Towards Personalized and Context-Aware Reminder Service for People with Dementia

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***Abstract*—A number of reminder systems have been developed to help elderly people with dementia. However, the existing reminder systems lack the awareness of human context, the sympathetic human-machine interaction, and the flexibility of personal adaptation. To cope with the limitations, we are currently studying a new reminder service for people with dementia. Specifically, we exploit a BLE-based indoor positioning system to capture the current location and context of the patient. We then use a virtual agent system for rich interactions. Finally, we develop a schedule management system for personalized reminders. To integrate these heterogeneous systems, we re-design and deploy the systems as three services with Web-API: Location Service, Agent Service, and Schedule Service. These services are loosely integrated by Coordinator Service, based on the service-oriented architecture, In this paper, we first present the system architecture, and then discuss the key idea to implement the services. We also demonstrate "reminder at the entrance" as a practical scenario of the proposed services. In order to evaluate the Agent Service, which is a key component of proposed service, we have conducted the a preliminary experiment with 17 people with dementia.**

I. Introduction

Dementia is a general term to describe a group of symptoms that impairment human memory, communication, and thinking. According to a report in 2015 [1], 46.8 million people are now suffering from dementia in all over the world. Thus, the *home care* for people with dementia becomes more essential, in order to assure the quality of life of the patient. However, sometimes the home care could be a burden to the family or caregivers in a specific context [2]. Hence, there are strong needs for *assistive technologies* that can support the independence of patients and decrease the burden to caregivers.

A *reminder system* is an assistive technology to support people with dementia. In general, the system provides information that reminds a patient of something in his/her life. Bourgeois [3] published the *memory book*, with which a patient can recall daily things and activities based on pictures and illustrations. The use of ICT (information and communication technologies) is recently a hot topic. The *COGKNOW project* [4] exploited ICT for home care of dementia. The project implements a configurable reminder service using dedicated home appliances and portable phones. The service notifies a user of the daily schedule (e.g., appointment of the medical clinic, meeting a guest, etc.). Hallberg et al. [5] showed the viability of *reminiscences with multimedia*. They implemented a semi-automated tool to remind patients of their old good days using pictures and videos. They also implemented a media-rich lifelog tool to record and review their on-going life. These tools aim to increase the patient's will to live by showing the past events and good reminiscence.

Although there are a number of reminder systems, we have found that the existing reminder systems have the following three problems:

- **Problem P1:** The reminder does not consider patient's context.
- **Problem P2:** The system lacks sympathetic human-machine interaction.
- **Problem P3:** The configuration of reminders is not flexible enough to cover individual needs.

The problem P1 means that most of the existing systems did not count situational information (i.e., context) of the patient. For example, a reminder appliance may emit a reminder in a scheduled time, even when the patient is not in the room. Even if the patient is doing other things (e.g., taking a bath, watching a TV), the reminder system has no way to know.

The problem P2 reflects the fact that most existing reminder systems provide mechanical reactions only, which include text, voice message, pictures, and e-mail. The mechanical reactions would sometimes impair the dignity of the patient, and decrease the motivation to use the system.

The problem P3 says that the existing reminder systems do not allow users to modify dynamically what and how to remind. A typical system has a fixed set of pre-determined events to schedule, and all of the personalization must be done in the design time of the system. However, individual patients have different severity levels of dementia. Also, the symptoms and daily habits are changing as the time passes. Therefore, it

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is essential for the caregivers to personalize dynamically what and how to remind, according to their individual needs.

The above three problems motivated us to develop a next-generation reminder service, which counts patient's contexts, sympathetic interactions, and dynamic personalization.

Our research group is currently developing relevant systems that can be used to the new reminder service. First, we exploit an *indoor positioning system* based on BLE (Bluetooth Low Energy) technology [6]. This identifies the current location of the patient in the house, which can be used for the context(location)-aware reminders. We then use a *virtual agent system* [7] for the sympathetic interactions. The virtual agent is an animated chat-bot program with the speech recognition and synthesis technologies. A user operates the system via the agent in a screen, as if the user talks to a human operator. Finally, we develop a *personal schedule and belongings management system*, where individual users can create and execute own custom reminders, dynamically.

