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AMBIENT INTELLIGENCE FOR HOME-BASED ELDERLY CARE

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SUMMARY

Due to ageing demographic, home-alone elderly with mild dementia may face difficulty in managing their daily activities. If no intervention is taken, they may end up totally dependent on others, resulting in unnecessary burden to their caregivers. Hence, the aim of this project is to demonstrate how intelligence technologies empower home-alone cognitive impaired elderly in carrying out their activities correctly and independently. With the use of sensors and user interfaces, the elderly activities can be determined and monitored. Timely cognitive assistance can also be provided through prompts and reminders, enabling them to continue desirable activities in intuitive manner.

ABSTRACT

The focus of this project is to demonstrate how Ambient Intelligence (AmI) assists the home-alone cognitive impaired elderly in carrying out their Activity of Daily Living (ADL) correctly and independently within the smart home environment. ADLs are familiar tasks for day to day function that encompass meal preparation, drinking and eating etc. The target audience for our project includes frail elderly, particularly patients suffering from the early and middle stages of Dementia. These patients will suffer from memory loss and require aid in the form of constant reminders. To assist them in performing their basic ADL, multimodality sensors are employed with AmI, providing cognitive assistances according to recognized elderly activities and their utmost needs. Altogether, the following three aspects are required to fulfill the project end goals of assisting the elderly through AmI— Sensor Configuration and Management, Sensor Data Interpretation and Understanding, and lastly, Erroneous Activity Recognition and Reminding. Finally, the activities of the elderly can be recognized and cognitive assistance can be provided through suitable reminders, enabling them to live independently and perform their ADL comfortably in a relaxing and enjoyable environment.

INTRODUCTION

Patients with dementia suffer from memory loss in the early and middle stages of the disease, eventually hindering independence. Hence, these elderly patients will require aid in the form of various cues such as audio and visual reminders in order to live and perform their ADL correctly and independently. Eating, which consists of meal preparation and having the meal, is one of the most crucial activities the elderly have to perform well in order to live independently.

Hence, this project aims to provide assistance to the home-alone cognitive impaired elderly in their eating activity via AmI. AmI implies a seamless environment of sensing, computing, advanced networking and interactive interfaces by employing the use of multimodality sensors. It is capable of recognizing what the elderly behaves and their needs pervasively. Besides monitoring of the user, it also enables non-intrusive and personalized cognitive assistance to the elderly with special needs. As such, the dementia patients may remain more independent and mentally active during the early and middle stages of dementia, enabling them to perform their basic ADL.

There are three development aspects in order to fulfill the project end goals of AmI for home-base elderly care. Firstly, under **Sensors Configuration and Management**, various types of ambient sensors had to be evaluated, configured and operated in simulated pantry and dining area of the AmI lab at Institute for Infocomm Research (I^2R). The second aspect is **Sensor Data Interpretation and Understanding**. It includes the intelligent analysis and automated processing of the different sensor readings and further interpretation of the readings to understand the activities of the elderly and respective environmental states. Based on these observations, the Plan Libraries (PL), which consists of both the correct and erroneous plans for meal preparation, is created. The last aspect of the project is **Erroneous Activity Recognition and Reminding**. After determining the user activity and environmental states, according to predefined activity plans, we then have to state the correct and erroneous activity sequences. If the observed activities of the elderly deviate from the correct activity plan, audible or visual reminders will be provided to the elderly.

