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Research Article

Managing Disorientation of Time and Place in Dementia Patients Using Bluetooth Sensors

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Abstract: Assistive technology has the potential to support persons with dementia (PWDs) in their daily life activities and provide them quality of life services. This paper proposes a novel mechanism in order to manage disorientation or time and place problem of PWD through the use of Bluetooth low energy devices, smart watch and smart phone/tablet. The proposed mechanism was verified in a real environment having the facilities an ordinary PWD avail in his home environment and also in lab environment. All of the participants were volunteers from research group personal contacts. Volunteers spend time in the environment and results were generated. Experimental result showed that the proposed mechanism provided an accurate real time ubiquitous monitoring of PWD. Successful detection of PWD presence in real time and notification to caregiver observed in all cases.

Keywords: Dementia, mobile technology, low energy sensors, real time monitoring through wearable

1. INTRODUCTION

The world population has moved towards a greater portion of elderly people. Elderly population is facing different physical and mental problems due to the decline in health condition. The most common problems are Alzheimer and dementia. According to World Health Organization (WHO) 47.5 million of the world's population is experiencing dementia and in each year 7.7 million people are adding to this figure [1]. Dementia mostly effects older population and it is the foremost cause of the disability and dependency among the population. Dementia directly affects the part of the brain which is involved in learning. Dementia, the most serious form of memory disorder, is a group of symptoms caused by different disorders. Alzheimer, stroke, brain injury that affect the brain are different causes of dementia.

Dementia syndrome creates different types of physical, social and economic burden on family and caregivers. Dementia effects differently in each person. Three major stages of dementia have been identified so far, namely, early stage dementia, middle stage dementia and late stage dementia. More than half of the persons with dementia (PWDs) may face intellectual decline state. In this case PWDs lose their ability to remember, to comment, to make judgment and they may not be able to act independently. In all three major stages the most unfavorable problem faced by dementia patient is forgetfulness. Due to the forgetfulness problem the patient faces problems in performing ADL (activities of daily life).

In the middle stage of dementia the patient's forgetfulness problem may become severe, even patient may be lost in its own home environment. The patient may wander in its own home environment and even may face difficulty in finding different places (such as bedroom, washroom, lounge, etc.). As a result, PWD may be in one place in sitting or standing position alone and could not find a rest place. The inability of dementia patient to perform a series of tasks which are required

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to complete a particular job (such as making a cup of tea, changing clothes, brushing teeth, etc.) makes their life difficult. It is often observed that dementia patient, if sitting in a particular place or doing some activity, remains involved in the same activity which in turn may be harmful for their health. For example a PWD may continue to sit in front of television (TV) even he has watched his favorite TV show and no program of his interest is running on TV. This sitting may create different postural problems such as hunchback, forward hip tilt, muscle fatigue, aching muscle, and corns.

To conclude, the proposed system aims to detect the condition of disorientation of time and place for PWD using Bluetooth low energy (BLE) bacons, smart watch and mobile phone. BLE beacons are small devices which are positioned on a place which is relatively suitable in particular environment [2]. Bluetooth beacons are most suitable in indoor environment position as (Global Positioning System) GPS signals (the most widely used outdoor positioning technology) may not work in indoor environment due to the presence of walls and other obstacles. The algorithm proposed in the system analyzes the signals received from smart watch on smart phone/tablet and takes appropriate action.

1.1. Problem Statement

PWDs face a lot of challenges even when they are present in their own home environment; as a result, different types of psychological disorders such as aimless movement, repetitive locomotion with no identifiable goals develop in their personality. One of the problems with PWDs is that they become disoriented with time and place. This happens usually at the early stage of dementia and becomes worse in the late stages of dementia. The ultimate cause of this behavior may be the destruction of memory cells in the brain and trouble in recognizing people and objects. They also face difficulty in judging the passing time, passing events and confuse day and night. The other problem related to disorientation of day and time are that PWDs often get ready for appointments which are far away and they think that an event which has taken place in past days has just happened. These types of inabilities took PWD as well as their caregiver in a very frustrating situation. As a consequence the PWDs ability to function may reduce. Management strategies with the PWD having disorientation of time and place have been proposed in medical science such as hanging calendar with their bedside wall, placing labels, signs and directional signs on different place in a PWD environment. This is observed that more familiar environment leads to more safe and satisfied to PWDs.

1.2. Outcomes of the Problem

Dementia patient feels unsafe in the unfamiliar places and this may lead to a PWD in a worse condition. If PWD is present aimless in an environment it can be harmful to his health. For example sitting on a sofa with long hours may increase the risk of heart disease, diabetes, obesity, and more. The condition becomes worse for a PWD if he is sitting in an uncomfortable place such as stool, floor mat, wash room seats, toilet seat, etc. Remaining in an uncomfortable posture may cause neck pain, headache, low back pain, fatigue, Joint stiffness, pain etc.

