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Informatics Society

Aims and Scope

The purpose of this journal is to provide an open forum to publish high quality research papers in the areas of informatics and related fields to promote the exchange of research ideas, experiences and results.

Informatics is the systematic study of Information and the application of research methods to study Information systems and services. It deals primarily with human aspects of information, such as its quality and value as a resource. Informatics also referred to as Information science, studies the structure, algorithms, behavior, and interactions of natural and artificial systems that store, process, access and communicate information. It also develops its own conceptual and theoretical foundations and utilizes foundations developed in other fields. The advent of computers, its ubiquity and ease to use has led to the study of informatics that has computational, cognitive and social aspects, including study of the social impact of information technologies.

The characteristic of informatics' context is amalgamation of technologies. For creating an informatics product, it is necessary to integrate many technologies, such as mathematics, linguistics, engineering and other emerging new fields.

Guest Editor's Message

Kunihiro Yamada
Guest Editor of Thirteenth Issue of International Journal of Informatics Society

We are delighted to have the thirteenth and special of the International Journal of Informatics Society (IJIS) published. This issue includes selected papers from the Sixth International Workshop on Informatics (IWIN2012), which was held at Chamonix, France, Sep 4-7, 2012. The workshop was the sixth event for the Informatics Society, and was intended to bring together researchers and practitioners to share and exchange their experiences, discuss challenges and present original ideas in all aspects of informatics and computer networks. In the workshop 28 papers were presented at eight technical sessions. The workshop was complete in success. It highlighted the lasts research results in the area of networking, business systems, education systems, design methodology, groupware and social systems.

Each paper submitted IWIN2012 was reviewed in terms of technical content and scientific rigor, novelty, originality and quality of presentation by at least two reviewers. From those reviews 18 papers are selected for publication candidates of IJIS Journal. This thirteenth includes five papers of them. The selected papers have been reviewed form their original paper presented in IWIN and accepted as publication of IJIS. The papers were improved based on reviewers' comments.

We hope that the issue would be interest to many researchers as well as engineers and practitioners in this area.

We publish the journal in print as well as in an electronic form over Internet. This way, the paper will be available on a global basis.

Kunihiro Yamada received the M.E. degree from Ritsumeikan University in 1973 and Ph.D. degree in Design Science from Shizuoka University, Japan, in 2002. In 1973, he joined Mitsubishi Electric Corporation, and he has been engaged in the microprocessor design and its application development. In 2003, he joined Renesas Solutions Corporation, and he took charge of the Senior Vice President, Board Director. Since 2005, he has been a Professor of Department of Information and Graduate School of Embedded Technology, Tokai University, Japan. Now, his research interests include microprocessor of a new form, education, robotics, and mutual complement communication network system by wired and wireless. Moreover, since 2010, he is acting as the outside director of the Mega Chips Corporation for utilization of his research. He is a member of the Information Processing Society of Japan.

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Leveraging Human-Centric Computing to Enable and Support a Resilient, Prosperous, and Sustainable "Human-Centric Intelligent Society": Underlying Concepts and Highlight Technologies

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Abstract -Accelerated globalization has led to an alarming rise in increasingly intertwined, complex and daunting global-scale societal issues that significantly and directly impact people's lives worldwide – including energy, the environment/natural disasters, transportation/other vital infrastructures, population: explosive growth vs. aging societies, food/water supply, massive data security/management, etc. Simultaneously, continuous widespread expansion of practical-use ICT, along with continuous and explosive growth of massive data in society – in particular the advent of cloud computing and big data – have given emergence to opportunities and needs for ICT to provide "human-centric solutions" to handle such societal issues.

This conceptual paper provides an overview of how we foresee Human-Centric Computing (HCC) technologies as vital frameworks that will drive and provide much of the essential and practical means for enabling and supporting a resilient, prosperous, and sustainable "human-centric intelligent society" we envision for the future. We introduce some key underlying concepts pertaining to HCC, and highlight some relevant leading-edge HCC technologies that we envision will enable and support such a human-centric intelligent society.

(Note: This conceptual paper is based on a Keynote Speech delivered by Tatsuo Tomita, president of Fujitsu Laboratories Ltd., at the International Workshop on Informatics: IWIN 2012 held in Chamonix-Mont-Blanc, France).

Keywords: human-centric computing technologies, human-centric intelligent society, resilient prosperous sustainable society, big data, cloud computing, tailored services

1 INTRODUCTION

Against the backdrop of accelerated and continuous globalization in numerous realms of society and across a multitude of regions worldwide, there has also been an alarming rise in increasingly intertwined and complex global-scale societal issues – including energy, environmental sustainability, natural disaster preparation and recovery, population: explosive growth versus aging societies, data security and management, healthcare, food and water supply, transportation infrastructures, and financial data/system management sustainability, as some key critical issues impacting societies in both industrialized and developing nations.

Simultaneously, the continuous widespread expansion of practical-use leading-edge information and communication technology (ICT) along with continuous and explosive growth of massive data in society – in particular the advent and leveraging of cloud computing and big data – have given emergence to opportunities and needs for ICT to provide "human-centric solutions" to handle such globally intertwined, complex and daunting societal issues.

ICT – in particular Human-Centric Computing (HCC) technologies [1] – can and must play a stronger and more flexible comprehensive role toward enabling and supporting a resilient, prosperous, and sustainable "human-centric-" – not "technologic-centric-" – "intelligent society".

We foresee that HCC technologies as vital frameworks will drive the shift toward, and provide much of the essential and practical means for enabling and supporting a resilient, prosperous, and sustainable "human-centric intelligent society" [2] we envision for the future.

2 HUMAN-CENTRIC COMPUTING: CONCEPTS

2.1 Shift in Dynamics Between People and ICT

When envisioning a human-centric intelligent society supported by HCC, one important aspect to acknowledge is the shift in dynamics between people and ICT that has been occurring, and which we foresee will continue to occur – in the past, many intellectual activities conducted by people were often executed individually with few or no relations with each other's activities (Fig. 1).

Much ICT of the past focused primarily on automation to eliminate the need for human labor for certain tasks, and in that "technology-centric" era, it was necessary for people to adapt to ICT, rather than the ideal vice-versa. To some extent, currently this is still the case for some aspects of ICT.

However, as we see societies transition from a "technology-centric" to a "human-centric" era, we can observe that ICT will increasingly be developed from a "human-centric perspective", in accordance with people's and societies' needs.

2.2 Human-Centric Computing: Key Underlying Concepts

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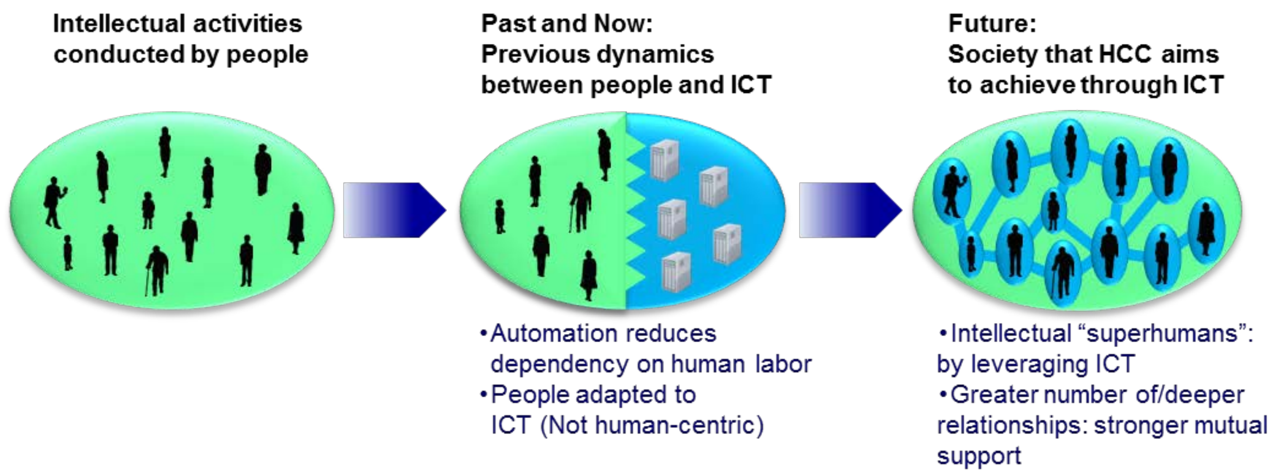

Figure 1: Shift in dynamics between people and ICT

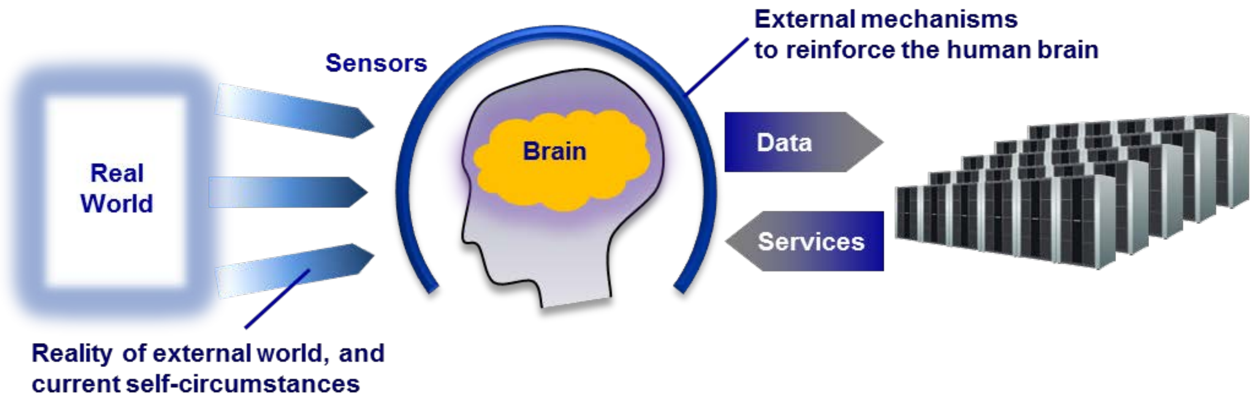

Figure 2: Human-centric computing model for assisting people in intellectual activities

Key underlying concepts for HCC are for ICT to accommodate individuals' needs, and for ICT to support and ensconce people by blanketing their lives with tailored ICT services [1].

In the future, we see an era in which HCC will enable people to have "super-human intellect", by leveraging ICT – in such a society, we will observe a greater number of and deeper social relationships among people and society as a whole, with such social interaction enabling stronger and mutual support and inter-related bonds.

Such collective and inter-social intellects will enable activities and decisions based on, for example, group relationships, communities, and regions, rather than on merely individual knowledge, personal experience, and self-decisions.

We also foresee that such HCC to enhance people's lives and enable activities and decisions based on more sophisticated educated assumptions and collective experience will be available at all times/24 hours a day, supporting people's lives always, whether they are awake or asleep, active or inactive.

2.3 Human-Centric Computing: Futuristic Model

Figure 2 illustrates an example of a futuristic "human-centric computing model" we envision in a "human-centric intelligent society". At the far left is the "real world", and at the far right is the "virtual world".

In this futuristic HCC model, sensors surrounding individuals in the "real world" will capture and recognize the reality of the external world, and current self-circumstances of the individual, while external mechanisms will be leveraged to reinforce the human brain. "Real-world" data shared with the "virtual world" would enable tailored services to be automatically delivered to people, depending on their preferences and both apparent and untapped needs.

We envision that sophisticated and supportive human-centric ICT will enhance people's activities, intellect, and lives through readily-available tailored services based on data derived via sensors from people and a multitude of devices and other objects. Similar to the way corrective vision makes use of eyeglasses and contact lenses to enhance vision, by reinforcing the capabilities of the human brain through external mechanisms leveraging ICT, we envision that HCC will facilitate through external mechanisms the ability of people to enhance their brains, to strengthen their capabilities pertaining to knowledge, memory, senses, various skills including communication, etc.

In this futuristic HCC model, we envision that users will be surrounded by multiple sensors to capture user circumstances and surrounding conditions, and related data will be considered as user context. Furthermore, tailored services available on the cloud, which fit user needs, will be proactively and autonomously offered to users.

Similar to the manner in which people accustomed to corrective vision and become unconscious of wearing eyeglasses or contact lenses, we envision that such tailored services enabled by ICT will unobtrusively and subtly blend into people's lives, to enhance people's intellectual abilities in a variety of situations and opportunities.

In such a human-centric society supported by ICT, users will always have the control and authority to decide which tailored services they wish to select and benefit from.

2.4 Blanketing People's Lives with Services: Healthcare Example

By smartly recognizing user conditions and circumstances, and by offering tailored services that accommodate user needs [3], HCC has the potential to positively impact peoples' lives in a multitude of ways – one such primary example is in the field of "healthcare".

When we consider healthcare services and the dynamics between patients and hospitals and other healthcare facilities, although preventive medicine indeed already exists, currently more common in many countries is a "reactive" approach, in which people usually visit hospitals and seek healthcare after the patients develop symptoms which they feel require medical attention – usually, patients explain their symptoms at hospitals, and based on the doctor's diagnosis, usually recommended or required healthcare is provided.

However, in a world well-supported by HCC and blanketed tailored services, we envision it will be possible to proactively and continuously monitor a potential patient's or a current patient's physical condition, via sensors and data logs across a designated period of time (Fig. 3).

The left half of Fig. 3 shows conventional healthcare approaches, which are not fully supported by HCC, which often require lengthy waits by patients to see physicians, followed often by very brief face-to-face examinations. Instead of taking the time and effort for a cumbersome hospital visit, potential patients may choose to self-medicate instead.

The right half of Fig. 3 illustrates how HCC can be leveraged to proactively offer data-rich patient information to physicians – for example, based on a recent data log. This would enable physicians to more efficiently and accurately make a patient diagnosis.

HCC-based patient-supportive ICT services could autonomously flag an alert when a potential patient displays symptoms which require medical attention, and could continue to monitor the status of the patient after treatment.

2.5 HCC as a Social Catalyst Impacting Social Behavior

We envision that HCC will also contribute significantly toward reinforcing the sustainability of societies. Through unobtrusive and subtle guidance leveraging relevant and timely information, we foresee that ICT will make it possible to offer directional guidance for social behavior of people.

Without sufficient information and lack of real-time data, and without an awareness of how such information is linked between people and relationships, in their social behavior people often make fragmented decisions based quite commonly mostly on assumptions.

However, if abundant and collective real-time data and timely information amassed from a vast number of individuals through HCC could be smartly shared in a data-rich society, such data could function as a "social catalyst" for social behavior, enabling individuals to make self-decisions based on abundant and relevant information (Fig. 4).

Such data as a social catalyst could gently guide individuals in their social behavior, thereby assisting people in making educated, logical and recommended decisions throughout various facets of their daily lives. In a way, such data derived by HCC can have an effect on people that is similar to the effect that so-called conventional social hormones have on human social behavior.

Similar to the way car navigation systems offer real-time directional guidance and support to drivers, in this way, real-time data derived through HCC can act as a gentle and supportive social catalyst for society as a whole.

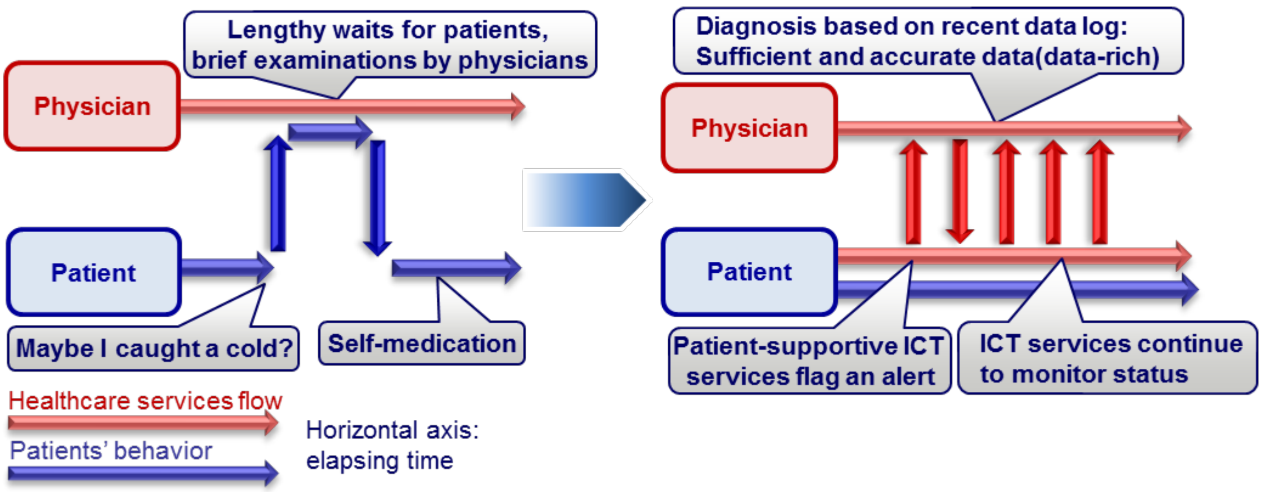

Figure 3: Life "blanketed" with services: healthcare example

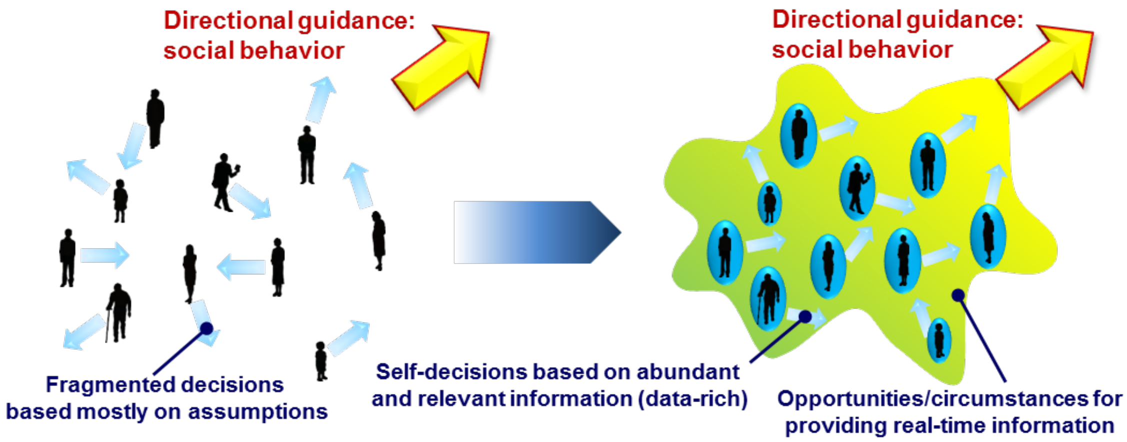

Figure 4: Social catalyst for social behavior

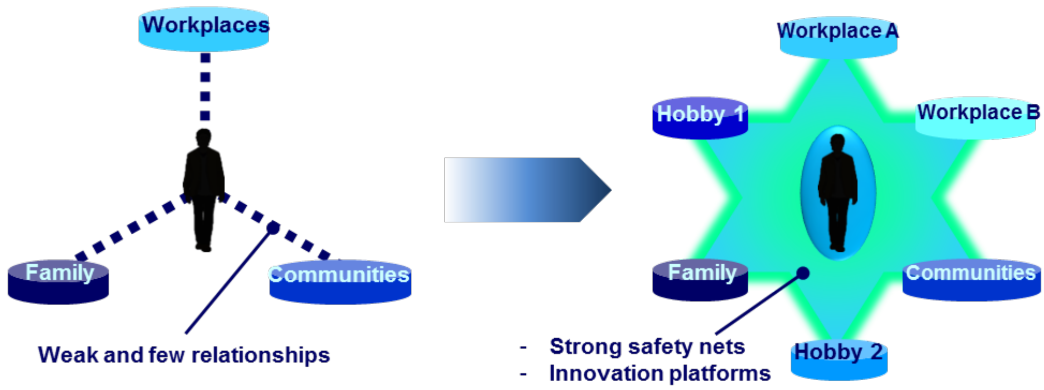

Figure 5: From "trees" to "networks: social communication

2.6 Social Communication: From "Trees" to "Networks"

It can be anticipated that Human-Centric Computing will also have significant impact on social communication, facilitating a shift from "tree-type" social communication to "networked" social communication [4].

Evolution of ICT sees us observing a transition from a conventional "tree-type" social communication approach of the past – in which aspects of an individual's workplace, family, and communities were usually separate and fragmented - to a shift toward "networked" social communication in which there are a multitude of links between facets surrounding an individual's daily life, including multiple workplaces, communities, family, hobbies, etc. (Fig. 5).

In a tree-type social communication approach of the past, societies and enterprises usually focused primarily on efficiencies. In the networked social communication era, more value is placed aspects such as innovation and social happiness.

As witnessed in recent years by the advent of social media, a networked approach to social communication enables strong safety nets and innovative platforms in society.

Such relationships can result in social capital [5] that is accumulated in multiple and lively, active communities.

3 HUMAN-CENTRIC COMPUTING: HIGHLIGHT TECHNOLOGIES

As ICT architecture that supports a human-centric society, we anticipate that such architecture will be "dual-loop", as illustrated in Fig. 6.

The right side of Fig. 6 shows a feedback loop which connects the real world with cyber space, by leveraging HCC. Various data related to people, things, objects, and events is gathered and reflected onto entities in the cyber space. Simultaneously, data will be recognized and understood in real-time, and synthesized as appropriate or ideal output such as tailored services, and fed back to the real world through a variety of methods.

The left side of Fig. 6 illustrates a feedback loop which connects cyber space with a model – massive data accumulated in cyber space is analyzed, and an appropriate model is extracted. Based on simulations results that utilize the model, visualization data is fed back to cyber space and the real world.

Technologies for HCC and for an "intelligent society" are the technologies that will realize these dual feedback loops in a "human-centric intelligent society", with the specific supporting technologies being platform technologies and cloud computing.

Following are highlights of a multitude of HCC technologies that will enable and support a human-centric

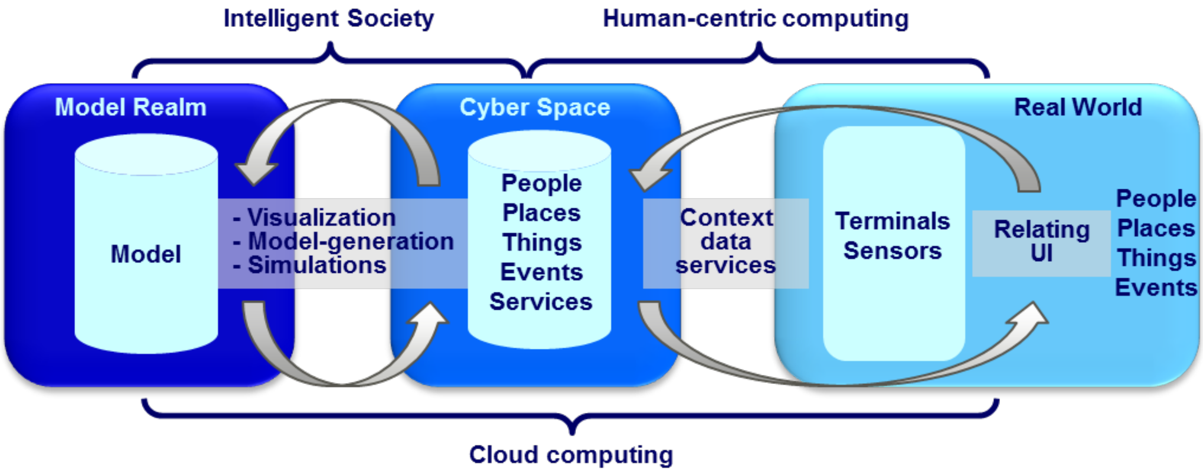

Figure 6: Dual-loop ICT architecture for human-centric computing

intelligent society we envision: the technologies can largely be categorized as being in either the aforementioned "HCC domain" or "intelligent society domain".

3.1 Technologies: Human-Centric Computing Domain

For technologies referenced in the HCC domain of Fig. 6, the objective is to support individuals through ICT so that people can become a step closer toward developing so-called "superhuman intellectuality", to enable safer, secure, and more prosperous lives and societies.

Technologies that support this effort include man-machine interfaces (MMI), robotics, multi-media processing technologies, sensor technologies, and context computing. Such technologies will offer mechanisms to expand input and output that links between computers representing cyber space and the real world.

3.1.1 HCC Technologies: Location-Aware Services

Location-aware services are one example of ICT related to HCC [6].

Figure 7 illustrates cloud computing-based platform technologies to provide location-aware tailored services to smart devices, such as smartphones and tablets. By gathering on the cloud sensor data derived from smart devices, and determining user location, depending on such locations these HCC-relevant technologies can pro-actively provide pre-registered tailored services to users' smart devices [7].

Location-management services developed and illustrated in the same figure use different positioning technologies depending on conditions, and can convert a measured position (a coordinate) into more abstract position information (such as a meeting room or other pre-defined area).

These HCC-relevant technologies enable users to benefit from timely location-aware services, without necessitating user-selection of services, or user-based access to required data.

Developers can use these HCC-relevant technologies to focus on developing higher-level services, enabling users to benefit from location-aware services in a variety of situations. With these technologies, companies can use multiple positioning technologies depending on various circumstances, and can develop services that are independent of any particular positioning technology for location-aware services suited to different situations.

In regards to potential applications of this technology, for example, this technology can be used at medical facilities in which nurses would enter patients' rooms, and the patient's information would automatically appear on the handheld mobile device carried by the nurses. This would increase the efficiency and accuracy of such healthcare.

Another example is in an office environment – this technology can be used to provide a mobile environment that shows all business applications of a user when the user is in the office, could extract business data and customer data when the user is in transit, and can display customer data when the user visits customers.

In the future, there are plans to incorporate this technology into "SPATIOWL", a cloud service that employs positional information. Practical implementation of this technology is anticipated in 2013 [8].

