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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

Yuko Murayama
Guest Editor of the first issue of IJIS

We are delighted to have the first and special issue of the International Journal of Informatics Society (IJIS) published. This issue includes the select papers from the first International Workshop on Informatics (IWIN2007), held in Naples, Italy, on 9th and 10th September, 2007. The workshop was the first 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. The workshop was complete in success with the presentation of ten papers which covered a wide range of topics in informatics such as computer supported cooperative work and groupware, intelligent transport system, distributed computing, multi-media communication, information systems, mobile computing, ubiquitous computing, etc.

Each IWIN2007 paper was reviewed in terms of technical content and scientific rigour, novelty and originality and quality of presentation by at least two reviewers. As a result of the deliberate review process, six papers were selected for publication of this issue. The selected papers were improved from their original IWIN papers according to the reviewers' comments.

In this issue, we have an invited paper, "Post Ubiquitous Society: Problems, Proposals and its Applications" by Norio Shiratori et.al. The paper overviews ubiquitous computing environment in terms of human aspects and proposes a novel paradigm, Symbiotic Computing. The paper presents the new direction of the informatics research area. We hope that the readers will enjoy the paper as well as the other five good papers on the wide range of topics.

We hope that the issue would be of interest to many researchers as well as engineers and practitioners in this area. This is an ambitious endeavor with a small start towards a journal with quality and novelty.

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

Yuko Murayama is a professor at Iwate Prefectural University. She had M.Sc. and Ph.D. both from University of London in 1984 and 1992 respectively. She had been a visiting lecturer from 1992 to 1994 at Keio University, a lecturer at Hiroshima City University from 1994 to 1998. She has been with Iwate Prefectural University since April 1998. Her interests include internetworking, network security and trust. She is a member of IEEE, ACM, IPSJ, IEICE, and ITE.

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Post Ubiquitous Society: Problems, Proposals and its Applications

Norio Shiratori†, Toshimitsu Miyamoto†, Debasish Chakraborty†,
Hideyuki Takahashi†, Shigeru Fujita††, Takuo Suganuma†, Atsushi Takeda‡

†Research Institute of Electrical Communication, Tohoku University
2-1-1 Kata-hira, Aoba-ku, Sendai, Japan
††Department of Computer Science, Chiba Institute of Technology, Japan
‡Tohoku Bunka Gakuen University, Sendai, Japan

Abstract -

Envisioning the next generation ubiquitous era when the advancement of computer and communication with its several boons may also bring some anxiety and inconveniences of various types to the society. To overcome these problems and to close the gap between human and computer we proposed a new information and communication paradigm, called *Symbiotic Computing*. Traditional ubiquitous computing environment can be considered as consisting of two computing aspects: *Mobile Computing* and *Pervasive Computing*. We then define the two axes of advanced ubiquitous computing: *Traditional Ubiquitous Computing* and *Web Computing*. To realize a symbiotic society, where human and computer will co-exist in a cooperative manner to the betterment of life and society, we proposed a new *3rd axis* to alleviate the predefined problems and by integrating these three axes, we created the *Symbiotic Computing* paradigm. In this paper we discussed about the concept, architecture and different applications based on this novel idea.

Keywords: symbiotic computing, ubiquitous information environment, mobile computing, pervasive computing, next generation network, S-gap

1 Introduction

Proliferation of computing into the physical world promises more than the ubiquitous availability of computing infrastructures. By the end of the decade, the number of PC users is expected to hit or exceed 1 billion by 2010, according to Microsoft CEO steve Ballmer, fueled primarily by new adapters in developing nations such as China, India and Russia, according to analysts, out of estimated world population of around 6.8 billion.

With the existence of large number of computers, with high processing power, coupled with wireless communication, next generation wireless is moving toward ubiquitous wireless communications systems and smooth high-quality wireless services. Computers will gradually become proficient at a wider range of activities previously requiring human intelligence, including their own design, and thereby introduce positive feedback into the development loop. This, coupled with currently expected progress in nervous system connection, may accomplish a direct machine-human brain link by 2025 [1]. The author here has predicted that in future processing capability and intelligence will be ubiquitous. The vast majority of processing devices will be transparently integrated and unidentifiable as individual machines.

Focusing towards next generation ubiquitous age we have been pursuing research on Symbiotic Computing from as early as 1994 [2]–[4]. In [5]–[8] we first define the concept of traditional ubiquitous computing environment with two computing aspects: *mobile computing* and *pervasive computing* [9]. Traditional ubiquitous computing enhances accessibility to the services using wireless network and embedded device technologies [10]–[13]. At the same time, web computing is emerging as very powerful tool to extend availability and usability of information which is widely distributed in the world [14]. Now, to define advance ubiquitous computing, foreseeing the situation around 2025, we integrated two computing axes: *traditional ubiquitous computing* and *web computing*. The advance ubiquitous computing is expected to contribute and enhance the Information Technology (IT) environment; however, at the same time, human and social aspects also need be considered. Otherwise a social imbalance with its related inconveniences and anxiety will grow up. To overcome such a situation and to strengthening the power of advance ubiquitous computing environment, we introduced a third new axis to define a new value, and by integrating these three axes, the new paradigm, called Symbiotic Computing is created. Based on this novel idea of Symbiotic Computing, symbiotic society will be realized, where human and ubiquitous information environment can cooperatively coexists and close the gap between these two entities.

Symbiotic computing is a basic idea that achieves an information processing environment, that can autonomously supports human activities, by understanding human behavior and sociality in the real world [15].

In symbiotic computing, human society and digital space interact with each other, based on “basic principle of symbiosis”, where they increase information precessing ability, activity, and stability by offering information and supports each other. As a result, it creates new relating for co-existence and co-propriety based on mutual understanding between them.

Symbiotic computing will enable digital space to provide advanced and intelligent services progressively and solve various problems that present Information Technology (IT) has, for example, the gap in the symbiosis world, and we named it as *S-gap*. The detail explanation of S-gap is given in Sec-

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tion 2.3.1. This contributes to the next generation information processing environment, where everyone can easily get necessary information and services from digital space for *anyone, anything* in addition to at *anytime* and in *anywhere*.

We construct a symbiotic computing model and an architecture of symbiotic space for achieving the concept of symbiotic computing. We also develop basic technologies for realizing the model and architecture. Moreover, these are used to establish the next generation information platform and we evaluate our proposal through application developments and trial experiments.

The organization of the paper is as follows. In Section 2, Ubiquitous Environment for Improved Human-Computer communication has been discussed, focusing on Ubiquitous computing, Ubiquitous networking and Symbiosis process, where we state the problem elaborate about our motivation. Our proposed symbiotic computing architecture, where we explained about the General, Network-ware, Social-ware and Perceptual-ware is described in Section 3. Section 4 consists of Evaluation of Symbiotic Computing Architecture, where we discussed about the systems we have developed as novel application of Symbiotic Computing and the envisioned scenario of revolutionary effect of Symbiosis around year 2025. The paper is concluded in Section 5.

2 Ubiquitous Environment for Improved Human-Computer Communication

Ubiquitous computing has as its goal the nonintrusive availability of computer throughout the physical environment, virtually, if not effectively, invisible to the user [16]. Unlike virtual reality, ubiquitous computing will integrate information displays into the everyday physical world. It proponents value the nuances of the real world and aim only to augment them. In ubiquitous computing it will be a world of fully connected devices, with cheap wireless networks, available and accessible everywhere, anytime.

2.1 Ubiquitous Computing

The basic concept of human-computer symbiosis was first found in an article written by J.C.R. Licklider in 1960 [17], where he imagined a very close coupling between the human and the electronic members of the partnership. Computer technology was at its early stages and he had given a general idea of Symbiosis computing; abstraction level was very high. The main aim for this partnership are two-folds, (i) to let computers facilitate formulative thinking as they now facilitate the solution of formulated problems, and (ii) to enable men and computers to cooperate in making decisions and controlling complex situations without inflexible dependence on the predetermined programs.

Ubiquitous computing began in the Electronics and Imaging Laboratory of the Xerox Palo Alto Research Center in the late 80s by Mark Weiser [18], [19] and his group. The inside story can be found in [20]. He had proposed a ubiquitous computing called Calm Computing, where the computing concept was to provide services naturally without disturbing human activities and thinking in the environment. Challenges in deploying ubiquitous systems is discussed in [21].

Way back in 1994, we proposed the idea of Symbiosis in [2], where we concretely defined the architecture and functionality of each part. In Figure 1 we have shown the concept of Ubiquitous computing which is based on two axes: Pervasive computing and Web computing. The extension of these two fields will bring us the Advanced Ubiquitous computing environment.

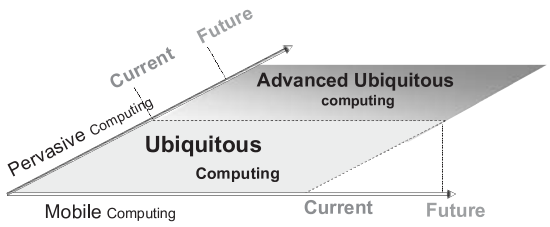

Figure 1: Two axes of computing that shapes Ubiquitous Computing field

2.1.1 Mobile Computing

The appearance of full-function laptop computers and wireless LANs [22] in the early 1990s led researcher to confront the problems that arise in building a distributed system with mobile clients [23]. The field of mobile computing was thus born. Although many basic principles of distributed system design continued to apply, four key constraints of mobility forces the development of specialized techniques: unpredictable variation in network quality, lowered trust and robustness of mobile elements, limitations on local resources imposed by weight and size constraints, and concern for battery power consumption.

The rapidly expanding technology of cellular communications, wireless LAN, and satellite services promises to make it possible for mobile users to access information anywhere and at any time. Regardless of size all mobile computers is equipped with a wireless connection to information network. The resulting computing environment, which is often called mobile or nomadic computing, no longer requires a user to maintain a fixed position in the network and enables almost unrestricted user mobility [24]. Mobility and portability create an entire new class of applications and new massive markets combining personal computing and consumer electronics.

Mobile computing brings about a new style of computing, Due to battery power restrictions, the mobile clients will frequently disconnected (powered off). Most likely, short bursts of activity, like reading and sending email, or querying local data-bases is separated by substantial periods of disconnection. Also, quite often, the mobile client will “wake up” in a totally new environment in some new location far away from home. Finally, due to mobility, the client may cross the

border between two different cells (coverage areas) while being active (the so-called hand-off process). Handoffs are relatively straightforward in cellular voice communication due to a higher loss of information that can be tolerated.

Mobile computing poses new challenges to the data management community and they can be grouped into the following categories:

1. Mobility Management and Scalability
2. Bandwidth Management
3. Energy Management

2.1.2 Pervasive Computing

It was first began with Mark Weiser 1991 paper [18] that explained the vision of ubiquitous computing, now also called as pervasive computing. The basic and most important part of that vision was the creation of environments completely fill with computing and communication capable devices, yet gracefully integrated with human users. This vision was far too ahead of time, when hardware needed to achieve this goal was just not existed and naturally Weiser and his group at Xerox PARC failed in their implementation. With recent progress in hardware and ubiquitous computing technologies, broadband convergence with mobile and broadcasting networks, emergence of RFID has enhanced the accessibility of real-world objects together with information on the Internet and we are now better positioned to begin the quest for Weiser's vision. Later Garlan et al. [25] in project 'Aura' discussed about a disruption free pervasive computing.

2.1.3 Ubiquitous Computing Environment

Weiser introduced the area of ubiquitous computing (ubicomp) and put forth a version of people and environments augmented with computational resources that provide information and services when and where desired [18]. For past many years, ubicomp researchers have attempted this augmentation with the implicit goal of assisting everyday life and not overwhelming it. Weiser's vision described a proliferation of devices at varying scales, ranging in size from hand-held "inch-scale" personal devices to "yard-scale" shared devices. This proliferation of devices has indeed occurred, with commonly used devices such as hand-held personal digital assistants (PDAs), digital tablets, laptops, and wall-sized electronic white-boards. The development and deployment of necessary infrastructure to support continuous mobile computation has arrived. Now the Ubiquitous Computing environment is consists of Mobile Computing and Pervasive Computing.

2.1.4 Web Computing

With the rapidly expanding reach of Internet people in this world is becoming merely the players of it. Whether by establishing or enhancing access, or through the utilization of publishing tools, there are various resources as mentioned below, which can help us extend our arena for self-expression to the entire world.

- E-mail and Calendaring
- Network and Internet Access
- Newsgroup (Usenet)
- Internet Searches
- Telnet and SSH
- Web Publishing (blog etc.)

The world wide web is revolutionizing access to information and communication for business and individuals alike. It is evolving faster, and involving more people, than any other technology in history. Transforming the Web from primarily a document transfer system to a platform for Web applications, involves developing an architecture that supports Web objects interacting with each other. Web computing involves hence a suitable Web object model, encompassing both document publishing and distributed object communication. Web services have emerged as a standard platform for Web computing. Nevertheless Web services only provide one-way request/reply communication from client to server. Developing fully interactive applications is difficult with current Web technology. Users can only get updates by hitting some button or clicking a ling on their browsers and re-generating an entire new page. The future web is envisioned as no longer a network of connected machines, but rather the indispensable thread of human connectivity that binds together cultures, economies, and societies. Content, communication, and context will continue to form the underpinnings of human connectivity, much like they do at present.

2.2 Ubiquitous Networking

Development of technologies for *ubiquitous networking* environments on which the ubiquitous computing is constructed is in progress in the world. From our viewpoint those technologies accelerate deployment of mobile and pervasive computing, extend the field of ubiquitous computing. Now many suggested technologies are based on the Internet, and the *next* generation network based on IP is proposed as NGN. Some researches are started that focus on a totally new networking technology which called as a *new* generation network [26]. Various activities of ITU-T can be found in [27] and [28].

2.2.1 Coming Technologies of the Internet

An ubiquitous networking environment based on the Internet realizes an access to contents on the Internet in anytime and anywhere by using mobile devices. Key technologies for this purpose are 1) small area wireless communication technologies 2) seamless handover between different networks 3) secure and scalable network infrastructure. Personal networking technologies just like ZigBee/IEEE802.15.4, RFID,

and wireless ad-hoc networking technologies [29]–[31] are in 1). In 2), the standardization and development of MobileIP [32][33] is important. Many other technologies that realizes mobility is proposed for various situations [34]–[36]. In 3), IPv6 [37] is now growing to introduce absolute number of devices to the Internet, and enhances efficiency of core networks. Many researches about traffic engineering and QoS-reservation is ongoing. Ubila project [38] is assuming an ubiquitous network connecting 10 billion devices and promoting practical researches in this field. Mobile IPv6 management information base is proposed by Keeni et al. in 2006 [39].

2.2.2 NGN: Next Generation Network

There are two big problems in the Internet as an infrastructure of ubiquitous computing. The first is *vulnerabilities*, in other words, insecureness. The lack of security function forces all protocols and systems in the Internet to deploy and maintain complete secureness each other. This is quite inefficient. The second is *low reliability* in performances. The basic principle of the Internet is best-effort. By this principle, much more systems that have a critical mission can not depend on the Internet.

Now a dependability is of great interest for networking technologies. Many telephone and cell-phone operators in the world is going to replace their operating telephone network by NGN, next generation network NGN is the next generation telephone network architecture that is based on IP technologies. The transport stratum of NGN enables end-to-end QoS control and can provide multimedia services with dependable performance. Various services are provided through the service stratum and it realizes the security.

2.2.3 NwGN: New Generation Network

NGN is one solution that solves a part of many problems in the Internet. But there still remains problems. One major problem is the complexity of the network. Now many network technologies are developed and deployed in ad-hoc manner. Without sufficient arrangement, the coming ubiquitous networking environment should become quite complex. Another problem is the handling of non-IP nodes. The ubiquitous networking environment has to bring in quite large number of small nodes. These small nodes may not use IP protocol. IP based network cannot support non-IP nodes well.

Some research groups are considering totally new network architecture. These are called as NwGN, new generation network [26]. GENI [40] is the testbed for developing new generation network. Akari project [41] is considering to *reinvent* the Internet by suggesting a whole new network architecture.

Extension of Ubiquitous computing field from year 2010 to 2025 is shown in Figure 2. Year 2010 is the era of Next Internet Technology, 2015 as Next Generation and 2025 as New Generation Networking.

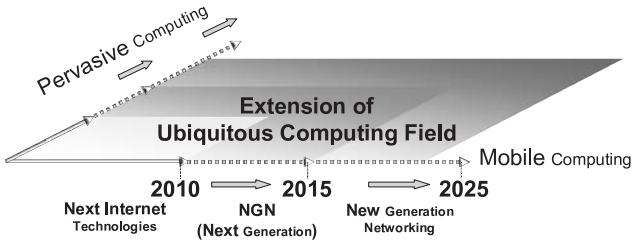

Figure 2: Networking innovations evolve axes of mobility and pervasive computing, extend ubiquitous computing field

2.3 Limitations of Ubiquitous Computing Environment

Now, in the IT society, social conveniences, security and safety that are commensurate with the cost of setting up information infrastructure and IT services, is not always available. Moreover, the information gap is getting wider and new misdeeds are coming up, which will prevent from social activation and thus creates a gap between Real Space (RS) and Digital Space (DS). We named this *gap* as S-gap and depicted in Figure 3.

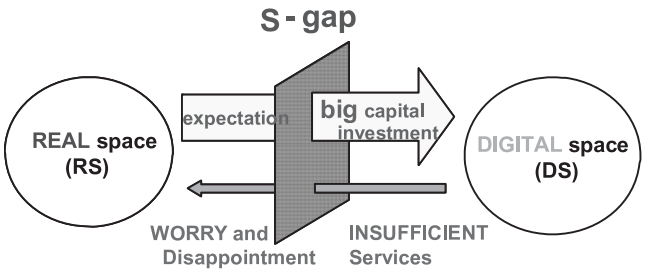

Figure 3: S-gap: Limitation of ubiquitous computing

Figure 4 illustrates the number of mobile Internet users in Japan from 2003 to 2008, of different age groups [42]. From this figure we can clearly see that the people below 10 years and above 60 years are left behind. They will not be benefited from the high-technologies and may find it difficult to cope with the changes in the society. And this is one of our primal concern and motivation to narrow this gap.

2.3.1 S-gap: Lack of symbiosis with human

The main reason of the creation of S-gap is as follows:

- Digital Divide
- Sense of Isolation
- Unease
- Distrust

In present IT society transmitting information from RS to DS is costly. Besides that, the information accumulated in DS

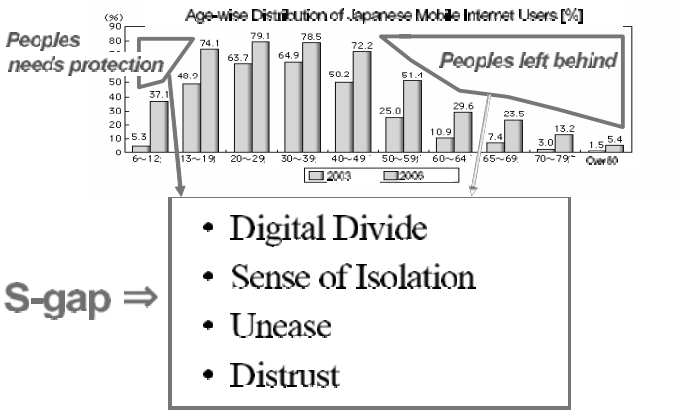

Figure 4: Utilization of Mobile Internet (Japan: 2007) WHITE PAPER Information and Communications in Japan, 2006

is not so useful in the Real Space (RS). That is, people in RS are not satisfied with the feedback received from DS, which is not so useful compare to the cost of transmission. For example, from *user's* point of view, the expectation is that the DS would solve the users' problems in RS anytime, anywhere. Also in daily life, it is supposed to give some advice and support to the user. From the *provider's* side, the information and services would be seen by many users and notified to the appropriate user at appropriate time. But these expectations are not fulfilled and as a result *disappointments* occur. Because, it the *user* is not sure what kind of service is available. Even if it is, users do not know how to use them. Also it takes time to execute them, even if they know how to use it. For the *provider*, it requires time to convert a lot of information obtained in everyday life into a certain data format. If it is too costly for the provider to supply services, the business would not work efficiently. Also, it may remain unclear to the provider whether the information is properly used or who use it.

To close the aforementioned S-gap, the concept of a new axis, the *3rd axis* comes as shown in Figure 5 and we called this 3rd Axis as S-bridge (Figure 6).

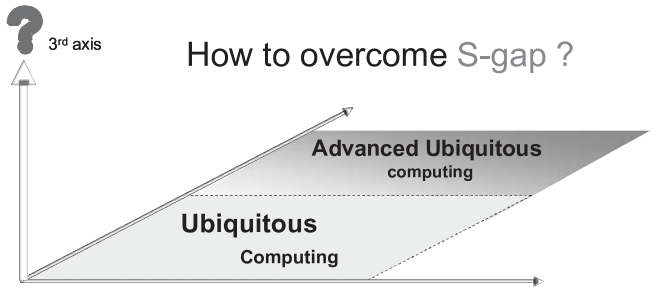

Figure 5: Towards post ubiquitous computing

Digital Divide: Depending on the closeness of the people in RS to the DS, received services also varies. The closer they live to DS more the benefits they can get. In order to get closer to DS and receive the services, they must know the architecture of DS, how to access and how to act in DS. This is an essential step where they adapt to DS, which a major impediment to DS.

Sense of Isolation: When people work in isolation, like working in a distant and separate office all by himself without any colleagues, the person can not feel the environment of the actual office and there is no one to help him out if he is any kind of trouble. Such a situation can create a sense of Isolation.

Unease: There are problems in not only RS but also in DS. It is also a serious problem that DS get expanded and complicated. The feeling of unease toward technical devices is a common phenomenon specially for elderly people due to the complexity and variety of functionalities of these devices. That makes them scared of using advanced technical gadgets and facilities and thus can not take the full advantage of the available resources and gap widened.

Distrust: People in RS can not take advantage of DS as much as they expect (S-gap). In addition, recently, people sometimes are anxious and even distrust DS. They might be wondering if their act bothers someone else, or the machines are infected with some virus, or their children access to some harmful contents, or the e-mail reaches someone who is not expected to receive. They might also worried about the hidden charges, processing of information, and so on and as a result loss the trust and dependability on the DS. We must ease this anxiety, otherwise RS wouldn't get closer to DS.

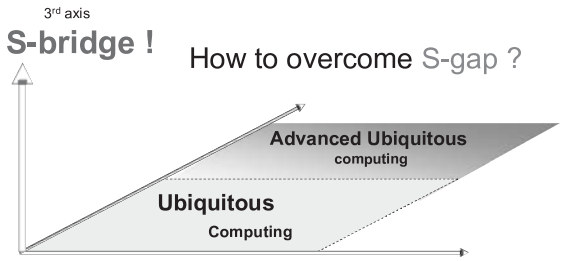

Figure 6: Towards post ubiquitous computing; S-bridge as the 3rd axis

2.3.2 Bridging the S-gap

As mentioned above, the current relation between RS and DS is still much different. Now, DS are parasitic on RS. When we ease this parasitic situation and balance DS and RS, "phenomenon to be solved" and for that we need the establish a bridge to close the gap between RS and DS, as shown in Figure 7.

It is important that RS and DS understand each other to achieve the symbiosis. Specifically, DS must collect a variety of information, knowledge and condition in RS like the environment info, users' info, etiquette, laws, local rules and task flows. On the other hand, RS must get the various specifications. For example, the architecture of systems, protocols and how to access to services, and figure out DS in more depth.

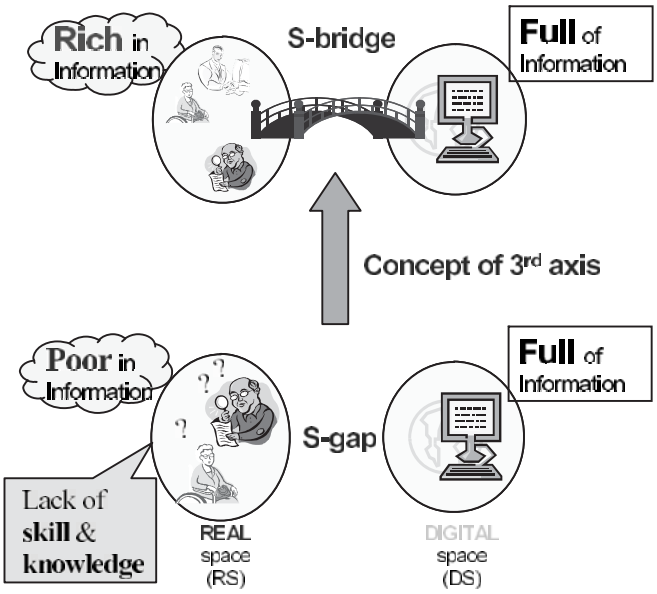

Figure 7: S-bridge: to close the gap between REAL and DIGITAL space

This mutual understanding will build the relation where RS and DS have any interactions as much as needed at the lowest cost when needed.

In the post-ubiquitous society, computing models are essential to promote the mutual understanding between RS and DS. In our project, we propose "symbiotic computing" as one of the computing models in the post-ubiquitous society. In the symbiotic society created by the symbiotic computing, RS and DS exchange their necessary information, knowledge and services to each other and the relation evolve into the real "symbiotic relation" so that we can solve the "phenomenon to be solved" and problem caused due to this S-gap will be eased by the S-bridge.

To address problems in recent IT society and to realize the Symbiotic computing, it is important to understand situations on the other side, specifically, to realize "Mutual Understanding" between Real Space (RS) and Digital Space (DS). This understanding consists of RS recognition and DS recognition as shown in Figure 8. RS recognition is a notion that the DS acquires social intelligence, individual characteristics, and environment information of the RS autonomously. This recognition is accelerated by the ubiquitous computing,. DS recognition is a notion that the DS presents and offers information, knowledge and service of the DS to the RS properly and intelligently. This recognition is enhanced by web computing. As mentioned above, mutual understanding is a state where the RS and DS can recognize each other.

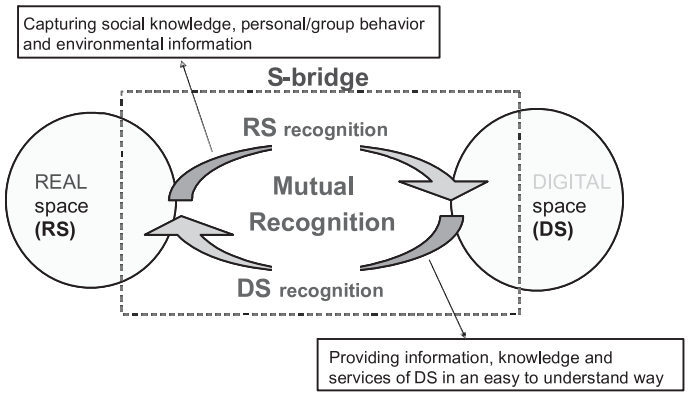

Figure 8: Symbiotic society: mutual-recognition between RS and DS solves S-gap problem

3 Proposal: Symbiotic Computing and its Architecture

3.1 Third Axis Concept: Symbiotic Computing

Symbiotic computing is realized by integrating three axes of computing: *ubiquitous computing*, *web computing* and *perceptual/social computing* - the newly added axis (value) as shown in Figure 9.

