of the human being. Referred to as personality to the set of mental qualities, thoughts, feelings, and emotions that characterize a person and differ from others. They arise as a result of needs and personal and social motivations and it persists over time, in different situations or moments [1].

For Robbins, the hereditary theory says that the definitive explanation of the personality of the individuals is in the molecular structure of the genes located on chromosomes. However, there are variables that can determine the personality as biographical characteristics, acquires skills, and learning style [2].

Different studies have been conducted, and thousands of individual characteristics, which determine different personality traits have been identified. This amount of features makes it almost impossible to predict the behavior of a person. This analysis was able to identify 16 groups that can be recognized as a constant and firm characteristic that predicts the behavior of a person in specific situations. These features have been integrated with indicator types MYERS-BRIGGS (MBTI), which is an inventory of preferences.

Psychological type is Myers (1980) clarification and development of part of Jung's theory personality. Myers suggested "16 kinds of people," describing all 16 primarily in terms of strengths and potential strengths. The central concept is preference, which means "feeling most comfortable and natural with." The theory assumes that each of us prefers some ways of behaving to others and that there are four main choices in this respect [3].

Is personality a determining factor in the motivation of human beings, this allows the individual to deal with situations and events and work to achieve their goals.

The motivation is closely related to the development of human being and this is possible to recognize it by the interaction of people with different situations, the motivation varies from person to person and personality may be a factor that determines the intensity or direction of motivation. It is possible to identify as main factors of motivation, the intensity, persistence, and the direction to achieve goals and these elements can be variables or indicators according to the type and characteristic of the personality. Talk about the features consider personal, biographical, psychological, and physical situations that are influencing the person and personality trait is not a simple subject, it is a topic which by its terms is extremely complex, and it is important to identify the complexity and characteristics of a complex system.

5 System

Based on the concept of a system, we can identify a system as a set of elements or parts that interact among themselves in order to achieve a specific objective, there is the elements mutual influence, so that the behavior of each of them influences or impacts on others. That a system be described must be identified its parts, interactions and relationships between them, as well as the value of each of its elements, i.e., the functions and the structure of the system. The use of the theories of systems as a description and analysis methodology originates from impulsive to simplify reality and understand the natural events. The theories of systems try to unite different disciplines by its range of applications and at the same time act as a platform for multidisciplinary perspectives [4].

The term agent is a concept that combines several disciplines ranging from artificial intelligence, software engineering, databases, distributed systems, to fields of knowledge such as psychology, sociology, medicine, economic theories, etc. An agent is a computer system located in some environment, within which it acts independently and in a flexible manner to meet its objectives. In addition to the interaction with the environment, an agent is characterized by the following properties [5].

A multi-agent consists of the description of each of the agents of the population under study, as well as rules of interaction between them. Once defined, this model gets underway which allows to observe a simulated reality [6].

6 Complex System

A complex system is composed of different elements or subsystems that interact dynamically, i.e., change over time is feedback in a nonlinear manner, i.e., that there is a proportional relationship between the causes of some and the effects of others. According to [7], a complex system is characterized because they are biological agents and psychic and social agents that have intentional or objective reasons which are diverse, dynamic, with different priorities and may be contradictory, in the same way are agents that act as modified reality and are modified by this, which have emergent properties that arise from interactions between them and present processes of self-organization in biological, psychic, and social agents; in the same way, they present states of chaos and predictability horizons, integrate actors and groups presenting homeostasis, perception, action, adaptation, and resiliency [8].

Therefore, it is possible to identify the human being as a complex system, in which human acts according to their reality and is able to modify it, as well as be modified by the environment.

Complex adaptive systems are born from the evolution of the concept of complexity and especially in the adaptation of the concept of adaptation of complex systems; these systems are naturally in biological systems or artificial systems that they have any relation to life [8].

Processes of thought and psychological characteristics of human beings by their diversity and multiplicity are complex systems, an analysis of them and the identification of each of its variables allows us to study them, predict their behavior or behavior patterns and identify the motivating factors according to the personality and characteristics.

For the realization of this prediction, a simulator system can be very important, since it allows to simulate their IDs, their evolution and support in the analysis and forecast as a basis for knowledge of factors that influence the development of a student.

7 Social Simulator

It is possible to define a social simulator as a model that seeks to imitate aspects and reality situations, so the conditions appear similar to reality, but have been created artificially.

Simulators from person to person are social simulations that are studying the reactions of individuals or groups.

Social simulation is the modeling or simulation of phenomena or social objects (society, organizations, markets, and human beings) that normally perform a computer [9].

Social simulation based on agents is one in which the computer simulation, i.e., the integration of artificial intelligence is integrated and the social sciences. On the other hand, an important element in social simulation is the use of computational agents that allow support of social simulation.

The agent is a concept that merges several disciplines such as artificial intelligence, software engineering, databases, distributed systems, and reaching areas of knowledge such as psychology, sociology, medicine, economic theories, etc.

An agent is a computer system located in any environment, within which it acts autonomously and flexible to thus meet its objectives. In addition to the interaction with the environment [10].

For models to define the object they represent, it is necessary to be built through a relationship with the reality which must be symmetrical, the relation of correspondence between the real object and the model must be reversed and convert some properties of the model to reality.

Intends to carry out a social simulator that allows to identify the characteristics and personality types and their relationship in the process of motivation, using a

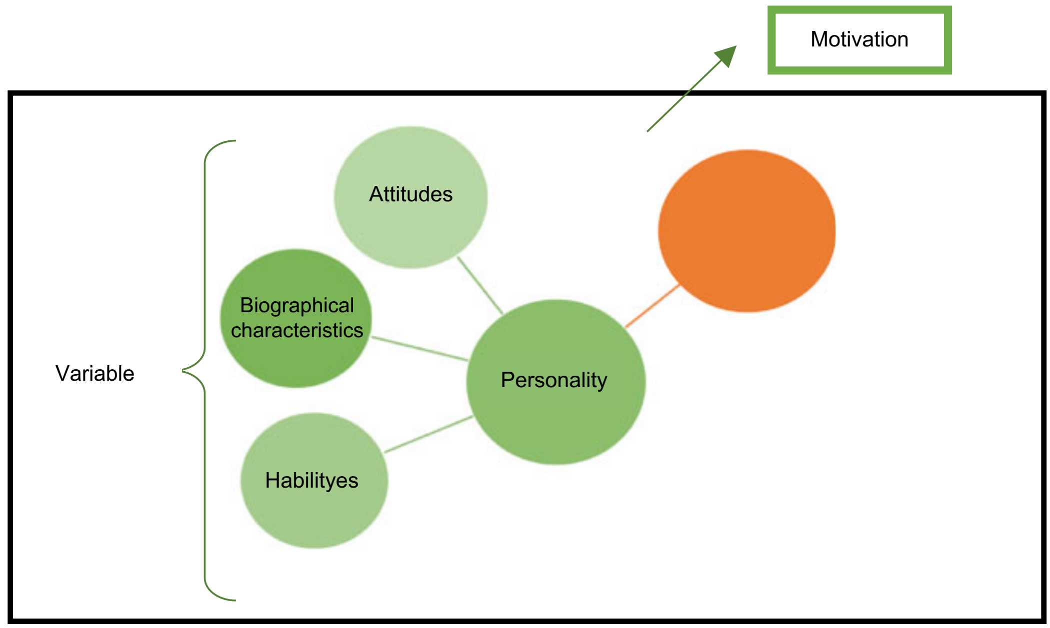

Fig. 1 Diagnosis of multi-agent system model

model of linear system, which is used to identify a subclass of models, in which it is possible to represent the complexity through related statistical theories.

A system that is consistent with a moment in which a knowledge society is built, in which activities are predominantly important activities that are sustained and closely linked to education. According to [11], the knowledge society is a new techno-economic paradigm, where science has transformed into one of the most productive activities; to ensure the success of this model all agree that is necessary to closely relate to education. The present work presents a model of social simulator that will be implemented in an educational environment to identify the personality characteristics and motivation that drive students. The realization of a social simulator represents the complexity of the elements of factors involved in the personality of a student and the factors that influence the same motivation to achieve their goals or objectives.

Previous, a diagram with the elements is shown to evaluate and consider in the system (Fig. 1).

8 Multi-agent Systems (MAS)

A multi-agent system (MAS) is a set of generally heterogeneous and independent, autonomous agents that work together, integrating resources and capacities to achieve the expected functionality. These systems have the ability to interact in a common environment and are able to coordinate, share knowledge, and negotiate to achieve the desired goal and resolve specific problems.

This network of agents goes beyond the capabilities or individual knowledge of agents [12]. It is possible to identify a multi-agent system, as an organized society consists of semi-autonomous agents that interact with each other, whether it is to collaborate in the solution of a set of problems or the achievement of a number of individual or collective objectives [13]. These systems composed of multiple computing elements interact with each other, called agents, who are responsible for the coordination of the intelligent conduct of a group of autonomous agents, which have the ability to coordinate their knowledge, goals, skills, and take decisions and plans [14].

A multi-agent system (MAS) is basically a network of organizations focused on solving problems and work together to find answers to problems that are beyond individual capacities or knowledge of each entity [15]. In previous concept, find similarities, coincidences, and it is possible to consider that these systems are part of a new technology trend, their abilities to solve problems that require coordination and communication model oriented to objects in many ways, allowing the construction of dynamic systems capable of adapting to changes to suffer their environment [16].

9 Design of Multi-agent System Model

The model of multi-agent system for diagnosis of personality types consists of a system that will be able to make the diagnosis of personality identified, in particular, those defined, the system is composed of a set of subsystems of intelligent agents, which interact and perform specific activities focused on perceive, analyze, evaluate, and present preliminary diagnosis. This model features a responsible agent to receive information, through the questions made to patients through applied questionnaires, an agent that integrates the information received, an agent coordinator responsible for control between communications generated between agents, and a responsible agent generates the diagnosis or the identification of the type of personality presenting the user once it has analyzed the information received by the agent's data.

Open distributed systems can be modeled as open multi-agent systems that are composed of autonomous agents that interact with one another using particular mechanisms and protocols. In this respect, interactions form the core of multi-agent systems. Thus, perhaps not surprisingly, the agent research community has developed a number of models of interactions including coordination [17], collaboration [18], and negotiation [19]. Figure 2 shows a graph with the components that comprise the model of multi-agent system with the component that comprises it, such as the coordinating agent, the personality identifier agent, the agent that determines the type of motivation, as well as the knowledge base and the algorithm that determine the patterns of behavior of each type of personality.

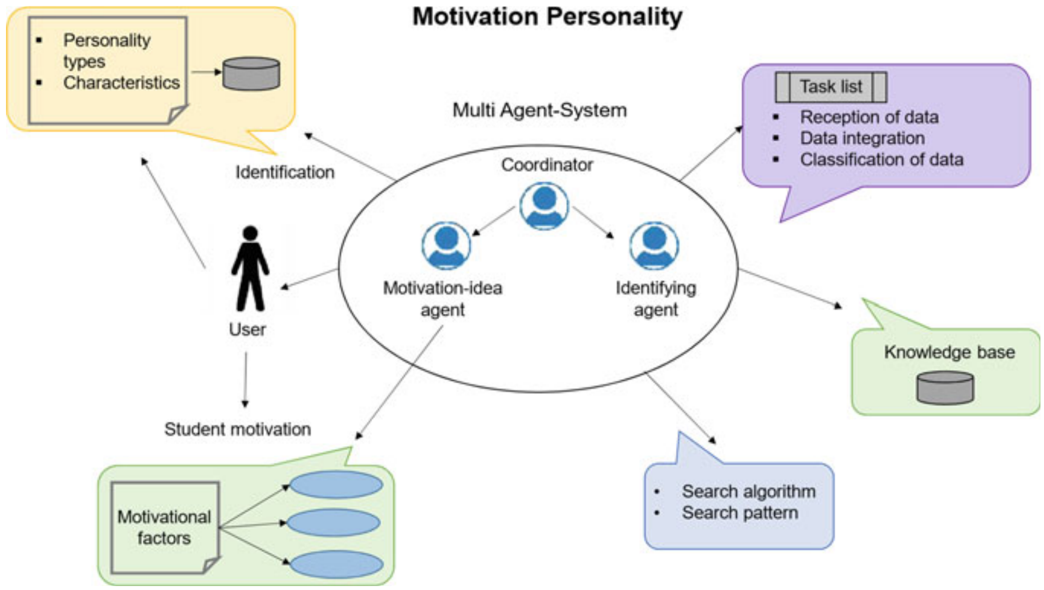

Fig. 2 Model of multi-agent personality-motivation system

10 Conclusions

A model of multi-agent complex system will support the academic area, with the achievement of a diagnosis or identification of the personalities of the students on the basis of the analysis of the information and the established knowledge base.

This type of system allows to integrate different processes, by agents of communication and interaction with the environment with other agents, as well as the ability to consider a large number of variables to integrate a differential diagnosis and to adapt to situations in a changing environment.

This article discusses the design of a model of a diagnosis or identification of personality type based on the use of a complex system with multi-agent with specific tasks for each agent, including the agent coordinator. The intelligent agents will use reasoning algorithms with software patterns, in which they have access to a knowledge base and determinate personality types.

The integration of the different agents and appropriate technologies provides benefits that can be exploited in different areas and serve as support in making appropriate decisions.

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Towards a Social Simulator Based on Agents for Management of the Knowledge Base for the Strengthening of Learning Competences

Consuelo Salgado, Ricardo Rosales, Felipe Lara-Rosano, Sergio Vázquez and Arnulfo Alanis Garza

Abstract In this article, we present a proposal to develop a simulator based on agents, which allow the detection of student behavior patterns, the curriculum, and the labor sector that make up the environment of the school environment with the work environment. The model describes the relationships and iterations of three agents: Student Agent, Study Plan Agent, Employer Agent, these iterations along with their knowledge base will result in the identification of opportunities and strengthening of learning competencies to incorporate the student in the labor sector before the request of a need or request of the current work environment. The detection and action of these particularities will allow orienting the study plan towards the learning needs and strengthening of the competences in the future graduates of the university and achieve the appropriate insertion in a context based on the knowledge and skills of the labor sector.

Keywords Complex systems · Agent-Based simulator · Competitions · Higher level education

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1 Introduction

The definition that most people know about the system is that all the elements act in a certain way together to achieve a common goal. This conception is focused on traditional systems, delimited and with their own characteristics to address certain situations, leaving complexity aside.

But there are systems that cannot be analyzed and explained from a traditional perspective, given the complex relationship between their components and the lack of specific characteristics between them, these are known as complex systems that arise based on the number of unpredictable behaviors and environmental conditions of the same system that can be emulated with an agent-based model.

This project was born from the interest of identifying the relationship of the educational program of Bachelor of Informatics with the incursion of graduates in the productive and labor sector. The objective is to present a proposal of a social simulator based agents that allows to identify the strengths and improvements of the learning competences of the curriculum and the demands of the labor sector at a certain moment.

2 Background

The sense that we can give to the complex can be from the explanation of the human being to do something, as something that is composed of several elements, to something that is difficult to understand because of the variety of the elements so it is integrated and the relationship that occurs between them. The complexity as described [1] is a reality composed of a network of entities that influence temporarily stable situations, or patterns causing stability, you can also associate changes that give small changes in the environment, chaotic changes the existence of a nonlinear dynamic and the appearance of new properties due to sudden changes.

Complexity is a way of studying aspects of nature and society, where it focuses on the characteristics that represent them [2] and defines them as complex systems.

2.1 Complex Systems

A system is composed of united, directed, and interrelated parts, which have a purpose and final objectives. Defining a complex system depends on the properties of the environment and the phenomenon being analyzed, of the emerging behaviors that foster feedback, therefore, giving an exact definition could be considered almost impossible since it depends on the viewpoint of the person who defines it, so there is no universally accepted definition of a complex system [3]. In order to reach an exact definition, it would be necessary to observe the iteration of the systems, subsystems, processes, and other components in the time and space of the phenomenon, the information that is shared between them should also be observed before a defined action or any change in the environment.

In another effort to conceptualize complex systems, as mentioned [4] that these systems are characterized by invariable and unpredictable dynamics, in addition, several characteristic features. These systems have two fundamental properties: the first is that they are structured and the second characteristic is complexity [5].

2.2 Computer Simulation

The models allow to represent the system, and depending on the language used can be mathematical, computational, logical, conceptual, or theoretical [6]. The simulation is a special type of model that allows to experiment artificially on the system, in order to explore different behaviors and alternative solutions [7].

For this project, we considered, use the benefits of agents. The term agent is a concept that combines several disciplines ranging from the artificial, intelligence, software engineering, databases, distributed systems, to fields of knowledge such as psychology, sociology, medicine, economic theories. The modeling of agent-based systems, as mentioned [8] depends to a large extent on the specific needs to be addressed in the environment and on the characteristics that allow them to take the initiative, share and communicate knowledge, maintain the character social, cooperating and negotiating, as well as committing to common objectives [8].

Modeling and simulation from the point of view of the complexity sciences are focused on addressing the emergence of properties from the interaction between a large numbers of agents [9] with them it is intended to represent something that implies thinking in terms of temporality and variable behaviors [10].

On the other hand, as mentioned [11], the simulation based on agents as a method can allow to treat in a simple way the complexity, the emergence and the nonlinearity typical of many social phenomena. This simulation explains how the different structures that want to be modeled arise from the individual actions of the agents.

Computational simulation is considered as an essential calculation tool that through the variation of the parameters allows testing existing models in the ranges of parameters impossible to reach through experimentation, and allows the visualization of the obtained results [12]. When a system is constructed, it is possible to predict how it will behave by studying the behavior of agents in various conditions through simulation [13] therefore, a computational simulator can be represented in a system that will produce a response predictive based on the behavior of another system [14].

2.3 Higher Education, Skills and Labor Sector

Education is a human right for all, throughout life, and that access to education must be accompanied by quality [15]. When talking about education, it also includes the higher level that can be conceived as a goal of transformation and creativity for the solution of problems or situations of social, ecological, production, technological, ideological and cultural, in a more efficient and effective way [16].

The Institutions of Higher Education have the task of training students based on a system that fosters an educational environment that solves current social problems together with students, also helping to prepare better professionals for the future [16].

The system to which we refer to the curricula that are applied in universities for the training of students, which is defined by [17] as the structured set of subjects, practices and activities of teaching and learning and containing the purposes of general training, the fundamental contents of the study and the criteria and procedures for evaluation and accreditation.

At the Faculty of Accounting and Administration of the Autonomous University of Baja California, the curriculum for the Bachelor of Computer Science designed in 2009 is currently being developed and was designed to meet the labor, social, and technological demands of the region. a study of relevance. This plan consists of three stages: basic, disciplinary and terminal where the subjects are intentionally located in the three stages mentioned for the achievement of the competences.

Education is much more than collecting knowledge, or building it, education should focus on proposing answers to problems and needs that are faced in the changing conditions in which one lives now [16] and through educational competences can promote the search of those answers and the attention to situations in all the areas that the individual is.

This program of Bachelor of Computer Science is based on a competency plan that focuses on the development, growth, and enrichment of skills, attitudes, practices, knowledge, values and that together are focused on demonstrating what the future professional is capable of doing graduated.

The development and management of Information and Communication Technologies (ICT) belongs to a very competitive and changing labor sector that is based on the needs of companies or organizations. In the case of the Bachelor's Degree, the graduate that involves people, processes and infrastructure, seeks a position in a demanding, closed and demanding work environment.

On the other hand, organizations present changing needs, in addition, which demand innovation and implementation of ICT and experts who are at the forefront.

The problem that will be addressed is the student's relationship, the educational program and the labor sector conceived as a complex system, where said relationship is defined by the new characteristics and unrepeatable needs that define it, although the program and the requirements of the work environment are interconnected in some way do not go hand in hand in the training and terminal competences of the degree.

3 Proposal of the Agent-Based Simulator

In professional education, the design of educational programs can be considered as a complex system that seeks emerging solutions to innovate in the teaching process and equalize knowledge, skills, and competencies to integrate into different environments to its graduates.

The proposal is a social simulator based on agents that shows how they adapt to their changing environment through the analysis of the variables that allow such activity to be achieved. Up to this moment, the idea of a first design of a model of linear, cyclic and dynamic type has been conceived that showed certain behavior as a result of the variables do not change with time and that the parameters will be fed intentionally with values to analyze the behavior of the system components in the environment.

The objective is to present a simulator based on agents that allows the identification of improvements and the strengthening of learning competences in a school environment to match the student's abilities with the needs of the work environment. In other words, the Bachelor of Computer Science is competitive and adapts quickly to its context and allows to reorganize.

The proposed model is a dynamic agent-based simulator composed of agents: Student Agent, Study Plan Agent and Labor Sector Agent (see Fig. 1), where the characteristics are variable in each one of them and in the environment, in addition to the behavior changes over time with alterations that are barely perceived or that can be very marked and at the same time that they are identified as the stimuli or as the responses of the same system.

The relationships that exist with the agents are between the student, the curriculum and the labor sector that contains all the information relevant to the dynamics that occurs in this environment, allowing to analyze it and estimate results based on possible behaviors.

Each of the agents of this model has its activities defined in the simulated environment. These iterations are described below:

1. The Labor Sector Agent contributes to the needs of information and communication technologies.
2. The Degree Program Agent receives the needs of the Labor Sector Agent.
3. The Degree Program Agent defines the rules and policies to adapt the contents and knowledge required by Labor Sector Agent.
4. The Degree Program Agent sends the appropriate content and knowledge required by the Student Agent.
5. The Student Agent receives the contents and knowledge to place them in their knowledge base.
6. The Student Agent sends the adaptation results of the contents and knowledge.
7. The Degree Program Agent stores the results of adapting the contents and knowledge of the Student Agent in its knowledge base.
8. The Student Agent sends the results of adaptation of the contents and knowledge to the Labor Sector Agent.

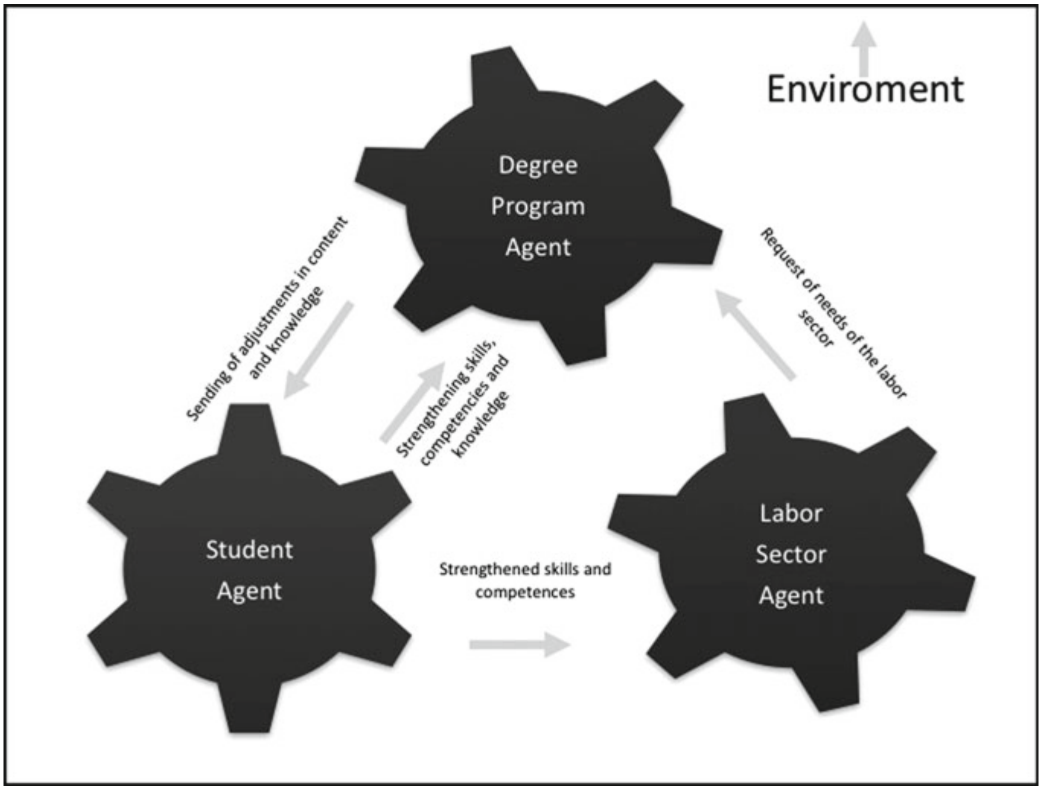

Fig. 1 Proposal of the agent-based simulator

4 Methodology

For the development of the social simulator, the tasks, procedures, and techniques that are required to achieve the objective will be considered. This project is divided into several stages as can be seen in Fig. 2.

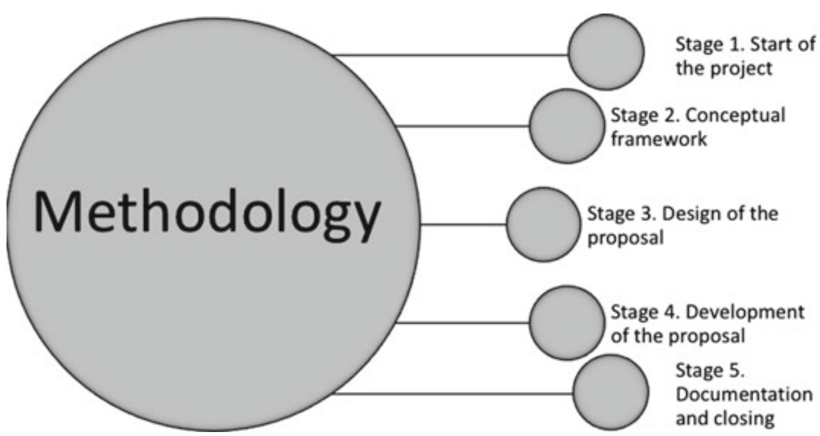

Fig. 2 Methodology for the development of the social simulator

As shown in Fig. 2, the methodology considers five stages to achieve the development of the proposal, which are described below:

- Stage 1. Start of the project: This stage is the beginning of the project where the involved will trace the strategies of the project together with those involved and analyze the proposed methodology.
- Stage 2. Conceptual Framework: This stage is very important given that the scope of the project will be defined, which will lead to the integration of the conceptual framework of the proposal.
- Stage 3. Design of the proposal: With the information obtained and analyzed, it will begin with the activity of identifying the characteristics that are required for the simulator and with them modeling it.
- Stage 4. Development of the proposal: In this stage, the simulator will be built using the specialized software for it; The tests will also be carried out to detect the changes that are required and fine-tune the details to implement it and initiate actions with the results.
- Stage 5. Documentation and closing. In this the necessary documentation for the use and application of the simulator will be made, in addition, the final report and the publication of the product will be made.

5 Conclusions

The relationship of the educational program of Bachelor of Computing and the labor sector can be conceived as a complex system that is defined by the characteristics of the components, the needs, and the unrepeatable and unpredictable changes.

The proposal aims to ensure that graduates or future graduates are competitive and that they adapt quickly to the work context through the analysis of the student's internal variables, the study plan, competitiveness, and the work environment.

The proposal is a simulation tool that allows to show how the graduate adapts to his changing environment through the improvement of skills, opportunities, and strengthening of skills and analysis of values that allow such adaptation to be achieved.

Up to this moment the idea has been conceived, with a complexity approach, of a first design of a simulation based on agents of the linear, cyclical and dynamic type that would show certain behavior as a result of the variables and the parameters will be intentionally fed with values to analyze the behavior of each of the agents.

With the future development of this idea, the agent-based simulation tool will allow you to show how the student or future graduate adapts to the changing work environment through the opportunities, improvement, and strengthening of skills and analysis of the resulting values.

6 Future Works

The present work is a proposal of a simulator based on agents that will allow to detect behaviors through the needs that are presented in the environment of the System by each one of the agents.

The future works contemplated for the development of this project consist of defining the characteristics of each one of the agents and of being necessary to include other agents to facilitate and specialize the learning.

Another activity that must be carried out is formalization to formalize agents through their capabilities.

In addition, define the variables and subvariables that allow storing the values in the knowledge base and as well as outline the agent-based simulator to develop it with specialized software.

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Use of Intelligent Agent Through Low-Cost Brain–Computer Interface to Analyze Attention and Meditation Levels by Gender

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Abstract The realization of activities in daily life can generate cognitive processes such as paying attention and having meditation to what is done, and with the use of these abilities, it is sought to obtain better results or to carry out the desired activity of the best possible way. Although people have the same capacities, there are activities where there may be differences between men and women or vice versa, for this reason, it is important to consider through gender, what are the attention level and the level of meditation presented during the performance of a specific activity. With this information, clustering of the elements is applied to visualize different levels and how it behaves in each gender, as well as in general.

Keywords EEG (Electroencephalogram) · Mindflex · Attention · Meditation · Intelligent agent · Brain–computer interfaces

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1 Introduction

People perform activities that generate different cognitive processes, understanding that there are influences that affect these processes such as physiological factors where the most important are sight and hearing [1]; through neuropsychology it has been revealed that music activates certain brain areas related to the attention that is one of these cognitive processes [2].

This paper explains the design and development of an experiment to collect information about attention and meditation in different people, in order to analyze the data obtained from the test subjects and start to visualize characteristics of the population, to get to this point, it was determined for this article to focus on the gender information of the person and having the data, it is sought to group it into two groups that represent a high level and the other a low level, both levels for the two characteristics to be evaluated.

2 Background

This section describes the definitions of terms that are important for the study. It also explains the tools that have been developed.

2.1 Intelligent Agent

If a computational system can perform in an automatic way to reach goals and this system is located in an environment, this is considerate as agent. The condition to be intelligent agent is that it can perceive information about an environment and send a corresponding action [3] and for this reason the mindflex diadem is considered an intelligent agent because it perceives information of the electrical pulses generated in the neuronal communication in the brain and as it passes through the different algorithms it processes the information and as a result a score is obtained for the attention and the meditation. These data are part of the actions you can perform.

2.2 Music

The music used as music therapy is a modern approach in the implementation of different types of therapy, not based on an idealistic concept about the healing ability of music, but rather on research and scientific techniques. The goal of music therapy is to alter the patient's behavior, aiming at correcting habits and attitudes that cause health risks in a global way [4]. In an application example, María del Mar [2] used a methodological process to guarantee the stimulation of attention in the classroom for students, focusing on hearing, movement, and improvisation based on film music. Assuming an increase in learning and using Disney's musicals allowed the acquisition of meaningful and functional learning of the students.

2.3 Attention

Attention is defined as the cognitive capacity that allows selecting the desired or required information modality at a given moment [5]. It has been previously observed that attention can be stimulated with the appropriate musical educational strategies. For example, if a person has attention problems during childhood, then the lack of attention may persist in adolescence and reflects the difficulty of following instructions to perform specific tasks, or in problems of acquiring concepts [6]. "The selective nature of attention and its importance for guiding goal-directed behavior has been one of the most extensively studied areas of Western psychology and neuroscience" [7].

2.4 Meditation

Meditation is something complex to define, for example, the following explanation was found: "Meditation is a state of no-mind. Meditation is a state of pure consciousness with no content. Ordinarily, your consciousness is too full of rubbish, just like a mirror covered with dust. The mind is a constant traffic: thoughts are moving, desires are moving, memories are moving, ambitions are moving—it is a constant traffic! Day in, day out. Even when you are asleep the mind is functioning, it is dreaming. It is still thinking; it is still in worries and anxieties. It is preparing for the next day; an underground preparation is going on. This is the state of no meditation. Just the opposite is meditation. When there is no traffic and thinking has ceased, no thoughts move, no desire stirs, you are utterly silent—that silence is meditation" [8]. To clarify the idea, you can review the information found in the topic of cognitive science and define it as "a family of complex emotional and attentional regulatory training regimes developed for various ends, including the cultivation of well-being and emotional balance" [7].

2.5 Measurements for Electrical Signals of the Human Brain

Different frequency changes are distinguishable in the spectrum of measured electric signals of the human brain. The detection of brain signals and their transmission to the signal processing unit is implemented with the use of the EEG signal measuring sensors that are placed on the head and the signal processing and transmitting electrical units [9]. There are tools that help us obtain this information and it is described in the following paragraphs.

Open EEG offers hardware, data, and freeware schemes to build the EEG system. Open EEG uses the ForceTrainer and MindFlex toys to obtain the same data in a more economical way, although it is not officially a development platform, so some modifications have to be made and the hardware is to obtain data in other contexts.

Most processes occur in the brain band, which contains the EEG hardware. The microcontroller in the brain band sends data from the EEG chip and sends the updates to a base station. In this investigation, a modification was made to the Mindflex device, which is detailed with the specifications of Knuth [10].

2.6 Measurements for Attention and Meditation

The MindFlex headband has a signal processing unit, also developed by the ThinkGear technology of NeuroSky, which can determine the value of attention and meditation [9]. eSense is an algorithm developed by the company NeuroSky, with the purpose of measuring levels of attention and meditation of people; for the different measurements of eSense, the scales of values are between 1 and 100. Taking this scale, from 1 to 20, it indicates a strongly low level; between 20 and 40 indicates a reduced measurement; from 40 to 60 at any time is considered neutral; a value between 60 and 80 is considered slightly elevated, and can be interpreted as higher than normal. Finally, values of 80–100 are considered high, meaning that they are strong indicative of the weight levels of that measurement.

When a sensor measures 0, it is indicating that ThinkGear is not making measurements, and this, most of the time, may be due to noise. The value of attention eSense indicates the intensity of the level of focus or mental attention of the user, such as that which occurs during intense concentration and directed (but stable) mental activity. Its value varies from 0 to 100. Distractions, wandering thoughts, lack concentration, or anxiety can decrease the levels of the attention meter [11]. The value of meditation eSense indicates the level of a user's mental "calmness" or "relaxation". Its value ranges from 0 to 100. Distractions, wandering thoughts, anxiety, agitation, and sensory stimuli may lower the meditation meter levels.

3 Related Work

In the following paragraphs, some papers related to the investigation are explained. It is important to know what information was obtained to carry out this work.

3.1 Assistive Context-Aware Toolkit

Assistive Context-Aware Toolkit (ACAT) developed by Intel labs is a free platform to allow people with neuronal diseases or disabilities to have full access to computer skills and applications using interfaces tailored to their condition [12]. One of the most recognized uses of this application was the one given by scientist Steven Hawking, who used this technology in combination with a series of sensors connected to different parts of his body, so that the scientist could express verbally his ideas, using a database of all the publications made by the scientist, pretending with this that the system learned about the drafting methodology of Hawking.

3.2 The Design and Preliminary Implementation of Low-Cost Brain–Computer Interface for Enable Moving of Rolling Robot

The paper explained the design of transmitting a command to a robot based on brainwave data, collected via Mindflex. They used three brainwave states to command the wheeled robot to move forward, turn left, and turn right. They worked with the alpha and beta brainwave which are processed using backpropagation neural network [13].

3.3 Evaluation of the Neurosky MindFlex EEG Headset Brain Waves Data

The paper explained the development of a system to do different activities such as measuring, data collecting, data processing, and visualizing software to investigate how brainwave signals alternate in time and how they depend on the changes of brain activity. The program helps in the development of individual processing algorithms. On the other hand, the EEG headset can be interfaced to other devices owing to this application and the control of these devices can also be solved [9].

3.4 Psychophysiological Evaluation of a Simple EEG Device

The paper described the evaluation of a simple EEG device, the Mindflex, by means of psychophysiological measurements. The Mindflex EEG controlling signal is speculated to be a complex function of EEG attention signal and electrode impedance. Such control results in what seems to be a stochastic ball lifting when the user plays with the game included. It should, however, be noted that the physiological EEG signal is indeed needed for a voluntary foam-ball lifting. In the opposite case, the foam ball would not move in a controlled manner [14].

4 Methodology

The brain wave data were obtained while the test subjects listened to a playlist and solved a "letter soup" at the same time. A modified Mindflex coronet was used [11] that returns 11 signals in a range of 420 s, obtaining an array of 11×420. The processes to obtain this information will be explained.

The data from the NeuroSky must be performed, so library used in Arduino will do this job since the library will take the information and turns into friendly format values separated by commas [10]. Data is received by serial port into Matlab and it is recorded by 7 min (420 s) for each person. The program contains information about a user so that it would be easy to identify the data during the next process.

From the set of data obtained for all users, the signal belonging to the concentration was separated and K-means grouping method is used due to its simplicity and versatility [15]. They were grouped using two centroids, in which one of them represents low attention and the second centroid represents high attention. Thanks to this study, it can see what gender predominates in each centroid [16].

Motor imagination is a process that consists of a cognitive process where a person plans a movement without executing it [17]. It is important in the way in how headband is on the user. That is based in the International System 10 20, electrodes place headband electrodes were placed in Fp1, A1 and A2 points [18].

5 Experiments y Results

The purpose of the creation of the experiment is to obtain the information extracted from the "MindWave" device to analyze the characteristics related to the attention and meditation levels, which will be labeled to make the identification of the gender to which the test subject belongs and then perform a grouping to generate groups with different levels. In its implementation, a series of parameters were applied where the subjects were found in the same conditions at the time of the test.

It was decided that the user performed an action with the intention of focusing their attention and meditation on a specific situation while the EEG data were taken, then the action to be performed was to solve a "letter soup", where the user has to find a series of words that are not visible to the naked eye, since they are placed in a grid that is filled with several letters and the way to find them is to see the union of letters to form a word.

Another point that was considered is the use of music, as mentioned above, music is an element that can influence the development of an activity by the user; therefore, music was used that is designed to influence the attention, and for this, we decided to implement the experiment with a playlist that exists in an online music reproduction platform; for this case, we chose to use the Spotify software and as a consequence reproduce the list called "Perfect Concentration".

A final point that was integrated into the test was the time to measure the characteristics in each person; for this case, it was decided to use 7 min to perform the activity and thus be able to play the first three complete songs of the playlist and also play about seconds of the fourth song to be able to meet the specific minutes to work on the activity. The development considered that the time was necessary since the letter soup has a certain number of words to look for in a certain time with the objective that the person was focused on carrying out the activity and thus have a considered time to be looking for the terms.

5.1 Data Obtained

For the correct performance of this research, 62 subjects of different gender (31 male and 31 female) were tested regardless of age, race, social group, level of studies, etc. Tables 1 and 2 show the data obtained by men and women.

5.2 Color Results

A topic to highlight is that for the realization of the tests, they were given to choose a color down desired by the test subjects, to mark the localized words, of which, most of the women preferred the green color in some of its tonalities, followed by the color blue, while men greatly preferred the color blue, followed at par, by the color green and black (Table 3).

5.3 Attention Results

The analysis is intended to identify the difference in attention levels for men versus women. From each test subject, 420 measurements were taken with the EEG, obtaining with this a data set of 26040 rows by 11 columns of which 61.37% showed an average concentration of 30.7037 and the remaining 38.62% of the total population showed an average concentration of 67.63; on a scale of 1–100 for the concentration levels provided by the eSense algorithm (Table 4).

Table 1 Obtained data by men

Person	Gender	Color	Words	Average attention	Average meditation
1	Male	Blue	14	7	1
2	Male	Blue	9	59.15	61.32
3	Male	Blue	7	40.66	68.94
4	Male	Blue	11	63.92	24.73
5	Male	Blue	8	44.56	72.51
6	Male	Blue	14	27	70
7	Male	Blue	15	55.66	59.74
8	Male	Blue	10	53.27	86.61
9	Male	Blue	6	61	43
10	Male	Blue	11	31.27	49.79
11	Male	Blue	9	43	44
12	Male	Green	10	47	43
13	Male	Green	12	48.29	50.87
14	Male	Green	13	45.06	46.95
15	Male	Green	13	12.13	79.47
16	Male	Green	13	40	50
17	Male	Green	12	47.7	59.78
18	Male	Black	7	59.08	65.15
19	Male	Black	10	47.29	38.08
20	Male	Black	6	59.71	81.89
21	Male	Black	14	52.65	74.2
22	Male	Black	12	73	70
23	Male	Black	9	25.04	47.34
24	Male	Red	8	47.37	46.33
25	Male	Red	13	24.6	15.6
26	Male	Red	13	41.86	87.74
27	Male	Red	7	25.15	93.14
28	Male	Purple	11	22.41	51.41
29	Male	Purple	19	40	40
30	Male	Brown	16	35.74	64.92
31	Male	Orange	16	39.3	60.23

Table 2 Obtained data by women

Person	Gender	Color	Words	Average attention	Average meditation
32	Female	Blue	13	47	63.53
33	Female	Blue	10	36.8	47.05
34	Female	Blue	19	36.31	81.51
35	Female	Blue	12	42.56	75.46
36	Female	Blue	7	45.5	79.24
37	Female	Blue	20	53.46	65.69
38	Female	Blue	16	41.3	48.74
39	Female	Blue	6	65.99	51.1
40	Female	Black	9	43.64	43.09
41	Female	Green	9	90	73
42	Female	Green	8	11.63	58.47
43	Female	Green	15	94.57	22.95
44	Female	Green	11	40.99	54.24
45	Female	Green	15	41	56
46	Female	Green	8	30	44
47	Female	Green	13	75.01	43.02
48	Female	Green	12	40.31	66.23
49	Female	Green	17	41.4	54.6
50	Female	Purple	11	70	16
51	Female	Purple	15	29	64
52	Female	Purple	8	35.03	54.2
53	Female	Purple	9	56.29	55.37
54	Female	Purple	18	89.47	29.82
55	Female	Purple	13	41.04	50.1
56	Female	Red	20	16	93.8
57	Female	Red	10	52.78	46.08
58	Female	Red	13	36.58	63.67
59	Female	Red	8	21	64.15
60	Female	Red	9	75	56
61	Female	Orange	13	50.85	73.4
62	Female	Yellow	17	16	54

Table 3 Average data obtained by color

Average data obtained by color				
Gender	Color	Words	Average attention	Average meditation
Male	Blue	10.36	44.23	52.88
Male	Green	12.17	40.03	55.01
Male	Black	9.67	52.8	62.78
Male	Red	10.25	34.75	60.7
Female	Blue	12.88	46.115	64.04
Female	Green	11.38	52.94	52.24
Female	Purple	12.33	53.47	44.92
Female	Red	12	40.272	64.74

Table 4 Attention outcomes

Attention obtained data		
Gender	Counted data	Average attention
Male	8095	30.70
Male	4925	67.63
Female	7887	30.70
Female	5133	67.73

Table 5 Meditation outcomes

Meditation obtained data		
Gender	Counted data	Average meditation
Male	6785	71.66
Male	6235	35.79
Female	8121	71.66
Female	4899	35.79

5.4 Meditation Results

Likewise, it is concluded that from this set of data, regarding the levels of meditation; of 100% of the data taken, 42.76% of the general population has an average of meditation levels of 35.7859 while the remaining 57.24% has an average of meditation levels of 71.6621 on a scale of 1–100 (Table 5).

6 Conclusion

The men found a total of 304 words, while the women found 343 words, that is, 39 words more than the men, under the same circumstances all. The largest number of words located in a test, women have 20 words located, while the highest value of men is 19 words.

Based on the high levels of attention, 48.96% are men while 51.04% are women. On the other hand, in the highest values of meditation, 45.52% corresponds to men and the remaining 54.48% to women, and these results may leave us uncovered that women obtain levels of care with higher values than men, performing some activity in specific and under the same time-space conditions; however, it is important to understand that the difference is minimal to determine that it is something general.

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System Development for Automatic Control Using BCI

Antonio Meza, Rosario Baltazar, Miguel Casillas, Víctor Zamudio, Francisco Mosiño and Bladimir Serna

Abstract Brain-Computer Interface (BCI for its acronym in English) is a device that allow the communication between a user and adapted environment. The Ambient Assisted Living (AAL for its acronym in English) can be potentially used to assist people with some motor disability. In this article, we show the low-cost system development that permit an actuator control through commercial EEG signal acquisition, detecting a flickering. The system is also tested to evaluate its feasibility with an offline analysis in Matlab. The experiments and results are shown.

Keywords EEG (Electroencephalogram) · Embedded systems · Brain-computer interface · Muse · FFT

1 Introduction

Ambient Assited Living focus to develop a cooperative and smart automated environment, offering help to perform daily activities. At this point, the techniques used in AAL have been successfully applied to promote and support independent living in elderly people [1].

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However, the beneficiaries are not only the elderly people, but also that group in which people who suffered some type of accident. Nowadays, they need to re-incorporate themselves into the activities that they used to do before their accident.

Brain-computer interface are devices that permit users send directions to a computer application using the brain activity. This activity is measured and processed by the BCI system. Current BCI systems rely primarily on Electroencephalograms (EEG) to measure the brain activity, and although initially these systems were designed as assisted devices for disabled people, devices for healthy people have recently emerged [2].

Nowadays, several low-cost BCIs, such as Emotiv EPOC (EMOTIV Inc. San Francisco, CA, USA) and Neurosky (NeuroSky Inc., San Jose, CA, USA), are commercially available. These devices are compact and available to all public [3] and they can be used to do research.

Some headbands are capable to detect artifacts (eye blinking), but also manufacturer give us a chance to work with its information, therefore we can develop applications in AAL to support people with motor disability.

2 Related Work

For the elaboration of this project an investigation of related works were made to see the applications that we have with the BCI. With the found information, we performed the next classification:

– Home
– Domotic
– Assisted living
– Assistive system
– Assistive technology
– AAL

Each item in the previous classification has different applications, however, the main purpose is on assistance technology and/or domotics.

In the article *"An embedded implementation of home devices control system based on brain computer interface"* [4] presents an embedded architecture for systems of control of houses through motor imagery paradigm, where the implemented processing was made with public data-sets to perform a classification and then (future work) it could be implemented in a devices control at home.

In the Introduction some commercial EEG were seen, but it is striking that just as it is handled in embedded systems, there is low-cost material in the EEG. As it was described in *"Online Adaptative filters to clasify left and right hand motor imagery"* [5], a low-cost commercial device is used for the Brain signals acquisition, where later a processing is made with *Matlab*. The main focus of this work is the signal classification, where up to 80% is reported.

The main purpose in some articles [6–8] is the mind signals treatment using a pattern recognition method that allows the signals classification either by paradigms such as motor imagery or SSVEP (Steady State Visual Evoked Potentials), or hybrids (combination of both paradigms for a better results), where later, as a future work, apply these techniques to an automated environment.

Another work cited by *Belwafi* [9] presents a job based on EEG signals, where the future application is the home devices control. However two problems are described: The work to be done with the filters to the signals acquired (Signal processing), and the other problem is the embedded architecture design, making reference to the software/hardware used. Anyway, the work's purpose is focused in EEG signals treatment for later use in home devices (translated as "future work").

More applications were found in assistance's field, focused on rehabilitation or the medical sector [3, 10–13]. Through these articles, it can be identified that most of them have the Signal treatment purpose, and the future work is the treatment's application. Nowadays, the studies are carried out and gradually these studies will be added to real applications.

3 Methods and Materials

3.1 Methodology

Previously, the parts that shape the project were described. Below, in Fig. 1, you will see a sketch that describe each element and what it does.

The Muse headset is placed in the test user-patient, where then the muse headset is Bluetooth paired through an app developed in Android studio. Then, the developed app will be delivering information to the ESP32 trough Bluetooth too. Finally, integration software is carried out with actuators and communicate EEG signals with the automated environment (previously prepared).

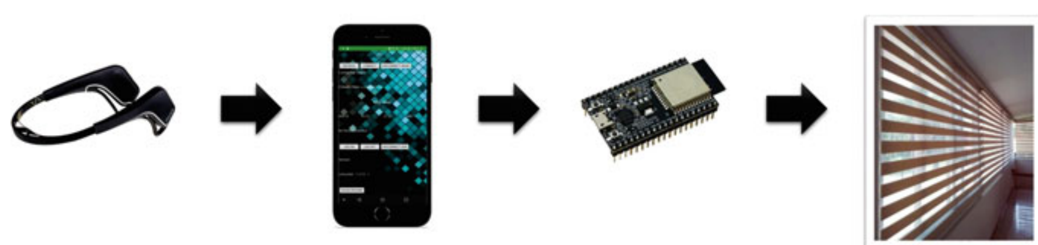

Fig. 1 General flow description from the currently project

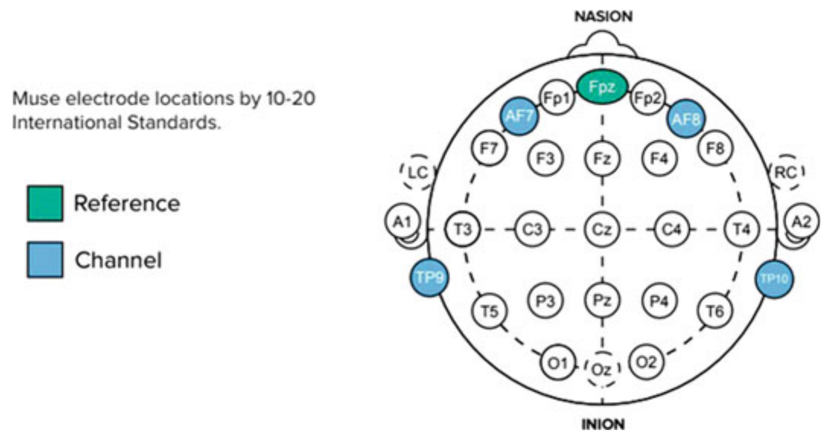

Fig. 2 Electrodes position according muse headset [14]

3.2 Data Acquisition

Data acquisition was taken with muse Headband [14], which is used in commercial areas and research topics (hospitals and Universities around the world). The data acquisition is taken wirelessly (Bluetooth). The electrodes location is based on the international 10/20 system (Refer to Fig. 2). These electrodes are: TP9, TP10, AF7, AF8, FPZ, at a sampling frequency of 256 Hz. The reference electrode is Fpz, while TP9, AF7, AF8, TP10 are dry electrodes [14].

3.3 EEG Filter Design

We implement a method to prove that we are really getting flicker information, so we analyze data from Muse headband (.muse) and convert it to Matlab file (.mat). In order to reduce the signal-to-noise ratio, the common average reference (CAR) method was used [15].

$$V_i^{CAR} = V_i^{ER} - \frac{1}{n}\sum_{j=1}^{n} V_j^{ER} \tag{1}$$

where:

$$V_i^{ER}$$

is the potential between the ith electrode and the reference, and n is the number of electrodes.

Some filters techniques are suggested (*Accurate Decoding of Short, Phase-Encoded SSVEPs*) and applied as Band pass and Butterworth filter (4th order) [16].

3.4 EEG Signal Processing

After pre-processing, EEG signals should be processed and suitable features should be extracted from raw EEG signals. Fast Fourier Transform (FFT) include two types of features: amplitude and frequency of sorted FFT. Fast Fourier Transform of the EEG signal is sorted, then a finite number of the amplitudes or frequencies of the FFT is selected as feature. The number of the selected amplitudes or frequencies is the parameter of this type of feature extraction strategy [17].

$$f(\omega) = \mathscr{F}[f(t)] = \int_{-\infty}^{\infty} f(t)e^{-j\omega t}dt \qquad (2)$$

where $\mathscr{F}$ is the operator of the Fourier transform [18].

The raw signals were offline analyzed. We realize in *"Accurate decoding of short, phase-Encoded SSVEPs"* [16] that they are using a range between 5 and 20 Hz to seek eye-artifact. Besides, it can be seen that they get acceptable results using a 4th order Butterworth filter.

3.5 Signal Processing in Mobile Application

At this moment, there are libraries developed by Muse Developers [14], which allows us obtain headband's technical information, as well as EEG data, accelerometer, gyroscope, etc., allowing us make applications in Android studio software

3.6 Embedded System

The embedded system used for this project is the ESP32 from the ESPRESSIF company. The reason why ESP32 was implemented is the low power consumption since it designed for mobile devices and IoT applications. At the same time it has a hybrid chip with Bluetooth and Wi-Fi [19, 20]. which will allow the communication between Muse headset and ESP32 micro-controller. Another feature that stands out is its robust design to operate in industrial environments within a temperature range of −40–125 C.

3.7 Functionality

Blinds function can be explained as automaton with a transition diagram [21] defined as follow:

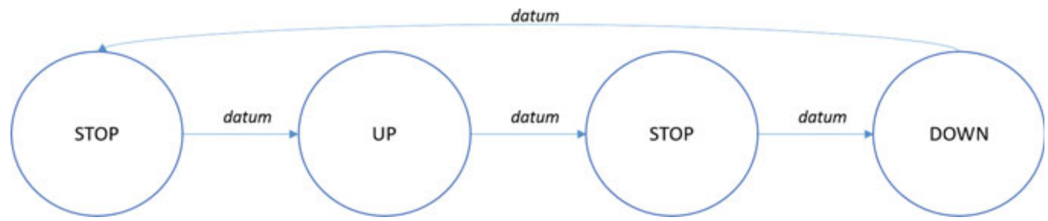

Fig. 3 Description behavior with an automaton

We propose send a datum through Bluetooth which will change the blind's state. We aim program a threshold with raw EEG data. Every time that a person blink (forced) a threshold is exceeded therefore we code a datum and a automated blind will receive a signal, either move or stop a blind. (See Fig. 3).

4 Experiments and Results

Ten people were randomly selected, whose age rank between 23 and 50 years. No one has used the muse headset before or had performed experiments that would involve the use of EEG signal recording.

Experiment 1 Experiment 1 consisted in turning a led on/off using a forced blink. The user/patient had to know how much force had to apply to avoid activating the LED when it was not necessary. Then, they had to apply this action for automated blind.

Experiment 2 Experiment 2 was carried out in a similar way as the first one. In this case we record data from headband with the purpose to be analyzed in offline mood and demonstrate trough a pre-processing and FFT that we are taking blinking information from EEG data

Results:
Within the first results corresponding to Experiment 1, very good results were not obtained regarding the control of on/off of an LED. Corrections were applied. We migrate the "on/off experiment LED" to "move up/move down blinds" getting good results.

Among the main factors that influenced was the position of the Muse headband, because it is inferred that the position of the sensors will not always be the same due to bone issues of the skull. Details of placement of the headband were taken care of to obtain more precise results.Not only we trust in information we get from muse headband, but also we make an offline analysis in which we compare a forced blink with non-forced blinking.

