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Behaviour patterns detection for persuasive design in Nursing Homes to help dementia patients

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Abstract— **Nursing homes usually host large accounts of persons with different levels of dementia. Detecting dementia process in early stages may allow the application of mechanisms to reduce or stop the cognitive impairment. Our ultimate objective is to demonstrate that the use of persuasive techniques may serve to motivate these subjects and induct re-learning mechanisms to stop mental impairment. Nevertheless, this requires the study of the behaviour of each patient individually in order to detect conduct disorders in their living ambient. This study presents a behavior pattern detection architecture based on the Ambient Assisted Living paradigm and Workflow Mining technology to enable re-learning mechanisms in dementia processes via providing tools to automate the conduct disorder detection. This architecture fosters the use of Workflows as representation languages to allow health professionals to represent persuasive motivation protocols in the AAL environment to react individually to dementia symptoms detected.**

I. Introduction

The number of dementia patients that are in Nursing Homes has a clear increasing trend [1]. It has been proposed to apply specific motivation protocols adapted to the special characteristics of individual subjects. For example,Wieloch et all [2] has pointed out the effects of re-learning mechanisms based on the plasticity of the nervous system. Furthermore, Chatterjee et all [3] and Pinto-Fontanillo [4], describe how the persuasive technology can be used to decelerate the cognitive impairment process in subjects suffering dementia processes. In that way, the use of persuasive motivation techniques [5] allows to motivate people to change behaviour disorders and promote healthy behavior patterns.

In that framework, it is a major problem to decide a correct treatment when discovering dementia symptoms in the subject. Furthermore, symptoms of dementia usually includes changes in the behaviour of individual subjects [6] that may compromise the security of the subject and other people. Nevertheless, this requires the analysis of the situation of the individualized behaviour model of the subject. This task may take a large effort in terms of time and resources. Individualized behaviour has been modeled previously by using Workflow Mining technologies [7] based on processing logs of daily actions of patients. We ague that the application of these techniques to dementia patients can help the automation of the conduct disorders discovery.

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Nevertheless, to achieve a controlled environment to gather the data required by that models it is mandatory to use natural, invisible and non intrusive interfaces. Ambient Assisted Living (AAL) [8] environments can afford that problem. Creating AAL environments in Nursing Homes, allows to bring patient information to the doctors when abnormal behavioral patterns arise.

In this study, we propose the architecture of a computerized support system to detect individual behavior patterns using machine learning algorithms for detecting dementia symptoms and apply systemic persuasive strategies for re-learning processes in the subjects. Our approach is based on AAL environments to permit active and reactive protocols.

This work is developed in the framework of the National Spanish project eMotiva where a pilot involving the National Association of Physicians in Nursing Homes (SEMER) is being carried out.

In the following sections the eMotiva architecture is proposed. First section is dedicated to introduce the problem of dementia illness and how persuasive models can help. The following section describe the Workflow technology and how can be used for detecting abnormal behaviour patterns of individuals. After that, the Ambient Assisted Living paradigm and its utility in Nursing Homes environments is explained. To end up, the eMotiva platform is explained.

II. Methods

Currently, the number of illnesses caused by aging is growing. In the case of dementia, it is estimated that in Europe there are approximately 5,752,754 people with dementia and this number is increased by 824,000 new cases per year [1]. Dementia is associated with certain behavioral disorders [6]. Therefore, in the diagnosis of dementia are identified several mental and behavioral symptoms. Examples of these symptoms are personality changes, delusions, hallucinations, anxiety, agitation, hostility, erratic or insomnia. In fact, it is demonstrated that 50% of Alzheimer patients has depression [9].

To alleviate the degenerative process of dementia patients it is necessary to stimulate a continuous re-learning processes based on the neural system plasticity. The studies agree on the relevance of detecting the dementia in early stages and apply mechanisms to reduce or stop the cognitive impairment [4]. We incorporate the motivation loop in our system through persuasive technology. The persuasive technology [5] was designed to change attitudes or behaviours of the users through persuasion and social influence, but

not through coercion. Using persuasive technologies it is possible to react to certain disorders by applying motivation protocols to correct or encouraging the activities of the patient. Our approach is to empower motivation by using a set of multimedia contents to assist the therapy, integration and re-learning routines of subjects [3].

