Development of a robot partner system to support the elderly based on sensor data

Kohei Yamamoto
Graduate school of System Design
Tokyo metropolitan University
6-6 Asahigaoka, Hino, Tokyo, 191-0065 Japan
yamamoto-kouhei4@ed.tmu.ac.jp

Shuai Shao
Graduate school of System Design
Tokyo metropolitan University
6-6 Asahigaoka, Hino, Tokyo, 191-0065 Japan
shao-shuai1@ed.tmu.ac.jp

Naoyuki Kubota
Graduate school of System Design
Tokyo metropolitan University
6-6 Asahigaoka, Hino, Tokyo, 191-0065 Japan
kubota@tmu.ac.jp

Abstract— In recent years, the number of elderlies living alone has been increasing year by year due to the declining birthrate and aging problem, which has become a major problem especially in developed countries. There is a great demand for health support systems and monitoring systems using sensors to support the elderly in such situations. In this paper, we propose a robot partner system that can communicate based on sensor data in such a situation.

Keywords—robot partner, information structured space, elderly support

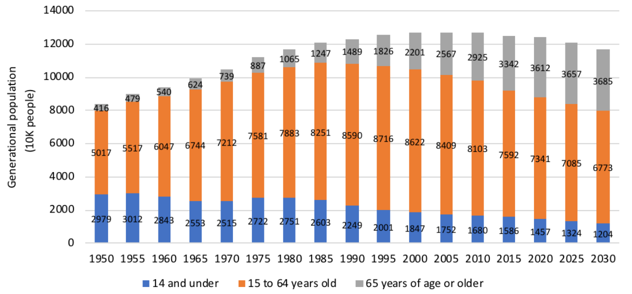

Figure 1 Population transition to the present and future forecast

I. INTRODUCTION

In recent years, the birthrate and aging population have become a major social problem in developed countries. Especially in Japan, the impact of the aging of the birthrate is remarkable, and it can be said that it is a more serious problem than in other developed countries. In response to this, various measures have been taken against the aging of the birthrate, but reports that the trend described above will continue to worsen are reported by the Ministry of Internal Affairs and Communications, etc.（Figure 1[1]）.

Under the influence of the declining birthrate and aging population, the number of residents living in medical institutions and welfare facilities, and the number of elderlies living alone living away from their families are expected to continue to increase. Due to the diversification of occupations, the shortage of human resources in medical institutions, and especially in occupations related to nursing care and welfare, is increasing. [2][3].

In particular, the increase in the elderly living alone has become a serious problem, and the accompanying increase in lonely death is also a major problem. In recent years, attention has been paid to the introduction of robot partners as a measure against lonely death. It is expected that the quality-of-life (QOL) of the elderly can be improved by communication systems and health support systems using robot partners. Many systems for health support have already been introduced, but more efficient health maintenance can be achieved by robot partners. In addition, it is expected that the elderly can avoid the trouble of using the system. Furthermore, for elderly people living alone who tend to have few opportunities for communication, talking with a robot on a daily basis leads to maintaining and improving communication skills. In fact, research and development using robot partners has been conducted to stimulate the communication skills of the elderly [4].

Against this background, this study deals with a system in which a robot partner can speak based on data obtained from various sensors installed in the living space of an elderly person living alone. This paper describes a robot system that uses a pneumatic sensor that can be installed on a bed as a sensor to monitor during sleep and talk about sleep. This paper is organized as follows. Chapter 2 describes related works. Chapter 3 describes the details of robot partners and sensors. Chapter 4 describes the details of the system and the results of the experiments performed. Chapter 5 presents a Conclusion and future work.

II. RELATED WORKS

Research on sensing and robot partners for monitoring elderly people is actively being conducted. The concept of information structured space has been proposed as a study on sensing for robot partners [5-6]. Figure 2 shows a conceptual diagram of the information structured space. It collects, transfers, and manages data from sensors placed in advance in the environment where the robot is used via a network. This makes it possible to interact between the robot and spatial knowledge. In the information structured space, data from sensors installed in the environment is stored in a database in

978-1-7281-6932-3/20/$31.00 ©2020 IEEE

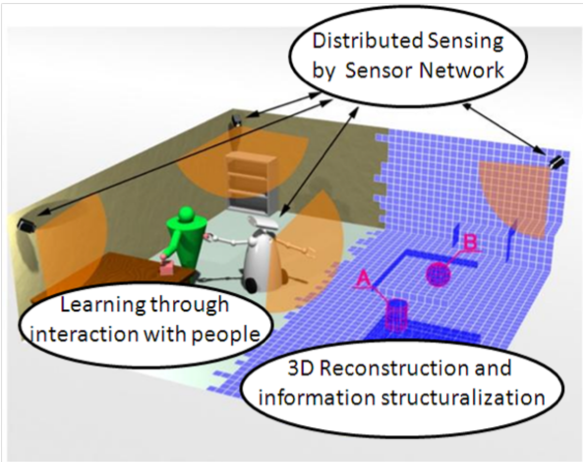

Figure 2 Conceptual diagram of the information structured space

a format that can be used by robots. As a result, even if sufficient information cannot be obtained only by the sensors built into the robot, by providing necessary information from the information structured space side, it is possible to provide a wider and higher quality service by the robot. To achieve the purpose of the information structured space, the following four properties are considered.

