Rule-Based Inquiry Service to Elderly at Home for Efficient Mind Sensing

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ABSTRACT

To support in-home long-term care, we are studying techniques of *Mind Sensing*, which externalizes internal states of elderly people as words through conversations with agents or robots. We have previously developed a prototype system of Mind Sensing, integrated with an activity recognition system and an LINE chatbot. However, the system was tightly coupled with the fixed systems, it was difficult to add or change the setting of questions from the chatbot to individual elderly people.

In this paper, we propose the *Mind Sensing Service*, which allows a service operator to define and manage the questions flexibly, and to automate the delivery of the questions and the collection of the answers. The proposed service consist of two elements: *actions* and *rules*. An *action* defines the contents of specific questions such as what message is sent to which elderly people. A *rule* defines the conditions on when, where, and by what event, in order to execute the action. The proposed service makes it possible to implement more systematic and flexible Mind Sensing.

CCS CONCEPTS

• Information systems → RESTful web services; **• Human-centered computing → Ubiquitous and mobile computing systems and tools**; **• Applied computing → Health care information systems**;

KEYWORDS

smart healthcare, smart home, Web service, mind sensing

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1 INTRODUCTION

According to Japanese Government, the number of Japanese people over the age of 65 is 35.15 million in 2017, which is 27.7% of the total population [3]. The number continues to increase and will reach 40% of the total in 2050. Similar situations are observed in most developed countries in the world. Such a super-aging society causes chronic shortage of human resources, nursing facilities, and the cost of social security. The Japanese government is therefore shifting the policy from the conventional facility care to *in-home long-term care*. It is ideal for all elderly people to live in their beloved homes. However, they generally face with various difficulties in daily life, due to the decline of physical and cognitive functions. Also, the home care would pose a heavy burden on family caregivers. In order to support these elderly people at home, the *assistive technologies* have been studied and developed in various organizations in recent years.

A promising technology to support the in-home long-term care is the *elderly monitoring system* using ICT. Exploiting sensors, wearable devices, and smart home technologies, the system tries to *recognize* daily activities of elderly at home. Various methodologies have been studied, for example, the method with ambient sensing [9] [8], the method with accelerometers of mobile phones [4], the methods with wearable sensors [11], and the method using a smart home with indoor positioning and power meters [10].

On the other hand, monitoring with sensors has a limitation that the system can detect only *externally observable events*. To perform person-centered home care, it is also important to recognize *internal states* of elderly people. Here, the internal state refers to a status of a person that cannot be observed externally, including moods, pains, conditions, desires, and intentions. Since the internal state is directly linked to human health, it is important to monitor within the home care [2]. However, the internal state is usually assessed through inquiries and counseling by experts. Hence, it is challenging to monitor the internal state regularly at home.

In order to overcome the limitation, our research group is studying techniques of *Mind Sensing* ("kokoro" sensing in Japanese [6]). It externalizes the internal states of elderly people as "words" via conversations with agents or robots.

In our previous study [5], we have developed the *memory-aid service*, which exploits a Mind Sensing method with an activity recognition system [9] and the *LINE chatbot*. Triggered by the time or an activity recognized in a smart home, the chatbot asks a user (i.e., elderly person) a question that externalizes the internal state as words. As the user answers the question by text (as well as voice and images), the conversation is automatically recorded in a database with a timestamp. The service then provides the *retrospective process*, where the user can review, correct, classify, and search the

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recorded information of own at any time. Thus, the service is designed for the memory-aid purpose of healthy elders as well as people with cognitive impairment.

To make context-aware questions, our previous system [5] regularly monitors the log generated by the activity recognition system [9]. When a specific activity of a user is detected, the system instructs the LINE chatbot to ask the user a question related to the activity. However, the previous system was tightly coupled with the activity recognition system and the LINE chatbot. That is, the Mind Sensing can be only triggered by the specific activity recognition, and the inquiry is performed only by the LINE chatbot. Also, all the questions were hard-coded within the program. Thus, our previous system lacks the flexibility, where it is quite difficult to add or change the configuration of Mind Sensing, adapting to individual elderly people.