In this paper, we try to integrate the above systems to achieve the new reminder service, called *Memory-PAL (Memory-aid service with Personalization, Agent, and Location technologies)*. To integrate the heterogeneous systems, we re-design and deploy the above systems as *services* with RESTful Web API: *Location Service*, *Agent Service*, and *Schedule Service*. These services are integrated by *Coordinator Service* based on the service-oriented architecture (SOA). In this paper, we first present the system architecture to see how Memory-PAL is achieved as the composition of the four services. We then discuss the key idea and design thoughts to implement each service.

To demonstrate the practical feasibility, we prototype a *reminder at entrance* service using the proposed Memory-PAL. In the service, when a patient is about to go out, the virtual agent spontaneously asks a destination and reminds personal belongings based on the destination. The service is useful to prevent the patient from forgetting essential items for the activity. We also conduct a preliminary evaluation to confirm the usability and practical utility for the Agent Service which is the main component of Memory-PAL. In the preliminary experiment, we confirm a usability and practical utility for the Agent Service. Moreover, we discuss how to provide the safety and smarter society with our proposed service.

II. PRELIMINARIES

A. Situation of Dementia

The progression of dementia usually begins with mild anterograde amnesia and often involves a variety of behavioral disturbances such as wandering and agitation [8]. People with dementia typically have the following symptoms:

- A decline in memory to an extent that it interferes with everyday activities, or makes an independent living either difficult or impossible.
- A decline in thinking, planning and organizing day-to-day things.
- Initially, preserved awareness of the environment, including orientation in space and time.

To maintain the quality of life of the people with dementia, the care by caregivers or families would become more important. In reality, however, the care is often a burden because of specific features of dementia, including BPSD (behavioral and psychological symptoms of dementia), aggressiveness, wandering, and sleep disturbance [9]. Indeed, it is not easy for general families to always delegate professional caregivers. Hence, there are many cases observed where the families have been *burned out* by the home care.

For this situation, the *assistive technology* is one of the promising solutions, where technologies are introduced to assist the people with dementia and surrounding people.

B. Reminder System

A *reminder system* is an assistive technology for the people with dementia. The system basically provides information that *reminds* a patient of something in daily life. What to remind includes showing a way of a routine, taking prescribed medicine, showing a schedule, notifying appointment, etc.

A variety of reminder systems has been proposed so far. The memory book [3], the COGKNOW project [4] and the reminiscences with multimedia [5] introduced in Section I are instances of the reminder system. There are many other systems and tools, such as memory diaries, bell timers, and alarm clocks [10]. Yasuda et al. [11] have proposed a remote reminiscence conversation and schedule prompter system using the videophone. It aims to help the patient perform household tasks, as well as improve their psychological stability.

However, as far as we investigate, there is no such existing reminder systems that can cope with all of Problems P1, P2 and P3 in Section I. This is the motivation of this research.

C. Indoor Positioning System

The *indoor positioning system (IPS)* locates and tracks objects within indoor space (inside buildings, underground, etc.), where Global Positioning System (GPS) does not work well. Enabling technologies of IPS include sound, ultrasound, image analysis, RFID, Wi-Fi and other radio-based approaches.