Graphics in Fig. 4 show both actions, (*forced and non-forced blinking*). Each channel gave us a datum every second (in average 250 per second, all depends with Bluetooth connection) and with this information we can graph information as follows:

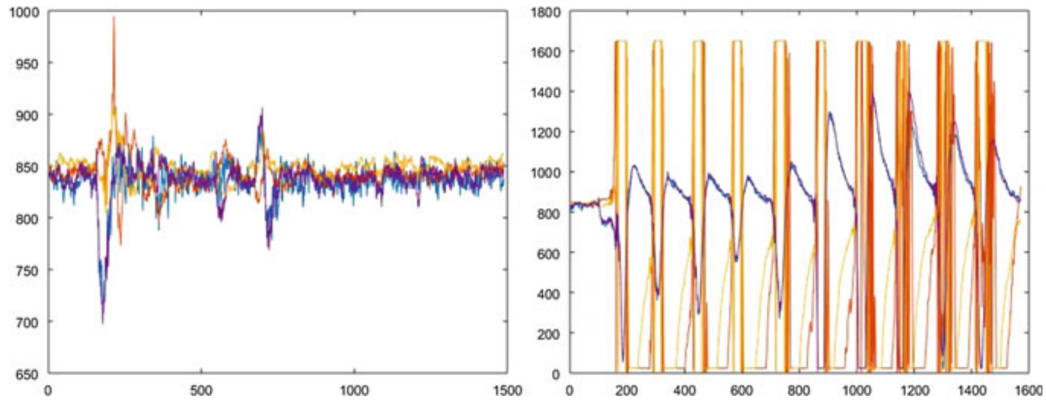

Fig. 4 Comparative graph from forced and non-forced blinking

Table 1 Statistical summary Experiment 2

	Experiment 2	
	Frequency	Amplitude
Average	6.068	90.806
Standard deviation	0.523	32.664
Variance	0.273	1066.94

In first graph, although there are some peaks, labeled as non-forced blinking, range is notorious lower (700–1000) than range in second graph (0–1600)

In parallel, we worked with the acquired signals to make an analysis that allowed us to know if the obtained signals were from muse headband (blinking signals). Using the recorded dataset and FFT in combination with filters processing, we obtain the results in Table 1.

Below, in Fig. 5, there are the graphs of an analysis made in Matlab, which consists of the pre-processing and filters of the EEG signal. We coded a range from 5–20 Hz (as it was mentioned in related work in [?]). Graphics show that frequency dominant is this range.

Finally, you can see in Fig. 6 that there is an app's screen-shot. In the app screen-shot we can visualize some buttons and spaces with important information. In section *"EEG data"* we get data from muse headband sensors (Chanel 1, 2, 3 and 4 respectively).

Also, there are some buttons that can help to pair the cellphone with muse headband and micro-controller.

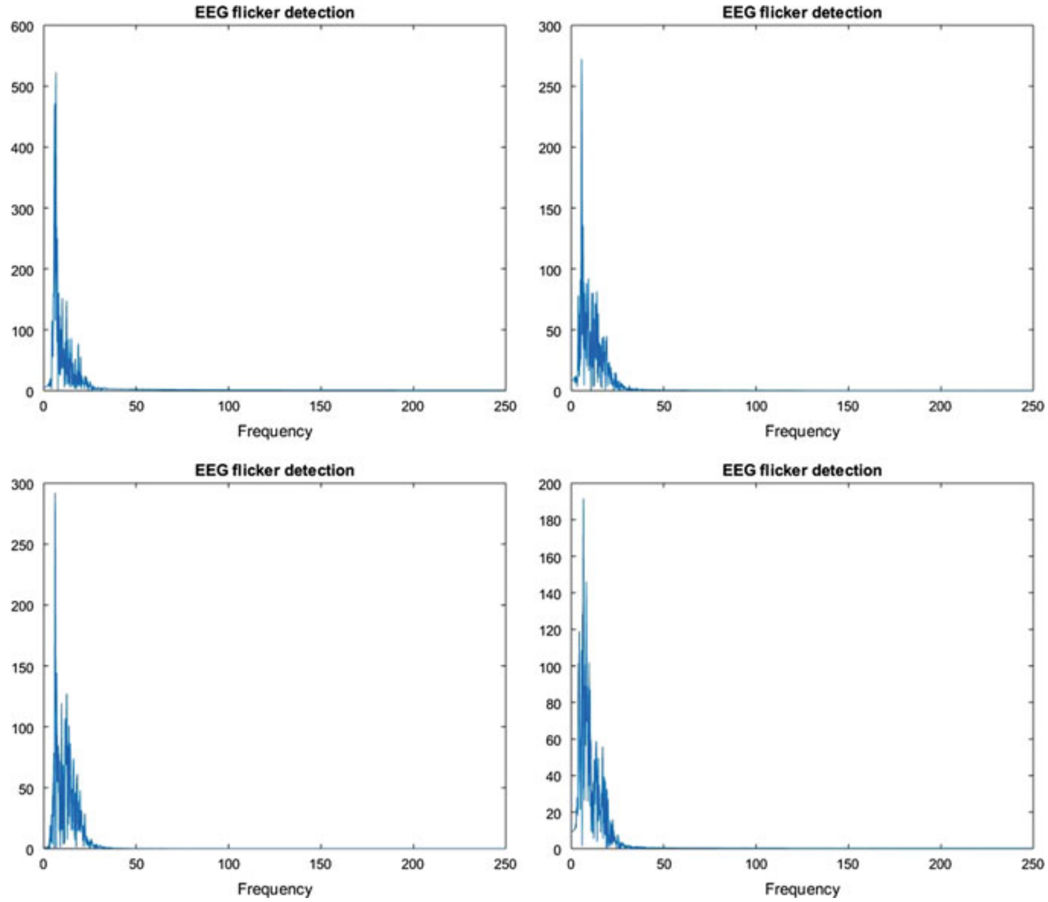

Fig. 5 Graph obtained from dataset. Muse headband was used all experiments

5 Conclusion

Currently work has yielded a learning series that have allowed us to know different tools that allow us make it simpler, a well-grounded project. Initially, the idea of implementing the application (app) using software with basic tools was proposed because the task that would be carried out, relatively, was simple. However, it was seen that moving the signal from the headband to the embedded system would be a more complex task. This forced us to migrate to other software that allowed to perform this task, and thank to this software you can do many more activities that could not be done with the first software.

Finally, it can be concluded from the project, that today there is a very wide diversity of commercial EEG that allows to develop projects with different purposes, where the focus of this in particular is the control of an automated environment. It is then where it can be observed that it is possible to extract EEG signals for the control of automated environments, in particular, the turning on and off of lights or the blind's control. The selected manufacturer continues working on the development of its own products, so one of its new products allows the monitoring of other biological

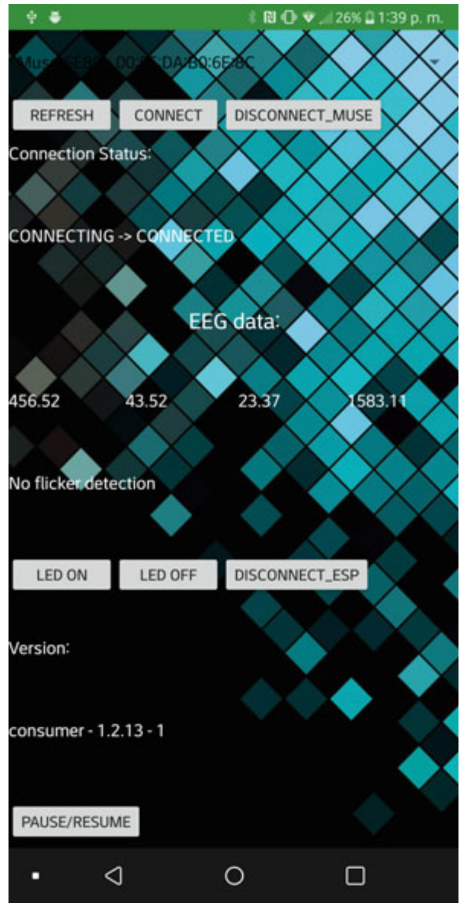

Fig. 6 Main screen app's developed with SDK's manufacturer

elements of the human body that could later be used as auxiliary agents of care in an automated environment.

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Medical Diagnostic Through a Mobile Application Controlled by Brain Waves: ConsultApp

Bladimir Serna, Rosario Baltazar, Miguel Casillas, Yesica Saavedra, Arnulfo Alanis and Antonio Meza

Abstract The technology just like exact sciences and computation take an important role in our daily life; the union of these generate applications with great utility and provide efficient communication alternatives; thinking in this objective the ConsultApp is developed with the purpose to give a communication alternative to verbally disabled people, with the benefit of expressing and transmitting their discomforts as well as medical conditions, through the use of an EEG (Electroencephalogram).

Keywords Mobile app · BCI (Brain–Computer Interface) · EEG (Electroencephalogram) · Smart agents (MindFlex)

Please note that the LNCS Editorial assumes that all authors have used the western naming convention, with given names preceding surnames. This determines the structure of the names in the running heads and the author index.

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1 Introduction

Nowadays, there are a large number of people with speech problems or difficulties in expressing correctly their physiological needs, according to the INEGI (acronym in Spanish of National Institute of Statistic and Geography in Mexico), by 2010 had 4,527,784 documented cases of people with disabilities, of which, 8.93% are people who have speech problems (approximately 401,538 people in Mexico [1]), it makes difficult for the medical staff or people that attends patients with these conditions to provide them with appropriate medical attention and interpret their discomfort; likewise, a patient gets complicated expressing their discomfort.

For this important reason, build a mobile application was considered connecting an EEG, looking for it to be accessible to the general public in cost–benefit, not limiting the patient, not being invasive, having a friendly interface and being functional in the resolution of basic communication conflicts; in other words, that allows patients to express their discomforts and/or sufferings, as well as being able to communicate in a simple way using two words, YES and NO.

2 Background

This section describes tools and concepts necessary to know how ConsultApp works.

- ***Android Studio***: It is the official tool to create applications based on the Android system and it is based on IntelliJ IDEA software [2].
- ***MindWave***: EEG headband developed by the company NeuroSky, which consists of three dry-type electrodes [3], located in the positions A1, A2, and Fp1 according to the international system 10–20 for electrode placement [4], which obtains the main characteristics of the frontal lobe, where attention, understanding, and meditation activities are processed [5], see Fig. 2.
- ***ThinkGear***: Chip developed by the company NeuroSky which is responsible for executing the eSense algorithm as well as processing the signals obtained by the MindWave diadema [6], showing graphs as shown in Fig. 1.
- ***eSence***: Algorithm developed by the company NeuroSky, which is responsible for obtaining the levels of attention and meditation after processing the data obtained by the sensors located in the MindWave diadema [7].
- ***Attention***: Attention is defined as the cognitive capacity that allows selecting the modality of information required by the desire at a given moment [8].
- ***Neural Communication***: Neurons, at the brain level, to communicate with each other, generate electrical pulses that are sent from neuron to neuron [9, 10], where there are receiving and transmitting parts of information. These electrical pulses are those that must be identified by an EEG to determine the identification events.

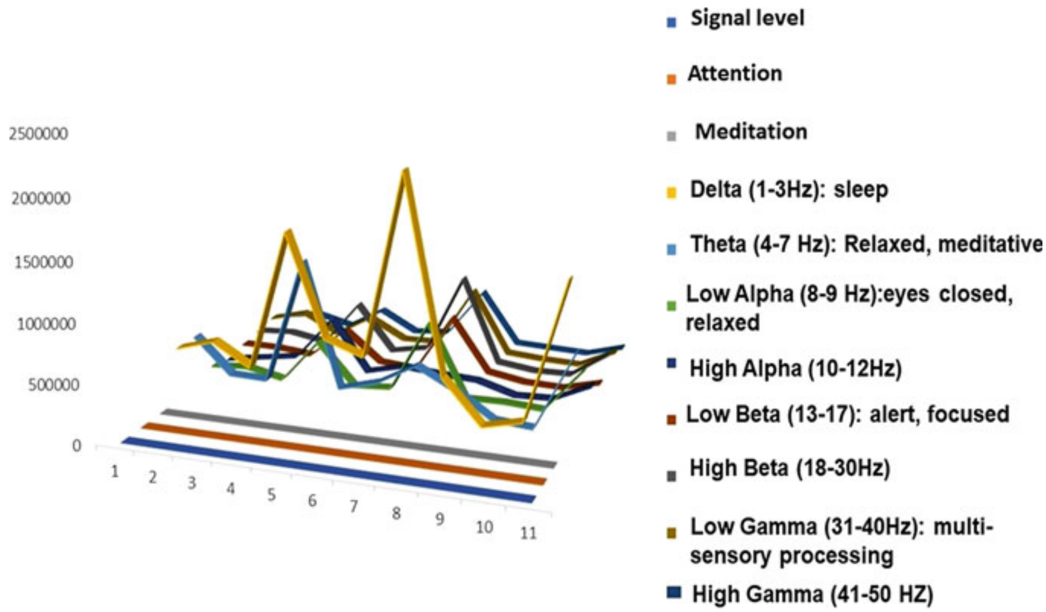

Fig. 1 Behavior of signals obtained by the EEG

3 Related Work

Some works generated with the purpose of improving the communication of people with verbal communication problems are shown in this section.

– ***ACAT*** **(Assistive Context-Aware Toolkit)**: Professor Stephen Hawking, suffered from ALS (Amyotrophic Lateral Sclerosis), which is a degenerative disease of neuromuscular type, that gradually destroys upper and lower motor and neuron cells in both extremities and the bulbar musculature [11]; as a result of this disease, he lost all bodily mobility, as well as the voice; reason why ACAT technology was developed [12], which consists of a software and a system of sensors placed on the right cheek as in the throat, to detect facial movements and predict the words that he is trying to pronounce. The software receives the information of the movements and converts them into words through the SwiftKey technology to later be read and heard by the speakers.
– ***Brain-To-Text***: Project developed by German scientists from the University of Bremen, using a totally invasive method, can translate 47 words, from a database of 100 saved words; for this, it is required to connect electrodes directly in the brain, having as restriction the operation to open skull [13].
– ***Imagined speech***: Project developed by INAOE scientists (acronym in Spanish of National Institute of Astrophysics, Optics and Electronics), which consists of classifying five words just by thinking them (Up, down, left, right, select); for this, method visual evoked potentials are implemented [14].

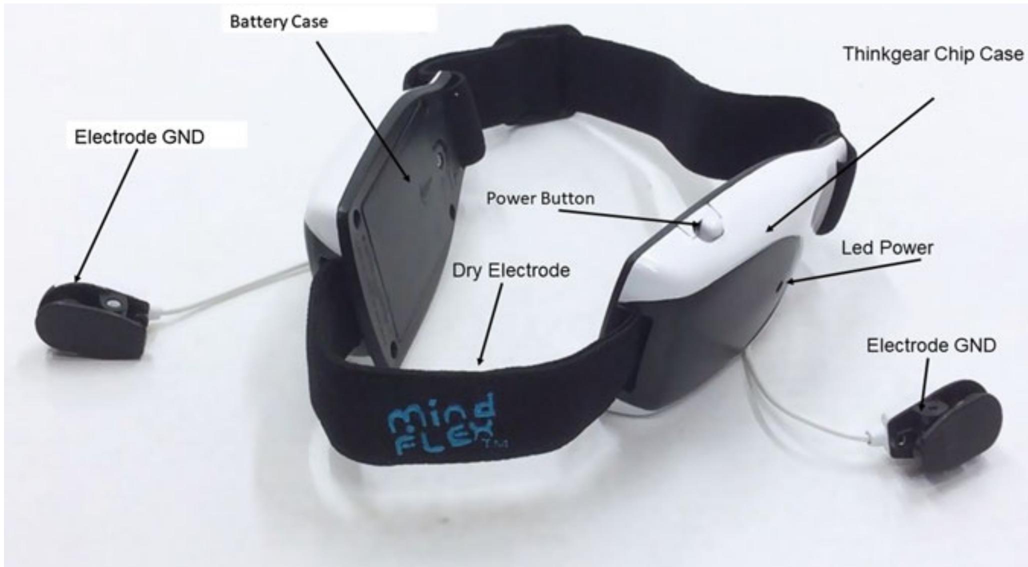

Fig. 2 EEG of the company NeuroSky

4 Methodology

To create *ConsultApp, Android Studio* is used as a framework for programming, as well as an EEG designed by *NeuroSky* (according to Katona [15], it is an EEG that can be used for scientific purposes); before to build *ConsultApp*, an application was developed that allows to see the levels of attention experienced by the patient in real time.

First, the requirements for the operation and creation of the mobile app are determined, and then the uses of an EEG, *Android Studio*, and medical advice were considered to perform the diagnosis of diseases through specific questions whose only answer is YES or NO; for the design phase, the visual and structural models of the application were decided, pretending with this the greater facility for its manipulation and easy understanding by the end user. Decision trees are implemented to discriminate (see Fig. 4) and based on the answers entered by the patient, determine which disease and/or discomfort afflicts the patient. Likewise, brain information is obtained through an EEG that uses *Thinkgear* technology, such as the one shown in Fig. 1.

The signal obtained by the headset is sent to a receiver that converts it into electric beats, from there it is extracted through an Arduino to be sent by Bluetooth to the mobile devices with which it will interact. Once the data is received in the mobile device, it is important to implement certain criteria to consider if the word is YES or NO; the maximum level of attention is 100. Most people present an average of 30–50 on a scale of 1–100 according to the data obtained from the *eSense* algorithm. For this reason and under previous training with the patient, concentration levels lower than 40 are equivalent to the word “NO”; if the concentration is higher than 51, it is equivalent to the word “YES”.

5 Development

The *MindWave* EEG diadem was used, which was obtained through MindFlex (Fig. 2), a development for entertainment by Mattel company. To obtain the EEG signal, a circuit was implemented through *Arduino* to extract the signal directly from the hardware and be sent via Bluetooth, as shown in Fig. 3, to the mobile device where *ConsutApp* will be installed.

Once *Arduino-Bluetooth* connection has been made, the programming of the mobile application which was codified in *Android Studio* following the design previously made where *ConsultApp* was built with functions in the following way:

– *ConsultApp* detects that the patient needs to communicate something, through brain waves emitted by the patient.
– *ConsultApp* generates a question and reads it out loud to the patient.
– Patient listens to the question and only responds with a “YES” or “NO” based on their level of care and under previous training.
– *ConsultApp* gets the answer and throws another question, based on the patient’s previous response, to determine what discomfort presents.
– If *ConsultApp* determines the discomfort, and the application makes it known to the doctor or staff, either through a text message or by reading it out loud.
– *ConsultApp* finishes the process and awaits new indications from the patient.

From the coding, the necessary questions were registered as well as the appropriate decision trees to obtain the expected result, and the diagram can be visualized in Fig. 4.

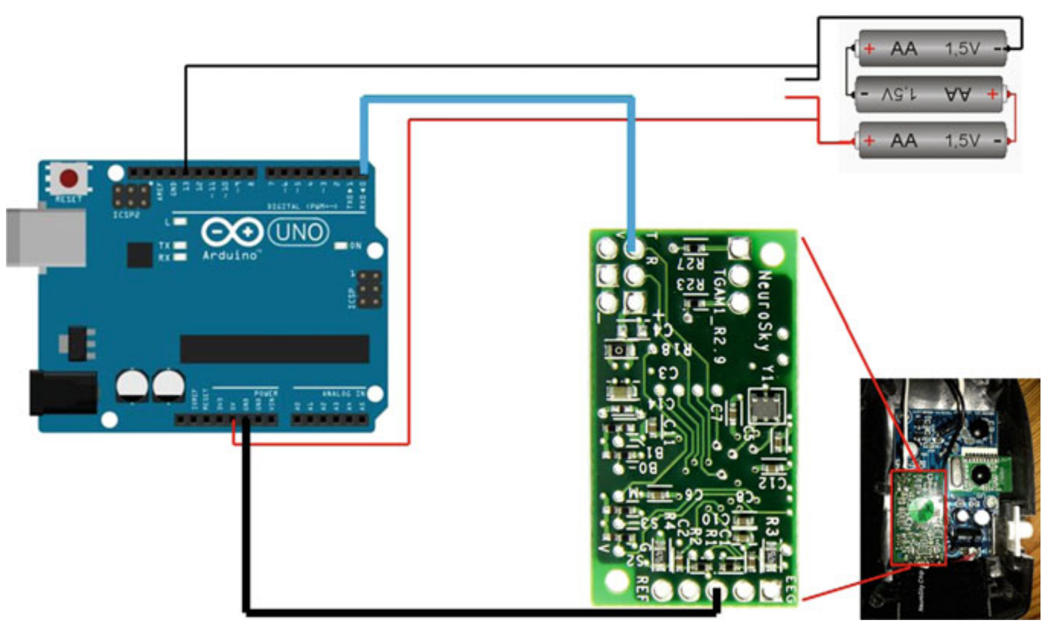

Fig. 3 Arduino-Bluetooth connection circuit

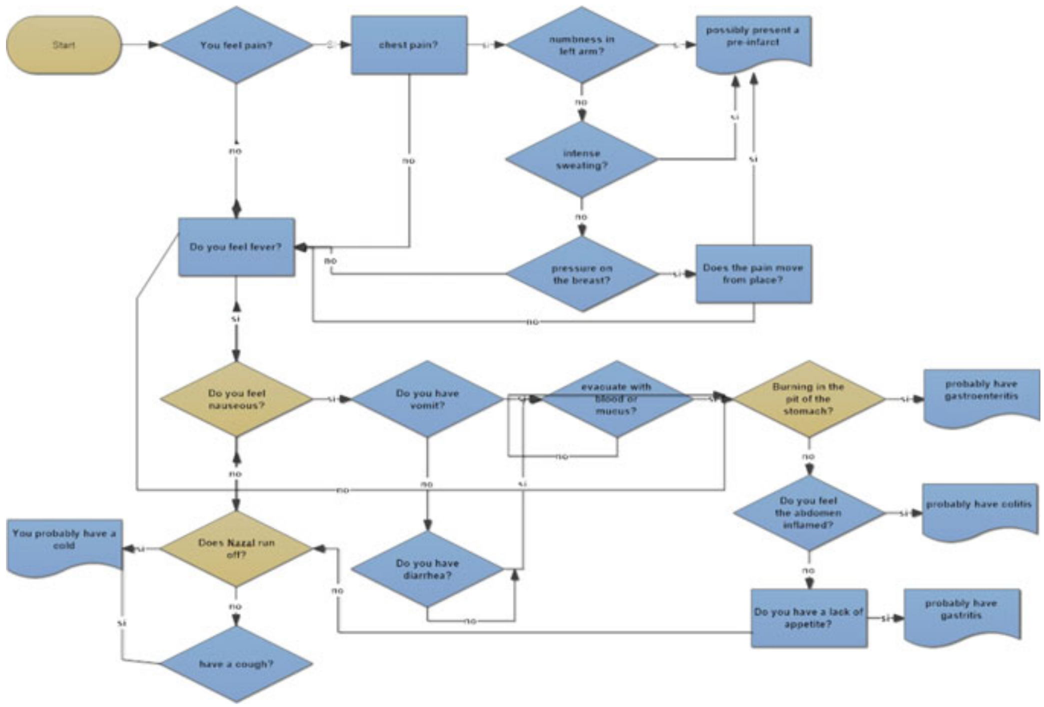

Fig. 4 Flowchart implemented for decision-making

6 Results

There is a mobile application linked by Bluetooth technology to an EEG with which information is obtained regarding the attention status of people, and this information is processed using the eSense algorithm, information obtained by the electrodes connected to the human skull. Depending on the levels of attention presented by the patient and prior to a training, if the patient tries to express an "YES" or "NO" is determined. As the first version, seven diseases range from

- Cold,
- Infections in the urinary tract,
- Vaginal infections,
- Vaginal infections caused by fungi,
- Vaginal infections caused by bacteria,
- Gastrointestinal diseases, and
- Symptoms before the infarction.

It is worth mentioning that for this test, tests were conducted with 15 different subjects, who after an approximate time of one hour of training to control the increase and/or decrease in the levels of attention, obtained control of their concentration and later were able to manipulate the app without major inconvenience.

In Figs. 5, 6, and 7, some of the questions made by the app are shown; in Fig. 9, you can see the diagnosis provided by ConsultApp.

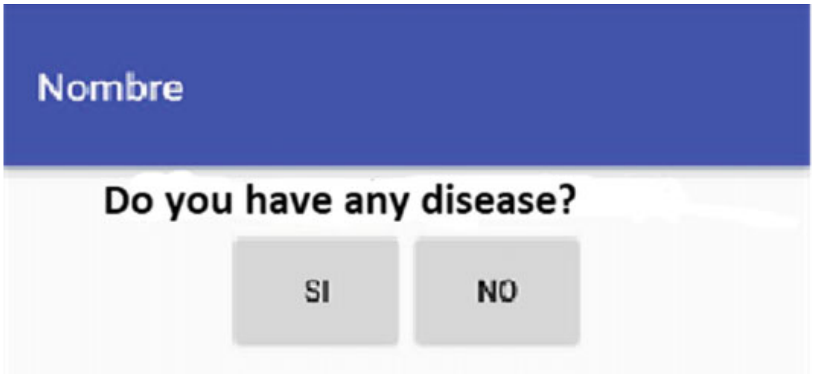

Fig. 5 Indicating if you have a discomfort

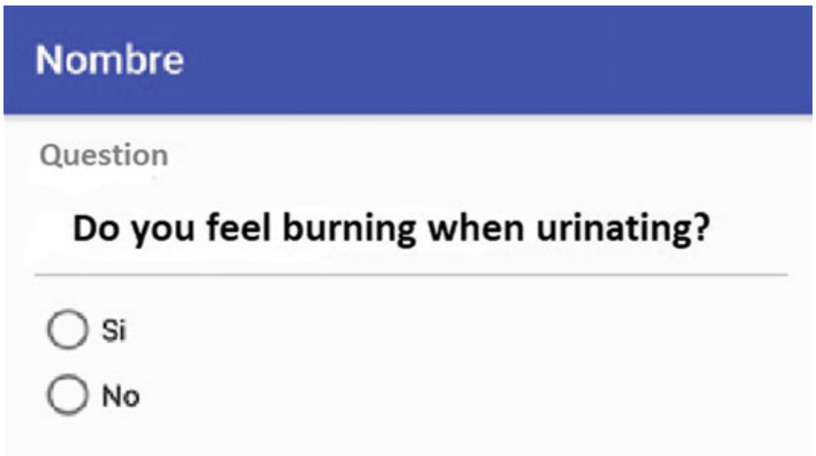

Fig. 6 Questions to detect diseases

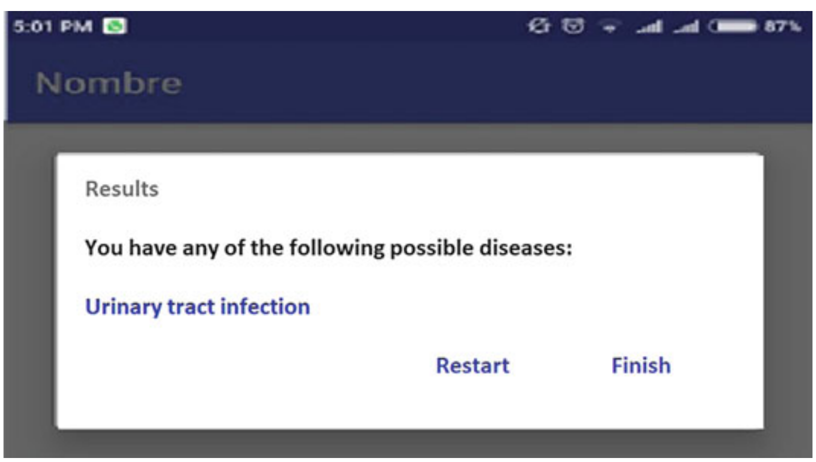

Fig. 7 Diagnosis of possible conditions of the patient

7 Conclusion

The immersion of technology is undoubtedly a great help for solving everyday problems; for this reason, ConsultApp was generated which is an app that was developed using artificial intelligence, brain–computer interfaces, medicine, and psychology.

For the correct operation of this application, two modules were implemented, manual control where the patient can answer the questions selecting the correct answer or the module where it responds with the stimuli generated by the levels of attention; a test was carried out with patients, using a game to help them have better control over decision-making; the game is called MindFlex and was developed by Mattel. The person who managed to control more quickly the changes of concentration took approximately 30 minutes, while there were people who lasted up to 2 or 3 days to control this part.

The application is completely functional and useful for the medical diagnosis as well as for the patient to be able to communicate and express their symptoms and discomforts.

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A Hierarchical Agent Decision Support Model and Its Clinical Application

Liang Xiao

Abstract In this paper, a hierarchical agent decision support model is proposed. The model helps to provide multifaceted decision support: grouping of specialist towards complex problems at the organisational level, planning and argumentation at the individual level, and service binding at the computational level. The approach includes an agent scheme, a conceptual decision model, and a set of functional signatures that drive the decision inference, accompanied with algorithms that guide their implementation. The model is specially designed to be adaptive. A clinical application of triple assessment of breast cancer is used for illustration.

Keywords Agent · Hierarchical decision support model · Functional signature

1 Introduction and Background

The growing specialisation and complex interrelationships in many domains today lead to collaborative and multidisciplinary decision-making. This means geographically and temporally spanned decisions depend on one another and cannot be made in isolation. Unfortunately, in many cases, individual decision-makers can hardly gain a full picture of decision situations, and this raises a risk to the successfulness, effectiveness, and efficiency of the overall decision outcomes. In addition, locally available components and services need to be linked, bound and executed dynamically in order to realise decisions strategically and automatically [1]. It is therefore important to design a model specifically for multidisciplinary decisions. In our vision, such a model shall help to organise a group of domain specialists to solve complex problems together, provide alternative plans to individuals in their own areas along with argumentation advices about their pros and cons and facilitate the binding of appropriate services to meet the computing needs in various decision circumstances.

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In this paper, we propose an agent-oriented model. *Agents* are computational entities with general features of autonomy, concurrency, decentralisation, pro-activeness, social ability and flexibility [2]. They are endowed with human-like mental and cognitive characteristics such as belief, goal, plan, commitment and so on. Among the *Agent-Oriented Software Engineering* (AOSE) methodologies, BDI [3] is useful for modelling beliefs and goals, Gaia [4] for agent roles and interactions, Tropos [5] and *i** [6] for goals, plans and inter-dependencies among agents, and KAOS [7] for decomposing goals into responsibilities, capabilities or constraints and assigning them to agents. In fact, the autonomy and decentralisation features make agents very suitable for distributed computing. The mental and cognitive characteristics make them very suitable for decision-making. The social-ability feature suggests agents are cooperative and best grouped together, often termed as *Multi-Agent Systems* (MASs), rather than run as stand-alone entities. Moreover, the flexibility feature suggests they can remain useful in ever-changing environment. Altogether, it would be very promising to apply agents for multidisciplinary decision-making in a distributed environment. Nevertheless, an agent paradigm alone is insufficient to make a powerful model. A range of works exists in modelling individual agents as personal assistants or advisers [2]. Another group of works concentrates on modelling decision algorithms, e.g. protocols that guide prescribing [8] or rules that guide diagnosis [9]. These works and others are often limited in the centralised nature of agent application to decision support. Even though some multi-agent models are proposed in association with joint goals, these are not explicitly intended to solve complex decision goals fitting in collaborative and multidisciplinary decision-making.

The design for decision models aiming at multiple parties can be divided into two schools of thought. Some emphasise [10] the diverse opinions and preferences that decision-makers have over alternative solutions. It is suggested that an opinion should be judged in terms of an individual's rank, level of expertise and relevance, among other factors. These factors being modelled, together with the personality and cognitive styles of decision-makers, a decision process among a group can be supported, and a commonly agreeable outcome finally synthesised through communication and negotiation. In contrast with such consensus-based decision approaches, the works on evidence-based decision support take a very different view. A prominent one is PRO*forma* [11–13], which is used in the clinical domain. It proposes a small number of generic task classes for composing task flows: An *Enquiry* is a task for obtaining information from a source. A *Decision* is any kind of choice (diagnosis, risk classification, treatment selection, etc.). An *Action* is any kind of external operation. A *Plan* is a 'container' for a collection or sequence of tasks. Clinical guidelines can be modelled into task networks and executed to guide decision-making. Though this approach and others are effective in joining decisions in a well-determined sequence of steps, they are limited in their central orchestration of decision logic encoded in a single piece of representation document. They do not explicitly differentiate decision tasks among their responsible parties, and the decision support cannot be offered seamlessly as an integrated part of the actual decision workflows in a distributed, real-life environment.

We believe an appropriate decision model coupled with a multi-agent paradigm would fit multidisciplinary decisions generically. Naturally, this leads to a hierarchical structure: at its upper level the organisational decisions should be solved on how an agent group might be arranged towards an overall goal, at its middle level the individual decisions on how local planning and argumentation should carry on and at its lower level the computational decisions on how an individual decision can be realised. Next, we propose our design of such a model in Sect. 2, its clinical application is illustrated by a case study in Sect. 3, the algorithms towards implementation and the adaptive features of the model are discussed in Sect. 4 and the paper is finally concluded in Sect. 5.

2 The Design of the Hierarchical Agent Decision Support Model

The design of the hierarchical agent decision support model is driven by answering a set of **4W1H** (*When-Who-What-Why-How*) questions as congregated below.

In the very beginning that multidisciplinary decisions are demanded, some kind of 'Event' may trigger a specialist or her representative agent's current 'Belief' to be updated and establish a 'Goal'. The 'Goal' under consideration is one that cannot be achieved by a single agent alone. Thus, a set of agents needs to be grouped together and each member assigned with a 'Sub-goal'. Different solutions of 'Sub-goal' composition may be available to complete the same 'Goal' and this becomes an **organisational-level decision**. No matter which solution is chosen, the participants now share this same 'Goal'. Then, a 'Plan' needs to be arranged locally to accomplish each agent's 'Sub-goal', again possibly chosen out of several alternatives. It might be the case that no 'Plan' can accomplish a given 'Sub-goal' successfully, and this implies the invalidation of the overall 'Goal' via this solution (an 'AND' relationship between 'Sub-goals'). A re-grouping of agents will then be necessary. While one or more 'Plans' can serve a local 'Sub-goal', all 'Arguments' that support or oppose the alternative options need to be evaluated and their corresponding weights aggregated. The 'Plans' should be ranked according to their gained weights and a preferred one recommended. This becomes an **individual-level decision**. It might be the case that the most preferred plan cannot accomplish its local 'Sub-goal' successfully, and this implies a re-planning process (an 'OR' relationship between alternative 'Plans'). Finally, the argumentation and plan execution processes may require external 'Services' to support their functions, and this becomes a **computational-level decision**. Overall, a three-layered agent decision support model is presented in Fig. 1.

In this view, an agent scheme with constituent components of 'Belief', 'Goal' and 'Plan' is put forward as follows:

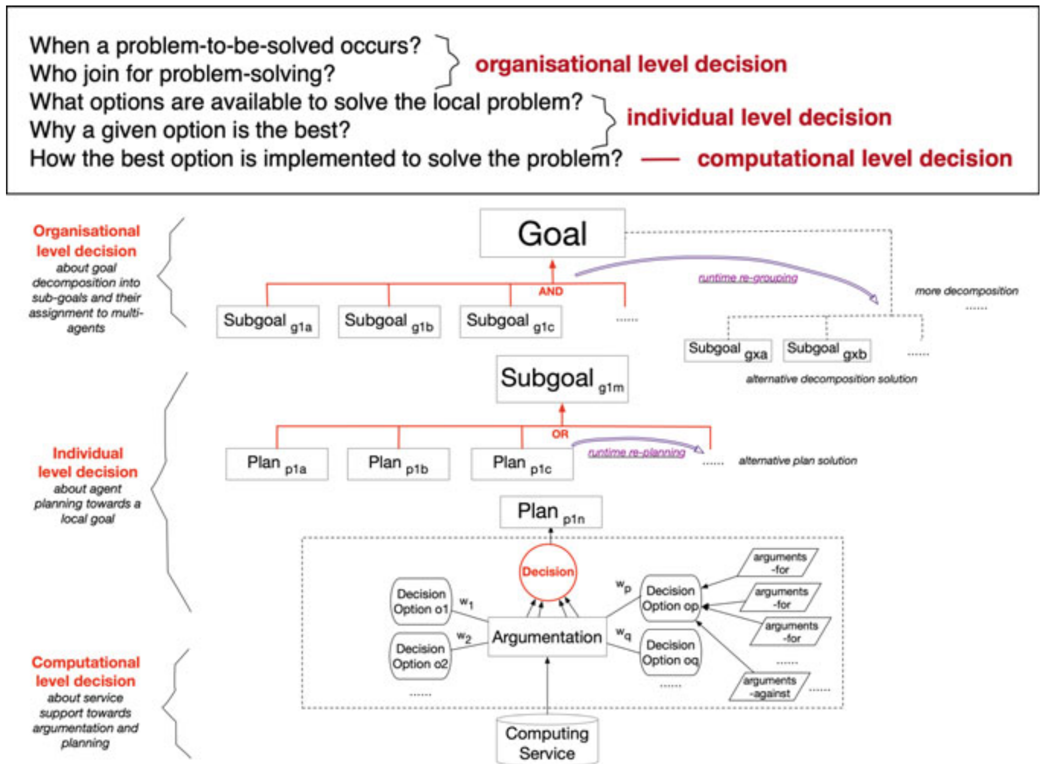

Fig. 1 A hierarchical agent decision support model with three layers

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Agent (Belief, Goal, Plan) $_{\textbf{Decision Knowledge}}$

Belief: a state or a situation an agent holds to be true.
Goal: a desired state to which an agent seeks to reach from its current state, representing a problem to be solved or to be explained.
Plan: following an internal processing and decision, a collection of actions an agent intends to carry out to achieve its *Goal*.
Decision Knowledge: knowledge that drives agents to make inference from *Belief* to *Goal* (once *Belief* updated) or from *Goal* to *Plan* (once *Goal* established), etc.

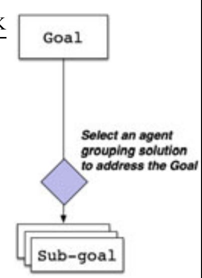
In addition, we define a set of *functional signatures* that answer the 4W1H questions more formally, which will help to build a conceptual model later. They have such a structure that input and output types are split up with a line in between, describing generic deduction or transformation that can be performed on any specific instances fitting these conceptual types. They are in an abstract form of *what* output can be expected from given input. Later, algorithms about *how* they can be implemented will be provided. An X operator may join-up multiple entities in either input or output or both, understood declaratively as ‘together with’ or procedurally as ‘applied to’, whichever is more intuitive. Different pieces of decision knowledge can come into play of an agent’s inference, designated as Agent $_{\mathrm{DK}}$ in general in the signatures. In total, five signatures are put forward.

Signature 1. Goal establishing: a ‘Goal’ (concept below the signature line) is established or derived (the signature line) when an ‘Event’ (or a newly generated ‘Belief’) occurs that may change the current ‘Belief’ (two concepts above the signature line, put together by an X operator). The ‘Goal’ will be shared among several agents, which are to be grouped later. This answers the ***When* (a problem-to-be-solved occurs)** question.

$$\frac{\text{Event X Agent (Belief)}}{\text{Agent (Belief, Goal)}}$$

Signature 2. Goal-driven agent grouping: An especially dedicated Choreographer Agent, possibly the one initialised by ‘Event’ will find all possible manners that a ‘Goal’ may be decomposed into ‘Sub-goals’ assignable to individual agents, a **Decision on Agent Grouping**. The most desirable grouping will be attempted in the first instance. When a group member fails at runtime then it may be substituted until no substitute is available, and in that case, the next most desirable grouping may be attempted. The Choreographer Agent, supplied with decision knowledge, will be responsible for finding grouping solutions, monitoring individual behaviour when a given solution is committed and substituting a problematic member or switching to another group until the goal is achieved. This answers the ***Who* (join for problem-solving)** question.

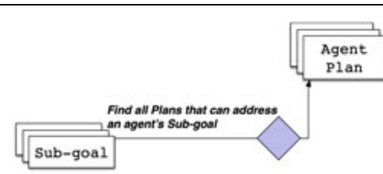
$$\frac{\text{ChoreographerAgent (Goal)}_{\text{DK}}}{\text{Agent}_1\ (\text{Sub-goal}_1) + \text{Agent}_2\ (\text{Sub-goal}_2) + \ldots}$$



Signature 3. Agent planning: With access to domain knowledge, an agent seeks all plans to satisfy its ‘Sub-goal’, a **Decision on Agent Planning**. When one is found to be able to transfer to the desired ‘Sub-goal’ state from its current state via an action, then it becomes a ‘Candidate Plan’. The mentioned states may be of local interest to this agent alone but can also be of general interest to the group. This answers the ***What* (options are available to solve the local problem)** question.

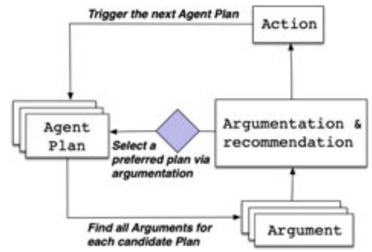
$$\frac{\text{Agent}_i\ (\text{Sub-goal}_i)_{\text{DK}}}{\text{Candidate Plan}_1 + \text{Candidate Plan}_2 + \ldots}$$

$$\frac{\text{Agent}_i\ (\text{Candidate Plan}_k\ (\text{Action}_k))\ \text{X Current state}}{\text{Sub-goal}_i\text{ 's state}}$$



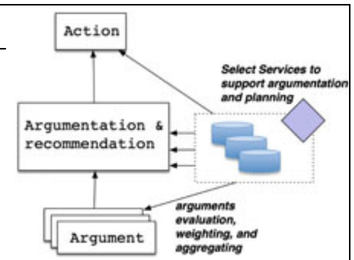
Signature 4. Argumentation: Following some reasoning and argumentation processes facilitated by computing services, a 'Preferred Plan' will be recommended among the alternatives, a **Decision on Agent Argumentation**. This answers the ***Why* (a given option is the best)** question.

$$\frac{\text{Agent}_i\ (\text{Sub-goal}_i,\ \text{All Candidate Plans})\ _{DK}\ \text{X Computing Services}}{\text{Agent}_i\ (\text{Sub-goal}_i,\ \text{Preferred Plan})}$$



Signature 5. Enactment: It is necessary to choose from all available services the 'Binding Services' that can effectively supplement agent computation, a **Decision on Service Binding**. These will enable agent's enactment of the 'Preferred Plan'. This answers the ***How* (the best option is implemented to solve the problem)** question.

$$\frac{\text{Agent}_i\ (\text{Preferred Plan})\ _{DK}\ \text{X All Services}}{\text{Agent}_i\ (\text{Binding Services})}$$



Altogether, these inference functions help to build a complete conceptual model as presented in Fig. 2. Such a design layers out decision-making hierarchically, on agent grouping, planning, argumentation and service binding. With an event-triggering component in the very beginning, they answer the 4W1H questions. Also, the re-grouping and re-planning connections help to address contingencies at runtime.

3 Case Study

Triple Assessment is a common procedure in the National Health Service of UK for women suspected with breast cancer and referred to specialised breast units. Patients may be presented by their GPs or following routine breast screening, i.e. NHS Breast Screening Programme (in England) or Breast Test Wales Screening Programme. In both situations, it is best practice to carry out, in the breast unit, a 'same day' clinic for evaluating the grade and spread of the cancer, if any, or a '*triple*' assessment: 1. Clinical and genetic risk assessment, 2. Imaging assessment by mammography or ultrasound and 3. Pathology assessment by core biopsy, fine needle aspiration or skin biopsy. Clinical guidelines have been collected systematically and used as the knowledge base for this case study. Some are more general [14–16] and cover

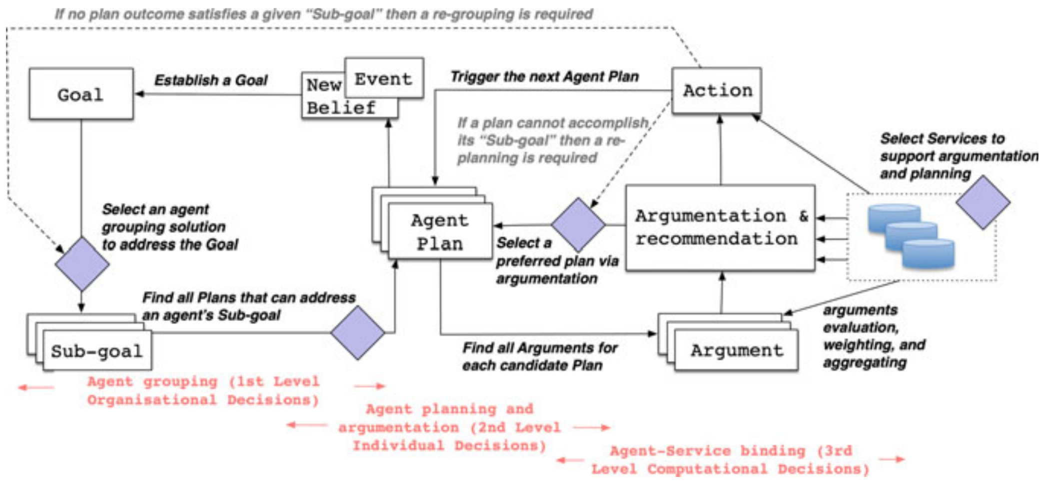


Fig. 2 A complete conceptual model to support decision-making hierarchically

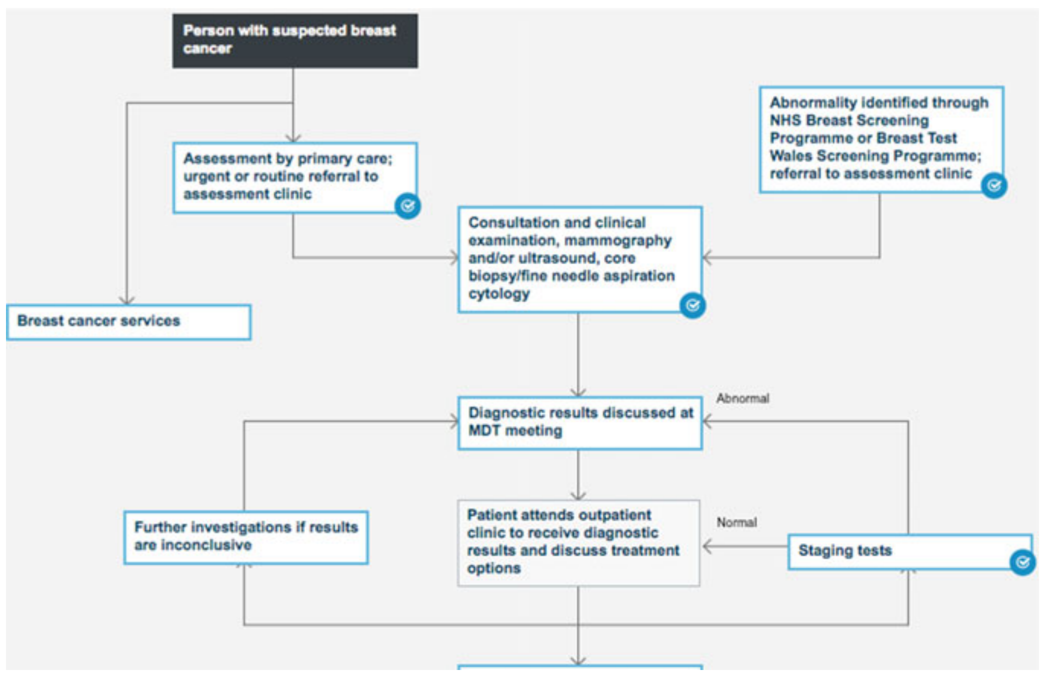


Fig. 3 A National Institute for Clinical Excellence (NICE) [15] guideline pathway

almost every stage of assessments until treatment. While others are more specific, for instance, GP referral guidelines [17] (CG27, pp. 23–25) about warning symptoms and signs that are suspicious, and radiologist assessment procedures [18] recommended by the NHS Breast Screening Programme (Fig. 3).

3.1 Organisational-Level Decision on Agent Grouping

Assume a 'Patient Agent' complains about an abnormal lump, an 'Event' occurs to a 'GP Agent' which updates its 'Belief' and establishes a 'Goal'. Signature 1 is instantiated as follows:

Signature 1. Goal establishing: Event of '**patient reports an abnormal lump**' X Agent $_{GP}$ (Belief on '**patient's current health condition**')
Agent $_{GP}$ (Goal of '**find out the nature of lump**')

The GP shall decide, following an examination, whether the patient can be ruled out of breast cancer and discharged, given the nature of the lump. Otherwise, the patient is suspicious of cancer and referred for further investigation. Signature 2 is instantiated as below for the latter occasion. The GP decides an urgent referral, as its plan, to a radiologist willing and capable of an imaging investigation. The GP Agent now has a complete specification in accord with our agent scheme: **Agent $_{GP}$ (lump**, **nature of lump**, **urgent referral of the patient for imaging investigation)**. Likewise, a Radiologist Agent can be specified as **Agent $_{Radiologist}$ (suspected area of breast**, **imaging investigation to find out the nature of lump)**. Table 1 illustrates the decision to make at this level and its design components.

Table 1 The decision to make (**When** and **Who**) and design components

	Decision to make	Design components	Problem to solve (part of 4W1H)
Organisation	Agent grouping	Event, goal, sub-goal	*When* a problem-to-be-solved occurs? *Who* joins to solve the problem?
Case study	Specification: *Signature 1 and 2*	*Event*: Patient reports an abnormal lump *Goal*: Find out the nature of lump Sub-Goal$_1$: find and solve health problem Sub-Goal$_2$: nature of lump Sub-Goal$_3$: imaging investigation	*When*: Reporting an abnormal lump *Who*: Cancer ruled out: *Patient, GP* otherwise: *Patient, GP, Radiologist, etc.*

Signature 2. Goal-driven agent grouping: Choreographer (Goal of '**find out the nature of lump**') $_{DK}$
Agent $_{Patient}$ (Sub-Goal$_1$ of '**find and solve health problem**') + Agent $_{GP}$ (Sub-Goal$_2$ of '**nature of lump**', '**urgent referral**') + Agent $_{Radiologist}$ (Sub-Goal$_3$ of '**imaging investigation**')

3.2 Individual-Level Decision (On Agent Planning)

Both GP and radiologist can have alternative planning behaviour, which leads to very different patient journey. These are distinguished as 'Candidate Plans' with contrasting implication. Signature 3 is instantiated for GP and radiologist as follows:

Signature 3. Agent planning: Agent $_{GP}$ (Sub-goal$_2$ of '**nature of lump**') $_{DK}$
Candidate Plan$_1$ of '**urgent referral**' + Candidate Plan$_2$ of '**non-urgent referral**' + Candidate Plan$_3$ of '**discharge**' Agent $_{Radiologist}$ (Sub-goal$_3$ of '**imaging investigation**') $_{DK}$
Candidate Plan$_1$ of '**do a mammogram investigation of both breasts**' + Candidate Plan$_2$ of '**do an ultrasound investigation of the affected area**'

Assuming ultrasound is found more appropriate, the plan completes the specification: **Agent $_{Radiologist}$ (suspected area of breast, imaging investigation to find out the nature of lump, ultrasound)**. The planning behaviour will result in a precise action, an ultrasound investigation, to be carried out in practice. Whatever the result, it contributes to the Sub-goal$_3$ of 'imaging investigation to find out the nature of lump'. Suppose an inconclusive or suspicious result is suggested, the Sub-goal's state will be updated, and a follow-up plan of 'further referral' will be in place. We now have an updated specification: **Agent $_{Radiologist}$ (ultrasound investigation result suspicious, imaging investigation to find out the nature of lump, further referral to a pathologist)**. Table 2 illustrates the decision to make at this level and its design components.

3.3 Individual-Level Decision (On Agent Argumentation)

An appropriate choice or a 'Preferred Plan' shall be selected among candidates via judging argumentation criteria. Such criteria are drawn upon from the guidelines and summarised as follows:

Candidate 1: Urgent referral, *argument-for*:
  Lump is discrete, hard with fixation
  Age is over 30 and Lump is discrete and persistent
  Skin presents unilateral eczema
  Nipple presents distortion or unilateral bloody discharge…
Candidate 2: Non-urgent referral, *argument-for*:
  Age is less than 30 and Lump presents
  Pain presents and no palpable abnormality ……

The guidelines help us to establish, declaratively, logical statements or correlations among clinical instances, and if evaluated as true, leading arguments in support for or against the candidates. In evaluating all arguments in relation with these candidates and aggregating the result indicated by evidence, the preference of options will be ordered and a final conclusion drawn upon. Suppose a woman has a lump that is discrete, hard and with fixation (an *attribute*) *predicates* as true (a *value*), then this is an argument (*argument-for*) that supports the *candidate* of ‘urgent referral’. All arguments supporting or opposing each candidate will be aggregated on the basis of their strength (*weight*), and the one with the strongest support will be recommended (or by a *recommendation-rule*). Signature 4 is instantiated for the case study as follows:

Signature 4. Argumentation: Agent $_{\mathrm{GP}}$ (Sub-goal$_2$ of ‘**nature of lump**’, All Candidate Plans) $_{\mathrm{DK}}$ X Computing Services
Agent $_{\mathrm{GP}}$ (Sub-goal$_2$, Preferred Plan of ‘**urgent referral**’)

Table 2 The decision to make (**What**) and design components

	Decision to make	Design component	Problem to solve (part of 4W1H)
Individual behaviour	Agent planning	Plan	*What* decision options are available?
Case study	Specification: *Signature 3*	GP’s Candidate Plan: ‘urgent referral’, ‘non-urgent referral’, ‘discharge’; Radiologist’s Candidate Plan: ‘do a mammogram investigation of both breasts’, ‘do an ultrasound investigation of the affected area’	*GP:* 1. *urgent* 2. *non-urgent* 3. *discharge* *Radiologist:* 1. *mammogram* 2. *ultrasound* ……

Similarly, when an imaging decision is to be made on the diagnosis of suspected breast cancer, two techniques are known to satisfy this goal. The guidelines for radiologist are as follows:

Candidate 1: Do a mammogram of both breasts, *argument-for*: Genetic Risk assessed as medium/high and Age is over 35 Nipple presents an inversion and …… *argument-against*: Pregnance is true or Age is less than 35 Candidate 2: Do an ultrasound of affected area, *argument-for*: … *argument-against*: …

An ultrasound will be a preferred option over mammogram, for example, whereas no argument is satisfied other than that the woman is found pregnant, an *argument-against* mammogram. The signature for the radiologist is as follows:

Agent $_{\text{Radiologist}}$ (Sub-goal$_3$ of '**nature of lump**', All Candidate Plans) $_{\text{DK}}$ X Computing Services
Agent $_{\text{Radiologist}}$ (Sub-goal$_3$, Preferred Plan of '**do an ultrasound of affected area**')

It is worth noting that further guidelines on imaging investigation are actually available, e.g. 'where the patient complains of a focal abnormality or where one is detected on the mammograms further views should be obtained (two-view mammography)'. Some of them are preoperative screening requirements, e.g. 'where malignancy is suspected, measure lesion size and distance from the nipple-areola complex'. These are relevant to the assessment per se but out of the scope of this discussion. Also, MRI scans are not generally recommended except while there is a discrepancy among current assessment results or breast density precludes accurate assessment. MRI is omitted here as an imaging candidate just for simplicity. The decision support process for pathologists is very similar and also omitted. Table 3 illustrates the decision to make at this level and its design components.

