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Author(s)	Miura, Motoki; Ito, Sadanori; Takatsuka, Ryozo; Sugihara, Taro; Kunifuji, Susumu
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Description	

An Empirical Study of an RFID Mat Sensor System in a Group Home

Motoki Miura†, Sadanori Ito‡, Ryozo Takatsuka†, Taro Sugihara†, Susumu Kunifuji†
† School of Knowledge Science, Japan Advanced Institute of Science and Technology, Japan
‡ Course of Ubiquitous and Universal Information Environment, Department of Computer and Information Sciences, Graduate School of Engineering, Tokyo University of Agriculture and Technology, Japan
Email: {miuramo, ryozo-t, sugihara, kuni}@jaist.ac.jp, sito@cc.tuat.ac.jp

***Abstract*— We have been developing an RFID (radio frequency identification) mat system to assist caregivers in a group home. In Japan, the number of *group homes* offering home-like care for elderly persons suffering from dementia has increased considerably. Even though the smaller number of people residing in a group home makes it suitable for family-like care, the scarcity of caregivers increases the burden, especially during the night. To augment caregiver attention, we developed floor mats with embedded RFID antennae and slippers with RFID tags. These can help caregivers be aware of the activities of persons suffering from dementia by specifying whether an individual has passed over a mat in a particular corridor. This not only helps the caregivers understand such persons by reviewing their activities but also keeps them informed about their current activities. We introduced the floor mats in a real group home and confirmed the feasibility of the system. In this study, we describe the system and lessons learned from our experiment.**

***Index Terms*— Ubiquitous home, Location awareness, Elderly persons care**

I. Introduction

A group home is a type of home-like care facility in Japan for elderly persons suffering from dementia. Since Japan is one of the fastest-aging societies, developing such facilities where elderly can live safely and at ease is crucial. In this aging society, people's needs for care services are greater, but the number of large-scale care facilities are still limited. Consequently, the demand for group homes for the elderly has increased.

A group home is a relatively small facility based on the principle of normalization; it offers family-like care enriching the quality of life by taking into account individuals' personalities. A group home is suitable for implementing this philosophy because the number of persons residing there is relatively low. During the daytime, up to nine elderly persons are taken care of by three caregivers. During the night, however, only one caregiver provides support for all nine individuals. It is therefore difficult for the caregiver to deal with concurrent events and to remember all behavioral events.

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A. Current Issues in Group Homes

Before starting our project, we interviewed five caregivers in a group home about their current issues, thoughts, and concerns about their work. The common and most important issue was a lack of attention. A caregiver often engages in the care of one elderly person. However, while doing so, another elderly person may require his/her help or have an accident. The caregiver has to recognize all events happening and deal with them in addition to household tasks. However, this is difficult, because of limitations of human cognition.

The second issue was the burden of writing a daily care report, which is necessary for third-party evaluation. The caregiver should describe appearances and activities such as meals and eliminations. Caregivers usually make a quick note, but do not track all events, especially in an emergency.

In addition to these points, caregivers are expected to deal with the elderly persons by considering their abilities and health status such as feelings and physical conditions. Takatsuka et al. [1] addressed the problem of communication with people with dementia requiring person-centered care, and proposed story-making as a tool for understanding people with dementia. To accomplish person-centered care, the caregivers should pay attention to the personalities and personality changes of each elderly person.

B. Our Motivation

First, we consider that the support of caregivers is necessary for realizing person-centered care. Even though group homes are suitable for ideal care, the workload tends to be heavy because of mental and physical overload. Support for understanding individuals can be especially helpful for improving the quality of care and eliminating mental and physical overload. Thus, we decided to provide additional information, which includes individuals' activity logs, for caregivers.

Our research group has been focusing on the approach of augmenting group homes by introducing information, sensing, and communication technology. To promote this research, we have been developing an experimental group home named "AwareRium" with built-in sensors such as

ultrasonic position detectors, active RFID readers, and floor-pressure sensors. The basic concept is similar to that of Aware Home Research Initiative [2]; however, we focus on providing support for caregivers living with people suffering from dementia [3].

