Dementia Sign Detection System using SNS Agency Robot, Ultra-small Sensor, and Wearable Device

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***Abstract*— In dementia diagnosis, it is important to determine whether there is cognitive decline and impairment of life functions. In this study, we propose a dementia sign detection system that can detect cognitive function disorders and life function disorders by linking the SNS agency robot with ultra-small sensors inside and outside an elderly person's home and a wearable device (e.g., a smartphone) that can capture the elderly's behaviors outside the house. In this paper, we present the results of a verification experiment conducted to verify the feasibility of this system.**

Keywords*— *dementia, SNS agency robot, ultra-small sensor, wearable device

I. Introduction

In Japan, in the elderly population (aged >65 years), the proportion of people living alone has increased year after year. The ratio was 4.3% for men and 11.2% for women in 1980 and increased to 13.3% for men and 21.1% for women in 2015. It is expected that the ratio will continue to increase to 20.8% for men and 24.5% for women by 2040 [1]. Elderly people who live alone are more likely to stay at home and have limited contact with society; therefore, there is a risk that dementia may progress unknowingly.

According to a study by Sado et al. at Keio University, the cost of medical and long-term care for people with dementia was 14,500 billion JPY in 2014, which is expected to grow to 24.3 trillion JPY in 2060. Recently, drugs that can delay the progression of dementia have been developed, and it is possible to prolong the healthy period by beginning to use such drugs in the early stages of dementia. Therefore, early detection of signs and prevention of dementia in elderly that live alone can lead to much longer life expectancies, which would significantly reduce burden on society.

In dementia diagnosis, it is important to determine whether there is cognitive decline and impairment of life functions. It is extremely difficult to distinguish between early Alzheimer's disease and forgetfulness associated with aging; however, it is critically important to distinguish these phenomena accurately. To diagnose dementia, it is important to evaluate both cognitive function disorder and life function disorder. Conventionally, these evaluations are performed using a screening test, e.g., the Dementia Assessment Sheet for Community-based Integrated Care System-21 items (DASC-21) [2], where a doctor with specialized knowledge interviews relatives and caregivers about the daily lives of the elderly. However, this incurs significant demands on doctors, relatives, and caregivers. Doctors must consider time costs and physical and mental burdens of moving, asking, scoring, and providing feedback to the elderly. In addition, if the elderly person is living alone and it is difficult for the doctor to conduct a question-based interview with close relatives or caregivers, the elderly patient will be physically and mentally burdened by having to go to the doctor for the interviews. Therefore, especially if an elderly person lives alone, dementia can progress unknowingly, and the patient may miss opportunities to receive hearings.

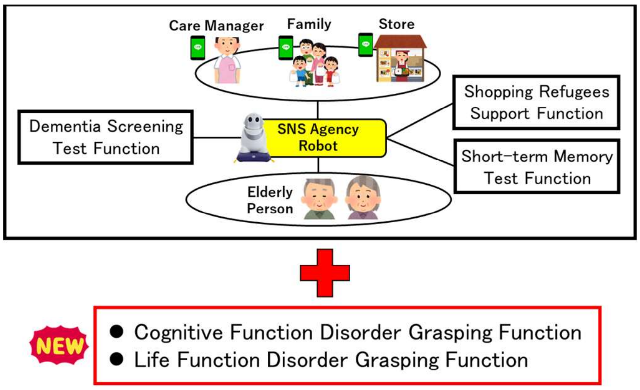

Fig. 1. SNS agency robot and extension

We have developed an Social Networking Service (SNS) agency robot for elderly people who cannot use a smartphone but wishes to communicate with close relatives remotely (Fig.1) [3]. In addition, we have developed a dementia screening system by implementing a revised Hasegawa simplified intelligence evaluation scale (HDS-R) [4], which is clinically highly reliable and widely used in Japan as an SNS agency robot [5]. However, with this system, the robot only asks the elderly person nine specific questions; thus, it cannot be used on a daily basis, and the elderly may become excessively sensitive to the dementia test. Therefore, we have developed a system to detect signs of dementia by focusing on events that occur in daily life [6]. Using various events (e.g., birthday) in the daily life of the elderly as triggers, the robot asks the elderly questions that are directly related to a specific event; thus, the robot only asks natural questions. On the other hand, we have developed a shopping

