Orientation Training System for Elders with Dementia Using Internet of Things

Lun-Ping Hung[1(✉)], Chien-Liang Chen[2], Chien-Ting Sung[1], and Chia-Ling Ho[3]

[1] Department of Information Management, National Taipei University of Nursing and Health Sciences, Taipei City, Taiwan
lunping@ntunhs.edu.tw

[2] Department of Computer Science and Information Engineering, Aletheia University, Taipei City, Taiwan

[3] Department of Marketing and Logistics Management, Taipei City University of Science and Technology, Taipei City, Taiwan

Abstract. Dementia is an irreversible disease, its prevalence increases with age, the elderly with dementia increasing with years become a nonnegligible population, the government and the public shall be prepared for this tide. The information and communication technology is improved continuously in recent years, the Internet of Things technology becomes mature increasingly, which is helpful to the life aspects of home, traffic and shopping, and it can be combined with clinical knowledge and experience for the environment of health care, promoting the senile dementia treatment field to face how to use the complete architecture of Internet of Things to provide an effective adjuvant therapy mechanism. The early dementia temporal orientation training mechanism can be built by using the concept of health care Internet of Things. The infrastructure proposed in this study combines xBeacon sensing equipment with novel hybrid operation modes, including Received Signal Strength Indication (RSSI) positioning, event analysis method and intelligent cutting algorithm, to reduce the slightly disabled patients' troubles in direction judgment and the probably derived anxiety and unease. The effective record and analysis of routine behavior pattern support the elderly to maintain the mobility in daily life independently, promoting the "home-based care for the aged" and "Aging in Place" visions and the attainment of objectives effectively.

Keywords: Orientation training system · Dementia · Internet of Things

1 Introduction

The dementia is a progressively degenerative and irreversible disease, it affects memory, thinking, behavior and sentiment. Differing from generally simple aging or hypomnesia, it is a disease of cerebral defuctionalization, a progressive cerebral degeneration syndrome. The symptoms include the failure of memory, and the cognitive function is affected, including the degeneration of linguistic ability, sense of space, judgment, computational ability, personality change and abstract thinking, and there will be behavioral and psychiatric symptoms, including disturbing behavior,

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heteroptics, acousma and delusion. Most findings indicate that besides pharmacotherapy, the non-pharmacotherapies, such as environmental adjustment (familiar, stable and secure environment), activity arrangement, change in communication mode, cognitive training, reminiscence therapy, light, massage, music therapy, aromatherapy, pet therapy, multi-sensory stimulation therapy and art therapy, can improve the dementia patients' behavioral and psychiatric symptoms and slow down the development of course.

The morbidity of dementia increases with age. Taiwan Alzheimer's Disease Association estimates according to the estimated data of total population growth in the "Taiwan Population Projection" published by National Development Council in August 2016 and the dementia 5-year prevalence, the population of dementia was about 240 thousand in 2016, that will be more than 460 thousand in 2031, when there will be more than 2 persons suffering from dementia per 100 Taiwanese. The course is divided into mild cognitive impairment, mild (initial stage), moderate (intermediate stage) and serious (late stage). The disease degenerates at uncertain time, there are individual differences. The mild cognitive impairment (MCI) is a transition region between normal aging and the initial symptom of dementia. Clinically, about 10–15% of MCI develops into dementia annually, there will be problems in complex assignments or social environment, but the simple daily life is not affected [1]. The Cognitive Abilities Screening Instrument (CASI) is a clinical diagnosis tool extensively used in the field of dementia, for evaluating the patient's indexes of capacity for action. The cardinal symptoms of dementia are hypomnesia and cognitive impairment. The present diagnosis is still based on cognitive function degeneration. The CASI is developed from several common scales, including the questions in The Mini-Mental State Examination (MMSE), The Modified Mini-Mental Scale (3MS) Test, The Hasegawa Dementia Screening Scale (HDSS) and HDSS revision (HDS-R) [2]. The CASI remedies the defect of "cognitive psychological function test limit" in the MMSE and enhances other evaluation abilities. The score of CASI can be obtained after CASI analysis, and it can be converted into the score of MMSE for different studies' and clinical diagnoses' reference. The CASI contains the following tests of 9 dimensions: Attention (ATTEN), Mental manipulation (MENMA), Short-term memory (STM), Long-term memory (LTM), Orientation (ORIEN), Language (LANG), Drawing (DRAW), Abstract thinking and judgment (ABSTR) and Animal-name fluency (ANML). The scale characteristics have enlarged the fractional scale of short-term memory and temporal orientation which are most likely to be abnormal, so that it is easy to find and track any change in the score of the dimensions of the patient.