To cope with the limitation, this paper presents a new service that allows more flexible and systematic Mind Sensing. Specifically, we introduce a *rule-based inquiry system*, to allow individual users to define custom Mind Sensing. In the proposed service, a Mind Sensing is defined by a *rule* and associated *actions*. An action consists of the address of the target user, the concrete question to ask, and the message service to deliver the question. A rule is either *time-based* or *event-based*. A time-based rule executes a given set of actions based on designated time and frequency. A event-based rule executes a given set of actions based on the event notified from the external smart home service. Based on the rules, the proposed service automatically sends questions and collects answers to and from the target users.

The created rules and actions are managed within a database. The user can easily add, update, and delete them through GUI of Web application. The proposed service makes it possible to ask questions with a high degree of freedom in Mind Sensing. Thus, it can be expected to acquire various aspects of internal states of elderly people. In this paper, we implement a prototype of the proposed service, and conduct a case study. Through the case study, we check the feasibility of the proposed service, and collects user's feedback for further improvement.

2 PREVIOUS STUDY: MEMORY-AID SERVICE FOR HOME ELDERLY CARE [5]

2.1 Overview and System Architecture

In [5], we have developed the memory-aid service to support elderly people at home who are anxious about age-related forgetfulness, as well as cognitive impairment. The key idea is to provide an *external memory* for a user (i.e., an elderly person), so that the user can easily record whatever important for the user, and can retrieve the recorded information at any time. Major challenges were (1) how to encourage the user to record the essential information (including the internal states) in the external memory, and (2) how to use and maintain the recorded data for better quality life.

Figure 1 shows the system architecture of the memory-aid service, consisting of the following two functionalities:

Chatbot-based Mind Sensing is a mechanism that externalizes and records the information in user's mind, through conversations with the LINE chatbot on a mobile phone. Triggered by time or an event, the chatbot autonomously asks a question to the user

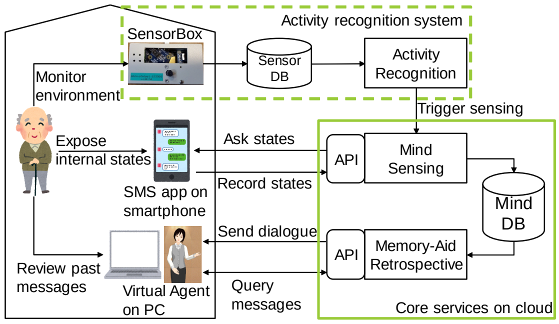

Figure 1: System architecture of memory-aid service [5]

over the LINE app. We integrated the activity recognition system [9] in order to generate context-aware questions. Typical questions include "What are you doing now?", "How are you feeling today?", "Did you sleep well?", "What did you do today?" and "Where do you want to go?"

As the user responds to the chatbot by manual text input or the speech-to-text input of the mobile phone, the text message is sent to Web-API, and recorded in a database with a timestamp. Moreover, regardless of the questions, the user can spontaneously talk to the chatbot to record any information, such as memorandums, schedules, appointments, and thoughts.

Memory-Aid Retrospective is an application that provides an opportunity where the user can *look back* the recorded information. Exploiting voice interaction with a virtual agent [7] and intuitive graphical user interface, the user can perform two types of retrospective processes on a PC.

In the *short-term* retrospective process, the system displays the list of *fresh* messages recorded within one day before now. While viewing the list at the end of the day, the user can remember what happened today. To maintain the quality of the data, the application tells the the user to correct typos and errors in the existing records, or to add supplementary messages if necessary. Moreover, for every record, the user can associate user-defined *categories* that explain the type of the information.