TABLE I. CORRESPONDENCE BETWEEN EVALUATION ITEMS AND DEVELOPED SYSTEM

Classification	Evaluation item	(1)	(2)	(3)	(4)
Instrumental ADL	Did you take the medicine?	○			
	Did you clean up after eating?	○			
	Can you go to the exact (inspection) location exactly as you were told (or by looking at the map)?			○	
	Number and time leaving the room	○			
	Number and time dumping garbage in the trash	○			
	Number and time the TV was turned on and off		○		
	Number and time opening and closing the curtain	○			
Basic ADL	Number and time going to the toilet	○			
	Did you take a bath?	○			
Recent memory	What is your meal menu?	○			
	What is today's inspection?	○			
	Confirmation of hospitalization date or discharge date	○			
Activity amount	Time spent in bed and number of times you got out of bed	○			
	Time spent on the sofa and number of times you sat on the sofa	○			
	Number of steps, walking speed, length of one step, range of activity, number of falls/stumbling			○	
	Conversation time, number of times, voice volume				○

refugee support system by implementing a shopping support function on the SNS agency robot, which enables the elderly to place an order with a store by simply talking to the robot [7]. In this system, using the order history as triggers, the robot can ask the elderly questions related to their order history in a natural manner.

The developed system can detect signs of dementia without causing discomfort to the elderly. In addition, the signs of dementia can be detected by simply installing a robot in the elderly person's home; thus, we can reduce the physical and mental burdens because they do not need go to the doctor to conduct interviews. In addition, this system can automatically perform a series of hearing, recording responses, and scoring, which had previously been performed by doctors; therefore, we can reduce the doctor's time costs and physical/mental burdens.

However, the developed dementia sign detection system only focuses on cognitive function disorder, and it is impossible to grasp the life function disorder, which causes cognitive deficits that prevent self-reliance in daily activities. Therefore, in this study, we propose a dementia sign detection system that can detect cognitive function disorders and life function disorders by linking the SNS agency robot with ultra-small sensors inside and outside an elderly person's home and a wearable device (e.g., a smartphone) that can capture the elderly's behaviors outside the house. In this paper, we present the results of a verification experiment conducted to verify the feasibility of this system.

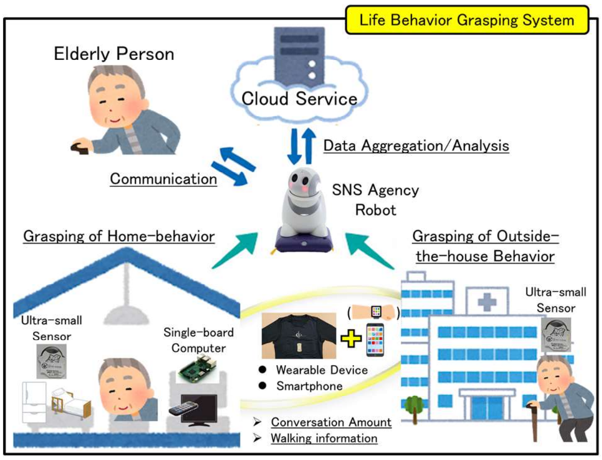

Fig. 2. Overall system process

II. RELATED WORK

To verify the feasibility of dementia diagnosis support by the communication robot, the NTT Data Kansai analyzes the difference between the conversation log result using the communication robot and a doctor's diagnosis result, and examines the effect of the dementia diagnosis support by the communication robot [8]. However, with this system, the test is performed in a dedicated room, which causes the patient to be acutely aware of the dementia test, which incurs physical and psychological burdens. In addition, this system cannot grasp the state of the elderly outside the home. With our system, it is possible to grasp the behaviors outside the home; thus, the comprehensive living behaviors of the elderly can be understood both inside and outside the home.

III. LIFE BEHAVIOR GRASPING SYSTEM USING SNS AGENCY ROBOT, ULTRA-SMALL SENSOR, AND WEARABLE DEVICE

First, in reference to DASC-21 [2], which can be used to quickly evaluate cognitive function and life function disorders, we examined the evaluation items to grasp both cognitive function and life function disorders using a robot. The study was carried out in cooperation with Professor Tsujino of the Department of Neurology, University Hospital Nagasaki. Table I shows the study results. Each item can be roughly classified into instrumental activities of daily living (ADL), basic ADL, recent memory, and activity amount.