2. RELATED RESEARCH

Assistive technology has the potential to provide care to PWDs in their different problems. Research has proposed several assistive solutions to address the challenges faced by PWDs in the following areas such as medication adherence system, memory loss problem, incontinence problem, wandering, remote control operating problem and sleepiness problem.

PWD's most troubling problem is forgetfulness. Due to forgetfulness the caregiver as well as a PWD face different problem in order to manage the activities of daily life. Proper medication at proper time is very critical for the health of PWDs. The study by Moshnyaga et al. [3] assists caregiver as well as PWD in order to get proper medication at proper time. The system uses Kinect as visual sensor, speaker, reed-switches, sensor, actuators and (light-emitting diode) LEDs to assist PWD and sends notification to caregivers about medication intake.

In order to improve quality of life of dementia patients the technique of memory places has been used [4]. Method of Loci and augmented reality technique were used which help PWD to create their own memory places. This work exploited the fact that a PWD can also learn new things and use this phenomenon in their application. Engagement in meaningful activities may play a positive vital role to improve the memory problems of PWDs. MemPics program has been developed for PWDs for Long term care residents [5].

One of the most occurring problems of PWD is wandering. Due to their memory decline the PWD often wander in their familiar places and could not find the safe way to reach their destination. The main problem of wandering behavior is that nobody can predict at what time or in which situation wandering behavior will occur and at which intensity it will affect the PWD. This problem makes the detection of wandering a challenging task [6]. The framework proposed by Ou et al. [7] transmits the GPS trajectory from the device worn by elderly to caregiver smart device or laptop ubiquitously. The caregiver remains aware about the presence of its loved one anytime anywhere.

Wang et al. [8] proposed usability study of WanderHelp application. The application helps PWD to lessen the risk of wandering and as a result endures the safety of PWD. On the basis of spatial and temporal dimensions the PWD environment has been divided and then three types of zones have been created, namely, green zone, red zone and amber zone. As soon as the location of PWD is detected in danger zone the location of elderly is send to caregiver mobile.

A wandering monitoring system has been introduced by Sansrimahachai [9]. This system analyzes the travelling pattern in real time. The stream event input is based on GPS data obtained from mobile device. Speed, altitude and heart-rate data was also used as stream input. In this work, the geolocation data was processed dynamically as soon as collected without any storage. Message oriented middleware (MOM) provides infrastructure support in message transportation between servers and clients. Geolocation data combined with heart rate sensor data is sent to wandering detection system (WDS) through MOM. WDS continuously and dynamically detect wandering episode over stream events.

The Alziomo app [10] provides geofencing and activity recognition for PWD and detects fall through the use of Android smart phone. The caregiver may set certain predefined activities and physical zones as dangerous for PWD and may associate the notification upon these activities recognitions.

Operating mobile phone may be a difficult task for PWD as they cannot keep track of sequence of activities in order to complete a job. The system proposed by Sasaki [11] detects the repetitive incorrect button pressing of remote control through smart phone antenna. The smart phone antenna receives the electromagnetic signals from PWD remote control and input these signals to the algorithm which detects the phase change of the waves. In case of detection of phase change the smart phone will send an alert to PWD caregiver to inform them that their loved one is having problem in operating remote control. Through this way the behavior problems of elderly can be detected.

An assistive system using sensors to detect soiled diaper for PWD is proposed by Wai et. al [12]. The sensor deployed/attached to diaper senses the wetness event and immediately send an alert to nursing staff. The system provides context-aware intervention of wetness event so that caregiver could monitor patient's diaper condition anywhere anytime. The reminders are sent to caregiver along with the location of PWD. Therefore, the system is applicable to a nursing home in which more than one patient needs to be monitored continuously. The context of patient is detected through sensors attached in patient bad or wheelchair. This helps caregiver to care a PWD without any annoyance and waste of time.

Sleep monitoring and support system for early dementia patients through the use of sensors placed on patient's bed and PIR (passive infrared sensor) sensor on bedroom wall is presented in [13]. The bed sensor is used to detect in and /out of the base status and PIR sensor is used to pick up the motion of PWD in his room. The sleep pattern data obtained from sensor has been visualized to support PWD. This work also proposed a set of measures that can be used to assess the quality and quantity of sleep.

Android based mobile application has been developed [14] to support a PWD in different tasks such as calling caregiver or medical professional in case of emergency and playing mind games to improve mental skills. The application detects fall using built in sensor on mobile device.