In this paper, a temporal orientation training mechanism conforming with clinical dementia is designed by xBeacon cut orientation assisted search technique in the concept of temporal orientation in dementia treatment, the disease development rate is reduced by giving appropriate stimulation and training, the patient's anxiety and unease resulted from disorientation can be reduced by the training process. The research objective is to enhance the safety and effectiveness of temporal orientation training, so that the patients are trained in an environment closer to the reality for greater effectiveness.

2 Literature Review

According to the references about dementia, the fields of medical treatment to technology-assisted life are covered. Many studies mentioned the necessity of patient position information, because one of the common symptoms of the patients with dementia is getting lost. It is often heard that the patients went out but forgot the way home, and had accidents, psychologically worrying their families and making the care difficult. Holthe et al. proposed a technology-assisted electronic calendar system, and proved that the electronic technology assisted with the patient's memory effectively [14]. Baruch et al. developed a home environment-based system in 2004. Related systems are installed in the living room and bedroom, a sound reminder is given when the time is up, so as to remind the patient to do what he wants to do, and the patient's anxiety and confusion are reduced successfully [15].

In terms of the studies about preventing the patient with dementia from getting lost, Ogawa et al. developed a system combining a low power consuming smart phone with PC. The patient with dementia carried the smart phone in the limited range for indoor location tracking, when the patient walked out of the range, the system sent the patient's positioning information via E-Mail to a relevant person's phone automatically, and the patient's smart phone gave warning sound to prevent the patient from being missing [16]. Ikarashi et al. designed a home-based tracking system for the patients with dementia by using GPS (Global Positioning System), PHS (Personal Handyphone System) and PC, the patient moved freely at home and his movement track was recorded to track the patient with dementia [17]. The above studies used the architecture of Internet of Things and different methods, the patient's position was detected successfully. The findings show that if the patient's position is known, the carer's burden and mental stress can be reduced, and the patient is prevented from getting lost effectively, reducing accidents. These findings show the importance of patient location positioning.

To sum up the aforesaid viewpoints, performing the Internet of Things technology and health care domain expertise can assist the patients with dementia with autonomous life and reduce the carers' burdens. As this study shall detect the patient's position intensively and instantly, the power consumption is a major consideration. The xBeacon based on Bluetooth wireless transmission is selected as front-end sensor to solve the power consumption problem, with a portable and handy mobile device, the trainer's burden can be reduced. This study uses xBeacon sensing equipment and RSSI positioning function to track the position information of the patient with mild dementia. A training mechanism about direction-sense is provided, so as to help the patient in training direction-sense more effectively, to enhance the patient's independence ability by such a design, the anxiety and unease are reduced effectively, and the dementia-induced degeneration is mitigated.

3 Research Method Procedure and Analysis

The system architecture is divided into front end sensing layer, middle end transmission layer and back end data layer and application layer. The sensing layer of this system uses xBeacon and smart phone as front-end sensing equipments for environmental induction and information gathering. The transmission layer uses Bluetooth wireless transmission, WIFI and the 3rd-Generation communication technology for data transmission. The data layer uses hybrid positioning calculation system to calculate the received information data and store them in database. The application layer provides different pictures for different users. The home-based positioning system displays different pictures according to different permissions.

3.1 Node Signal Strength Positioning Design and Application

This is signal strength localization method, the "region" of the location can be marked out rapidly. The more annunciators are laid, the more accurately the region of the location can be marked out. This study assumes that the sensors **P** on the patients are distributed over area **M** randomly, $\mathbf{M_n}$ is the possible region of each sensor, and the sensors are in their range of $\mathbf{R_n}$. When there is not any mobile node, the possible range of each sensor is the entire M-region. In the experiment, the possible position range of sensor is reduced by the bisecting normal $\mathbf{L_n}$ between different mobile nodes, so as to obtain more accurate positioning result. In order to find the location of sensor, the training assistant can be regarded as a mobile node. The mobile node is the site where the reader stops. When the reader stops in environmental region, the reader collects the information of sensors in the range, and averages the sensor intensity values received in situ as the comparative data of each mobile node. The mobile node **C1** receives the information of sensor **P** and **C2** receives the information of sensor **P**, the stored comparative data are different as the distances are different.

