Experiments and Applications of Support System for Caregivers with Optical Fiber Sensor and Cleaning Robot

Junko Ichikawa and Norihiko Shinomiya

Graduate School of Engineering
Soka University
Tokyo, Japan
Email: shinomi@ieee.org

Tetsuya Kon

Core System Japan Co., Ltd.,
Tokyo, Japan
Email: con@core-system.jp

***Abstract*—This research aims to propose a supporting system with sensor network technology and cleaning robots to alleviate workload of caregivers in welfare facilities. Our focus is to reduce the labor load of nurses that has increased with elderly population growth. On the basis of the system requirements clarified from a site survey in a nursing facility, this paper proposes an integration method of sensors that keeps monitoring situations in a facility and cleaning robots that can approach an incident location detected by the sensing system to confirm safety of facility residents.**

Keywords–monitoring system; sensor network; cleaning robot; nursing.

I. Introduction

Global society has encountered the serious problem of aging nowadays. Especially, the number of over 65 years old Japanese citizens has been monotonously rising since 1950 and accounted for more than 25% of its population in 2013 [1]. The demand for nursing home care has also been increasing in accordance with the growth of senior citizens.

In Japan, the number of facilities that support elderly people is over 25,000 sites, and *group homes* account for about 47% [2]. The group home is a facility where caregivers stay overnight and look after the elderly with senile dementia. In recent situation, each caregiver needs to take care of approximately 10 elderly people during nighttime because of the increase in facility residents. However, this situation is likely to be difficult for caregivers to give enough attention to accidents in a whole facility.

In order to solve the lack of nurses, video monitor systems in group homes have been developed. Caregivers can monitor elderly people behavior through cameras installed in living rooms, bathrooms and entrances 24 hours a day, every day of the year. However, such a monitoring system directly displays and records private behavior with image and sound. Thus, this invasive surveillance would make elderly people stressed [3].

On the other hand, the use of sensor network is conceived as a solution that can prevent such invasive surveillance. Sensor networks can indirectly retrieve environmental information by setting many sensor nodes. Nonetheless, sensor systems can faultily recognize a normal situation as an emergency because they only gather indirect information such as pressure. For instance, something falling on the floor can be regarded as a fall of an elderly person, and this incorrect report confuse caregivers. Thus, another technique is needed to confirm a reported situation by sensor networks.

Use of robots in the care field has attracted much attention. The Ministry of the Economy, Trade and Industry in Japan began *Robotic Care Equipment Development and Introduction Project* that aims at alleviating burden of caregivers in 2013. This project supports development of robotic care equipments for monitoring systems in nursing facilities. According to the Ministry, these systems need a robot which possesses data communication and sensing functions to notify an accident to the care takers [4]. Such a robot is expected to collect more detailed information, which cannot be detected only with wired sensor networks because it can move and conduct interactive safety confirmation process with facility residents.

Hence, this research proposes a Support System for Caregivers (SSC) with optical fiber sensors and a cleaning robot, which can monitor behavior of elderly people and notify caregivers of an emergency without violating their privacy. The goal of our system is confirmation of safety of an elderly person using optical fiber sensors and a consumer-electronics robot instead of image sensors such as a video camera. In addition, the system identifies the place where a facility resident falls down, and informs caregivers of the situation of the resident.

In Section II , some works of daily life monitoring system for the elderly are described. In Section III, some requirements are analyzed based on our hearing researches to caregivers. In addition, the overview of our support system for caregivers and system components are presented in Section IV. Furthermore, in Section V, the prototype system is tested, and we explain experiment results.

II. Related Work

In order to assist the elderly to safely spend their daily life, some monitoring systems have been proposed. For example, a homecare monitoring system is proposed by Bourennane et. al. [5]. The research suggests that the utilization of multi-sensor networks realizes behavior observance of an elderly person, who lives alone at home. Due to the observance, the proposed system provides the alert function in case of dangerous accidents. However, this research does not suppose the use of such a system in welfare facilities where many elderly people inhabit.