Hence, the architecture is prepared to incorporate different persuasive strategies models to achieve specific objectives in a continuous motivation loop for the re-learning process. For example, the strategy *simulate cause-and-effect scenarios* can be applied by means of simple multimedia games to reinforce the attention and stimulate the use of memory, the strategy *suggestion* can be used when detecting abnormal behaviours or as programmed therapy to engage the knowledge about the environment and temporal conditions, the strategy *social roles* is used by means of avatars inspired in the family to increase the social involvement and memory of the persons with degenerative processes.

A. Behavioural patterns detection

The main problem of the use of persuasion technologies in dementia patients in an effective way is the detection of conduct disorder patterns. As it is said previously, modifications on patient behaviour patterns must be detected to discover the degenerative process in dementia illness. Nevertheless, each patient has different behavioural patterns. That suppose that behaviour patterns that target dementia illness in a specific patient can be normal patterns in other patients. As an example, if the patient usually stay at home, this can be a symptom of social withdraw, but, also can be due to patient personality. In that case, it is necessary to compare the current behaviour with the previous one of the patient to detect conduct changes, and, unfortunately, this requires an individual study for each patient.

Behavioural patterns are difficult to be detected in individuals. The implementation of an individualized model of the behaviour of a simple user is a very complex task. In order to implement it, the participation of specific behaviour experts for its design and definition is required. Those experts in elderly care, only after observing the behaviour patterns of each patient for a sufficient period of time, will be able to define the behaviour model of the patient. Then, the professional is allowed to compare the model with the current status of the patient. This methodology has two important disadvantages: firstly, it requires too many human and time resources, and secondly, the final result may not reflect the current status of the person due to the influence of time.

Since the manual design has insurmountable disadvantages, a computer aided design is needed to solve that problem. Firstly, it is necessary the definition of a representation language able to represent the user behaviour in a formal way. A formal representation language allows the use of techniques to learn and compare models using computer based algorithms, which automate at maximum the erroneous behavioural patterns detection. In the literature, the process definition problem is usually solved by using workflow technology [10]. Although workflows are traditionally oriented to describe industrial and business processes, they are currently being used more and more for the standardization of complex process. To represent the human behaviour in a general way, and particularly the behavioural disorder patterns, it is necessary the use of a formal representation language with a wide expression capability. This is because, the human behaviour is complex to specify. In previous works, workflows have been used for used for complex fields. For example, a workflow based language for cardiologic care protocols standardization was presented by Naranjo et all [11]. The use of workflows for defining human behaviour has been probed [12]. In this study some efforts on defining workflows that describe patient behaviour interaction with AAL environments are presented. For eMotiva architecture, the autors propose a general purpose Workflow representation languages named LAP (Life Assistance Protocols) [13]. These protocols has been tested describing daily care protocols for chronic patients. Authors propose this formalism due to its wide expression capability and low complexity.

By using a formal workflow representation language, it is possible to help health professionals to infer behavior patterns of the user assisted by pattern recognition techniques. Using Workflow Mining technology, it is possible create a behaviour model of the patient, by inferring workflows of an individual at a specific moment [7]. According to workflow mining metodology, it is possible to use the past actions performed by an actor to infer the real process flow using pattern recognition techniques. Workflow Mining algorithms generalize automatically the flow of individual sequential or parallel activities and generates a complete graph that describes the possible flow combinations of the actions. The result of these algorithms applied to human behaviour discovery are formal workflows that describes the flow of the actions taken by a human in a bounded time. The comparison of current human behaviour workflows with past ones allows the detection of subtle changes that target to dementia illness. For example, a decrease in the number of times an individual goes out to dinner or social meetings target to a social withdraw that is a symptom of dementia.