In the long-term retrospective process, the user can view and search all the existing records. By simple user interface assisted with the virtual agent, the user can retrieve messages by category, keywords, and date. Thus, the user can find important information whenever necessary, which would relieve the anxiety for the forgetfulness.

2.2 Prototype

We have implemented a prototype of the memory-aid service as a Web application operated on both a smart phone and PC. In particular, we implemented the chatbot with the LINE Messaging API [1]. To manage the data obtained by the Mind Sensing, we deployed MongoDB. For inserting and retrieving data via the Internet, we implemented REST Web-API using the Jersey RESTful Web Services framework.

To evaluate the practical feasibility, the prototype system has been deployed and operated within actual households. Especially, Subject A (a 77-year-old man) and Subject B (70-year-old man) are actively cooperating on our experiment. The current rules of the mind sensing are as follows. When the activity recognition system detects the wake up of the subject, the chatbot on mobile phone asks the physical condition of the subject. When the system detects any activity, the chatbot asks a question depending on the context. In the end of the day, the chatbot encourage to perform the retrospective process.

2.3 Limitation of the Previous System

The previous prototype system was tightly coupled with the activity recognition system and the LINE chatbot. Therefore, the capability of Mind Sensing was limited by the capability of these systems. In the previous system, based on the result of the activity recognition, the following message is automatically sent to the user via the LINE application and stored in the database.

```
_id: "5d2abade3efbc011fb13f849"
timestamp: "2019-07-14T14:17:18+0900"
from: "LINE bot"
to: "U921012a7a9b4c86ec69782677ed2a3f3"
dataType: "text"
contents: "Hi, Haruhisa. How are you? It is 14:17
on July 14th. In the living room, are you eating?
[Question number:14005]
(Accuracy:71.428%) (Detected by humidity sensor)"
```

The item `to` represents an unique ID associated with each user. The item `contents` describes a question that aims to externalize the internal state of the user. In this example, the question contains the time, the location, and the recognized activity (i.e., "eating"), the accuracy, and the type of sensor used for recognition.

To perform the Mind Sensing for a user, the system regularly monitors the database for the latest recognition result. When the system finds a new activity of the user, the system checks the type, the location, and the time of the activity, and generates a question by filling concrete values within a preset *message template*.

On the other hand, the above procedure of generating the questions is hard-coded within the system. If a user wants to change the question, the user has to directly edit the message template in the source code, which is cumbersome. Furthermore, the Mind Sensing can be triggered only by the activity recognition system. Although there exist various events captured by other smart home services (e.g., appliance operations, energy usage), they cannot be cooperated with the Mind Sensing. Also, the user may prefer to use another message delivery service than LINE, for instance, an email. However, the previous system does not allow it. Thus, the previous system lack the extensibility and flexibility, which limits the capability of the Mind Sensing.

3 PROPOSED METHOD

3.1 System Architecture

To achieve more flexible and systematic Mind Sensing, we propose the *Mind Sensing Service* in this paper. The proposed service exploits a rule-based system which allows individual users to define custom Mind Sensing methods. The key idea is to *de-couple* the definitions of the Mind Sensing from the surrounding systems.

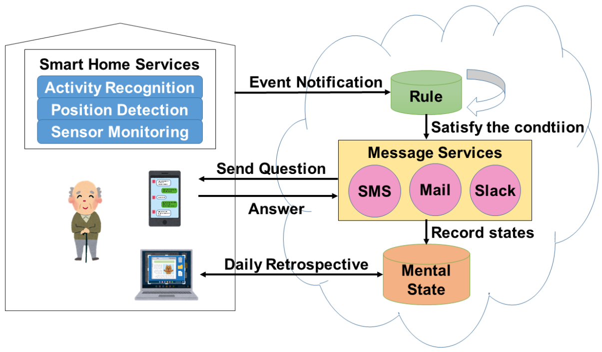

Figure 2: System architecture of proposed service

Figure 2 shows the system architecture of the proposed service. In the proposed service, each Mind Sensing is defined by a *rule*, specifying which question is sent, to whom, at when, by what event, and with which message service. Once a rule is defined, the service automatically sends the questions to the target users, and collects the answers. In Figure 2, there are various smart home services to support elderly users at home, including activity recognition service, indoor positioning service, and anomaly detection service. Each of these services generates events and manages the event log. The proposed service can accept these events, and use the events in triggering conditions of Mind Sensing.