3. RESEARCH DESIGN AND METHODOLOGY

In PWDs the disorientation of time and place is an issue which creates health problems for them as well as it is a great challenge for caregiver to cope with this. Disorientation of time and place problem may be minimized by using different methods such as providing visual cues in the environment, putting a clock and simple calculator with PWDs, putting easily readable labels in PWDs environment, etc. Mostly the PWDs are accompanied by their caregiver. The absence of caregiver may create problems for PWDs. No real time ubiquitous method has been proposed in this situation. The use of pervasive assistive solution to provide real time monitoring for the detection of episodes of disorientation which also may notify the caregiver about the severity of situation holds much attraction to provide assistance to PWD and caregiver.

3.1. PWDs Specific Need and Technical Challenges

The episode of disorientation may occur anytime with PWDs. In order to monitor a PWD aimless presence in his home environment and to notify about the episode of disorientation to caregiver (and PWD himself) it is necessary that PWDs presence in its home environment should be observed in real time manner. BLE has the potential to detect the presence of PWD in his home environment. BLE technology enables smart devices to perform some action when in close proximity to a beacon. When PWD worn smart device reaches to close proximity to these BLE devices then smart devices may perform action which has been programmed in it.

3.2. Required Features and Advantages

In order to detect the presence of elderly, the system should report the PWD's aimless presence in real time. The system should inform caregiver (as well as PWD) about the danger situation must be done in seamless way so not to create any sensory overload and without imposing constraints to parties which are involved in the process.

The anticipated features of the proposed system include:

- Real time monitoring of PWD in his home environment
- Providing ubiquitous notification to caregiver about the situation

The benefits of acquiring the proposed system are:

- Caregiver does not need to be present in PWD environment
- Caregiver may give instruction to PWD through some pre-define SMS, voice message or even he may call to his loved one if he finds PWD in uncomfortable position.
- PWD doctor or Psychologist may use the data of PWD's presence to see which area in PWD's environment is mostly chosen by him

3.3. Placing BLE Devices in Home Environment

Different BLEs may be installed in the PWD environment such as:

1. Kitchen
2. Washroom-1
3. Washroom-2
4. Garden/Lawn area
5. Bedroom-1
6. Bedroom-2
7. Car porch
8. Living Room/TV lounge
9. Terrace /Balcony
10. Hallway
11. Study

Different BLEs installed in the home environment so that elderly presence can be detected. Fig. 1 depicts a possible placement of BLE beacons a home environment.

3.4. Home Environment Zone Division

On the basis of the criticality of PWD's presence, the home environment has been divided into the following four zones.

3.4.1. *Highly Risk Zone*

Highly risk zone is the area of PWD home environment in which the aimless presence of PWD is considered very unsafe and dangerous even for a short period of time. Kitchen, store and wash rooms are the places in PWD environment which are considered in highly risk zone. The other areas of PWD environment including in highly risk zone may be boundary areas and car garage of home.

3.4.2. *Moderate Risk Zone*

Moderate risk zone is the area of PWD home environment in which the aimless presence of elderly is considered at low level of risk. The PWD may be present in the locations of this area in order to perform his daily life activities like watching TV or reading books in library. The caregiver may set the danger time for elderly presence according to specific elderly needs.

3.4.3. *Low Risk Zone*

It is the safer area in PWD environment in which presence of PWD is considered at very low risk. The time slot of presence of elderly will be greater as compared to highly and moderate risk zone.

3.4.4. *No Risk Zone*

It is the safest area in PWD environment in which presence of PWD is considered at resting position.

Fig. 1. Possible Placing of Bluetooth beacons (Green circles show BLE beacon placing)

The time slot of presence of elderly will be greatest in this zone.

3.5. System Architecture

To overview the proposed architecture a system diagram is presented in Fig. 2. The proposed architecture mainly has a network of miniature BLEs installed in the PWD environment, smart watch which is worn by the PWD and a smart phone which is available in the PWD environment.

