Towards Game Based Monitoring and Cognitive Therapy for Elderly using a Neural-Fuzzy approach

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Towards Game Based Monitoring and Cognitive Therapy for Elderly using a Neural-Fuzzy approach

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***Abstract*— As the proportion of older adults grows, the number of special care provisions to help individuals with declining cognitive abilities needs also to increase. Information Communication Technology (ICT) is beginning to play an increasing role in facilitating the work and research of specialists to support and monitor individuals with cognitive impairment within their everyday environments. In addition, advances in artificial intelligence and the development of new algorithmic approaches can be used to approximate the computational processes of human behaviour in different circumstances. In this paper, we report on the development of a software system using game based therapies for older adults in Mexico suffering from cognitive impairment, where this system has been deployed in a unique day therapy centre. We further propose an evaluation module based on using an Artificial Neural Network (ANN) approach to monitor the user performance, a Fuzzy Logic based module to detect significant changes in performance that might indicate a possible cognitive decline, and a bio-signals sensor in order to gather information about the emotional state of the patient during the interaction.**

Keywords*— *Alzheimer, Artificial Neural Networks, Cognitive Impairment, Computer Assisted Therapy.

I. INTRODUCTION

The world's elderly population is growing significantly and this is coupled with the growing, the number of elderly people developing cognitive impairment in older age. In the case of Mexico, the National Institute of Neurology and Neurosurgery (INNN) reported in 2010 more than 350,000 people affected by Alzheimer's disease and that annually 2,030 patients died from the condition [2].

Despite the information showing an increasing morbidity and mortality from mental disorders, we still lack a broad and comprehensive program to provide comprehensive care and rehabilitation for elderly. Moreover, according to some studies from Instituto Nacional de Psiquiatría in Mexico (Juan Ramón de la Fuente), people with chronic physical illnesses are more likely to suffer from mental disorders. For example, those who live with diabetes, now the leading cause of death in the country (México), are up to twice likely to suffer depressive events than healthy people.

This topic is of great importance for our country, because according to mortality statistics from INEGI, in 2010, 82.694 people died of diabetes mellitus nationwide, while in 2011 the figure was 80,788 deaths from the disease in question [1], then the.

We also can mention that, in the particular case of Mexico, the retirement age is not being considered as a crucial factor related to the cognitive impairment in elderly but, according to a study, professional activity may be an important determinant of mental exercise and social integration, so there is a significant decrease in the risk of developing dementia associated with older people who continue to be engaged in work or some vocation at and beyond retirement age. This is, in line with the "use it or lose it" hypothesis [4]. Besides, due to the growing rate of the ageing population, government funds may be insufficient to cover all their needs. Additionally, it is important to notice that not all the people will be able to qualify for a pension (and the probability of finding a part-time job decreases dramatically with age).

On the other hand, an increasing number of devices and new solutions to multiple human needs rely on Artificial Intelligence (AI) and other advanced computer-based technologies. A range of artificial intelligence techniques has been used in the design of advanced assistive technologies. Examples include text-to-speech systems for people with low vision; a digital programmable hearing aid that incorporate a rule-based AI system to make real-time decisions among alternative signal-processing techniques based on current conditions; and jewellery like device that allows people with limited mobility to control household appliances using simple hand gestures. In addition, significant research has been done to design obstacle-avoiding wheelchairs, among several other applications [6].

Affective computing (AC) is concerned with emotional interactions performed with and through computers. It is defined as "computing that relates to, arises from, or deliberately influences emotions" as initially coined by Professor R. Picard (MIT Media Lab) [16]. AC seeks to facilitate research through the recognition, modelling of human affective states. Practical applications of AC based systems seek to achieve a positive impact on human everyday lives by monitoring, communicating or affecting the emotive states of people. Affective sensing can be considered as being physiological sensors that can be used as part of an intelligent emotional recognition system to elicit an individual's physiological responses and interpret their emotional states in response to stimuli or task specific interactions.

Considering all these previous reasons, the Institute of Memory (supported by The Alzheimer Institute of Leon Guanajuato, Mexico) was established in 2005 due to the lack of specialized institutions in the treatment for patients with cognitive impairment, with the aim of creating (among several therapies) an interactive program of cognitive stimulation to enable both the intervention and prevention of cognitive decline in the elderly.