 ISBN: 978-1-61208-382-7

TABLE I. Data of visited nursing facility

Residents	100
Occupancy rate	100 %
Caretakers (day)	10
Caretakers (night)	5
Living quarters	two-story
Private rooms (quad)	14
Private rooms (double)	22

Another instance is a monitoring system in group homes [3]. The paper suggests a method to monitor facility residents with videos and install such equipments into the group homes. Nevertheless, the use of cameras is hesitated in terms of privacy problems. Moreover, such a camera system cannot be sited in bathrooms where accidents such as tumble frequently occur.

Both the proposed systems partly solves the problems in care of the elderly; however, a support system that considers the use in facilities where many incidents simultaneously happen and privacy issues is required. Thus, this paper proposed the support system, which is to find an abnormal behavior of residents in welfare facilities and prevent invading privacy of the elderly.

III. Support System for Caregiver

This section summarizes some requirements for SSC that gained from our hearing researches to caregivers. This section also discusses necessary elements for the systems based on the requirements.

A. Assumed Situation

In this research, welfare facilities which fulfills the following conditions is assumed to be the location where our system works. One of conditions is that the facility takes care of senior citizens all day and night. Additionally, a capacity of sickbed is comparatively large.

B. Factual caregivers' burden from site surveys

We interviewed caregivers who have been working at a nursing facility, and table I shows the overview information about the facility. Additionally, this facility has a sensor network system, which involves a pressure sensor and an infrared radiation sensor in the private room to detect the elderly falling down or moving away from the bed.

The survey indicates that welfare facilities using sensor networks face the following problems related to the increase of health care burden of caregivers. One of problems is false detection of sensors, and the other problem is that caregivers have a huge amount of work beside nursing. Whenever a false detection by sensors occurs, caregivers would feel both physical and mental burden because caregivers should confirm safety of residents by visiting a private room each time. Furthermore, we have identified that caregivers have a lot of work other than nursing such as cleaning, managing health information and planning the care. Furthermore, work during night is harder than one during daytime because a smaller number of caregivers are in the facility senior at night. The interviewees stated that they did not have enough time to take after each resident because of their workload.

C. System Requirement

From the above interview, this section clarifies some requirements for our system. First, the function to confirm false detection is needed because the confirmation process forces nurses to spend much extra time and confuses them. Another requirement is a function to reduce workload besides nursing. The interviewees listed cleaning, recording health information and scheduling care plans as their major extra work for them. In those three kinds of works, healthcare information systems developed by Fujitsu [6] and ND software [7] provide solutions to record health information and care planning. Thus, this research focuses on reduction of burden caused by cleaning.

IV. Prototype of SSC

This section presents details of system components, such as sensor device, network management, SSC manager and robot in our prototype system.

A. System Overview

Our system presupposes a situation that an elderly person suddenly would fall down on the floor, and caregivers might not become aware of the accident because they may work at a separated place distant from the point of the incident. Moreover, it is expected to reduce the burden of care such that caregivers have to keep their eye on elderly people all day long and get ready for rushing over to them whenever they need care.

This support system involves sensors embedded in a floor to detect the fall which can be identified by more than two sensors continuously retrieving pressure over certain time interval. Also, a robot with a touch sensor is required to confirm the safety of an elderly person. Figure 1 shows the system overview of support system for caregivers. An agent of Simple Network Management Protocol (SNMP) regularly observes the state of sensors and sends a trap ID to a manager in case of detecting the elderly falling down. The manager constantly retrieves the information and monitors a behavior of an elderly person. When the manager recognizes the fall, it specifies a route to the incident location and sends the commands for a robot to act on the routing information. After the robot moves toward the location and arrives at the goal, it generates a beep to check if the elderly person retains consciousness. The robot sends the state information to the manager according to the touch sensor pushed by the elderly in response to the beep. Then, the manager notifies caregivers about the abnormal situation.

