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An Early Detection System for Dementia using the M2M/IoT Platform

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Abstract

The number of elderly people living alone has been increasing in Japan. If dementia has been detected at an early stage, the progress of disease can be slowed. Therefore, early detection of dementia is so beneficial to the patient therapy. Most of dementia symptoms can be detected by housemates, noticing some changes of behavior in elderly people. However, it is difficult to detect early symptoms of dementia in elderly people living alone. In this study, we proposed a system which detects the symptoms of the elderly people living alone by using the M2M (Machine-to-Machine) /IoT (Internet of Things) platform. We installed sensors inside the house of elderly people living alone. These sensors can detect behavior by initial symptoms of the dementia. Also, these sensors' data will be used as behavioral data of dementia patients. In addition, we conducted a questionnaire about their habits and personalities. These questionnaires' results were used as an attribute data of the subjects. The system analyzes the two data and then determines the presence or the absence of dementia.

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Keywords: Sensor Network, Home Network, Healthcare, Dementia, Elderly People

1. Introduction

In recent years, Japanese society has been suffering from aging. There have been many studies estimating the number of elderly people living alone will be increasing frighteningly. Moreover, patients who suffered from senile dementia also would be increasing. In 2025, we estimated the number of elderly people with dementia would be

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increased to 7 million[1]. Dementia is disorder of memory and judgment caused by dying brain cell. Therefore, patients suffering from dementia are unable to live with ordinary social life.

If dementia has been detected at an early stage, the progress of disease can be slowed. Therefore, early detection of dementia is essential to the patient's therapy. Usually, housemates can detect dementia by noticing the subject being temperamental person. However, it is difficult to diagnose dementia at an early stage of the progression in elderly subjects living alone.

1.1. Previous Study and Tasks

In our previous study, the authors proposed system which can detect a suspicion of Alzheimer's disease, a kind of dementia, at an early stage [2-4]. This system installed sensors inside the house of elderly people living alone. Sensors detected behaviors by initial symptoms, and then these data were sent to a database in cloud server. The system analyzed sensors' data in the cloud and determined the suspicion of dementia.

However, the system used preselected sensors and analytical methods to determine the suspicion of dementia for instance. Alzheimer's disease is individually different in case of dealing with initial symptoms. Therefore, we need to add various types of sensors and select proper analytical methods to detect the symptoms. Moreover, the system hasn't constructed a platform that can be modified easily when we want to increase the number of the subjects and add analytical method.

1.2. Purpose

In this study, we proposed a platform of M2M system. The system can add new sensors and use a variety of analytical methods to correspond a variety of characteristics of Alzheimer's disease patients by using a hierarchical configuration of the device, gateway and cloud. Furthermore, we examined division of functions about device, gateway and cloud in the signal processing, such as characteristic of amount extraction. As an example, we have developed a detection system about forgetting to close a faucet that is seen in early stage of Alzheimer's disease by using M2M Platform.

1.3. M2M Platform

The basic configuration of the M2M platform and objectives are described in Figure 1. The platform includes sensors, actuators, the M2M device engine, gateway and server/cloud. Based on this configuration, the constructor selects each component and combines them appropriately to realize the construction simple and with low cost [5].