B. Ambient Assisted Living in Nursing Homes

Workflow Mining algorithms use log of patient's performed actions to infer their behaviour flow. In order to capture the data required it is mandatory to build a monitorized environment in the user ambient.In fact, Nursing Homes are controlled environments to monitorize elderly people. For that, Nursing Homes are the best place to test the technology proposed. Empowering Nursing Homes using technology allow us to collect the data necessary for Workflow Mining Algorithms.

Nevertheless, the collection of data must be as less intrusive and invisible as possible in order to avoid affecting the behaviour of patients. In this way, AAL paradigm can deal with this problem. AAL [8] is the concept that embraces all the technological challenges in the context of Ambient Intelligence to face the problem of providing easy to use,

accessible, affordable, sustainable and efficient solutions that improve the level of independence, promote the social relationships, leverage the immersion in the environments and encourage the psychological and physical state of the person. In practical terms, AAL refers to the technological environments that are sensitive and responsive to the presence of people and provide assistive propositions for maintaining an independent lifestyle. The potential benefits of AAL solutions are already clearly recognised, and societal trends indicate that they will be attractive to a large and increasing number of people. AAL concept is usually associated to technological context in which elderly people can increase their life independence.

AAL is the solution that appears in the horizon since the related technologies and applications to be developed will be focused on the main characteristics of Ambient Intelligence(AmI) [14]. AmI implies a seamless environment of computing, advanced networking technology and specific interfaces. It is aware of the specific characteristics of human presence and personalities, takes care of needs and is capable of responding intelligently to spoken or gestured indications of desire, and even can engage in intelligent dialogue. AmI should also be unobtrusive, often invisible. So one of the key features of AmI and AAL is that the technologies should be fully adapted to human needs and cognition, and totally controlled regardless of the specific condition of the user. Thus, AAL puts the technology in the hands of any person in a way that is transparent to him and specifically developed to manage his needs. In that way, seniors will have all the advantages of the AAL services and will avoid all the disadvantages of using technology.

In that environment, the application of new technologies can improve the quality of life of senior citizens. The creation of AAL spaces in Nursing Homes can assist in the detection, grading and treatment of behavioral disorders and specifically in dementia patients. The capture of data via non invasive ambiental sensors and the posterior sequential analysis of acquired actions performed by dementia patients, via workflow mining algorithms, can provide a view of the degenerative symptoms that are present in user behaviour. In addition, AAL actuators can be used for application of methodologies for the motivation to improve quality of life providing support to patients lifestyle in a continuous and mobile way.

III. Results

In this paper, eMotiva architecture is presented. eMotiva is an AAL-based architecture to detect behaviour patterns of subjects in Nursing Homes to allow the application of persuasive technologies to correct conduct diseases. The eMotiva achitecture gives the computational environment to monitorize patients to detect erroneous behaviour models and correct them by using preprogrammed and fully controlled pervasive models. The main objective of eMotiva is the promotion of the social inclusion as therapy via the use of digital content in response to behaviour disorders.

Figure 1 shows the eMotiva architecture schematically

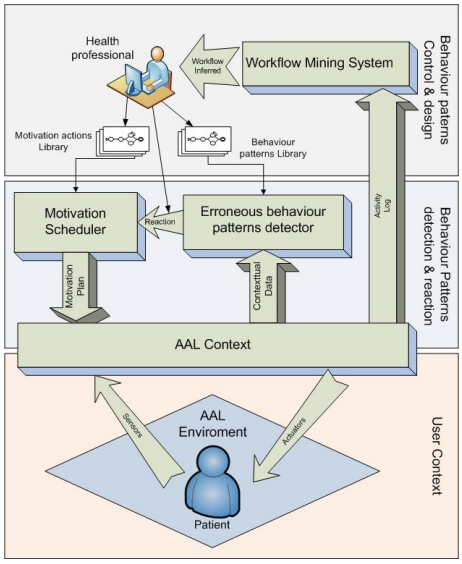

Fig. 1. eMotiva Architecture

The eMotiva architecture is composed by three layers; the user context layer, the behaviour patterns detection and reaction layer and the behaviour patterns design and control layer.

