Analyzing, Developing and Personalizing Smart Services for Assisting Elderly at Home

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(Degree)
博士（計算科学）
(Date of Degree)
2016-09-25
(Date of Publication)
2017-09-01
(Resource Type)
doctoral thesis
(Report Number)
甲第6752号
(URL)
https://hdl.handle.net/20.500.14094/D1006752

Doctoral Dissertation

Analyzing, Developing and Personalizing Smart Services for Assisting Elderly at Home

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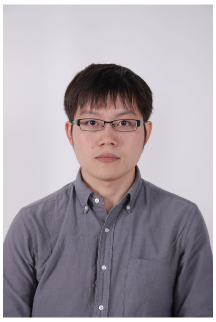

Analyzing, Developing and Personalizing Smart Services for Assisting Elderly at Home

Seiki Tokunaga

Abstract

We are facing a hyper-aging society, and Japan is forecast to become a society with 39.9% of aged people by 2060. Accordingly, the number of people with dementia is increasing, which is a social problem. On the other hand, many welfare and nursing care facilities suffer from chronic shortage of workers. Dementia care will therefore take place increasingly in the home, which imposes a burden on the family as caregivers. Under these circumstances, assistive technologies, which support elderly people at home, are attracting considerable attention.

Although a wide variety of assistive technologies have been developed, we focus here on assistive technology designed for elderly people living at home. Specifically, elderly people living at home have some risks (e.g. falling, heat disorder). Hence, We think the use of current ICT assistive technology would reduce such risks. This is the motivation for this dissertation.

In this dissertation, we show how to actualize a smart service for elderly people living at home in terms of analysis, design, development and evaluation. Specifically, we focus on three services: remote monitoring service, smart reminder service for people with dementia and personalized care service for elderly people living at home.

For the remote monitoring service, we provide a guideline for the relationship between sensor accuracy and sensor reliability in our proposed model. The result would be useful for some service providers. Second, we design and develop a new reminder service that provides situational reminders at home. The proposed reminder provides sympathetic and intuitive interaction with a chat 3D agent.

Finally, we try to integrate and isolate a care operation system that provides a new concept of care for elderly people living at home. The proposed architecture provides scalable and personalization for elderly people living at home.

Keywords elderly at home, remote monitoring service, reminder service, virtual agent, Person-centered care, service integration

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Chapter 1

Introduction

We are facing a hyper-aging society, and Japan is forecast to become a society with 39.9% of aged people by 2060. Accordingly, the number of people with dementia is increasing, which is fast becoming a social problem. On the other hand, many welfare and nursing care facilities suffer from a chronic shortage of workers. The Japanese government has begun to support and encourage home care rather than building new facilities. Needless to say, dementia care will also rely on home acre, which imposes a burden on the family as caregivers. Under these circumstances, assistive technologies which support people with dementia are attracting considerable attention.

In recent years, many such technologies have been researched. For example, the remote monitoring service is one assistive technology which allows a family to monitor an elderly person remotely. Also, a care robot is a robot which aims to support or assist elderly people in their daily life. However, existing assistive technologies have some problems in terms of their adoption for use with individuals.

In this dissertation, we try to actualize a smart ICT service from four perspectives: analysis, design, implementation and evaluation. Chapter 1 proceeds as follows. In Section 1.1, we focus on a remote monitoring service (RMS) for elderly people. In Section 1.2, we design and develop a reminder service for people with dementia. Finally, in Section 1.3, we propose a next-generation care service which is scalable and flexible for use with individual elderly people living at home.

1.1 Analyzing Remote Monitoring Service for Elderly People Based on Sensor Reliability

In this research, we assess the reliability and sensor accuracy of a remote monitoring service. A variety of remote monitoring services for elderly people with physical sensors are available on the market which capture the health status of elderly people. However, there are no guidelines with regard to sensor accuracy for RMS, although the service is widely provided. If the service provider offered guidelines it would benefit both them and the end-user.

In this paper, our most important contribution is to describe the relationship between the sensor accuracy and reliability of RMS. We construct a theoretical three-actor model which consists of RMS. Then we conduct a simulation to show the relationship between the sensor accuracy and reliability of RMS with the model.

1.2 Interactive Memory-Aid Agent Service for People with Dementia

A number of reminder systems have been developed to help elderly people with dementia. However, the existing reminder systems lack awareness of the human context, sympathetic human-machine interaction, and the flexibility of personal adaptation. To address these 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 redesign and deploy the systems as three services with Web-API: Location Service, Agent Service, and Schedule Service. These services are loosely integrated by a Coordinator Service based on service-oriented architecture, In this research, we first present the system architecture, and then discuss the key idea to implement the services. We also demonstrate A “reminder at the entrance” as a practical example of the proposed services. In order to evaluate the

Agent Service, which is a key component of the proposed service, we conducted a preliminary experiment with 17 people with dementia

[*1]

1.3 VirtualCareGiver: Personalized Smart Elderly Care

In recent years, many smart care services to help elderly people at home have received a lot of attention, because of the aging society. Since many countries are faced with an aging society, smart care robots (e.g. powered suits, paro) are a promising way to increase the quality of life and help to support independence of elderly people. However, their use is not widespread yet because some are too costly to deploy at home and are hard to personalize because of system complexity. Moreover, care robots take some time to adapt to.

In this paper, our goal is to provide a personalized and efficient care service for elderly people. Our key idea is to abstract a general care as a template which enable to scale for a wide variety of elderly people. To demonstrate the feasibility, we conducted the experimental evaluation with actual subjects [*2]. Moreover, we also discuss the result and limitation of our method.

[*1] The aim and procedure of the experiment were explained to the subjects and caregivers, and their consent for the video recording was obtained in accordance with the guidelines of the ethical committees of Chiba Rosai Hospital(No: 26-6).

[*2] The aim and procedure of the experiment were explained to the subjects and staff, and their consent for the video recording was obtained in accordance with the guidelines of the ethical committees of Kobe University(No: 28-02).

Chapter 2

Preliminaries

2.1 Aging society

2.1.1 Dementia

Dementia usually begins with mild anterograde amnesia and often involves a variety of behavioral disturbances such as wandering and agitation [1]. People with dementia typically have the following symptoms. A decline in memory to such an extent that it interferes with everyday activities, or makes 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 people with dementia, the care given by caregivers or families is becoming 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 [2]. It is not always easy for families to delegate responsibility to professional caregivers and there are many cases where the families have been burned out by the home care.

In this situation, assistive technology is one of the promising solutions, whereby technologies are introduced to assist people with dementia and their carers.

2.2 Remote monitoring service

Remote monitoring services (RMS) provide an elderly family some methods to monitor and confirm an elderly people with safety in remote. If a system detects an anomaly, it notifies the family or caregiver. Many researchers have tried to improve and develop a wide variety of RMS. Fleury and colleagues [3] conducted a simulation using a real smart home. The smart home collects various data (e.g. When do the elderly get up in the morning?) relating to the lifestyle of the client. The authors classified seven activities with support vector machines. As regards RMS, sensor accuracy is a very important factor because the sensor directly influences the reliability of RMS. Hence, some researchers have tried to improve the accuracy of the sensor to provide high-reliability RMS [4-7]. In addition, Kangas and colleagues [8] researched the accuracy of the operation of three indoor localization platforms. Shin and colleagues [4] developed an automated system with an infrared motion sensor which assisted the independent living of the elderly. In addition, they showed that their system had an accuracy of 95.8 in terms of positive predictive value (PPV). Ogawa and colleagues [9] conducted a simulation in which two elderly people were monitored. They developed something like a smart house, which collected information on elderly lifestyles with a sensor of some description (e.g. infrared sensor).

2.3 Reminder system for people with dementia

A reminder system is an assistive technology for people with dementia. The system basically provides information that reminds a patient of something in daily life: a routine, taking prescribed medicine, a schedule, an appointment, etc.

A variety of reminder systems has been proposed so far. The memory book [10], COGKNOW project [11] and reminiscences with multimedia [12] introduced in Section 4.1 are instances of the reminder system. There are many other systems and tools, such as memory diaries, bell timers, and alarm clocks [13]. Yasuda and colleagues [14] 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 her/his psychological stability.

2.4 Person-centered care

Person-centered care is a philosophy that recognizes that individuals have unique values, personal history and personality and that each person has an equal right to dignity, respect, and full participation in their environment [15].A person-centered philosophy of care is well understood and put into practice in care homes in order to improve the quality of care and the quality of life for people with dementia. The concept seems effective for elderly people in general. The larger part of this individual continues to be the possession of her/his uniqueness, the retention of the need for self-recognition and identity as well as the preservation of the ability to act and respond to the environment that surrounds her/him. Currently, each caregiver provides care for each elderly person at home. However, in Japan, there is a caregiver shortage. Hence, we need to discover how best to adopt the PCC concept to make up for this shortage of caregivers.

2.5 Overview of dissertation

This dissertation is organized as follows. In Chapter 3, we introduce a method which enables us to analyze a theoretical remote monitoring service. Moreover, we show the relation between sensor accuracy and reliability.

In Chapter 4, we design, develop and evaluate a new reminder service for people with dementia. The proposed reminder service resolves three problems that existing reminder systems have.

- The reminder does not consider the patient's context
- The system lacks sympathetic human-machine interaction
- The configuration of reminders is not flexible enough to cover individual needs.

In Chapter 5, we propose a new concept system which provides a smart care system for elderly people living at home. The proposed system provides scalable care by a virtual agent for a wide variety of elderly people based on a registered care task. Finally, we conclude this dissertation with a summary and suggest future work in Chapter 6.

Chapter 3

Analyzing Remote Monitoring Service for Elderly People Based on Sensor Reliability

3.1 Introduction

Many countries and societies are faced with an aging society [16]. In order to keep older people's quality of life (QoL) and individual freedom, their families and caregivers need a method to monitor their wellbeing. They have a strong need for a remote monitoring service.

A remote monitoring service for elderly people (RMS) is an effective way to support elderly people safely [17]. RMS provides the family with ways to monitor and confirm with the elderly person's safety remotely. If a system detects an anomaly, then it notifies the family or caregiver.

Many researchers have tried to improve and develop a wide variety of RMS. Fleury and colleagues [3] conducted a simulation using a real smart home. The smart home collects various data (e.g. When do the elderly get up in the morning?) relating to their lifestyle. The authors classified seven activities with support vector machines.

With RMS, sensor accuracy is a very important factor because the sensor directly influences the reliability of RMS. Hence, some researchers have tried to improve the accuracy of the sensor to provide high reliability RMS [4-7]. In addition, Kangas and colleagues [8] researched the accuracy of the operation of three indoor localization platforms. Jae and colleagues [4] developed an automated

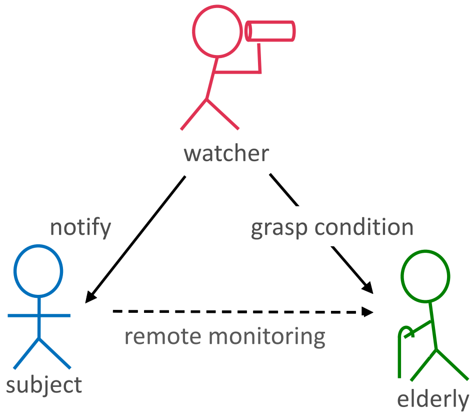


Fig. 3.1. Three-actor model

system with an infrared motion sensor, which assists the independent living of the elderly. In addition, they showed that their system has an accuracy of 95.8 in terms of positive predictive value (PPV). Ogawa and colleagues [9] conducted a simulation in which two elderly people were monitored. They developed something like a smart house, which collected information on lifestyle with a sort of sensor (e.g. infrared sensor).

However, there are no standards with regard to sensor accuracy for RMS. In this paper, our most important contribution is to represent the relationship between sensor accuracy and the reliability of RMS. Specifically, we achieve the goal using a four-step method, generalization by three-actor model, designing the algorithms of the three-actor and simulations of RMS. As the first step, we generalize the RMS to capture the perspective with the three-actor model which we proposed previously[18]. That model enables us to generalize the RMS by means of the interactions among the three actors. Second, we design algorithms to work the actor in RMS. Using the algorithms, we can express how often the elderly become ill. Third, we decide the aging parameter for an elderly person model which is the key actor in this simulation. Finally, we conduct some simulations using the built elderly model by changing the sensor accuracy.

3.2 Modeling of remote monitoring service for the elderly

In this section, we describe the essential component, the *three-actor model* (section **3.2.1**), and the *modeling of an elderly person* (section **3.2.3**) and *watcher* (section **3.2.4**). We can conduct the simulation of RMS using these components.

3.2.1 Three-actor model: a modeling framework of remote monitoring service

Figure 3.1 shows the three-actor model, which we have previously described [19]. In this model, we can generalize various remote monitoring services by mean of three actors (called a subject, a watcher, and an elderly) and relationships among the actors. The subject monitors the elderly people living in a remote location. A typical example of a subject is a family of the elderly people or a caregiver. The watcher can be a human or a machine. For example, the human watcher could be a mailperson. The watcher could also be a machine representing a system, which monitors elderly people by mean of sensors. Finally, the elderly person represents an abstracted elderly person who is indirectly monitored by a subject via a watcher.

3.2.2 Relationships between aging and health of the elderly

We assume that the relationships between aging and health for the elderly have a negative correlation. This concept is based on earlier researches [1],[20]. Kuwahara researched aging with the follow-up method [20]. He conducted a questionnaire survey of 16,432 aged 65 years or older in a city. Three years later he conducted the same questionnaire for the same area. He found that the ADL (Activities of Daily Living) had shifted from 80.8% to 77.2%. Also WHO showed that health level decreases as the population ages [1]. In this research, we build an elderly model based on the WHO statistic (see Section 3.3.2).

3.2.3 Elderly state model

Figure 3.2 shows a transition model of an elderly healthy state. Specifically, the elderly model has two kinds of states (normal, ill). The left of Fig 3.2, Q_0 (nor-

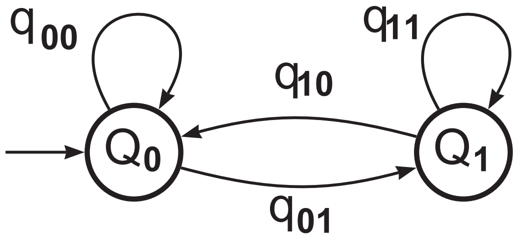


Fig. 3.2. Elderly state model

mal) shows that the elderly state is normal. On the other hand, Q_1 represents the elderly state as ill. In addition, if the elderly state is normal, which moves from a normal state to an ill state with the probability q_{01}. Moreover, the elderly state the similarly moves other states with the probability q_{00}, q_{10}, q_{11} depending on the current elderly state. In the following, we show the each of transition algorithms.

$$q_{01}(t) = \alpha + b * f(t) \tag{3.1}$$

$$f(t) = \ q_{01}(t-1) + \epsilon * (1 + \text{aging\_gradient}) * f(t-1) \tag{3.2}$$
$$(f(0) = 1,\ 0 \leq f(t) \leq 1)$$

First, we explain eq. (1). The left-hand q_{01} means the probability of transition. The elderly model moves from a normal state to an ill state with the probability of q_{01}. The right value α means the initial probability of transition. In addition, the α is $0 \leq \alpha \leq 1$. The α means the potential to become ill at the first time. The right-hand $b * f(t)$ means the aging function. Finally, the $\alpha + b * f(t)$ can be no more than one, because of the limitation of probability.

Based on the concept that we explained in Section **3.2.2**, we design the aging function if the model has aged, when the possibility of becoming ill has increased. In other words, this function represents the healthy level is decreasing as the population ages. The right value b means an aging parameter. If the b becomes increased, the elderly become worth. The right value $f(t)$ is the aging function which represents a decline of the health with aging. Besides this, the above function of the parameter t represents a timeline. The $f(t)$ is consists of ϵ and an aging_gradient, the former is a tuning parameter. In this simulation, we assume the long term as the simulation term, so if the parameter become too big, then the model tends to become a dead state which means the elderly model always becomes ill. To prevent such problems, we set the tuning parameter as ϵ which enables us to prevent the death state. Moreover, we set the parameter as *aging_gradient*, and this could set a trend of illness for the elderly model.

$$q_{10}(t) = \gamma - b * f(t) \ \ (0 \leq f(t) \leq 1, \ 0 \leq q_{10} \leq 1) \tag{3.3}$$

Next, we explain eq. (3). The left-hand q_{10} represents the probability of transition. Specifically, if the current elderly state is ill, then the elderly model transits the state of ill to normal at the probability q_{10}. In addition, if the elderly state is normal, which moves from a normal state to an ill state with the probability of q_{01}. In eqs. (2) and (3) we have similarly designed the elderly model so that the possibility of becoming normal is decreased if the elderly model has aged. Consequently, we design the probability, which represents the elderly state moving from ill to normal. The right value γ represents an initial probability of $0 \leq \gamma \leq 1$. Moreover, the $-b * f(t)$ is a function which means the decrease of a probability to move normally. It is the same function that we previously explained in eq. (2). While we design the aging that the possibility, to become normal is decreased, we define the probabilityq_{10} is decreased by $b * f(t)$.

$$q_{00}(t) = 1 - q_{01}(t) \ \ (0 \leq q_{00} \leq 1) \tag{3.4}$$

$$q_{11}(t) = 1 - q_{10}(t) \ \ (0 \leq q_{11} \leq 1) \tag{3.5}$$

Equation (4) and (5) represents the probability, which the elderly state stays the same states. We can calculate the probability of staying in the same state with the probability of transition (i.e. q_{01}, q_{10}). For example, in eq. (4), we can calculate the probability of the elderly model staying normal. In addition, the eq. (5) represents the probability the elderly model staying ill.