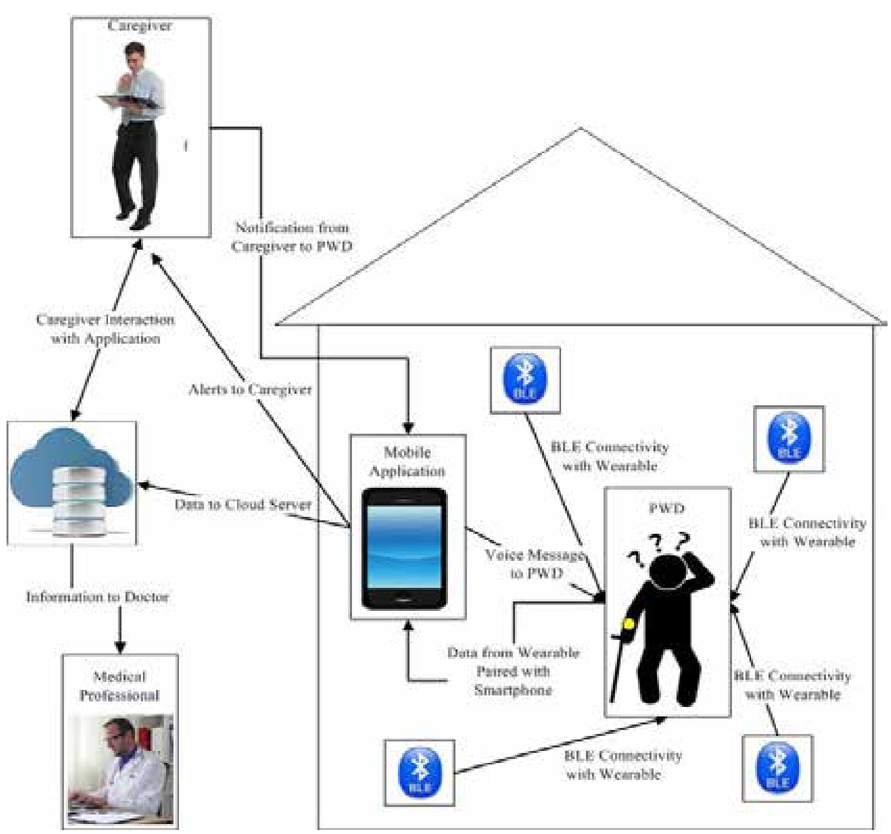

Fig. 2. The System Architecture

The caregiver has desktop application for profile building and watch PWD activity data, and smart phone to receive messages about danger situation. The details of the components of the system are given below.

3.5.1. *BLE Network*

Each BLE beacon may broadcasts its ID; the RSSI (received signal strength indication) may be used if a network of BLE nodes is deployed in an environment. RSSI can be used to extract position information about the BLE device as BLE beacons can only broadcast their IDs not any other information. The BLE receiver can calculate the distance of BLE by solving the free space lose equation. This work exploits the method used to find the position information of the respective BLE [15]. According to proposed architecture every BLE be installed on different position in the home environment of a PWD (for example as described in the Fig. 2) so that beacons may be received on smart watch. Every BLE has a unique identifier which will act as its ID. Every beacon will send a scanning message to master beacon every λ seconds interval. The Bluetooth available on smart watch will act as a *Master Beacon* and the other deployed BLEs in home environment will act as *Slave Beacon.* The processing flow of the proposed system starts with the *Slave* BLE beaconing. The algorithm which will run of smart watch is given below.

3.5.2. *Smart Watch Application*

The smart watch application listens to BLE installed in the environment. As PWD moves in its home environment with smart watch on his wrist, different BLEs may communicate with smart watch. As soon as the smart watch enters in the range of BLE, the BLE starts communication about its presence. This ID actually tells the location of PWD in its home environment. The BLE communicates its ID with smart watch, upon receiving the ID signals from smart watch the application installed on wrist watch adds a few parameters and then send this data packet to smart phone which is already paired with it. The function of smart watch is like a bridge which sends the location information to smart phone of PWD.

Algorithm:
Step-1 Start pairing with Slave BLEs
Step-2 Receive signals from paired slave BLE
Step-3 Discard signals which have lower RSSI if signals are received from more than one BLE
Step-4 Prepare data packet containing the ID of BLE and RSSI
Step-5 Add time stamp to data packet
Step-6 Send data packet to smart phone

3.5.3. *Mobile Application*

The mobile application running on smart device such as smart phone or tablet plays vital role in proposed architecture. The smart phone should be present in home environment of PWD or PWD may be trained to put this device near him. The main algorithm to detect the danger situation is installed on smart phone. The mobile application provides infrastructure support for receiving the data from PWD worn smart watch. The application runs on mobile phone as selected by caregiver. Upon receiving the data from smart watch it calculates the occurrence of danger situation.