3.4 Computational-Level Decision on Agent-Service Binding

An Electronic Health Record (EHR) service is often used to store ongoing findings, investigation results or intermediate decisions, and useful for sharing between members of decision-makers in the due process. In addition, a referral component can be useful in this case study, for the GP Agent to judge the referral criteria and recommend plan options. These may be found and matched from a component or service library as the agent's 'Binding Services'. Signature 5 is instantiated as follows. Table 4 illustrates the decision to make at this level and its design components.

Table 3 The decision to make (**Why**) and design components

	Decision to make	Design component	Problem to solve (part of 4W1H)
Individual behaviour	Agent argumentation	Argumentation	*Why* a given decision option is the best?
Case study	Specification: *Signature 4*	Argumentation: *{Candidate $_n$ ((arguments-for(,,), weight) $_i$, (arguments-against(,,), weight) $_j$), recommendation-rule}*	GP Option of '*Urgent referral*' (Preferred): Support: *Lump discrete, hard with fixation, Skin ……* Option of '*Non-urgent referral*': *N/A*
			Radiologist Option of *mammogram:* Against: *pregnancy* Option of *ultrasound* (Preferred): *N/A*

Table 4 The decision to make (**How**) and design components

	Decision to make	Design component	Problem to solve (part of 4W1H)
Computation	Agent-service binding	Computing service	*How* the above decisions are reached and later committed?
Case study	Specification: *Signature 5*	Components/Services: *EHR & Referral*	*Patient EHR* with patient data operation capabilities *Referral* with referral criteria judging and recommendation capabilities

Signature 5. Enactment:

Agent $_{\text{GP}}$ (Plan of '**urgent referral**') $_{\text{DK, Engine}}$ X All Services

---

Agent $_{\text{GP}}$ (Binding Services of '**EHR**' and '**Referral**')

It is illustrated in Fig. 4 that service binding is seamlessly integrated with agent planning and argumentation. While a plan is being selected, an argumentation process is demanded. The latter calls for the instantiation of bound components, between which a relationship is established. In the case study, the attributes of a 'patient', as a 'Patient EHR' instance will be checked against given values to ascertain argument criteria, and an associated 'referral', as an instance of 'Referral' may have its method invoked. *Candidate$_1$*, for example, has an argument declaring that if the attribute '*age*' of a patient has a value over *30*, and if the '*lump*' checks against *isDis-*

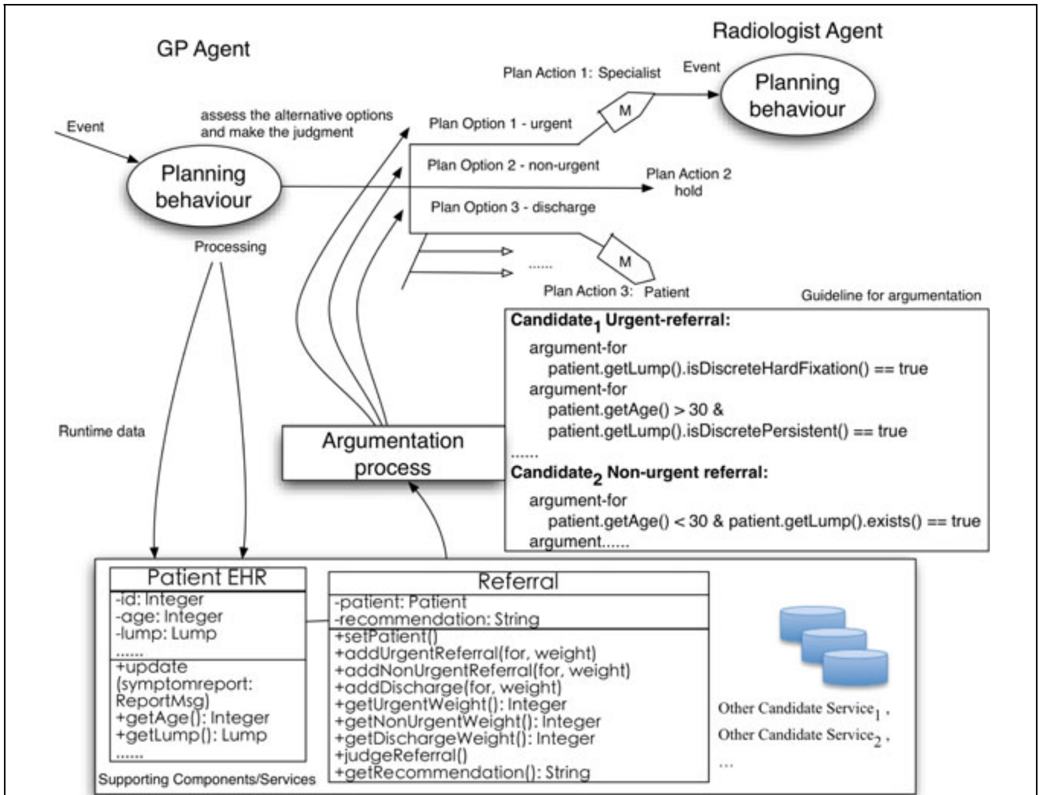
Table 5 The hierarchically structured model parts and the matching algorithms

	Decision to make	Design components	Problem to solve (4W1H)	Algorithm
Organisation	Grouping	Event, goal, sub-goal	*When* a problem-to-be-solved occurs? *Who* joins to solve the problem?	A
Individual behaviour	Planning	Plan	*What* decision options are available?	B
	Argumentation	Argumentation	*Why* a given option is the best?	
Computation	Service binding	Computing service	*How* the above decisions are reached and later committed?	C

cretePersistent() as true, then the referral will fire *addUrgentReferral(for, weight)*. Similarly, $Candidate_2$ has its arguments evaluated and if successfully, the invocation of *addNonUrgentReferral(for, weight)*. Both will update the weight of corresponding referral options (code segment *a*). The argumentation can be seen, facilitated by these components, as broken down into several pieces of if-then rules for judging argument criteria and calculating the strength of candidates. Later, on completion of evaluating all arguments for each candidate, their strengths are aggregated and an invocation of *judgeReferral()* suggests the right choice (code segment *b*). In this situation, the criterion of determining a preferred candidate is that it shall have the maximum weight, defined as a *recommendation-rule*. Finally, the suggestion will be returned to guide the planning behaviour via the invocation of *getRecommendation()* (code segment *c*).

4 The Algorithms Towards Implementation

The organisational, individual and computational levels of decisions in relation with **4W1H** (*When-Who-What-Why-How*) are resolved and documented in Tables 1, 2, 3 and 4 following the case study, with a focus on *what* target problems they are to solve. These are summarised in Table 5, with a final column added on *how* they are to be solved by algorithms towards implementation, discussed in this section.



Argumentation via the invocation of components:

If patient.*getLump*().isDiscreteHardFixation() == true
    Then referral.*addUrgentReferral*(for, 1);
If patient.*getAge*() > 30 & patient.*getLump*().isDiscretePersistent() == true
    Then referral.*addUrgentReferral*(for ,1); ……
If …
    Then referral.*addNonUrgentReferral*(); *(a)*

Referral's method specification:

public *judgeReferral*() {
    recommendation = referralResult (
        max(*getUrgentWeight*(), *getNonUrgentWeight*(), 0)); } *(b)*

Planning specification:

referral.*getRecommendation*().equals("urgent")
    action_1 : ……
referral.*getRecommendation*().equals("non-urgent")
    action_2 : …… *(c)*

Fig. 4 Integration of agent planning, argumentation and service binding

4.1 Goal-Driven Agent Grouping (First-Level Decision)

When a goal is established, a decision needs to be made for grouping the participants. The decision knowledge can often determine these as role players, e.g. the triple assessment needs GPs, radiologists, pathologists, etc. as speciality but not particular individuals. In the clinical domain, characteristics to be judged include qualification, familiarity and preference by the patient from previous contact, and so on. While a decomposition is available and a sub-goal is targeted, all potential participants can be called for (line *a*) and those factors considered in selecting one to join the group (line *b*) are shown in Algorithm A of Fig. 5. Once a group is formed, each group member has its sub-goal driving them to establish alternative candidate plans, and judge and select a preferred one. The candidate plan options will be searched through from the decision knowledge base, and those that match an individual agent's sub-goal or its intended state will be put together (line *c*). These options are ordered (line *d*) and the most preferred one selected (line *e*) and executed (line *f*). The enactment process checks if the outcome actually satisfies the desired sub-goal state at runtime, and if not, it tries to establish the next plan (line *g*-*h*). This continues in a recursive manner until the grouping solution yields a successful result; otherwise, another grouping solution may be attempted. In here, the next algorithm on individual planning and argumentation will be invoked.

4.2 Agent Planning and Argumentation (Second-Level Decision)

A group member presented by the previous decision may have a number of candidate plans that are found to satisfy its sub-goal. They need to be evaluated and a preferred one is eventually executed. It is shown in Algorithm B of Fig. 6 that addresses this by preparing prerequisite data (line *a*–*c*) before these plans being judged (line *d*–*j*). First, all data items required for judging arguments but not yet available are found out (line *a*–*b*). They may be collected via dynamically generating questions and prompting users to answer them, retrieving lab test and exam results (as applicable to the clinical domain), or directly from other data sources (line *c*). The necessary data being ready, all arguments in relation with each alternative can be evaluated on whether being true or not. Their weights are added to the strength of supporting (line *e*–*f*) or opposing (line *g*–*h*) the candidate, if evaluated as true. After that, the net support of each candidate can be aggregated (line *i*). Finally, they are compared for the ordering of preference towards a recommendation (line *j*).

```
G := G0
Glist := decompose(G)
while not empty(Glist) do
  get next Gi from Glist
    // find all agents able and willing to play the role that satisfies sub-goal
    Alist := callForParticipation(matchRole(Gi))                                  (a)
    if not empty(Alist) then
      // select a candidate agent from the list
      Agenti := select(Alist)                                                     (b)
      // find from the decision knowledgebase all candidate plans
      Olist := options(satisfy(DK, post-condition(Gi)))                           (c)
      // invoke the argumentation function and order the options
      Oordered-list := argumentation(Olist)                                       (d)
      Oi := select(Oordered-list) // get the best possible option for now         (e)
      Pi := plan(Agenti, Oi)
      // will re-plan if the sub-goal cannot be satisfied
      while not succeeded(Pi) do
        execute(Pi)                                                               (f)
        Si := belief(Agenti)
        // check if the execution of this plan yields the desired state
        if satisfy(Si, post-condition(Gi)) then                                   (g)
          succeeded(Pi)
          belief(Agenti+1, Si) // share patient data and decisions
          pre-condition(Gi+1) := post-condition(Gi) // link the goal states
        else
          Oi := select-next(Oordered-list) // get the next best possible option
          Pi := plan(Agenti, Oi) // re-plan for this agent                        (h)
        end-if
      end-while
    end-if
  end-while
```

Fig. 5 Algorithm A for goal-driven agent grouping

4.3 Agent-Service Binding (Third-Level Decision)

A preferred plan chosen as the result of the previous decision may require some services to meet the computational need of its execution. They may be chosen from a number of alternative ones, either locally available or globally recognised. It is shown in Algorithm C of Fig. 7 that addresses this by finding the service candidates from a service library (line a–d) prior to the preferred ones chosen (line e–g) to support argumentation and planning. A service becomes a candidate if it can process the current plan's arguments (line b–c). When two services are found to overlap in capabilities, the one with lower quality metrics is abandoned (line f). The final list of services may be presented for user selection (line g).

```
P_list := options(satisfy(DK, post-condition(G_i)))
Q_list := Q_0
// argument search and data preparation for each candidate plan
while not empty(P_list) do                                                        (a)
   get next P_i from P_list
   // find out all prerequisite but unknown data items for judging arguments
   A_list := arguments(satisfy(DK, post-condition(P_i)))
   while not empty(A_list) do
      get next A_i from A_list
      if unknown(pre-condition(A_i)) then
         add(pre-condition(A_i), Q_list)
      end-if
   end-while
end-while                                                                         (b)
// categorise required data into user enquiry, lab testing, or other sources
sort(Q_list, Q_list-symptom, Q_list-test, Q_list-source)
// get all prerequisite data ready via user interaction or external extraction
collect(userEnquiry(Q_list-symptom) , labTest(Q_list-test) , dataSources(Q_list-source))   (c)
// now it's time to calculate net-support strength for each candidate plan
while not empty(P_list) do                                                        (d)
   get next P_i from P_list
   A_list := arguments(satisfy(DK, post-condition(P_i)))
   while not empty(A_list) do
      get next A_i from A_list
      if argumentFor(A_i, P_i) then                                               (e)
         total-for-weight(P_i) += weight(A_i)
         reason-for(P_i) += description(A_i)                                      (f)
      else if argumentAgainst(A_i, P_i) then                                      (g)
         total-against-weight(P_i) += weight(A_i)
         reason-against(P_i) += description(A_i)                                  (h)
      end-if
   end-while
   net-support(P_i):= (total-for-weight(P_i) – total-against-weight(P_i)) /N(A_list)   (i)
   // order candidates and include reasons for/against them for user approval
   order(net-support(P_i), reason-for(P_i), reason-against(P_i))                 (j)
end-while
```

Fig. 6 Algorithm B for agent planning and argumentation

4.4 Adaptation in the Hierarchical Decision-Making Structure

This agent-oriented decision model is adaptive in three dimensions:

(1) While new participants are available, this implies an increased solution space in the knowledge base in support of agent grouping. This update above the line in Signature 2 of Agent Grouping shall determine the accommodation of new agents below the line. As Algorithm A allows agents to be dynamically grouped and re-grouped, and it is at runtime agents to determine the way of coordination, new care pathways can be formed to solve the problem. For example, a new agent may be invited between the GP Agent and the Radiologist Agent in this manner for delivering additional care.

```
S_list := S_Service-Library
S_s-list := S_0
P := P_chosen
while not empty(S_list) do                                                        (a)
   get next S_i from S_list
   A_list := arguments(P)
   while (not empty(A_list) & !failedService(S_i)) do
      get next A_i from A_list
      if !processable(S_i, A_i) then
         failedService(S_i) // S_i can't process this argument
      end if
   end while
   // S_i becomes a candidate as it can process the plan's arguments               (b)
   if !failedService(S_i) then
      add(S_i, S_s-list)
   end if                                                                         (c)
end-while                                                                         (d)
if exist(S_i, S_j) &within(S_i, S_s-list) &within(S_j, S_s-list) &duplicate(capabilities(S_i), capabilities(S_j)) then (e)
   // remove the duplicate services with lower quality metrics
   remove(min(QoS(S_i, S_j)), S_s-list)                                           (f)
end-if
select(S_s-list)                                                                  (g)
```

Fig. 7 Algorithm C for agent-service binding

(2) While new plan candidates emerge, this implies an advance of the current knowledge in support of individual planning. The update above the line in Signature 3 of Agent Planning shall determine the accommodation of new plan options below the line, and these candidates have a chance to win and get recommended, as suggested in Signature 4 of Argumentation. As Algorithm B allows plan options to be dynamically fetched and preference ordered, agents determine whether or not to choose them as the actual plan at runtime. For example, a new imaging technique may be chosen for the Radiologist Agent automatically in the future, without altering the current model.

(3) While new services become available, this implies an updated service list above the line in Signature 5 of Enactment. This shall give them a chance to become binding services below the line. As Algorithm C allows services to be dynamically bound, and assuming new services are indeed preferable over previous ones in terms of service qualities such as capabilities, dependability, performance, etc., agents will eventually swap to them for plan execution at runtime. For example, EHR service may be replaced dynamically with more powerful features and lower cost in the future.

5 Conclusions

In this paper, an agent model for solving multidisciplinary decisions is proposed, including a conceptual decision model coupled with an agent scheme, a set of functional signatures that drive the inference, and implementing algorithms. A case study of the triple assessment of breast cancer is used for the illustration of the approach.

The multifaceted features of multidisciplinary decisions have been generalised in a 4W1H question set. A hierarchical decision structure is proposed in seeking the answers to them. The agent-oriented design components at various levels are considered and integrated into the model. The implementing Algorithm A, B, and C can help to realise the model, so that agents deployed across decision-making sites can determine the organisational structure for accomplishing a complex decision goal, each agent determines its preferred plan, and suitable services bound for argumentation and plan execution. The fundamental issues of multidisciplinary decision-making have been identified and addressed, and this represents a major distinction from other works. For example, the approaches in the area of agent-oriented clinical decision-making include Singh [19], HealthAgents [20], and HeCaSe2 [21]. These and many others often propose specific agent types and specific workflows to solve decision problems emerged in specific environments, and these can hardly be generalised and made applicable to new settings.

Our model, accompanied with the functional signatures, drives decision-making processes dynamically in the hierarchy, so that agents always retrieve up-to-date decision knowledge and apply the appropriate services to deduce their decision-making behaviour. Thus, agents in our approach are different from those fully autonomous agents that seek their own interest via voting, bargaining or negotiation within a group setting [2], and those attached with explicit and fixed functional requirements as in other AOSE approaches. Rather, our model is complied with the discipline of agent-oriented model-driven architecture [1], leading to systematic model-driven development that fits perfectly in the ever-changing decision environments. In addition to the shaping of an adaptive agent architecture, some software engineering advantages are achieved: (1) computing units of higher qualities or capabilities might be swapped in later, if necessary, as a result of the loose coupling between agents and components or service; (2) procedural and declarative types of knowledge on decision-making can be separately defined, on what options are available for selection (planning) and which option should be selected (argumentation), making more fine-grained separation of knowledge specification, and better knowledge maintainability.

The approach is illustrated using a clinical application to demonstrate its feasibility. Nevertheless, we believe it will fit other environments and solve a diverse range of decision problems. The model may offer a potential solution to researchers and developers concerned with multidisciplinary decisions, and in particular those interested in an adaptive design.

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Comparative Study of Bio-Inspired Algorithms Applied to Illumination Optimization in an Ambient Intelligent Environment

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Abstract One of the primary concerns of humanity today is developing strategies for saving energy and promoting environmental sustainability. This paper suggests the development of an intelligent Internet of Things based system with the use of meta-heuristics that will be able to find optimal energy saving configurations. This system takes into account the activity of the users, size of area, state of lights, and blinds. A comparative study of four optimization techniques (GA, PSO, DBDE, and BSO) with the use of the Friedman test is shown.

Keywords IoT (Internet of things) · Ambient intelligence · Energy management · Bio-inspired optimization · Control illumination

Please note that the LNCS Editorial assumes that all authors have used the western naming convention, with given names preceding surnames. This determines the structure of the names in the running heads and the author index.

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1 Introduction

The technology is playing a crucial role in tackling energy costs and reducing carbon footprint through initiatives such as low-carbon vehicles and low-impact energy-efficient building. With the help of Information Communication Technology (ICT), skills are provided to detect and monitor the use of energy through the use of intelligent measurement systems as well as centrally managing or automating devices and environmental controls such as temperature and lighting control systems. The growing number of embedded and network-enabled physical devices collectively termed as the "Internet of Things" (IoT) has become an enabler for facilitating richer context awareness through integration of communication and sensing capabilities into everyday consumer devices, vehicles, homes, and inhabited spaces [1]. With the addition of pervasive networking, such artifacts can be associated together and remotely accessed to make highly personalized systems [2].

This paper presents a system for optimization and energy efficiency in the control of indoor lighting and temperature, through the search for configurations of blind states and lamps, using heuristic techniques such as Particle Swarm Optimization, Bee Swarm Optimization Binary, Genetic Algorithms, and Discrete Binary Differential Evolution.

2 Related Work

Strategies and systems have been developed for the control of lighting in workspaces, among which diffuse logic has been used [3, 4]. In others, it is used as the reference correlation between the luminance at a given location and the luminance of each light [5].

Some systems have used LED technology [6] in addition to considering user satisfaction in order to save energy [7]. Other systems use optimization algorithms to solve the problem of distributed illumination control with local sensing [8] or find only optimal configurations of lamp states in a workspace to provide visual comfort to an end user using Genetic Algorithms [9].

It is worth mentioning that in the works related to lighting control it is not taken into account if the lighting provided is adequate for each activity according to visual comfort standards and also that lighting is provided at a central point of the stage, regardless of whether the user can be located in different areas of workspace and the lighting is not the same in the center as in any other area.

3 Optimization Algorithms

3.1 Particle Swarm Optimization

Particle Swarm Optimization tries to simulate behavior involving flocks of birds and schools of fish, which have no collisions to be looking for food [10] and builds on the concept of social metaphor [11]. This meta-heuristic uses a velocity vector for each particle which tells them how fast it will move the particle in each of the dimensions, the method for updating the speed of PSO is given by Eq. 1, and it is updating by Eq. 2. The pseudocode for the PSO is shown in 1.

$$v_i = \varphi_0 v_i + \varphi_1 (x_i - B_{Global}) + \varphi_2 (x_i - B_{Local}) \tag{1}$$

$$x_i = x_i + v_i \tag{2}$$

where v_i is the velocity of the i-th particle, φ_0 is adjustment factor to the environment, φ_1 is the memory coefficient in the neighborhood, φ_2 is the coefficient memory, x_i is the position of the i-th particle, B_{Global} is the best position found so far by all particles, and B_{Local} is the best position found by the i-th particle.

Algorithm 1 Particle Swarm Optimization

for each particle i **do**
  Start position of each particle
  Start best position $p_i \leftarrow x_i$
  if $f(p_i) < f(g)$ **then**
    update the best position $g \leftarrow p_i$
  end if
  Start velocity of particle v_i
end for
while Stopping criterion not met do **do**
  for each particle **do**
    Start velocity of particle
    if $f(actualparticle) < f(p_i)$ **then**
      Update best position of particle $p_i \leftarrow actualparticle$
      if $f(p_i) < f(g)$ **then**
        Update best position of swarm $g \leftarrow p_i$
      end if
    end if
  end for
end while

3.2 Binary Bee Swarm Optimization

BSO is a combination of the algorithms Particle Swarm Optimization (PSO) [10] and Bee Algorithm (BA) [12], and uses the approach known as “social metaphor”. This algorithm mimics the honey bees intelligent behavior for foraging, seeking better food sources along a radius search with Eqs. 3 and 4. The pseudocode for the BSO is shown in Pseudocode 2.

$$v_i = \varphi_0 \times v_i + \varphi_1(v_i - B_{Global}) + \varphi_2(v_i - B_{Local}) \tag{3}$$

$$s(v_i) = 1/(1 + e^{-v}) \tag{4}$$

where v_i is the velocity of the ith particle, φ_0 is adjustment factor to the environment, φ_1 is the memory coefficient in the neighborhood, φ_2 is the coefficient memory, x_i is the position of the ith particle, B_{Global} is the best position found so far by all particles, and B_{Local} is the best position found by the ith particle.

Algorithm 2 Bee Swarm Optimization

```
Start the swarm particles, Start the velocity vector for each particle in the swarm
while Stopping criterion not met do
  for i = 1 to n do
    if i-particle's fitness is better than the local best then
      Replace the local best with the i-particle.
    end if
    if i-particle's fitness is better than the global best then
      Replace the global best with the i-particle.
    end if
    Update the velocity vector and particle's position
    Choose the best sb particles
    for all best sb particle do
      Search if there are some better particle in the search radio and if exist it replace the particle with the best particle in the search radio
    end for
  end for
end while
```

3.3 Genetic Algorithm

A genetic algorithm is basically a search and optimization technique based on the principles of genetics and natural selection. These are implemented in computer simulations where the population of abstract representations (called chromosomes or the genotype of the genome) of candidate solutions (called individuals, creatures, or phenotypes) to an optimization problem aims to find better solutions [13]. The operation of a simple genetic algorithm can be shown in 3.

Algorithm 3 Genetic Algorithm

```
Decode chromosome
while The unemployment condition is not satisfied do
    Evaluate fitness function for each chromosome
    Select mates and Mating
    Mutation and Crossover
    Convergence Check
end while
```

3.4 Discrete Binary Differential Evolution

Differential Evolution (DE) is a parallel direct search method using parameter vectors NP D-dimensional. The initial vectors must be initialized with random values covering the whole parameter space [14]. The pseudocode for the binary version of DE is shown in Pseudocode 4.

Algorithm 4 Discrete Binary Differential Evolution

```
Start population
while Stopping criterion not met do do
    Find individual with best fitness XBest.
    for each individual do
        Mutates and Crosses
    end for
end while
```

4 Solution Framework

As part of the methodology and modeling of the problem, the following was considered:

- Scenario analysis and detection of variables: The analysis of the scenario focused on lighting and energy, to detect which variables intervene and which activities are carried out with greater recurrence in a university campus.
- Design and modeling: The system is designed for the collection of data with sensors and the implementation of heuristics to search for state configurations, the representation of the variables is determined and how they will be handled in the implementation of the heuristics.
- Fitness function definition and implementation of bio-inspired algorithms with their respective experiments.

A system for lighting control is proposed where the presence of the user to the stage is detected. Said user indicates to the intelligent environment what activity he wants to perform with the help of a mobile device or user application. From the data collection of sensors in the environment and the use of decision rules, the state of windows and air conditioning is terminated to provide thermal comfort to the user. These rules are designed so that turning on the air conditioning will be the last resort, in order to achieve energy savings. In order to offer the adequate lighting (visual comfort) for each activity performed by the user, the system makes use of bio-inspired algorithms to determine the configuration of lights and Persian blinds states in which natural light is also considered as a source of illumination with the intention to save energy. To offer visual and thermal comfort to the user, the system repeats the process every 30 minutes. This range of time was proposed because the lighting and outside temperature are quite variable during the day. This range can be changed for experiments in future work. Due to changes in temperature and variation of the lighting outside during the day, the system is considered dynamic because it adapts to conditions of the day by collecting environmental data.

4.1 Representation of the Variables According to the Scenario

This problem uses a binary presentation for the possible states of Persian blinds, lights, and windows. A binary string represents a possible solution or individual of the bio-inspired algorithms. To interpret the states of each Persian blinds, 2 bits of the binary string are taken into account as shown in Table 1. In Table 1, the possible states of lights are shown taking into account 3 bits of the binary string.

The lighting in different areas of the laboratory is not the same. To determine this we measured the illumination in different regions of the laboratory. A lux meter was placed on the different areas of the laboratory and measurements were obtained by taking into account the possible states of each Persian blind. According to measurements of lighting, weights are assigned to each light and Persian blind to determine the amount of lighting that is provided to the laboratory in each region. Figure 1a shows the regions of the laboratory for the measurements. In Fig. 1b colored areas are shown, which are assigned weights based on measurements of illumination. For example, in the red area: Lamps L1 and L4 are assigned a weighting of 100% of their light output because they are the closest to the point X1, and in the green area:

Table 1 Binary Representation and States of Persian Blinds and Lights

Binary string	State persian blinds
00	Open
01	Medium open (M)
10	Closed (C)
11	Without persian blind (W)

Binary string	Level of illumination light
000	0
001	1
010	1
011	2
100	2
101	3
110	3
111	4

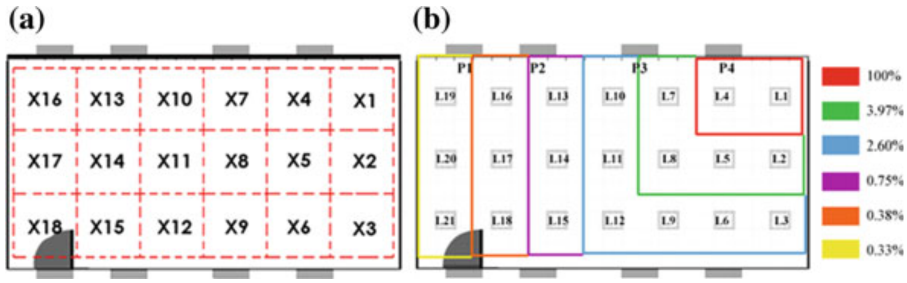

Fig. 1 Segmentation laboratory in 18 regions and weights assigned to each Persian

the lamps (L2, L5, L7, L8) are assigned a weighting of 3.97% of their luminous flux since the amount of lux contributing to point X1 is lower. Table 2 shows the weights that were assigned to each Persian blind depending on state and region that the user is located.

To calculate the amount of lighting required for each activity, Eq. 5 is used. The desired average luminance values (Lx) are taken based on [15], of which activities were taken into account: reading (750 Lx), working computer (500 Lx), staying or relax (300 Lx), projection (450 Lx), and exposure (400 Lx). In this case, by default, the maintenance factor takes the value of a clean environment. In the proposed fitness function Eq. 6, the sum of the luminous flux provided by each light and Persian blind (with their assigned weights) is subtracted from the value of the amount of illumination required for the activity. For this problem, the most appropriate solution is the minimum of all the solutions.

$$\phi_T = \frac{E \times S}{\eta \times f_m} \tag{5}$$

where ϕ_T is total luminous flux (Lm) required in a specific zone, E is desired average luminance (Lx), assigned value for each activity, taken from the standards [15], S is surface of the working plane (m^2), η is light output (Lm/W), f_m is maintenance factor, which depends on whether the environment is clean ($fm = 0.8$) or dirty ($fm = 0.6$).

$$Cv_i = \phi_T - \sum_{n=1}^{k} \phi_{Ln} - \sum_{r=1}^{w} \phi_{Pr} \tag{6}$$

where Cv_i is visual comfort and is in function of the required lighting Lx, ϕ_T is the total luminous flux required (lx) for certain activity, area, and lamp conditions, ϕ_{Ln} is the illumination (Lx) of the light n to the zone i, ϕ_{Pr} is the illumination (Lx) of the blind r to the zone i, k is total number of lamps, and w is total number of blinds.

Table 2 Weights assigned to each Persian blind and region

Region	Persian	Weighting assigned (%)			
		State of persian blind			
		Open (%)	M (%)	W (%)	C (%)
X16, X13	P1	19.80	6.96	68.30	2.32
	P2	2.86	3.68	4.32	2.32
	P3	1.91	1.63	2.18	2.32
	P4	1.90	1.77	2.04	2.32
X17, X14	P1	9.56	2.45	12.70	0.54
	P2	1.63	0.68	2.73	0.54
	P3	2.45	1.63	0.95	0.54
	P4	0.68	0.68	0.68	0.54
X2, X5	P1	0.68	0.68	0.68	0.54
	P2	2.45	1.63	0.95	0.54
	P3	1.63	0.68	2.73	0.54
	P4	9.56	2.45	12.70	0.54
X3, X6	P1	0.81	0.68	0.27	0.27
	P2	0.81	0.54	0.95	0.27
	P3	1.91	0.68	1.77	0.27
	P4	0.13	1.09	3.96	0.27
X11, X8	P1	0.68	0.68	0.68	0.54
	P2	1.63	0.68	2.73	0.54
	P3	9.56	2.45	12.70	0.54
	P4	1.63	0.68	2.73	0.54
X9, X12	P1	0.80	0.68	0.27	0.27
	P2	1.91	0.68	1.77	0.27
	P3	0.13	1.09	3.96	0.27
	P4	1.91	0.68	1.77	0.27
X1, X4	P1	1.90	1.77	2.04	2.32
	P	21.91	1.63	2.18	2.32
	P3	2.86	3.68	4.32	2.32
	P4	19.80	6.96	68.30	2.32
X18, X15	P1	0.13	1.09	3.96	0.27
	P2	1.91	0.68	1.77	0.27
	P3	0.81	0.54	0.95	0.27
	P4	0.81	0.68	0.27	0.27
X10, X7	P1	1.91	1.63	2.18	2.32
	P2	2.86	3.68	4.32	2.32
	P3	19.80	6.96	68.30	2.32
	P4	2.86	3.68	4.32	2.32

5 Results and Comparison

Below are the results of the lighting control system that uses bio-inspired algorithms, which controls lights, Persian blinds, and takes into account outdoor lighting to save energy and provide adequate lighting to a user. These results were made for each area and with different activities that the user can perform. The input parameters for each algorithm were found experimentally and are shown in Table 3. In Table 4, the results of the system are shown, applying the algorithms, where the values of the media fitness and the standard deviation are shown to later make a comparison and determine which algorithm offers the most efficient configurations of lights and Persian blind states. In order to understand these results, it is taken into account that as long as a possible solution is closer to the value of zero, then it is considered a good solution. For example, in the X9 zone performing the reading activity, a value of 0.1889 in fitness was obtained for the GA and a value of 0.729 in fitness for the DBDE. Therefore, the value that is considered most optimal in this minimization problem is the 0.1889 solution using GA. For this comparison, the Friedman test in Table 5 shows the rankings of each algorithm based on their results. With this test, it can be concluded that the genetic algorithm has better configurations of states of lights and Persian blinds to provide visual comfort, followed by BSO, DE, and PSO.

Table 3 Input parameters

Algorithm	Parameter	Value
Genetic algorithm	No. generations	100
	Population	80
	Mutation	0.8
	Elitism	0.2
Particle swarm optimization	Iterations	100
	No. particles	80
	Phi0	1
	Phi1	0.5
	Phi2	0.8
Bee swarm optimization	Iterations	100
	No. bees	80
	Phi0	1
	Phi1	0.5
	Phi2	0.8
	Radio search	6
	% Bee explorer	10
Binary differential evolution	No. generations	100
	Population	80
	F	0.8
	Cr	0.5

Table 4 Results of illuminations optimization using GA, PSO, BSO, and DBDE

		GA		PSO		BSO		DBDE	
Region	Activity	Media fitness	Standard deviation	Media fitness	Standard deviation	Media fitness	Standard deviation	Media fitness	Standard deviation
X-1	Read	0.0391	0.0317	66.856	84.961	25.891	11.621	7.203	5.882
	Computer work	0.1014	0.1705	180.909	118.025	61.453	34.902	80.082	12.126
	Stay	46.3517	10.8323	234.34	70.161	155.642	29.139	155.935	18.713
	Projection	5.2859	10.4528	140.794	43.084	71.07	21.4	100.123	18.518
	Exposition	0.0485	0.043	191.135	116.865	108.994	43.567	127.114	27.014
X-2	Read	0.1262	0.1483	45.397	29.98	7.388	7.789	4.951	4.217
	Computer work	0.0443	0.0345	39.669	24.838	61.938	51.199	5.481	7.585
	Stay	0.0484	0.0407	122.952	59.794	30.235	22.346	54.924	14.113
	Projection	0.0563	0.0452	66.206	56.812	16.352	13.434	13.725	11.002
	Exposition	10.3332	12.0515	47.987	33.701	16.38	15.937	20.014	7.15
X-3	Read	0.1078	0.1648	33.44	44.448	7.462	8.9	6.397	15.084
	Computer work	0.044	0.0482	4.205	4.9	4.357	2.684	0.938	0.581
	Stay	0.0283	0.0337	37.323	23.228	3.302	3.433	14.141	13.46
	Projection	0.0443	0.0436	16.641	23.34	10.014	10.086	1.263	0.993
	Exposition	0.0833	0.0916	20.465	21.922	6.419	5.41	2.245	1.484
X-8	Read	0.2271	0.1481	18.278	20.313	55.093	27.01	6.388	7.093
	Computer work	0.1041	0.0887	85.706	32.779	47.463	32.811	35.142	21.461
	Stay	0.1734	0.0883	157.322	42.165	87.684	41.793	114.775	22.109
	Projection	0.1922	0.1262	119.485	52.174	39.269	29.987	74.243	18.202
	Exposition	0.1958	0.112	143.964	77.011	38.092	21.045	67.219	22.237
X-13	Read	0.0368	0.0205	80.409	83.961	24.33	20.172	14.823	11.457
	Computer work	0.1766	0.1181	149.984	40.885	85.981	28.53	110.976	19.818
	Stay	46.2129	13.4147	244.516	28.977	152.067	42.332	178.69	26.968
	Projection	1.5672	2.6039	210.362	136.447	38.905	40.677	132.757	24.807
	Exposition	15.4388	11.4107	211.886	56.233	123.799	32.753	159.133	15.267
X-15	Read	0.0581	0.0707	17.92	27.409	28.043	27.276	1.693	1.255
	Computer work	0.076	0.0768	32.715	36.1	4.397	3.264	1.785	1.977
	Stay	0.0905	0.0921	56.591	22.893	8.216	5.296	40.538	16.616
	Projection	0.076	0.1078	16.469	14.727	4.016	3.971	2.531	2.142
	Exposition	0.0274	0.0342	26.122	15.727	3.719	2.609	8.01	6.348

Table 5 Average rankings of the algorithms (Friedman test)

Algorithm	Ranking
GA	4
PSO	1.111111111
BSO	2.511111111
DE	2.377777778

6 Conclusions and Future Work

From the presented methodology, the highlights are the weighting to lights and Persian blinds depending on its state and the area, the decision-making about states of each window and air conditioning control to achieve energy saving. The system offers energy sustainability since it takes into account the lighting and temperature of the exterior to help to regulate visual and thermal comfort on the stage unlike the related works, based on the iCampus paradigm. The use of bio-inspired algorithms was proposed to control lighting. A comparison was made with the results of the algorithms to determine which offers the most optimal solutions to provide visual and thermal comfort of the user. Friedman test determined that the Genetic Algorithm has better results over the other three algorithms applied. A future work is proposed to implement the system in a real scenario to get more experiments. This work has provided the service to offer a single user so that it would be interesting to provide the service to different users with different needs performing different tasks simultaneously, converting this into a multi-objective problem. It is intended to apply this proposed system to more scenarios such as offices, hospitals, etc. and not be limited to a campus lab. In addition to expanding the collection of environmental data in other seasons of the year, since climatic conditions play a very important role in lighting and temperature.

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Toward a Model of Management Processes to Support or Increase the Competitiveness of a University Professor

Nora Osuna-Millan, Ricardo Rosales, Felipe Lara-Rosano and Arnulfo Alanis Garza

Abstract This article proposes the revision of the information required to establish the management processes to support or increase the competitiveness of a University professor, where complex processes intervene that must be attended by means of a model based on agents; it also presents the need to identify the characteristics that can and should drive a substantial improvement in the teacher's performance, intelligent agents based on the perception of information from the environment, to produce a result that can be communicated to another or others through a model based on intelligent agents, which allow to strengthen the competitiveness of a teacher.

1 Introduction

An university professor today is committed to administrative and research activities, which complement his activity in front of a group according to [1], these are necessary for the functioning of the Faculty and the strengthening of it in its performance; the problem arises when these activities are not balanced, the professor may be demotivated by various environmental factors internal and/or external to the teaching-learning process and/or professional training of it.

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The fact that the teacher is assigned to different learning units—subjects without analyzing their protective characteristics, at the same time as their risk characteristics; where the first provide security and the second can generate a situation of insecurity for the same [2, 3].

There are several studies [1] that indicate that new teachers, assigned in an average term of subject or part-time and full-time teachers are minimizing their competitiveness by generating a state of comfort, lack of motivation, lack of training, generalized evaluation, insecurity, in consequence, the quality of teaching—education is diminished.

2 Background

The diversification of the tasks of a university teacher between the accumulation of extra or delayed work and cognitive effort has generated, in them, diverse health problems [1], for which reason it is necessary to generate tools and strategies that mitigate this problem and support the teacher in generating a more competitive environment that is reflected in quality education.

In Mexico, it is essential to develop strategies that support the best performance of students which will be fully related to the teacher's, this allows recognizing the level of competence that the teacher provides to their students, studied and reviewed by various measurement tools [4].

Education in Mexico allows us to observe the complexity involved in the quality of education, its volume and scope, and the participation of the main interest groups [5]. University professors must overcome the temptation of routine, the fact that the same techniques are considered applicable to all groups, there are characteristics that may coincide in some groups and/or students but there are characteristics that are unique to each group and/or student, routine, inertia, non-criticism of basic mental schemes repeated and applied by custom of teachers [6].

The multidimensionality and complexity of an educational institution require that its main actors innovate in order to seek new solutions to emerging problems in the educational field that strengthen their competitiveness [7].

The objective of the proposed research is to develop a process simulator for the management of the competitiveness of an university teacher as a knowledge base for quality university education, which will allow identifying the variables that increase or allow the competences of the professors to be maintained independently of the complexity of the interaction context and/or scenarios in which it performs.

3 State of the Art

3.1 Agents

The use of agents is increasingly required for the creation of intelligent and simulation systems, the need to make predictions and support in the prevention of current and future problems is of great interest for the whole society in general.

An agent can be defined as an entity that reacts to different perceptions or reception of information from the environment, to which it responds through decision-making based on experiences see Fig. 1 barely known or recognized at that time [8]. An agent is a container of software that has autonomy and behaves like a human being, that looks for the best solution for a problem, for a multi-agent system it is necessary that the agents relate to share information and generate reactions to it, all oriented to the collaboration among them to achieve a better result, these are social, reactive, adaptive, and autonomous [9].

3.2 Agent-Based Model

The complexity sciences allow to approach the emergent properties from the communication between diverse agents and this can be captured through a Model based on agents and its simulation [10].

The simulation can represent an imaginary activity, a reality, a probable scenario, which allows us to see realities that do not yet occur, a prediction [11, 12]. Computational simulation allows the identification of anticipated or predictive solutions in the near future, through the scenario of certain variables that can be found in the environment. This is part of agent-based modeling [13]. A model facilitates the understanding of a theoretical or imaginary description of a process, set of processes, or a complex reality [14].

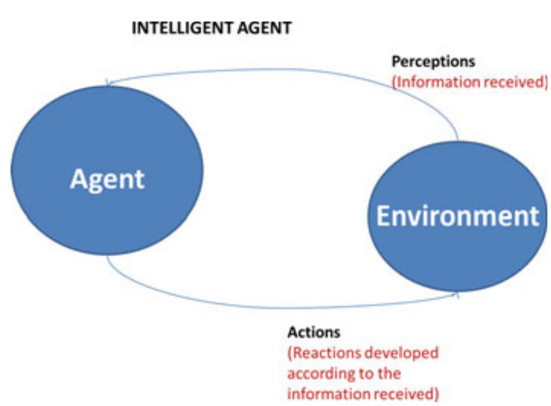

Fig. 1 Intelligent agent

3.3 The Complexity and An University Teacher

The complexity in which the university professor is involved can be grouped into the following sections: the teaching-learning process, interpersonal relations and the administration or the institutional context, these three elements allow the teacher to be competent in the activity developed, when performing in the best way the (efficient) processes for which it is responsible, confirm that its main stakeholders consider that the work it develops is the one that is required (effective) and is productive when performing the greatest number of activities in the smallest unit of time and possible costs.

The management of the competitiveness of a university teacher as a knowledge base for quality university education through a computer simulator is undoubtedly a strategy that will make it possible to address in a different way the evaluation of the experience, teaching-learning process, attention to students, attention to teaching and administrative activities, through the analysis of the abstraction of processes, the emergence of processes, activities, interpersonal relationships in various scenarios; At the same time it will allow the coordinators of career area, immediate superiors or top management the efficient decision-making, which will be focused on generating strategies that strengthen the variables that allow the teacher to maintain and/or increase the competitiveness of the same and generate a quality education in the applicable field.

Implementing a science-oriented approach of complexity to this project will allow a disruptive approach to the process in which university teachers are developed, which will influence the achievement of quality education.

4 Methodology

The proposed methodological strategy allows the development of work through an approach to the surroundings of the main actor; the previous will generate a scenario of reality that occurs in the university world of the teacher and thus efficiently shows the skills, behavior, performance, interests, competencies, and objectives, as well as the simulator.

The interaction of the main interest groups, as well as the communication at all times with the client, is essential to obtain the information required for the development of the model.

The work will be carried out in four stages: Start, Planning, Execution and Monitoring and Control; Delivery and retrospective [14, 15], each of them is presented below.

1. The Start stage includes the definition of the conditions in which the project is generated, problems to solve, resources involved, identification and determination of the main interest groups, risks, scope, costs, time, restrictions, criteria

of Acceptance if applicable and equipment. Where the creation of the Project Charter and/or project case, simplifies or summarizes this stage.

2. Subsequently, the Planning phase begins, which includes the completion of the General plan for the administration of the project resources and/or the plans for the management of the development of small functionalities to be delivered; These include times needed for the efficient fulfillment of the activities, as well as the sequence in which they will be developed.
3. In the stage of Execution, Monitoring and Control will develop the activities aimed at creating the deliverables or functionalities for this project will start the modeling based on agents for a simulator of management processes that support and/or increase the competitiveness of a university professor.
4. Delivery and Retrospective: Once the scope of the work is completed, the product is delivered to the client or in this case to future work, on the results a retrospective should be performed that allows to visualize the activities developed correctly so that they can be replicated in projects or following tasks and the tasks carried out incorrectly so that they do not repeat themselves, finally the final report will be developed that complements the development of the project.

The methodology used allows managing to work through a combination of traditional and agile methodologies of project management.

4.1 Teacher System

The multiple scenarios in which a University Teacher can develop are diverse, see Fig. 2, so creating the design to simulate a real environment will allow to visualize in a more efficient way the needs, experience, preparation, interests, capacities, personalities that allow improving the competitiveness toward higher quality education in the process of teaching and learning.

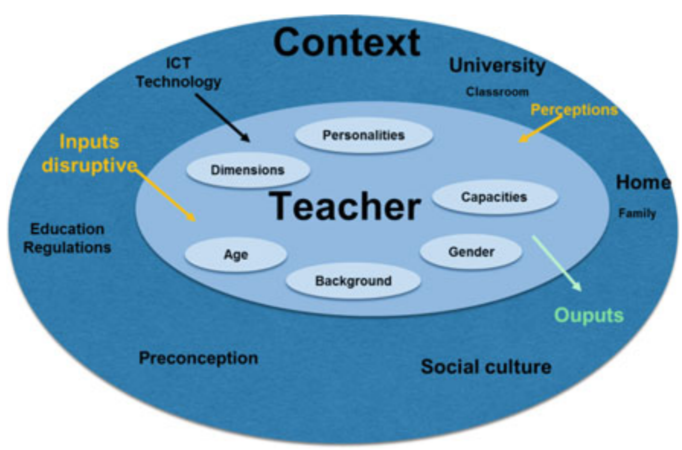

Fig. 2 Teacher system

The emergence of situations that strengthen the skills and self-motivation of a University Professor are diverse and include many disciplines, which will allow a complex simulation of the Factors that support the teacher and those that affect them, this will allow managers to generate strategies that allow the University Professors not to lower the level of quality that the institution itself requires [16].

5 Conclusions

The generation of a model of management processes that support or allow to maintain or increase the productivity of a teacher will undoubtedly generate great support to those in charge of managing the relationship of teachers with students in the teaching-learning process. The system that describes a teacher illustrates the parameters that have been identified at the time and that can affect this positively or negatively. Once the model is concluded, it will help to identify the relationships with other actors and the way in which different scenarios, interactions and shared information support the teacher.

6 Future Works

The work to be developed will be the realization of the Management Process Model that allows to increase or maintain the competitiveness of a professor, as well as the subsequent construction of the computational social simulator, the implementation of the platform with the simulator, the realization of tests and validation and finally the publication of results.

Another of the future lines is to include the formal description of each of the agents involved in the model that are included in the environment surrounding the university professor so that this allows a better understanding of the teacher's interaction in their environment, as well as identifying themselves Personality, capabilities, age environment, gender, experience and dimensions presented by the Professor, which will allow to develop a knowledge base based on logic rules. Fuzzy define the tuples of the agents, implement the knowledge base based on fuzzy logic with rules Type 1 and Type 2.

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Part IV
Business Informatics

An Agent-Based Infectious Disease Model of Rubella Outbreaks

Setsuya Kurahashi

Abstract This study proposes a simulation model of rubella. SIR (Susceptible, Infected, Recovered) model has been widely used to analyse infectious diseases such as influenza, smallpox, bioterrorism, to name a few. On the other hand, agent-based model begins to spread in recent years. The model enables to represent the behaviour of each person on the computer. It also reveals the spread of infection by simulation of the contact process among people in the model. The study designs a model based on smallpox and Ebola fever model in which several health policies are decided such as vaccination, the gender-specific workplace and so on. The infectious simulation of rubella, which has not yet vaccinated completely for men in Japan, is implemented in the model. As results of experiments using the model, it has been found that preventive vaccine to all the men is crucial factors to prevent the spread in women.

Keywords Agent-based model · Infectious disease · Rubella

1 Introduction

Infectious diseases have been serious risk factors in human societies for centuries. Smallpox has been recorded in human history since more than B.C 1100. People have also been suffering from many other infectious diseases such as malaria, cholera, tuberculosis, typhus, AIDS, influenza, etc. Although people have tried to prevent and hopefully eradicate them, a risk of unknown infectious diseases including SARS, a new type of infectious diseases, as well as Ebola haemorrhagic fever and Zika fever have appeared on the scene.

A model of infectious disease has been studied for years. SIR (Susceptible, Infected, Recovered) model has been widely used to analyse such diseases based

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on a mathematical model. After an outbreak of SARS, the first SIR model of SARS was published and many researchers studied the epidemic of the disease using this model. When an outbreak of a new type of influenza is first reported, the U.S. government immediately starts an emergency action plan to estimate parameters of its SIR model. Nevertheless, the SIR model has difficulty to analyse which measures are effective because the model has only one parameter to represent infectiveness. For example, it is difficult for the SIR model to evaluate the effect of temporary closing of classes because of the influenza epidemic. The agent-based approach or the individual-based approach has been adopted to conquer these problems in recent years [1–4]. The model enables to represent behaviour of each person. It also reveals the spread of an infection by simulation of the contact process among people in the model.

In this study, we developed a model to simulate rubella based on the infectious disease studies using agent-based modelling. What we want to know is how to prevent an epidemic of infectious diseases not only using mechanisms of the epidemic but also decision-making of health policy [5]. We aim to study the relationship between antibody holding rate of men and the spread of infection by constructing infection of rubella virus with the agent-based model and repeating simulation experiment on a computer. Although our previous study described the infectious disease model of smallpox and Ebola [6], this paper proposes a new model of rubella which has caused crucial problems for pregnant women in recent years. In Sect. 2, as examples of infections that occurred in the past, we will explain smallpox, Ebola hemorrhagic fever, Zika fever and rubella. Section 3 describes related research on infectious disease models. Section 4 explains the basic model and describes the rubella model. Section 5 explains the experimental results and Sect. 6 discusses them. Finally, we summarize the whole in Sect. 7.

2 Cases of Infectious Disease

2.1 Smallpox

The smallpox virus affects the throat where it invades into the blood and hides in the body for about 12 days. Patients developed a high fever after that, but rashes do not appear until about 15 days after the infection. While not developing rashes, smallpox virus is able to infect others. After 15 days, red rashes break out on the face, arms and legs, and subsequently they spread over the entire body. When all rashes generate pus, patients suffer great pains; finally, 30% of patients succumb to the disease. For thousands of years, smallpox was a deadly disease that resulted in thousands of deaths.

2.2 Ebola Haemorrhagic Fever

A source of Ebola infection is allegedly by eating a bat or a monkey, but it is unknown whether eating these animals is a source of the infection. Due to the recent epidemic, which began in Guinea in December 2013, 11,310 deaths have been confirmed. The authorities of Guinea, Liberia and Sierra Leone have each launched a state committee of emergency and have taken measures to cope with the situation. The prohibition of entry over the boundary of Guinea is included in these measures.

2.3 Zika Fever

Zika fever is an illness caused by Zika virus via the bite of mosquitoes. It can also be potentially spread by sex according to recent report [7, 8]. Most cases have no symptoms and present are usually mild including fever, red eyes, joint pain and a rash [9], but it is believed that the Zika fever may cause microcephaly which severely affects babies by a small head circumference.

2.4 Rubella

Rubella is a type of viral infection caused by the rubella virus [10, 11]. In Japan, there were epidemics (1976, 1982, 1987, 1992) once every 5 years, but after a male and female infant was the subject of periodic vaccination, no big epidemic occurred. However, in 2004, 40,000 people outbreaks were estimated and ten congenital rubella syndromes were reported. A large epidemic occurred in Asia in 2011, and from 2013 to 2014, an epidemic exceeding 14,000 cases occurred mainly in adult males who did not take the vaccine [12]. The epidemic recurred in 2018, as of October the number of annual infections of rubella was about 1300 people, the National Institute of Infectious Diseases announced emergency information on rubella epidemics. The Centers for Disease Control and Prevention (U.S.) raised the rubella alert level in Japan to the second 'recommendation' among the three levels [13]. They recommended that pregnant women who are not protected against rubella through either vaccination or previous rubella infection should not travel to Japan during this outbreak.

3 Related Work

3.1 Smallpox and Bioterrorism Simulation

Epstein [14, 15] made a smallpox model based on 49 epidemics in Europe from 1950 to 1971. In the model, 100 families from two towns were surveyed. The family includes two parents and two children, thus the population is each 400 from each town. All parents go to work in their town during the day except 10% of adults who go to another town. All children attend school. There is a communal hospital serving the two towns in which each five people from each town work. This model was designed as an agent-based model, and then simulation of infectious disease was conducted using the model. As results of experiments showed that (1) in a base model in which any infectious disease measures were not taken, the epidemic spread within 82 days and 30% of people died, (2) a trace vaccination measure was effective but it was difficult to trace all contacts to patients in an underground railway or an airport, (3) a mass vaccination measure was effective, but the number of vaccinations would be huge so it was not realistic and (4) epidemic quenching was also effective, and reactive household trace vaccination along with pre-emptive vaccination of hospital workers showed a dramatic effect.

3.2 Individual-Based Model for Infectious Diseases

Ohkusa [16] evaluated smallpox measures using an individual-based model of infectious diseases. The model supposed a town including 10,000 habitats and a public health centre. In the model, one person was infected with smallpox virus at a shopping mall. They compared between a trace vaccination measure and a mass vaccination measure. As a result of simulation, it was found that the effect of trace vaccination dropped if the early stage of infection was high and the number of medical staff is small, while the effect of mass vaccination was stable. Therefore, timely and concentrate mass vaccination is required when virus starts spreading. The estimation about the number, place and time of infection is needed quickly and the preparation of an emergency medical treatment and estimation system is required for such occasions. Regarding measles epidemics, agent-based simulation models of measles transmission have been developed using the Framework for Reconstructing Epidemiological Dynamics, a data-driven agent-based model to simulate the spread of an airborne infectious disease in an Irish town, and so on [17, 18].

Summary of related work From these studies, the effectiveness of an agent-based model has been revealed, yet these are not sufficient models to consider a relationship between antibody holding rate of men and women, and commutation routes and the gender-specific workplace. In addition, authorities need to make a decision regarding measles–rubella mixed (MR) vaccine to men. This study takes into account these extensions.

4 A Health Policy Simulation Model of Infectious Disease

We designed a health policy simulation model of infectious disease based on Epstein's smallpox model. The model includes smallpox, Ebola haemorrhagic fever and rubella.

4.1 A Base Model of Smallpox

We assume all individuals to be susceptible which means no background of immunity. 100 families live in two towns.