Algorithm 1 algorithm of watcher

```
1: periodicMonitor(t,accuracy,elderly_status)
2: if time.mod(t) == 0 then
3:     estimated_elderly_state = estimateElderlyState(accuracy)
4: end if
5: return estimated_elderly_state
```

3.2.4 Modeling of watcher

The watcher is an actor, which has to monitor the elderly. Specifically the watcher obtains the elderly condition with a monitoring sensor, and notifies the subject about the elderly state. In our model, we hypothesize that the watcher uses a motoring sensor. We also hypothesize that the watcher can estimate the elderly state using the data from the monitoring sensor. Based on the hypothesis, that the we define the watcher's Algorithm 1. In the following, we explain the algorithm. First, the watcher has an interface we call it periodicMonitor. The interface has an parameter t which means that how periodically the watcher monitors the elderly people.

Line number of 3, estimateEldelyState() is a function used to estimate the elderly state. Specifically, this function estimates whether the elderly state is normal or ill. In this paper, we assume that the watcher can estimate the elderly state by means of a sensor, which has some accuracy. Therefore, we do not care a technology that how the RMS sensor has implemented (e.g. using an IR sensor). We only focus on the accuracy of the sensor. In the estimateEldelyState(), the accuracy is a parameter which represents the accuracy of the monitoring sensor. In addition, the **accuracy** is $0 \leq \text{accuracy} \leq 1$. Let us consider an example, we assume that the accuracy = 0.85 would be if the watcher estimates the elderly state 100 times. Then, the result shows that the watcher detects 85 times with accuracy. On the other hand, the watcher fails to detect 15 times. Finally, if the watcher estimates the elderly people as ill, then the watcher notifies that the elderly state is that of ill subjects. Thus, we can actualize the role of the watcher in a simple way.

3.3 Simulation and evaluation: simulation of remote monitoring service

3.3.1 Abstract of simulation

Our research goal is to reveal how RMS sensor should be accurate. We developed the RMS simulator based on the model which we explained in Section 3.2.3. We also conduct simulations with five types of elderly model (A, B, C, D, E) and some types of RMS sensor accuracy. The five types of elderly models are based on the reports the relationship between aging and health in the world [19]. In the first simulation in Section 3.3.4, we confirm that as the model ages it becomes ill. The second simulation in Section 3.3.5 aims to reveal our research goal. In the third simulation in Section 3.3.6, we want to make the RMS sensor accurate enough to be a universal sensor which enables us to detect whether the elderly model is healthy or ill.

Moreover, we conduct a simulation by changing the RMS sensor accuracy so as to select the reliability that the user wants.

3.3.2 Condition of simulation

1. We set a simulation term as thirty years (i.e. 10,950 days) in every simulation. And model begin to simulate from 55 years old to 85 years old.
2. The number of trials for each simulation is 100. In addition, we use the average score as the simulation result.
3. The sensor incorrectly estimates regardless of elderly status.

In the following, we explain the settings of the simulation in detail. In this simulation, we define the status of monitoring as follows. Positive means "ill," negative means "healthy," true positive (TP) is when the system correctly detected ill days, true negative (TN) is when the system correctly detected healthy days, false positive (FP) is when the system failed to identify the healthy days, and false negative (FN) is when the system failed to identify the ill days. In our simulation, we use the frequency of the false positive (we describe this as ♯ FP). Because this issue

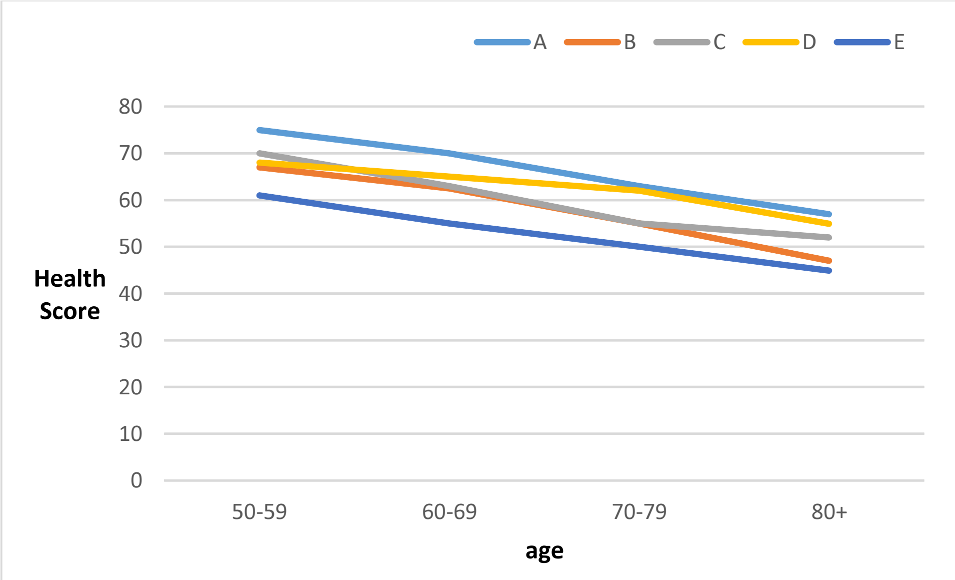


Fig. 3.3. Statistic data reported in [1]

is the most critical for the user, we want to confirm how the FP value changes with the aging model and the sensor accuracy. Specifically, if the accuracy were 0.9000 the simulation result would be that the remote monitoring service would detect with 90% reliability. For example, a fail means that the elderly state is ill, but the monitoring sensor detects it as normal. The first condition shows how to define a good remote monitoring sensor. Moreover, we calculate the power of remote monitoring service in each simulation. The second condition represents the term of simulation. We assume that in the simulation the elderly is monitored in four years. The third condition shows the number of trials. In each simulation we conduct some trials. The number of trials in the simulation is 100. Furthermore, we calculate the average detection power in the simulation. Finally, in this simulation the sensor estimates the fail ratio. The sensor does not behave differently with a difference in elderly status. Hence, if the sensor value is 0.7, then the RMS detects elderly with the 70% but nevertheless the elderly status is ill or normal.

3.3.3 Building of elderly model

In Section 3.2.2 the statistical data showed the relationship between aging and health status. In the following, we build some elderly models based on the data. Figure 3.3 shows the reported statistical data*1. The y-axis represents a healthy score; the higher the health score the more normal the elderly. The x-axis represents the age group which represents the specific range of age (e.g. from 80 years old to 85 years old). In this simulation, we are not interested im the difference among real countries, so we anonymize data as A, B, C, D and E. Model A represents the generalized model for some country. For example, the average score of people in country A is 75 when they are 50 to 59 years old. Moreover, A represents the most healthy model when people are around 50 years old (see Fig. 3.3). Using the data, we have the potential to create a more realistic model. In the following, we call A, B, C, D and E as the model which represents the generalized data for each country. For example, if we parameterize the E model, the model should be more ill than another model. This is because the E has the worst score in other countries. The parameter in Section 3.3 was defined according to the WHO data. Moreover, we conduct the simulation using the generated parameter, which enables us to simulate the approximate real situation. We set the elderly parameter as below.

- First we compute a regression analysis using the number shown in Fig. 3.3. Then we can obtain a coefficient (we call it aging gradient in Section 3.2.3) which represents how the elderly become worse (many or a few and so on.)
- We conduct some prepared simulations so as to decide the ϵ parameters which are described in Section 3.3.
- Set the health score A in 50-59 years as the base value $q_{01} = 0.95$ which is sufficiently high to avoid a death state. We then convert the relative value so as to set the default value of q_{10} and q_{01}.

3.3.4 Simulation 1: confirmation of elderly model

Abstract of simulation 1

Simulation 1 aims to confirm that as the elderly model ages, it becomes ill. The expected result is that we set the aging parameter b, to confirm that the elderly model might be sicker because of the aging parameter. We set the five types of b which are based on WHO statistics. The expected results are as below.

Table 3.1. Regression and empirical parameters

country	b	ϵ	q_{01}	q_{10}
A	0.701694915	0.00002711501	0.05	0.95
B	0.76779661	0.00002460707	0.151333333	0.848666667
C	0.666101695	0.00002518301	0.113333333	0.886666667
D	0.470847458	0.00003410494	0.138666667	0.861333333
E	0.616610169	0.00003420245	0.227333333	0.772666667

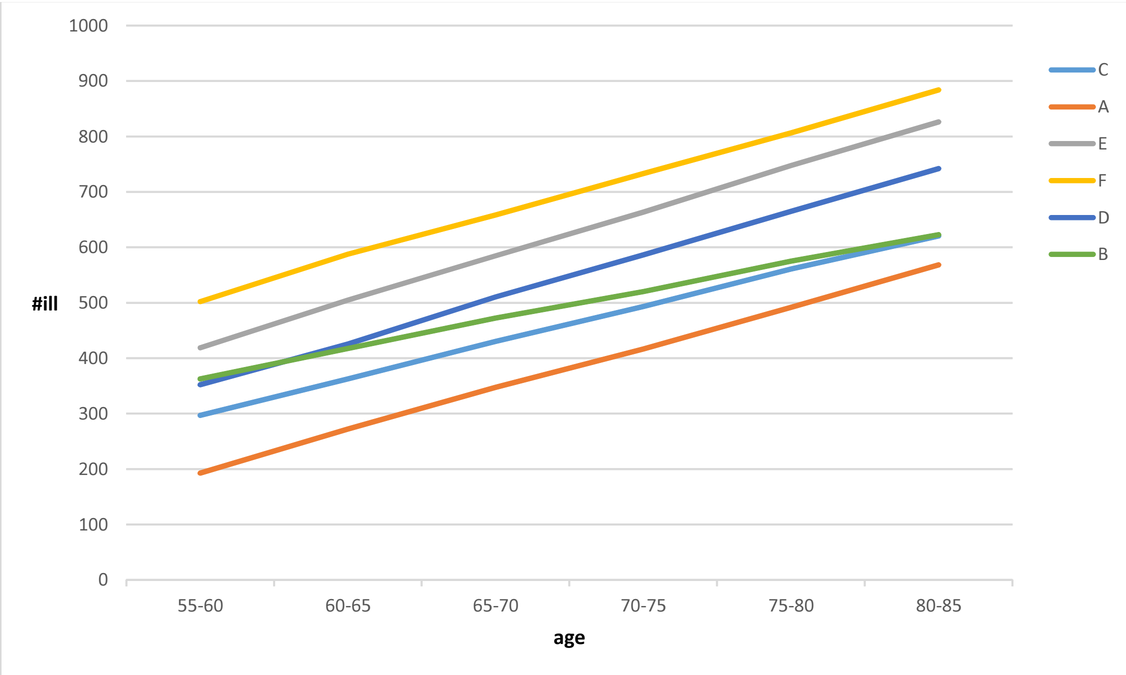


Fig. 3.4. Relationships between aging and number of illness

Confirm point1 E has the lowest healthy score in the models, so model E would be worse than others

Confirm point2 A is the most healthy model, because the table shows that model A has the best health score compared with other countries.

Confirm point3 As all models age, they become worse.

Result of simulation 1

Figure 3.3 shows the result of the simulation. The x-axis represents the age of the model whose term is periodically separated in five years, and the y-axis represents the frequency of illness. The frequency of illness represents how the elderly model becomes ill in the simulation terms (i.e. 10days, 5years). For example, if the elderly model becomes ill three times in the seven-day simulation then the frequency of illness = 3. Hence, if the y-axis becomes higher, then the model becomes worse. For example, model E has the worst (highest) score for becoming ill (confirm point 1). On the other hand, model A has the best (lowest) score for becoming ill (confirm point 2). Likewise, we confirmed that the all elderly model has become aging, then the model become ill. Hence, we can confirm that the elderly model become sicker as the model is aging. In addition to this, model C is more healthy than model B when the models are 55 to 60 years old. But when the models are 80 to 85 years old, then C is more sickly than B. This is because the parameter b for C is bigger than that of B. The parameter increases to become ill for the models. In Fig. 3.4, we can confirm that each type of model has become ill as the model ages (confirm point 3).

3.3.5 Simulation 2: relationship between the RMS sensor accuracy and FP

Abstract of simulation 2

In this simulation, the goal is to reveal the relationship between the monitoring sensor accuracy and the elderly model. We conduct the simulation with the five types of elderly model. Moreover, we define the accuracy of remote monitoring service as the frequency of false positive detection (FP value). Of course, for the RMS end-user the sensor accuracy would be as high as possible, but sometimes it may cause difficulty for some reason (e.g. cost, limitations of provider). So in this simulation we aim to show the relationship of sensor accuracy and RMS reliability. We think of the RMS reliability as FP value, because this value directly represents RMS accuracy.

step2-1 Conduct the simulation for the five types of elderly model by incre-

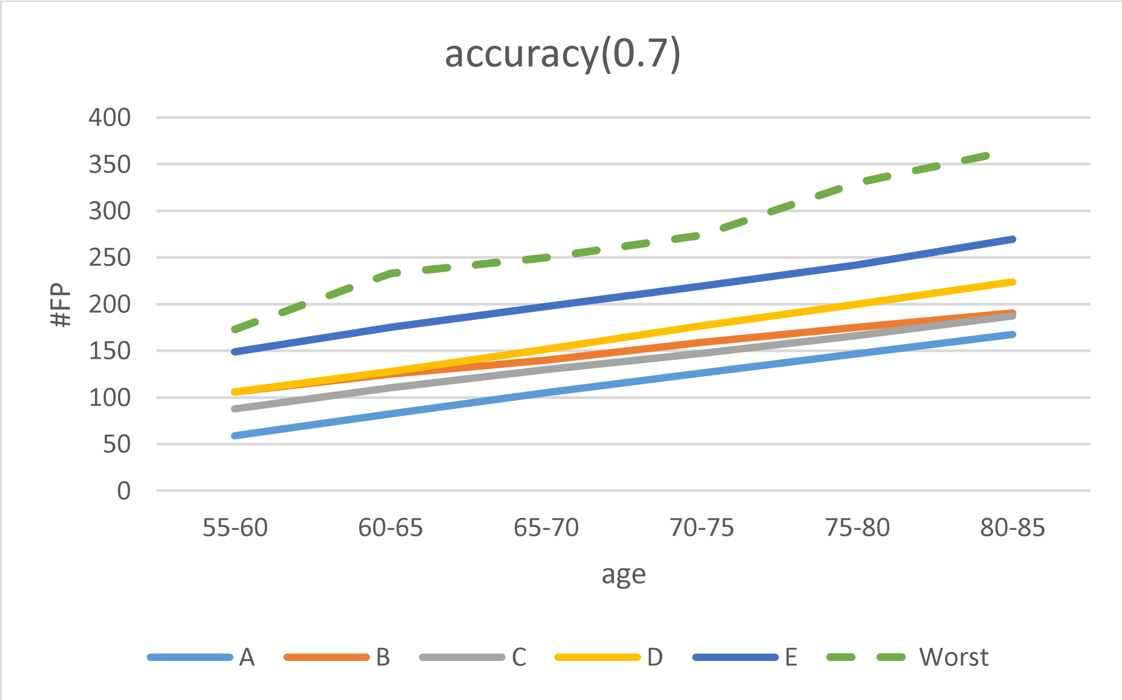


Fig. 3.5. Result of Simulation 2: set the sensor accuracy 0.7

menting the sensor accuracy from 0.700 to 0.999.

step2-2 Using result of step2-1. Confirm the relationship with sensor accuracy and FP value.sing result of step2-1. Confirm the relationship with sensor accuracy and FP value.

step2-3 Count the FP value every 5 years. We count up from 70 years old to 75 years old (Following we note it as 70-75).