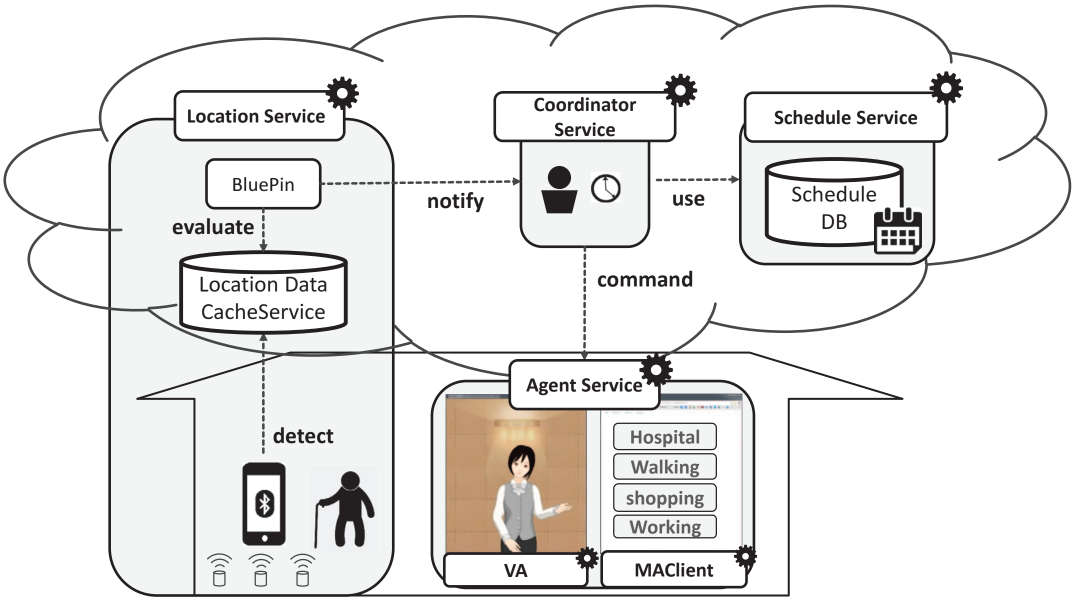
Our research group is also developing an IPS, called *BluePin* [6], using the BLE (Bluetooth Low Energy) technology. BluePin adopts a proximity-based positioning method with *beacons*. When a station detects a beacon (emitted by an object), the station produces symbolic location data, called *location label*, representing that the object is near the station.

IPS is a promising technology for people with dementia since it can capture the current location of the patient at home or care facility. The location information highly reflects the current activity and context of the patient. Therefore, we try to use BluePin to address Problem P1 in this paper.

D. Virtual Agent System

The *virtual agent* (VA) is a human-looking animated chatbot program that can communicate with a human user via voice [12]. There are a few studies that adopt the VA for dementia

Fig. 1. Service Architecture of Memory-PAL



care. Yasuda et al. developed a system where a VA serves as a conversation partner of people with dementia [13].

Our research group has developed a system which exploits a VA as user interface of the home network system (HNS) [7]. When a user says "Turn on a TV", the system interprets the voice as a command `TV.on()` . Then the system sends the command to the HNS to turn on the TV. Also, the VA autonomously speaks various information obtained from the HNS and the Internet.

VA is a promising technology for people with dementia since it can assist a patient based on less-mechanical and (simulated) human-to-human conversation. In order to cope with Problem P2, we try to integrate the virtual agent system.

E. Goal and Scope of Paper

Our goal is to construct a new reminder service, called Memory-PAL (Memory-aid service with Personalization, Agent and Location technologies). It aims to help people with dementia in a more context-aware, sympathetic and personalized way. In this paper, we first present the overall architecture of Memory-PAL. Then, we propose a key idea and design thoughts of the essential components. Although we develop a prototype system, the detailed implementation and evaluation with actual subjects will be left for our future work.

III. Memory-PAL: A New Reminder Service

A. System Architecture

In order to achieve the goal, we need to integrate heterogeneous and distributed systems. Therefore, based on the service-oriented architecture (SOA), we first abstract every system as a service, and then implement the whole system as a composition of the services. Figure 1 shows the system architecture of Memory-PAL. We can see that the system consists of four services: *Location Service, Agent Service, Schedule Service* and *Coordinator Service*.

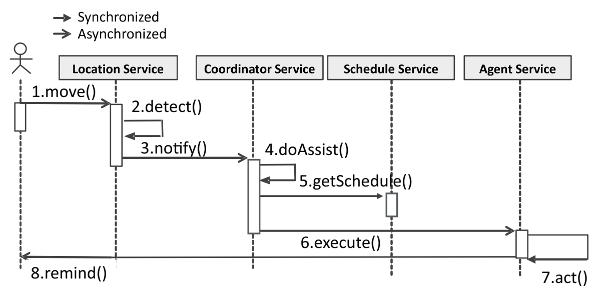


Fig. 2. Sequence of Reminder Service by Memory-PAL

The location service is a service that wraps an IPS (e.g., BluePin) and relevant services. The service identifies the current location of the patient in the house, and evaluates the predetermined contexts. The agent service wraps a virtual agent system, which directly interact with the patient. The schedule service manages the personal schedule and belongings of individual patients. Depending on the status of a patient, a caregiver of the patient can dynamically register, update and delete the custom reminders. The coordinator service integrates the above three services and actuates the remind.

