Personalized Motivation in Dementia Management through Detection of Behavior Patterns

Ana Belén Sánchez-Calzón, Carlos Fernández-Llatas, Juan Carlos Naranjo, Teresa Meneu
[1]ITACA - Health and Wellbeing Technologies,
Universidad Politécnica de Valencia, Valencia, Spain
{absanch;cfllatas; jcnaranjo, tmeneu}@itaca.upv.es

***Abstract*— Dementia is one of the most common diseases in elderly people. Many people with dementia eventually become totally dependent on others for their care. With proper treatment, symptoms of dementia can be significantly reduced and stabilized. A successful treatment depends on recognizing which symptoms person experiences, making a careful evaluation, and identifying possible causes and methods to treat. Nursing Homes usually host a considerable number of people with dementia. To detect the disease in early stages may allow work on the development of mechanisms to reduce the cognitive impairment. The personalized motivation may help to adapt the patient environment, allowing adequate stimulating events, providing an opportunity for physical and psychosocial activity. The requirement is to study the behavior of patients in order to detect conduct disorders in their routines. This study presents a behavior pattern detection architecture based on the Ambient Assisted Living paradigm, and Process Mining technology allowing re-learning mechanisms in dementia disorders.**

Keywords-Dementia; eHealth; Monitoring; Motivation; Cognitive enhancement.

I. INTRODUCTION

Nowadays, dementia is one of the most devastating diseases of the elderly, causing a progressive decline of physical and mental functioning. International official organisms estimate that there are currently 30 million people with dementia in the world, adding about 5 million new cases annually. Detailed population-based studies of prevalence of dementia estimate that number of people affected will be over 100 million by year 2050, in different world regions [1]. People with dementia experience forgetfulness, depression, disorientation and confusion, becoming unable to plan and organize activities, even simple everyday tasks. Dementia is a loss of brain function [2]. The decline of memory, as well as other problems with language, decision-making ability, the capacity to discern and personality are necessary aspects for diagnosis. Symptoms of dementia include difficulty with many areas of mental function, such as language, memory, perception, emotional behavior, and cognitive skills [2].

It is estimated that 30-40% of people with dementia living alone at the time of diagnosis [2]. From that moment there is an increase in dependency, an increase in the risk of serious accidents, and difficulties to follow a proper treatment for the disease. To stop the advance of the dementia in elderly people it is needed to perform an individual comprehensive monitoring of the person. On one hand this allows detecting the dementia presence in early stages, and on the other hand, permits the evaluation of the state of the patient illness. Early identification of motor and cognitive changes, characterizing the beginning of this disease, may improve the therapeutic treatment and planning changes in lifestyle resulting [3].

The deployment of this kind of individual monitoring of patients is very demanding and requires the use of intelligent environments based in paradigms like Ambient Assisted Living (AAL) [4]. The use of advanced sensors, capable of detecting and monitoring the movement in people with cognitive impairment, allows collecting relevant data on the overall activity of the person. The results of studies show that the time a patient with Mild Cognitive Impairment spent to travel a given distance is greater than that used by healthy people. In addition, elder patients with cognitive impairment have a greater variation in the proper conduct of their daily activities [3].

There are multiple techniques for unobtrusively monitoring naturally occurring computer interactions to detect sustained changes in cognitive performance. Researchers have shown the importance of the early detection of cognitive decline. That detection is associated to a gently behavior change on the user. In this way subtle changes on the patient's behavior might suppose the presence of dementia illness in an early stage. The detection of these kinds of behavior changes has been approached using Process Mining techniques [5]. This approach is based on the inference of a basic workflow based model of the user behavior, and to compare that model with posterior behavior models of the same user. Differences among models show the behavior changes and, finally, will help the detection of dementia. An early detection allows for more effective clinical intervention, working on algorithms for inferring a user's cognitive performance using monitoring data from computer games and psychomotor measurements [6]. The research methodology of eMotiva Project is being tested into a Nursing Home, primarily focuses on detection of behavior patterns in dementia patients, besides engage in a cognitive, physical and language rehabilitation. The integrated cognitive stimulation program is a treatment of cognitive impairment aimed at maintaining and enhancing several cognitive processes affected by dementia [5] [7].

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Current best practices in care of elderly are based on comprehensive approaches that include actions, such as the stimulation and maintenance of cognitive processes. It has been shown that stimulation of ongoing cognitive activity can decelerate the degenerative process involving the diseases associated with dementia [8]. The modern society has experienced a rapid growth in the use of computers by elders. E-mail, Web browsing, computer games etc. are among the most common routine activities for this group of users. This work is developed in the framework of the National Spanish Project eMotiva. A pilot study is being carried out, relating the National Association of Physicians in Nursing Homes (SEMER).