Result of simulation 2

Figs. 3.5, 3.6, 3.7, and 3.8 show the results for Simulation 2. The x-axis represents the model of age and the y-axis the frequency of false positive (FP) in the simulation. Moreover, we show the worst FP value for comparison. From the simulation result, we focus on the models A and E; the latter is that most correctly detected with a sensor, and the other is that most incorrectly detected with the sensor. In Fig.3.5, when the sensor accuracy is set as 0.7, the FP for model E whose age is 55 years to 60 years is about 150 times. On the other hand, FP for model A (55-60) is only about 50. When the sensor accuracy is set as 0.95 (see

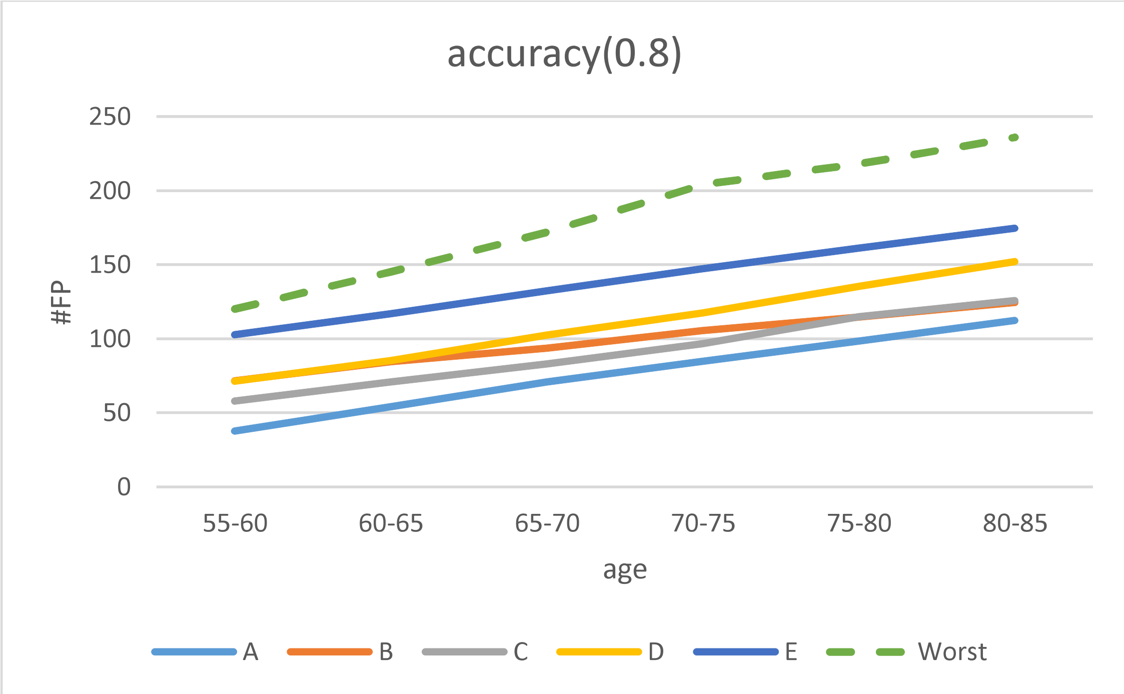


Fig. 3.6. Result of Simulation 2: set the sensor accuracy 0.8

Fig. 3.8), then the FP for model E is only 25. Next, we confirm the FP for ages 80 to 85. When we set the accuracy as 0.7, then the FP for model E is greater than 250 times in five years (see Fig.3.5). When accuracy is 0.95, then the FP for model E is less than 45 times in five years (see Fig.3.8). So, based on the result of simulation 2, we can confirm that the frequency of FP is influenced by how the elderly model becomes ill.

3.3.6 Simulation 3: how sensor should be accurate for the universal?

Introduction of simulation 3

This simulation aims to reveal how the sensor accuracy is required which has little sensitivity to the difference of elderly model. So any user can use the we call it universal in this section. Our approach is to increase the RMS accuracy from 0.900 to 0.999. And we confirm with the most aged term 80 years old to 85 years old which the models become sicker. And we confirm both the sensor accuracy for elderly and effect the most aged period from 80 years to 85 years old. Because the most aged model becomes sicker than other generations it needs to be monitored with high accuracy.

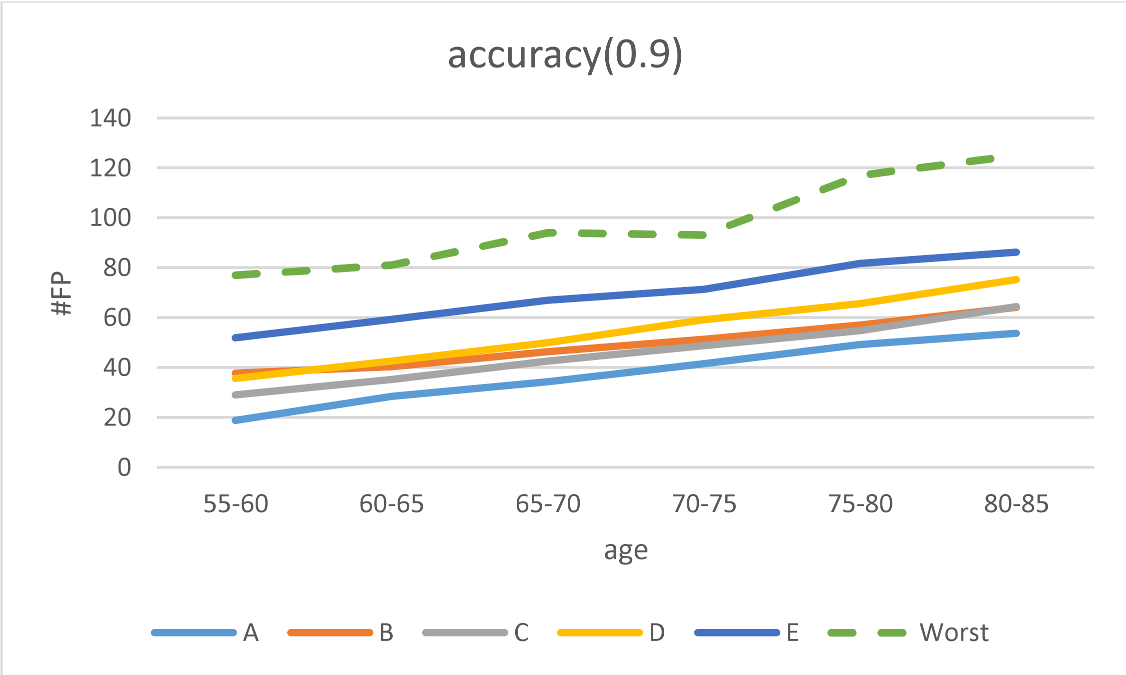


Fig. 3.7. Result of Simulation 2: set the sensor accuracy 0.9

Result of simulation 3

Figure 3.9 shows the result of the simulation. The x-axis shows the accuracy of the RMS sensor and y-axis means FP value. If we set the sensor accuracy as 0.900, the FP value of E is bigger than that of A. However, if we set the sensor as 0.990 and 0.999, then there is little difference for FP value among all models. So in this simulation, if the sensor is 0.990 or more, then the ♯ FP is approximately the same (i.e. A: 0.525, B: 0.633, C: 0.475, D: 0.740, E: 1.000). Hence, when the user wants to keep the FP value under one, s/he should select the sensor whose accuracy is 0.999 or more. We could confirm the guideline that enables how a sensor should be accurate so as to guard the increasing of FP value.

3.4 Discussion

3.4.1 Guideline for selecting RMS

Based on the result of Sections 3.3.5 and 3.3.6, we discuss how to select the RMS for the user. For example, thinking about model A, which is the healthy model, although the sensor accuracy changes from 0.7 to 0.8, there is little difference

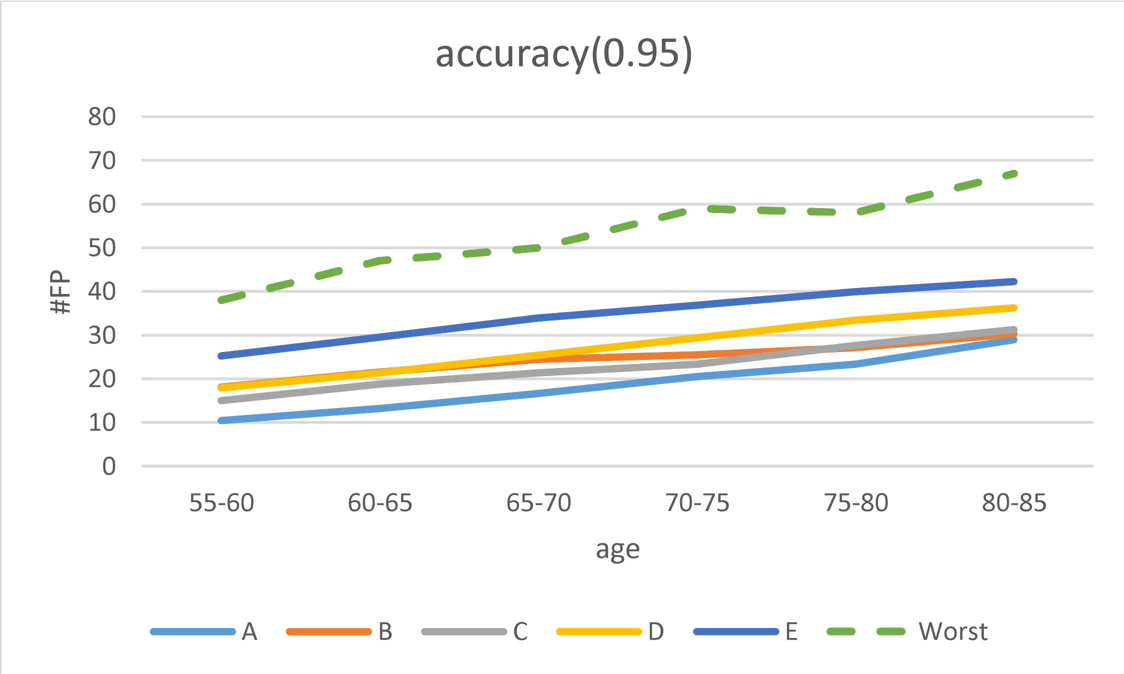


Fig. 3.8. Result of Simulation 2: set the sensor accuracy 0.95

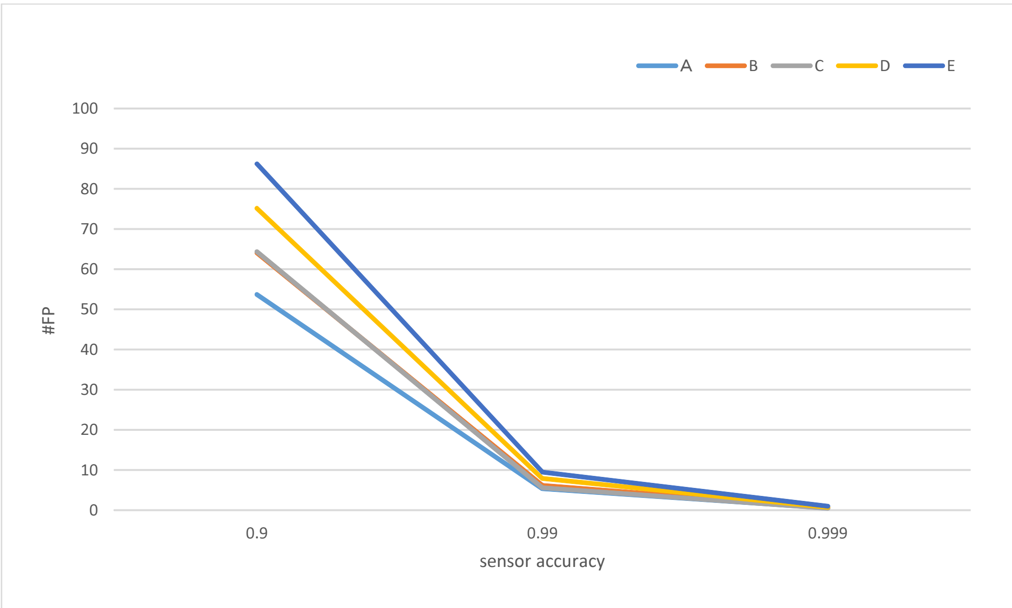
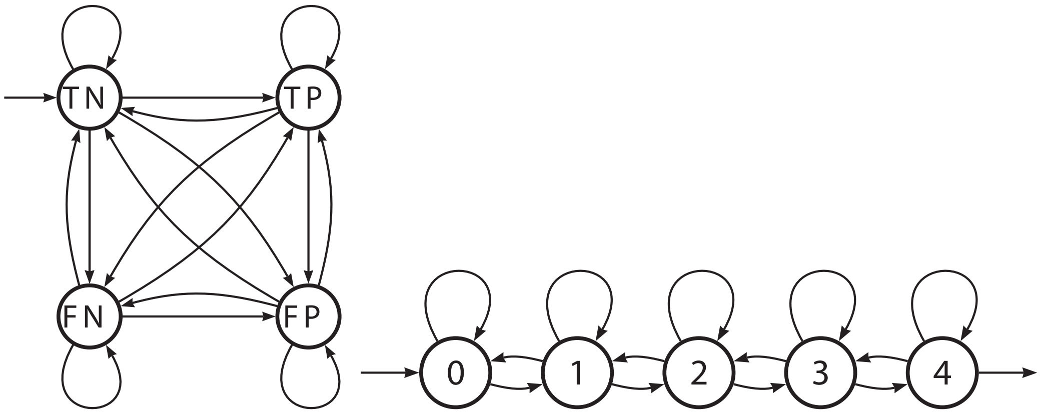


Fig. 3.9. Result of simulation 3: How should sensor accurate to decrease the difference of model

in FP. Hence, if the user wants to monitor some healthy elderly and comparing RMS which have not so high accuracy, then the user may decide with other points (e.g. operational cost). On the other hand, for the model which was worse, the simulation result showed that if the sensor accuracy is not so high, then the FP



(a) 4state model (considering the disease process)

(b) 5state model (considering the staging process)

Fig. 3.10. Examples of Extended State Machines

becomes bigger (see Figs. 3.5 and 3.6). Finally, we introduce an application example. For instance, when the user wants remote monitoring of healthy elderly people of 75 years old for five years, then, based on our simulation result, if the user selects the RMS which has 90% accuracy, then the FP is at most 50. So this guideline enables the user to select the RMS. For instance, consider the case when the user has to monitor many people at once (e.g. in a daycare facility). In this case, the user will decrease the FP value as much as possible because some people often become ill, but others do not. If the user selects sensor 0.999 that will help the user to keep FP value under one.

3.4.2 Extension of state model

In this paper, we have conducted a simulation to reveal the relationship between sensor accuracy and RMS. This simulation was conducted with a simple elderly model with two states, health or illness. The simulation result shows the user how at least the accuracy is required that enables to need the reliability. However, the real RMS for the elderly has a dynamic severity which depends on the progressive course of the disease. We have to consider the transition probability to the severity disease by taking into account the disease process. For example, when the RMS sensor estimates the status of the patient who is in hospital for a long time, it may estimate the patient is healthy, and that judgment may be either true negative (TN) or false positive (FP). However, thinking the hypothesis the RMS sensor estimates based on his/her disease process. FP means that the patient has the capture a sign of the disease. So, the patient estimated as FP has the much high probability than that of being estimated as TN. Hence, when the RMS sensor estimates are based on the above disease process, then also transition probability has to take into account the disease process, too. That simulation would be more realistic. We show the extended four-state model which enables every TN, FN, TP and FP to affect response to transition probability (see Fig. 3.10(a)).

In addition to this, our simulation adopts the two-state model which simulates the elderly's health status (ill or normal). However, if the model has more states than two, it may have the potential to simulate more. Using such a model, we can change sensor accuracy based on the progressive course of the disease. Figure 3.10(b) shows an example of a five-state model which represents the progression of cancer. For example, if we consider modeling the cancer patient, then the model would have five states. The zero state, which is called staging in medical terms, represents mild symptoms, and the four state means severe symptoms. Then we have to simulate increasing the sensor accuracy if the patient's state worsens. Also, it may be possible not only simply increasing sensor accuracy also which depends on the patient's context. If the patient state transits from a more mild state such as 3 to 2. Then the RMS judge that the patient need to monitor with high accuracy because the patient need to monitor severe symptoms so as not to be severe.

However, considering simulation which has the probability depended on the elderly's status, then we have to quantity numerous influence. We have no way to quantify the numerous effects that RMS has in reality, so our future work will be to quantify the real influences, which will enable us to provide a simulation which has a similarity to the real world.

3.5 Summary

In this paper, we have revealed the relationship between sensor accuracy and reliability of RMS. Our research has focused on modeling and simulating a remote monitoring service for the elderly. Specifically, we have proposed a three-step methods: generalization by a three-actor model, designing algorithms of the elderly and a watcher and developing the elderly model based on WHO statistical data. Finally, we conducted several simulations. The simulation result shows the relationship between sensor accuracy and the elderly models. Moreover, we discuss an RMS guideline based on the results. We hope our simulation result will assist RMS users and providers.