Next, we developed a system that can evaluate each item of instrumental ADL, basic ADL, recent memory, and amount of activity (Table I). Here we used a PaPeRo i (a built-in single-board computer) by NEC Corp. as the communication robot [9]. Fig.2 shows the overall process of this system. Fig.3 shows the configuration of this system. Note that items (1) to (4) in Table I correspond to the following systems.

(1) A home-behavior and cognitive function grasping system using an SNS agency robot and an ultra-small sensor.

(2) A TV remote control signal analysis system.

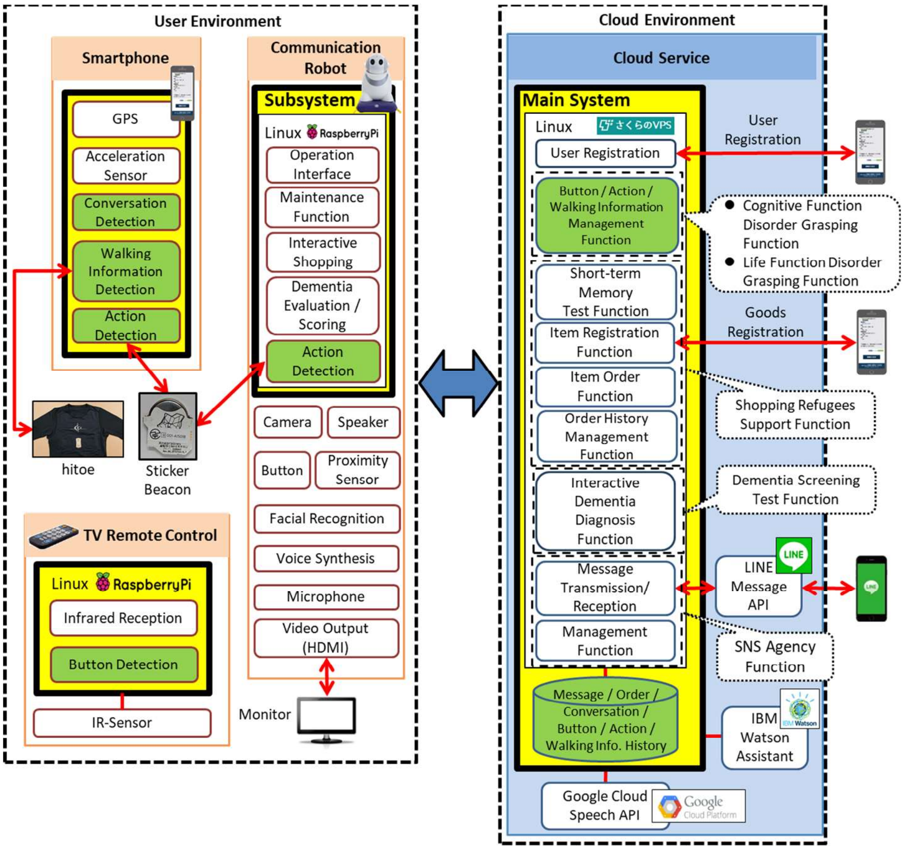

Fig. 3. System configuration

(3) An outside-the-house behavior grasping system using an ultra-small sensor and a wearable device.

(4) A conversation amount measurement system.

Systems (1) to (4) are described in greater detail as follows.

A. Home-behavior and cognitive function grasping system using SNS agency robot and ultra-small sensor

We developed a system to capture the behavior of elderly people at home, e.g., how often they go to the toilet and use garbage disposal facilities, using an ultra-small sensor. In addition, the SNS agency robot asks questions that are triggered by the activities of the elderly. In addition, the robot recognizes and memorizes the answers. Specifically, using ultra-small (coin-size) sensors (Estimote Sticker Beacon [10]) (Fig.4) equipped with an acceleration sensor and Bluetooth communication (Bluetooth Low Energy) to home appliances, furniture, etc., we developed an SNS agency robot system to detect various situations in the home, e.g., opening the refrigerator at dinner time, and asks questions and remembering responses about the identified situation, e.g., what the elder person wants eat for dinner. By attaching this sensor to the trash box or bathroom door, it is possible to identify the number of times garbage was discarded or the number of times the bathroom was used. Note that most of the evaluation items listed in Table I can be examined with this system.

