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# A Message from the General Chair

It has been a great pleasure for me to serve as the General Chair of the International Workshop on Informatics (IWIN2007), September 9 and 10, 2007, Napoli, Italy, sponsored by Informatics Society. I received a number of high quality submissions for consideration at the IWIN2007. These papers covered a broad range of topics in Computer supported cooperative work and groupware, Intelligent transport system, Distributed Computing, Multi-media communication, Information systems, Mobile computing, Ubiquitous computing, and so on. They demonstrated many practical applications that would be of interest to a large number of professionals. Each of the papers was of exceptional quality and presented a unique contribution in the field. After the review process, with extensive discussion with the program chair, I am able to accept top quality, technical papers on various areas of Informatics at the conference as well as for publication in the conference proceedings. These papers were selected considering various criteria including the quality, significance, current interest among the professionals, available resources, and conference scope. We want to thank all of my colleagues for their interests and contributions in the IWIN2007. It was indeed an honor to work with a large group of professionals around the world for making the IWIN2007 a great success.

We are looking forward to seeing you all in the conference. We wish you all a great and enjoyable meeting in Napoli, Italy.

Tadanori MIZUNO
General Chair
The International Workshop on Informatics

# Session 1: Information Processing

# Implementation of Integrity Maintenance Method of Query Result by Bitemporal Database

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***Abstract*** - In many mission-critical systems, databases are updated by transaction processing, and are queried by batch processing to make statistics and so on. It is necessary that the processing of both can be executed at the same time for the efficient system operation. The integrity of the query result can be maintained by using a bitemporal database even while the database is being updated. However, in actual operations of mission-critical systems, various kinds of problems occur such as the entry mistake and being behind in the data entry. Therefore, the bitemporal database has to be able to support these problems. In this paper, we show the case to have applied the bitemporal database to a mission-critical system, as an implementation of the method to maintain the integrity of the query result. By this case, we confirmed that this integrity was maintained even while the database was updated, and that various kinds of corrections done by the actual operations of the system were reflected in the query results. Furthermore, we confirmed that it was effective for the data corrections not only for a short term but also for a long term, and that the correction of the data could be managed at both of the internal process and the business procedure individually.

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

## 1 INTRODUCTION

In many mission-critical systems such as retail systems, financial systems and manufacturing systems, data are entered from online-terminals (this is abbreviated to ”online entry” in the following) and reflected in databases by transaction processing. Then, regular or any time, the databases are queried by batch processing to query a great deal of data in a lump for making of statistics documents, analysis documents and so on. For example, regarding the retail system, the sales data are entered from stores and reflected in its database. Then, settlement of accounts processing is performed regularly such as daily or monthly, and it is processed by the batch processing to query a great deal of data in a lump. Therefore, it is necessary that the online entry, and the query of batch processing can be concurrently executed for the efficient operation of the system.

Here, the snapshot database [2], which stores only the latest state of data, has a problem that the integrity of query result isn't guaranteed when a great deal of data are queried in a lump during the database updating. Database systems are equipped with the transaction processing [4] that uses lock control for concurrency control, and simultaneous accesses of plural users to the database are controlled to maintain the integrity by it. And, even if mass data handling is performed, a method to divide a long time transaction into plural transactions by mini-batch [4] was shown. However, a long time is necessary for querying a great deal of data. So, even if the query processing could avoid conflict with the update processing for each data of the database, one part of the query result may become after update although the other part is before update.

On the other hand, the temporal database manages the data that change in chronological order, and many researches were performed about it [3], [6], [7], [11], [13], [14]. In the temporal database, 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 reality; the transaction time is the time during which the fact was present in the database as stored data. And, temporal databases are classified as valid time database, transaction time database and bitemporal database: The valid time database manages valid time; the transaction time database manages transaction time; the bitemporal database manages both of valid time and transaction time [12].

It was shown that the transaction time database can express states of the database of the designated past transaction time as the snapshot [5], and it isn't affected by current updating of data. However, in actual system operations, when error data were detected by batch processing, we have to correct the data and redo the batch processing. In this case, there is a problem that the corrected data are not reflected in the query result of the redo batch processing, because the transaction time of the corrected data becomes after the designated time of the query.

Besides, the version-control data model manages not only the time of addition and deletion of data, but also the derivation relations of the versions [8], [9]. So it can manage both set of the version that derived from the data set of the designated transaction time: the one set is created in chronological order by the normal data entry; the other set is created by the data correction. So, the corrected data can be reflected in the querying result. This model is important in the fields of software development, version management of CAD, and so on. But, in the case of applying it to the mission-critical system that needs high data input frequency, there is the problem that

both of detecting correction data and deriving a new version have to be executed frequently.

Here, by the bitemporal database, we can query the result that has integrity and reflects data corrections even while the database is being updated. However, to apply a database to mission-critical systems, the database has to cope with various kinds of corrections that occur in actual system operations. And, we could not find the case that have applied a bitemporal database to an actual mission-critical system and then that have evaluated it. In this paper, we show the bitemporal database can maintain the integrity of the query result, in which various kinds of data corrections occurred in the actual system operation are reflected, even while it is being updated. Furthermore, we applied it to a mission-critical system and evaluated its effect in actual system operations. As a result, we confirmed that the above-mentioned integrity was maintained, moreover, it was effective for the data corrections for a long term and the corrections of the data could be managed at both of the internal process and the business procedure individually.

In section 2, we show the problem of the query of a transaction database during the database being updated, which we should solve, and show it is solved by the bitemporal database in section 3. In section 4, we show an implementation case of a bitemporal database in a mission-critical system and the operation of the system. Finally, in section 5, we evaluate the implementation and operation of the system, and discuss about them.

# 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 with Update Processing**
The query processing is executed concurrently with the transaction processing that update the database with high frequency.

ii. **Query of Mass Data in a Lump**
Mass data are queried in a lump, so the processing takes time.

iii. **Redo after Data Correction**
When error data was detected in the query result, we have to correct the data such as change, deletion and addition. Then, the data have to be queried again by the same condition.

Such a query processing is a general form in mission-critical systems like processing of the settlement of accounts of retail systems, in which query of mass data is executed by batch processing. Transaction processing of database systems equips various kinds of integrity constraints [4], and the method that maintains the integrity of the database by the cooperation even when it was updated by a group of people was proposed [10]. Therefore, the integrity of the database is maintained in many

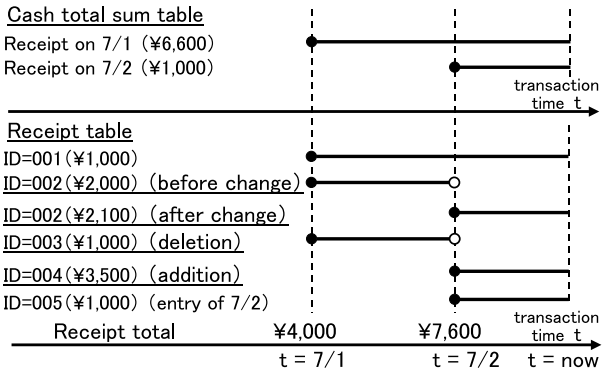



Figure 1: Snapshot of transaction time database.

cases. However, the confirmation of the integrity, which has to query mass data, has to be executed by batch processing. For example, the comparison of plural tables, the calculation of the receipt total to compare with the actual cash total sum, and so on. Therefore, the batch processing has to be redone after correcting data when error data was detected.

## 2.2 Query Method during Database Beimg Updated

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. While the data isn't deleted yet, $t_d$ is expressed by "$now$", which shows the time when querying is executed [1], [12]. When we change a data, the deletion time of the data is set to the time of the change. Thereby it is logically deleted. Then, a new data is added to the database as the data after change. 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 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 error data 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, the 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.

Here, including 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 update frequency of data.

## 3 QUERY OF 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 section attribute of the transaction time, which is generated by systems and isn't made public to the users. Here, $T_a$ 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. While the data isn't deleted yet, the instance of attribute $T_d$ is expressed by "$now$".

- $V = \{V_a, V_d\}$
  This expresses the time section attribute of the valid time, i.e. the time section of the corresponding fact was true in the real world. Here, $V_a$ shows the beginning time of the time section, and $T_d$ shows the ending time. In the case that the data is true yet when we query it, the instance of attribute $V_d$ is expressed by "$now$" same as $T_d$. 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 the designating valid time by querying the database.

- $A = \{A_1, ..., A_n\}$
  This expresses the other attributes.

### 3.2 The Query Method of Bitemporal Database during Being Updated

Because the bitemporal database manages the transaction time, the integrity of the snapshot is also kept even if the database is updated while querying it, in the way like the transaction time databases shown in section 2.2. Moreover, because it manages the valid time, we can query the state of the real world of the designating valid time.

Data of the database on 7/2

Cash total sum table

| Date | Ta | Td | Va | Vd | sum |
|---|---|---|---|---|---|
| 7/1 | 7/1 | now | 7/1 | now | 6,600 |
| 7/2 | 7/2 | now | 7/2 | now | 1,000 |

Receipt table

| ID | Ta | Td | Va | Vd | Receipt | (1) | (2) | (3) | Kind of data |
|---|---|---|---|---|---|---|---|---|---|
| 001 | 7/1 | now | 7/1 | now | 1,000 | ● | ● | | |
| 002 | 7/1 | 7/2 | 7/1 | now | 2,000 | ● | | | before change |
| 002 | 7/2 | now | 7/1 | now | 2,100 | | ● | | after change |
| 003 | 7/1 | 7/2 | 7/1 | now | 1,000 | ● | | | deletion |
| 004 | 7/2 | now | 7/1 | now | 3,500 | | ● | | addition |
| 005 | 7/2 | now | 7/2 | now | 1,000 | | | ● | entry on 7/2 |

Snapshot of receipt table

(1) $t_1$ = 7/1, $t_2$ = 7/1

| ID | Ta | Td | Va | Vd | Receipt |
|---|---|---|---|---|---|
| 001 | 7/1 | now | 7/1 | now | 1,000 |
| 002 | 7/1 | 7/2 | 7/1 | now | 2,000 |
| 003 | 7/1 | 7/2 | 7/1 | now | 1,000 |
| | | | | Sum | 4,000 |

(2) $t_1$ = 7/2, $t_2$ = 7/1

| ID | Ta | Td | Va | Vd | Receipt |
|---|---|---|---|---|---|
| 001 | 7/1 | now | 7/1 | now | 1,000 |
| 002 | 7/2 | now | 7/1 | now | 2,100 |
| 004 | 7/2 | now | 7/1 | now | 3,500 |
| | | | | Sum | 6,600 |

(3) $t_1$ = 7/2, r[Va] = 7/2

| ID | Ta | Td | Va | Vd | Receipt |
|---|---|---|---|---|---|
| 005 | 7/2 | now | 7/2 | now | 1,000 |
| | | | | Sum | 1,000 |

Figure 2: Snapshot of bitemporal database.

The snapshot of $R$, of which transaction time is $t_1$ and valid time $t_2$, consists of the data that satisfy the both following conditions: its instance of transaction time section $T = \{T_a, T_d\}$ includes $t_1$; its instance of valid time section $V = \{V_a, V_d\}$ 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. In the bitemporal database, the actual receipt date can be managed. Therefore, as shown in 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.

# 4 APPLICATION TO MISSION-CRITICAL SYSTEM

We applied the bitemporal database to a local government system of city hall, which was a mission-critical system. In this section, we show the overview of this system, and the implementation of the bitemporal database.

## 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 subsystems for the business. 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 Characteristic of the Database

Each business needed the record data management of the 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.
- **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.

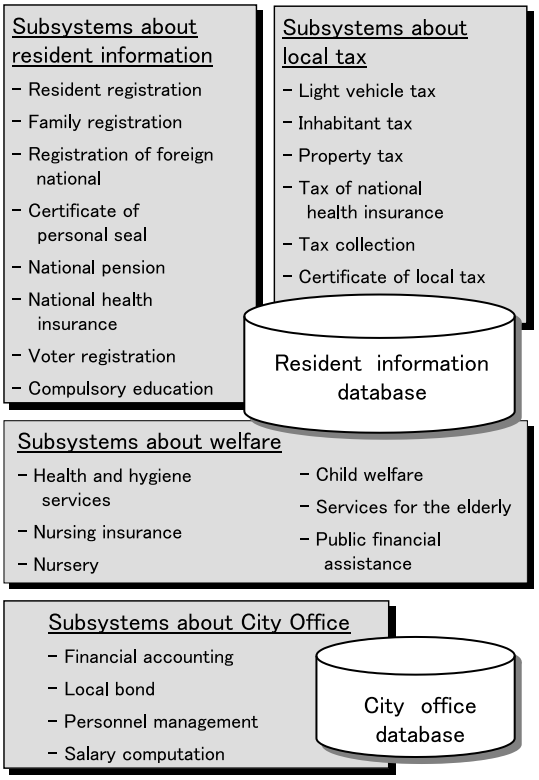



Figure 3: Composition of local government system.