Chapter 4

Interactive Memory-Aid Agent Service for People with Dementia

4.1 Introduction

Dementia is a general term used to describe a group of symptoms that impair human memory, communication, and thinking. According to a report in 2015 [21], 46.8 million people are now suffering from dementia all over the world. Thus, home care for people with dementia is essential, in order to ensure the quality of life of the patient. However, sometimes home care can be a burden to the family or caregivers in a specific context [22]. Hence, there is a strong need for assistive technologies that can support the independence of patients and decrease the burden on caregivers.

A reminder system is an assistive technology designed to support people with dementia. In general, the system provides information that reminds a patient of something in his/her life. Bourgeois [10] published a 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 currently a hot topic. The COGKNOW project [11] exploited ICT for home care of dementia sufferers. 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. medical appointments, meeting someone, etc.). Hallberg and colleagues [12] showed the viability of reminiscences with multimedia. They implemented a semi-automated tool to remind patients of their former good days using pictures and videos. They also implemented a media-rich lifelog tool to record and review patients' on-going life. These tools aim to increase the patient's will to live by showing past events and encouraging good reminiscences.

Although there are a number of reminder systems, we have found that they 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.

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

Problem P2 reflects the fact that most existing reminder systems provide mechanical reactions only, which include text, voice message, pictures, and email. The mechanical reactions can sometimes breach the dignity of the patient, and decrease the motivation to use the system.

Problem P3 is that the existing reminder systems do not allow users to modify dynamically what and how to recall. A typical system has a fixed set of predetermined events to schedule, and all of the personalization must be done in the design time of the system. However, individual patients have different levels of dementia. Also, symptoms and daily habits chang as time passes. Therefore, it is essential for the caregivers to personalize dynamically what and how to recall, according to 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 with the new reminder service. First, we exploit an indoor positioning system based on BLE (Blue-tooth Low Energy) technology [23]. 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 [24] for the sympathetic interactions. The virtual agent is an animated chat-bot program with speech recognition and synthesis technologies. A user operates the system via the agent on a screen, as if the user is talking 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 redesign and deploy the above systems as services with RESTful Web API: Location Service, Agent Service, and Schedule Service. These services are integrated by a Coordinator Service based on 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 ways 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 for a destination and recalls personal belongings based on the destination. The service is useful for preventing the patient from forgetting essential items for the activity. We also conduct a preliminary evaluation to confirm the usability and practical utility of the Agent Service which is the main component of Memory-PAL. In the preliminary experiment, we confirm the usability and practical utility of the Agent Service. Moreover, we discuss how to provide for a safer and smarter society with our proposed service.

4.2 Preliminaries

4.2.1 Dementia

Dementia usually begins with mild anterograde amnesia and often involves a variety of behavioral disturbances such as wandering and agitation [1]. 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 people with dementia, the care by caregivers or families is important. In reality, however, such care is often a burden because of the specific features of dementia, including BPSD (behavioral and psychological symptoms of dementia), aggressiveness, wandering, and sleep disturbance [2]. Indeed, it is not easy for families to delegate care to professional caregivers. Hence, there are many cases where families have been burned out by having to provide home care. In this situation, assistive technology is a promising solution, whereby technologies are introduced to assist people with dementia and their circle.

4.2.2 Reminder system

A reminder system is an assistive technology for people with dementia. The system basically provides information that *reminds* a patient of something in daily life. It includes showing a routine, taking prescribed medicine, showing a schedule, notifying of appointments, etc. A variety of reminder systems has been proposed so far. The memory book [10], the COGKNOW project [11] and the reminiscences with multimedia [12] introduced in Section 4.1 are instances of the reminder system. There are many other systems and tools, such as memory diaries, bell timers, and alarm clocks [13]. Yasuda and colleagues [14] 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 his/her psychological stability. However, as far as we know, there is no such existing reminder system tthat can cope with Problems P1, P2 and P3 described in Section 4.1. This is the motivation for this research.

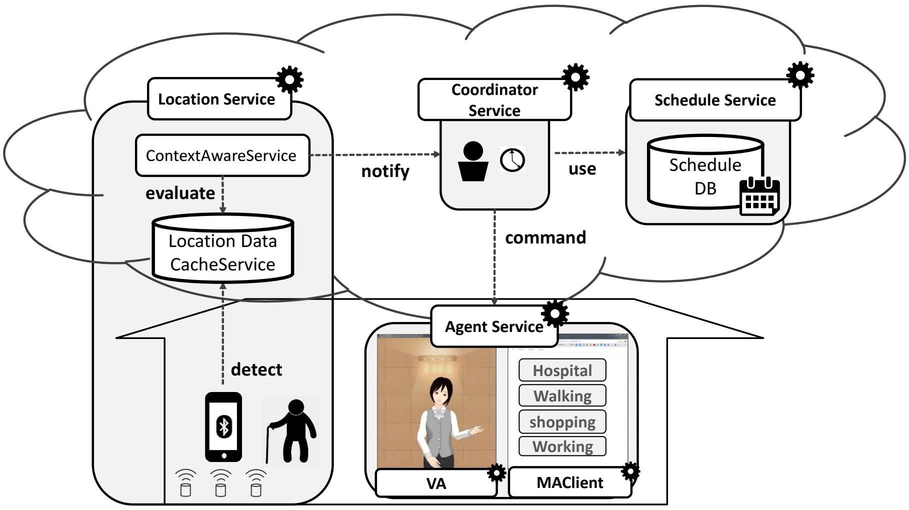


Fig. 4.1. Service Architecture of Memory-PAL

4.2.3 Indoor positioning system

The *indoor positioning system (IPS)* locates and tracks objects within indoor space (inside buildings, underground, etc.), where the 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 [23]*, using 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*, meaning 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 in a care facility. The location information strongly reflects the current activity and context of the patient. Therefore, we try to use BluePin to address Problem P1 in this paper.

4.2.4 Virtual agent system

The *virtual agent* (VA) is a human-looking animated chatbot program that can communicate with a human user via voice [25]. There are a few studies that adopt

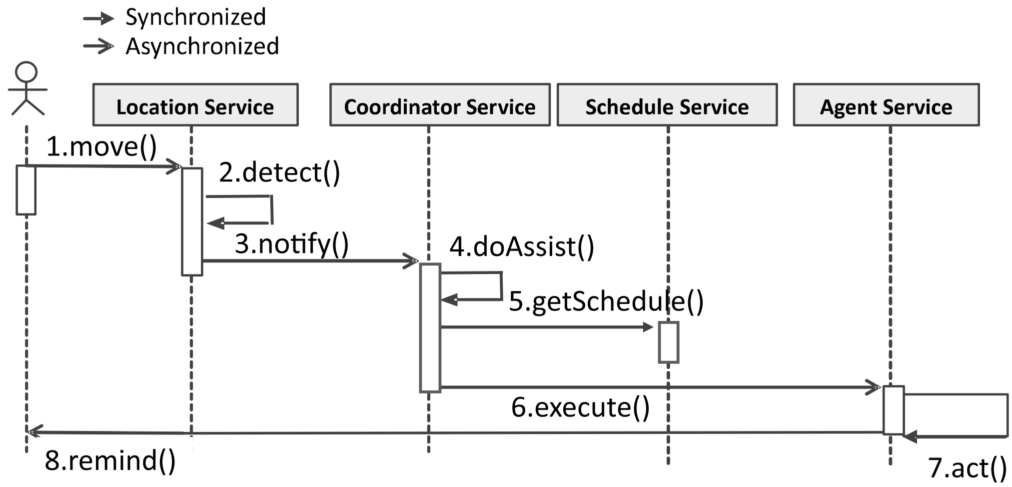


Fig. 4.2. Sequence of reminder service by Memory-PAL

the VA for dementia care. Yasuda and colleagues developed a system where a VA serves as a conversation partner of people with dementia [26].

Our research group has developed a system which exploits a VA as user interface of the home network system (HNS) [24]. When a user says "Turn on the 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 repeats various information obtained from the HNS and the Internet.

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

4.2.5 Goal and scope of paper

Our goal is to construct a new reminder service, called Memory-PAL (Memoryaid 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 the essential components. Although we develop a prototype system, detailed implementation and evaluation with actual subjects will be left for future work.

4.3 Memory-PAL: a new reminder service

4.3.1 System architecture

In order to achieve the goal, we need to integrate heterogeneous and distributed systems. Therefore, applying 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 4.1 shows the system architecture of MemoryPAL. We can see that the system consists of four services: *Location Service*, *Schedule Service* and *Coordinator Service*.

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 pre-determined 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 reminders.

The Coordinator and Schedule Services are deployed on the cloud. The Agent Service is deployed at home. The Location Service ranges over the home and cloud.

In the following, we explain the sequence of the reminder service using Memory-PAL. Figure 4.2 shows the whole sequence of integrating and providing the reminder service using Memory-PAL. First the user goes from the living room to an entrance, then the Location Service detects the change of current user’s position Hence, the BLE-based positioning service provides the context where the current user is. Then the Location Service notifies the Coordinator Service that the user is near the entrance. Then the Coordinator Service works with its primary function *doAssist()*. As the next step, the Coordinator Service gets the user’s schedule with Schedule Service, and then tells the Agent Service with function *execute()* to play some roles. Finally, the Agent Service reminds the patient of his/her daily schedule, etc.

4.3.2 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 4.2.3). We assume that a patient carries a smartphone with BLE and that BLE beacon modules are deployed in 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 Fig. 4.1. This service stores the location label for a certain time period. BluePin watches the location label in the cache. When the location of the patient changes, BluePin emits a pre-determined event associated with 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, h `http://memory-pal/location?userId=tokunaga` returns the current location label of user "tokunaga."

4.3.3 Schedule Service

Schedule Service conducts the schedule management for people with dementia. A caregiver (or even a patient) registers daily events and belongings with the reminder. To achieve personalized reminders, we have designed a schedule database (called ScheduleDB, for short), which manages personal schedules and belongings. Figure 4.3 shows an ER diagram representing the data schema of ScheduleDB. The diagram follows the notation defined in [27]. A square represents a table (i.e. an entity). A relationship may be defined between a pair of entities.

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

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 to 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 the 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 with 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 that the user tokunaga goes to a daycare service 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 the user' s schedules. We implemented Scheduler Service as RESTful web service. For instance, GET `http://memory-pal/schedule?userid=tokunaga&date=2016-01-15` , returns a schedule of user "tokunaga" on the date "2016-01-15." The returned schedule contains all the associated information. The query specifies variables of userid and datetime.