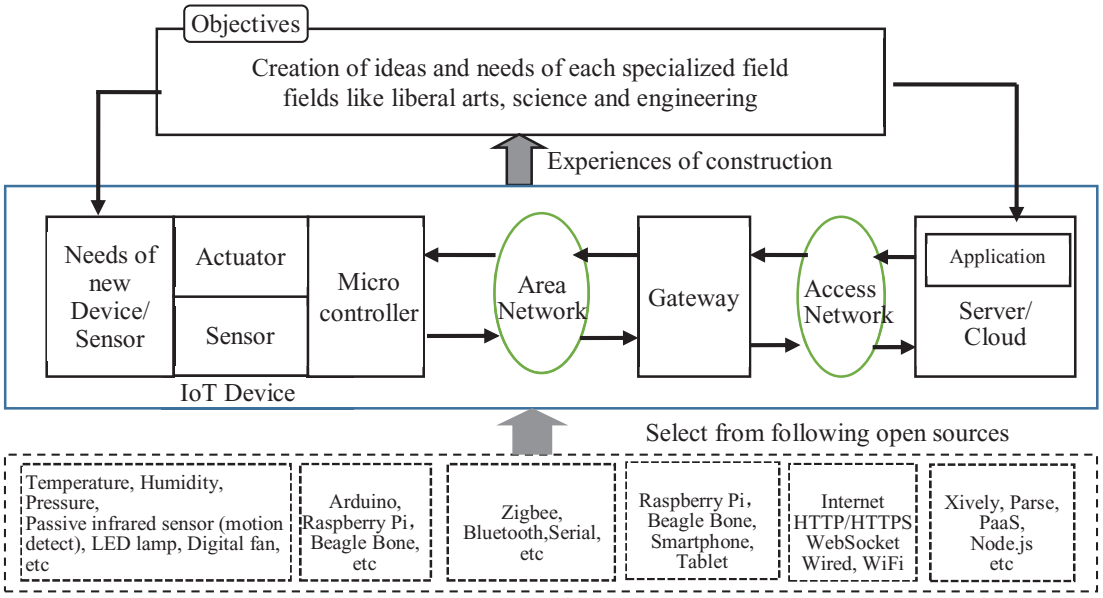

Fig. 1. The Basic Configuration of The IoT Platform and Its Objectives[5]

2. SYSTEM OUTLINE

2.1. System Configuration

A diagram of the system configuration is demonstrated in Figure 2. We constructed the system along the M2M/IoT platform. First, sensors detect behavior by initial symptoms. Next, M2M device perform a simple signal processing, for example, Fourier transform, to these sensor values. Then, M2M gateway performs a complicated processing such as feature extraction and determines behavior by initial symptoms based on pattern recognition and prearranged threshold. The cloud or M2M server collects number of detection behaviors and accumulates these. Finally, M2M server/cloud derives function that determines suspicion of dementia by analyzing data has stored on the cloud. The system automatically determines suspicion of dementia by using this function.

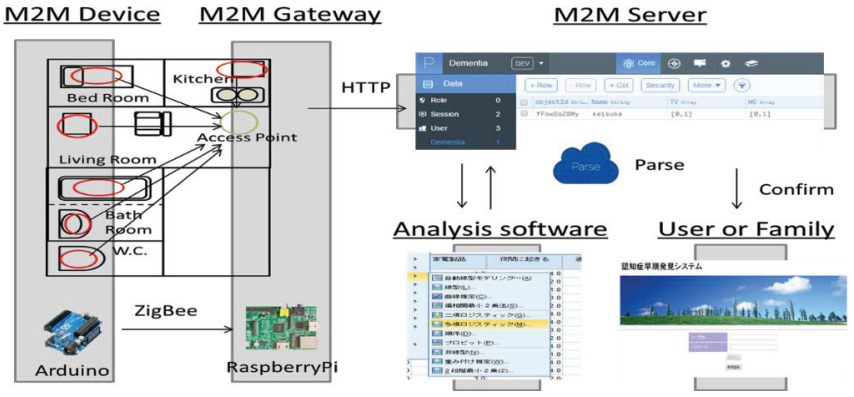

Fig. 2. System Configuration Diagram

2.2. M2M Device/M2M Gateway

Figure 3 shows the system configuration diagram of M2M device part and M2M gateway part. M2M device part detects behavior of initial symptoms by using M2M device (Arduino) and various sensors such as motion sensors which are installed in the M2M devices. The devices perform a simple signal processing such as Analog-digital conversion and Fourier transform to these sensor values. Furthermore, the devices send these values to a M2M gateway (Raspberry Pi) via M2M area network (ZigBee6). M2M gateway part performs a complicated processing in features like extraction on received sensor's values and determines behavior by initial symptoms on the basis of pattern recognition and prearranged threshold. M2M server/cloud (Parse) accumulates numbers of detection. This data will be used as behavioral data.

