Design of User Interface for Elderly Care Supervision System Based on Sensor Network

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Abstract. The world trends toward aging society because of low total fertility rate and long human life, and we have to face the issue that youth in the feature will have heavier load to take care of the elderly living than that at present. In order to solve such problem, cyber physical system is implemented, which is a collaborating system by integrating computational elements and physical entities. In this work, we develop the framework of the elderly care supervision system based on sensor network, and it is verified in a long-term caring facility for dementia caring. Moreover, user interface runs the developed software. Caregiver, family member, and system manager can manipulate the friendly user interface to obtain information of the elderly activity and the anomaly. The resultants will demonstrate that how activity recognition and elderly living analysis are implemented by application program runs on mobile device.

Keywords: Cyber physical system · Elderly care · Human-computer interaction · Sensor network · Activity analysis

1 Introduction

Facing the issues of total fertility rate (TFR) of the world declining and population aging, it implies that an aging society is coming. According to the reports [1, 2], TFR of the world declines from 4.85 in 1970 to 2.63 in 2015. Additionally, regions with the lowest five TFRs of world were in Asia in 2015, they were South Korea, Hong Kong, Taiwan, Macau, and Singapore. Low TFR means that youth will have heavy load in the elderly care in the future due to the ratio of elder to youth increases year by year. In [3], the report reveals that caregiver support ratio is 7 in 2010 in America, and it will drop to 3 in 2050. Therefore, how to manage manpower efficiently in the elderly care is an important task now.

Cyber physical system (CPS) is a collaborating system by integrating computational elements and physical entities. In the past, researchers investigated approaches based on CPS to take care of people living in smart home. For physical entities of CPS, diverse sensors are deployed in building, including, temperature sensor, humidity sensor, ambient light sensor, current sensor, positioning sensor, passive infrared motion sensor,

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and depth camera, etc. Moreover, sensors on wearable devices are capable of collecting vital signs and people action, such as, accelerometer, gyroscope, heart rate variability, body temperature. In the literature [4–7], the applications based on CPS were presented, including, activity analysis/recognition, anomaly detection, home energy saving, and preference estimation, etc. In [4, 5], Weng et al. analyzed human activity in home for determination of energy-saving service. Their improved method was performed on multi-resident environment. In [6], Gu et al. used data mining instead of machine learning for recognition of 25 daily activities.

A common management technology is applied to those sensors and transmits sensing data to cloud server through Internet. Cyber layer subscribes data from cloud server. Subsequently, analysis technologies are applied to sensing data, such as activity recognition (AR) and anomaly detection (AD). The objectives of AR are to recognize the elderly activity as well as to generate activities of daily living (ADL). The objective of AD is to detect abnormal activity/behavior by analyzing recognized results, and then warning sign is activated. In the previous work [7], we proposed a scheme to analyze sensing data as well as to recognize people activity. The analyzed data were mono-type sensing data collected in the single-woman home [8]. Our scheme can recognize activity, detect anomaly, generate ADL, and estimate personal preference in activity habit.

In this work, we develop the framework of the elderly care supervision system based on sensor network, and it is verified in a long-term caring facility for dementia caring. The user interface displayed information of deployed sensors, elder's activity and anomaly is designed for caregiver, family member, and system manager. The elderly ADL recognized by analyzing ambient sensing data and body sensing data are stored in cloud server; moreover, the system detects the elderly anomaly and then lights up a bulb for warning. Caregiver can obtain information of elder's activity and abnormal event informed by the portable device. Family member can remotely look over his/her grandparent's health status shown on the portable device. For system managers, they operate the portable device to monitor connection status of ambient sensors. The rest of this paper is organized as follows: the interview to the long-term caring facility and the scenarios for the elderly care are described in Sect. 2. Sensor deployment and architecture are, respectively, introduced in Sects. 3 and 4. Activity analysis is presented in Sect. 5. The user interface and functions will be shown in Sect. 6, and the concluding remarks will be drawn in Sect. 7.

2 Interview and Scenario Design

In order to understand trend of elder care in upcoming aging society and requirement of caring facility, we visited and interviewed health professionals, doctors, and caregivers. Table 1 lists the interview summary with respect to four major aspects, namely, safety, health, caregiver load, and quality of care. According to the insights gained from the interviews mentioned above, we proposed three scenarios in our design, namely, straying detection, sleep pattern detection, and night-time bed-leaving detection.