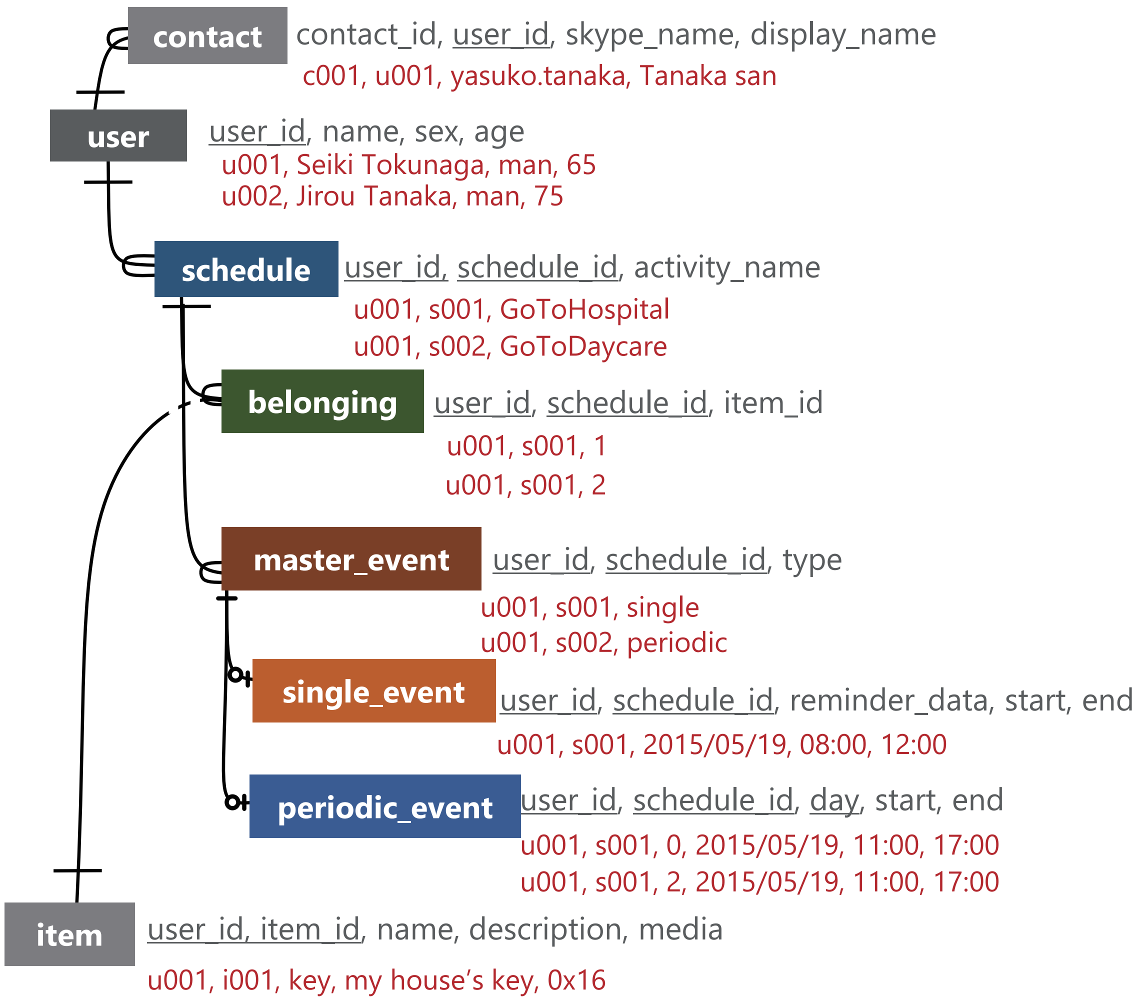


Fig. 4.3. Data scheme of scheduleDB

4.3.4 Agent Service

Agent Service provides human-computer interactions for people with dementia. It consists of two kinds of user interfaces. One is Virtual Agent (VA) and the other is Memory Aid Client (MAClient). The VA is a human-like 3D chatbot program (see the bottom of Fig. 4.1). Using the speech-to-text and text-tospeech 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) like a human being. Our research group has been developing a service-oriented virtual agent using MMDagent toolkit [24]. So, we extensively reuse it for 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,

```
{
    "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. 4.4. Operation format of coordinator

invoking some actions associated with the state transition. The actions include say(), motion(), recognize(), execWebService(). The detailed information can be seen in [24]. Memory-Aid Client (MAClient) visualizes reminder information in a screen, and provides a 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 VA with visualized information. The API is also implemented as a RESTful Web service, so that various client applications can use the service easily.

4.3.5 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 Fig. 4.1, 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, noting that the user is at L. When notified, the Coordinator Service obtains the 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 4.4 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 specify the agent's motion and speech in the value of "agent." They also 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 screen, since a state of the Agent Service corresponds to a screen displayed.

The Coordinator Service implements the location-aware and personalized reminder service with the algorithm doAssist(s, L, t) shown in Algorithm 2. As regards 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.

4.4 Implementation: reminder at entrance

We have developed a prototype system of MemoryPAL based on the proposed design. 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

Algorithm 2 doAssist(s: Screen_Id, L: Location, t:Time)

$operationFormat = AgentService.getAgentFormat(s)$

$schedule = ScheduleService.getSchedule(userID, t)$

$operation = generateOperation(L, schedule, operationFormat)$

$AgentService.execute(operation)$

about to leave home from the entrance, a virtual agent first asks for the 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 4.5 shows a sequence of state transitions executed by Agent Service, where the VA and the MAClient interact with the user. Initially, Agent Service is in 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 USEROUTGO. Next, according to Algorithm 1 (see Section 4.3.5), Coordinator Service triggers doAssist(S001, USEROUTGO, 2016-04-12T10:30:40).

In doAssist(), Coordinator Service first obtains an operation format available at S001 from Agent Service. Then, it loads the user's schedule from Schedule Service with user ID and the current time 2016-04-12T10:30:40. Now the hospital 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 the 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) 10 seconds after. Then, Agent Service notifies Coordinator Service of an event HOSPITAL, and Coordinator Service executes doAssist(S002, HOSPITAL, 2016-04-12T10:30:50). Similarly to the previous state transition, Coordinator Service now commands Agent Service to make a reminder of belongings that must be carried 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 is 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 the 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.).

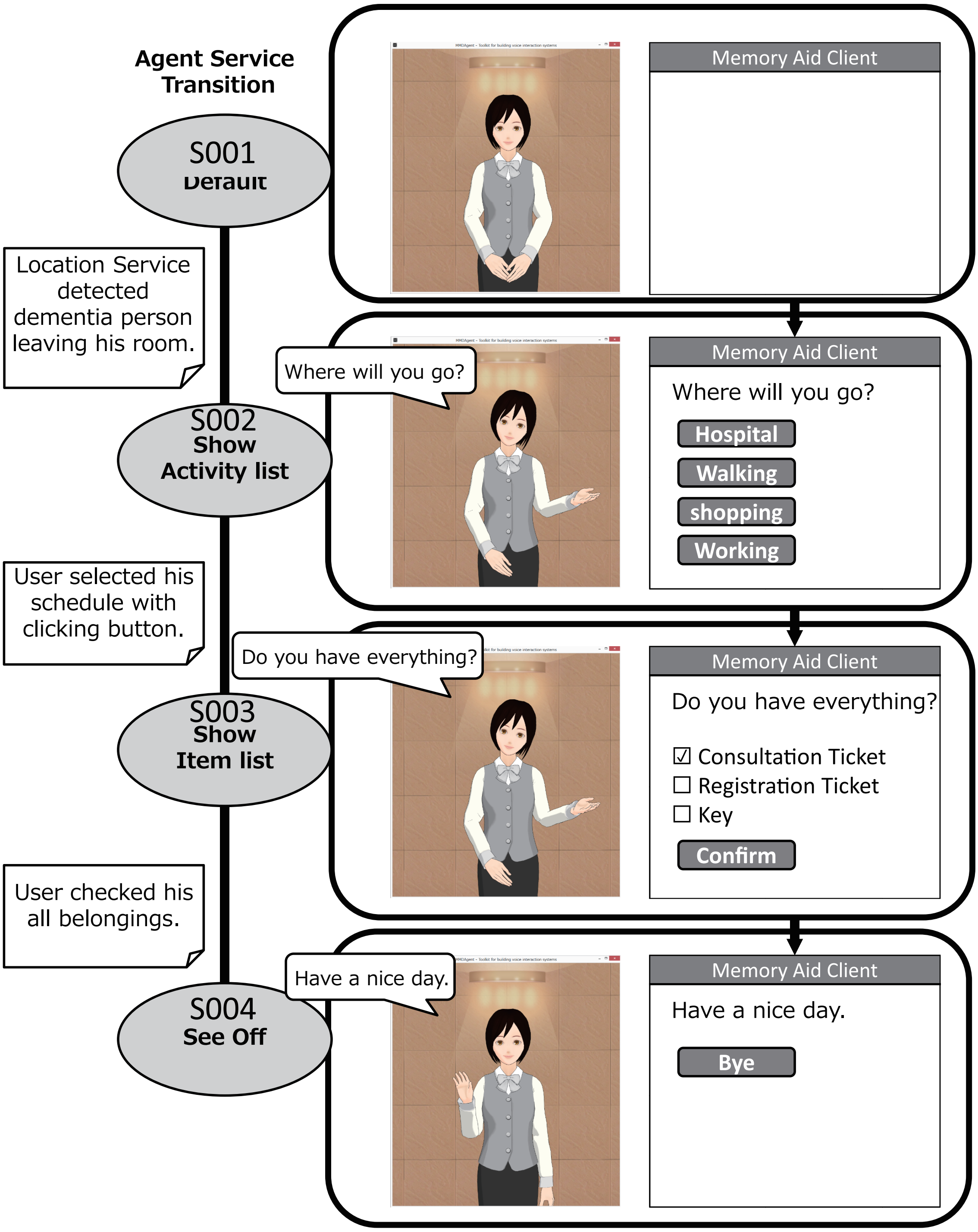


Fig. 4.5. Sequence of agent service

4.5 Discussion

4.5.1 Experimental evaluation

In this section, we explain the experiment evaluation in order to confirm the system' s feasibility and usability. We conducted the experiment at Chiba Rosai Hos-

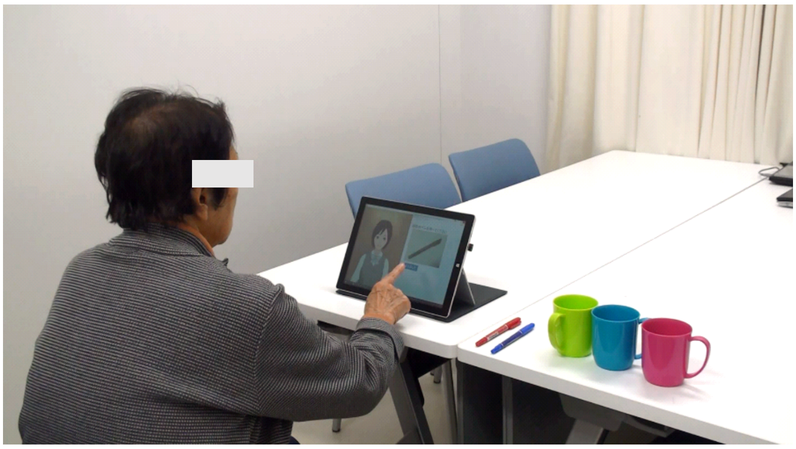


Fig. 4.6. Scene of experiment

pital. The goal of the evaluation was to confirm that the patients could interact with the Agent Service using some interactions (e.g. voice, touch). In particular, we have confirmed the interaction and reactions after the patient used the Agent Service. Moreover, we show the validity of the possibilities of the adoption of with considering the result of each interface. Seventeen patients participated in the experiment. The age range was 46 to 84. In the experiment five men participated and the others were women. The MMSE score for the subjects ranged from 15 to 29 [28].

4.5.2 Experimental environment

We conducted the experiment at the Rosai hospital. The five participants comprised a patient, a caregiver, a recorder, an adjuvant and a system administrator. Section 4.6 describes the experimental scene. We deployed the Agent Service with Surface Pro 3 which has a touch panel and a built-in mic. The tablet was connected to the system administrator' s device using Wireless LAN. The system administrator controls the Agent Service and ensures that the operation Agent Service has started. The patient interacts with Agent Service in front of the t. Among the interactions, the observer conducts the help for the operation and instruction of the subjects. The recorder records each experimental scene with a video camera.

Table 4.1. Result of experiment

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	F	84	27	3	4	4	4	4
7	M	68	29	4	4	5	4	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	4	4
11	F	80	15	5	3	5	4	5
12	F	71	24	5	3	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

4.5.3 Experiment description

We have explained the features of Agent Service, that provides four components for the VA and MAClient. Using Agent Service, we expect the subjects would feel useful to people with dementia. However, we have not confirmed that people with dementia can interact with Agent Service. In order to validate the evidence, we conduct an experimental evaluation. In the experiment, we focus on the following five points to confirm the feasibility and usability of Agent Service for patients.

Q1: Can the subjects listen to what the VA says? Q1 aims to check that both voice volume and quality has feasibility to dialogue for the subjects.

In particular, we confirm that the subjects can listen to what the agent says.
Q2: Can the VA system recognize what the subject says? This question aims to validate that the VA system can recognize what the subjects say. We judge that the voice recognition system have the feasibility for the what the dementia says.
Q3: Does the interface of Agent Service have an appropriate design? Q3 aims to judge that the Agent Service has an appropriate design to display the contents to remind patients (e.g. display his/her schedules, belongings).
Q4: Can the subjects control the MAClient using touch panel? Q4 aims to confirm that the dementia patient can control the MAClient using touch screen. The proposed system provides two kinds of system input such as control with voice and touch input.
Q5: Are the contents of MAClient effective for the memory aids? Q5 aims to verify whether the contents of MAClient help patients to understand what the agent says and input assistance. The MAClient displays the contents which are expected to remind the subjects (such as Registration Cards, house key). We have seen that showing the above items with images is comprehensible by subjects.

4.5.4 Settings of experiment

In the following, we show the scenario that we have used. These scenarios are intended to answer Q1 to Q5.

Preliminary scenario This scenario aims to evaluate Q1 and Q2 through simple dialogue with agents. We confirm that the subjects could have a voice dialogue with an agent after the dialogue.
Screen Touch scenario This scenario checks Q3 and Q4 using simple interaction with the agent. After the subjects have dialogue with the touch screen of MAClient, they can recognize and touch the button.
Check belongings scenario This scenario checks Q5 that has evaluated as the interaction with check list. This scenario is used to confirm that when

the subjects go out, then the MAClient displays his/her belongings based on the destination. (a) represents the checkbox that the user has to have.

Understanding instruction scenario

This scenario aims to check Q5. Specifically, we confirm whether showing some images on the screen of MAClient was helpful for understanding the instruction given by the agent. In the experiment, subjects move a cup or pen on the instruction of the agent. We compare the case that displays images on the screen or not.

Moreover we collected a questionnaire from the caregiver who observed the experiment and scored each evaluation item.

- Q.1 Could the subject recognize the agent? Can he/she talk to the agent?
- Q.2 Could the subject control the MAClient with a touch screen?
- Q.3 Could the subject understand what the agent says?
- Q.4 Could the subject understand the instruction of the agent?
- Q.5 Could the subject offer a response to the instruction of the agent?

4.5.5 Discussion

All the subjects*1 completed the scenario which we have described. Table 4.1 shows the experiment result. The head of table Q.x corresponds to the above evaluation items. We also calculate the coefficient of correlation for each result. In this experiment, we used Spearman rank correlation because we could not assume that the scores would follow a normal distribution: 4.2. * and ** represent the significance level, hence * is the 5

Result of Q1: We received feedback that the speed of speaking is fast. Table 4.2 shows that the result of Q.3 is about 4.2 points. We concluded that most subjects understand what the agent says. We think that this result comes from MAClient performs complementary when the subjects miss what the agent says. Table 4.2 shows that correlation of Q.3 and MMSE is 0.19. Next, we found that there is almost no correlation between understanding

Table 4.2. Result of experiment: spearman rank correlation matrix

	Age	MMSE	Q.1	Q.2	Q.3	Q.4
MMSE	-0.29					
Q1	-0.32	-0.07				
Q2	-0.22	0.39	0.25			
Q3	-0.42	0.19	0.62**	0.79**		
Q4	-0.43	0.29	0.22	0.66**	0.79**	
Q5	-0.21	0.12	0.56*	0.73**	0.85**	0.60*

of dialogue with agent and
*1 we helped some subjects when they could not recognize the instruction of the agent MMSE. This is because the understanding of dialogue relates to individual body condition, which means some subjects have weak hearing. Hence, we have to adjust the agent' s voice based on the individual body condition.

Result of Q2: All of the subjects could recognize the agent and they could hold a dialogue with the agent during the experiment. However, the voice recognition system can recognize some subjects' speech input voice only. Also, the system could not recognize the voice input the first time. The system could recognize the voice input when the subjects spoke twice or more. After the preliminary scenario, subjects alternatively used the touch interface as the dialogue interface. Although they spoke to the system when the fail of recognition causes no response, they looked uneasy. The main reason for the low accuracy of recognition is that a built-in microphone could not pick up the subject' s voice. To improve the accuracy of voice recognition, we need to use a directional microphone instead of a built-in microphone.

Result of Q3: All the subjects could recognize the message and button on the screen of Agent Service. But some subjects felt the contents on the screen were small. We think that the above problems can be resolved by resizing the contents on the screen. We also have to adapt the personalized contents size on the screen to the individual. Some subjects could not recognize the button on the screen, and they tended to look for it off the screen. This is because they were unfamiliar with software buttons on the screen. Hence, we would like to design the button to look like an actual physical button. Moreover, we gathered from a caregiver that if the button has a sound effect, then it would be better. Result of Q4: Table 4.1 Q2. The majority of subjects have a lot of trouble pushing the button on the screen. Sometimes they push the button too hard causing failure to recognize. But most subjects became familiar with touch during the experiment, so they could touch the button on the screen to have a dialogue with the agent. Table 4.2 shows that the correlation coefficient between Q.2 and MMSE is 0.39. This shows that we could not find a significant correlation between them. In addition to this, some subjects who usually use a smartphone touched the button on the screen without difficulty. Hence, we have confirmed that whether the subjects could use the contents on the screen strongly depends on being familiar with a smartphone or tablet.

Result of Q4: The table 4.1 Q2. the major of subjects have a lot of trouble to push the button on the screen. Sometimes they push the button too strong, That causes the fail to recognize as the touch event on the device. But most subjects could become familiar with touch sense during the experiment. So they could touch the button on the screen to dialogue with the agent. Table 4.2 shows that the correlation coefficient between Q.2 and MMSE is 0.39. Above result shows that we could not indicate a significant correlation between them. In addition to this, some subjects who usually use smartphone touched the button on the screen without difficulty. Hence, we have confirmed that whether the subjects could use the contents on the screen strongly depends on that they are familiar with smartphone or tablet.

Result of Q5:

We have confirmed that showing the images enabled subjects to understand the objects (e.g. cup, medicine). In another case, the agent instructed subjects to move the objects without showing the pictures. As the result of the experiment, we have confirmed that almost all subjects could move the object accurately. One subject failed to move the object because he was distracted by VA. He moved objects without making sure what they were. In order to prevent this, the VA should point to the target of the picture on the screen. Moreover, we have confirmed that three subjects look baffled when the agent instructs without showing pictures of objects. We also gathered that instruction with the pictures was easier to understand than without the pictures. Based on the results, we have concluded that instruction with images is useful for the subjects. We have confirmed the subjects go out. In this scenario, the subjects could understand the experiment situation, but they could not touch the check list for two reasons: one is the lack of instruction by the agent and the other is lack of familiarity with general web user-interface (UI) The lack of instruction is that the agent only says “please confirm the belongings” and hence the subjects do not know what to do next. So, the agent needs to say “please confirm the belongings and also check the buttons.” The subjects are not familiar with the general Web checklist. To resolve the problem, we need to redesign the UI so the subjects can understand it better.

4.6 Summary

In this research, 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 need to evaluate the practical feasibility of the whole of Memory-PAL through longer-term experiments with actual people with dementia.

Chapter 5

VirtualCareGiver: Personalized Smart Elderly Care

5.1 Introduction

The care robot is a one assistive technology which aims to support or assist elderly people in their daily life. Our research group has also tried to adapt a Virtual Agent (VA) for a care robot. Virtual agent is an animated, human-like graphical chatbot robot program. Using VA would support some simple tasks such as greetings; reminder schedules instead of human caregivers who would be freed up to do tasks which are currently impossible because of the lack of human resources. For such care by robots, including VA, the robots need to execute tasks based on every elderly person's preference because requirements vary. Hence, using care robots may ease the burden of caregivers and provide personalized care for individual elderly people living at home.

Existing care robots have three drawbacks to personalization, however.

- **Problem P1**: Development cost for personalization is larger.
- **Problem P2**: Adapting a care robot to individual life style is challenging.
- **Problem P3**: Deploying a care robot at home is quite expensive.