The coordinator and schedule services are deployed on the cloud. The agent service is deployed at home. The location service is ranging over the home and cloud.

In the following, we explain the sequence of providing the reminder service using Memory-PAL. Figure 2 shows the whole sequence of integrating and providing the reminder service using Memory-PAL. At first user goes from living to an entrance, then the Location Service detects the change of current user's position Hence, the BLE based positioning service provides the context that where the current user is. Then the Location Service notifies to the Coordinator Service that the user comes near the entrance. Then the Coordinator Service works with its primary function *doAssist()*. As the next step, the Coordinator Service get the user's schedule with Schedule Service, and then commands to the Agent Service with function *execute()* to play some roles. Finally, the Agent Service remind his/her daily schedule or belongings.

B. Location Service

The location of a patient within a house is useful information that reflects the current situation of the patient. Also, what the patient has to remember heavily depends on the location. For example, when a patient gets close to the entrance, it means that the patient is about to go out. When a patient is in the kitchen, the patient may be trying to cook something. So the reminder system can use the location information to execute useful reminder actions.

To achieve such location-aware reminder actions, we exploit the IPS, BluePin (See Section II-C). We assume that a patient carries a smartphone with BLE and that BLE beacon modules are deployed on various places at home (e.g., entrance, living, kitchen). When the patient gets close to a beacon module, the smartphone detects the location and uploads the location label to the cloud. In the cloud, the location label is cached in LocationData Cache Service, as shown in Figure 1. This service stores the location label for a certain time period.

BluePin is watching the location label in the cache. When the location of the patient is changed, BluePin emits a predetermined event associated to the location change. For example, suppose that we associate an event "USER OUTGO" with the transition of the location from the living room to the entrance in advance. When the patient's position actually moves from the living room to the entrance, BluePin notifies "USER OUTGO" event.

To facilitate the integration, Location Service is deployed as a RESTful Web service. Hence, the location information can be consumed easily by accessing a URL. For example, http://memory-pal/location?userId=tokunaga returns the current location label of user "tokunaga".

C. Schedule Service

Schedule Service conducts the schedule management for people with dementia. A caregiver (or even a patient) registers daily events and belongings for the reminder. To achieve personalized reminder, we have designed a *schedule database* (called ScheduleDB, for short), which manages personal schedules and belongings.

Figure 3 shows an ER diagram representing the data schema of ScheduleDB. The diagram follows the notation defined in [14]. A square represents a table (i.e., an entity). A relationship may be defined between a pair of entities.

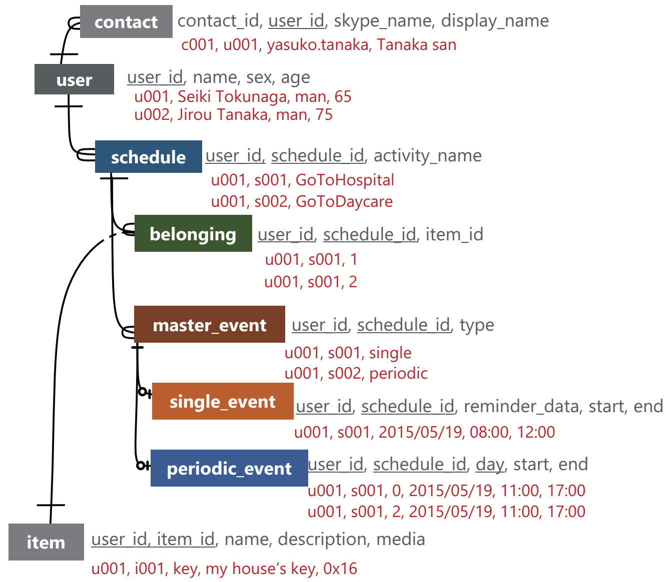


Fig. 3. Data Scheme of ScheduleDB

- (+——∈) represents a parent-child relationship,
- (+——· · ·) represents a reference relationship,
- (+——○+) represents a sub-type relationship

In the following, we describe details of each table.