The family includes two parents and two children. Therefore, the population is each 400 in each town. All parents go to work in their town during the day except 10% of adults commute to another town. All children attend school. There is a communal hospital serving two towns in which five people from each town work. Each round consists of an interaction through the entire agent population. The call order is randomized each round and agents are processed or activated, serially. On each round, when an agent is activated, she identifies her immediate neighbours for interaction. Each interaction results in a contact. In turn, that contact results in a transmission of the infection from the contacted agent to the active agent with probability.

The probability of contact at an interaction is 0.3 at a workplace and a school, while 1.0 at a home and a hospital. The probability of infection at a contact is 0.3 at a workplace and a school, while 1.0 at a home and a hospital. In the event the active agent contracts the disease, she turns blue to green and her own internal clock of disease progression begins. After 12 days, she will turn yellow and begins infecting others. Length of noncontagious period is 12 days, and early rash contagious period is 3 days. Unless the infected individual is vaccinated within 4 days of exposure, the vaccine is ineffective. At the end of day 15, smallpox rash is finally evident. Next day, individuals are assumed to hospitalize. After 8 more days, during which they have a cumulative 30% probability of mortality, surviving individuals recover and return to circulation permanently immune to further infection. Dead individuals are coloured black and placed in the morgue. Immune individuals are coloured white. Individuals are assumed to be twice as infectious during days 1–19 as during days 12–15.

4.2 A Model of Ebola Hemorrhagic Fever

In the event the active agent contracts the disease, she turns blue to green and her own internal clock of disease progression begins. After 7 days, she will turn yellow and begins infecting others. However, her disease is not specified in this stage. After 3 days, she begins to have vomiting and diarrhoea and the disease is specified as Ebola. Unless the infected individual is dosed with antiviral medicine within 3 days of exposure, the medicine is ineffective. This is an imaginary medicine to play the policy game. At the end of day 12, individuals are assumed to hospitalize. After 4 more days, during which they have a cumulative 90% probability of mortality, surviving individuals recover and return to circulation permanently immune to further infection. Dead individuals are coloured black and placed in the morgue. Immune individuals are coloured white. Other settings are the same as smallpox.

4.3 A Model of Rubella

Rubella is a viral infectious disease characterized by fever and rash. Since symptoms range from subclinical to complications, it is difficult to judge as rubella only with symptoms. If a pregnant woman until about 20 weeks of pregnancy infects rubella with a virus, there is a possibility that the baby will develop congenital rubella syndrome (CRS). In consequence, congenital heart disease, hearing loss, cataract, pigmentary retinopathy and the like occur as congenital abnormalities.

For this reason, the pre-inoculation of the vaccine is extremely important. In Japan, however, only junior high school girls were eligible for regular vaccination of rubella vaccine from 1977 to 1995. In the past, vaccination was recommended for children under the age of 3, but due to the frequent occurrence of meningitis caused by the vaccine strains, the use was discontinued after that. Thereafter, the national epidemic of measles occurred mainly in the 10–20 generations in 2007. ‘Prevention guideline on specific infectious diseases related to measles’ was announced by the Ministry of Health, Labour and Welfare, and rubella was also designated as a disease to take measures. And during the 5 years from 2008 to 2012, as a periodical inoculation at the first period (1-year-old child), the second period (before elementary school entrance), the third period (first grader of junior high school) and the fourth period (third grader of high school), MR vaccine was to be inoculated. From fiscal 2013, as a rule, measles–rubella mixed (MR) vaccine is inoculated in infants of the first period and children before elementary school entrance of the second period. According to a survey of 2016, females possess about 95% of antibodies in all ages, while males only possess about 90% of 20–34 years old, and 76–84% of 35–55 years old. The antibodies holding rate in middle-aged males stays low.

Regarding the infection process, fever, rashes and lymphadenopathy (especially the posterior portion of the auricle, the back of the auricle, the neck) appear after a latency period of 14–21 days from infection. Fever is observed in about half of rubella patients. In addition, inapparent infection is about 15–30%.

5 Experimental Results

5.1 A Basic Model of Rubella

The process of infection in a rubella model is plotted in Fig. 1. The model employs with the basic parameters to the disease. An orange line and a blue line indicate the number of infected and recovered people, respectively. When a player adopts a basic model, it takes approximately 150 days until convergence of the outbreak and more than 29 people have infected.

However, the result of executing the experiment many times is greatly different. Figure 2 shows the histogram of the results of 1000 runs. The horizontal axis shows the number of infected people, the vertical axis shows occurrence frequency, the blue

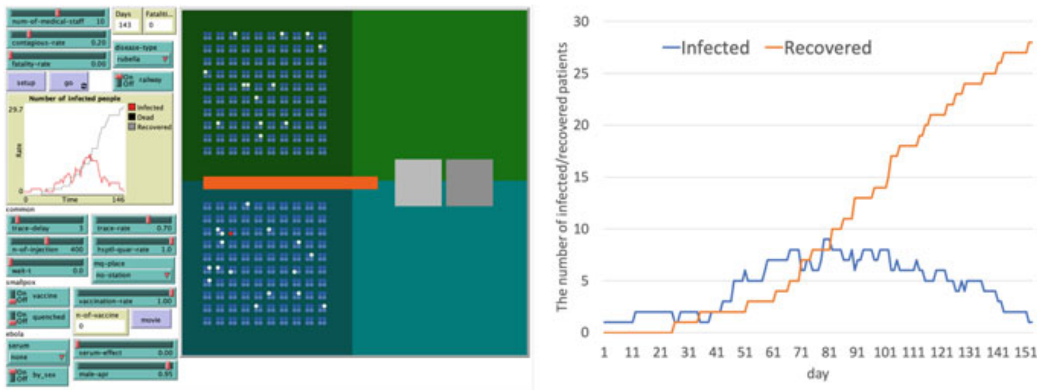

Fig. 1 The simulation model and the experimental result of the rubella basic model

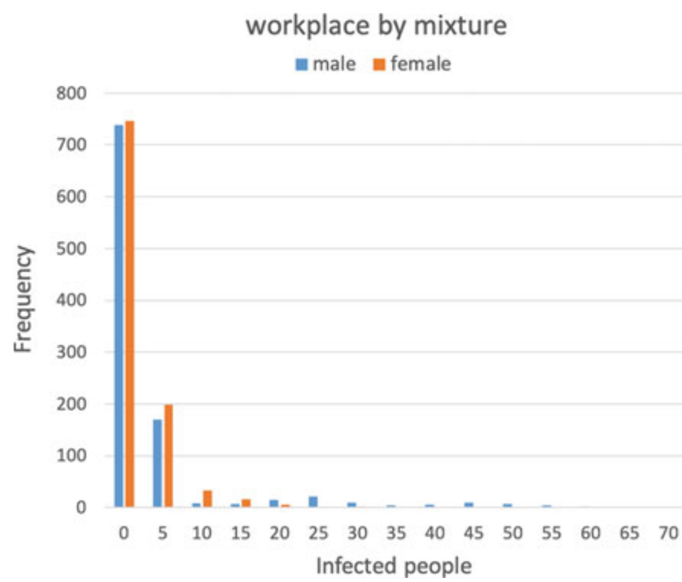

Fig. 2 The frequency chart of the rubella basis model

line shows male and the orange line shows female. Infections do not spread in the cases of about 75%, and the number of infected people is about five for males and females in the cases of about 20%. As a result of the experiment, in most cases, it is found that infection has not spread.

5.2 A Model of the Workplace Separated the Sexes

Next, the results when men and women are working separately in the workplace are shown in Fig. 3. As the results show, the frequency of infection by more than 20 men has increased to over 10% of the total. This result is thought to be caused by a low antibody holding rate of males. However, the total number of women infected has not increased.

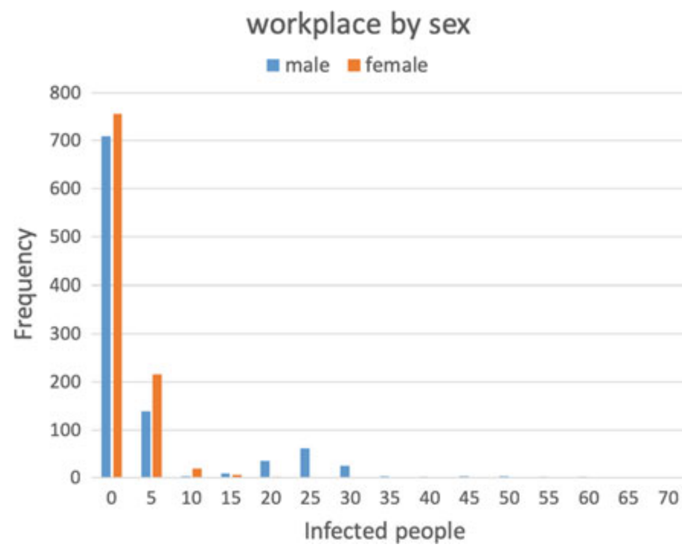

Fig. 3 The experimental result of rubella model of the workplace separated the sexes

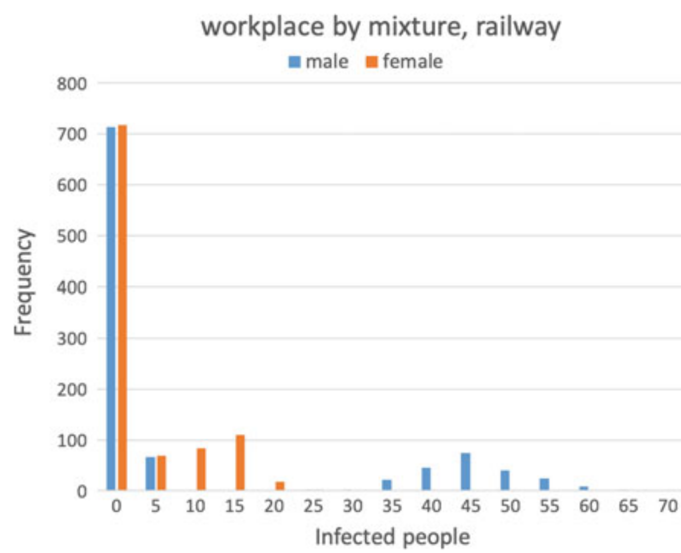

Fig. 4 The experimental result of rubella model with a railway

5.3 A Model with a Railway

Next, we conducted an experiment with a model that introduced the railway to commute. In this model, adults commute by railway. As the experimental result in Fig. 4 shows, the number of infected men has not only increased dramatically but also the number of women infected has increased.

In the basic model without the railway, the frequency of infection of one or more women became 25%, but in the model using the railway, it has increased to 28%. Especially, the case where more than ten women were infected was 21% or more, which was a severe result. Figure 5 shows the experimental results when men and women work separately in a railway model. The result is more serious. The frequency

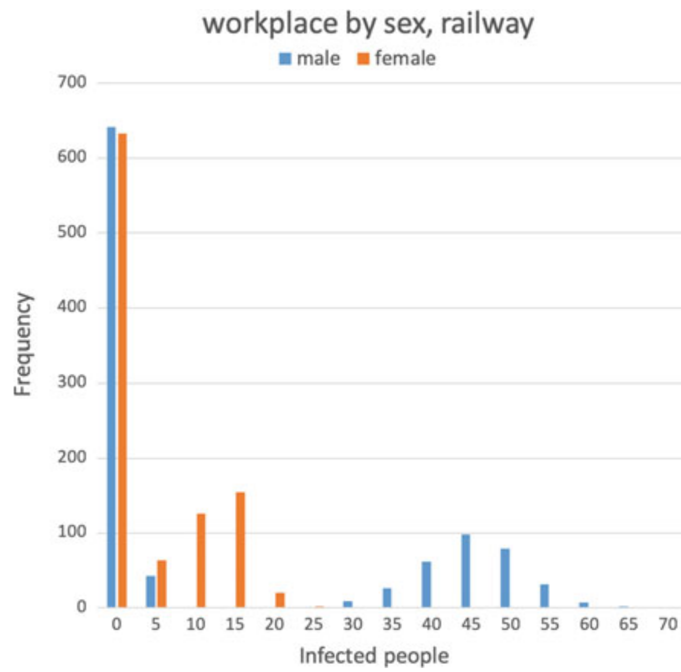

Fig. 5 The experimental result of rubella model of the workplace separated the sexes with a railway

of infection of one or more women increases to 37%, and the case where more than ten women were infected was 30%.

5.4 A Model of Vaccination to Men in Order to Prevent Infection Spread

It was estimated by the gender-specific workplace model that the low infection rate of middle-aged men as low as 80% is the cause of infection spread. Based on this, we experimented in the case of strengthening medical policy promoting vaccination for males and raising the antibody holding rate to 95%.

Figure 6 shows experimental results at the gender-specific workplace, railway use and male antibody holding rate of 95%. According to this, both males and females, the proportion of infected people who expanded to more than one person has drastically decreased to less than 15%. By combining other infection prevention measures, it is possible to control the spread of infection of rubella.

6 Discussion

From these experimental results, the rubella virus infection is not represented by a simple statistical distribution. It is considered that the infection process is a complicated system in which positive feedback works by accidentality of infection route

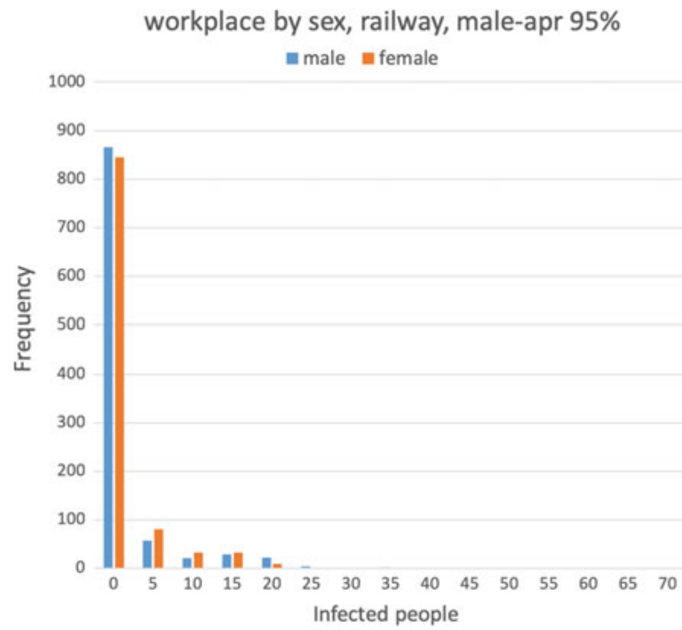

Fig. 6 The experimental result of rubella model of the workplace separated the sexes with a railway and 95% antibody holding rate

and interaction between infected people. It is also speculated that the spread of infection will start in a workplace where many men do not possess antibodies. One of the major factors of infection spread is commuters with many opportunities to come into close contact with the unspecified majority in a train. In addition, it became clear that raising the antibody holding rate of males is an important measure to prevent the spread of the whole infection.

7 Conclusion

This study proposes a simulation model of rubella. It also evaluates health policies to prevent an epidemic. As health policies, vaccination to men, avoidance of separated workplace by sexes and avoidance crowds in a train were implemented in the model. As a result of experiments, it has been found that vaccination to middle-aged men and avoidance crowds in a train are crucial factors to prevent the spread of rubella. Using a public transportation to commute, however, is inevitable in a modern society. Even if 95% of people including men and women were vaccinated, it would not prevent the epidemic completely. By combining other infection prevention measures, it is possible to control the spread of infection of rubella.

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Analysis of the Effect of Financial Regulation on Market Collapse Process in Financial Network

Takamasa Kikuchi, Masaaki Kunigami, Takashi Yamada, Hiroshi Takahashi and Takao Terano

Abstract This study focuses on the influence of the market collapse process of financial institutions under financial regulation on financial systems. For this purpose, the authors expand simulation models of systemic risks expressing financial regulation and the financing behavior of financial institutions. Using this model, scenario analysis is performed how the collapse process in the financial system changes due to the balance sheet constraint. Our numerical experiment shows that (1) as the amount of marketable assets is increased, the type of failed process with high occurrence changes, and (2) when there is a balance sheet restriction, the frequency of chain collapse is suppressed.

Keywords Agent-based simulation · Systemic risk · Financial regulations · Simulation analysis

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1 Introduction

The financial crisis triggered by the Lehman shock began an international movement to strengthen financial regulations, a movement that has gained momentum in recent years [1]. While many consider that the strengthening of regulation has improved the stability of financial institutions, others are concerned that it may also lower the liquidity of the market and reduce the incentives of financial institutions [2, 3].

Under various financial regulations, the authors analyzed the influence of the behavior of financial institutions on the financial system using an agent model [4, 5].[1] In a previous study [5], we analyzed the effect of balance sheet constraints on (1) the stability of the financial system and (2) the impact on the total sales volume of marketable assets. Our numerical experiment showed that (1) the number of failed financial institutions in the financial system could be reduced and (2) the liquidity of marketable assets could be reduced by imposing a balance sheet restriction (hereinafter BS restriction). In this research, we analyzed the simulation log as a whole from a macroscopic point of view, including the number of failed financial institutions and the total amount of marketable assets traded (hereinafter macro-level analysis).

On the other hand, in the field of simulation analysis, there is research to analyze specific logs not only from a macroscopic point of view but also from a micro viewpoint [10] (hereinafter microlevel analysis). There are also studies that analyze the intermediate level between micro and macro by classifying a simulation log [11] (hereinafter mezzo-level analysis). From the perspective of mezzo-level analysis, our research has room to pattern the classification of the propagation process of failure in financial system. Furthermore, from a microlevel viewpoint, it is possible to analyze what failure process each simulation log presents.

In this paper, we focus on the influence of the process of financial institutions' collapse under regulation of the financial systems. For this purpose, the authors expand simulation models of systemic risks expressing financial regulation and the financing behavior of financial institutions. Using this model, a scenario analysis is performed to examine how the collapse process in the financial system changes due to balance sheet constraint.

2 Model

2.1 Outline

The agents are financial institutions with balance sheets and financial indicators (e.g., a capital adequacy ratio). The market value of securities fluctuates in response to the

[1] Computational approach has been employed to analyze the dynamics of financial crisis [6–9]. The complete list is given in [4, 5].

price fluctuations of marketable assets. There are two kinds of networks: lending networks to businesses, and interbank networks for short-term investment and funding involving financial institutions. Additionally, each financial institution is directly connected to the central bank and can access central bank deposits and lending facilities. Furthermore, each financial institution engages in (a) investment behavior (increasing or decreasing securities and/or lending to business corporations on its balance sheet) and (b) financing behavior (filling any difference between balance sheet debits and credits).

The authors proposed an extended model based on the model by May and Arinaminpathy (the M-A model hereinafter) [8] to analyze aspects of bankruptcy chains through changes in the balance sheets of individual financial institutions [4, 5].

The proposed model has the following characteristics:

1. Each financial institution has a simplified balance sheet and engages in short-term lending and borrowing through the interbank network;
2. Each financial institution is permitted to observe the impact of its collapse on the capital of other financial institutions with which it has lending relationships; and
3. An institution suffers from bankruptcy when its capital is insufficient to absorb a given financial shock, a feature that is important in representing the chain of failure.

Our model also expresses the following:

1. Deterioration in the financial and credit situation of financial institutions through fluctuations in the market prices of assets held (capital adequacy ratio);
2. Increase in cash flow shortfall and liquidity risk due to the deterioration of the financing environment in the I/B market; and
3. Central bank funding to prevent bankruptcy.

Thus, our model has become an agent-based model that focuses on the endogenous mechanisms of the financial crisis (as shown in Fig. 1).[2]

2.2 Agents

In the M-A model, each financial institution

$$a_{\_i}(\mathrm{i}=1,\ldots,N),\ A=\left\{a_{\_i}|\mathrm{i}=1,\ldots,N\right\}$$

has a simplified balance sheet as follows (Table 1): Each balance sheet consists of (1) cash CA_i; (2) marketable assets $MA_i^{bookvalue}$; (3) nonmarketable assets $nonMA_i$;

[2]Note that, since we look at the impact of surplus operating behavior and price fluctuations of market assets on the financial condition and cash flow of financial institutions, we do not deal with trading networks of nonmarketable assets and trading networks between the central bank and commercial financial institutions.

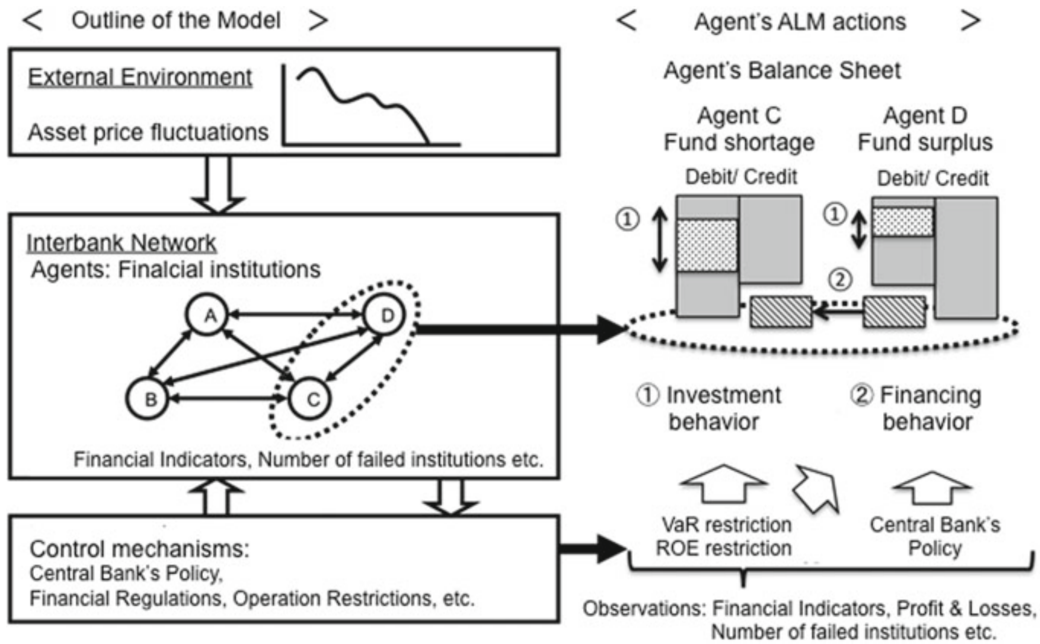

Fig. 1 Conceptual model: the model explicitly describes the asset and liability management (hereinafter ALM) actions such as investment and financing activities. Funding changes because of price fluctuations in the asset market express the impact of ALM actions on operational collapse

Table 1 Balance sheet items of commercial financial institutions

Debit	Credit
Cash *CA*	Debt *D*
Nonmarketable asset *nonMA*	Equity *E*
Marketable asset $MA^{bookvalue}$	Short-term financing *SF*
Short-term investment *SI*	

(4) debt D_i; (5) equity E_i; (6) short-term investment SI_i; and (7) short-term financing SF_i.

The financing gap and fund surplus/shortage institutions are then defined as follows:

$$Gap_i = D_i + E_i - CA_{i\_}nonMA_i - MA_i^{bookvalue}$$
$$C^{surplus} = \{a\_i | Gap_i >= 0\}$$
$$C^{shortage} = \{a\_i | Gap_i < 0\}.$$

Note that the status of each financial institution remains unchanged.

We define unrealized profit or loss (UP_i) and the capital adequacy ratio (CAR_i) in the following:

$$UP_i = MA_i^{t\,marketvalue} - MA_i^{bookvalue}$$
$$CAR_i = (E_i + UP_i)/\left(non\,MA_i + MA_i^{bookvalue}\right).$$

Furthermore, $MA_i^{t\,marketvalue} = (MA_i^{bookvalue}/P_0)*P_t$, where P_t is the market price of the marketable assets in step t.

Additionally, financial institutions face demands that they maintain a minimum capital adequacy ratio ($CAR\,demand_i$). Where institutions facing a shortage of capital have ordered that funds be supplied to institutions with a capital surplus, *CAR demand* is the lowest capital adequacy ratio surplus requested of institutions facing a capital shortage.

2.3 Network

Financial institution a_i engages in short-term investment and funding with other financial institutions

$$W_i^{Interbank} = \left\{a_{\_j} | m_{\_ij} = 1\right\}$$

and tries to eliminate the funding gap between itself and connected institutions. Then, $M = (m_{\_ij})$ is the adjacency matrix of the I/B network.

2.4 Financing Behavior

Financing of shortage institutions by surplus institutions

<u>(Step 1)</u> Cash-hungry institution agents make requests for financing from cash-wealthy institutions that lend to the interbank network and evenly split their own financing gap. The minimum order size is within a specified range.

A cash-hungry institution $a_{\_i}$ requests financing from a cash-wealthy institution $a_{\_j}\left(amount_i^j > 0\right)$

$$\text{Order}\left(\text{i, j}, amount_i^j\right).$$

Additionally, $a_{\_i}$ denotes all cash-wealthy institutions that lend to the interbank network and obey the instruction to evenly split the value of their own financing gap. Here,

$$\left(a_{\_i}, a_{\_j}\right) \in C^{surplus} \times C^{shortage}.$$

δ: minimum order size ∈ Z, $amount_i^j = \max(\mathrm{ceil}(Gap_i'/\#\,(C^{surplus} \cap W_i^{Interbank})), \delta) \in Z$.

(Step 2) a_j checks the financial condition and amount of self-funding available for a_i to perform the contract judgment.

- *Contractual conditions*:

$$CAR_i >= CAR - demand_j \text{and}$$
$$amount_i^j =< Gap_j' - \Sigma amount^{j\,other\ implemented-orders}.$$

- *Noncontractual conditions*:

Other than those above

Then, transactions to which a_j has already committed $amount^{j\,other\ implemented-orders}$.

(Step 1) This step is an alternate to Step 1. If noncontract, a_i will (1) change the order destination to another cash-wealthy institution a_k, and/or (2) reduce the order amount.

$$\mathrm{Order}\left(\mathrm{i},\ \mathrm{j},\ amount_i^j\right) \rightarrow \mathrm{Order'}\left(\mathrm{i, j},\ amount_i^k\right)$$
$$\mathrm{Order}\left(\mathrm{i},\ \mathrm{j},\ amount_i^j\right) \rightarrow \mathrm{Order'}\left(\mathrm{i, j},\ amount_i'^j\right)$$
$$\mathrm{Order}\left(\mathrm{i},\ \mathrm{j},\ amount_i^j\right) \rightarrow \mathrm{Order'}\left(\mathrm{i, k},\ amount_i'^k\right).$$

Then, $k \in C^{surplus} \cap W_i^{Interbank}$, $amount_i' = \mathrm{floor}\ (amount_i/2) >= \delta$.

(Step 2) If a_i cannot meet $Gap_i' >= 0$, the result is collapse.

Other short-term investments and funding

Assuming cross-trades (both transactions) are carried out [12], we consider the following short-term funding or investment transactions between financial institutions. A certain percentage of the balance sheet amount then becomes the upper limit.

Between cash-hungry–cash-hungry and cash-wealthy–cash-wealthy institutions:
a_i is the upper limit of l times between a_j of the same status and generates the following order:

$$\mathrm{Order}\left(\mathrm{i, j},\ amount_i^j\right) \text{ or } \mathrm{Order}\left(\mathrm{j, i},\ amount_j^i\right).$$

Between cash-wealthy–cash-hungry institutions:
a_i is the upper limit of l times between a_j of the same status and generates the following order:

$$\mathrm{Order}\left(\mathrm{i, j},\ amount_i^j\right).$$

Then,

$$amount_i = \text{ceil}\left(\left(CA_i + MA_i^{bookvalue} + nonMA_i\right) * \varepsilon\right),$$
$$l = \text{floor}\left(\left(CA_i + MA_i^{bookvalue} + nonMA_i\right) * \zeta / \, amount_i\right).$$

2.5 The Effects of Bankruptcy

Individual bankruptcy

If the capital adequacy ratio is equal to or less than the threshold value, or if the funding gap is not filled, for example, owing to a failure of cash flow, financial institution a_i will experience bankruptcy:

$$CAR_i < \alpha \text{ or } Gap_i' < 0.$$

Chain-reaction collapse

If financial institution a_i experiences bankruptcy, financial institutions a_j that are involved in short-term operations with the first financial institution are regarded as nonexposed with regard to these investments, and it is assumed that the capital cancels out:

$$E_j' = E_j - SI_j^i.$$

If the following conditions are satisfied, financial institution a_j also suffers bankruptcy, and a chain-reaction collapse occurs:

$$E_j' < 0 \text{ or } Gap_j' < 0 \text{ or } CAR_j < \alpha.$$

2.6 Evaluation

This paper considers situations with and without BS restrictions to evaluate the loads of individual financial institutions and the financial system. Specifically, the number of surviving financial institutions (number of failed financial institutions) is used as a macro indicator.

Furthermore, as a mezzo index is related to collapse process, we categorize the collapse processes that the proposed model is able to take. Here, the bankruptcy process is a series of flows in which bankruptcy of financial institutions occurs in relation to the selected institution. In this paper, we set the collapse process as the following four patterns: (1) a pattern in which the selected institution does not collapse ("Non-collapse"), (2) chain collapse that originates with another company

("Other responsibility collapse"), (3) chain collapse that originates from the selected institution ("Self-responsibility collapse"), and (4) a pattern in which the company fails alone ("Unlinked collapse").

3 Analysis of the Model Behavior

In this paper, as an additional analysis of the previous study [5], we analyze the influence of balance sheet constraint on the collapse process of financial institutions. Here, we compare two cases, one that does not limit the parameter occurrence range of marketable assets (Case 1: without a balance sheet restriction) and one with a BS restriction (Case 2: with a BS restriction) (Sect. 3.2). Then, scenario analysis is performed under the following conditions:

(a) Select a financial institution and change the balance of marketable assets owned by that financial institution;
(b) Assume a case where the price of marketable assets declines sharply (Sect. 3.1).

First, in Sect. 3.3, as in the previous study [5], we reconfirm how the number of failed financial institutions, which is an indicator of the stability of the system, varies depending on the BS restriction (Fig. 3). This is a macro-level analysis.

Next, in Sect. 3.4, we examine the occurrence frequency of the four types of collapse process defined in Sect. 2.6 changes (Table 3). This is a mezzo-level analysis. We also extract samples of the simulation log to confirm that the failing process is actually different due to the balance sheet constraint (Fig. 4 and Table 4). This is a microlevel analysis.

3.1 Price Time Series of Marketable Assets

The price of risky assets is assumed to follow in the discretized stochastic differential equation below [13]:

$$P_{t,j} = P_{t-1,j} + r_f P_{t-1,j}\Delta t + \sigma P_{t-1,j}\tilde{\varepsilon}\sqrt{\Delta t},$$

where t is the time step, j is the trail number, $P_{t,j}$ is the price of a marketable asset (j times, step t) (= 100), r_f is the risk-free rate, σ is the volatility, and $\tilde{\varepsilon} \sim N(0, 1)$. In this simulation, we set 1, step = 1 day = 1/250 year and Δt = 1/250, T = 125 (assuming 6 months is the budget-closing period for a bank account). Additionally, taking into account long-term government bond yield levels and stock markets in each country, $r_f = 2\%$ and σ = 25%. In total, 100,000 sample paths were generated, and marketable asset prices in the final step are used to adopt the lowest price time series (Fig. 2).

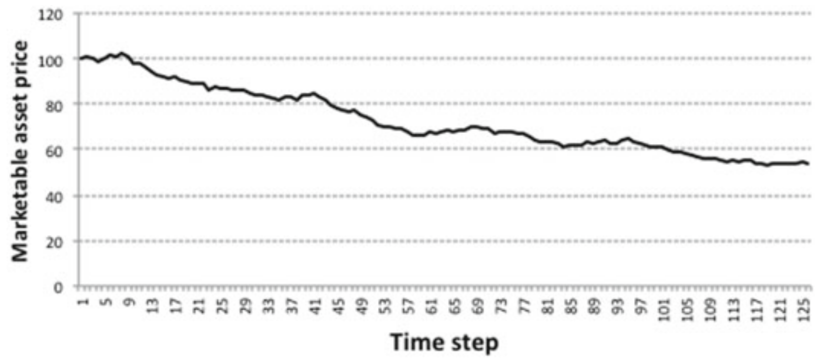

Fig. 2 Price time series of marketable assets employed in this simulation. A total of 100,000 trials and the adopted price time series became the lowest price

3.2 Common Settings

Table 2 provides the parameters used in our experiment. We prepared two patterns of parameter ranges for marketable assets, corresponding to the two cases (with or without BS constraints). In this simulation, we focus on financial institutions that constitute an important and core network in the system. Thus, we refer to the previous study [14] and set the number of financial institutions to 20 companies (#1–#20, including 10 each of surplus and shortage institutions), and the I/B network is a complete graph. Regarding the financing gap, since surplus institutions outnumber shortage institutions, surplus institutions were subjected to the following adjustment:

$$(Financing\ gap\ adjustment) = \Sigma(nonMA_i + MA_i^{book\,value}) * \iota / \# C^{surplus}.$$

Table 2 Parameter set used in this simulation

Parameters	Value
Number of institutions N	20
Interbank network $W^{Interbank}$	Complete graph
Cash CA	U(10, 25)
Nonmarketable asset $nonMA$	100
Marketable asset MA *(without BS constraints case)*	U(20, 60)
Marketable asset MA *(with BS constraints case)*	U(20, 30)
Financing gap Gap	0.05 BS amount <= Gap <= 0.10 BS amount
Capital adequacy ratio CAR	U(0.12, 0.22)
CAR demand	U(0, 0.03)

Additionally, for balance sheet items outside the table, we set the capital based on a given capital adequacy ratio. Liabilities taking into account the financing gap were determined by back calculation such that credit and debit match. We then set short-term investment and funding in the following: α: 0%; δ: 1; ε: 5%; ζ: 50%.

As mentioned at the beginning of Chap. 3, when scenario analysis is carried out, one company out of 20 companies is selected (hereinafter selected institution). Then, we change the balance of marketable assets held by the selected institution, $MA =$ 0, 20, 50, 90 (we simulate 100 patterns, respectively).

3.3 Stability of Financial System

The numerical experiments were pursued 400 times for each of the two cases (with and without BS restrictions) based on the parameters shown in Table 2. Figure 3 shows a box-and-whisker plot for every five steps for the number of remaining financial institutions, representing the stability of the system (top panel: Case 1, bottom panel: Case 2). The case without a BS restriction shows that the variation of the remaining number of institutions is large and that there is a greater distribution in the range where the remaining number is small. The average number of remaining institutions at the final step for Case 1 is 10.2 while it is 19.7 for Case 2. The case with BS restriction has fewer failed financial institutions. Thus, it can be said that the stability of the financial system can be improved by imposing a BS restriction.

3.4 Changes in Collapse Process

In this section, we confirm how the frequency of occurrence of the four types of collapse processes changes for each case (with/without BS restrictions). As in the previous section, we used the same initial parameter set (Table 2), and we changed the balance of marketable assets owned by the selected institution.

Table 3 shows the occurrence frequency of each type of collapse process for each marketable asset held by the selected institution. If there is a balance sheet constraint, the failure process is only non-collapse ($MA = 0, 20, 50$) or only unlinked collapse ($MA = 90$). Compared with the case without the balance sheet constraint, in the case of $MA = 50, 90$, it is understood that the occurrence frequency of the chain collapse is suppressed. In this way, by focusing on the propagation process of failures, by analyzing the occurrence frequency, it is possible to identify the factor that caused the instability of the system.

Furthermore, in Table 3, additional analysis can be conducted for cases where the failure process with the peak occurrence frequency is different ($MA = 50$, Case 1: peak of other responsibility failures, Case 2: non-collapse). Figure 4 shows the transition of the average capital ratio in the simulation log extracted as a sample (Trial #31). In Case 1, the level of marketable assets held is high. It can be seen that the fall

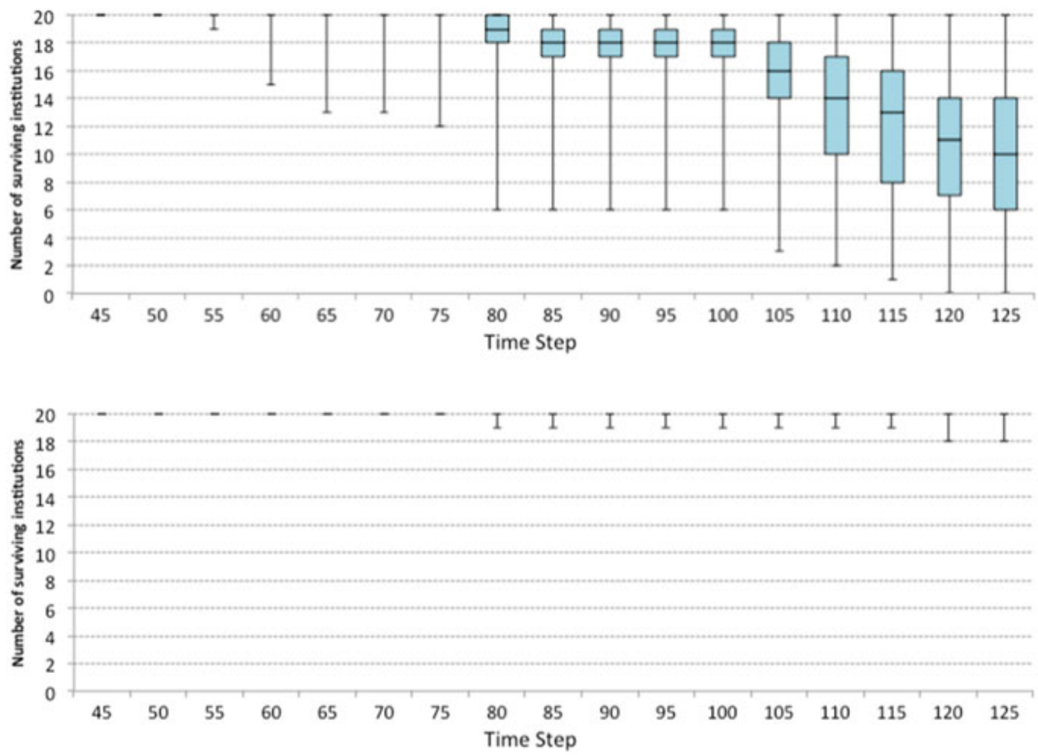

Fig. 3 Box-and-whisker plot of the number of financial institutions surviving at each five-step interval (top panel: Case 1 without a BS restriction; bottom panel: Case 2 with a BS restriction). This is a macro-level analysis. It can be seen in the case without a BS restriction that there is a greater variation in the residual number and a greater distribution throughout the range where the number of residuals is small. This is the same result as the previous study [5]. Note that time steps below 45 are omitted because no bankruptcies occur at this stage

in the average capital adequacy ratio increases due to the decline in marketable asset prices. It means that the soundness of the financial system has been compromised and there are many financial institutions concerned about collapse. As a result, without the BS restriction, there is a chain-like collapse of other responsibilities as shown in Table 4. In this way, a drilled down approach to each simulation log is possible.

4 Concluding Remarks

In this paper, we expanded a simulation model of systemic risk that expresses the financial regulation and financing behavior of financial institutions proposed by the authors in previous papers [4, 5].

In addition, under various management constraints and market trends, we conducted a scenario analysis for two cases where a BS restriction is not assumed (Case 1: without a BS restriction) and then assumed (Case 2: with a BS restriction), depending on the parameter occurrence range of the marketable assets.

Table 3 The occurrence frequency of each type of collapse process for each marketable asset held by the selected institution (top panel: Case 1 without a BS restriction; bottom panel: Case 2 with a BS restriction). This is a mezzo-level analysis that is classified by the four collapse patterns (Sect. 2.6). When there is a balance sheet constraint, the occurrence frequency of chain collapse is suppressed. By analyzing the occurrence frequency, it is possible to identify the factor that caused the instability of the system

Patterns	*MA* of the selected institution			
	0 (%)	20 (%)	50 (%)	90 (%)
1. Non-collapse	**88.0**	**72.0**	15.0	0.0
2. Other responsibility collapse	12.0	28.0	**77.0**	26.0
3. Self-responsibility collapse	0.0	0.0	0.0	24.0
4. Unlinked collapse	0.0	0.0	8.0	**50.0**
Patterns	*MA* of the selected institution			
	0 (%)	20 (%)	50 (%)	90 (%)
1. Non-collapse	**100.0**	**100.0**	**100.0**	0.0
2. Other responsibility collapse	0.0	0.0	0.0	0.0
3. Self-responsibility collapse	0.0	0.0	0.0	0.0
4. Unlinked collapse	0.0	0.0	0.0	**100.0**

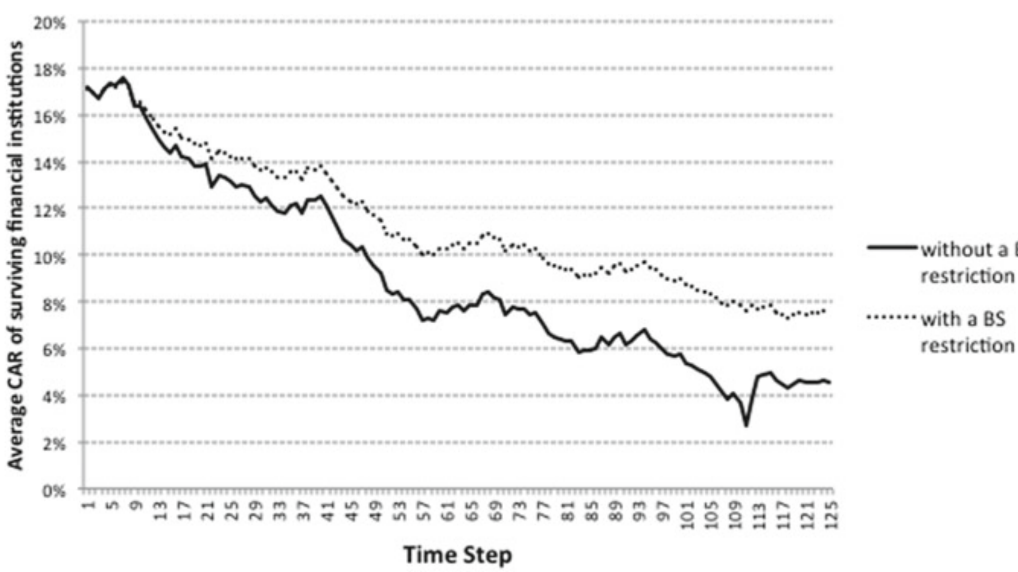

Fig. 4 Average capital adequacy ratio of surviving financial institutions at each step (solid line: Case 1 without a BS restriction; broken line: Case 2 with a BS restriction). This is a microlevel analysis of trial #31 in $MA = 50$ cases. In a case without a BS restriction, it can be seen that the decline in the average capital adequacy ratio is increasing

Table 4 Collapse financial institution and collapse time step (left panel: Case 1 without a BS restriction; right panel: Case 2 with a BS restriction). This is a microlevel analysis of trial #31 in $MA = 50$ cases. In Case 1, a chain collapse of other responsibility has occurred from step 110 to step 113. A drilled down approach to each simulation log is possible. Note that agent #1 is the selected institution this time

Time step	Without a BS restriction	With a BS restriction
106	#9	–
108	#19	–
110	#17	–
111	#1, #5, #13, #18	–
112	#4, #15, #16	–
113	#6, #7	–

The overall trend regarding the stability of the financial system shows that there were fewer failed financial institutions under situations where BS restrictions are imposed (Fig. 3), and that the stability of the financial system can be enhanced under such restrictions. This is the same result as the previous study [5].

On the other hand, from the scenario analysis, it is found that (1) the collapse process with a high occurrence frequency changes as the balance of marketable assets is increased; (2) the BS restriction suppresses the occurrence frequency of the chain failure. For the simulation log, not only the macro-index (Fig. 3), but also the mezzo-level analysis (Table 3) and microlevel analysis (Fig. 4 and Table 4) were carried out. By doing so, it became possible to approach the factors causing system instability.

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Causal Analysis of the Effect on Performance of Start-Ups from External Supporting Activities

Hirotaka Yanada and Setsuya Kurahashi

Abstract The purpose of this study is to investigate the relationships between the performance of start-ups and external support to them. We analyzed the questionnaire research on the basis of the answers which were obtained from 2,897 (1st research) people of start-ups. As a research method, we used two methods using a propensity score. This point is one of the novelties of this research. First, we tried a matching method, and we found that most external support alone did not have the causal effect of improving performance, but the other significant causal effects were found in part. Subsequently, we confirmed the effects again using a weighting method.

Keywords Start-up company · Propensity score matching · External support

1 Introduction

In the context of rapid advancement of information technology, including so-called "fintech" where finance and IT are integrated, start-up companies have recently gained momentum. Japan has seen various movements to support the growth of emerging *companies* with innovative technology and creativity as the innovation leader. A wide variety of external support activities for start-up companies have also attracted much attention. There exist numerous factors that are related to corporate performance enhancement. External support should be an extremely important factor not only for general enterprises with great performance but also for start-up companies. Researchers have reported a lot about start-up companies, studying the relevance between their characteristics and business performance. To the best of our knowledge, however, little attention has been given to the relevance between external support received by such start-up companies and their business performance as a performance enhancement factor. Recently in Japan, venture capital (VC) firms have provided start-up companies with generous support other than financial support. Such

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efforts aim, for example, to offer a good business environment for start-up companies assisting them in recruiting and providing them with offices so that start-up companies can concentrate on their business cultivation. There have been reported many attempts to support the growth of start-up companies (hereinafter, "start-ups") and small companies in order to increase their corporate value by putting their business on track.

2 Purpose of This Study

In this research, we analyze the relevance between external support and corporate performance using individual data collected by a panel survey. Taking advantage of the benefit in covariate (cofounder) adjustments using propensity scores developed by Rosenbaum [1], a total of nine indexes based on four categories are set as treatment variables for external support, and a total of four indexes are set as observational variables for performance. A propensity score is defined as a predictive probability for treatment variables where an observed covariate is conditioned. This approach adjusts cofounders by integrating several covariates into one variable. Many researchers agree that this approach is currently the most effective method in the field of observational study for approximating the observational study findings to the findings of the study based on random assignment experiments (Guo [2]; Hoshino et al. [3]).

Figure 1 shows the theoretical model based on these conditions mentioned above. The purpose of this research is to estimate the causal effects (a total of $36 = 4 * 9$) of external support based on nine indexes on performance enhancement in each of the four indexes using the abovementioned data collected from start-up owners through a panel survey. In order to confirm the robustness of the estimated causal effects, we attempted to apply several analysis methods using propensity scores.

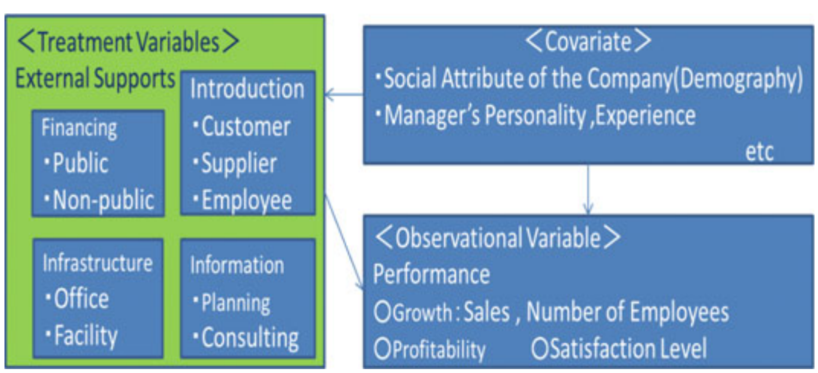

Fig. 1 A theoretical model of performance improvement of start-ups. This figure shows the theoretical model based on these conditions. Three factors including treatment variables (external supports), covariate (demography, personality, experience), and performance (observational variables) are related to performance improvement of start-ups

3 Related Work

Growth is one of the representative indicators that symbolize start-up's performance. Regarding growth factors of companies, there is accumulation of research in the field of industrial organization theory and entrepreneurial research. Based on a survey of enormous previous research, Storey [4] presented three frameworks "management resources," "company characteristics," and "management strategy" as growth factors for small and medium enterprises. Among "management strategy" in particular, he focused on the four functions "management training," "introduction of external shareholders," "planning," and "management staff procurement."

Also, in the empirical research on the growth factors of enterprises, there is one that deals with the effect of the support policy. Lerner [5] who analyzed the effect of US small business support policy "SBIR program" revealed that companies receiving government subsidies grew faster than other companies. However, this research is targeted not only to start-ups but also to SMEs as a whole.

In the research targeting Japan, Ms. Kutsuna [6] who conducted a questionnaire survey targeting founded enterprises in Osaka City showed almost the same analysis result as Storey [4] mentioned above. In addition, Ejima [7], along with Key et al. [8] and Madsen [9], highly appreciates the contribution of so-called entrepreneurial orientation (EO) to the growth (employment and sales). On the other hand, he noted that the policy support from the government and universities does not necessarily have the same effect depending on the specific policy measures and conditions but only points out the possibility of mutual complementary relationship with the company's strategic attitude and organizational management factors. Furthermore, Okamuro et al. [10] revealed that there is a high possibility that companies that intend to expand the scale of business or companies that gained public subsidies at the start of business will expand employment after that.

In Japan, the basic law on small and medium-sized enterprises was revised substantially (1999.12.3 promulgated and enforced), and the basic idea shifted from the conventional relief type to the self-support type. In this paper, using the data of the 2000s after the enforcement of this law and integrating the start-up's business characteristics and managerial qualities, we analyzed a causal relationship between the actual situation of performance such as growth and external support. Therefore, our study has novelty not seen in previous research.

4 The Panel Survey on Business Start-Ups

As for the analysis that we conducted in our research, the Panel Data Research Center at Keio University provided us with the individual data of the Panel Survey on Business Start-ups entrusted by the Japan Finance Corporation Research Institute [11]. As for the continuous survey subjects, this survey targets 2,897 client companies of the Japan Finance Corporation Research Institute that started operation in 2006 (except for real estate firms). After 2006, setting December as the survey starting month, a total of five surveys were conducted ending in 2010. These were questionnaire surveys sent out by mail.

The number of valid respondents steadily decreased from 2,897 companies during the first survey and finally to 1,359 companies with the fifth and final survey. About two-thirds of the organizational structures at the time of their founding were unincorporated enterprises. As for the gender of entrepreneurs, 83.8% were men with an average age of 41.9. The top 38.0% were in their 30s. By industry, 15.2% were in the restaurant and lodging industry, followed by 14.5% in the service industries directed at individual consumers, 14.5% in the retail business, and 12.8% in the medical and welfare sector.

In addition to companies saying that they were not currently in business, this survey considered those companies with which the branches of TEIKOKU DATABANK, commissioned to collect the questionnaire sheets, and the Japan Finance Corporation Research Institute confirmed that they were not in business and to be closed. Judging from this, the ratio of companies closed by 2010 reached 15.2%, whereas those companies that continued their business until the end of 2010 reached 83.3%. By the close of the business year, 28.4% of the companies closed in 2008 (following the second or third year when their business started). The restaurant and lodging industry had the highest percentage, 23.2%.

5 The Method for Analyzing the Panel Data

This chapter refers to how various variables were structured from the initial data and then explains the method for analyzing the relevance between external support and corporate performance. For the analysis, we narrowed down the samples into those (N = 1053) who responded to the survey in the final year and who seemed to be continuing their business at the end of that same year. Table 1 shows the summary table of received time of nine support types in the survey data.

5.1 Variable Structuring

The following four indexes described below are used for dependent variables as performance parameters. The first index is the growth index. This index is a continuous variable in units of 10 thousand yen and indicates the monthly sales in the final business year. The second index is the same growth index that indicates the number of employees in the final business year, in units of the number of employees.

The third index indicates the profitability in the final business year. This index is a binary variable, expressing "1 = black" or "0 = red." The fourth index indicates the overall satisfaction in the final business year. Specifically, this index is a five-point variable, expressing each point from "0 = Totally dissatisfied" through "4 = Totally satisfied."

Table 1 Distribution of received times for each type of support (treatment) (%)

	0times	once	twice	3times	4times	5times	N
Public financial	57.9	20.3	10.8	6.3	3.6	1.1	1053
Nonpublic financial	43.8	39.5	11.6	4.0	0.9	0.2	1053
Offices infrastructure	80.1	16.8	2.7	0.4	0.0	0.0	1053
Facilities infrastructure	81.4	14.3	3.0	1.0	0.2	0.1	1053
Customer introduction	39.5	25.8	15.9	10.5	6.4	1.9	1053
Supplier introduction	53.7	26.7	11.9	5.0	1.8	0.9	1053
Employee introduction	75.1	17.2	5.2	1.6	0.8	0.1	1053
Planning information	47.2	34.1	11.0	5.7	1.5	0.5	1053
Consulting information	56.7	28.8	9.1	3.8	1.4	0.2	1053

Note Distribution in sample used for later analysis

As already mentioned, treatment variables express whether there is external support, and these variables are divided into a total of nine indexes from four different categories. In detail, the first category is funding which is categorized into the following two indexes based on the support source: public funding provided by a public institute and private funding provided by private banks. The next category is the infrastructure support which is categorized into the following two indexes based on support targets: office and facilities. The next category is the referral support categorized into the following three indexes: sale destination, the supplier, and the employee. The last category is the information support setting with a total of nine treatment variables, including planning support to provide instructions and advice for business planning, and consultation support to offer consultation services related to starting business and business management. As for these categories, the survey asked about the use of these kinds of support on a single-year basis in every survey throughout all 5-survey years. Where the buildup approach is used based on the number of uses of these supports, these treatment variables can be expressed using a six-point scale with 0 through 5 times. However, we need to binarize treatment variables in order to simply estimate propensity scores using the binary logit model. Table 1 shows that the variable distribution of the number of uses of each support varies, but the majority is biased toward zero times. Therefore, use of binary variables, where treatment variables with zero times are set to 0 (control group) and the other variables are set to 1 (treatment group), achieves a properly balanced distribution for the control group and the treatment group.

The following covariates are incorporated to estimate propensity scores: various business dummies (construction, manufacturing, information communications, transportation, wholesale, retailing, restaurant and lodging, medical and welfare, educational and learning services, services for individual consumers, enterprise services, and real estate), corporation dummies, venture dummies, FC dummies, the manager's gender, the manager's academic credentials, the manager's years of business experience, the manager's experience, the manager's marital status, the manager's children, the manager's motivation toward business expansion, the degree of confidence in knowledge at the initial survey year (throughout all the following degrees, the number of checks at the initial survey year is indexed), the degree of confidence in marketing, the degree of confidence in technology, the degree of confidence in management, the degree of confidence in networking, the degree of difficulty in marketing, the degree of difficulty in management, the degree of difficulty in finance, the degree of difficulty in managing employees, the degree of difficulty in funding, the monthly sales in the initial survey year (all the following items are about the initial survey year), the number of employees, profitability, and the number of employees.