Problem P1 means that the developer has to develop a personalized care robot. To adapt to the growing number of elderly people, we need to develop care robots in an efficient way. Second, P2 reflects the challenge of the care robot automatically learning the individual lifestyle. Moreover, it requires long-term machine learning as well as costly robot operation and maintenance. Problem P3 suggests that deploying a care robot in the home is quite expensive. We think P3 reduces the motivation of elderly people to use one.

The above three problems motivated us to develop a next-generation care system, which considers elderly people's preference with sympathetic interactions, and flexible personalization. To actualize the above goal, we considered an architecture that automatically provides personalization for individual elderly people. Our architecture consists of three components; CareTemplate, VirtualCareGiver, and VirtualCarePersonalizer. CareTemplate is a skeleton of care program that defines what should be executed by the virtual agent. For example, when a care program plays music, CareTemplate involves the operation playMusic(). If a program greets the elderly, CareTemplate involves greet(). Then, VirtualCarePersonalizer (VCP) implements actual care by customizing the CareTemplate based on the personal profile and context of the elderly. For instance, if an elderly person likes folk songs, VCP chooses a famous folk song for playMusic().If the elderly person is hard of hearing, VCP produces a loud and slow voice for greet(). We assume that such personal information is provided by a care manager, the family or the elderly themselves. The implemented care is finally instructed to a VirtualCareGiver (VCG) deployed in individual homes. VCG works as a (virtual) care robot executing given personalized care, using the virtual agent, as well as other smart devices at home. To confirm the effectiveness of the proposed service, we conducted an experimental evaluation with actual 11 subjects. We found that the proposed care robot is effective at both displaying valid font size and speaking with valid volume. It is also useful for music care, which plays patients' favorite songs. We discuss the limitation of our care robot and future work in the light of the evaluation.

5.2 Preliminary

5.2.1 Person centered care

Person-Centered Care (PCC) is a holistic (bio-psychosocial-spiritual) approach to delivering care that is respectful and individualized, allowing negotiation of care, and offering choice through a therapeutic relationship where persons are empowered to be involved in health decisions at whatever level is desired by the individual who is receiving the care. The concept is based on various sources, including [29], [30]. In addition to this, dementia care mapping is a practical way to provide PCC in the long term [31]. Care mapping consists of four processes, mapping, feedback, planning and executing care. The mapping is a way to monitor and log the elderly lifestyle (e.g. walking, eating, and having a chat) during the course of a day. Currently, the mapping process is executed by human caregivers, and hence the burden is too heavy for them. Second, feedback aims to improve the current quality of care by analyzing the individual lifestyle data which we obtain in the mapping process. The planning improves the current care based on the mapping and feedback. Finally, the caregiver executes care based on the plan made in the previous processes. The repetition of four processes improves care, which will be person-centered, responsive to individual needs. However, because of the shortage and of caregivers, it is difficult to execute person-centered care for each elderly person. Hence, it is also quite difficult to provide person-centered care at home. Assistive technology is one promising solution, whereby technologies are introduced to assist elderly people.

5.2.2 Virtual Agent system

The virtual agent (VA) is a human-looking animated chatbot program that can communicate with a human user via voice [25]. There are a few studies that adapted the VA for elderly care. Yasuda and colleagues developed a system where a VA serves as a conversation partner of people with dementia [26]. Our research group has also developed a system which exploits a VA as a user interface of the home network system (called HNS) [32]. When a user says "Turn on the 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 voices various information obtained from the HNS and the Internet. VA is a promising technology for elderly people, since it is based on less mechanical and (simulated) human-to-human conversation. Using the VA, our research group has proposed a

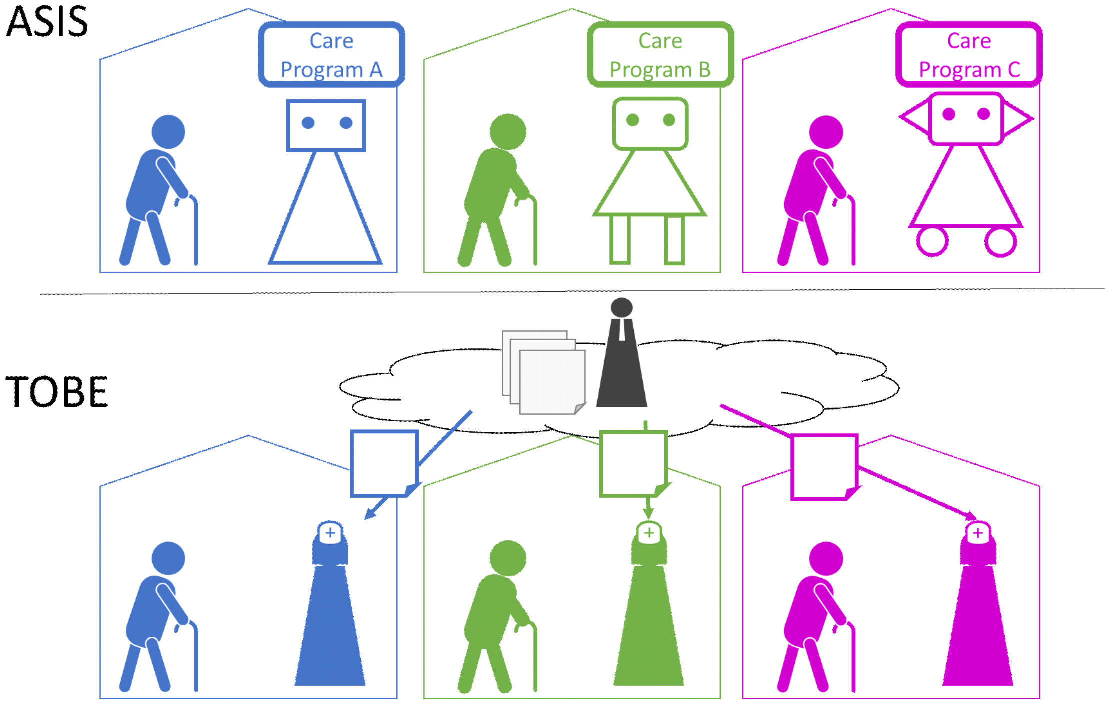


Fig. 5.1. Overview of research goal

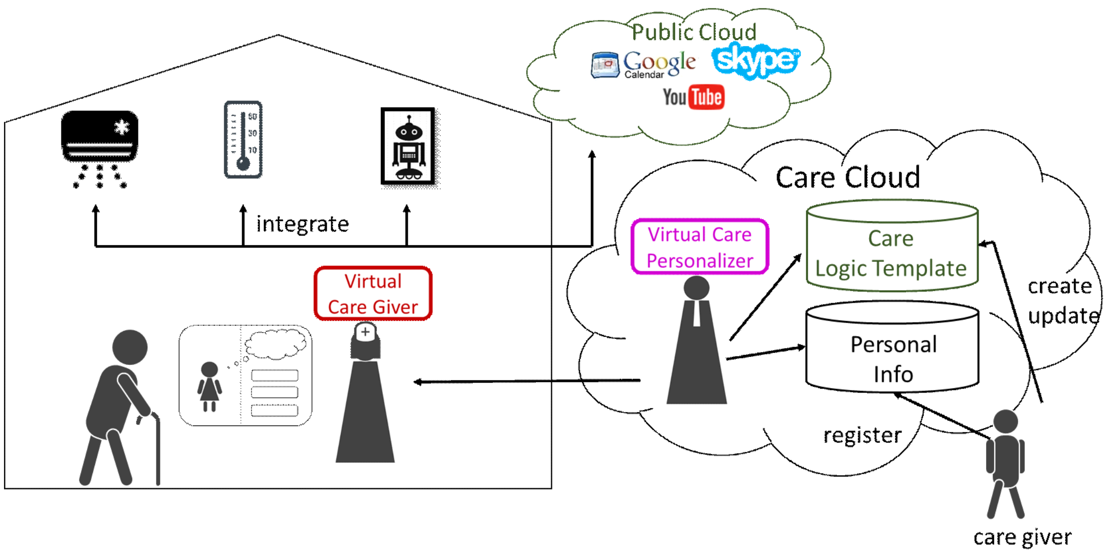


Fig. 5.2. Overview of personalized smart agent on cloud

new concept of reminder service using a virtual agent [33], [34]. In this research, we re-engineer the VA in order to adapt it for use by a wide variety of elderly people.

5.2.3 Goal and scope of paper

In this research, our goal is to develop a personalized care service for elderly people which integrates smart services. Figure 5.1 shows the difference between that model (see top of Fig. 5.1) and the conventional one (see the bottom of Fig. 5.1). The conventional approach is to deploy a different care robot at each home. Hence, it is costly to deploy in terms of money and the time spent learning it. On the other hand, our proposed method is to deploy identical care robots. Moreover, care for elderly people is personalized on the cloud and can help elderly people in a reasonable and scalable way. We proceed as follows. First, we propose a key idea and system architecture to develop the integration agent. Then, we give an example of how to provide personalized care for elderly people using the proposed method. Finally, we show the result of experimental evaluation with actual subjects.

5.3 Cloud-based personalized home elderly care using smart agent

5.3.1 System architecture

In order to achieve the research goal, we develop a service integration agent which consists of three components; VirtualCareGiver (VCG), CareTemplate and VirtualCarePersonalizer (VCP). Figure 5.2 shows the architecture that we propose. The key idea is a detachment of logic of care and execution part on the cloud. The logic of cares is developed as a skeleton care template in order to adapt it for a wide variety of elderly people. In addition to this, the logic of care is deployed on the cloud and personalized with a personalized engine (VCP) and personal information. In addition to this, VCG also integrates with public web services (e.g. Google Calendar, Skype, some physical sensors and robots) in order to execute more useful care. For example, integrating with Google Calendar provides a schedule reminder service for elderly people. Integrating Youtube enables us to play a video or music to provide recreation for elderly people. Figure 5.3 shows a whole sequence of providing personalized care for the elderly person "Toku-

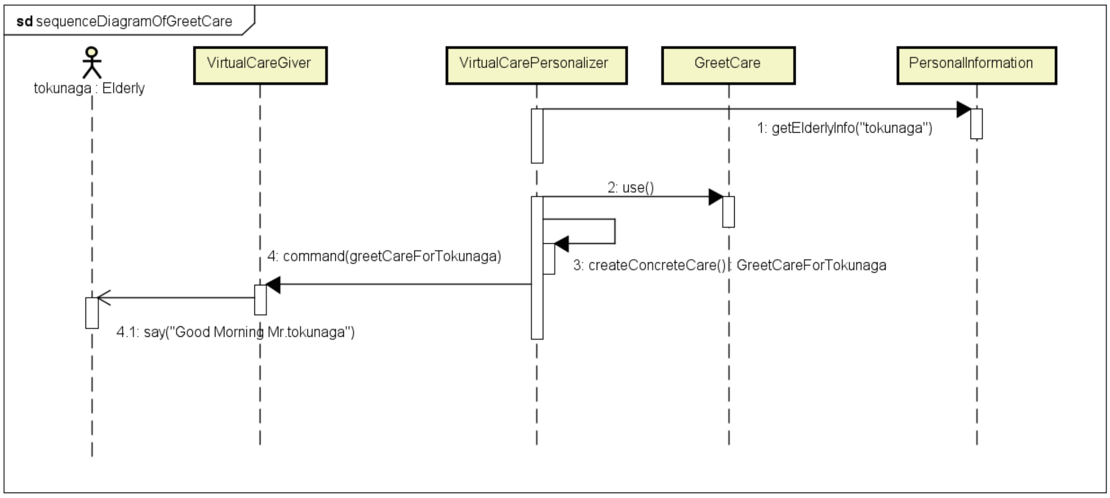


Fig. 5.3. Sequence of GreetingCare

naga." First, VCP gets personal information with API getElderlyInfo(). Then VCP generates concrete care with GreetCare using personalized(). GreetCare is the skeleton logic which aims to greet a user. After creating care, VCP offers the care to VCG with invokeCare() with care information. Finally, VCG executes "greetCareForTokunaga" which aims to greet the user. In the following section, we explain each component in detail.

In order to achieve the research goal, we develop a service integration agent which is consists of three components; VirtualCareGiver (VCG), CareTemplate and VirtualCarePersonalizer (VCP). Figure 5.2 shows the architecture that we propose. The key idea is a detachment of logic of care and execution part on the cloud. The logic of cares are developed as the skeleton care template in order to adapt for wide variety of elderly people. In addition to this, the logic of care is deployed on the cloud and personalized with a personalized engine (VCP) and personal information. In addition to this, the VCG also integrates with public web services (e.g. Google Calendar, Skype, some physical sensors and robots) in order to execute more useful care. For example, integrating with Google Calendar provides schedule reminder service for elderly people. Integrating Youtube enables to provide the play some video or music to provide the recreation for elderly people.

Figure 5.3 shows a whole sequence of providing personalized care for elderly

"Tokunaga". At first, the VCP gets personal information with API getElderlyInfo(). Then VCP generates concrete care with GreetCare using personalized(). The GreetCare is the skeleton logic which aims to greet for a user. After creating care, the VCP offers the care to VCG with invokeCare() with given concrete care information. Finally, the VCG executes cares "greetCareForTokunaga" which aims to greet for the user. In the following section, we explain the each components in detail.

5.3.2 Personal information

We have to consider what information should be collected in order to actualize the personalized care. The data in our proposed architecture include name, nickname, birthday, sex, address, contact member, family member, hobby, favorite movie, and favorite song. Using the above personal information, the system can provide personalized care. For example, using the user's name, the system can greet the user with his/her name. In another example, VCG could play music based on the user's favorite song, which is expected to improve the care. For example, user "Tokunaga" likes the traditional song "Enka", so VA should play "Enka" to comply with the user's preference. If the user has some physical difficulty (e.g. hard of hearing, poor eyesight), VCG should behave in accordingly. For example, if the user "Tokunaga" is hard of hearing, then VA should speak loudly and play a video with high volume. In another instance, if the user "Nakamura" has poor eyesight, then VCG should display the contents more clearly. We assume that the caregivers or family would register the above personal information.

VirtualCareGiver (VCG) is a care robot that provides the actual care for a user at home. Figure 5.4 shows the interface of VirtualCareGiver which we have developed. The left of Fig. 5.4 represents VirtualAgent, which performs motions (e.g. smile, bow, shaking hands) of a human being. The right of Fig. 5.4 is called MAClient and displays some useful information (e.g. checklist, senences, and video) for elderly people. Using the different screen VA and MAClient, VCG can display some messages on screen and say something using text-to-speech technology. VCG executes care by VCP. We also designed a VCG with WebAPIs

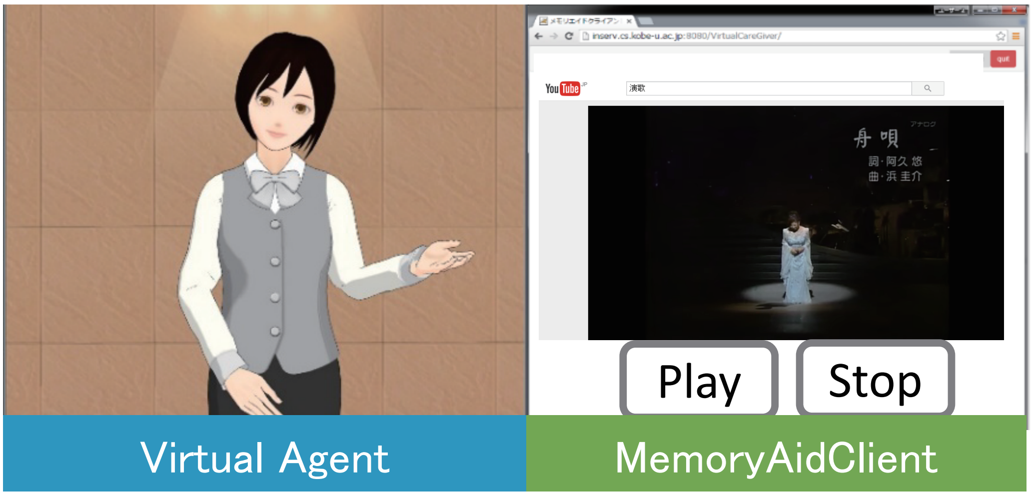


Fig. 5.4. Interface of VirtualCareGiver

which can be integrated with another system such as smart home, a physical sensor with HTTP protocol (see the left of Fig. 5.4). The offered care tasks are defined in CareTemplate. Also, VCG has setAnswer() and getAnswer() APIs which enables it to interact with users. For example, VCG generates a question using displayCheckList(["yes," "no"], "normal"), then returns some questionId (e.g. 1234) which identifies each question as following API lists. Then, the user answers "yes" for the id: 1234. After that we can obtain the user's answer through getAnswer(). In addition to this, the APIs have features to meet the needs of the individual. For example, if a user is hard of hearing, then we assume VCG says sentences loudly or plays music with high volume. Specifically, †represents the voice parameter which the API can control, and ††is a font parameter which controls the font size on the screen. Hence, using these parameters efficiently, we achieve the personalization in order to meet the user's physical needs. Moreover, we can integrate other web interfaces such as Skype, Google Calendar, YouTube and so on. The integration enables us to provide more practical care for elderly people.

5.3.3 VirtualCareGiver

VirtualCareGiver (VCG) is a care robot that provides the actual care for a user at home. Figure 5.4 shows the interface of VirtualCareGiver which we have developed. The left of Figure 5.4 represents the VirtualAgent which perform motions (e.g. smile, bow, shaking hands) to act like human-beings. The right of Figure 5.4 is called MAClient that displays some useful information (e.g. checklist, sentence, and video) for elderly people. Using the different screen VA and MAClient, VCG can display some messages on screen and say something using text-tospeech technology. VCG executes cares by VCP. We also design that the VCG has Web-APIs which aims to integrate with another system such as smart home, physical sensor with HTTP protocol (see the left of Figure 5.4). The offered care tasks are defined in CareTemplate. Also, the VCG has setAnswer() and getAnswer() APIs which enables to interact with users. For example, the VCG generates a question using displayCheckList([“yes”,“no”],“normal”), then the VCG returns some questionId (e.g. 1234) which identifies each question as following API lists. Then, the user answered “yes” for the id: 1234. After that we can obtain the user’s answer through the getAnswer(). In addition to this, we design the APIs have feature to meet the needs for individual elderly. For example, if a user has hard of hearing, then we assume VCG says sentence loudly or plays music with high volume. Specifically, the †represents the voice parameter which the API can control, ††is a font parameter which controls the font size on the screen. Hence, using these parameters efficiently, we achieve the personalization in order to meet the user’s physical needs. Moreover, we design to integrate other web interfaces such as Skype, Google Calendar, YouTube and so on. The integration enables to provide more practical cares for an elderly people.

- *getAnswer(questionId)*: Obtain an answer from a specific questionId. The questionId identifies each question which the VCG issues
- *setAnswer(questionId)*: Set an answer for a specific question which belongs to questionId
- *playVideo(videoId,†volume)*: Play the video with given videoId and volume. The volume parameter controls the sound volume in order to adapt to the individual.
- *dispalySentence(sentence, ††fontSize)*: Display sentence on the screen. The

API can control the font size in order to meet elderly people's needs.

- *dispalyCheckList(list,††fontSize)*: Display list with given list parameter and font size, whose parameters are same as displaySentence()
- *doMotion(motion)*: Act like a human (greeting, bye, bowing, and so on *[1])
- *say(sentence, †voiceLevel, †voiceSpeed)*: VCG says some sentence with given sentence. The API can control both the size and the speed of voice using voiceLevel and voiceSpeed.

5.3.4 CareTemplate

CareTemplate is a skeleton of care program that defines what should be executed by the virtual agent. CareTemplate consists of a combination of simple VCG's APIs (greeting(), say(), doMotion()). In addition to this, the skeleton variable is converted with personal information. For example, `#elderly.name` is expected to be replaced with elderly's name. In addition to this, the care template is managed on the cloud. Hence caregivers can update and create care tasks suitable for an elderly person. We assume that CareTemplate is shared among caregivers who use the proposed system. The above design enables the new user t0 start the program at less cost. In the following, we show three examples of CareTemplate (see Figs. 5.5 and 5.6).

Figure 5.5 shows greet() which is a kind of logic of CareTemplate. The greet() aims to provide greeting instead of human caregivers. The # represents the template which is replaced with personal information. In this case, elderly.name is converted into the name of elderly people. Let us consider an example. A user "Tokunaga" is a man of 70. The `#elderly.name` is converted as "Tokunaga" with personal information. Finally, the logic of say() invokes the sentence "Good morning, Tokunaga." Hence, the greet() logic is able to adapt individual elderly people only have to set the personal information. Figure 5.6 is playMusic() and is also a CareTemplate which aims to plays music. The playMusic() plays the favorite music of the user.

*[1] If you want to know more, please see [32]