Table 1. Interview summary with respect to four major aspects

Major aspects	Sample issues
Safety	• Safety First! It's important to provide immediate notification for falling accidents • Need information and communication technology (ICT) to help or prevent straying and to detect night-time bed-leaving for the elderly
Health	• It is important to help the elderly to establish regular life activities patterns • Healthy life styles are helpful, e.g., exercises, enough sleep, healthy diet
Caregiver load	• There exists shortage of caregiver in most elderly care facilities • Paper work is time-consuming, ICT could improve efficiency in caring tasks
Quality of care	• With sensor network, caring process could be personalized and optimized • User interface design could help caregiver/medical professionals to quickly understand the elderly health and care condition

2.1 Scenario 1: Stray Detection

Wandering behaviors and getting disoriented situations are commonly seen in the elderly with dementia. Therefore, in this scenario, beacon sensors first collect the position and the time data of the elderly as shown in Fig. 1(a). Then, with the forbidden area detection, the proposed system could notify caregiver immediately to find the elder as well as to offer in-time assistance.

2.2 Scenario 2: Sleep Pattern Detection

Dementia and sleep are closely related with one another. The elderly with dementia tends to have irregular sleep pattern, and lack of sleep increases the risk of dementia later in life. Thus, in our design shown in Fig. 1(b), motion sensor detects elder's action automatically when he/she sleeps on the bed. The duration of activity between two active signs of motion sensor is analyzed for estimation of sleep pattern. Moreover, through sleep pattern and anomaly detection, our system could actively notify caregiver to pay attention to elder's sleep.

2.3 Scenario 3: Night-Time Bed-Leaving Detection

Caring facility concerns the issue of the elderly safety during night time. It is high possibility that elder falls when he/she gets out of bed at night. Therefore, sensor deployed on bedside detects incident of night-time bed-leaving. In addition, the system activates night light near the bed, so that it is helpful to decrease the risk of falling. Meanwhile, the system turns on the bulbs in nursing station, and it notifies caregiver to take care of the elderly immediately. Figure 1(c) shows the flowchart of the scenario 3.

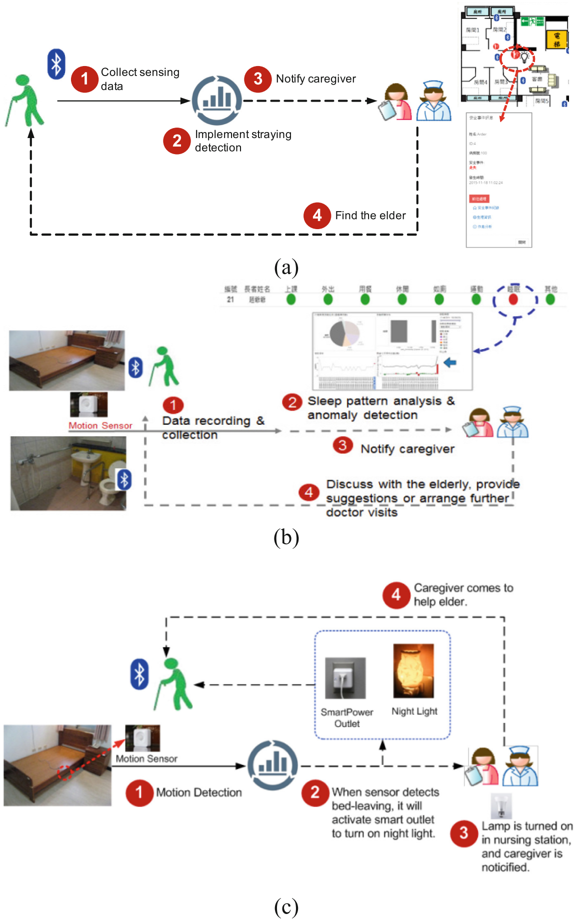
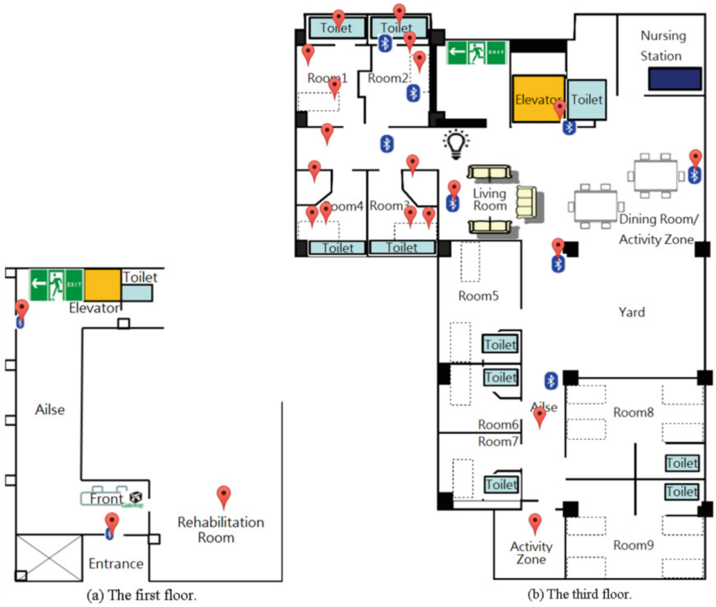