A *rule* specifies an enabling condition when the Mind Sensing is executed. The condition is based on either *time* or *event*. A time-based rule is triggered when the designated time is arrived, while an event-based rule is executed when an event matching the condition is notified. Each rule is associated by a set of *actions*. An action corresponds to an inquiry to a user, consisting of the address of the user, the concrete question to ask, and the message service to deliver the question. We adopt various messaging services, including SMS (short messaging service), Email, and Slack, to inquiry the questions to the target user. By supporting interaction with various devices such as smartphone and PC, we can perform Mind Sensing, according to the lifestyle of individual user.

As the user responds to the question in the natural language text, the answer is then recorded in the database with a timestamp. The stored conversations between a user and a chatbot are later used in services such as Memory-Aid Service. This allows users to review, correct, classify, and search the information they recorded themselves. In addition, through appropriate access control, they can be accessed by third parties such as doctors and caregivers for person-centered care treatments.

3.2 Action

An *action* defines a configuration of concrete inquery of Mind Sensing. The configuration includes three items: `targets` specifies target user(s) to inquiry, `messageBody` specifies the content of the question message, and `serviceType` specifies a service to deliver the message.

It is possible to specify multiple users in `targets`, and a designated question can be sent to the multiple users simultaneously. When an action is executed, the system refers to a *name aggregation table*, which maps a user ID within the proposed service to a user ID of the concrete message service specified in `serviceType`. After resolving the user ID, the service invokes Web-API of the message service, passing the text described in the `messageBody`, the destination address of the user ID. For example, suppose that we define the following action: `act1 = {targets: ["Maeda"], messageBody: "How is your current condition?", service: "LINE"}`. The *act1* defines an action that the LINE chatbot send a message "How is your current condition?" to a LINE user ID corresponding to "Maeda".

3.3 Time-Based Rule

A *time-based rule* (TBrule, for short) is a rule that *repeatedly* executes actions at time interval within a set period. It defines an inquiry without depending on any event from external services. The TBrule can be used when asking questions regularly or when sending messages at a fixed time. A TBRule is defined by four items: `actions` specifies a list of actions to execute, `since` specifies the start time, `until` specifies the end time, and `interval` specifies minutes of the repetition interval. For example, suppose that we define the following TBrule: `tbrule1 = {actions: ["act1"], since:"10:00", until:"16:00", interval: 60}` . The *tbrule1* defines a TBrule that action act1 is executed every hour from 10 o'clock to 16 o'clock every day.

When the service starts, all TBrules in the database are read. Each TBRule has the tasks that are executed every *interval* from the start time on the server. The task checks if the current time is within the execution period (between *since* and *until*) and executes the action if it is.

3.4 Event-Based Rule

An *event-based rule* (EBrule, for short) is a rule that is triggered by an event notified from an external service, based on when, where, and what event is notified.

An EBrule is defined by three items: `actions` specifies a list of actions to execute, `conditions` specifies one or more conditions to be satisfied by the event, and `breakTime` specifies minutes of cooling time to the next execution.

When an event is notified, an EBrule is triggered only if all the *conditions* are satisfied. Each condition is defined by the 5W perspective (i.e., WHO, WHOM, WHAT, WHEN, WHERE). This perspective can cover most events issued by external systems. Each *condition* is defined by six items: `from`, `to`, `event`, `since`, `until`, `location`.

cid	: condition ID
from	: The subject of event
to	: The object of event
since	: Whether the event took place after this time
until	: Whether the event took place before this time
event	: The contents of event
location	: The location of event
description	: The description of event

For example, suppose we define the following condition: `con1 = {from: "Activity recognition", to:"Maeda", since:"06:00", until:"10:00", event:"Waking up", location:"Bedroom", }` The *con1* defines a condition that activity recognition service detects user *Maeda*'s waking up in the bedroom.