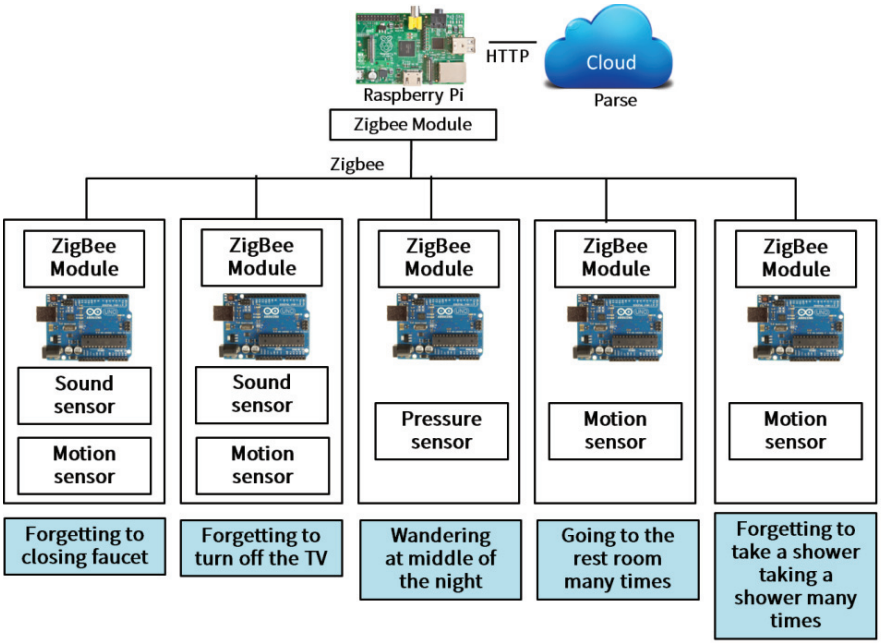

Fig. 3. M2M Device/M2M Gateway

2.2.1. Detection System of Forgetting to Closing Faucet

Figure 4 shows the system configuration diagram of forgetting to close a faucet. The system determines if it was sound of water or not by using pattern recognition [7]. The M2M device part detects presence of person using motion sensor which is installed in the device. When the human detection sensor's value is below the threshold, the M2M device acquires sound data using microphone. In addition, this part applies digital conversion and Fourier transform on the sensor values. The M2M gateway part performs feature extraction on received sensor's value and substitute the extracted feature quantity into equation (1). Equation (1) is used to detect water sound.

$$\begin{aligned} y = {} & -1.721 \times X_1 - 0.2596 \times X_2 + 0.8559 \times X_3 - 0.4026 \times X_4 - 0.2754 \times X_5 \\ & + 0.27 \times X_6 - 0.2441 \times X_7 - 0.4726 \times X_8 - 0.0018 \times X_9 + 0.2795 \\ & \times X_{10} - 0.3369 \times X_{11} + 0.4083 \times X_{12} + 7.2243, \end{aligned} \tag{1}$$

Here X1~X12 is future extraction. When the calculation results is equal to or less than zero, forgetting to closing the faucet will be detected.

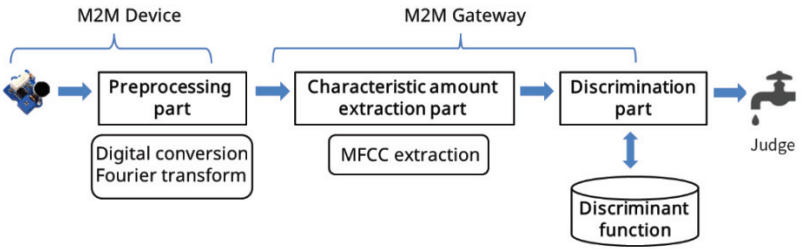

Fig. 4. Detection System of Forgetting to Closing Fauce

2.2.2. Attribute Data

The system determines suspicion of dementia using the attribute data of the subject in addition to acquired behavioral data by the sensor. Attribute data includes habits and personalities of Alzheimer's disease patients. These data are acquired by the questionnaires. As indicated in Table 1, we created questionnaires based on responses with interviewed patient's housemate and the patient's symptoms[8].