Fig. 1. Flowcharts of three scenarios, including (a) straying detection, (b) sleep pattern detection, and (c) night-time bed-leaving detection.

3 Deployment

The issue of deployment is divided into three major topics, including, space field, devices, and subjects. Figure 2 portrays two floors of the institution for dementia caring facility, where Fig. 2(a) indicates the first floor of institution including the entrance and a larger space of rehabilitation room as well as Fig. 2(b) represents the third floor of institution accommodates nine rooms including toilets, a living room, a nursing station, a dining room, a yard, and a activity room.



(a) (b)

Fig. 2. Sensor deployment in (a) the first floor, and (b) the third floor in the caring facility (Color figure online)

The red pins on Fig. 2 represent the positions where devices/sensors are deployed. These devices are anchor nodes which provide the elderly positioning information; motion sensors which sense people action for analyzing the elderly activity status; air mentors that detect air quality; bulbs which adjust the light saturation and colors to alarm caregivers in nursing station what situation is; and badges (mobile nodes) are wearable devices which send signal periodically to anchor nodes in order to track the elderly position. In the experimental environment, the tested elders' ages range from 70 to 80 years old and live in Room 1, Room 2, Room 3, and Room 4 on the third floor as shown in Fig. 2(b). They wear badges, and their families accept the agreement for personal positioning owing to privacy.

4 System Architecture

We push messages to data bus and send messages to all subscribers which interested in our channel. Therefore, subscribers receive only topics of the interest without receiving all information from data bus, so applications can easily obtain accurate information on the desired system to supervise. The abilities of multi-channel data bus have three: (1) pub/sub: publish and subscribe message for data bus by topic; (2) cross-platform: supports message passing for different platform and virtual machines; and (3) immediacy: instant information delivered to the data bus and various services instantly receive data.

In order to allow that CPS integrates every type of device, CPS has a service model for data normalization, so that the system can obtain information in a variety of environments, such as medical, home. In addition, the information is converted into a unified format. In this work, the system supports the health and environmental equipments, it integrates data formats and units from various manufacturers, so that we can collect messages and control devices through Internet. Figure 3 shows the diagram of devices and equipments connection in this work. It is established for intelligent health care system, and it is helpful to improve quality of personal health management.

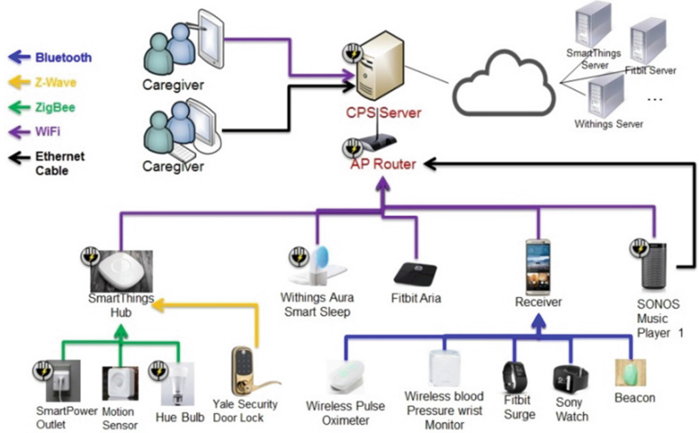


Fig. 3. Diagram of devices and equipments connection (Color figure online)

5 Activity Analysis

According to the interview summary mentioned in Sect. 2, caregivers in caring facility concern elders' position and their states. There are two ways to obtain people's position in this work. Tracking people using wearable devices, such as, beacon sensor, smart watch, and smart phone, is a direct method. Meanwhile, some wearable devices provide more functions to measure vital signs and then are capable of transmitting data to cloud server via wireless communication. However, in some situations people feel uncomfortable by wearing device, such as the elderly with dementia. Position tracking will be failed as people take off the devices. The other method is to analyze sensing data derived from ambient sensors, such as passive infrared motion sensor. While people appear in room, sensors deployed around the room will be activated. The objective of activity analysis is to mine useful information by analyzing sensing data. In the previous work [7], we proposed methods to recognize people activity with respect to his/her position. There are eight daily activities recognized, and those activities are highly related to functions in rooms. In this work, we emphasize on three types of activity analysis, and the details are described as follows.