As such in February 2011 the Alzheimer Foundation Leon (FAL) proposed a joint venture with Leon Institute of Technology (ITL) to develop a software system called Mente Activa that allows the use of therapies through cognitive stimulation exercises to benefit FAL patients who suffered from cognitive impairment or dementia, given that observing a patient's activities can be used to monitor and assess cognitive performance and decline. For example, early stages of incipient dementia may cause forgetting certain steps in familiar tasks or difficulty in performing new and complex tasks.

An initial version of this system has now been deployed and is being assessed by patients at the Memory Institute and a Geriatric Center of DIF Leon (a public agency for Integral Family Development). An additional need to monitor patient's cognition both during the therapy sessions and remotely from home has been identified as useful for diagnosing cognitive impairment and monitoring progression of cognitive decline. We therefore further propose an extension to the existing system though the incorporation of an intelligent evaluation module that would analyse patient performance data acquired from the Mente Activa system. This might give us a more accurate picture of the patient's cognitive abilities, like the progressive decline of their abilities, to facilitate more targeted support from the specialists.

In a previous work [7], we exposed an analysis of some other software tools (SmartBrain, DIANA, Lumosity) used in favour of improve the cognitive performance across the world, and we discovered that there is a necessity of develop another system with a different approach specially focused in our cultural and language context. There is other proposal with similar goals, called Abueparty [17], however, in our research we are aiming to include a bigger field of stimulation areas related to cognitive impairment. In our research we describe the development and deployment of the software system and current work on the integration of an intelligent evaluation module to facilitate proper monitoring of patients progressive conditions at both the treatment centre and at home.

The rest of the paper is organised as follows. Section II lays the groundwork and introduces some important points about Artificial Neural Networks and Fuzzy Logic respectively, the AI topics related in our approach to monitor and measure the users performance, also introduces an important tool used in our system, WEKA, the popular suite of algorithms for data analysis and predictive modelling. Section III points out our approach in order to clarify its structure and how it is organized is related to our evaluation module approach that is being developed in order to detect important interaction changes on the user's performance with the software and its activities. In section IV the conclusions and future work of this research is presented.

II. Related Topics

In order to lay the groundwork we will talk about the main two topics used in our approach. Foremost, we will talk about ANN, given that this model will be used for recognize every single user interaction with each activity assigned to the user.

A. *Artificial Neural Networks*

Artificial Neural Networks (ANNs) denote a set of connectionist models inspired in the behaviour of the human brain. In particular, the Multilayer Perceptron (MLP) is the most popular ANN architecture, where neurons are grouped in layers and only forward connections exist [8]. They can be seen as a mathematical model or computational model that tries to simulate the structure and functional aspects of biological neural networks.

It consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation. ANN is an adaptive system that can change structures itself based information that affect the process during computation of connecting approach.

ANN has simple nodes (we can say neurons) which connected with other nodes to form a neural network. They work together to transform, process, and translate signal to something understood by human. It has an algorithm called Back Propagation that can alter its weight to get desired signal strength.

B. *Fuzzy Logic*

Due to the user performance must be assessed using a perspective considering several factors (including the whole set of exercises), and this reasoning could manage a certain degree of subjective to the eyes of an specialist, we are proposing to implement a Fuzzy Logic module, in order to throw appraisals of the whole user interaction with the system and recommend more exercises taking in consideration mainly the areas to improve, and the difficulty. There are several implementations using this kind of logic, including also this area of application (Dementia Care), for example in the work titled "A Fuzzy Ambient Intelligent Agents Approach for Monitoring Disease Progression of Dementia Patients" [15] we can find a good approach suggesting that Fuzzy Logic is an appropriate tool for the modelling patient's habitual behaviours.

Fuzzy logic is a form of many-valued logic or probabilistic logic; it deals with reasoning that is approximate rather than fixed and exact. Compared to traditional binary sets (where variables may take on true or false values) fuzzy logic variables may have a truth value that ranges in degree between 0 and 1 (crisp sets). Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false [5]. In this manner, Fuzzy Logic Systems (FLS) have been successfully applied in many areas.