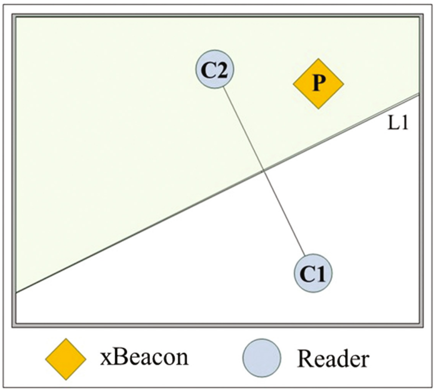

Fig. 1. Region segment of two mobile nodes (Color figure online)

As shown in Fig. 1, the sensor is placed in the area coverage, marked as English coded yellow diamond, the reader stops in two different positions randomly, marked as number coded circle. The signal strength value of Sensor **P** is received during stopping. The bisecting normal $\mathbf{L_1}$ between two points divides the area **M** into $\mathbf{M_a}$ and $\mathbf{M_b}$ blocks. In terms of mobile node **C1** and mobile node **C2**, as the Sensor **P** is closer to **C2**, the strength value of **C2** is greater than that of **C1**. Therefore, the location of Sensor **P** is in the region $\mathbf{M_a}$ on the left of bisecting normal **L1** between mobile nodes **C1** and **C2**.

As shown in Fig. 2, If the **r(P, C)** is the signal strength value from Sensor **P** to Point **C**. When the reader stops at mobile node **C**, **d(Ci, Cj)** is the distance between points **Ci** and **Cj**. The following theorem can be concluded from the aforesaid description, if a space contains a sensor and mobile nodes **C1** and **C2**, if **r(P, Ci)** $\leq$ **r(P, C2)**, **d(P, Ci)** $\leq$ **r(P, C2)**. Therefore, by dividing mobile nodes, all the possible ranges of sensor will be convex polygon. There are **C * (C−1)/2** bisecting normals according to mobile node C, and the increasing mobile nodes will duplicate the number of bisecting normals and reduce the possible range of sensor effectively.

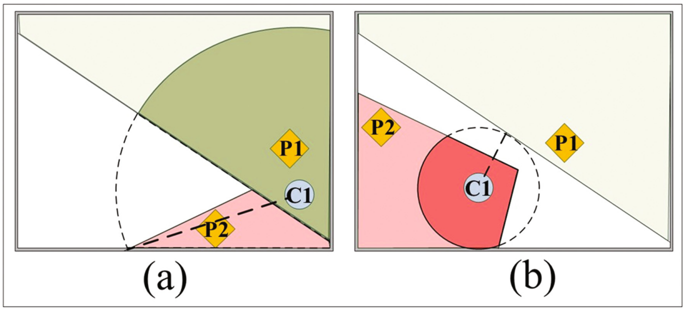

Fig. 2. Segment of sensor signal strength

3.2 Hybrid Indoor Signal Location Algorithm Intelligent Cutting Positioning Design

In this study, the accuracy of signal strength can influence the subsequent strength cutting method and positioning of mobile endpoint. In order to test the signal difference of xBeacon, different models and brands of Android intelligent mobile devices are used for experiment, it is used as reader to test whether the read RSSI values are different or not when different devices are used. This study will use three intelligent mobile devices, which are Redmi note, Samsung and ASUS, the measurement is conducted in a clear indoor environment and a home environment full of signals and compartments respectively to find the difference. As the indoor environment is complex, the electronic signals, electronic products, power supplies, indoor layouts and compartment materials will result in errors in xBeacon signal collection, not only influencing the signal strength, but also causing reflection and refraction problems, leading to signal distortion. According to Table 1, the mobile device of the same brand will have signal errors in different indoor environments. When the signal has errors, the indoor positioning accuracy will be lost.