```
define greet()
  say("Good morning #{elderly.name}")
end
```

Fig. 5.5. Logic of greeting care

```
define playMusic()
  doMotion("smile")
  say("Good Morning #{elderly.name}. I play your favorite song")
  playMusic("#{elderly.favoriteSong}")
end
```

Fig. 5.6. Logic of music care

Developers are able to develop care efficiently using CareTemplate. An additional advantage is that if the care which the user wants has already been registered, the user can quickly start the care service using the given CareTemplate. Figure 5.5 shows greet() which is a kind of logic of CareTemplate. The greet() aims to provide a greeting like that of human caregivers. The `#{}` represents the template which is replaced with personal information. In this case, `#{elderlyInfo.name}` is converted into the name of elderly people. Referring back to "Tokunaga," the `#{elderlyInfo.name}` will be converted as "Tokunaga" with personal information. Finally, the int the logic of say() could invoke with sentence "Good morning Tokunaga". Hence, the greet() logic is able to adapt to individual elderly people who only have to set the personal information. Figure 5.6 is a playMusic() which is also a logic of CareTemplate. The playMusic() plays the user's favorite music.

- greet(): Greeting with his/her name
- playMusic(): Playing his/her favorite song

Fig 5.5 shows *greet()* which is a kind of logic of CareTemplate. The greet() aims to provide greeting instead of human caregivers. The `#{}`represents the template which is replaced with personal information. In this case, `#{elderlyInfo.name}` is converted into the name of elderly people. Let us consider the example to adapt for a user “Tokunaga” who is a man whose age is 70 years old. Then, the `#{elderlyInfo.name}` is expected to be converted as “Tokunaga” with personal information. Finally the int the logic of *say()* could invoke with sentence “Good morning Tokunaga”. Hence, the greet() logic is able to adapt individual elderly people only have to set the personal information. Fig 5.6 is a *playMusic()* which is also a logic of CareTemplate. The playMusic() plays his/her favorite music which also adapts the individual needs.

5.3.5 VirtualCarePersonalizer

VirtualCarePersonalizer (VCP) is a component which generates and adapts personalization of care on the cloud. VCP's main work is to convert template partition into personal information. Specifically, VCP replaces the APIs which appear in CareTemplate in order to meet individual preferences. For instance, let us consider the example of playMusicCare for the user “Tokunaga” whose favorite song is “Enka.” VCP converts the APIs playMusic(`#{elderly.favoriteMusic}`)into playMusic(“Enka”) based on the user's preference. Apart from considering the preference of the user, VCP converts care based on the physical difficulty of individual elderly people. For example, when the user is hard of hearing, then the VCP control turns up the volume and delays the speed of talking. Specifically the say(“hello”) is replaced by say(“hello,” “loud,” “slow”).

5.4 Use case scenario

We describe two kinds of use case. One is called use case scenarios (greeting care, playing music care), and the other is a sequence diagram with which we confirm the flow of the proposed architecture. Moreover, we also consider two kinds of persona in order to adapt our personalized system. One is the user “Tokunaga” as before. Tokunaga's favorite song is “Enka.” The other is “Nakamura” who is a woman in her eighties and likes folk song. In the following, the templates are changed based on the users' personal information. We assume VCP generates care based on personal information. Figure 5.5 represents the use cases of greet()

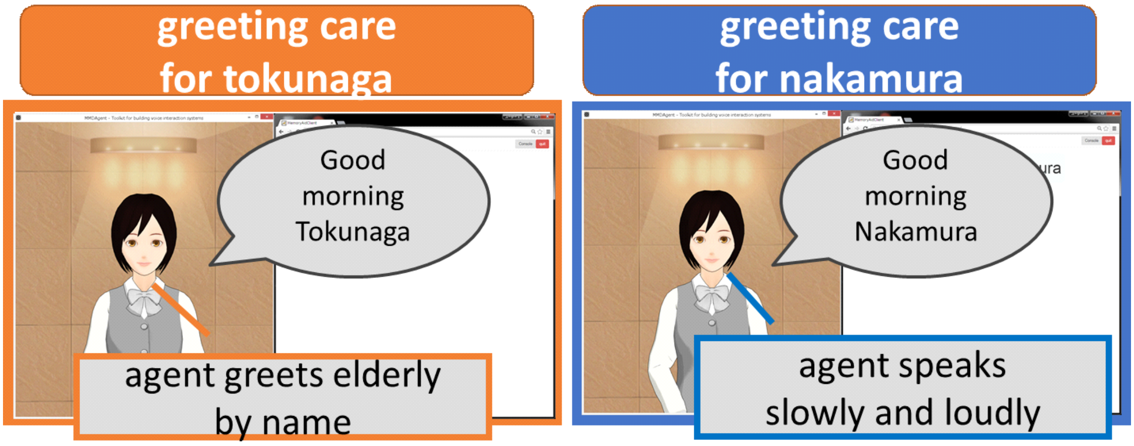


Fig. 5.7. Personalized greeting care

which adapts individual persona users. Based on the personal information the care templates greetCareForTokunaga() and greetCareForNakamura() are generated with VirtualCarePersonalizer and CareTemplate. The difference between template greetCareForTokunaga() and greetCareForNakamura() is the content of the messages. This difference comes from the personal information. So, the developers are able to develop the GreetingCare which they just only use the API greet(). We also give examples of music care. See the template playMusic() which plays Tokunaga's favorite song using Youtube. The playMusic() is also personalized for both Tokunaga and Nakamura. VCP replaces the music in order to use personal information. Hence, we can confirm that the CareTemplate is simple to develop, which resolves P1 and P2.

5.5 Experimental evaluation

5.5.1 Experiment overview

We conduct an experiment in order to confirm how elderly people feel when they receive personalized care. The subjects participated in the experiment one at a time.

Figure 5.10 shows the experimental scene. A PC on a table displays VCG. The system supporter sits next to the subject who supports the system. VCP, CareTemplate and personal information are deployed on the server. We also conducted a

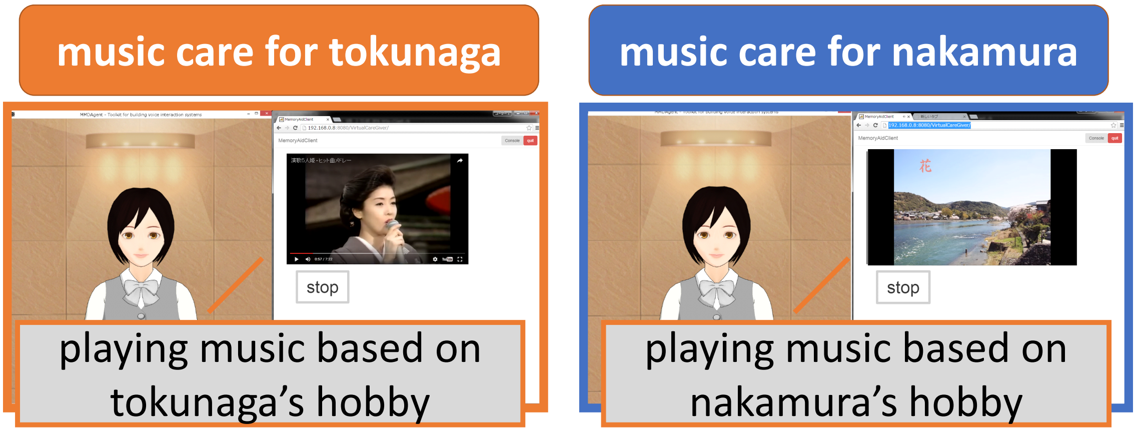


Fig. 5.8. Personalized music care

questionnaire for four staff at the location of the experiment. Three people are caregivers and one is a business owner. In order to answer the question "Why is it important to deploy VCG in the daycare center?", we also have conducted the interviews for the staff to improvement our proposed system. The questionnaire for the staff was as follows.

Q2-1 Do you feel the VCG is useful in the day care center?

Q2-2 Do you want to use the VirtualCareGiver in the day care center in the future?

5.5.2 Experimental procedure steps

The experiment consisted of four steps as follows.

Step1 Before the experiment, we collected personal information from subjects via a questionnaire (see the left of Fig. 5.9).

Step2 On the day, we deployed the experimental environment (i.e. VCP, VCG and CareTemplate) in the daycare center.

Step3 Each subject interacted with VirtualCareGiver using the scenario which we developed.

Step4 After the experiment, we also conducted an interview (see the right of Fig. 5.9) to confirm how users feel after Step2. The questionnaire score

preliminary

Q1. What is your name?
Q2. What is your nickname?
Q3. What is your hobby?
Q4. How old are you?
Q5. What is your favorite song?
Q6. Do you have a hard of hearing?
Q7. Are you a visually impaired?
Q8. Do you have an impaired hand function?

after

Q1. Do you feel glad by calling your name?
Q2. Do you feel glad to talk about your hobby?
Q3. Is the playing music is good?
Q4. Do you feel glad to confirm about your health status?
Q5. Do you feel useful about to confirm that the confirmation of taking medicine?
Q6. Do you feel good to talk with your previous work?
Q7. Are you able to read the sentence which is displayed on the screen?
Q8. Do you feel good about the question that do you have someone who wants to meet?
Q9. Can you listen the voice of VCG clearly?
Q10. Do you get scared for the VCG?

Fig. 5.9. Contents of questionnaires

ranged from one (lowest) to four (highest).

5.5.3 Scenario care

ScenarioCare, which was developed for the experiment, consists of four parts: greeting, confirmation of basic personal information, quiz and playing music. The contents of ScenarioCare consists of CareTemplate as follows.

greet() : Greets with his/her name. The VCG also introduce itself (e.g. "How are you. My name is Mei (The name of agent)").

confirmPersonalInfo() : Confirms basic personal information such as "How is your health?" "Do you already take medicine?"

quiz() : Quiz about his/her hobby (e.g. sports, picture, TV program, dancing).

playMusic() : Plays his/her favorite music based on his/her personal information.

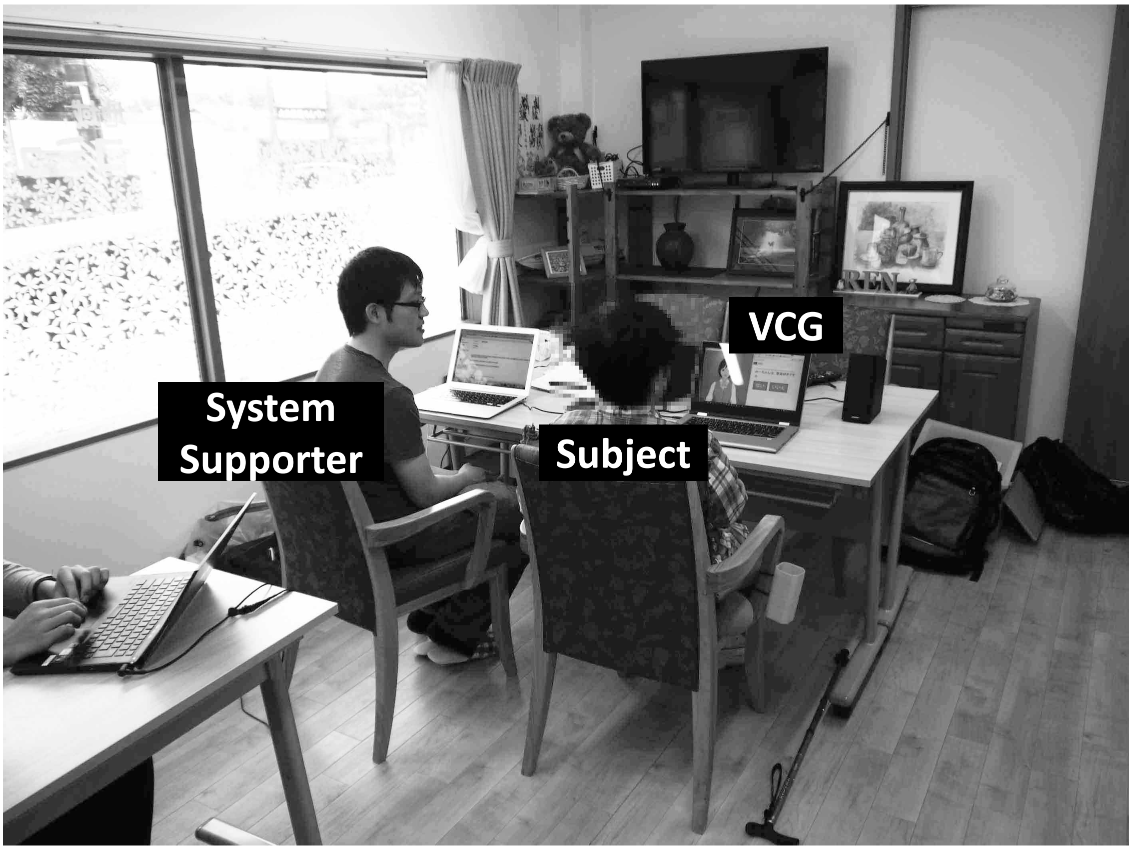


Fig. 5.10. Experimental scene

5.5.4 Result of experiment

Figure 5.11 shows the result of the experiment. The average score is 3.58. The highest score is 4.00 for Q7 and the lowest score is 2.90 for Q8. Most subjects gave positive comments on VCG. Some subjects answered that "I was very surprised that VCG played my favorite song." Another subject said that "I was very glad to talk about my past job and listen to my favorite song." Playing personalized music is especially useful for the subjects. As shown in Fig. 5.11, the scores for Q7 (about font size) and Q9 (about sound) were much higher than other results. Hence, the proposed system scores highly for visibility and listening. On the other hand, there were some comments on improvements, such as "I would like to talk about my hobby in detail." We thought this comments derived from the topics of hobby which VCG spoken was too simple for the subjects. Another subject said that "I would like to talk about my husband who has died," and other

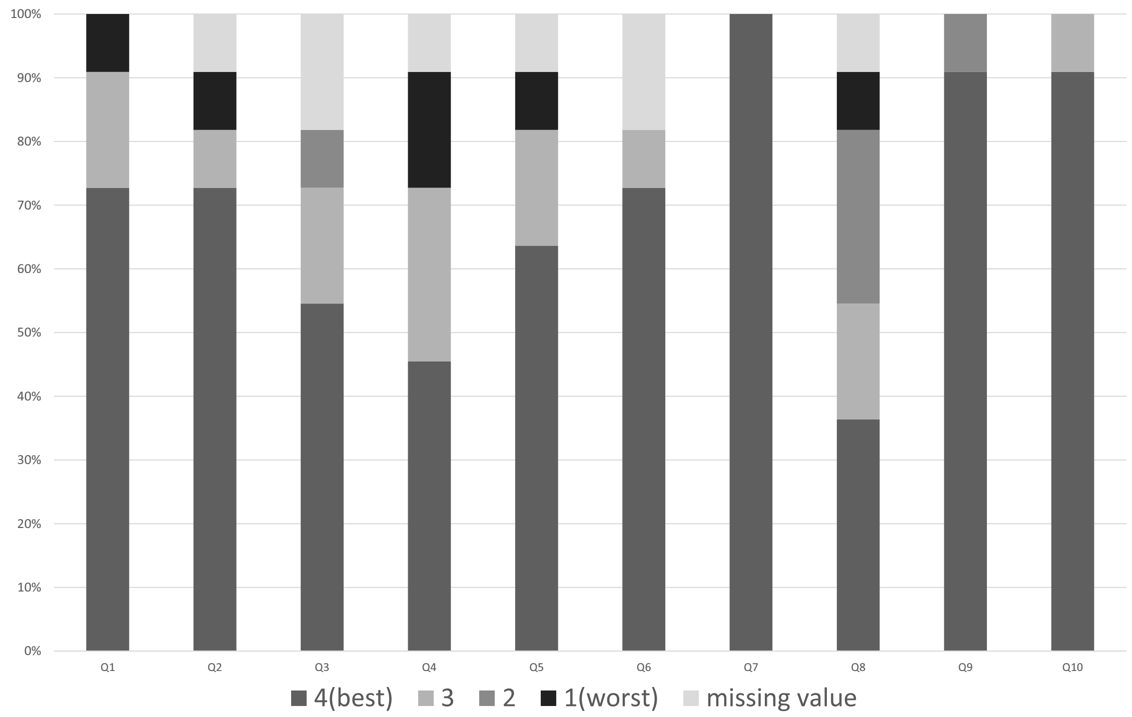


Fig. 5.11. Result of questionnaire

subject stated that "I got nervous because this was the first time I talked with a robot." The former comment suggests the specific conversation topic should be heavily personalized. The latter comment shows that the subject become nervous when talking with VCG because of a lack of familiarity. The score for Q10 (acceptability of agent) is also high, and hence this score shows that the contents are acceptable to the subjects. Some subjects said that "the agent looked so beautiful" and "she looked tender." In addition to this, one interesting comment from a subject was that "I feel sad that I have to interact with a machine instead of a human in the near future." This comment suggests that elderly people may feel lonely talking with robots instead of human caregivers.

5.5.5 Response from CareGivers

We also show the comments from the caregivers. All caregivers made positive comments about VirtualCareGiver. Q2-1 was designed to discover whether VirtualCareGiver is useful or not.

The following responses were received to Q2-1.

- VirtualCareGiver has possibilities such as remote monitoring for an elderly person who lives alone.
- It is sometimes easier to talk with robots than humans, because people do not have to pay attention to robots.
- I would like to use it, because of the shortage of caregivers in the near future.
- It would be useful when I do not have enough time to care for an elderly person if the robot can act as a substitute for me.

The following responses were received to Q2-2 as to whether VirtualCareGiver is helpful or not in the daycare center

- If elderly people or caregivers can use VCG anywhere at any time, it would be more useful for us.
- If VCG had a physical body such as a doll, then elderly people could touch it. It would seem more friendly to them.
- VCG should cover a wider variety of topics.
- The pitch of voice is too high to listen to for elderly people.
- The pronunciation of the agent is sometimes poor.
- If VCG could speak elderly people's dialect, then they would speak more.
- VCG should ask questions of elderly people as they respond more easily.
- It would be useful if VCG could confirm the elderly people's status at their home.

Finally, we show the suggestions the caregivers made for the improvement of VCG.

- If the elderly people or caregiver can use the VCG at anywhere at any time, it will be more useful for us.
- If the VCG has physical body such as doll, then the elderly people could touch. It seems more friendly for them.
- VCG should cover more wide variety topics.
- The pitch of voice is too high to listen for the elderly people.
- The pronunciation of agent seems sometimes bad.

- If the VCG could speak elderly people's dialect, then the elderly would speak more.
- VCG should ask questions for elderly people as they respond more easily.
- It seems useful if the VCG could confirm the elderly people's status at their home.

5.5.6 Discussion

We have confirmed that most subjects feel positive about VCG. As regards Q7 and Q9 which ask about clarity of font size and whether the sound is clear or not elderly people seem to approve. On the other hand, Q8 has a worse score than others because of the perceived limitation of topic contents. VCG currently supports to ask that do you have anyone whom wants to meet. Thus, the above interaction does not persuade elderly people to talk. In order to resolve the problem, the system needs to learn personal information to talk with them. We have confirmed that when VCG asks about their previous work, many subjects tend to speak freely. After the questionnaire, we asked how they felt about being asked about previous work. Some subjects responded that they felt good because no one else listened to their accounts. The result for Q3 (playing music) was scored well by most elderly people, because some subjects sang along when VCG played their favorite song. However, we also found that currently VCG has only simple topics. This is because it strongly depends on CareTemplate. Thus, our proposed method could only cover the preliminary questions. It is difficult to learn new topics or automatically generate conversation. Hence, sometimes the elderly people seem boring for the topic because of the duplication of the topics which VCG talk. In order to cope the problem, we have to consider some reasonable learning feature to learn the topic during a conversation. We have also confirmed the feasibility of the proposed service. Although a subject has participated as walk-in, the proposed service could generate the personalized care based on her personal information. This result shows that VirtualCareGiver has the potential to cope with Problem 3, as we said in the introduction. We also want to discuss the viewpoint of caregivers. All caregivers are positive about using VirtualCareGiver in the field. Most caregivers say that "It would be helpful if the robot could listen to what the elderly people worry about when the human caregiver does not have enough time to respond." Another comments shows that the robot decrease the unwanted concern, a very important aspect for both elderly people and caregivers. On the other hand, a caregiver says that "If VirtualCareGiver has a physical body such as a doll, then the elderly people could touch it. It would be more friendly for them." We have to determine whether it would be better if VirtualCarGiver had a physical body or were shown as virtual on the screen. We also were given a negative comment about VCG's bad pronunciation. The pronunciation strongly depends on the text-to-speech program. In that program, when the text is given, then the program automatically converts it to the voice file. However, sometimes the conversion fails to produce a natural voice file. This is a challenging issue.