T1 Fuzzy Sets (T1 FS) theory was first introduced by Zadeh [10] in 1965. Zadeh extended the notion of binary membership to accommodate various "degrees of membership" on the real continuous interval [0, 1], where the endpoints of 0 and 1 conform to no membership and full membership, respectively, just as the indicator function does for crisp sets, but where the infinite number of values in between the endpoints can represent various degrees of membership for an element x in some set on the universe. The sets on the universe X that can accommodate "degrees of membership" were termed by Zadeh as fuzzy sets [11].

As we can see, the Fig. 1 shows a schematic diagram of a T1 FLS. Knowledge is embedded within the rulebase in the form of rules whose antecedent and consequent are T1 FSs that partition the input and output domains. The crisp inputs are fuzzified into T1 FSs, which are converted to a new T1 FS by the inference engine. The defuzzifier transforms this new T1 FS into a crisp output. In summary, though FS operations are used in a T1 FLS, it still maps crisp inputs into a crisp output [9].

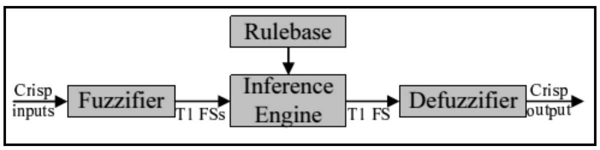

Fig. 1. A T1 FLS

C. *Weka*

WEKA (Waikato Environment for Knowledge Analysis) is a popular suite of machine learning software for data mining tasks written in Java, developed at the University of Waikato. WEKA is open source software available under the GNU General Public License.

Its algorithms can either be applied directly to a dataset or called from Java code. WEKA contains tools for data preprocessing, classification, regression, clustering, association rules, and visualization. It is also well-suited for developing new machine learning schemes [2].

Due to Weka is a widely used and proved tool and that, it has an API for use its algorithms directly from the Java code, we are integrating this tool directly in Mente Activa.

III. System Development

Although there are a number of systems on the market (Smartbrain, DIANA for example) specifically designed for supporting specialists and patients in the treatment of cognitive impairment, in the case of Mexico in particular, these tools are not fully adaptable to language specific customs and usages (the use of European context for the exercises and activities, the lack of historical and cultural facts related to Mexico, and Spanish accent). This makes such tools almost impossible to use as a support system for patients suffering from cognitive decline. Most patients are also unfamiliar with the use of computers, mouse, etc. For this problem, it seems to be necessary a support tool, with the aim of provide the characteristic therapy data to the specialist and suggest a series of exercises based on performance. Given that therapeutic monitoring can be insufficient due to shortage of specialists, the quality of the therapy can decrease.

Due to the previous reasons, in 2011 Leon Institute of Technology in collaboration with the Alzheimer Institute of León began the developing of a cognitive stimulation software called Mente Activa:

- Mente Activa is a software for the prevention, detection, evaluation and monitoring of older adults with cognitive impairment and dementia. The software allows cognitive stimulation through the use of interactive games specially designed by psychologists, running on computers with touch screen and multimedia items.
- The design, planning and development of Mente Activa required the collaboration of a multidisciplinary team, initially formed by five psychologists, one neuropsychologist, one neurologist, one graphic designer and two experts on education. The system includes the following areas of cognitive stimulation: language, gnosis, executive functions, calculus, attention, memory and orientation. In fig. 2 we can see some examples of activities according to the mentioned areas.

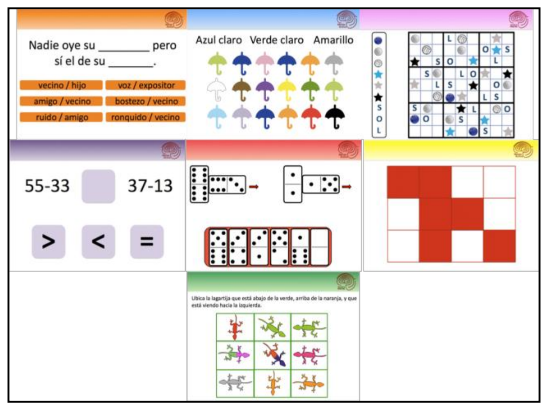

Fig. 2. Examples of some activities

- The computer programming and implementation was made by a team of programmers from Leon Institute of Technology. These students, from different semesters and chosen due to their programming skills and interest on participating in a real development problem, were coordinated by a group of professors and researchers from the ITL.