5.1 Activity of Daily Living

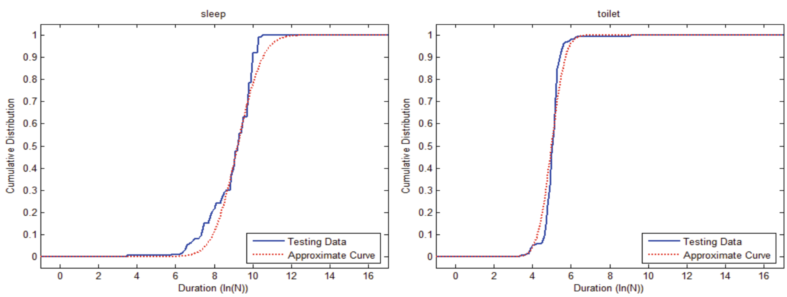
In the elderly caring facility, eight activities are recognized, including, “Sleep”, “Relaxing”, “Eating”, “Toilet”, “Go out”, “Exercise”, “Attend Class”, and “Others”. The elderly wears a badge which is a positioning sensor in order to acquire his/her position immediately. Furthermore, passive infrared motion sensors are deployed on bedside and on ceiling above bed. The objective of deploying motion sensors is to detect sleep status and incident of night-time bed-leaving. Figure 4(a) shows the pie chart of ADL one day, and the area of pie represents the ratio of total hours of activity to 24 h. Figure 4(b) illustrates the bar charts of activities one day, the bar size represents duration of activity.

(a) (b)

Fig. 4. Activity Analysis: (a) pie chart of ADL one day, and (b) bar charts of activities one day (Color figure online)

5.2 Preference in Duration of Activity

Everyone spends time in activity is different to another does. However, his/her preference in duration of activity is not change violently. Referred to [7], durations of all activities are collected and cumulative distribution functions (CDF) of scaled-durations of activities are computed. The CDF of scaled-duration of activity is approximate to that of normal distribution. Therefore, the 95 % confidence interval of normal distribution is a criterion to estimate duration of activity. For example, Fig. 5 shows two CDFs



(a) (b)

Fig. 5. Cumulative density functions of (a) “Sleep”, and (b) “Toilet”

corresponding to “Sleep” with the duration of 29,732 s and “Toilet” with the duration of 270 s.

5.3 Anomaly Detection

Three kinds of conditions are concerned as anomaly in caring facility, i.e., falling down, abnormal behavior, and straying. Wearable devices (such as, smart phone and smart watch) embedded accelerometer and gyroscope are helpful for detection of the elderly falling immediately. Furthermore, the factors that lead to the elderly falling after he/she gets out of bed are unsafe environment (such as, dimly-lit room) and un-awakened consciousness. In order to prevent accident, passive infrared motion sensor deployed at bedside is employed to detect incident of night-time bed-leaving.

While the elderly spends more time in activity than usual, the situation is considered as abnormal behavior. For instance, someone spends more time in the toilet, it is highly possible that people has fallen or fainted a period of time. Therefore, the estimated duration of activity (mentioned in Sect. 5.2) is employed to determine when abnormal behavior begins.

For straying, it is an emergency that the elderly with dementia leaves caring facility without any caregiver notifies it. To solve such problem, the elderly wears a badge embedded with positioning sensor. The system detects whether people locates in forbidden area, such as, front gate. If elder enters the forbidden area, the system sends warning message to notify caregiver.

6 User Interface and Functions

We develop framework of elderly supervision system based sensor network. Figure 6 shows the diagram of the proposed system, and it is verified in the caring facility. Caregiver, family member, and system manager can browse information via the designed user interface performed on portable device. The details of functions of user interface are introduced as follows.