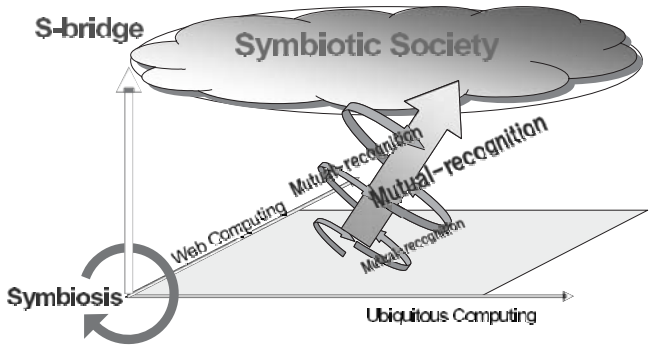

Figure 9: Symbiosis: 3rd axis concept

Definition1: Symbiosis When an autonomous and intelligent digital space (DS) and a real space (RS) are closely related to each other and human activities in RS are supported without thinking how DS works, we call this "Symbiosis" between DS and RS. Generally, "Symbiosis" means "a relationship between different types of animals or plants in which each provides for the other the conditions necessary for its continued existence". It is same as "Symbiosis" in our project in terms of providing service to each other, but different at our focus on relation between DS and RS.

Definition2: Symbiotic Computing Enhancing the autonomy and intelligence of DS leads to the symbiosis of DS and RS, where people belongs, and makes it possible that people receive DS services anytime. We call this way of information processing "Symbiotic computing".

Definition3: Symbiotic relation "Symbiotic relation" is a process in which people provide knowledge and do other things for DS so that both RS and DS develop.

The purpose of Symbiotic Computing is to make the computing model so that the human society (Real Space: RS) and the virtual society (Digital Space: DS) live symbiotically. Concretely, we will develop the technology to build an S-bridge between RS and DS, or the symbiotic computing technology.

Symbiotic computing is a basic idea that achieves an information processing environment, which autonomously supports human activities, by understanding human behavior and sociality in the real world.

In symbiotic computing, human society and digital space interact with each other, based on "basic principle of symbiosis", where they increase information processing ability, activity, and stability by offering information and supports each other. As a result, it creates new relation for co-existence and co-prosperity based on mutual understanding between them.

3.2 General Architecture of Symbiotic Computing

The symbiotic computing architecture consists of three parts; *perceptual-ware*, *social-ware* and *network-ware* (Figure 10). Each ware has both 'fundamental technology' and 'developing technology'. The former is the existing technology that would be the base of the symbiotic computing, and the later is the new technology that we proposed and developing for the symbiotic computing project.

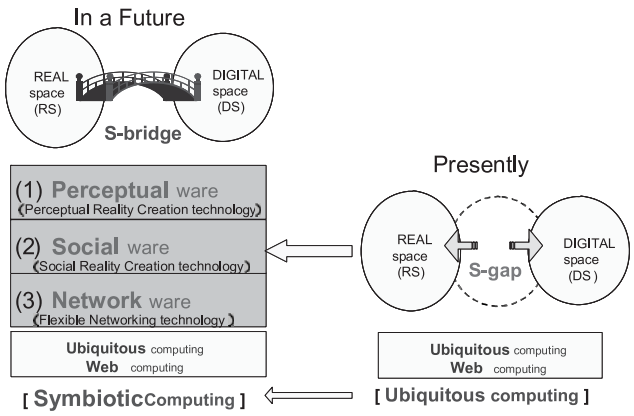

Figure 10: Architecture of symbiotic computing

Figure 11 shows a model of Symbiotic computing which realizes mutual understanding to make up a bridge to accomplish synthesis of RS and DS based on the ubiquitous, web and perceptual/social (P/S) computing. Here, P/S computing consists of Perceptual computing for perceptual reality and Social computing for social reality. These computing are based on perceptual-ware and social-ware described earlier. Perceptual computing acquires signals and data from RS and DS through the Network computing, and processes (identify, express, and operate) them by functions described in the box of Perceptual computing in Figure 11. Then it sends them to Social computing. Using such signal and data, Social computing recognizes users' activities in society based on social intelligence and individual model, using some of the functions and technologies shown in Social computing box, in order to provide such activities with some appropriate advice and information.

3.3 Network-ware

Network-ware is a device or software which removes the communication gap between RS and DS to support the communication between men, software and devices.

Fundamental technologies:

1. Flexible networking technology:
   (a) Flexible QoS control technology
   (b) Application level GW technology
   (c) Flexible network middleware organizing technology
   (d) Wireless network organizing technology
2. Ubiquitous networking technology:
   (a) Wireless ad hoc networking technology
   (b) Sensor networking technology
3. Wired and wireless seamless connection technology

Developing technologies:

1. (N1) Symbiotic Wireless and Ad hoc Networking: This technology provides channels with appropriate quality, changing the wireless ad hoc network compositions dynamically depending on requests from the perceptual-ware and social-ware. For example, it obtains the social relation between users from the social-ware, so that control QoS routing of the ad hoc network based on it.
2. (N2) Access Network Selection: This technology is for the election of access networks from the terminal providing services for users to the backbone network with considering users' communication requests, presence and locations, which are obtained from the perceptual-ware.
3. (N3) Ubiquitous Network Self-Configuration: This technology sets up ubiquitous networks at once, distributes a variety of software automatically to provide services and starts communication services. The extension of IdobataLAN for ubiquitous networks.
4. (N4) Symbiotic Application-Level Casting: This technology uses unicast, anycast and multicast effectively at application level on broadband networks based on situations of ubiquitous networks and users' social information from the social-ware so that it can keep the QoS of multiuser bidirectional communicating applications.

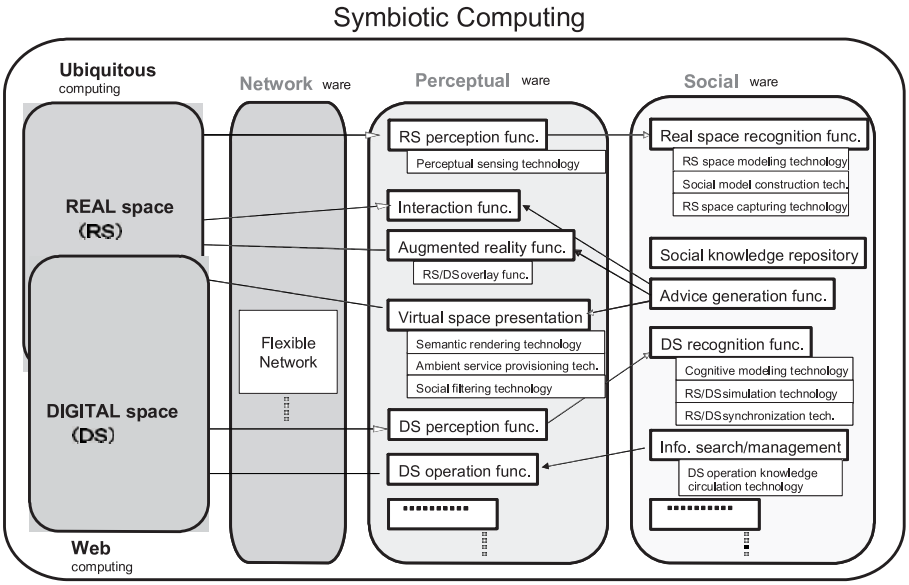

Figure 11: Model of symbiotic computing: integration of RS and DS

3.4 Social-ware

Social-ware is device or software which removes the logical gap between RS and DS to promote resolving user's problems and cooperating each other.

- (S1) Social Modeling: This technology regulates human and agent activities by recognizable model. This technology, for example, (1) forbids increasing prices unreasonably at online auction sites by the owner's making some bids, and (2) controls access with the perceptual-ware technology depending on users' age to the web sites that forbid underage accessing.
- (S2) RS/DS Simulation: This creates dynamically and simulates possible actions caused by actions of the social-ware technology. This technology, for example, predicts what kind of actions will take place by applying the social-ware technology when choosing either charging by a packets or flat rate for creating a new social model building technology.
- (S3) RS Space Capturing: This technology captures a "space" in RS as a semantic model in DS. This technology captures architectures of a real space and activities caused by those who are in the space as logical models (social model) and space models in DS. For example, this RS capturing technology allows to build a laboratory, seminar room and professor's room in DS without starting programming and establishing a 3D model.
- (S4) DS Space Modeling: This designs semantic models of "spaces" in DS. This technology enables to build logical models (social models) and space models in DS without the RS space-capture technology. For example, social networks (ex., mixi), which is mainly based on websites built in DS, are the social spaces that do not exist in the real space.
- (S5) Cognitive Modeling: This technology converts semantic models into recognizable models This technology converts logical models in DS into recognizable logical model in the social-ware. Things like URIs, e-mails, chat and changes of traffic in the existing DS are converted into formats that the social-ware can handle.
- (S6) RS <-> DS Synchronization: This synchronizes situations in RS and semantic models in DS. This technology enables, for example, to make a deal in RS, while making a deal in DS. All the things that are around you can be recognized through the social-ware.
- (S7) DS Operation Knowledge Circulation: This mechanism circulates necessary information for DS management and maintenance efficiently. For example, the management and maintenance knowledge of a video conference system, which is one of DS, or the information of unsecured web sites are converted into recognizable models by the social-ware in order to circulate them.

3.5 Perceptual-ware

Perceptual-ware is device or software which removes the sensory gap between RS and DS to accelerate obtaining and providing information.

- (P1) DS-RS Perceptual Overlaying: This technology allows to build a tangible agent environment, where images in DS are laid on those of RS with a special device so that people in RS can interact with those who are in DS (agents or remote users).

- (P2) Ambient Service Provisioning: This technology combines functions that are around users like PCs, appliances and cell phones, so that users can receive services that they request anytime, anywhere.
- (P3) Social Filtering: This technology filters providing services dynamically for the privacy protection at an appropriate level depending on the requests from the social-ware, when providing services.
- (P4) Perceptual 3D Space Sharing: The advanced technology of a 3D symbiotic space on PC. For example, displaying high-resolution images in a 3D space, controlling a display quality at a perceptual level, mobility of users in a 3D space and obtaining users' requests dynamically from biologic information like skin potential and line of sight.
- (P5) Semantic Rendering: People consider information in DS as "recognized spaces" and design some parts of them to display and publish them, like the existing web pages. The audiences can travel in those spaces seamlessly, browse information in DS and interact each other.
- (P5) Perceptual Sensing: This technology is for storing and managing information of environments and users from not only dedicated sensors but also the existing devices, PCs and information appliances. They are combined dynamically and semantically depending on the requests from the social-ware in order to make a variety of services, not for fixed purposes.

4 Evaluation of Symbiotic Computing Architecture

4.1 Children watch-over system

In this paper we experiment whether warning of the information extraction can be achieved. The main point of this experiment is that no user inputs his/her personal knowledge to the system. The system gets GPS information only about him/her and gets public area knowledge from web. Figure 12 shows our experiment model of knowledge flow. The user does not take any action to evaluate, pushing the button or inform his/her favorites. The knowledge about ID which is assigned to the participant considering for our experiment is generated with the use of open to the public information such as web pages with the knowledge management tool. The knowledge about ID is a user model able to forecast the user's behavior. The system changes its GPS information to the position using map data and makes personal user model using knowledge management tools with the personalized schedules, social knowledge and the public regional information. For example, if an ID with GPS stays at the position for a few hours in a bookshop, the system will make a positive point to user's profile that he/she is likely to read a book. There are various existing system where a lot of warning mail is transmitted when the child is taking a different route than his/her usual one. This could create plenty of false positive warning which is annoying for the parents.

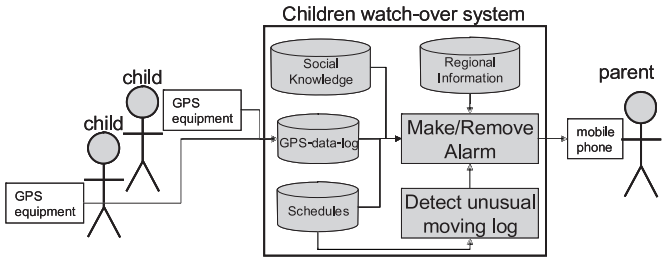

Figure 12: Children watch-over system

Figure 13 shows our demonstration area which is a typical residence area near Tokyo. We have three scenarios, (i) route-3 shows a normal going/coming-back from school to home, (ii) route-4 shows that the child go off his/her normal route to go the park, (iii) route-5 shows that the child has gone to some other place. The ordinarily services make plenty of waning messages for case (i) and (ii). But our proposed system only send warning message for case (iii). The route-4 shows that the system estimates that the child will probably go to the park.A naive position-oriented child-watch-over system makes much more warning mail for case (i), i.e. route-3 case (ii), i.e. route-4. On the other hand, our proposed system makes only send a single warning mail for case (iii), i.e. route-5.

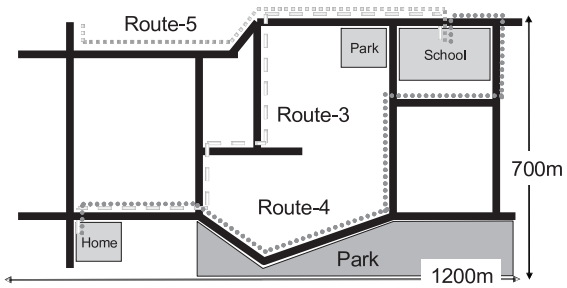

Figure 13: A Map of Watch-over Child Experiment Field

The proposed system use DB with five tables which are shown in Table 4.1.

No.	Schema
1	ID, Position, Data, Time
2	ID, Relation, ID
3	Building ID, Position, Name
4	Event ID, Position, Data, Time
5	Environment, Name, ID

Table 1: Information tables in DB

Route No.	No. of warning-mail by proposed system	No. of warning-mail by simple function
4	5	644
5	96	208

Table 2: Comparison of Number of warning mails

The proposed system shows much fewer number of warning mails compare to the existing ordinary Simple Function method as shown in Table 4.1.

4.2 Group Learning Support System

In this section, in order to evaluate the effectiveness of the Symbiotic Computing, we focus on a group learning domain consists of a teacher and several students. Group learning is a task domain of intelligent cooperative works for the purpose of educating the students, in which each student in a group effectively acquires knowledge by exchanging information with the teacher and other students.

In group learning, generally, it is effective for each student to study by oneself and discuss with group members alternatively over and over. Through self-study, every single student will be able to develop his/her own ability of thinking. In addition, through the group discussion using the result of the self-study, each student will be able to learn other solving methods about the difficult points he/she found during self-study. Thus, both the self-study and group discussion are important, and if they are executed alternately at an appropriate moment, the effect of group learning will be radically enhanced.

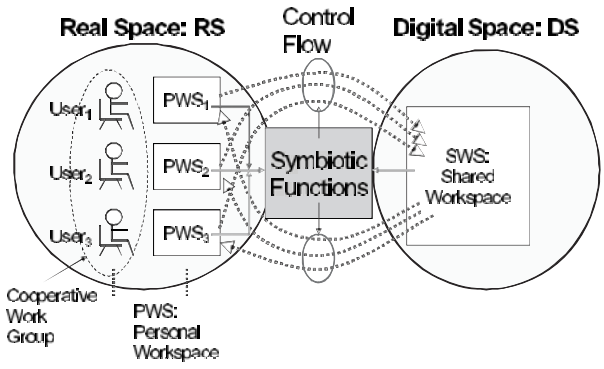

Figure 14: Symbiotic Function for group learning support system.

Based on the basic motivation mentioned above, we respectively provide the PWS (Personal Workspace) in RS as an environment for self-studying, and the SWS in DS, which is shared on a network, as a space for group discussion. Here, we expect the group learning to proceed effectively by shifting current space between the PWS and SWS appropriately in response to the progress of the study in RS. This shifting is performed by the "Symbiotic Function" as shown in Figure 14. The control of information flow between PWS (RS) and SWS (DS) is based on situations of the learning activities and progress in PWSs/SWS. By switching the PWS and SWS in proper timing, the group learning process can be controlled effectively to improve results of the learning.

We implemented a prototype system of the group learning support system with the Symbiotic Function, according to the Model of Symbiotic Computing. The user interface of the system is as shown in Figure 15.

For the purpose of evaluating the effectiveness of the proposed method, we conduct an experiment, applying this scheme to the group learning domain. On one session, one teacher and three students carry group learning on one problem which has multiple solving methods. The work duration for each session is 20 minutes, and the goal is to find solving methods of the problem as many as possible within the time limitation.

In this experiment, not automatically, but a teacher and students shift the PWS and SWS by determining from the progress of the study. In order to evaluate the effect of shifting the PWS and SWS, we conduct the experiment with three types of systems; S1, S2, and S3, as follows.

1) A system which always presents both the PWS and SWS without shifting (existing scheme: S1).

2) A system which shifts the PWS and SWS,

   2-1) on response to the request from the students (proposed scheme 1: S2).

   2-2) on response to the request from the teacher (proposed scheme 2: S3).

We carry out the experiment twice with each type of system as mentioned above. In each time, group members solve two mathematical problems related to geometry as follows:

(P1) Calculating the area of a triangle.

(P2) A problem regarding a circle and a tangent line.

We consider graduate students as examinees. As one group can carry only one session on one problem, we can not allot more than one system to a group for our evaluation. Thus, we respectively allot different groups of examinees, G1, G2, and G3 to the three types of system, S1, S2, and S3. Figure 16 shows the snapshot of the experiment.

Experimental result is shown in Table 3.

Table 3 shows number of solutions which at least one student could make it to, as a result of group learning for each question of (P1), (P2) and each situation of (S1), (S2) and (S3).

As it is indicated in Table 3, for the question (P1), five solutions can be found with (S3) which is the case when the teacher changes the SWS enabled and disabled. One solution can be found with (S2) when the SWS is changed enabled and disabled according to the order of students. One solution can be found with (S1) when the SWS is always enabled.

As for the question (P2), eight solutions can be found in (S3), seven can be found in (S2), and five can be found in (S1),

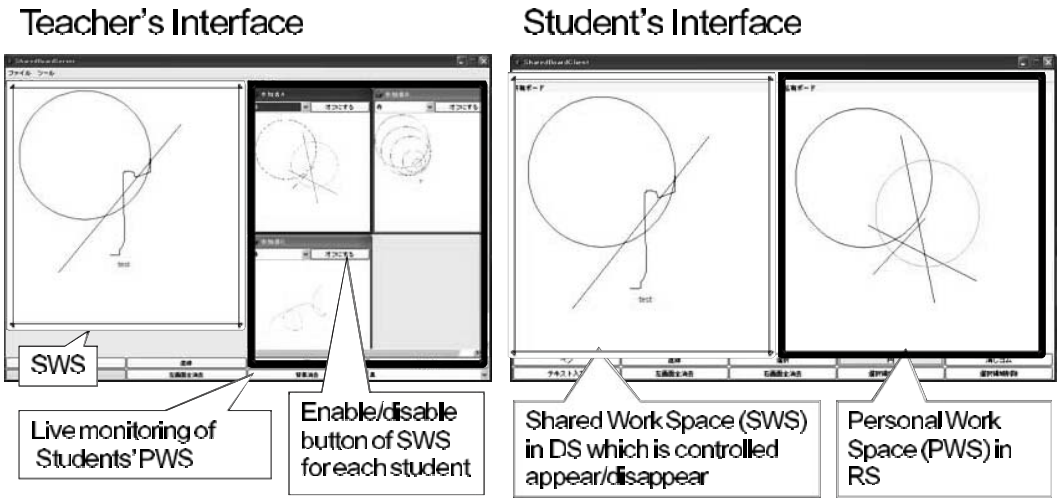

Figure 15: User interface of the group learning support system.

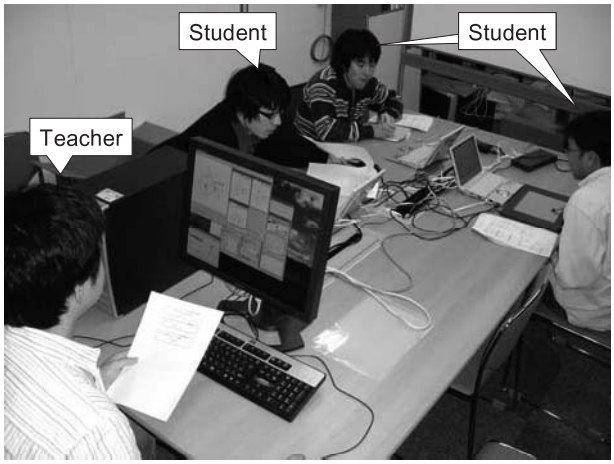

Figure 16: Snapshot of the experiment.

respectively. These results show that the cooperative work is effectively proceeded by using the proposed scheme. Finally we conclude that the Symbiotic Function with the model of Symbiotic Computing can accelerate the exchange of knowledge between RS and DS, and would improve performance of human activity in RS.

4.3 2025: Revolutionary effect of Symbiosis

In Figure 17 we have shown the futuristic situation of year 2025 and the influence of our proposed support system on the society and how effectively it can help to overcome various social and important aspect of life.

5 Conclusion

In this paper we first defined the problems that can appear in post ubiquitous society and it impact on social environments. Though the advancement of technology will bring

Given Problem	Number of acquired solutions		
	(S1)	(S2)	(S3)
(P1)	1	1	5
(P2)	5	7	8

Table 3: Number of acquired solutions compared with traditional system (S1) and proposed system (S2 and S3).

comfort but it will also create problems, and will create a *gap* between human and computers, socially to some particular group of people. To overcome these problems, we introduced a new computing paradigm called, *Symbiotic Computing*. We described the basic concept and architecture of symbiotic computing and a few applications we have developed to show the actual effect of symbiotic computing. Based on the novel concept of this new paradigm a society can be built where human and ubiquitous information environment will coexist in a cooperative manner.

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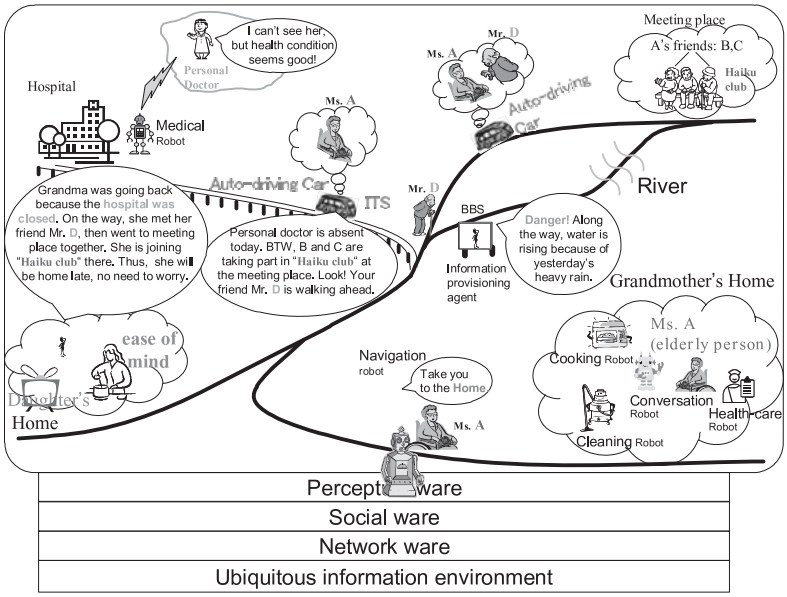

Figure 17: Towards 2025: support system for people and future society

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Norio Shiratori received his doctoral degree from Tohoku University, Japan in 1977. Presently he is a professor of the Research Institute of Electrical Communication, Tohoku University. He has engaged in research related to symbiotic computing paradigms between human and information technology. He was the recipient of IPSJ Memorial Prize Winning paper award in 1985, The Telecommunication Advancement Foundation Incorporation award in 1991 and many others. He was the vice president of IPSJ in 2002 and a fellow of IEEE, IPSJ and IEICE.

Toshimitsu Miyamoto received his Masters degree in Information Science from Graduate School of Information Science, Tohoku University in 1999. Currently he is pursuing his doctoral degree in Information Science in the same institute. His research interest includes eLearning support system.

Debasish Chakraborty received his doctoral degree from the Graduate School of Information Science, Tohoku University, japan in 1999. Presently he is working as a visiting Associate Professor in the Research Institute of Electrical Communication, Tohoku University. He was TAO research fellow and a NiCT foreign research fellow at Tohoku University Research Center. His main research interests are multicast routing algorithm, QoS, Internet traffic analysis, and wireless and ad hoc networking.

Hideyuki Takahashi is a research fellow of Research Institute of Electrical Communication of Tohoku University, Japan. He received his doctoral degree in Information Sciences from Tohoku University in 2004. His research interests include ubiquitous computing and agent-based computing. He is a member of IPSJ.

Shigeru Fujita is an associate professor at Faculty of Information and Computer Science, Chiba Institute of Technology, Japan. He received his PhD., M.Eng. and B.Eng in March 1998, 1994 and 1992 in Computer Science from Chiba Institute of Technology. His research interests include applied multi-agent technology, ubiquitous computing, cognitive science, knowledge management and human-machine symbiosis.

Takuo Suganuma is the associate professor of Research Institute of Electrical Communication of Tohoku University, Japan. He received a Dr.Eng. degree from Chiba Institute of Technology. He received UIC-07 Outstanding Paper Award in 2007, etc. His research interests include agent-based computing, flexible network, and symbiotic computing. He is a member of IEICE, IPSJ and IEEE.

Atsushi Takeda received both the B.E degree in Electronic Engineering and M.S in Information Science from Tohoku University in 2000 and 2002, respectively, and the Ph.D. degree from Tohoku University in 2005. He has been with Tohoku Bunka Gakuen University as an Assistant Professor since 2005. His current research interests include communication network, agent computing and network security.

Implementation of Integrity Maintenance Method of Query Result by Bitemporal Database

Tsukasa Kudou†, Masahiko Ishino‡, Kenji Saotome*, Nobuhiro Kataoka** and Tadanori Mizuno***

†Mitsubishi Electric Information Systems Corporation, Japan
‡Mitsubishi Electric Information Technology Corporation, Japan
* Hosei Business School of Innovation Management, Japan
** School of Information Science and Technology, Tokai University, Japan
*** Faculty of Information, Shizuoka University, Japan
kudou-tsukasa@mdis.co.jp

Abstract - Generally, databases of mission-critical systems are updated with entry data by transaction processing, and are queried to make statistics and so on by batch processing. So, it is necessary that both processing can be executed simultaneously for the efficient system operation. In principle, a bitemporal database system can not only maintain the integrity of the query results even under simultaneous data entry, but also query the corrected data to provide valid query results. However, in the actual operation of a mission-critical system, various problems occur such as data-entry mistakes and data-entry backlogs. Therefore, the bitemporal database has to be able to support these problems. In this paper, we show an application case of a bitemporal database into a mission-critical system, to investigate an implementation of a method for maintaining the integrity of the query results under real-world conditions. As a result, we have confirmed that integrity was maintained even while the database was being updated, and that various kinds of corrections done by the actual system operations were reflected in the query results. Furthermore, we confirmed that the method is effective in not only the data corrections for a short period confirmation work but also the correction management of data for a long period of real-world use, and that data correction can be managed in both internal processes and business procedures individually.

