Technologies to Monitor Cognitive Decline

A Preliminary Case Study

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Abstract— **Dementia is a progressive and often gradual decline in mental ability that affects thinking, remembering and reasoning. In addition to Alzheimer's disease, the most common form of dementia, there are many other causes of cognitive decline, such as age related memory loss. Technological and medical advancements have pushed life expectancy higher, thus increasing the number of elderly people and consequently the number of patients that need to be hospitalized. This puts financial pressure on medical institutions which, in conjunction with the shortage of geriatric care professionals, has prompted these institutions to seek various cost-cutting strategies. In particular, technological solutions can address these problems through monitoring and assisting patients with cognitive decline and providing support to their caregivers. The aim is to provide a smart environment that lessens the demand for caregivers to manually assess patients' behavior in specific tasks and hence evaluate cognitive decline. Additionally, within these environments it becomes feasible to implement assistive applications that can support dementia patients while performing everyday tasks. In this respect, this paper proposes the fusion of machine vision and an RFID system that can effectively address the above issues. We will also describe two scenarios that correspond to two different activities the patient can perform and provide an insight into the solutions that are used to support patients and their caregivers in these scenarios.**

Keywords-component; pervasive health-care, human activity recognition, RFID, dementia, information fusion, smart environments.

I. INTRODUCTION

Cognitive decline is an umbrella term that encompasses a number of conditions that have a disruptive effect on the normal course of living for affected people. Cognitive decline is considered a normal consequence of ageing and occurs gradually. On the other hand, cognitive decline caused by dementias causes a sharp deterioration of the cognitive functions such as memory, learning, concentration, use of language and other mental functions. However caused cognitive decline is affecting an increasing number of people, especially considering the fact that old age is one of the factors that increases the risk of dementia onset.

The increase in the incidence of dementia is attributed to steadily extending human lifespan, causing a shift in median age of the population, thus increasing the number of elderly. This trend, which is evident across the developed world, is exerting strain on medical institutions due to limited funding and care resources available. Furthermore, the demographic shift is expected to continue for the foreseeable future, thus putting health institutions in a struggle to cope with the increased care provisioning demand. It is estimated that half the elderly have cognitive problems, requiring presence of a cares; while, half of elderly over the age of 85 exhibit symptoms that characterize Alzheimer's disease to a varying degree [8]. From mild decline to severe dementia, cognitive decline is one of the biggest threats to independence and quality of life, while making it an expensive disease to monitor and treat.

Because of this, an increasing body of research is perusing various technological solutions to mitigate the problem of cognitive decline. Steady decrease in device form factor, coupled with increase in computational capabilities, has enabled monitoring of many aspects of elderly' life, from the amount of physical activity, up to various physiological parameters. Our idea is concerned with using Radio Frequency Identification (RFID) technology and video to provide a monitoring and analysis framework for patients with mild cognitive decline, building on our previous work in [9]. The main purpose of the framework is to assist the caregivers/therapists in evaluation the degree of cognitive decline in a manner that lessens the requirement for therapist being present and their annotation workload, while the patient is carrying out specific tasks. In addition, in such framework it is feasible to implement the assistive applications for patients, thus mitigating the effects of cognitive impairments on daily life.

In addition, monitoring patients with cognitive decline is essential since many research groups point out the importance of assessing variations (both in short and long term) in patterns of behavior and movement that can be indicative symptoms of early dementia [5], [6]. Early detection of dementia symptoms is vital, since specific drugs are only effective on the onset [5]. Once the system for monitoring patients is implemented, it becomes possible to adjust it for the purpose of early dementia detection as well, depending on the specialists' opinion which domain of behavior is important to monitor. This is a part of our future work.

Monitoring and evaluation of cognitive decline is a process that currently involves healthcare staff monitoring the activities of the patient, while the patient is conducting various tasks prompted by the therapist. However, there are two apparent disadvantages to evaluate the patients' cognitive decline in such manner. Firstly, patient monitoring requires therapist to take notes of the steps of the activities of patients, which is a laborious task and also error prone (e.g. due to tiredness of the therapist). Secondly and more importantly, monitoring the patients in this manner can result in behaviour false positives,

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when compared to the behaviour of the patient in their natural environment, such as at home. Presence of the therapist will affect the course of patient's behaviour since the patients typically will try to do their best to show their independence, in order to avoid being moved to residential care, for example. A study carried out in [12] found inconsistencies between patient behaviour in prompted tasks and behaviour in natural environment. Given these issues, it becomes evident the need to shift the patient monitoring task from therapists to a less obtrusive technology, while the existing framework could be engaged to provide assistive applications.

This paper is organized as follows. We first describe the related work and relevant systems in the area of patient monitoring with cognitive impairments. Then we describe our planned approach and requirements that stemmed from our research of cognitive decline. Lastly the paper draws the main conclusions.