Although these advanced sensors are effective in augmenting the functionality of group homes, it is difficult to install them in existing group homes without large renovations. Moreover, although the floor-pressure sensors can detect events such as the approach of a person to a particular area, they cannot distinguish between individuals unless identification tags are attached to them.

In this study, we present our system for augmenting a conventional group home with simple mat sensors. We describe the requirements, design, and implementation of the system, and show lessons learned from our experimental results.

II. System Requirements and Design

As we have seen in section I-B, we want to provide caregivers with activity logs for each elderly person, so we should consider individual actions. However, attaching personal identification devices to the elderly person's body should be avoided because it requires special maintenance for caregivers. For the same reason, battery-powered devices are unsuitable because the caregivers must change or charge the batteries regularly.

In addition to this, we cannot fully modify existing group homes, because many were established after minor renovation of conventional houses. Even if the solution can be pre-installed during construction, the mechanism should be simple.

After considering the requirements and limitations, we chose a simple radio frequency identification (RFID) technology to detect personal activities of elderly persons by embedding tags in their slippers [4]. Our system employs special floor mats with embedded RFID readers that can detect a person's approach to the mat and store the information. The information can be used for future reference or provided directly to the caregiver. The tag is sufficiently small to be embedded, and moreover, elderly persons always wear slippers in the home. Thus, we can record activities individually without any burden for the elderly persons. Moreover, the passive RFID tags do not require additional work, such as charging batteries. These characteristics minimize additional maintenance tasks for caregivers.

Figure 1. RFID antenna sheet, regulation circuit box, and reader box.

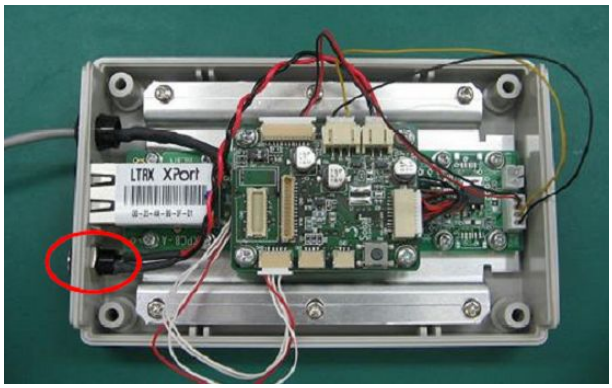

Figure 2. RFID reader box.

Figure 3. Slippers with RFID tags (in actual operation, the tags are embedded).

III. Usage Scenarios

Caregivers usually provide assistance to the elderly based on their individual abilities and personalities. Understanding personal activities based on location-aware data is advantageous to the caregivers for the following reasons:

1) At night, some elderly persons frequently visit the restroom. Relevant notification along with identification helps the caregivers determine whether the individual requires assistance. In addition, the caregivers will know when the individual would normally return from the restroom. Identification can also be used to record the frequency of restroom visits for each person. In case of higher frequency, the caregiver could be notified about the patient's lack of sleep.
2) Sometimes, people with dementia perform redundant activities such as brushing their teeth every ten minutes. If the system generates a person's activity log, patterns could be identified that help in determining the person's basic state of mind and devising countermeasures.

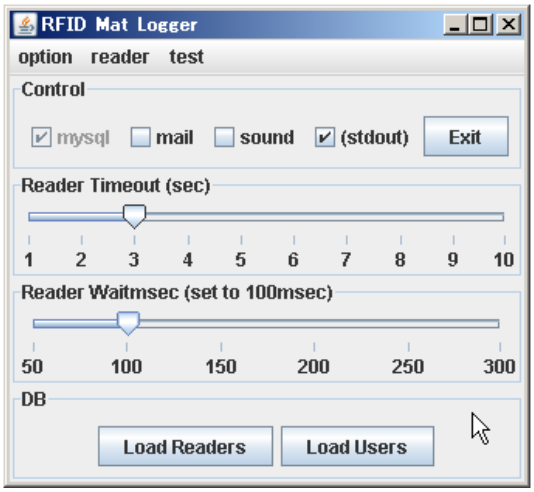

Figure 4. Event logger application.

