ALPHA: an eAsy inteLligent service Platform for Healthy Ageing

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Abstract Dementia is one of the biggest global public health challenges facing our generation. Alzheimer's disease (AD) is the most frequent cause of dementia in elderly people over 65 years of age. The typical characteristic of AD is impairment of memory. As the disease progresses, other cognitive domains such as language, praxis, visuo-spatial and executive functions become involved, eventually resulting in global cognitive decline. Behavioral Psychological Symptoms of Dementia (BPSD) problems are constant in AD and have a highly negative impact on the quality of life of patients and their families. ALPHA project aims at developing an intelligent situation-aware system to collect and process information

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about Alzheimer Disease patients' life style. Starting from various data provided by caregivers and a set of non-invasive sensors and devices, ALPHA will provide clinicians with new quantitative and qualitative information about patients' abnormal behavior which, along with medical data, will enhance the accuracy and reliability of monitoring and assessing the patient's health status. Clinicians will be supported by a suite of specifically designed tools and interfaces to analyze the metadata captured, improve management of personalized care plans and interactions with both patients and caregivers. Furthermore studies of antique records of a former psychiatric hospital will give the chance to widen the knowledge of behavioral disorders thus allowing to compare the ancient and the recently ones and to probabilistically determine relation between type of dementia and behavioral disorders.

1 Introduction

Dementia, including Alzheimer's disease, is one of the biggest global public health challenges facing our generation. Today, over 35 million people currently live with the condition and this number is expected to double by 2030 and more than triple by 2050–115 million [1]. Dementia is a degenerative condition with no known cure. Symptoms, such as memory loss, cognitive impairment, difficulty in communicating and changes in mood get worse over time. These experiences are distressful for the individuals and upsetting for their relatives. To date, the patient and her/his caregivers are the primary source of information during follow-up visits. Information such as the description of abnormal behaviors manifested by the patient are essential for the assessment of health status and for the quality of drug therapy, especially in the early stages of the disease. Patients and caregivers, however, may not be reliable in providing such information, for example in assessing whether an improvement in symptoms has resulted from use of a particular medication or in describing quantitatively anomalous behaviors.

The eAsy inteLligent service Platform for Healthy Ageing (ALPHA) project aims to develop a new, intelligent, situation-aware system able to collect, process and store information about the daily lifestyle of AD patients; starting from heterogeneous data both provided by caregiver inputs and from a set of non-invasive sensors and devices, ALPHA will provide clinicians with new quantitative and semantic information about the behavior of patients which, in conjunction with medical data, will enhance the accuracy and the reliability of the monitoring and assessment of the patient's health status. It is clear that the system does not replace direct contact between patients and physicians, but it may permit AD patients to increase their chances of better care provision, so reducing the risk for inappropriate or useless support and the need to frequently recur to healthcare facilities.

Furthermore, a subsystem will be designed and created in order to provide clinicians with advanced analysis and care planning tools; in particular, an Alzheimer patient profile interoperable with standard Electronic Health Records (EHR) will

be defined to integrate clinical information with a passive monitored data system, also to enhance care coordination.

2 Related Works

Understanding the nature of human activities is itself a significant research question in many disciplinary traditions, such as in psychology, sociology, and ergonomics. The variety of perspectives creates problems, since each discipline may exploit different tactics to uncover human actions. Understanding how to represent human activities for the purpose of having intelligent environments draws upon these different traditions, and represents a significant multidisciplinary challenge [2]. An emerging field of application for human behavior representation and recognition techniques is Ambient Intelligence [3]; Nater et al. [4] propose a data-driven hierarchical approach for the analysis (by means of visual scenes). In [5], a model-based behavior analysis system for assisted living is proposed. Monitoring human behavior is achieved with unsupervised learning algorithms. Behavior is defined as a recognizable pattern in a sequence of events or activities and is represented by means of Hidden Markov Models (HMM).

The state of art provides also a lot of examples of solutions to monitor some of Abnormal Behaviors (AB) related to AD such as Wandering, Sleeping Disorders and Anxiety. Some solutions can be useful to prevent wandering behavior of Alzheimer patients. There are, however, few examples of outdoor wandering prevention tools. Campo et al. [6] developed methods for determining normal trajectory classes and triggering alarms when the trajectories are unusual. They compared each extracted path to all types of trajectories in order to classify them using a neural network. OutCare [7] determined a set of points of interest on a map, the system use the GPS signal to detect patient's location by analyzing the distance between his/her position and the nearest point of interest. Another kind of interesting AB is related to sleeping disorders. ICT solutions aiming to monitor those have been described in the literature. Poree et al. [8] proposed a sleep recording system to perform the monitoring of sleeping disorders; the solution adopts five electrodes: two temporal, two frontal and a reference. This configuration enables to avoid the chin area to enhance the quality of the muscular signal and the hair region for patient convenience. The electroencephalopgram (EEG), eletromyogram (EMG), and elctrooculogram (EOG) signals are separated using the Independent Component Analysis approach. Occhiuzzi and Marrocco [9] investigated the feasibility of the passive RF identification technology for the wireless monitoring of human body movements in some common sleep disorders by means of passive tags equipped with inertial switches. Panagiotakopoulos et al. [10] detected and tracked the anxiety disorders of patients. In their study a context-aware approach is proposed, aiming to provide medical supervisors with a series of applications and personalized services targeted to exploit the multi-parameter contextual data collected through a long-term monitoring procedure.