Keywords: temporal database, bitemporal database, query, integrity, mission-critical system

1 INTRODUCTION

In many mission-critical systems such as in retail, finance and manufacturing, data entered from online-terminals are committed to the database in discrete transactions (hereinafter "online entry"). Also, at regular intervals or as needed, batch query jobs are performed, often accessing a massive amount of data, to make statistical documents, analysis documents and so on. For example, in the case of a retail system, the sales data are entered from terminals in each store, and reflected in the central corporate database. Then, settlement of accounts processing is performed on a daily or monthly basis by executing queries involving a great deal of data from all of the stores for the given period. Here, if we divide the time zone of the online entry and the batch processing, the batch processing has to be performed in night, and moreover its time may pass away by the extension of the online entry time. Therefore, it is necessary that online entry can continue concurrently with the various queries being processed to produce the reports.

In this situation, a snapshot database [2], which stores only the latest state of the data, has the problem that the integrity of the query results isn't guaranteed when data are changed by the online entry system, between or while individual queries in the batch job. Database systems, which employ transaction processing [4] equipped with lock control to manage concurrency, maintain the integrity of their data even when simultaneous accesses by many users arise. And, even if a large amount of data is queried, the method to divide a long time transaction of large batch into many mini-batches [4] is used. However, a long time is necessary for querying a great deal of data, so, even if the each query processing avoids conflict with the online entry, some portions of the query results may come after the online entry although other portions come before.

On the other hand, the temporal databases manage the data that changes in chronological order, and a lot of researches have been performed about them [3], [6], [7], [11], [13], [14]. In temporal databases, time can be captured along two distinct time lines: the valid time and the transaction time [7]. The valid time denotes the time a fact was true in the real-world; the transaction time is the time during which the fact was present in the database as stored data. Temporal databases are divided into three types: valid time databases, transaction time databases and bitemporal databases. Valid time databases manage only the valid time, transaction time databases manage only the transaction time, and bitemporal databases manage both the valid time and the transaction time [12].

It has been shown that a transaction time database can express prior states of the database at designated past transaction times as a snapshot [5], unaffected by continuing online entry. However, in actual system operations, when errors in the data are detected during batch processing, we have to correct the data and restart the batch job from the beginning. In this case, the problem arises that the corrected data is not reflected in the query results of the redone batch job, because the transaction time of the corrected data comes after the designated time of the query.

The version-control data model manages not only the times

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when data is added or deleted, but also derived relations between versions [8], [9]. As a result, it can manage both version sets that are derived from the designated transaction times: one set is created in chronological order by normal data entry; the other set is created out of order by data correction. So, corrected data can be reflected in the query result. This model is important in software development, CAD, and other systems which rely on strict version control. But, in applying it to mission-critical systems that require a high data input frequency, processes for detecting corrected data and deriving new versions have to be executed so frequently that performance suffers.

Using a bitemporal database, we can obtain query results that have verifiable data integrity and reflect the corrected data even while online entry continues concurrently. Here, to apply this to mission-critical systems, we have to confirm that it can support a wide range of corrections which occur during actual system operations. On the other hand, this database must manage records with two kinds of time attributes, which increases the difficulty of applying it to information systems by complicating the query procedures and increasing of the amount of data. Therefore, there are very few cases where it has been implemented, and we could not find a case in which a bitemporal database had been used and evaluated in an actual mission-critical system.

In this paper, we show that a bitemporal database can maintain the integrity of the query results in real-world conditions. That is to say, various kinds of corrections which were applied to the data during actual system operations are properly reflected in the query results, and batch queries were run concurrently with live online entry. Furthermore, we applied it to a mission-critical system and evaluated its effect on actual system operations. As a result, we confirmed that the above-mentioned integrity was maintained. Moreover, we confirmed the following effects: first, data correction could be managed over a long period of real-world use in addition to the use in confirmation work in a short period; second, the data corrections of internal processes and business procedures could be managed individually.

To handle the implementation problems, we improved the following points. First, we created work files for batch processing jobs by constructing a temporary table of the database (hereinafter "work table"). We then processed the data step-by-step using this work table in order to simplify each individual query procedure. Second, we implemented the system such that each record is defined to be valid until it is superseded. Thus, because we could maintain complete bitemporal data by only storing one data for a change of real-world, the overall increase in the amount of data was minimized.

In section 2, we expound on the problems that arise when a transaction time database is queried concurrently with online entry, and in section 3, we show that this problem is solved by utilizing a bitemporal database. In section 4, we show an implementation case of a bitemporal database in a mission-critical system and show the operation of the system. Finally, in section 5, we evaluate and consider the implementation of the bitemporal database.

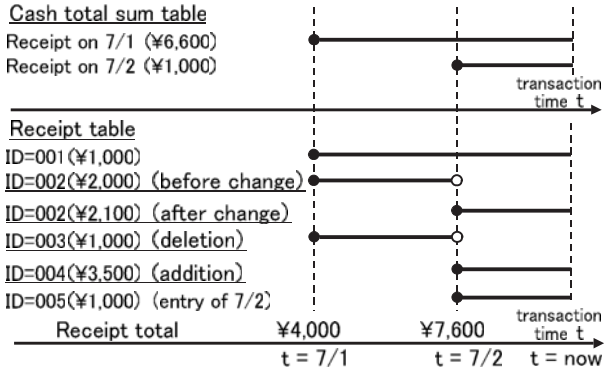


Figure 1: Snapshot of transaction time database.

2 PROBLEM OF TRANSACTION TIME DATABASE

2.1 Query Processing to Deal with

In this paper, we deal with the following query processing.

i. **Concurrent Execution of Query and Online Entry**
Query of batch processing is executed concurrently with the online entry from many online-terminals that update the database with high frequency.

ii. **Query Large Amounts of Data in a Single Batch**
Massive amounts of data are queried in a lump, so the processing takes time.

iii. **Redoing Batch Queries after Data Correction**
When data errors are detected in the query result, we have to correct the data such by making changes, deletions or additions. Then, the queries have to be executed again on the same data without updates from further online entry.

Such query processing is standard in mission-critical systems like the settlement account processing of retail systems, in which queries are run on massive amounts of data and executed by batch processing. Transaction processing of a database system equips various kinds of integrity constraints [4], and a method that maintains the integrity of the database by the cooperation even when it was updated by a group of people has been proposed [10]. Therefore, the integrity of the database is maintained in many cases. However, the confirmation of the integrity, which has to query large amount of data, has to be executed by batch processing. For example, the comparison of several tables, the calculation of the receipt totals to compare with the actual cash total sum, and so on. Therefore, the batch processing has to be redone after correcting data when data errors are detected.

2.2 Query Method during Online Entry

In the transaction time database, the transaction time is expressed by $[t_a, t_d)$. In this expression, t_a shows the time that the data was added to the database, and t_d shows the time that

the data was logically deleted from the database. As long as the data hasn't been deleted yet, t_d is expressed as "now", which shows the time when querying is executed [1], [12]. When we change some data, the time t_d of the data is set to the time of the change. Thereby it is logically deleted. Then, new data is added to the database to replace the old data logically. By this way, the data once added is left in the database without being deleted physically. Therefore, we can get the snapshot at transaction time t by querying the data in the condition of $t_a \leq t < t_d$, and the integrity of the snapshot is kept even if the database is updated by the online entry while we are querying.

Figure 1 shows the application example of querying snapshot in a retail system. By comparing the receipt table of July 1st with the cash total sum table of the same day, three data errors were detected: an entry mistake of $ID = 002$, an overlap entry of $ID = 003$ and entry leakage of $ID = 004$. And, corrections of data by change, deletion and addition were done on July 2nd. Moreover, a new receipt data of $ID = 005$ was added on July 2nd. In the snapshot of July 1st, these update on July 2nd were not reflected. By this characteristic, even if the database were updated by the online entry during the query, the integrity of the query result can be maintained.

2.3 Problem about Query of Correction data

In the actual business system, the right query result of the receipt table of July 1st, which total is adjusted with the cash total sum table, is necessary. However, there is a problem that it is impossible to query current corrected state of July 1st. Because, by the snapshot on July 1st, the data before correction is queried in the example of Figure 1; by the snapshot on July 2nd, the receipt data on July 2nd $ID = 005$ is queried, too.

Here, in the following examples, we express the transaction time by making its unit a day. In the implementation, its unit is determined according to requirements for the system such as frequency of the online entry.

3 QUERYING BITEMPORAL DATABASE

We show that the problem in section 2.3 can be solved by the bitemporal database.

3.1 Composition of Bitemporal Database

The relation of the bitemporal database R is expressed as follows.

$$R(K, T, V, A) \tag{1}$$

We show each attribute as follows.

- $K = \{K_1, ..., K_m\}$
  This expresses the set of attributes constituting the primary key of the snapshot queried by designating both time attributes: the transaction time and the valid time.
- $T = \{T_a, T_d\}$
  This expresses the time period attribute of the transaction time, which is generated by system and isn't made public to the users. Here, T_a shows the time that the data was added to the database (hereinafter "addition time"), and T_d shows the time that the data was logically deleted from the database (hereinafter "deletion time"). As long as the data hasn't been deleted yet, the instance of attribute T_d is expressed as "now".
- $V = \{V_a, V_d\}$
  This expresses the time period attribute of the valid time, i.e. the corresponding fact was true in the real-world. Here, V_a shows the beginning time of the time period, and T_d shows the ending time. In the case that the data is still true when we query it, the instance of attribute V_d is expressed as "now" like T_d. Regarding the valid time, the data once added is left in the database without being deleted physically like the transaction time, too. And, we can get the snapshot of a designated valid time by querying the database.
- $A = \{A_1, ..., A_n\}$
  This expresses the other attributes.

3.2 The Method for Querying Bitemporal Database during Online Entry

In the bitemporal database, the integrity of the snapshot is also kept even while it was being updated by the online entry, like the transaction time databases shown in section 2.2, because it manages the transaction time. Moreover, we can query the state of the real-world of any designated valid time, because it manages the valid time.

The snapshot of R, transaction time of which is t_1 and valid time t_2, consists of the data that satisfy the both following conditions: its instance of transaction time period $T = \{T_a, T_d\}$ includes t_1; its instance of valid time period $V = \{V_a, V_d\}$ includes t_2; Therefore, its relation $R_1(t_1, t_2)$ is expressed as follows.

$$R_1(t_1, t_2) = \{r | r \in R \wedge r[T_a] \leq t_1 \wedge t_1 < r[T_d] \wedge r[V_a] \leq t_2 \wedge t_2 < r[V_d]\} \tag{2}$$

Here, $r[T_a]$, $r[T_d]$, $r[V_a]$ and $r[V_d]$ show the respective instance of attributes T_a, T_d, V_a and V_d of r, the data included in R. Therefore, in the case that an error data was detected in the query result and corrected at transaction time t, we can query the corrected data by the snapshot designating times as follows: the condition of transaction time t_1 is $t_1 > t$; valid time t_2 is the same with last query.

3.3 Effect to Data Corrections

Figure 2 shows the query results, which is executed by designating transaction time t_1 and valid time t_2, in the case of Figure 1. Regarding the bitemporal database, the receipt data in real-world conditions can be queried. That is, as shown in

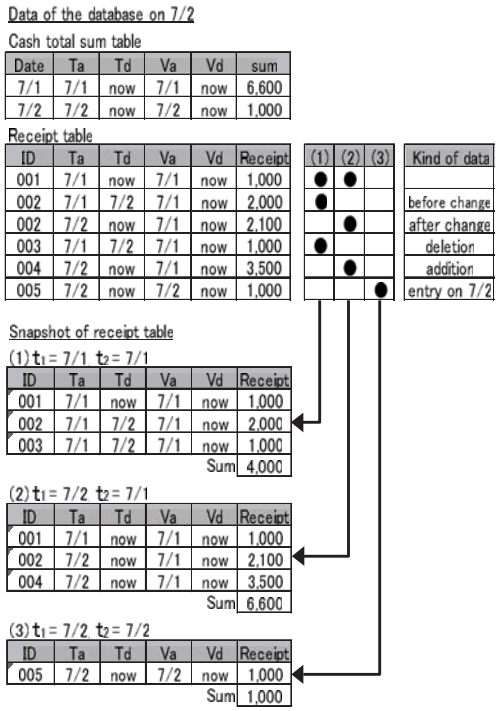


Figure 2: Snapshot of bitemporal database.

item (2) of Figure 2, we can query the corrected state of July 1st by designating t_1 July 2nd and t_2 July 1st in the condition of Equation (2): the change, deletion and addition on July 2nd are reflected; the receipt on July 2nd is not reflected. Incidentally, item (1) of figure 2 shows the query result of data before correction, the same as on July 1st in figure 1, and item (3) shows the query result of data entered on July 2nd.

Moreover, even while data are being corrected, we can get a snapshot that has integrity. The data corrections are also done by the usual online entry. Therefore, as shown in section 3.2, when we query the database by designating transaction time t_1, we can get the corrected result, which was performed by t_1. And, this query result isn't influenced by the online entry, including data corrections, ongoing at that time.

4 APPLICATION TO A MISSION-CRITICAL SYSTEM

We applied the bitemporal database to a local government system. In this section, we show the overview of this system, the implementation of the bitemporal database and the operation of its batch processing.

4.1 Overview of Local Government System

4.1.1 Composition of the system

The local government system is a mission-critical system for the public administration business of local government like a city hall. And, as shown in Figure 3, it consisted of various kinds of subsystems to assist the local government business.

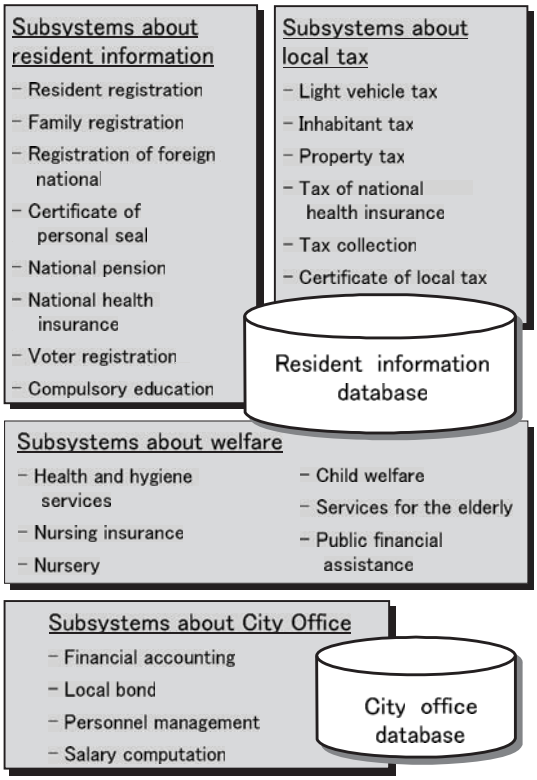


Figure 3: Composition of local government system.

They were classified by business contents as follows.

- **Subsystems about Resident information**
  They were used for the business, such as management and certificate of the residents who live in the city.
- **Subsystems about Local Tax**
  They were used for the business of the local tax, such as levy and certificate about tax.
- **Subsystems about Welfare**
  They were used for the business of welfare, such as qualification management, levy and grant.
- **Subsystems about City Office**
  They were used for the business of the office work of local government, such as personnel management, salary computation and financial accounting.

4.1.2 Characteristics of the Database

Each business needed the record data management in chronological order. We show the examples of the record data as follows.

- **Transfer of Resident**
  Each resident has his or her transfer records: they begin by birth or transfer into the city; via change of address, marriage and so on, they end by death or transfer to other city.

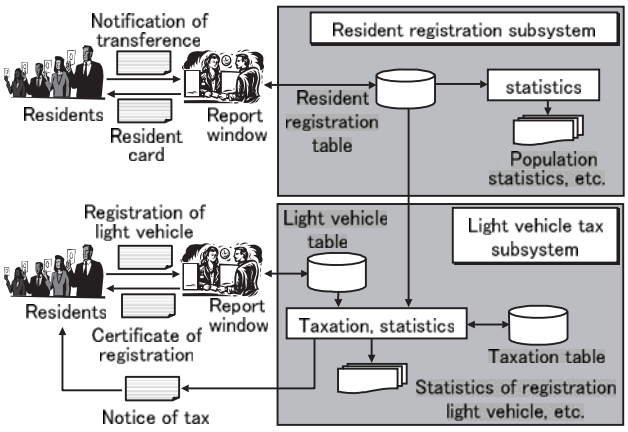


Figure 4: Dataflow example of local government system.

- **Taxable Article**
  The taxable article such as a light vehicle has the transfer records: its registration, transfer, disuse and so on.
- **Qualification of Welfare**
  The qualification of welfare has the acquisition and loss records, which are managed for the premium payment, the certificate of issuance, the insurance payment and so on.
- **Transfer and Diligence of Staff**
  The records of each staff of the local government were managed: his or her transfer, diligence, paid salary and so on.

Figure 4 shows the dataflow of the resident registration subsystem and the light vehicle tax subsystem, as the example of the data flow of the local government system. Notifications were accepted with the report window of the city hall, and its data were entered by the online entry and accumulated in the database to be queried by various processing of the system. And, the processing to query a great deal of data is processed by batch processing, such as making statistics, tax calculation, and so on.

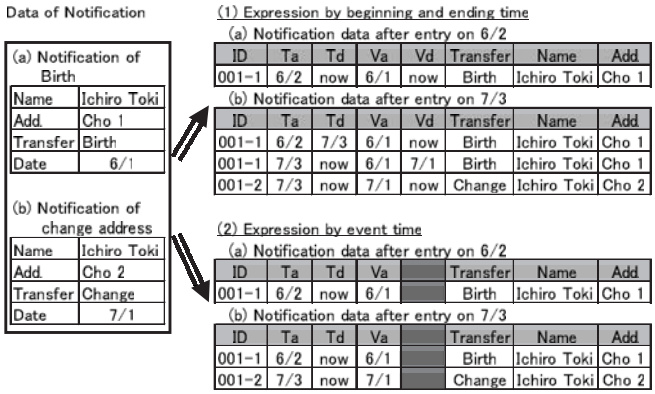
4.2 Implementation of Bitemporal Database

4.2.1 Policy of Implementation

We used the commercial relational database and added attributes of the transaction time and the valid time to each table, to compose a bitemporal database.

4.2.2 Implementation of Transaction Time

Since transaction time is used as one of primary key attributes of the database, the unit of transaction time had to be decided based on the frequency of data entry. In this system, data were entered from terminals, and the data entry took several seconds at least. So, we made the unit of transaction time 1 second.


Data of Notification

(a) Notification of Birth

Name	Ichiro Toki
Add.	Cho 1
Transfer	Birth
Date	6/1

(b) Notification of change address

Name	Ichiro Toki
Add.	Cho 2
Transfer	Change
Date	7/1

(1) Expression by beginning and ending time

(a) Notification data after entry on 6/2

ID	Ta	Td	Va	Vd	Transfer	Name	Add.
001-1	6/2	now	6/1	now	Birth	Ichiro Toki	Cho 1

(b) Notification data after entry on 7/3

ID	Ta	Td	Va	Vd	Transfer	Name	Add.
001-1	6/2	7/3	6/1	now	Birth	Ichiro Toki	Cho 1
001-1	7/3	now	6/1	7/1	Birth	Ichiro Toki	Cho 1
001-2	7/3	now	7/1	now	Change	Ichiro Toki	Cho 2

(2) Expression by event time

(a) Notification data after entry on 6/2

ID	Ta	Td	Va		Transfer	Name	Add.
001-1	6/2	now	6/1		Birth	Ichiro Toki	Cho 1

(b) Notification data after entry on 7/3

ID	Ta	Td	Va		Transfer	Name	Add.
001-1	6/2	now	6/1		Birth	Ichiro Toki	Cho 1
001-2	7/3	now	7/1		Change	Ichiro Toki	Cho 2

Figure 5: Expression of valid time.

4.2.3 Implementation of Valid Time

As for the valid time, because it depended on the business, we decided its unit from the necessity about the business. We show the examples of the unit of the valid time as follows.

- **A Minute:** the diligence of the office staffs.
- **A Day:** the transfer of residents, the transfer of taxable articles, the acquisition and loss of the qualifications of the welfare, the period of bank transfer and the transfer of the office staffs.
- **A Month:** the payment information of salary of the office staffs.
- **A Year:** the amounts of tax such as the light vehicle tax.

In the implementing of the valid time attribute, we used both expressions shown as follows.

- **Expression by Beginning and Ending Time**
  We expressed the valid time of some tables by the beginning and ending time: the table that needed to subscribe the time becoming valid or invalid beforehand such as the bank transfer period; the tables that needed to manage beginning and ending time by the set such as the acquisition and loss of the qualification.
- **Expression by Event Time**
  Data were changed or added by an event and maintained until the next event occurrence. For example, the state of a resident was changed by the event of transfer such as his or her birth or change of address, and the state was maintained until the next transfer.

When we changed a data expressed by the beginning and ending time, the following procedure was executed and two records are added as shown in item (1) of Figure 5. In Figure 5, T_a, T_d, V_a, V_d are the same as the notation in section 3.1.

- $ID = 001 - 1(T_a = 6/2)$: deletion time T_d is set to the original data.

- $ID = 001 - 1(T_a = 7/3)$: the data after change of the valid time is added, the ending time V_d of which is set to July 1st that is the beginning time of the next record.
- $ID = 001 - 2(T_a = 7/3)$: the data, address of which has been changed into 2-chome, is added.

Here, the data $ID = 001 - 1(T_a = 6/2)$ shows the record between June 2nd and July 2nd of the transaction time, and the data $ID = 001 - 1(T_a = 7/3)$ shows the record after July 3rd.

On the other hand, when we change a data expressed by the event time, only a record $ID = 001 - 2(T_a = 7/3)$ is added as shown in item (2) of Figure 5. Therefore, data increase in the case of the expression by the event time is less than the expression by the beginning and ending time. Incidentally, in this case, the state in the real-world of the designated valid time is expressed by the data that event time is eve of the designated time, if there is no data that event time agrees with it.

4.2.4 Support for Behind Entry Data

There was business that had to create documents like statistics at the end of business hours of the designated date, though the data of the real-world were behind in their notifications to enter the system. Therefore, we created them based on the notification date to the local government. For example, some kinds of resident transfers should be notified within 14 days from the actual transfer date: birth, change of address, transfer into the city and so on. However, statistics such as population statistics or transfer statistics of residents had to be created after the business end of the designated date to be reported to the next day. Therefore, we managed the notification date in addition to the transfer date that is a valid time in the table of the resident registration subsystem. The notification date is a user-defined time [7], [11], which is the time attribute defined by user in the temporal database.

Figure 6 shows the example of the snapshot by the notification date, in which N_a, N_d show the beginning and ending time of the notification date. Here, the ending time becomes the notification date of the next notification. That is, the time period attribute of the notification date is the same with the valid time, and we can query the database by the notification date in the same way with the valid time. Figure 6 shows the example of the data, notification date of which is June 2nd and was corrected on June 3rd. Item (1) of Figure 6 shows the query result designating both the notification date and the transaction time June 2nd, and its data are before the correction. And, Item (2) shows the query result designating notification date June 2nd like item (1) and the transaction time June 3rd, which reflected all kinds of corrections: the change of $ID = 002 - 1$, the deletion of $ID = 003 - 1$ and the addition of $ID = 004 - 1$.

4.3 Implementation of Online Entry

The notifications of the residents were accepted with the report window of the city hall, and its data were entered from the business screen of the online-terminals. Regarding business, this entry had the following characteristic.

- The simultaneous entry of the identical resident from more than one terminal could not happen in the general business, because the entry was done by the notification of the resident.
- The entry time at the report window was comparatively long to confirm the notification contents.

Therefore, we used the optimistic lock to reduce lock period, which used the addition time of the transaction time and executed by the following procedure.

i. The corresponding data is read from the table without acquiring a lock.

ii. The data is changed with the business screen.

iii. Once again, the data is read from the table with the record locking by the same condition as the last time.

iv. If it is being locked or its addition time is updated, the data is judged that has been updated by the others, so that the table is not updated. In the other case, the table is updated by the changed data.

4.4 Implementation of Data Correction

We added the data correction feature, which is shown as follows, to the business screen in addition to the data entry feature of the notification.

- **Correction as Internal Process**
  The corrections of the data entry error, in the entry data confirmation works of system operations, were done as the internal process of the local government.
- **Correction as Business Procedure**
  The other corrections were done as usual business procedure of the local government.

Data of the database

Data on 6/2 [Na, Nd]:User-defined time(Notification date)

ID	Ta	Td	Va	Vd	Na	Nd	Transfer	Name	Add
001-1	6/2	now	6/1	now	6/2	now	Birth	Taro Jisei	Machi 1
002-1	6/2	now	5/31	now	6/2	now	Into City	Jiro Henko	Machi 2
003-1	6/2	now	5/21	now	6/2	now	Birth	Sabro Sakujo	Machi 3

Data on 6/3

ID	Ta	Td	Va	Vd	Na	Nd	Transfer	Name	Add.	(1)	(2)
001-1	6/2	now	6/1	now	6/2	now	Birth	Taro Jisei	Machi 1	●	●
002-1	6/2	6/3	5/31	now	6/2	now	Into City	Jiro Henko	Machi 2	●	
002-1	6/3	now	5/31	now	6/2	now	Into City	Jiro Henko	Machi 5		●
003-1	6/2	6/3	5/21	now	6/2	now	Birth	Sabro Sakujo	Machi 3	●	
004-1	6/3	now	5/21	now	6/2	now	Into City	Shiro Tsuika	Machi 4		●

Snapshot of the database

(1) Transaction time=6/2, Notification date=6/2

ID	Ta	Td	Va	Vd	Na	Nd	Transfer	Name	Add
001-1	6/2	now	6/1	now	6/2	now	Birth	Taro Jisei	Machi 1
002-1	6/2	6/3	5/31	now	6/2	now	Into City	Jiro Henko	Machi 2
003-1	6/2	6/3	5/21	now	6/2	now	Birth	Sabro Sakujo	Machi 3

(2) Transaction time=6/3, Notification date=6/2

ID	Ta	Td	Va	Vd	Na	Nd	Transfer	Name	Add
001-1	6/2	now	6/1	now	6/2	now	Birth	Taro Jisei	Machi 1
002-1	6/3	now	5/31	now	6/2	now	Into City	Jiro Henko	Machi 5
004-1	6/3	now	5/21	now	6/2	now	Into City	Shiro Tsuika	Machi 4

Figure 6: Snapshot by user-defined time: notification date.

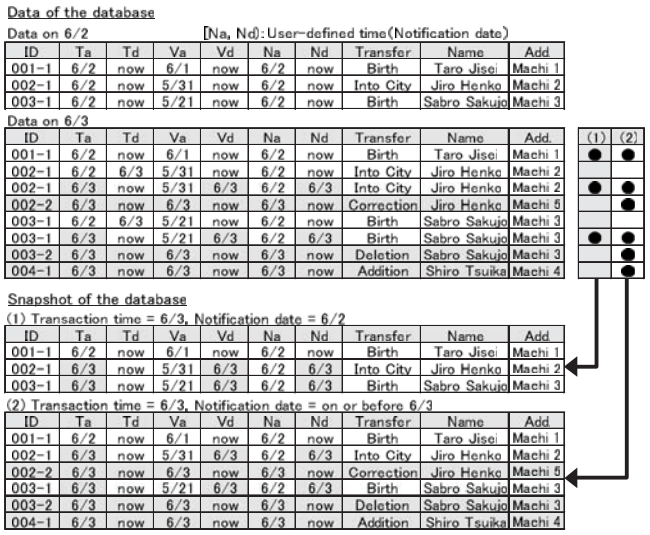


Figure 7: Correction as business procedure.