If application receives beacon from *Master BLE* then it starts the detection algorithm. The algorithm will wait for the next beacon and upon receiving the next beacon from the *Master BLE* the time difference of the current profile will be calculated. If this difference is less than the threshold set by the caregiver then no action will be taken and algorithm will set the position of elderly profile with total time reflecting the presence of PWD in a specific region of the home. This process

Algorithm:
Step-1 Receive data packet(s) form Master BLE.
Step-2 Mark PWD presence in respective zone (Highly Risk Zone, Moderate Risk Zone, Low Risk Zone, No Risk Zone)
Step-3 Accumulate data packet(s) with the same source, calculate time interval and update time interval and profile variables
Step-4 Match time interval with threshold time (set by caregiver)
Step-5 If (time interval ≥ threshold time) then send alert to caregiver or PWD (depends upon caregiver choice) with PWD presence information in critical zone and time interval.
Step-6 If (time interval < threshold time) go to step-3.
Step-7 Maintain PWD profile data through profile variables and send it to cloud database (on daily/weekly/monthly basis)

will continue in coming times and time counter will reflect the total time elapsed in a same position. If the elapsed time found to be equal to or greater than the preset threshold time then the situation will be set at danger situation.

3.5.4. *Web-based Desktop Application*

The web based application intended to provide support to caregiver in order to maintain a PWD specific need's profile. It has an easy interactive interface which enables a caregiver to perform different actions which may improve the quality of life of PWD. The caregiver may login to the web based application anytime anywhere to create or edit the profile of its loved one. The caregiver may create the critical zones according to its choice and set the danger time slot. This time slot will be used by the mobile application to detect the danger situation. The caregiver may send PWD mobility data to medical professional for better treatment of PWD.

3.5.5. *Profile Building*

Caregiver may interact with the web application in order to create PWD detailed profile in which he can specify the special needs of the PWD. All PWDs may have different needs and their time and place profile may reflect diverse needs. Profile building facility makes caregiver freedom over specifying the special needs of his loved one. At any time caregiver may alter the profile and edit any information regarding his priorities.

3.5.6. *Notification to Caregiver*

As soon as the mobile device detects a danger situation it will inform caregiver about the situation. Mobile device may send an alarming message to caregiver about the position of elderly. The action to be taken in danger situation will be based on the preference set by caregiver. Caregiver may set a reminder voice message in order to inform PWD to change his position if PWD is found in trouble or may take appropriate action depending upon the health/mental status of PWD. The reminder to PWD in this case may be in the form of a voice message, in a loud sound so that PWD may hear it easily. The text of the message may be set and altered by caregiver anytime depending on the mental health status of a specific PWD.

The profile will be maintained on daily basis and will be saved in a cloud database which can be used for future processing of some other task. The profile may be used by the doctor of PWD in order to find out the facts about PWD mobility in his home environment.

4. RESULTS

4.1. Experimental Evaluation

The main objective of this evaluation is to discuss the performance of the proposed mechanism. The system has been tested to evaluate its effectiveness and how it can detect the presence of PWD in its home environment and provide alerts to caregiver about danger event. The system tested for the following parameters.

Is system providing real time detection of elderly presence in his home environment?

Is system detecting context aware real time danger situation?

Is system providing alert to caregiver in case of the detection of danger situation?

Is system providing caregiver the facility of defining user specific profile?

Is system providing enough support to caregiver to define four risk zones?

Is system supporting doctor to view the mobility pattern of PWD?

The smart watch used in the system evaluation was supported by Android OS having android Wear platform. The compatible beacons with smart watch were used. The mobile application has been developed on an Android smart phone having Marshmallow 6.0 API. Web application was hosted on a Linux PC with 3.10GHz Intel Core i3-2100 processor and 4 GB memory. For the initial study the research group tested the proposed system in a real environment as well as lab environment. The evaluation of the mechanism was done on the following parameters:

- Test case
- Functional Testing and Usability Testing
- Performance Testing

- Security and Compliance Testing
- Compatibility Testing
- Recoverability Testing
- Device Testing

4.1.1. *Test Case Participants and Test Environment*

The experimental setup for test case-1 and test-case-2 have been built in a home having 4 different rooms, one kitchen, 4 wash rooms, a lawn area, a car garage, a store room, and boundary wall area on three sides. Different BLEs were installed in the testing environment. Initially the ranges of every BLE beacon have been tested for their possible communication. Every BLE was checked whether it is working perfectly or not (it is giving beacons to its M*aster BLE* about its presence). A total of 18 BLEs were installed in the environment. Every volunteer spent a total of 20 hours in the environment in different timings of the day. For the system testing initially the algorithm was set to send notification to caregiver if volunteer presence is found in a zone in a short period of time (5 min, 7min, 9 min, 10 min, etc.).

Every beacon was set to send beacon on every 10 second hence a total of 6 beacons may be received in one minute interval from a BLE. Transmitting power of every beacon was analyzed and it is made sure that Bluetooth of smart watch is receiving the beacons from every BLE in the environment. The presence of participant was considered in a particular zone from which beacon it is getting the high RSSI.