2.1 ALPHA Contribution

ALPHA will improve, moving beyond previous approaches, the detection and classification of abnormal behaviors by extending well assessed approaches for normal behaviors and integrating them with methods emerging in different fields of application for the detection of faults. In particular, ALPHA will extend hidden Markov approaches by (i) incorporating information from heterogeneous sensors, (ii) exploring how Markov models can be combined with a priori rules formally describing behavior to better capture it, and (iii) using behavioral multiple models associated with different levels of disease progression to estimate long term behavioral trends and classify behaviors, (iv) using the historical and archival data extracted from clinical records of psychiatric hospitals no longer in use which, in the past, combined with advanced molecular biology technologies, allowed to reach the unexpected goal such as the isolation of causal genes for inherited Alzheimer's disease [11]. In addition, abnormal behaviors will be detected and classified from historical records by means of the definition and runtime verification of correctness properties.

3 Abnormal Behaviors

ALPHA focuses on the monitoring of abnormal behaviors deriving from AD. For this reason it is worth to survey which are the common ABs that affect patients with AD and then describe the ones that are subject of our work.

- *Aggressive Behaviors*: Patients with Alzheimer Diseases could show aggressive behaviors both verbally and physically. The reasons which could entail such behaviors are: fear, anxiety or frustration due to difficulties to communicate their feelings.
- *Anxiety*: When PADs are agitated or nervous, they usually show irritable and restless behaviors. Documented cases show that these emotion states cause to wander or touch everything.
- *Quick changes of the state of mind*: The mood of the patient changes quickly and due to not apparent reasons. However, these quick mood changes are due exclusively to the disease.
- *Depression*: People with dementia who suffer from depression may show more behavior problems, such aggression. It is hard to describe the difference between depression and some of the symptoms of Alzheimer's disease.
- *Wandering*: Wandering behavior is quite common among people with dementia. Some wander in the house, others try to get out, others still walk at night when other people sleep.
- *Sleeping Disorders*: Abnormal sleep can be the result of a wide variety of causes, and is not thoroughly understood in cases involving people with dementia. It is known that people who suffer from dementia spend less time in deep

sleep, awaken more often during the night, are more likely to wander at night, and nap more often during the day.

3.1 Anxiety

A person with Alzheimer's may feel anxious or agitated. He or she may become restless, causing a need to move around or pace, or become upset in certain places or when focused on specific details. Anxiety and agitation may be caused by a number of different medical conditions, medication interactions or by any circumstances that worsen the person's ability to think. Ultimately, the person with dementia is biologically experiencing a profound loss of his/her ability to negotiate new information and stimulus, as a direct result of the disease. People with dementia may also show behavioral symptoms including agitation, hoarding and demanding constant company (not wanting to be left alone) or closely following their caregivers around. Many of the things that can cause people to feel depressed can also cause people to feel anxious, and vice versa. The exact causes of these conditions vary from person to person and there are often several contributing factors.

3.2 Wandering

The term *wandering* is used throughout this document to refer to a variety of behaviors that may result in people with dementia becoming lost or having their safety at risk. Wandering refers to the need to keep on the move, often seen in people with Alzheimer's disease; wandering behavior may appear to be aimless, confused, stereotyped and sometimes quite focused, the person may be trying to get to a particular destination or accomplish a task such as meeting someone or going to work. It may occur at any time of the day or night, and may take the person out of the home. It is important to give attention to outdoor wandering that can expose the person to such dangers as traffic or extreme weather conditions. Wandering is a direct result of physical changes in the brain, leading the person to want to move around, search for someone or something or remove himself/herself from their current surroundings. It is important to understand that wandering, like walking, is not in itself a dangerous activity. But short-term memory loss and the impaired ability to reason or to make judgments can contribute to unsafe wandering behaviors.

3.3 Sleeping Disorders

People with Alzheimer's often have problems with sleeping or may experience changes in their sleep schedule. Scientists do not completely understand yet why these sleep disturbances occur. As with changes in memory and behavior, sleep changes somehow result from the impact of Alzheimer's on the brain. When managing sleep changes, non-drug coping strategies should always be tried first. The amount of sleep disruption in AD patients usually depends on the stage of disease in which they are. Patients in the early stages of AD may sleep more than usual or wake up disoriented. As the disease progresses, patients may begin to sleep during the day and awaken frequently throughout the night.