user
: A user table stores personal information for every user. Specifically, each entity includes user_id, name, sex, age. The user_id is the primary key to identify a user in a ScheduleDB.

schedule
: A schedule table stores abstract schedules for the users. A user may have multiple schedules as a children-parent relationship. A pair of user_id and schedule_id is specified as a composite primary key, which allows a user to define multiple schedules.

belonging
: A belonging table aims to store personal belongings associated with a schedule. A belonging corresponds to something that the user has to bring for the schedules. For example, when a user tokunaga goes to a hospital, he has to bring his registration ticket and his health insurance card. The table stores the registration ticket and the insurance card as belongings of the schedule "Go to hospital" of togunaga. The belonging table has a reference relationship with an item table, so that an item may be used by a belonging for different schedules.

master_event
: A master_event table stores metadata of each schedule. It specifies a type of each schedule. The type is either single event or periodic event, as defined in the sub-type relationships.

single_event

A single_event table defines a schedule as an event that will occur only once on a specific day. For example, a user registers an appointment for a doctor.

periodic_event

A periodic_event table defines a schedule as an event that will occur periodically on specific days in every week. Specifically, we define [user_id, schedule_id, day] as a composite primary key, so that the event is scheduled on the given days of every week. The values 0, 1, 2, ..., 6 represent Sunday, Monday, ..., Saturday, respectively. Let us consider an example that the user tokunaga goes to a daycare service on every Tuesday. Then [u001, S002, 2] is registered in the table.

item

An item table stores a set of items owned by each user. It is referenced by the belonging table. The table includes user_id, item_id, name, the description of items and the image of an icon in a binary format.

contact

A contact table stores the contact persons associated with a user. Indeed, there would be cases where the virtual agent cannot give sufficient correspondence to a patient (i.e., anger). For those cases, the patient needs to contact to someone (e.g., caregiver or his family) via internet phone service (e.g., Skype). In the current implementation, we assume to store Skype id of caregivers.

Based on the above Schedule DB, Scheduler Service provides API, which allows client applications to query user's schedules. We implemented Scheduler Service as RESTful web services. For instance, GET\http://memory-pal/schedule?userid=tokunaga&date=2016-01-15'', returns a schedule of user "tokunaga" on the date of "2016-01-15". The returned schedule contains all the associated information. The query specifies variables of userid and datetime.

D. Agent Service

Agent Service provides human-computer interactions for people with dementia. It consists of two kinds of user interfaces. The one is *Virtual Agent* (VA) and the other is *Memory Aid Client* (MAClient). The VA is an human-like 3D chatbot program (See the bottom of Figure 1). Using the speech-to-text and text-to-speech technologies, the VA can recognize the human voice and can speak a given sentence. The VA is also able to perform motions (e.g., smile, bow, shaking hands) to act like human-beings.

Our research group has been developing a service-oriented virtual agent using MMDagent toolkit [7]. So, we extensively reuse it for the dementia care. The developed VA is internally defined as a finite state machine. The VA has a state. When an event is given, the VA moves from the current state to another state, with invoking some actions associated to the state transition. The actions include `say()`, `motion()`, `recognize()`, `execWebService()`. The detailed information can be seen in [7].

```
{
  "agent":    { "motion": "angle agent's head" ,
                "say":   "What will you do"},
  "output":   {"type": "text", "message": "What will you do"},
  "input":    {"type": "list",
                 listItems:{ Hospital,
                             DayCare,
                             Walking}
                 }
          }
}
```

Fig. 4. Operation Format of Coordinator

Memory-Aid Client (MAClient) visualizes reminder information in a screen, and provides graphical user interface (e.g., button, list, etc.) to collect responses from a user. The MAClient is supposed to be displayed on a touch interface, so that the patient can intuitively interact with the agent service. Moreover, the MAClient can display images or movies that are quite helpful for the reminder. The MAClient exposes two kinds of API: `input()` and `output()`. The `input()` API displays input GUI components (e.g., list, button, etc.), with which the user can input commands to Agent Service. The `output()` API displays output GUI components (e.g., text, label, etc.)

Integrating VA and MAClient, Agent Service provides API that can execute some care using virtual agent with visualized information. The API is also implemented as a RESTful Web service, so that various client applications can consume the service easily.