Table 1. Attribute Data

(1) Sex	(2) Age
(3) Keep a diary	(4) Without a palate
(5) Always lose things	(6) Often regret
(7) Have much pride	(8) Be hopeless with money
(9) Be at a loss for words	(10) Short tempered
(11) Often forget plans	(12) Get on well with one's neighbors
(13) Does not eat enough	

2.3. M2M Cloud/Server

M2M server/cloud stores data that acquired the behavioral data and the attribute data from the gateway. The user selects arbitrary analytical methods on the interface. Then, the system creates a discriminant function using an analytical method selected by the user based on the data stored on the cloud. After that, the system automatically determines suspicion of dementia by using this function. Finally, the user can confirm the results of the analysis through M2M application.

2.3.1. Proposal of Analysis Platform

We prepared three types of analytical methods. Moreover, we developed platform that can easily add to the analytical method to correspond with the diversity of Alzheimer's disease patients' characteristics.

(1) Analysis based on behavioral data/ compared with group
This type determines a person to take action seen in Alzheimer's disease at an early stage. The analytical methods determine more suspicion of Alzheimer's disease using Discriminant Analysis Method and Multiple Logistic Regression.

(2) Analysis based on behavioral data or compared with the previous behaviors

Although it is somehow difficult to determine a suspicion of Alzheimer's disease based on comparison with the group, it determines a person who changed his behavior when compare with the past behaviors. In this analytical method, we used Discriminant Analysis Method to determine a suspicion of Alzheimer's disease. When the amount of variation of distinction score is more than or equal to 2.5 point (at least three times), suspicion of Alzheimer's disease will be concluded.

(3) Analysis based on behavioral data and attribute data
Determination of dementia for person who doesn't show the behaviors that addresses the initial symptoms of the disease. We implement the attribute data to acquire the behavioral data that are hard to get. The analytical methods determine the suspicion of Alzheimer's disease by using Multiple Logistic Regression.

3. EVALUATION

3.1. M2M Device/M2M Gateway

3.1.1. Evaluation Method

After the system implementation, we installed the system inside the house and performed experiments. Subsequently, we tried to answer the following questions.

(1) Do sensors detect predicted the behavior data of elderly people?
(2) Does it detect the false environmental sound?
(3) Does it give a wrong diagnosis of dementia for healthy person?
(4) Do sensors give discomfort the patient inside the house?
(5) Do sensors interfere with your daily life?

3.1.2. Scenarios Evaluation

We performed experiments using scenarios. Table 2 shows the scenario evaluation. We made multiple scenarios for each type of initial symptoms. As shown in Table 3, we assumed that one day is 4 hours scenario. Then, we investigated whether the environmental sound is detected in the scenario or not.

Table 2 Evaluation Scenario

Symptoms	Content of the Scenario
Memory loss (High motivation of life)	Forgetting to closing faucet, Forgetting to turn off the TV, Vacuum the floor
Memory loss (Low motivation of life)	Forgetting to turn off the TV, Forgetting to take a shower, Going to the rest room many times
Sleep disorders	Get a nap, Can hardly sleeping , Wandering at middle of the night
Wandering	Wander inside the house, Wandering at middle of the night