① Information sharing
The information in the database can be used regardless of the specifications of sensors and robots. Easy connection / disconnection with the information structured space

② Affinity with humans
Each sensor does not transfer the collected data directly to the information structured space, but converts it to a format that can be understood by humans before transferring

③ Reversibility of conversion
The information collected in the information structured space allows each sensor to perform inverse transformation according to each characteristic

④ System versatility
The subsystem using the information structured space can repeatedly add and delete various packaged modules according to the purpose.

A study similar to information structured space is Smart Home. Smart Home also makes it possible to estimate human behavior from data from various sensors embedded in the living space, monitor and record daily activities [7]. In these research themes, not only sensors but also home appliances in the living space can be connected to the sensor network so that more diverse data can be collected and services using the estimated results and emergency response It is also expected to be able to do. There are also studies that monitor elderly people with dementia based on data from sensors, mainly movement sensors and door entry point sensors [8]. By continuously monitoring sensor data, it is possible to respond

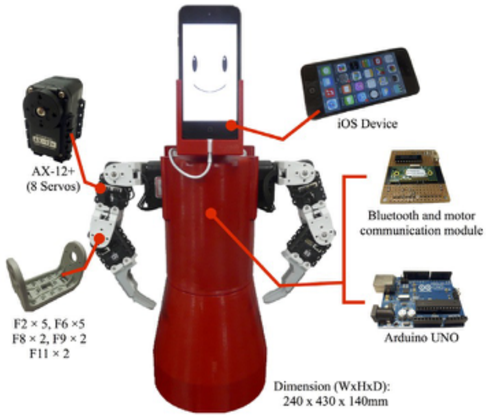

Figure 3 Schematic diagram of robot partner "iPhonoid-C"

quickly to behaviors and emergencies that are different from normal life.

III. System Overview

This chapter describes the details of the components of the proposed system.

A. Robot partner

This section describes the robot partners used in this system. In recent years, various robot partners have been developed, but they are not widely used in ordinary households. One of the possible causes is that the introduction cost is high. In addition, in order to respond to various situations and users, flexible extensibility is very important. In our laboratory, we have developed a robot partner that uses a smartphone as a control device to reduce the introduction cost of the robot partner and to make it easier to add content [9]. Smartphones are now widely used and equipped with various sensors such as acceleration sensors, cameras, and microphones, and can be used for robot voice recognition, image processing, and attitude control. Also, by implementing the content as an application, functions can be easily added. Figure 3 shows the robot partner "iPhonoid-C" used this time. This was designed around a smartphone as described above, and this time an iOS device was used. The body is made with a 3D printer, except for the servomotor and microcomputer, so it can be made and improved easily and cheaply.

B. Air Pressure Sensor

This time, we use the information of the sleeping body for the utterance of the robot partner. Biological information during sleep was measured using an air pressure sensor. Figure 4 shows how this air pressure sensor is actually installed between the bed and the sheets. At this time, the position of the sensor was adjusted and set so that the sensor was just under the shoulder blade when the user went to bed. Next, Figure 5 shows a schematic of the internal structure of this sensor. The air pressure sensor used this time has a two-layer structure in which a cylindrical natural rubber tube is wrapped by a polypropylene sheet as shown in this figure. The inner rubber tube is blocked on one side, and when the rubber