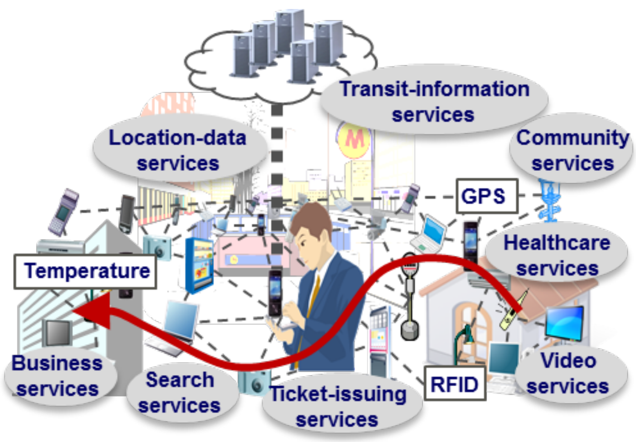

Figure 7: Location-aware services

3.1.2 HCC Technologies: DNA-Based Bio-Sensor Technology

The advent of new infectious diseases, such as SARS and newer viruses similar to SARS, has highlighted the importance of fast detection and preventive measures. There is active research to determine the proteins that cause diseases such as cancer and diabetes, for the objective of early detection and treatment [9].

Figure 8 illustrates a HCC-relevant novel bio-sensor technology that uses DNA to accurately detect proteins 100 times faster than previous methods, and requiring only 1/100 the sample volume, the first technology of its kind in the world [10], [11].

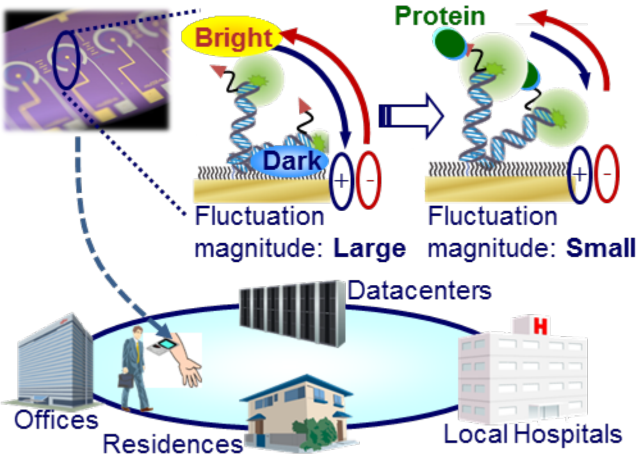

Figure 8: DNA-based bio-sensor technology

The technology employs an electrical field to induce a cyclical motion in negatively charged DNA, and measures the DNA movement as the fluorescentdye applied to the ends of the DNA lights up in the cycle. When the target protein binds to the end of the DNA, the magnitude of the fluctuations between light and dark becomes smaller, enabling detection of protein. This technology enables faster, more accurate detection of proteins as biomarkers of diseases, paving the way for its use in daily health management and maintenance, and early detection and treatment of disease.

Next, to capture target protein, an antibody with high affinity for protein is needed. Conventional antibodies require the employment of a mammalian immune system in order to be developed, thus being costly and not amenable to maintaining a fixed level of quality.

This HCC-relevant technology has been employed to successfully chemically synthesizing artificial antibodies known as DNA aptamers. With high-quality, low-cost DNA aptamers, this technology could be applied to the food industry, where there is a need for reducing the time required to conduct large-scale inspections. For example, in the case of milk, inspections to detect the presence of toxic proteins that are not killed during heat sterilization have been unable to be conducted due to high-cost and significant time required.

3.1.3 HCC Technologies: Socially-Interactive Teddy Bear Robot Prototype

Robotics will also play an important role in the Human-Centric Computing domain, to support people and society.

Figure 9 shows a photo of a "socially-interactive teddy bear robot prototype" that employs various HCC-relevant leading-edge technologies: an extremely unique, user-friendly robot that demonstrates how a MMI can be used to facilitate unobtrusive and user-friendly social interaction.

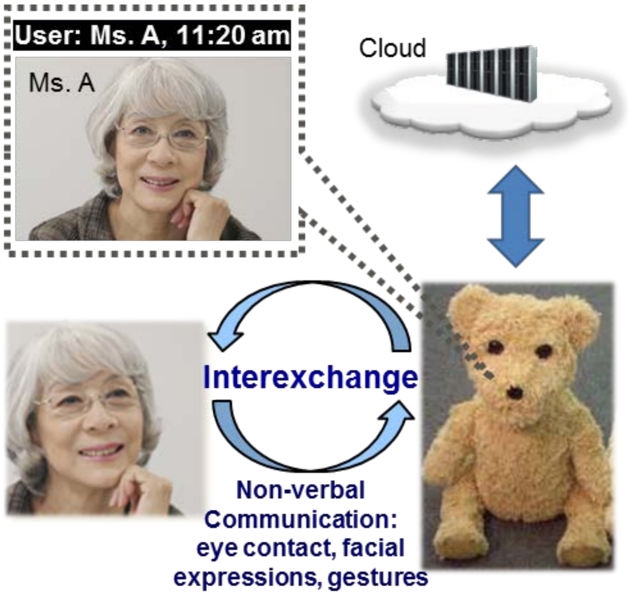

Figure 9: Socially-interactive teddy bear robot prototype

Although it looks very friendly, warm and cuddly, this robot prototype features leading-edge HCC technologies, including: a nose camera, 13 touch sensors, advanced image recognition, and innovative software. The prototype robot can monitor the user's physical condition – such as body temperature, level of alertness, physical activity, and facial expressions such as the degree of a user's smile – such data can be stored on the cloud, and remotely viewed. The prototype robot can also react to touch and sight, with its own movements and sound.

This robot prototype employing HCC technologies can be used in nursing homes or at residences for the elderly to gently remotely monitor senior citizens and interact with them in a warm, friendly manner. It can also be used for educational purposes with young children.

This socially-interactive teddy robot prototype is an interactive companion that can blend into daily life and deliver people-friendly services.

In this way, robotics employing HCC can unobtrusively and gently support individuals in society.

3.2 HCC Technologies: Intelligent Society Domain

When we refer to the "intelligent society" domain of a human-centric intelligent society as outlined in Fig. 6, various innovative and practical HCC-based ICT will be necessary to support such a society.

3.2.1 HCC Technologies: Multimedia Information Retrieval, Classification, and Exploration System: MIRACLES

Figure 10 illustrates a HCC-relevant technology that interactively extracts required data from within massive data on the Internet, by analyzing and visualizing text data and image data. The system is called MIRACLES, which stands for Multimedia Information Retrieval, Classification, and Exploration System.

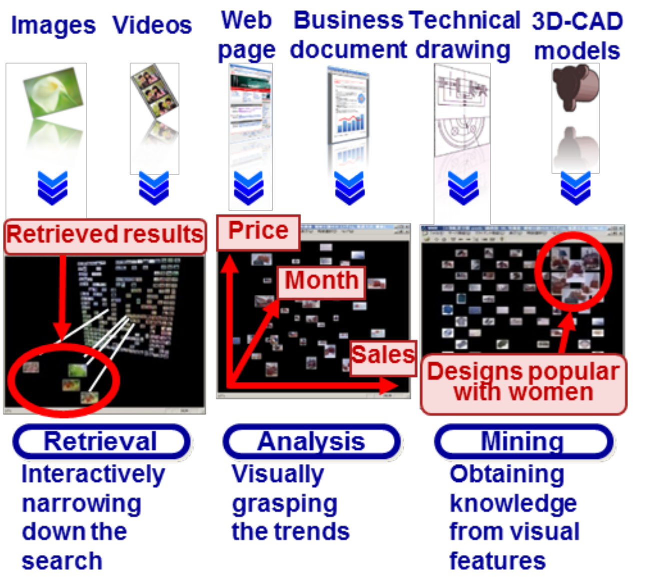

Figure 10: Multimedia Information retrieval, classification, and exploration system (MIRACLES)

The user enters keywords related to the data they seek, and the system retrieves images and text corresponding with those keywords. Next, the system creates categorizes and allocates the data in 3-D, so that similar data is featured near one another. Users can view and walk through the 3-D space, retrieving desired data.

This example shows a marketing application of this system, in which results are extracted for best-selling women's bags. Keywords are searched, then the retrieved data is allocated in 3-D under the categories "price", "month", and "sales".

In this way, this HCC-relevant technology enables interactive retrieval of desired data, such as social preferences and trends, etc.

3.2.2 HCC Technologies: Agricultural Knowledge Management

Cloud computing is already playing an important role in the field of agriculture. An ongoing issue in many countries is how agricultural knowledge and expertise can be passed down to next generations, despite diminishing agricultural human resources in numerous societies – especially among younger generations.

One such example of HCC-relevant cloud computing for agricultural applications is an agricultural cloud as illustrated in Fig. 11 – this technology enables the leveraging of experience and expertise to be passed down to future generations as tacit knowledge [12].

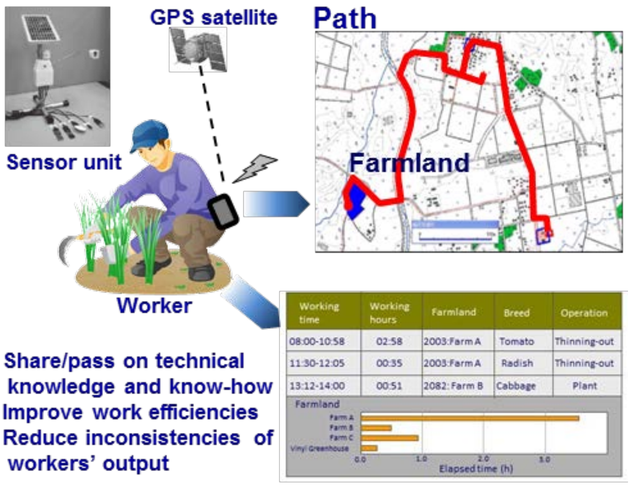

Figure 11: Agricultural knowledge management

This HCC-relevant agricultural cloud known as "Akisai" employs sensors to manage and monitor weather and soil conditions related to crops, to allow fertilizers and agrochemicals to be applied with optimal timing, leading to significant improvements in productivity. Agriculture draws from many years of accumulated experience and expertise.

Traditionally, agricultural products have been produced through a combination of experience and instinct, in other words a farmer's known-how. By using ICT to process this expertise, nearly anyone can access the practical knowledge of farmers, and achieve a leap in productivity.

By leveraging this innovative agricultural cloud technology, younger generations can play a far more active role in enterprise, enabling such valuable knowledge to be put to broader and more effective use.

In this way, there is growing potential for the application of HCC-relevant ICT in agricultural management.

3.3 HCC Technologies: Cloud Computing Technologies

In order to achieve a human-centric intelligent society through HCC, we envision that cloud computing [13], [14] will play an integral role (Fig. 6).

3.3.1 HCC Technologies: Next-Generation Server Enabling Both High-Performance and Flexibility

With the spread of cloud computing, the role expected of datacenters delivering cloud services is significantly evolving.

For example, big data, transmitted by large volumes of sensors in such as fields as life-logging, medicine, and agriculture, is collected in datacenters and put to use. For these applications and increasing diversity of services, datacenters are expected to deliver efficient and flexible processing.

Figure 12 illustrates a next-generation server that employs resource pool architecture to enable the delivery of high-performance server and storage capabilities as needed [15], [16].

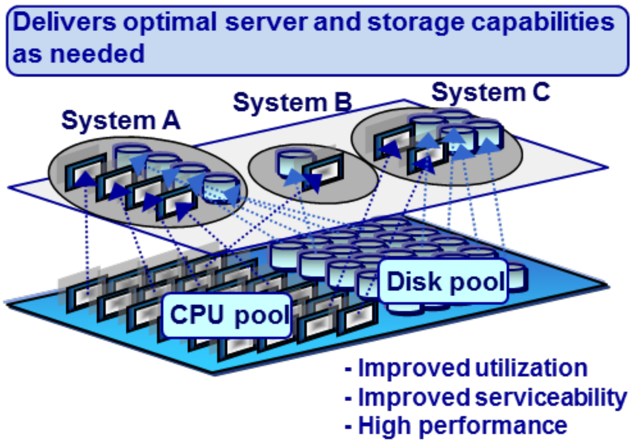

Figure 12: Next-generation server employing resource pool architecture

In accordance with user requirements for CPUs, HDDs, and other needs, necessary resources can be allocated from the pool, enabling servers to be configured on demand.

Using server resources from the pool, storage capabilities are delivered by configuring the middleware, which controls HDD management and data management functions.

The disk pool is connected to the CPU pool via a high-speed interconnect disk area network, enabling the delivery of the same disk access capabilities as the local disks in a typical server.

Providing flexible and high performance IT infrastructure based on cloud computing and HCC-relevant technologies will contribute to processing big data and the realization of ICT services.

3.3.2 HCC Technologies: Power-Saving System Control Technology For Container Datacenters

With the spread of cloud computing, the market scale for datacenters is growing, as is the amount of energy consumed by these datacenters.

In order to respond to the increasing need for datacenters, in addition to conventional large-scale data centers, the industry has seen progress in the commercialization of container datacenters, which require low up-front investment and can be quickly constructed.

Figure 13 outlines a power-saving system control technology for container datacenters that reduces total energy consumption by up to 40% when compared to conventional technology [17].

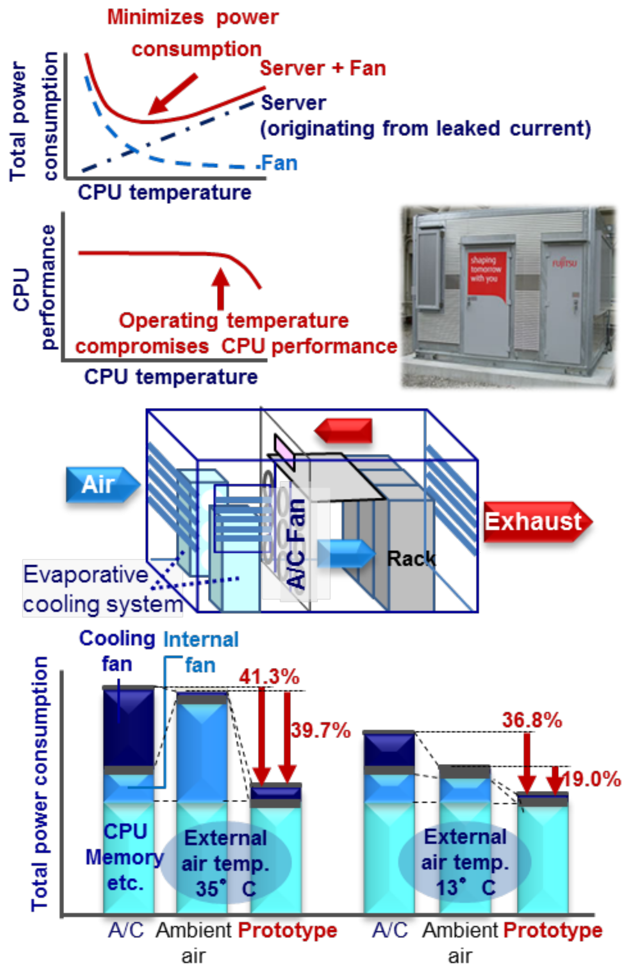

Figure 13: Power-saving system control technology for container datacenters

Total power consumption in servers is comprised of consumption from CPU and memory, combined with that of the server's own internal fans and the cooling fans in the room - by removing the internal fan, that portion of the power requirement was reduced.

By leveraging information regarding CPU temperature and server power consumption information, this technology enables simultaneous control all of the container cooling fans in order to minimize overall energy consumption.

Furthermore, based on CPU temperature and location information, the technology controls local container A/C fans to ensure that the system never reaches an operating temperature where CPU performance is comprised.

These two air-conditioned controls for servers without internal fans conserve power consumed by datacenters, helping to facilitate the spread of cloud computing that employs HCC-relevant technologies.

3.3.3 HCC Technologies: Energy Harvesting Technology

As observed in numerous countries worldwide, as societies experience transitions in energy sources and explore new types of energy, new developments in energy harvesting are underway [18].

Energy harvesting involves the harvesting and conversion of energy – such as light or heat, for example – from one's surroundings into energy. Figure 14 illustrates a hybrid energy harvesting device, which can generate electricity from heat and light available in the environment, and can be used in combination with cloud services. The hybrid power generator features dual-mode operation that can handle both photo-voltaic and thermo-electric modes [19], [20].

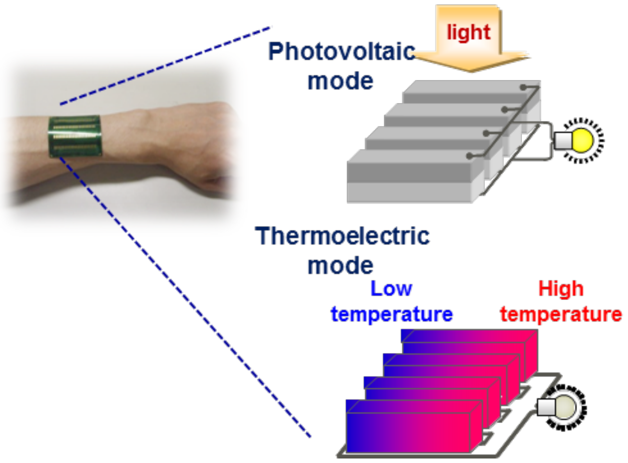

Figure 14: Hybrid energy harvesting device

With this technology, with a single device, it is possible to derive ambient energy from two separate sources – such as heat or light – which previously could only be handled by combining individual devices.

Furthermore, because the cost of this hybrid device is economical, this technology paves the way to widespread use of energy harvesting devices which generate self-sufficient power from the surrounding environment.

Since there is no need for electrical wiring or battery replacements, this energy harvesting technology could enable the use of sensors in previously unserved or underserved applications and regions – when used with sensors and cloud services, the technology has great potential for powering a variety of sensor networks and medical-sensing technologies.

4 CONCLUSION

Accelerated globalization has led to an alarming rise in increasingly intertwined, complex and daunting global-scale societal issues that significantly and directly impact people's lives in both industrialized and developing countries worldwide.

Simultaneously, the continuous widespread expansion of practical-use leading-edge ICT along with continuous and explosive growth of massive data in society – in particular the advent and leveraging of cloud computing and big data – have given emergence to opportunities and needs for ICT to provide "human-centric solutions" to handle such globally intertwined, complex and daunting societal issues.

We outlined how we envision how Human-Centric Computing (HCC) technologies as vital frameworks will drive the shift toward, and provide much of the essential and practical means for enabling and supporting a resilient, prosperous, and sustainable "human-centric intelligent society" we envision for the future.

We foresee that leveraging leading-edge HCC technologies - such as those which we highlighted in this paper - will play an essential role in enabling and supporting a resilient, prosperous, and sustainable human-centric intelligent society we envision for the future.

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Olfactory Measurement Method at Health checkup with Olfactory Display using Pulse Ejection

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Abstract - A decline in olfaction is reported to be an early symptom of diseases such as Alzheimer's and Parkinson's disease. Thus, from a medical point of view, understanding the condition of the olfactory system is important. However, unlike sight and hearing, olfaction is not examined at a regular health checkup. Because scents linger in the air and measurements require a great deal of care and time. In this study, we construct olfactory measurement method for health checkups. We use inkjet olfactory display. Thus, pulse ejection for scent presentation is able to minimize odor elimination. Measurement algorithm uses binary search. Therefore, we can measure the detection threshold at 192 levels in total by changing the number of stimultaneous ejections and ejection time. For measurement result, we can quantify the detection threshold. Furthermore, only 5 min is needed to measure the detection thresholds. From this knowledge, measurement time, burdens on the patient and operator and problem such as odor elimination were cleared up so that olfactory measurement in health checkups is expected to work out in the future.

Keywords: olfactory display, olfactory characteristics, pulse ejection, interface application, medical check

1 INTRODUCTION

Olfaction is used to detect dangers such as rotten food and gas leaks. Moreover, a decline in olfaction is reported to be an early symptom of diseases such as Alzheimer's and Parkinson's disease. If we detect it, the possibility of the recovery is increased. Thus, from a medical point of view, understanding the condition of the olfactory system is important. The predominant measurement method for olfaction is Toyota and Takagi (T&T) olfactometry and venous olfactory test. However, unlike sight and hearing, olfaction is not examined at a regular health checkup. Because these methods have some problems.

The health checkup is the health care service that local government and health insurance union provides publicly. It is mainly carried out by schools, and having a health checkup is needed once a year. In health checkup, various measurements including body measurement, eye exams are performed in a mass. Moreover, the measurement is carried out for hundreds of people per day. However, in current olfactory checks, it takes a great deal of care and time. On the other hand, health checkup is carried out in a gymnasium and classrooms as schools, so same people have to be measured at a time in the place where there is not enou-gh ventilation. In olfactory check, it is necessary to pay adequate attention not to fill a room with scent. However, if olfactory measurement is carried out, scented paper and bags filled with scents are used in each olfactory check, and a considerable amount of waste which is scented is generated. So, scent is scattered in the room. From the viewpoint of these, existing olfactory examinations are difficult to carry out at health checkup. Hence olfactory examinations are not standard in health checkups today.

In this study, we construct olfactory measurement method using olfactory display which can control scents precisely enough to be used in olfactory measurement. For the measurement, we use olfactory display by using a technique based on an inkjet printer mechanism. It uses pulse ejection for scent presentation so that we can measure without diffusion of scent. However, human olfactory characteristics to pulse ejection are unknown. So, in this study, we measure it as a trial.

2 MEDICAL KNOWLEDGE

2.1 Disease about Olfaction

Alzheimer's and Parkinson's disease occupy approximately 60% of dementia in Japan and are generally well known[1]. Alzheimer is easy to be mistaken for forgetfulness, and the early detection is difficult. However, here is the risk becoming too late if discovery becomes late. Patients with these disease have risk that olfactory impairment is caused[2]. About lower respiratory infection and inflammatory disease in stage of old age, etiology is discussed in relation to rhinosinusitis. Checking the condition of the olfactory system leads to early detection of disease such as Alzheimer[3].

2.2 Existing Olfactory Examinations

To discover whether any olfactory impairment has occurred, a suitable assessment technique is required. In Japanese, T&T olfactometry is usually employed to take such measurements. T&T olfactometry measures a patient's olfactory thresholds by presenting, in front of the nose, paper scented with a basic odorant[4]. Tests thus use five smells. Each test begins at the lowest scent concentration, which is then increased until the examinee detects the odor. This value is set as the detection threshold. Next, the concentration is further increased until the examinee recognizes the scent. At this point, the examiner displays a choice of words to express the quality of the smell. If the correct answer is selected, the corresponding concentration is set as the recognition threshold. Each basic smell is given a score at one of eight levels from -2 to 5, where 0 corresponds with the mean Japanese detection threshold. The result is finally plotted in an olfactogram on graph paper[5].

Intravenous test is also employed to determine the level of olfactory impairment. In this test, Alinamin injection with a strong garlic odor is injected via the cubital vein, and the interval between the start and end of the reported smell perception is timed. In normal participants, the start time for perception is around 5–10 s and the end time is 60–90 s. Although this test is a limited method, which is done in a general clinic, implementing this test could be important in determining the prognosis of olfaction impairment and deciding upon a treatment regimen. Except for respiratory dysosmia, this test is helpful for olfactory anesthesia. If a long time elapses without recovery of olfaction, the patient will have only a small chance of recovery. Therefore, this test is crucial for early diagnosis and treatment of olfaction impairment[6]. However, a disadvantage of the test is that in one-third of cases, participants experience pain near the injection site from elbow to shoulder[7].

2.3 Olfactory Threshold

Olfactory thresholds are values used to express the intensity of a scent. Typically, four types of olfactory thresholds are used: detection, recognition, differential and identification [8].

- Detection threshold: the minimum concentration at which a scent can be detected when the patient does not need to recognize the type of smell.
- Recognition threshold: the minimum concentration at which the type of scent can be recognized. Its value reflects the ability of the patient to express the quality and characteristics of the scent.
- Differential threshold: the minimum concentration at which a patient can distinguish the strength of a scent. Its value reflects the patient's ability to detect changes in the stimulus and to quantify the change.
- Identification threshold: the minimum concentration at which a patient can identify a scent presented beforehand.

In a general olfactory examination, acuity is measured by using these thresholds. For example, T&T olfactometer measures detection threshold. In this study, we measure the detection thresholds. Measuring detection threshold can help to find an early symptom of diseases.

3 OLFACTOORY MEASUREMENT METHOD FOR HEALTH CHECKUP

Olfactory examinations are not carried out at health checkups on grounds that scent scatter in the air, waste such as scented paper and bags filled with scents is generated, measurements require a great deal of care and time and so on. Through the solution of the issue, olfactory examination can be utilized in health checkup. To this end, we work out olfactory measurement method aiming to use at health checkup. This method makes it possible to measure detection threshold. By using this measurement method, we can easily carry out the olfactory measurement at the place such as a classroom and a gymnasium. Detection threshold is simple examination that people can understand scented or odorless. Thus, we adopted detection threshold from olfactory threshold because it takes shorter time than other olfactory threshold. As for measurement method, we discussed with ear, nose, and throat doctor, and made many improvements. Hence it is more practical measurement method. We measure the detection threshold with this method as a trial.

The issue such as diffusion of scents, waste and a great deal of care to measure is cleared up by olfactory display we developed, using a technique based on an inkjet printer mechanism. This olfactory display can use a scent presentation technique to emit scent at the picoliter level for a short duration that we call “ pulse ejection ” . It has use of the wind and carries scent to user's nose directly, so that user can feel it. Pulse ejection emits aroma chemical minutely small doses, so that user can feel little scent when user departs from the device. Thus, it isn't necessary to worry about scent diffusion. This device uses wind to carry scent and has ink tank filled with aroma chemical in place of ink. Once scent is restocked with tank, more than ten thousand times of ejection is possible. Hence waste isn't generated at measurement. Scent intensity is controlled with the number of simultaneous ejections (NSE) and ejection time. The device is controlled with PC and can change NSE and ejection time freely. Thus, care to measure is alleviated because we can emit scent just to operate a PC. Although detection threshold can be measured at 192 levels in this measurement method by using the olfactory display, measurement can be finished in a short amount of time. By measuring olfactory threshold with this olfactory display, like sight and hearing, it is possible to quantify the human olfactory characteristics. For example, the scent intensity of T&T olfactometry is eight levels. However, by using this device, we can measure more finely and quantify it more precisely. Moreover, if the human olfactory characteristics can be quantified, we can apply it to the field of multimedia. And, if the scent intensity is decreased, problems such as lingering scent may be diminished.