Table 3. Scenario Detail

<table>
<tr><th>Scenario time</th><th>Experiment time</th><th>Memory loss (High motivation)</th><th>Memory loss (Low motivation)</th><th>Sleep disorders</th><th>Wandering</th></tr>
<tr><td>4:00</td><td>0:00</td><td rowspan="3">Retiring</td><td rowspan="3">Retiring</td><td>Retiring</td><td></td></tr>
<tr><td>5:00</td><td></td><td>Wake-up</td><td></td></tr>
<tr><td>6:00</td><td></td><td></td><td></td></tr>
<tr><td>7:00</td><td></td><td>Wake-up</td><td>Wake-up</td><td></td><td>Wake-up</td></tr>
<tr><td>8:00</td><td></td><td></td><td>Going to the rest room</td><td></td><td></td></tr>
<tr><td>9:00</td><td></td><td>Have breakfast
Forgetting to closing faucet</td><td>Have breakfast
Going to the rest room</td><td>Have breakfast</td><td>Have breakfast</td></tr>
<tr><td>10:00</td><td></td><td rowspan="2">Vacuum the floor</td><td>Watching TV
Forgetting to turn of the TV</td><td></td><td></td></tr>
<tr><td>11:00</td><td>1:00</td><td>Going to the rest room</td><td rowspan="2">Can hardly sleep</td><td>Wander in house</td></tr>
<tr><td>12:00</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>13:00</td><td></td><td>Have lunch</td><td>Have lunch</td><td>Have lunch</td><td>Have lunch</td></tr>
<tr><td>14:00</td><td></td><td></td><td rowspan="2">Going to the rest room
Watching TV
Forgetting to turn off the TV</td><td></td><td></td></tr>
<tr><td>15:00</td><td></td><td>Watching TV
Forgetting to turn off the TV</td><td rowspan="2">Can hardly sleep</td><td rowspan="2">Wander in house</td></tr>
<tr><td>16:00</td><td>2:00</td><td></td><td>Going to the rest room</td></tr>
<tr><td>17:00</td><td></td><td></td><td>Watching TV
Forgetting to turn off the TV,</td><td></td><td></td></tr>
<tr><td>18:00</td><td></td><td>Have dinner</td><td>Have dinner</td><td>Have dinner</td><td>Have dinner</td></tr>
<tr><td>19:00</td><td></td><td></td><td>Going to the rest room</td><td></td><td></td></tr>
<tr><td>20:00</td><td></td><td>Take a shower
Forgetting to closing faucet</td><td>Watching TV</td><td>Take a shower</td><td>Take a shower</td></tr>
<tr><td>21:00</td><td></td><td></td><td>Going to the rest room</td><td></td><td></td></tr>
<tr><td>22:00</td><td>3:00</td><td rowspan="6">Retiring</td><td rowspan="6">Retiring</td><td rowspan="2">Retiring</td><td rowspan="2">Retiring</td></tr>
<tr><td>23:00</td><td></td></tr>
<tr><td>0:00</td><td></td><td>Wandering at middle of the night</td><td>Wandering at middle of the night</td></tr>
<tr><td>1:00</td><td></td><td rowspan="2">Retiring</td><td rowspan="3">Retiring</td></tr>
<tr><td>2:00</td><td></td></tr>
<tr><td>3:00</td><td>4:00</td><td>Wandering at middle of the night</td></tr>
</table>

3.1.3. Evaluation result and Discussion

Table 4 shows the accuracy rate of each detection system in each scenario. As a result, the accuracy rate of detection system exhibited between 80% and 100%. In contrast, the accuracy rate of the detection system of

forgetting to turn off the TV usually occurred between 30 % and 40 % in most of all scenarios. The detection system determines using pattern voice recognition. In the system, we created discriminant function that determines forgetting to turn off the TV for all TV broadcast programs. However, since the system depeneds on the feature amount of sound and Tv programs' sound. The detection of forgetting to turn off the TV may won't detect. Therefote, we need to review the discriminant function or the detection method in the future work.

Figure 5 shows the evaluation results of the questionnaire. In the result, there is no problem if the sensors are installed inside the house. Whereas, detection system of forgetting to closing the faucet and detection system of wandering at the middle of the night has gotten a low rate of usability. In detection system of wandering at the middle of the night, we placed pressure sensor and Arduino on the top of the bed. Thereby, sensors and wiring may touch the human body during the sleeping time. In detection of forgetting to closing faucet, we put the sensor and Arduino in one of the water supply's sides. As a consequence, the subject said that there is the possibility that water falls on the system. Accordingly, we need to re-examine installation locations of the sensors in the future.

Table 4. Accuracy Rate of Each Detection System in Each Scenario

Scenario	Detection Item	Accuracy Rate
Memory loss (High motivation of life)	Forgetting to closing faucet	93.3%
	Forgetting to turn off the TV	46.0%
Memory loss (Low motivation of life)	Forgetting to turn off the TV	36.0%
	Going to the rest room many times	87.5%
	Forgetting to take a shower	100.0%
Sleep disorders	Wandering at middle of the night	83.3%
Wandering	Wandering at middle of the night	93.6%