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 online entered 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 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 decide from 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 into 1 second.

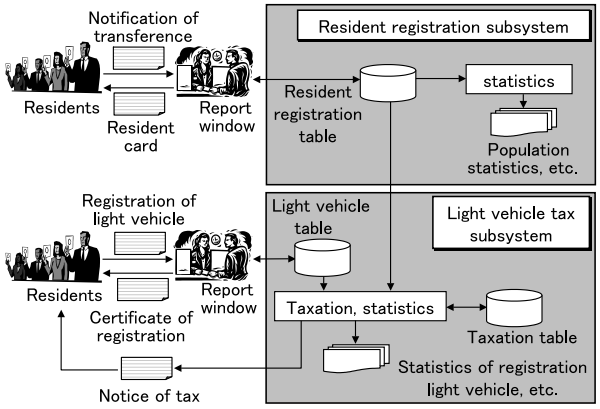



Figure 4: Dataflow example of local government system.

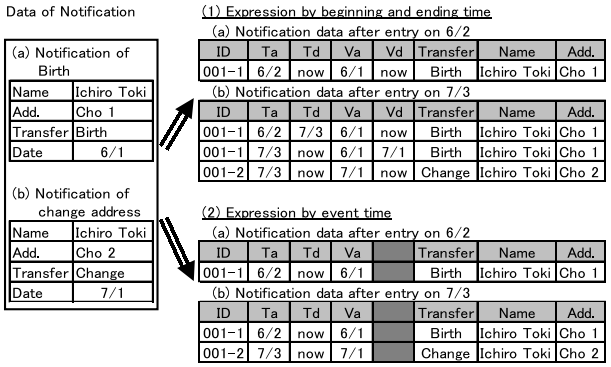



Figure 5: Expression of valid time.

#### 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**
  There were data of the system that state were changed 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, of which the ending time $V_d$ is set to July 1st that is the beginning time of next record.
- $ID = 001 - 2(T_a = 7/3)$: the data that address is 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 on 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 of residents such as population statistics, transfer statistics of residents had to be created after the business end of the designated date to be reported on 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


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.

time of the notification date. Here, the ending time becomes the notification date of the next notification. That is, the time section 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 that the data that notification date is June 2nd were corrected on June 3rd. Item (1) of Figure 6 shows the query result designating both 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 online entered from the business screen of the terminals. Regarding business, this entry had the following characteristic.

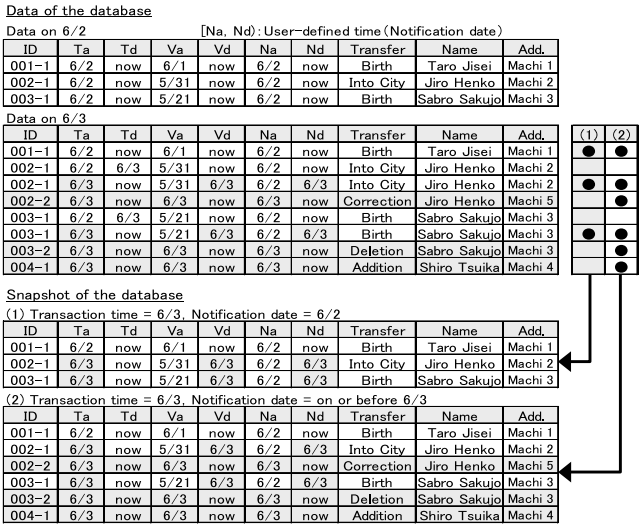
- For the entry was done by the notification of the resident, the simultaneous entry of the identical resident from more than one terminal could not happen in the general business.
- The entry time at the report window was comparatively long to confirm the notification contents.

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


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 | 6/3 | 6/2 | 6/3 | Into City | Jiro Henko | Machi 2 | ● | ● |
| 002−2 | 6/3 | now | 6/3 | now | 6/3 | now | Correction | Jiro Henko | Machi 5 | | ● |
| 003−1 | 6/2 | 6/3 | 5/21 | now | 6/2 | now | Birth | Sabro Sakujo | Machi 3 | | |
| 003−1 | 6/3 | now | 5/21 | 6/3 | 6/2 | 6/3 | Birth | Sabro Sakujo | Machi 3 | ● | ● |
| 003−2 | 6/3 | now | 6/3 | now | 6/3 | now | Deletion | Sabro Sakujo | Machi 3 | | ● |
| 004−1 | 6/3 | now | 6/3 | now | 6/3 | now | Addition | Shiro Tsuika | Machi 4 | | ● |

Snapshot of the database

(1) 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 | 6/3 | 6/2 | 6/3 | Into City | Jiro Henko | Machi 2 |
| 003−1 | 6/3 | now | 5/21 | 6/3 | 6/2 | 6/3 | Birth | Sabro Sakujo | Machi 3 |

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

| 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 | 6/3 | 6/2 | 6/3 | Into City | Jiro Henko | Machi 2 |
| 002−2 | 6/3 | now | 6/3 | now | 6/3 | now | Correction | Jiro Henko | Machi 5 |
| 003−1 | 6/3 | now | 5/21 | 6/3 | 6/2 | 6/3 | Birth | Sabro Sakujo | Machi 3 |
| 003−2 | 6/3 | now | 6/3 | now | 6/3 | now | Deletion | Sabro Sakujo | Machi 3 |
| 004−1 | 6/3 | now | 6/3 | now | 6/3 | now | Addition | Shiro Tsuika | Machi 4 |

Figure 7: Correction as business procedure.

iv. If it is being locked or its addition time is updated, the data is judged that has been updated by the others and 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**
  This correction of the entry error data was done in the step of the internal process of the local government.

- **Correction as Business Procedure**
  This correction was done as usual business procedure of the local government.

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 was 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: notification date was before or at June 3rd, i.e. $N_a \leq 6/3$ and transaction time was June 3rd.

## 4.5 Operation of Batch Processing

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

### 4.5.1 Query of Data at End of Business Hours

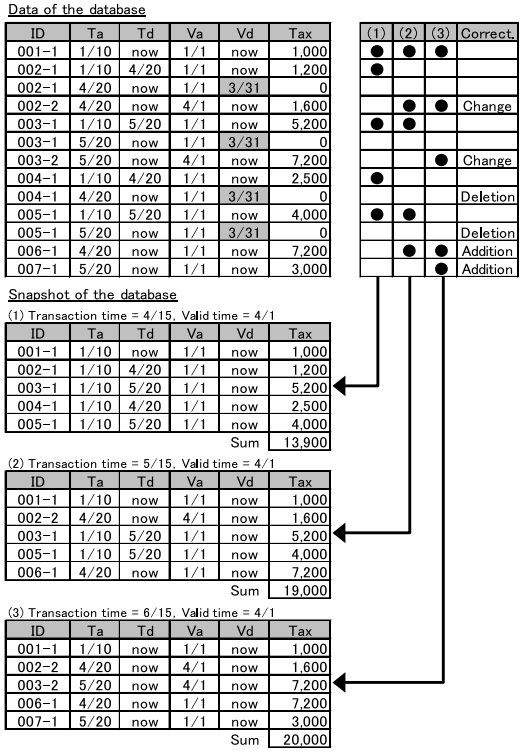
Various statistics such as the population statistics were created daily or monthly on the end of the business hours of the day, and their results were reported on the next day. In the conventional system operation, they had been made by the night batch processing after the business hours of the report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

In the batch processing, query results were checked at the first step. And, when error data were detected, the batch was redone after the data were corrected. 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 paragraph 4.2.4.

### 4.5.2 Query by Designating Valid Time

In the taxation processing, the base date of the taxation was set and it was done after the date. However, since the notification of the transfer of taxable article usually took time until its notification to the local government, corrections of the taxation for the delay of the notification had to be done.

In the case of the light vehicle tax, the taxation processing had been executed with the base date of April 1st, and since then, its correction processing were regularly performed. Figure 8 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.




| 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 |

| 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 |

| 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 |

| 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 |

Figure 8: Query Results by designating valid time.

# 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 correction.

Since the queries in batch processing became to be able to execute during 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 the batch processing overlaps on the same day, it enabled to make the schedule of batch processing flexibly, in which, for example, the low processing of priority was executed later such as on 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 paragraph 4.2.4. In the statistics, which were created at the end of business hours of the designated date by using these data to report on 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 at the end of business hours of the designated date.

#### 5.1.2 Query of Correction for a Long Term

Like the taxation processing as shown in Figure 8, some business needed to manage its correction for a long term 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. And, we could easily create the transfer statistics by querying total in the last time and this time and the total of the transfer between the both times. Moreover, it could be executed during the online entry, because this query processing 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 managing transfers, because the correction records in this step did not be needed by the business procedure, these corrections were performed as the internal process of the system. On the other hand, after the data were used by the business procedure, their corrections were 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 of 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 one change as shown in item (1) of Figure 5: a data after change of the valid time and a data after change of all. 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 table 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 the table of the application system, this increase was 20% in a year even if maximum and was less than twice within 5 years of 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, about the query procedure, though it was complicated in some procedure such as the query joining more than one table, we could build the system within the function range of a commercial relational database by using a module language.

### 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 online entries were performed. Moreover, we confirmed that this is effective for the system operation, because the night batch processing to query the data at the end of business hours of 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, which had been about 1.5 hours a day in 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 development 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 time was 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 Term

The data, which are correcting for a long term, have to be managed by its records of correction since the base time of the business until the time query. The bitemporal database manages both 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 term, 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 doesn't accumulate records for business procedure, but these correction records are accumulated inside the database by using the transaction time. Therefore, we consider that this correction is effective in the management of the change process of data, and in the system that needs to adapt inspection of a high level.

## 6 CONCLUSION

We applied the bitemporal database to the mission-critical system, so that we confirmed that the corrections of data were reflected in the query result, of which integrity was maintained by it in the actual systems operation, even while the database was being updated. Furthermore, we confirmed that it is effective for the data corrections not only for a short term but also for a long term such as managing the records to create the transfer statistics. Also, the corrections of the data could be managed at both of the internal process and the business procedure, so that we confirmed that we could query only the records of one kind when necessary and it was effective in the business.

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# A Sharing Method of Real Objects Differ in Syntax each other through Virtual Sticker between Distant Mixed Reality Spaces

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***Abstract*** - In remote collaboration based on real objects, the difference of the space structure between the remote real spaces should be considered. In conventional method it is difficult for users to collaborate based on the real objects which differ in syntax each other. To address this issue, we focus attention on a sticker or a sheet which can be attached on a physical object according to its surface. And as a method which Mixed Reality (MR) technology is combined with it, we propose an information sharing method of semantics which each remote user interacts with a real object, by using virtual sheet which can be attached to each real object according to its surface and can absorb the difference in syntax between these real objects. Then we implemented a prototype system which has pointing function and conducted experimentation. As a result it proved that it is possible to share the information of the interactions without losing the meaning between the real objects which differ in syntax each other.

***Keywords***: Augmented Reality, Collaborative Workspace, Work Support System.

## 1 INTRODUCTION

Earlier it was also popularly practiced as remote collaboration system, remote users collaborated with sharing electronic data through a network[1]. In these systems, users could not treat information of real world and objects. So they could not get the sense of touch and could not do an intuitive manipulation. Later MR(Mixed Reality) made it possible, that they took in information of the real world in a virtual world. And then MR was applied to collaboration ways, in that users work with sharing virtual information in remote places. It 's hoped that remote work support systems or cooperative work systems in that users feel as if a remote participant works in the same workspace will be come to realization.