The paper presents the implementation of an active integral system of monitoring and motivation for dementia patients. The execution of the monitoring subsystem is based on recognizing patterns in time series, while the personalized motivation is based on computer technologies motivation.

The research objective is to promote social inclusion as a therapeutic method, using digital content in response to behavior disorders. The purpose is the integration and deployment of the infrastructure for monitoring and encouraging people with dementia in a nursing home environment. The aim is the stimulation, reinforcement and maintenance of those cognitive processes affected by dementia.

Evaluation results regarding usability and improvement on the dementia management are being gathered by pilots in focus group in a Nursing Home in Valencia (Spain).

The following sections explain, in the first instance, the main objects that the project aims to obtain with their execution, as well as the methodology employed to the investigation development. In the following section, the eMotiva platform is explained, including a succinct description of the ongoing technology being used for detecting behavior patterns of patients. After that, the ongoing work in Nursing Home environment is explained, detailing the progress and achievements with the intervention, in the sense of utility and functionality of the platform. Finally, a discussion about main contributions of the project is presented, enclosed to outcomes.

II. MOTIVATION AND OBJECTIVES

There is no known cure for dementia. It is a disease that reveals how language skills disorders deprive people of their basic skills to be beings with feelings, thoughts and expression. Dementia patients require constant attention, because there is a serious loss of cognitive function, and gradually worsen over time, affecting memory, thinking and behavior [9].

Each incidence of the Dementia has two victims: the person with the disease and the caregiver. Caregivers are faced with the meaning of mind and dependence on the Dementia patient [10].

The main objective of the research is to create a tool that facilitates the association between health-care professionals and elder people with cognitive impairment caused by diseases associated with dementia, to provide them with personal and social benefits, encouraging inclusion social and therapeutic method through the use of digital content. The purpose of the research presented is to improve the daily environment of people with dementia, those who come daily or live permanently in residential institutions. The implementation of system has represented the creation of smart spaces based on the paradigm of Ambient Intelligence.

The research team work on spaces with wireless sensors and pattern recognition algorithms, also computational tools of motivation with multimedia content, which make possible the detection of patterns and the generation of integrated actions based on motivation for a correct treatment. This system supports residencies for physicians can design their own models of motivation, and to provide new models to detect behavior patterns. In this sense, the physician becomes self-sufficient in configuring the system, improving sustainability. Wireless sensor infrastructure is done through advanced radio interfaces and high energy efficiency, based on the wireless communications network *Zigbee* [11], providing complex network connectivity (scalable and configurable).

The applied methodology that is being used is goal-oriented and carried out in different stages described below:

- Development and application of intelligent tools for analyzing, designing and detect patterns in people with dementia.
- Creation of innovative multimedia motivational tools, a set of serious games, which make possible influencing attitudes and subsequent behavior of people with dementia, in order to improve or alleviate their degenerative process.
- Creation of a network infrastructure of sensors and actuators, radio interfaces using low energy to facilitate the interconnection of monitoring and motivation devices.
- Creation of a Smart Environment to monitor people with dementia in institutional residence. Implementation of the system with the tools developed in several pilots in a residence associated to the Spanish Association of Physicians in Nursing Homes (SEMER).

The interesting aspect about this platform is the motivation that occurs in people who are indisposed to move and train. Each physical and cognitive game presents a challenge and an attempt to improve day by day. It is important to focus on those games where people interact with self movement, recreations where the user moves and works against sedentary activity. The wireless controller that is used in games is able to detect motion and rotation in three-dimensional space. There is a significant increase in physical activity and, as a therapeutic tool, games help improving motor skills. The wireless controllers stimulate different motor skills and likewise help improving coordination and reflex.

From the psychosocial point of view, there is the conviction that human factors (attitudes, attention, motivation, memory, etc.) affect the interaction with computers. Regarding to social interaction, the use of this type of technologies promotes learning process, reflection

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and cognitive changes [12]. Moreover, video games are presented as elements that promote motivation, being playful. Video games generate emotions and cause effects on emotional interaction of people. The general atmosphere of the games developed (nice and visually pleasing relaxing landscapes) creates a climate of tranquility and animosity. The purpose is to manage in a properly way the cognitive impairment, to maintain or enhance cognitive aspects such as orientation, memory, different visual-spatial and executive abilities, or language.