Test cases: Research group created several test cases in order to check the performance of the proposed mechanism on mobile devices. Beside with the flow of a use case various business rules are also tested.

The following activities were communicated to perform during this test case.

- Watching TV for at least half hour
- Afternoon sleep for one hour
- Usual washroom activities
- Making breakfast and afternoon meal ready to eat
- Walk in the car porch area for 30 minutes
- Taking two rounds of inside boundary of home
- Ordinary walk inside the environment
- Dishwashing in kitchen
- Visit in store room once
- Spend some time in lawn area

Test case-1: In test case-1 two male volunteers spent 12 hour times in the specially built environment which was discussed above. Both volunteers spend the time in the environment and performed activities of daily life which were communicated to them beforehand. Each volunteer performed at least 7 activities so that its presence in real time may be observed and the communicated through the system. In this test case the notification was first delivered to volunteer in the form of loud voice message which was preset by research group in the mobile application. Upon receiving the notification through voice the volunteer was advised to push a button provided on mobile application for the indication of successful event.

Test case-2: In test case-2 two female volunteers spent 16 hour times in the specially built environment which was discussed above. Both volunteers spend the time in the environment and performed activities of daily life which were communicated to them beforehand. Each volunteer performed at least 7 activities so that its presence in real time may be observed and the communicated through the system. In this test the notification was not delivered to volunteer through voice instead a volunteer a group member himself called the volunteer to inform about the event.

The result from these test cases have been observed satisfactory and based on these results functional and usability testing with different volunteers has been done.

4.1.2. *Functional and Usability Testing*

The system has been evaluated with 16 technology experts (mean age = 37 years, SD = 3.9) who were either the users of mobile technology or the persons who belong to the field of software development and 16 undergraduate student participants (mean age = 24 years, SD = 2.21). The expert participants acted as caregiver and student participants acted as dementia patient. The research group used department of computer science building for the evaluation purpose as the building had necessary equipment and gathering study participant was very much convenient there. The same experiment was repeated in two consecutive days, with total of 8 participants each day, in order to get an acceptable number of results. For the experiment two class rooms, three teachers' rooms, two wash rooms, and a kitchen were selected as these locations were available in the close proximity in the department of computer science. BLEs were installed in these locations and paired with smart watches. This arrangement reflected the setting of an ordinary dementia patient's home environment.

The participants of the study were called through personal invitation. Their consent was taken before involving them into the study. The purpose and objectives of the study were made clear to all of them.

All of the participants were invited in a 4 hours long session. The research group explained the overall working of the proposed system in detail. Each expert participant of the group was paired with one student participant. Expert participants were explained the use of web application installed on the desktop computers of the lab. The participants were then allowed to login to the web application with their mock IDs. The process of profile building for a specific dementia patient was demonstrated to them in detail and given a sheet on which dementia levels were listed so that they can select any one level for their patient's profile and may set appropriate time duration for patient's presence. They were given choice on creating a patient's specific profile reflecting the dementia levels as indicated in Table 1.

Expert participants were requested to set a short interval of time (all intervals less than 13 minutes) for each zone so that results can be obtained without waiting too much. Each student participant had their smart phone on which the proposed mobile application was installed. Each participant was provided a smart watch to be worn throughout the experiment. Each participant was given a schedule to be followed to remain in a specific area so their presence in that specific area can be recorded and communicated through mobile application to their peer expert participant.

Table 1. Clinically Defined Dementia Stages

Levels	**Dementia Stage**
Level-1	No Cognitive Decline
Level-2	Very Mild Level
Level-3	Very Mild Cognitive Decline
Level-4	Mild Cognitive Decline
Level-5	Moderate Cognitive Decline
Level-6	Moderately Severe Cognitive Decline
Level-7	Very Severe Cognitive Decline

The same process on mobile application was also explained to them so that they can build their patient's profile on their ease. Each expert participant built one mock profile to mimic one elderly dementia patient. Student participants also installed proposed mobile applications on their mobile phones. Smart watches were given to student participants and their role of participation was explained to them. Student participants saved their peer's mobile numbers on student participant mobile applications. Expert participants saved the mobile numbers of their peer student participants on their mobile phones as the notification will be received on their pone by these numbers. All students participant were asked to strictly follow the schedule of presence in the environment. This schedule which was handed over to student participants is reflected in the Table 2.