MATERIALS AND METHODS

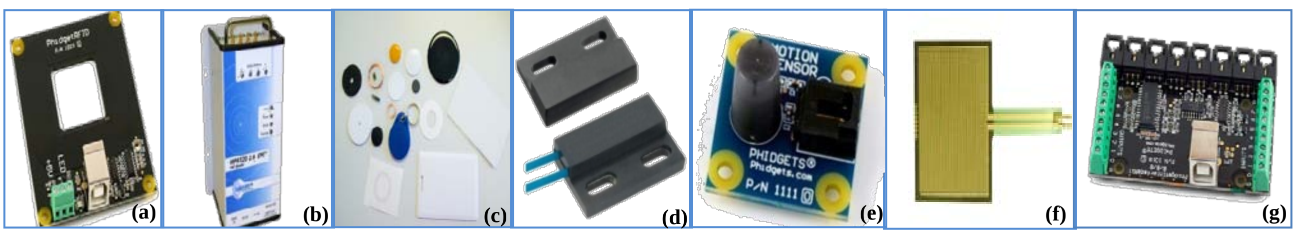

Figure 1: RFID system and Ambient Sensors
(a)PhidgetRFID;(b)SamsysRFID ;(c)RFID Tags;(d) Reed Switch;(e)Motion Sensor;(f)Pressure Sensor;(g)Interface Kit 8/8/8

I. Understanding and Analysis of Multimodality Sensors

The tag IDs can be assigned to the utensils for easy identification by the Radio Frequency Identification (RFID) System. As a result, presence of utensils at the desired locations can be detected so as to send out the appropriate audio reminders to aid the user in taking and using the utensils correctly. Characterized by a particular sensing range and detection of infrared heat produced by human beings, motion sensors are installed at the pantry and dining areas. This enables the determination of locations of the elderly at different points in time. Due to its sensitivity to changes in applied pressure, pressure sensors are deployed at the dining chair and on the floor to detect the presence of the elderly at specific places. Reed switches are used to monitor the opening and closing status of entrance door and cupboard door at pantry area. As an electrical magnetic switch, the clear-cut differences in values of the reed switches allow us to tell the action of the elderly from the environment status.

II. Sensor Configuration and Management

After analyzing the uses of the multimodality sensors, different locations are first experimented to find out the best positions in which our sensors can be placed for detecting different activities of the elderly. The sensitivities of various sensors are also calibrated such that the detection can be optimized by the orientation and number of sensors deployed. For instance, the distance of the sensors from the pantry and dining area has to be taken into consideration. This is to minimize the chances of detection by the wrong sensor, i.e. the motion of the elderly at the pantry area is also sensed by the motion sensor at the dining area. The height and angle at which the RFIDs and motion sensors are placed will also affect the sensitivity of the detection. Thus, all possible positioning is tested out to achieve the best results, i.e. the RFID at the pantry area is able to detect the tag when utensils are taken out and they cannot detect anything when the utensils are in cupboard. The 3 pressure sensors (FSR) are also arranged in a triangular pattern on the dining chair because the pressure of the elderly will be dispersed around the chair.

III. Sensor Data Interpretation and Understanding

In order to acquire data from various ambient sensors, the Phidget Interface Kit 8/8/8(Fig. 1g) is used. Similarly, Phidget RFID is used to detect the utensils used by the elderly. Both data acquisition units are connected to the computer by the USB ports. Hence, the readings from all the sensors can then be read from data acquisition unit through running Web Services using any supported programming languages. In addition, respective sensor readings are acquired and visualized through flash-based applications using the API provided by Phidget. The same API is used to illustrate the different sensor readings graphically. The output from the RFID reader will depict whether a certain RFID tag is sensed by the reader or not. These data collected will be interpreted through threshold based data processing and will be used to determine the changes in states/events made by the elderly. The acquired sensor data are then displayed through Graphic User Interface (GUI) and Sensor Data Visualization (SDV) developed with Flash Actionscript 3.

RESULTS AND FINDINGS

In the previous section, detailed explanations on analyzing of multimodality sensors data, data processing and, comparison of correct and erroneous activity sequence through different experiments are included. Hence, this section comprises of our achievements and relevant findings in this project, the user interfaces developed in particular.

