Support System for Caregivers with Optical Fiber Sensor and Cleaning Robot

Junko Ichikawa, Tetsuya Kon, Kazuhiro Watanabe and Norihiko Shinomiya
Dept. Information Systems Science
Soka University
Tokyo, Japan
shinomi@soka.ac.jp

***Abstract*—Population aging is one of the serious issues in developed nations. Because of the increase in the number of senior citizens, the demand for care of them has been enhanced. Consequently, some facilities such as group homes are provided in order to support their life. However, shortage of caregivers in group homes provides lack of attentions to situations or accidents of the elderly. Therefore, this research aims to propose a supporting system with sensor network technology and robots for caregivers in such facilities that can reduce workload of nurses and assure safety of facility residents.**

Keyword—monitoring system; sensor network; robot; nursing.

I. Introduction

Society is aging globally, and the number of the elderly dramatically is increasing especially in developed countries. Japan also encounters this serious problem. The rate of aging of Japan, which is defined as the percentage of the population of over 65 years old has monotonously been rising since 1950 and exceeded 24% in 2012 [1]. Furthermore, it is expected to exceed 30% in 2025. Following the increase in the number of elderly residents, some social problems have emerged such as insurance structure issues and health problems. Because many of them suffer from physical issues, the demand for health caret enhances.

In Japan, the number of facilities that support elderly people is over 25,000 sites [2], and *group homes* account for 47% of these facilities. A group home is a facility where caregivers stay overnight and nurse the elderly with senile dementia. In these facilities, one caregiver is usually required to take care of approximately 10 elderly people during night time. In this situation, caregivers are possibly not aware of accidents of the elderly. For example, falling from a bed and wandering aimlessly in a facility might not be found, and elderly people can be fatally injured.

In order to solve the problem, the video monitor systems in group homes have been developed [3]. Caregivers can monitor elderly people behaviours through cameras which are installed in living rooms, bathrooms and entrances in group homes 24 hours of day. However, such monitoring systems directly display private behaviours with images and sounds. Thus, it may make elderly people stressed because of invasive surveillance.

Using sensor network is conceived as a solution for prevention of the invasive surveillance. Sensor networks can indirectly retrieve environmental information and situations by setting many sensor nodes. An advantage of sensor networks in the fact that they detect the information without use of videos. Nonetheless, detection of abnormal behaviours with sensors can be a misjudged recognition. For instance, something falling on the floor can be regarded as a fall of an elderly person, and this incorrect reports confused caregivers. Thus, another technique is needed in order to confirm a reported situation by sensor networks. Robots that function autonomously are expected to collect more detailed information, which cannot be found only with wired sensor networks because they can move to the incident location and conduct interactive confirmation processes using sounds.

Hence, this research proposes a Support System for Caregivers (SSC) with optical fiber sensors and a cleaning robot, which monitors behaviours for elderly people and notices the caregiver about an abnormal behaviour. Section III 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. Furthermore, section IV describes the design and utilized technologies in our prototype system. Finally, the progress of development and the results of preliminary experiments are demonstrated in sectionV.

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. [4]. The research suggests that the utilization of multi-sensor networks realizes behaviour 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.

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 behaviour of

 ISBN: 978-1-61208-319-3

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

Our system presupposes the situation that elderly person suddenly fall down on the floor, and caregivers does not become aware of the accident. This system aims at the goal which are to detect a fall quickly and to confirm safety for elderly person without cameras by using sensors and robots. In addition, the system informs caregivers about the place where the elderly fells down and the information of safety confirmation. Thus, the system supports caregivers to notice accidents that are not aware so far. Moreover, it is expected to reduce the load of care because even though caregivers do not watch the elderly people carefully all of the day, they were able to know when the elderly person needs care.

B. System Overview

In this system, sensors embedded in a floor are used to detect fall. A situation of fall is acknowledged by that more than two sensors continue to simultaneously retrieve pressure over certain time interval. Furthermore, a robot with touch sensor is used to confirm safety of elderly person.