Next, let us define the following EBrule: `ebrule1 = {actions: ["act1"], conditions: ["con1"], breakTime: 30}` . The *ebrule1* defines a rule that action act1 is executed only when the condition `con1` is fulfilled. That is, when that activity recognition service detects that *Maeda* wakes up, then send him a question "How is your current condition?" by LINE. Once ebrule1 is executed, it will not run for the next 30 minutes.

To receive the event notification from external systems, the proposed service exposes REST API, with a method *postEvent(from, to, event, time, location)*. When the external system executes the API, the service evaluates conditions of every EBrule against the given values of the parameters. For example, when *postEvent("Activity recognition service", "maeda", "10:42:24", "Waking up", "bedroom")* is executed for the above *con1*, it returns *false* because the perspective of the WHEN is not met.

4 CASE STUDY

4.1 Outline

As a case study, we conduct an experiment to obtain the user's mental state by sending questions using the proposed service. The purpose of the case study is to verify the operation of the system and to gather user's opinion for better improvement. In the experiment, a questioner created 42 questions in total by referring to the mental illness questionnaire sheets, and created rules to ask the subjects three questions twice a day in the morning at 6:30 and in the evening at 21:30. Each subject answered every question with a four-level choice. The answer was stored in a database for later analysis. After the user answered 42 questions in 7 days, we finally sent a review of the past week and feedback that intervened in the mental state of the subject.

4.2 Creating Rules

For the experiment, we implemented a Web application that allows the questioner to easily create and update actions and rules on a Web browser. Figure 3(a) shows the screen of the prototype, where the user creates actions and rules. It shows a list of actions MorningAction0-3, each of which is defined by targets, messageBody, and serviceType. The rule at the bottom of the figure shows a TBrule, executing MorningAction0-3 at 6:30 every morning.

In this experiment, we needed to send four messages at each time, twice a day, at 6:30 and 21:30. Accordingly we created eight actions: `MorningAction0,1,2,3` and `EveningAction0,1,2,3`. Actions `MorningAction0` and `EveningAction0` are greeting messages to start an inquiry. `MorningAction1,2,3` and `EveningAction1,2,3` define concrete three questions asked in the morning (or evening, respectively). For example, `MorningAction1` is described as follows: `MorningAction1 = {targets: ["maeda", "yasuda",..., "nakamura"], messagebody: "Q1. Do you think you feel satisfied with your daily life?", service: "LINE"}`.

We then created two TBrules `MorningRule` and `EveningRule`. In both rules, the interval was set to 1440 minutes, so that MorningRule and EveningRule were executed exactly once a day. Thus, each subject received three questions following a greeting message every morning at 6:30, as well as every evening at 21:30. For example, `MorningRule` is described as follows: `MorningRule = {actions: ["MorningAction0", "MorningAction1","Morning`

(a) Question setting screen (b) Interaction screen

Figure 3: Screenshots of applications in case study

```
Action2", "MorningAction3"], since: "06:30", until: null,
interval:1440} .
```

4.3 Results and Feedback

Figure 3(b) shows the screen of LINE application, where a LINE chatbot were interacting with the subject. The chatbot sent a message asking the mental state by `MorningAction0,1,2,3` at 6:30, as defined in `MorningRule`. In the bottom of the figure, the subject responded to these questions.

In this case study, the questioner, who made the questions from questionnaire sheets of mental illness, defined the actions and rules via the Web application by herself. She said that the proposed service was very useful, and much more efficient than the manual survey she had been doing before. On the other hand, she requested some improvement on the usability.