3) An irregular action such as roaming around or walking down a corridor at high speed can represent a state of high emotion. Our system can detect these irregular actions and inform the caregivers.

In addition, an activity log generated by the system can provide fundamental and objective data for the daily care reports. Browsing the log can be advantageous in enhancing caregivers' memory with accurate description of phenomena.

IV. Implementation

Our system consists of RFID readers, mat antennas, and a control PC for hardware, and a data logger application as software.

A. Hardware

The details of our initial prototype of the RFID mat made using copper tape are described in [5]. To reduce the effort of preparing multiple antenna sheets, we employed enamel wire stuck on a thin plastic film (Figure 1). We prepared three types of antenna sheets of different sizes (300 mm × 400 mm, 300 mm × 650 mm, and 300 mm × 1200 mm) to suit different locations. The differences in operation due to antenna size are regulated by variable resistances in the regulating circuit box (90 mm × 50 mm × 26 mm). The RFID reader box (Figure 2, 125 mm × 80 mm × 32 mm), consists of an HHPA module developed by Sobal Corp.[1], a power supply circuit, and a LAN module (XPort[2]). The HHPA module is compatible with ISO15693-2 tags, and can provide an output of 1 W. The LAN module is used to report tag data to a control PC.

An RFID tag sheet (OMRON V720SD13P01) was embedded into the slippers (Figure 3). The reader can detect slippers within a range of 5 to 10 cm. As the stride length of an elderly person is shorter and they tend to walk more slowly than a younger person, the performance of the reader/antenna is sufficient.

B. Software

We developed a simple event logger that monitors the detection events of the RFID tags in Java6 (see Figure 4). The event logger manages connections to all the readers and gathers tag information by polling them. When an RFID tag is detected by an RFID reader, the tag ID is called back to the event logger by the reader. Then the event logger generates a data pair (tag ID, reader ID) and registers them as an "enter" event. When the tag leaves the field, the event "exit" is registered. To prevent irrelevant detections or missing events, the user can set "Reader timeout" with the slider. When the reader detects an "enter" event within the timeout, the last "exit" event is canceled. Thus, the event logger stores "raw" data (reader ID, tag ID, date/time entered, date/time exited) in a MySQL table via a Hibernate3 Java O/R mapping library. The "Reader waitmsec" slider allows the user to set a polling interval time for each reader. The "Load Readers" and "Load Users" buttons restore the descriptions of readers and tag IDs from the database tables, respectively. The application can add extra readers dynamically, which is beneficial in maintaining readers with less effort.

Since the "raw" data is too primitive to handle, the event logger also stores summary data, consisting of the number of enter events and a moving distance for each person for every ten minutes. The moving distance is calculated by accumulating the linear distance between the currently visited floor mat and the last-visited mat. The location of a floor mat is defined in advance. The summary data can be used by caregivers to grasp activity tendencies.

As the slippers are expendable supplies, a person may use multiple slippers during long-term operations. Thus, we designed the database table so that it can relate multiple tags to an individual. All tags related to one person are not distinguished during the operation, as it is difficult to enforce wearing left/right slippers on persons from dementia.

V. Applications

We have developed four applications that visualize the mat log data in several ways.

1) **LogViewer:** Figure 5 shows a simple data browser for the raw data. The browser loads the raw data from the MySQL table and places person's icons on a floor map of the group home. The caregiver can review past activities of the persons by moving the knob on the slider located below the window. Thus, caregivers can review past events, even though they were engaged in caring for another person at the time.
The logviewer enables caregivers or administrators to annotate a scene. When the user presses the

[1] http://www.sobal.co.jp/rfid/rfid-hhpa.html
[2] http://www.lantronix.jp/products/ds_xport.shtml