In this study, measurement algorithm is specific one using binary search to combine with these parameters. Value of these parameters is changed in order to take dynamic range widely. Hence a lot of people who have from good sense of smell to a little good sense of smell can be measured. This measurement method is aimed at the utilization of screening in the future. It is also aimed at finding fear of olfactory impairment. If the fear is found at this measurement, the patient shall go to hospital and measure precisely by existing olfactory examinations. Existing olfactory examinations can measure precisely but isn't suitable for measurement with many people at a time in the place such as a gymnasium and classrooms as schools. Hence we worked out olfactory measurement method aiming at health checkup. This time we examined olfactory characteristics by using it at the beginning.

Then, we could quantify the human olfactory characteristics.

4 OLFACTORY MEASUREMENT METHOD

4.1 Olfactory Display

Figure 1: Olfactory Display

We developed an olfactory display shown in Fig. 1. This display uses the technique used in ink-jet printer in order to produce a jet which is broken into droplets from the small hole in the ink tank. The device can change the ejection time at 667 μs intervals so that measurement can be controlled precisely.

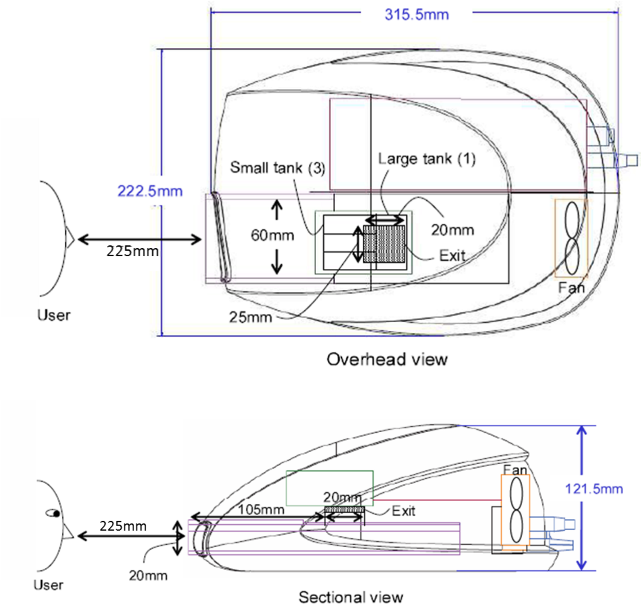

Figure 2: Plane and side view of the olfactory display

Figure 2 shows internal design of the olfactory display. The display can set up an ejection head. This head can store three small tanks and one large tank, thus this display can contain 4 kinds of scents maximum. In this study, we used large tank. The display is equipped with a fan and there are 10 phases of wind velocity control in the range of 0.8 m/sec-1.8 m/sec. The scent presentation hole is a rectangle of 2 cm length and 6 cm width.

It is possible to change the ejection quantity and the kinds on 100msec rate at this display. The ejection quantity (EQ) is calculated as follows.

$$EQ(pL) = UAEQ(pL/time) \times NSE \times V(times) \quad (1)$$

Here, UAEQ is the unit average ejection quantity (the average ejection quantity from each minute hole in the head), NSE is the number of simultaneous ejections (the number of minute holes in the head that emit at one time), and V is the volume (explained below). There are 127 minute holes in the head connected to the small tank and 255 minute holes in the head connected to the large tank. Moreover, the display can emit scent from multiple holes at the same time, so NSE is adaptable to 0-127 (small tank), 0-255 (large tank). In addition, the user can set the number of ejection times 1-150 in 100 msec from one hole, which we denote the “ volume ” . By setting the volume, ejection control of 667 μs for a unit is possible. The concept of volume is shown in Fig. 3. Volume is converted at time and expressed in “ ejection time ” in the measurement.

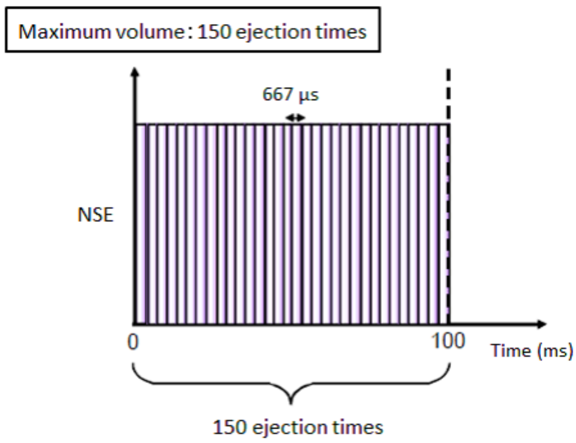

Figure 3: Concept of Volume

UAEQ from one minute hole on large tank is 7.3 pl. It was confirmed to be approximately constant without depending on the residual quantity of ink on examination. In this study, we adjust EQ by changing NSE. We put the change of EQ into “ scent intensity ” and denote as follows. And scent is diluted by 5% with ethanol and water. So scent quantity is practically calculated as follows.

$$Scent\ Intensity = UAEQ(pL/time) \times NSE \quad (2)$$
$$Scent\ Quantity = EQ \times 0.05 \quad (3)$$

4.2 Measurement Algorithm using binary search

In this study, we use NSE from 0 to 255 and ejection time 8 ms and 4 ms. We previously measured olfactory character-

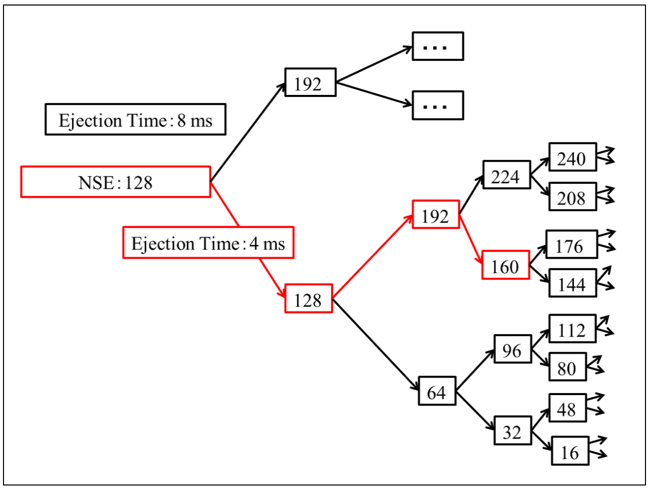

Figure 4: Measurement Algorithm for Detection

istics by using 100 ms and 13.3 ms ejection time. However, average of detection threshold was low, and hence people who have a good sense of smell were found little difference[9]. We repeat preliminary experiment and adjust value to measure people who have a good sense of smell. Thus, we adopted 8 ms and 4 ms.

We use the algorithm shown in Fig. 4. This algorithm is binary search algorithm NSE with ejection time. NSE is decreased if the answer is correct and increased if the answer is incorrect. We begin with 128 NSE and an ejection time of 8 ms. NSE is changed from 0 to 255 in the measurement, and hence we start measurement from median NSE. For the first measurement, the ejection time changes to 4 ms if the participant's answer is correct and stays at 8 ms if the answer is incorrect. We give an example and explain the way of value change. First, we begin with 128 NSE and an ejection time of 8 ms. For the first measurement, the ejection time changes to 4 ms if the participant's answer is correct. Second, NSE changes to 192 which is the value added 64 that is half 128 value to 128 if the participant's answer is incorrect. Next, NSE changes to 160 which is the value subtracted 32 that is half 64 value from 192 if the participant's answer is correct. Similarly, we measure until a change level becomes 2.

5 EXPERIMENTAL OUTLINE

The screening value which can determine the possibility of olfactory disturbance in a short time is needed. However, olfactory measurement by using olfactory display with pulse ejection is not worked out. So the human olfactory characteristics are numerically unknown. Then, we measure it precisely as a trial. We also timed the measurement and use it as a reference for future measurement method.

5.1 Experimental Environment

In the experiment, the olfactory display connects with a personal computer. The measurer controls the personal computer. The measurer and participant sit face to face, so participant can't see the measurement display. Each participant was required to sit in front of the olfactory display and place their

Figure 5: State of the experiment

chin on the chin rest such that the distance from the olfactory ejection point to the nose was fixed at 22.5 cm as shown in Fig. 5. The patient experiences a feeling of oppression if he gets too close the device and he can't feel scent if too far from one. For this reason, this is the value we adjusted to meet conditions. The fan of the display was switched on during experiments to stop participants being able to tell when the scents were delivered to them. A previous experiment found that a scent will not linger in the air if the wind speed is higher than 1.2 m/s[10], and so the wind speed in the current experiment was set to 1.8 m/s.

5.2 Experimental Method

By following olfactory measurement method shown in Section 3, we conducted olfaction examinations on 44 participants, measuring their detection threshold. A description of the participants is given in Table 1. Participants were 33 men and 11 women in their 20s to 40s. There were many participants in their 20s and all participants had perfect olfactory function.

Table 1: Description of Participant(people)

	Male	Female	Sum
20s	26	9	35
30s	6	2	8
40s	1	0	1
All	33	11	44

To determine the detection threshold, we use isoamyl acetate, which smells like banana. This scent is simple chemical substance, and hence it does not come under an influence by a production area and the preservation organization unlike natural fragrance and there is an advantage to be superior in reproduction. We use this scent in the measurement because scent of banana is relatively easy to detect. We use the triangle test to judge the detection threshold in the measurement. In the triangle test, three stimuli are presented at random, where one of them is scented and the other two are odorless. The participant then answers when the scented odor was presented in the

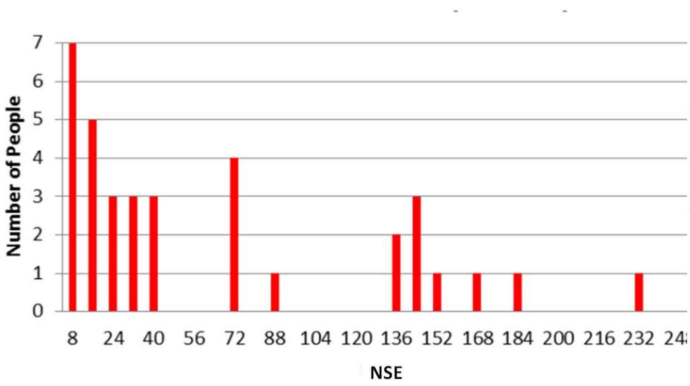

Figure 6: Detection threshold in 4ms

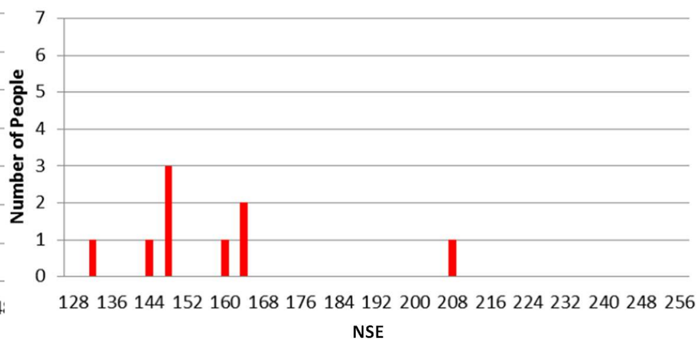

Figure 7: Detection threshold in 8ms

three times. In the experiment, Measurer uses the application for olfactory measurement. The measurer clicks the ejection button on the computer to present the scent. When the scent is ejected, the countdown starts with the auditory cue. Scent emission then commences 0.5 s after giving the cue“Go” according to previous study[11]. After the participant answer, measurer chooses from options and input the participant's answer. This operation is assumed once, and repeated seven or eight times. When the measurement is finished, the participant's detection threshold is recorded on the computer. Then, at the same time to find a value of the detection threshold, we timed measurement from beginning to finishing.

6 RESULTS

6.1 Measurement Result of Detection Threshold

The results of detection threshold measurements for the 44 participants are listed in Table 2, which shows average, standard deviation, max and min on the 4 ms and 8 ms results. Depending on measurement algorithm, NSE is from 2 to 255 when ejection time is 4 ms, and from 128 to 255 when ejection time is 8 ms. Here, the standard deviations are large. Thus, a definite expression of a person's olfactory ability can be obtained. Minimum value participants can detect is 2 in 4 ms, and it fits in minimum value in measurement algorithm. Hence, measurement for person who has a good sense of smell was possible in this measurement. Moreover, Maximum value participants can detect is 206 in 8 ms. It was found that the detection threshold for participants who have perfect olfactory function depended on personal olfactory ability in this measurement method.

Figures 6 and 7 show distribution of measurement result. In fact, we measure detection threshold at 192 levels. However, we show the measurement result at 48 levels in Fig. 6 and 7, so that distribution of the number of people can be easy to understand. Abscissa axis shows NSE, which is detection threshold of each person. Vertical axis shows a number of people and expresses it how many participants who became each detective threshold there is. From the result, participants who have good sense of smell can detect subtle scent. On the other hand, participants who have not so good sence of smell can't detect stronger scent than the scent person who have good sense can detect. When the scent is presented with multimedia such as TV, the scent intensity fall inside this range. This result can be applied to the field of multimedia. However, we didn't measure the people who have olfactory disturbance this time. When we measure them, the much stronger scent is needed.

Table 2: Result for detection threshold

	4 ms (35 people)	8 ms (9 people)
Average	60.06	155.78
Standard Deviation	62.64	21.39
Max	228	206
Min	2	130

We measured the detection threshold precisely in this study, and hence a measurement finishes has been completed up to eight times. It cannot take time for the per person measurement at health checkup. Because the screening of olfactory impairment is a purpose at health checkup, it is thought that such delicate measurement is not necessary. We measure detection threshold at 192 levels, however, we show the measurement result at 48 levels in Fig. 6 and 7. Through this, it is revealed that personal ability to smell is seen even if the number of the measurement is reduced to some extent. So we also need to examine how much has to quantify it finely.

6.2 Measurement Time

The average measurement time was 4 minutes 21 seconds and the standard deviation was 37.1 seconds. Thus, measurement could be finished within 5 minutes regardless of participants. Measurement time for per person has to be kept to the minimum at health checkup. According to ear, nose, and throat doctor, olfactory measurement has to be finished within 5 minutes at least. As consider it as a guide, this measurement method has possibility to carry out at health checkup.

In this measurement, participants had no experience in olfactory check, so they got bewildered and got thoughtful, and hence there were many persons who took time more than radical measurement time. It is thought to shave off time if olfactory check is carried out at health checkup and persons are used to measure. In fact, measurement of us who are used to measure olfactory check was finished in 3 minutes 40 seconds. Moreover, we measured finely, so it took much time. As cited in chapter 6.1, it was found that personal ability to smell is seen even if the number of the measurement is reduced to some extent. Thus, a number of levels are decrease so that measurement time can reduce more than result in this time. To carry out at health checkup, it is needed to determine the screening value for measuring olfactory threshold. By using this result, we perform further experiments to examine the screening value. If we determine it, the measurement time is more short and the possibility to carry out the olfactory measurement at health checkup is increased.

7 CONCLUSION

A decline in olfaction is reported to be an early symptom of diseases such as Alzheimer's and Parkinson's disease. However, olfaction is not examined at a regular health checkup on grounds that scent scatter in the air, waste such as scented paper and bags filled with scents is generated, measurements require a great deal of care and time and so on.

In this study, we worked out olfactory measurement method aiming to use at health checkup. We used inkjet olfactory display which can use pulse ejection for scent presentation to minimize odor elimination. Measurement algorithm uses binary search. Therefore, we could measure the detection threshold at 192 levels in total by shift in the number of simultaneous ejections. By using this measurement method, we think the problems of predominant olfactory measurement are cleared up. However, the human olfactory characteristics to pulse ejection are unknown. So we tried to measure it. For measurement result, only 5 min was needed to measure the detection thresholds.

On the other hand, the olfactory threshold is quantified with computing control. The device could measure it finely and clear up the problems. This time, we examined it on a trial basis. However, to carry out at health checkup, we will examine the screening value for olfactory measurement based on this result. And we try to measure in more short amount of time. We hope that this study is useful in the future.

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Evaluation of Lump-sum Update Methods for Nonstop Service System

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Abstract - In many mission-critical systems, the lump-sum update of large amounts of data is performed. On the one hand, with the development of internet business, nonstop online services have become to be provided in many mission-critical systems. So, the lump-sum update has to be performed concurrently with the online entry. However, in the actual mission-critical systems, there are various kinds of lump-sum update operations corresponding to their business. In this paper, we define the lump-sum update models from the point of view of both the actual business process and characteristics of the target data, and show the problem of the conventional update methods. Then, we propose a novel update method for this problem, which utilizes the transaction time database, and show its evaluation results of the efficiency of both the lump-sum update and online entry comparing with the conventional update method. Based on these results, we show the proposal method is effective in the case where the update data is related to each other.

Keywords: Database, batch processing, mini-batch, transaction, mission-critical system, nonstop service.

1 INTRODUCTION

In many mission-critical systems, their databases are usually updated by two methods. The first is entries from online terminals (hereinafter "online entry") such as ATM (Automatic Teller Machine) in a banking system, which is performed at any time in the online service time zone and its result is immediately reflected in the database. Because the online entries are performed concurrently by many users, their ACID properties are maintained by the transaction processing based on the lock function of the database. So, the result becomes as if they were performed in a certain order.

The second is the lump-sum update of large amounts of data in the database. For example, large amounts of account transfer in a banking system, which is entrusted by a company, is performed as a lump-sum update. This process is not required rigorous immediacy, so it is performed at the designated time by the system administrator. Therefore, in the old days, it was performed as the night batch to avoid the online service time zone by the method locking the whole target data and updating them in a lump (hereinafter "batch update"). However, in recent years, the electronic commerce has been expanding due to the progress of the internet business, and many systems have become to provide the nonstop online service, such as above-mentioned ATM. As the result, it has become necessary that the batch update is performed concurrently with the online entry.

On the other hand, the mini-batch has been put to practical use, which divides the lump-sum update into small update units to reduce the individual lock time and performs them sequentially [2]. However, because the mini-batch updates data one after another, the state on the way of the update is queried, in which some data is not updated yet and the other is already updated. That is, the ACID properties of the transaction are not maintained as the whole mini-batch processing.

Here, in our previous study on query methods in a mission-critical system, we showed that there are various kinds of batch operations and the appropriate method should be adopted for each case [3]. This suggests that the various requirements exist for the lump-sum update process according to the business operations, too. So, in this paper, we focus on a local government system as an example of the mission-critical systems and define the lump-sum update models from the point of view of both the actual business process and characteristics of the target data, in which lump-sum update is divided by both the conflict with the online entry and relevance between the update data. Then, we show the requirement of the lump-sum update method for each update model. And, in some case where it is performed concurrently with the online entry, we show there is the problem that the consistency of the data cannot be maintained by the conventional update methods.

For this problem, we propose a novel update method to maintain the ACID properties even in the above-mentioned case. It utilizes the transaction time database, which is a kind of temporal database and supports the record management on the transaction time when some fact existed in the database [4]. Hereinafter we call this method "temporal update". Moreover, we evaluate the efficiency of both the lump-sum update and online entry about the following update methods by developing prototypes: the batch update, the mini-batch and the temporal update. Based on these results, we show the database can be updated in the practical efficiency by the temporal update method, even for the update model that was challenging for the conventional methods. In addition, we show that an appropriate method has to be adopted based on the business operations, for not only the lump-sum update but also the online entry.

In Section 2, we define the lump-sum update models from

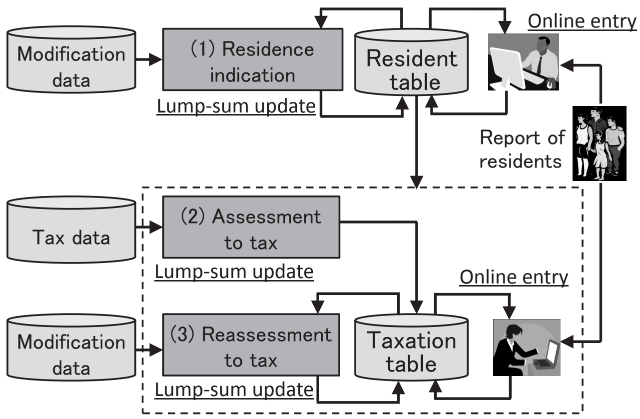

Figure 1: Business processes with lump-sum update

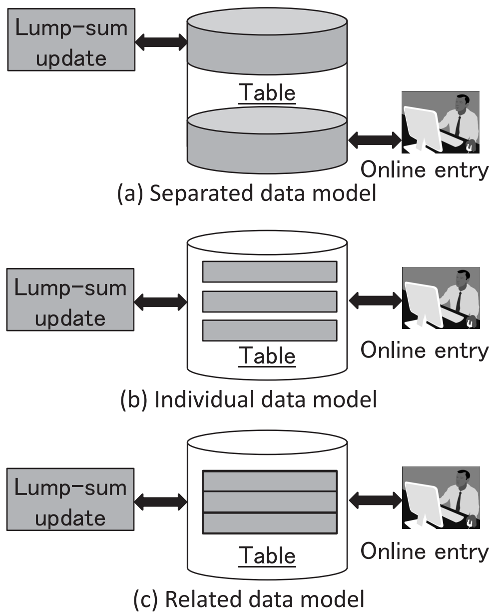

Figure 2: Lump-sum update models about business

the point of view of the business operations, in Section 3 we propose the temporal update method and in Section 4 we show the prototype to evaluate its efficiency and characteristic. In Section 5, we evaluate the update methods from the point of view of update models, and in Section 6 we show our considerations.

2 MODELING OF LUMP-SUM UPDATE IN MISSION-CRITICAL SYSTEMS

2.1 Business Process with Lump-sum Update

In the actual mission-critical systems, there are various kinds of lump-sum update processing corresponding with each business process. Figure 1 shows examples of them about the tables in a local government system, which is updated also by online entries. We show the requirement of the lump-sum update based on these cases below.

Resident table of Fig. 1 stores the data of resident cards, which is used by the various business of the local government office for the attribute information of the resident: name, address and so on. Here, because residents belong to each household, the consistency of the resident data in the same household has to be maintained. In addition, as for a resident, since a series of records from birth to death and so on is managed, the consistency among the records also has to be maintained. In the online entry for this table, the change of the resident such as moving and birth is reflected in the table immediately. And, if the resident requests his or her resident card simultaneously, it is published immediately reflecting the change. On the other hand, for the example of the lump-sum update of this table, the residence indication is given. This business is performed to change addresses to be easy to understand, so it is performed in the whole target district at the same time. That is, since a great deal of data is updated for this business process, it is performed by the lump-sum update in the local government system.

Similarly, Taxation table in Fig. 1 stores the taxation data of the residents. There is no correlation among the data, because taxation is performed for each resident individually. Since the taxation is managed by the fiscal year, the assessment to tax is performed to add the tax data of the target year at first. Here, several tax declarations from residents are late for this assessment, and several changes of residents also occur after it. So, the reassessment to tax is performed at regular interval to correct the taxation. Since these business processes are performed for a large number of residents, they are executed by the lump-sum update. On the other hand, when a resident is going to move out, his or her taxation is calculated based on the change by the online entry at the report window of the local government office and reflected in Taxation table immediately. On this basis, the settlement of tax is performed at the same time.

2.2 Lump-sum Update Model about Business

The lump-sum update during the online entry, which is shown in Fig. 1 from the viewpoint of the business processes, corresponds to the following three types of lump-sum update models from the viewpoint of the update data, which is shown in Fig .2. Here, from the viewpoint of the business requirement, we assume that the online entry can update optional target data at the optional time and the update cannot be predicted beforehand. In other words, since it is the business of the report window about residents, the online entry cannot be suspended even during the lump-sum update.

(a) **Separated data model:** the case that the lump-sum updated data and online entry data are isolated as the business process. It corresponds to "(2) Assessment to tax" in Fig .1. In this case, the lump-sum update can be executed without considering the online entry. As the other example of this case, there is the business process to append the budget data of the new fiscal year in accounting systems.

(b) **Individual data model:** the case that the lump-sum update and online entry are concurrently executed on the same data, and this data independent from the other data.

It corresponds to "(3) Reassessment to tax" in Fig .1. In this case, these updates don't effect to the other data, even if there are conflicts between the lump-sum update and online entry. As the other example of this case, there is the process of a great deal of the account transfer in banking systems.

(c) **Related data model:** the case that the lump-sum update and online entry are concurrently executed on the same data, which is related to the other data. It corresponds to "(1) Residence indication" in Fig .1. As for the residents' information of the same household and the records of each resident, their consistency has to be maintained before and after the update. On the other hand, the change of a resident is processed by online entry: transference between households by moving, addition to a household by moving in and so on. Therefore, the lump-sum update has to be processed as a transaction that satisfies the ACID properties for online entries.

2.3 Problem of Conventional Lump-sum Update Method

The row lock function is provided by present database management systems, by which each single data of the table can be locked [5]. So, as for "(a) Separated data model" of Fig .2, we can execute the lump-sum update without affecting the online entry by locking only its target data, because the target data is not covered by online entry. So, it can be executed as the transaction processing by the batch update as follows: its commit is executed if the update succeeded; its rollback is executed if the update failed. In addition, in this model, the mini-batch can be also used for this lump-sum update updating data sequentially, because its target data is not covered by online entry. However, in this method, when the update failure occurred, it is necessary to perform the separate compensating transaction to cancel the whole update [2].

As for "(b) Individual data model" of Fig .2, the online entry becomes a waiting state when it competes with the lump-sum update, because the both may update the same data. So, the lump-sum update is executed by the mini-batch, because the batch update suspends the online entry for a long while. It is the method to update data one after another using the row lock function, which locks the currently updated data only, and it makes the influence on the online entry smaller because the update time of the individual data is short [2]. However, it performs the commit to each update. So, even though the failure occurred and the rollback was executed, the data already committed remains in the state of having been updated. That is, the committed data cannot be canceled in this method, because it may have been already used by the online entry. So, it is necessary to complete all the updates finally with removing the cause of the failure and continuing the update process.