IV. System Evaluation Module

As we mentioned previously, our system can be used to detect changes on the performance of the user, and this could help in the early detection of dementia and Alzheimer. At the moment we are working on the design and implementation of an intelligent module that analyses the performance of a user, based on the execution of the game and the emotional state of the user, allowing automatic feedback to the user. This could be visualized in a better way in Fig. 3, where we can see the hierarchical dependencies of the modules.

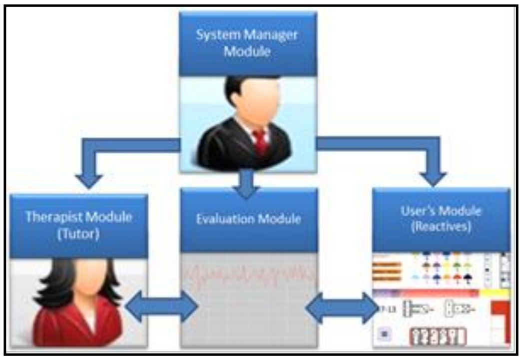

Fig. 3. Propose of Software Restructure

Due to the necessity of recognizing the emotional state of the user through the interaction with the different activities, we will gather and analyse the electro dermal activity using a skin conductance meter device, as it has been found that this signals are correlated with the individual's emotional state. For this purpose, we are using the e-Health Sensor [12], and additionally we are gathering some other data: pulse, airflow, body temperature, and electrocardiogram. Using this technique, the system could detect alterations associated with emotion, cognition, and attention [13], these emotional states could be very useful to the fuzzy logic module in the selection of activities specially designed for the user's needs.

The development of the proposed performance evaluation module involves the analysis and evaluation of different AI algorithms that allow us to monitor the user's characteristics and performance on the simulation exercises. At current phase, we are working on a Neural Network based scheme: Artificial Neural Networks, given that there is evidence demonstrating that it is possible for a computer system to recognize patterns of human behaviour through the interaction with a smart environment using neural networks as classifiers [14].

Also we are considering Fuzzy Logic, because the analysis of the behaviour and performance of humans involves uncertainty, such as uncertainty that two people can have different expressions and perceptions of the same stimulus.

In more precise terms, the software gathers two main features during the user interactions: the number of mistakes per activity, and the time needed for complete each game. It is noteworthy that the input data is being normalized, due to this could help to improve the network performance: This preprocess normalizes the input data between -1 and 1. Note that this is only internally; the output is scaled back to the original range.

Using this information, every interaction of the user is classified with an ANN into one of three classes: healthy, mild impairment and moderate impairment, taking into account that the ANN is being trained with previously labelled data according to the clinical diagnosis made by the specialist. The worst cases are not considered due to the difficulty of applying human testing in those cognitive conditions.

Once being classified, the total amount of activities are matched with the patient diagnostic, and considering also further information as: age, sex, hour when the interaction was made, etc. a system module based on Fuzzy Logic will provide a membership degree to its own diagnostic, and based on rules, the changes on the user performance can be assessed in uncertain terms with a significant meaning for the specialist.

At current time, the patient interactions are being designed using templates of exercises (proposed by psychologists) where the seven areas of cognitive stimulation are being considered. Also, we are working with real information gathered from patients of the Memory Institute and the Geriatric Centre of DIF Leon, and the preliminary tests are demonstrating that this approach could be very assertive recognizing the different kinds of user interactions. In the Fig. 4 the architecture of the proposed module is being shown.