However, when users treat real objects, there were two types of remote collaboration system. The one is an asymmetric remote collaboration system and the other is a symmetric one. The asymmetric system was such as only worker manipulates his or her own real object and the other user (he is a director or a supporter) directs him watching a view of worker. But it was impossible, that both users, who had their own real objects in remote places, treated their own real object each other and collaborated through them (it 's symmetric remote collaboration system). Different manipulations of each remote user make some discrepancies between states of each real object, so it 's too difficult to make the same state in remote place. If they tried to actualize such as symmetric collaboration system, they must make completely the same structure of objects between remote workspaces by using some actuators or mechanical architectures.

In this research, the change in thinking makes it possible, remote users have their own real object and collaborate naturally, without discrepancy between states of real objects. We treat workspaces not as based on world coordinate system, but as based on the virtual sticker that is put on the surface of the real object.

Remote users have their own real object that is target of the work in each workspace. They put the virtual sticker on the surface of their real object and then they manipulate them. Processes of the manipulations and their effects are displayed upon the sticker and shared between the remote workspaces. A function of the sticker is an elastic essence. Even though they have real objects that differ in syntax (that means size, shape···), they can put the virtual sticker on the various object and collaborate through them by sharing information.

We propose " A Sharing Method of Real Objects Differ in Syntax each other through Virtual Sticker between Distant Mixed Reality Spaces ". We also implemented the prototype system called " MR Shared Surface " that makes our concept actualize, and evaluated it.

## 2 BACKGROUND AND PROBREM

There are some examples of remote collaboration or communication with real object. Tangible interface provides interaction with digital world through real object to us. By applying tangible interface to remote environment, "PsyBench " [2] that Ishii and the others developed realized remote collaboration based on interaction with real object. In "PsyBench " system, XY-stage is built by putting electric magnet under a table in each remote places and magnets are set under bottom of objects on the table. It makes physical state on the table coincide between remote places.

Sekiguchi and others developed "RobotPHONE "[3] that realized remote communication by sharing motion of teddy bear-shaped robot through Internet and making it coincide. These systems that use tangible interface offer a sense of touch and make manipulation intuitive, however, there are some problems. One is that, there are physical restrictions on mo-

tion of objects, as effects of manipulation to real objects are realized through magnetic or mechanic actuator. Another problem is unnatural behaviors such as a real object moves suddenly. Cause of it is that, there is no information of awareness where the other user is going to manipulate.

## 2.1 Remote Collaboration in Mixed Reality

Feeling of Mixed Reality :MR that is technology to do excellence of electronic data such as CG or a letter to reality space is applied currently in various fields such as work support in the field of industry [4], entertainment [5] or medical care technology [6]. MR let users communicate or collaborate with treating information of the real world. Simon and others developed "3-D Live "[7] that observer can watch a real-time 3D image of whole body of remote user from all angles he or she want in real space.

Dieter and others developed a system that's 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 face-to-face users work in the same real space, but in remote places they collaborate by sharing 3D window.

There is an example that user treat directly the real object in remote collaboration. Suzuki and others proposed a remote support system[9]. In this system they assume relation as a worker and a director and the director direct by pointing with watching an immersive worker 's view. From a remote place the director can watch a stereo image of worker 's view through a HMD (Head-Mounted Display) and manipulate a virtual pointer displayed in the worker 's real space instead of his or her finger. The worker feels like the remote director is pointing in his or her work space. In this system, one user as the worker can treat real objects directly, but the other user as the director can treat only virtual objects. There is "lazy Susan "[10] by Uesugi et al. as an example of trying collaboration both remote users have own real object in Mixed Reality. In "lazy Susan " effects of interaction with real objects passed on to remote place by shooting a video of manipulation to real objects and projecting it onto a table in remote workspace. There is a disc it can rotate on the table, and a motion of it coincide between remote places. It makes user aware the other user, the collaboration alive and the sense of share workspace enhance. However there is a problem that it causes some trouble in manipulation if the view is changed by rotation by remote user without local user 's willingness. And it is a tabletop system so that workspace is fixed essentially. Iso and others proposed to adapt to the differences in room structure. In "ComAdapter ", they tried to describe user ' s posture, physical relationship and so on in different rooms. There are some discontinuous scenes when they describe dynamic situation in the rooms or the process of the user 's motion. This system aims natural living-room communication when room 's structures are different. On the other hand, we set out a remote collaboration system with manipulating one target object.

We proposed to share the virtual information based on the

Table 1. Classification of a pair of real objects

| Kind of sort | (1) They have commonality in the function | (2) They have commonality in the way of the operation | (3) They have the same alignment of the contexture | (4) Their sizes and shapes are completely the same |
|---|---|---|---|---|
| | Yes | Yes | Yes | Yes |
| | | | | No |
| | | | No | |
| | | No | | |
| | No | | | |

real objects in remote workspaces before[11]. Remote users have the same replicas of the target real object in each workspace, and then each replica has coordinate system based on themselves (It 's called object coordinate system in this paper). A process of the manipulation to the replicas and its effect are showed with virtual object with Mixed-Reality and shared based on the replicas between remote places. But remote users must have the same replicas in the research.

## 3 PROPOSAL

In remote collaboration system based on real objects, it is necessary that, the semantics of the works are shared between remote workspace, even if there are difference in syntax of the objects. We explain how the semantics can be shared in various range of differences and in which relation the collaboration is useful by sorting out the range of difference of syntax and relation of the pair of any real objects.

The table 1 shows the classification of a pair of real objects. First classification is if two real objects that are used in collaboration have a common ground in the function. The commonality in the function means the capability to share the semantics of the work. On the other hand, if they do not have common ground in the function, it is impossible to share the semantics. For example, sharing the semantics is possible between two objects, that the function of both objects are to input sentences. But if one object is to input sentences and the other is to input musical performances, there is no common ground in the function. So the semantics is not able to share in such a case.

Second classification is in the sort of " Yes " in the first classification. It is that, if two objects have commonality in the way of the operation. If we think about objects to input sentences, there is an example do not have common ground in the way of operation, a keyboard and a pen. A keyboard inputs sentences electronically and a pen does by free hand. In such a case, there is only information that is shared, the sentence. The sentence is not tangible information, so they

can not take advantage of using real objects. Two objects should have commonality in the way of the operation.

Then it goes to third classification from the " Yes " of the second classification. It is that, if they have the same alignment of the contexture. The difference in alignment of the contexture between remote places causes a discrepancy of the structure in real objects or world. Fortunately, alignments of the contexture are kept in most objects that have commonality in the way of the operation.

Finally it goes to fourth classification from the " Yes " of the third classification. It is that, if their sizes and shapes are completely the same. There are a lot of objects that have the same function, the way of the operation and the alignment of the contexture, but difference in the sizes or shapes. It is very useful that remote users collaborate with sharing objects that have difference in seizes or shapes. Because there are commonality in the function and the operation, it is capable to share such objects.

## 3.1 A Sharing Method of Real Objects Differ in Syntax each other through Virtual Sticker between Distant Mixed Reality Spaces

It is too difficult that remote users collaborate with treating their own real objects before. Even in our last research, each user must have object of the same shape and size. The collaboration with the real objects has big restriction. So we propose " A Sharing Method of Real Objects Differ in Syntax each other through Virtual Sticker between Distant Mixed Reality Spaces ". We focus attention to a property of stickers that can be attached on a physical object according to its surface, and bring it in the technology of Mixed Reality. In our approach, the virtual sheet which is put on the surfaces of real objects is defined, and the information of processes and effects of the work is shared flexibly on them. Using the virtual sheet makes it possible that, participants can collaborate in distant workspace with keeping essential semantics, if they have real objects that are different in syntax (syntax points the shape, the size, or the structure of the objects in this paper).Users can collaborate with awareness of interaction between remote participant and the object through the virtual sticker.

## 3.2 The Function of the Virtual Sticker

There are mainly two functions of the virtual sticker.
(1) To share the information of the interaction to the real object between remote workspaces

The information of the interaction to the real object by each user is made into a model as the virtual object (It is called sharing virtual model). And sharing the information of the interaction is actualized by sending and receiving the data of sharing virtual model bi-directionally through each virtual sticker.

(2) To resolve the difference of the syntax between objects by putting flexibly

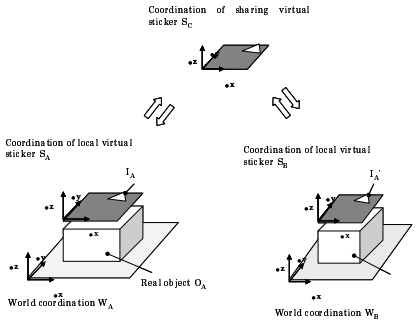


Figure 1. Information sharing mechanism

They can put stickers on various-shaped surfaces of the objects generally with keeping some kind of a picture that is printed on them.

The virtual sticker also has this function. By drawing the information of the interaction on the sticker instead of the picture (the sharing virtual models are transformed like a sticker), the information of the interaction is displayed on each real object with matching their syntaxes.

## 3.3 The Difference of the Syntax

The virtual sticker resolves some differences of the syntax. We explain the differences in this section.

(1) The combination of real objects that contain the different in the size

Though there are a lot of patterns of the difference, the most popular case is the difference in the size. Even the same kinds of the object (for example; some kinds of controllers, calculators, phones or devices) have various sizes. There are bigger one or smaller one, it might be a professional, abridged, portable, or kids edition. By using the virtual sticker, the collaboration that the objects contain these differences can be actualized.

(2) The combination of real objects that are 2D and 3D

Through the virtual sticker the information of the interaction can be shared between the objects of 2D and 3D. When participants do works, they can use 2D information like a design or a manual that relate to 3D target real object. The other has the 3D object in remote workspace and collaborate between 2D and 3D through the sticker. Semantics of the information of the interaction to objects are shared so that remote work support or remote collaboration can be actualized even between 2D and 3D objects.

## 3.4 The Way of Sharing the Information of the Interaction

This section explains the way of sharing the information of the interaction between remote users in our research. To begin with we define two coordinate systems.

(1) The coordinate system of the sharing virtual sticker

This is the coordination of the original virtual sticker, before the sticker is put on the object. In this research, the sharing virtual models are transformed into this coordinate

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

$$I_{SA} = \begin{pmatrix} x_{sa} \\ y_{sa} \\ z_{sa} \\ 1 \end{pmatrix}$$

$$I_A = M_A I_{SA}$$

system, when the information of the interaction is send and receive between remote workspaces.

(2) The coordinate system of the local virtual sticker

This is the coordination of the virtual sticker, after the sticker is put on the object according its surface. The information of the interaction that is shared between remote workspaces is displayed based on this coordinate system in each workspace in our research.

Sharing the information of the interaction is actualized by changing its translation and orientation between each coordinate system as the figure 1.

First, the information IA that user UA interacts with the real object is based on the world coordination WA. It is changed into the translation and orientation based on coordinate system of the local virtual sticker SA. Then it is changed into the coordinate system of the sharing virtual sticker SC, and also transformed into the coordination of the local virtual sticker SB that is set on the real object OB user UB has. Finally, it is changed into the translation and orientation based on WB and displayed as the sharing virtual model IA ’. By doing these operations in the same way about the information of the interaction IB of user UB, the information of the interaction can be shared.

Its processes are described as these expressions. We set ISA as the translation and orientation of the virtual objects based on SA. IA and ISA are described that,

By using the modeling matrix MA that is made up with homogeneous matrix, the translation and orientation are transformed from the world coordination into the coordination of the local virtual sticker.

On the other hand, when the position is transformed opposite way, it takes inverse matrix SA-1.

# 4 IMPLEMENTATION OF MR SHARED SURFACE

## 4.1 The Architecture of the Implementationn

In this research, we implemented “ MR Shared Surface ” that is a one of the virtual stickers ’ prototype system. Two participants can collaborate between remote workspaces

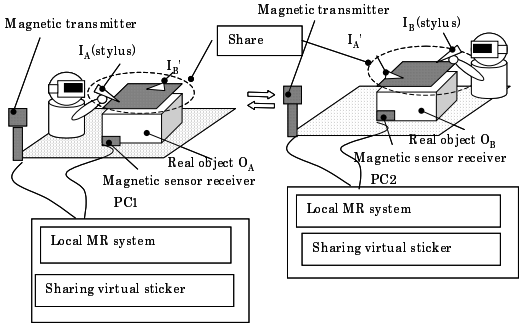


Figure 2. Architecture of MR Shared Surface

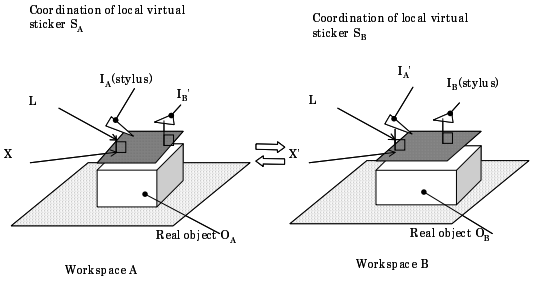


Figure 3. The display of the sharing virtual model

through “ MR Shared Surface ”. The figure 2 shows the architecture of it.