5.2 Causal Relationship Between External Support and Performance: Propensity Score Matching

Based on the above-described framework, propensity scores are estimated using logistic regression analysis based on the abovementioned nine external support categories as dependent variables. As for score estimation, we use the stepwise (forward selection) method to select appropriate methods based on the AIC.

Propensity score matching is widely used in the field of observational study as a method for decreasing biases caused by observed covariates between the treatment group and the control group (Stuart [12]). The purpose of using this method is to estimate propensity scores from observed covariates and to create a matching sample with unbiased covariates between the groups using the estimated propensity scores. This pair-matching-based method selects and matches two samples with values in proximity to propensity scores in the treatment group and the control group and compares matched samples between both groups. There exist some methods for matching two samples from two groups. In this paper, we use the nearest neighbor matching using caliper 0.25 (1:1) based on statistical software, R, in order to estimate the average treatment effect for treated (ATT) of the treatment group. The result with a significant difference (under 5%) suggests the existence of the performance enhancement effect due to the relevant external support.

Table 2 shows the C statistic which is the fit index for the logistic regression model when propensity scores are calculated by an external support category. This index is a numerical value that indicates the degree where the condition "Strongly Ignorable Treatment Assignment" is satisfied. This value ranges from the minimum, 0.632, to the maximum, 0.756, which was confirmed to be of a decent level.

Table 2 C statistic when calculating propensity score per external support (AUC)

	Public financial	Nonpublic financial	Offices infla	facilities infla	Customer intro	Supplier intro	Employee intro	Planning inform	Consulting inform
c statistic	0.7545	0.6650	0.6539	0.7163	0.7203	0.7266	0.7561	0.6581	0.6320

Note The c statistic is the fit index for the logistic regression model of propensity scores

5.3 Confirmation of Estimated Causal Effect: IPW (Inverse Probability Weighting) Estimated Quantity

The previous section brought out that the causal relationship between external support and performance enhancement would be confirmed by means of propensity score matching. Rosenbaum and Rubin proposed three methods, matching, stratified analysis, and covariance analysis, for specific adjustment based on the estimated propensity scores. However, researchers have indicated various flaws in each of these methods. As for matching, as an example, the following major flaws have been indicated: (1) Causal effect estimates can be calculated, whereas accurate standard errors and marginal expectations for dependent variables cannot be calculated, (2) an underspecified matching method produces arbitrariness, and (3) 1 to 1 (1:1) matching could waste much data in a group having many subjects (Hoshino [13]). In order to validate the robustness of the causal relationship confirmed in the previous section, using the IPW estimation method which complements the abovementioned flaws, we attempted to investigate the causal effect in combinations of the same external support and performance category. An IPW estimator indicates an estimated amount using weighting based on the reciprocal of the propensity score (Austin [14]). In specific, companies receiving external support are weighted with the reciprocal of the propensity score and those receiving no external support are weighted with the reciprocal of 1—propensity score. With that, the average corporate performance values are compared between companies that received external support and those that received no external support. If the calculated propensity scores are highly accurate, we can consider the difference in these average values to be the effect of the relevant external support. This is also referred to as propensity score weighting, thus the concept for propensity score matching. This can solve matching flaws and can calculate the standard errors for causal effects that have been indicated and the marginal estimators for dependent variables.

6 Analysis Results of the Causal Effects Using Propensity Score Matching

This section validates the treatment effects of each external support category. As already mentioned, we used nine treatment variables (external support) and four dependent variables as performance indexes. Therefore, we conducted a total of 36 (=9 * 4) propensity score matching sessions. Table 3 shows the results of analyzing these treatment effects. In each external support category, the average performance values were compared between the group with companies that received support (treatment group) and the group that received no support (control group). A statistically significant difference produced between both groups (ATT: Average treatment effect) suggests that the relevant external support should be effective in enhancing the targeted performance.

Table 3 Verification of the effect of external support after propensity score matching

Intergroup differences (ATT) and standard errors, and their statistical testing results

N = 1,053	Public finance (443)		Jon-public finance(592)		Offices infla(209)		Facilities infla(196)	
	Difference	SE	Difference	SE	Difference	SE	Difference	SE
Sales	56.574	88.679	56.065	77.555	−9.675	65.871	19.927	82.601
Profitability	−0.039	0.049	−0.093**	0.042	−0.067*	0.040	0.027	0.050
Satisfaction	−0.081	0.092	−0.166**	0.084	−0.010	0.084	0.100	0.100
N of employee	1.153	0.991	0.583	0.777	−0.757	0.711	1.000	0.807

	Customer intro(637)		Supplier intro(488)		Employee infla(262)		Planning Inform(556)		Consulting inform(456)	
	Difference	SE	Difference	SE	Difference	SE	Difference	SE	Difference	SE
Sales	111.520	79.222	14.985	63.445	10.500	94.154	−86.337	58.474	11.483	72.150
Profitability	0.015	0.048	−0.059	0.042	−0.045	0.048	0.047	0.040	0.128***	0.039
Satisfaction	−0.066	0.096	−0.115	0.088	−0.189*	0.098	−0.021	0.083	0.055	0.080
N of employee	1.206	0.825	−0.404	0.769	1.224	1.097	−1.46*	0.870	0.620	0.759

Note 1 * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$
Note 2 Numbers in parentheses on the right side of the support name indicate the number of the treated
This table provides intergroup differences (ATT; caliper = 0.25) and standard errors, and their statistical testing results

Table 3 shows intergroup differences (ATT) and standard errors, and their statistical testing results. The majority of support categories did not confirm any statistically significant difference between the treatment group and the control group, whereas some interesting results were observed.

The ATT for the profit and loss (profitability) status by information support including consultation was 0.128 ($p < 0.01$). This indicates that the group of companies receiving information support including consultation increased the proportion of profit-earning companies approximately by 13%. This result confirmed the causal relationship that information support including consultation has effects on the profit and loss (profitability) information.

In addition, at the level under a significant level of 5% ($p < 0.05$), the analysis confirmed that private funding support had negative effects in the profit and loss (profitability) status and the satisfaction level. Specifically, the group of companies that received private funding support decreased the proportion of profit earning approximately by 9% through receiving this support. The satisfaction level was also reduced approximately by 0.2 points (six-point scale). Our research is inadequate to clearly identify what actually caused these results. The causes could include, as for profit and loss, downward pressure on profits due to interest burden, and failures in facility investment attempted based on financing arrangements. As for the satisfaction level, the repayment of debts into the future might serve as psychological pressure more than a feeling of satisfaction through fundraising.

The purpose of propensity score matching is to enhance the comparability between the treatment group and the control group. Confirming whether this purpose has been achieved or not requires checking the balance to see how much the covariate difference in each of both groups shrank before and after matching. Here, we checked information support including consultation where significant causal effects were confirmed, private funding support, and three combinations where causal effects were confirmed.

Table 4 shows the results of comparison of covariate changes using a small p-value before and after propensity score matching. Strictly speaking, this comparison was to confirm whether the standardization difference became smaller in each individual covariate and whether the variance ratio approximated to 1. Through the differential in a small p-value, our comparison overall confirmed that covariates were appropriately adjusted.

To complement some flaws that were indicated for propensity score matching estimation, using another method, we attempted to verify the causal effects that were confirmed in the previous section. The following section describes the reconfirmation of the causal effects using an IPW estimator. In the IPW estimator, weighting with the propensity score reciprocal serves to correct the bias in the headcount proportion affected by covariates. Therefore, the use of the IPW estimator surely means a treatment with random allocation. We also calculated accurate standard errors and the marginal expectations for dependent variables, which have been indicated as flaws in matching.

Table 5 shows the results of our calculation. This table confirmed the significant effects of both positive and negative that are similar to those described in the previ-

Table 4 Minimum p-value of covariate before and after propensity score matching

Causality	Consulting inform ⇒ Profitability		Nonpublic finance ⇒ Profitability		Nonpublic finance ⇒ Satisfaction	
	Covariate	Minimum p	Covariate	Minimum p	Covariate	Minimum p
Before	Will to expand	2.22E–16	Years of experience	2.22E–16	Years of experience	2.22E–16
After	Age	0.001	Venture	0.023417	Venture	0.023417

Note The results of comparison of covariate changes using a small p-value before and afterpropensity score matching

Table 5 Relationship between external support and performance by IPW estimator

Causality	Consulting inform ⇒ Profitability			Nonpublic finance ⇒ Profitability			Nonpublic finance ⇒ Satisfaction		
	Average	Effect	SD	Average	Effect	SD	Average	Effect	SD
With support	0.693	0.080	0.0207	0.626	▲ 0.057	0.0207	2.889	▲ 0.091	0.042
Without support	0.613		0.0207	0.683		0.0207	2.980		0.042

Note 1 All figures: $^{***}p < 0.01$
Note 2 The significant effects of positive and negative in information support including consultation and private funding support

ous section in both of information support including consultation and private funding support. In other words, this result indicates that the group of companies receiving information support including consultation increased the proportion of profit-earning companies approximately by 8%. This value was actually smaller than the matching method result, 13%. The result of receiving private funding support decreased the profit-earning proportion approximately by 6%, and the satisfaction level was decreased approximately by 0.1 points. The diminution was smaller than that of the matching method, whereas the negative effect as the conclusion remained the same.

These results confirmed the same results in three combinations from external support where the causal effects were observed on performance changes using both methods, the matching method and the representative weighting method, based on the IPW estimator.

7 Conclusion

External support activities for start-ups have been an important factor that enhances their business performance. Through this research targeting start-ups that received financing support from the Japan Finance Corporation Research Institute, we analyzed the causal effects between external support details and performance enhancement using portions of panel data.

Although no significant effects were observed a basis of a single external support category, our analysis confirmed the positive effect of information support including consultation on profitability, and the negative effect of private funding support on profitability and the satisfaction level. One of the novelties found in this research is analyzing causal effects on start-up support using multiple methods based on propensity scores. External support for start-ups has attracted increasing attention not only for the related parties but also in the economy as well as society.

This paper demonstrated analysis results obtained based on the existing individual data which was collected from start-up owners, and propensity scores as one of the causal effect analysis methods which have recently developed. This research assumes that each external support, which was set for this research, was implemented independently. We have high expectations that more meaningful studies will be made in the future using various novel or unique methods, for example, by combining multiple external support categories more effectively in order to discover another causal effect that brings about enhancement for business performance.

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Analysis of Workstyle and Self-learning to Raise Human Capital

Ryuichi Okumura and Hiroshi Deguchi

Abstract The purpose of this study is to clarify how workstyle and self-learning affect human capital. Considering that both the economic value and the spiritual value of human capital have been evaluated, we attempted to analyze this two-sidedness of human capital in this study. It became clear that when young workers do work that can improve their own abilities, they raise spiritual human capital but lower economic one. We conclude that companies need to develop workstyle that can enhance the economic human capital by improving their skills.

Keywords Human capital · Indexing · Self-learning · Workstyle

1 Introduction

1.1 Scope and Purpose of This Study

The research object of this study is the human capital of Japanese workers. We focused on workstyle and self-learning as factors of increasing human capital. In general, school education is regarded as an important element to promote the increase in human capital. Knowledge, skills, and abilities acquired by school education certainly have positive effects on the students' future working. However, under special employment system in Japan called "the membership-based model" and under unique recruitment process in Japan where employers hire all new graduates at once, human capital accumulated through working is more important than that accumulated through school education. Japanese companies tend to decide whether to employ a person by judging the person's potential rather than abilities.

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In addition, Japanese students tend to choose more stable and better-known companies in which they can earn a bigger salary. They do not choose unattractive companies in terms of salary, even if they can make use of their own skills and abilities. Generally, Japanese workers acquire skills unique to each company through working, so it is difficult for them to make a career change.

Since Japanese workers obtain human capital mainly in companies, rather than in schools, the turnover rate of Japanese workers is lower than that of workers in foreign counties. Therefore, in this study, we focused on workstyle as a matter related to elements that enhance human capital. It is noted that we removed OJT (On-the-Job Training) from the analysis in this study.

Japanese workers tend to raise human capital through working, and thus excluding OJT as an element related to human capital may seem unnatural. Certainly, in the time period from the end of World War II to the end of the 1980s, Japanese companies expanded and continued to grow by passing knowledge, skills, and know-how of workers down to their subordinates. Today, however, OJT has become less effective than it used to be as a way to raise human capital, because in recent years, the economic environment has been changing drastically and the previous business models have been becoming obsolete at an accelerated pace.

As a result, skills and know-how gained by senior workers of a company and accumulated there become obsolete quickly, and subordinates now need to keep acquiring new skills and new know-how by themselves or from the outside. Okuyama [9] states that how to design the evolution of human capital greatly affects the success or failure of corporate management [10]. However, the environment changes so quickly, so it is difficult for even management leaders to confidently answer what skills they should acquire in the future. Rather, it is now important that each worker himself or herself finds or develops his or her own ability, skills, and know-how to help his or her company growth. We think that they can create company organizations that can respond quickly to the changes in the environment by learning things and developing their abilities. Therefore, in this study, we picked up the self-learning as the second factor that can raise human capital.

If we clarify what kind of workstyle and self-learning contributes to the enhancement of human capital, we can obtain useful hints for both company growth and worker's own growth. But the human capital we target in this study is different from that in the human capital theory. Adam Smith pointed out as follows. "A man educated at the expense of much labour and time to any of those employments which require extraordinary dexterity and skill, may be compared to one of those expensive machines" [2].

In modern times, human capital has become diversified to the extent that it cannot be expressed by the analogy of physical capital. Today, intellectual workers have become centered in industrial development. In the past era of the industrial revolution, factory workers supported industrial development. They are required to perform predetermined work at a fixed time and do not need to create new work or devise ways to make better outcomes. On the other hand, productivity of intellectual workers nowadays depends greatly on their motivation. So it has become a matter of concern for company management to increase workers' satisfaction and to create the environment where they can demonstrate their full potential. Therefore, in this study, we do not only consider economic meaning but also a spiritual one regarding human capital. We think that it is useful for companies to clarify what sort of workstyle and self-learning can enhance the human capital, because the only way to maintain the nation's whole production scale seems to raise the human capital of each worker, especially under economic situations of countries like Japan where the total number of workers is decreasing. In Japan, the number of working women is increasing and that of people who get reemployed after retirement is also increasing. For many citizens, occupational life is becoming a major weight of their whole life.

We believe that increasing the level of satisfaction in occupational life is becoming more and more important in terms of welfare. Measuring human capital from two perspectives, i.e., economic and spiritual aspects enables us to focus on both individual happiness and economic development.

1.2 The Structure of This Study

The structure of this study is as follows. First, we illustrate that human capital had been studied mainly as an economic concept and the idea of including the spiritual meaning in human capital has appeared. Then, we attempt to index new human capital concept that combines economic and spiritual aspects by using the individual questionnaire data from a survey targeting Japanese workers. It is difficult to measure the size of human capital itself. Therefore, we set proxy indices strongly related to human capital.

In this study, we use the outcomes of the human capital increase, for example, the annual income amount as its surrogate index. In indexing human capital, we must think about the time lag of the human capital increase. It takes time to accumulate human capital by working and self-learning. But, since the data we are using this time are not panel data, we cannot know exactly what types of workstyle and self-learning increase human capital. Therefore, it is assumed that the workstyle of employed workers and the situation of self-learning do not change easily, and that they keep the same workstyle and self-learning situation for such a long period. Furthermore, we also have a problem that we do not know the amount of change in human capital a worker has accumulated or lost during the period from the start of working for a company to the time of investigation. In addition, we cannot measure the size of the past human capital of workers. Therefore, we assume that all employed workers had approximately the same amount of human capital at the time of joining a company and have increased it by working for the company. Subsequently, we analyze the relationship between the size of the surrogate index of human capital and the workstyle and self-learning situations. In other words, we analyze what kinds of workstyle are adopted by workers with large human capital, and what kinds of self-learning they are doing. Finally, we consider matters to be done by companies and nations in order to raise the human capital of workers.

2 Theory

2.1 Human Capital Theory

The study on human capital is generally called human capital theory. Economists such as Mincer, Schulz, and Becker conducted researches in the period from the late 1950s to around 1970 and built theories. Studies on human capital have been conducted for more than half a century, but today the importance of investment in human capital is increasing more and more with the advancement of globalization [5].

According to OECD (1999), the following three methods are generally cited as those for measuring human capital. First, there is a way to examine the acquisition cost of certified knowledge, that is, the cost of school education and training that is admitted publicly. The second method is to actually test human ability. The third one is to estimate productivity based on the achievement level that individuals have acquired through efforts, such as income level, employment guarantee, occupational status, and identity guarantee [8].

As mentioned at the beginning of this article, since Japanese companies place emphasis on OJT within each company, the investment amount of education at schools is not enough to measure human capital. Although the method of actually testing human ability is the most direct and appropriate, the required contents of human capital change depending on jobs, industries, and positions, so uniform evaluation is difficult. Therefore, the third method, that is, the method of estimating productivity based on the achievement level acquired by individuals through efforts, the annual income, and the position is a practical measurement method.

Becker, a leading American economist who leads human capital theory representing the Chicago school, stated in his book "Human Capital" as follows:

> Virtually all the implications of the theory of investment in human capital developed in Part One depend directly or indirectly on the effect of human capital on the earnings and productivity of persons and firms. Consequently most of my empirical work has been concentrated on measuring and assessing these effects [3].
>
> Although a full analysis would also hold discrimination, nepotism, luck, and several other factors constant, a reasonable first approximation would say that if two people have the same investment in human capital, the one who earns more is demonstrating greater economic talent [3].

Human capital in the human capital theory has been positioned mainly as a concept related to economic value. "Productivity increase model" constructed by Becker (1964) and Mincer (Mincer 1962, 1974) relies on human capital theory, and they believe that productivity is obtained by participation in OJT training and workshops and consequently workers' wages rise [9].

As long as they work, workers gain proficiency in their jobs through participation in various training and training courses, and become able to earn more wages. Therefore, it is possible to position the height of wages as a representative index indirectly representing the size of human capital.

2.2 Human Capital Including Spiritual Value

Over the past half century, as globalization has advanced and consumer needs have changed, the main Japanese industries have changed from those with high reliance on capital equipment such as factory production to those with a high proportion by intellectual production. As a result, the value created by the human brain has become more important than the value created by physical capital equipment, and the meaning of human capital is also changing. This is why it is inevitable for corporate managers to consider efforts to raise worker motivation and job satisfaction when considering improving organizational productivity. In response to this, it is becoming more important that human capital does not only create economic value but also increases spiritual value. However, in the existing human capital theory, we have mainly defined human capital with economic indices such as annual income and productivity. We have not regarded human capital as a multifaceted concept including spiritual aspects.

Goldsmith states that "Economists have a long-standing interest in the determinants of real wages. Mincer and Becker suggested that personal productivity, and hence real wages, depend critically on human capital formation [4]". He points out that not only the wage level affects the spiritual state of workers but also the spiritual state of workers affects the wage, that is, their earning capacity. We can infer that the spiritual and economic aspects are closely related.

By the way, in the OECD report in 2001, the human capital is defined as follows:

> Economists have traditionally identified three factors of production: land, worker and physical capital. Beginning in the early 1960s, increasing attention was paid to the quality of worker, particularly the level of education and training in the workforce. This gave rise to the concept of human capital embodying skills and other attributes of individuals, which confer a range of personal, economic and social benefits. Skills and competencies are largely acquired through learning and experience but may also reflect innate capacities. Some aspects of motivation and behavior, as well as attributes such as the physical, emotional and spiritual health of individuals are also regarded as human capital. The definition of human capital used in this report is:
>
> The knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being [1].

Since this definition does not only include the economic aspect of human capital but also does the spiritual aspect, we think that it conforms to the human capital of this era, but the method in order to measure its size is still unclear. Therefore, in this study, we attempt to index human capital including spiritual aspects.

3 Indicating Human Capital

3.1 Datasets

In this study, using the individual questionnaire data from the survey targeted to those working in Japan, with reference to the definition of human capital of OECD [8], we attempt to construct human capital indices including noneconomic value. As we have seen, it is difficult to accurately measure the size of human capital. Therefore, when indexing, the following assumption is made. First, we assume that changes in human capital are related to changes in annual income, productivity, employment satisfaction, etc. And we do not measure the size of human capital itself but utilize events that may increase due to the formation of human capital as proxy variables. Specifically, we use four variables as the surrogate variables of human capital, i.e., annual income, productivity, satisfaction level of work, and satisfaction with regard to ability demonstration. Second, we extract two factors from the four kinds of data, namely economic factors, spiritual factors. And, we judge comprehensively the size of human capital from the size of both factors.

In this study, we used the questionnaire data held by Mitsubishi Research Institute, Inc. This survey system has targeted at people aged 20–69 years living in Japan and has obtained 30,000 responses by a web survey. We have implemented it in every June since 2011. The data obtained from 2015 to 2017 which annual income was stable steadily were adopted, and those obtained from student workers were excluded. Workers in Japanese companies tend to retire at age 60, and after that companies tend to hire them as non-regular workers, so we also excluded people in their 60s from the data samples. Regular workers in their 60s are only one of every three workers [7]. We gained 13,730 individual data in total.

We set Annual income and Productivity as indices related to Economic well-being of the definition of human capital by OECD [8], and Satisfaction level of work and Satisfaction level on ability demonstration as indices related to personal and social well-being. Human capital is not the only factor affecting the four indices. However, we think that human capital is the most important one that affects all indices of annual income, productivity, job satisfaction, and capacity utilization. Therefore, we regarded the size of the factor common to them as approximately representing the size of human capital. The questions we used to create these indices are as follows: annual income, satisfaction with regard to work or academic achievement, the degree of satisfaction concerning ability demonstration, and the average working hours per day. Since students are excluded from the analysis subjects, we regard the answer result of the second question as satisfaction of work only.

Regarding satisfaction of work and capacity demonstration, we used a five-point Likert scale, that is, “Satisfied”, “Somewhat satisfied”, “I do not know”, “Somewhat dissatisfied”, and “Dissatisfied”. Regarding the annual income and the working time, we use category data such as “500,000 yen to less than 1 million yen” and “6 to 7 h”. Since we asked about the degree of satisfaction concerning the ability demonstration without limiting to work-relating ones, the result of this question may include the satisfaction of demonstrating the ability in NPO activities, family life, etc. In addition, the questions on the satisfaction level of the annual income, job satisfaction, and the ability include "I do not know" in those options. Therefore, we removed samples for which answers of at least one of the questions are "I do not know" from the analysis target.

Annual income: Median of each option. We regarded this as a proportional scale. We considered "no annual income" as an abnormal value and excluded it from the subject.

Productivity: We calculated this by dividing the annual income (ten thousand yen) by the annual working hours (hours). Annual working hours were set as $\{$(working hours of the day on weekdays) $\times$ 245 days$\}$ + $\{$(working hours per day on holidays) $\times$ 120 days$\}$. We excluded samples with weekday working hours less than 1 h as abnormal values.

Satisfaction level on job satisfaction and ability demonstration: We rated the satisfaction levels using numerical numbers of 5, 4, 3, 2, or 1 (higher ratings mean higher satisfaction levels), then estimated each threshold between values for two adjacent options in the five-point scale and calculated each average of two adjacent threshold values to regard it as a value for an option. The calculation was performed using the function *polychor* in the *polycor* package of statistical software *r*.

The following table shows the descriptive statistics of the input variable and the correlation coefficient (see Table 1).

3.2 Construction of Indices

Using the data set in the previous section as input variables, we performed factor analysis by maximum-likelihood estimation using statistical analysis software JMP® 14.0 (SAS Institute Japan Co., Ltd., Tokyo, Japan).

The eigenvalues are 1.89, 1.53, 0.38, and 0.20, and two factors account for 85.5% of the total variance of the four items. We judge that the two-factor structure is valid. Therefore, we assumed a factor of 2 again and performed factor analysis by maximum-likelihood estimation and Varimax rotation (see Table 2).

The first factor consists mainly of "individual annual income" and "productivity" and indicates high factor loadings amount to the content related to the economic value of workers. So, we name it "economic factor". The second factor consists mainly of "job satisfaction" and "ability demonstration" and indicates high factor loading amount to the content related to the spiritual work value of the workers. So, we name it "spiritual factor". Here we try to think about the meaning of the two factors. The economic factor of human capital means the ability to contribute to economic activity. The greater the annual income and productivity are, the greater this factor is. In addition, we interpret that as the value of this factor is higher, the worker can give more positive value to companies through working.

Table 1 Description statistics of input variables and correlation coefficient

Index	Average standard	Deviation	Minimum	Maximum	Individual annual salary	Productivity	Ability demonstration	Job satisfaction
Individual annual salary	495.44	371.16	25.00	10000.00	1.00	0.80	0.08	0.09
Productivity	2313.68	2067.93	57.08	68493.15	0.80	1.00	0.07	0.08
Ability demonstration	2.87	1.12	0.93	5.28	0.08	0.07	1.00	0.62
Job satisfaction	2.90	1.24	0.97	5.32	0.09	0.08	0.62	1.00

Table 2 Result of factor analysis: Maximum likelihood method and Promax rotation. Correlation coefficient between factors is 0.0013

Index	Factor 1	Factor 2
Individual annual salary	**0.98**	0.04
Productivity	**0.81**	0.06
Ability demonstration	0.04	**1.00**
Job satisfaction	0.05	**0.62**

On the other hand, the spiritual factor of human capital means the ability to utilize the capabilities of himself or herself to increase the satisfaction of performing work and the ability to enhance satisfaction to perform work itself. We interpret that workers with higher spiritual factors feel that their abilities are demonstrated and increase their satisfaction with work. We think that the higher the score of these two factors, the more human capital is formed for the worker.

4 Analysis of Factors to Raise Human Capital

Next, we conduct a regression analysis to clarify the workstyle and self-learning types of the workers with large values of these factors. The data we used are the same piece of data used for the factor analysis. The workstyle and self-learning menus are as follows (Table 3). For each of questions for both, a five-point scale format of "Applicable", "Somewhat applicable", "Neither applicable nor inapplicable", "Somewhat inapplicable", and "Inapplicable".

We use economic factors and spiritual factors as dependent variables and workstyle and self-learning menus as independent variables. We also use gender, age, final academic background (over university graduate/other than that), the number of workers (500 or more/less than 500) within a company, and industry (manufacturing industry/nonmanufacturing industry) as control variables. Furthermore, we performed logistic regression analysis using statistical analysis software JMP® 14.0 (SAS Institute Japan Co. Ltd., Tokyo, Japan).

According to Basic Survey on Wage Structure [6] in 2018, many chief managers are in their early 40s, many managers are in their late 40s, and many directors are in their early 50s. There are many non-managers in their 20s and 30s. In other words, workers under age 40 are more likely to work based on instructions from their superiors, while they tend to do management work after reaching the age of 40. They possibly change their workstyle a lot around their age of 40. So, we performed the analysis by grouping workers from 20 to 39 years of age into the first group, and those from 40 to 59 years of age into the second one. The following prediction formulas are created.

$$
\begin{aligned}
\mathrm{Y} = \alpha_0 + \alpha_1\mathrm{Gen} + \alpha_2\mathrm{Age} + \alpha_3\mathrm{Edu} + \alpha_4\mathrm{Sca} + \alpha_5\mathrm{Ind} \\
+ \beta_1\mathrm{W}_1 + \beta_2\mathrm{W}_2 + \ldots + \beta_{17}\mathrm{W}_{17} + \varepsilon
\end{aligned}
\tag{1}
$$

Table 3 Workstyle and self-learning type

Workstyles	Self-learnings
I choose work over which I can prioritize my own or my family's time	I learn by reading books
Even if there is a personal event in the evening, I work overtime if I do a sudden job	I learn through participation in lecture meetings
If I do not finish my work I will work at home	I learn through learning programs on television and radio
I do work with satisfaction and fulfillment	I learn by correspondence courses
I do work that I can contribute to society	I learn on the online course of the Internet
I do work that can improve my ability	I learn liberal arts such as English conversation at an institution or at school
I work with a foreign language	I have voluntary study sessions with fellows who share the same interests
I work with loyalty to the company	I learn at the community center
I constantly aim to improve my position in the company	I learn at university public lectures
I engage without concern even in occupations engaged by workers of the opposite gender	I participate in study sessions and gatherings at temples and churches
I always come to the office earlier than starting hours	I use early morning time for my self-learning
I communicate well with people involved in work for the purpose of smoothly performing work	I read e-books on personal computers, mobile phones, etc.
I go home when I finish my work even if my colleagues are still working I always take paid vacations properly	I am engaged in lectures and learning support as a lecturer
If I find a company with better treatment, I would like to change the company.	
I am particular about working as a regular worker	
I work without stress	

$$\begin{aligned} \mathrm{Y} = \gamma_0 + \gamma_1\mathrm{Gen} + \gamma_2\mathrm{Age} + \gamma_3\mathrm{Edu} + \gamma_4\mathrm{Sca} + \gamma_5\mathrm{Ind} \\ + \zeta_1\mathrm{Z}_1 + \zeta_2\mathrm{Z}_2 + \ldots + \zeta_{13}\mathrm{Z}_{13} + \varepsilon \end{aligned} \tag{2}$$

Y	Economic factor or Spiritual factor
Gen	Gender
Age	Age,
Edu	Last academic background
Sca	Company size
Ind	Industry type

W Workstyle menu
Z Self-learning menu

α_0 to α_5, β_1 to β_{17}, γ_0 to γ_5, and ζ_1 to ζ_{13} are regression coefficients, and ε is a residual.

Regarding the multicollinearity, since the correlation coefficients between the parameter estimation values are all less than 0.4 to −0.4, no strong correlation is found.

The ratios of industries are almost the same when the samples divide by age, and even if t-test is carried out, there is no significant difference between manufacturing industry and nonmanufacturing industry. On the other hand, there is a difference in the ratio of male to female in each group. The p-value is less than 0.001, and a significant difference is observed between female and male. Therefore, it should be noted that there is a possibility that biased gender between the two groups may have an influence on the estimation result.

According to the analysis results (Table 4), men have larger economic factors than women, whereas spiritual factors show the opposite tendency. As the age becomes higher, the value of the economic factor becomes higher as well, indicating that the economic human capital is raised as working experience becomes longer. It is noted that the value of the economic factor is higher if workers have higher academic backgrounds or there are more workers in a company.

The workstyle of "I work with a foreign language" is likely to increase economic factors when workers are in their 20 s and 30 s. At the ages from 40 to 59, the workstyles of "I constantly aim to improve my position in my company" and "I go home when I finish my work even if my colleagues are still working" also have the potential to increase economic factors in the human capital. Meanwhile, the following workstyles may increase spiritual factors for workers at their 20 s and 30 s; "I do work with satisfaction and fulfillment", "I do work with which I can contribute to society", "I do work that can improve my ability", "I choose work over which I can prioritize my own or my family's time", "I work with loyalty to my company", "I communicate well with people involved in my work to perform work smoothly", and "I work without stress". For workers aged 40–59, "I do work with which I can contribute to society" and "I choose work over which I can prioritize my own or my family's time" are excluded.

From this result, the following is suggested. First, any single workstyle type does not increase economic and spiritual factors at the same time. In order to raise both factors simultaneously, we need to combine multiple workstyles appropriately.

Second, at the ages between 20 and 39, the only workstyle type that we could confirm the possibility of raising economic factors is "I work with a foreign language". This is not always applicable to any kinds of companies and is limited to specific industries and occupations where people perform foreign transactions, do business with foreign customers, work together with foreigners in the same workplace, etc.

Third, “I constantly aim to improve my position in my company” and “I go home when I finish my work even if my colleagues are still working” are workstyles that may increase economic factors for workers aged from 40 to 59 years. And these two workstyles seem to be incompatible. But, as long as a job-type employment system is common in the West, two workstyles can be reconciled. Therefore, enterprises may be able to raise economic factors if they change their employment system from “membership type” which is said to be unique to Japan to “job-type” common in the West.

Fourth, there are many workstyles that may increase spiritual factors. Especially, “I do work with satisfaction and fulfillment”, “I do work that can improve my ability”, “I communicate well with people involved in my work to perform work smoothly”, and “I work without stress” are common to both age groups, so it is important to improve the workplace environment and review work contents to realize these workstyles.

Fifth, at the ages from 20 to 39 years, “I work with loyalty to the company” increases spiritual factors, but on the contrary, “I constantly aim to improve my position in my company” decreases the spiritual factor. Both are ways of working to enhance the commitment to the company, but it shows the opposite tendency as to whether it is heading to the company organization or to the individual.

Finally, “I do work which can improve my ability” at the ages from 20 to 39 years increases the spiritual factor but conversely lowers the economic factor. When he or she was young, without thinking about his or her own ability to demonstrate, it is a shortcut for promotion to become a way of work unique to that company. But that reduces the motivation to work. It clearly shows the problem of young workers in Japanese companies. It should be a future task of companies to create workstyles in which young people can raise both human and economic capital (Table 4).

Meanwhile a regression model showing the relationship between two factors constituting human capital and self-learning is as shown in Table 5. Self-learning menus that may increase economic factors at the ages from 20 to 39 years are two: “I learn liberal arts such as English conversation at an institution or at a school” and “I am engaged in lectures and learning support as a lecturer”. The only self-learning menu that may increase economic factors for people aged from 40 to 59 years is “I learn through participation in lecture meetings”.

In addition, self-learning menus that may increase spiritual factors at the ages from 20 to 39 years are “I learn by reading books”, “I have voluntary study sessions with fellows who share the same interests with me”, and “I use early morning time for my self-learning”. Self-learning menus that may increase spiritual factors for people aged from 40 to 59 years are “I learn by reading books”, “I learn through participation in lecture meetings”, “I use early morning time for my self-learning”, and “I am engaged in lectures and learning support as a lecturer”.

These results indicate the following things.

First, the self-learning menus that may increase economic factors for workers under the age of 40 are different from those for workers after reaching the age of 40. Normally, companies do not change the menus of support for workers’ self-learning according to the workers’ age. However, if the self-learning menu that enhances

Table 4 A regression model showing the relationship between two factors constituting human capital and workstyle. This table shows the relationship between economic factor and spiritual factor and workstyle. The table head is divided into two groups, a group of 20–39 years old and a group of 40–59 years old. Furthermore, they are divided into economic factor and spiritual factor, respectively. On the front side, from the top, Intercept and control variables Gender, Age, Last academic background, Company size, Industry Type, 17 workstyles, The number of samples, F value, The degrees of freedom adjusted R-square statistic, and so on are followed in order

	20–39 years old				40–59 years old			
	Economic factors		Spiritual factor		Economic factors		Spiritual factor	
	Estimate	Standard error	Estimate	Standard error	Estimate	Standard error	Estimate	Standard error
Intercept	−1.039	0.091***	−1.255	0.091***	−0.980	0.124***	−1.078	0.107***
Gender (0: male, 1: female)	−0.096	0.012***	0.043	0.012**	−0.180	0.013***	0.107	0.012***
Age	0.026	0.002***	−0.003	0.002	0.019	0.002***	0.000	0.002
Last academic background (0: Bachelor university graduate, 1: others)	−0.073	0.012***	−0.015	0.012	−0.141	0.012***	−0.017	0.01
Company size (0: 500 or more, 1: less than 500 people)	−0.094	0.012***	−0.035	0.012**	−0.199	0.012***	0.005	0.011
Industry (0: Manufacturing, 1: Nonmanufacturing)	−0.009	0.012	0.011	0.012	−0.000	0.012	−0.012	0.01
I choose work over which I can prioritize my own or my family's time	0.010	0.012	0.048	0.012***	0.013	0.012	−0.020	0.01
Even if there is a personal event in the evening, I work overtime if I do a sudden job	−0.007	0.01	−0.006	0.01	0.002	0.011	−0.036	0.01**

(continued)

Table 4 (continued)

	20–39 years old				40–59 years old			
	Economic factors		Spiritual factor		Economic factors		Spiritual factor	
	Estimate	Standard error	Estimate	Standard error	Estimate	Standard error	Estimate	Standard error
If I do not finish my work I will work at home	−0.006	0.01	−0.022	0.01*	0.005	0.01	−0.018	0.009*
I do work with satisfaction and fulfillment	−0.003	0.013	0.208	0.013***	0.003	0.014	0.242	0.012***
I do work that I can contribute to society	0.003	0.012	0.035	0.012**	−0.014	0.013	0.012	0.011
I do work that can improve my ability	−0.034	0.013*	0.059	0.013***	−0.003	0.015	0.073	0.013***
I work with a foreign language	0.062	0.011***	−0.005	0.011	0.066	0.012***	−0.003	0.01
I work with loyalty to the company	0.013	0.012	0.095	0.012***	−0.021	0.013	0.126	0.011***
I constantly aim to improve my position in the company	0.012	0.011	−0.024	0.012*	0.039	0.012**	−0.012	0.011
I engage without concern even in occupations engaged by workers of the opposite gender	−0.005	0.012	−0.020	0.012	0.005	0.012	−0.018	0.01
I always come to the office earlier than starting hours	−0.031	0.009**	0.011	0.009	−0.008	0.01	−0.008	0.009

(continued)

Table 4 (continued)

	20–39 years old				40–59 years old			
	Economic factors		Spiritual factor		Economic factors		Spiritual factor	
	Estimate	Standard error	Estimate	Standard error	Estimate	Standard error	Estimate	Standard error
I communicate well with people involved in work for the purpose of smoothly performing work	0.007	0.012	0.046	0.012***	0.020	0.012	0.056	0.011***
I go home when I finish my work even if my colleagues are still working	0.012	0.01	−0.012	0.01	0.034	0.011**	0.018	0.01
I always take paid vacations properly	−0.000	0.009	0.009	0.01	0.019	0.01*	−0.013	0.008
I will change my job if I have a good company	−0.009	0.009	−0.139	0.009***	−0.048	0.009***	−0.173	0.008***
I am particular about working as a regular worker	−0.005	0.011	0.009	0.011	−0.011	0.011	−0.014	0.01
I work without stress	0.009	0.011	0.181	0.011***	−0.011	0.011	0.162	0.009***
The number of samples	6,413		6,413		7,317		7,317	
F value	22.886		110.249		59.620		151.035	
The degrees of freedom adjusted R-square statistic	0.070		0.273		0.150		0.311	

Note * $p < 0.1$, **:$p < 0.05$, *** $p < 0.01$

worker's human capital changes depending on the worker's age, companies need to change self-learning menus with the worker's age.

Second, self-learning menus that may increase spiritual factors in both age groups are "I learn by reading books" and "I use early morning time for my self-learning". Therefore, we think that it is effective for companies to subsidize book purchase expenses and to promote the so-called "Asa-katsu (morning activities)" in Japanese.

Third, at the ages from 40 to 59 years, "I learn through participation in lecture meetings" may increase both economic and spiritual factors. Therefore, we think that it is effective for companies to do this as a self-learning activity support menu for senior workers (Table 5).

5 Concluding Remark

In this study, we attempted to create an index focusing on the two aspects of human capital and analyzed the relationship between human capital and workstyles/self-learning. As a result, we were able to obtain several suggestions. The following are three important points which should be considered by companies.

First, it is suggested that, when young workers do work that can improve their own abilities, the human capital of the spiritual aspect is raised but the economic human capital is lowered. It should be a future task for companies to create workstyles that can simultaneously enhance worker skills and economic human capital.

Second, for senior workers, it is suggested that learning through participation in lecture meetings increases both spiritual and economic factors. This should be considered as a self-learning menu for which companies should support workers.

Third, "I constantly aim to improve my position in my company" and "I go home when I finish my work even if my colleagues are still working" are workstyles that may increase economic factors for workers aged from 40 to 59 years. As long as a job-type employment system is common in the West, two workstyles can be reconciled. Therefore, enterprises may be able to raise economic factors if they change their employment system from "membership type" which is said to be unique to Japan to "job-type" common in the West. On the other hand, the main support measures of the Japanese government concerning self-learning are to subsidize the expenses of educational training for workers. But, as clarified in this study, self-learning menus that can enhance both economic factors and spiritual factors are not limited to attending lecture courses only, but also include lecture activities, voluntary study sessions with fellows who share the same interests, learning by reading books. The government may need to revise the scope and target of benefits for educational training payment.

Table 5 A regression model showing the relationship between two factors constituting human capital and self-learning. This table shows the relationship between economic factor and spiritual factor and self-learning. The table head is divided into two groups, a group of 20–39 years old and a group of 40–59 years old. Furthermore, they are divided into economic factor and spiritual factor, respectively. On the front side, from the top, Intercept and control variables Gender, Age, Last academic background, Company size, Industry Type, 13 self-learning menus, The number of samples, F value, The degrees of freedom adjusted R-square statistic, and so on are followed in order

	20–39 years old				40–59 years old			
	Economic factors		Spiritual factor		Economic factors		Spiritual factor	
	Estimate	Standard error	Estimate	Standard error	Estimate	Standard error	Estimate	Standard error
Intercept	−1.192	0.075***	−0.180	0.087*	−0.898	0.105***	−0.514	0.107***
Gender (0: male, 1: female)	−0.093	0.012***	0.054	0.013***	−0.183	0.013***	0.128	0.014***
age	0.026	0.002***	0.000	0.003	0.019	0.002***	0.008	0.002***
Last academic background (0: Bachelor university graduate, 1: others)	−0.074	0.012***	−0.022	0.013	−0.149	0.012***	−0.020	0.012
Company size (0: 500 or more, 1: less than 500 people)	−0.097	0.012***	−0.059	0.013***	−0.213	0.012***	−0.022	0.012
Industry (0: Manufacturing, 1: Nonmanufacturing)	−0.014	0.012	0.001	0.014	−0.012	0.012	−0.017	0.012
I learn by reading books	0.014	0.01	0.043	0.011***	0.009	0.01	0.036	0.011**
I learn through participation in lecture meetings	0.014	0.016	0.016	0.018	0.071	0.016***	0.049	0.016**
I learn through learning programs on television and radio	−0.010	0.016	0.027	0.018	0.006	0.017	−0.037	0.017*

(continued)

Table 5 (continued)

	20–39 years old				40–59 years old			
	Economic factors		Spiritual factor		Economic factors		Spiritual factor	
	Estimate	Standard error	Estimate	Standard error	Estimate	Standard error	Estimate	Standard error
I learn by correspondence courses	−0.006	0.015	−0.031	0.018	−0.030	0.018	−0.032	0.019
I learn on online courses of the Internet	−0.006	0.016	−0.011	0.019	0.020	0.019	−0.010	0.02
I learn liberal arts such as English conversation at an institution or at school	0.039	0.017*	0.011	0.02	0.006	0.02	−0.036	0.02
I have voluntary study sessions with fellows who share the same interests	0.017	0.018	0.051	0.021*	−0.008	0.021	−0.003	0.021
I learn at a community center	−0.034	0.022	−0.054	0.026*	−0.047	0.026	0.006	0.026
I learn at university public lectures	0.012	0.023	−0.016	0.026	0.046	0.026	−0.016	0.027
I participate in study sessions and gatherings at temples and churches	−0.010	0.022	−0.031	0.025	0.002	0.022	0.001	0.023
I use early morning time for my self-learning	−0.002	0.017	0.058	0.019**	0.010	0.018	0.066	0.018**

(continued)

Table 5 (continued)

	20–39 years old				40–59 years old			
	Economic factors		Spiritual factor		Economic factors		Spiritual factor	
	Estimate	Standard error	Estimate	Standard error	Estimate	Standard error	Estimate	Standard error
I read e-books on personal computers, mobile phones, etc.	−0.006	0.01	0.003	0.011	0.008	0.011	0.005	0.011
I am engaged in lectures and learning support as a lecturer	0.061	0.019**	0.029	0.023	−0.022	0.019	0.054	0.02**
The number of samples	6,413		6,413		7,317		7,317	
F value	27.132		7.037		69.939		10.116	
The degrees of freedom adjusted R-square statistic	0.068		0.017		0.145		0.022	

Note * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

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Study on Popularization of QR Code Settlement in Japan

Tietie Chen and Yoko Ishino

Abstract Cashless payment is an often-discussed topic in Japan. To date, cashless payment is becoming the standard in most countries. However, Japan is lagging behind in terms of cashless settlements. The Japanese government is trying to raise the penetration rate of cashless settlements from the current 20 to 40% by 2025, showing subsidization policies. This study focuses on a QR code settlement system, which can be installed more easily with fewer costs than credit card systems. This study aims to clarify how much the introduction of QR code settlement affects small-to-medium-sized companies, where cash and credit card payments are mainstreams, in Japan. We perform a probability-based risk simulation to calculate how many benefits will be obtained if a small-sized Japanese pub restaurant introduces QR code payments. The simulation was carried out assuming 12 scenarios in total. Finally, it was found that the introduction of the QR code settlement would make the risk of running a pub restaurant lower, irrespective of business standing.

Keywords QR code · Cashless payment · Probability-Based risk simulation

1 Introduction

Cashless payment is a settlement method that uses credit cards, electronic money, direct debit payment, or other digital methods. In cashless payment, people pay and receive counter value without using cash such as banknotes and coins. Globally speaking, cashless payment is becoming the standard in most countries, since it makes speedy payment and activation of the economy possible. However, the delay of popularization of cashless payment in Japan is often pointed out.

According to the Cabinet Office, Japan's cashless payment ratio from the private final consumption expenditure in 2018 was about 20%. However, cashless payment ratios in China and U.S.A. are 60% and 46%, respectively, both differing vastly from

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Japan's situation. Counterfeit notes are extremely rare in Japan, and this contributes to immense public trust in cash. Thus, cash remains the mainstream payment method today.

This has triggered the Japanese government to set a policy in order to elevate the cashless payment ratio to 40% by 2025, an estimate which is twice as high as the current ratio. So far, cashless payments have not spread widely. However, a big movement has started to be witnessed. From October 1, 2019, consumption taxes will rise, and simultaneously a reduced overall tax rate will be implemented. Additionally, the government has introduced two policies of reward points and terminal installation support for small-to-medium-sized retailers. This has led many companies to believe that if a system for cashless payment is installed by October 2019, they can receive installation support from the government while attracting new customers who would come to seek reward points. In the past, Korea and Australia implemented tax benefits with payment-terminal installation support, leading to a sudden increase in card-payment terminals.

In Japan, many large-scale stores, including chains, already have installed systems for credit card payments, because payment by credit cards is the majority of current cashless payments. However, most small-to-medium retail stores, which occupy the majority of stores, have not yet installed credit card readers. There are a few reasons for this, a primary one being the difficulty in maintaining a card-payment environment because start-up and maintenance costs are often higher than the usage payback, which in turn consumes much of the operating funds.

This has led to a focus on a QR code payment, which can be installed more easily with fewer costs than credit card systems. In China, a QR code payment called Alipay run by Alibaba comprises the main cashless payment method. Therefore, considering the demand inbound from China, QR code payment could be beneficial to the Japanese economy. The Ministry of Economy, Trade and Industry has established a committee to standardize codes and payment systems and promote QR code payments.

As of January 2019, more than 10 mobile settlement services using QR codes have been provided for people in Japan. Based on the main business type of the company that provides such service, these QR code payments can be roughly classified into three groups, an IT group, a communication carrier group, and a bank group. Three major QR code payment services, PayPay, LinePay, and RakutenPay, which belong to the IT group, have a competitive advantage so far. Their unified specifications are yet to be established but these companies are competing to take the lead.

The objective of this study is to clarify how much the introduction of QR code settlement affects small-sized companies, where cash and credit card payments are mainstreams, in Japan. Therefore, we carry out a probability-based simulation to calculate how many benefits will be obtained if a small-sized company introduces QR code payments. As there are several uncertain factors, including the oncoming government policies, more than ten scenarios have been developed and used in the simulation. Based on these inquiries, this study aims to also estimate the extent to which QR code payments will spread.

2 Related Work

2.1 QR Codes in a Cashless Society

The QR code, which stands for Quick Response Code, is the trademark for a type of matrix barcode first designed in 1994 for the automotive industry by Denso Wave Incorporated in Japan [1]. The company waived its rights to the patent, and so QR codes can be freely used without patent restrictions. The QR code consists of black squares arranged in a square grid on a white background. The required pattern is extracted from both horizontal and vertical components of the image. QR codes are commonly used in a variety of ways from payment systems to consumer advertising [2]. A smartphone can be used as a QR code scanner. QR codes are convenient since it adopts the "scan-and-go" approach, where it is not necessary to input long complicated data (e.g., long URLs) manually. The QR code is gaining popularity in cashless societies around the world. They can be used to store bank account information or credit card information, and can also be specifically designed to work with particular payment provider applications. These mobile applications are especially popular in China [3]. Although there are some security risks in using QR codes in payment, several technical measures are available to mitigate such risks.

2.2 Diffusion of New Payment System

Several previous studies investigated the diffusion of a new payment system. They found that several factors might explain the acceptance or resistance of consumers to use new mobile payment. Several literature [4–6] revealed that there are positive factors (e.g., perceived ease of use, perceived usefulness, trust, flow, satisfaction, compatibility, and relative advantage) and negative factors (e.g., need for interaction, perceived risk and cost) that might influence on user's behavior when starting to use the mobile payment.

Another research aimed to analyze the determinants of technology adoption behavior regarding near field communication (NFC) payment system [7]. The NFC system is a communication standard developed by Sony and Philips in the first decade of this century to unify the existing communication technology supported by an internal chip (microprocessor) that enabled data transfer within a maximum distance of 10 cm from the receiver. The effect of user attitudes toward new payment systems highlights the need to ensure that users improve their perception and general opinion regarding new payment systems.

The purpose of another research was to determine the benefits of digital payments and its influence on the rural sector of India [8]. The study conducted a convenient sampling survey with a selected number of respondents in the rural part of Southern India.

While the foregoing studies are a few examples, many researchers tried to verify the hypothesis on consumer behavior in introducing a new digital payment method using a method of Structural Equation Modeling (SEM). In this study, however, we approach the problem by performing probability-based risk simulation based on reasonable financial data derived from published data.

3 Japanese Government's Strategy on QR Code Payments

The Government of Japan announced that the consumption tax rate will be increased from the current 8 to 10%, beginning in October 2019. Learning from past recession experiences, when the consumption tax was raised from 5 to 8%, the government will attempt to ease the effects of the increased taxes by, for example, providing reward points to customers who make cashless payments, such as through credit cards and QR codes on their smartphones, which the government will then subsidize. The government initially announced that it would give back 2% to consumers, equaling the increased tax amount. Recent announcements suggest, however, that reward points will be offered up to 5% for a limited duration of 9 months after the consumption tax increase on October 1, 2019. In this case, the return to consumers would be more than the tax increase, amounting to 2%, implying a real tax reduction. Moreover, the government also plans to extend the target for distributing premium gift certificates. In addition to households that are not subject to inhabitant tax and families with children under 2 years old, the government also makes it possible for pensioners with lower incomes to purchase the premium gift certificates that can shop for up to 25,000 yen at 20,000 yen. The government wants to use policies to boost consumerism simultaneous to the tax increase as well as promote a cashless society in Japan. This also reflects the desire to increase productivity by promoting a cashless society, since the acceleration of an aging population with the declining birthrate has been creating permanent labor shortages in Japan.

The government also believes that the main reason why a cashless society has not progressed in Japan is because of the insufficient infrastructure for cashless payments. In an effort to tackle this problem, on November 14 2018, it was revealed that the government was considering a system set up to provide a zero-sum cost adjustment to medium-to-small-sized retailers and restaurants, so that they can install cashless payment terminal devices virtually free of charge. The Ministry of Economy, Trade and Industry is still working on a policy where two-thirds of the installation cost will be paid by the government, with the remainder offset by payment service companies.

In December 2018, the main payment service companies in the QR code payment industry were "PayPay", a new investment and set up of Yahoo and Softbank, "Line Pay" by Line Corporation and "RakutenPay" by Rakuten Inc. These three companies are competing to take the lead in the industry, and when one payment service company implements a usage promotion measure such as "Merchant fee is free," the others often follow suit. It is hard to say that the characteristics and strategies of each company are clearly defined.

4 Simulation Method

4.1 Choosing a Target of Simulation

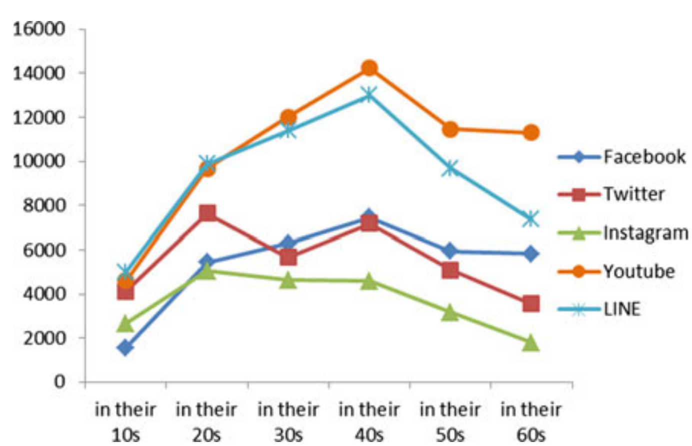
To choose the appropriate target of simulation, we first attempt to clarify who the target users for QR code payments should be. People who use social networking services (SNSs) or social media are already familiar with smartphone operations. Thus, they are expected to have no hesitation with respect to QR code payments. Figure 1 shows the number of users per generation in 2018 for each SNS in Japan. Overall, users in their 40 s are the largest in number. This makes us assume that the main marketing target for QR code payments should be users in their 40 s. However, Twitter and Instagram have more users who are in their 20 s. Users in their 20 s, who generally have a lower income and may not have established credit history yet, already use social media to a great extent. Therefore, the wider marketing target should be 20- to 49-year-old demographics. We set a Japanese-style pub restaurant for the simulation model because the user attributes are almost the same between such pubs and SNSs.

4.2 Purpose of the Simulation

In this study, we focus on how introducing QR code payments can bring benefits to pubs where cash and credit card use is mainstream, rather than focusing on the competition among QR code settlement companies, such as PayPay, LinePay, and RakutenPay.

The main costs for pubs when introducing cashless payment are the infrastructure costs, such as scanners, and fees (affiliated store fees) to be given to payment companies. As for the infrastructure costs, there are two reading methods of QR code settlement. One is to let consumers read the QR code of the store, and the other is

Fig. 1 Number of users by age group on each SNS (from www.make-light.work/web/2018sns/)



the method that a shop reads the QR code of each consumer. In the former method, the equipment installation costs will be free.

Next, the affiliated store fees provide a certain percentage of the monthly sales amount, and the percentage differs from industry to industry. For an ordinary credit card, the affiliated store fee of around 5% is charged in restaurants. The usual affiliated store fee for QR code payments was about 3.2% at the beginning of 2018. Since the summer of 2018, some QR code settlement companies (i.e., PayPay and LinePay) have been executing a special campaign where their fees are free of charge. This is because they want to extend the number of affiliated stores employing their own QR code payment.