5 CONCLUSION

In this paper, we have proposed *MindSensingService* to capture internal mental states of elderly people at home. Introducing a rule-based system, we have de-coupled the definition of Mind Sensing from surrounding systems, which allows more systematic and flexible Mind Sensing. We also conducted a case study asking questions for understanding mental states of the subjects. The proposed service allows to define the method of Mind Sensing independently of specific systems or messaging service. Thus it is expected to acquire various aspects of the internal states. As for future research, we plan to conduct a clinical experiment with more elderly people to evaluate practical feasibility and limitations.

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REFERENCES

[1] 2018. LINE Messaging API. https://developers.line.biz/ja/services/messaging-api/.

[2] Giuseppe Di Cesare, Cinzia Di Dio, Massimo Marchi, and Giacomo Rizzolatti. 2015. Expressing our internal states and understanding those of others. *Proceedings of the National Academy of Sciences* 112, 33 (2015), 10331–10335. https://doi.org/10.1073/pnas.1512133112

[3] Government of Japan. 2018. Annual Report on the Aging Society (2018). http://www.cao.go.jp/.

[4] Jennifer R Kwapisz, Gary M Weiss, and Samuel A Moore. 2011. Activity recognition using cell phone accelerometers. *ACM SigKDD Explorations Newsletter* 12, 2 (2011), 74–82.

[5] Haruhisa Maeda, Sachio Saiki, Masahide Nakamura, and Kiyoshi Yasuda. 2019. Memory Aid Service Using Mind Sensing and Daily Retrospective by Virtual Agent. In *10th International Conference, DHM 2019, Held as Part of the 21st HCI International Conference, HCII 2019*, Vol. LNCS 11582. Springer, 353–364.

[6] Masahide Nakamura, Kenji Hatano, Jun Miyazaki, Kiyoshi Yasuda, Noriaki Kuwahara, Hiroaki Kazui, Sachio Saiki, Seiki Tokunaga, Mihoko Otake, Naoki Kodama, and Naoko Kosugi. 2019. Developing a System for Self-care and Mutual-aids of Elderly People at Home Based on Externalization of Internal States. *JSPS KAKENHI, Grant-in-Aid for Scientific Research (A)* 19H01138 (2019).

[7] Shota Nakatani, Sachio Saiki, Masahide Nakamura, and Kiyoshi Yasuda. 2018. Generating Personalized Virtual Agent in Speech Dialogue System for People with Dementia. In *Digital Human Modeling 2018 (DHM 2018), Held as Part of HCI International 2018*, Vol. LNCS 10917. Springer, 326–337. Las Vegas, USA.

[8] Long Niu, Sachio Saiki, and Masahide Nakamura. 2018. Using Non-Intrusive Environmental Sensing for ADLS Recognition in One-Person Household. *International Journal of Software Innovation (IJSI)* 6, 4 (August 2018), 16–29.

[9] Kazunari Tamamizu, Seiji Sakakibara, Sachio Saiki, Masahide Nakamura, and Kiyoshi Yasuda. 2018. Machine Learning Approach to Recognizing Indoor Activities based on Detection of Envi-ronmental Change. In *11th World conference of Gerontechnology (ISG2018)*, Vol. 17. 118s. St. Petersburg, USA.

[10] K. Ueda, M. Tamai, and K. Yasumoto. 2015. A method for recognizing living activities in homes using positioning sensor and power meters. In *2015 IEEE International Conference on Pervasive Computing and Communication Workshops (PerCom Workshops)*. 354–359. https://doi.org/10.1109/PERCOMW.2015.7134062

[11] Zhihua Wang, Zhaochu Yang, and Tao Dong. 2017. A Review of Wearable Technologies for Elderly Care that Can Accurately Track Indoor Position, Recognize Physical Activities and Monitor Vital Signs in Real Time. *Sensors* 17, 2 (2017). https://doi.org/10.3390/s17020341