I. Erroneous Activity Recognition and Reminding

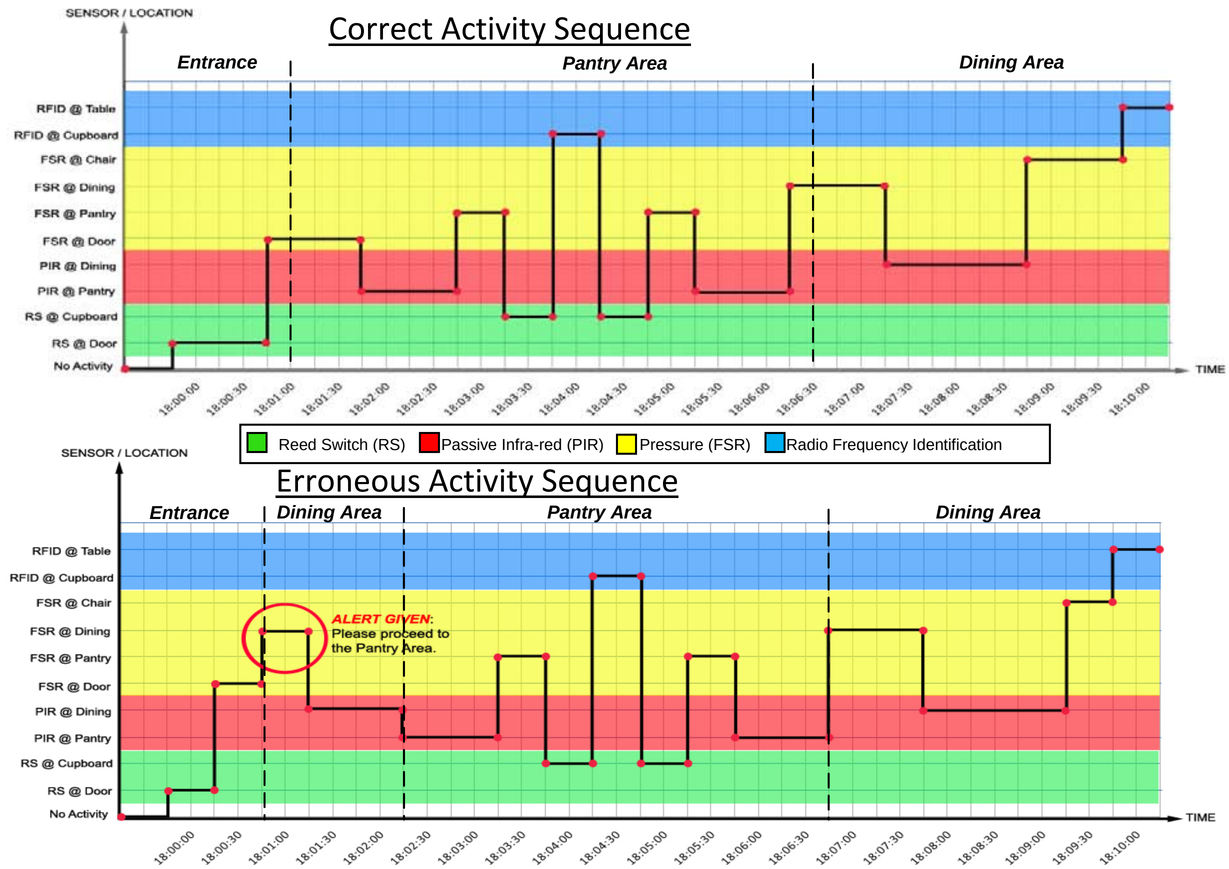

Fig 2: Plan Library: (a) Correct Activity Sequence (b) Erroneous Activity Sequence

The experimental analysis aspect of the project can be divided into two parts - firstly, data collection and secondly, data processing, analysis and visualization. In order to replicate the correct activity sequence (Fig. 2a), the data collection process is first carried out according to the sensor plan with 5 seconds in real time per interval, which translates into 10 minutes when depicted on the graphs. Similarly, the erroneous activity sequence (Fig. 2b) is carried out according to the Sensor Plan, depicting an error in the elderly person's actions.