E. Coordinator Service

Coordinator Service integrates the above Location, Schedule and Agent Services, in order to achieve a location-aware and personalized reminder service. As shown in Figure 1, the coordinator service is notified by the location service. That is, when a user gets close to a certain location *L*, the location service executes `notify()` method, telling that the user is at *L*. When notified, the coordinator service obtains user's schedule, using the schedule service with the current time *t*. Based on the derived schedule, the coordinator service generates *assistive operations*, which will be executed by the agent service.

Figure 4 represents an example of the assistive operation generated by the coordinator service. The format is defined by JSON, specifying a set of parameters of the agent service. Each key (agent, output or input) corresponds to a parameter to be passed by the VA, `output()` or `input()` of the MAClient, respectively. This example supposes an assistive operation, where the agent asks where the user is going to go. The data specifies the agent's motion and speech in the value of "agent". It also specifies to display a text as a script, as well as a menu list by which the user inputs the destination.

Note that the agent service was internally implemented by a state machine. So, the coordinator service must be aware of the current state to execute appropriate reminder operations. For this, the coordinator service uses the ID of the current

Algorithm 1 doAssist(s: Screen_Id, L: Location, t:Time)

$operationFormat = AgentService.getAgentFormat(s)$
$schedule = ScheduleService.getSchedule(userID, t)$
$operation = generateOperation(L, schedule, operationFormat)$
$AgentService.execute(operation)$

screen, since a state of the agent service corresponds to a screen displayed.

After all, the coordinator service implements the location-aware and personalized reminder service by an algorithm `doAssist(s, L, t)` shown in Algorithm 1. As for parameters, s is a screen_id that represents a scene of the agent service (e.g., "s0001" representing the scene "Where will you go?"), L is the location notified by the location service (e.g, "Entrance"), t represents the current time. First, the coordinator service obtains the data format that is supported by the given screen_id s, from the agent service. It then obtains the schedule of the user based on the current time t. Next, it generates the appropriate assistive reminder operation based on L, the schedule and the format. Finally, it executes the command on the agent service.

IV. Implementation: Reminder at Entrance

Based on the proposed design, we have developed a prototype system of Memory-PAL. Using the prototype system, we have implemented a service, called *Reminder at Entrance*. In the service, when a user (i.e., person with dementia) is about to leave home from the entrance, a virtual agent first asks a destination, and then reminds the user of necessary belongings based on the destination. This section shows how the proposed four services collaborate to implement the service scenario.

To explain the scenario, we assume that the following conditions hold for the user and the house.

- To detect the location of the user, we installed BLE beacon modules in the entrance and a living room.
- To post location data to Location Service, the user carries a smartphone with a BluePin client installed.
- For interactions with Agent Service, we installed a tablet PC in the entrance of the house.
- The date is `2016-04-12T10:30:40`, where an appointment in a hospital is registered in Schedule Service.

Figure 5 shows a sequence of state transitions executed by Agent Service, where the VA and the MAClient interact with the user. Initially, Agent Service is at the default state, S001, and is waiting for an event.

When the user moves from the living room to the entrance, Location Service detects the change of user's location. Then, Location Service notifies Coordinator Service of an event `USER_OUTGO`. Next, according to Algorithm 1 (see Section III-E), Coordinator Service triggers `doAssist(S001, USER_OUTGO, 2016-04-12T10:30:40)`.

In `doAssist()`, Coordinator Service first obtains an operation format available at S001 from Agent Service. Then, it loads user's schedule from Schedule Service with user ID and the current time `2016-04-12T10:30:40`. Now the hospital