The research group did several functional testing during the development of the desktop application, smart watches application and mobile application. Desktop application was tested according to the parameters which were necessary to be observed in the system. The user interface was designed in a manner so that caregiver and medical professional do not feel any difficulty in operating the application. The smart watch application was built so that it can receive and send BLE beacons and may send these messages to smart phone application. The main algorithm which detects the episode of disorientation runs on mobile phone so special contribution was given to it so that algorithm runs successfully. For usability testing the three applications (smart watch, mobile phone and desktop) have been tested on the basis of learnability, easy to use, error rate, satisfaction, interface and design and user friendly so that system can be used with its full context of use. During the usability testing the experts suggested valuable improvement in the design of

Table 2. Schedule Given to Student Participants

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Date:- ______________________________

Student Participant Name: _________________________

Time Slots	Time	Zone	Time Duration	Check List
Time Slot-1	10:00 AM to 10:15 AM	High Risk Zone	15 minutes	Yes / No
Time Slot-2	10:20 AM to 10:40 AM	Medium Risk Zone	15 minutes	Yes / No
Time Slot-3	10:45 AM to 11:05 AM	Low Risk Zone	15 minutes	Yes / No
Time Slot-4	11:10 AM to 11:20 AM	No Risk Zone	15 minutes	Yes / No
Time Slot-5	11:30 AM to 11:50AM	High Risk Zone	15 minutes	Yes / No
Time Slot-6	12:15 PM to 12:35 PM	Medium Risk Zone	15 minutes	Yes / No
Time Slot-7	12:40 PM to 01:00 PM	Medium Risk Zone	15 minutes	Yes / No
Time Slot-8	01: 00 PM to 01:20PM	Low Risk Zone	15 minutes	Yes / No

the application. Functional testing was done on the basis of efficiency, system performance, control and flexibility, and context and purpose. All expert participants were given a list on which they were asked to report the received message's exact time at which they received messages. The list which was given to their peer participant was then shared to them so that they can match the time of event and the time of received messages.

After experimental session a carefully designed 7 points Likert scale questionnaire [16], containing ratings from strongly disagree to strongly agree, was given to each expert participant to take their views about the system. This questionnaire was designed with the help of benchmark questionnaires SUS [17] and SUMI [18]. Their responses against usability attributes and system performance were then analyzed. Their response against efficiency, system performance, control and flexibility, context and purpose, learnability, easy to use, error rate, satisfaction, interface and design and user friendly have been summarized in the Table 3. It was observed that expert participants were mostly satisfied with system performance (mean = 6.69, SD = 0.602) and error reconciliation rate (mean = 6.69, SD = 0.602). Most participants found the system difficult to use (mean = 5.69, SD = 0.704) and suggested valuable improvement in the design of mobile application and desktop application. Interface and design also received a lower rating as compared to other attributes. All attributes were rated in the range of 5 to 7, no attributes received low rating, which reflects that all the participant were very much in the favor of the system. In order to depict the responses variability a graph has been

Table 3. Participants Response Summary Reflecting Mean, Median, Minimum, Maximum and Standard Deviation

	Efficiency	System Performance	Control and Flexibility	Context and Purpose	Learnability	Easy to Use	Error Rate	Satisfaction	Interface and Design	User Friendly
N	16	16	16	16	16	16	16	16	16	16
Mean	6.06	6.69	6.00	6.44	6.06	5.69	6.69	6.38	5.88	6.00
Median	6.00	7.00	6.00	6.00	6.00	6.00	7.00	6.00	6.00	6.00
Minimum	5	5	5	6	5	5	5	5	5	5
Maximum	7	7	7	7	7	7	7	7	7	7
Std. Deviation	0.680	0.602	0.516	0.512	0.680	0.704	0.602	0.619	0.806	0.516