The user context layer is compounded by the AAL context, the sensors, and the actuators that are in touch with the users. The sensors and actuators are invisible and non intrusive, following the AAL paradigm. The sensors gather the raw information of the user, which is stored in the AAL Context.

The behaviour patterns detection and reaction layer is thought to provide a semi-automatical response to anomalous behaviour patterns to individuals. This layer is compounded by the erroneous behaviour patterns detector and the motivation scheduler modules. The erroneous behaviour patterns detector module is able to detect anomalous behaviours of individuals that must be corrected. The detection of those patterns is made by an algorithm that allows comparison of workflows that describe behaviour patterns with the real actions performed by patients. 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 2 shows an example where a flow of actions performed by a patient in a day is compared to a usual workflow. The differences in the execution are marked in the picture. On one hand, the green transitions and states represent the segment of the path followed by the patient that matches with the workflow. On the other hand, the red transitions and states represents the segment of the path of the patient that are out of the usual workflow defined for the patient. The numbers in the transitions represents the number of times that this transition has been reached. In the example of the figure, it is shown how and when the actions performed by the patient are out of the workflow path and

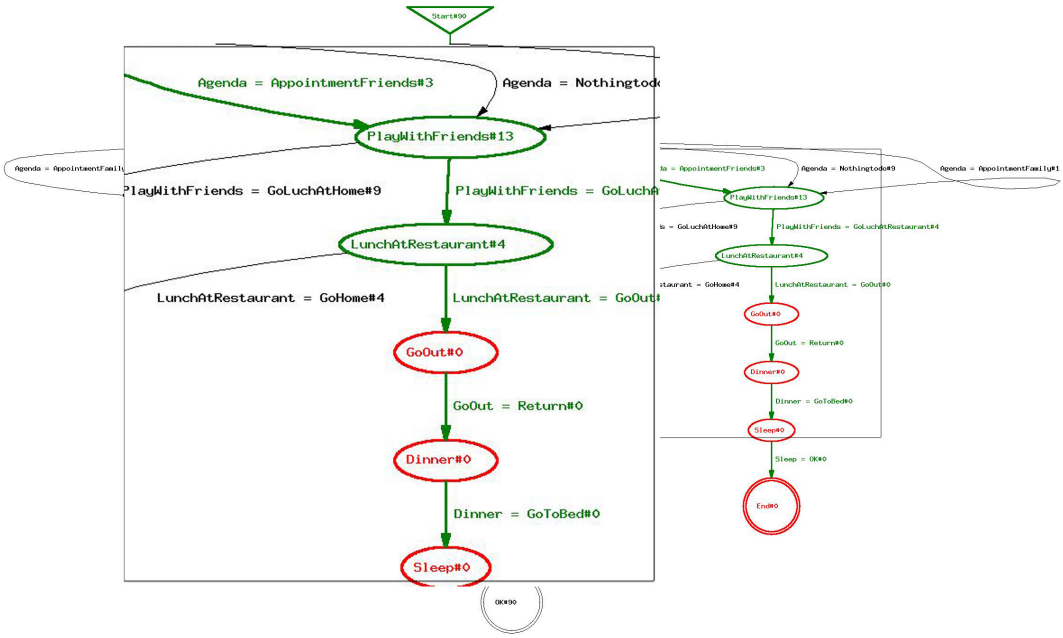

Fig. 2. Comparison of a workflow with a real execution

what actions are performed instead the usual ones. With that information, the health professional is able to decide what are the motivation plan to apply to the patient. It is possible to preprogram a motivation plan in order to react automatically to specific anomalous behaviour patterns. The motivation scheduler is a module for assigning motivation plans to patients. Motivation plan can be assigned manually by health professionals or as a reaction to specific behaviour pattern detection. The health professional has a tool to graphically represent motivation plans as workflows. The motivation plan designed is computer readable and can be executed in the AAL environment. This plan will execute the actuators and coordinate the Nursing Home workers in order to apply the adequate persuasive model to the specific patient to correct his behaviour.