II. Related Work

The past decade witnessed a lot of research activities in the domain of Ambient Intelligence. The projects can be divided based on the technology employed, the manner in which of the information is processed and applications built. We will review the most relevant work in Ambient Intelligence that supports healthcare of patients suffering from cognitive decline. The aim is to make smart environments unobtrusive for their occupants, while achieving the main task of elderly monitoring and assistance. In this respect, there are a number of aspects such as: monitoring patients and recognizing their activities, assistance in performing common household tasks, recognizing changes in their behaviour and ultimately improving their quality of life. The paragraphs that follow describe the main aspects of the most relevant projects in the area of elderly monitoring and assistance.

The Aware Home, developed by Georgia Institute of Technology in the USA [1, 2], is a living laboratory for interdisciplinary research, development and evaluation. Among numerous projects that are aimed at improving services at home, some of them address assistive technologies for older adults such as Cook's Collage, Memory Mirror, Digital Family Portrait and others. These applications monitor the subjects and keep the caregivers (or their children) informed about their activities but also act as memory support, helping elders to perform the common daily activities. Information is captured by different sensor modalities, including optical, audio and electromagnetic.

Tapia and Corchado [3] describe the system designed at the University of Salamanca in Spain, consisting of a number of agents that obtain information from the environment and users in order to achieve reasoning and planning mechanisms. Their design includes different technologies, such as RFID, ZigBee and various types of wireless networks. One of the main objectives is improving assistance and healthcare for Alzheimer's patients by scheduling daily tasks of the medical staff in a dynamic manner. The authors report a significant time savings by the nurses when dealing with indirect tasks, which include making reports, monitoring, visits and other obligations that do not require the nurse to be with patient constantly during the task.

Another system aimed to provide better assessment, diagnosis, treatment and evaluation of behavioural problems for the elderly is developed at the Carnegie Mellon University [4]. The authors emphasize the importance of close and continuous monitoring that provide the specialists with better assessment of individual's behaviour and allow them for more appropriate interventions. In addition to video data upon which they rely in most cases, audio and other types of sensors are also employed to recognize complex activity such as falls, wandering and aggression.

There are a number of projects in the current literature that take advantage of the improvements in Ambient Intelligence to provide tracking and analyzing individual's movement both in short and long term in order to determine early stages of dementia. Along this line, Kearns et al. [5] designed the HERMES (Health Research Management and Evaluation System), preventative system that relies solely on ultra-wideband RFID systems to determine patterns of subject's movements during certain period. Kearns claims that our bodies communicate changes in our minds and variations in patterns of movements could announce pathological changes in the mind. Their system consists of RFID readers positioned in the corners of the facility and active tags mounted on wristbands. The tags provide subject's location with accuracy of 15 cm. After the system has been tested, the assessments were juxtaposed with the ones gained by cognitive tests, confirming their hypothesis; the subjects whose exams suggest a certain degree of cognitive impairment showed patterns of wandering.

The other project that examines possibilities of dementia prevention, with very similar aspects to our research, is conducted at the Oregon Health & Science University in Portland, USA. Kaye [6] argues that for the purpose of dementia prevention, it is intrinsic to enable detection of trajectories of change over many years and to get deeper into sensitive domains such as determining the information about increasing variability in patients' behaviour. In the system, designed at the Oregon Center, the information on activity patterns are captured by passive infrared pyroelectric motion sensors, while magnetic contacts positioned on doors and RFID technology are used for determining the identification and the flow of subjects (inferring subject's absences from home and presence of visitors). Furthermore, RFID provides additional information on individual's location while the walking speed is obtained with motion sensors. This approach is now being tested.

Although the Ambient Intelligence has been improved and is set to continue improving, most of projects do not offer comprehensive information about the context or they deal with a limited number of activities. In addition, relying only on one type of sensors usually provides lower level of accuracy in comparison to the systems that fuse information from diverse sensors. Even if some of mentioned projects acquire the data from different types of sensors, most of them do not utilize more technologies to determine the same activity independently. This strategy could provide the robust system

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for activity recognition, characterized by redundancy but with the obvious trade-off of decreasing cost effectiveness. Concerning the trend of RFID technology development that contributes to lowering costs, it seems likely to expect the aforementioned trade-off to be reasonable in near future when employing RFID systems for identifying the activities that are already monitored by machine vision or other sensors.

III. OUR APPROACH

The aim of the project is to investigate the use of machine vision, combined with RFID in order to monitor the patient's activities. In many scenarios, one technique alone has proven to be insufficient, hence the need to be complemented with another.

Video processing is mainly intended for tracking the patients as they walk around the room; while, on the other hand, RFID is used to augment video tracking system by providing the identification of patients and objects they are interacting with. Furthermore, these technologies are detecting the same domains whenever it is achievable, which results in decreased error possibility (e.g. manipulated objects are often identified both with video and RFID system).