The emotional aspects become central, considering the first-person games have the potential to induce emotions in the players. People may be emotionally involved with what happens on the screen, which increases their motivation to perform the task, developing a sense of immersion, in other words, a direct participation in a world of objects. Emotions represent an important part of motor learning, a way of reinforcement or avoidance certain behaviors [13]. They produce a significant motivation, helping prevent apathy, inactivity or passivity.

The games aim to raise enough motivation so users feel connected to their internal dynamic, which includes a playful and entertaining feature, besides a high value of perceptual stimulation and the incorporation of progressive and gradual levels of difficulty, encouraging the motivation.

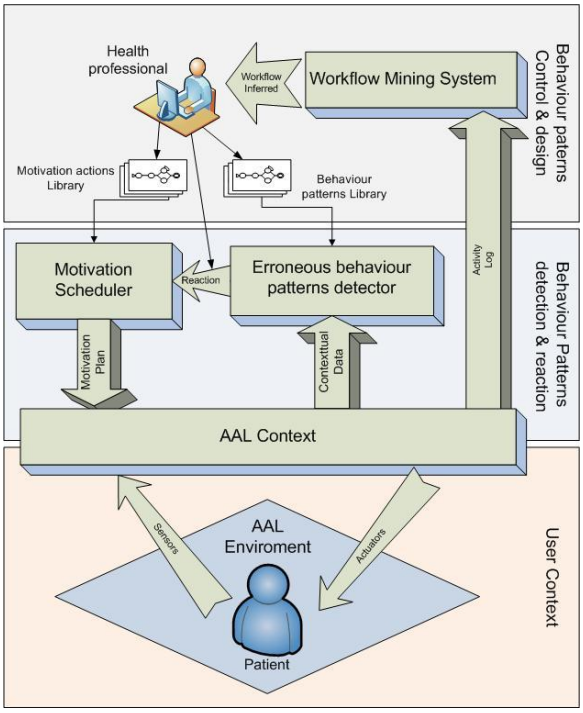

Figure 1. eMotiva Architecture

III. EMOTIVA PLATFORM

The project presented aims to create an intelligent environment to monitor people in nursing homes. The aim is to help staff Nursing Homes through the use of serious games to alleviate the cognitive decline in dementia patients, a sensing system to monitor the activity of residents, and a support system to detect anomalous behavior in patients (events), providing reasons and solutions to help to correct those behaviors.

Figure1 shows the eMotiva architecture. This architecture is mainly composed by three layers: the user context layer, the behavior patterns detection and reaction layer, and the behavior patterns design and control layer.

- The user context layer is in charge of keeping a continuously actualized picture of the user data. This layer has the similar function that the AAL context. This layer is composed by the sensors, and the actuators that are in touch with the users. The sensors gather the raw information of the user, which is stored in the context layer. The data gathered by that layer is used by the rest of modules to perform intelligent individualized user behavior detection. The monitoring and motivation platform is deployed by using a choreography paradigm [14]. All the sensors and actuators are connected as services to a choreographer, and the choreographer allows the communication among the services installed. In that architecture is possible to make service composition using workflow technology. Thanks to that, it is possible to preprogrammed motivation workflows that can be described by the professionals. Professionals can use workflow technology to predefine motivation sessions. In eMotiva, a workflow engine based on Timed Parallel Automatons (TPA) [15] was created in order to allow professionals the composition of services to perform the convenient games according to the individual used needs.

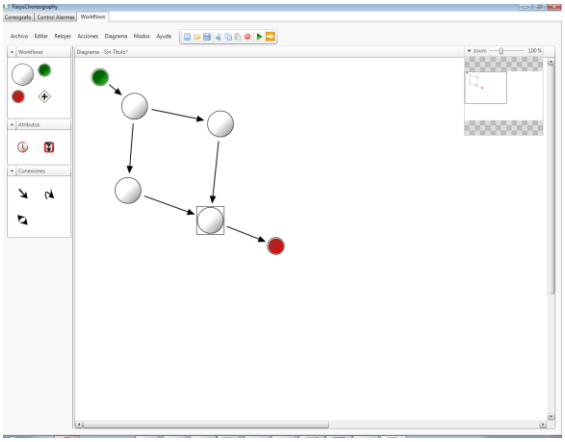

Figure 2. Screen capture of the workflow design tool is shown

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- The behavior patterns detection and reaction layer is able to react to anomalous behavior patterns to individuals. This layer is compounded by the erroneous behavior patterns detector and the motivation scheduler modules. The erroneous behavior patterns detector module is able to detect anomalous behaviors of individuals that must be corrected. This module is based on Artificial Intelligence technologies to allow the detection of those patterns. This quick reaction layer uses a rule engine to detect specific situations preprogrammed by health professionals, to detect specific situations. For example, that module is able to detect the presence of patient in prohibited spaces like the kitchen, or patient that is too much time in bathroom. In addition to this, an algorithm that allows comparison of workflows describing behavior patterns with the real actions performed by patients was implemented. This algorithm, called WIAA (Workflow Instance Aceptor Algorithm), shows how the flow of the current actions of the subject fits with the expected flow. In case of differences, these are highlighted. The result of the algorithm can be shown to health professional in a graphical way.