The correction by the internal process was executed with using the transaction time as shown in Figure 6. Item (2) of Figure 6 shows the query result of the notification that was notified on June 2nd and corrected on June 3rd, which was queried by designating the notification date June 2nd and the transaction time June 3rd. This correction was done as the internal process, so that it was not shown on the official documents such as the transfer record of the resident card.

On the other hand, the corrections as the business procedure have to be recorded on the official documents. For example, regarding the resident card, there were three kinds of corrections of business procedure: the official authority correction for the change, the official authority deletion for the deletion and the official authority mention for the addition. And, these corrections were recorded on the resident card.

Figure 7 shows the examples of the corrections done as the business procedure. Here, the examples are the same corrections that were done as the internal process in Figure 6. Item (1) of Figure 7 shows the snapshot queried by the same designating time as item (2) of Figure 6, which transaction time is June 3rd and notification date is June 2nd. For the corrections were done as the business procedure, the notification dates of them were June 3rd, and the correction result did not reflect in the query result. On the other hand, for the corrections were done with the notification date and their records were accumulated, both before and after correction records were queried by designating the both times as follows: the notification date was June 3rd, or before, and the transaction time was June 3rd. The relation of this snapshot is generally expressed as follows.

$$R_2(t_1, t_3) = \{r | r \in R \wedge r[T_a] \leq t_1 \wedge t_1 < r[T_d] \wedge r[N_a] \leq t_3\} \quad (3)$$

Here, t_1 and t_3 are the designated transaction time and notification date respectively, and $r[T_a]$, $r[T_d]$ and $r[N_a]$ are same as equation (2).

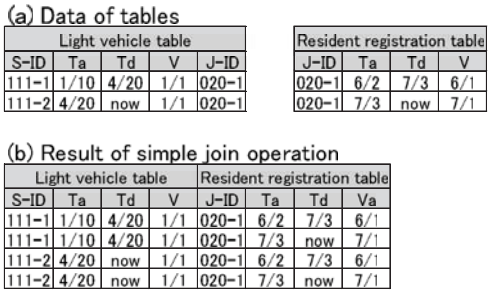


Figure 8: Problem of join operation on a bitemporal database

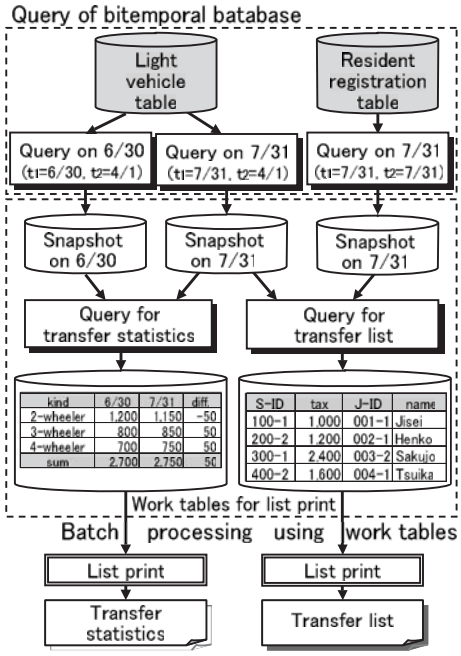


Figure 9: The composition of batch processing

4.5 Implementation of Batch Processing

Since the bitemporal database managed the records of the both time, the transaction time and the valid time, its query procedure became complicated. For example, as shown in Figure 8, the light vehicle table had the foreign key $J-ID$, which was the main key of the resident registration table. However, because each table had chronological records individually, the query result of join operation between them by $J-ID$ became the direct product about the time attributes. That is, the time attributes of these tables were not synchronous each other, so they could not be used as the key of join operation.

To solve this problem, we composed temporary files by the work tables in the application system, which are usually composed by the sequential access method (SAM) file. And, we processed data by the query function of the database, in the whole batch processing, to simplify each individual query procedure and maintain its performance. Specifically, as shown in Figure 9, the snapshot of each table was queried at

the beginning of the batch processing to output the result into the corresponding work table, and the following processing was performed by querying this work table.

Here, Figure 9 shows the example of the batch processing, which outputs were the transfer statistics of the light vehicle between June and July and the transfer list in July. Since the base date of the light vehicle tax was April 1st, each time of the snapshot was designated as follows: the transaction time $t_1 = 6/30$ and $7/31$, the last day of each month, and the valid time $t_2 = 4/1$, the base date. And, the snapshot of resident information for the transfer list was queried with designating both of the times on July 31st, which was its latest information. As a result, the query of this snapshot did not become complicated, because it was performed about each table individually. And, the join operations about the work tables did not become complicated, too, because it could be performed by the same way as a snapshot database.

4.6 Operation of Batch Processing

The data entered to the system was queried by various kinds of batch processing as shown in Figure 4. Regarding the designating time, the queries were divided into the following two kinds.

4.6.1 Query of Data at End of Business Hours

Various statistics such as the population statistics were created daily or monthly at the end of the business hours of the day, and their results were reported to the next day. In the conventional system operation, they had been made by the night batch processing after the business hours of the report window. In this application system, we could execute the batch processing during the business hours of the next day and so on, because we queried the data of the end of business hours by designating the transaction time. As a result, we could reduce the night batch processing.

In the batch processing, query results were checked by the first step. And, when error data were detected, the batch was redone after the data correction. Regarding the batch processing, all kinds of the corrections reflected in the query result, as shown in Figure 6: the change, deletion and addition. Here, as for the data that took time until its notification to the local government, they were queried by using its notification date as shown in section 4.2.4.

4.6.2 Query by Designating Valid Time

In the taxation processing, the base date of the taxation was designated and the taxation was done after this date. However, corrections of the taxation about the delay of the notification often occurred, because the transfer notifications of taxable articles to the local government usually took time.

In the case of the light vehicle tax, the taxation processing had been usually executed with the base date of April 1st, and since then, its correction processing was regularly performed.

Data of the database

ID	Ta	Td	Va	Vd	Tax	(1)	(2)	(3)	Correct
001-1	1/10	now	1/1	now	1,000	●	●	●	
002-1	1/10	4/20	1/1	now	1,200	●			
002-1	4/20	now	1/1	3/31	0				
002-2	4/20	now	4/1	now	1,600		●	●	Change
003-1	1/10	5/20	1/1	now	5,200	●	●		
003-1	5/20	now	1/1	3/31	0				
003-2	5/20	now	4/1	now	7,200			●	Change
004-1	1/10	4/20	1/1	now	2,500	●			
004-1	4/20	now	1/1	3/31	0				Deletion
005-1	1/10	5/20	1/1	now	4,000	●	●		
005-1	5/20	now	1/1	3/31	0				Deletion
006-1	4/20	now	1/1	now	7,200		●	●	Addition
007-1	5/20	now	1/1	now	3,000			●	Addition

Snapshot of the database

(1) Transaction time = 4/15, Valid time = 4/1

ID	Ta	Td	Va	Vd	Tax
001-1	1/10	now	1/1	now	1,000
002-1	1/10	4/20	1/1	now	1,200
003-1	1/10	5/20	1/1	now	5,200
004-1	1/10	4/20	1/1	now	2,500
005-1	1/10	5/20	1/1	now	4,000
				Sum	13,900

(2) Transaction time = 5/15, Valid time = 4/1

ID	Ta	Td	Va	Vd	Tax
001-1	1/10	now	1/1	now	1,000
002-2	4/20	now	4/1	now	1,600
003-1	1/10	5/20	1/1	now	5,200
005-1	1/10	5/20	1/1	now	4,000
006-1	4/20	now	1/1	now	7,200
				Sum	19,000

(3) Transaction time = 6/15, Valid time = 4/1

ID	Ta	Td	Va	Vd	Tax
001-1	1/10	now	1/1	now	1,000
002-2	4/20	now	4/1	now	1,600
003-2	5/20	now	4/1	now	7,200
006-1	4/20	now	1/1	now	7,200
007-1	5/20	now	1/1	now	3,000
				Sum	20,000

Figure 10: Query Results by designating valid time.

Figure 10 shows the example, in which the taxation processing had been executed on April 15th and its correction processing was performed every month since then. We queried by designating the valid time the base date of April 1st and the transaction time the taxation processing date or the correction processing date. By this condition, we could query the result, in which the corrections done until each processing date were reflected.

5 EVALUATION AND CONSIDERATION

5.1 Evaluation about Query of Correction Data

5.1.1 Query of Data at End of Business Hours

Even if error data were detected in the batch processing, it became possible to redo the processing after correcting these error data, during the online entry of the usual business data. In the online entry, the correction of entry data could be performed as the internal process by using the transaction time, in addition to the usual correction done as the business procedure. The integrity of the query result was maintained about both of these data corrections.

Since the queries in batch processing became to be able to execute during the online entry, the night batch processing

and its attendant work such as the waiting for the online entry beyond business hours was reduced. Therefore, the system operation load as the overtime work could be reduced. Moreover, when several batch processing overlaps on the same day, it was enabled to make the schedule of batch processing flexibly, in which, for example, the low processing of priority was executed later such as the next day.

Here, the fact in the real-world wasn't always reflected in the system instantly like the resident's transfer as shown in section 4.2.4. So, as for the statistics, which were created by the data of the end of business hours on the designated date to be reported to the next day, we queried by using not their valid time but their notification date that is the user-defined time. In this way, we could query the state of the data of the end of business hours on the designated date even if here are notification backlogs.

5.1.2 Query of Correction for a Long Period

Like the taxation processing as shown in Figure 10, some business needed to manage its correction for a long period and grasp the status of the correction in the transfer statistics. Regarding the business like this, we could also query the result that reflected all kinds of corrections, which included the change, deletion and addition, done until the designating date. Even in this case, we could easily create the transfer statistics by querying the total in the last time and this time, and the transfer total between the both times. Moreover, it could be executed during the online entry, because this query procedure used the snapshot, too.

5.1.3 Management of Correction Data

The online entry data were confirmed and corrected before they were used by the business procedure. Regarding the business that managed the records such as the resident registration, the correction records in this step did not be needed by the business procedure. So, these corrections were performed as the internal process of the system operations. On the other hand, after the data were used by the business procedure, their corrections also had to be done as the business procedure. Both of these corrections, as the internal process and as business procedure, could be managed individually by the bitemporal database.

5.2 Evaluation of Implementation of Database

In the record management of the bitemporal database, the problems about the increase of the amount of data and the complication of the query procedure occurred.

About the amount of data, two records needed to add the database for each change in the real-world as shown in item (1) of Figure 5: one of them was the record of the before, of which ending time of the valid time was updated, and another was the record of the after. We could reduce these two records to one record by the method that used the expression by the event time as shown in item (2) of Figure 5. Therefore, we adopted the expression by the event time to the tables except the tables that needed to manage the ending time of the valid time in particular.

As a result, the increase of records to the amount records needed in the original business became almost only the correction records as the internal process. Regarding this application system, this increase was 20% in a year even if maximum and the amount of data was less than twice using for 5 years, the life cycle of the system. Incidentally, in recent years, the price of the unit capacity of the storage media was falling and the increase of the amount of data didn't become a problem in the aspect of the system building cost.

Next, to simplify each query procedure, we used the work tables as temporary files of the batch processing, and processed data step-by-step. As a result, we achieved the necessary query performance for the business, in the function range of the commercial relational database. Incidentally, since inserting a great deal of data into the work table with indexes degrades the performance, we generated indexes after inserting or importing of data in this case.

5.3 Consideration

5.3.1 Query of Data at End of Business Hours

We confirmed that the corrections of data were reflected in the query result and its integrity was maintained by the bitemporal database, even while the online entry was performed. Moreover, we confirmed that this is effective for the system operation, because the night batch processing to query the data of the end of business hours on the designated date could be reduced by executing it in the business hours of the next day and so on.

For example, the batch processing and its attendant work of the overtime of the local government, having about 40,000 populations, could be reduced about 1.5 hours a day from the conventional system. In addition, for the system operation in the overtime was ridded of, the batch processing could be transferred from the system department to the control department of the business. As a result, the work of contact and adjustment, such as the request of the batch processing or the receipt of the documents of it, could be reduced. In recent years, the nonstop services are expanding with the internet application such as the electronic government, the electronic commerce. Therefore, we consider that the operation to query by batch processing without stopping the online entry is effective in such a field.

Moreover, we found that the notification date, which is user-defined time, should be managed apart from the valid time in some kinds of business, because, in the actual business operation, all the fact of the real-world may not reflect in the system instantly. For example, in the resident registration subsystem, both times were used according to the business contents: the age calculation of the resident used the birthday that is the valid time; the statistics of the residents used the notification date of the transfer that is the user-defined time.

5.3.2 Query of Correction for a Long Period

The data, which were correcting for a long period, had to be managed by its records of correction from the base time of the business until the query time. The bitemporal database manages both the times: the valid time that expresses the base time and the transaction time expresses the query time. We confirmed that this is effective such as to grasp the records of data for a long period and to create the transfer statistics.

5.3.3 Management of Correction Data

The bitemporal databases could manage correction records about the both of the correction: as the internal process and as the business procedure. The correction as the internal process didn't accumulate records for business procedure, but these correction records were accumulated inside the database by using the transaction time. Therefore, we considered that these records are effective for the management of the change process of data in the system, especially in the mission-critical systems that need to adapt inspection of a high level.

6 CONCLUSION

For the efficient operations of mission-critical systems, it is necessary both batch processing and online entry can be executed simultaneously even under the actual system operation such as data-entry mistakes and data-entry backlogs. We applied a bitemporal database into a mission-critical system, and throughout its actual system operations, we confirmed that the data corrections were reflected in the query results, and that the integrity of the query results was maintained even while the database was being updated by online entry. Furthermore, we confirmed that it is effective about not only the data corrections for a short period confirmation work but also the correction management of data for a long period of real-world use, and that data correction can be managed in both internal processes and business procedures individually. In recent years, the nonstop services are expanding with the development of internet applications. Therefore, we consider that the system operation being able to query by batch processing without stopping the online entry become effective in such a field.

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Tsukasa Kudou Tsukasa Kudou received the master's degree in Engineering from Hokkaido University in 1980 and received the Dr. degree in industrial science and engineering from Shizuoka University, Japan, in 2008. In 1980, he joined Mitsubishi Electric Corp. He was the researcher of parallel computer architecture, the engineer of application packaged software and business information system. Since 2005 he is the engineer of Mitsubishi Electric Information Systems Corp. Now, his research interests include database application and software engineering. He is a member of IEIEC and Information Processing Society of Japan.

Masahiko Ishino received the master's degree in science and technology from Keio University in 1979 and received the Ph.D. degree in industrial science and engineering from graduate school of Science and technology of Shizuoka University, Japan, in 2007. In 1979, he joined Mitsubishi Electric Corp. Since 2005, he is the system engineer of Mitsubishi Electric Technology Corp. Now, His research interests include management information system, industrial engineering, application system of data-mining, and information security system. He is a member of Information Processing Society of Japan, Japan Industrial Management Association and Japan Society for Management Information.

Kenji Saotome received a BE from the Osaka University, Japan in 1979, and a Dr.Eng in Information Engineering from the Shizuoka University, Japan in 2008. From 1979 to 2007, he was with Mitsubishi Electric, Japan. Since 2004, he has been a professor of Hosei business school of innovation management. His current research areas include LDAP directory applications and single sign-on system. He is a member of the Information Processing Society of Japan.

Nobuhiro Kataoka received the master's degree in Engineering from Osaka University in 1968 and received the Ph.D. degree in Information Science from graduate school of Information Science Tohoku University, Japan, in 2000. In 1968, he joined Mitsubishi Electric Corp. He was the engineer of basic software, middle software and application packaged software. From 1992, he was transferred to corporate information management department and managed to expand ERP (SAP) all over the corporation. Since 2000 he is a Professor of Tokai University. Now, His research interests include management information system and business process modeling. He is a member of IEEE, IEIEC, and Information Processing Society of Japan.

Tadanori Mizuno received the B.E. degree in industrial engineering from the Nagoya Institute of Technology in 1968 and received the Ph.D. degree in computer science from Kyushu University, Japan, in 1987. In 1968, he joined Mitsubishi Electric Corp. Since 1993, he is a Professor of Shizuoka University, Japan. Now, he is a Professor of graduate school of Science and technology of Shizuoka University. His research interests include mobile computing, distributed computing, computer networks, broadcast communication and computing, and protocol engineering. He is a member of Information Processing Society of Japan, the institute of electronics, information and Communication Engineers, the IEEE Computer Society, ACM and Informatics Society.

Method for Sharing Real Objects with Different Syntax through Virtual Stickers between Distant Mixed Reality Spaces

Shun YAMAMOTO†, Hidekazu TAMAKI†, Yuichi BANNAI‡and Kenichi OKADA*†

†Keio University, Japan
‡CANON Inc., Japan
* Japan Science and Technology Agency, Japan
{ shun, tamaki, okada}@mos.ics.keio.jp and bannai.yuichi@canon.co.jp

Abstract - In remote collaboration based on real objects, the differences in space structure between remote real spaces should be considered. In conventional methods, it is difficult for users to collaborate based on real objects which differ in syntax. In order to address this issue, we focus on a sticker or a sheet which can be attached to the surface of a physical object. Also, we propose a semantic information sharing method which involves Mixed Reality (MR) technology, where each remote user interacts with a real object by using virtual sheets which can be attached to the surface of each real object, and can eliminate the differences in syntax between these real objects. We implemented a prototype system, which has a pointing function, and conducted experiments. As a result, it was proven that it is possible to share information regarding the interactions without losing the meaningful relations between real objects which differ in syntax.

Keywords: Mixed Reality, Remote Collaboration, Computer Supported Coperative Work.

1 Introduction

Remote collaboration systems where remote users collaborate by sharing electronic data through a network were popular in the past[1]. In such systems, users could not treat information regarding real-world environments and objects, and therefore it was impossible to experience the sense of touch or to implement intuitive manipulation. Later, MR (Mixed Reality) made it possible to take information from the real world and transfer it to a virtual world. MR was applied to collaboration work, where users work at remote sites by sharing virtual information. It is hoped that remote work support systems or cooperative work systems where users feel as if remote participants are present at the same workspace will be realized in the near future.

However, there are two types of remote collaboration systems depending on how users manipulate real objects. One is an asymmetric remote collaboration system, and the other is a symmetric one. In asymmetric systems, only one worker manipulates his or her own real object, while the other user (a director or a supporter) issues directions while watching the progress of the worker. However, in asymmetric systems it is impossible for both users who have their own real objects in remote places to manipulate their own real objects and to collaborate through them. Such functionality is intrinsic to symmetric remote collaboration systems. Different manipulations implemented by each remote user result in discrepancies between the states of each real object, and therefore it is too difficult to reproduce the same state at the remote place. If the users attempt to actualize the state of the object, such as in a symmetric collaboration system, they must create the exact same structure of objects at both remote workspaces by using actuators or mechanical systems. In this research, a different approach makes it possible for remote users to have their own real objects and to collaborate naturally without discrepancies between the states of the real objects. We regard workspaces as based not on the world coordinate system but on a virtual sticker which is placed on the surface of the real object.

Remote users have their own real objects which represent the target of the work in each workspace. They place the virtual sticker on the surface of their real object and then manipulate the object. The processes of the manipulations and their effects are displayed with respect to the sticker and shared between the remote workspaces. The function of the sticker is flexibility to the form of surface. Even though they have real objects which differ in syntax (in other words, size, shape, and other properties), the users can place virtual stickers on various objects and collaborate through them by sharing information.

In this way, we aim for the creation of a remote collaboration environment where remote users can have their own real objects and can manipulate them freely without the need for mechanical synchronization. Users can share their manipulation procedures with each other, and can communicate instructions to remote sites even if the objects at the remote sites differ in syntax.

In this paper, we propose a method for sharing real objects with different syntax through the use of virtual stickers between distant mixed reality spaces. We also implement a prototype system referred to as ”MR Shared Surface” as a realization of our concept, and evaluate it.

2 Background and Problem

2.1 Remote Collaboration with Real Objects

There are some examples of remote collaboration or communication using real objects. Tangible interfaces provide interaction with the digital world through real objects. For example, ”PsyBench” [2], which was developed by Ishii et

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al., realized remote collaboration based on interaction with real object by applying tangible interfaces to remote environments. In the "PsyBench" system, the XY stage is built by placing an electric magnet under a table at each remote site, and magnets are set under the bottom of the objects on the table. This makes the physical state of the objects on the table to coincide between remote sites.

Sekiguchi et al. developed "RobotPHONE" [3], which realizes remote communication by sharing the motion of a robot shaped as a teddy bear through the Internet and making the respective motions at the two sites coincide. These systems, which use tangible interfaces, offer a sense of touch and make manipulation intuitive, however, there are also certain problems. One problem relates to the fact that there are physical restrictions with respect to the motion of the objects, as the effects of the manipulation to real objects are realized through magnetic or mechanic actuators. Another problem involves unnatural behaviors such as the sudden movement of real objects caused by the lack of information regarding the manipulations performed by the remote user.

2.2 Remote Collaboration in Mixed Reality

Mixed Reality (MR) represents technology which transfers electronic data, such as CG or a letter into real space, and this technology is applied currently in various fields, such as work support in the field of industry [4], entertainment [5] or medical care technology [6]. MR lets users communicate or collaborate by manipulating information from the real world. Simon et al. developed "3-D Live" [7], where observers can observe a real-time 3D image of the whole body of the remote user from all angles, as in real space.

Furthermore, Dieter et al. developed a system called "Studierstube" [8]. In "Studierstube", users share a 3D window displayed in real space and can collaborate through interaction with the 3D window. Not only do face-to-face users work in the same real space, but in remote places they also collaborate by sharing the 3D window.

There is also an example where users directly manipulate real objects in remote collaboration. Suzuki et al. proposed a remote support system [9] which assumes a relation of a worker and a director between the users, where the director directs the worker by pointing while observing the manipulation from an immersive point of view from the perspective of the worker. From a remote place, the director can observe a stereo image of the object from the perspective of the worker through an HMD (Head-Mounted Display) and can manipulate a virtual pointer displayed in the worker's real space by using his or her finger. The worker sees where the remote director is pointing in his or her work space. In this system, one user, namely the worker, can manipulate real objects directly, while the other user, namely the director, can manipulate only virtual objects. There is also "Lazy Susan" [10] developed by Uesugi et al. as an example of collaboration between remote users which have their own real objects in MR. In "Lazy Susan", the effects of interaction with real objects are passed on to the remote site by shooting a video of the manipulation and projecting it onto a table in the remote workspace. There is a disc which can rotate on the table, and its motion coincides with the motion produced at the remote site. This system makes the user aware of the other users, the collaboration is lively, and the sense of sharing the workspace is enhanced. However, there is a problem which causes trouble with manipulation if the view is changed when the remote user performs a rotation of the object without the same motion being performed by the local user. Also, it is a tabletop system, and therefore the workspace is essentially fixed. Iso et al. proposed a system adapting to the differences in room structure. In "ComAdapter", they attempted to describe the user's posture, the physical relations, and so on, in different rooms. Some discontinuous scenes arise when dynamic situations in the rooms or user motion is described. This system targets natural living-room communication when the structure of the respective rooms is different. On the other hand, we present a remote collaboration system targeting the manipulation of a single target object.

In a previous work, we proposed the sharing of virtual information on the basis of real objects in remote workspaces [11]. Remote users have access to the same replicas of the target real object in each workspace, and then each replica has a coordinate system based on the object itself (referred to as object coordinate system in this paper). Manipulations to the replicas and their effects are displayed by using virtual objects with MR and are shared based on the replicas between remote places. However, remote users were required to have the same replicas in the previous research.

3 Proposal

3.1 Sharing Semantics between Real Objects with Different Syntax

In remote collaboration systems based on real objects, it is necessary that the semantics of the work is shared between remote workspaces, even if there are differences in the syntax of the objects. We explain how the semantics can be shared in various ranges of differences and in which relation the collaboration is realized by sorting out the range of differences in syntax and the relations between pairs of any two real objects.

Figure 1 shows the classification of a pair of real objects. The first classification is used when two real objects which are used in collaboration share a common function. The common function indicates the capability to share the semantics of the work. On the other hand, if they do not have share a common function, it is impossible to share the semantics. For example, sharing the semantics is possible between two objects whose function is to input sentences. However, if one object is used for inputting sentences and the other is used for inputting musical performances, the objects do not share a common function. Therefore, the semantics is impossible to share in such a case.

The second classification is used in the case where the first classification holds. It reflects the case when two objects share a common way of operation. If we consider objects

for inputting sentences, an example of objects which do not share common way of operation can be given with a keyboard and a pen. A keyboard inputs sentences electronically and a pen does that mechanically. In such a case, only the information is shared, namely the sentence. The sentence is not tangible information, and therefore users can not take advantage of using real objects. Two objects should therefore share a common way of operation.

The third classification is implemented in case the second classification holds. It is used if the objects share the same alignment in the contexture. The difference in alignment of the contexture between remote sites causes a discrepancy between the structures of real objects or world environments. Fortunately, alignments in the contexture are maintained in most objects which share a common way of the operation. Finally, the fourth classification is implemented if the third classification holds. It is used if the sizes and shapes of the objects are exactly the same. There are many objects which share the same function, way of operation and alignment in the contexture, but have different sizes or shapes. It is very useful for remote users to be able to collaborate by sharing objects which differ in seize or shape. Since they share common functions and ways of operation, it is possible to share such objects.

3.2 Method for Sharing Real Objects with Different Syntax

In the past, it was too difficult for remote users to collaborate by manipulating their own real objects. Even in our last research, each user was required to have an object of the same shape and size. Collaboration with real objects has severe restrictions, and therefore we propose a method for sharing real objects with different syntax through the use of virtual stickers between distant mixed reality spaces. We focus on the properties of stickers which can be attached to the surface of a physical objects, and can bring the object into the MR. In our approach, the virtual sheet which is placed on the surface of real objects is defined, and the information regarding the processes and the effects of the work is shared flexibly by utilizing those stickers. Using virtual stickers makes it possible for participants to collaborate if they are located at distant workspaces by keeping the essential semantics, even if they have real objects which are different in syntax (syntax refers to the shape, the size, or the structure of the objects in this paper). Users can collaborate by focusing on the interaction between remote participants and objects through the virtual sticker.

3.3 Functions of the Virtual Sticker

There virtual sticker has two main functions.

(1) Sharing information regarding the interaction between real objects in remote workspaces

The information regarding the interaction between the user and the real object is transformed into a model of the virtual object (referred to as sharing virtual model). Sharing the information of the interaction is actualized by sending and receiving the data regarding the sharing of the virtual model bi-directionally through each virtual sticker.

(2) Resolving the differences in syntax between the objects by implementing the virtual sticker flexibly.

Generally, users can place stickers on surfaces of objects of various shapes with some kind of picture printed on the sticker. The virtual stickers also have this function. By drawing the information regarding the interaction with the sticker instead of the picture (the sharing virtual models are transformed as stickers), the information of the interaction is displayed on each real object while matching their syntaxes.

3.4 Differences in Syntax

Virtual stickers resolve differences in syntax. We explain these differences in the following section.

(1) The combination of real objects of different size

Although there are many types of differences, the most common case involves difference in size. Even the same kinds of objects (for example, controllers, calculators, phones, and so on) often have various sizes. Sizes can be big or small, and various editions might exist, such as professional, abridged, portable, or ones for children. By using virtual stickers, collaboration can be realized by using objects characterized by such differences.