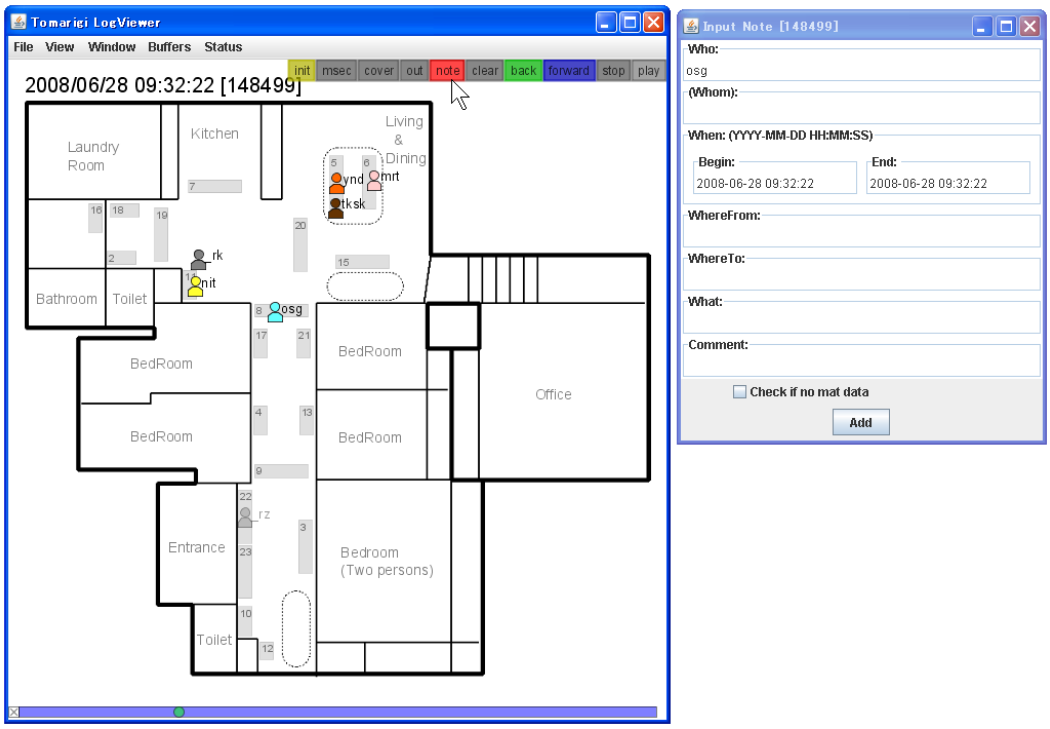

Figure 5. Logviewer (left) and annotation window (right).

[Note] button, the [Input Note] window appears. The user can store his/her observations and diagnosis by typing in the appropriate fields.

2) **Voice Announcement Monitor:** As the caregiver is usually busy, it is difficult for him/her to watch the window of the logviewer for each event. Therefore, we implemented a voice announcement function. When a person needing assistance is detected in the corridor, the system announces: "Mr. XX (owner of the slippers) is in corridor (location of the antenna mat)." This effectively allows caregivers to know the current situation without looking at the monitor, especially in case 1 described in section III. The announcement function is customizable for real-world situations. For example, it can be programmed to report the frequency of restroom use. The voice announcement function was developed using the speech synthesis module of the Galatea Toolkit [6].

3) **Daily Activity Monitor:** The logviewer can see the raw data, which represents the detailed phenomena occurring in the home as a replay. This representation is effective for observing interactions between persons. However, the caregiver sometimes wants to focus on one person. The daily activity monitor (Figure 6, Figure 7) displays the one-day summarized data for the specified date and person. The visit count (number of enter events) is represented by a blue-filled bar, and the moving distance within ten minutes is shown as a white bar. From this view, the caregiver can easily recognize (1) when and how much the person moved, (2) when and how long the person sat on a chair or sofa (if the bar consists only of a blue-filled part, the person moved only his/her foot, but did not move enough), (3) when the person slept or was inactive, and (4) when and how much the person moved during the night.

4) **Web Activity Monitor:** We also prepared a web interface to observe changes in personal activities (Figure 8). The web activity monitor shows the long-term changes. The amount of movement in a day can be seen by the daily activity monitor, but the graph is suitable for comparing persons and understanding activity trends. The web monitor was developed using PHP and the GD graphics library.