Our approach is similar to [13], but applied on a different scenario. The usage of a bracelet is seen as intrusive, especially for patients that are prone to agitation, such as Alzheimer's patients. Our system is less obtrusive as it can detect manipulated objects without the need for an RFID reader being attached to the patient. The most noticeable challenge is that each object that is intended for the specific scenario must be RFID tagged; which, depending on the number of objects may be a laborious task. However, once the RFID infrastructure is installed, it can provide further advantages, beyond the application described here. For example, inadequate hand hygiene is indicated as one of big problems in hospitals because it causes nosocomial infections very often [7]. With existing RFID system it is possible to determine how frequently every patient washes his/her hands and this with a minimal effort (tagging the soap in the bathroom and positioning an antenna with a low range on the appropriate place).

We have identified a number of scenarios for the purpose of tracking the patient's ability to carry out daily activities. These scenarios have been devised on the basis of research conducted on cognitive decline. So far, we implemented two possible scenarios that correspond to two different activities the patient can perform on their therapy sessions. Each of these activities will be described in the following paragraphs and an explanation will be given as to how the proposed technologies can aid in patient monitoring.

A. *Cooking Aid*

Cooking is certainly one of the common daily activities. Due to memory impairments, an individual is no longer capable of carrying out this activity confidently, resulting in increased dependency on the carers. The common problems in cooking that elderly (or dementia patients) are faced with, are choosing the appropriate ingredients (e.g. taking salt instead of sugar), recalling past actions (e.g. putting some ingredients twice or never) and resuming the process (if an individual is interrupted) [1] .

Assuming that all ingredients are in the range of the RFID antennas and that they are all tagged, many of the mentioned issues could be solved successfully. The system can check which of the ingredients are on their usual places (e.g. fridge, shelves). Therefore, it determines the set of available ingredients before cooking and notices the moment when any of them is temporarily out of the range, in other words is being used. Thus, it has the perception of the ingredients that have already been used during certain cooking session but also has the insight in the possible dishes that could be prepared (if the appropriate data base of recipes exists). In that way, via display or voice commands, the software recommends possible dishes, controls the process of cooking (e.g. in sense of giving instructions), warns for possible mistakes and informs what the subject has already done. In this scenario, the vision system acts as a complement by tracking the patients and providing the verification of already determined objects that the patient is manipulating. Also in this scenario, tagging all ingredients is the most noticeable additional challenge but once it is done, numerous therapy sessions can be performed.

While assisting the subject to perform one of the common household tasks, the system is able to include measurement of the subject's behaviour change over the short or long term and variability of cognitive functions as well. For example, one of the relevant factors can be the number of mistakes during a preparation of certain dishes.

B. *Memory Card Games Set*

There are many studies that point out cognitive stimulation therapies for dementia patients (e.g. [10], [11], [14]) as a very powerful strategy for improving their mental functions and quality of life. Card games are often used for that purpose, especially with the patients who liked to play cards in the past or with those who just like to deal with numbers. Moreover, it solves the very common problem of motivation for the therapy participation. Our system takes the whole task of monitoring the patients while performing memory card games, only by using RFID system. We have the deck of tagged cards (with passive tags) and four RFID antennas with a very short range, which makes our system inexpensive. When the patient put a certain card down, an ID number is read and mapped to a card name. The system continuously reads the cards that are in the range of antennas, so that it determines whether the card is put down or just was read by the accident (e.g. in the moments when a patient scruples and holds the card very close to the antenna). Also, the order of putting cards is detected easily and with low error probability. .Incorrect actions can also trigger an auditory response to indicate to the patient that the performed step is incorrect.

For the initial trials, we realized two, sorting and solitaire games for mild and early stage of dementia, respectively. We developed the software for assessing the patients while they are playing the sorting game (e.g. by colour, odd or even number and so on) and solitaire and we are currently working on tracking changes in some sensitive domains. Also, implementation of other games is in progress.

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The need for automation of this process stems from the laborious nature of monitoring the patient by the therapist, while the patients play memory card games. As it was mentioned, this is a laborious and also error prone task. In addition the patients would be more relaxed and they would enjoy the card games more when the therapists are not present.

IV. Conclusion

We proposed the approach to recognizing activities of the patients with cognitive impairments through the fusion of machine vision and RFID technology. While machine vision is mature technique but constantly improving, RFID has appeared recently as very promising technology in dealing with a lot of issues of tracking objects and persons within the smart environment systems employed in hospitals and geriatric residences at relatively low cost. Moreover, it does not intrude on privacy. The fusion of video and RFID system allows for constant monitoring of the subject's movements and patterns in his or her daily routine. In addition to providing assistance to caregivers/therapists and supporting patients while performing everyday tasks, by analyzing changes in behavioral patterns over time, it is possible to provide early warnings of dementia. Even for patients with already diagnosed dementia, it is valuable to track changes in everyday routine. With appropriate software, described applications can be used to obtain diagnosis data. Furthermore, once the system is installed, the applications are numerous depending on the specialists', caregivers' and patients' needs.

It should be mentioned that our work has only begun and we are in the process of carrying out experiments and trails with real patients will follow in due course. The results of the experiments and the trials will be disseminated in our future publications.

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