The second part comprises of data processing, analysis and presentation. After the respective sensor readings are acquired, processed and visualized through flash-based applications using the API provided by Phidget, the readings are then analyzed and presented using Microsoft Excel 2007. In order to present a more comprehensive view and understanding of the conditions of the sensors, the graphs are presented in the form of both sensor states and sensor readings (Appendix A and B). The presentation of data is a problem for the PIR sensor in particular. This is due to the fact that the model being a replica of the actual home is significantly smaller in size. The close proximity between both the PIR sensors often leads to overlap in the readings, despite efforts to cover up a PIR when not in use. As a result, the sensor readings for the PIR are first analyzed and manipulated before translation into the graphs. With regard to the other sensors such as the FSR, Reed Switch and RFID, they only record specific sensor readings. For example, in the case of the Reed Switch, it only records the values "0" (door open) and "999" (door close), which enables sensor readings to be visualized much more easily.

Finally, all the sensors are presented in the form of the Plan Library, which consists of sequences of different activities (taking utensils, placing them on table, sitting on chair, etc) for meal preparation. It can be classified into correct activity sequence (Fig. 2a) and erroneous activity sequence (Fig. 2b). The correct activity sequence depicts the predefined activity sequence that the elderly person is supposed to follow, indicating the time in which the various sensors should be activated, with elderly conditions interpreted from environment/sensor statuses. The Erroneous activity sequence depicts an error carried out by the elderly person. As the activity of the elderly does not coincide with the correct activity sequence stated in the plan definition, reminders will be triggered. Three categories of errors have been identified—completion error, realization error and initiation error. Completion error occurs when the elderly does not complete his activity according to the plan definition such as idling at the pantry area after taking out the utensils. Realization error occurs when the elderly completes the correct activity but does not follow the correct sequence as stated in the plan definition. For example, the elderly proceed to the dining area without taking the utensils. Lastly, initiation error occurs when the elderly initiates an activity that is not in the plan or starts an activity that is not corresponds to current activity sequence such as throwing the utensils on the floor.

As elderly patients suffering from the early and middle stages of Alzheimer's disease will suffer from memory loss, they require aid in the form of constant reminders. For instance, if it is identified as a completion error as the user forgets to start eating, an audio reminder will be sent out as "Kindly begin eating." Furthermore, visual reminders in the form of a buzzer that lights up and sounds upon detecting the error have also been implemented. Both reminders will work in tandem, enabling the elderly to carry out his basic ADL correctly and independently.

II. Sensor Visualization Development

The **SDV** (Appendix C.1) developed aims to showcase the real-time readings from different ambient sensors as well as detected subject and environment status. The sliders in the SDV for ambient sensors enable the intensity of the sensor readings to be monitored together with the environment status, with the right end of the bar indicating the highest intensity value. The animations built into the SDV interface also provide a clearer illustration of the subject and environment status of the sensors. With the status of all the ambient sensors in the same window, it enables the caregiver to conveniently track sensor changes in the cognitive environment.

In addition, the **RFID SDV** (Appendix C.2) is a user interface where respective utensil images are shown according to the assigned tag ID. This provides a clearer picture of which object, attached to a specific tag ID, and is sensed by the RFID reader of a particular area, such as the dining table. Hence, the SDV developed will allow the care giver to monitor elderly activity easily.

III. Plan Recognition Visualisation

The rationale behind developing the plan recognition visualization is to check the activity that the elderly is performing as well as to showcase reminding functionality or cognitive assistance to the elderly by seamlessly integrating the reminders into the environment and providing in-situ alerts when erroneous activity is detected. In the case of the elderly facing a serious or dangerous condition, the activity recognition system, captured in the Graphic User interface (GUI) (Appendix C.4), enables the caregiver to examine the elderly patient's past actions. That enables the caregiver to understand the real problems and details of what the elderly person was really doing in order to provide effective treatments and medications.

Two offline GUIs, with sensor readings as well as offline activity plans, have been developed, with the stimulated visualization according to the predefined activity sequences, including both correct and erroneous activity sequence. The **first offline GUI** illustrates the correct activity sequence which showcases elderly activities that are in accordance to the plan definition. While the **second offline GUI** (Appendix C.4) illustrates the erroneous activity sequences which showcases the elderly erroneous activities that does not correspond to the plan. Hence, stimulated reminders are also implemented to remind the elderly according to the predefined plans to correct his/her actions. Similarly, an **online GUI** has also been developed to display the elderly patient's current activity by acquiring, interpreting and displaying real live sensor readings as well as the subject and environment states. With the built-in of animations, the elderly activities can be monitored and observed remotely with ease. However, as it is not part of our project scope for tracking the elderly fine-grained movements around the environment, the online GUI will only showcase the coarse-grained movements and activities at dedicated areas.