“ MR Shared Surface ” is constructed with the local MR system that controls devises and the sharing virtual sticker that makes it possible to share the information of the interaction in remote places.

## 4.2 The Local MR System

“ MR Shared Surface ” detects the position of a stylus that user has by his or her hand and laps over a virtual pointer on it. It is the sharing virtual model in “ MR Shared surface ”. Like the figure 3, the sharing virtual model is displayed. As the figure 3 shows, we drop a perpendicular line from the stylus that user has. L is defined as a length between the perpendiculars and X is a foot of a perpendicular. 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 that is the normal direction of length L from X ’. “ MR Shared Surface ” operates this process bi-directionally.

## 4.3 The Conversion through the Virtual Sticker

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

To deform any convex quadrilateral A to other convex quadrilateral B, A is converted into a normal rectangle once and then conversed inversely into B.

$$\lambda \begin{pmatrix} x_2 \\ y_2 \\ 1 \end{pmatrix} = \begin{pmatrix} h_0 & h_1 & h_2 \\ h_3 & h_3 & h_5 \\ h_6 & h_7 & h_8 \end{pmatrix} \begin{pmatrix} x_1 \\ y_2 \\ 1 \end{pmatrix}$$

$$\begin{cases} x_2 = \dfrac{h_0 x_1 + h_1 y_1 + h_2}{h_6 x_1 + h_7 y_1 + 1} \\ y_2 = \dfrac{h_3 x_1 + h_4 y_1 + h_5}{h_6 x_1 + h_7 y_1 + 1} \end{cases}$$

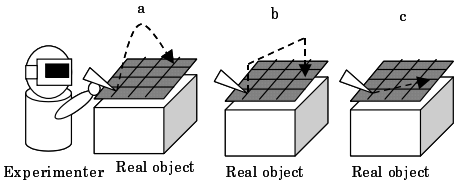


Figure 4. The type of pointing motion

### 4.4 Synchronization of the Virtual Information

To share the virtual scene in remote places, a change of the virtual objects must be passed on to the other workspace and coincide when one of the virtual objects changes in the local workspace. First, all virtual objects are registered with ID number. Second, when one of the virtual objects changes, the system detects it and passes on the ID number and a kind and degree of the change to the remote workspace. Then the virtual object of the ID number passed on is changed as the same kind and degree. The kinds of changing are the rotation, the translation and the change of displayed virtual object by switching over virtual nodes. If the kind of the change is rotation or translation, an updated position and orientation is passed on to the other workspace and if it is the switching over the nodes, a number of the selected node is also passed on.

## 5 EVALUATION

### 5.1 Purpose of the Evaluation

The purpose is that, we find out if " MR Shared Surface " actualizes our concept or not. It means that, we evaluated if semantics of the works were shared through " MR Shared Surface " in the case that real objects had difference in syntax between remote workspaces.

In this paper, we evaluated if " MR Shared Surface " actualizes our concept in pointing manipulation with stylus that was the most basic interaction.

### 5.2 Evaluation of the Pointing Manipulation

In this evaluation, two participants did tasks at a time between remote workspaces. One was the experimenter and the other was a subject. The virtual sticker that was put on the real object was divided many tiles (6 cm on a side), and there were serial numbers on each tile.

Table 2. The combination of the virtual stickers

| No. | The experimenter | The 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 | Extend elevation | 3D figure |
| 9 | 3D figure | Extend elevation |

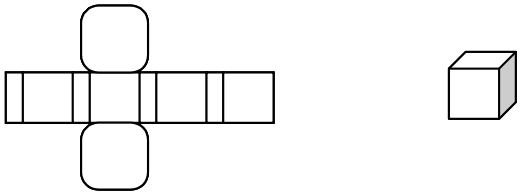

Figure 5. Extend elevation and 3D figure

The experimenter pointed tiles of the virtual sticker spread on the surface of real object one by one. He or she took three pointing motions (As Figure 4 shows).

pointing motion " a "

The experimenter pointed any tile with describing a figure of a mountain with the pointer.

pointing motion " b "

The experimenter pointed any tile with moving his or her pointer at a right angle.

pointing motion " c "

The experimenter pointed any tile with hugging the surface of the objects.

These pointing motions were not differentiated, when the subjects observed from directly above. The point was that, if

Table 3. The population

| Character | Student |
|---|---|
| Number | 15 (14 males, 1 female) |
| Age | 21 – 25 years old |

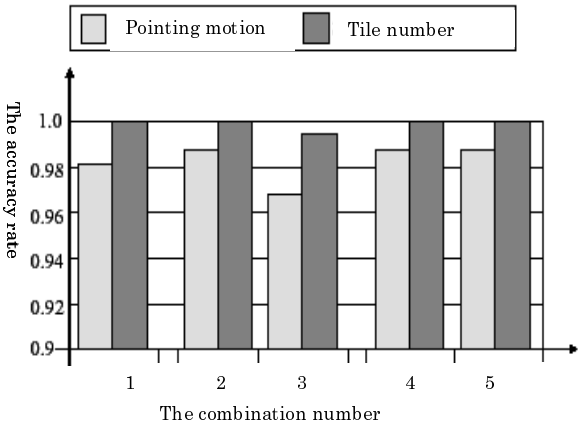


Figure 6. Result 1

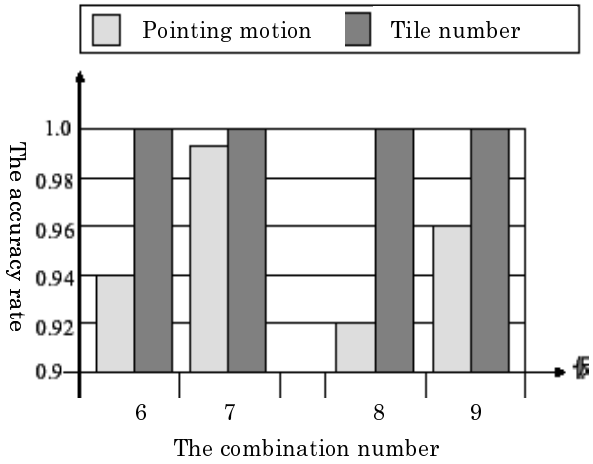


Figure 7. Result 2

the interaction of 3D movement that 2D-pointer using a projector could not express generally could be detected or not.

The experimenter followed random combinations of " a " to " c " and a tile number that were made previously to points the tiles. The subject did not know the pattern. He or she observed the pointing of the experimenter in remote space on the virtual sticker and answered what kind of the pointing motions and a number of the tile in each point.

There were two sets of the trial that concluded five points on each task. The combinations of the virtual stickers between the experimenter and the subject were switched around every task (except congruent squares). Table 2 shows the combinations of the virtual stickers.

In this evaluation, all answers of the subjects were recorded and we obtained the accuracy rate.

### 5.3 Conclusion and Discussion of the Evaluation

The figure 6 shows the conclusion of the accuracy rates about the combinations of flat virtual stickers. The accuracy rates of the pointing motion and the tile number were higher than 98

The only one mistake about the tile number (the combination from the large square to the small square) was that, the subject answered the number of the next tile. The reasons of that mistake would be that, though the area of the small square 's tile was small (quarter of the other tiles), the size of the pointer was the same as the others, or the display resolution was not enough. Also the accuracy rate about pointing motion was lower than the other cases, because the pointer 's movement was contracted in only parallel direction of the virtual sticker. That made unnatural movements of the pointer. Anyway, all accuracy rates were higher than 96

Then the figure 7 shows the conclusion of the accuracy rates, when one participant had 3D figure of the real object.

As the figure 7 shows, all accuracy rates about tile numbers were 100

The accuracy rates about the pointing motion in the combination " from the frat square to the cylindrical surface " and the combination " from the extend elevation to the 3D figure " were lower than others. The similarity between these two combinations is that, the subjects had to move the 3D object at varying angles to observe the pointing. At the same time, the experimenter could point easily on 2D flat areas. This load to the subjects caused the decrease in the accuracy rates.

However, every rate was higher than 92

The conclusion is that, the information of the interaction can be shared through " MR Shared Surface ", when at least one user has the flat virtual sticker.

## 6 CONCLUSION AND FUTURE WORK

In this paper, we focused attention on a sticker or a sheet that could be attached on a physical object according to its surface. And as a method which Mixed Reality (MR) technology is combined with it, we proposed " A Sharing Method of Real Objects Differ in Syntax each other through Virtual Sticker between Distant Mixed Reality Spaces ". We defined an information sharing method of semantics which each remote user interacts with a real object, by using virtual sheet which can be attached to each real object according to its surface and can absorb the difference in syntax between these real objects. Then we implemented a prototype system " MR Shared Surface " which had pointing function and conducted experimentation. As a result it proved that it is possible to share the information of the interactions without losing the meaning between the real objects that differ in syntax each other.

In the future, we will implement the function of various interactions and share them between remote workspaces. And we will make it improve to adapt objects that are shaped various 3D figures.

## 7 ACKNOWLEDGMENTS

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# Interdisciplinary practice and speculation of an information system student

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**Abstract.** I found my place at a university from an enterprise, and experienced two different universities while graduating within six years. I became a member of a Ph.D. program in the field of information engineering, and taught at a university. Simultaneously I was trying to consider the experience that I led as a student for my cause. It is this time that applicants of a university can enter, and quality of a student begins to deteriorate steadily. We bring up a student in various ways and were desperately searching for the perfect teaching method. We take in effective the teaching method that is most beneficial in the practical application. While we use the upbringing method that I studied in my Ph.D. process, we have used trial and error to shape it. Effective learning may not be the best method and hardship is necessary. In addition, we found not only a certain coating but also a passionate professor encourages the student. Lastly, the remainder lies on the student's initiative.

**Keywords:** Education, Learning, Information-technology, Motivation, Effect

## 1 Introduction

I have experienced working out of an OS, CG, computer aided design, and led new face teaching / engineered teaching at an enterprise for 15 years. I have experienced being a part-time teacher at a university and a National College of Technology through a decade of enterprise changes. I became a member of a Ph.D. program for three years. I had a valuable opportunity to receive a position and learn once again. I have taught at a university for more than six years. I learnt the difficulty of teaching and experienced the freshness of learning.

On the other hand, I wrestle with course generations changing the information system technologies, and the teaching experiences staying current with that of enterprises. I also think about the upbringing and curriculum for an engineer to be directly related to IS(Information Science) [(1)~(3)] and IT(Information Technology) [(4)~(6)] .

Therefore we must considered learning and teaching through a conventional enterprise for experience and for lectures/seminars at a university. We collate this with a recent learning theory [(7)]. We gather what they have to perform with, and what they need to learn, paying attention to careful details.

## 2 Our conventional experience

We have looked into the spirit of the student recently. Many students are serious, and always attend class, but they do not hear the lecture. They take notes diligently, but do not understand what they write. A student takes Work Units without attending the class regularly, and they enjoy the "college life".