On the other hand, as for "(c) Related data model" of Fig .2, it is difficult to update data by these conventional methods. First, as for the batch update, when the target data is being tried to update by the online entry concurrently, it obstructs the online entry in the same way as the individual data model. Next, as for the mini-batch, the ACID properties cannot be

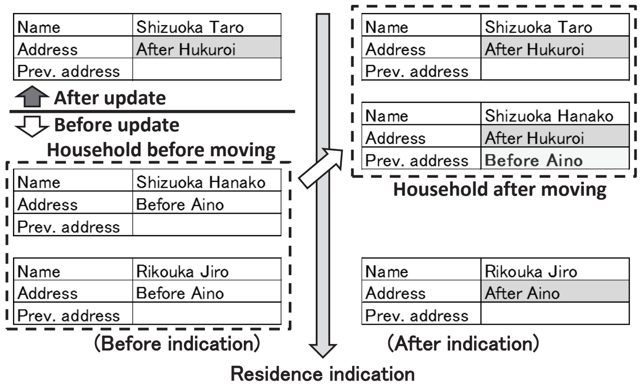

Figure 3: Online entry example of the related data model

maintained as the whole lump-sum update because each update is executed as the individual transaction, although its influence on the online entry is small. Therefore, as for the related data model, there is a problem that the integrity of data isn't able to be maintained by the conventional lump-sum update methods.

For an example of this, we show the case of a resident transference between households by moving, during the residents indication processed by the mini-batch in Fig .3. Here, the household that he or her belonged before this moving is not updated yet by the resident indication; the household after this moving was already updated. On the other hand, both of the present address and previous address are listed in the resident card. And, when this moving is processed by online entry, both of the before and after moving household data is locked by the transaction. However, because only the after moving household data has been updated, two types of addresses are listed in the resident card of this resident at the same time: the previous address is before the update; the present address is after the update. Thus, the problem that the integrity of the data isn't maintained occurs.

3 PROPOSAL OF A NOVEL LUMP-SUM UPDATE METHOD

For the problem shown in Section 2.3, we propose a novel update method, that is, temporal update method. It utilizes the transaction time database that is a kind of temporal database.

In the transaction time database, the time history that some fact was valid in the database is managed. The data once stored in the database is not deleted physically, and the time when the data became invalid is set to delete the data logically. The relation [1] of the transaction time database is expressed as $R(K, T, D)$. First, attribute K expresses the set of attributes constituting the primary key of the snapshot queried at the designated transaction time. Second, T is the time period attribute of the transaction time, which is generated by the system and isn't made public to users. T is expressed by the time set $\{T_a, T_d\}$: T_a shows the addition time that data was added to the database; T_d shows the deletion time that data was logically deleted from the database. As long as the data doesn't be deleted yet, the instance of the attribute T_d is expressed by "now", which shows the current time and

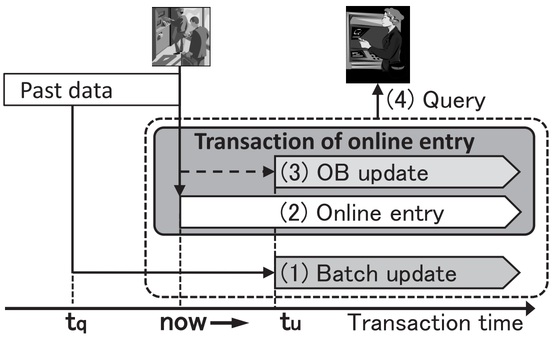

Figure 4: An example of temporal update method

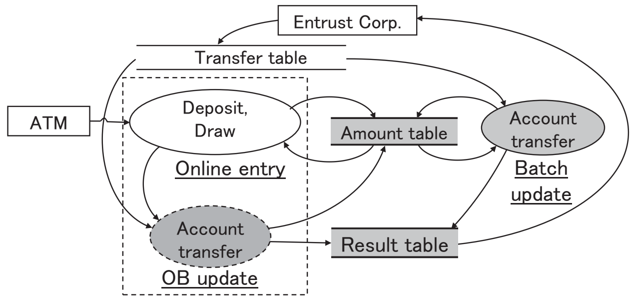

Figure 5: Dataflow of prototype

changes with the passage of time [7]. Third, D expresses the other attributes. Therefore, since the time history is managed, the snapshot at any designated past time can be queried. Moreover, the query result for a designated transaction time t becomes the snapshot of the time, and it is similar to the usual database that is called a snapshot database.

For the proposal method, We extend K by adding P, which shows the update process: the online entry, batch update and so on. So, the configuration of K is expressed by the attribute set $\{K_1, K_2, ..., K_n, P\}$. Here, n is the number of attributes except P. Figure 4 shows an example of this method, in which the account transfer is executed by the lump-sum update during the online entry from ATM in the banking system. Here, the time period of the lump-sum update process is between t_q and t_u. Using the transaction time database, the integrity of the snapshot result at the past time t_q can be maintained even during the online entry, because it updates the data at now.

As shown in (1) of Fig. 4, we perform the account transfer using this snapshot by the lump-sum update, and add the updated result to the database as the data which addition time is t_u. Here, since this data is separated from the online entry data by the above-mentioned primary key attribute P, we can add it by the batch update in the same way as (a) of Fig. 2. On the other hand, data is updated by the online entry from the ATM concurrently with this update as shown by (2). However, as shown in Fig. 3, since the batch update result is not reflected in the online entry, the process of the account transfer has to be executed individually in the same transaction of this online entry as shown by (3). Hereinafter, we call this process "OB update". Thus, since three types of data are added by different update process classified by P, the valid data is sorted out in the query process (4).

Briefly, in the temporal update, if the online entry is executed during the batch update, the process of the later is also executed individually as the OB update in the same transaction of the former. Incidentally, the OB update continues until the completion time t_u, because t_u have to be set previously.

4 EXPERIMENTS

4.1 Composition of Prototype

To confirm that we can put the temporal update method to practical use, we constructed the prototypes of both this method and conventional methods, which are the mini-batch and batch update, and evaluated their efficiency and characteristics. The prototype intends for the processing of a banking system shown in Fig. 4, and we show its data flow in Fig. 5. That is, the withdrawals and deposits to the bank accounts from the ATM are processed by the online entry to update the balance of "$Amount\ table$". On the other hand, large amounts of the account transfers, which are ordered by the trust company, are processed by the lump-sum update. Basing on the bank account and debit of "$Transfer\ table$", this process updates the balance of $Amount\ table$ and adds its result to "$Result\ table$". Each table is expressed by the following relations. Here, $Transfer\ table$ doesn't need to be the transaction time database, because it isn't updated.

$$Amount\ table(Account, Balance, T, P)$$
$$Result\ table(Account, Result, T, P)$$
$$Transfer\ table(Account, Debit)$$

Here, each attribute shows the following data: "$Account$" shows the bank account; "$Balance$" shows the bank balance of it; "$Result$" shows the result of account transfer from the bank account; "T" and "P" shows what described above. Incidentally, the instance set of P is as follows.

$$P = \{Batch\ update, Online\ entry, OB\ update\}$$

As for the bank account which account transfer is successful, $Balance$ of $Amount\ table$ is updated, and the result data is added to $Result\ table$, of which $Result$ is "0" (success). On the other hand, as for the bank account which doesn't exist or doesn't have sufficient balance, $Amount\ table$ isn't updated, and the result data is added to $Result\ table$, of which $Result$ is "1" (failure).

That is, the process of this lump-sum update was so complex that we implemented its prototype by Java, because it varies depending on the bank account presence, account balance and debit. And, we used MySQL for the DBMS (database management system); its storage engine InnoDB for transaction feature; JDBC to access the database with the row lock from Java.

We show the procedure of each lump-sum method below.

(1) **The mini-batch:** the row lock with the update mode is executed before each update of $Amount\ table$, and its commit is executed every specified update number. In this experiment, we used 1 and 80 for this number.

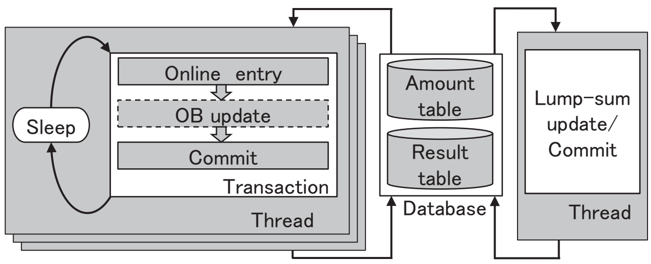

Figure 6: Program composition of prototype

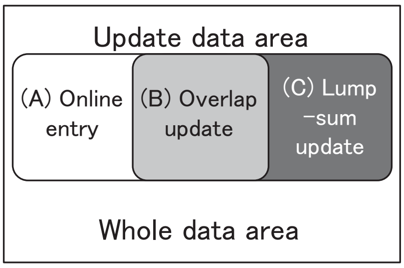

Figure 7: Evaluation data about deterioration of efficiency

(2) **The batch update:** at first the row lock on all the target data with the update mode is executed; and then, the lump-sum update by executeBatch statement of Java and the commit at the end are executed.

(3) **The temporal update:** though the target data isn't locked specifically before the batch update of this method, the added data is locked as the row lock until the commit by the InnoDB feature. Here, the commit is executed after the last addition. Incidentally, as shown in Fig. 4, the corresponding OB update is executed in the online entry transaction.

4.2 Experimental Environment

We performed this experiment by the Core i5 PC (Windows 7) in a stand-alone environment with MySQL5.1.40 and InnoDB. Here, we set InnoDB as follows: the isolation level is Repeatable read; "innodb_locks_unsafe_for_binlog" of startup option is "1" (enabled) to suppress the next-key lock [6].

We simulated the behavior of this prototype using thread programs of Java as shown in Fig. 6. That is, for the online entry, plural thread programs are executed to simulate the concurrent processing from multiple terminals. Here, the execution interval of each terminal was set to 0.5 second to simulate the load of practical environment. That is, supposing that the actual online entry interval of each terminal is 30 seconds, 16 terminals simulate the load by about 1000 terminals that are 60 times of 16 terminals. We used "sleep" method for this process. And, the commit was executed at every processing, and the OB update was also executed between the online entry and commit during the temporal update.

As the data environment, we stored 100 thousand data in $Amount\ table$, and performed 80 thousand of account transfer by the lump-sum update, such that those all succeed. On the other hand, to evaluate the deterioration of efficiency by

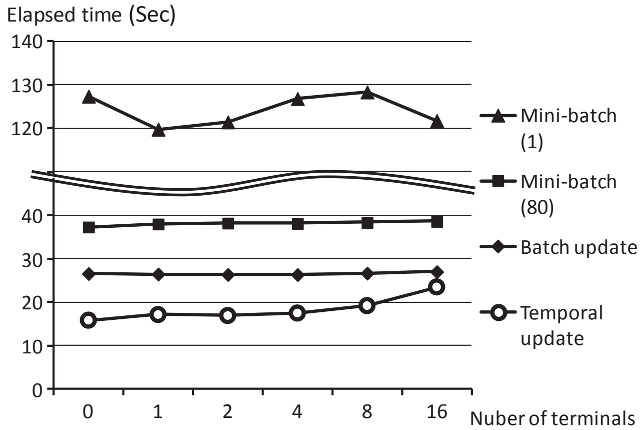

Figure 8: Elapsed times of each lump-sum update methods

Table 1: Elapsed time of lump-sum update (Sec)

Method	No-conflict	Half conflict
Mini-batch (1)	121.8	133.3
Mini-batch (80)	38.6	40.1
Batch update	27.0	29.0
Temporal update	23.5	22.4

the competition between the online entry and lump-sum update, we set the data of $Transfer\ table$ so that the data of $Amount\ table$ is classified as shown in Fig. 7 as follows: (A) updated by only the online entry, (B) updated by both of the online entry and lump-sum update and (C) updated by only the lump-sum update. We change their number based on each experimental purpose.

5 EVALUATIONS OF LUMP-SUM UPDATE METHODS

To evaluate the efficiency of each update method, we executed them without conflicts with the online entry, that is, there is no overlap update data area shown at (B) in Fig. 7. Figure 8 shows their elapsed time. Incidentally, the elapsed time is not the transaction time T but the real time measured by "currentTimeMillis" method of "System" class of Java. Its horizontal axis shows the number of online entry terminals, that is, the number of thread programs executed concurrently. Here, the case that only the lump-sum update was executed is shown at "0" of the scale. As shown in Fig. 8, the elapsed time of the mini-batch to commit at every update (hereinafter "mini-batch (1)") is more than 3 times the mini-batch to commit at every 80 update (hereinafter "mini-batch (80)"), and it is about 5 times the batch update. In addition, the temporal update is most efficient, but the elapsed time become long gradually with increasing the number of terminals. It is considered that this is an influence of the OB update shown in Fig. 6, which is performed only in the temporal update process. We discuss this in Section 6.1.

To evaluate the efficiency and characteristics of the lump-sum update and online entry in the case of their conflict, we

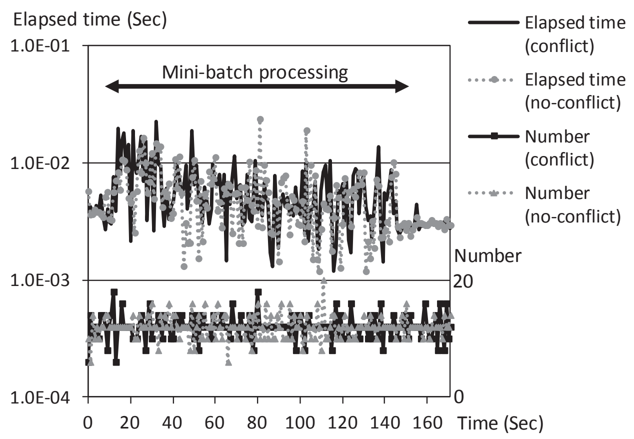

Figure 9: Efficiency of online entry during mini-batch (1)

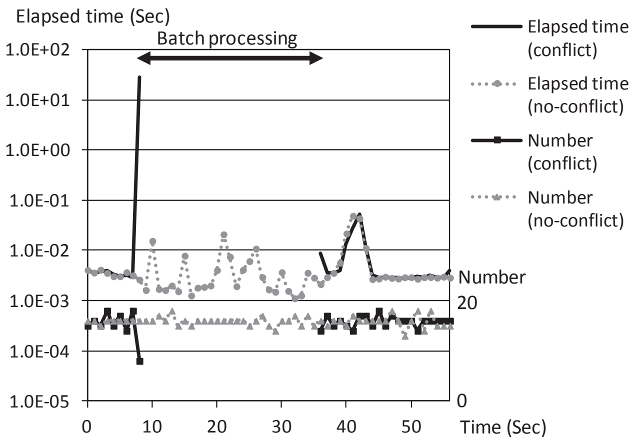

Figure 11: Efficiency of online entry during batch update

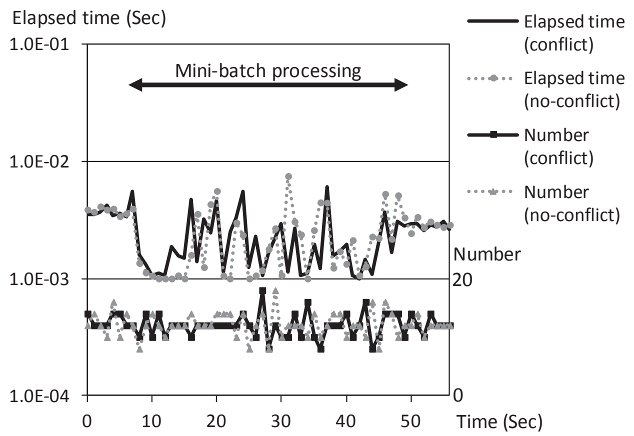

Figure 10: Efficiency of online entry during mini-batch (80)

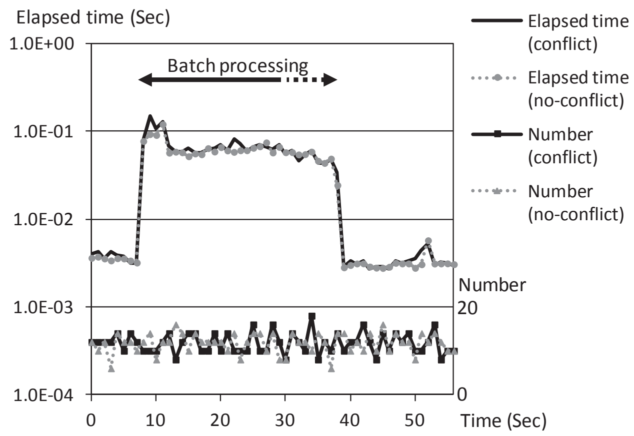

Figure 12: Efficiency of online entry during temporal update

executed them as following: the number of online entry terminals is 16; 8 of them conflict with the lump-sum update as shown at (B) in Fig. 7; the other doesn't as shown at (A). As for the conflicting data, to avoid a deadlock, it was updated in ascending order of bank account by both of the lump-sum update and online entry. Table1 shows the elapsed time of each lump-sum update method in both of the following case side by side: in the left side, there is no conflict as shown at (A) in Fig. 7, and it corresponds to the data which number of terminals is 0 in Fig. 8; in the right side, half of the terminals cause the above-mentioned conflict. As for the temporal update, both of the elapsed time is similar, whereas the other lump-sum update methods take more time in the case of the conflict. Therefore, the elapsed time of the temporal update is also least in the case of the conflict.

Next, from Fig. 9 to Fig. 12 show the efficiency of online entries conflicting with each lump-sum update method as for both the elapsed time and number of starting transactions per second. Here, the elapsed time is the average time of the update starting at the corresponding time. The left vertical axis of each figure shows the elapsed time by the logarithmic scale and the data is divided as follows: the data of terminals with conflict; the data of the other terminals without conflict (shown "no-conflict" in these figures). Similarly, the right axis shows the number of starting transactions. In addition, these figures show the time zone of the lump-sum update. Here, as for the temporal update, the completion time t_u of Fig. 4 is set beforehand and the OB update continues until t_u. So, its time zone of the batch update is shown by the solid line, and its OB update after the batch update is shown by the broken line. Incidentally, the elapsed time of the temporal update, which is shown in Table1 and so on, corresponds to the time zone of this batch update shown by the solid line.

The elapsed time of online entries is fluctuating during the execution of the mini-batch or batch update, and it is the least in the mini-batch (80). On the other hand, as for the batch update, the online entries, which conflict with it, is waited until its completion. As for the temporal update, though no online entry waited for a long while, the elapsed time of online entry transactions became more than 10 times. Because they include the OB updates. But, the elapsed time fluctuations of online entries are smaller than the other methods.

Table2 shows the evaluation about the lump-sum update models shown in Fig. 2. There are constraints of lump-update method to apply it to each model as shown in Section 2.3. As mentioned above, as for the separated data model and indi-

Table 2: Evaluations about lump-sum update model

Lump-sum update model	Online entry elapsed time	Lump-sum update elapsed time	Available method about the model
Separated data model	MB (80)	T	MB, B, T
Individual data model	MB (80)	T	MB, T
Related data model	T	T	T

(Notes) MB: Mini-batch; B: Batch update; T: Temporal update

vidual data model, the mini-batch (80) gives the least impact to the online entry. However, since it cannot be applied to the related data model, the temporal update method has to be applied to this model. Moreover, the elapsed time of the temporal update method was the least among the target lump-sum update methods of this simulation.

6 CONSIDERATIONS

In the actual mission-critical system, it is expected that there are various kinds of system operations and restrictions about both of the lump-sum update and online entry. In this section, we discuss the temporal update method based on the evaluation results in Section 5.

6.1 Efficiency of Temporal Update Method

The temporal update had the highest efficiency about the elapsed time of the lu -sum update in the above-mentioned experiment. The reason for this is because only the insertion of data is executed in the temporal update, whereas the batch update executes querying of the data to update it. And, as for the temporal update, since the commit is executed collectively after updates, the increase of the load by the commit was suppressed as well as the batch update comparing with the mini-batch. Moreover, as for the temporal update, the updated data isn't queried until the completion time t_u even if its commit is executed. So, in the case that the target data is increased, its update process can be executed one after another of dividing set with maintaining the ACID properties. That is, even in the case of extremely large number of updates, it is possible to apply the temporal update by executing them one after another.

In addition, the temporal update maintains its efficiency even in the case of conflict with the online entry as shown in Table1, whereas there are declines in the other methods. Its reason is because the other update methods have to wait for the lock completion of the online entries, whereas the temporal update method executes only the data insertion that doesn't need to lock them. By the way, since the online entry in the actual system operations updates data randomly, it often causes the deadlock with the batch update or mini-batch (80). On this point, the temporal update has an advantage, because it doesn't lock the data being updated by the online entry.

On the other hand, the elapsed time of the temporal update become longer with the increase of the online entry terminals as shown in Fig. 8. As mentioned above, there isn't the conflict between the lump-sum update and online entry. So, this is considered to be caused by the load of the OB update, to which the processing such as the update of $Result\ table$ is added. And, its adjustment is the future challenge.

Here, as for the temporal update method, its completion time needs to set beforehand, so some margin is necessary for it. But, we consider it is valid from the view point of efficiency not only for the related data model but also for the other models. For example, it is valid for the update that has to be processed in a short time and processing time can be estimated beforehand. That is, the appropriate update method should be selected based on the business requirements.

6.2 Online Entry Method

Since the OB update is executed in the temporal update, the online entry takes longer time than in the mini-batch as shown in Fig. 9, 10 and 12. Though the adjustment of this part is the future challenge as mentioned above, this time is within about 0.1 seconds, which is different from the wait time for the lock in the batch update as shown in Fig. 11. Therefore, it is considered that we can apply it to actual mission-critical systems within a certain range of load even under the present condition.

As for the mini-batch (80), since it updates the plural data collectively, the online entries have to complete in a short time. That is, when its target data is locked by an online entry, its update process has to wait with locking the other data updating collectively. Moreover, it makes the other online entries that try to update these data await state. In other words, there is the problem that the conflicts may spread to the unrelated online entries. Therefore, the online entry transaction cannot include the processing that needs a long while, such as waiting for user input. This problem is similar as for the temporal update, because the data updated by the batch update become to be valid at the completion time t_u as shown in Fig. 4. That is, the following updates have to be serialized: the online update before t_u, the validation of the batch update and the online update after t_u.

Therefore, based on the requirement of the target business, the appropriate method has to be selected for not only the lump-sum method but also the online entry. For example, as for above-mentioned case, there are some choices. As for the mini-batch (1), it is appropriate for the case where the various kinds of online entry methods are used though the restriction on the lump-sum update time is loose. On the other hand, if the online entry time is short, the appropriate lump-sum method can be selected based on the requirement of the business: efficiency, the lump-sum update models and so on. Incidentally, the batch update is not appropriate for the case of conflict with the online entry as shown in Fig. 11.

7 CONCLUSIONS

With the spread of nonstop online services caused by the development of the internet business, the lump-sum update has to be executed concurrently with the online entry in the mission-critical systems. In this paper, first, we showed the lump-sum update model from the view point of the businesses of mission-critical systems, and showed that the conventional update methods have the problem in the case to update data relating to each other. Second, we proposed the temporal update method for this problem, and showed it has the practical efficiency through the evaluations by the prototype. Third, we showed that it is necessary to select the appropriate method for both of the lump-sum update and online entry, based on the evaluations including both the proposal method and conventional methods.

Future study will focus on the implementation method of the temporal update for the actual mission-critical system, especially the improvement of the online entry response.

ACKNOWLEDGMENT

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Pocket Agent Devices for Personal Wireless Communications

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Abstract –There are many blind spots in the environment, where radio waves are attenuated. For example, the inside of a factory or tunnel can function as a blind spot for radio waves. Mobile phones or GPS devices are unable to successfully transmit or receive signals in such locations. We propose a new solution for such scenarios, where wireless telecommunication service is available in blind spots, using a “Pocket agent device”. We have proposed various Pocket agent devices, each with their own advantages and disadvantages, which are summarized in this paper. For the purposes of developing a suitable agent device, we conducted experiments for characterization by path-loss models both indoors and outdoors. Statistical models were obtained where considerable measurement data was available. First, we considered the free-space path-loss model. The free-space path-loss model is adapted for the area between the transmitter and receiver that is free of obstacles. Next, we investigated the path loss exponent, which indicates how fast path loss increases with distance. We used the log-normal path-loss model here. Finally, we used this model to explore the available routes for communication. By using this method, an agent device is able to acquire a signal in a shorter time than when using alternative algorithms. This approach significantly increases the battery life of the device by reducing energy consumption.

Keywords: Pocket agent device, blind spot, wireless telecommunication, path loss, routing

1 INTRODUCTION

Today’s world is dominated by ubiquitous computing [1] that is characterized by the marrying of computer power with everyday systems such a cellular phones, MP3 players and personal video, GPS, and radio frequency product identification and tracking systems. In recent years, a wide range of promising wireless communication protocols have emerged in many domains. For example, long-range wireless protocols, such as mobile worldwide interoperability for microwave access and high-speed downlink packet access, are essential for connection to the Internet, whereas short-range wireless protocols, such as IEEE 802.11, are used for mobile communications. In particular, hopping 802.11 networks are attractive solutions for providing last-mile-hop broadband or wireless access in urban environments. Bluetooth are popular wireless protocols that permit connections among personal communication devices and consumer electronics, such as cellular phones and personal digital assistant devices.

On the other hand, the concept of mobile wireless sensor network in the context of pervasive ubiquitous networks has emerged in recent years, although Marc Weiser envisaged this concept as early as in 1991[1]. Networks of sensors based on networking technology [3] have built up in many cities. Such sensor networks are capable of being used to facilitate and extend crime prevention, security, environmental monitoring, agricultural products support, and so on. There are many static sensors and wireless communication spots in urban areas, making sensing and communications possible over a wide area. In such urban areas, emergency communication has become easy as a result of the spread of mobile communication devices.