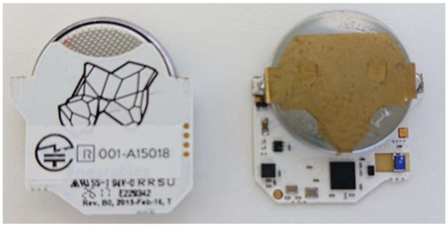

Fig. 4. Ultra-small sensor (Estimote Sticker Beacon [10])

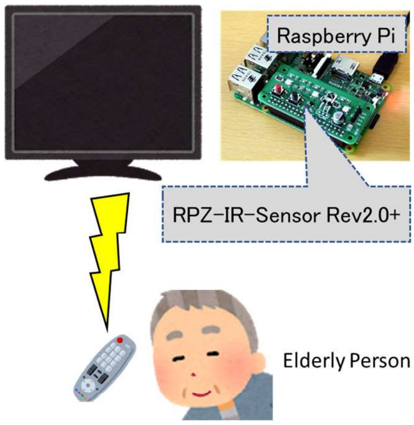

Fig. 5. Overview of TV remote control signal analysis system

Fig. 6. Wearable device (hitoe [11])

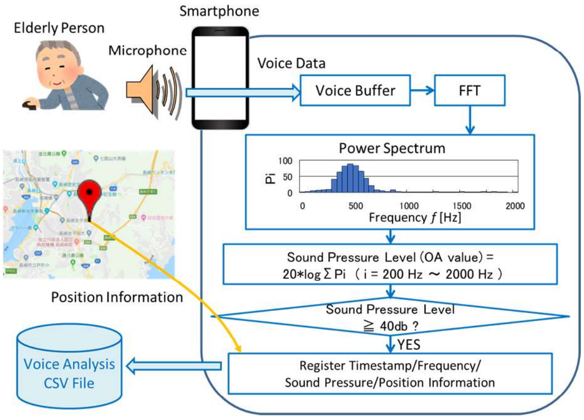

Fig. 7. Overview of conversation amount measurement system

B. TV remote control signal analysis system

We developed a TV channel monitor that receives and analyzes the infrared signal of a TV remote control system using a Raspberry Pi 3 Model B and an RPZ-IR-Sensor Rev2.0+ expansion board, which has an infrared transmission/reception function (Fig.5). With this system, it is possible to identify the "number and time the TV was turned on and off," which is one of the evaluation items of the instrumental ADL.

C. Outside-the-house behavior grasping system using ultra-small sensor and wearable device

Using an ultra-small sensor and wearable device (e.g., a smartphone), we developed a system that understand the elderly person's behaviors outside the house by collecting their movement information outside the house and an ultra-small sensor installed outside the house. Walking information, e.g., the number of steps and walking speed, is collected using hitoe [11] (Fig.6), which is a wearable device that can measure heart rate and the like. In addition, this system can grasp in-house behaviors by linking the smart sensor installed in the house with the smartphone. The behavior in the home is primarily detected by system (1); however, behaviors in the house can also be grasped by this system; thus, it can be used as a backup for system (1).

D. Conversation amount measurement system

We developed a system to determine whether the elderly person is talking. This system (an Android application) measures the amount of speech by analyzing the frequency spectrum of the speech acquired from the microphone in a smartphone using discrete Fourier transform (Fig.7). With this system, it is possible to grasp the "conversation time, number of times, and voice volume," which is one of the activity amount evaluation items.