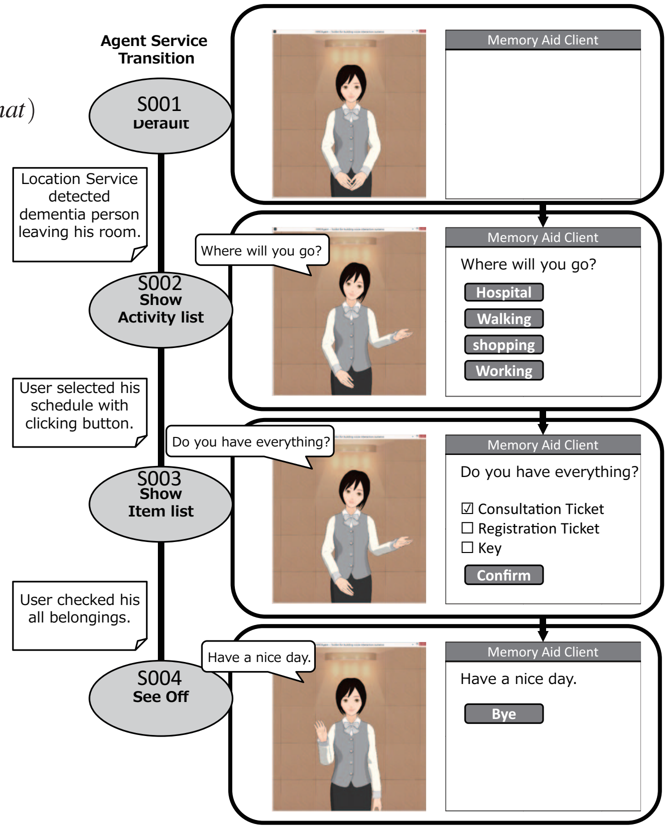


Fig. 5. Sequence of Agent Service

appointment is obtained since it is scheduled today. Coordinator Service then generates a list of possible destinations, including the appointment, and commands Agent Service to ask the destination with the list. Upon receiving the command, Agent Service tells the VA to say "Where will you go?", and displays the list of destinations in form of buttons within MAClient. Finally, Agent Service changes its state to the next state S002.

Suppose that the user presses the button "Hospital" (or says "hospital" to the VA) ten seconds after. Then, Agent Service notifies Coordinator Service of an event `HOSPITAL`, and Coordinator Service executes `doAssist(S002, HOSPITAL, 2016-04-12T10:30:50)`. Similar to the previous state transition, Coordinator Service now commands Agent Service to make a reminder of remind belongings that are necessary to carry to the hospital. Finally, Agent Service moves to the next state S003.

Next, the user confirms and checks the listed items one by one, and presses the "Confirm" button. Then, an event `CONFIRM` is notified, and Agent Service moves to the next state S004, where the VA says "Have a nice day" to see the user out.

It can be seen, in the above service scenario, that Memory-PAL was able to cope with Problems P1, P2 and P3 of the conventional reminder systems. More specifically, Location Service provides user's location as a context used for the reminder, which copes with P1 (*The reminder does not consider patient's context*). Agent Service with the VA and MAClient provides sympathetic human-machine interactions for the person with dementia, which overcomes P2 (*The system lacks sympathetic human-machine interaction*). Coordinator Service integrated with Schedule Service is able to take personal schedules and belongings into account, which solves P3 (*The configuration of reminders is not flexible enough to cover individual needs.*).

V. Discussion

A. Experimental Evaluation

We have conducted a preliminary experiment of Memory-PAL using the prototype system. In this experiment, we especially aim to evaluate the usability and acceptance of Agent Service for actual people with dementia. More specifically, we want to see how the subjects are capable to interact with Agent Service.

In the experiment, 17 people with dementia participated as subjects of the experiment. The average score of Mental State Examination (MMSE) was 23. The MMSE is one of most popular tests for evaluating the degree of problems with memory or other mental abilities [15]. We instructed the subjects how to use Memory-PAL, and each subject actually interacted with the agent service, where the agent presented some reminders. After they used Memory-PAL, we conducted a questionnaire to ask each subject how the subject felt in using Memory-PAL. The questionnaire consists of the following five questions, each of which takes 5-level scale from the best to the worst. We have also collected further comments and requirements for Memory-PAL by a free description.

- Q.1 Were you able to recognize and speak to the agent?
- Q.2 Were you able to interact with the agent with the touch panel?
- Q.3 Did you understand what the agent told?
- Q.4 Did you understand the instructions from the agent?
- Q.5 Were you willing to respond to the agent?

Table I shows the result of the experimental evaluation. Each row represents the result of each subject, while each column shows profile data or a question The last row represents the average of each column.