However, it is not possible to foresee future disasters or accidents. There are many blind spots, such as in tunnels or buildings far from urban areas, inaccessible to radio waves required for communication; in these spots, there are not enough sensing devices or the necessary communication infrastructure to effectively handle emergency communications. In many cases, mobile devices are unable to communicate any information in such a zone. Bidirectional communications are important when a disaster or an accident occurs. For example, someone trapped in a tunnel cannot communicate with the outside world. He or she is instead forced to wait for a person passing through the tunnel.

In order to resolve the issue of communications blind spots, single-hop wireless networks based on a physical movable device are attractive solutions for providing last-one-hop broadband or wireless access in many environments. We have proposed various “Pocket agent devices”. These devices are useful when in communications blind spots. There are advantages and disadvantages with each type of device. In this paper, these pros and cons are summarized.

There are some technical issues to be solved for the development of our proposed Pocket agent devices:

(1) The device must be lightweight so that it can be carried easily. In this paper, we present lightweight functional devices. Then we compare the advantages and

disadvantages of four kinds of Pocket agent devices equipped with functional devices.

(2) It must be small in size. In this paper, we also discuss small functional devices.

(3) It should be battery powered, with enough battery life to perform effectively. In this experience, after the flight of the agent device using the proposed routing method, 87% of energy was preserved. The energy remaining in the agent device after flying was sufficient to perform bidirectional communication.

(4) As mobile technology matures, however, wireless networks are employed in more applications, and provide mobile users ubiquitous & continuous access to computing resources. Wireless networks are more prone to failures, and loss of access due to weak transmission power, terrain, interference, etc. Therefore, the reliability requirements of wireless networks should be rigorously assessed. Therefore, a spatial map of the local signal strength should be acquired for control of an agent device. We conducted RSSI measurement experiments in indoor and outdoor environments. We performed a simulation of the spatial map of the local signal strength.

(5) A mobile terminal has to determine the line-of-sight (LOS) of Agent device-to-Cellular phone station, Agent device-to-GPS satellites, and so on. In this paper, we assume that the nearby window in a room is the line-of-sight of radio waves. The window coordinates of the room are detected from an image by rapid object detection. In future, we will try to find the LOS by RSSI measurement. However, currently, the detailed positioning of base stations is not publicly disclosed by infrastructure companies, as this information could be used by rival companies to evaluate a region's market development.

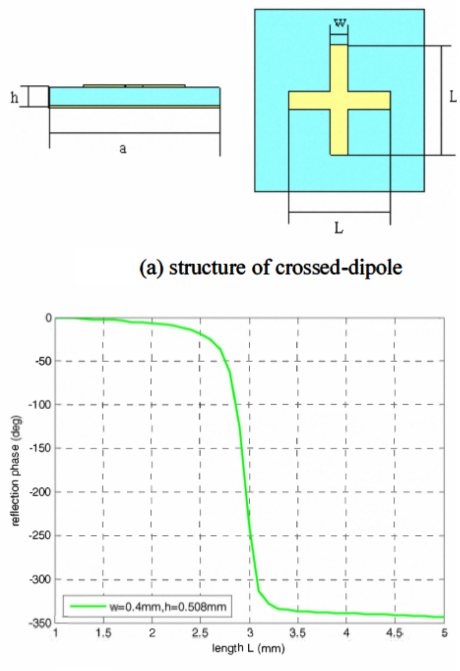
For issues (1) and (2), ubiquitous computing aims at providing context-aware information services for individuals, anytime anywhere, by dint of ever-present computers and networks. Such computing devices will become very small in size. However, this paradigm shift in computing is not yet a reality for the general public due to a number of technical and social challenges [2]. We have therefore researched those communication devices and sensors that an individual can own. A user with a Pocket agent base device can use it for communications via other devices connected to the base device. We have conducted a feasibility study of Pocket agent devices using a variety of small & light devices. We summarize the main contributions of this paper as follows. In this paper, we focus mainly on issues (3), (4), and (5). The most profound technologies are those that weave themselves into the fabric of everyday life until they are indistinguishable from it [1]. In order to achieve this, the Pocket agent device should be able to act autonomously. We have driven the research in this direction by solving issues (3), (4), and (5). We measured path loss at the UHF band relevant to agent devices. We investigated how the path loss exponent indicates how fast path loss increases with distance. We used the log-normal path loss model in order to explore communication routes.

The rest of this paper is organized as follows. In section 2, we present related work that considers networks in disaster situations. Section 3 describes the concept of Pocket agent devices, and describes the architecture of these devices as designed by our researcher for wireless telecommunication in communications blind spots. Further, we analyze device architectures. Section 4 analyzes RSSI variability and routing of communications. Finally, our conclusions are given in Section 5.

2 RELATED WORK

First, we researched solutions of last-one-hop or multi-hop wireless communications. Micro strip reflect arrays convert a spherical wave produced by its feed into a plane wave through varying the structure and the dimensions of the reflect array elements. Predominantly, there are three versions of reflect array element structures including variable size patches, identical patch with variable length stubs, variable patch rotation angles. And the variable size patches method is the most popular way of varying the phase of the incident wave because of its simplicity. Micro strips reflect array is fixed to a base such as a building and is employed to reflect radio waves to a blind spot. Therefore, it cannot change the set location easily. On the other hand, the proposed Pocket agent device can move communication functional devices physically.

Figure 1 (a) shows the structure of crossed-dipole, the length of each square unit cell a is 5mm, the substrate thickness h is 0.508mm, the width of the crossed-dipole w is 0.4mm and the length of the crossed-dipole on the face of the substrate is L. Figure 1 (b) shows the reflection phase curve versus the length L of the crossed-dipole. The center frequency of the reflect array is 35GHz and the length of the square element is 5mm which is approximate 0.6 wavelengths at the center frequency [4].



(a) structure of crossed-dipole

(b) phase response of crossed-dipole

Figure 1: Refract Array

The ballooned wireless ad hoc network has been proposed to ensure communication remains possible in a disaster situation [5]. Figure 2 shows a structure of ballooned wireless network node. A balloon utilize even though the disaster happened. The volume of balloon is 3.5 m^3 and filled up by helium gas which provides 28Kg as buoyancy. On the other hand, the total weight includes the balloon (8.5 kg) and wireless access node (8 kg) and the supporting ropes (1.5 kg). Thus, the residual buoyancy is 10 kg which is enough to keep the balloon 40-100 m high in the sky. The volume of this balloon is 3.5 m^3. The weight is 18 kg. These systems are intended to provide a communications infrastructure. As such, they are heavy and not feasible for personal use. The proposed Pocket agent device is small and light; therefore, it is portable and can be carried in the pocket.

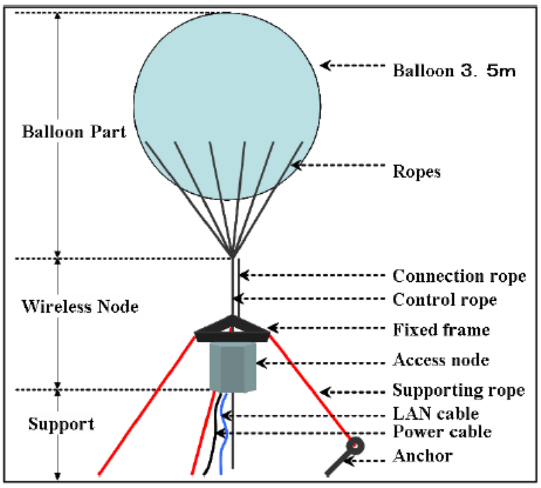


Figure 2: Balloon Network Node

VoIP using multi-hop 802.11 networks become attractive solutions for providing last-mile broadband access in urban environments. Voice over Internet Protocol (VoIP) over a wireless local area network (WLAN) is poised to become an important Internet application. However, two major technical problems that stand in the way are: 1) low VoIP capacity in WLAN and 2) unacceptable VoIP performance in the presence of coexisting traffic from other applications [6]. If there is no person around the user, communication is not possible. As for Pocket agent devices, personal communications are enabled in such conditions as well by moving communication functional devices physically.

Next, we describe studies of radio wave propagation. The free space propagation model is used to predict received signal strength when the transmitter and receiver have clear, unobstructed line-of-sight path between them. Satellite communication systems and microwave line-of-sight radio links typically undergo free space propagation. The electric wave which came out of the antenna will be decreased in the distant place, and will become weaker ,the received power of electric wave which is transmitted in free space, without any obstacle in circumferences, is expressed by Friis's transfer formula [7].

The received power: P_r is expressed by the following equation.

$$P_r = \frac{G_{r\times}P_t}{4\times\pi\times d}\times\frac{\lambda^2\times G_r}{4\times\pi} = \left(\frac{\lambda}{4\times\pi\times d}\right)^2\times G_r\times G_t\times P_t \quad (1)$$

Where,
Transmitted electric power: P_t
Transmit and receive antenna gain: G_t, G_r
Received electric power: P_r

Propagation loss: L is expressed by the equation (2).

$$L = \left(\frac{4\times\pi\times d}{\lambda}\right)^2 \quad (2)$$

Where,
Distance between transmission and reception: d ,
Wavelength: λ

The Friis free space model is only a valid predictor P_r for values of d which are in the far-field of the transmitting antenna. In mobile radio system, it is not uncommon to find that P_r may change by many orders of magnitude over a typical coverage area of several distances. The free-space loss model considers the area between the transmitter and receiver as an area free of obstacles that can absorb or reflect the transmitted energy, besides to consider the atmosphere perfectly uniform and no absorbent. However, in practice, this model is not accurate to describe the real behavior of the radio mobile channel [14] [15] [16] [17]. Therefore, it's necessary to modify this model in order to consider the complexity of the environment analyzed [13].

Next, we refer to Log-distance Path Loss Model [9].

Both theoretical and measurement-based propagation models indicate that average received power decrease logarithmically with distance, whether in outdoor or indoor radio channels. The average large-scale path loss for an arbitrary Transmitter-Receiver separation is expressed as a function of distance by using a path loss exponent n. $n = 2$ apply for free space, and n is generally higher for wireless channels. The log-distance path loss model presents by equation (3).

$$PL(d) = PL(d_0) + 10\cdot n\cdot\log(d/d_0) \quad (3)$$

Where n is the path loss exponent which indicates the rate at which the path loss increases with distance, d_0 is the close-in reference distance which is determined from measurements close to the transmitter, and d is Transmitter-Receiver separation distance. The component $PL(d_0)$ is due to free space propagation from the transmitter to a 1 m reference distance (d_0).

Path loss - Link budget calculations require an estimate of the power level so that a signal-to-noise ratio or, similarly, a carrier-to-interference ratio may be computed [8]. Because mobile radio systems tend to be interference limited (due to other users sharing the same channel) rather than noise limited, the thermal and man-made noise effects are often insignificant compared to the signal levels of co channel users. Thus, understanding the propagation mechanisms in wireless systems becomes important for not only predicting coverage to a particular mobile user, but also for predicting the interfering signals that user will experience from other RF sources.

Finally, we refer to log-normal path loss model [9].

The log-distance path loss model does not consider the fact that the surrounding environmental clutter may be vastly different at two different locations having same Transmitter-Receiver separation. This leads to measured signals which are vastly different than the average value predicted by equation (3). The log-normal path loss model presents by equation (4).

$$PL(d) = PL(d_0) + 10 \cdot n \cdot \log(d / d_0) + X_\sigma \qquad (4)$$

The term X_σ models the path loss variation across all locations at distance d from the source due to shadowing, a term that encompasses signal strength variations due to artifacts in the environment (i.e., occlusions, reflections, etc.). Accordingly, received signal strengths at locations that are of equal distance from the transmitter are considered normal random variables. The term $PL(d_0)$ simply gives PL at a known close in reference distance do which is in the far field of the transmitting antenna (typically 1 km for large urban mobile systems, 100 m for microcell systems, and 1 m for indoor systems) and X, denotes a zero mean Gaussian random variable (with units of dB) that reflects the variation in average received power that naturally Occurs when a PL model of this type is used. Since the PL model only accounts for the distance which separates the transmitter and receiver, and not any of the physical features of the propagation environment, it is natural for several measurements to have the same Transmitter-Receiver separation, but to have widely varying PL values. This is due to the fact that shadowing may occur at some locations and not others, etc. While accounts for signal variations over large scales, the received signal strength can vary considerably over small distances (in the order of wave length) and small time scales, due to multipath fading [10]. As a result, packet loss can exhibit wide variations even when d changes. Indoor RF signal propagation models, including models that take into account the number, delay, and power of indoor multipath components [11]. This model can be used over large and small distances [12], while empirical studies have shown that it can effectively model multipath indoor channels. There has been a study of implications of the log-normal path loss model [18] [19]. The approach significantly increase the lifetime of the system by conserving energy that the sensing nodes otherwise would use for communication [20]. And, Efficient Receiver-Initiated Link Layer for Low-Power Wireless has been described [21].

We proposed the direct-routing algorithm by using log-normal path-loss model. This method is faster than other algorithms, and as such, it will reduce the energy consumption of devices that use it.

3 CONCEPT OF PROPOSED DEVICES

3.1 Concept of Pocket Agent Device

As shown Fig. 3, there is a high possibility that radio waves are intercepted inside a tunnel, which is surrounded by thick concrete. We call such a spot a "radio blind spot." Wireless devices in a radio blind spot cannot communicate with those that are outside the tunnel, as shown in Fig. 4. The concept of routing using a Pocket agent device is shown in Fig. 5. The inside of a tunnel surrounded by thick concrete is in most cases opaque to the radio waves required for wireless communication. We call such a zone a communications blind spot. This blind spot is shown as the area surrounded by the dotted line in Fig. 5.

We describe the workflow of the service below.

A Pocket agent device is equipped with a GPS receiver or mobile Wi-Fi router. Therefore, in a communications blind spot, such a device needs to move to an exit, or a nearby window, in order to receive a satellite signal or cellular phone signal. As shown in Fig. 5, a sensing device, such as a Bluetooth GPS, and a wireless router, such as a mobile Wi-Fi router, are moved to the exterior of a communications blind spot. In this way, the receiving and transmitting functions of these devices are recovered.

After that, the portable device equipped with Bluetooth and Wi-Fi communicates with an external sensing device and wireless router. Bidirectional communications thus become possible from a communications blind spot.

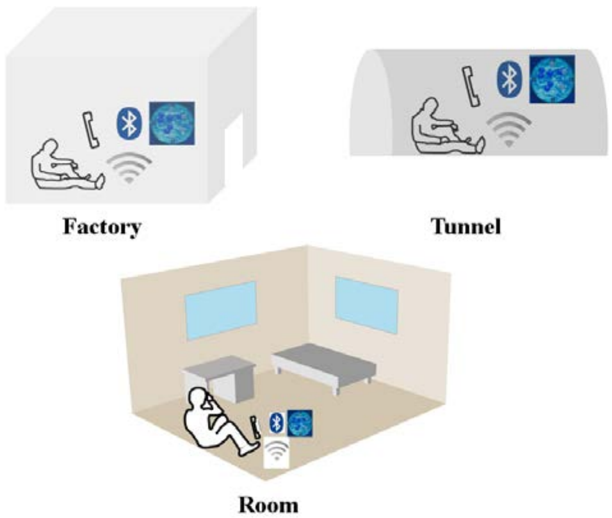


Figure 3: Various blind spots.

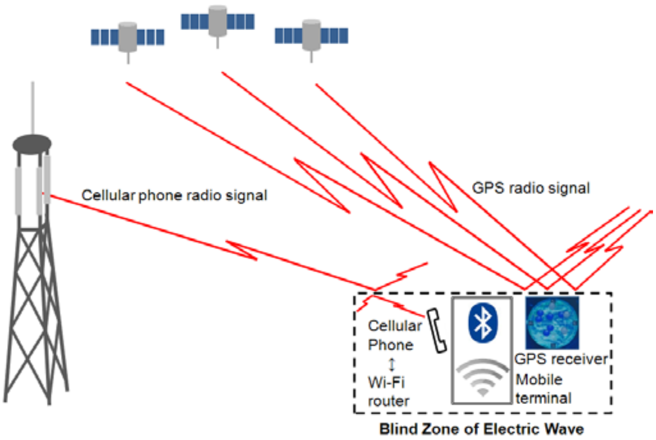


Figure 4: Communications in a blind spot.

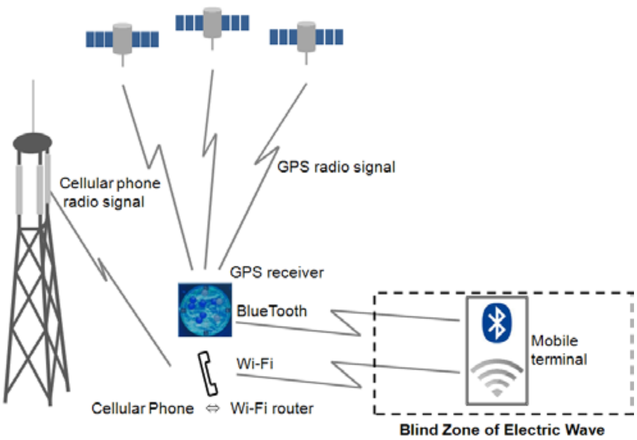


Figure 5:
Pathway of the proposed communication
in a communications blind spot.

The scenario is shown in Fig 6. We prepare a mobile terminal in a communications blind spot. We then measure the received signal strength indication (RSSI) of the line. We calculate the RSSI map around the device along with the path-loss variations. An RSSI map is made from the values experienced by the mobile terminal. The communication path is then explored. The route to the target point can be calculated from the RSSI map. We can decide upon the target point. As the agent device moves, so too does this point. We finally establish a communication path. The agent device communicates bidirectional. We can receive positional information through GPS. We can then send the message along with positional information to a terminal at another location.

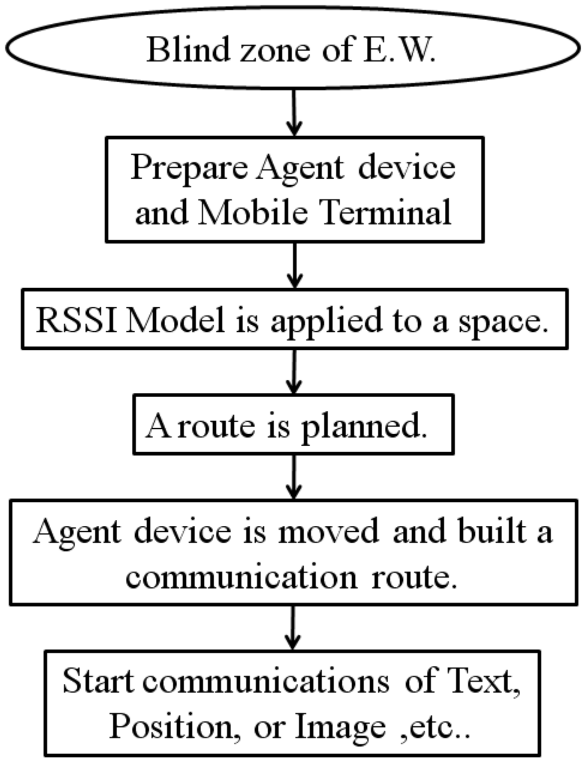


Figure 6: Scenario in a communications blind spot.

3.2 Architectures of Pocket Agent Devices

We have so far considered various agent devices. We show the devices in Figs. 7 - 10.

(1) Pocket Agent Device: Ball Type

The structure of an agent base device in the form of a ball is shown in Fig. 7 (c).

The ball form of the Pocket agent device is equipped with a sensing device, such as a Bluetooth GPS (a) [26], a router, such as a mobile Wi-Fi router (b) [27], and so on. In order to absorb collision shocks, these devices are wrapped with low-rebounding rubber or low-repellence urethane foam.

Furthermore, the low-rebounding rubber or low-repellence urethane foam is covered with synthetic rubber [22].

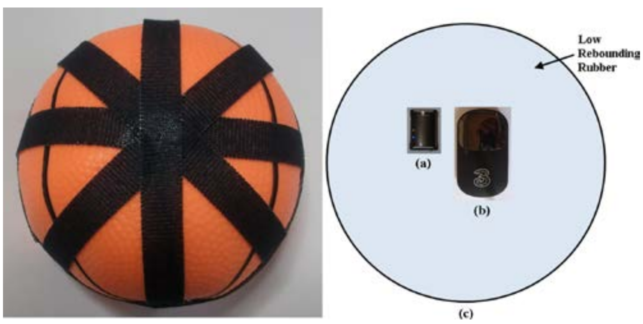


Figure 7: Parts of Pocket agent device.
(a) GPS; (b) Mobile Wi-Fi Router,
(c) Pocket agent base device [Ball Type]

(2) Pocket Agent Device of Vehicle Type

An agent base device in the form of a vehicle, as shown in Fig. 8 (c), is equipped with a sensing device, such as a Bluetooth GPS (a) [26], a router, such as a mobile Wi-Fi router (b) [27], and so on.

The vehicle form of the Pocket agent device constructs a communications path by moving on the ground in a communications blind spot [23].

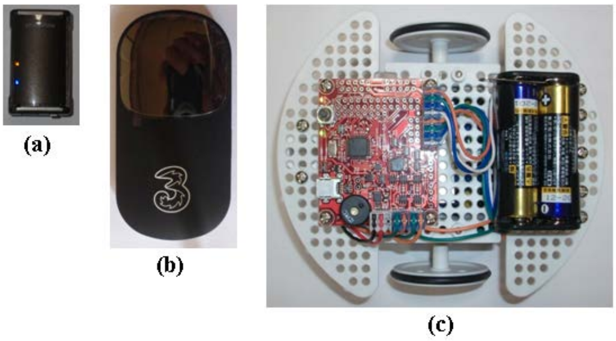


Figure 8: Parts of the Pocket agent device.
(a) GPS; (b) Mobile Wi-Fi Router,
(c) Pocket agent base device [Vehicle Type]

(3) Agent Device: Flyer Type

An agent device in the form of a flying machine is shown in Fig. 9 (c). This type of agent base device is equipped with a sensing device, such as a Bluetooth GPS (a) [26], a router, such as a mobile Wi-Fi router (b) [27], and so on.

Constructing a communications path through the agent device is possible even if there is an obstacle on the ground or in the path of any communications signals [24].

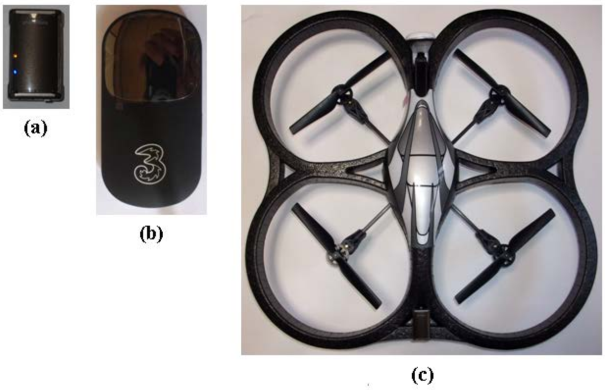


Figure 9: Parts of the agent device.
(a) GPS; (b) Mobile Wi-Fi Router,
(c) Agent base device [Flyer Type]

(4) Agent Device: Robot Type

An agent base device in the form of a robot is shown in Fig. 10 (c). The agent device is equipped with a sensing device, such as a Bluetooth GPS (a) [26], a router, such as a mobile Wi-Fi router (b) [27], and so on. The agent device constructs a communications path from a communications blind spot to a zone where communications are possible by autonomously searching the RSSI using the RSSI receiver. Once a path is established, it enables bidirectional telecommunications [25]

Figure 10: Parts of the agent device.
(a) GPS; (b) Mobile Wi-Fi Router,
(c) Agent base device [T Robot Type]

3.3 Comparison of Four kinds of Pocket Agent Devices

We compared the advantages and disadvantages of the various Pocket agent devices. Our findings are summarized in Table 1. Sometimes, there is an LOS at a high altitude such as a high window and the top of a building. Flyer type can reach the LOS. If the obstacles are spread on the ground, the flyer type can fly over the obstacles. Therefore, the flyer type has many advantages in different cases. We want to encourage the development of the flyer type.

Table.1 Comparison of Pocket Agent Devices.

Operating Conditions	Construction of Agent Devices	Advantages	Disadvantages
Road, High Windows	 Ball Type	①Cheap (≒12 ,000 yen) ②Easy to carry. (≒12cm, 214g) (GPS:44×112×57, 18g) (Router:86×46.5×10.5, 90g) ③Is inflammable. (No electric parts on the surface) ④Can, if wrapped in adhesives, adhere to, e.g., high windows.	①May roll too much when thrown. ②Throwing ability is required.
Flat Road	 Vehicle Type	①Comparatively Cheap (≒17,000 yen) ②Easy to carry. (≒13cm, 308g) (GPS:44×112×57, 18g) (Router:86×46.5×10.5, 90g) ③Is stable.	①A route plan is required. ②Unable to move past obstacles.
Obstacle on a Road, High Windows	 Flyer Type	①High flexibility of movement. (Movable to X, Y, and Z directions) (≒11.5cm, 47g: Only the base device of the flyer)	①Additional weight of a launcher is required.(≦10g) ②Flight control is difficult.(gyro, acceleration sense, image recognition etc.) ③It is difficult to carry. ④It is relatively expensive. (≒20,000 yen)
Road	 Robot Type	①Autonomous movement is possible. “Walking in a confined area”, “Walking on uneven surface”, “tipping-over control”, “getting up from a fallen position” and “human-interactive operations in open spaces” (20 degree of freedom, 2-axes gyro, 3-axes velocity sensor, 3-axes force sensors, and CPU + motion planning) ②Can be installed in communications blind spots, and can move autonomously to detect communications paths. (RSSI measurement + motion planning) ③Highly compact electrical system packaging (Height: 37cm, Weight: 1.5kg)	①It is relatively expensive. (≒510,000 yen)

4 PROOF OF CONCEPT

4.1 Indoor Testing Environment

We conducted RSSI-measurement experiments in the room of a building in an urban area. The relation between a transmitter (Pocket WiFi) and receiver (Wireless LAN adapter) is shown in Fig. 11. For every measurement, the height of the transmitter was moved by 20 cm for the x and y coordinates, from 0 cm to 160 cm.