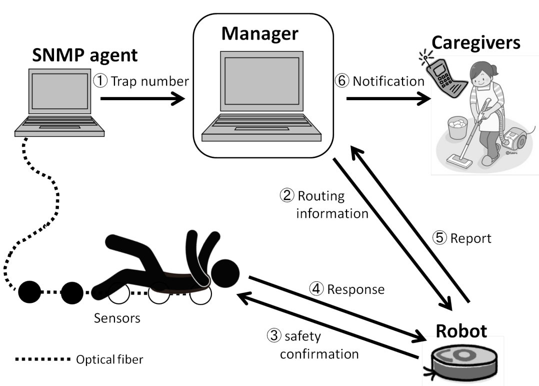

Fig. 1. System component diagram

The system overview of support system for caregivers is shown in Figure 1. An agent of Simple Network Management Protocol (SNMP) regularly observes the state of sensors and sends trap number to a manager. The manager retrieves the information and monitors a behaviour of an elderly person. When the manager recognizes the fall, it calculates a route to the incident location for a robot. The manager sends the route to a robot, and the robot moves toward the location following the route. After the robot arrives the location, it beeps in order to check whether or not the elderly person is unconscious. If the elderly does not push the touch sensor as the response to the beep, a robot reports on the state of the elderly to the manager. Then, the manager notifies caregivers about the abnormal situation.

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. Sensor Device

The system uses sensor technologies to detect the accident. Generally, wireless sensor networks are set to observe the motion such as falling [5]. A wireless sensor gathers a lot of information to distribute the sensor nodes among a wide area. However, wireless sensor networks demand to supply an electric power to all sensor nodes.

To solve this issue, the *hetero-core spliced optical fiber sensors* have been developed. The fiber sensor does not need to be supplied power, and furthermore, the sensor can work as not only sensing device but also communications links [6].

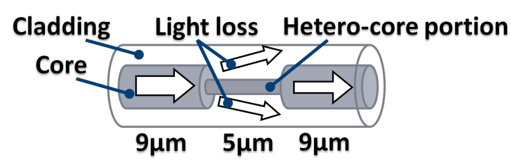

Fig. 2. Structure of hetero-core spliced optical fiber sensor

A structure of a hetero-core spliced optical fiber sensor is shown in Figure 2. It is composed of two single mode transmission fibers. One fiber has 9 μm core diameter, the other is 5 μm diameter. A few millimeters of 5 μm core diameter fiber is inserted into 9 μm core diameter fiber segmented into some parts. The part where the 5 μm core fiber is inserted 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 spliced optical fiber sensor can work as sensor by measuring the light leakage. By utilization of the sensor, the smart pressure sensing mats to monitor human activities can be developed. The mats detect motions of walking and tumbling by surveillance of the change of an optical signal attenuation [7].

B. Sensor Network Management

Optical Sensory Nerve Network (OSN) with hetero-core spliced optical fiber sensors is a network that realizes communication and sensing simultaneously [8]. The OSN uses SNMP to manage sensor network equipments and distinguishes the sensor states by trap [9].

Figure 3 shows the structure of the binary switch sensor. The switch sensors are one of the hetero-core spliced optical fiber sensor module, and one hetero-core portion is inserted in the sensor. When the button is pressed, the curvature of hetero-core portion changes, and the sensor is given the optical loss. Figure 4 shows the component of sensor network management system. First, the media converter (A) converts from voltage