After all, the student takes their time to study voluntarily, steadily systematically, and goes to great lengths. It is not related to the personal efficiency of the student. It does directly correspond to the time that the student spends at a university and laboratory. We display the ability, technique and knowledge where the individual stands as displayed below. (See figure 1)

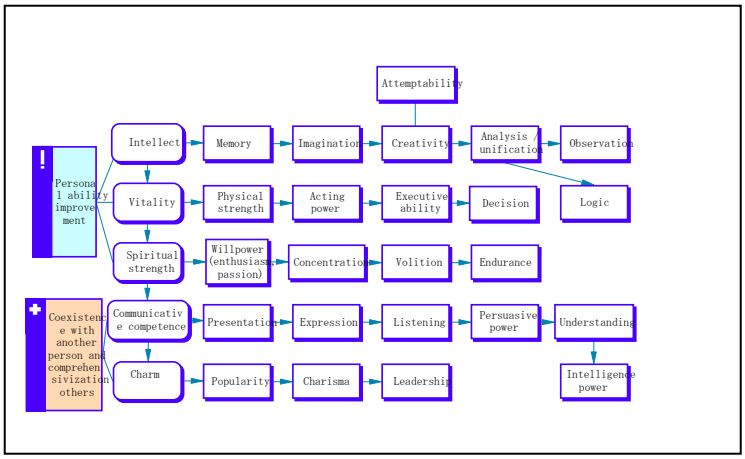


**Figure 1:** Ability /technology / knowledge

After we teach the student through lectures and seminars, we noticed that there was a problem, in particular to the category next to the student. First of all, there are many students whom cannot continue to concentrate. Concentration does not continue throughout lecturing and seminars. There are students surfing the net, and games that grasp their interest. Secondly, there are many students who have no self-expression and self-assertion. In addition,

when they argue with another person, they have no patience. It is an inferior ability to not comprehend another's opinion. Thirdly, they do not practice independence or self-restraint. They cannot make a plan while also needing help to decide the heading of their graduation thesis. Their tolerance for stress is poor. They are not able to bear with problems and excessive pressure. They also give up immediately and do not attend the university. To deal with these problems, it becomes important for the consciousness of a learning person to make positive behaviors an everyday habit.

**◎The durability of consciousness of a student**

(1) Step one development

Regarding studying and a career, it is useful not only to handle everyday routine work, but also to handle issues utilizing one's information accumulated from their history. It is important we feel change, and to progress step by step. The everyday habits stack up greatly over three years.

(2) Take in the advantages of a social network

There is a reason why there are so many cultures and opinions, each with varying minds. When people follow the same story, there are many differing views and understandings. Therefore, we had better to repeat the content which was heard from an individual, and we must consider the differences that we have learned. Then, we will find out a more rigid path of what the speaker had intended by comparing results.

(3) To have many models and schemas

It is easy to understand that you have many models and schemas. When we appreciate a new idea, we are thinking about using of the application and transformation that we have imagined.

(4) Increasing the efficiency of a job

As you exercise discipline and stack up steadily by an everyday process, you can reach the status of higher levels when you make an effort. Your brain raises the access speed itself and it is automatically activated.

(5) Imitation

It is useful that we imitate good patterns about learning, both regarding languages and programming.

(6) Expression

It is necessary that you can express your opinion. When we write a document in particular, we had better use idioms and so forth to avoid dialogue like expressions.

(7) Formative ability of an image

We make effort to express what we think, and it needs to grasp a structural basis as well. While we repeat it, the image formative ability improves.

(8) Understanding and flexibility for novelty

When we think about invisible objects (e.g. software, art), there are many cases that it is difficult to appreciate "what is important" or "what kind of structure does it become". When we explain about the structure, the individual becomes progressively better at expression..

(9) Attention and sense

When distributing a document, it is common for it to be distributed from a more experienced person earlier. In case you distribute a document, ignoring the more experienced person, would render you senseless.

(10) Accurate error correction

This has to progressively improve on a daily basis. For example, when there is a shift to the left regarding the decimal place on financial statements, it becomes a big problem when we overlook this. When such a careless mistake influences such a great amount of responsibility, you must not overlook it. The ability to find this is vital.

(11) Imagination and creativity

When you imagine and endeavor to follow how another person thinks, you have the advantage to possibly understand new comings and goings easily with new detection.

(12) Do one's best

When reference materials come out, if the student does one's best in their current state, we should be able to adapt quickly for individual needs. When a slipshod job is produced, good reference materials cannot be utilized well.

(13) Level

Which level is the individual in? Is it used at a local club level, university level, Japanese national level, or is it used at a universal level? There is generally an existence of a top to bottom order in the world regarding any profession and any society. It is important to grasp which level one's self is in for the current group. You may reach a level that has to be used in a universal atmosphere unexpectedly, but have already completed the essential necessities eagerly.

(14) Concentration

The students (they almost search for a remembrance without thinking) who cannot concentrate have just only thought about solving the problems. They are thinking about others and begin to do personal behaviors. Therefore, at first it is necessary to stop this habit. After they develop patience, they can begin training for the new way of thinking.

(15) Training the new way of thinking

It is impossible even if students are ordered by a teacher to suddenly change they must be open to the new way of thinking. At first we will try to let students begin with their current habits. They try to imagine a hobby and a good memory from their childhood. Let students be reminded of these times and try to express a thought from their hearts. It appears from their hearts, which remains a personal experience and impression. It is useful to express many times these experiences that come from the heart. They try to express a new thought in words for themselves this way. If they repeat this and raise a level, it will come to be gradually a natural process when thinking about other problems.

(16) Output

They make an effort in various ways, but there is the student who cannot make necessary output. As for this, they

work on a certain constant level, but there are many cases that they do not make more effort. For example, they look for a program on the web, and when discovered; they halt any attempt at creativity. We cannot be creative unless it is possible for remodeling within ourselves to some extent. Progress is not possible after all, unless this step is exceeded. They finish by exceeding the necessary output.
(17) About learning
If knowledge increases, understanding deepens, and synergy rises. Systematization is made in the brain, and understanding progresses more and more. If they understand and make systematization in a structure with knowledge, applications can be come to work. For example, when we use the application that had a similar command, we can handle the command in the same way, and it is easy to comprehend the way of many handles. The student who relies upon his memory only cannot learn systematically, and then they may not acquire the systematic knowledge.
(18) Necessity of a repetition exercise
There is both learnt and acquired knowledge with exercise of the body. We must practice these individually many times and this is only an exercise. People don't learn to swim by simply having it explained, just as we need hands on experience to understand how to operate a personal computer. To learn how to utilize a computer's abilities we use the body and the cerebellum rather than thinking with the brain. Then, we try to think by comparing it to writing a paper, learning a foreign language, or playing tennis.

To write a paper is to assemble the idea of what we are thinking in our minds. English conversation and listening comprehension influences an exercise of repetition just the same as a program. Tennis and swimming become better only by exercise of repetition. Therefore, it is important that we balance and strengthen our cerebrum and our cerebellum.

## 3 Learning and teaching

By the way, three following items are described for a point of view science of learning in the American[8].
(1)Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom.
(2)To develop competence in an area of inquiry, students must: (a) have deep foundation of factual knowledge, (b) understand facts and idea in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application.
(3)A "mentacognitive" approach to instruction can help students learn to take control of their own learning be defining learning goals and monitoring their progress in achieving them.

| Item | Paper | English | Tennis | Remarks |
|---|---|---|---|---|
| Basic acquisition | Learning a typical pattern | From sound, word, phrase to sentence,managing a fixed form pattern | Learning stroke, volley, smash | Used than learning |
| Application | Put an opinion of self and repeat | Apply a fixed form pattern to conversation | Repetition while moving | unconsciously |
| Intellect | ◎ Cerebrum nucleus | ○ | △ | Cerebrum |
| Physical strength | ○ | △ | ◎ | Cerebellum |
| Response | △ | ◎ Speech center | ◎ Motor center | Spinal cord, Cerebellum |

**Table.1** Article and English and comparison of tennis

We review my class and seminar that I carried out so far and try to arrange such a thing.

### 3.1 Lecture

A lecture from a department summarizes a section of a textbook by presentation (a presentation document distributes a copy) commonly displayed with PowerPoint. We let students promote understanding because a student solves an exercise afterwards. Students acquire what they learned through practice from an exercise by this repetition. We perform a mini-test during the end of a class to confirm understanding. We let students write a description-style problem, an exercise to write their opinions.

A term-end examination firstly tests to see whether the students remember the important materials, secondly they are being tested on calculation; thirdly an important point can be described by a description type problem. We test these three items on the subject. We believe that the students who can solve all these three items are growing.

In a graduate class, the writing specifications have heavier importance. Students obey specifications, and programming shall become an individual's work by using programs such as CGI and JAVA. Surprisingly, there are many graduate students who cannot write specifications. We train a point of this way of writing and an expression method and a description. Students investigate a subject voluntarily and understand the new subject. After each member discusses their subject, they exercise to let them deepen contents and understanding.

### 3.2 Seminar

In our laboratory, students become assigned to a seminar from the latter period of the three years. In consideration of the item which they studied in a class and training thus far, we will check the necessary items in a future seminar. We decide which matter to study by using seminars from now on. Because a graduation thesis is important, a fourth year student practices graduation thesis brainstorming for the purpose of making a document and the specifications which let you learn it in three years. In addition, we let the students study how they managed the graduation thesis schedule themselves by using schedule management system.

(1) Third year seminar
We describe below a necessary understanding item till now. Students can create smooth programming, and can debug, too.
(a)Literacy operation (OFFICE application on the Windows system and command operation on UNIX/LINUX).
(b)Understanding the theory of a system in a client server.

Next, we describe contents and an item to learn in the department seminar's three years.
(a)Expression of a document, mutual communication between seminar students, discussion power.
(b)A program test and design specifications obtaining the description ability from software design.
(c) Ability to understand the basics of a network, structure and develop an explanation of the movement.
(d) Construction of a Windows and an LINUX server.
(e) Construction of a system by an exercise program jointly developed by a team with a combination of the program.

We oblige students to make a document and weekly report for training to improve documentation in our seminar. A weekly report describes contents and the problems that were carried out this week. A percentage list shows the result of the current week with a circle graph, and lets them report the results that were made from them. We understand a gap of recognition between the professor and the student occurs, but by this description future help and guidance will be provided. A weekly report and up to date specifications are distributed for all the members at the time of a seminar beforehand, and each copy is personally reviewed. We show a format example of a weekly report for figure 2.

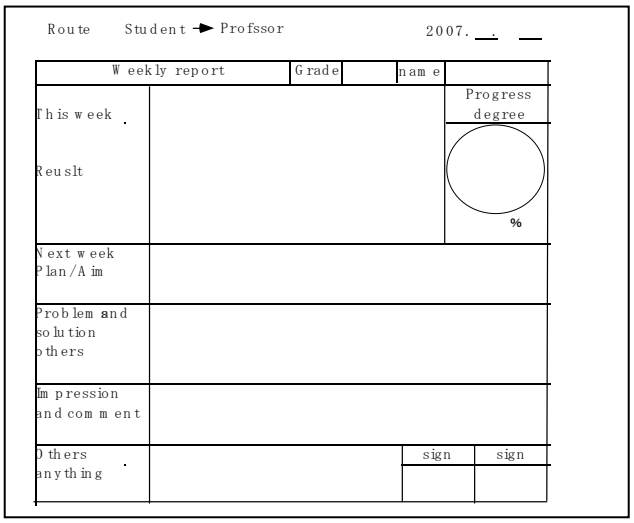


**Figure 2** A format example of a weekly report

In a review of this weekly report, students listen to comments by the teacher. By distributing it to all the members, students adopt the ideology that the reports are useful for themselves and make progress in their level to describe. This is obtained by imitating a good method used by peers. We hand out a structured format of the minutes to each student beforehand and let them describe the minutes according to them. The student in charge of the minutes distributes it by an email to all the members, if necessary the teacher returns comments at that time. A record is left at the same time as ability to describe a document is developed by this writing exercise, with each assignment being recorded. Therefore, there is the effect that one does not forget homework.

(2) Forth year seminar
A seminar student makes a graduation thesis with specifications according to a procedure from software development. A teacher reviews these specifications for the graduation thesis. The teacher and the student estimate goals after having understood through collaboration about scale, process of clarification and the program development's specifications.
Thus; it is important that "each other is understood", if there is not an equal understanding "the student starts it after they have made themselves understood." A sense of responsibility fades and the assignment will not be completed within the allotted time. On the other hand, we let them draw a system image of a graduation thesis in a figure, and it is important that they check progress. There is the danger that the creative process is prolonged, and unless this is settled there can be an expression without a target. As students with time make prototypes before summer vacation, a system image with a graduation thesis can be settled and is ready for problem solving as well.

## 4 Consideration

### 4.1 The ability of necessity for a teacher

We will try to think of important topics that must be learnt. With age, it shall change between the ratio of the technology and knowledge, and the ratio of human relations, the management and communication. During a person's 20's, the ratio of technology and knowledge holds 90% focuses on work, but during one's 50's, the ratio of management and communication to be related with a person's wisdom and shall come to exceed 80%.