(2) Combinations of 2D and 3D real objects

By using virtual stickers. the information of the interaction can be shared between 2D and 3D objects. When two participants perform work one user might utilize a 3D real object while the other user utilizes a 2D object, such as the development plan, the design scheme, or the manual of the 3D object. The semantics of the information of the interaction with objects is shared in order to be able to realize remote work support or remote collaboration even between 2D and 3D objects.

3.5 Mechanism for Sharing Interaction Information

This section explains the way of sharing information regarding the interaction between remote users in our research. We begin by defining two coordinate systems.

(1) The coordinate system of the shared virtual sticker

This is the coordinate system of the original virtual sticker before the sticker is placed on the surface of the object. In this research, the sharing of virtual models is transformed into this coordinate system when the interaction information is transferred between remote workspaces.

(2) The coordinate system of the local virtual sticker

This is the coordinate system of the virtual sticker after the sticker is placed on the surface of the object. In our research, the interaction information, which is shared between remote workspaces, is displayed based on this coordinate system in each workspace.

Sharing interaction information is actualized by changing its translation and orientation in each coordinate system, as

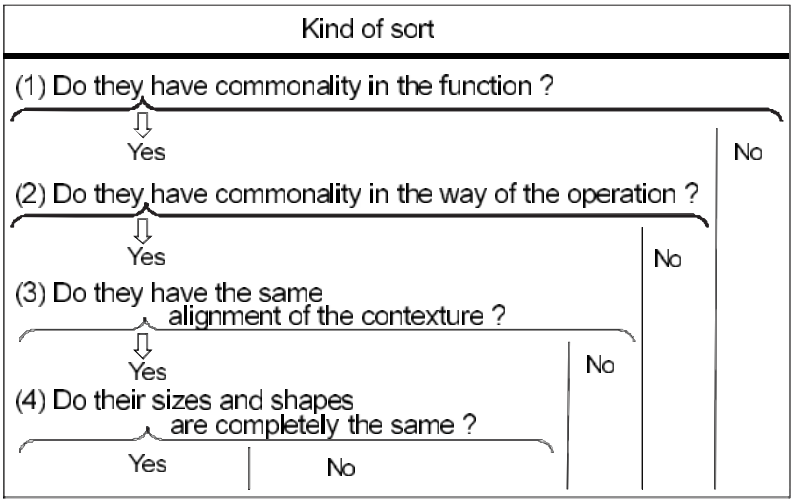

Figure 1: Classification of a pair of real objects

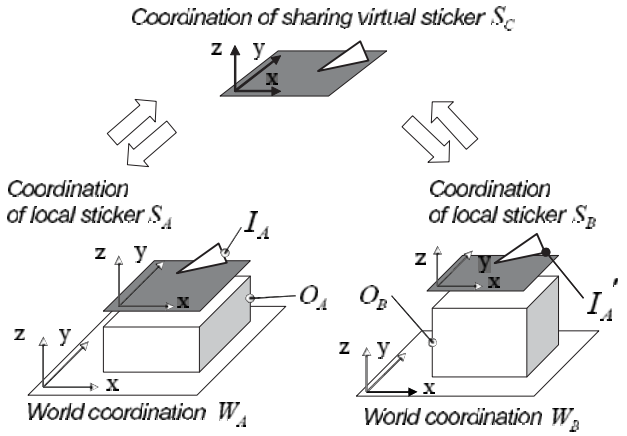

Figure 2: Mechanism for sharing information

shown in Figure 2.

First, the information I_A which indicates that user U_A interacts with the real object is based on the world coordinate system W_A. It is changed into the translation and orientation based on the coordinate system of the local virtual sticker S_A. Then, it is changed into the coordinate system of the sharing virtual sticker S_C, and is also transformed into the coordinate system of the local virtual sticker S_B which is set on the real object O_B manipulated by user U_B. Finally, it is changed into the translation and orientation based on W_B and displayed as the sharing virtual model I'_A. By performing these operations in the same way with respect to the interaction information I_B of user U_B, the information of the interaction can be shared.

Its processes are described by using the following expressions. We set I_{SA} as the translation and orientation of the virtual objects based on S_A. I_A and I_{SA} are described that,

$$I_A = \begin{bmatrix} x_a \\ y_a \\ z_a \\ 1 \end{bmatrix} \tag{1}$$

$$I_{SA} = \begin{bmatrix} x_{sa} \\ y_{sa} \\ z_{sa} \\ 1 \end{bmatrix} \tag{2}$$

$$I_A = M_A I_{SA} \tag{3}$$

By using the modeling matrix M_A, which is a homogeneous matrix, the translation and orientation are transformed from the world coordinate system into the coordinate system of the local virtual sticker.

On the other hand, when the position is transformed the opposite way, it takes an inverse matrix S_A^{-1}.

4 Implementation of MR Shared Surface

4.1 The Architecture of the Implementation

In this research, we implemented a ”MR Shared Surface”, which is one of the prototype systems for virtual stickers. Two participants located at remote workspaces can collaborate through the ”MR Shared Surface”. Figure 3 shows the architecture of the shared surface. ”MR Shared Surface” is constructed with the local MR system that controls the devices and the sharing of the virtual sticker, which makes it possible to share interaction information between remote places.

4.2 The Local MR System

We used the video see-through HMD by CANON. A video camera and a liquid crystal display are mounted in the HMD.

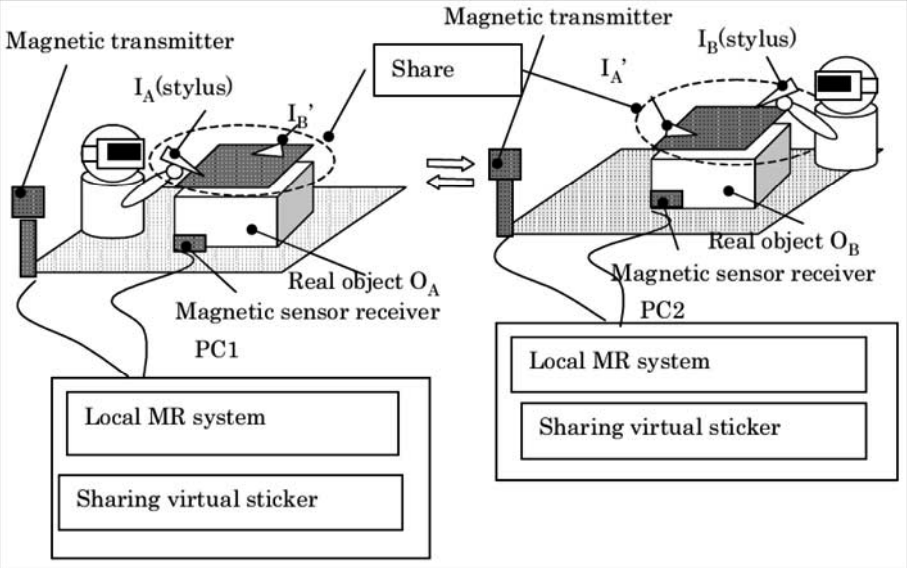

Figure 3: Architecture of the MR Shared Surface

This HMD and the stylus have a Fastrak receiver, which is a magnetic sensor allowing six degrees-of freedom, where is the position and the orientation are ignored. Other sensor receivers are mounted on the replicas, which are the target of the work. Alignment of real space and virtual space is performed by using a hybrid method involving a magnetic sensor and marker. For the purpose of displaying and manipulating the virtual objects, we used a MR Platform Plus [12] system by CANON. Two PCs, representing remote sites, were connected through a network.

4.3 The Sharing Virtual Sticker

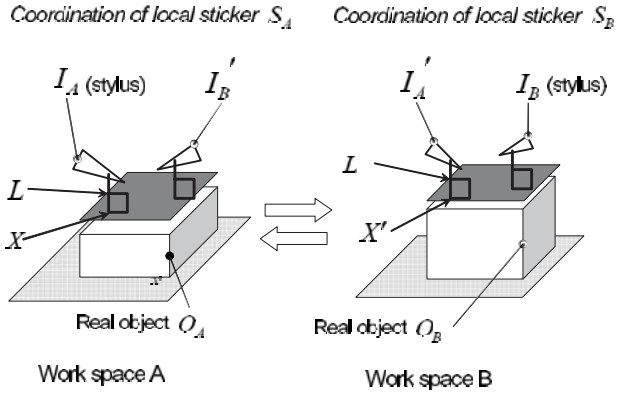

Figure 4: The display of the sharing virtual model

”MR Shared Surface” detects the position of the stylus utilized by the user, and overlaps it with a virtual pointer. This represents the sharing virtual model in ”MR Shared surface”. As shown in Fig. 4, the sharing virtual model is displayed, and a perpendicular line is drawn from the stylus handled by the user. L is defined as the distance between the perpendicular lines, and $X$is the foot of the perpendicular line. In the other workspace, point X' is also defined in relation to X on the virtual sticker. The virtual pointer is displayed at the position of the normal direction at length L from X'. ”MR Shared Surface” performs this process bi-directionally.

4.4 Conversion Through the Virtual Sticker

This section explains the communication of expansion and contraction between the local virtual sticker and the sharing virtual sticker. 2D projective transformation from a rectangle to any convex quadrilateral is that,

$$\lambda \begin{bmatrix} x_2 \\ y_2 \\ 1 \end{bmatrix} = \begin{bmatrix} h_0 & h_1 & h_2 \\ h_3 & h_4 & h_5 \\ h_6 & h_7 & h_8 \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \\ 1 \end{bmatrix} \tag{4}$$

$$\begin{cases} x_2 = \frac{h_0 x_1 + h_1 y_1 + H_2}{h_6 x_1 + H_7 y_1 + 1} \\ y_2 = \frac{h_3 x_1 + h_4 y_1 + H_5}{h_6 x_1 + H_7 y_1 + 1} \end{cases} \tag{5}$$

In order to transform any convex quadrilateral A into another convex quadrilateral B, A is converted into a normal rectangle once and then converted inversely into B.

4.5 Synchronization of the Virtual Information

In order to share the virtual scene between remote places, any changes in the state of the virtual object must be passed on to the other workspace, and the changes must coincide when one of the virtual objects changes in the local workspace. First, all virtual objects are registered with an ID number. Second, when one of the virtual objects changes, the system detects it and passes on the ID number and the kind and magnitude of the change to the other workspace.

5 Evaluation

5.1 Purpose of the Evaluation

The purpose of the evaluation is to confirm whether or not ”MR Shared Surface” realizes our proposed concept. In other words, we evaluated whether the semantics of the works were shared through the ”MR Shared Surface” in the case where there were differences in syntax between real objects located in remote workspaces.

In this paper, we evaluated whether ”MR Shared Surface” realizes our concept with respect to a pointing manipulation implemented with the stylus, which is the most basic type of interaction.

5.2 Evaluation of the Pointing Manipulation

In this evaluation, two participants located at remote workspaces performed one task at a time. One participant played the role of the experimenter, and the other was the subject. The virtual sticker which was placed on the real object was divided into a number of square tiles (with 6 cm sides), and serial numbers were attributed to each tile.

The experimenter pointed tiles on the virtual sticker spread on the surface of the real object one by one. The experimenter performed three pointing manipulations (as shown in Fig. 5 shows).

pointing motion ”a”

The experimenter pointed a random tile by drawing the shape of a mountain with the pointer.

pointing motion ”b”

The experimenter pointed a random tile by moving his or her pointer at a right angle.

pointing motion ”c”

The experimenter pointed any tile by sliding the surface of the object.

These pointing motions were coincided when the subjects were observed from directly above. The point was to confirm whether it was possible to detect a 3D movement which generally could not be displayed with a 2D pointer.

The experimenter followed random combinations of motions ”a” to ”c” and a tile number . The subject, who was unaware of the pattern, observed the pointing motion performed by the experimenter located at the remote site on the virtual sticker and answered what kind of pointing motion was performed and the number of the tile at each iteration.

There were two sets of trials, where each task scored five points. The combinations of the virtual stickers between the experimenter and the subject were switched at every task, except for congruent squares. Table 1 shows the combinations of the virtual stickers, and figure 6 shows the object used in trials No. 8 and No. 9 in Table 1. The subjects were 15 males and females aged 21 to 25.

In this evaluation, all answers of the subjects were recorded, and the accuracy rate was calculated.

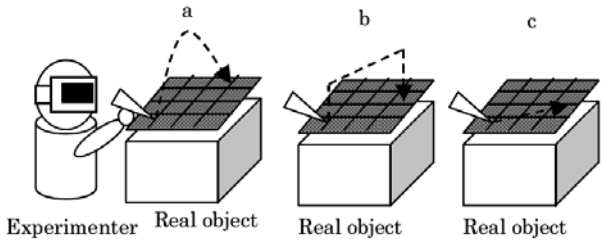

Figure 5: Type of pointing motion

Table 1: The combinations of virtual stickers

No.	Experimenter	Subject
1	Square	Square
2	Small square	Square(normal)
3	Square(normal)	Small Square
4	Box	Trapezium
5	Trapezium	Box
6	Box	Cylindrical surface
7	Cylindrical surface	Box
8	Extended elevation	3D figure
9	3D figure	Extended elevation

5.3 Conclusion and Discussion of the Evaluation

Figure 7 shows the conclusion of the accuracy rates regarding the combinations of flat virtual stickers. The accuracy rates of the pointing motion and the tile number were higher than 98%.

The only mistake with respect to the tile number (the combination corresponding to the motion from the large square to the small square) was that, the subject answered the number of the adjacent tile. The reason for this mistake is attributed to the fact that although the area of the small square tile was small (quarter of that of the other tiles), the size of the pointer was the same as the others, or that the display resolution was not sufficiently high. Also, the accuracy rate regarding the pointing motion was lower than in the other cases since the pointer movement was limited to a direction parallel to the virtual sticker. This generated unnatural movement of the pointer. In any case, all accuracy rates were higher than 96%.

Furthermore, Fig. 8 shows the conclusion regarding the accuracy rates, where one participant had a 3D model of the real object.

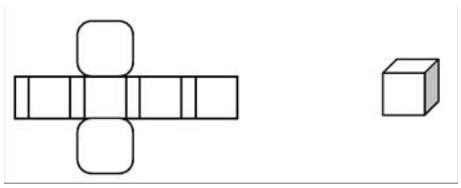

Figure 6: Extended elevation and 3D figure

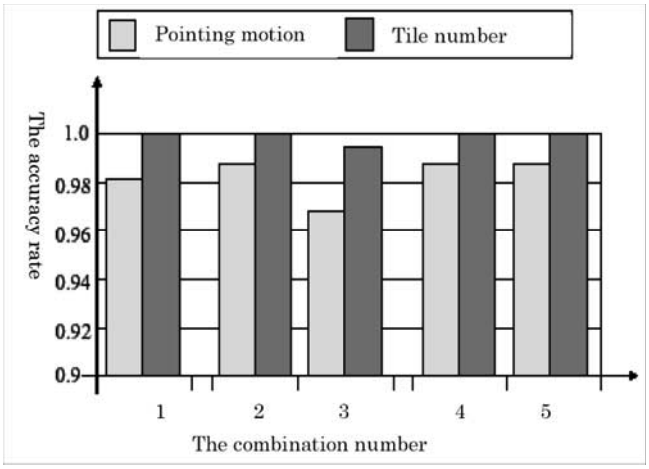

Figure 7: Result 1

As the figure 8 shows, all accuracy rates regarding tile numbers were 100.

The accuracy rates regarding the pointing motion in the combination of motion ”from flat square to cylindrical surface” and the combination ”from extend elevation to 3D figure” were lower than the others. The similarity between these two combinations is that the subjects moved the 3D object at varying angles in order to observe the pointing motion. At the same time, the experimenter performed the pointing easily on 2D flat areas. This additional load to the subjects caused the decrease in the accuracy rates.

However, even in this case, the rate in each case was higher than 92%.

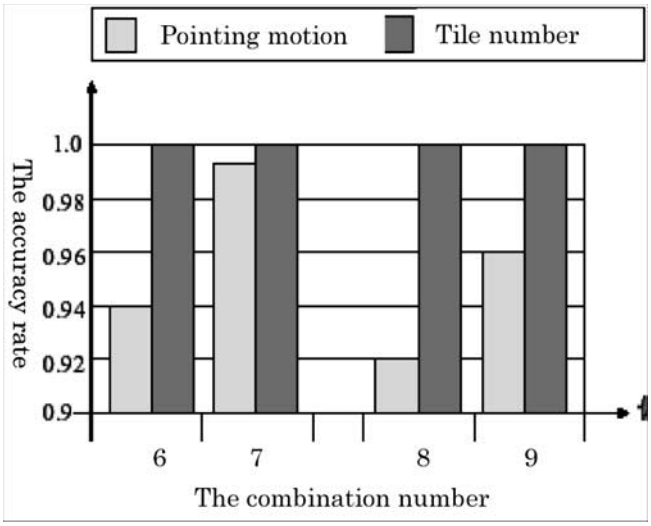

Figure 8: Result 2

The conclusion is that the information regarding the interaction can be shared through ”MR Shared Surface” when at least one user utilizes the flat virtual sticker.

6 Conclusion and Future Work

In this paper, we focused on a sticker or a sheet which could be attached to the surface of a physical object. As a method which is based on MR technology, we proposed a method for sharing real objects with different syntax through the use of virtual stickers between distant mixed reality spaces. We defined a method for sharing of semantics, in which each remote user interacts with a real object, by using virtual sheets which can be attached to the surface of any real object, where the sheet can absorb the differences in syntax between the real objects. Then, we implemented a prototype system referred to as ”MR Shared Surface”, which featured a pointing function, and conducted experiments. As a result, it was proven that it is possible to share the information regarding the interactions without losing the meaningful relations between the real objects which differ in syntax.

In the future, we intend to implement the function of various interactions and to share those interactions between remote workspaces. Also, we will attempt to improve the adaptation to various 3D objects.

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Shun Yamamoto received a B.S. degree from the Department of Information and Computer Science of Keio University, Japan in 2007. He is currently working toward an M.S. degree in Open and Environment Systems at Keio University. His research interests include Mixed Reality and remote collaboration.

Hiekazu Tamaki received a B.S. degree from the Department of Information and Computer Science at Keio University, Japan in 2006, and an M.S. degree in Open and Environment Systems at Keio University in 2008, and joined NTT Corporation in 2008. He is currently working at NTT Corporation.

Yuichi Bannai received B.E. and M.E. degrees from Waseda Univ. in 1978 and 1980, respectively, and joined Canon Inc. in 1980. He is currently a scientist of Canon Inc., Japan. He also received an M.S. degree from Michigan State University in 1988, and a Ph.D. from Keio University in 2007. His research interests include image processing, human-computer interaction, CSCW, and mixed reality. He received the best paper awards from ICAT’07 and IPSJ in 2007 and 2008, respectively. He is a member of ACM, IEEE CS, IPSJ, and VRSJ, and a chairman of SIG Scent and Body Response in VRSJ.

Kenichi Okada received B.S., M.E and Ph.D. degrees in instrumentation engineering from Keio University, in 1973, 1975 and 1982, respectively. He is currently a professor at the Department of Information and Computer Science at Keio University. His research interests include CSCW, groupware, human-computer interaction and mobile computing. He is a member of IEEE, ACM, and IPSJ. He was a chairman of SIGGW, a chief editor of the IPSJ Journal, and an editor of IEICE Transactions. Dr. Okada received the IPSJ Best Paper Award in 1995, 2001, 2008, as well as the IPSJ 40th Anniversary Paper Award in 2000.

Research about Recommendation System by Attribute Relationship Matrix in Shopping

Masahiko Ishino[†], Tsukasa Kudou[‡], Kenji Saotome[*]
Naokazu Yamaki[**], Teruhisa Ichikawa[***], and Tadanori Mizuno[****],
Tsukasa Kudou[†], and Kenji Saotome[‡]

[†]Mitsubishi Electric Information Technology Corporation, Japan
[‡]Mitsubishi Electric Information Systems Corporation, Japan
[*]Hosei Business School of Innovation Management
[**]Faculty of Engineering, Shizuoka University, Japan
[***]Faculty of Informatics, Shizuoka University, Japan
[****]Graduate School of Science and Technology, Shizuoka University, Japan

Abstract – In recent years, more and more shops have been performing recommendations to the customers in order to guide the purchase motive and increase sales. We propose a mathematical programming model for the recommendation system. This technique utilizes data-mining, Analytic Hierarchy Process (AHP), conjoint analysis, and most notably, adds a learning function to handle changes in the tastes of the customers.

We examined this mathematical model in a functioning brick-and-mortar shop, with the result that both the customers and the owner of the shop were very satisfied.

Keywords: Recommendation System, Data-mining, Mathematical Programming , Analytic Hierarchy Process

1 INTRODUCTION

We propose a method that uses a mathematical programming model to recommend goods that are suited to consumer's tastes at the time of purchase. Previous research applied collaborative filtering [1] and contents analysis [2] using purchase history data. Although widely utilized in business, methods of recommending goods based on the similarity of purchase history data for every customer require great deal of data.

These methods are not applicable to recommendation of new goods. Moreover, a gap exists between the sales promoter's intuition and the recommendation made using a mathematical programming model that only depends on data analysis of each customer's tastes. In the present research, we propose a method of recommending goods that unites the sales promoter's intuition and a mathematical programming model, and apply it to a model shop. Using a collaborative filtering, extent to which particular goods matches customer's tastes is quantified for all individual goods contained in each commodity category.

A target customer usually has limited purchase history for a set of goods, thus we have to make assumptions when the customer has little or o purchase for a particular set of goods. Usually, sales promoters narrow the target customers to include only the most likely consumers and focus on the main goods when considering a sales strategy on the spot. If the amount of purchase history data in a specific period is relatively limited, collaborative filtering is applied, decreasing the presumed evaluation value gap and many of the resulting cases uniformly recommend goods which the customer has never purchased before. The current paper proposes a new method of identifying goods which can be recommended [3] [4] [5],[6],[7],[8],[9].

2 METHOD FOR RECOMMENDING GOODS

A method for recommending goods that unite the sales promoter's intuition and the mathematical programming model is explained below. The relationship between the taste characteristics of "customer attributes" and "goods attributes" is generated using the mathematical programming model. Furthermore, an "Attribute Relationship Matrix" which attaches weights to those taste characteristics is created. This method is our original logic of thinking that other examples do not have.

Moreover, the sales promoter evaluates the recommendation candidate goods that extracted using the mathematical programming model are narrowed to actual recommendation goods. "Analytic Hierarchy Process (AHP)" [10] which is a typical evaluation method is used.

The list of recommendation goods is narrowed down following the flow of selected goods illustrated in Figure 1, identifying the recommending candidate goods extracted by data-mining (mathematical programming model) as alternatives, and adding the subjectivity evaluation using AHP in the spot. A large-scale AHP which presupposes many alternatives and two or more evaluator is used in the present study. Attribute conversion is originality on the combination method of data- mining + AHP.

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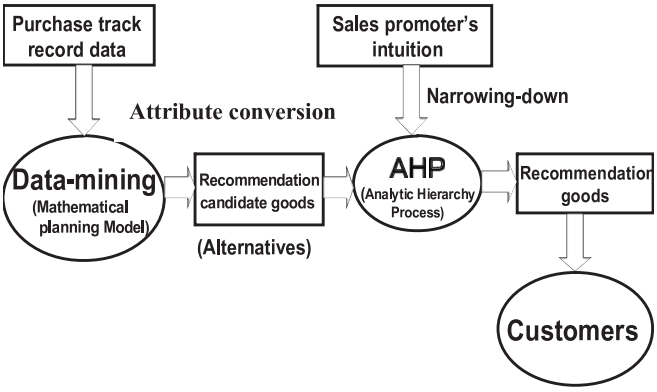

Figure 1: The flow of recommending goods selection

2.1 Analysis using Attribute Vector of Goods and Customers

We assume that each customer's taste in goods is based on the weight accorded to goods attributes (brand, type, specification, price, etc.). The characteristics of all goods are determined by some attributes and some levels and are expressed with an attribute vector. Similarly, all customers have attributes (area, age, sex, taste genre, etc.), and the customers are identified by some attributes and some levels. The goods profile is expressed with an attribute vector in the following equation (1).

$$G^d, d = 1 \sim m \in B^m \quad (1)$$

B^m : m dimensions binary vector

Here, m is the attribute number and level. The number of goods is shown as k in Table 1.The element of an attribute vector is "0" or "1". The attribute vector of the goods belonging to the goods set G_j purchased by customer c_i is set as I_c. For example, when four attributes and the level of each attribute are set at two, they can be expressed using the goods attribute matrix G shown in Table 1. The element of the matrix applicable to the attribute showing the feature of each goods is set as "1". This method is our original logic of thinking that other examples do not have.

Table 1: Example of goods attribute matrix G^T

goods	brand-1	brand-2	type-1	type-2	specification-1	specification-2	price-1	price-2
g 1	1		1		1		1	
g 2		1		1		1	1	
g 3	1			1		1		1
...								
g k	1		1			1	1	

(The number of goods k that refers to g_k in Table 1.)

A customer c_i is similarly characterized according to attributes. The customer profile is expressed with the attribute vector in the following equation (2).

$$C^d, d = 1 \sim n \in B^n \quad (2)$$

B^n : n dimensions binary vector

Also here, n is the number and level of attributes. The number of customers is shown as l in Table 1.The element of an attribute vector is "1" or "0". The attribute vector of the customer belonging to the customer set C_i that purchased goods g_j is set as I_g. For example, when four attributes and the level of each attribute are set at two, an attribute can be expressed with the customer attribute matrix C shown in Table 2. The elements of the matrix showing the level applicable to the attributes of each customer's features is set as "1".

Table 2: Example of customer attribute matrix

customers	location-1	location-2	age-1	age-2	male	female	genre-1	genre-2
c 1	1			1	1		1	
c 2		1	1		1			1
c 3	1			1		1	1	
...								
c l		1		1		1		1

(The number of goods l that refers to c_i in Table 2.)

2.2 Weight of Attributes

We generated the taste degree vector showing the weight (the element has a part-worth) of the customer's priority for each good's attribute using Conjoint Analysis. And, we generated the taste degree vector showing the weight prioritizing the customer's attribute that selects the goods.

The goods attribute taste degree matrix for all customers is defined as equation (3).

$$U \in R^{m \times l} \tag{3}$$

The goods part-worth vector for customer c_i serves as the next equation (4). The part-worth of the goods g_j for the customer c_i is shown as u_{ji}.

$$U_i^T = (u_{j1}, u_{j2}, \cdots, u_{jm}) \tag{4}$$

The taste evaluation value of goods g_j to customer c_i is expressed with equation (5).

$$E_{C_i} = U_i^T G_j \tag{5}$$

"Conjoint Analysis" presumes that part-worth reproduces the purchase history ranking of each good by customer c_i as much as possible in descending order of the taste evaluation values, and part-worth is given as a solution of a mathematical programming problem. Moreover, part-worth of a goods attribute without a purchase history cannot be decided. "Collaborative Filtering" decides the undecided part-worth value using the purchase history of the goods of a similar attribute, and a taste degree vector is generated for every customer. Part-worth presumption value is completed by adding. The taste evaluation value E_c of goods U_i is calculated using the completed vector U, and goods with high taste values are recommended out of the goods set g_j.

Goods without a history can also be recommended. Recommendations about new goods are also possible because goods are expressed by the attribute vector.