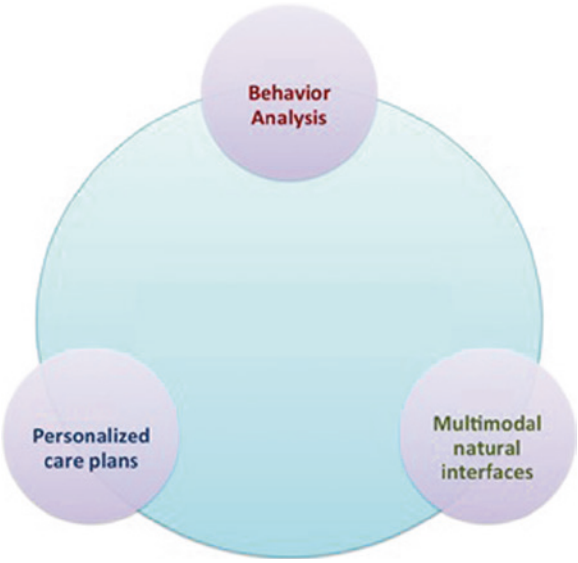
4 Proposed Approach in ALPHA Project

The approach for achieving the outlined tasks can be described according to three main stages. In detail, all three phases include significant components of innovation and research. As a matter of fact, ALPHA will adopt agile development methodologies and relying on continuous interactions between research tasks and development activities. The three main project phases are:

- *Behavior Analysis*: The main objective of the activity is to design and realize a subsystem that will enable to understand patient behaviors and detect and annotate abnormal ones. In particular, in order to describe and analyze patient behaviors, specific formal methods will be studied and adopted, international standards will be used to classify observed patient behaviors. In addition, analysis tools will be developed according to two different approaches: statistical and formal checking;
- *Multimodal Natural Interface*: The objective of this activity is to define advanced interfaces for different kinds of users such as patients, caregivers and clinicians. Multimodal and natural interaction metaphors and techniques will be analyzed and user interfaces will be selected, adapted and validated;
- *Personal Care Plans*: The main objective of the activity is to design and realize a subsystem to provide the clinician with advanced analysis tools and care planning. First, the work package will uniquely define an AD patient profile by using LOINC codes (Logical Observation Identifiers Names and Codes) in order to be interoperable with standard EHR systems. Using LOINC codes will ensure understanding and reusability of the designed model, overcoming language differences. An innovative risk profiling model combined together with recent epidemiological data and diachronic clinical data coming from clinical records of psychiatric hospitals no longer in use will also be defined, in order to better comprehend genetic and neuropsychiatric diseases, and determine probability-based contemporary manifestation and evolution of them. The work package will define and realize advanced tools to analyze the amount of data collected by ALPHA.

Finally, a care plan tool will be realized to assist clinicians in managing personalized care plans (Fig. 1).

Fig. 1 ALPHA Approach



5 Software Architecture

The system has been designed as a three-layered Service Oriented Architecture and is being realized as a specialization of Uranus [12], an OSGi-based platform [13] for indoor and outdoor vital signals monitoring. At the bottom layer, a set of software components collects data from a variety of sensors such as: (1) accelerometers, for the detection of patient's motion; (2) electrodermal sensors, for the detection of the patient's degree of stress and agitation; (3) actigraphs, for the measure of the quality of sleeping; (4) ambient sensors, for the collection of parameters such as temperature, light and sound in the surrounding environment. Currently, this layer is in charge of setting up the communication between sensors and the rest of the platform and is able to handle three kinds of connections: Wi-Fi, Bluetooth and USB. The middle layer is in charge of processing and correlating all the data-flows in order to detect abnormal behaviors and provide the clinicians with new quantitative and semantic information. Such data, in conjunction with other clinical data, will enhance the accuracy and the reliability of the assessment of the patient's health status. The top up layer includes a set of functionalities for presenting to the clinician relevant clinical information inferred from the collected data in a proper way. It would be almost completely useless, indeed, for the clinician, the full set of collected data. On the contrary, the clinician will be driven by the system directly to *the point of interest*; that is, the system will automatically emphasize abnormal signals during the manifestation of an abnormal patient behavior. Finally, in the frame of the ALPHA project, a subsystem will be designed and created in order to provide the clinician with advanced analysis tools and care planning; in particular an Alzheimer

patient profile interoperable with standard Electronic Health Records (EHR) will be defined to integrate clinical information with a passive monitored data system, also to enhance care coordination.

6 Conclusion

There are approximately 65 million people in Europe over the age of 65 and this number is expected to rise in the foreseeable future. Since about one person out of twenty over the age of 65 suffers from AD (and less than one person out of a thousand under the age of 65), there is an enormous number of people for whom ALPHA could have a beneficial impact. From a social perspective, the project has a real chance to produce a major impact on society as a whole, in terms of the quality of services provided to patients. ALPHA will lead to a higher quality of services provided to patients, improving the quality of the entire care process. It will also enable a more intensive, frequent and continuous follow-up of therapy after patients leave specialized centers and a continuous monitoring of patients progress during the whole care process. Additionally, also the working conditions of doctors, nurses and medical staff will be significantly improved.

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