Therefore, if these conditions would continue permanently, there would be no need to conduct simulation studies. Under these conditions, if retailers employ a QR code settlement, they will apparently earn more than not employing it. Actually, however, free affiliated store fees will likely be abandoned after a few years. Thus, our motivation is to find the risk of employing a QR code settlement under such circumstances.

We set a small-sized pub with monthly sales of less than 3 million yen as the model for the simulation study, since small-sized retailers will be heavily affected by the abandonment of this advantageous condition. In the simulation, we set the affiliated fees by credit cards as 5% of the sales amount by credit card payment. In contrast, QR code payment fees remain at zero until the third year. From the fourth year onwards, it will become 3.2% of the sales amount.

4.3 Simulation Settings

We investigated published data [9] in order to know how often and why consumers use a pub restaurant and on average how much money they spend there. Additionally, we also investigated the survey about credit card usage [10]. Based on this information, we defined the problem as follows. The key performance indicator (KPI) for this simulation is set as the net present value (NPV), calculated for a 5- or 10-year period. Store sales are obtained by multiplying the average spending per customer and the number of customers. Incidentally, the needed cost of the employee education related to the QR code settlement is not considered here.

We must consider the relationship between QR code payment and other payments. Customers are categorized into three groups: credit card payers, QR code payers, and cash payers (no overlapping). In this research, in order to simplify the problem, the identical person's transference between payment statuses is not considered directly, and the number of people in each status in each year is obtained following the flow shown in Fig. 2.

Other main settings are as shown in Table 1. The crucial point when calculating the number of customers in each state indicated in Fig. 2 is as follows. We calculate the number of customers sensitive to prices using Eq. 1. Equation 1 contains percentages of the price-conscious customers displayed in Table 1, which are derived

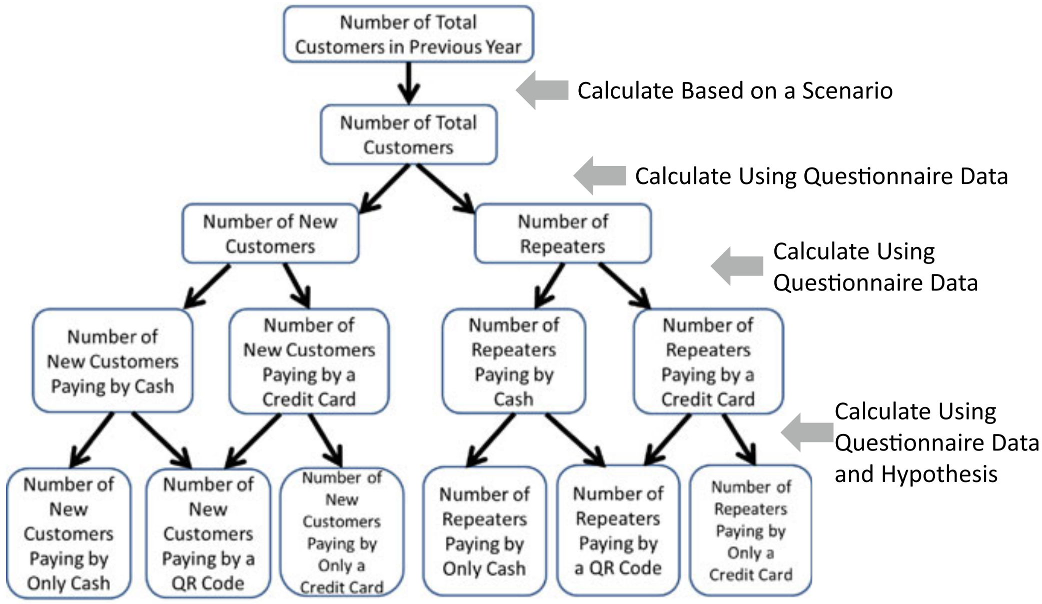


Fig. 2 Calculation method of the number of customers in a payment segment

Table 1 Values used in simulations based on the published data

Average spending per customer per month	3912 yen
Number of customers for the first year	7740 people
Percentage of new customers to all customers	40.0%
Percentage of credit card users	13.2%
Percentage of the price-conscious out of new customers	33.0%
Percentage of the price-conscious out of repeaters	42.1%
Percentage of people who use QR code payment against all the price-conscious	90.0%
Percentage of variable costs (excluding fees relating to cashless payment) to the sales amount	65.0%
Discount rate	10.0%

from published data [9]. Then, we assume that 90% of price-sensitive customers will use QR code payments instead of credit card payments. This is because people can register a credit card for a QR code payment, and so, they are able to get points from both a QR code service and a credit card service. It seems favorable for all price-sensitive customers to use QR codes. However, considering some people do not like going through the hassle of setting up new payment methods, we chose 90% instead of 100%.

$$N_{\text{Customers sensitive to prices}} = N_{New\ customers} \times 0.33 + N_{Repeat\ customers} \times 0.421 \quad (1)$$

4.4 Set Scenarios

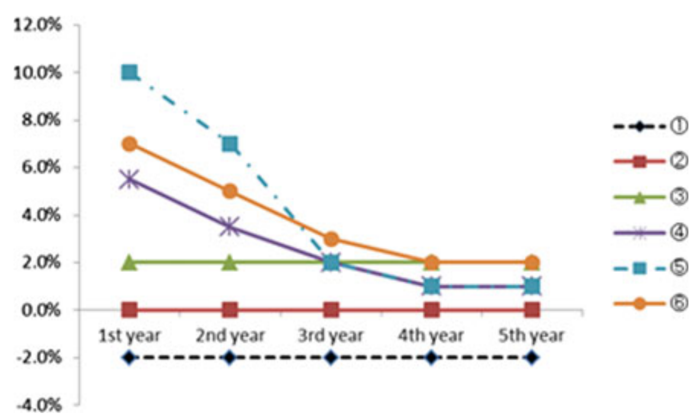
We consider the following six patterns with different degrees of effects caused by introducing QR code payments.

(1) Not introducing QR payment (this results in a customer growth rate of −2%).
(2) Introducing QR payment with no obvious effect (a customer growth rate of 0%).
(3) Introducing QR payment, resulting in 2% increase every year in customer growth rate.
(4) Introducing QR payment with a medium degree of effect, which goes away after a few years.
(5) Introducing QR payment with a huge temporary effect, which goes away after a few years.
(6) Introducing QR payment with its initial impact being somewhat between (4) and (5), which becomes larger than (4) or (5) after the third year and continues for a prolonged period.

The customer growth rate set for each pattern is shown in Fig. 3.

Additionally, we consider two groups of retailers: those whose business has done well since their first year (operating profit ratio of 6%), and those whose business is not doing well (operating profit ratio of 3%). We assume that the fixed cost for the first year stays unchanged indefinitely in both cases. There are 12 scenarios in total (6 patterns $\times$ 2 cases $=$ 12). We believe that variable costs to sales amount ratio, number of customers, and sales amount will stochastically move in reality. Therefore, we use a triangular distribution, which increases and decreases monotonically from the set ratios within a range of –10% to + 10%. We carried out this simulation using risk-analysis software called Crystal Ball.

Fig. 3 Customer growth rate in each pattern



5 Results

In each of the 12 scenarios, 100,000 trials were conducted to get NPVs for a 5-year period, with results shown in Figs. 4 and 5. When setting 5-year period NPVs as KPIs for both groups of pub restaurants with operating profit ratio of 3% and of 6%, the magnitudes of the obtained KPI values differ depending on the pattern, and it was in the following order: (1) < (2) < (3) < (4) < (6) < (5). The NPV was lowest when not introducing QR payments. In the case of pub restaurants whose business is not going well, the NPV becomes negative with a probability of 43.6%. Even for pub restaurants whose businesses are going well, the NPV becomes negative with a probability of 14.1%. Even in case of a customer growth ratio of 0%, if QR payments are introduced, the affiliated store fees for credit cards will decrease, making the NPV higher than for not introducing QR payments. This reduces the probability of NPV becoming negative (23.3% for pub restaurants with operating profit ratio of 3%, and 5.2% for pub restaurants with operating profit ratio of 6%).

The above reveals that introducing QR payments is beneficial, regardless of business status. When considering the possibility of reducing the probability of NPV becoming negative, it is better to proactively introduce QR code payments for pub restaurants in a not-so-good business state.

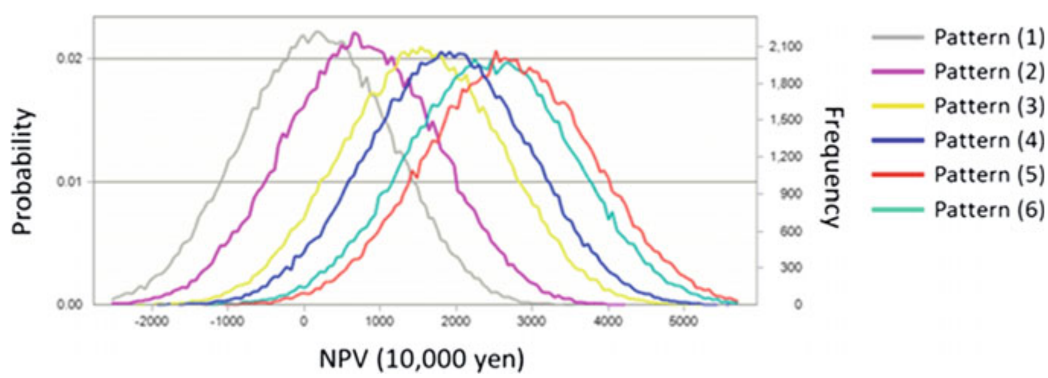


Fig. 4 Probability distribution of NPV for pub restaurants with operating profit ratio of 3%

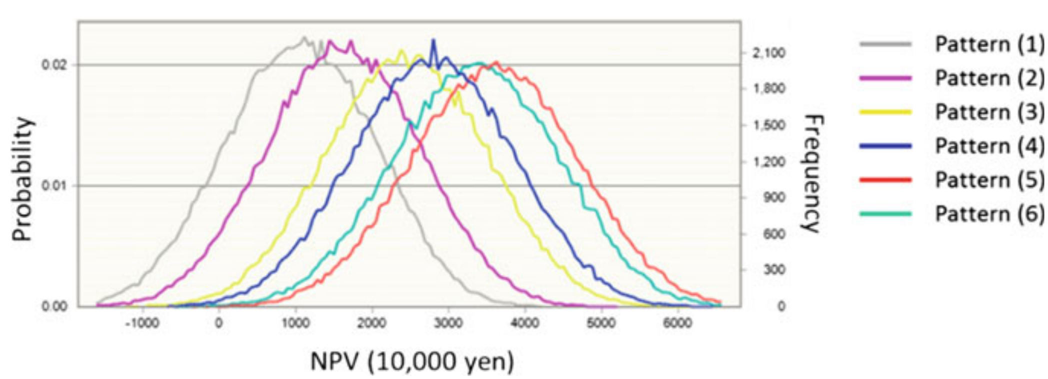


Fig. 5 Probability distribution of NPV for pub restaurants with operating profit ratio of 6%

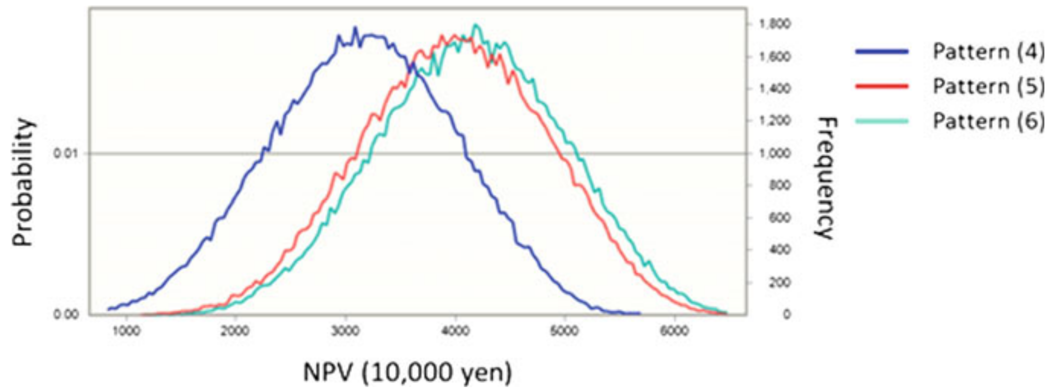


Fig. 6 Probability distribution of NPV of 10-year period for pub restaurants with operating profit ratio of 6%

Although the value of NPV for a 5-year period was obtained in the order of (4) < (6) < (5), we also set NPVs for 10 years as KPIs to investigate the effect of longer periods. Figure 6 illustrates the probability distribution of KPI values for a 10-year period for pub restaurants with an operating profit ratio of 6%. In Fig. 6, blue, red, and green lines display the patterns (4), (5), and (6), respectively, and the magnitudes of KPI were followed in the order of (4) < (5) < (6). For patterns (4) to (6), with different increases of customer growth ratios, the order of KPI values changes for a 5-year and 10-year period. The KPI value was the highest for a 10-year period in the pattern (6), with the longest period of customer growth ratio. Therefore, to maintain the customer growth rate for the long term, it is necessary to add various services to QR code payments, continuously creating attractive values for customers, so that QR code payment will be used for a longer period.

6 Conclusions

In this research, setting a Japanese pub restaurant as a model, the simulation was carried out assuming 12 scenarios in order to develop a strategy as to whether to adopt QR code settlement. Finally, it was found that the introduction of the QR code settlement makes the risk of running a pub restaurant lower. The NPV of a pub restaurant with high operating profit ratio is naturally larger than the NPV of those with low operating profit ratio. However, considering the ratio of the increase in NPV value caused by QR code settlement to sales, the effect for a pub restaurant with low operating margin is considerable, and as a result, it is desirable to positively incorporate QR code settlement for such pub restaurants.

However, in the simulations, we assumed that 90% of customers would transition to QR code payments from credit cards and cash. In reality, this percentage is difficult to predict, leaving the assumption in doubt.

Cashless payments, including QR code payments, give the advantages of improved convenience for consumers, increased operational efficiency for retailers, and improved convenience for overseas tourists. Moreover, the government expects advantages, such as improved transaction transparency, leading to the prevention of tax evasion, and utilization of the payment digital data as big data. Thus, the government will provide subsidies to businesses that introduce a payment infrastructure for the QR code.

Given the results of this study, we anticipate that the introduction of QR code payments will spread on a massive scale because the benefits brought to retailers including pub restaurants will be huge. However, whether this will just be a temporary or permanent (as with China) phenomenon in Japan depends on the benefits, convenience, and degrees of added values associated with the QR code. It is therefore important to make the positive effects last as long as possible.

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Part V
MAS in Transportation Systems

Modeling a Multi-agent Self-organizing Architecture in MATSim

Youssef Inedjaren, Besma Zeddini, Mohamed Maachaoui and Jean-Pierre Barbot

Abstract The development of new information and communication technologies is contributing to the emergence of a new generation of real-time services in various fields of application. In the area of intelligent transport systems, these new services also include connected and autonomous vehicles that enable vehicles to collect and disseminate information, safety alerts and make driving smarter. In this paper, we propose a self-organizing architecture of agents and we project it on a multi-agent transport simulator (MATSim). In order to improve the performance of the Driver-Agent in the simulation, an alternative approach to score the DriverAgent plans is proposed.

Keywords Autonomous vehicles · Agent · Multi-agent system · Self-organization · MATSim · Scoring

1 Introduction

The simulation of road traffic is booming nowadays. It is increasingly used in the context of traffic management. It is proving to be an effective tool for analyzing a large number of problems that cannot be solved by analytical methods. Nowadays, simulation is considered a necessary step for people working on road development projects or flow control. The inability of road networks to meet the demands of

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an exponential number of vehicles is the main reason for problems of congestion, pollution, etc. These are real problems for the road transport system. The problems of road transport are due to the inadequate demand for the number of vehicles and the saturation capacity of the road. To mitigate these problems, the solution would be to make the road smart. Given these facts, many researchers have embarked on work to find solutions to solve this problems. A system will be called multi-agent [1] if there is more than one agent and these agents interact in the same environment. There are three types of multi-agent simulations: The macro-simulation approach involves modeling general aspects of the system such as, density, the average speed of vehicles on the road, etc. A meso-simulation is an intermediate level between the micro and the macro. In the case of road traffic, global traffic can be considered as a collective behavior of the different vehicles. Finally, a micro-simulation approach allows to model each of the vehicles with specific characteristics such as the width of the vehicle, the maximum speed allowed, etc. From these three levels of simulation that we have just presented, we retain the microscopic approach, because it adapts better to the concept of multi-agent. For the simulation, we use the traffic simulator MATSim (Multi-agent Transport Simulation) [2] that is a framework for agent-based micro-simulation. The work that we present in this paper focuses on proposing a self-organizing model with different agents with different roles each, then we try to improve the performance of the DriverAgent using a methodology for scoring that we inject in MATSim for this purpose. The paper is organized as follows: First, we propose a global architecture with three different types of agents (DriverAgent, RSU (Roadside Unit) Agent, and TrafficControlAgent). Second, we propose a self-organizing approach of agents comparing it to the literature related to agents coordination. In the second part of the paper, we present a new scoring function for MATSim, then we discuss the results of DriverAgents plans improvements, using the current and the proposed scoring function.

2 Related Work

We organize our discussion around three points: Global Architecture, Coordination approach, and scoring module in MATSim.

2.1 Global Architecture

In the literature, there are different types of cooperative architectures, like a network of wireless sensors, as in [3], where the nodes are vehicles, electromagnetic sensors, and intersection controllers, and the cooperation between these components is done mainly via the road sensors, which broadcast information about their position to the vehicles that will then be able to calculate their position and send the result to the controller, who will be able to make decisions on changing traffic lights on intersection. Another architecture to model the transportation infrastructure based on learning methods to allow vehicles to move by minimizing the waiting time at intersections by exchanging information with the traffic lights is proposed in [4]. Concerning our architecture, we built it based on cooperative systems, drawing on the researches already presented, by implementing roadside units at intersections with a central controller to manage the network.

2.2 Organization Approaches

Several research works have focused on centralized or decentralized approaches focusing on the coordination of autonomous vehicles.

In terms of security, a centralized architecture is particularly vulnerable. It offers only one gateway, its centralized controller, which is the main weakness of the entire network. An example of centralized architecture is proposed in [5], where a reservation scheme is used to control an intersection with vehicles traveling with similar speed on a single direction on each road. Each vehicle is treated as a driver agent, which request the reservation of space–time cells to cross the intersection during a particular segment of time defined between estimated arrival hour and the intersection. On the other hand, the main challenge faced in the implementation of decentralized approaches is the broadcast series on the network that can have the effect of polluting and therefore slowing the data exchange between different entities of the network. As an example, the authors in [6], designed a controller based on fuzzy logic, which permits a fully autonomous vehicle to yield to an entering vehicle in the merging zone, or to cross if it is possible and do not cause a lateral collision. The fuzzy controller controls the accelerator and brake pedals of the autonomous vehicle.

2.3 Scoring in MATSim

In our discussion on simulator features, we focus on the scoring module, that is one of the main elements of the simulation in MATSim, there are many documents already published treating this part of MATSim, such as [7] that presented and tested the performance of an alternative activity scoring function in MATSim which can be used to observe induced/suppressed demand effects. The results show that the proposed piecewise linear function represents the behavior of people on the same if not better level than the logarithmic form. Another enhancement of MATSims utility function is proposed in [8]. This paper proposes a new MATSim utility function for the performance of activities, based on an asymmetric S-shaped curve with an inflection point as presented by [9] the new function can cope with a flexible number of activities in an activity-travel schedule as it formulates an optimal activity duration by its functional form. In our proposition, the utility function is based only on the time spent while traveling, in order to improve the performance achieved by the plans generated by such new utility function.

3 Architecture of Our Model

The basic organizational structure of our system contain three types of agents having each one characteristic that distinguishes it from others: driver agent, RSU agent, traffic control agent (see Fig. 2).

3.1 Driver Agent

In literature There are two types of agents: Reactive agents and deliberative agents [10].

Our model of the driver agent (see Fig. 1) is based on a deliberative behavior. As a type of behavior that is linked to a cycle, that is to say, when an agent receives information from the environment via its sensor, it does not directly trigger an action, this information goes through a set of states, before the agent makes the decision on the consequences of his actions on the environment.

DriverAgents communicate through messages exchanged via the communication module. Each of the agents has a sensor that not only provides information on its state, but also on the state of the environment. This information is sent to the communication layer that processes it and then routes the results to the agent's memory. The module

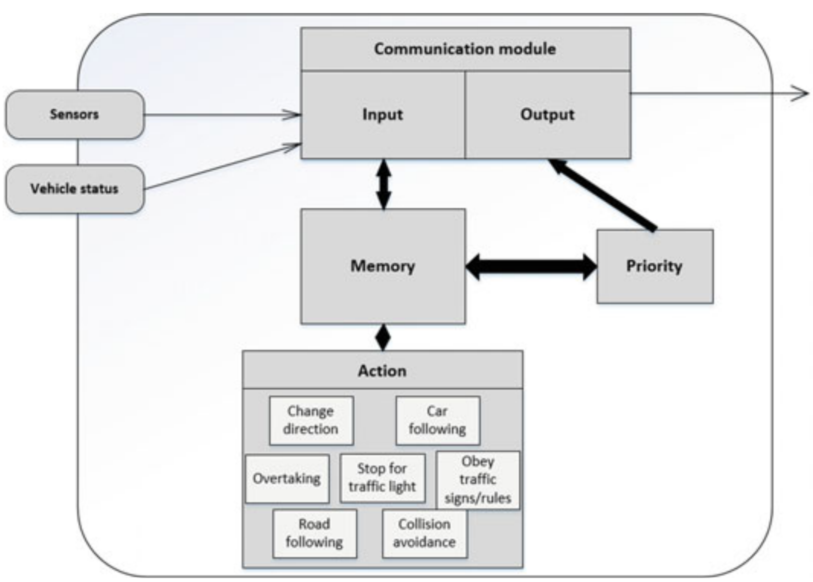

Fig. 1 DriverAgent model

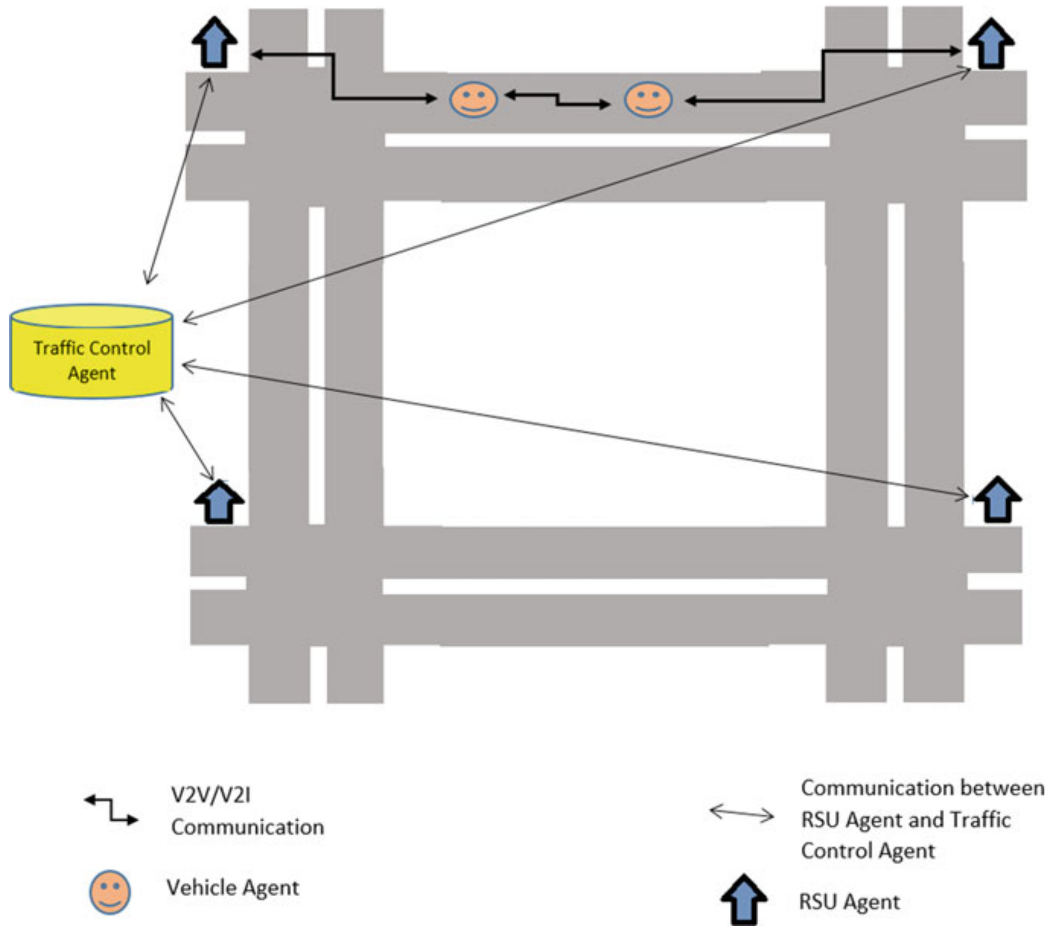

Fig. 2 Global architecture

Priority chooses the highest priority action based on the prediction of the position of other vehicles on the environment, and sends it to the communication module. This only dynamic component drives the road network. Each driver agent is equipped with sensor information allowing the agent to perceive its environment.

3.2 *RSU Agent*

This static component represents a specific point of the transport network: at each intersection, we introduce an RSU agent. It produces, in real time, information about the current state of traffic within the road segments that it manages. The RSU agent can exploit the average speeds, the time inter-vehicles to take information on the status of traffic: fluid, dense or blocked.

3.3 Traffic Control Agent

The traffic control agent collects the information on road conditions from RSU agents and then synthesizes the data. Once the traffic control agent has a more complete view of the road network, it broadcasts information to RSU agents.

4 Self-organizing Model

Self-organization [11] refers to a process where a system changes its internal organization to adapt to changes in its goals and the environment without explicit external control. Due to the dynamism and openness of contemporary agent environments and the ever-increasing distribution, complexity and dynamic changes in application requirements, understanding the mechanisms that can be used to model, assess, and engineer self-organizing behaviour in Multi-Agent Systems is an issue of major interest.

In the proposed model, a virtual environment is decomposed into partitions called cells. As shown in Fig. 3, the environment is supported by an underlying self-organizing system that consists of micro- and macro-level entities. At the micro-level, each driver agent controls a specific area (cell). The driver agent controlling an area assumes a critical role: area function management. The area function management is related to the driver agents responsibility to: (a) autonomously manage environmen-

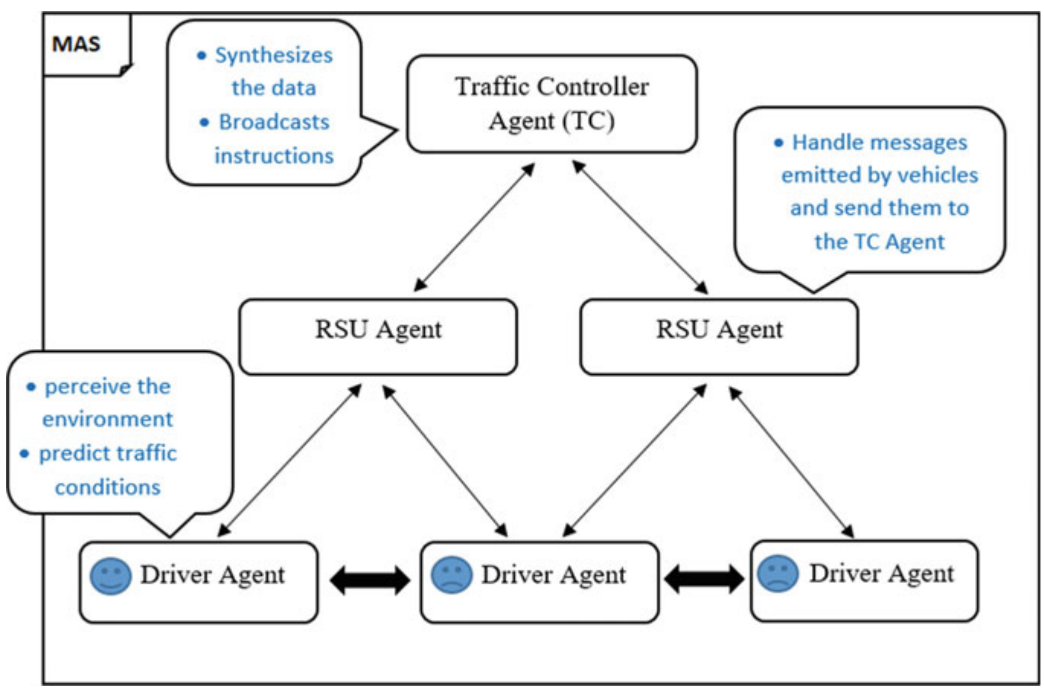

Fig. 3 Organization interactions

tal information about its controlled area; (b) be aware of the driver agents located in its defined area; and (c) inform its neighboring of propagating events. At the macro-level, the RSU agents called coordinators monitor and guide a collection of driver agents controllers. A coordinators main responsibility is to produce, in real time, information about the current state of traffic in the network. The definition of coordinators is necessary since purely decentralized organization can lead to undesired behavior and performance as we mentioned before, and because our architechture is hybrid. In the self-organizing system, interactions happen in two ways: horizontal and vertical.

Controller Interactions. A horizontal controller-to-controller interaction occurs when a Driver Agent Controller offers to merge with its neighboring controller to share information, Driver agents collaborate to monitor the road network. Indeed, they produce information contributing to knowledge in real-time traffic conditions or predict traffic conditions. All events observed by the vehicle during its movement must be transmitted to other vehicles. Depending on the neighboring controller load, this may result in merging the two cells and releasing a controller. A vertical bottom-up controller-to-coordinator (V2I) interaction occurs when a controller is overloaded and requires information about the current state of traffic within a specific road segment. All events observed by the vehicles during their movement must be transmitted to the controllers (driver agents), which transmit this message to the nearest coordinator (RSU agent). A vertical top-down coordinator-to-controller (I2V) interaction occurs when a coordinator wants to advise one of its subordinate controllers to produce alerts and inform drivers of an event occurring, he warns drivers on their way to the place of an accident for example.

Coordinator Interactions. Horizontal Controller coordinator-to-coordinator interactions occur when a coordinator (RSU Agent or Traffic Control Agent) is in need of additional information or resources in order to have a global or local vision on the traffic in the network. A vertical bottom-up coordinator-to-coordinator interaction occurs when a coordinator has already handled the messages emitted by the controllers and wants to inform its parent coordinator (Traffic Control Agent) of disruptions to normal traffic situation. A vertical top-down coordinator-to-coordinator interaction occurs when a parent coordinator has already synthesized the data collected from the coordinators and once it has a more complete view of the road network; it broadcasts information providing assistance to child coordinators (RSU Agents).

5 Extending MATsim

MATSim (Multi-Agent Transport Simulation) [12] is a framework for agent-based micro-simulations (traffic simulator). It consists of several modules that can be used independently. Reference [13] provides a detailed description of the frame. Because of its micro-agent-based approach, each individual in the system is modeled as an individual agent, and each of these agents has custom parameters such as available modes of transportation and scheduled daily activities. As the simulation framework has a modular structure, the agent's parameters can be easily extended with new parameters. MATSim tries to optimize the travel demand in large scenarios. The optimization of the travel demand is done following an evolutionary algorithm, by going through different modules (execution, scoring, and replanning) [14].

The contribution in the second section of this paper is to provide MATSim with a new scoring function in order to meet our experimental needs. In this section, we describe the modifications that have been introduced in the simulator.

5.1 Scoring

As a result of the traffic flow simulation, MATSim events are produced to calculate the effective utility of each daily plan, taking into account the effects of interaction between agents. A good daily plan is specified by a utility function. MATSim currently uses an effective utility function described in [15]. The elements of the utility function are

- A positive contribution for performing an activity.
- A negative contribution (penalty) for traveling.
- A negative contribution for being late.

As long as we work on autonomous vehicles, our main goal is to ensure users safety and to save his money, that's why we must avoid possible congestions, and subsequently the loss of time and money. That's why, we propose the custom scoring function (1) below:

$$U_{plan} = \sum_{i=1}^{n} (u_{travel,i}) \tag{1}$$

where n is the number of activities an agent has in his daily plan. In general, traveling decreases the score (negative utility).

$$U_{travel,i} = \alpha_{mode} + \beta_{TT,mode}.TT + \beta_{cost,mode}.Dist + \beta_{CongT}.CongT \tag{2}$$

where α_{mode} is a constant depends on the mode used (car, bike, bus...), $\beta_{TT,mode}$ is the marginal utility of traveling, $\beta_{cost,mode}$ is the marginal utility of cost for the specific mode, β_{CongT} is the marginal utility of the congestion.

The novelty is that our new scoring function depends only on the utility of traveling (1), so we overlook the utility of exercising an activity. Then, we add a new factor inside the utility of traveling formula (2), a factor that reacts on driver agents who enter a link and find it with a level of congestion bigger than a fixed threshold (3). The Algorithm 1 illustrates the congestion engine injected in MATSim.

structure *CongestionEngine* {
eventsManager : EventsManager;
procedure *handleEvent (event : LinkEnterEvent)*
if *(Congestion ( ) = true)* **then**
| EventsManager.processEvent(CongestionEvent);
end
endProcedure
function *Congestion ( ) : Boolean ;*
if $(Road.carsOnTheRoad.size() >= Road.maxNumberOfCarsOnRoad)$ **then**
return true;
else
return false;
end
endFunction
}

Algorithm 1: Congestion engine

5.2 Case Study

Berlin Example We execute the simulation using MATSim, and we apply it on the example of Berlin [16]. For each simulation on MATSim, you need at least three types of files: configuration file, network file, and population file. So to run the simulation we load the configuration file directly, the latter which will contain the path to the network file and the population file. Regarding the population file, the number of agents in this example is 15931. We execute the simulation twice: The first results were with the current scoring function of MATSim, while the second results were with the new scoring function.

Results At the end of all iterations, we analyze the output plans file, we extract the results and we represent them on a histogram (see Fig. 4) with agents on the abscissa and the number of replannings done for each agent as ordinates. So, after the analysis, we found out that more replannings are done with the new scoring function, which means that the plans generated by our utility function are more improved in terms of the time spent while traveling. Moreover, the more replannings are done at each

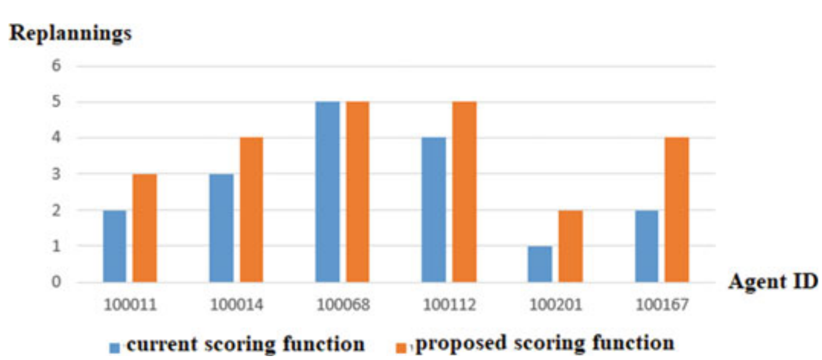

Fig. 4 The effect of the new scoring function on agents plans improvement

execution, the more optimization and a better itinerary are calculated in order to gain a better score, which impacts positively the performance of a given plan. So, the new scoring methodology that we propose is more effective, especially with congestion scenarios.

6 Conclusion

The main goal of this paper was to propose an architecture of agents (Driver agent, RSU agent, Traffic control agent) to model the transportation system, then project it on a traffic simulator to run the simulation where we can observe and optimize the routes and the time spent traveling by the DriverAgent. For that, we use a special traffic simulator called MATSim. Our addition to the simulator is to propose an alternative scoring function which can be used to observe induced congestion effects. Future works will be headed to propose a platform that represents communications between a wide range of autonomous transport systems, and to deploy a large number of scenarios highlighting the vulnerabilities of autonomous transport systems, particularly in a context with a large number of interactions between vehicles in real traffic situation.

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Coupling Multi-agent and Macroscopic Simulators of Traffic

Xavier Boulet, Mahdi Zargayouna, Gérard Scemama and Fabien Leurent

Abstract Traffic simulations exist in multiple scales and each of these scales presents some advantages and is useful in certain contexts. Usually, multi-agent simulations use more detailed models and give more precise results than macroscopic models but their high calculation cost does not allow them to simulate very big areas such as an entire region. To overcome these limitations, multiscale simulations emerged with the coupling of two or more simulations of different scales. This paper presents a generic solution to combine a macroscopic simulator working on a large area, which contains a smaller area simulated by a multi-agent simulator. The main challenge is to assure the coherence between both simulators on the smallest area since it is simulated by both simulators at the same time. We first highlight the issues to tackle and the problems to solve when coupling two existing simulators, then we propose solutions for the coupling, and finally evaluate them on an example scenario.

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1 Introduction

To understand the mobility problems in a local area, such as traffic congestion or public transport overcrowding and to propose an efficient mobility policy, simulation is a necessary tool to bring the best solution before impacting the real traffic. However, simulating the only zone of interest is myopic and simulations should consider the surrounding areas, which can influence the behavior of the local area. Conversely, a policy change on the local area would have consequences on the rest on the multimodal transportation network. In our use case, we consider an area of interest inside a large city where we desire to manage the multimodal traffic and propose new ways of mobility which imply a change of transportation supply during the simulation. To do so, we simulate both the area of interest and the larger city at different scales at the same time in order to predict abnormal flows of travelers travelling by the area of interest especially in the case of a disruption of public transport in another part of the city. This is why we are interested in multiscale simulations: to allow the simulation of different point of views of a phenomenon with at least two simulators of different scales working in interaction.

This paper is structured as follows. In Sect. 2, we present related studies and existing software for multiscale simulation between a macroscopic model and a multi-agent model. In Sect. 3, we define our precise context and present a specification of the middleware that we propose. In Sect. 4, we present our experimental results before to conclude the paper.

2 Related Work

There are many existing simulations combining a microscopic or multi-agent model with a macroscopic one. For instance, [1] proposes a dynamic traffic model focusing on the visualization, without bidirectional exchange between the macroscopic and the microscopic representation. It allows to zoom on any part of the macroscopic simulation and to see it with a multi-agent model. Reference [2] instead decomposes the network into microscopic and macroscopic clusters that exchange data, these clustering can change during the simulation to follow a phenomenon like a shockwave. These two examples concern the combination of two models inside the same simulator but there are other works about coupling two different simulators. One of the first coupling between two simulators of different scales is in [3, 4] with the microscopic traffic simulator PELOPS and the macroscopic simulator SIMONE where they have to solve problems like the difference between time steps of the simulators and how to generate the mobility behavior of travelers with the distribution of time gaps and speed fluctuations for the microscopic model. MICMAC [5] proposes the coupling of the microscopic model SITRA B+ and the macroscopic one SIMRES. Hystra [6] is focused on the coherence between both models and defines the conditions that they have to verify to be able to work together.

All of these works are focusing on two specific existing models, which are used to simulate the same area. In this paper, we propose to focus on the use case of a small area simulated with a multi-agent simulator inside a larger area simulated with a macroscopic model. We do not constrain both models and we try to propose a generic approach to this case to be able to use any already existing simulator (e.g., SM4T [7, 8]). So, instead of modifying the used models to be coherent together, we insert a middleware between them that handles the exchanged data and the synchronization between simulations.

3 Middleware for Coupling Traffic Simulations

3.1 Context

As we explained in the introduction, both simulators interact together to have every advantage of the two scales of simulation. The macroscopic simulator works on the bigger area which represents the region and the multi-agent system works on a smaller area included in the first, which represents the neighborhood (Fig. 1).

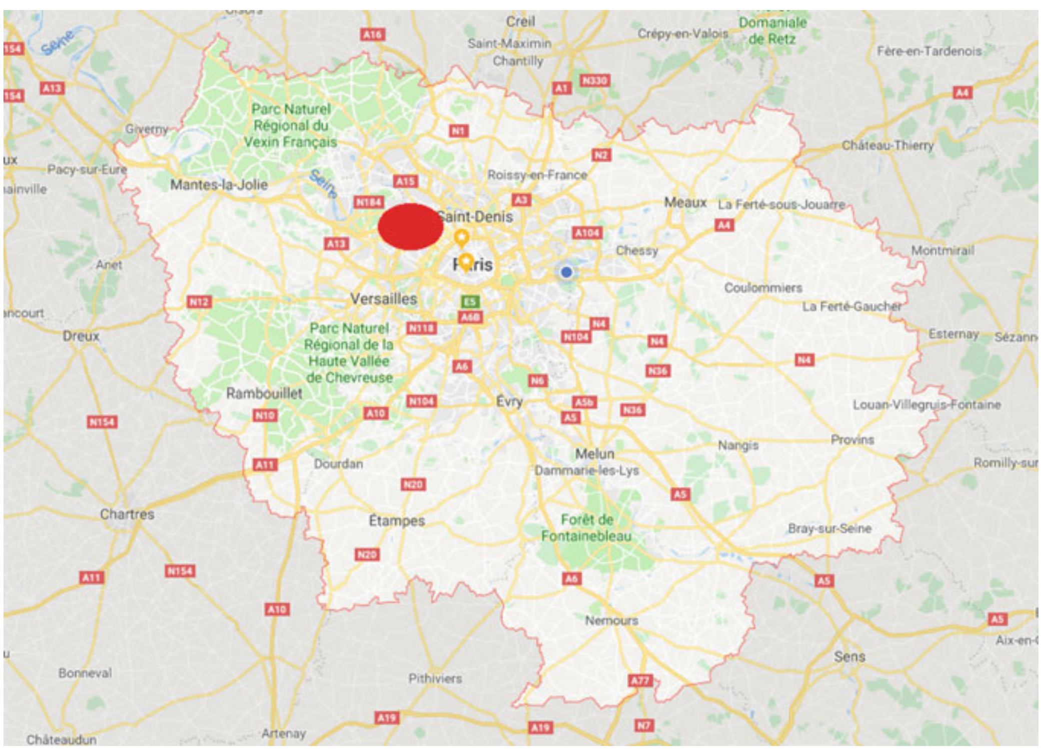


Fig. 1 Multiscale simulation of the region (in red the local simulation zone)

Both simulators can work independently, they have their own demand represented by time-dependant origin–destination matrix, their own way to assign the travelers on their network and their own behavior model to calculate the speeds of their travelers.

Even if they can be executed independently, we need both simulations to be coherent when they are used together. For instance, if we observe a congested road in the macroscopic simulator, we should observe the same congestion at the same time in the local simulator. To ensure this coherence, we consider three possible corrections of the simulators:

– The correction of the demand. The demand is usually made of the origin–destination matrix of the area of interest. The designer has to decide which simulation comprises the most correct information and should therefore correct the other. The regional simulator usually has a more complete view of the demand. Indeed, mobility surveys usually concern a regional scale. However, if a more precise study of the demand has been made for the area of interest for the local simulator, then the local simulation should correct the macroscopic simulation.
– The correction of the travelers' itineraries. Travelers itineraries are the result of the assignment model of the considered simulation. Simulations might not use the same assignment mode, and the designer has to define which one should correct the other.
– The correction to the travelers' movements. Travelers' movements define their speeds and travel times. The simulators have possibly different models for travelers movements, the designer has to decide which model should correct the other.

These three corrections are necessary to be able to observe the same phenomena of congestion, delay, path changing, etc., in both simulators.

The first step is then to chose which simulator will correct what. If only one simulator corrects everything, then we don't need two simulators in interaction, the correcting one can be used alone, then his results can be used by the second simulator that will be run alone in the second time. In our use case, we consider that the macroscopic simulator is used to bring a demand that has already been assigned to the multi-agent simulator and the latest will correct the behavior of the travelers.

3.2 The Middleware

The three types of scale that we consider for the middleware are: the entities representation, the spatial representation, and the time step.

– The representation of mobile entities: The macroscopic models work with flows of travelers, whereas, the multi-agent simulator represents travelers individually.
– The spatial representation: Macroscopic simulators represent the transport network in a simplified way. The network is often aggregated and some links can be deleted to optimize computational cost [9]. The more detailed models use bidimensional layers with grid cellular automata model [10] or continuous space [11].

– The time step: A regional assignment works with aggregated period of time (15 mn, 30 mn, 60 mn, etc.) while a microscopic simulation usually considers a few seconds time steps.

In our case, we consider that the macroscopic simulator works with flows on travelers, on an aggregated network and a time step of 10 mn. The multi-agent simulator works with agents representing individual travelers, on a more detailed network (more roads and intersections) and with a time step of 1 mn.

We consider that the multi-agent simulation corrects travelers' movements while the macroscopic simulation corrects the demand and the travelers' assignments.

The middleware has to manage the correction while coordinating the two simulators with different time steps, different entities representation and different movement model.

3.3 *Synchronizing the Simulators*

The middleware becomes the scheduler of the multiscale simulation. It launches simulator to execute a time step, retrieves the dynamic simulation data and can block both simulations until the data that they need are available.

At each time step, the multi-agent simulator has to be fed with the demand and the assignment from the macroscopic simulator, and at each time step the macroscopic simulator has to been fed with the links speed of the multi-agent simulator (Fig. 2).

At this point, the designer faces a deadlock situation: each simulator needs the other to be executed first to be corrected. We have two choices:

– We either correct the demand and the assignment for time step 1 (TS1), then we execute (TS1, ..., TS5) and we will be able to bring the average of the movement behavior calculated during (TS1, ..., TS5) and feed it to the macroscopic simulator.
– Or we correct the demand and the assignment for TS1, we execute TS1 and we use the movement behavior calculated in TS1 to correct the macroscopic time step 1, then we run the macroscopic time step 1 and we will be able to correct the demand and the assignment for every multi-agent simulation time step (TS1, ..., TS5).

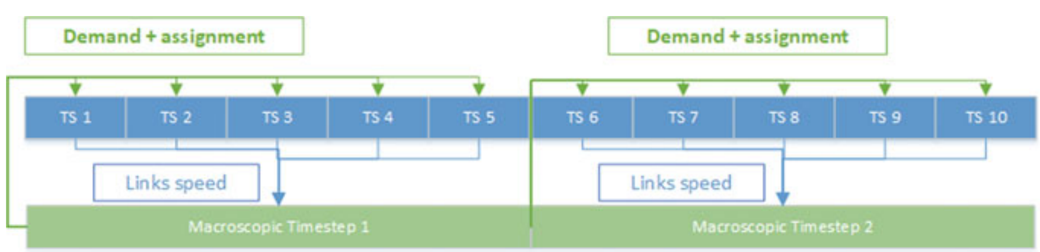


Fig. 2 Parallel execution of two simulators

In the first case, the multi-agent simulator does not receive the travelers from the macroscopic simulator until TS6 and instead of having a small input on every time step, we will have a huge input every five time steps so the correction of the demand will be incorrect. In the second case, the macroscopic time step 1 will only be corrected with the links speed from TS1, so if there is a huge congestion at TS2 it will not be taken in account in the macroscopic simulator until his second time step so the correction of the behavior will be incorrect.

Our proposed solution is to introduce a rollback for the macroscopic simulator:

– We correct the demand and the assignment for TS1 and run TS1.
– We correct the movement behavior for the macroscopic time step 1 and we run it.
– We correct the demand and the assignment for TS2 and run TS2 thanks to macroscopic results.
– We correct the macroscopic time step 1 with an average speed of TS1 and TS2.
– etc..

3.4 Transformation Between Agents and Flows

In this part, we focus on the demand correction between both simulators. Whenever travelers in the macroscopic simulator enter in the area of interest, they need to be created in the multi-agent simulator but we have two different representations of our travelers since there are flows in the macroscopic model and we want new agents.

Reference [1] presents how to change the traveler's representation between flows and agents dynamically inside a single simulator. Even if this is not our case, the same transformations can be made between two simulators to obtain the right representation of the travelers. The easiest part is the transformation from agents to flows since it corresponds to the calculation of the average density and speed. If the aggregation of information is straightforward with averaging functions, the reciprocal transformation, from flows to agents, needs the creation of new information. Reference [1] presents a method based on gaz cinetic theory. It consists of creating agents at position in a probabilistic way. So when travelers enter the area of interest, they can be created and divided on their link of arrival.

3.5 Correction of Assignment and Behavior on Different Network Representation

Our last focus is on the difference between the networks used by both simulators. When the simulated area is large enough, the network can be aggregated in order to speed up the simulation [12].

Figure 3 shows an example of a network with an aggregated representation (left) and a detailed one (right). We consider that every node of the aggregated represen-

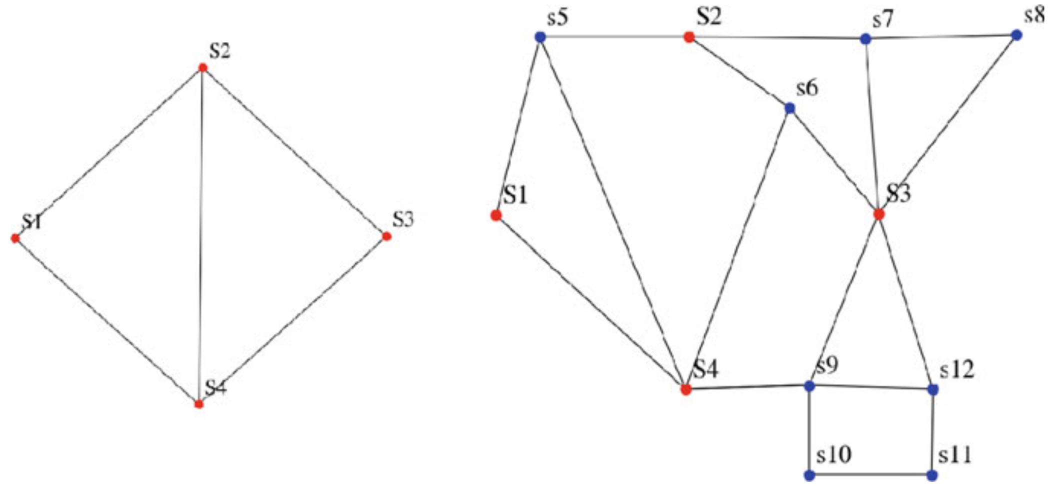


Fig. 3 Two different representations of the same network

tation can be found in the detailed one since a node usually represents an existing physical place and if this place is present in the macroscopic simulator, it will necessarily be in the most detailed one too. This is not the case for the links since in the aggregation process new links can be created between nodes even if these links are not existent physical roads, they can be the aggregation of some existing links. Our goal is to determine how to correct the assignment and the movement behavior despite this difference.

For the assignment, the first step is to find for every link in the macroscopic network, every path corresponding in the detailed network. For every couple (S_i, S_j) in the macroscopic network, we have to find every path with S_i as origin and S_j as destination such as no other macroscopic node belongs to this path. Here is an example in the following figure: The link (S_2, S_4) corresponds to the paths (S_2, s_5, S_4) and (S_2, s_6, S_4) (Fig. 4).

Then, we know that every traveler passing by the link (S_2, S_4) will pass on one of the two corresponding paths. From there, the assignment model of the multi-agent simulator will determine which path they have to take and it will assign them. So, the correction of the assignment from the macroscopic simulator to the multi-agent simulator is, in fact, an assignment made by the multi-agent simulator constrained by the assignment of the macroscopic one.

Finally, we need to correct the movement behavior from the multi-agent simulator to the macroscopic one. To do so we will once again use the macroscopic links and their corresponding detailed path. But some incoherence is inevitable as we can see in the Fig. 5.

Two paths with different time travel can be aggregated into the same macroscopic link. In this case, the travelers taking these different paths will have the same speed on the macroscopic simulator but not in the multi-agent simulation. We chose to give the macroscopic link a travel time corresponding to the weighted average of the microscopic path time travel, the weight being the number of travelers on each path.

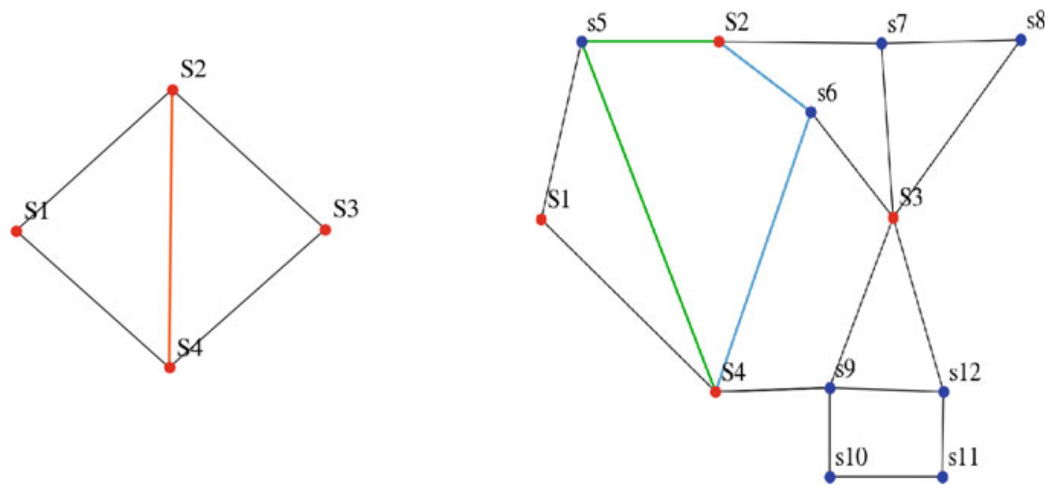
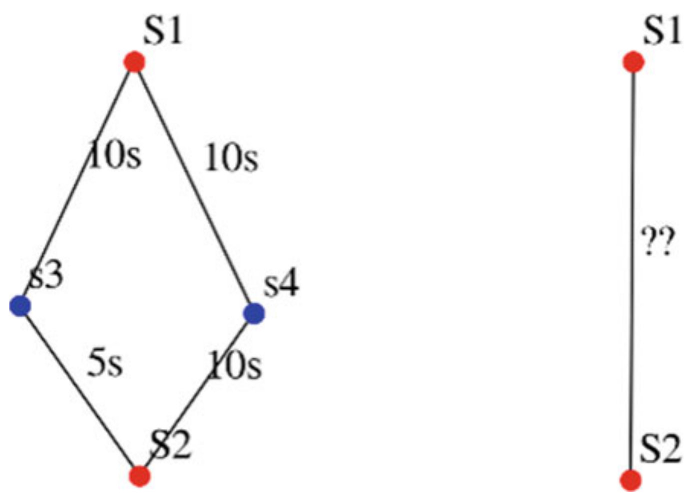


Fig. 4 Highlight of the paths corresponding to a macroscopic link

Fig. 5 Correction of the macroscopic link speed



4 Experiments

To validate the proposed middleware, we implemented two simulators and used our middleware to make them work together. The macroscopic simulator works with flows on travelers, on an aggregated network and a time step of 10 mn. The multi-agent simulator works with agents representing individual travelers, on a more detailed network and with a time step of 1 mn. The macroscopic simulator assigns flows of travelers always on the shortest path from their origin to their destination based on these paths travel time during the last time step, the multi-agent simulator assigns travelers using a K-shortest path algorithm so two travelers with the same origin and destination do not always take the same path. The multi-agent simulator uses a fundamental diagram to determine the speed on the links so they are slowed down when there are too many travelers. Finally, the demand used for this simulation is almost constant and low during most of the simulation with a peak corresponding to a rush hour.