It is distinguished from the specialist to the managerial class at a company. This mix is needed for both the person whom a teacher studies professionally and the person whom a teacher leads as students. When a teacher learns the coaching of a topic and the leadership recently, they can teach a student effectively[(9)~(10)].

### 4.2 Excellent teacher or bad teacher

From conventional experience and practice, we thought about a good teacher and a bad teacher. A teacher has a laboratory unlike the company, but there are generally no subordinates. Therefore, a teacher must perform simple tasks such as copying and trivial routine duties of documentation efficiently. The person who works only by instructions at the managerial class of a company may feel embarrassed and a sense of failure when he is commanded to lecture and copy documents overnight. It is an important thing that a teacher has a feeling of freedom, and whether they can be inspired or not. In addition, a teacher has an equal sense with a student compared to that of one's son or daughter, and it will be asked whether communication of mutual understanding is possible. He may break through the first barrier. If the teacher can clear that, they can handle a college/university life well.

(1) Excellent teacher
· The person whom has a flexible feeling, and can cope with change.
· They can understand feelings of the students./ The person who tries to be able to understand, and has good communication.
· The person who has charisma (an impression to be different has given this teacher an ability or a good point of sense or technology when dealing with a student)
· They are full of curiosity./ Enjoys teaching the material./ Are interested in the people.
· A democratic person./ A polite person./ An equal with the student.

(2) Bad teacher
· A person without flexibility.
· The person whom deeply attaches to one's thought, and is not going to receive a new thing.
· They are not curious./ They dislike the subject matter./ Dislikes the people./ They are not interested in the interpersonal relations.
· A person of authoritarianism. / A coercive person./ Not satisfied unless they feel superior.

## 5 Conclusion

A student should study voluntarily by oneself. A teacher helps effectively and gives enthusiasm and devises it to let students continue. There are various students who should be praised or needed to receive pressure. Therefore, a teacher sees through the nature and character of a student well, and it is necessary to teach them effectively and timely. A teacher must be aware of being open to learning in spite of teaching. They make an effort and devote themselves with enthusiasm every day. This study has received assistance from the scientific research costs subsidy "18500737", in addition to the above.

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# Session 2: Information Systems

# Post Ubiquitous Information Society: Problems, Proposals and its Applications

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***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 symbiosis 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***: Ubiquitous Computing, Web Computing, Symbiotic Computing, Real-Space, Digital-Space, S-gap, S-bridge

## 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.

Focusing towards next generation ubiquitous age we have been pursuing research on Symbiotic Computing from as early as 1994 [6]–[8]. In [4], [5], [9] we first define the concept of traditional ubiquitous computing environment with two computing aspects: *mobile computing* and *pervasive computing*. Traditional ubiquitous computing enhances accessibility to the services using wireless network and embedded device technologies [11]–[14]. At the same time, web computing is emerging as a very powerful tool to extend availability and usability of information which is widely distributed in the world [10]. 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 to 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, symbiosis society will be realized, where human and ubiquitous information environment can cooperatively coexists and close the gap between these two entities. The importance of quality of human life and information utilization in advanced ubiquitous system is discussed in [15].

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.

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. But, due to the lack of required skill and knowledge of people in Real Space (RS) and insufficient support provided by the Digital Space (DS) to the RS, incoveniences and uneasiness between DS and RS is a real possibility, which we termed as *gap* in the symbiosis world. The detail explanation of it is given in Section 2.2.1. 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*[1].

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

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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. 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

Ubiquitous computing began in the Electronics and Imaging Laboratory of the Xerox Palo Alto Research Center in the late 80s by Mark Weiser [1], [2] and his group. The inside story can be found in [3]. 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.

Way back in 1994, we proposed the idea of Symbiosis in [6], where we concretely defined the architecture and functionality of each part. In Fig. 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.

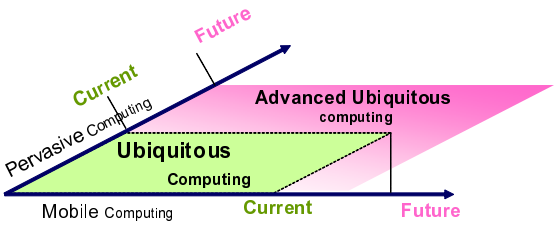


Figure 1: Two axes of computing that shapes Ubiquitous Computing field

#### 2.1.1 Mobile Computing

The 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 are 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. 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.

#### 2.1.2 Pervasive Computing

It was first began with Mark Weiser 1991 paper [1] 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.

#### 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 [1]. 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.

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 link 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 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 Fig. 2.

Fig. 3 illustrates the number of mobile Internet users in Japan from 2003 to 2006, of different age groups [16]. From this figure we can clearly see that the people below 12 years and above 50 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.

#### 2.2.1 S-gap: Lack of symbiosis with human

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

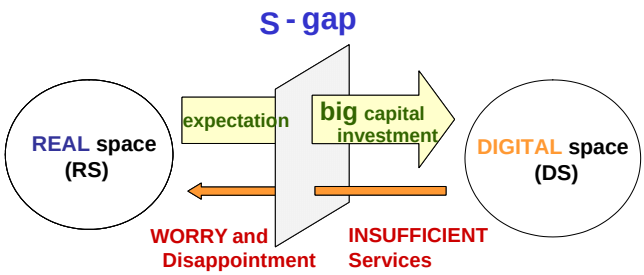


Figure 2: S-gap: Limitation of ubiquitous computing

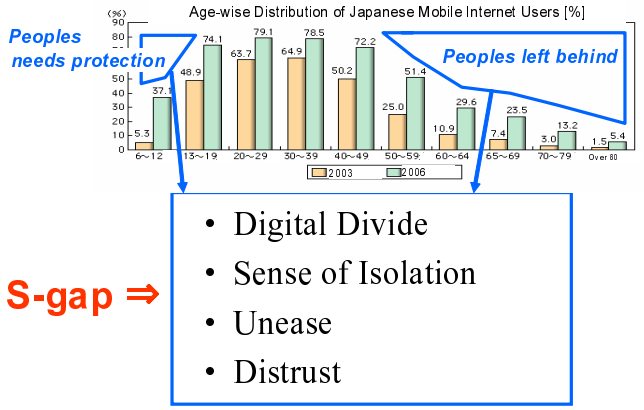


Figure 3: Utilization of Mobile Internet (Japan: 2006) WHITE PAPER Information and Communications in Japan, 2007

- 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 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 considering 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, 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 (Fig. 2), the concept of a new axis, the *3rd axis* comes as shown in Fig. 4 and we called this 3rd Axis as S-bridge (Fig. 5).

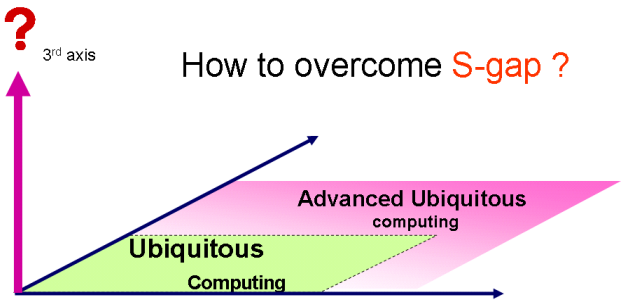


Figure 4: Towards post ubiquitous computing

**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 not only in RS but also in DS. It also cause a serious problem as DS gets 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 is 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 would not get closer to DS.

### 2.2.2 Bridging the S-gap

As mentioned above, the current relationship between RS and DS is still not very smooth. 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 to establish a bridge to close the gap between RS and DS, as shown in Fig. 6. Here, DS contains all the necessary information required in the RS. But due to the lack of knowledge and skill

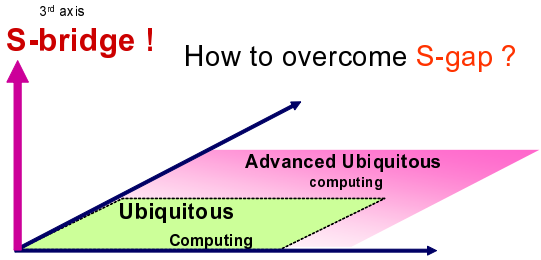


Figure 5: Towards post ubiquitous computing; S-bridge as the 3rd axis

people may not utilize and take the advantage of full range of benefits from DS. S-bridge will help to bridge this gap, so that RS will also become rich in information.

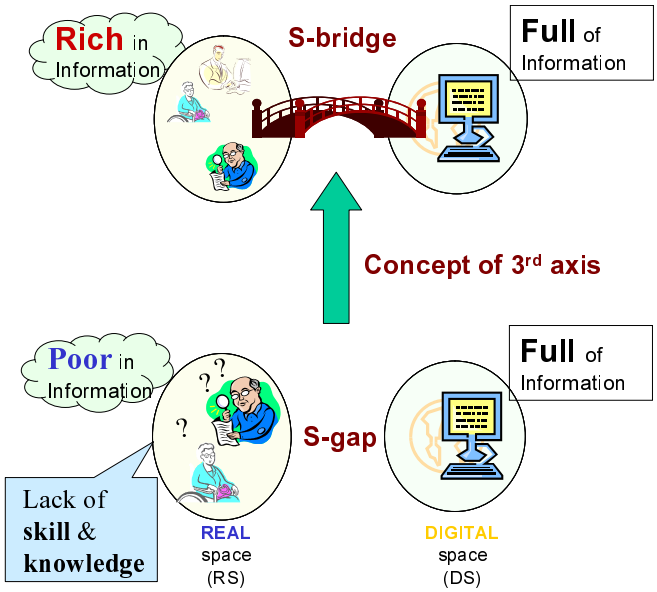


Figure 6: S-bridge: to close the gap between REAL and DIGITAL space

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 information, users' information, 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 detail. This mutual understanding will build the relationship where RS and DS have any interactions as much as possible at the lowest cost when required.

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 Fig. 7. RS recognition is a notion where 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 where 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.

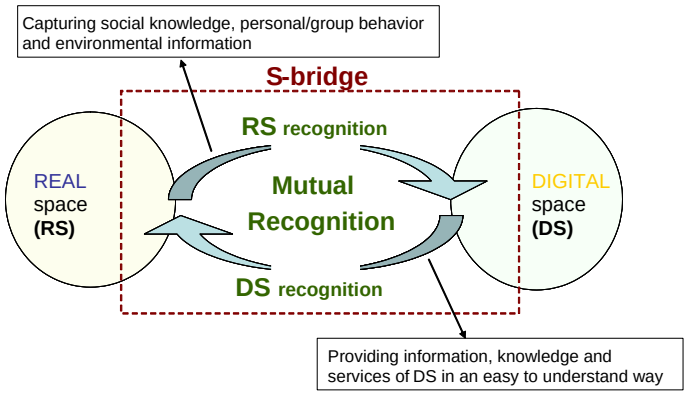


Figure 7: Symbiotic society: mutual-recognition between RS and DS solves S-gap problem

## 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 Fig. 8.

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 relationship between DS and RS.

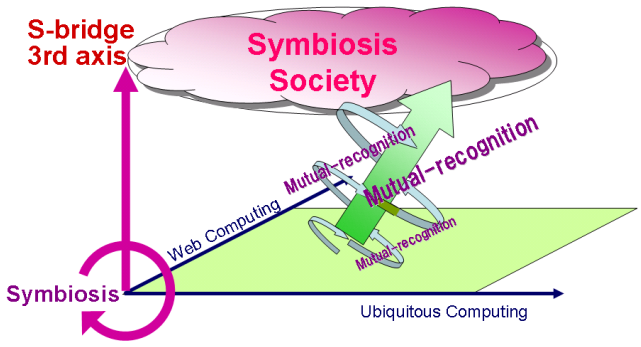


Figure 8: Symbiosis: 3rd axis concept

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 - It 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* (Fig. 9). 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.