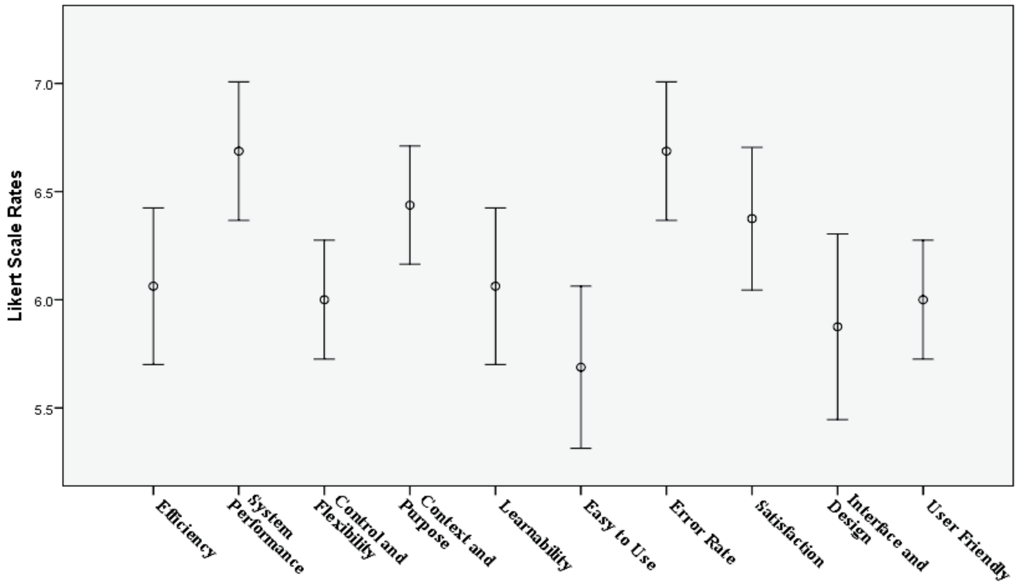

Fig. 3. Participants Response Summary with Mean and Standard Deviation

shown in Fig. 3.

4.1.3. *Performance Testing*

The performances of the applications have been tested under different conditions. Initially a less number of BLEs were installed in the PWD environment so that performance of the system may be checked and as the performance was observed satisfactory more BLEs were installed which overall cover a PWD environment. The notification capability of the application was checked in different conditions.

4.1.4. *Security and Compliance Testing*

As the applications were in their evolutionary stages no security and compliance test has been done. The research group is planning to conduct a comprehensive security and compliance test in order to ensure that application's data and networking security requirements are met as per standard guidelines.

4.1.5. *Compatibility Testing*

Since the algorithm to detect episode of disorientation runs on mobile application and this mobile application runs as a background process it is necessary to check that the voice notification is allowed all the time on mobile application and also mobile phone is not in silent/vibrate mode so that voice notification as well as call sound can be heard by PWD. This is made sure that the algorithm doses not suspend its working during any voice call and/or any other application. The PWD may use his smart watch anytime without disturbing the BLE signal receiving process. Different tests on screen size of mobile devices, screen resolution and network connectivity were also done.

4.1.6. *Recoverability Testing*

Recoverability parameters such as crash recovery and transaction interruptions have been checked up to some initial level. Obviously both smart watch and mobile phone should be power on during the PWD observation time. This is the responsibility of the caregiver to keep the BLE and mobile devices charged so that no interruption observed during the process on battery basis. This was observed during the test cases that if battery of any device involved in the process discharges the whole process is disturbed and algorithm needs to recover itself from this situation.

4.1.7. *Device Testing*

The research group used Android smart watch with android Wear operating system, the compatible BLE beacons, android smart phone running Marshmallow 6.0 version and Linux PC with i3 processor. No other devices were used to run the system but in future the research group is planning to use BLE beacons form other commercial vendors and different mobile devices running the operating system other than Android OS.

5. DISCUSSION AND IMPLICATIONS

The experimental results showed that the proposed mechanism is providing real time aimless presence detection in a home environment. The presence of participants was recorded through the proposed architecture and then matched with the previously discussed profile. As every participant strictly observed the discussed profile of his presence the experimental checking was made possible. The system produced satisfactory results against each participant's presence. The system has also been checked for sending the notifications. The system produced real time notification to caregivers' mobile devices in all cases. The system provided caregiver the facility to build four different zones in a home environment. All the parameters described in experimental evaluation section were tested in initial study and pleasing results were found.

The evaluation of the proposed study has some limitations. The results were evaluated with small number of participants who were not dementia patient. One of the reasons was that the research group found only a small number of dementia patients in their contacts and the research group had limited number of recourses through which the experimental setup was not feasible to perform. The research group is planning to do the evaluation with real dementia patients in future. The evaluation has been performed on Android devices only, no other devices has been used. The proposed work needs to be tested in other platforms.

6. CONCLUSION

This paper presents application and implementation of context aware aimless presence detection of PWD in its home environment using Bluetooth low energy (BLE) beacons. Mobile devices are used with BLE beacons which capture the beacons from BLE and then this data is used to find the presence of PWD. PWD may observe the episode of disorientation of time and place and may be aimlessly present in different location in his home environment. This problem may lead to serious health issues and caregiver may need to be present 24 hours with PWD. By using assistive technology systems on PWD mobile device real time presence in home environment is monitored. The proposed system assists caregiver by providing alerts/ notifications if the danger situation is detected. The caregiver may build a PWD special profile fulfilling the special needs a particular PWD and may alter the profile anytime anywhere according to the need of PWD. In this way the proposed system can enhance the quality of life of PWD and caregiver.

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8. Conflict of Interest

All authors declared no conflict of interest.

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