It can be seen that most subjects were able to speak and interact with the agent. Hence, we can believe that using the agent for the dementia care would be a promising approach. Although there are individual differences on the degree of dementia and the expertise for IT, the interaction using the touch panel also worked well. Indeed, we have found that subjects who are familiar with IT system tends to be good at using the Agent Service than others. Interestingly, most subjects could understand well what the agent spoke, which reflects the fact that the text-to-speech feature of the agent is quite matured enough for elderly people.

On the other hand, we have found that the agent service sometimes failed to recognize the speech of the subjects. This depends on the way of speech of individual subject. The current voice-to-text feature of the agent service could not achieve enough accuracy for the various quality of speech. Our future work is to investigate how to improve the accuracy of the voice recognition, by applying fine tuning to individual users.

TABLE I
Result of Preliminary Evaluation

No	Sex	Age	MMSE	Q.1	Q.2	Q.3	Q.4	Q.5
1	F	79	20	5	5	5	3	5
2	F	83	16	2	3	3	3	3
3	F	81	25	3	5	5	5	5
4	F	79	16	3	1	2	2	3
5	F	80	25	4	4	5	4	4
6	M	84	27	3	4	4	4	4
7	F	68	29	4	4	5	5	4
8	F	77	26	3	5	5	5	4
9	M	83	26	3	3	3	3	3
10	F	71	24	4	4	5	5	4
11	F	80	15	5	3	5	4	5
12	F	71	26	5	4	5	4	4
13	M	80	16	4	3	4	4	3
14	M	60	25	3	4	5	5	4
15	M	46	27	4	4	5	5	5
16	F	78	29	3	3	3	2	3
17	F	75	19	3	3	3	3	3
AVE.		75	23	3.58	3.64	4.23	3.88	3.88

B. Towards Safer & Smarter Societies

In the context of safety within the dementia care, we can consider two social problems: the *heat disorder* and the *night wandering*. The proposed Memory-PAL was originally developed for the daily reminder service. However, we show that it can contribute to avoiding these problems, by applying small extensions.

The heat disorder is an illnesses caused by a too warm environment [16]. In summer, people with dementia (especially elderly people) sometimes forget to turn on air-conditioners, because their senses of heat may be declined, or they want to be patient to save energy. Exposing a body within a too warm environment causes the heat disorder even in a house, which may lead to the death.

To avoid the serious heat disorder, the Memory-PAL can be used to emit a heat alert to the user, by integrating a temperature sensor service. Our research group has proposed a framework of the *sensor as a service* [17], which efficiently creates sensor Web services. Using a publish/subscribe mechanism of the framework, we can easily define an action that a temperature sensor invokes the API of Memory-PAL, when the temperature exceeds a threashould (e.g., 32 degree).

The night wandering represents a syndrome that a person with dementia goes out of home and gets lost in the late night [18]. The reason of the night wandering is that the memory problem in the brain motivates wrongly the person to go somewhere outside (for work, to meet a friend, etc.).

The Memory-PAL can be used to stop the person going out, by repeatedly speaking the current situation. The context of the night wandering can be detected based on the location of the patient and the current time. The location can be detected by the location service of Memory-PAL as shown in Section III-B. Therefore, based on the time, the coordinator service commands to the agent service, so that the agent repeatedly speaks to the patient "It's late at night. There is no appointment. Please go back to the bed room". Another approach useful for people with dementia is to show reminiscence movies to attract more attentions than going out. Implementation of these extended features are left for our future work.

VI. CONCLUSION

In this paper, we have presented a context-aware and personalized reminder service, called Memory-PAL (Memory-aid service with Personalization, Agent and Location technologies), for people with dementia. The Memory-PAL consists of Location Service, Schedule Service, Agent Service and Coordinator Service. These services are developed as Web services, and integrated based on the service-oriented architecture (SOA). We have implemented a prototype of Memory-PAL that performs a practical use case: Reminder at Entrance. Finally, we have conducted a preliminary evaluation especially to see the usability and feasibility of the agent service.

Our future work is to complete the implementation of Memory-PAL based on the proposed design. Moreover, we have to evaluate the practical feasibility of the whole Memory-PAL, through longer-term experiments with actual people with dementia.

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