DISCUSSION

With the world's ageing population, increasing life expectancy and high healthcare costs, it has introduced a wide array of social and clinical challenges. It is estimated that the rapidly increasing number of people suffering from Alzheimer's disease could cripple healthcare services in the next few decades [1]. In the face of an increasingly ageing population, several alternative methods all around the world have been proposed. There has been active research on customized socially assistive robotics that can help to assist the elderly suffering from cognitive changes related to dementia [6]. However, it has been revealed that older people seem more concerned about a harmonious integration of robots in the social and physical environment of the home. [6] Hence, these considerations need to be taken into account in order to implement domestic robotic devices which can be more acceptable and adequate to satisfy not only the functional but also the psychological needs of the elderly. So, the AmI approach to home-based elderly care is a more suitable approach to facilitate elderly with cognitive impairments [3]. It is non-intrusive and can preserve their dignity on a moralistic level [2]. The less anxious and stressed the person with dementia feels, the more likely they are to be able to use their skills to the best advantage. AmI also helps to reduce the burden of the caregivers and the developed visualizations can also facilitate in the communication between the elderly and caregivers.

By comparing other similar methods, there are still several limitations and challenges to be fulfilled in this project. Firstly, assisting dementia patients is a complex and complicated problem. This is especially true in order to detect random and unpredictable activities from dementia patient, making it difficult to assess the possible errors made such that cognitive assistance is administered when the user deviates from the correct sequence. Also, current technology is not able to completely detect and recognize all possible daily activities. Moreover, it is still in preliminary to provide the personalization ability to estimate and adapt to varying user states, and to respond with indicated gestures of desire. Furthermore, as no two patients are exactly alike, it is imperative that the individual patient's profile and specific needs are accounted for. Those parameters such as the stage of dementia, health conditions, mobility, etc. affect the currently automated plan and activity recognition processes.

Lastly, we highlight some of the possible extensions and enhancements to the current project. The implementations of our system can be integrated with knowledge-based inference engine and prompting pervasive devices to improve the current situation such that prompts appear on the television while the elderly loses track on what he are currently doing. In addition, wearable sensors and video cameras can also be considered to detect the fine-grained activities of the elderly. This is because our system cannot sense the exact movements and fine-grained activities of the elderly, with only a few sensors to track general location and coarse movements of the elderly within the dining and pantry areas. Hence, it is not able to address the full-fledged help for completing sequential eating routines such as hydration – a need that is commonly neglected among the cognitively impaired. Moreover, as our project is only limited to the pantry and dining area, we believe that the monitoring area can be easily extended into other parts of the house. Infrared detection by cameras and motion sensor can be used to recognize the location and fine granularity activities of the elderly. In the near future, our AmI system will enhance the Quality of Life (QoL) of many cognitive-impaired elderly staying alone at home with above mentioned improvements.

CONCLUSION

The inability of current healthcare practices to address the daily needs of the elderly with dementia has prompted calls for new paradigms of care. One promising approach lies in exploiting smart environment technologies with AmI for consumer-driven, home-based elderly care. In this project, the use of multimodality sensors with smart environment to support dementia patients' independence and safety monitoring via AmI were explored. The actual sensors were configured and calibrated in our smart home environment and meal preparation plans were also defined. Although there is existing research to help the cognitive-impaired elderly in routine, in the context of dementia patient monitoring, we highlighted similar projects existent which aid dementia patients, as well as its possible drawbacks. Despite sophisticated improvements that we will need to implement in future to improvise our system, AmI is to date, the most promising solution to the problems we are trying to solve.

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[3] Nanyang Girls' High School, Mr Mark Oliver Shone

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