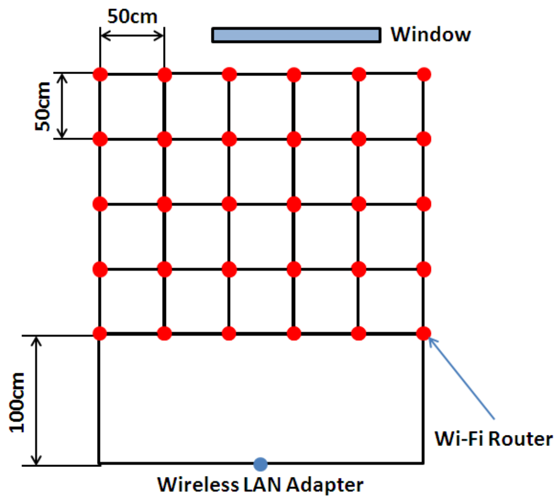


Figure11: Positioning of transmitter and receiver.

Radio waves in the room in the industrial, scientific, and medical (ISM) bands are shown in Fig. 12. About 17 waves were simultaneously received by the wireless LAN adapter. As such, we assumed that there was substantial interference in the room.

Figure12: RSSI in the ISM bands in the room.

4.2 Indoor propagation experiments

We measured 300 points of RSSI data per place in the room. We show data of mid row points in Fig. 13. The approximation lines are presented by equation (4). While n is 2 for free space, but is generally higher for wireless channels.

The component PL0 is due to free space propagation from the transmitter to a 1 m reference distance. And Xσ denotes a zero mean Gaussian random variable that reflects the variation in average received power that naturally Occurs when a PL model of this type is used. Since the PL model only accounts for the distance which separates the transmitter and receiver, and not any of the physical features of the propagation environment, it is natural for several measurements to have the same Transmitter-Receive separation, but to have widely varying PL values. The term Xσ models the path loss variation across all locations at distance d from the source due to shadowing; the term that encompasses signal strength variations due to artifacts in the environment (i.e., occlusions, reflections, etc.). Multipath delay spread Time dispersion varies widely in a mobile radio channel due to the fact that reflections and scattering occur at seemingly random locations, and the resulting multipath channel response appears random, as well.

The received signal strength can vary considerably over small distances due to multipath fading. As a result, packet loss can exhibit wide variations even when d changes. Indoor RF signal propagation models are influenced from the amount of number, delay, and power of indoor multipath components.

We employ the popular log-normal path-loss model. This model can be used over large and small distances, and empirical studies have shown that it can effectively model multipath indoor channels. We investigated the implications of the log-normal path-loss model on deploying and moving an agent device. The measured RSSI values vary according to the surrounding physical environment. For example, the received signal strength y at 80 cm height is expressed in equation (5).

$$y = -24.034 + 10 \times (-5.488) \times \log(d/d_0) + x_{\sigma(2.665)} \quad (5)$$

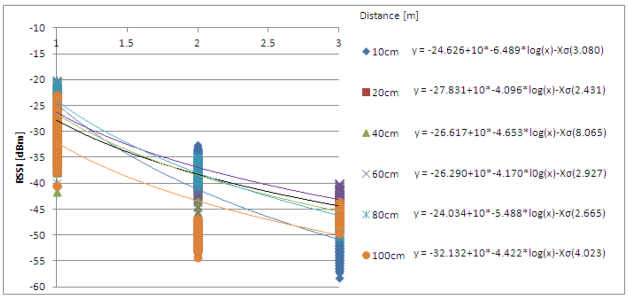


Figure13: RSSI in the room

4.3 Indoor Experiments & Results

First, we simulated RSSI in the room. We used the log-distance path-loss model for the simulation. We used equation (5) without the path-loss variation (term X_{σ}) to calculate the 3D distribution of RSSI in the room.

The RSSI values are shown in Fig. 14. The PL model only accounts for the distance which separates the transmitter and receiver, and not any of the physical features of the propagation environment; it is natural for several measurements to have the same Transmitter-Receiver separation, but to have widely varying PL values.

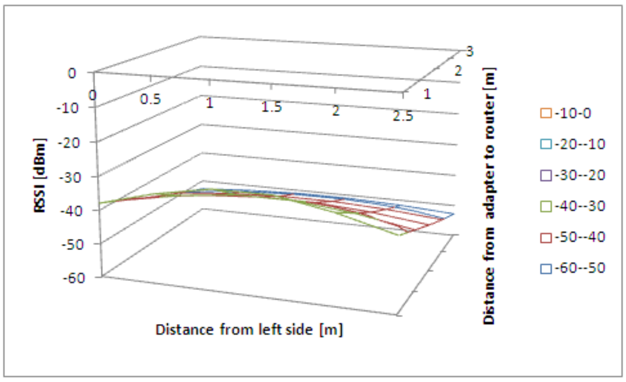


Figure14: The distribution of RSSI by the simulation (without Gaussian noise).

Next, we simulated RSSI with the log-distance path-loss model with log-normal shadowing. We used equation (5) for the simulation. This equation contains the Gaussian distribution term. The model gives a similar result to the measured RSSI. We show the results in Fig. 15.

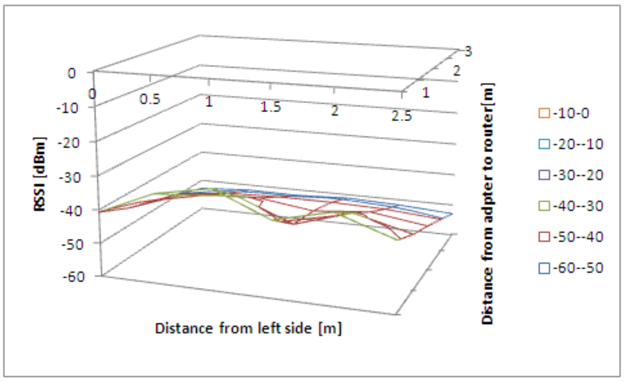


Figure15: The distribution of RSSI with Gaussian noise by the simulation (with Gaussian noise)

Finally, we measured the 3D distribution of RSSI in the room. The measured RSSI values are shown in Fig. 16. The measured values contain more variations than the simulated values, due to the number of other radio waves detected in the room. These waves were received by the wireless LAN adapter. Some values do not match the values expected from a Gaussian distribution. However, the map derived from the measured values showed the same tendency as the map derived from the simulation values. Therefore, we assume that the log-normal path-loss model can be used to explore communications routes.

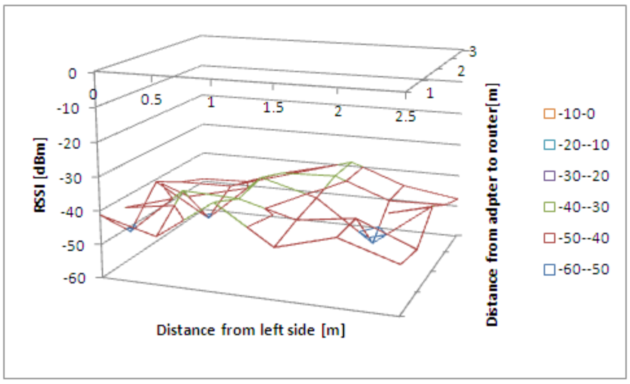


Figure16: The RSSI measured in the room

4.4 Search of the Route of Communications Using the Log-Normal Path Loss Model

We investigated the communications path between a Pocket WiFi device and a wireless LAN. We show cells of transmitters in Fig. 17. The positions of transmitter and receiver are shown in Fig. 11.

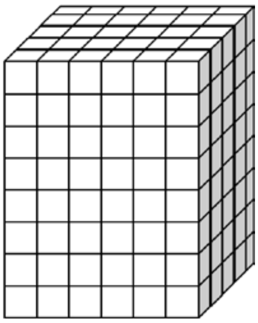


Figure17: The cells of transmitters

The agent device, represented as a transmitter in this case, searches the appropriate RSSI in order to communicate with the receiver. While an agent device in our proposed system may use both a wireless LAN and cellular phone network, the agent device should search for an equal or stronger RSSI position that is able to communicate with the mobile terminal. The target cell is shown as a red circle in Fig. 18. As shown in Fig. 11, there is a window near the cell in order to communicate with GPS or cellular phone networks. As shown in Fig. 1, the agent device is equipped with a GPS receiver and/or mobile Wi-Fi router. As such, an agent device may need to be moved to a nearby window in order to receive a satellite signal or a cellular phone signal. The target cell should match to the above-mentioned RSSI conditions. Moreover, the RSSI is expected to be stronger than -90 dBm. Figure 18 shows the basic method for routing. The route may pass through all the cells in a box. A box has 240 cells. We show the path that passes through a cell as a gray circle in Fig. 18. Equation (6) presents the number of possible routes from a source cell to a target cell. And, Equation (7) presents the time complexity of the algorithm in the worst case.

$$G_n = (n-1)! \tag{6}$$

Where, $n = 240$, $\therefore D_n = 1.695E + 466$

$$N = O(n^{240}) \tag{7}$$

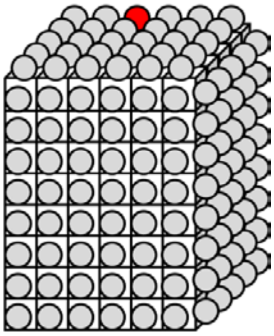


Figure18: Method 1: Search of all transmitter cells.

An agent device should reach the target cell as quickly as possible. If it takes a long time to reach the target cell, the agent device will use more (and potentially all) the battery energy. An agent device should reduce its energy consumption by using the other algorithms. We have to search for a shorter path to reach the target cell for an agent device. Dijkstra's algorithm can be used for this purpose. Equation (8) presents the number of possible routes moving from a starting cell to a target cell And, Equation (9) presents the time complexity of the algorithm.

$$D_n = \frac{1}{2} \times n \times (n-1) \tag{8}$$

Where, $n = 240$, $\therefore D_n = 28{,}680$

$$N = O(n^2) \tag{9}$$

We show Dijkstra's algorithm in Fig. 19. An agent device can find the shorter route. An agent device tries to pass D_n routes in a box by Dijkstra's algorithm. The route is shown with the line in Fig. 19.

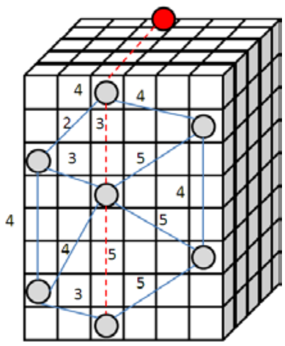


Figure19: Method 2:
Search by Dijkstra's Algorithm

We also propose a direct-routing algorithm to further decrease the time it takes for an agent device to reach the target cell.

$$DI_n = 1 \pm \alpha \tag{10}$$

$$N = O(1) \tag{11}$$

We show the behavior of the proposed algorithm in Fig. 20. We can decide upon the target cell by using the log-normal path-loss model. The route is then connected directly to the target cell. The route is shown with the blue line in Fig. 20. The route takes only one path in the box. Some simulation values may not match to the actual measurement values; in rare cases, an agent device may have to find the cells around the target cell by trial and error. The numbers of trial-and-error routes are presented as term α in equation (10). And, Equation (11) presents the time complexity of an algorithm.

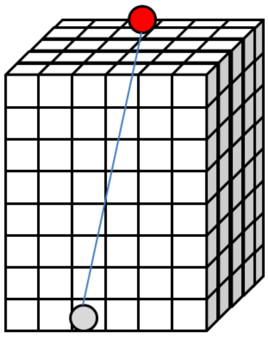


Figure20: Method 3:
Search by predicting signal attenuation

4.5 Outdoor Testing Environment

We evaluated RSSI and broadband speed around the communications blind spots. There are many tunnels in Kanagawa prefecture that are around 200 m in length. We conducted the experiments in these tunnels, using them as the communications blind spots. There is a roughly 1.5 m width sidewalk in the tunnels. Dense forest surrounds each of the selected tunnels.

The positions of these tunnels on Google Maps [28] are shown in Fig. 21.

Figure21: Tunnel locations for the experiment.

The specifications of the tunnels are shown in Table 2.

Table2 Tunnels' Specifications.

Tunnel name	AIKAWA	OOSAWA	RYOUMUKAI
Length	146m	223m	233m
Width	9.75m	9.25m	9.25m
Hight	4.50m	4.50m	4.50m

Figures 22, 23, and 24 show photographs of the tunnels.

Figure22: Picture of RSSI experiment in AIkawa tunnel

Figure23: Picture of RSSI experiment in Oosawa tunnel

Figure24:
Picture of RSSI experiment in Ryoumukai tunnel

4.6 Outdoor propagation Experiments

Although dependent on the position of each satellite at the time, the GPS radio signal from a satellite near its zenith will be intercepted by the outer wall of a tunnel. If a device tries to derive its position from the signal of three or more sets of satellites inside a tunnel, it is difficult to receive the signals of all satellites simultaneously.

On the other hand, the visual angle of the transmitting point of the base station from the inside of a tunnel is used for the calculation of distance which the direct wave of mobile phones, such as 3G Cellular phone signal, reaches into a tunnel. Calculation is possible by equation (9). (It is also possible in buildings such as factories to calculate the range of radio waves from the height of the opening of an entrance using the same equation.) The figure containing the parameter for calculation is shown in Fig. 25.

The distance from a base station to a tunnel's entrance is expressed by the following equation (12).

$$a = \frac{h_t}{\tan\Theta} \qquad (12)$$

Here,
a : The direct radio-wave range from the tunnel entrance.
h_t : The tunnel height.
Θ : The visual angle that the extension line from a base station antenna to the exit edge of a tunnel makes from a road surface..

Pr (RSSI) is approximated by equation (13).

$$\Pr = P_0 - 10 \cdot n \cdot \log(d / d_0) \qquad (13)$$

Here,
Pr : Received power at a distance d
P_0 : Power received at close-in reference point
d : Distance of separation between a transmitter and receiver
d_0 : Reference point at small distance

The base station is architected with the cell or sector composition. The range of radio waves in a tunnel changes according to these architectures and the numbers of base stations. These compositional differences influence the signal-to-interference ratio [9]. Furthermore, the received power is influenced by multi-path fading that result from the reflections from a wet road surface. The distance calculated by the equation is therefore a rough value. Additionally, the positioning of base stations is not publicly disclosed by infrastructure companies, as this information could be used by rival companies to evaluate a region's market development. Therefore, due to the lack of information about the positioning of base stations, we research the RSSI in tunnels. We then propose an alternative solution to the problem in Chapter 4.8.

The range of Class 1 Bluetooth transmissions is about 100 m. The range of a Wi-Fi standard broadcast is also about 100 m. Therefore, a tunnel with a length of up to 200 m can be covered by choosing the exit that is nearer to the person inside the tunnel. It is presumed that the 100 m range is also a practical communication distance in a building like a factory. The area of "the productive facility, the green tract of land, and the environmental facility" is defined by the use of the space beyond a fixed scale (e.g., the sum total of plottage is 9,000 m^2 or more, or building area is 3,000 m^2 or more) in Japan. Therefore, the longest diagonals of many factories are presumed to be 100 m or less.

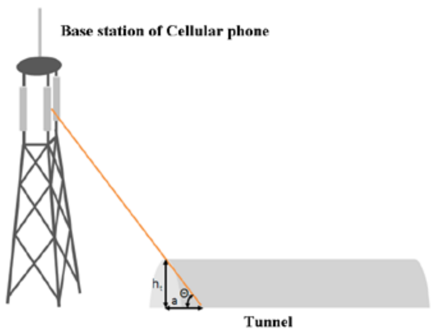


Figure 25: The range of access of
the direct cellular phone signal in a tunnel.

4.7 Outdoor Experiments & Results

We measured the RSSI using Pocket WiFi [29]. The RSSI outside a tunnel is shown in Fig. 26 (a). Communication by 3G Cellular phone signal is available here. The RSSI inside a tunnel is shown in Fig. 26 (b). In this case, communication by 3G Cellular phone signal is not available. The display of Pocket WiFi shows "No Service".

(a) (b)

Figure 26:
Cellular phone signal conditions.
(a) Outside of a tunnel;, (b) Inside of a tunnel

We measured the GPS signal strength. The signal strength outside a tunnel is shown in Fig. 27 (a). The positioning by GPS signal is available here. The RSSI inside a tunnel is shown in Fig. 27 (b). The positioning by GPS signal is not available here. The display shows that the entire satellite signal is 0.

(a) (b)

Figure 27: GPS signal conditions.
(a) Outside of a tunnel;, (b) Inside of a tunnel

We measured the RSSI in three tunnels. The RSSI of the left-side exit is shown in Fig. 28.

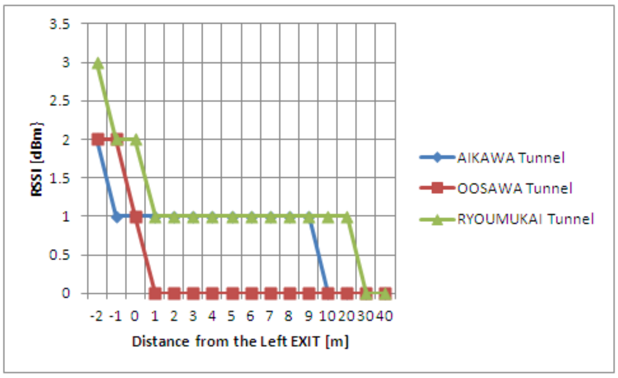


Figure28: RSSI in the tunnels (left-side exit)

The RSSI of the right- side exit is shown in Fig. 29.

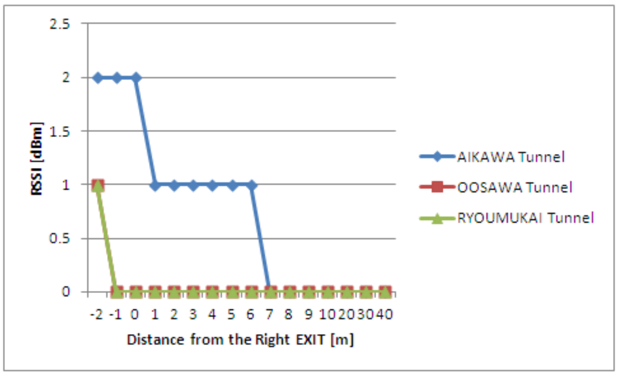


Figure29: RSSI in the tunnels (right-side Exit)

The RSSI of the right-side exits of Oosawa and Ryoumukai tunnell is poor due to the circumference of the exits being surrounded by mountains. The environment around the right-side exit of the Oosawa tunnel is shown in Fig. 30. (The tunnel in the photograph is another tunnel.) The difference of the RSSI value is caused by these geometrical features.

Figure30:
Photograph of the right-side exit of Oosawa tunnel

We set Pocket WiFi at the exit of the tunnel (i.e., at 0 m), and measured the RSSI from inside the tunnel.

The RSSI values show the tendency of free-space path-loss model, as shown in Fig. 31.

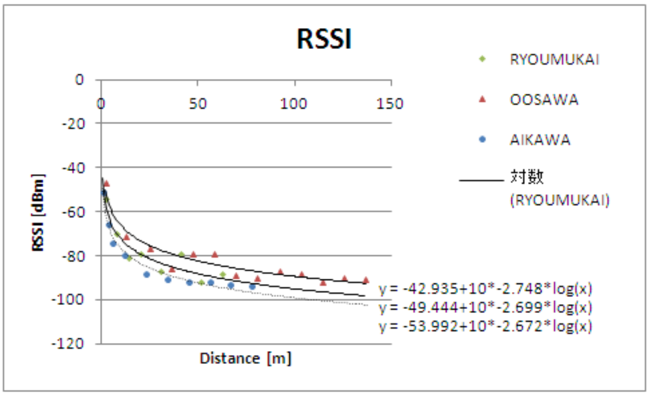


Figure31: RSSI in the tunnels

Next, we confirmed RSSI and broadband speed for the different types of device.

The models used for the experiment are shown in Fig. 32.

The ball-type agent device is equipped with Pocket WiFi. Pocket WiFi is put in the ball as shown in Fig. 32 (a).

Pocket WiFi for the vehicle form was placed on the ground as shown in Fig. 32 (b).

The flyer type's Pocket WiFi was installed at a height of 1 m from the ground as shown in Fig. 32 (c).

There are two communication methods for the flyer-type agent device: one where communication starts after the agent device lands on the ground, and the other, where communication starts during the flight. In the case of the former, its effectiveness is near equal to the value measured by the model of 32 (b), and, in the case of the latter, it is near equal to the value measured by the model of 32 (c).

The Pocket WiFi for the robot type is put in a box as shown in Fig. 32 (d).

(a) (b) (c) (d)

Figure32: The four kinds of simulation model.

SIDDR [31] was used for the measurement of RSSI.

Broadband Speed Test [32] was used for the measurement of the broadband transmission speed.

The screen of measurement results of RSSI and broadband speed is shown in Fig. 33.

In this experiment, the AC/DC adaptor was used for the power supply of the Wi-Fi router.

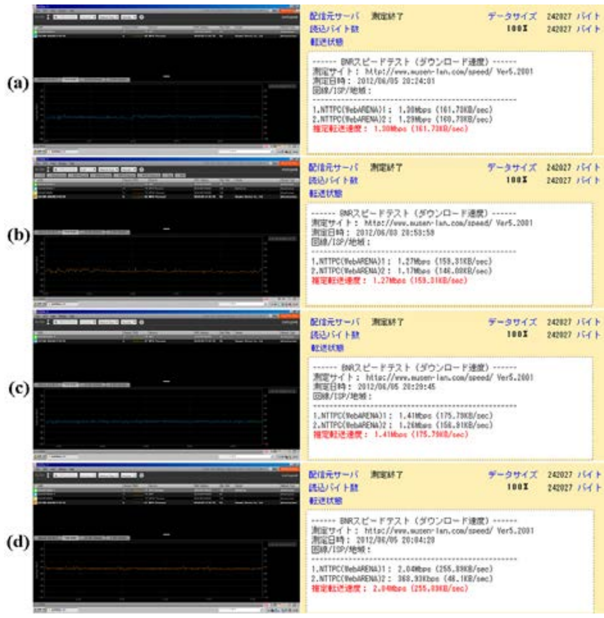


Figure33: RSSI level and Broadband speed

Figure 34 shows the RSSI of the four kinds of simulation model.

Since the RSSI of type (a) is surrounded by low-repellence urethane, the RSSI is weaker than for type (b). The RSSI of type (c) is stronger than that of type (b), and the RSSI of type (4) is the strongest of the models. This results from the reflection of radio waves from the metal surface of the case. At the result, the RSSI goes up.

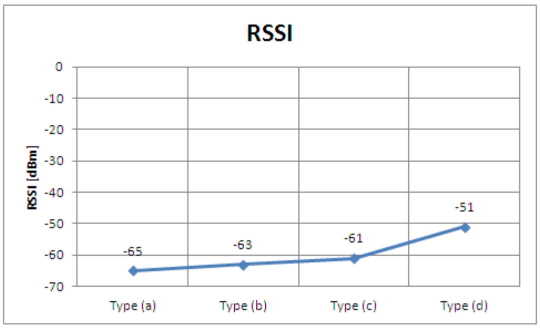


Figure34:
RSSI of the four kinds of simulation models

The measurement result of the broadband speed is shown in Fig. 35. The RSSI and the speed are correlated with each other. Although we believe that the relationship between type (a) and type (b) is the opposite, we assume that the difference of these values is within the range of measurements' error. The similarities of RSSI and broadband speed are related to the architectures.

At the result of this experiment,

Type (d) > Type (c) > Type (a) > Type (b)

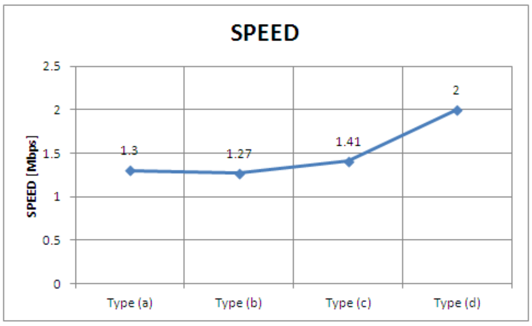


Figure35:
Broadband speeds of the four kinds of Simulation models.

4.8 Controlling the Agent Device

We conducted the experiment with the flyer-type agent device. The control flow is shown in Fig 36. We prepared a mobile terminal and a program in the mobile terminal. We used the Eee-PC 900A with an 8.9 inch display [30] as a mobile terminal in this experiment (an iPhone or other smart-phone, or an iPod could also be used). The agent device is equipped with the photoMate Mini GPS Recorder 887 [26], Pocket WiFi C01HW [29], and a built-in camera. We measured the RSSI of one line. We show the RSSI in Fig. 39. This program calculates the RSSI map around the person, along with the path-loss variations. We show the RSSI map in Fig. 40. A RSSI map is made from data measured by the mobile terminal.

We operated programs for the measurement of RSSI, extraction of RSSI from the image, mapping the data in 3D, display of the map in the window, and the controlling of Agent device. We programmed this agent device with the following control sequence. First, the agent device moves forward after taking off perpendicularly. Next, the agent device moves to the right or the left. This moving sequence takes three steps, although it should be noted that the steps are fewer than required with other algorithms.

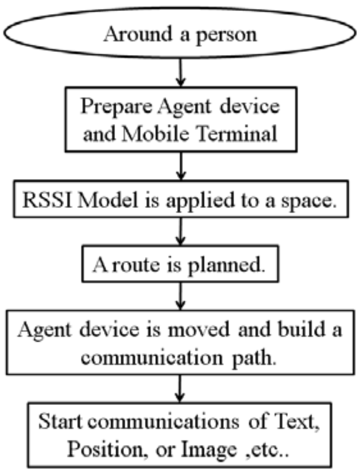


Figure 36: The control flow.

We show a more detailed control flow chart in Fig. 37.