B. Sensor Device

The system uses sensor technologies to detect the accident. Generally, wireless sensor networks are set to observe the motions such as falling [8]. A wireless sensor gathers a lot of information to distribute the sensor nodes among a wide area. However, wireless sensor networks need to supply an electric power to all sensor nodes. Therefore, sensors which do not need to be supplied power are suitable for our system.

One of the prospective sensors is the *hetero-core spliced optical fiber sensors*, and a structure of the sensor is shown

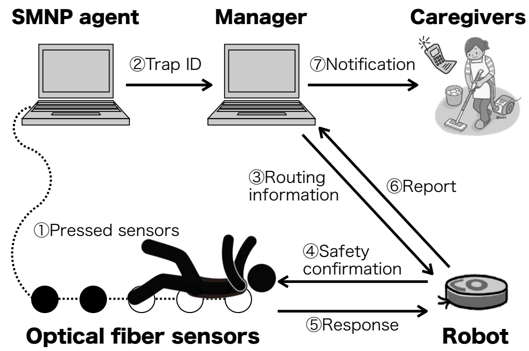

Figure 1. System component diagram.

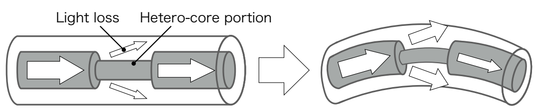

Figure 2. Structure of hetero-core spliced optical fiber sensor.

in Figure 2. It is composed of two single mode transmission fibers. One fiber is cut in two, and the other which has a smaller diameter is inserted between cut fibers. The spliced potion is called *hetero-core portion*. When the hetero-core portion is bent from outside by pressures, light waves leak into the cladding region. The hetero-core portion of an optical fiber sensor can work as a sensor by measuring the light leakage. Furthermore, plural hetero-core sensors are distinguished by changing light leakage of each of the sensors. We carried out an experiment in order to check whether the sensors were correctly distinguished. In this experiment, two sensors are pressed at a minute intervals, and a combination of sensor states is detected. The states were recognized by the difference in loss shown in Figure 3.

C. SSC Manager

An SSC manager fulfills two types of roles: detecting the state of sensors and routing for robot.

1) Detecting the State of Sensors by SNMP: One of the roles of SSC manager is to detect the state of sensors, which is realized by using Optical Sensory Nerve Network (OSN) with hetero-core spliced optical fiber sensors. OSN is a network that realized communication and sensing simultaneously, and it uses SNMP to manage sensor network equipments and distinguishes the sensor states by trap [9][10].

Figure 4 shows the component of sensor network management system. First, the media converter (A) generates light which went through sensors, and the media converter (B) receives the light. Then, an SNMP agent measures the optical loss and issues trap to an SNMP manager. The manager can detect the sensor pressed location to check the trap because the trap previously was set to a threshold voltage per each sensor. The SSC manager regularly analyzes the sensor information provided by an SNMP agent that observes state of each sensor and detects an emergency. If the SSC manager finds the situation, it calculates the route and sends the routing information to the robot.

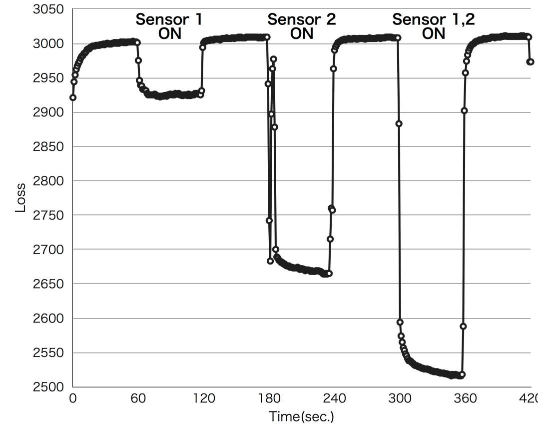

Figure 3. Identification of sensor states.