VI. Installation

To validate the effectiveness of our system, we deployed the antennas and readers in an actual group home, named "Tomarigi" (perch in English). Six elderly persons with dementia live in the home. Even though the RFID mat sheet is thin (thickness 2 mm), placing the sheet directly on the floor of the common space could cause patients to trip. Therefore, we placed the antenna sheet under a carpet (Figure 10), which covers the entire floor of the living and dining rooms and the corridor. Figure 11 illustrates the deployment of an antenna in front of the restroom. Figure 12 shows the corridor and highlights the antenna positions, and Figure 5 displays the positions of antennas in the group home. We installed 21 floor mat sensors in total. Note that the dotted shapes in the figure represent a dining table and two sofas. The boxes

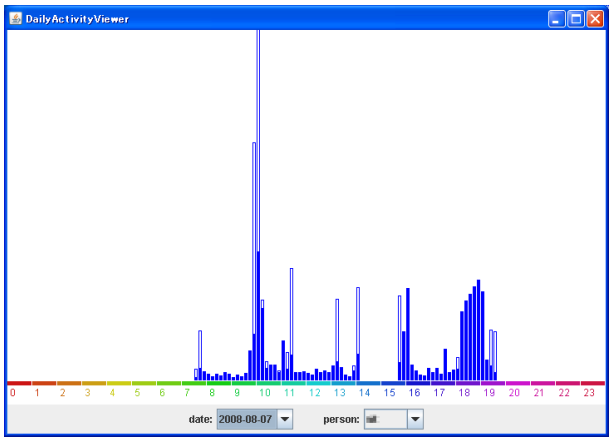

Figure 6. Daily activity view of person A.

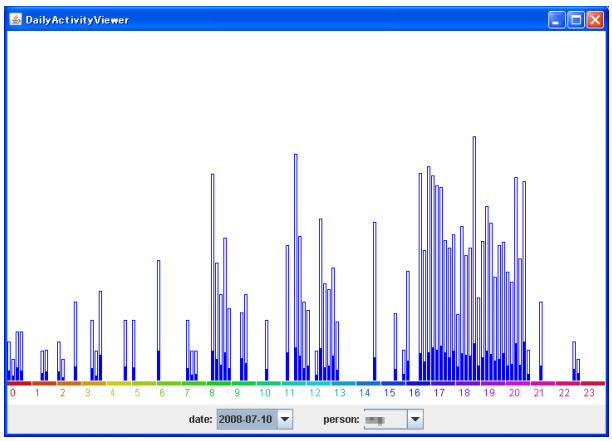

Figure 7. Daily activity view of person B.

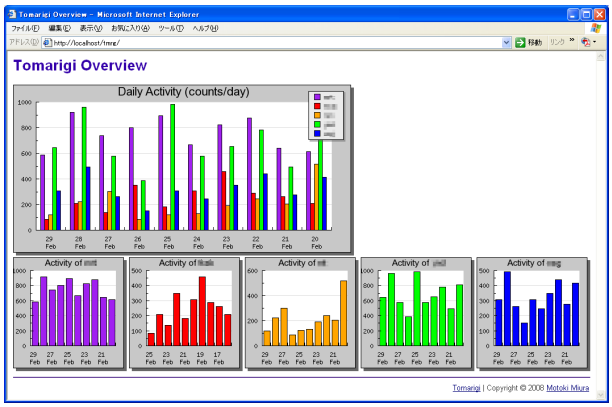

Figure 8. Web activity monitor.

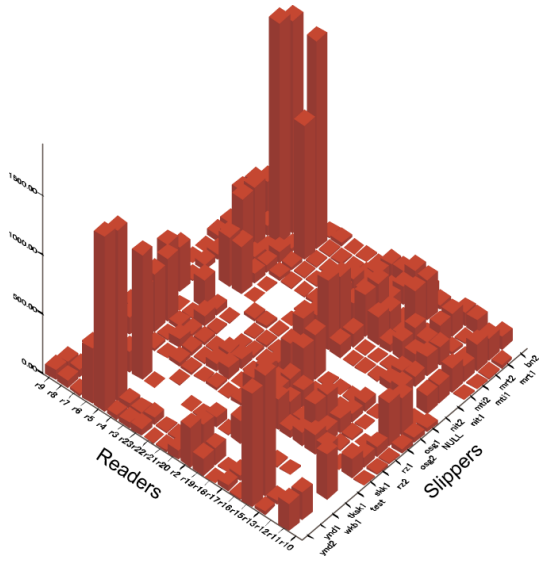

Figure 9. Histogram of detected numbers for each reader/slipper.