The behaviour patterns design and control layer is in charge of providing knowledge about how the plans are executed in the Nursing Homes and helping health professionals to evaluate the behaviour 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 [15]. This algorithm is able to infer workflows from the user activity logs and present it to health professionals. Using these graphical information, the health professionals, could individually detect erroneous behaviour patterns of the user and provide corrective motivation protocols.

The wide variety in human behaviour 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 behaviour is not conclusive. Hence, the Workflow Mining system is able to provide a comparative view of the user activities at different stages. In figure 3, two workflows have been inferred using different samples taken at different time. The comparison between the workflows shows the behaviour changes of the subject. The comparison was made by using the EDWA(Edition Distance Workflow Algorithm). This algorithm searches the differences between two workflows, highlighting the derivations and states added and removed. In the example of the figure, the red arrows indicates removed derivations. On the contrary, the added derivations are marked in green. Using this graph, the health professional can analyze the effects of the motivation protocols and detect new behaviour disorders in the patient actions.

IV. Conclusions

Dementia illness can be detected in early stages finding behaviour disorders in patients. This requires an Individualized Human Behavior Modeling. To solve that, the authors propose the use of Workflow Mining techniques can be used to help health professionals in the detection on behavior disorders in individuals.

Once the dementia illness is diagnosed, the application of persuasive protocols allows to alleviate the degenerative process of dementia patients.

In this way, an Ambient Assisted Living based architecture to help health professionals on diagnosis and motivation of dementia illness is presented.

The architecture promotes the use of workflow technology to help dementia treatment via discovering conduct disorders in Nursing Homes patients. Dementia symptoms are founded by comparing the workflow based behaviour models of the individual patients. A workflow mining algorithm is used to discover the patient behavior model taking as the entry point

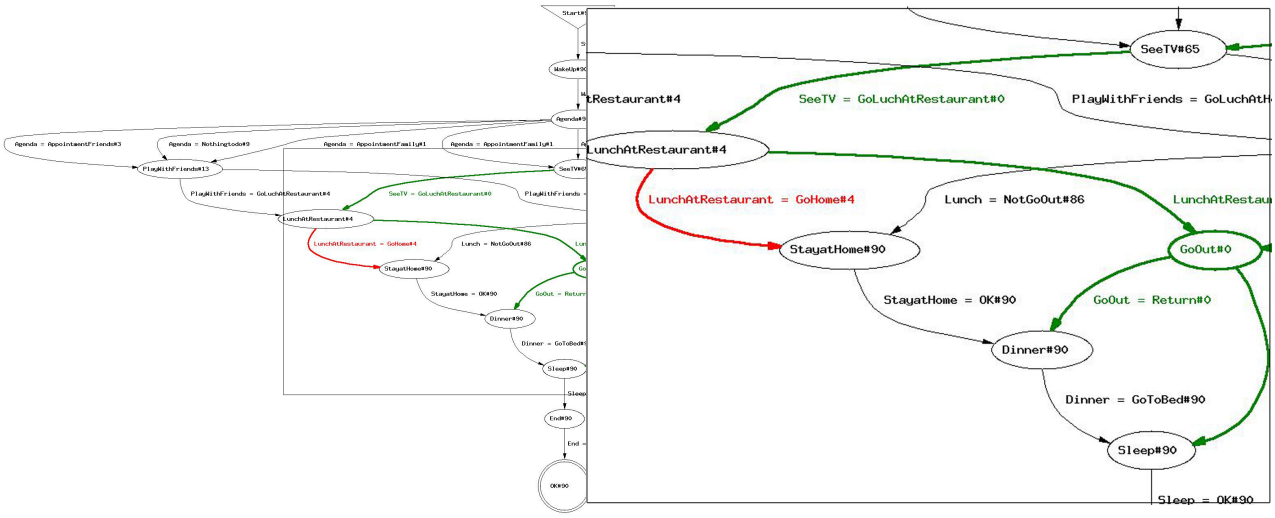

Fig. 3. Comparison of two workflows

the data gathered by a specific module based on Ambient Assisted Living paradigm.

This architecture is being tested in the national founded project eMotiva. This project aims to demonstrate the acceptance of a computerized support system for treatment of dementia.

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