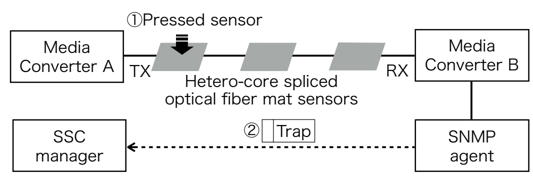

Figure 4. Sensor states detection by SNMP.

2) Routing of Robot: The SSC manager also has a routing function to give a route to a robot. In order to calculate the path, the manager generates a grid graph by Java Universal Network/Graph Framework (JUNG) as shown in Figure 6. This framework is an open source library for Java in order to analyze and visualize the structure of graphs. Furthermore, a shortest path algorithm that has been studied in the field of graph theory is adopted. The algorithm is a solution to obtain a path with the minimum weights from a given source vertex to a destination vertex in a graph consisting of vertices and edges. After the calculation, the manager creates and sends a set of command to robot in order to move it toward the destination.

D. Robot

The system uses a robot to confirm safety for the elderly in order to reduce misinformation of the sensor and to alleviate the labor load of caregivers. The following is the requirements for a robot that is suitable for our system.

First, an appearance of the robot does not offend a user, and any cameras are not attached on the robot. Furthermore, the robot can autonomously move or can be controlled remotely. In order to confirm safety, the robot has beep function and a touch sensor. Finally, it needs to be equipped with vacuum cleaner function.

As a robot which fulfills these requirements, a vacuum cleaning robot, such as Roomba [11] is likely to be selected. Recently, Roomba has penetrated in general households; thus, it is easily configured in our system. Roomba designed simply that does not threaten the elderly. Additionally, it can beep sounds as its alert, and a bumper is installed on ahead of the body, which is used as a button in our system. Besides, though it autonomously moves around rooms in it's cleaning mode, its

 ISBN: 978-1-61208-382-7

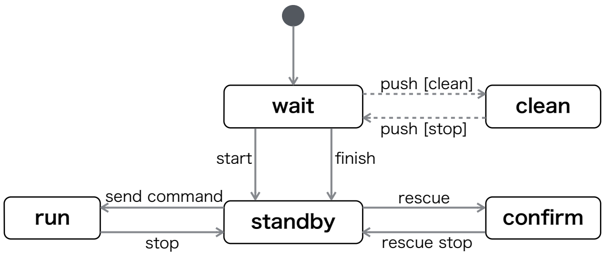

Figure 5. State diagram of Roomba.

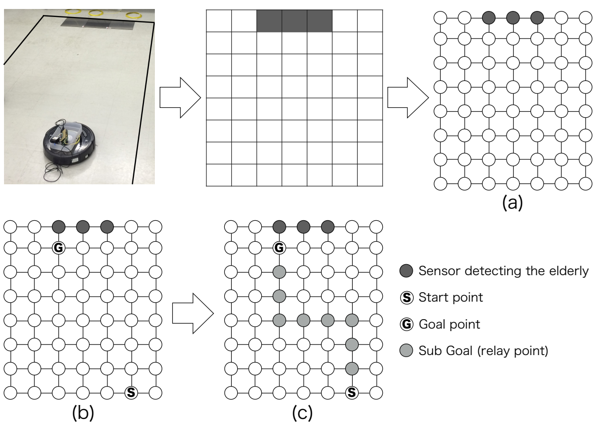

Figure 6. Generated logical map by manager.

movements are able to be controlled by programs from remote locations. Figure 5 shows the state diagram of Roomba in our supporting system.

V. Experiment Results

This section explains results of SSC trial experiment, examining the sensor management and robot control function. At first, points which the robot stops and changes direction on are shown as white node in Figure 6. In the experiment of robot control function, we use 3 mats that sensors are embedded in. When more than two adjacent sensors would respond, the manager could judge the exact place as the accident location which is shown as gray nodes in Figure 6(a). Then, the manager sets both the current place of the robot as a start point and one of the pressed sensors as a goal point as shown in Figure 6(b). Additionally, the manager calculates a path between the start and the end, and Figure 6(c) shows the relay points. Finally, the SSC manager sends the robot a set of commands on a path to a relay point, and the robot moves along the commands as shown in Figure 7.