The taste degree matrix of a customer attribute toward the target goods g_j is defined as equation (6).

$$V \in R^{n \times k} \tag{6}$$

The customer part-worth vector of goods g_j is shown in equation (7). The part-worth of the customers c_i about the goods g_j is shown as v_{ij}.

$$V_j^T = (v_{i1}, v_{i2}, \cdots, v_{in}) \tag{7}$$

The taste evaluation presumption value of customer c_i toward goods g_j is shown in equation (8).

$$E_{g_j} = V_j^T C_i \tag{8}$$

Good g_j is a part-worth presumption value E_g so that the purchase history ranking for every customer may be reproduced as much as possible in descending order, by taste evaluation value. The customer with a high taste evaluation value is recommended out of the customer set. Since a customer's feature is expressed by the attribute vector, the recommendation about a new customer is also possible. The priority and part-worth value by the taste evaluation value of the goods as seen by the customer and should be recommended are expressed, and priority and part-worth value by the taste evaluation value of customers who perceive goods similarly and should be recommended are also carried out.

2.3 Attribute Relationship Matrix

The next matrix [which makes the customer attribute into a row and the goods attribute into a column] based on these part-worth values is defined as equation (9). This matrix is called "attribute relationship matrix".

$$W \in R^{n \times m} \tag{9}$$

Matrix W is expressed with equation (10).

$$W = \begin{bmatrix} w_{11}, w_{12}, w_{13}, \cdots, w_{1m} \\ w_{21}, w_{22}, w_{23} \cdots, w_{2m} \\ \vdots \qquad\qquad \vdots \\ w_{n1}, w_{n2}, w_{n3}, \cdots, w_{nm} \end{bmatrix} \tag{10}$$

This method is our original logic of thinking that other examples do not have.

The evaluation presumption value of the target goods g_j as seen by the customer c_i can be expressed with equation (11).

$$p_i = W^T C_i = U_i \tag{11}$$

Namely,

$$U = W^T C \tag{12}$$

Similarly, the receiving target customers' evaluation presumption value for the good g_j can be expressed with equation (13).

$$q_j = WG_j = V_j \tag{13}$$

Namely,

$$V = WG \tag{14}$$

Both sides are transposed from equation (15),

$$V^T = G^T W^T \tag{15}$$

In equation (16) both sides are multiplied.

$$V^T C = G^T W^T C = G^T U \tag{16}$$

However, generally, since W is not materialized from equation (16), the solution of the minimization problem to the matrix W is obtained from equation (17).

$$\left\| U - W^T C \right\|^2 + \left\| V - WG \right\|^2 \rightarrow \min \tag{17}$$
$$st. \quad W \geq 0$$

Moreover, as shown in Figure 2, the purchase results after recommendation are fed back to the next recommendation.

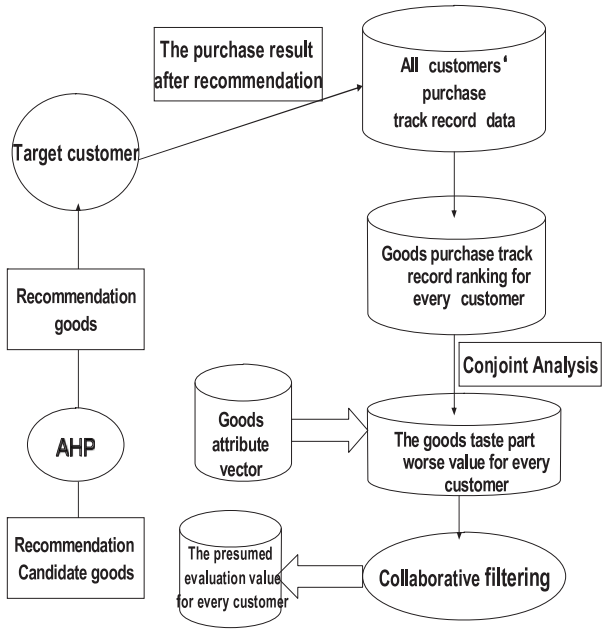

Figure 2: The learning function of recommending goods

The difference between a presumed value and the purchase history d after recommendation is set as s .

$$d = GW^T C - s \tag{18}$$

Adding the feedback function of the purchase results after the recommendation shows equation (19). Here, n is the number of times feedback repetition occurs.

$$\left\| U - W^T C \right\|^2 + \left\| V - WG \right\|^2 + \sum_{n=1}^{k} \left\| d_n \right\|^2 \rightarrow \min \tag{19}$$
$$st. \quad W \geq 0$$

The solution of the minimization problem to the matrix W is obtained from equation (19). Generally, equation (19) is solved using at the method of least squares.

3 The SELECTION METHOD OF RECOMMENDING GOODS

By AHP, the recommendation goods are selected from many recommendation candidate goods by a one-pair comparison in the spot.

3.1 Selection Procedure

Recommendation goods are narrowed down using the procedure described below.

(1) A hierarchy diagram is generated for the recommendation candidate goods to be evaluated.
(2) The importance of evaluation items is calculated.
(3) The importance calculation for the recommendation candidate goods (as alternatives) is carried out using the pair comparison method or the absolute comparing method.
(4) Recommendation goods are selected according to the importance ranking of alternatives.

3.2 Weighting Importance Evaluation in Real Shop

Using the above-mentioned recommendation method, shown in Fig. 2, the recommendation candidate goods for a customer were selected and the evaluator of the spot set up a target and evaluation items for AHP. The target of the spot was considered to be a sales expansion.

Evaluation items, such as customer satisfaction, goods specification and profit, were considered. The AHP tool was utilized, comparing a pair of recommendation candidate goods. Customer satisfaction was most important, and given a high priority in the evaluation. Importance ranking was carried out at the time of order, giving a high weight value to the recommendation candidate goods of each customer, and recommendation goods were selected. After the goods recommendation for specific customers, the rates of purchase were compared, and the sale of goods was expanded.

4. Experiment in Model Shop

The application experiment was attempted in the model shop, treating miscellaneous goods. From customer purchase history data for the past two years, goods were extracted according to the recommendation target customers, and were entered as object data of 60,000 transactions.

(1) Candidate customers: 50 customers were selected from the purchase history top layer.
(2) Customer attributes: location (4), age (4), sex (2), and a taste genre (2).
(3) Goods attributes: brand (5), type (5), specification (2), and price range (2).

cf. ( ): indicates the number of levels.

4.1 Goods Taste Evaluation for Specific Customer

The taste evaluation value E_c for each good is calculated using the completed taste degree vector U, and goods with a high taste evaluation value are recommended. The goods taste evaluation value for the specific target customer using part-worth is shown in Table 3. It recommends the goods with the highest evaluation presumption value E_c .

Table 3: Example of a specific customer's goods taste evaluation value E_c

goods	brand-1	brand-2	type-1	type-2	specification-1	specification-2	price-1	price-1	Evaluation Value
g r1	0	4	0	3	0	2	0	1	10
g r2	1	0	5	0	1	0	1	0	8
g r3	0	1	0	3	0	2	0	1	7
...									
g rk	1	0	1	0	0	1	1	0	4

4.2 Extraction of Recommendation Goods

Next, extraction of the recommendation goods according to the "Attribute Relationship Matrix" is shown.

$$W \in R^{n \times m} \tag{20}$$

Customer C_j evaluation presumption value p for the target goods is shown by the equation (21).

$$p = W^T C_j \tag{21}$$

A target customer's evaluation point q estimates goods g_j using equation (22).

$$q = WG_j \tag{22}$$

Table4 shows a part-worth matrix. The customer and goods attributes for which part-worth serves as a large value in this matrix are assigned a high degree of recommendation.

Table 4: Example of a customer and goods attribute part-worth value matrix

	brand-1	brand-2	type-1	type-2	specification-1	specification-2	price-1	price-2
location-1	5	3	4	2	1	2	1	1
location-2	1	2	5	1	4	3	1	1
age-1	2	1	2	1	1	2	1	3
age-2	3	1	4	2	1	2	3	1
male	2	1	3	1	5	2	4	1
female	4	1	4	3	1	6	1	1
genre-1	1	4	2	2	3	3	2	1
genre-2	2	2	3	5	1	2	4	1

The attribute vector of customer of "location-1, age-1, male, and genre-1" serves as equation (23).

$$C^T = (1,0,1,0,1,0,1,0) \quad (23)$$

The evaluation presumption value p of the target goods for customer c_i serves as equation (24).

$$p = U^T = W^T C = (10,9,11,6,10,9,8,6) \quad (24)$$

The taste evaluation value of the goods attributes in equation (24), "brand-1, type-1, specification-1, and price-1" is high. These goods attributes with high taste values are recommended out of the goods set.

4.3 Selection of Operation of Recommendation Candidate Goods by AHP

The experiment applied the selection method by AHP evaluation to the model shop where specific goods out of five classifications, "bag, wear, tableware, stationery, and accessories," are recommended as candidates for a goods group with high taste evaluation values, based on the strength of goods attributes (brand, type, specification, price) to a specific customer. Model shop management strategy data were changed to the general name of goods. As shown in Figure 3, the recommendation candidate goods for a specific customer were mentioned, and the target setup and evaluation items were identified by the evaluator of the spot. The targets identified were expansion of sales and the accomplishment of evaluation items such as customer satisfaction, goods specifications, and profits.

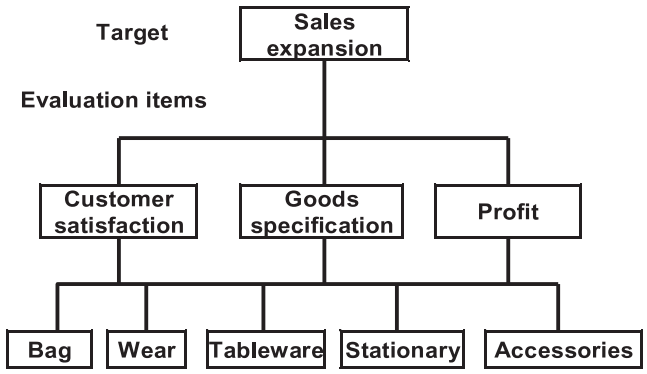

Figure 3: Example of recommending goods classification for evaluation

The large-scale AHP software was used to perform a one-pair comparison among the recommendation goods alternatives for every valuation basis.

An example of the results of the valuation-basis importance value calculation of the whole evaluator group is shown in Figure 4. The weight value of the valuation bases was highest for customer satisfaction, followed by goods specification, and then profits growth. This supports the recommendation goods suitable to customer taste, and the intention giving priority to customer specification.

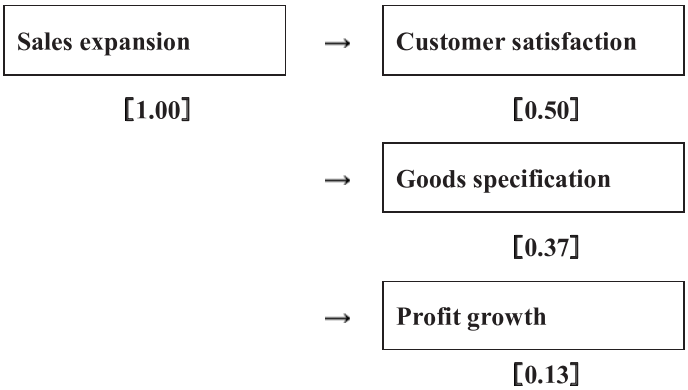

Figure 4: Example of the valuation-basis importance value for recommendation goods

Next, as an example, a one-pair comparison of the recommendation goods alternative set was performed, and its weighted values are summarized in Table 5. For the target customers, the highest weighted value was for "bag" among the recommendation candidate goods.

Table 5: Example alternatives weight values for recommending goods classifications

Alternatives of recommendation goods	Weight
Bag	0.34
Wear	0.31
Tableware	0.18
Stationery	0.06
accessories	0.11

4.4 Example of Recommendation

The application example of the recommendation method in a model shop are shown in Table 6. By the demand of the shop, I showed superiority than an existing method by the experiment of few customers of high-ranking regular customer.

(1)Recommendation goods were selected for specific customer, and the evaluation from the sales promoter was compared with the purchase results. Although the evaluation of stationery was "×" (the customer did not purchase), the customer purchased the stationery("○").

(2)Although the evaluation of accessories by the recommendation method was "×", the sales promoter was recommended the accessories to the customer, but who did not purchase .

(3)Although the evaluation of tableware by the recommendation method was "○", the sales promoter was recommended the tableware to the customer, that did not purchase.

Table 6: The result of recommendation system in the shop

No.	Goods	Recommendation method	Evaluation of the model shop	Customer's purchase
1	Wear ①	○	○	○
2	Stationery ②	○	×	○
3	Wear ②	○	○	○
4	Tableware ①	○	○	×
5	Stationery ②	○	×	○
6	Bag ①	○	○	○
7	Tableware ②	○	○	×
8	Accessories ①	×	○	×
9	Bag ②	○	○	○
10	Accessories ②	×	○	×

Below, we describe the results of our application of this method to a real shop.

The rate of purchase resulting from each recommendation method is compared in the rate comparison table 7. Our **At**tribute Relationship Matrix method showed a significantly higher rate of purchase other both the method currently used in the shop and the collaborative filtering.

Table 7: Rate of purchase by recommendation

Method of recommendation	Rate of Purchase (%)
Method currently used in the shop	56
Collaborative filtering	67
Attribute Relationship Matrix method	77

These results show that Attribute Relationship Matrix method successfully recommended goods which suited customer's tastes. Many new products were included in the pool of recommended goods. The promoter was extremely satisfied with the results of this experiment.

5 CONCLUSIONS

The proposed method of recommending goods on the spot has the following advantages. We showed a procedure for developing recommendations based on the attributes of both the customer and goods, even when we don't have a complete purchase history for that customer.

5.1 Consideration

(1) We have identified which attributes, including functions, performance, price, brand, etc. most influence customer's tastes.

(2) We can make recommendations that suit the customer's tastes, even for new goods.

(3) We have defined the strength of the correlation between the attributes of both goods and a customer in the "Attribute Relationship Matrix". Using this "Attribute Relationship Matrix", goods can be recommended to a customer with the appropriate characteristics, and target customers can be identified for goods with particular characteristics.

(4) Using AHP, we analyzed the goals and criteria used by those responsible for marketing, resulting in the evaluation weight value, allowing us to select the most effective goods for recommendation.

5.2 Effect of application

(1)We have shown that it is possible to recommend the goods effectively based on good and customer attributes, even when there is no purchase history data for goods. Using the Attribute Relationship Matrix method, the strength of the relationship between the characteristics of customer and the characteristics of goods is known.
The selecting goods which are candidate for the particular customer is easy.

(2)Recommendation system made on the spot by sales promoter ware used, but limited to the personal knowledge of the sales promoter about the individual customer or to the instincts that sales promoter way have developed. Furthermore, recommendation system made based only on purchase history are limited as well, and only by combining the two, as we have in this method, can we achieve the best possible sales and the highest degree of customer satisfaction.
The proof of our method was difficult on the shop, but the owner of the shop was extremely satisfied with the results of recommendations made to the top ten customers.

6. The next research subject

Further research on this subject should focus on the utilization of the goods recommendation method for practical use.

Corresponding to the needs in the shop at the time of applying a technique, a future subject is correspondence to a dynamic change. Since the taste evaluation value by the mathematical technique is presumed using the past purchase history data, change of the taste of the customer by change of fashion of goods is not supported. The dynamic learning function of the attribute relationship matrix method is examined.

In the future, research on utilization in the spot will be further advanced by the new method that recommends goods, which unite the intuition of the spot and the mathematical programming model. We are continuing improvement of the recommendation method, in order to gather the customer's rate of purchase more.

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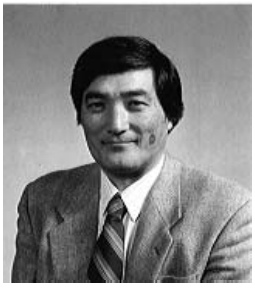
Masahiko Ishino received the master's degree in science and technology from Keio University in 1979 and received the Ph.D. degree in industrial science and engineering from graduate school of Science and technology of Shizuoka University, Japan, in 2007. In1979, he joined Mitsubishi Electric Corp. Since 2005, he is the system engineer of Mitsubishi Electric Technology Corp. Now, His research interests include management information system, industrial engineering, application system of data-mining, and information security system. He is a member of Information Processing Society of Japan, Japan Industrial Management Association,Japan Society for Management Information.



Naokazu Yamaki received the master degree in the Department of Mathematics of Faculty of Science Division from the Tokyo University of Science in 1970 and received the Doctor of Engineering degree from the Tokyo University of Science.

Now, he is a Professor of graduate school of Science and technology of Shizuoka University. His research interests include mathematics programming and product engineering, soft wear engineering and operations research. He is a member of the Japan society for management, Japan Industrial Management Association, The Operations Research Society of Japan, and Scheduling Society of Japan.

Teruhisa Ichikawa received the degree in administration engineering from the Keio University in 1965 and received the Ph.D. degree in Science and Technology from Keio University, Japan, in 2006. In 1965, he joined Mitsubishi Electric Corp. Since 1999, he was a Professor of Niigata University of International and Information Studies, Japan. Since 2002, he is a Professor of Faculty of Informatics from Shizuoka University, Japan. His research interests include information systems, project management and modeling. He is a member of Information Processing Society of Japan, the Japan Society for Management Information and Information Systems Society of Japan.

Tadanori Mizuno received the B.E. degree in industrial engineering from the Nagoya Institute of Technology in 1968 and received the Ph.D. degree in computer science from Kyushu University, Japan, in 1987. In 1968, he joined Mitsubishi Electric Corp. Since 1993, he is a Professor of Shizuoka University, Japan. Now, he is a Professor of graduate school of Science and technology of Shizuoka University. His research interests include mobile computing, distributed computing, computer networks, broadcast communication and computing, and protocol engineering. He is a member of Information Processing Society of Japan, the institute of electronics, information and Communication Engineers, the IEEE Computer Society, ACM and Informatics Society

Tsukasa Kudou received the master's degree in Engineering from Hokkaido University in 1980 and received the Dr. degree in industrial science and engineering from Shizuoka University, Japan, in 2007. In 1980, he joined Mitsubishi Electric Corp. He was the researcher of parallel computer architecture and the engineer of business software. Since 2005 he is the engineer of Mitsubishi Electric Information Systems Corp. Now, his research interests include database application and system quality assurance. He is a member of IEIEC and Information Processing Society of Japan.

Kenji Saotome received a BE from the Osaka University, Japan in 1979, and a Dr.Eng in Information Engineering from the Shizuoka University, Japan in 2008. From 1979 to 2007, he was with Mitsubishi Electric, Japan. Since 2004, he has been a professor of Hosei business school of innovation management. His current research areas include LDAP directory applications and single sign-on system. He is a member of the Information Processing Society of Japan.

Evaluation of Local Pipelining for Reprogramming Wireless Sensor Networks

Hiroshi Mineno, Takuya Miyamaru[†],
Yoshiaki Terashima[§], Yuichi Tokunaga[§] and Tadanori Mizuno[‡]

Faculty of Informatics, Shizuoka University
3-5-1 Johoku, Naka-ku, Hamamatsu, 432-8011, Japan
mineno@inf.shizuoka.ac.jp
[†]Presently, Nagoya Works, Mitsubishi Electric Corporation
5-1-14 Yadaminami, Higashi-ku, Nagoya, 461-8670, Japan
Miyamaru.Takuya@ap.MitsubishiElectric.co.jp
[§]Information Technology R&D Center, Mitsubishi Electric Corporation
5-1-1 Oofuna, Kamakura, 247-8501, Japan
Terashima.Yoshiaki@eb.MitsubishiElectric.co.jp
Tokunaga.Yuichi@ds.MitsubishiElectric.co.jp
[‡]Graduate School of Informatics, Shizuoka University
3-5-1 Johoku, Naka-ku, Hamamatsu, 432-8011, Japan
mizuno@inf.shizuoka.ac.jp

Abstract -
Wireless reprogramming is a useful service for wireless sensor networks to upload new code and modify functions. The latest reprogramming protocols use the technique called pipelining. Although it can accelerate the speed of code distribution, it requires a lot of control packets which affects energy efficiency and reliability. Improving energy efficiency and reliability is an important challenges in reprogramming. In this paper, we present a technique for code distribution called Local Pipelining. Local pipelining assigns a number of segments to a group that consists of a neighborhood. The number of segments is based on the number of control packets and the speed of code distribution. By adjusting this value according to remaining energy that group has, Local pipelining can control the amount of control packets and improve energy efficiency and reliability in the entire network.

Keywords: Reprogramming, Wireless sensor networks

1 Introduction

The recent advances in MEMS and low power wireless communication technology have led to the development of wireless sensor networks (WSN). A WSN consists of a number of sensor nodes, and they collect and transfer sensing data to the network autonomously. Many WSN applications, which including environmental monitoring, security, and position tracking, have been developed.

In WSNs, reprogramming that updates code on sensor nodes is one of the most important services. Because WSNs are a relatively new field of study, many applications contain developing technologies (ad-hoc routings, data processing, position estimations, etc.), and these technologies are implemented as specific code on the sensor nodes. It is therefore possible that these codes will be modified or extended in the future for long-running applications using WSNs. Thus, a method to easily reprogram many deployed sensor nodes is necessary. Recently, much research on wireless reprogramming has been conducted[1][2]. Wireless reprogramming distributes new code easily to a lot of sensor nodes using wireless multihop communication. The purpose of general protocols in WSN is to aggregate a lot of small data from the edge nodes to the base station, whereas the purpose of wireless reprogramming protocols is to distribute large data from the base station to the edge nodes[3][4][5][6]. The pipelining method, which quickly distributes bulk data to the entire network has been proposed in some studies[7][8][9]. In pipelining, code is divided into several segments, which are transferred in parallel. By dividing code into smaller segments, we can increase the degree of parallelism and speed up the distribution. However, the number of control packets is also increased, and this results in higher energy consumption and lower reliability.

Here, we present the code distribution technique called local pipelining, in which a number of segments is assigned to a group consisting of several sensor nodes. Normal pipelining fixes the number of segments as one value in the entire sensor network. So if we set a large value for the number of segments in order to speed up updating, this causes an increase in the number of control packets. In contrast, the local pipelining scheme can adjust the number of control packets depending on the condition of each group. First, we present a method of local pipelining that can freely adjust the number of segments and control packets depending on the remaining energy. Adjusting this value for each group contributes to improved energy efficiency and transfer efficiency. Second, we analyze the case of several pipelines that have a different number of segments. This is helpful in cases where we have to reprogram various multiple networks.

This paper is organized as follows. In section 2, we explain some issues related to pipelining and analyze the control packets needed in the transfer process. An overview of local

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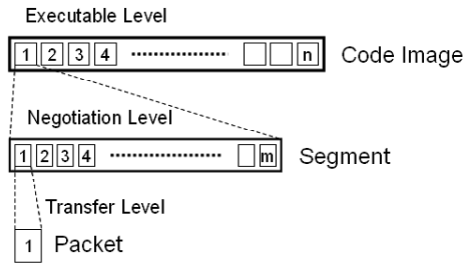


Figure 1: Structure of segment

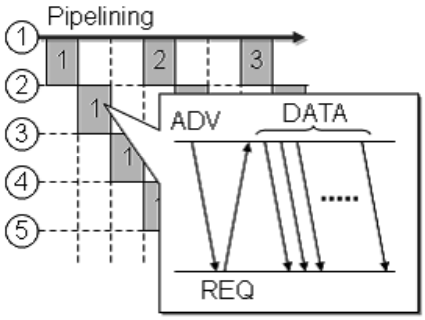


Figure 2: Handshake

pipelining and its features is introduced in section 3, which also describes the transfer algorithm. We describe the performance of local pipelining using several formulas in section 4, and evaluate it in section 5. Also included in section 5 is a description of the implementation of local pipelining on TinyOS [11]. This evaluation includes a simulation of the number of sending packets, completion times, and the propagation process. Finally, section 6 summarizes the paper and mentions future work.

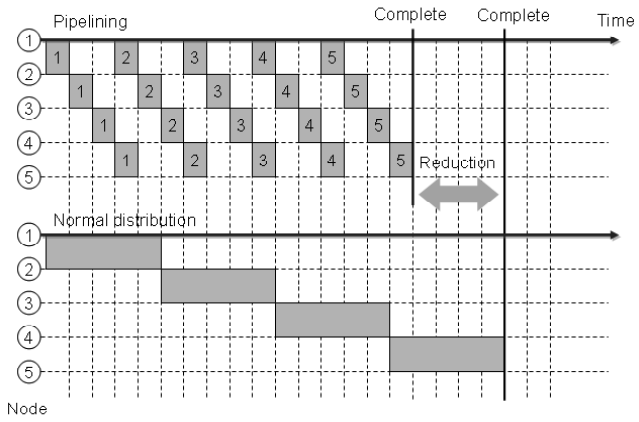


Figure 3: Pipelining

2 Related Issues

2.1 Pipelining

Many wireless reprogramming protocols share design challenges. We deal here with the three important challenges that follow [1].

- **Reliability:** The complete code must be correctly received by the target nodes, and the downloaded code must be executed correctly on the sensor node.
- **Energy efficiency:** The energy used in reprogramming is provided by the sensor node battery. This battery also supplies energy for sensing, which is the primary role. Thus, the energy consumption for reprogramming should be reduced as much as possible.
- **Completion times:** The completion time of reprogramming affects the sevice using a WSN. When we reprogram the network, we have to stop service and wait until the update is completed. Therefore we have to minimize the completion time of reprogramming.

Pipelining is proposed as a means to speed up distribution despite these challenges. In pipelining, code is divided into several segments, as depicted in Figure 1, and each segment consists of several packets, which form a transfer unit. Figure 3 shows how distribution can be sped up by overlapping the transferring segments. The figure compares the process of pipelining with normal distribution. There are five sensor nodes deployed linearly in Figure 3. In the pipelining scheme, while node 4 is transferring segment 1 to node 5, node 1 is transferring segment 2 to node 2 simultaneously. The result is that pipelining can complete downloading earlier than normal distribution. Thus, we can reduce the completion time by overlapping the segments. In this case, we need at least three hops spaced between segments to avoid the hidden terminal problem.