containing the regulation circuits are attached to the wall near the mat antenna. The RFID reader boxes are also attached to the wall, below the ceiling. We connected each reader box and hub with network cables. We did not adopt a wireless LAN because we found that a microwave oven disturbs the network. A PC collects all data from the readers by polling every 100 ms. The log browsing interface and voice announcement function were not activated as part of this experiment.

We made tag-embedded slippers for both the elderly persons and caregivers. Seven caregivers and five elderly persons, not including one person who used a wheelchair, wore the slippers. To prevent mix-ups, the slippers were of different colors.

VII. Lessons Learned from Operation

We began logging data on January 17, 2008. We could collect about 4000 event logs per day. The slippers were seldom misplaced because each person recognized them as personal belongings. A histogram (Figure 9) reveals a tendency of staying near the dining table (readers 5 and 6) or the sofa (reader 15) for a long time.

In addition, we learned the following from the experiments.

- The number of floor mat sensors can be reduced if the caregivers want to observe a limited number of places.
- In this experiment, the readers could sense most of the slipper tags properly. However, some flooring with embedded iron pipes may affect reader/antenna performance.
- The slippers were replaced after about four months. Thus, a simple mechanism to add new slippers is crucial for long-term operation.
- The daily activity viewer (see Figure 6 and Figure 7) was highly effective because it could characterize personality and living habits through the daily graphs. For example, person A (Figure 6) led a well-regulated life, whereas person B (Figure 7) did not sleep well during the midnight.

VIII. Related Work

The Aware Home Research Initiative [2] is one of the major attempts to explore augmented home environments. RFID technology is already popular for realizing augmented home environments and sensor networks, even

Figure 10. Deployment of an antenna in the living room (No. 5 and No. 6 antennas in Figure 5).

Figure 11. Deployment of an antenna in front of a restroom (No. 2 antenna in Figure 5).

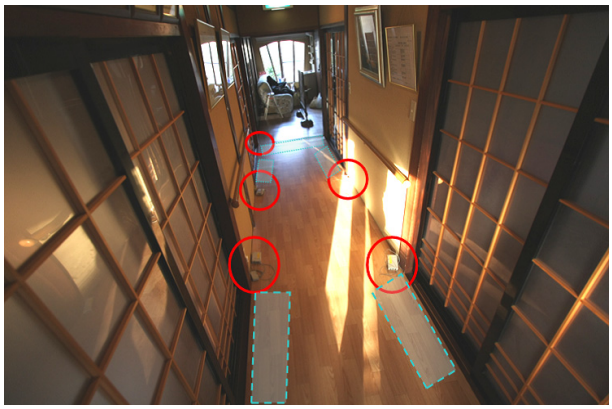

Figure 12. Deployment of an antenna in a corridor (before mounting RFID reader boxes).

in the case of health care systems for the elderly [7]. iWalker [8] is a rollator-mounted way-finding system for elderly persons with cognitive and visual impairments. The rollator is equipped with an encoder and a digital compass to guide the user. A small RFID antenna is attached at the bottom of the rollator, and it detects RFID tags embedded in the floor to minimize localization errors. Kawsar et al. had introduced sentient artifacts [9], which represent sensor-augmented objects that are used in everyday tools such as toothbrushes, mirrors, and chairs. Fogarty et al. have attached microphone sensors to water pipes and recognized daily activities based on the patterns of water usage [10].