VI. Conclusion and Future Work

This paper proposes a support system for caregivers, which uses an optical fiber sensor and a cleaning robot. This system aims to monitor the elderly without the use of video recording in order to prevent privacy invasion. The hetero-core fiber sensors and a vacuum cleaning robot enable our system to detect fall of an elderly person accurately. However, the experiment is not considered to lessen the gap between a calculated route and an actual moving route of a robot, which is a remaining issue of this study.

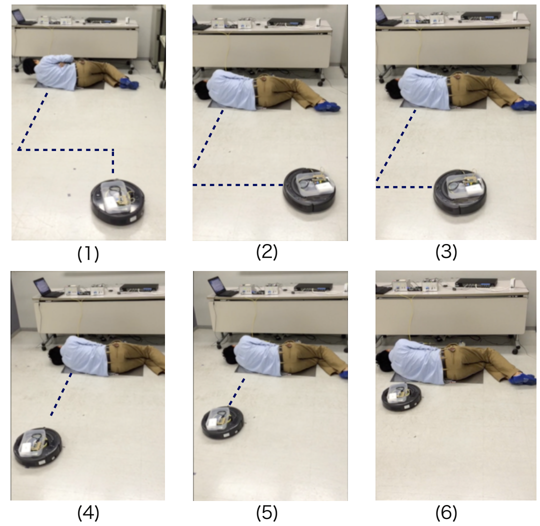

Figure 7. Routing control of Roomba.

References

[1] Cabinet Office, government of Japan. Statistics and analysis of population aging in japan in 2013. [retrieved: August, 2014]. http://www8.cao.go.jp/kourei/whitepaper/w-2014/zenbun/26pdf_index.html

[2] Ministry of Health, Labour and Welfare, government of Japan. Survey of number of elderly supporting facility in 2012. [retrieved: August, 2014]. http://www.mhlw.go.jp/toukei/list/24-22-2.html

[3] T. Sugihara, T. Fujinami, and R. Takatsuka, "An analysis of problems on development and installation of mimamori-care support camera system for persons with dementia in group home," Sociotechnica, vol. 7, 2010, pp. 54–65.

[4] Ministry of the Economy, Trade and Industry of Japan. Revision of the four priority areas to which robot technology is to be introduced in nursing care of the elderly. [retrieved: September, 2014]. http://www.meti.go.jp/english/press/2014/0203_02.html

[5] W. Bourennane, Y. Charlon, F. Bettahar, E. Campo, and D. Esteve, "Homecare monitoring system: A technical proposal for the safety of the elderly experimented in an alzheimer's care unit," IRBM, vol. 34, no. 2, 2013, pp. 92–100.

[6] FUJITSU. Hope wincare-v2. [retrieved: September, 2014]. http://jp.fujitsu.com/solutions/medical/products/archive/wincarev2/

[7] NDSoftware. Nursing care supporting software honobono next. [retrieved: September, 2014]. http://www.ndsoft.jp/next/kinou_kyotaku.html

[8] A. Stefano, A. Marco, C. Paolo, L. Janet, and V. Alessio, Monitoring of Human Movements for Fall Detection and Activities Recognition in Elderly Care Using Wireless Sensor Network: a Survey, 2010.

[9] L. S. Goh, K. Watanabe, and N. Shinomiya, "Feasibility evaluation of multi-point sensing for hetero-core spliced optical fiber sensor using internet-based protocol." IEEE ICST, Dec 2013, pp. 569–572.

[10] N. Abe, Y. Hanada, N. Shinomiya, and Y. Teshigawara, "A demonstration of sensing and data communication in optical sensory nerve network with hetero-core fiber optics sensors," IEICE Technical Report. USN, vol. 107, no. 294, Oct 2007, pp. 67–71. http://ci.nii.ac.jp/naid/110006453275/

[11] iRobot. Roomba. [retrieved: June, 2014]. http://www.irobot-jp.com