2.2 Negotiation Scheme

Because pipelining deals with several segments, it is necessary to keep track of segments that are lacking. Therefore, a negotiation scheme is needed to request missing segments. This scheme uses a three-way handshake that has three types of messages (Advertise, Request, Data). This scheme is proposed to reduce message redundancy by SPIN [10]. The epidemic property is important since WSNs experience high loss rates, asymmetric connectivity, and transient links due to node failures and repopulation. The latest reprogramming protocol uses this scheme to improve reliability. Figure 2 illustrates the three-way handshake. First, a source node advertises an ADV message, which includes its own segment, to neighboring nodes. Second, if the destination node receives the ADV message, it compares its own segment with the received segment information and decides whether it needs the segment advertised by the source node. If it needs this segment, it requests the segment to source node by sending an REQ message. Finally, if the source node receives the REQ message

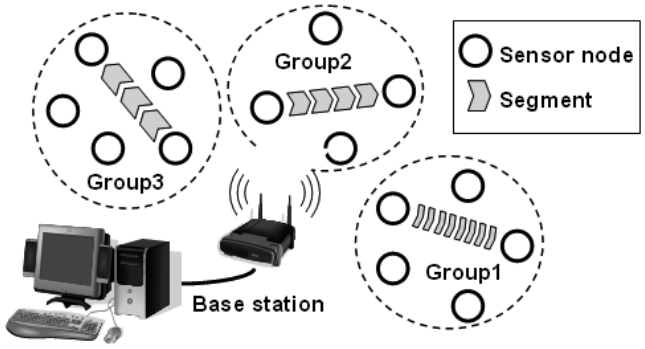


Figure 4: Local pipelining

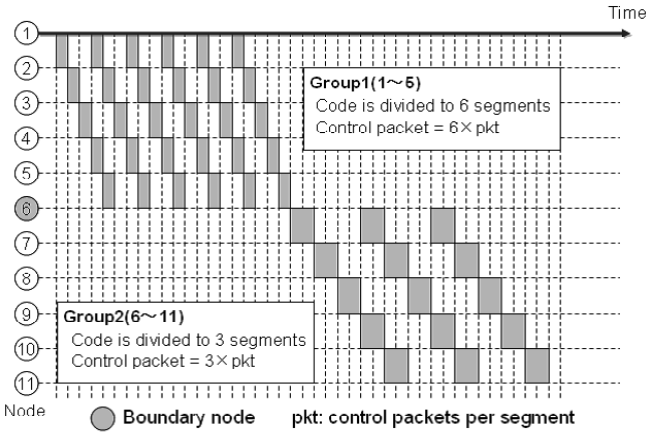


Figure 5: Distribution of Local pipelining

from the destination node, it starts to forward a DATA message that consists of sequential packets. By using this three-way handshake, we can reduce the redundancy of transferred segments.

2.3 Energy issue in pipelining

In pipelining, we can accelerate the speed of code distribution by dividing code into smaller segments (increasing the number of divided segments) and increasing the degree of parallel. However, we cannot increase the number of segments without reason, because, this can affect the energy efficiency and reliability, depending on the control packets. Pipelining uses one negotiation per segment, and one negotiation requires control packets that include ADV and REQ messages. Thus, if we increase the number of segments, the ADV and REQ messages in corresponding segments will also increase. This affects the energy efficiency and reliability. First, a lot of energy is used to send messages, it is one of the most energy-consuming actions in the sensor node. The number of messages greatly affects energy efficiency. Second, when many messages are sent, message collisions may occur.

For these reasons, it is necessary to reduce or adjust the control messages required for pipelining.

3 Local pipelining

3.1 Overview

The goal of local pipelining is to freely adjust the number of control packets depending on the condition of each group. Normal pipelining, which is used by Deluge [7] and MNP [8] fix the number of segments as one value in the entire network. In this case, if we set a large value for the number of segments in order to speed up processing, this causes an increase in the number of control packets.

The amount of remaining energy varies depending on which nodes are deployed. Therefore, some sensor nodes bear a large burden of control packets. However, we cannot decrease the number of segments to fall in step with the subset of sensor nodes, because this degrades performance. Therefore, we propose a local pipelining to achieve a realistic distribution for each node while maintaining good performance.

In local pipelining, the number of segments is not assigned to an entire network, but rather, a value is assigned to each group, which is a set of neighboring nodes, as shown in Figure 4. It is only necessary to set the value of each group depending on the available of energy. In this way, we can achieve the following setting. If there is some leeway in the energy, we can divide code into smaller segments for faster distribution or into larger segments to constrain the number of control packets.

3.2 Distribution Process

Figure 5 shows the distribution process of local pipelining. In this figure, we assume that group 1 includes node 1 to node 5, group 2 has node 6 to node 11, and group 1 divides code into six segments, and group 2 divides code into three segments. If one pkt control packet is needed for each segment, group 1 needs $6 \times pkt$ and group 2 needs $3 \times pkt$.

Because local pipelining deals with several networks each of which has a particular number of segments, it is necessary to transfer data by using a distribution technique that is different from normal pipelining. This process involves changing the number of segments and retransmitting new segments in the transfer. This process is handled by a boundary node deployed at the edge of a group. Node 6 is the boundary node in Figure 5. The boundary node must wait until all segments from other groups have been received, and when the download is completed, it starts forwarding with its own number of segments. That is to say, the boundary node has the same role as a base station.

3.3 Transfer Algorithm

To achieve distribution like this, we extended the negotiation scheme described in section 2. First, we added a field that includes information about a group to ADV and DATA messages. Group information can be determined depending on the amount of remaining energy and other information. A corresponding group table containing group information and the amount of remaining energy is established in advance. For

Table 1: Example of group table

Group	Remaining energy
1	80% - 100%
2	60% - 80%
3	40% - 60%
4	20% - 40%
5	0% - 20%

```
[ When a segment is received. ]

IF ownGroup == rcvMsg.group
        /* send segment as the same number of segment */
        GOTO Advertise phase
ELSE
        IF downloadComplete == TRUE
                /* send segment as the new number of segment */
                setOwnSegmentSize()
                GOTO Advertise phase
        ELSE
                /* wait until all segment data is complete */
                GOTO Receive phase
        ENDIF
ENDIF
```

Figure 6: Transfer algorithm

example, if the remaining energy is in the range from 80% to 100%, it corresponds to group X. If the remaining energy is in the 60% to 80% range, it corresponds to group Y. By making a corresponding table like Table 1, we have the option of changing the information depending on the group. Second, we added the transfer algorithm shown in Figure 6. This algorithm is used when a segment is received. Received messages include the information about the group the source node belongs to. First, the node compares the group in the received message with its own group. If the received group is the same as own group, it goes to the advertise phase. In the advertise phase, the node sends ADV messages that include the received segment. This process is the same as in normal pipelining. If the received group is different from its own group, the node is a boundary node. When a boundary node receives a segment, it prohibits transferring of the segment. It must wait until all segments have been completed. This is because to reset a new number of segments it must have all the data. If all segments are downloaded, it sets its own number of segments and goes to the advertise phase. Otherwise, it stays in the receive phase.

4 Performance Analysis

4.1 Speed of local pipelining

In this section, we analyze the performance of local pipelining, normal pipelining, and cases without pipelining. In particular, we focus on completion time and the number of messages, which affect energy efficiency and speed of distribution. First, we explain the effect of normal pipelining. We

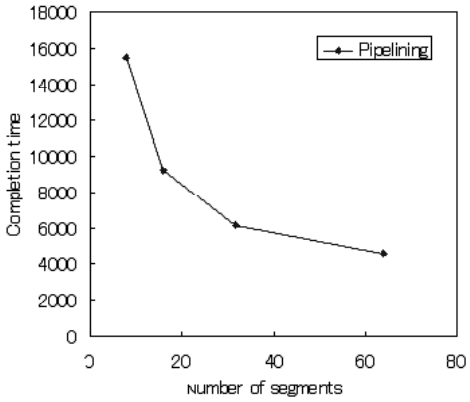


Figure 7: Completion time of normal pipelining

assume a linear deployment as in Figure 3, and the network size is n hop. Then we try to forward the static size code image, which is divided into m segments, and where t times is needed to send one segment. To avoid the hidden terminal problem, we need at least three hops between segments. Although handshake is supposed in our proposed local pipelining scheme to overcome this problem, we need at least three hops between segments to avoid the hidden terminal problem completely in the case of linear deployment as shown in Figure 3. Therefore, completion time T_p is expressed as follows.

$$T_p = (n + 3(m - 1)) \cdot t \tag{1}$$

In the case without pipelining, completion time T_n is expressed as follows.

$$T_n = n \cdot m \cdot t \tag{2}$$

These formulas conduce the result in Figure 7. This result is the theoretical completion time of normal pipelining, and it is assumed that n is 100 hops, and the time until all data sending has ended is 1024. For example, if $m = 16$, the completion time of normal pipelining is $(100 + 3(16 - 1)) \cdot 1024/16 = 9280$. This figure is obvious proof of the relationship between the number of segments and completion time. This relationship means that as we increase the number of segments, we can accelerate the speed of distribution. In contrast to pipelining, the speed of distribution in cases without pipelining is slow. In this condition, the theoretical completion time is fixed as $T_n = 100 \cdot 1 \cdot 1024 = 102400$. If n and m are large enough, it is obvious that $T_p < T_n$.

Second, we express the effect of local pipelining. Local pipelining involves several networks that have a different number of segments depending on the group. When the boundary node receives the segment of another group, it waits until all data is complete, and retransmits its own number of segments. Therefore, the completion time of local pipelining can be expressed as the sum of the completion time for each group. Then, there are k groups in the linear network, each group network size is n_i, they have m_i segments, and they need

time t_i to send one segment. The theoretical completion time of local pipelining T_{lp} is expressed as the following.

$$T_{lp} = \sum_{i=1}^{k} (n_i + 3(m_i - 1)) \cdot t_i \quad (3)$$

In each group, $T_p < T_n$ is approved. Therefore, the sum of completion time T_{lp} is less than the case of not using pipelining. This means that local pipelining is superior to not using pipelining in completion time, but it is inferior to normal pipelining.

4.2 Control packets

Next, we describe the control packets needed in normal pipelining and local pipelining. First, we introduce the control packets per segment. A segment has two types of control messages, ADV messages and REQ messages. These messages are not necessarily one message. If a source node advertises an ADV message and receives no requests for it, it needs to retransmit the ADV message. By the same reason, if a destination node send an REQ message to a source node and the DATA does not arrive, it needs to retransmit the REQ message. At this point, we assume the number of ADV messages per segment as N_{adv}, and the number of REQ messages per segment as N_{req}. One segment needs $N_{adv} + N_{req}$ control packets. Thus, one node needs $m \cdot (N_{adv} + N_{req})$ control packets. In normal pipelining, the sum of control packets in an entire network is as follows.

$$C_p = n \cdot m \cdot (N_{adv} + N_{req}) \quad (4)$$

In contrast, local pipelining has several m, and several k groups which have n_i sensor nodes. The sum of control packets in an entire network is as follows.

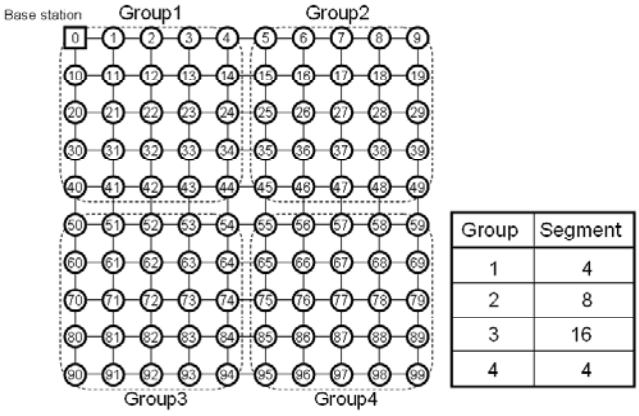
$$C_{lp} = \sum_{i=1}^{k} n_i \cdot m_i \cdot (N_{adv} + N_{req}) \quad (5)$$

These formulas show that local pipelining can freely adjust and reduce the number of control packets depending on circumstances while maintaining the speed of distribution. For example, there are four groups in an entire network, and each group has five nodes. Each group is assigned a number of segments as follows. Group 1 has 16, group 2 has 8, group 3 has 16, and group 4 has 8. In this case, $C_{lp} = 48 \cdot 5 \cdot (N_{adv} + N_{req}) = 240 \cdot (N_{adv} + N_{req})$. In contrast, the case of normal pipelining, m is fixed as 16. Therefore, $C_n = 20 \cdot 16 \cdot (N_{adv} + N_{req}) = 320 \cdot (N_{adv} + N_{req})$. It is obvious that $C_p > C_{lp}$.

5 Evaluation

5.1 Simulation Environments

In this section, we describe an evaluation of local pipelining using the TinyOS network simulator (TOSSIM [12]). The goal of this simulation was to prove that local pipelining is superior to normal pipelining from the view point of energy efficiency, and that it can transfer data without problems.



Group	Segment
1	4
2	8
3	16
4	4

Figure 8: Sensor node deployment

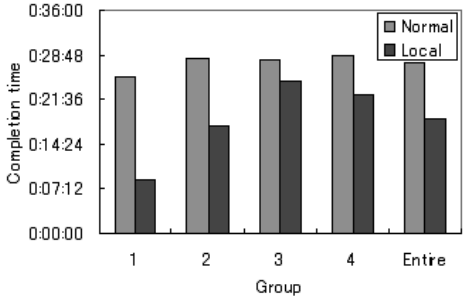


Figure 9: Average completion time of each node

First, we describe the implementation of local pipelining on TinyOS. The implementation was based on MNP [8] which is a state-of-the-art reprogramming protocol and includes normal pipelining. We extended the function of MNP's control packets described in section 3, and added a transfer algorithm. In this implementation, we had to be careful about the group arrangement. The groups were arranged as in Figure 8 without regard for the remaining energy. Because TOSSIM cannot duplicate the sensor node battery, so we assume that groups are determined depending on location, as shown in the Figure.

Next, we explain the simulation environment. We assumed each node had a transmission radius of 50 feet (meaning that nodes can receive messages within a 50-foot radius). Nodes were deployed in a reticular pattern (Figure 8), and each node had 40 feet of spacing. The network had four groups that had 5×5 subnetworks, and each group had the number of segments indicated in Figure 8. We assumed that normal pipelining (MNP) had a fixed number of segments, where the value was 16 divisions. The base station had a complete code image, and started forwarding each segment in the early stage of distribution.

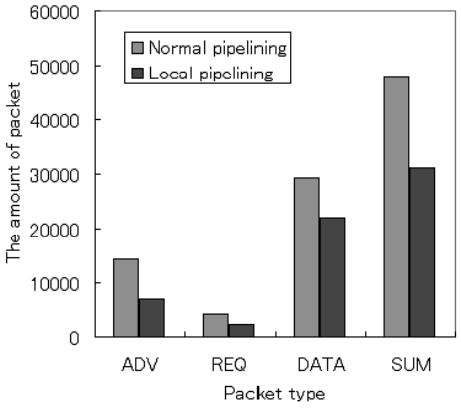


Figure 11: Number of packets

5.2 Completion times and propagation

In this section, we investigate the distribution speed between local pipelining and normal pipelining. Figure 9 shows the average completion time of each node under simulation, classified by group. Because the number of segments is fixed in normal pipelining, the completion time for each group has about the same value. In contrast, local pipelining has various numbers of segments, which affects the completion times. In this environment, this result indicates that local pipelining can distribute code faster than normal pipelining.

Figure 10 illustrates the propagation process of segments under simulation, when the node has downloaded all segments. In this figure, normal pipelining has equable propagation, where each node is received almost at the same time. This is because the same number of segments is used in the entire network. On the other hand, local pipelining is inequable propagation. The borders of the groups bring about the delay. This delay is caused by the network's waiting until all segments have been downloaded completely. There are especially large delays in the boundary nodes placed where that the difference in the segment numbers is very large.

5.3 The number of messages

Next, we evaluate the energy efficiency depending on the number of messages. Figure 11 plots the number of the messages in the entire network, with a comparison between normal (MNP) and local pipelining. It is clear that local pipelining requires fewer messages than normal pipelining. ADV, and REQ are control messages, and DATA includes segment data (but also includes start-download and terminate-download messages in MNP). Control packets depend on the number of segments, as explained in section 4. Therefore, local pipelining, which has different numbers of segments, is effective in adjusting the number of control packets. In linear deployment, which uses the same parameters, control packets are indicated by $(4{+}8{+}16{+}4){\cdot}25{\cdot}(N_{adv}{+}N_{req}) = 800(N_{adv}{+}N_{req})$ in local pipelining. On the contrary, normal pipelining requires $16 \cdot 100 \cdot (N_{adv} + N_{req}) = 1600(N_{adv} + N_{req})$ control packets. Therefore, the number of control packets in local pipelining is smaller than in normal pipelining.

6 Summary and future works

In this paper, we presented our local pipelining technique, which can freely adjust several numbers of segments corresponding to groups. By adjusting this parameter, we can reduce the number of control messages depending on the circumstances. This method improves energy efficiency, because sending messages is one of the actions that consumes the most energy. To verify the effectiveness of local pipelining, we evaluated it using the TOSSIM simulator. In this simulation, we mainly evaluated the number of messages and the completion time. We found that local pipelining can reduce the number of messages, and the average completion time of each node is shorter than in the case of normal pipelining. This means that local pipelining achieved a partial improvement in energy efficiency.

Our future work is as follows. First, we will try to reduce the delay of local pipelining. At the group border, some delays occur, which are the waiting times for all segment downloading to be completed. This design is easy to implement and ensures correct distribution. The delay can be improved by transferring the received segments incompleted. If a node receives enough segments so that we can change the number of segments, we can transfer the received segments with own number of segment divisions. Our second task in the future is to study other metrics affected by adjusting the number of segments. In this paper, the metric considered was the remaining energy. However, we believe that local pipelining can improve other metrics (hardware richness, condition of communication, etc). Thirdly, we have to evaluate our proposed local pipelining performance under more realistic conditions, such as several topologies and groups as well as ideal grid condition. Although there are some assumptions in our proposed local pipelining yet, we will study more useful reprogramming wireless sensor networks method based on this work.

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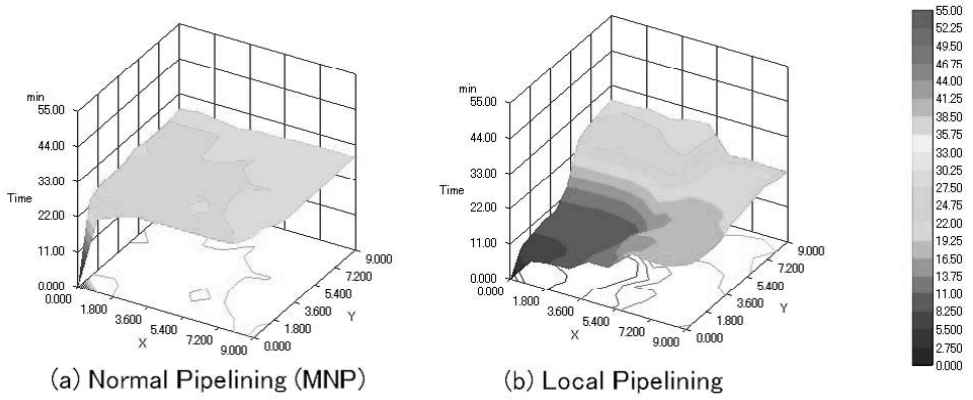

Figure 10: Propagation

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Hiroshi Mineno received his B.E. and M.E. degrees from Shizuoka University, Japan in 1997 and 1999, respectively. In 2006, he received the Ph.D. degree in Information Science and Electrical Engineering from Kyushu University, Japan. Between 1999 and 2002 he was a researcher in the NTT Service Integration Laboratories. In 2002, he joined the Department of Computer Science of Shizuoka University as an Assistant Professor. His research interests include sensor networks as well as heterogeneous network convergence. He is a member of IEEE, ACM, IEICE, IPSJ and Informatics Society.

Takuya Miyamaru received his B.I. and M.I. degree from Shizuoka University in 2006 and 2008, respectively. His research interests included reprogramming wireless sensor networks. Presently, he is a engineer of Nagoya Works, Mitsubishi Electric Corporation, Japan. Currently he has been engaged in developments for compact controller for factory automation systems. He is a member of Information Processing Society of Japan.

Yoshiaki Terashima received the B.S. degree from Saitama University in 1984 and the Ph.D. degree from Shizuoka University in 2005. He is a head researcher in Information Technology R & D Center, Mitsubishi Electric Corporation, Japan. He is currently leading the Disaster Rescue Network Project that realizes network-sensor data fusion based on ad-hoc disaster rescue network. His research interests include distributed processing architecture and testing methodologies for ad-hoc network. He is a member of Information Processing Society of Japan and the Institute of Electronics, Information and Communication Engineers.

Yuichi Tokunaga received the B.E. degree from Tokyo University of Science in 1990. He is a head researcher in Information Technology R & D Center, Mitsubishi Electric Corporation, Japan. He is currently leading the development of the diagnostic and monitoring system that uses wireless sensor networks. His research interests include time synchronization and positioning methodologies for wireless sensor networks. He is a member of Information Processing Society of Japan.

Tadanori Mizuno received the B.E. degree in industrial engineering from the Nagoya Institute of Technology in 1968 and received the Ph.D. degree in computer science from Kyushu University, Japan, in 1987. In 1968, he joined Mitsubishi Electric Corp. Since 1993, he is a Professor of Shizuoka University, Japan. Now, he is a Professor of graduate school of Science and technology of Shizuoka University. His research interests include mobile computing, distributed computing, computer networks, broadcast communication and computing, and protocol engineering. He is a member of Information Processing Society of Japan, the institute of electronics, information and Communication Engineers, the IEEE Computer Society, ACM and Informatics Society.

Adaptation to Small Building with Mutual Complement Communication Systems by Wired and Wireless

Kunihiro Yamada[*],Takashi Inoue[*],Masanori Kojima[**],Kouji Yoshida[***],and Tadanori Mizuno[****]

[*]Shonan Institute of Technology, Tokai University,Japan
[**]Osaka Institute of Technology,Japan
[***]Syounan Institute of Technology,Japan
[****]Shizuoka University,Japan
yamadaku@tokai.ac.jp

Abstract- We have been evaluating "Mutual complement Communication system by Wired and Wireless" for home-network. At this time, we have tried to apply this network to the comparatively small scale business building and we found the very nice result. Compare to home network, we found that many difference in the result of the wired and wireless communication. The bad result is from the reason of multiple transformer and the good result is from the reason of business type cocking system and lighting system. Furthermore, regarding wireless communication, the additional bad result is from the reason of the security reason with small in/out door with metal material.

Keywords: multimedia and communication technology, network, PLC, ZigBee, building.

1 INTRODUCTION

We found 100% network communication result at the Mutual complement Communication system by Wired and Wireless at 3 floor level under 200 m2 home housing[1]. This network system is using 2 different characteristic network; wired and wireless. 2 network are operating simultaneously and get good communication result totally. As wired, we use normal power line in the home. We call it PLC (Power Line Communication). Communication data is on the power line as the carrier signal. As wireless, we use ZigBee (IEEE802.15.4) RF devices [2] [3].

In the home, there are PC internet system, hot water system[4], AV; Audio Video system, home telephone, inter phone and security system as individual devices but not communicated. It is important to have a unified network to work for safety and global environment issue[5]. We aim the solution by using Mutual complement Communication system by Wired and Wireless. The significant point of this communication system is because a network is realizable at low cost. Realization of low cost is because the price fall of a mutual complement network communication terminal (substrate circuit) and attachment become unnecessary. In the logic top, the communication performance has obtained 96.6% in two points[5].In actual old evaluation, the performance of a mutual complement network is 100% (making 3 stories of steel rods into the maximum) of home houses. It is possible to obtain 100% of communication performance by putting in a routing function in such situations. In practical use, although there is no necessity for 100% performance, the work of a communication environmental improvement and attachment it become unnecessary for every house by this high communication performance.

At the relatively small office building, there were power line, internet information line, security system, TV line, telephone, lighting system and other control lines. And furthermore, there are elevator lines[6]. By using these unified network, we can get less additional construction fees in the later. In order to check this idea, we have done Mutual complement Communication system by Wired and Wireless in the relatively small office building. As wired network, when getting electric power through multiple transformer, as we expect, PLC communication is very bad. On the other hand, we found that there are good communication result by 200V business lighting system and business professional cocking system because of 3 line 100V lines. There fore there is less issue of different phase trable in the PLC communication. As wireless, the additional bad result compare to home network is from the reason of the security reason with small in/out door with metal material.

But in order to communicate through multiple transformer, by using wireless, it is important to use Mutual complement Communication system by Wired and Wireless.

2 COMMUCATION CHARACTERISTIC

The In order to guess the communication performance of the mutual complement network by the two communication systems, wired and wireless, an individual communication performance is mersured first [1]. PLC has obstacles by home appliances, such as crosstalk of noise and low impedance. Therefore getting a good communication quality was difficult. In

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recent years, the PLC communication performance is improved by the adoption of spread spectrum technology. But there are still more error correction idea for the noise by the electric white goods appliance [7].

We have done actual communication performance test in multiple houses. More than 40 home electric appliances were operated and we have tested PLC communication performance. Fig.1 is a result of the measurement. The X-axis shows Packet Error Rate(PER), then 0% will be the best and error is 0%. The Y-axis expresses the frequency distribution of all communication courses with %.0%of PER is 70% of frequency distribution from Fig.2.and 100% of PER is 20% of frequency distribution.

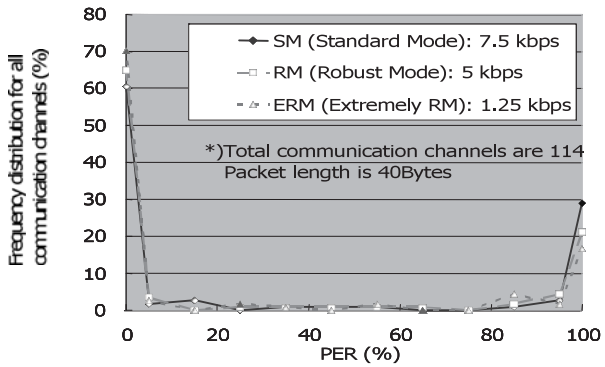

Fig.1. Testing result of PLC (100kHz–400kHz) in typical Japanese home

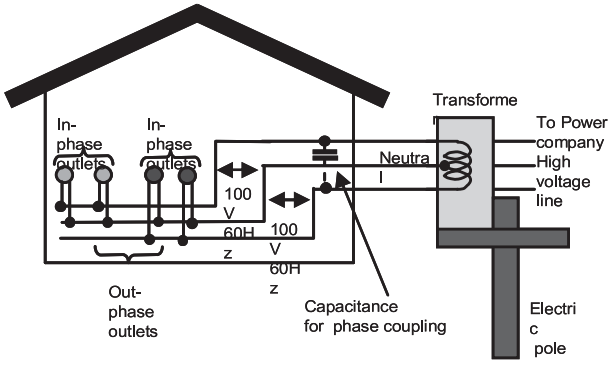

Fig.2. Power line of Normal home

IEEE802.15.4 currently called Zigbee by one of the WPAN (Wireless personal area network) plans as radio is used. This has the performance of a low rate (20Kbps or 250K bps) by low power consumption. Measured value is Fig.3 about the communication performance in the ordinary homes of this Zigbee. The electric field intensity of distance and an electric wave is shown. In prospect distance (open air), electric field intensity is decreased as it separates from near an output antenna so that naturally. In particular, on the second floor, PER showed 40% and a very large value from the first floor in the house of ferro-concrete. Moreover, on the third floor, PER shows 70% and a still larger value from the first floor, and communication performance gets still worse.

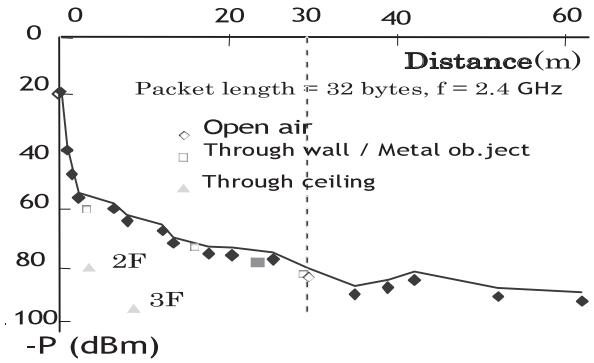

Fig.3. Distance vs electric(dBm)

3 MUTUAL COMPLEMENT NETWORK OF WIRED AND WIRELESS

The preceding clause showed the characteristic of the cable communications PLC and the wireless communications Zigbee. It is difficult to carry out to indoor network completeness with one of communication methods. PLC has a problem of single phase 3 line electric supply, and it has bad communication performance between the electric sockets between unusual appearances. Moreover, even if it puts in a signal coupling instrument between unusual appearances, it does not become sufficient performance improvement.