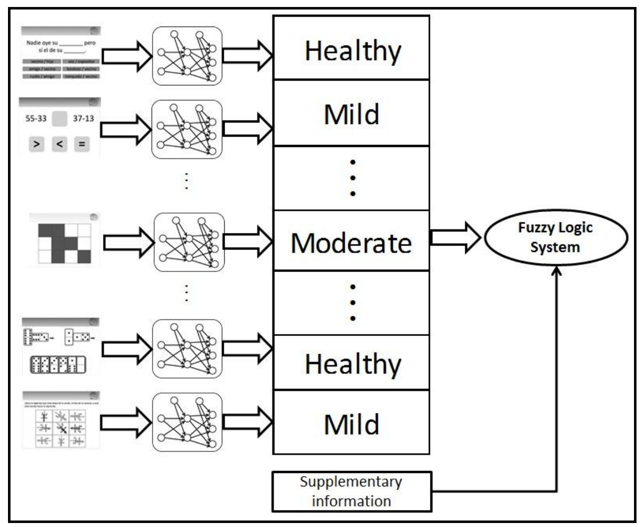

Fig. 4. Structure of the Intelligent System

For the next image, we are considering the three kinds of cognitive states of our interest: moderate, mild and healthy, and as we can see, there are two inputs gathered from the user interaction with an activity, and a single hidden layer.

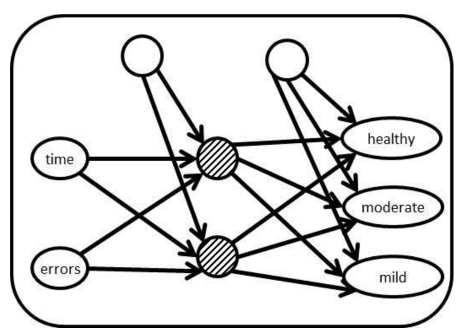

Fig. 5. Basic ANN design for every activity

For example, in the next figure Fig. 6, we can see one of the activities used, where the user has to select a piece in order to continue the game but taking in consideration that the remaining tiles must amount the lowest score possible.

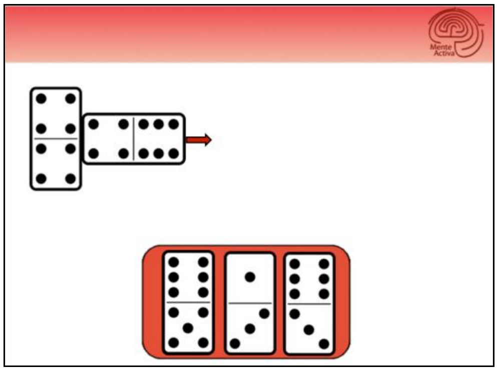

Fig. 6. Example of an Attention activity

V. Preliminary Results

At this stage, the first tests are being made with two groups of 10 patients each (previously diagnosed by psychologists of the Memory Institute) with a mild cognitive impairment, and another group of 6 volunteers in a healthy cognitive state (this quantity will increase, and also we are collecting more data from patients with a moderate cognitive impairment). We are using a cross validation of 2 folds in order to measure the ANN performance, and in the other hand, we are training the ANN models with the whole set of instances and then testing again with the same set. These firsts results shows a percentage of classification between 90% and 100% (see Table 1), but it is noteworthy that these tests are using templates with the easiest activities, so we can expect bigger performance differences in more difficult activities.

TABLE I.

Percentages of classification between two classes[a]

Num. of Activities	*Area*	*Average*	*σ*
3	Attention	96.66	5.77
7	Calculus	92.5	5.2
2	Executive Functions	100	0
7	Gnosis	89.28	15.92
7	Language	90	5.77
4	Orientation	90	8.16

a. Using the same set to train and classify

Conclusions

In this paper, we report our experience on the design and developing of a game-based stimulation and monitoring system for people with dementia. Additionally, a clear application of a machine learning technique can be seen, and although the preliminary results in classification are satisfactory, it is necessary a major amount of additional tests with more information, despite this need, due to the continuous usage of the software in the Memory Institute and the Geriatric Centre of DIF Leon, the future work with bigger amounts of data is assured. Moreover, there are several studies demonstrating the feasibility on recognizing emotions using bio-sensors, and currently we are also working with preliminary tests but, the future work will consist on integrating these two modules in order to generate a synergy able to suggest to the specialist a more accurate session of exercises based on the personal performance of the patients and the interest shown during the interactions.