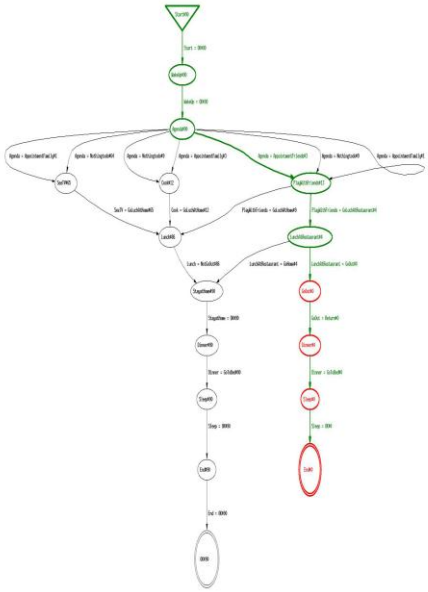

Figure 3. Screen capture of the Comparison of a workflow inferred by PALIA and compared with an execution instance Using WIAA

- The behavior patterns design and control layer is in charge of providing knowledge about how the plans are executed in the Nursing Homes, helping health professionals to evaluate the behavior evolution of patients. This layer is compounded by Workflow Mining System that is able to present graphically the activities flow of the user actions to health professional. The core of the Workflow Mining System is based on PALIA Algorithm [16]. This algorithm is able to infer workflows from the user activity logs and present it to health professionals. Using this graphical information, the health professionals could individually detect erroneous behavior patterns of the user and provide corrective motivation protocols.

  The wide variety in human behavior makes difficult to detect dementia symptoms with a static view of the subject flow. In this way, a workflow representing the usual flow of the user behavior is not conclusive. Hence, the Workflow Mining System is able to provide a comparative view of the user activities at different stages.

  Figure 3 shows an example of workflow inferred by PALIA Algorithm compared with an execution instance using WIAA algorithm. The green states represent the states that the instance has visited. And the red ones are those that are not foreseen by the original workflow.

As it was mentioned previously, the eMotiva Choreographer is in charge to allow the interconnection of the different services installed in the system. The choreographer dispatches the messages among the modules using a specific XML message protocol called XMSG, based on the combination of FIPA [19] and SOAP [20] protocols. There are Java, DotNet and Android choreographer versions that can interchange messages, to allow the interconnection among services programmed in different platforms. In figure 4, a graphical view of the choreographer is shown

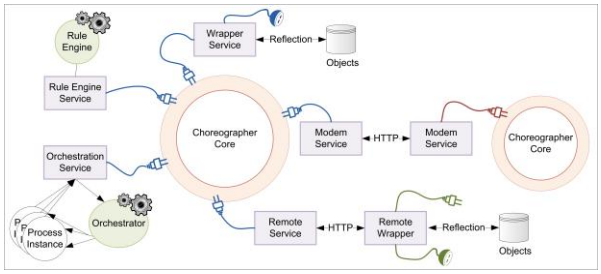

Figure 4. Choreographer Architecture

The choreographer has some facilities to allow a better communication of services. There are TCP and Message Queue Connectors that allow interconnect different choreographers among themselves, rule Engine Services and configuration services that allows starting

and stopping individually services without to re-start the choreographer.

IV. MOTIVATION RESULTS

The introduction of new techniques for detection of particular behaviors in patients with cognitive impairment, and the introduction of a system to propose appropriate activities to correct the behavior or detect the cause of its origin are useful for professionals in Nursing Homes. To measure the eMotiva system acceptance by professionals of the Nursing Home, a methodology based on TAM (Technology Acceptance Model) [17], it is completing a questionnaire to gather opinions about the usefulness and simplicity of use perceived by users. At this stage of research, according to the initial proposal, it has achieved the integration and deployment of the necessary infrastructure for monitoring and motivation of patients in Nursing Home. The current infrastructure is detecting behavior patterns, and providing mechanisms for personal motivation. The research team is working on stimulation, reinforcement and maintenance of cognitive processes.