Copyright (c) IARIA, 2014. ISBN: 978-1-61208-319-3

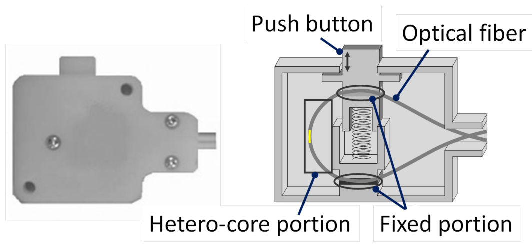

Fig. 3. Binary switch sensor module

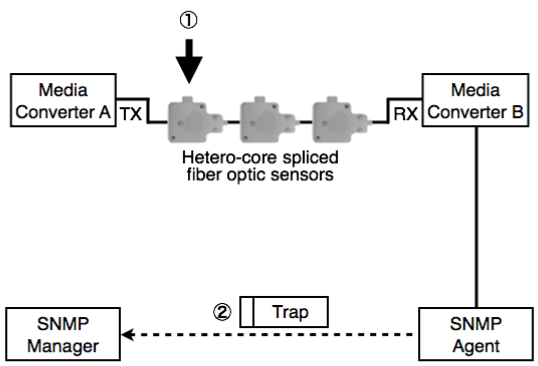

Fig. 4. Sensor states detection by SNMP

to light signal, and it sends the signal. Next, the signal went through the sensors to the media converter (B), and it is converted to voltage. When the binary sensors are pressed, the optical loss is occurred. An SNMP agent measures the optical loss and issues trap to an SNMP manager. The trap previously was set to a threshold voltage per each sensor. Thus, the manager can detect the sensor pressed location to check the trap.

C. SSC Manager

An SSC manager fulfills two types of roles: detecting the state of sensors and routing for robot. As a sensor manager, it handles sensor information; additionally, it calculates a route for guiding a robot with its routing function.

1) Detecting the State of Sensors: The manager regularly analyzes the sensor information provided by an SNMP agent that observes state of each sensor and detects an abnormal situation. The abnormal situation is defined as the state which is more than two sensors continue to simultaneously retrieve pressure over the time interval, which is set 5 seconds. If the manager finds the situation, it sends routing information to robot.

2) Routing for Robot: The manager also has a routing function to give a route to a robot. In the routing process, the manager adopts a shortest path algorithm that has been studied in the field of graph theory. A shortest path 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.

First, the manager makes a map which represents the layout of a facility and obstacles, such as furniture, walls and doors. On the map, it marks possible turning points for a robot and two specific location points. One of the location points describes the position where an elderly person falls down, and the other is the present location of the robot. The manager regards these points as vertices and calculates the shortest path from the current location to the incident location which passes though the turning points based on the Dijkstra's algorithm [10].

After a robot receives the routing information from the manager, it moves along the given shortest path. However, the robot does not move precisely on the given path because the tires of the robot may slip on floor. Thus, the route given to a robot needs to be revised.

The revision of the route is conducted by certain time intervals. When the gap between the present location detected by sensors and the given path exceeds a certain distance, the manager provides the robot a route to return from the current location to the closest turning point on the given path. When the robot returns on the given track, it resumes moving along the path.

D. Robot

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

- Appearance of the robot does not offend a user.
- Any cameras are not attached on the robot.
- The robot can autonomously move.
- The movement can be controlled remotely.
- In order to confirm safety, a robot has beep function and a bumper.

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 its cleaning mode, its movements are able to be controlled by programs from remote locations.

The following describes the behaviour of confirming safety by Roomba. Roomba that is provided the routing information by the manager shifts to the location where a elderly person falling down. After Roomba arrives the location, in order to check whether the elderly has consciousness, it beeps a sound during certain time. The manager observes the reaction from the elderly person to the beeps. When the bumper on the Roomba body is pushed within the certain time, the manager judges that the person is conscious. In contrast, when the bumper is not pushed, the person is judged as unconscious by the manager.

V. Experiment Results

This section explains results of SSC trial experiment, examining the sensor management and robot control function. SSC

 ISBN: 978-1-61208-319-3

is developed by Java Universal Network/Graph Framework (JUNG). This framework is an open source library for Java in order to analyze and visualize the structure of graphs. The library contains many algorithms in graph theory such as a shortest path algorithm.

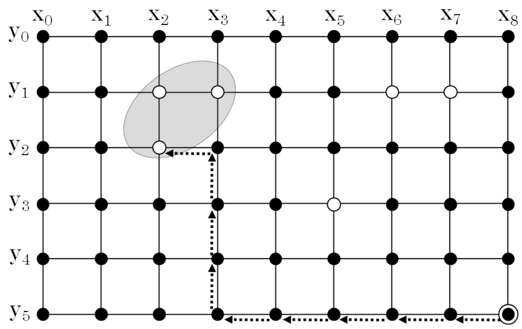

Fig. 5. Logical map and robot path calculated by manager

TABLE I
SEPARATED COMMANDS FOR A ROBOT IN A MANAGER

Order	Command
1	Go Straight 30cm
2	Go Straight 30cm
3	Go Straight 30cm
4	Go Straight 30cm
5	Go Straight 30cm
6	90 right spin
7	Go Straight 30cm
8	Go Straight 30cm
9	90 left spin
10	Go Straight 30cm