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References

[1] FUENTES, Mario. “Salud mental: una agenda invisible”. Ref. July 16, 2013 from < http://www.mexicosocial.org/index.php/mexico-social-en-excelsior/item/309-salud-mental-una-agenda-invisible.html >

[2] Instituto Nacional de Neurología y Neurocirugía, ENFERMEDAD DE ALZHEIMER, 03 de Agosto de 2010 http://www.innn.salud.gob.mx/interior/atencionapacientes/padecimientos/alzheimer.html.G. Eason, B. Noble, and I.N. Sneddon, “On certain integrals of Lipschitz-Hankel type involving products of Bessel functions,” Phil. Trans. Roy. Soc. London, vol. A247, pp. 529-551, April 1955.

[3] The University of Waikato. Weka 3: Data Mining Software in Java. Accesed August 14, 2013 from <http://www.cs.waikato.ac.nz/ml/weka/>

[4] DUFOUIL, Carole. “Older Age at retirement is associated with decreased risk of dementia. Analysis of a healthcare insurance database of self”

[5] Novák, V., Perfilieva, I. and Močkoř, J. (1999) Mathematical principles of fuzzy logic Dodrecht: Kluwer Academic. ISBN 0-7923-8595-0

[6] Martha E. Pollack. “Intelligent Technology for an Aging Population”. American Association for Artificial Intelligence. AI Magazine Volume 26 Number 2 (2005).

[7] Javier Navarro, Faiyaz Doctor, Carlos Lino, Rosario Baltazar, Columba Martínez, Jaime Torres, Luis Bermúdez, Bertha Gutiérrez (2013). “Game Based Monitoring and cognitive therapy for elderly”. Workshop Proceedings of the 9th International Conference on Intelligent Environments. Vol. 17. pp. 116-127

[8] S. Haykin, Neural Networks. A Compreensive Foundation, second ed., Prentice-Hall, New Jersey, 1999.

[1]INDESOL has financially supported this project since February 2011 under the scheme of Joint Social Investment Program. INDESOL is a Mexican governmental office commissioned to carry out training, information dissemination, and support initiatives related to social policy and institutional development, coordinating with public and private institutions for the operation and maintenance of projects with high social impact.

[9] Dongrui Wu, “Affective Computing and Fuzzy Logic: Overview and Outlook,” Machine Learning Lab, GE Global Research, Niskayuna, NY USA. Unpublished Tech Report, 2013.

[10] L. A. Zadeh, “Fuzzy sets,” Information and Control, vol. 8, pp. 338–353, 1965.

[11] Timothy Ross. “Fuzzy Logic with Engineering Applications”. 3rd Ed. John Wiley & Sons, 2009. pp. 15-16. ISBN 0470748516

[12] http://www.cooking-hacks.com/index.php/documentation/tutorials/ehealth-biometric-sensor-platform-arduino-raspberry-pi-medical

[13] Poh, Ming-Zher, Nicholas C. Swenson, and Rosalind W. Picard. "A wearable sensor for unobtrusive, long-term assessment of electrodermal activity."Biomedical Engineering, IEEE Transactions on 57.5 (2010): 1243-1252.

[14] F. K. Al-Bin-Ali and N. Davies. Applying Neural and Regression Classifiers for Recognizing Activities in Intelligent Environments. Intelligent Environments, 2005. The IEE International Workshop on (Ref. No. 2005/11059)

[15] Faiyaz Doctor, Rahat Iqbal, Raouf N. G. Naguib. A Fuzzy Ambient Intelligent Agents Approach for Monitoring Disease Progression of Dementia Patients. Biomedical Computing and Engineering Technologies (BIOCORE) Applied Research Group. Fac. of Engineering & Computing, Coventry University, UK

[16] R.W. Picard (1997), "Affective Computing," MIT Press, Cambridge, 1997.

[17] Victoria Meza-Kubo, Alberto L. Morán. 2012. "UCSA: A Design Framework for Usable Cognitive Systems for the Worried-well". Personal Ubiquitous Comput. May 2012. xx, yy (Zzzz 201X), pp-pp. ISSN:1617-4909 (Online First). DOI: 10.1007/s00779-012-0554-x