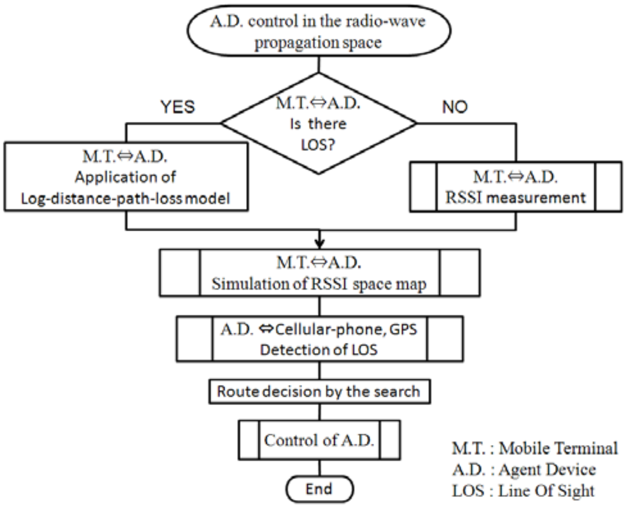
(a) Main flow: The detailed control flow that used the path loss model between an agent device and a LAN adapter is shown in Fig. 37 (a). The agent device is equipped with a wireless router with a cellular phone line, and GPS. First, it is determined whether the line-of-sight of an electric wave is effective between a mobile terminal and an agent device. The mobile terminal judges whether the characteristic of the radio wave propagation is similar in the case of free spaces, or is being influenced by shadowing, multi-pass fading, etc. If it is in a free space outdoor environment, it is possible to use the log-distance path loss model that assumes that n is two. However, at the place where it is easy to receive interference such as shadowing and/or multi-pass fading as in urban areas, then since RSSI is varied, the log-distance path loss model cannot be used in its original form. In this case, the RSSI between a mobile terminal and an agent should be measured only once. It is more desirable to be able to carry out a real-time operation by using the log-distance path loss model in case of outdoor environments. Users rarely visit the same outdoor place repeatedly. The log-distance path loss model is memorized at a mobile terminal. Users in urban areas typically spend more time indoors for habitation, work, etc.; therefore, it is comparatively easy to measure the RSSI in indoor environments only once. In this case, the parameter that serves as a variation factor from an actual measurement is memorized at a mobile terminal. The mobile terminal calculates the distance from itself to the agent device. The parameter is use for model fitting. Then, an RSSI space map is simulated using these results. These processes are performed as a batch process. Once it memorizes what was surveyed, the mobile terminal and the agent device use the map for a real-time operation. Next, the LOS of the electric wave between the agent device and a cellular phone base station, or a GPS is detected. Data from both sides determine the migratory pathway of an agent device. Once it memorizes what was surveyed, a real-time operation uses the map for driving the agent device. The migratory pathway of the agent device is determined from the RSSI data obtained from both sides. Moving an agent device in accordance with this course is controlled by using the API. Next, each predefined process is described.

(b) RSSI measurement predefined process Fig. 35 (b) is a flow of measurement of the RSSI between the mobile terminal and the agent device. The RSSI between a mobile terminal and an agent is measured by batch processing only once. Real-time measurement is also possible. However, the agent device should move many points to measure the RSSI, leading to wastage of electric power. The n parameter is calculated using the RSSI by the mobile terminal. Next, the standard deviation for the curve is obtained using actual measurement data and the log-distance path loss model. The n parameter and standard deviation are stored in the memory of the mobile terminal.

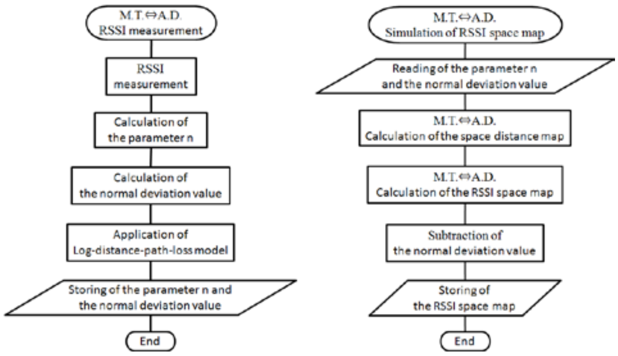
(c) Simulation of the RSSI space map predefined process Fig. 35 (c) shows the flow chart of the space map simulation between the agent device and the mobile terminal. The n parameter and standard deviation are read from the memory of the mobile terminal. Next, the distance to each position in the map of the space, which is used to carry out a simulation, is computed by the mobile terminal. The space map of the RSSI is yielded from the n parameter, the standard deviation value, and the distance to each position in the map, and the space map is stored in the memory of the mobile terminal. These processes are performed in batches. Once it memorizes what was surveyed, the mobile terminal and the agent device use the map for real-time operation.

(d) Detection of the LOS predefined process Fig. 35 (d) shows the flow chart of the detection of LOS between the agent device and the cellular phone base station or a GPS satellite. If the transmitter point (such as a base station of a mobile phone) and transmitted signal strength are disclosed, the RSSI is measured between the agent device and a cellular phone base station or a GPS satellite. The RSSI between an agent and transmitter is measured by batch processing only once. Then, the n parameter is calculated using the RSSI by the mobile terminal. Next, the standard deviation for the curve is obtained using actual measurement data and the log-distance path loss model. The n parameter and standard deviation are written and read to and from the memory of the mobile terminal. Next, the distance to each position in the map of the space, which is used to carry out a simulation, is computed by the mobile terminal. The space map of the RSSI is obtained from the n parameter, the standard deviation value, and the distance to each position in the map, and is written to the memory of the mobile terminal. If the transmitter point (such as a base station of the mobile phone) and the transmitted signal strength are not disclosed, window coordinates of the room are detected from the image by rapid object detection. The window coordinates are stored in the memory of the mobile terminal.

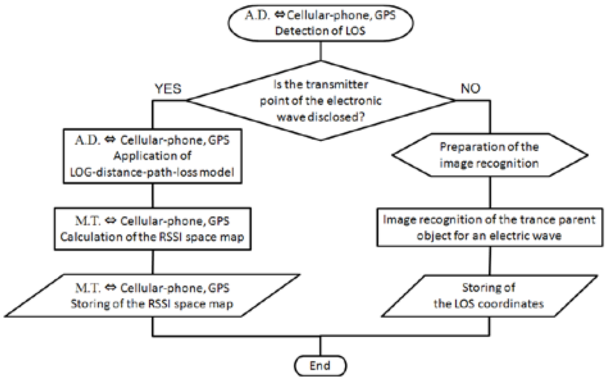
(e) Controlling of the agent device predefined process Fig. 35 (d) shows the control flow of the agent device that uses the RSSI space map. The migratory pathway of the agent device is determined from RSSI data obtained at both sides. The RSSI maps of the communication pathway of both the sides of the agent device or the LOS coordinates are read from the memory of the mobile terminal. These RSSI data are compared to the threshold values. An RSSI that is more than the threshold value becomes a candidate target point. (For example, the threshold value that can communicate prepares the restriction beyond -90dBm etc.) The coordinates of the target point are obtained by arbitrating RSSI maps (or LOS coordinates) of both sides of the agent device. The coordinates of the target point are stored in the memory of the mobile terminal. Calculation from the RSSI space maps and storing of target point coordinates in the memory is done via batch processing, and the execution is carried out only once. API is used to control the movement of an agent device in accordance with this course. The flyer-type agent device flies to the target point. Finally, the information communication is performed.



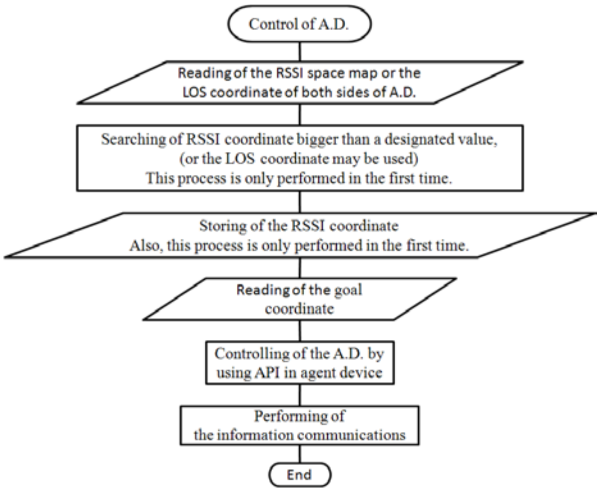
(a) Main flow of the agent device control



(b) RSSI measurement (c) Simulation of the RSSI space map



(d) Detection of LOS



(e) Controlling of the agent device

Figure 37: Detailed control flow chart

We show an example of another control method in Fig. 38. First, the mobile terminal measures the RSSIs of all cells. Further, the RSSI is expected to be higher than -90 dBm. The agent device, represented as a transmitter in this case, searches the appropriate RSSI in order to communicate with the receiver. While an agent device in our proposed system may use both a wireless LAN and cellular phone network, it should search for an equal or stronger RSSI position from where it can communicate with the mobile terminal. As shown in Fig. 5, the agent device is equipped with a GPS receiver and/or a mobile Wi-Fi router. As such, an agent device may need to be moved to a nearby window in order to receive a satellite or cellular phone signal. As shown in Fig. 11, there is a window (LOS) near the cell in order to communicate with GPS or cellular phone networks. We assume that the nearby window of the room is the LOS of the radio waves. The window coordinates of the room are detected from the image by rapid object detection. The target cell should satisfy the above-mentioned RSSI conditions. Figure 18 shows the basic method for routing. The route may pass through all the cells in the box having 240 cells. We show the path that passes through a cell by gray circles in Fig. 18. The agent device takes off, and is then aimed at the target cell. It flies according to the program of the mobile terminal toward its goal.

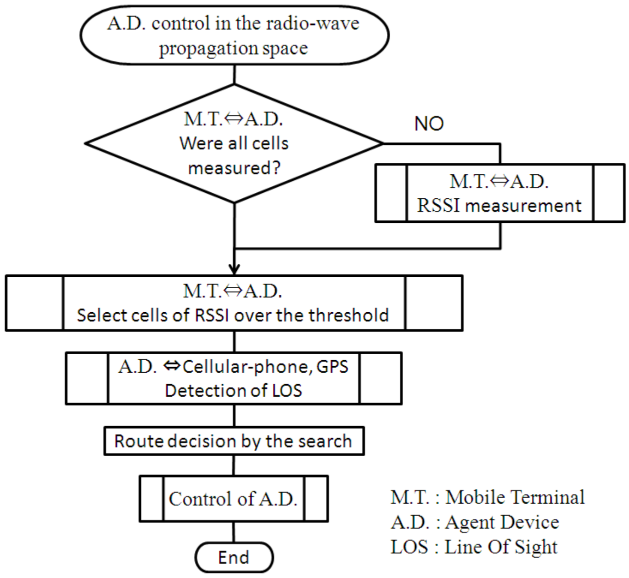


Figure 38: Example of the other control method (Search of all transmitter cells)

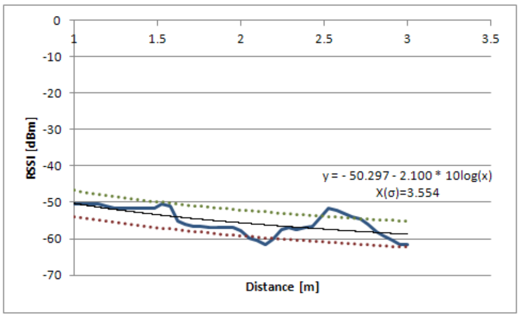


Figure 39: RSSI on a center raw line.

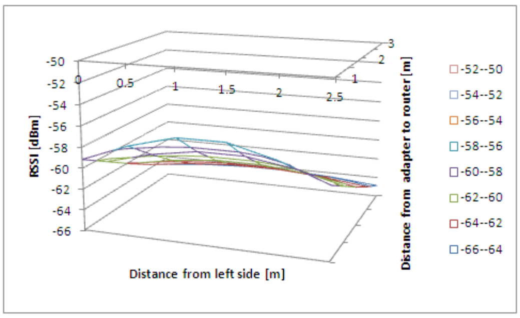


Figure 40: Calculated RSSI map.

We describe in more detail the control sequence. We measured the RSSI on a center raw line in order to approximate to the log-normal path-loss equation. The n and X (σ) terms in the equation were derived from the measurement. In this case, n was 2.100 and $X(\sigma)$ was 3.554. We then made a map by using the approximation from the measured data. The map is shown in Fig. 40. The map is displayed on the display of the mobile terminal, as shown in Fig. 41, by the control program. The position of the target was decided from the map. The RSSI of this position should be more than -90 dBm, and the position should be a nearby window for receiving a GPS signal or cellular phone signal. We assumed that the nearby window of the room is the line-of-sight of the radio waves. The window coordinates of the room were detected from the image by the rapid object detection using Haar-like features [33]. Figure 42 shows the image of the detected object. A goal point was decided from this RSSI map and the coordinates of the window. The cell size is $50cm \times 20cm \times 50cm$ in Fig. 43. We decided to use the dotted line circle as a goal position, as shown in Fig. 43. The RSSI of the goal was -64.213 from RSSI map as shown in Fig. 41. We used Excel and Processing language [34] on the Windows OS for controlling the agent device. The program for controlling the agent device shows the RSSI map in a window. A search of the communication path is then performed. First, the agent device takes off, and is then aimed at the target RSSI value. The trajectory of the device by is shown schematically in Fig. 43. The agent device flew according to the program of the mobile terminal toward this goal. We show the relation of the positions between the mobile terminal and the agent device in Fig. 44. The agent device moved toward this goal after taking off perpendicularly. The flyer-type agent device flew to the target point. The contact sheet of the movie is shown in Fig. 45. Finally, the information communication is performed. In this instance, this flight took approximately $6s$ to arrive at the goal. 87% energy remained after flying using this routing method. The agent device can fly for 12 min. The energy remaining in the agent device after this flight was enough to perform bidirectional communication. The agent device will use more (and potentially all) battery energy if other methods are employed. We show the remaining energy in table 3.

Table 3: Remaining energy after the flight to the goal

	energy
Proposed search method	87%
Search method of all transmitter cells	0%
Dijkstra's Algorithm	0%

This method took approximately $6s$ to arrive at the goal. The time for taking off and going forward was 3 s each. Because RSSI measurement is a batch process in the proposed method, it does not take any additional time. The search method will take approximately $3.3\mathrm{E}+565hr$ to arrive at the goal for all transmitter cells in the worst case. On the other hand, Dijkstra's algorithm will take approximately $1.6hr$ to arrive at the goal in the worst case. The RSSI measurement time was $16.7ms$ in this experiment.

We have summarized these driving times in table 4.

Table 4: Time required for Pocket agent driving

	Time
Proposed search method	$6S$
Search method of all transmitter cells	$3.3\mathrm{E}+565hr$
Dijkstra's Algorithm	$1.6hr$

We could receive position data by using GPS and image data by using the built-in camera. We could then send the message and attached data to an iPad set at a distant place by using Pocket WiFi. We were able to transfer information satisfactorily. The text information (a), house-position information (b), and image of the room (c) are shown in Fig. 46.

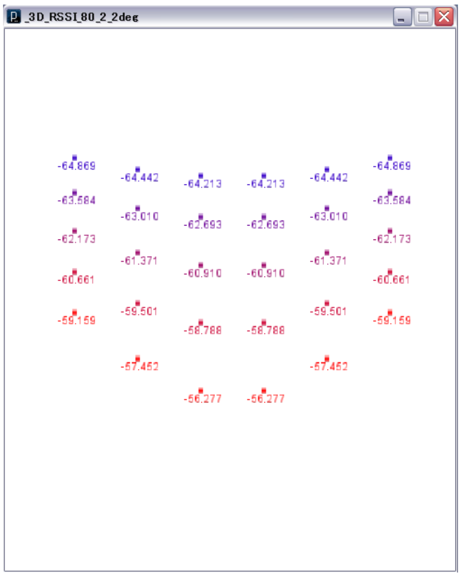


Figure 41: RSSI map in the window.

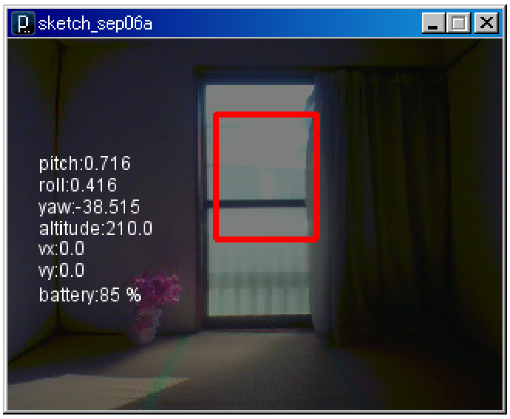


Figure 42: Recognition of the window in the room.

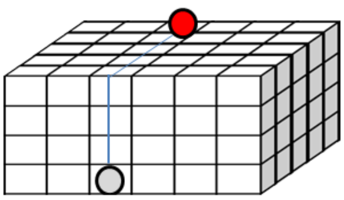


Figure 43: Path and goal position.

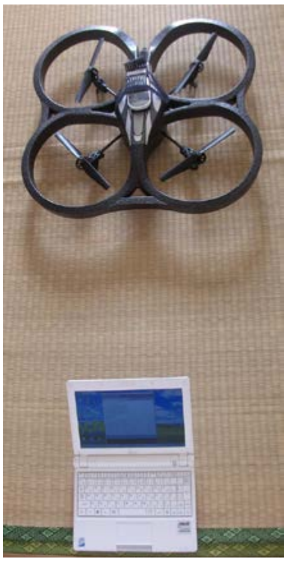
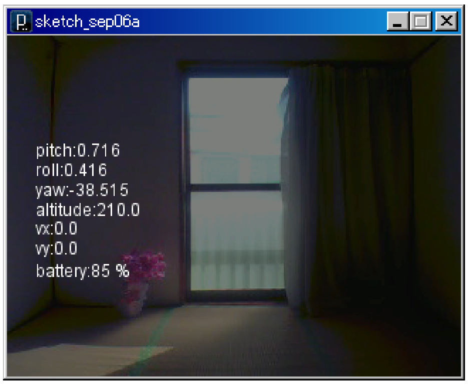


Figure 44: Mobile terminal and agent device.

Figure 45:
The contact sheet of the movie of the agent device.

(a)

(b)



(c)

Figure 46: Information from the agent device.
(a): The text information, (b): The house position information, (c): The image of the room information

5 CONCLUSION

In this study, we proposed various architectures of Pocket agent devices. We then compared these architectures, and summarized their advantages and disadvantages. We conducted experiments at indoor and outdoor locations. First, we simulated RSSI using the log-distance path-loss model. Next, we simulated RSSI using the log-normal path-loss model. These simulated results were compared with the actual measured RSSI. The measured value showed the same tendency as the simulation value. We assumed that the log-normal path-loss model can be used to explore the route for communications. A goal point was decided from this RSSI map and the coordinates of the window. We proposed the direct-routing algorithm by using the log-normal path-loss model and the rapid-object detection using Haar-like features. According to this method, an agent device is able to arrive at the goal in a shorter time than when using other algorithms, thus reducing energy consumption.

For future work, we will research more applications of Pocket agent devices using the direct-routing algorithm.

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Task-Driven Device Ensemble System Supporting Seamless Execution of User Tasks Despite Multiplexed Interruptions

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Abstract – In the real world, multiple tasks that people conduct in their daily lives are often interrupted. In particular, when multiplexed interruptions occur while people are conducting tasks, they often forget to complete tasks that they were in the midst of accomplishing, prior to such numerous interruptions. It would be possible for people to accomplish such multiple tasks more efficiently if information and communication technologies (ICT) were leveraged to assist and support them in completing their tasks.

We have been proposing a "task-driven device ensemble system", which employs a user's handheld mobile device linked with various electronics devices available in the user's surroundings, to support execution of user tasks. We have expanded on this system to enable seamless execution of user tasks even when faced with multiple interruptions of such tasks. This paper provides an overview of requirements of our proposed system, and describes a prototype system we implemented, in addition to describing a sample case study of how the system can support retailers with their task execution. We also evaluate usability and practicality of our proposed system. Our qualitative and quantitative evaluation results verify that our proposed system satisfies the following targeted requirements and objectives, thus demonstrating that the system is sufficient for practical use.

Keywords: device ensemble, UPnP, task-driven, multiplexed interruptions, human centric

1 INTRODUCTION

We are currently conducting R&D in "Human-Centric Computing", in which information and communication technologies (ICT) subtly and unobtrusively support users, without the need for explicit user-operation. In the real world, depending on the users' real-time situations, users are often interrupted while they are in the midst of accomplishing various tasks in their daily lives – at times, if such interruptions are multiplexed, users may forget to complete some of those tasks.

For instance, it is reported that today's knowledge workers experience task interruptions on the order of every 4 to 11 minutes [1]. In addition, as illustrated in a hospital scenario in Ref. [2], nurses are assigned numerous patients and must complete routine tasks. However, if a nurse is interrupted during a task, while bearing in mind the priority of various tasks, the nurse is required to complete a multitude of tasks within limited time – if ICT could be leveraged to assist them in task management, nurses would have more time to focus on the tasks themselves as their core duties, thereby helping to prevent medical malpractice.

We have been proposing a "task-driven device ensemble system", which employs the users' handheld mobile devices such as smartphones, linked with electronic devices readily available in user surroundings, to enable greater efficiencies for task execution by individuals. In view of the aforementioned, the primary issue is how well the task-driven device ensemble system can handle multiplexed task interruption.

This paper describes a newly designed task-driven device ensemble system that operates seamlessly even with multiplexed task interruptions. The remainder of this paper is comprised as follows:

In Chapter 2 we describe related work. In Chapter 3, we present the concept of task-driven device ensemble systems, and our proposed newly designed task-driven device ensemble system. In Chapter 4, to evaluate usability of our proposed task-driven device ensemble system, we describe a prototype system that supports store clerks at retailers for consumer electronics and home appliances. In Chapter 5, we verify the results of our usability and performance evaluations. Chapter 6 describes our conclusion and future works.

2 RELATED WORK

There is already a considerable body of research addressing human behavioral support that is dependent on a person's context, or context-aware navigation systems [3]–[13], as well as research related to device collaboration. At the same time, very little work has been conducted on the two fields in combination.

Examples of work on context-aware navigation systems or human behavioral support are as follows: "Task-based mobile service navigation system" [3] employs a task model that analyzes real-world problems, thereby making it possible to search for service provider sites when a user specifies a task. iHospital [4] instantaneously supports business tasks in the real world. By providing hospital staff with Bluetooth-enabled communications units so that they can determine the location of other staff, and by sharing each other's status using mobile phones equipped with messaging capabilities, they are able to quickly respond to emergency surgeries. Wieland et al. [5] proposes and describes the implementation of a system for creating workflows based on sensor-detected contexts. WTAS [6] models tasks using a Petri net and decides which task should be performed based on the user's context as ascertained using wearable sensors. Once a task is decided, information such as maps is provided to support the execution of the task. Most of these papers focus on how to acquire the user's context and leverage it in supporting the user's tasks. Although these papers share the same objective as our work in this paper, they do not involve the linking of devices.

There have been a number of works addressing device collaboration [14]-[20], particularly using Universal Plug and Play (UPnP) [21], such as the following examples: Mets et al. [14] describes a context-aware multimedia management system for the home environment using UPnP. All content is integrated in a way that prevents the user from being aware of its location, and the MediaRenderer [22] closest to the user is automatically selected. Gashti et al. [15] makes use of UPnP proxies. In addition to enabling UPnP services (this includes fine-grained services that would ordinarily be called "functions") to be employed across subnets, each user's device and service information is registered, making it possible for users to automatically use services depending on the context. Ubiquitous e-Helper [16] is a composable UPnP-based service platform for linking among smartphones. Each of these studies uses UPnP to link between devices, and contexts. At the same time, they do not go as far as to consider interruptions in tasks.

The following are works that combine context-aware navigation and device linking: Task Computing [23] proposes a task-centric technology for supporting people in performing tasks using services in the user's vicinity. In this study, human tasks are regarded as collections of services in nearby devices. In its implementation, however, the system first collects nearby services and then displays available tasks to the user based on these services. By contrast, in the system we propose, tasks are defined based on the user's context and then services on nearby devices are collected to execute those tasks. To add to this, their research is focused on an ontology for service linking. Bidot et al. [24] proposes, and then discusses the implementation and evaluation of, a workflow-management system in which workflows are created based on contexts and devices are controlled according to workflows. This system involves device ensembles. For example, to achieve the goal of helping a user relax at home, the system will control the lighting, as well as the air conditioning and a music player. UPnP is employed for this, and the Device Manager (DM) exists on household and other networks. This approach does not, however, take into account linking between the user's handset and nearby devices when the user moves around. While these works share the same goal as our research, they differ in their implementation from the task-driven device ensemble (device collaboration) that we have originally proposed.

Each of these works is focused on collecting contextual information and suggesting tasks for the user. In contrast, we are focused on what happens after a task is executed, i.e. multiplex interruptions that occur during a task and the recovery from these interruptions. These works also employ an ontology, whereas we do not. Generally speaking, the cost of constructing and maintaining an ontology is quite high, and therefore it can be said that our approach is more practical than these works. Table 1 illustrates the characteristics of our approach and these works.

Table 1: Comparison between our approach and the related works

Characteristic	Our Approach	Masuoka et al. [23]	Bidot et al. [24]
Context awareness	○	○	○
Device collaboration (with user's handheld mobile device)	○ (○)	○ (○)	○ (×)
User task definition	○	×	○ (+ workflow)
Support for multiplexed interruptions	○	×	×
Use of ontology	×	○	○

3 TASK-DRIVEN DEVICE ENSEMBLE

3.1 Concept behind the Task-Driven Device Ensemble

To support users in executing tasks, we have proposed a task-driven device ensemble in which the task at hand is first determined by the user's context, and then devices necessary for that task are discovered and are linked together. Figure 1 illustrates the concept behind the task-driven device ensemble.