Although it is satisfactory in the space which Zigbee can keep seeing, it is weak with the obstacle which interrupts a field of view. Then, the communication performance over a floor worsens like the first floor and the second floor. Since the characteristic of these two communication methods is generated according to respectively independent conditions, It is thought that it is mutually suppliable, and also in order to use enough the mutual complement function of a cable and radio to guess the communication performance when using two communication methods simultaneously below, these portions need to consist of unified semiconductors and modules. The valuation basis of the communication quality in network modeling is defined. It is the right data (truth). The data (truth?) which may be right, and the data (imitation) which is not right are classified, and when continuation transmission of the packet data of 40 bytes of both sides is carried out 10 times, the truth criterion of judgment of the data by the side of reception is shown in Table.1.

Table.1. Truth table of reception data.

Classification of reliable	Judgment conditions	Symbol
The truth data	The same data in received in the Truth condition two times successively.	Truth
Possibly the truth data	The Truth data in received two times, but not successively.	Truth?
The false data	Except the above	False

Note: At Fig.1,

As for the frequency of Fig.1, Truth, Truth?, and False is 70%, 10%, and 20%. On the other hand, in the case of radio, it was assumed that the phenomenon between node nodes happened by the same establishment using a typical PER value on each six stories. When it is considered, respectively that PER(s) between a same story and contiguity story and the first floor and the third floor are 2%, 50%, and 70%, the number of phenomena of each conditions is expressed with a figure 8 left-hand-side part, and, as for the frequency by weighted average, 'Truth' 82%, 'Truth?' 14%, and 'False' 4% are obtained. The communication quality at the time of a cable and radio combined use is shown in Table.2. A cable and radio independent communication quality will acquire 96% of value, if Wired's Truth (70%) and Wireless's Truth (82%) improve to 94.6% and 'Truth ?' times 'Truth?' is 'Truth' (1.4%).

Table.2. The Communication quality in % when the wired and wireless communication media are used simultaneously.

		Wireless		
		Truth 82	Truth? 14	FALSE 4
Wired	Truth 70	57.4	9.8	2.8
	Truth? 10	8.2	1.4	0.4
	FALSE 20	16.4	2.8	0.8

Next, the actual proof experiment of the mutual complement network system of a cable and radio was conducted in the dwelling in 3 stories of Ichinohe [8]. Actual proof examination results are all the combination of the first floor to the third floor, as shown in Table.3, and 100% of rate of a data-communications success was obtained.

Table.3. The house of an evaluation experiment. This unit is % display

		Overall success rate			Wired single success rate			Wireless single success rate		
		Floor of reception								
		1F	2F	3F	1F	2F	3F	1F	2F	3F
Floor of transmission	1F	100%	100%	100%	98%	80%	74%	100%	83%	55%
	2F	100%	100%	100%	82%	81%	75%	81%	87%	84%
	3F	100%	100%	100%	75%	76%	76%	60%	83%	93%

It was 86.7%, when the cable independent strike rate was averaged and the radio independent strike rate was averaged 71.1%. In a cable independent, the same story is also presumed to be what a strike rate has about 70% or less of combination, and time, and depends on the difference in phase of the power line to which electricity is supplied, and is in agreement with Fig.4 of the power distribution situation of each story which actually checked.

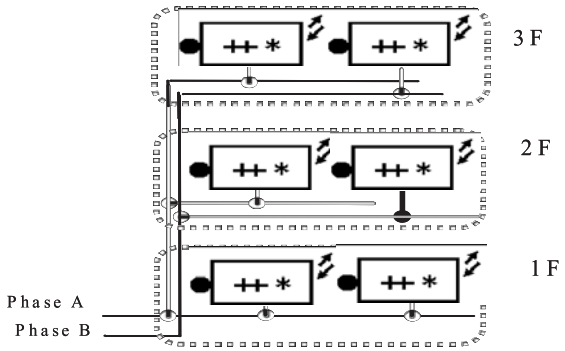

Fig.4. An actual check of the power distribution condition.

In the case of wireless communications, in the case of the same story, it is a strike rate of 100%, and when the second floor is different about 90%, whenever the strike rate of about 60% and a story increase in the case of a contiguity story, range worsens. A communication error performs the supplement at the time of generating at the time of cable independent communication or radio independent communication. Since the error ratio as a mutual complement network is a cable- communications error ratio x wireless-communications error ratio. If it is searched for from the independent strike rate of Table.3. Table.4 is obtained.

Table.4. Assumed success rate between Unit Cells

Floor of transmission \ Floor of reception	1F	2F	3F
1F	100%	97%	88%
2F	97%	98%	96%
3F	90%	96%	99%

If the strike rate of Table.4 is averaged, it becomes 95.7% and is mostly in agreement with 96% of the value of a simulation. In this experiment, since either was communicated by the communication for two points, although it is 95.7%, with a calculated value, an actual measurement becomes 100%, as shown in Table.3.

Although the communication performances of the cable in a home and radio which we have generally got were 70% and 82%, as a result of performing the communication quality assessment of the mutual complement network system of a cable and radio in the dwelling in 3 stories of Ichinohe, the communication strike rate of 100% was acquired as mentioned above, without coping with communication environment in any way. As an average, the strike rate of 95.5 is expectable. A possibility of obtaining an effective network was found out without having improved communication environment in any way to a home or the comparatively small space about a home. I think that 96% of communication quality can be obtained by how to carry out the mutual complement of radio and the cable. Furthermore, in order to measure improvement in communication performance, when the communication for two points was improper, how to go via some relay nodes was examined. The case where each node reached with the first floor, the second floor, and the third floor, and attaches every one a total of six nodes to two phases of a power supply as shown in Fig.5is examined.

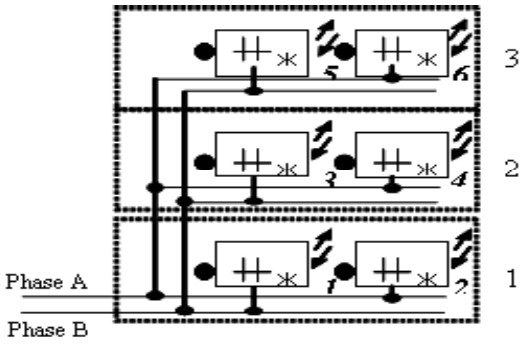

Fig.5. Routing node example at three-story house

The propriety of communication between each node is shown in Table.5. In the case of wred,when was same phase , it thought that communication was possible, and when it was different phase , impossible. In the case of wireless,when was the same floor,it thought that communication was possible,and when it was different floor impossible.

When not knowing the number of stories and the same phase and the the diffrent phase of a power supply in which the node of a communication place exists according to this condition, as shown in Table.6 and Fig.6,

the number of times of communication per route is distributed from 1 time to 6 times. Moreover, when the number of stories is found and it cannot communicate at once, the number of times of communication per route can be reduced even to a maximum of 3 times by using the algorithm of going via the node of the same story as a dispatch node or the purpose node. Furthermore, when the same phase or the different phase phase a power supply is known, it becomes the two or less number of times of communication per route between all nodes.

Table.5. Communication between two nodes
P : Success by PLC communication
Z : Success by 802.15.4 communication
X : Communication impossible

Sending node No. \ Receiving node No.	1	2	3	4	5	6
1	—	Z	P	x	P	x
2	Z	—	x	P	x	P
3	P	x	—	Z	P	x
4	x	P	Z	—	x	P
5	P	x	P	x	—	Z
6	x	P	x	P	Z	—

Table.6. Comparison of communications per route when the floor number and power supply phase are known.

Floor list	Unknown	Known	Known
Same/different phase list	(unknown)	(unknown)	(known)
Number of routing times	Number of communications per route		
1 time	18	18	18
2 times	—	—	12
3 times	24	24	—
4 times	48	—	—
5 times	36	—	—
6 times	24	—	—

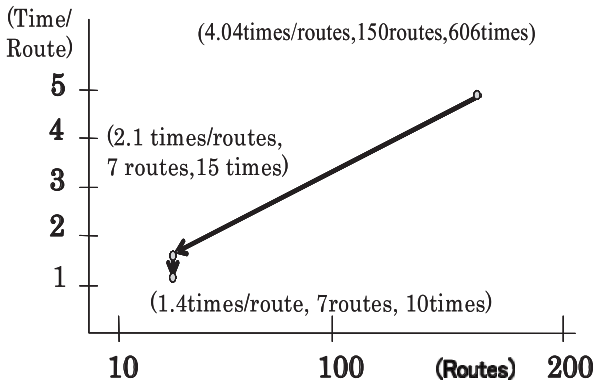

Fig.6. Number-of-times reduction of routing

4 COMMUNICATION PREFORMANCE EVALUATION AT A SMALL BUILDING

We have done the communication performance test by wired and wireless mutual complement network at 3 type different relative small building. We call them A building, B and C. A is the office building with 1586m2 floor, B is the university building with 5365m2 floor and C is the graduate school building with 1920m2 floor.

The measurement result of the each building are showed at Table.7,Fig.6.The equipment list of the building which affects to wired PLC communication and wireless ZigBee is showed on Table.9.

Same situation of each building is that 200V electric fluorescent lamps are equipped, then PLC communication result is better at different phase power line. A is the relatively small building with only one transformer. Normally PLC communication is worse because of multiple transformer, so PLC communication was good because of 1 transformer. Also, in A building , there is 1 restaurant with 200V professional cocking systems, then it was easy for different phase communication because of 200V system connects to 200V; two phase. Success rate of PLC was 98%. On the other hand, the success rate of wireless ZigBee was 8.4%, very bad. Why so bad was because of small windows which can offer open space to ZigBee RF signal and because of metal material wall and door. It was impossible between walls and doors. Even at stairways with open air, it also showed bad success rate because of metal materials stairways.

At B building, PLC only communication success rate was 74.4%. The different phase communication with PLC was OK even at different floors with 200V systems. Between different transformers, as we expected before, the PLC communication was impossible. ZigBee only communication rate was 60.3%. In B Building, there was wide open space at stairways and hallway, so it was easy for wireless ZigBee communication. Especially at stairways space, it was OK for ZigBee communication even between 2 floors difference.

In C building, close to B building case, PLC success rate was 61%. There were multiple transformers in C Building, so as expected before, it was impossible for PLC communication between the transformers. Also relatively small building has 1 electrical box (distribution panel) in 1 floor. In this building, different from B building, the PLC communication between different distribution panel was impossible.

Therefore the PLC communication in the same floor with different phase was OK, but the communication between different floor was impossible. Total ZigBee communication rates was 48.8%. The tendency was equal to B building, but little bit worse communication rate because of narrow open area than B building. Regarding B and C building, the efficiency of the Mutual complement Communication system by Wired and Wireless was proved. Both buildings have the difficult position where PLC and ZigBee communication was impossible. Even if one communication is interruption, aid is given by other the communications of one.

At A building, the efficiency of Mutual complement Communication system by Wired and Wireless was low, because PLC can communicate almost all places.

Table.7. Mutual complement network performance evaluation of each building

Building name	Summary	Number of Tr	Communication performance					
			PLC		Zigbee			MCN
			Tr		Same room	Same floor	Dif floor	
			Com	Dif				
A	1586.4m^2 B1～7F	1	a	-	a	d	x	b
B	5365m^2 B1～4F	3	b	x	a	c	c	a
C	1920m^2 B1～4F	3	c	x	a	c	c	a

Note: a: 95% or more
b: 90% or more
c: 70% or more
d: 70% or less
Tr: Transform(s)
Com: Common
Dif: Different
-: It does not exist.
MCN: Mutual Complement Communication Network

Table.8. The communication performance in each building of PLC and Zigbee (%)

	PLC	Zigbee
A	98	11.1
B	74.4	55.8
C	52	43.8

Table.9.The factor which determines the communication performance of each building

	PLC	Zigbee
A	performance good. In existence of 200v fluorescence lighting and cooking apparatus	Only the inside of the room can be communicated. a small window, a metaled door, the wall of a steel rod.
B	Except for between transformers, it is performance good.	Good on stairs. Good to a length of 30m in a passage.
C	Except for between transformers, it is performance good.	Good on stairs. Good to a length of 30m in a passage.

4.1 PLC characteristic in the relatively small building

Normal power wiring example in the relatively small building is showed as Fig.9 based on the one of C building. 6600V, high voltage from power station was transformed to 100V/200V with R/T/N phases by the transformer and distributed to each home's distribution panel.

From distribution panel, 100V was distributed to each consent (power outlet) by the connection of RN and NT separate from 200V. The PLC communication on different Phase during 100V appliances must become back to transformer. In the transformer, the quality of the PLC communication between different phases becomes worse because of noise and electrical transform. When using 200V appliances, PLC communication can be sent to the destination point without backing to the transformer.

The PLC communication signal is on R and T phase of AC line, if R and T was tied by 200V appliances, the communication between different phases becomes easy because of the R & T bridge. At the relative small building where we have done this experiment test, each building was using many 200V appliances. Therefore the improvement of PLC communication performance was done between the different phase where PLC does not like.

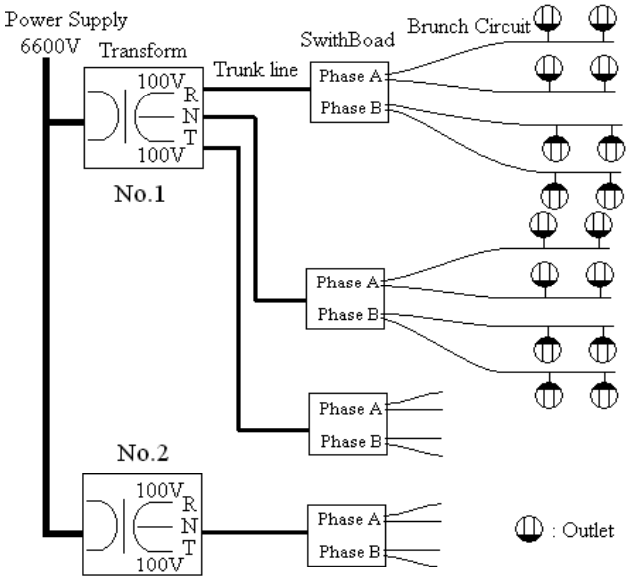

Fig.7 The power line routing diagram in C building.

Note: There are 3 transformers, but 1 is for motor power duty, so we have not described the one. Main Power line has 3 phases; R,N and T phase. These are separated to each power outlets through power distribution panel.
Phase A: R-N Phase B: N-T

The experiment test result by wired PLC line is showed on Table.10. It shows the result of C building. C building has 3 transformer. The transformer for normal appliances are 2 and showed as Fig.7. This transformer has 3 main power lines. No.1 transformer is for B1~2F and No.2 transformer is for 3F, 4F, computer room, server room. Then main power line of each transformer comes to each power outlet in the room through each floor's power panels. Basically each floor uses 1 main power line.

At our experiment, we got very nice testing result (means PER=0%) when same main power line, that is same floor even at different phases. This nice result is from the following reason; 200V fluorescent lamp acts as the bridge between R and T phase which contains PLC signals, PLC signal does not need to come back to transformer and PLC signal reaches to different phase line directly not through transformer.

But regarding the PLC communication between different floors with different main power lines, PER becomes up (worse) and it was impossible to make PLC communications. The reason of the worse result is as follows; when communication to different main power line, the PLC signal comes to outside transformer once , also gets many noise and may attenuate PLC signal power.

It was impossible to make PLC communications through different transformer. The theory of transfor-

mer is as follows; primary coil gets magnetic flux at the metal core by AC current and secondary coil gets electromotive force. In order to get PLC communication, actual connection of wire is necessary. Primary coil and secondary coil is not connected, so PLC communication must not happen. It is impossible for PLC communication during transformer.

Table.10. PLC communication success rate (%)

Transform	Floor						
No.1	PC	100					
	4F	50	100				
	3F	-	18	100			
No.2	2F	-	-	0	100		
	1F	-	-	-	4	100	
	B1	-	-	-	-	0	100
		PC	4F	3F	2F	1F	B1
		No.2			No.1		

Note: PC: Computer room / Server room
-: it dose not evaluate

In order to show each route communication performance easily, we defined load level number as Table.11. It is trial to show PLC communication characteristic by load level number.

The decision items to decide load level are 4 items; transformer, main power lines, phase and brunch circuit as Fig.9. Load level 1 shows lowest load on the communication route and highest communication success rate when transmit and reception power outlets are on the same power lines with same brunch circuit. According to different brunch circuit, different phase, different main power line and different transformer, load level becomes higher and communication becomes more difficult.

Actual experiment result and load level at C building are shown as Fig.8. Black dot shows actual experiment value and black line shows load level according to the black dots. According as load level becomes high, PLC communication performance becomes worse. At this experiment, when same main power line, PLC communication success rate was 100%. This was the result because of 200V appliances which can enable the PLC communication between different phase which PLC does not like. There is difference between black dot and line of Level4 and level5, but black line may be expected to show theoretical value because the PLC communication between different phase is worse than same phase.

According to above result, at the relatively small building with many 200V appliances, when same main power line, PLC will be effective communication method regardless of phase difference before level 3.

Table.11. The definition of the communication load level in PLC

Load Level	Transform	Trunk line	Phase	Brunch Circuit
1	Y	Y	Y	Y
2	Y	Y	Y	N
3	Y	Y	N	—
4	Y	N	Y	—
5	Y	N	N	—
6	N	—	—	—

Note: Quantification is defined for the load of the course from the wall socket to the target wall socket which transmits. Reference figure fig7
Y is in the same wiring and is yes.
N is in different wiring and is NO

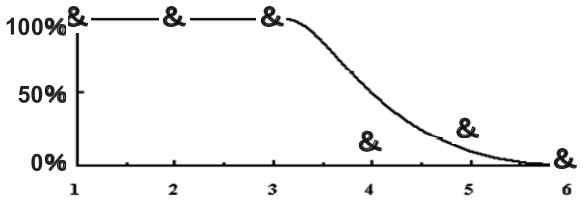

Fig.8. Relation between the communication load level and a communication performance.

Note: "&" mark is an actual measurement.
A communication performance falls in proportion to the communication load level

The distribution of PER at small building is shown as Fig.9. The total routes of this PLC experiment in these 3 buildings were 139 routes. At small building, the frequency distribution was 64.7% with 0% error, 26.6% with 100% error and 8.7% with 0~100% error, then these data was almost close to normal house case.

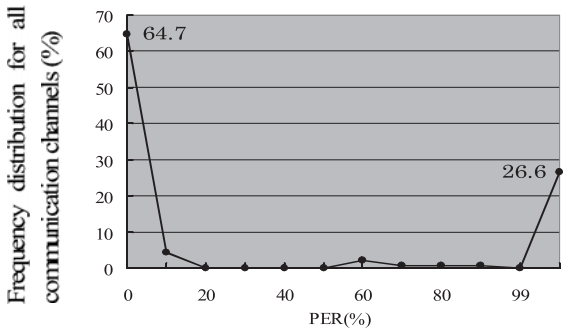

Fig.9. The PLC experiment result at 3 small buildings with total 139 case.

We compare the PER of Fig.1 at normal houses to the PER of Fig.9. at small buildings, then we show the result at Table. 12. At small buildings, PER100% number is 3.4 points lower than the PER100% of normal house and PER 0% number is 5 points higher. This means that PLC communication performance at small building is better than the one at normal houses. The reason of this better performance is as follows; many 200V appliances at small building will give good bridge function to different phase communication.

Table.12. The average value comparison of PER at home network and small building.

PER	Home	Building	Diff
100	30	26.6	3.4
0	60	65	5

Note: Compare to home network, PLC performance in small building is better than home network. (%). Diff: Difference

4.2 ZigBee performance at small bulding

Regarding RF ZigBee communication, we have done this experiment with 500 packets with 20 sec interval.

A building locates in city center area and has relative small windows and narrow metal stairs. Because of iron metal door, ZigBee can not make communication well. The communication success rate was only 8.4%. B and C building are university building with open wide air. The RF ZigBee rate of B building was 603% and C was 48.6%. Near by stairs, the ZigBee communication between floors was OK and we got nice RF communication performance. The actual experiment value of RF communication in B building was showed by Fig.10.

At the university building with wide open air, ZigBee can communicate even between 2 floors with high communication success rates. ZigBee communication performance in small buildings is affected much by wall density and material

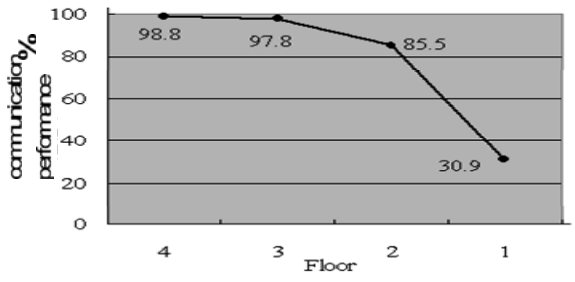

Fig.10. The ZigBee communication success rate from 4th floor to other floors at B building. Near stair place, the communication perforance is still OK even between 2 floors distance.

4.3 The performance of Mutual complement Communication system by Wired and Wireless

After actual experiment, we found that Mutual complement Communication system by Wired and Wireless originally for home network is still effective for relatively small building.

As A building with only 1 transformer shows, wired PLC communication can be effective highly. But it is difficult for the buildings with multiple transformers to have good PLC communications under multiple transformer and main power lines. Especially, through different transformer, it was impossible to have PLC communication.

From this experiment, Regarding PLC communication, in order to solve multiple transformer problems and main power line problems, ZigBee communication at the open air and stair place must be effective and Mutual complement Communication system by Wired and Wireless shown on Table.7 must be effective at relative small buildings. Moreover, as shown in Fig.11, compared with the home, it has checked that the variation in a communication performance was also large.

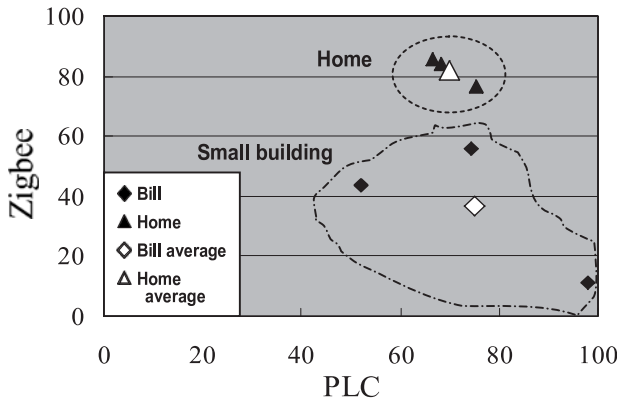

Fig.11 The difference in the communication (PLC and Zigbee) performance of a small building and a home.A small building has the large distribution of a communication performance.

5 CONCLUSION

We have done actual experiment in order to adapt Mutual complement Communication system by Wired and Wireless originally for home network to 3 small buildings. As the result, we found that Mutual complement Communication system by Wired and Wireless originally is still effective for relatively small building without any additional modification about communication environment. We also found that in small building there are more difference in communication performance by wired and wireless compare to

home network. In wired, multiple transformers will affect to communication performance.

On the other hand, 200V business professional kitchen system and business fluorescent lamp will give good affect to wired PLC communication. As for ZigBee communication, from the security reason, small builfding's door and windows are small and metarised, therefore the ZigBee communication will get worse performance . From above result, the performance of mutual complement Communication system by Wired and Wireless in buldings is different from the one of normal home as following 2 two items;

The first item as for PLC, it is impossible between multiple transformers to have PLC communication. On the other hand, 200V appliances as "bridge function" will help PLC high performance communication between each floor's distribution panels and different phase.

The 2nd item ,the ZigBee communication area is relative narrow. Only within room distance and same floor level with good condition. Also at stair portion and open air, we can expect higher communication performance, almost equal to 100%.

Regarding the adaptation Mutual complement Communication system by Wired and Wireless to small building, from our actual experiment, the PLC communication with bad performance by multiple transformer and main power lines must be gated by ZigBee communication. In normal home network, we do not need to consider this issue. But in small buildings, we must consider this gating. Regarding gating position, there must be open air position or stair position in the bulding. We must put the gate function to bridge PLC and ZigBee at power outlet position for network communication at each floor.

In normal home network, we do not need to consider any additional equipment regarding Mutual complement Communication system by Wired and Wireless, but in the building case, we must put special node outlet with PLC and ZigBee function. At this report, we have determined communication load level regarding PLC communication, furthermore in order that this value becomes more and more, we must pay attention more about PLC communication. Also regarding ZigBee, we would like to determine ZigBee communication load level from now on.

At relative small buildings, there are 4 or 5 routes like power lines, internet lines, security lines, TV lines, telephone lines and so on. It is important to monitor these lines and to integrate these lines, therefore we believe that Mutual complement Communication system by Wired and Wireless must be beneficial for these integration.

By this study, the important characteristic at the time of being adapted for a home in this mutual complement network was able to be known. When floor area and a class increase, as for Zig-bee of wireless communications, a communication performance falls remarkably by becoming a small building, so that more clearly than Fig.11. However, PLC of wired communications can expect improvement in the communication performance by 200v apparatus, if the fall of the characteristic by the increase in a transformer is removed. By these, evaluation of this mutual complement network to a small building can be understood that an effective thing is shown, if addition of the transformer of supply electric power is removed also in a still larger dwelling to application at home.

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Kunihiro Yamada received the B.E. degree in electric engineering from the Ritsumeikan University in 1973 and received the Ph.D. degree in industrial scirnce and engineering from Sizuoka University, Japan, in 1992. In 1973, he joined Mitsubishi Electric Corp. Since 2005, he is a Professor of Tokai University, Japan. Now, he is a Professor of professional graduate school of embedded technology of Tokai University.

Takashi Inoue Enrollment in Software development engineering department form School of Information Science and Technology Tokai Univiersty

Masanori Kojima received the B.E.degree in electric engineerimg from Osaka University , Japan ,in 1973.He joined Kyoto Works,Mitsubishi Electric Corp the same year and has been engaged in the circuit design of television and VCR. Dr Kojima is a member of IEICE of Japan , IEE of Japan and ITE of Japan.

Kouji Yoshida recieved his Dr.(2001) from Shizuoka Univ. in Japan. He went on to be a Computer Scientist in the Information Engineering Works at Mitsubishi Electric Corp. He is a Professor at Shonan Institute of Technology. He is currently a Research and education Scientist in the Institute of Technology. His major research includes distance learning and information technology. He is one of the members of IPSJ, IEICE Japan.

Tadanori Mizuno received the B.E. degree in industrial engineering from the Nagoya Institute of Technology in 1968 and received the Ph.D. degree in computer science from Kyushu University, Japan, in 1987. In 1968, he joined Mitsubishi Electric Corp. Since 1993, he is a Professor of Shizuoka University, Japan. Now, he is a Professor of graduate school of Science and technology of Shizuoka University. His research interests include mobile computing, distributed computing, computer networks, broadcast communication and computing, and protocol engineering. He is a member of Information Processing Society of Japan, the institute of electronics, information and Communication Engineers, the IEEE Computer Society, ACM and Informatics Society.

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