In this experiment, 54 sensors are embedded in a floor at intervals of 30cm. At first, manager recognizes connection relationship of the sensors and model it with a graph as shown in Figure 5. When arbitrary sensors are pressed, the manager detects the change of the sensor states. The pressed sensors are shown as white nodes in Figure 5. When more than two sensors are adjacent each other, the manager judges the place as the accident location where an elderly person falls down. In Figure 5, adjacent sensors (x_2, y_1), (x_5, y_3) and (x_6, y_1) are pressed, so the manager set the place of the sensors as an incident location. Then, the manager recognizes the present place of robot (x_8, y_5). Furthermore, the manager calculates the shortest path between the place of the robot and one of the sensors. The path calculated by the manager is indicated as arrows of broken line. Finally, the manager generates routing information as a set of commands to send the robot. Table I describes the set of commands, which corresponds to the shortest path in Figure 5.

VI. CONCLUSION AND FUTURE WORK

In summary, this paper proposes a support system for caregiver, which uses a optical fiber sensor and cleaning robot. This system aims to monitor the elderly without the use of video recording in order to prevent privacy invasion. By using the hetero-core optical fiber sensor network and a vacuum cleaning robot, the network realizes detection of tumble of a elderly person and confirmation of the detection. First, some requirements to realize the assumed system are summarized, and the system overview and components are also mentioned. Furthermore, the concrete technologies such as hetero-core fiber sensors and Roomba that suits for our system requirements are introduced, and the prototype system consisting of the equipments is described. In addition, two types of roles of an SSC manager, which are the sensor management system and robot control function are shown, and an experiment results of these functions are presented. However, the experiment is not considered an initial direction of the robot. Furthermore, to decrease the gap between an distance calculated and a distance moved robot also remains an issue as future works.

REFERENCES

[1] Cabinet Office, government of Japan, “Statistics and analysis of population aging in Japan in 2012.” [Online]. Available: http://www.cao.go.jp/index-e.html [retrieved: Oct, 2013]
[2] Ministry of Health, Labour and Welfare, government of Japan, “Survey of number of elderly supporting facility in 2012.” [Online]. Available: http://www.mhlw.go.jp/ [retrieved: Sep, 2013]
[3] S. Taro, F. Tsutomu and T. ryozo , “An analysis of Problems on Developmenr and Installation of Mimamori-care support Camera System for Persons with Dementia in Group Home” in *Sociotechnica*, 7, pp. 54-65, Mar. 2010.
[4] 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,” in *IRBM*, 34, pp. 92-100, Apr. 2013.
[5] Abbate, S., Avvenuti, M., Corsini, P., Light, J. and Vecchio, A, “Monitoring of human movements for fall detection and activities recognition in elderly care using Wireless sensor network: a survey” in *InTech*, pp. 2688-2710, Oct, 2010.
[6] K. Watanabe, K. Tajima and Y. Kubota, “Macrobending Characteristics of a Hetero-Core Splice Fiber Optic Sensor for Displacement and Liquid Detection,” in *IEICE Trans. Electron.*, Vol. E83-C, No.3, pp. 309-314, Mar. 2000.
[7] M. Nishiyama, H. Sasaki, S. Nose, K. Takami, and K. Watanabe, “Smart Pressure Sensing Mats with Embedded Hetero-Core Fiber Optic Nerve Sensors,” in *Materials and Manufacturing Processes*, Vol. 25, pp. 264-267, Apr. 2000.
[8] 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,” in *IEICE Technical Report*, Vol. 107, pp. 67-71, Oct. 2007.
[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,” in *Proceedings of the 2013 Seventh International Conference on Sensing Technology*, pp. 569-572, Dec, 2013.
[10] Dijkstra, E.W. “A note on two problems in connexion with graphs,” in *In Numerische Mathematik*, 1, pp. 269-271, 1959.
[11] iRobot “Roomba” [Online]. Available: http://www.irobot-jp.com/index.html [retrieved: Sep, 2013]

 ISBN: 978-1-61208-319-3