We looked at the difference of travel time during their entire journey in the area of interest between the flows of travelers in the macroscopic simulator and the traveler agents created from these flows. These agents can be as much as 10% slower or faster than the corresponding flows. This difference is minimized by our choice of correcting macroscopic links speed with a weighted average of the microscopic path time travel and obviously, these numbers depend on the way the aggregated network has been constructed compared to the detailed one.

We then focused on the peak of demand which created some congestion and slowed down many links of the area as expected. Our objective was to see if the macroscopic links slowed down by the movement correction had an increase of their number of travelers at the same time. Once again, it depends a lot on the network, but every macroscopic link slowed down by the correction saw the planned increase of travelers corresponding to the congestion, in some cases, one or two time steps later.

These results suggest that the middleware is working well in this sample scenario, and performs the needed corrections between simulations running at different scales.

5 Conclusion

In this paper, we tackle the problem of multiscale simulation, and adopt a middleware-based solution. The idea is to reuse existent simulators and add a third part: the middleware. We have presented the problems faced during the coupling of simulations working at different scales, and provided a specification of the middleware. The experimental results on a sample scenario suggest that this solution is a relevant one, and provides the right corrections between the two simulations. In our future works, we plan to generalize the middleware model for any type of simulations, and to implement a real-world middleware working on two real operational simulations.

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A Multi-agent System for Real-Time Ride Sharing in Congested Networks

Negin Alisoltani, Mahdi Zargayouna and Ludovic Leclercq

Abstract Sharing rides can be an effective solution for traffic management in populated urban areas. Real-time ride sharing is a dynamic and complex optimization problem. Indeed, the problem data are not known a priori in a dynamic context. However, most of the approaches in the literature consider that the missing data concerns the travelers, which are revealed online. Very few consider traffic changes during optimization or execution. More precisely, they assume that the predicted travel times used during optimization remain the same when executing the vehicle schedule, which is usually not the case in practice. In this paper, we propose a multi-agent system to solve the real-time ride-sharing problem. In this system, two models are defined to deal with dynamic traffic conditions. On the one side, the currently observed average speed in the network is used to predict travel times when calculating the optimal schedule for the ride-sharing fleet. On the other side, the traffic situation is updated every 10 s using a simulator as the plant model to represent the real traffic dynamics. The experimental results with real data on the city of Lyon show that the proposed multi-agent system is efficient in terms of congestion reduction, especially during peak hours and if sufficient rides are shared. The system can also reduce the provider's cost with a small increase in passengers waiting time and travel time.

Keywords Real-time ride sharing · Multi-agent system · Simulation · Optimization · Network congestion

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1 Introduction

In recent years, intelligent transportation systems made it possible for operators to adapt in real time the transportation supply to travel demand via new mobility services. Among these services, ride sharing is becoming popular [1]. Ride sharing is a transportation mode in which passengers can share a car and travel costs. Dynamic ride sharing refers to a system which supports an automatic ride-matching process between participants on very short notice or even en route [2]. The dynamic ride-sharing problem involves two subproblems:

(1) How to serve the demand and to manage a fleet of vehicles and (2) How to accurately predict the travel times to determine vehicles availability and pickup/drop-off times.

The first subproblem is complex and has attracted a great number of research proposals. Satisfying both passengers and providers constraints, maximizing the number of served passengers, online assignment for a huge number of requests in large-scale problems and other challenging goals make this problem very interesting. This subproblem is corresponding to a fleet management optimization problem with multiple objectives [3]. One of the main challenging parts of dynamic ride-sharing problems is the automated matching process that should take place very fast. In the literature, the optimal assignment is formulated as an integer linear programming problem, and then different approaches are taken to optimize the problem. In this research, we propose a multi-agent system solving the mathematical problem and giving the optimal assignment in a few minutes for the considered area. The algorithm searches for the matches between riders just in the feasible area for each passenger. Then, the matching between two travelers is possible only if their feasible areas have an intersection. This method narrows the exploration of the space to feasible states only. As the number of assigned passengers increases for a car, the intersection of feasible areas gets smaller and the algorithm can compute the assignment of the current fleet of cars. New cars are added if necessary to serve the residual demand.

The second subproblem is less studied in the literature but it is very important for real-world operations. Network congestion can have significant impacts on the ride-sharing service. The optimization system of the ride-sharing service uses estimates for the predicted travel time coming from a "prediction model". When the rides are realized, a gap can exist between the estimation and the real traffic condition, that is represented by the "plant model". This gap may require dynamic adjustment of the initial assignment to fit with the observed conditions. When simulating a dynamic ride-sharing service, it is important to properly distinguish the prediction and the plant model to ensure that we are not overconfident in our travel time prediction.

In most of the researches, including multi-agent proposals, the plant model and the prediction model coincide [4–6]. However, there are a few researches that do consider traffic conditions on ride sharing. Goel et al. [4] for instance propose an approach where the pickup and drop-off locations for passengers are selected from a fixed set. They consider an overhead randomly chosen of 10–20 percent to reflect different traffic conditions when computing the end time for a driver. Even with this consideration, the authors just use the prediction model and assume that the travel times during the assignment process stay the same during the execution of the vehicle schedules. In some researches, only the plant model is considered. In [5, 7, 8] for instance, the authors use a simulator to assess the dynamic ride sharing but it is not the optimal matching. Other works use only static travel times in the optimization process [9, 10].

In this research, we present a multi-agent based solution to the real-time ride-sharing problem. In our method, we define the plant model that is different from the prediction model to assess the impact of traffic conditions on the dynamic ride-sharing system performance for large-scale problems. The considered prediction model is based on the last observed travel times, while the considered plant model is a trip-based Macroscopic Fundamental Diagram (MFD) model which is able to reproduce the time evolution of average traffic conditions for a full road network [11, 12].

2 Multi-agent System

The multi-agent system model is composed of a passenger agent, an optimizer agent, and an operator agent. The passenger agents send their requests to the optimizer agent who computes the optimal routes for all the received requests and sends the schedule to the passenger, and then to the operator agents. Each operator agent manages its own fleet of cars. The optimizer agent also informs the passenger agent about the car that is going to serve him. The main components of the system are shown in Fig. 1. The passenger agents are avatars of human travelers and the operator agents are avatars of existing operators. The optimizer agent is an artificial entity, mainly responsible for the system calculations.

To assign optimal routes to the cars, the system has two main parts. The fleet management part deals with the matching process between riders and assigning the optimized match of riders to the vehicles. Then in the simulation part, we see

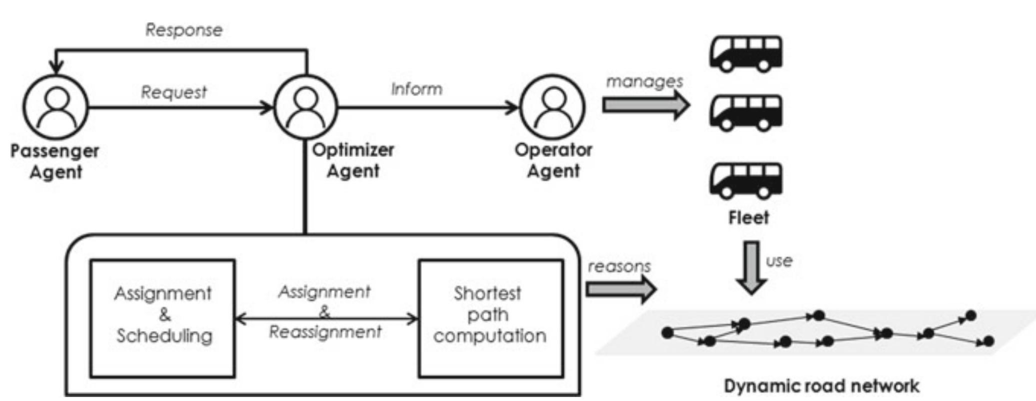

Fig. 1 Multi-agent system

how the optimal car schedule is realized considering the complete dynamic traffic conditions. Optimization is performed every 10 min based on the prediction model while the simulation is working based on the plant model and is updated every 10 s.

2.1 Optimization Problem Design for Dynamic Ride Sharing

The main characteristics of the system we designed are described as follows:

1. Demand characteristics:
   - Real-time door-to-door ride sharing (the passenger gets service at the exact defined origin and destination).
   - Passengers determine origin and destination.
   - Passengers determine the number of requested seats that can then be more than one.
   - Passengers define the earliest time for picking up from the origin and the latest time for dropping off at the destination. The total travel time for the passenger, including waiting time, time for picking up, trip time and time for dropping off should be in this time window.
   - Each passenger defines a number to restrict the sharing. We call it "number of sharing". This number puts limitations on the number of passengers that can be in the same car at the same time. So the service has to satisfy the number of sharing constraint for all the passengers that are on the same trip.
   - Detours are possible but with limitations. The maximal detour constraint is defined to avoid a large increase in total travel distance.
   - A request has an origin, a destination, a time window, a number of seats and a number of sharing.
   - A service time is added to each trip to reflect the time to stop, getting in and out of the car.
2. Service characteristics:
   - In this research, the ride provider has a fleet of autonomous cars. The fleet should provide a response to the requests in seconds.
   - The service is provided by a number of autonomous cars that are initially all in the same depot. Local depots are uniformly distributed over the network to represent locations where cars can wait for further assignments. A new car is generated from the central depot if only no existing en route car or local depots car can serve the current demand. Note that after serving the assigned passengers, cars go to the nearest local depot. As the system receives a request, the assignment algorithm tries to match the new requests to the en route car schedules by satisfying time window, number of sharing, and detour constraints. If there is no possible choice, the algorithm finds the optimized schedules to be assigned to the new empty cars waiting in the depots.

– The optimization process is performed every optimization time horizon by the optimizer agent (10 min) and the network conditions have straight impacts on the assignment as the congestion changes the vehicles speed and travel time. The optimal cars schedules are determined every 10 min for all the requests for the next time interval.

We have defined a behavior for the optimizer agent that finds the optimized schedule for the autonomous cars. The agent solves a constrained optimization problem to minimize the total travel time and distance for vehicles and the total travel time and waiting time for passengers. The constraint functions in the problem are on capacity, time window, number of sharing and the quality of service. The optimized solution for the model will be sent as the schedule to the fleet. Then the assigned cars leave their location or take a detour to serve the new demands. Recall here that the optimization problem is solved with predicted travel time but then the simulation of the vehicle operation is matched with another model with a more refined and up-to-date description of the system dynamics: the plant model.

2.2 Solution Methods

To solve the optimization problem efficiently, we could refer to heuristic methods but we notice that a proper exploitation of the constraints can help to narrow the search of feasible solutions even if the size of the space is very large. This is why we design our own solution method based on the classical branch and bound algorithm but with specific properties to fit with fleet management problem.

The algorithm performs in two parts. In the beginning, when there is no en route vehicle, the first part of the algorithm builds a tree of routes and tries to add feasible points to the best branch of the tree at each step. The feasibility of points is checked with respect to the model constraints. A destination point can be added if and only if its origin has been added to the route before. When the algorithm finds a feasible point for a route, it makes a new route by adding this feasible point and put it in the previous routes set. In the following, the branches that cannot satisfy any of the model constraints will be removed from the tree. In the end, the best route is the route that has a minimum objective function. Then, if there are en route cars in the system, when receiving new demands, the second part of the algorithm starts to work. It checks the vehicles schedule remaining points to find the routes that can still be feasible after adding a new demand to them. If the algorithm finds any feasible route, then it adds the new demand to the route and if there is more than one feasible route, it adds the demand to the route that leads to the minimum increase of the objective function. But if it can not find such a feasible route, in the first part of the algorithm it assigns the optimal branch (as explained before) to an empty car which is waiting in the nearest depot.

Figure 2 shows a small example of the algorithm functioning.

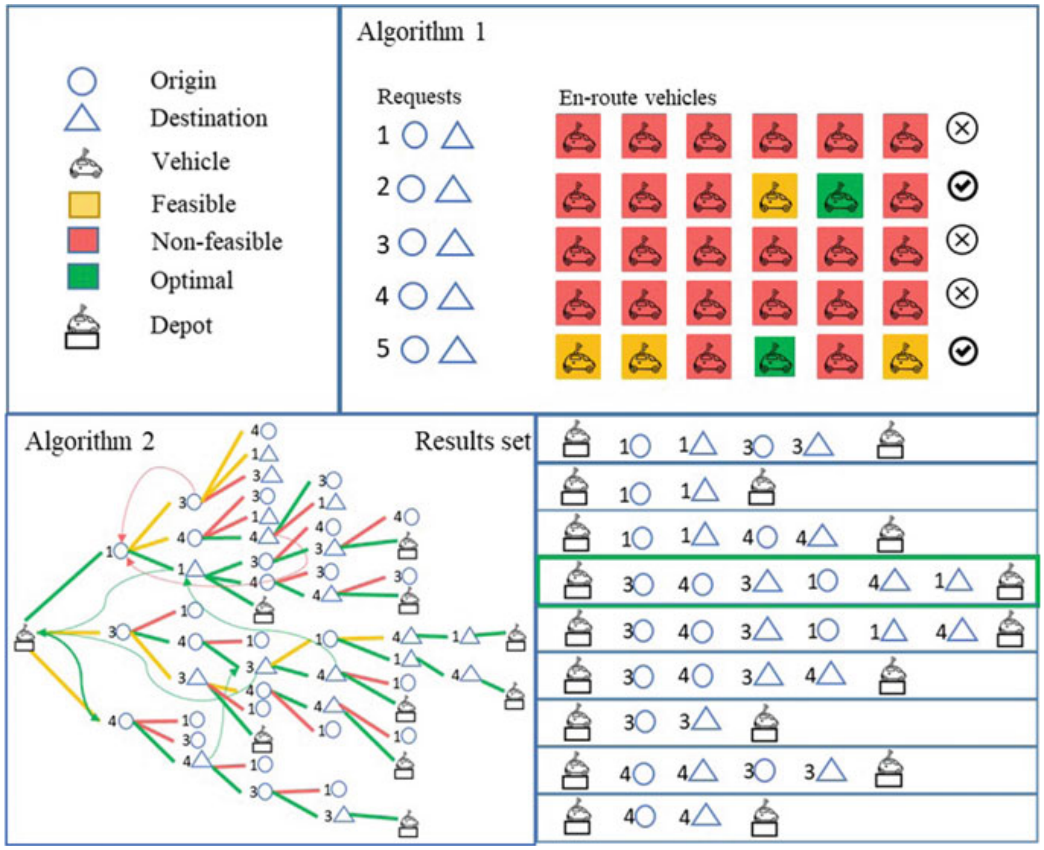

Fig. 2 Optimization algorithm

3 Simulation Models

A simulation platform is used as the plant model to simulate the function of the dynamic ride-sharing cars and personal cars that are in the network at the same time. This simulator is able to simulate the time evolution of traffic flows on the road network. In this research, we use the trip-based MFD [13] to accommodate individual trips while keeping a very simple description of traffic dynamics. The general principle of this approach is to derive the inflow and outflow curves noting that the travel distance L by a driver entering at time $t - T(t)$ when $n(t)$ is the number of en route vehicles at time t and the average speed of travelers is $V(n(t))$ at every time t, should satisfy the following equation:

$$L = \int_{t-T(t)}^{t} V(n(s))ds \tag{1}$$

In our research, the state of all the vehicles is available for the system at every time t. The cars can have two situations. They are waiting in depots for new passengers or they are servicing the assigned passengers. In addition to the shared cars that are circulating to serve the passengers, there are other cars that are serving the rides that are not shared in the network. So the accumulation at each time t is the summation of the number of shared autonomous cars and number of what we call personal cars in the system. Therefore, at each time t the average speed of travelers can be computed. Both shared trips and non-shared or personal trips can pass the length in a time period, based on the currently observed average speed at that time. We use this principle in our plant model which is described in the next section.

At each simulation time step, the simulator computes the current speed of the cars considering the current traffic situation (the number of en-route vehicles). Then the vehicle can cover a distance based on the current speed, every simulation time step. So we update the situation of cars every time step, with computing the speed on time. The simulation time step that we use in our plant model is 10 s. So, the state of en route cars is updated every 10 s.

To make travel time prediction during optimization, we predict the traffic situation for the next optimization time horizon (every 10 min) and we assign the passengers to the cars based on this prediction. So at each optimization time horizon, the direct travel time from each point i to j is computed based on the current average speed and the shortest path between two points, for the next 10 min. Then the optimization algorithm assigns all the requests for the next 10 min to the en route cars or empty waiting cars.

4 Results

In the proposed research, we use a realistic O-D trip matrix for the city of Lyon in France. The network is loaded with travelers of all ODs with given departure time in order to represent 4 h of the network with more than 62000 requests based on the study of [14]. This network has 1,883 nodes and 3383 links. The area is shown in Fig. 3. The origins set contains 94 points and the destinations set contains 227 points on the network. We do the experiments for the morning peak hour from 6:30 AM to 10:30 AM for 4 h. The trips number during this time period is 62450. 23 different scenarios are defined with number of sharing 0, 1, 2, and 3,[1] market shares 20, 60, and 100%[2,3] two intervals for pickup and drop-off time window (5 and 10 min). Here, we put a part of results to show the system performance.

Table 1 shows the cars travel time and number of cars for different numbers of sharing when the market share is 100 percent comparing with the case that all the trips are done with personal cars. Results show that with sharing, the number of cars

[1]Number of sharing 0 means that the car serves just one passenger without sharing like traditional taxi services, number of sharing 1 means that it is possible to share the passengers trip with one other passenger, and so on.

[2]Market share shows the percentage of trips that are using the sharing service.

[3]Only the trips that are fully inside the studied area are considered as candidates for the service. So, the market share of 100% corresponds to 22% of all trips.

Table 1 Simulations results for market share = 100%

Sharing properties		Simulation results					
Market rate	Number of sharing	Total travel time for shared cars (h)	Total travel time for personal cars (h)	Total travel time for all cars (h)	Number of shared cars	Number of personal cars	Total number of cars
0	0	0	10756	10756	0	62450	62450
100	0	1557	9480	11037	10138	51215	61353
	1	1331	9386	10717	5433	51215	56648
	2	1291	9356	10647	4327	51215	55542
	3	1274	9345	10619	3833	51215	55048

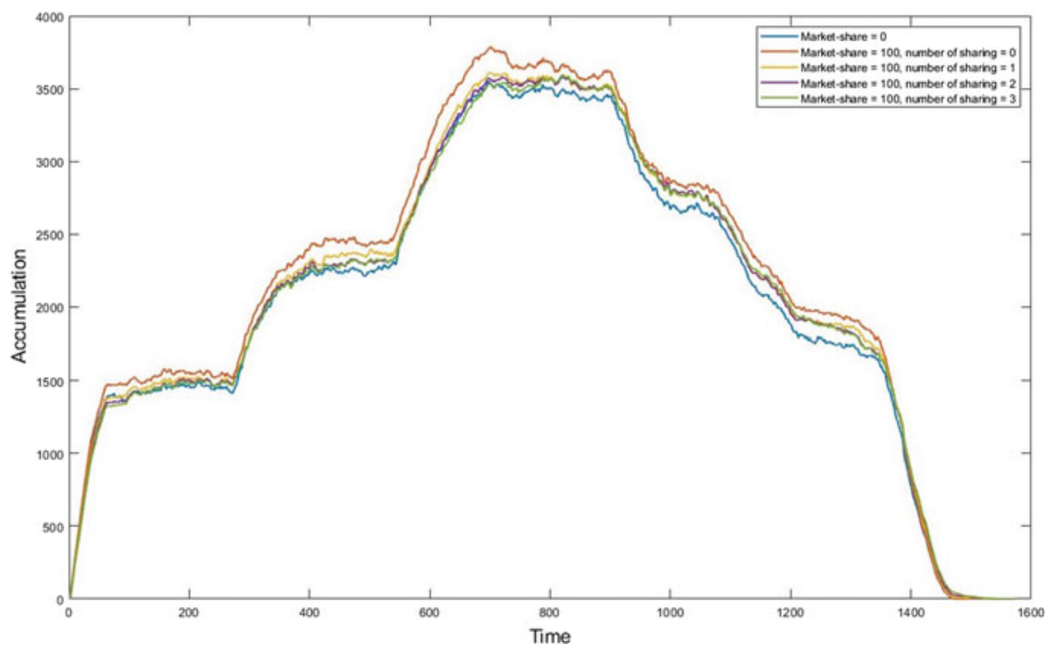

Fig. 3 Cars accumulation for different market shares

and total travel time is less than the case without sharing or even the case with zero market rate.

When all the internal trips are served with service cars without any sharing, the number of needed service cars is 10138 and the total travel time for shared trips is 1557 h. But then with sharing the ride between just two travelers, the number of needed cars decreases to 5433 (the optimization algorithm defines the number of needed cars) and the total travel time is 1331 h. It means that with almost half number of cars, the travel time is 226 h less than before. With applying more sharing, the number of needed cars and the total travel time decrease then for number of sharing 2 and 3, our proposed ride-sharing system works even better than the situation that all the trips are done with personal cars. It should be mentioned that the increase in passengers travel time and waiting time is negligible compared to the service improvements in our results.

Figure 3 shows the accumulation of cars in the network for different number of sharing compared with the case that all the trips are done with private cars. When a fraction of trips are served with service cars, the distance increases (because the car should also pass the distance between the waiting point and the origin and also the distance between the destination to the next waiting point) so the accumulation of cars moving in the system increases. But when we share the trips and increase the number of sharing, the accumulation of cars decreases and we have better traffic condition and less cars moving in the network. The results also show that for medium-scale network, the sharing cannot improve the congestion comparing with the case that we have just private cars in the network.

5 Conclusion

We defined two models to deal with dynamic traffic conditions in our proposed multi-agent real-time ride-sharing system. Current mean speed in the network is used over the next 10 min to predict travel times when calculating the optimal schedule for the cars. Then, cars travels are simulated and the traffic situation is updated every 10 s using a trip-based MFD model as the plant model to represent the traffic dynamics. Our proposed system has different settings options for number of sharing, market rate, and time window. We have assessed the impacts of these characteristics on traffic congestion and system performance.

The experimental results show that choosing a proper setting for the ride-sharing system leads to significant improvement in network traffic conditions. When the number of shared cars decreases in the system, the accumulation decreases. Also, the total travel time for the cars reduces as each separate car can serve the assigned shared rides with less trip numbers. But on the other side, the cars travel distance increases and each car stays more in the system. So finding a trade-off between different values for system characteristics is necessary to have more efficiency in terms of handling congestion. Choosing these settings also depends on the objective functions importance. Some settings are more efficient from the providers' agent point of view while others can make more value for passengers agent. For example, decreasing the time window can reduce the passenger's travel time and waiting time while it increases the number of cars that the provider should equip to serve the demand.

In future researches, we will implement our system on larger networks with more number of trips to assess the effect of sharing on congestion in large-scale networks. We will improve the optimization algorithm introducing spatial clustering on the network. Also, we will try to switch the plant model to a more refined one.

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Dynamically Configurable Multi-agent Simulation for Crisis Management

Fabien Badeig, Flavien Balbo and Mahdi Zargayouna

Abstract Multi-agent-based simulation (MABS) is the processing of a multi-agent model of a complex system by a simulation platform that controls its execution. The objective is the understanding of the dynamic of this complex system with the experimenting of different configurations for the same multi-agent model. Following a scheduling process, an activated agent has to act according to his context, that is his current perceptible simulation state. In this paper, we propose to delegate the context computation process to the scheduling process. This approach has several advantages. The first is an optimization of the context computation, a single computation being used for several agents. The second advantage is a more configurable design process and a simplification of the reusability of agent behaviors in different simulations. The model that we propose gives a formal framework to support this context computation delegation while preserving agents' autonomy. We describe a crisis situation to illustrate the benefits of our model and compare our approach with a classical simulation scheduling approach.

Keywords Simulation design · Scheduling policy · Multi-agent environment · Crisis situation

1 Introduction

Multi-agent systems (MAS) deal with the coordination of autonomous agents interacting in an environment to solve problems. This bottom-up modeling approach has often been used to model complex systems, for instance in social sciences [1], in the military domain [2], or in transportation [3].

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Multi-agent-based simulation (MABS) combines the advantages of the MAS paradigm, with the advantages of simulation. MABS is consequently a fitting solution to model complex processes and understand their dynamics. These features explain the uptake of MABS by several domains and why it is becoming one of the main directions for the deployment of multi-agent systems [4]. However, the agent-centered design of MABS has two limitations. On the one hand, the simulation design is hardly configurable. Indeed, the MABS designer has two options to test new configurations, he can either modify the scheduler, and/or change the agent behavior associated to a context.

These two options often imply that the user of the simulation is either its designer or has only a set of predefined configurations he could use. The second limitation is related to the computational efficiency of the simulation process. Using their context, the agents decide which action they have to perform. For each agent, the context computation takes into account his available information including his own state, his accessible information about other agents, his local environment perception, etc. This context computation is automatic and repetitive for each scheduled agent. Indeed, in the majority of MABS frameworks, all agents must automatically compute their new context before performing an action, even if their context has not changed since their last execution. This computation is repetitive because the agents compute their context at each execution, even if they have the same context than others. This context computation process is time consuming and is one of the barriers to increased use of MABS for large simulations.

In this paper, we propose an approach that improves the *configurability* of the simul ation process by delegating the context computation to the multi-agent environment. Thus, the designer can change the simulation behavior by modifying the agent context computation without modifying the agent's implementation. In addition, our approach is more *dynamic* than a classical approach because the modification of the agent and simulation behaviors are possible both offline (by the designer) and online (by the agents). Finally, our approach is *computationally efficient* because the same context computation can be used for several agents who desire to be activated with the same context conditions.

The remainder of the paper is organized as follows. Section 2 presents the issues related to the activation process in simulation. In Sect. 3, we position our work in a practical context of crisis management. The agents design model is provided in Sect. 4. Section 5 presents our experiments and results. The paper concludes with some perspectives to this work.

2 State of the Art

The execution of a multi-agent-based simulation (MABS) model necessitates a scheduling process (performed by a scheduler) that synchronizes the agent's execution. In this section, we give a presentation of the MABS frameworks focused on this activation process.

In the current MABS framework, we distinguish three ways for the scheduler to activate the agents. The first activation mechanism is the default activation mechanism. It consists of activating the agents with only one method. In this case, the scheduler keeps a minimal description of the agent like his internal clock or his identification information, and activates the agents either by calling a default method [5] or with a control message [6]. In this case, the scheduler responsibility toward the agents is minimal and the agents compute locally the perception–decision–action loop.

The second activation mechanism consists of activating the agents directly with a reference to the next action to perform. In this case, the scheduler keeps, in addition to the minimal description of the agent, an information about the next agent action to perform. The agent delegates to the scheduler the call of his actions. In the logo-based multi-agent platforms such as the TurtleKit simulation tool of MADKIT [7], an agent has an automaton that determines the next action that should be executed. The action activation is delegated to the scheduler.

The third and last activation mechanism is called *contextual activation*. It consists of activating the agents with some kind of context information. In this case, the scheduler keeps a detailed description of the agents and computes each context for the agents according to the agent focuses and the accessible descriptions. The JEDI framework [8] and the Repast Simphony simulation platform [9] are the only two proposals where the choice of the action that is executed by an agent can be computed by the scheduler. In the JEDI framework, the computation of the agent action decision is based on an interaction matrix where a cell is a conditioned interaction between two agents. The interaction is conditioned following the MABS state, i.e., a specific context. For instance, an interaction is possible between two agents following their proximity. At each of these contexts, an action is associated and will be executed by the activated agent. This matrix is given by the designer and does not change during the simulation. This proposal is limited by the choice of the matrix to specify the interaction. Indeed, the number of components that can be taken into account to condition an interaction is limited to the matrix dimensions. Moreover, this matrix cannot be changed by the agents, their autonomy is therefore limited. The Repast Simphony simulation platform natively uses the first scheduling options (i.e., with a default agents' method to call and no information given to the agent), but it also allows a sort of *contextual activation* based on "watchers". Watchers allow an agent to be notified of a state change in another agent and schedule the resulting action. The designer specifies which agent to watch and a query condition that must be verified to trigger the resulting action. This activation process is coherent with our definition of a contextual activation. However, it is limited by the expressiveness of the watcher queries language to express the activation context. Indeed, the queries are boolean expressions that evaluate the watcher and the watchee using primitives such as *colocated* and *linked_to* and the logic operators AND and OR. More importantly, it is not possible to integrate complex conditions about other components (different from the watcher and the watchee).

We propose a simulation model called EASS (Environment as Active Support for Simulation) proposing a complete contextual activation. The context computation is delegated to the environment and where agent activation is based on context evaluation. Our proposal is based on the accessible description of the MABS components inside the environment and the computation of the agent's contexts by the environment. The language to express matching conditions is defined such that it is the most expressive possible to define a context.

3 A Crisis Management Simulation

We consider a crisis management application in transportation where several emergency services must be coordinated to limit the crisis consequences. The various activities in crisis response are coordinated between services. For instance, the task of evacuation may first need authorization from the mayor, it could involve military personnel for transport, the fire brigade to clear the road and aid agencies to provide shelter and food. The problem is further complicated by the shifting goals of the various organizations when their priorities change due to the highly dynamic nature of crisis situations. A crisis situation is a dynamic and complex phenomenon characterized by the initial situation (location and time, impact on population and infrastructure), and this situation requires a specific organization to limit the negative effects. In [10], we propose an organization-based modeling of a crisis in transportation. With the victim evacuation example, we illustrate in this paper how the agent behavior is modeled by the designer and dynamically supported by the scheduling process.

This task of evacuation consists of coordinating different emergency agents to secure and carry the victims. We consider two categories of emergency agents. The first is related to the emergency agents playing the role of *physician*. The goal of the physicians is to make a clinical diagnosis to stabilize the victim and to define the suitable evacuation. The second category is related to the emergency agents who play the role *medical porter*. The goal of the medical porters is to transport a victim to an emergency vehicle. In our implementation, each agent is situated on a two-dimensional space environment. The emergency agents have a perception field that limits their perception of the environment. In this example, the victims are objects because they are not autonomous. Figure 1 depicts an example of crisis situation with the stakeholders.

The evacuation process requires to follow sequentially two actions: 1/ A physician makes a diagnosis, 2/ Two medical porters carry the victim. The second action needs a synchronization of the two medical porters. Each medical porter has a specific capacity among *medical monitoring* or *victim handling*. The first capacity allows the medical porter to monitor the victim and to inform the physician of the victim state evolution. The second capacity is necessary to carry the victim. To transport a victim, two medical porters with complementary capacities are required. In this evacuation process, physicians and medical porters have to cooperate: a diagnosis of the victim has to be done before to transport him. Medical porters have to coordinate themselves to transport a victim together.

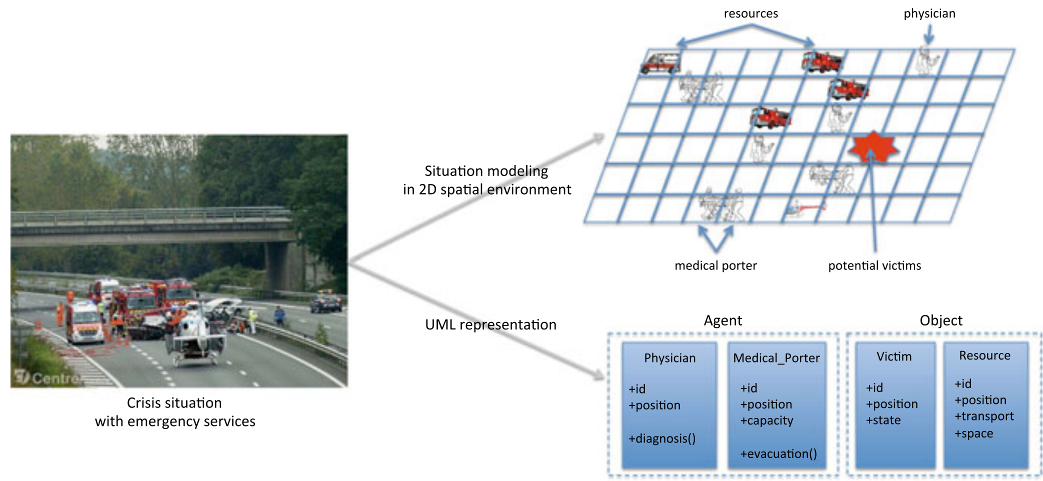

Fig. 1 An example of transportation crisis situation with emergency services to evacuate victims

4 Agents Design

One of the main roles of the MAS designer is to define the behaviors of the agents. In EASS, this is done by defining and composing "filters". A Filter is a set of parameterized conditions, i.e., the context, and the associated action to be performed.[1] A context is a set of constraints on the descriptions of the MAS components (agents, messages or objects). For instance, a filter could express the following context: "if there is a victim nearby (condition 1), and a free medical porter nearby (condition 2), then carry the victim (action)". The context here is made of conditions 1 and 2.

We propose to the designer an agent design process of three steps (cf. Fig. 2). The first step, called *enumeration* step, consists of specifying all the possible filters that could be useful to each type of agent (e.g., the *physician* and the *medical porter* in our example). The second step, called *behavior* step, is to design the behaviors of the agents, i.e., how the state of the agents is updated, and which filters are relevant in each state. The last step, called the *simulation* step, is to execute a simulation and to ensure its coherence.

4.1 The Enumeration Step

The *enumeration* step takes as input the description of the MAS model, and provides as output a filters library. The MAS model is composed of the description of the system entities (the categories of agents and objects) and the possible actions of the agents. For each agent type, the designer enumerates all the relevant contexts

[1]A formal definition of filters can be found in [11].

and associates, to each context, one or several actions. Then, according to these associations between contexts and actions, the designer defines the filter library.

For instance in the crisis simulation, one possible action for the physician is $move$ (moving toward a victim) and the context of this action is the perception of a victim in the physician field of view, which is not handled by another physician or a medical porter. With these two informations (the action and the context), the designer defines the filter that link the context with the relevant action.

The output of the enumeration step is a library of filters, associating contexts to actions, which is one of the two inputs of the behavior step.

4.2 *The Behavior Step*

Following Fig. 2, the behavior step takes as input the filters library defined in the enumeration step and the scenarios that the designer wants to simulate. The output of this step is a library of behaviors. A behavior is an organized collection of filters that is related to a scenario. Each behavior is defined in the form of an automaton where the nodes are agent states and the edges are filters from the library.

The scenario describes the workflow of a part of the simulation. The designer uses this workflow to define which filters are taken into account and when. For instance, consider a crisis scenario "priority to evacuation". In this scenario, the main objective is to evacuate the victims. However, a victim cannot be evacuated until it is handled by a physician who provides a first diagnosis. When designing the behaviors of physicians, the designer translates this scenario to a behavior automaton.

In this scenario (cf. Fig. 3), from state 1, where the physician is looking for a victim, the filter $Filter_1$ might match and the physician would go to state 2 where he would have found a victim without a porter. For this filter to match, the agent a

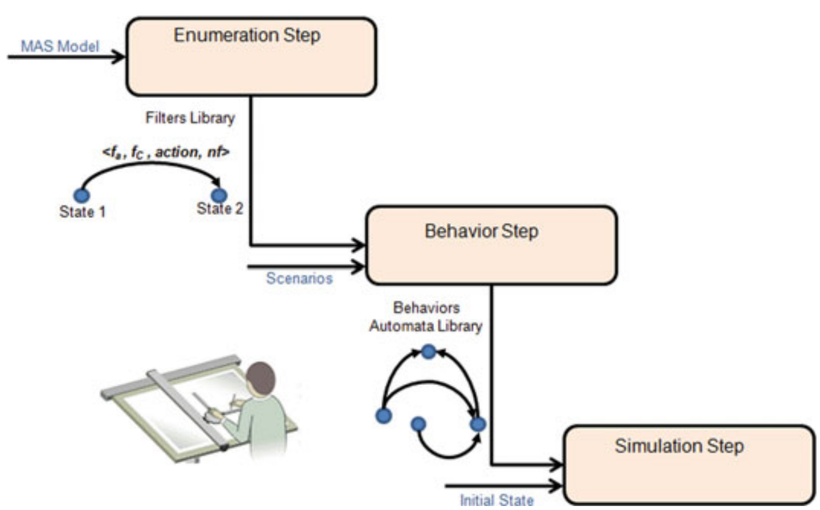

Fig. 2 The three steps of the agents design process

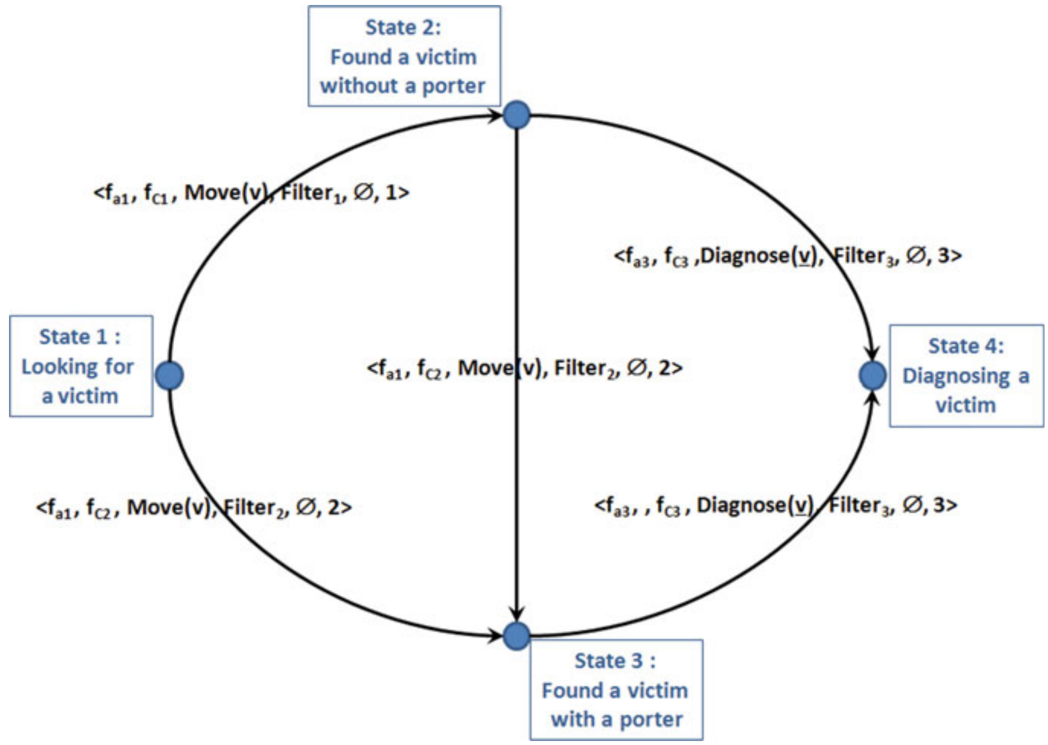

Fig. 3 Example physician behavior (priority to evacuation scenario)

has to be free, i.e., not engaged to handle another victim, the victim should be in the perception field of a and the victim should not be already handled by another physician or a medical porter. This filter is of priority 1. From state 1, there is another filter ($Filter_2$) that could match and take the physician to another state (state 3), in which he would have found a victim with a medical porter. The filter linking state 1 and state 3 (priority 2) are of higher priority than the filter linking state 1 and state 2 (priority 1). Indeed, the victims that are already handled by a medical porter would be evacuated immediately after the physician's diagnosis, while the others would still wait for a medical porter.

In state 2, the physician is engaged for handling a victim $\underline{v}$, but he has not reached it yet. Two other filters matching might change the state of the agent. The first is the same filter $Filter_2$ linking state 1 and state 3, i.e., another victim is found that is not handled by another physician but is however handled by a medical porter. A filter of higher priority ($Filter_3$) links state 2 to state 4, which is related to the case the physician has reached the victim, he should then diagnose it. The context assertion is the colocation of the physician and the victim. The same filter links state 3 to state 4.

This step provides the simulation with a library of behaviors that the agent might adopt during the simulation.

4.3 The Simulation Step

Finally, the simulation step is the process taking as input the behaviors library and the initial state of the world, and which runs the simulation. During the simulation execution, the agent activation has to be managed, as well as the priority and the pooling of the filters.

In our framework, the environment plays a main role as a dynamic component of the simulation system. Indeed, the environment manages the filters built during the modeling phase, as well as the descriptive information about the simulation components (agents and objects).

4.4 An Example of a Crisis Application Execution

This section illustrates the global scheduling policy execution through a scenario of crisis simulation example. During the initialization phase, the MAS components (physicians, medical porters, and victims) are registered in the environment. For each registration of an agent, a description is generated by the environment process where the pairs $(id, value)$ and $(time, 0)$ are added to this description. The agent identifier is automatically added to the list $potentialAgents$ of the default filter. After this registration, each agent, following his behavior automaton, adds his filters in the environment. In this example, there are three physician agents P_1, P_2 and one victim V_1. The physician agent P_1 adds the filers $F_{victim\ detection}$ and $F_{diagnosis}$ in the environment ($Fdetect$ and $Fdiag$). These filters do not exist, so the environment process adds the associated filters and initializes the parameter $potentialAgents$ with the identifier of P_1 for each of them. The physician agent P_2 adds the same filters and the environment process updates the parameter $potentialAgents$ with the identifier of P_2. At this moment, P_1 and P_2 share the same filters.

Once the simulation environment is initialized, the simulation starts. The current simulation time is $t_E = 1$. The filters with the highest priority are evaluated first and they are triggered according to the matching with the descriptions in the environment. Let's consider the case where one physician agent P_1 sees the victim V_1 while the physician agent P_2 does not see a victim.

P_1 is activated by the filter $F_{victim\ detection}$ to perform the action *move in a direction*, the filter variable unification gives the description of the victim V_1 with the information about $position$ and id which are necessary for the action execution. During the action execution by the agent P_1, his internal time is updated to 1.

P_1 has an internal time that is inferior to t_E and he is not activated. Consequently, he is activated by the default filter to perform the default action *move randomly*. During the action execution, their internal time is updated to 1.

All the agents have their internal time superior or equal to t_E (Recall that $t_E = 1$). Consequently, the time update filter F_{time} is triggered and the simulation time t_E is incremented to 2.

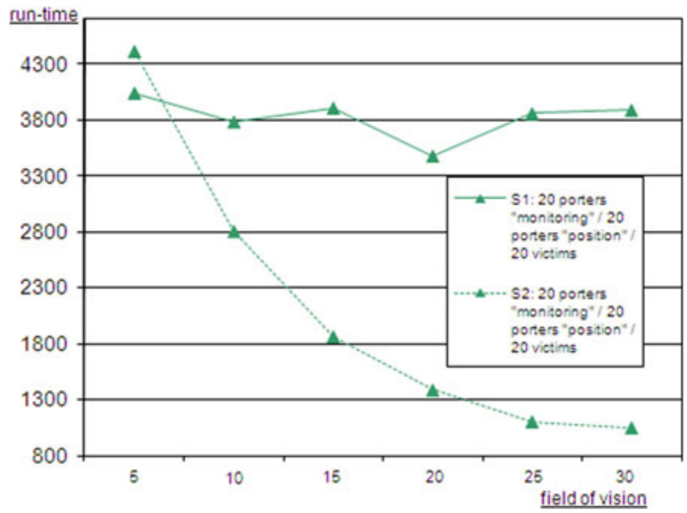

Fig. 4 Simulation run time comparison between contextual activation (S_2) and classical activation (S_1)

5 Experiments

This section presents the assessment of the EASSmodel. Our objective is to compare the cost of the context computation by the environment versus the context computation by the agents. A prototype of our ABS framework has been implemented as a plugin for the multi-agent platform Madkit [7]. The plugin is composed of an environment component with an API that enables the agents to add/retract/modify their descriptions and filters. We have executed the same agent behavior with a contextual activation and with a classical activation and compared the execution time. In the latter case, the scheduler activates the agents alternately and each of them computes locally his context. The results show that our contextual activation is always more efficient than the classical activation. The first explanation of this result is the use of the RETE algorithm that enables to optimize the matching process of the shared filters. The second explanation is related to the context computation process itself. With a classical scheduler, the context computation is based on the "exploration" of the perceived environment while it is based on an event (environment modification) evaluation process in our solution. The consequence is that the cost of the matching process in our solution increases with the number of entities that are taken into account by the filters (Fig. 4). The cost increases following the number of entities that compute their context and the size of the perceived environment in the classical solution.

6 Conclusion

In this paper, we discuss the role of the scheduling process in multi-agent simulation. We have proposed a new model, called EASS (Environment as Active Support for Simulation), where the context computation is externalized to the environment and where agent activation is based on this context evaluation. Whereas, classical approaches are agent-centered, our proposal is environment-centered because it delegates a part of the activity of the agents to the MAS environment. Our proposal is grounded on the PbC coordination principle [12] which argues in favor of MAS entities that have to be partially observable through a set of properties. For future work, we intend to test our platform on a complex, more realistic and bigger scenario of crisis management in transportation networks (as in [13]).

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Part VI
Agent-based Modeling and Simulation

Messaged Multi-agent System as a Tool for Strengthening Innovative Capabilities of Business Models

Michal Halaška and Roman Šperka

Abstract Business models raised on popularity in recent years among both researchers and practitioners. However, operational research in the area of business modelling is limited, especially regarding business processes. Greater focus is nowadays put on strategic layer and other perspectives of business models. Thus, the aim of the paper is to implement business model in the form of messaged multi-agent system at the operational layer with process perspective as building block of the model. This approach strengthens the innovative capabilities of business models. In our paper, first, correspondent literature review is presented. The focus is given on investigation of relations of business models and business process management discipline. Process perspective is emphasized because it is naturally capable of integration of other perspectives, e.g. dynamic perspective, revenue model, business logic, resource-based view, etc. Second, it is shown, how can messaged multi-agent system be used as a supporting tool incorporating business model dynamics through innovation, while integrating different business model perspectives. As a result, messaged multi-agent system is introduced. It represents unique implementation of a business model reflecting on a trading company, where interactions between process participants are mediated through messages. The presented results involve comparison of two business models' implementations, where the redesigned business model incorporates changes in pricing of the product and marketing campaigning. Process mining method and statistics are used to comment on the outcomes. Process mining plays a crucial role as it is used for validation of business logic, discovery of business process model and comparative analysis of both business models.

Keywords Business model · Business process management · Process mining · Simulation

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1 Introduction

Business models (BM) are highly emphasized in entrepreneurial practice as they specify and justify means of achievement of profit by the companies. Thus, simply put, business models describe how organizations do business. However, their significance is not only practical but also theoretical as they aspire to unite knowledge from practice and theoretical development in entrepreneurship. This also supports the fact that many companies with opportunities, market gaps, adequate resources, innovative products, etc. failed because of underlying business model. Thus, research in the area of business models gained attention in recent years. The research addresses many areas like model description, model construction, search for standard models, etc. However, there is only limited research dealing with business processes with regard to business models. That means that significant part of the research is focused on strategic level of business models and economic models concerning the logic of profit generation, and lesser attention is dedicated towards operational level of business models regarding business processes. Morris et al. [1] identify a total of 24 different possible business model components across 19 research articles dealing with business models. Among the most frequent components are companies' value offering, economic model and customer interface/relationship. Nevertheless, the business processes occur as a component only once. Previously, similar findings with no occurrence of business processes at all found also Hedman and Kalling [2]. And similar situation seems to still exist today [3].

Business process perspective is becoming very important nowadays for companies. There are two main reasons for this shift in companies' reasoning. First, companies deploy information technologies as there has to be an alignment between technologies and underlying processes to be beneficial for the company. Information technologies and technological development had considerable influence on business models. In fact, the term business model first occurred in 1960s [4]. But the widespread use and interest of researchers towards business models started with development of information and communication technologies in the early 2000s [5]. In a similar way, there is a relation between information technologies and business models, as mediocre technology pursued within a great business model may be more valuable than a great technology exploited via a mediocre business model [6]. There have been many examples of failed technological implementations due to inappropriate solution of business processes underlying information technologies in the past. The second is the ongoing shift from product-centric markets to service-centric markets (bypassing customer-centric markets). As the services become products itself, the underlying processes and their efficiency and effectiveness are much more important for the customers, because they are directly influenced by them and their imperfections. In such cases, business processes directly influence value creation and profit creation of certain business model.

Even today, researchers still tend to argue about what makes companies successful. And it is safe to say that proper management of business processes makes the difference in many cases. Business processes management goes hand in hand with the major shifts towards technological involvement and service-oriented approach of companies all over the world resulting in raising importance of business process management not only in practice but also with regard to theoretical development of future entrepreneurship and involvement of management of business processes within business models. One of the main reasons for companies to get involved in the process of development of new business models is to gain competitive advantage. Search for competitive advantage has become continuous process nowadays similar to business process management practice within companies, which accepted the process-centric approach. Business process management as well focuses on providing companies with continuous competitive advantages at the respective areas. As we show later, there are many linkages between business models and business processes and business process management, respectively. Thus, goals of this research paper are as follows: first, we pursue a question of what relations are established between business models and business processes and business process management, respectively, and second, we present a proof of concept in the form of case study with the following goal in mind: how can be implementation of multi-agent systems as message multi-agent system used to connect business model and business processes in today's environment requiring continuous business model innovation. The first goal is achieved through inspection of business model literature with focus on Scopus and Web of Science databases. To achieve the second goal, two business models of trading company are implemented in the multi-agent simulation framework called MAREA. Dynamic capabilities of the approach are shown with the use of simulation experiments of both models, which means 15 simulation runs for each business model. Even though the original business model is validated and verified based on real data, the case study is meant to be illustrative, designed to flesh out our ideas rather than to extract theoretical concepts.

In the following section, we present recent state-of-the-art of business models and its relations towards business processes and business process management. In the third section, we introduce methodology used in the paper. In the fourth section, we present a case study. In the last section, we conclude and discuss the results.

2 Relation of Business Models and Business Process Management

There exist a lot of ambiguity with respect to business models among the researchers and practitioners regarding terminology, boundaries of business models, confusion with similar terms like, e.g. economic model, revenue model, etc., resulting in misunderstanding and misuse of such business models [4]. This ambiguity is worsened when researchers combine business model's theory with their interests from different areas. Thus, for our purpose, it is necessary to examine the topic closer and identify the common ground between business models and business process management, especially considering recent development in the area of business models.

According to Osterwalder et al. [5] in early 2000s, business models were perceived from two different angles. In the first case, business model was perceived simply as a way of doing business. In the second case, business model was perceived as a conceptualization of doing business. Authors distinguish between two conceptual levels of business models (second case) and one instance level of business models (first case). Put simply, authors basically distinguish between reference business model and its real-world implementation. The distinction between conceptual model and the implementation is one of the former approaches towards business model classification. The little portion of research within the area of business models, which deals with business processes is mainly interested in case studies dealing with implementation of specific business under different circumstances [3] (employment of new technologies, changes in customers' demands and behaviour, etc.). Nevertheless, business processes should receive more attention at the conceptual level of business models as well due to growing technological standardization and employment of new technologies, orientation of business towards services, need for continuous innovation of business models, etc. Regarding the necessity of survival of the companies by continuously looking for innovation, static and dynamic business model perspectives are important, where the static perspective focuses on the company's current form and its model, while the dynamic perspective focuses on the future changes of current company's model. Due to the need for continuous improvements with regard to processes, business process management similarly differentiate between as-is (static) and to-be (dynamic) perspectives.

Casadesus-Masanell and Ricart [7] define business model as the reference to the company's logic, the way it operates and how it creates value for stakeholders and distinguish business model, strategy and tactics, referring to the strategy as a choice of appropriate business model and to tactics as residual choice resulting from chosen business model. According to Zott and Amit [8], strategic decisions and in consequence, also business models are affected by many contingency factors, e.g. organization structure, information and communication technologies, etc. Many of the contingency factors are closely related to business processes and thus, are also of special interest to business process management scholars and practitioners. The development of business models is not comprehensive and mainly dependent on researchers' interest. Nevertheless, the main areas include use of information technologies in companies, value creation, competitive advantage, companies' performance, etc. [9]. Thus, besides contingency factors, strong relation to technological innovation and changes and holistic approach towards explaining how companies do business, there is linkage between areas of interest with respect to business models that are corresponding to those of business process management. Moreover, even though business process management is mostly focused on operational level, it has implications on tactic and strategic level as well, further supporting the need of further incorporation of business processes at the conceptual level of business models.

If we consider another definition of business model, according to Chesbrough and Osterwalder, organization's business model is defined through three key aspects: (1) definition of integration of company's key components and functions in delivering value to the customers, (2) their relation between internal parts of company and supply chain and (3) generation of value and profit through interconnected components and functions [10]. Again, the definition of business model is corresponding with the goals of business process management. Also, frequently mentioned focus of business models, e.g. value creation, efficiency, effectiveness, performance, core logic, identification of core activities, etc. [10, 11], are similar and well relatable to those of business process management. There are several business model definitions and business models that have natural linkages towards concepts of business process management, be it the way they are defined, be it the factors influencing them that have to be considered as the part of the company's strategy or be it the goals of presented business models. However, those definitions of business models and business models itself like, e.g. [3, 10, 12], completely lack the process perspective let alone the integration of elements of business process management.

Moreover, industrial patterns and social behaviour will require future business models to simultaneously benefit economy, environment and society [13]. This will be hardly possible without proper incorporation of business processes into business models as they are crucial part of technologies, services and products of the companies as well as business process management for continuous innovation of business models as the dynamic capabilities are underpinned by organizational processes [14]. Thus, management of business processes is necessary for relation to business process' perspective, because companies with low dynamic capabilities and lower drive for innovation tend to fixate themselves on running processes. Recently, Ritter and Lettl [15] identify business model activities perspective and state the following definition of business model closely related to business processes: 'systematic and holistic understanding of how an organization orchestrates its system of activities for value creation'. Even though there are several authors [3, 14, 15] that acknowledges the importance of business processes and business process management, the incorporation of business process management knowledge within business model's theory is minimal and for the future insufficient. In the following section, we present methodology of the paper.