Motivational tools are being implemented in order to influence the attitude or behavior of people with dementia, to mitigate and slow the degenerative process. According to this, it has been crucial to find out what would be more interesting activities to reinforce certain conditions. A series of in-depth interviews [18] with medical and health professionals in Nursing Homes were done. They had asked about the admission procedures of patients, a description of their routine activities, interaction with caregivers, the main symptoms and behaviors found in a state of mild dementia, the methods developed by physicians to detect anomalous behavior in patients, types of intervention, the perceived relevance, as professionals, towards motivation, and the physical and psychological benefits the games can report. Interviews results contributed to the proper planning of the technical and psycho-sociological intervention.

In-depth interviews were accompanied by other qualitative research technique, participant observation, the basic method by which the social scientist obtains information about some aspect of the world. It allows finding and studying certain behaviors described in the exact moment they are happening [18]. Participant observation was done at Nursing Home, allowing the patients to share their background, experience and everyday life, meet directly with all information apprehended by patients about their own reality. It was important to get people their definitions of reality and the contacts with which they organize their world. Dementia patients were observed during the sessions, interacting with them and participating in their activities, in order to they were comfortable and relaxed, without changes in their routine and common behavior.

A network of sensors and actuators has been installed, using low power radio interfaces, which facilitate the interconnection of monitoring devices and motivation. It is interesting to contribute ideas to develop with location sensors, and to study their utilities.

Regarding the serious games developed, there is a brief description of them, aiming their main benefits. The first game is based on a graphical model as realistic as possible to allow the user to immerse themselves in a delightful environment, interacting with it. The user moves and works against a sedentary lifestyle. Wireless controllers detect motion in a space of three dimensions. There is an increase in physical activity, enabling improved motor skills. The wireless controllers stimulate different motor skills.

In the following package of games, patients work with touch screen, allowing interaction between the user and screen in a simple way. The games enhance the psycho-motor capabilities and several cognitive processes. They aim to raise enough motivation so that users feel connected to their internal dynamics, which includes a playful and entertaining feature, with a high value of auditory and visual stimulation, incorporating difficulty levels that encourage the patient to improve and keep learning.

Finally, a set of games have been developed to enhance cognitive processes such as perception, memory, attention, language and emotions. Players must answer a series of general knowledge questions, adapted to their particular condition, and also to associate a set of images and sounds to known events of their lives. These serious games are also played with touch screen, encouraging the patient to interact with user-friendly new elements, as the touch technologies are. The newness represent a relevant element of motivation for people, although in the case of patients with dementia may become an obstacle, due to fear of the unknown, not understanding things correctly, the incomprehension of a new task. The eMotiva Project has the challenge of overcoming these obstacles, showing high profits and earnings of ICT in all social groups, in this concrete case study, in people with dementia, helping to improve their treatment and quality of life.

V. CONCLUSIONS AND DISCUSSION

Dementia is the most destructive disease of the elderly. It leads to a progressive decline of mental functioning, experiencing lack of memory, depression, confusion, or inability to plan and organize activities, even simple everyday tasks. Dementia illness can be detected and treated in early stages finding behavior disorders in people. This requires an individualized and appropriate human behavior modeling. The eMotiva Project is designed at motivating and monitoring of Dementia patients in Nursing Homes. The aim is to promote social inclusion as a therapeutic method by the use of digital content in response to behavior disorders.

Mild Cognitive Impairment (MCI) is the stage between normal forgetfulness due to aging and the development of some type of dementia. People with cognitive impairment have mild problems with thinking and memory that does not interfere with daily activities. The purpose of eMotiva Project is to provide tools for the detection and study of patterns of behavior associated with the disease, as well as a

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set of tools to help alleviate the degenerative process, reinforcing the fundamental cognitive aspects.

Symptoms of Mild Cognitive Impairment include, for example, forgetting recent events or conversations, difficulty performs more than one task at a time, difficulty solving problems, or take longer to perform more difficult mental activities. The monitoring and motivation strategies developed are currently working on these points, and waiting for complete data collection, there is significant progress in meeting the objectives. The psychosocial intervention, the methods of motivation and reinforcement of physical and cognitive processes damaged by dementia are intended to provide benefits, such as the following: Speech problems such as difficulty finding the name of familiar objects, misplaced items, lost on familiar routes, changes in personality and loss of social skills, to lose interest in things previously enjoyed, flat mood, learning new information or routines, forgetting events in their life, difficulty reading or writing, wrong use of words, deficient understanding of language, withdrawing from social contact, difficulty in performing basic tasks and recognizing family members. This platform is being tested in the National eMotiva Project, aiming to reveal the validity and acceptance of a personalized computerized support system for treatment of dementia disease.

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