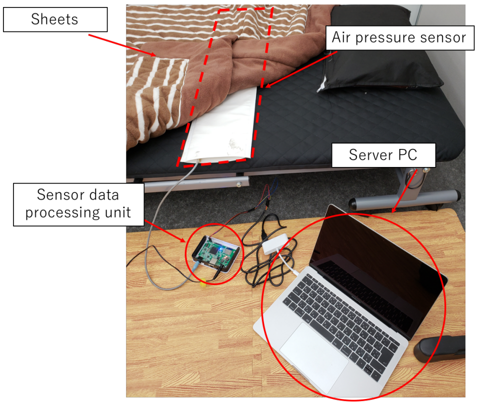

Figure 4 Air pressure sensor installation

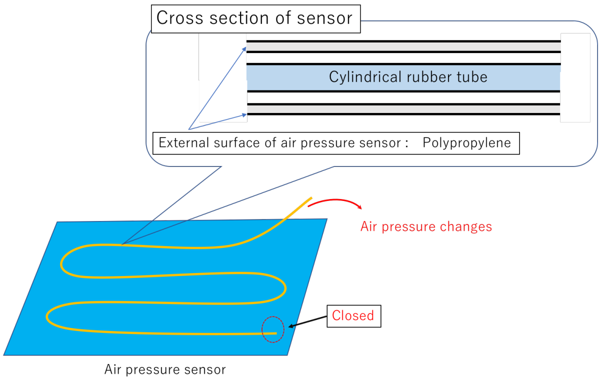

Figure 5 Internal structure of air pressure sensor

Table 1 Specifications of Air pressure sensor

Seat body	Width 420mm × length 165mm × thickness 0.75mm
Rubber tube dimensions	outer diameter 7 mm × inner diameter 5 mm
Sampling frequency	500Hz

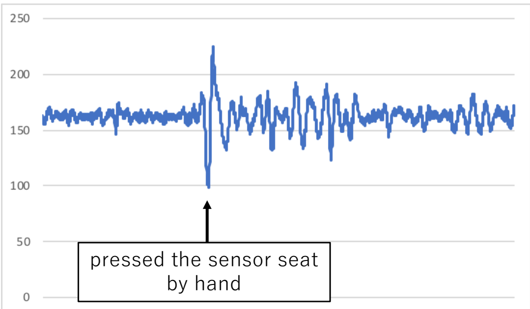

Figure 6 Example of output waveform

tube is compressed and expanded due to the vibration on the sheet, the air inside is pushed or drawn from the non-closed side. By measuring this change with a highly sensitive air pressure sensor, it is possible to measure the body vibration on the sheet. Table 1 shows the specifications of this air pressure sensor. Figure 6 shows the output waveform of the sensor obtained using this sensor

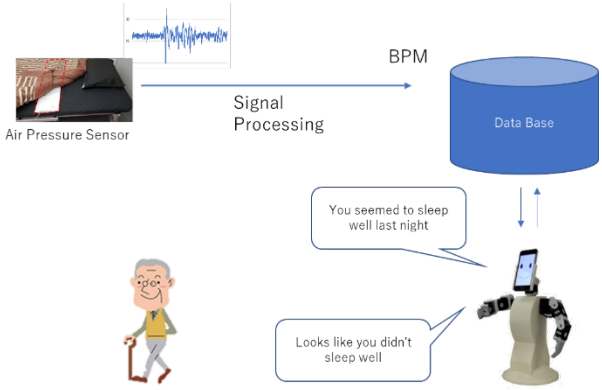

Figure 7 Overview of the proposed system

IV. Proposed System

By integrating these robot partners and the measurement system, we created a system that interacts with humans by referring to external sensors when the robot cannot obtain sufficient information. This time, the above-mentioned air pressure sensor was used as an external sensor. Details of these and simple experiments performed are shown below.

A. System overview

Figure 7 shows an overview of the proposed system. This system was designed based on the above-mentioned information structured space in consideration of increasing the types of sensors in the future. In other words, only the results of the processing were uploaded so that robots and others could interpret the meaning of the information uploaded to the database and use it easily. In the case of the air pressure sensor data of this time, only the heart rate data is recorded. The robot partner will proceed with the conversation while using these data.

B. Signal processing

In order to extract the biological information from the data measured using the air pressure sensor, we performed the procedure shown in Figure 8 this time. Since the data obtained from this sensor contains a lot of noise, the peak of the heartbeat was extracted using weighted root mean square (WRMS) after removing the noise by moving average (MA). The heart rate was then counted using a spiking neural network (SNN). Here, the following model was used for SNN.

First, when the internal state of the i-th neuron is $h_i(t)$, this internal state is calculated as shown in the following equation

$$h_i(t) = \tanh\left(h_i^{sys}(t) + h_i^{ext}(t) + h_i^{ref}(t)\right) \quad \text{(IV-1)}$$

Here $h_i^{sys}(t)$is the input from a neuron in the same layer as that neuron and is determined as follows.

$$h_i^{sys}(t) = \gamma^{sys} \cdot h_i(t-1) + \sum_{J=0}^{N} w_{ij}\, h_j^{PHP}(t-1) \quad \text{(IV-2)}$$

w_{ij} is the connection strength from the i-th neuron to the j-th neuron. In this paper, this value was fixed at 1 beforehand and was not updated. $h_j^{PSP}(t)$ is the presynaptic potential of

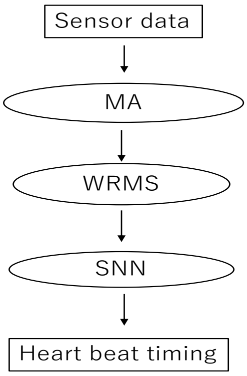

Figure 8 Data processing procedure

Table 2 Various parameters of SNN

threshold	0.5
Damping factor for refractory period	0.9
Damping factor of internal state	0.95
PSP damping factor	0.95
Size of refractory period	2