3 Methodology

In simulation experiments, we model a trading company interested in selling electronics, concretely LAN cables, composed of software agents. The model is based on multi-agent approach and interaction between agents is designed according to FIPA contract-net protocol [16, 17]. The behaviour of agents is defined by simple rules and interactions within environment, they are part of. MAREA framework is uniquely implemented as messaged multi-agent system [18], which allows us to bring in model dynamics supporting business model innovation and interconnecting different business perspectives securing business sustainability and profitability. Integration of messaged multi-agent system and business models may result in a scheme supporting business model innovation. The original business model in [18] was redesigned with focus on pricing and marketing campaigning. The behaviour of customers was adjusted to better reflect the reality in both models as pricing plays important role in redesigned model. Thus, there were implemented two types of customers: price sensitive and price non-sensitive customers. Both business models and both types of customers are described in more detail in Sect. 4. For analysis of dynamic capabilities of the multi-agent model, which is based on process perspective, there were done 15 simulation runs for each business model. The behaviour at the macro level of both models was analysed with use of analysis of variance. The micro-level behaviour of both models was analysed with use of process mining techniques. Furthermore, for discovery of process, maps and validation of business logic were used to process maps created with the use of process mining tool Disco.

3.1 Marea

MAREA is a multi-agent framework modelling processes of trading company with focus on purchasing and selling processes. It is based on generic model of a business company consisting of several types of agents: sales representative, purchase representative, marketing agent, customer agent, supplier, management agent, accountant agent and disturbance agent. The selling process is based on sales representative-to-customer negotiation, and purchasing process is based on purchase representative-to-supplier negotiation. The sales representative-to-customer negotiation is based on the following decision function [19]:

$$x_i^m = \alpha_i^* \frac{m_i}{p_x} \tag{1}$$

x_i quantity offered by m-th sales representative to i-th customer,
α_i^* preference of i-th customer (randomized),
m_i budget of i-th customer (randomized) and
p_x price of the product x.

Decision function for i-th customer determines the quantity that i-th customer accepts. If x_i < *quantity demanded* by customer, the customer realizes that according to his preferences and budget, offered quantity is not enough, he rejects sales quote. The composition of agents in our model resembles that of a real retailing company. MAREA framework consists of the simulation of multi-agent system and ERP system. Simulation designer is used to design simulation model and adjust simulation parameters. ERP system stores data, which are gathered every turn by management agent. Through ERP system, one can read and insert data. ERP system also keeps track of KPIs like—cash level, turnover or profit, by summing up other values.

Table 1 Descriptive statistics of time series and result of ANOVA test

	Original BM	Redesigned BM
Average profit	26718.37	38265.85
Median profit	27600.28	37797.68
Standard deviation	2857.16	5947.01
P-value	2.315E−07	

3.2 Process Mining

Process mining is a group of techniques that searches for hidden information and patterns in the data. It combines features of business process management and data science. The data needed for process mining analysis is produced by different information systems (e.g. process-aware information systems, enterprise resource planning systems, etc.) event logs or logs [20]. The minimal information needed in the log (see Table 1) is unique identifier of particular events, timestamps for ordering purposes and function that relates activity names to events.

There are five established areas of process mining. Process discovery techniques find patterns in logs and based on them build models of processes [21]. The second area is used for assessment of model quality, fitness and alignment of model and actual process [22]. Process enhancement is dependent on result of the previous two types of analysis and its aim is to enhance process models. Fourth type of process mining analysis—operational support—uses the combination of pre-mortem and post-mortem data and allows to work with processes in the real time. Lastly, deviance mining is a group of techniques used for the analysis of different variants located in the logs.

4 Business Model Simulation and Its Results

The company's model is based on real electronics retail company and the original model is verified and validated based on real data. For simplicity, we work with only one product (LAN cable). In our setup, we differentiate between two types of customers: price sensitive customers and price non-sensitive customers.

The specific property of price sensitive customer is that with rising price of a good, price sensitive customer is less likely to buy it. Furthermore, we compare two business models. The difference is that in the redesigned model, company raises the price of the good by 15% and employs marketing campaign under the assumption that 60% of their customers are price sensitive and the rest of them are price non-sensitive customers. This is achieved through the use of price sensitivity coefficient. For both business models, price sensitive customers have coefficient of price sensitivity equal to 0.8 and price non-sensitive customers have coefficient of price sensitivity equal to 1. Both business models work with 200 customer agents. The marketing campaigns

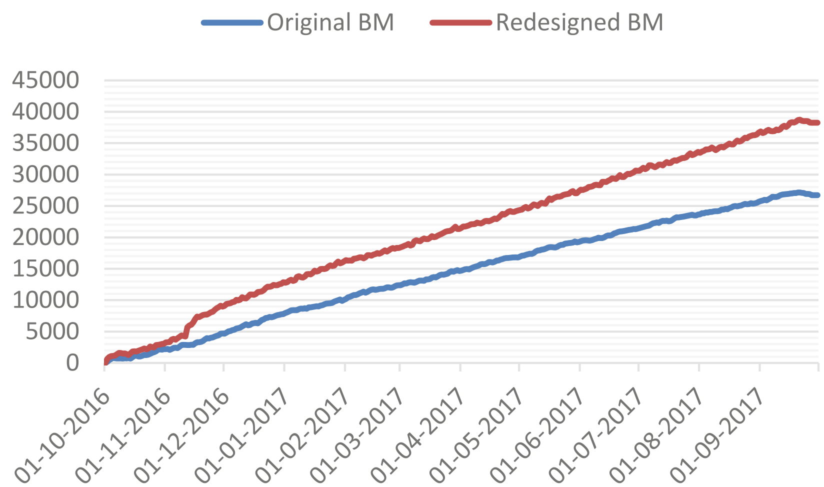

Fig. 1 Development of profit time series of both business models during simulation run

are done regularly (once a month) during the simulation run with budget constraint of 2145 units. Company cannot cross the budget constraint, and once the company spends the entire budget it cannot do marketing campaigning anymore. Marketing campaigns affect customers through the coefficient of marketing competition which is equal to 1.6 during the course of marketing campaigning. It last at most 2 weeks from start of marketing action, otherwise it is equal to 1. Moreover, marketing campaigns raise the probability of initiating a sale, and thus probability of creating sales request goes from 4 to 14%. The main question is, if the company will be more profitable with use of redesigned business model (see Fig. 1).

There was 15 simulation runs for every business model. Figure 1 shows the development of profit of both business models. The time series are calculated as average values of profit at the end of each round (one round is equal to 1 day) of each simulation run. According to Fig. 1, the redesigned business model provides company with better results in terms of profitability than the original business model.

Table 1 contains fundamental descriptive statistics for average time series for both business models in the form of average profit, median profit and standard deviation. Moreover, according to ANOVA test, the changes in business model had statistically significant impact on the level of profit that the company was able to achieve employing different business models as the p-value is equal to 2.315×10^{-7} that is much smaller than the 0.05 level of alpha significance. Finally, Fig. 2 shows part of the sales process of both business models, the marketing campaign raised the number of sales requests as well as number of sales requests revoked. Thus, it is necessary for the company to consider, if their resources will be able to handle higher requirements and maintain the process performance of resources without additional costs.

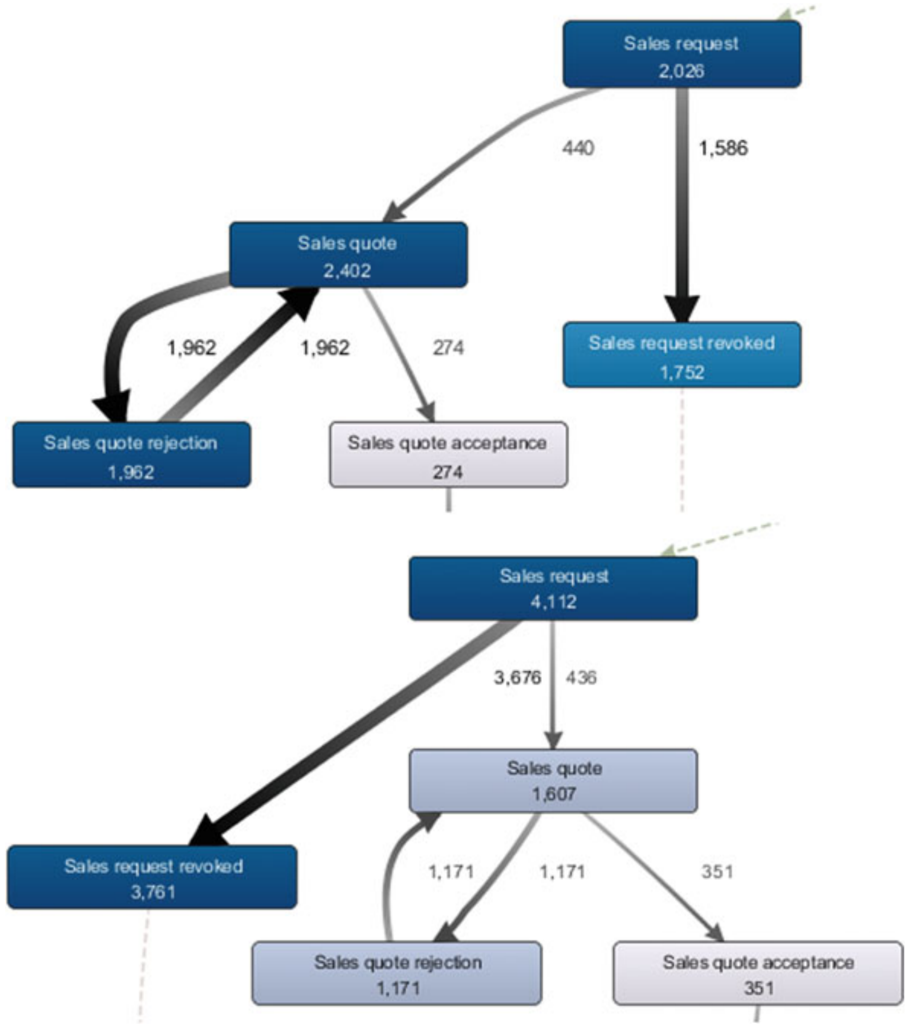

Fig. 2 Part of the sales process for original business model (top) and redesigned business model (bottom)

5 Conclusion and Discussion of Results

Business processes and business process management have several close linkages to business models, be it their goals, be it their perspectives, be it their focus or effort for continuous improvement through innovation. Even though there is a lot of common ground behind both concepts, the process perspective is of little interest regarding business models. While researching business models, many authors take into consideration only small part of business model components. Such approach allows researchers to conduct thorough investigation of those components. However, we believe business processes to be founding blocks of many different perspectives, in which business models should be built on. Thus, the disconnection of business process management knowledge from the theoretical background of business models seems to be problematic to us. This incoordination seems to have negative impact on implementation studies of business processes and business models as they become unsystematic and hard to grasp.

Due to continuous changes in the environment, there is a need for continuous innovation of companies' business models. With all the technological development, computer simulations seem to offer viable way on how to deal with the need for constant changes. We presented how can message multi-agent system be used towards business model innovation, while simultaneously interconnect different business model perspectives and components. In our simulation setup, we investigated the impact of change of business model on companies' profit. There were two changes to the business model: (1) the selling price of the product raised by 15%, and (2) company started to propagate the goods with the use of marketing campaigning.

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Information Modelling of the Storage-Distribution System

Robert Bucki and Petr Suchánek

Abstract The paper highlights the problem of modelling the storage-distribution system in which products are dispatched from the finished products warehouse directly to customers on the basis of the minimal correlated manufacturing, storing and transport costs. The pseudocode based on the specification assumptions followed by the subsequent project is emphasized as well. Various dispatching models are subject to the cost analysis. Equations of the system state are presented in order to illustrate the flow of products in the storage-distribution part of the logistics chain.

Keywords Distribution system · Heuristic strategies · Logistics · Logistics information system · Manufacturing process · Mathematical model · Minimal cost criterion · Simulation · Supply chain management

1 Introduction

The efficiency of final product distribution to end-customers within the supply chain is nowadays one of the key issues in logistics. The main goal of the supply chain is to ensure the distribution of products in the required time, at the lowest cost, at the required quality level and in an adequate manner [1]. The purpose of supply chain management SCM is to find an optimal supply model that ensures a continuous distribution process with minimal fluctuations and minimal inventories in connection with the previously mentioned as well as other specifics [2, 3]. One of the key trends in SCM support is the digitization of logistics with the growing implementation of intelligent technologies that are able to meet growing new requirements for quality,

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flexibility and the type of service [4, 5]. Logistics information systems have become capable of proposing plans for optimal distribution of goods based on current data [6]. Plans are based on mathematical models [7, 8] which allow them to verify their effectiveness through simulations carried out by the adequate information systems. The simulation results can then be used retrospectively for retrofitting the mathematical model, and repeating this procedure multiple times can ultimately result in an optimal distribution plan [9, 10]. The methodologies used in the paper are based on a heuristic approach such that it is possible to define heuristic algorithms and strategies whose efficiency in logistics, production logistics, supply chain management, etc. has already been demonstrated in a number of cases. Specific examples can be found, for example, in [11–14] and others. The goal of this paper is to present the mathematical model of the storage-distribution system for products made for various groups of customers. Products are made in accordance with available heuristic strategies which, in fact, are responsible for management of the storage-distribution system costs which result from following the minimum cost criterion. Manufacturing heuristic strategies generate various storage costs as products arrive at the finished products warehouse at different times so the minimal cost of storing finished products depends on the chosen heuristic strategy for the manufacturing process. The minimal sum of the manufacturing process cost and the storing cost decides about the choice of the manufacturing heuristic strategy leading to this result. Finally, the cheapest means of transport for the dedicated group of products and customers is searched for. The presented approach is equipped with the general pseudocode on the basis of which the simulator of the storage-distribution system is built. There are many constraints of the distribution process and they depend on numerous factors which differ even in case of similar distribution systems.

Some of them can be specified as follows:

(i) the number of means of transport and their characteristics (e.g. fuel consumption, state of the vehicle);
(ii) the weight of the load;
(iii) the number of ordered elements;
(iv) the transport difficulty of the order;
(v) the delivery priority;
(vi) the delivery distance;
(vii) the manufacturing time;
(viii) the storing time depending on the heuristic strategy;
(ix) the delivery delay time;

Moreover, each distribution system has its own goals which more than often form the multi-criterion models. Some of these criteria are specified as follows: (a) the "in time" criterion (i.e. orders are to be delivered in time); (b) the "on time" criterion (i.e. orders are to be delivered on time); (c) the priority criterion (i.e. orders with the highest priority are to be delivered as the first ones); (d) the cost criterion.

2 Mathematical Model

The delivery time is the function of the implemented delivery criteria, delivery constraints, manufacturing time, storing time, delivery delay time and delivery transport time (1):

$$T_{delivery} = f\left(Q_\chi, \Omega_\phi, T^Z_{pr\_\alpha}, T^{st\_Z}_\alpha, T_{delay}\right) \tag{1}$$

where: Q_χ—the χ-th implemented delivery criterion; Ω_ϕ—the φ-th implemented delivery constraint, $\phi = 1, \ldots, \Phi$; $T^Z_{pr\_\alpha}$—the production time of the order according to the α-th production approach; $T^{st\_Z}_\alpha$—the storing time of the order made according to the α-th production approach; T_{delay}—the delivery delay time;$T^{tr\_Z}_\alpha$—the delivery transport time of the order made according to the α-th production approach. The cost criterion is taken into account: $Q_\chi = Q_c \to \min$. It is assumed that finished products for the dispatch procedure are illustrated by the dispatch matrix of orders (2):

$$Z^{0\_del} = \left[z^{0\_del}_{m,n}\right],\ m = 1, \ldots, M,\ n = 1, \ldots, N \tag{2}$$

where: $z^{0\_del}_{m,n}$—the number of the n-th ready product elements for the m-th customer at the dispatch stage; at the same time: $z^{0\_del}_{m,n} > 0$ if the n-th order for the m-th customer is completed; $z^{0\_del}_{m,n} = 0$ if the n-th order for the m-th customer was not completed; $z^{0\_del}_{m,n} = -1$ if the n-th order for the m-th customer was not placed. Orders are made in the autonomic manufacturing system in accordance with the defined heuristic algorithms and manufacturing strategies described in detail in [15]. Finished orders are added to the dispatch matrix of orders Z^{0_del} at various moments depending on the α-th production approach, $\alpha = 1, \ldots, A$ i.e., at a different sequence and therefore, costs of storing in the finished products warehouse differ considerably. The time of storing order matrix elements till the last order element is added to the order matrix is expressed by the following matrix (3):

$$T^{st\_Z}_\alpha = \left[\Delta\tau^{st\_Z}_{\alpha\_m,n}\right],\ \alpha = 1, \ldots, A,\ m = 1, \ldots, M,\ n = 1, \ldots, N \tag{3}$$

where: $\Delta\tau^{st\_Z}_{\alpha\_m,n}$—the time of storing the n-th ready product elements for the m-th customer in the finished products warehouse made according to the α-th manufacturing approach before the order matrix is completed. The total time of storing elements of the order matrix elements made according to the α-th manufacturing approach is calculated as follows (4):

$$T^{st\_Z}_{tot\_\alpha} = \sum_{n=1}^{N}\sum_{m=1}^{M}\Delta\tau^{st\_z}_{\alpha\_m,n} \tag{4}$$

Let us specify the delay moment of starting the distribution process (5):

$$T_{delay} = \left[\tau_{delay\_\lambda}\right],\ \lambda = 1, \ldots, \Lambda \tag{5}$$

where: τ_{delay_λ}—the λ-th delay moment of starting the dispatching process, $\tau_{delay\_\lambda} \geq 0$.

For the purposes of this publication, we assume a unit of pricing which represents any set value of the cost irrespectively of the currency. Therefore, there is no specified currency (monetary units) throughout the text.

Let us introduce the unit cost vector of the dispatching process delay of the order (6):

$$C_{delay}^{unit} = \left[c_{delay\_\lambda}^{unit}\right] \tag{6}$$

where: c_{delay_λ}—the λ-th unit delay cost of the dispatching process, $c_{delay\_\lambda} \geq 0$.

Let us introduce the matrix of unit transport cost of the n-th product to the m-th ordering company by available means of transport (7):

$$C_{unit\_\beta} = \left[c_{\beta\_m,n}\right],\ \beta = 1, \ldots, B,\ m = 1, \ldots, M,\ n = 1, \ldots, N \tag{7}$$

where $c_{\beta\_m,n}$—the unit transport cost of the n-th product to the m-th company by the β-th means of transport.

Let us assume that there are the following types of costs which are subject to thorough analysis: operational and fixed costs, storing costs and dispatching costs.

Before the order reaches the matrix Z^{0_del} (i.e. it is completed) it generates costs as follows (8):

$$c_{pr\_\alpha} = c_{op\_\alpha} + c_{fc} \tag{8}$$

where: c_{pr_α}—the manufacturing cost with the use of the α-th approach; c_{op_α}—the operations cost with the use of α-th approach;c_{fc}—fixed costs of the analyzed manufacturing company.

Unit costs of storing products in the finished products warehouse are shown in the matrix of unit storing costs (9):

$$C_{unit}^{st\_Z} = \left[c_{unit\_m,n}^{st\_z}\right],\ m = 1, \ldots, M,\ n = 1, \ldots, N \tag{9}$$

where $c_{unit\_m,n}^{st\_z}$—the unit cost of storing the n-th product for the m-th customer in the finished products warehouse expressed in the monetary units.

Let us calculate the cost of storing the n-th ready product elements for the m-th customer in the finished products warehouse (10)

$$c_{\alpha\_m,n}^{st\_z} = c_{unit\_m,n}^{st\_z} \cdot \Delta\tau_{\alpha\_m,n}^{st\_z} \cdot z_{m,n}^{K} \tag{10}$$

Costs of storing products in the finished products warehouse are shown in the matrix of storing costs (11):

$$C_{\alpha}^{st\_Z} = \left[c_{\alpha\_m,n}^{st\_z}\right],\ \alpha = 1, \ldots, A,\ m = 1, \ldots, M,\ n = 1, \ldots, N \tag{11}$$

where: $c_{\alpha\_m,n}^{st\_z}$—the cost of storing the n-th product for the m-th customer in the finished products warehouse made according to the α-th manufacturing approach before the order matrix is completed.

The total storing cost of products made according to the α-th manufacturing approach before the order matrix is completed is calculated as follows (12):

$$c_{tot\_\alpha}^{st\_Z} = \sum_{n=1}^{N} \sum_{m=1}^{M} c_{\alpha\_m,n}^{st\_z},\ \alpha = 1, \ldots, A,\ m = 1, \ldots, M,\ n = 1, \ldots, N \tag{12}$$

The minimal storing costs of finished products made according to the α-th manufacturing approach before the order matrix is completed are detected as follows (13):

$$c_{tot\_\min}^{st\_Z} = \min_{1 \le \alpha \le A} c_{tot\_\alpha}^{st\_Z},\ \alpha = 1, \ldots, A \tag{13}$$

It is assumed that the company cost of making the order Z^K before it leaves the finished products warehouse involves manufacturing costs consisting of operations costs and fixed costs for the α-th approach as well as storing costs of products (14):

$$c_{com\_\alpha}^{Z} = c_{pr\_\alpha}^{Z} + c_{tot\_\alpha}^{st\_Z} \tag{14}$$

The minimal company cost of making the order Z^K is obtained as follows (15):

$$c_{com\_\alpha\_\min}^{Z} = \min_{1 \le \alpha \le A} c_{com\_\alpha}^{Z},\ \alpha = 1, \ldots, A \tag{15}$$

The company cost of the n-th product for the m-th customer is calculated as follows (16):

$$c_{\alpha\_m,n}^{z} = c_{\alpha\_m,n}^{op\_z} + c_{fc\_m,n} + c_{\alpha\_m,n}^{st\_z} \tag{16}$$

where: $c_{\alpha\_m,n}^{op\_z}$—the operations cost of the n-th product for the m-th customer; $c_{fc\_m,n}$—the fixed cost of the n-th product for the m-th customer.

The matrix of unit transport cost of products to the customer takes the following form (17):

$$C_{tr}^{unit} = \left[c_{tr\_m,n}^{unit\_\beta}\right],\ \beta = 1, \ldots, B,\ m = 1, \ldots, M,\ n = 1, \ldots, N \tag{17}$$

where: $c_{tr\_m,n}^{unit\_\beta}$—the unit transport cost of the n-th product to the m-th customer from the finished products warehouse by the β-th means of transport. The average unit transportation cost is calculated as follows (18):

$$c^{av} = \frac{\sum_{n=1}^{N} \sum_{m=1}^{M} c_{tr\_m,n}^{unit\_\beta}}{M \cdot N},\ \beta = 1, \ldots, B,\ m = 1, \ldots, M,\ n = 1, \ldots, N \quad (18)$$

Let Γ be the vector of transport difficulty coefficient (19):

$$\Gamma = [\gamma_n],\ n = 1, \ldots, N \quad (19)$$

where: γ_n—the transport difficulty coefficient for the n-th product, $\gamma_n > 0$.

Let D be the vector of distance from the finished products warehouse to customers (20):

$$D = [d_m],\ m = 1, \ldots, M \quad (20)$$

where: d_m—the distance from the finished products warehouse to the m-th customer. Transport costs of products to customers are shown in the matrix of transport times (21):

$$C_{tr}^{\beta} = \left[c(z_{m,n}^{0\_del})_{tr}^{\beta}\right],\ m = 1, \ldots, M,\ n = 1, \ldots, N, \beta = 1, \ldots, B \quad (21)$$

where: $c(z_{m,n}^{0\_del})_{tr}^{\beta}$—the transport cost of the n-th product to the m-th custom from the company's storage by the β-th means of transport.

At the same time, $c(z_{m,n}^{0\_del})_{tr}^{\beta} = \gamma_n \cdot d_m \cdot c_{tr\_m,n}^{unit\_\beta} \cdot z_{m,n}^{0\_del}$.

The total transport cost for order Z^{0_del} is as follows (22):

$$c_{tr\_total}^{\beta} = \sum_{n=1}^{N} \sum_{m=1}^{M} c(z_{m,n}^{0\_del})_{tr}^{\beta} \quad (22)$$

Let us calculate the total transport costs for the n-th order, $n = 1, \ldots, N$ to M customers by the β-th means of transport (23):

$$c_{tr\_total}^{\beta\_n} = \sum_{m=1}^{M} c(z_{m,n}^{0\_del})_{tr}^{\beta\_n} \quad (23)$$

Let us calculate the total transport costs for N orders to the m-th customer, $m = 1, \ldots, M$ by the β-th means of transport (24):

$$c_{tr\_total}^{\beta\_m} = \sum_{n=1}^{N} c(z_{m,n}^{0\_del})_{tr}^{\beta\_m} \quad (24)$$

Let us calculate the total distribution costs for order Z^{0_del} by the β-th means of transport in case of transporting N products to M customers (25):

$$c_{total}^{\beta\_M,N} = \sum_{n=1}^{N}\sum_{m=1}^{M} c_{\alpha\_m,n}^{z} + c_{delay\_\lambda} + \sum_{n=1}^{N}\sum_{m=1}^{M} c(z_{m,n}^{0\_del})_{tr}^{\beta} \tag{25}$$

The following examples analyze various dispatching options thoroughly:

Example 1 It is assumed that the n-th type products for the m-th customer are transported by the β-th means of transport, $\beta = 1, \ldots, B$ (i.e. the β-th means of transport has enough capacity to transport the n-th type products made for the m-th customer), then the minimal distribution cost is calculated as follows (26):

$$c_{tr\_total\_\min}^{\beta\_m,n} = \min c_{\alpha\_m,n}^{st\_z} + c_{delay\_\lambda} + \min c(z_{m,n}^{0\_del})_{tr}^{\beta} \tag{26}$$

Example 2 It is assumed that N products for M customers are transported by the β-th means of transport, $\beta = 1, \ldots, B$ (i.e. the β-th means of transport has enough capacity to transport products N for the m-th customer), then the minimal distribution cost is calculated as follows (27):

$$c_{tr\_total\_\min}^{\beta\_M,N} = \min \sum_{n=1}^{N}\sum_{m=1}^{M} c_{\alpha\_m,n}^{st\_z} + c_{delay\_\lambda} + \min \sum_{n=1}^{N}\sum_{m=1}^{M} c(z_{m,n}^{0\_del})_{tr}^{\beta} \tag{27}$$

Example 3 It is assumed that N products for the m-th customer are transported by the β-th means of transport, $\beta = 1, \ldots, B$ (i.e. the β-th means of transport has enough capacity to transport N products for the m-th customer), then the minimal distribution cost is calculated as follows (28):

$$c_{tr\_total\_\min}^{\beta\_m,N} = \min \sum_{n=1}^{N} c_{\alpha\_m,n}^{st\_z} + c_{delay\_\lambda} + \min \sum_{n=1}^{N} c(z_{m,n}^{0\_del})_{tr}^{\beta\_n} \tag{28}$$

Example 4 It is assumed that n-th type products are distributed to M customers by the β-th means of transport, $\beta = 1, \ldots, B$ (i.e. the β-th means of transport has enough capacity to transport n-th type products to M customers), then the minimal distribution cost is calculated as follows (29):

$$c_{tr\_total\_\min}^{\beta\_M,n} = \min \sum_{m=1}^{M} c_{\alpha\_m,n}^{st\_z} + c_{delay\_\lambda} + \min \sum_{m=1}^{M} c(z_{m,n}^{0\_del})_{tr}^{\beta\_n} \tag{29}$$

3 Equations of State

The state of the order matrix changes as follows (30):

$$Z^0 \to Z^1 \to \cdots \to Z^k \to \cdots \to Z^K \to Z^{0\_del} \to Z^{1\_del} \tag{30}$$

where Z^0—the initial state of orders; Z^K—the state of completed orders; Z^{0_del}—the state of orders before the dispatch process; Z^{1_del}—the state of orders after completing the dispatch process. When $\forall_{1 \le n \le N} \forall_{1 \le m \le M} z^K_{m,n} = 0$, then the order is completed which means it is subject to the dispatching process. To do so the following transformation is carried out: $\forall_{1 \le n \le N} \forall_{1 \le m \le M} z^0_{m,n} = z^{0\_del}_{m,n}$. At the same time: $\forall_{1 \le n \le N} \forall_{1 \le m \le M} z^{1\_del}_{m,n} = 0$ if the n-th element of the order matrix was dispatched to the m-th customer, $\exists_{1 \le n \le N} \exists_{1 \le m \le M} z^{1\_del}_{m,n} = z^{0\_del}_{m,n}$ otherwise; $Z^{0\_del}_{m,N} \to Z^{1\_del}_{m,N}$ if N elements of the order matrix are dispatched to the m-th dedicated customer, then $\forall_{1 \le n \le N} z^{1\_del}_{m,n} = 0$; $Z^{0\_del}_{M,n} \to Z^{1\_del}_{M,n}$ if the n-th type elements of the order matrix are dispatched to M dedicated customers, then $\forall_{1 \le m \le M} z^{1\_del}_{M,n} = 0$.

The state vector of transport vehicles availability at the delivery stage takes the following form (31):

$$S^{0\_del}_B = \left[s^{0\_del}_b \right],\ b = 1, \ldots, B \tag{31}$$

where $s^{0\_del}_b$—the state of the b-th transport vehicle at the 0-th delivery stage.

At the same time, $s^0_{del\_b} = 1$ if the vehicle is available, otherwise $s^0_{del\_b} = 0$. Moreover, $s^{1\_del}_b = s^{0\_del}_b$ if the vehicle is not used for the delivery process, $s^{1\_del}_b \neq s^{0\_del}_b$ otherwise. The state matrix of the finished products warehouse takes the following form (32):

$$S^{0\_del}_{st\_Z} = \left[s^{0\_del}_{st\_z\_m,n} \right],\ 0 \le s^{0\_del}_{st\_z\_m,n} \le s^{0\_del}_{\max\_st\_z\_m,n} \tag{32}$$

where $s^{0\_del}_{st\_z\_m,n}$—the state of the finished products warehouse at the 0-th delivery stage. At the same time, $\forall_{1 \le n \le N} \forall_{1 \le m \le M} s^{0\_del}_{st\_z\_m,n} = s^{0\_del}_{\max\_st\_z\_m,n}$ if the storage space of the n-th product for the m-th customer is maximally filled. This state requires either an immediate dispatch of this type of product (as the one with the highest priority) or the need for finding extra space or expanding the storage space for it. The diagram presented in (33) shows the possible flow of products from the dispatching store to the assigned customer (WH—wholesale; LC—Logistic centre; RE—retail).

$$z^{0\_del}_{m,n} \to \left\{ \begin{array}{llll} \to & & & \\ WH \to & & & \\ LC & \to & & \\ LC & \to WH \to & & \\ LC & \to WH & \to RE & \end{array} \right\} z^{1\_del}_{m,n} \tag{33}$$

4 Pseudocode

The thorough specification of the distribution system forms the basis for preparing the general pseudocode for the information support of the distribution procedure control.

The pseudocode presented below assumes the beginning of distribution procedures only then when all order matrix elements are made and passed to the distribution warehouse:

i. Introduce: A, B, M, N, Γ, Λ, $C^{st\_Z}_{unit}$, C^{dist}, C^{unit}_{tr}, C_{unit_β}, C^{unit}_{delay}, C_{op_α}, C_{fc}, D, Q_c, Ω_ϕ, Φ, Z^0
ii. $\alpha = 1$
iii. Production according to the α-th strategy till $\forall_{1\le n\le N}\forall_{1\le m\le M} z^K_{m,n} = 0$.
iv. $C_{pr\_\alpha} = C_{op\_\alpha} + C_{fc}$
v. $c^{st\_z}_{\alpha\_m,n} = c^{st\_z}_{unit\_m,n} \cdot \Delta\tau^{st\_z}_{\alpha\_m,n} \cdot z^{0\_del}_{m,n}$
vi. $C^Z_{com\_\alpha} = C^Z_{pr\_\alpha} + C^{st\_Z}_{tot\_\alpha}$
vii. $\alpha = A$? If *Yes* go to (viii). Otherwise, $\alpha = \alpha + 1$ and go to (iii).
viii. $C^Z_{com\_\alpha\_\min} = \min_{1\le\alpha\le A} C^Z_{com\_\alpha}$
ix. $\beta = 1$
x. $c(z^{0\_del}_{m,n})^\beta_{tr} = \gamma_n \cdot c^{dist}_m \cdot c^{unit\_\beta}_{tr\_m,n} \cdot z^K_{m,n}$
xi. $\beta = B$? If *Yes* go to (xii). Otherwise, $\beta = \beta + 1$ and go to (x).
xii. Is the (m, n) distribution method chosen? If yes go to (xx), otherwise go to (xiii).
xiii. $c^{\beta\_m,n}_{tr\_total\_\min} = \min c^{st\_z}_{\alpha\_m,n} + c_{delay\_\lambda} + \min c(z^{0\_del}_{m,n})^\beta_{tr}$
xiv. Is the (m, N) distribution method chosen? If yes go to (xx), otherwise go to (xv).
xv. $c^{\beta\_m,N}_{tr\_total\_\min} = \min \sum_{n=1}^N c^{st\_z}_{\alpha\_m,n} + c_{delay\_\lambda} + \min \sum_{n=1}^N c(z^{0\_del}_{m,n})^{\beta\_n}_{tr}$
xvi. Is the (M, n) distribution method chosen? If yes go to (xx), otherwise go to (xvii).
xvii. $c^{\beta\_M,n}_{tr\_total\_\min} = \min \sum_{m=1}^M c^{st\_z}_{\alpha\_m,n} + c_{delay\_\lambda} + \min \sum_{m=1}^M c(z^{0\_del}_{m,n})^{\beta\_n}_{tr}$
xviii. Is the (M, N) distribution method chosen? If yes go to (xx), otherwise go to (xix).
xix. $c^{\beta\_M,N}_{total\_\min} = \min_{1\le\alpha\le A} \sum_{n=1}^N \sum_{m=1}^M c^Z_{\alpha\_m,n} + c_{delay\_\lambda} + \min_{1\le\beta\le B} \sum_{n=1}^N \sum_{m=1}^M c(z^{0\_del}_{m,n})^\beta_{tr}$
xx. Implement the chosen distribution method.
xxi. Report.

5 Conclusions

The paper presents the way of mathematical modelling of the storage-distribution system for products made for various customers. The storage cost depends on the chosen manufacturing heuristic strategy. Additionally, different distribution options illustrate just a few of a big number of possible distribution approaches. The pseudocode enables us to build a dedicated simulator in order to carry out numerous simulations of the storage-distribution system. The results of the simulations are the subject of the thorough analysis letting us make the presented system more complex for subsequent calculations. The information system to be put forward for implementation requires subsequent testing as well as validation.

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JADE Modeling for Generic Microgrids

Guillaume Guerard and Hugo Pousseur

Abstract Around the world, smart grids are being developed to reduce the electric waste and to prevent blackouts. Simulating microgrid, an eco-district or virtual power plant, is challenging, considering their different behaviors and structures. Each one varies according to several aspects: social, economic, energetic, mobility, and the well-being of its inhabitants. This paper proposes a demand-side management of a microgrid with a systemic approach, the model is based on the JADE framework and generic data from the literature. This paper focuses on the ability of microgrid to regulate its consumption with flexibility.

Keywords Microgrid · Demand-side management · Multi-agent system · JADE

1 Introduction

The energy development has resulted in a change of paradigm in the twenty-first century. Industrial and political entities, practitioners and the scientific community are seeking for smarter cities [1]. The French Institute for Demographic Studies (INED) declares the world population will increase to 10 billion inhabitants at year 2050, while the urban population will double (increase by 63%). The extended urbanization requires new ways to understand and manage the complexity of the energy production and consumption, while the world tends to over-digitalize, to exploit big data, and to disrupt classic transaction through blockchains.

Nowadays, although the cities occupy only 2% of the planet's surface, they accommodate about 50% of the world population, consume 75% of the total generated

[1]UN Environment Program, Visions for Change. Recommendations for Effective Policies on Sustainable Lifestyle, 2011.

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energy, and are responsible for 80% of the greenhouse effect.[1] The development of smart cities is dependent on the level of intelligence of electrical networks, from the producers to the consumers, from the consumers to producers. The most important aspect is the coordination between all entities; a microgrid will be able to stimulate the consumers to modify their consumption in critical conditions to maintain the electrical infrastructure unaffected.

A microgrid contains various entities. Consumers are prosumers, i.e., they consume energy and have various small, modular generation systems together with storage devices. Such systems can be operated interconnected to the grid or islanded [1–3].

Smart grids and smart cities need to be understood. They are commonly described as complex system and the better way to analyze it is by modeling and simulating [2]. In this context, the goal is to create a context-free model in order to give decision-making tools for social, economic, and algorithmic questions about a smarter micro-grid.

This paper is divided into four sections. The second section presents the JADE architecture and the microgrid's model. The third section presents case studies. The fourth section concludes this paper.

2 Model

In this paper, the model is being developed on JADE[2] (Java Agent DEvelopment Framework), a software framework to built and to develop multi-agent applications [4].

There are several definitions to define multi-agent system. However, the definitions have common features. A multi-agent is defined as a system grouping several agents in the same environment. Each agent can interact with its environment and other agents, in order to solve a complex problem. They divide the problem into a number of smaller and simpler ones that can be solved in more efficient computational ways than using a single-agent system [5].

2.1 Simulation Model

Each simulated device is defined by an agent. This agent is qualified as reactive agent, it waits an order to be launched. Moreover, devices are divided into two different categories [6] as follows:

- **Cyclic device**: devices which the end task is known at launch, and the process is cyclic. For example, washing machine.

[2]Official website: http://jade.tilab.com/.

– **Acyclic device**: devices which the end task cannot be known. For example, heating, ventilation, and air-conditioning.

To enhance the quality of simulation, the running time of acyclic device is controlled randomly. Furthermore, device gets some features, which are given as follows:

- **Daily frequency**: the number of uses per day .
- **Time slot**: storing all interval times which the device has to been launched, based on the french national statistics agency values (Gaussian distribution over these values).
- **Operating modes**: list of modes, each mode is delimited by a minimum and maximum power consumption which the operating time is proportional and linear. It is possible for each mode to choose a power between its minimum and its maximum, this decision will have an impact on the execution time. For example, the washing machine gets several modes: cleaning, spinning, and rinsing.

In each smart house, an agent called *controller* stores all plugged devices and computes the best strategy. This part is centralized by choice for raising the realism; a decentralized system imply each device gets artificial intelligence and the same way of thinking. Moreover, to communicate with other houses, a *home* agent has a gateway to create a link between all *controller* agent. These agents are qualified as cognitive agent.

This division of tasks allows to lighten the *controller* agent and raise the security as a fence. Having an *home* agent helps to improve the cyber-security of a home because the *controller* agent is not directly on the home networks.

By contrast, *home* agent participates in a decentralized system. Based on the process of leader–follower, its goal is to discuss with other homes and find the best strategy according to the amount of available energy. If the system was centralized by a server, in the case where the server shutdown for any reasons, the system is broken. In the presented model, if a home is disconnected from the network, the system continues to run.

Each home is stored in an individual platform, JADE attributes a MTP address, allowing other platforms to communicate with it. In the case of large simulation, it is possible to distribute homes on several computers/servers.

An interface allows the user to configure the generic microgrid:

- Goal consumption by default, until the new order.
- Duration of one-day simulation.
- Number of connected smart houses.
- Time frequency for computing the new strategy.
- Device's number interval range.
- Use or not of global strategy.
- Duration of timeout control.

During the simulation, the *controller* agent and *home* agent have to take some decisions.

2.2 *Agent's Strategies*

The *controller* agent has a list of devices, with static information about devices as daily frequency and dynamic information as the current state (on, off). With these information and the goal's consumption, the *controller* agent seeks for the best combination by solving a 0–1 knapsack problem. Element gets a value and a weight, the algorithm searches the best combination of elements, maximizing the sum score and respecting the total weight constraint. A knapsack problem is modeled as follows [7]:

> Several objects are available (n), each object get two characteristic, a weight and a value. The knapsack is limited by a weight maximum (M). The goal is to find the best combination in order to obtain the maximum value (1) in terms of the weight imposed (2).

$$\text{maximize} \sum_{i=0}^{n} x_i * s_i \tag{1}$$

$$\text{subject to} \sum_{i=0}^{n} x_i * c_i \leq M \text{ and } x_i \in \{0, 1\} \tag{2}$$

In this context, the weight corresponds to the consumption. The literature about the knapsack problem have a large amount of application on consumption's scheduling. It is known that the knapsack problem is a useful tool to smooth the consumption curve under a value or to manage the energy distribution among various devices [8–10]

Each device is represented by a couple of consumption and score. To attribute a score, the *controller* agent updates regularly (in discrete time) a new value for each device based on (3).

$$score = \begin{array}{l} \mathbb{1}_{time\_of\_use} * \mathbb{1}_{state\_of\_use} \\ *\|frequency\| * \|consumption\| \end{array} \tag{3}$$

$$\mathbb{1}_{time\_of\_use} = \begin{cases} 1 \text{ can be launched at the current time} \\ 0 \text{ else} \end{cases} \tag{4}$$

$$\mathbb{1}_{state\_of\_use} = \begin{cases} 1 \text{ current state is off} \\ 0 \text{ else} \end{cases} \tag{5}$$

$$\|frequency\| = |\text{already time used} - \text{frequency per day}| \tag{6}$$

$$\|consumption\| = \begin{cases} \text{(consumption available -} \\ \text{average consumption device)} \\ 0 \end{cases} \tag{7}$$

The indicator functions (4) and (5) allow to verify the possibility to launch a device. If the device is already launched (5) or it is not able to use at the current time (4), the value is equal to zero, in this case the device cannot be launched.

The frequency norm allows quantifying the usefulness to launch a device depending on the number of uses per day (6) and the consumption (7). For example, the hot water tank is commonly heated two times per day during the night and after the morning. Once the hot water tank is used two times in the simulated day, it does not need energy until the next simulated day. The function (7) checks if there is more than enough energy unused to launch the device. Due to these functions, a value is attributed (3) and regularly updated for each device.

During the process, the *home* agent discuss with (n) other smart houses to communicate its consumption (c_i) in order to regulate the global consumption depending to the amount of available energy (GC), i.e $\sum_{i=0}^{n} c_i = GC$.

This situation can be compared to a consensus problem [11] where the smart houses form a graph communicating together to solve the same problem. The process is based on leader–follower allowing temporarily attribute a home as the current leader taking the decision for the neighborhood. The leader computes the new goal consumption of each home (g_i) as follows: all homes apply the same percentage on their current consumption

$$g_i = (2 - \frac{\sum_{j=0}^{n} c_j}{GC}) * c_i \tag{8}$$

In the configuration, it is also possible to choose any overall consumption. In this case, the home consumption is only based on the default goal consumption given at the beginning.

2.3 Progress of a Simulation

At the beginning, each smart house launches necessarily two agents: *home* agent and *controller* agent. The *home* agent declares itself to other houses already launched. An outside agent called *life conditions* allows to give the current simulation time, each home is based on the same time. The *controller* agent waits for new devices until the total number is respected and until the home time is synchronous with the current time simulation. For each new device, it declares itself to *controller* agent, and gives all its features on a directory. Both processes are shown in Figs. 1 and 2.

Once the simulation is launched, the *controller* agent at a discrete frequency, computes the current best strategy according to the goal consumption and launches devices if necessary. Then, the launched devices give feedback at the controller to report its values.

During the same time, the *home* agent discusses with other homes about the process of leader–follower. For voting the new current leader, a random timeout value is attributed at each home. The first home where the timeout is finished, declare itself

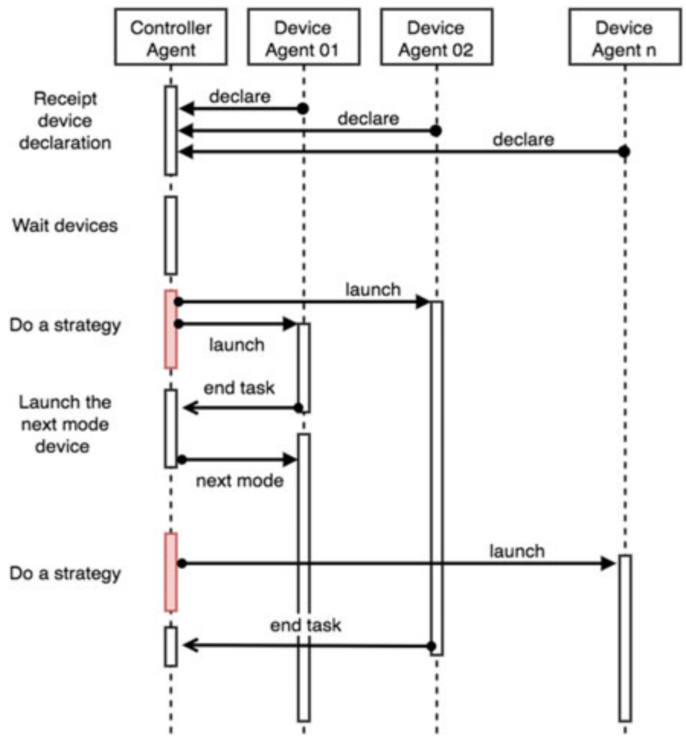

Fig. 1 Process of controller agents

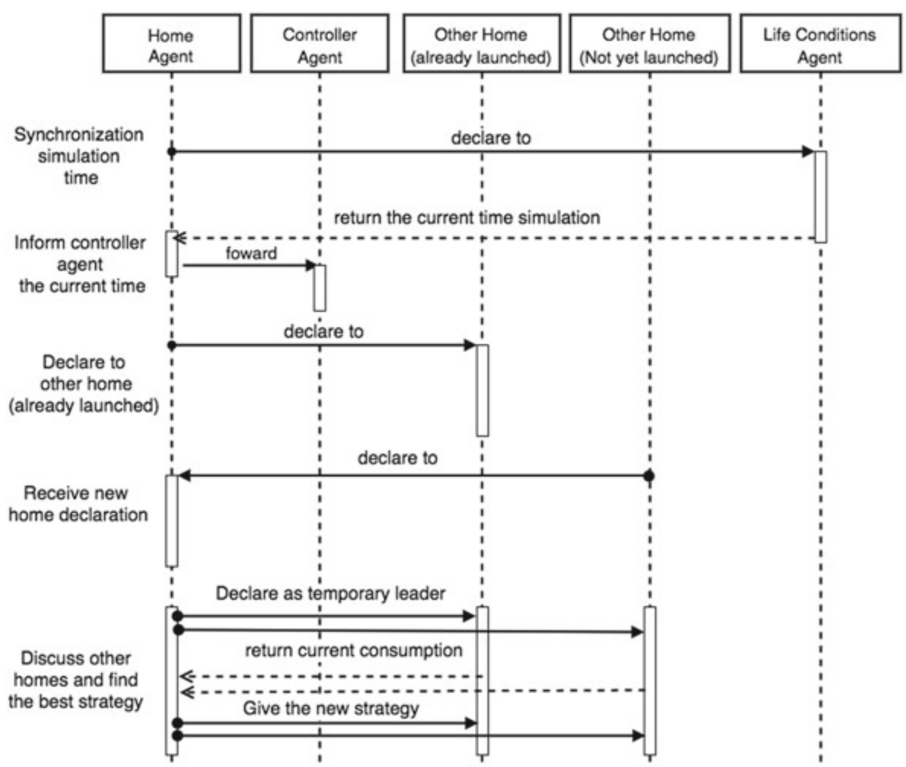

Fig. 2 Process of home agents

to other home as leader, waits answers with the house consumptions and establishes the new global strategy. Then it sends the new goal consumption. The current leader lost its status.

Sometimes, the communication between houses is broken, to avoid to block the process, the leader starts a timeout, in the case where homes don't give answer, the leader computes their new strategy. It believes their consumption by an average of the last known house's consumptions.

At the end of a simulation, all consumption for each home are stored in an individual Comma-Separated Values file, where each line indicates the time in seconds and days, number of activated devices, the current goal consumption and the current consumption.

3 Results

Two cases are shown in this paper. Each home returns CSV file with it consumption, a Python script allows to join consumption, analyzes them, and plots curves. For each consumption result, two curves have been plotted, one represents the real consumption, and the other shows the goal.

3.1 A Microgrid

In this test, consumption's goal evolves in function of the hours of a day.

Simulations characteristics:

- 5 houses
- 15–25 devices per house
- goal consumption:
  - in $[\![10h, 18h]\!]$, quadratic function whose the max is 5000
  - else, 3000
- 5 simulated days

The regulation (8) is applied according to their current consumption. In the Fig. 3, the two curves are similar (the blue one for the goal, the red one for the consumption), which means that the neighborhood and home's consumption are regulated within a goal.

For a smart house, the average consumption has only 1.2% error compared to its goal. The minimum of the whole simulation has less than a 10% error and the maximum less than a 15% error. 90% of all values have less than 5% of error compared to each house goals. But it is important to evaluate and catch errors and limitations. The next simulation tests its limits.

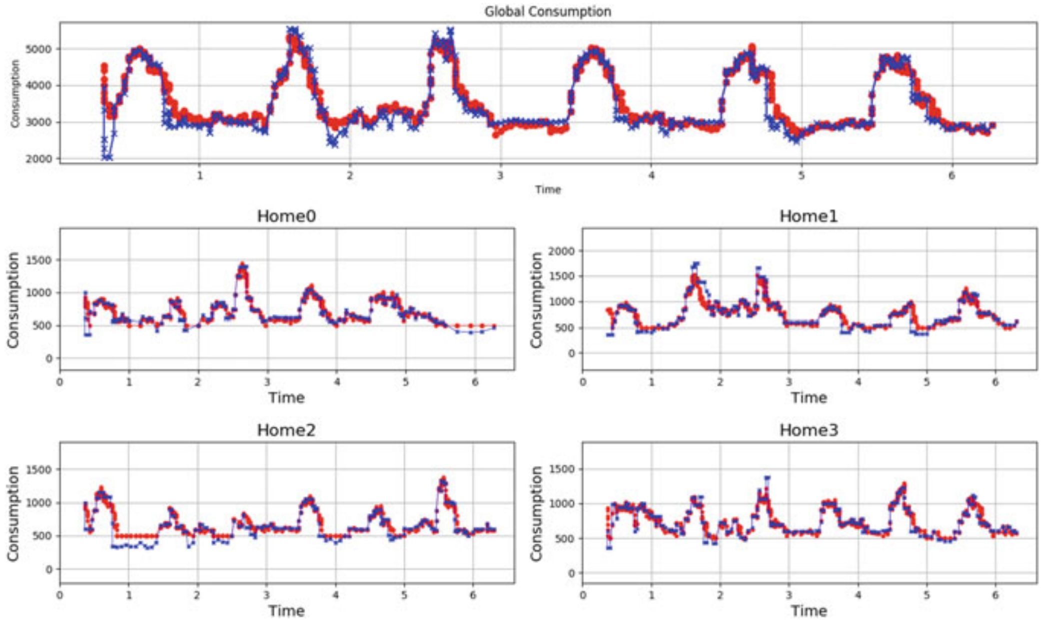

Fig. 3 Power production available in the neighborhood

3.2 Limits

All simulations get unwanted behaviors, in order to identify these ones a test has be done with the following characteristics:

- 5 homes
- 25–40 devices per home
- Goal consumption:
  - in $[\![10h, 18h]\!]$, quadratic function whose the max is 7500
  - else, 2500
- 7 simulated days

In the Fig. 4, the top chart represents global consumption of the neighborhood. Below two house consumption's curves are available. In both charts, the blue graph is the goal and the red graph is the consumption. At the top chart, a gap between the goal value and the system response happens when the consumption needs to be regulated at the minimum goal.

The regulation is not perfect, there are several reasons for possible error:

- The dynamic programming knapsack problem resolution has to create a $n * m$ matrix, where n is the number of device and m equals at weight. To reduce the matrix size, each weight is rounded to the nearest tenth.
- For acyclic devices, consumption is determinate through a Markov chain.

During this test, the system chooses to regulate the consumption of all homes to 500 but homes cannot be regulated at this value. This notion of physical problem

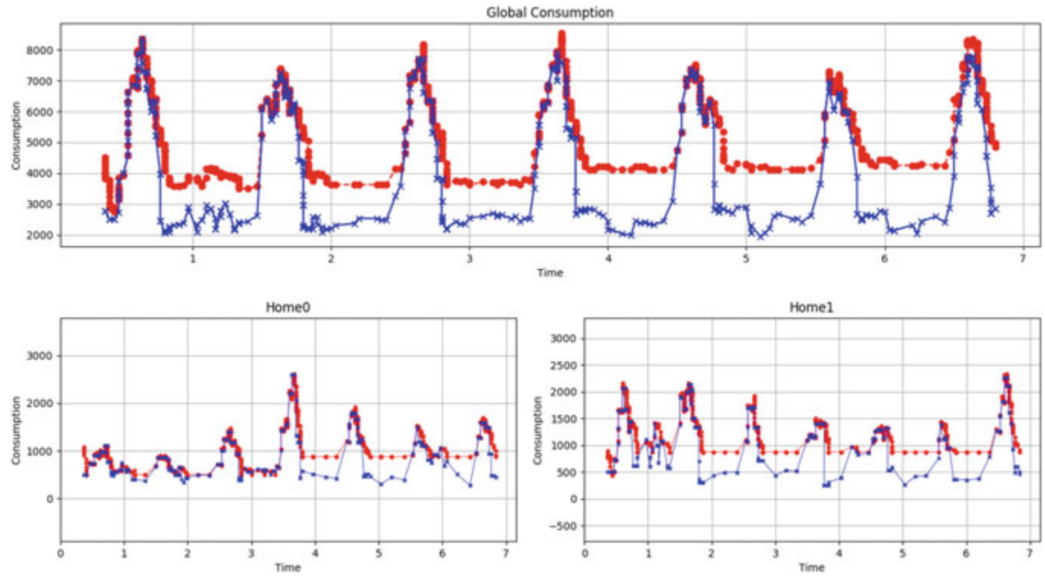

Fig. 4 Power production available in the neighborhood

is really important to know the limits of the simulation and to highlight potential problem during the implementation of this system in the real life.

These results have strengthened confidence about the presented model in the architecture and process chooses to realize this simulation. These different results show the possibility to easily create scenarios with various parameters, strategies, and goal consumption.

3.3 Enhancement

The behaviors of users are limited, the user gives use's preferences for each device. To raise the realism and flexibility of this model, it is important to add users perturbations. So that the model will be developed on Gama Platform,[3] facilitating the interface creation and interactions with the simulation. The final goal is to create a simulation more adaptable that can change easily before or during the test, and the possibility to interact with the simulation to disrupt the routine execution and verify that implementation can work in real life.

[3]Official website: http://gama-platform.org.

4 Conclusion

This paper has highlighted the necessity to implement some flexible demand-side management strategies. The simulation regulates the consumption on a local scale (house) and global scale (neighborhood). The results of this study indicate that the consumption can follow an order with the condition that the consumption is schedulable. In first though, a toy model is done. This one works in good conditions with few errors, few perturbations, and few changes. The next step would be to add some human disruptions in order to raise the realism and the credibility.

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