Chen et al. have investigated the problem of detecting the social interaction patterns of elderly persons in a nursing facility using audio/video records [11]. They focus on the recording of social interaction and events. Video recognition technology can be applied, but several difficulties still exist. First, the elderly tend to wear similar clothes. Second, the lighting conditions are not good, especially at night. For such reasons, we chose the RFID technique for its robustness. De Silva et al. have presented a system for the retrieval and summarization of activities in a ubiquitous home environment using footstep sensors [12]. This approach is helpful in browsing and recalling the setting of past events, but it cannot be used for identification. However, we focused on a person-centric care system that can distinguish different individuals.

IX. Conclusion and Future Work

We described an RFID floor mat system that enhances caregiving in a group home. We explained the system requirements and design, which minimize both the elderly persons' and caregivers' burdens. We introduced the mat system to a group home and confirmed the feasibility of our approach. We could also find some lessons learned from the experimental operation.

In future, we plan to continue collecting data and providing the services to caregivers mentioned in this paper. We will keep developing methods and applications that are effective for caregivers in group homes.

We do not think the caregivers and helpers in group homes can be replaced by this system. We hope the system can increase the attention on persons with dementia, and help the caregivers to deeply understand the elderly persons by employing a diversified perspective.

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Motoki Miura is currently working as assistant professor in the School of Knowledge Science, Japan Advanced Institute of Science and Technology. He received B. S., M. E., and D. E. degrees in electronics engineering from the University of Tsukuba in 1997, 1999, and 2001, respectively. From August 2001 to March 2004, he worked as a research associate at TARA Center, University of Tsukuba. His research interests include human computer interaction and usability, learning environments, and creativity support systems. He is a member of IEICE, JSAI, IPSJ, JSSST, ACM, IEEE CS, and JCS.

Sadanori Ito is an associate professor in the Graduate School of Engineering, Tokyo University of Agriculture and Technology. He received his M.S. and Ph.D. degrees in Knowledge Science from Japan Advanced Institute of Science and Technology in 2000 and 2003. His research interests include knowledge-based systems, creativity supporting systems, ubiquitous/wearable computing, and their social applications. He is a member of IPSJ, ACM, and HIS.

Ryozo Takatsuka is currently a graduate student at the School of Knowledge Science, Japanese Advanced Institute of Science and Technology, and has also worked as the chairperson of the board of directors of the Nonprofit Organization for Grouphome TOMARIGI for elderly persons with dementia since 1999. He received a B.E. degree from Fukui University, an M.E. degree from Kanazawa University, and a D.E. degree from the University of Tokyo in 1969, 1971, and 1977, respectively. He worked as a research fellow at Fukui University (1977–1980), Virginia Commonwealth University (1981–1982), and Kanazawa Medical University (1982–1987). Then, he worked as the head of the In Vitro Fertilization Office for KEIAI Hospital (1987–1990) and for TOWAKO Maternity Clinic (1990–1999). He is a member of the Japanese Society for Dementia Care and the Japanese Society for Artificial Intelligence.

Taro Sugihara is currently working as assistant professor in the School of Knowledge Science, Japan Advanced Institute of Science and Technology. He graduated from the advanced course of Tokuyama College of Technology and received a B.S. degree in engineering from the National Institution for Academic Degrees and University Evaluation (NIAD-UE) in 2000, and M.E. and D.E. degrees in engineering from Kyoto Institute of Technology in 2002 and 2005, respectively. His research interests include human-computer interaction, especially user behavior, and adult education. He is a member of ACM and the Human Interface Society.

Susumu Kunifuji is currently a professor at the School of Knowledge Science, Japan Advanced Institute of Science and Technology (JAIST). He received B.E., M.E., and D.E. degrees from Tokyo Institute of Technology in 1971, 1974, and 1994, respectively. He worked as a researcher at the International Institute for Advanced Study of Social Information Science, FUJITSU Ltd. (1974–1982), chief researcher at the Institute for New Generation Computer Technology (1982–1986), manager of the International Institute for Advanced Study of Social Information Science, FUJITSU Ltd. (1986–1992), professor in the School of Information Science at JAIST (1992–1998), and director of the Center for Information Science at JAIST (1992–1998). He is a member of IEICE, JSAI, IPSJ, SICE, and JCS.