Fig. 10 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 computings are based on perceptual-ware and social-ware described earlier. Perceptual

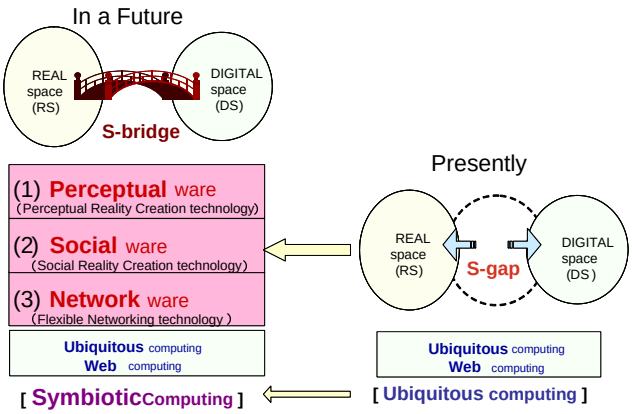


Figure 9: Architecture of symbiotic computing

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 Fig. 10. 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 it can 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 [17] 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.

## 3.4 Social-ware

Social-ware is a 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 unreasonable increase in prices at online auction sites by the owner making some bids by himself, 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 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.

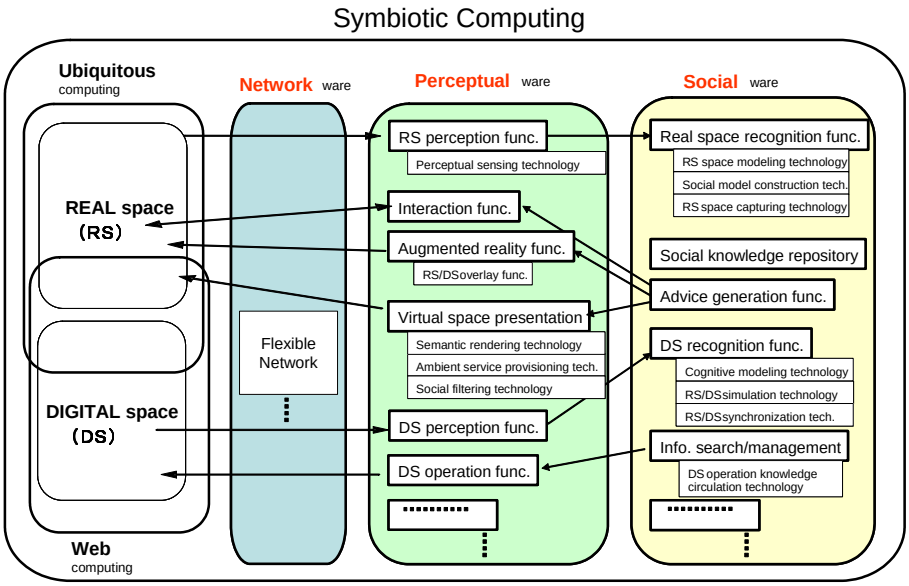


Figure 10: Model of symbiotic computing: integration of RS and DS

- (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 the 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 a 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 Elders watch-over system

Relationships among the neighbors are getting diluted in different kinds of local communities. The social structure, where inhabitants of local community, taking care of the children and old people is no more exists. So, there is a need for the inhabitants to cooperate with each other to respond appropriately to reduce or prevent any mishap happening to other. There is a system available where a family can watch over their grand father, mother and children by a monitoring camera. However, those who will watch over is limited due to their other engagements. So, we are dependent on the neighbors again. They are not only larger in numbers than the family members, they are also close to the subject. But because of the privacy related issues, a constant process must be needed to control the level of transparency between the watched person and the neighbors.

Our proposed uEyes system for Multimedia Care-support Services for Gently Watching Over is realized based on symbiotic computing. In Fig. 11, community of watching persons cooperatively watches over a target person. We call this kind of watching task as "Community-based watching-over"

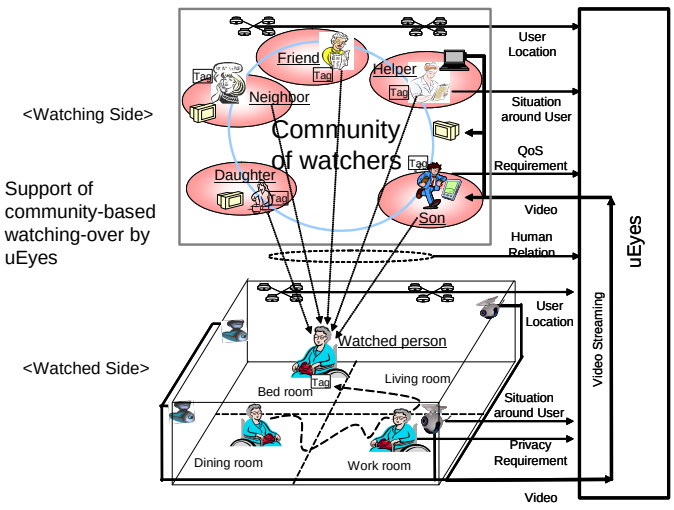


Figure 11: uEyes: A ubiquitous care-support system for supervising elderly people

In uEyes we introduced some distinguished features for watching: *network computing*, *perceptual computing* and *social computing*, based on the concept of Symbiotic computing as shown in Fig. 12. We design and implement the features of uEyes by effectively combining the environmental information acquired from real world and knowledge on social activities of people. The knowledge on social context such as human relationship, general behavior of elderly people, life style of the watched person, structure of house etc. is introduced and effectively used to infer the situation of the users. These features enhance the social awareness of the system to make it gentle and safe to the users. Based on the advanced features, live video streaming system is autonomously constructed according to the users' situation in runtime. As a result, watch-over service that fulfills the detailed users' requirements can be effectively provided. By implementing a prototype of uEyes of watching over elderly people and performed some experiments based on real-life scenarios, for instance where an elderly person is watched by his family and his neighbors in the local community. We confirmed that, when the elderly person is in his bedroom, a live video streaming system with low quality was configured to keep his privacy. In an emergency situation, the privacy level was lowered and the situation was automatically conveyed to the members of the local community with high quality video. From the results obtained from these case studies, it was confirmed that uEyes can provide real-time multimedia watching service for elderly people with reasonably QoS and privacy to meet user's requirements.

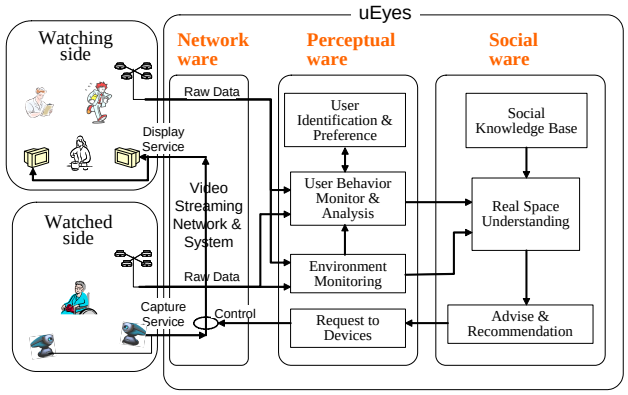


Figure 12: Design of uEyes based on symbiotic computing architecture

# 5 CONCLUSION

In this paper we first defined the problems that can appear in post ubiquitous society and its impact on social environments. Though the advancement of technology will bring comfort but it will also create problems, and will create a *gap* between human and computers, specially 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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# MUD Approach to organization design in the IRM environment

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***Abstract*** - To use Information as company resources, the company has to transform its old organization to new one before effectiveness of information usage is realized.

There was no typical way to analyze and design the organization.

In Japan, traditional top managements are likely to think that they are to do the design of organization structure. It is widely believed that only top management handles the organization restructuring. This is the rule of thumb that no body has doubt in business society in Japan.

To say about Japanese decision process, top-down is not the common way, also, not bottom –up. In most cases, our decision process is MUD (Middle-Up& Down).

MUD is the typical style to get consensus and arrive at final decision on the matters of corporate key items.

RINGI document and NEMAWASHI are very Japanese way to get a great consensus of opinions. These customs are never saved even though IT is promoted through out company.

In this paper, we propose top down design methods of organization following conceptual 4 levels of structure to harmonize information system development through the decision process of MUD.

***Keywords***: IRM, RINGI, NEMAWASHI, MUD, consensus based decision

## 1 INTRODUCTION

Had we thrown away old good customs in our IT modern age? No, still, we stick to the old classical ways of management styles.

Our decision system is still Muddy approach.

It works specially in the case of information system development project.

Too many companies have spent money to IT area, but they miss sufficient ROI.

Why? In most cases, those companies are just to implement IT for help of human labor. CIO insists just on the implementation of new OS from Microsoft, and new speedy LANs. They have never thought they should change organization itself to adapt to new environments of IRM. If top managements use the information confronting for the new business acquisition, those information is to be very strategic one.

To compete and win against competitors, top management would use information system.

And utilize Data-Bases for this object, then s/he may obtain good strategic information in given time-frame.

This paper reports that new top management of an old company decided to implement IRM concept and transform the company who has 100 years history. The president is the fifth CEO since the company foundation in 1905 year. The president, he wrote RINGI document for getting the fund of first computer systems about 30 years ago. Of course, he also wrote COBOL programs of the system. Since then, the New Monthly Pay system continued to be used until new system implemented by this time.

The reason why in such a long time, old COBOL based system is used, is that nobody could change company organization except the owner of the company.

In COBOL source codes, he described department names, section names, group names. If company changed those organizations, some one would amend those COBOL sources of using descriptions of department names, so on.

The company must re-develop new monthly payroll system. The payroll system is complicatedly related with the promotion system internally.

Only president knew how to improve these systems, but he has no time to spare his time to the system improvement.

Triggered by the idea of IRM concept, Mr. New President decided that by the MUD process.

He concluded restructuring of existing organization for better performance.

## 2 CURRENT ANALYSIS OF THE COMPANY

It is common among the company nobody has fear on company loss.

Employees never think company vision is important.

Top management never tries to communicate with his employees in terms of vision.

Short term success is more weighted than long term success.

Innovation of company culture is neglected.

All those factors influenced the company's performance.

M&A is once decided as the new strategy, it resulted in no synergetic effect yielded.

Quality circle activities are kept low level only in the factory. Dark atmosphere surrounded the company.

Finally, old top management decided to withdraw himself appointed an executive vise president as new president .

Renovation mood is up.

After one month, new president ordered to the MIS manager (KATYO) to organize a project team to make change of the old company.

At this time, the president pointed 5 view points as improving company performances.

No.1: change your administrative procedures to get drastically performance up

No.2: more high quality of information may get quick and better decisions

No.3: heterogeneous specialists could work together to increase productivity

No.4: more winning chances in the competition domain against business competitors to get killer competitive intelligences

No.5: new business creativity is produced utilizing internal information/Data-Base resources

These 5 points were kind of policies for the project.

## 3 TYPICAL PROCESS ON COMPANY DECISION

We are taught that American/European style of decision is top-down approach and our Japanese approach is bottom up approach.

My experiences showed our way is Middle to Top then Middle to Down, that is to say, MUD approach. It is really muddy way, and troublesome process to do and time consuming.

Unique business words are used in the environment of Japanese society. Typical ones are NEMAWASHI, RINGI document and INKAN.

In Japanese management environment, middle level manager, KATYO are keys to manage company soundly.

At this company, MIS manager triggered the project.

The company is the world leading engineering manufacturer of environmental facility with total sales $650 million. New president found its information systems development organization in disarray. There were no formal methodologies in place, and standards were rare.

The company had a 3:1 ratio of programmers to systems analysts like so many other company. Approximately 80% of the project time is spent in programming.

Instead of specifying information requirements at each organization level and engineering an overall system architecture. their development staff was spending most of their time writing computer software.

Without current organization analysis, they just make program and found the software rarely satisfied user requirements. Staff spent considerable time for re-writing programs.

As a result, the company found itself in a constant "firefighting" mode and little progress was made towards achieving the company's major goals.

In the first contact, he had a meeting spending 2 hours for the several above problems with CIO.

CIO said he would totally agree with his suggested problems and strongly suggested the section manager to improve this situation.

CIO contacted with vise president in charge for marketing who is deemed as no.2 in the company.

Although the VP was relatively cool, but he said the company actually has problems, and pointed out systems section may solve by quick and dirty approach.

Then section manager met with the president for 1 hour explaining problems and wanted to get Idea from president. The president gave special fund to him for hiring consultant. The president was the section manager when current section manager was college new face at systems section.

As problems stated above, president pointed out 5 cutting point on the new project start.

Then with the hired consultant, he went to the engineering department and had several meetings with designers and buyers, drawing engineers, clerks, .Also, he went factory that is not so big, profitable busy production field. There, he met foremen, section managers and IE department managers. He drafted project team members and organizations.