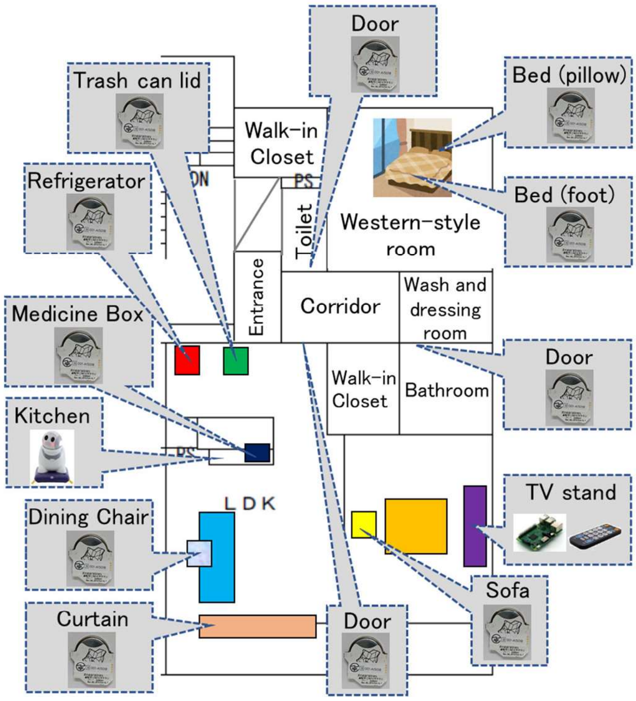

Fig. 8. Installation of sensors in university staff housing

IV. Evaluation Experiment

To evaluate our prototype system, we conducted a demonstration experiment by placing PaPeRo i (the built-in Raspberry Pi 3 Model B) and 13 ultra-small sensors in a room in a university's staff housing facilities and campus. We installed 11 ultra-small sensors in the university staff housing (Fig.8). On campus, we installed ultra-small sensors (one each) on the doors of staff rooms and student labs.

- Experimental conditions

Participant:

Nagasaki University staff (Male, 50s)

Test site:

Nagasaki University staff housing and university campus

Test period:

From December 18, 2019, to December 22, 2019

For the evaluation method, we conducted an initial study to determine whether we could obtain the expected behavioral

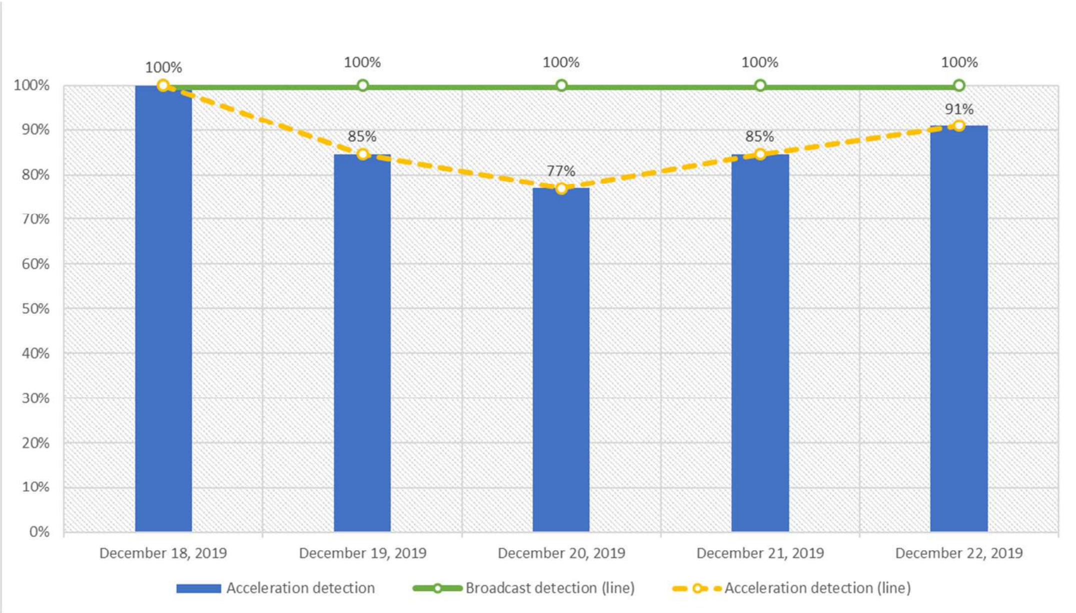

Fig. 9. Change of sensor detection rate

information inside and outside the house. Fig.9 shows the sensor detection and acceleration detection results obtained during the experimental period. Over the experimental period, the sensor achieved a broadcast detection rate of 100%. The detection rate of the acceleration sensor was 87.3% on average. All acceleration sensors on the university campus were detected; however, some of the acceleration sensors in the university staff housing facilities were not detected due to a problem with the position of the sensors under a bed. Therefore, although some behavior information was obtained, it is necessary to examine sensor position where in greater detail. We are currently examining whether the evaluation items in Table I can be quantified from the obtained information.

V. CONCLUSION

In this paper, we have described a system that links an SNS agency robot with ultra-small sensors inside and outside an elderly person's home and a wearable device to sense the elderly person's behavior outside the house. We also proposed a dementia sign detection system that can detect cognitive function disorders and life function disorders. In addition, a verification experiment was conducted to verify the feasibility of the proposed system. In future, we plan to investigate whether appropriate evaluation items (Table I) can be quantified from the information obtained by the proposed system.

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