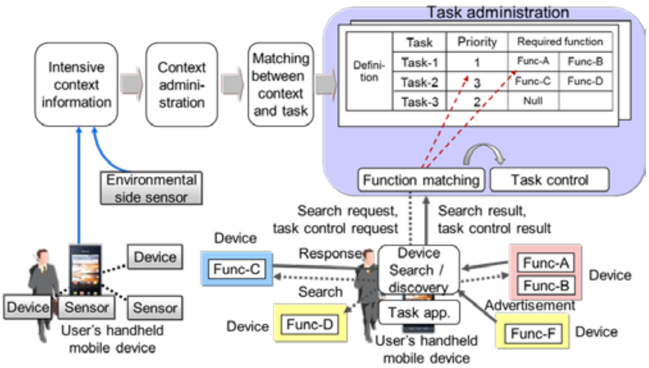

Figure 1: Concept behind the task-driven device ensemble

We presume that users will always be carrying with them handheld mobile devices such as smartphones equipped with multiple sensors. In the cloud, this sensor data can be combined with other environmental sensor data and abstracted in the user's context.

The task that best matches the user's context is selected. A task administration mechanism manages the priority of each task and the functions required to execute tasks. Tasks for users to perform are defined in advance by the users themselves, or particularly in the case of fixed job tasks, by a field manager. The task manager searches for devices in the user's vicinity that feature functions needed to perform a task - if all the functions are discovered, the task is selected, devices that have the required functions are linked, and the task is executed.

If multiple tasks can be executed given the functions in the devices, the highest priority task is selected and executed. If the task can be performed on the user's handheld mobile device itself even without being linked to any nearby devices, there is no need for requested functions for the task. In such a case, the requested functions in the task definition table shown in Fig. 1 are defined as null.

3.2 Proposed Task-Driven Device Ensemble

We propose a task-driven device ensemble that allows multiplexed interruptions, in which it possible for the user to resume a previous task after encountering multiple task interruptions. In the workplace, in particular, there is typically a flow for tasks. At the same time, user task flows do not simply proceed in a linear order. Taking into consideration the priority of the tasks at hand, users may occasionally be interrupted during a task in order to perform a new task, only to return to the previous task upon completing the interrupting task.

To implement such a system, we expanded a basic task-driven device ensemble system, by adding a task state administration function to the task administration server. Figure 2 illustrates the task administration function added to the task administration server. If, during the execution of Task-2, a higher priority Task-1 arrives, the already-running Task-2 is put into interrupt mode and pushed onto the interrupt stack. Once Task-1 is complete, Task-2 is popped off the stack. This, in turn, enables multiplexed interruptions to be handled correctly.

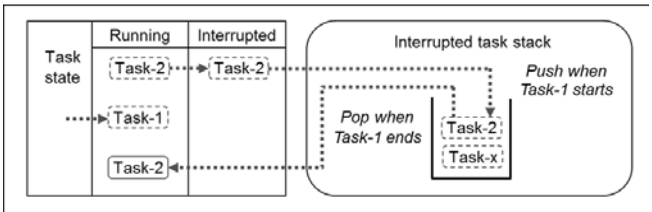

Figure 2: Task state administration for handling multiplexed interruptions

Figure 3 outlines the sequence whereby an already-running application for Task-2 is interrupted by an application for Task-1.

(1) When the start request message for Task-1 arrives, the task control compares the priority of Task-1 with the priority of Task-2, which at that moment is running on the user's handheld mobile device (e.g. smartphone). Because Task-1 has a higher priority, the sequence proceeds to step 2.
(2) The task control causes the function matching unit to determine whether the functions required by Task-1—that is, Func-A and Func-B—can be supported by the devices nearby the user's handheld mobile device.
(3) The function matching unit sends a search request message to the user's handheld mobile device's device search/discovery unit.
(4) To determine whether nearby devices can support the functions required by Task-1, the device search/discovery unit multicasts a UPnP search message to nearby devices.
(5) Devices that are able to offer any of the needed functions respond to the search request message.
(6) The device search/discovery unit sends the search results received from the devices to the function matching unit.
(7) The function matching unit checks if Task-1 can be executed by those devices. In this case, it decides that Task-1 can be executed, and it notifies the task control of this result.
(8) Before starting the Task-1 application, the task control sends a suspend request message to the task execution control on the user's handheld mobile device in order to suspend the Task-2 application.
(9) Upon receiving the suspend message, the task application execution control suspends the Task-2 application.
(10) The task application execution control sends a reply message informing of the Task-2 application's suspension.
(11) After the Task-2 application has been suspended, the task control requests the start of the Task-1 application.
(12) The task application execution control starts the Task-1 application.
(13) Task-1 is executed using device collaboration with the devices near the user.
(14) Upon the completion of Task-1, the Task-1 application notifies the task application execution control of the completion.
(15) The task application execution control sends the task control notice that Task-1 is complete.
(16) The task control requests that the Task-2 application, which had been suspended by the Task-1 application, be resumed.
(17) The task application execution control resumes the suspended Task-2 application.

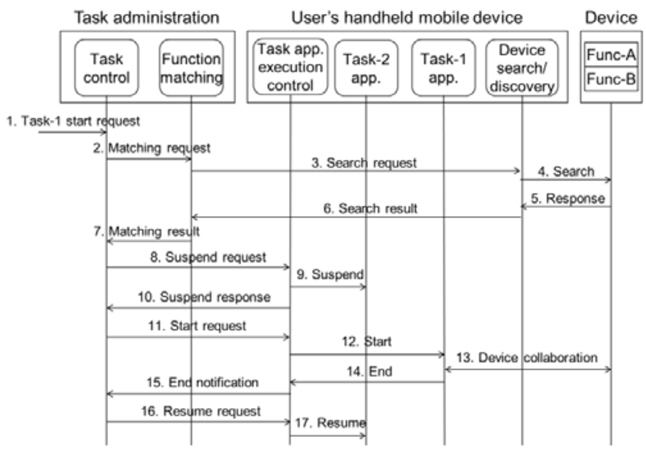

Figure 3: Sequential chart of task interruption control

The interworking between the task administration server and the user's handheld mobile device enables automated task switching, thus preventing users from forgetting to accomplish tasks, without additional burden to the user. As a user support system, it is ideal if user intervention can be kept to a minimum to minimize erroneous user operation, thus enabling appropriate task switching via the user support system.

3.3 Benefit of the Proposed Task-Driven Device Ensemble

The most prominent distinctive characteristic of our proposed concept is the comprehensive integration of context awareness, device collaboration and multiplexed task interruption. This comprehensive integration is realized in the following sequence: In addition to the user context (e.g. user location), device context (i.e. presence of the device in the user’s vicinity and its functions) are identified in the cloud. Executable tasks and their priorities are identified according to these contexts along with task definitions, and multiplexed interruption control based on the highest-priority task is executed for the user’s handheld mobile device. The task is executed via collaboration between the user’s handheld mobile device and nearby devices.

Device collaboration execution is enabled only when a device equipped with functions required to execute the task is available and present nearby the user – it can be difficult for the user to discern the appropriate timing for execution of device collaboration. In our proposed concept, by integrating device collaboration with context awareness, and leveraging the cloud to recognize device context and to request the user’s handheld mobile device to execute the appropriate task when device collaboration required for the task is possible, we enable the task to be executed with suitable timing, while eliminating the need for the user to be aware of device collaboration feasibility.

During a particular task execution, if a separate higher-priority task needs to be executed, the integration of context awareness and multiplexed task interruptions enables the system to prompt the user to execute the higher-priority and lower-priority tasks at their appropriate timing. In such a case, the data for the interrupted lower-priority task is preserved and stored, and execution of the lower-priority task resumes after completion of the higher-priority task, thus preventing the user from forgetting to complete the lower-priority task.

As aforementioned, device collaboration is possible only when a collaborative device is available and present nearby the user. Therefore, if the collaborative device becomes unavailable (e.g. if the device is switched off) during the task execution, the task execution cannot be completed: In this case, the task should be suspended, and meanwhile any other existing tasks that are executable should be executed and completed. This task control (i.e. task suspension and execution) that accommodates changes in device context during device collaboration is realized by the multiplexed interruption mechanism, and hence can be said to be a benefit resulting from the integration of device collaboration with multiplexed task interruption.

4 PROTOTYPE SYSTEM

We developed a prototype system based on the concept described in the preceding chapter, in order to evaluate its usability and practicality. This chapter is comprised of a description of the system design, implementation and a service scenario.

4.1 System Requirements

Requirements and quantitative objectives for the prototype system were set as follows:

(1) Management of multiplexed task interruptions and resumption
As described in the previous chapter, for the purpose of supporting human tasks, the system should be able to manage multiplexed interrupted tasks and then enable suspended tasks to be resumed.
As a numeric objective, in view of the system’s practical use, it should be able to handle 20 multiplexed interruptions which is anticipated will be sufficient for use at nearly any feasible worksite or field.

(2) Real-time task processing
For reasons of usability and to enable a user-friendly and stress-free experience for users, the time between user operations and the delivery of device collaboration results should be within 2.0 seconds, comparable to the minimal average latency experienced when a TV is turned on by remote control.

(3) Scalability for simultaneous task execution
The task administration server handles numerous users’ handheld mobile devices, and processes the tasks of these handheld mobile devices simultaneously. Therefore, scalability is important. As a numeric objective, in light of practical considerations, each server should have a capacity of handling 10,000 users’ handheld mobile devices.

For the system requirements and objectives, we have designed an implementation structure as described in the following section.

4.2 Implementation

Figure 4 illustrates the structure of the prototype system and Table 2 outlines the system’s hardware specifications. The system has been implemented using C++ for the nearby devices and Java for everything else.

On the server side, the system consists of a context administration server and task administration server, and the device side consists of user’s handheld mobile devices and nearby devices. Each of these is discussed below.

Context administration server
The role of the context administration server is essentially to derive the user’s context from information collected by the user’s handheld mobile device and sensors in the user’s environment. With this said, our research is primarily

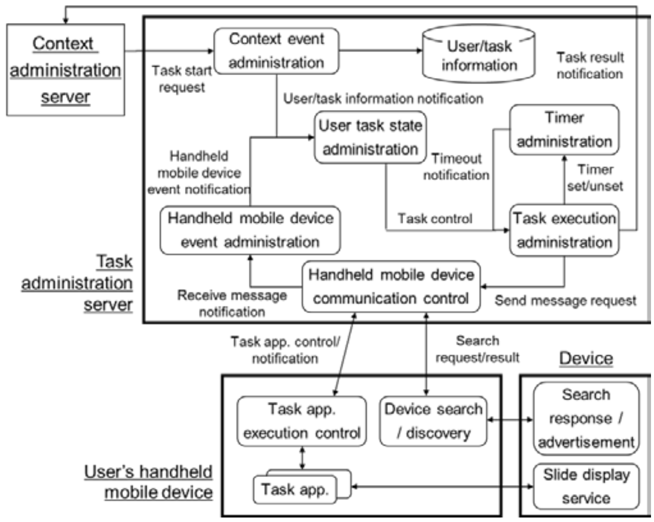

Figure 4: Prototype system configuration

Table 2: Hardware specifications of prototype system

Equipment Name	Specification
Context administration server	CPU: Xeon 2.4GHz × 2, Memory: 1GB, OS: Fedora
Task administration server	CPU: Xeon 3.06GHz, Memory: 1GB, OS: Windows Server 2003
User's handheld mobile device	Android smartphone, OS: Android 2.1
Device (notebook PC)	CPU: Celeron 1.2GHz, Memory: 2GB, OS: Windows XP Professional SP3

focused on the task administration server. Therefore, for the purpose of this study we have implemented a pseudo-context administration server that only sends task start requests and receives task execution result notifications.

Task administration sever

The task administration server executes tasks at the request of the context administration server and sends acknowledgement of task execution results to the context administration server. The functions of the server are as follows:

(1) Context event administration
Upon receiving an event from the context administration server, this function will employ user information and task information to determine which users and tasks relate to the event. It will then send a notification to the user task state administration function containing information about the user and the executable task. To satisfy system requirement (3), a thread for processing the events is generated in advance for each user. This enables reduction of thread creation overhead that causes performance degradation when the tasks of numerous users' handheld mobile devices are processed simultaneously. This also has a great effect on real-time task processing of system requirement (2).

(2) User task state administration
In accordance with each of the server's event administration functions, this function manages each user's task execution state, i.e. whether a user is executing a task or waiting to execute a task. To satisfy system requirement (1), it deploys the task state administration mechanism that was described in Figs. 2 and 3 of Section 3.2. This will ensure that users can resume suspended tasks without fail, even when there are multiple interrupting tasks.

(3) Task execution administration
This function receives instructions from the user state administration function, issues search requests for functions needed by users' handheld mobile devices, and issues requests for the execution, interruption and resumption of task applications.

(4) Handheld mobile device event administration
This function awaits events from user's handheld mobile devices. Upon receiving an event, it will notify the user state administration function of the event.

(5) Handheld mobile device communication control
This function controls communications with users' handheld mobile devices and sends/receives messages.

(6) Timer administration
This function manages timers when various kinds of requests are resent by the task execution administration function.

Users' handheld mobile devices

Android smartphones were used for the users' handheld mobile devices, and UPnP was employed for controlling the devices and searching for functions available on the devices and user handheld mobile devices. We used a UPnP library developed by Fujitsu for use with Android. The functions of the prototype user handheld mobile devices are as follows:

(1) Task applications
These are applications intended to support the execution of tasks. We developed applications based on a test scenario for supporting sales clerks at an electronics retail store. Details of the scenario are described in section 4.3.

(2) Task application execution control
This function awaits events from the user state administration function. Upon receiving an event, it will execute, suspend, or resume a task application, and then acknowledge the result.

(3) Device/service search
This function will use UPnP's M-SEARCH to search for devices or UPnP services (functions for executing tasks) that have been specified by the task administration server.

Nearby devices

For this prototype, we employed a notebook PC as a nearby device. The implemented features are as follows:

(1) Search response/advertisement
Search response will respond to the user handheld mobile device if the searched service (functions) exists on the device. Advertisements will periodically multicast the services offered by the device.

(2) Slide display service
In terms of the UPnP services on our prototype, we only developed a slide display service.

4.3 Service Scenario

As illustrated in Table 3, we developed a task application to support sales clerks working at an electronics retail store. Because the purpose of our study was to perform a basic test with multiple task interruptions, we selected a relatively simple scenario. Even for more complicated scenarios, the process during multiplex interruptions will remain basically the same.

We envision a work support flow for these applications as follows:

(1) Store clerk A is replenishing merchandise (default state).

(2) If a customer visits the store, the customer care task application will interrupt clerk A's merchandise replenishment job. We assume that each customer can be identified by means of a store membership card, etc. Clerk A operates the customer care task application to access the customer's information and then serves the customer.

(3) If there is a display device available, such as a notebook PC, that can be used to explain a product, the task application for product explanation is executed and the previous customer care task application is interrupted. Clerk A operates the current product explanation task application and then gives an explanation using product sales slides shown on the nearby display device.

Table 3: Task applications of prototype system

Application Name	Device Collaboration	Overview
Merchandise replenishment	×	The staff can confirm the number of sales items to be replenished.
Customer care	×	The staff is notified that there is a customer to be taken care of.
Product explanation	○	The staff can explain the sales items by displaying description slides on a nearby PC display.

5 EVALUATION

We evaluated the prototype system for usability and practicality. This chapter discusses the system's qualitative and quantitative evaluations.

5.1 Qualitative Evaluation

We confirmed that the implemented prototype operates with accuracy. Figure 5 is a screenshot of an actual user's handheld mobile device. It displays the various phases of the system's operation. First, store clerk A is executing the merchandise replenishment task. Second, a customer arrives at the store, and the customer care task interrupts the previous task. Third, store clerk A serves the customer, and the explanation task interrupts the previous task. Last, the interrupted tasks resume in sequential order.

This demonstrates that the task applications were executed properly and that transitions with multiple task interruptions worked well.

As we focus on task administration in this research, we verified that the basic mechanism of the task administration was realized. Specifically, we confirmed multiplexed interruption coupled with nearby device discovery required for a task execution, resumption of the interrupted lower-priority task after completion of the higher-priority task, and task execution through collaboration between the user's handheld mobile device and the nearby device.

At this stage, we have not yet implemented functions necessary for the process prior to the task administration illustrated in Fig. 1 – in other words, sensor data collection via the sensors in the user's handheld mobile device, generation of user context based on sensor data, and matching between the user's context and task execution conditions. We intend hereafter to implement these functions and evaluate the practicality of our proposed concept in its entirety.

(a)Merchandise replenishment (b) Customer care (c) Product explanation

Figure 5: Screenshots of user's handheld mobile device in prototype system

5.2 Quantitative Evaluation

In terms of quantitative objectives, we evaluated the prototype system for the number of multiplexed interruptions, processing time, and scalability.

Number of multiplexed interruptions

We estimated the number of possible multiplexed interruptions for the system. To accomplish this, we measured the elapsed time for multiplexed task interruptions (namely, the processing time required for interrupting and resuming) for each number of concurrent multiplexed interruptions. We then measured the time interval from when the pseudo-context administration server sends a new task execution notification, through the interruption of the previous task by the new task, and up until the screen of the newly executed task is displayed. 5 measurements were taken and averaged for each number of concurrent multiplexed interruptions from 2 to 20. Figure 6 shows these measurement results.

This graph shows an average time between 1.9 to 2.3 seconds for the entire range of measurement, despite variations in time intervals resulting from fluctuations in the handheld mobile device load due to wireless network traffic and other factors. These results indicate that, for up to at least 20 interruptions, the number of multiplexed interruptions does not have an impact on processing time. Therefore, the maximum number of multiplexed interruptions is at least 20. This, in turn, satisfies the quantitative objective for system requirement (1).

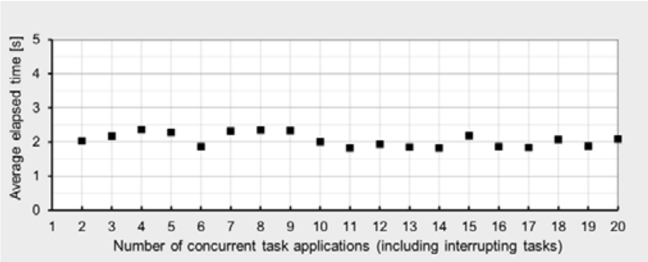

Figure 6: Elapsed time for task interruption

Processing time

We measured processing time in terms of usability. For this purpose, 2 kinds of time were measured: (1) the amount of time for handheld mobile device-side device collaboration to have an impact on practical usability; and (2) server-side task event processing time.

With respect to (1), we evaluated the operability of a task application running on the user's handheld mobile device. To do so, using the product explanation task, we measured the time elapsed between when the user presses the slide control button and when the result of the designated slide control is actually displayed on the PC through the device collaboration.

Table 4 shows the average elapsed time after performing this operation 5 times.

Although the slide show start time includes the time required for Adobe Acrobat Reader to launch and is therefore longer than other operations, all of the operations run in a sufficiently short enough amount of time. This confirms that the device collaboration mechanism works for users without any stress, and that this satisfies the quantitative objective for system requirement (2).

Table 4: Elapsed time for device collaboration

Operation	Elapsed Time (sec)
Start slide show	2.0
Change slide	0.3
End slide show	0.4

For (2), we evaluated the task-related event processing time of the task administration server, i.e. the server response time when responding to context changes, such as when task execution becomes possible, from the context server, as well as the task administration server response time when responding to operations on users' handheld mobile devices. To do so, we measured the processing time of the task administration server while gradually increasing its processing load. The specific evaluation criteria are outlined below:

(1) Task execution without interruption:
Under the condition that there is no task application running in the user's handheld mobile device, the time between the pseudo-context administration server requesting the execution of the merchandise replenishment task and the task administration server requesting that the user's handheld mobile device executes the task.

(2) Task execution with interruption:
Under the condition that the merchandise replenishment task application is running in the user's handheld mobile device, the time between the pseudo-context administration server requesting the execution of the customer care task and the task administration server requesting that the user's handheld mobile device executes the task.

(3) Task resuming:
The time between receiving notice of the completion of the customer care task from the user's handheld mobile device, up through notifying completion of the task to the pseudo-context administration server and sending a request to the user's handheld mobile device in order to resume the merchandise replenishment task.

Figure 7 shows the average time for each of the above processes, each of which was measured 30 times.

Each processing time displays a slight upward trend on account of increased server load, but even the longest time was only 130 milliseconds. Therefore, it can be said that task execution and handheld mobile device processing can be performed in almost real time.

This satisfies system requirement (2). Discrepancies between the processing times are considered to be due to differences between each of the executed processes. This graph also demonstrates that task interruptions require CPU power and that resuming tasks consumes the largest amount of CPU power.

If searching for devices or services (functions) is performed prior to the execution of a task, the search time should be added to (1) or (2) in Fig. 7. According to UPnP specifications, the wait time for M-SEARCH must be greater than or equal to 1 second and should be less than 5 seconds inclusive. As a result, this wait time is dominant, and in consideration of usability, it should be set to 1 second.

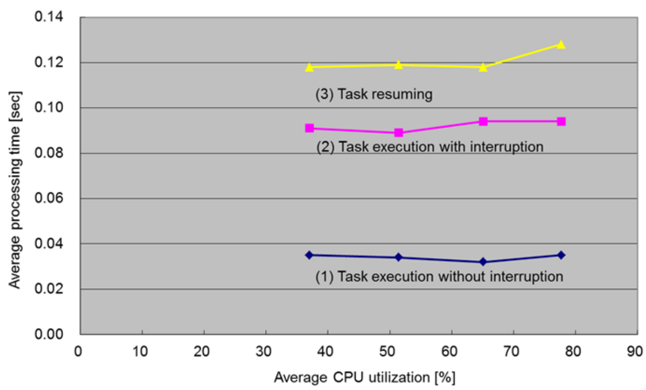

Figure 7: Task event processing time of prototype system

Scalability

We evaluated the prototype system for scalability. For this purpose, we estimated (1) the capacity of the task administration server, and (2) the processing performance of the task administration server.

With respect to (1), our prototype system consumes exclusively 1 thread per user. Therefore, the system capacity is equivalent to the number of threads that can be simultaneously generated on the server. In the case of our prototype system, this number was 12,000.

For (2), we measured the number of tasks that the task administration server was able to process in one hour while gradually increasing the server processing load. We defined the maximum server capacity to be the largest number of tasks possible before CPU utilization reached 80%. We measured processing performance for 2 scenarios: 1) The simplest single-task scenario, and 2) the most complicated 3-task scenario. The single-task scenario only executed the merchandise replenishment task from Table 3. The 3-task scenario executed the 3 tasks and interruptions in the order listed in Fig. 5.

The results are shown in Figs. 8 and 9. The number of tasks processed per hour was approximately 760,000 for the single-task scenario and 670,000 for the 3-task scenario. In both scenarios, only 1 task is processed at a time, so if a user were to perform each task in an average of 3 minutes, for a single user it would be possible to process 20 tasks in an hour. Therefore, the potential system capacity would be approximately 38,000 users for single-task scenarios and 33,000 users for 3-task scenarios. This difference is considered to be due to the additional overhead required for task interruptions and resuming.

The previous capacity estimate of 12,000 user threads is thought to be due to limitations in the settings of the Java programming language, which is used on the server. In any case, these results satisfy the quantitative objective for system requirement (3) of our prototype system.

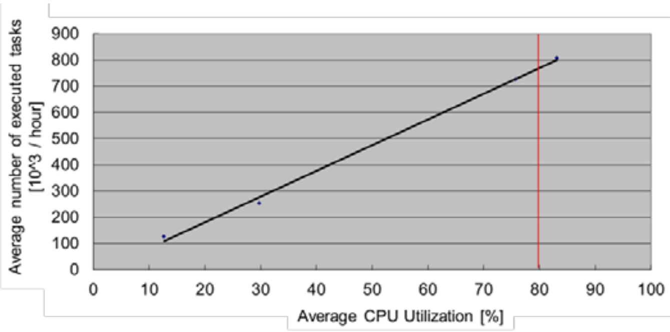

Figure 8: Task processing capacity for single-task scenario

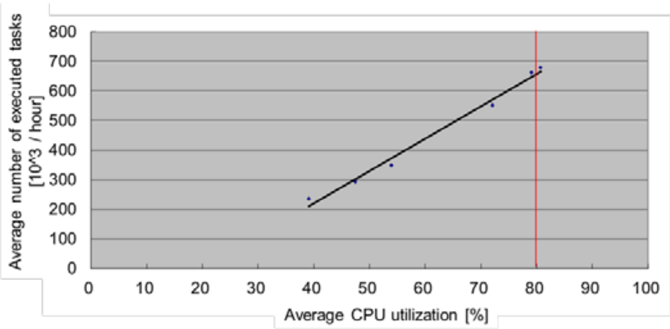

Figure 9: Task processing capacity for 3-task scenario

6 CONCLUSION

We proposed an expanded "task-driven device ensemble system" that supports user behavior, via seamless execution of user tasks despite multiplexed interruptions. We also implemented a prototype system envisioned to support store clerks at retailers, and evaluated the prototype system to verify that it indeed operates with precision as intentionally designed. Our quantitative evaluation results were: (1) Seamless execution of user tasks even with at least 20 multiplexed interruptions, (2) Real-time processing within 2.0 seconds via linked devices, and task processing time of less than 130 milliseconds in the task administration server, (3) Scalability of system capacity for at least 12,000 users per server. Our results verified that the implemented prototype system satisfied our requirements and objectives, and is sufficient for practical use.

In our future works, we aim to achieve the following: (1) Increase system capacity, (2) System expansion to include operability with non-UPnP devices, (3) Conduct user-derived/user-centric evaluation. For (1), although the system capacity of our current prototype system is dependent on and limited by the number of user threads that the system can simultaneously generate, to enable practical use, in future works we will eliminate this limitation by dynamically allocating one of the pooled threads to the requested event processing as needed. In regards to (2), we will target system operability that includes linking with non-UPnP devices that are widely available. Regarding (3), although for this work our evaluations were primarily to verify our prototype system performance, in future works we intend to evaluate user experience and efficacies through field trials.

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