Therefore, this study will use hybrid algorithm to design intelligent cutting positioning mode, combined with the RSSI signal value collected by xBeacon, the location is judged according to the location fingerprinting database, and the node signal strength localization method is used to mark out the patient's possible region, the location is judged by algorithm under the effect of dual positioning, so as to enhance the patient positioning precision. The convex polygon region is used for patient positioning, convenient for the carer to find the patient under the guidance of visual effect, enhancing the safety, and the patient's anxiety during disorientation can be reduced by training.

Table 1. The signal values of xBeacon in indoor

	1 m	2 m	3 m	4 m	5 m
Open space environment in indoor					
Samsung	−59 ~ −61	−65 ~ −67	−70 ~ −72	−74 ~ −75	−78 ~ −80
ASUS	−54 ~ −55	−66 ~ −68	−69 ~ −72	−77 ~ −78	−80 ~ −82
Redmi note	−60 ~ −61	−65 ~ −67	−71 ~ −73	−75 ~ −77	−78 ~ −80
Signal interference environment in home					
Samsung	−61 ~ −64	−65 ~ −68	−70 ~ −74	−76 ~ −78	−78 ~ −81
ASUS	−54 ~ −57	−66 ~ −69	−69 ~ −73	−77 ~ −78	−80 ~ −83
Redmi note	−60 ~ −61	−64 ~ −68	−71 ~ −73	−74 ~ −77	−80 ~ −82

3.3 Development of Temporal Orientation Training Mechanism for Dementia

This study uses xBeacon cut orientation assisted search technique to design a supplemental training mechanism for temporal orientation of clinical dementia, combined with a new generation BLE device, node signal strength cutting and sensor division technique to create an indoor environment training mechanism. The action track is followed by immediate addressing of the location of the patient with dementia. The training assistant leads the patient with dementia to walk on the preset path for the first time, and reminds the patient of the route to impress the patient. Afterwards, the patient walks on the preset path alone with xBeacon. The training assistant does not need to accompany the patient in the training process, but to watch the patient's movement aside. In case the patient got lost, the patient's range and right location are searched for according to the system menu guidance, and then the training is completed with assistance.

The dementia temporal orientation training mechanism is divided into 3 parts, xBeacon sensor end for transmitting information, kernel program end for information operation and processing and mobile application end for result visualization. The mobile application device with the patient receives the signal information of xBeacon sensor in the range. There are two types of sensors used in the environment. One is placed in a fixed position in the environment to assist in locating the patient. The second type is mounted on the patient for finding the patient during training. The mobile device receives the signal strength of xBeacon in the regions and related codes. These regions include bedroom, kitchen, living room, bathroom and dining room which are indoor environments for the patient with dementia.

The kernel program end is the relay software for receiving information, the database for storing information and the finder for calculating information. The relay software receives the sensor information from the mobile device via Wi-Fi. According to the uses of sensors, the data are classified and the signal strength data are converted into the database storage format, written in the database after data processing. The database stores the ID number of each xBeacon, signal strength and each patient's information. The relay software writes the received information in the database, the positioning calculation system reads the database information to judge the location. The possible position range of sensor is marked out and cut according to the sensor strength values received by different mobile nodes. When the positioning is finished, the hybrid positioning calculation system stores the result in the database, as shown in Fig. 3, the mobile application end receives the range of sensor after calculation, which is visualized on the screen of mobile device, the location of the patient with dementia is searched for on the indoor map on the screen.

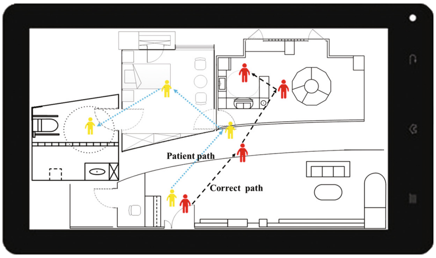

Fig. 3. The diagram of visualized system

4 Conclusion

This study develops an assistant mechanism for dementia temporal orientation training, the cooperative temporal orientation training mode for assistant and patient is created preliminarily, helping the patients with mild dementia and problems in temporal orientation maintain viability. With the support of information and communication technology, the system can record the training process and prevent the patient from getting lost. In addition, based on the architecture of Internet of Things, the patient's treatment situation can be known and tracked instantly, implementing technology assisted treatment to upgrade the medical care effect. It can even assist the doctors in deciding on clinical treatment in the future development.

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