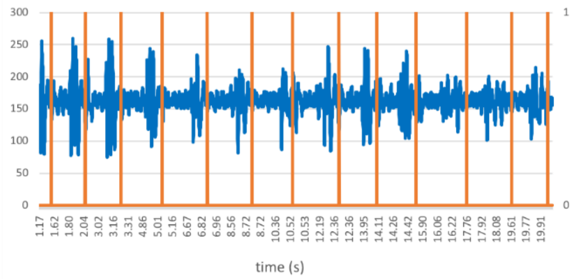

Figure 9 An example of the results obtained by these processes

the j th neuron at time t. N is the number of neurons in that layer, and γ^{sys} is the damping factor. $h_i^{ext}(t)$ is an input from the outside, and this time is considered as the variation of WRMS.

Various parameters of SNN were set as shown in Table 2. Figure 9 shows an example of the results obtained by these processes. In the figure, the one shown in blue is the original data, and the one shown in orange is the estimated heartbeat timing.

C. Experiment

These robot partners and measurement systems are integrated to interact with humans. This section describes the situation where a robot partner interacts with a human using this system. First, Figure 10 shows the environment in which the experiment was performed. Robot partners and sensors were installed as shown in the figure. The other settings were based on the solitary living room.

First, Figure 11 shows a scene where a robot partner and a human are interacting. Here, using the face recognition function and the voice recognition function of the iOS device, the activity details of the day are recorded while communicating. Next, the case of uttering based on sensor data is described. Figure 12 shows an attempt to make an

Figure 10 Experiment environment

Figure 11 Utterances using only sensor information mounted on the robot partner

Figure 12 Utterance by sensor information installed in the environment

appropriate utterance based on information from the sensor when the utterance cannot be made, such as when a person is lying on the bed. In addition, based on the obtained biological information, utterances about health support are also performed.

V. .CONCLUSION AND FUTURE WORK

This paper described the development of a robot partner for the purpose of health support and watching over elderly people living alone. The information of sensors installed in the environment is very important for robot partners which communicate with people. Aiming at a system that can judge the situation from the sensor information and make appropriate utterances and responses, we would like to add various sensors such as an RGB sensor and proceed with further development.

REFERENCES

[1] "2016 information communication white paper" , Ministry of Internal Affairs and Communications, Retrieved October 1 2019 , from http://www.soumu.go.jp/johotsusintokei/whitepaper/ja/h28/html/na000000.html

[2] "General condition of 2017 care service facility, establishment investigation" , Ministry of Health, Labor and Welfare , Retrieved October 1 2019 , from https://www.mhlw.go.jp/toukei/saikin/hw/kaigo/service17/index.html

[3] "2017 care work fact-finding" , Care work stability center , Retrieved October 1 2019 , from http://www.kaigo-center.or.jp/report/h29_chousa_01.html

[4] J. Woo, K . Wada, N . Kubota , "Robot Partner System for elderly people care by using sensor network", IEEE International Conference on Biomedical Robotics and Biomechatronics 2012 (BioRob2012), pp.1329-1334, 2012

[5] N. Kubota, D. Tang, T. Obo, S. Wakisaka, "Localization of Human Based on Fuzzy Spiking Neural Network in Informationally Structured Space", Proc. of 2010 IEEE World Congress on Computational Intelligence (WCCI 2010), pp.2209-2214, Barcelona, Spain, 2010.

[6] T. Obo, N. Kubota, B. H. Lee, "Localization of Human in Informationally Structured Space Based on Sensor Networks", Proc. of 2010 IEEE World Congress on Computational Intelligence (WCCI 2010), pp.2215-2221, Barcelona, Spain, 2010.

[7] Akhlaghinia, M. J., Lotfi, A., Langensiepen, C., & Sherkat, N. "A fuzzy predictor model for the occupancy prediction of an intelligent inhabited environment". In 2008 IEEE International Conference on Fuzzy Systems (IEEE World Congress on Computational Intelligence) (pp. 939-946). IEEE, 2008.

[8] Lotfi, A., Langensiepen, C., Mahmoud, S. M., & Akhlaghinia, M. J. . "Smart homes for the elderly dementia sufferers: identification and prediction of abnormal behaviour". Journal of ambient intelligence and humanized computing, 3(3), pp.205-218, 2012.

[9] Woo Jinseok, and Naoyuki Kubota: "Human-Robot Interaction Design Using Smart Device Based Robot Partner." International Journal of Artificial Life Reserch (IJALR) 6.2, pp.23-43, 2016