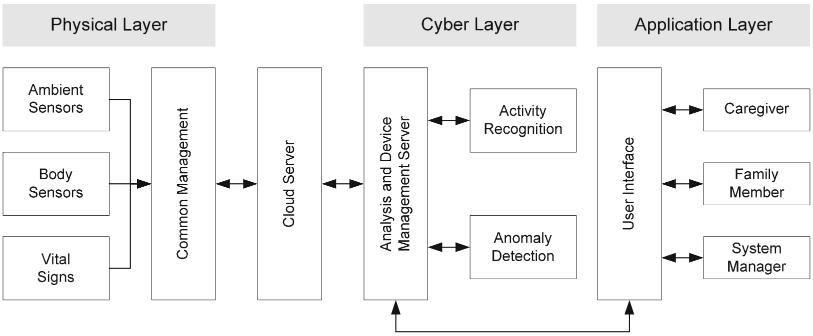


Fig. 6. The diagram of elderly care supervision system

6.1 Main Page

Figure 7 shows the main page of the designed user interface, where three buttons placed on for caregiver, family member, and system manager. Caregiver monitors elder's activity and abnormal event. Family member can remotely look over his/her elderly member's health status. For system managers, they monitor connection status of sensors deployed in the facility.

Fig. 7. Main page of the designed user interface

6.2 Descriptions of Functions

Caregiver can browse four kinds of information by pressing left-hand side buttons on page as shown in Fig. 8, including, real-time monitoring, safety incident, activity of daily living, and information of vital sign. For real-time monitoring, Fig. 8 shows four elders' positions with different icons. The green-circle represents the No. 19 elder is normal. The red-icons are warning signs. The red-triangle, the red-rectangle, the red-star represent the anomalies of night-time bed-leaving, straying, and falling, respectively.

Fig. 8. Interface of real-time monitoring (Color figure online)

Pressing the red-icon or the button of safety incident, caregiver obtains the 3-min history trajectory of unsafe incident. For example, Fig. 9 displays the history trajectory of the elderly straying.

Fig. 9. Interface of safety incident (Color figure online)

The function of ADL is to reveal the elderly activity status. The first function is to list the summaries of the eight activities as shown in Fig. 10(a). Green-circle and red-circle represent normal status and abnormal status yesterday, respectively. Pressing the elder's name, the user interface displays four charts of the elderly ADL as shown in Fig. 10(b), including, the percentages of eight activities per day (top-left), ADL per day (top-right), normal/abnormal activities per month (bottom-left), and difference between normal ADL and recognized ADL (bottom-right). The top two charts are generated base on activity recognition mentioned in Sect. 5.1. The chart of normal/abnormal activities per month summarizes the results of anomaly detection mentioned in Sect. 5.3. In order to observe whether the elderly activity changes violently or not, the bottom-right chart illustrates the difference between normal ADL and recognized ADL. The normal ADL is computed by averaging 7-day ADL prior to the observational day. Caregiver and family member are authorized to monitor the elderly health status by pressing the button of information of vital sign, which is shown in Fig. 11.

(a) (b)

Fig. 10. Interfaces of the elderly (a) activity status yesterday, and (b) activity of daily living (Color figure online)

Fig. 11. Interface of vital signs (Color figure online)

Those vital signs include body temperature, heart rate variability, and blood pressures (systolic and diastolic). We use green-, yellow-, and red- icons represent normal status, warning, and abnormal status, respectively.

System manager can remotely monitor sensors via user interface after pressing the button of device management on the main page. Figure 12 lists details of sensors deployed in the caring facility, including numbers of active sensors and inactive sensors, sensor type, sensor position, sensor status, interfacing type, and device manufacturers.

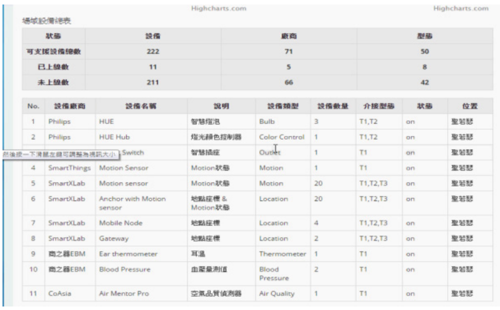


Fig. 12. Interface of device management

7 Conclusion

In this paper, we introduce the elderly care supervision system. The developed system is implemented based on sensor network, and it is verified in the long-term caring facility for dementia caring. Devices and equipments are deployed in the caring facility, which are connected to cyber layer via data management technology. According to the interview to caregivers, four major aspects are concerned in three scenarios for the elderly care. Therefore, activity analysis methods referred to the previous work are presented for detections of elders' activity statuses and anomaly. Finally, caregiver and family member can browse the elderly activities via the designed user interface. System managers can monitor connection status of sensors via the user interface as well.

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