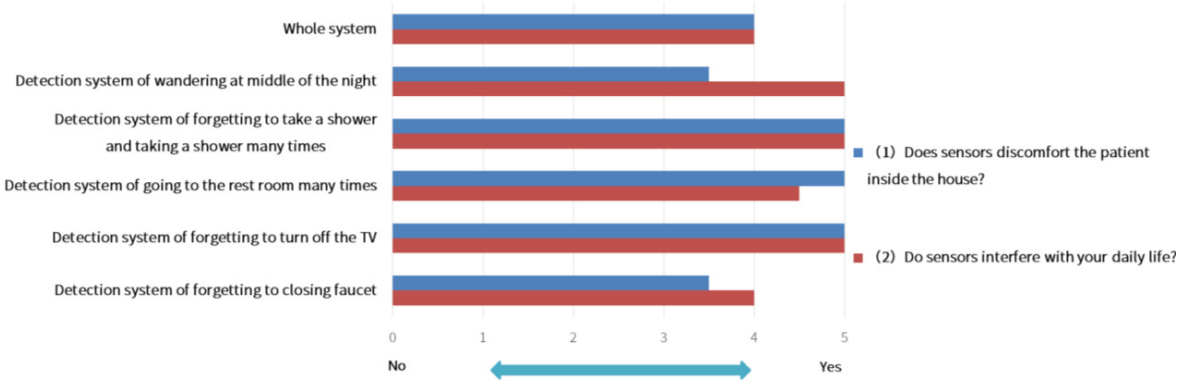

Fig. 5. Evaluation Results of The Questionnaire

3.2. M2M server/cloud

3.2.1. Evaluation Method

We implemented the system inside the patients' house. After that we evaluated the following answers.

(1) Can the system distinguish the disease even if the user has a large number of detections? And can the user easily confirm the result of analysis?
(2) Can the system insert the attribute data of the user based on the questionnaires?
(3) Can the system perform an analysis of the plurality of the patterns?
(4) Can the system add a new analytical methods easily based on collected data?

4. CONCLUSION

We proposed a system witch can detect a suspicion of Alzheimer's disease at an early stage for the elderly people living alone by using the M2M/IoT platform. We evaluated adequacy of detection system and usability of the system in environment by pseudo patients.

In the future work, we will install the system in Alzheimer's disease patients' homes and collect the data of these disease patients. Moreover, we will add sequentially a new sensors and analytical methods. We will formulate sensors and analytical methods which valid in early detection of dementia to correspond a variety of characteristics of Alzheimer's disease patients.

Acknowledgements

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References

1. Specially Promoted Research Supported by the Health and Labour Sciences Research Grant in 2014, Study for Elderly Population Projections with Dementia in Japan, 201405037A, 2014 (in Japanese).
2. Yuki Abe, Maher Aljehani and Masahiro Inoue, Early Detection System of Senile Dementia by Analyzing Behavioral Data of Actual Patients, The 34th Chinese Control Conference & SICE Annual Conference 2015 (CCC&SICE2015), July 30, 2015.
3. Yuki Abe, Machiko Toya, and Masahiro Inoue, Early Detection System Considering Types of dementia by Behavior Sensing, IEEE Global Conference on Consumer Electronics, GCCE2012, Proceedings, pp.348-349, Oct. 3, 2013.
4. Yuki Abe, Machiko Toya, and Masahiro Inoue, Early Detection System of Senile Dementia by Behavior Sensing, IEEE International Symposium on Consumer Electronics, ISCE2013, Proceedings, June 3, 2013.
5. Nobuhiro Ohe, Masahito Ishihara, Hironobu Yonemori, Shinji Kitagami, Masahiro Inoue, Jun Sawamoto, Tetsuo Shiotsuki, A Method of Prototype Construction for the Active Creation of IoT Application Ideas and its Evaluations, International Journal of Internet of Things, Volume 5, Number 1, Science and Academic Publishing, March 2016.
6. The ZigBee Alliance Control your World, http://www.zigbee.org/, 2016/04/22
7. Hiroyuki Nishi, Kin Kin, Yoshimasa Kimura and Toshio Kakinoki, "Life sound discrimination algorithm using Neural network," IEICE Tech. Rep., vol. 114, no. 390, ICM2014-43, LOIS2014-50, pp. 61-65, Jan. 2015(in Japanese).
8. Naoto Yamashita, Research of Needs for Home Care Support of Dementia and Development of The Support System, 2013(in Japanese).