5.6 Related works

In this section, we analyze and compare the difference between the existing systems and our care robot. SenseCare uses a semi-automatic lifelog summarization system and a smart phone [35]. Our research focused on collecting and analyzing the data to improve the life of the elderly. On the other hand, our proposed method focuses on executing care directly in place of real human caregivers. Kosugi and colleagues have proposed a live communication platform which aims to improve communication for seniors [36]. It has some similarity with our proposed method as it consists of a plug-in framework that can be extended dynamically on the basis of a common interface. The research had a different goal from ours as it aimed to improve human-to-human communication. Conversely, our research goal is to provide VirtualCareGiver which works semi-automatically in the home to improve the QoL for individual elderly people. The therapeutic seal robot paro has been used for mental healthcare in the elderly care field (e.g. daycare center, hospital). Tamura and colleagues found the pet-type robot AIBO is useful instead of animal-assisted therapy to avoid any danger or injury [37]. Looije and colleagues have shown that a computer-based robot agent can aid healthy behavior by persuading and guiding elderly people [38]. The above researches aim to improve the elderly's daily life with pet robots, but our care robot focuses on improving quality of life with an agent on the PC screen. Hence, the research scope and methods are very different. HAL is a cyborg-type robot which aims to improve bodily function, supported and enhanced by being worn [39]. Mukai and colleagues developed RIBA-II which aims to free caregivers from heavy physical work and to compensate for the lack of nursing care staff [40]. Therefore, these researches have a different goal from ours that focuses on how to compensate the elderly person's impaired body.

5.7 Summary

In this paper, we have proposed a smart care service integration agent that provides personalization and integration for elderly people. Our proposed service consists of three components: CareTempate, VirtualCareGiver (VCG) and VirtualCarePersonalizer (VCP). CareTemplate is a skeleton of care program that defines what should be executed by the virtual agent. VCG is a robot agent, which executes care tasks in the home. VCG executes care instead of human caregivers. VCP manages and generates personalized care in order to meet individual needs on the cloud. To demonstrate its feasibility, we performed an experimental evaluation where the subjects used the proposed system. The result shows that personalization as regards the static contents (music, font size) wefre particularly well adapted for individual use. Our future work will cover a variety of personalized topics based on individual hobbies,and a long-term experiment with a wider variety of elderly people.

Chapter 6

Conclusion

In this chapter, we conclude this dissertation, and provide a broad perspective on our future work. Specifically, we focus on three kinds of smart ICT services, a remote monitoring service, a reminder service for people with dementia and a care service for elderly people. First, we have revealed the relationships between sensor accuracy and the reliability of RMS. Our research has focused on modeling and simulating a remote monitoring service for the elderly. Specifically, we have proposed generalization by a three-actor model and designed algorithms for the elderly and a watcher. As a third step, we developed an elderly model based on WHO statistical data. We also conducted several simulations. The simulation result shows the relationship between sensor accuracy and the elderly models. Moreover, we discuss an RMS guideline based on the results. Second, 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 in relation to 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 Agent Service. Our future work is to complete the implementation of Memory-PAL based on the proposed design. Moreover, we need to evaluate the practical feasibility of the whole of Memory-PAL through longer-term experiments with actual people with dementia. Finally, we have proposed a smart care service integration agent that provides personalization and integration for elderly people. Our proposed service consists of four components, Virtual Care Giver (VCG), Virtual Care Personalizer (VCP), Care Template and Personal Information. VCG is a robot agent, which executes care tasks in the home. VCG performs care tasks which VCP generates. Personal information enables us to personalize cares based on the registered information. VCP manages and generates personalization of care tasks in the cloud. Care Template is a framework which manages simple care tasks for elderly people to offer for VCG. To demonstrate the feasibility, we conducted an experimental evaluation with 11 actual subjects.

6.1 Future Directions

6.1.1 Remote Monitoring Service for Elderly People

In this research, we used a simple sensor which only has the fail ratio regardless the elderly status. The sensor estimation is completely independent every time. However, the usual system has the difference fail ratio, which aims to decrease the FP. However, as we discussed in Section 3.4.2, the sensor and progression of a disease may be strongly related but we have no method for digitizing the progression of the disease. One reason for difficulty in simulating disease is possibly the absolute lack of consumer data on progression of disease. On the other hand, in recent years, many devices which monitor [41],[42],[43] health status have been provided. Many devices are connected to the Internet, so that a user can manage his/her personal health record more easily. In the near future we expect to use such data for our research, which will enable more complex and more personalized RMS simulation.

6.1.2 Reminder Service for People with Dementia

In the context of safety within dementia care, we can consider two social problems: heat disorder and night wandering. The proposed MemoryPAL was originally developed for the daily reminder service. However, we show that it can contribute to avoiding these problems if we apply small extensions. Heat disorder is an illnesses caused by too warm an environment [44]. In summer, people with dementia (especially elderly people) sometimes forget to turn on air-conditioners, because their sense of heat may have declined, or they want to save energy. Exposing a body to too warm an environment causes heat disorder even in a house, and may lead to death. To avoid serious heat disorder, Memory-PAL can be used to emit a heat alert to the user if a temperature sensor service is integrated. Our research group has proposed a framework of the sensor as a service [45], which efficiently creates sensor Web services. Using a publish/subscribe mechanism, we can easily define an action whereby a temperature sensor invokes the API of MemoryPAL when the temperature exceeds a certain threshold (e.g. 32 degrees). Night wandering means a person with dementia leaves home and gets lost in the night [46]. The reason for night wandering is that the memory wrongly persuades the person to go somewhere outside (for work, to meet a friend, etc.). Memory-PAL can be used to stop the person going out by repeatedly speaking about the current situation. 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 4.3.2. 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 bedroom." Another approach useful for people with dementia is to show reminiscence movies to distract them from going out. The implementation of these extended features remains for our future work.

6.1.3 Personalized Smart Care Service for Individual Elderly People

One challenge is the improvement of care contents, and another is providing sensor-based care. In this paper, our proposed architecture focuses on how to provide personalized care for elderly people. Thus, our proposed architecture does not cover the contents of care. VCP and CareTemplate provide template-based care, but sometimes the content of care may be unsatisfactory for elderly people. That may in turn decrease the motivation to use our proposed service continuously. To solve the problem, we hope to improve the quality of care based on the user's reaction. Specifically, a user receives certain kinds of care which are executed by VCG, which also collects information on whether the given care is valued by the user. The collection of evaluations which are evaluated from users would improve cares which VCP generates based on the score. To actualize the above idea, we have to consider both how to evaluate the given care and how to improve the generated care for individual users based on the stored evaluation. The second problem is providing more situational care which is integrated with sensor data. Currently, CareTemplate only covers static values, specifically personal information such as name, sex, address and so on. Hence, it does not cover integration with other kinds of data (e.g. sensor data, motion data and so on). Elderly people living alone appear to be at higher risk of falling and heat disorder. We think in this context that CareTemplate needs to be extended to cover sensor data. Smart care integrated with sensor data should be able to detect both the falling risk and heat disorder. We need now to consider how to provide care integrated with sensor data using CareTemplate.

Acknowledgements

This dissertation could not have been accomplished without the collaboration of many other people.

First, my thanks to Professor Zhi Wei Luo and Professor Itsuo Hatono of Kobe University for valuable guidance in the process of examination. I would like to express my appreciation to Professor Kuniaki Uehara of Kobe University for providing me with insightful comments and advice, in-depth discussion, constructive suggestions and the great opportunity to study in his laboratory.

I also would like to express my appreciation to Associate Professor Masahide Nakamura of Kobe University for similar help. Without his assistance, I could not have finished my work. I would like to thank him so much for his kindness and help in all aspects of my research and daily life. I am grateful to Assistant Professor Sachio Saiki of Kobe University, who gave me strong support in countless situations. Thanks are also due to Assistant Professor Shinsuke Matsumoto of Osaka University, who provided generous support on innumerable occasions.

Special thanks to all who made useful suggestions at conferences and all friends who shared their wide knowledge of various topics and technologies. I wish to express my appreciation to Kiyoshi Yasuda of Chiba Rousai Hospital for helpful comments on my research in the field. I could not have accomplished my work without his advice. I also would like to thank Hiroyasu Horiuchi and Kazunari Tamamizu. whose help was invaluable. Acknowledgments I would like to express my gratitude to all the teachers and students in the cs24 laboratory and the students who have graduated in the last five years. It was a pleasant and fruitful experience to work with them, and I thank them for creating such a good and friendly research environment. Finally, I would like to express my gratitude to my family for their moral support and warm encouragement.

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2. Seiki Tokunaga, Hiroyasu Horiuchi, Sachio Saiki, Shinsuke Matsumoto, Masahide Nakamura, and Kiyoshi Yasuda, "Implementation and Evaluation of Interactive Memory-Aid Agent Service for People with Dementia," In 18th International Conference on Human-Computer Interaction (HCII2016), vol.9745, pp. 357368, June 2016. (Toronto, Canada)
3. Seiki Tokunaga, Hiroyasu Horiuchi, Hiroki Takatsuka, Sachio Saiki, Shinsuke Matsumoto, Masahide Nakamura, and Kiyoshi Yasuda, "Towards Personalized and Context-Aware Reminder Service for People with Dementia," IEEE World Congress on Computational Intelligence 2016 (WCCI2016), pp. 2946-2953, July, 2017. (Vancouver, Canada)
4. Hiroki Takatsuka, Seiki Tokunaga, Sachio Saiki, Shinsuke Matsumoto, and Masahide Nakamura, "Integrating Heterogeneous Locating Services for Efficient Development of Location-Based Services," In The 17th International Conference on Information Integration and Web-based Applications & Services (iiWAS2015), pp.430-439, December 2015. (Brussels, Belgium)
5. Seiki Tokunaga, Hiroyasu Horiuchi, Sachio Saiki, Shinsuke Matsumoto, Masahide Nakamura, and Kiyoshi Yasuda, "Design of Memory Aids Agent Service Based Location and Time for People with Dementia," In The 2015

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6. Seiki Tokunaga, Akihiro Okushi, Sachio SAIKI, Shinsuke Matsumoto, and Masahide Nakamura, "Consumer-Oriented Receiptlog Service Platform for Effective Applications," In Joint 7th International Conference on Soft Computing and Intelligent Systems and 15th International Symposium on Advanced Intelligent Systems (ISIS2014), pp.398-403, December 2014. (Kita-Kyushu, Japan)
7. Seiki Tokunaga, Sinsuke Matsumoto, Sachio Saiki, and Masahide Nakamura, "How Should Remote Monitoring Sensor Be Accurate?," In The 1st International Workshop on Reliability of eHealth Information Systems (ReHIS2014), pp.31-36, October 2014. (Natal, Brasil)
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A.2 Journal Papers

1. Seiki Tokunaga, Kazunari Tamamizu, Sachio Saiki, Masahide Nakamura Kiyoshi Yasuda "VirtualCareGiver: Personalized Smart Elderly Care," International Journal of Software Innovation (IJSI), vol.15, no.1, 2017. (to

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2. Seiki Tokunaga, Sachio Saiki, Shinsuke Matsumoto, and Masahide Nakamura, "On Estimating Quality of Elderly Monitoring Service Based on Sensor Reliability," Intelligent Automation & Soft Computing, doi: 10.1080/10798587.2016.1140328,February 2016.
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