This type of activities are called NEMAWASHI, approach is called MIDDLE UP and DOWN .He knows that in the company nothing gets done unless the people involved all agree.

During NEMAWASHI process, he may create the revolution project team.

Note: NEMAWASHI is literally translated: Root Binding. Gardener carefully wraps all the roots of a tree together before he transplants it.

After this, he carefully makes the RINGI document then passes through it among those executives. The RINGI procedure is a kind of Formal Circle Activity at top management level. Approval of the plan or project is indicated by the executive person affixing his seal. By this process, the plan can be implemented very efficiently.

RINGI is also tiresome process even to Japanese business man. Smooth implementation of action after decision is assured for quicker solution.

By smooth RINGI process, he obtained permission on the project initiation.

The project activity is just like a Quality circle. Japanese are accustomed to circle activity since 1500 years ago.

Since Buddhism came to Japan in Year 537 AD, HOZA is a problem solving group activity.

At TOKUGAWA era, 400 years ago, SYOUGUN (Governor of Japan) employed GONINGUMI rule for controlling 5 farmers as a team stick to land. This was very political procedure.

After WORLD WAR, DEMING taught circle activity to improve quality of product made in Japan. The company likes small group activities .Constantly the company are carrying over 30 groups. Revolution project of company is being executed just like a quality circle activity.

At this project, not only organization restructuring, but also systems and data-base and usage of information at all the levels are carefully reviewed and redesigned.

## 4 ENTERPRISES RESOURCES DEFINITION

Okada[1] insisted that Organizational analysis need functional entity diagrams as upper level expression of data flow diagram.

We define following resources as design objects.

Project itself is defined on project description worksheet.

Organization Entity descriptions are defined by each division, department, section and so on.

Business line functions like marketing, production so on are defined in next step to be related with function, then staff functional entity is to be defined like Personal department, General Affairs department, so on.

See Fig1.IRM scheme of Y Electric Co., Ltd as real example of IRM installation.

After functional entity is defined, it is related with Information requirement definition.

At top level, strategic and tactical information requirements are collected.

Human resource is defined in the resource entity description, then machine resource is also defined and related with organization entity. Skill entity is defined on the skill description worksheet and related with personal entity. Positions, jobs, human /machine resources, skills, objectives, and project are clearly defined and internally related with each other..

Procedure rules are clearly defined and summed up into procedure manuals for operators/ workers, clerks at bottom level. Manager's manuals are documented and distributed.

Director's IRM handbooks are simply documented and distributed. For top executives, very simple descriptions are personally assembled and explained to each executive management.

A few years ago, Y Electric Corporation had developed a smart manual for the employees so the company simulated same administrative manual to keep IRM resources on maintenance(Figure 1). The team described job descriptions and make job flowcharts practical. We made quantitative analysis on the how much time spent to each job by whom,

Then we succeeded to develop standard time for indirect jobs.

This current enterprise analysis is important for new system development.

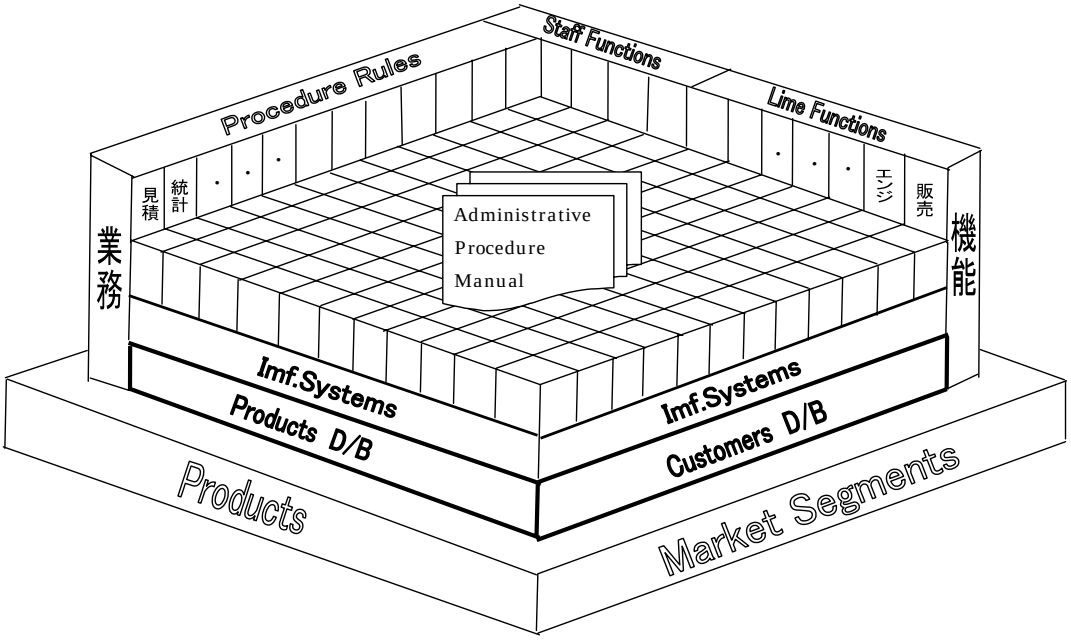


Fig.1 IRM scheme of Y Electric Co., Ltd.

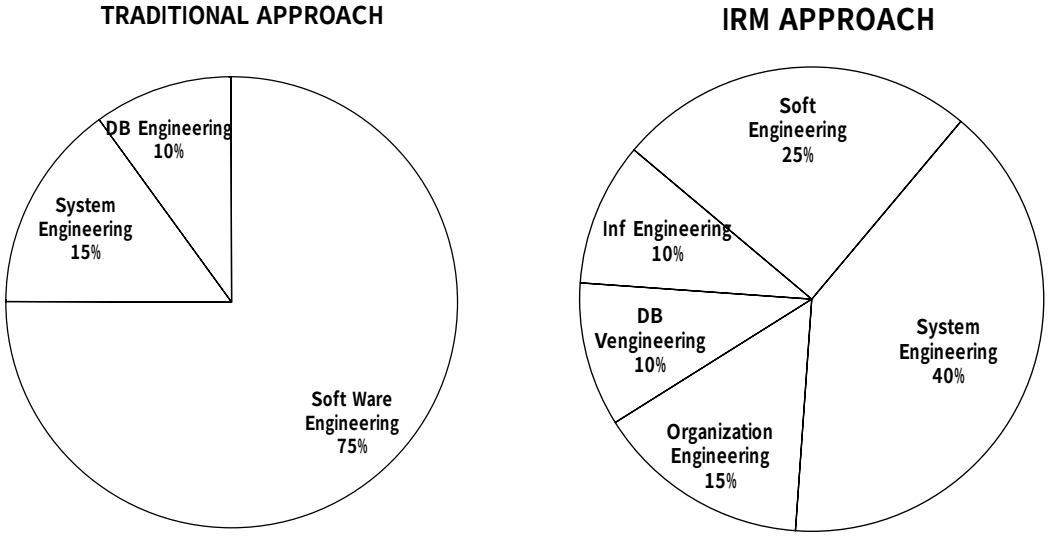


Figure 2: TRADITIONAL / IRM

Traditional approach showed only 15% of total work spent in the area of system engineering and 10% of total work spent in the area of data base engineering (Figure 2).

75% of total time spent Software engineering.

Our experiences showed 15% spent in the organization engineering, 10% in the information engineering, 40 % in the system engineering and 25% in the software engineering and database engineering is 10%.

Project management workload is deemed as overhead, it counts about 7-8%.

Considerable time is spent up-front on studying problems. On this point, as analysts of organization, we make many "why" questions to Top managements, then division and middle managements and managers, then we arrive at bottom level clerks/operators.

We find lack of information at each levels or needs for information and information requirements. We usually observe many organizational islands. Those islands eagerly desire information but failed to get.

Also, we make clear some key person who has a lot of information never communicate with the other key person. This kind of battle causes significant loss of company performances. Specifically, we find these problems in the older company.

## 5 ACTUAL QUANTITATIVE ANALYSIS

The company has been suffering from downstream of orders from Governmental bureau Of Environment Control. Government has diminished funds for expanding Facilities and Equipments for dioxin prevention.

However, their organizations show unbalanced figures. For 50 years,

The number of employees are controlled under one thousand, and half of those people are assigned to divisions for Governmental area.

Sales volume is under 35% of total.

Also, indirect departments have increased number of staff, occupied 18% of total number.

Most headaches for President are that the company may not expect new business seeds for more 3 years. They earn still 20 years old technology in environment field.

And, subsidiary small enterprises are bringing profits to the parent company.

Those enterprises do the facility maintenance and operation support business.

These businesses are very stable.

Problems are opened and decision was made to stop the down of sales volume,

Rapidly change the personnel assignment.

Information system is quickly refreshed and sufficient information flow in each level of managements, managers, even clerks, operators, workers.

Three years was so short time that all employees were excited with new project cut-over.

## 6 CONCLUSION

In this paper, actual redesign of organization structure was executed in parallel.

Information system was installed with new DATA-BASE. A true IRM environment represents the antithesis of the "trial & error" approach. Considerable time is spent up-

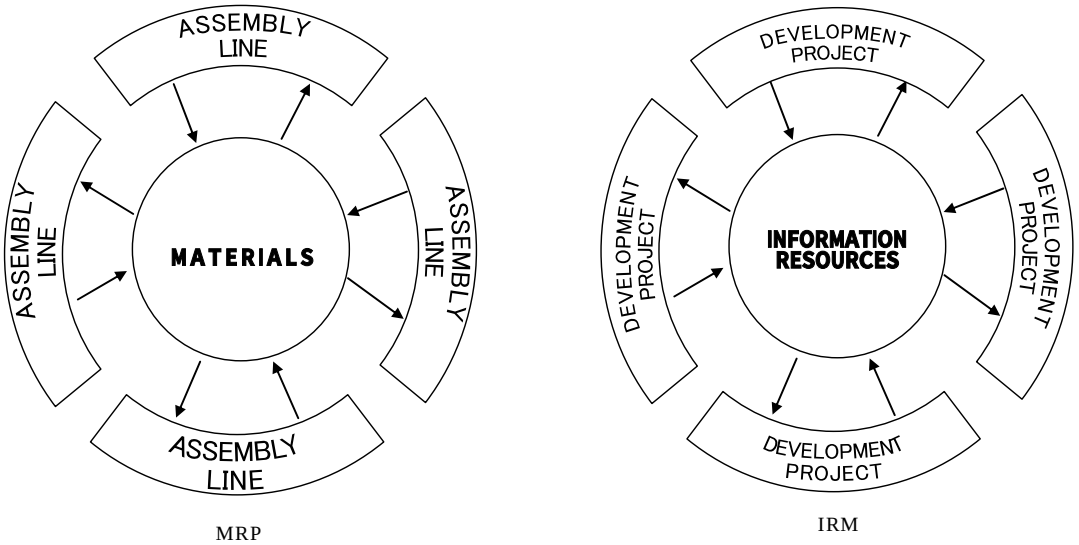


Figure 3: MRP/IRM Analogy

front studying management problems, specifying information requirements of those organization structure levels then design all the architectures of information system and data-base. Table 1 shows how many resources the company specified and each design decision was severely made we finally got how sophisticated the project is if we count the design magnitudes. This example is considered as a medium size. The giant company, Kansai Electric Power reported that they defined more than 9 thousand data elements in a system. [2]

After I proposed the report of consultation, the manager of information systems has made s small change to his jobs. He selected 4 sharp staff. One is information staff. One is Data-Base staff. One is organization staff. One is systems staff. CIO is a board member who can get any support from the staff and CIO has no responsibility for routine jobs like key entry jobs, data processing jobs, and programming jobs. Line routine job was released from CIO responsibility.

The department has recently started new job for researching intelligence of competitors.

That is badly requested from President/CEO and VP/marketing and rested untouched project.

Ordinarily, this kind of reorganization is not opened to public, because those remodeling is kept secret [3] [4] [5].

The company decided to announce the success of rebuilding of organization structure for reborn.

Fortunately, the company is in an engineering type business, their managements and employees understand the analogy of IRM/MRP.

IRM concept is well understood by them (Figure 3)

They honestly obey our instructions for three years.

A key factor to success is the leadership by president/CEO.

He was a section manager of computer system thirty years ago. Based on his IT experiences, he tried dramatic renovation on his old and classical company.

The methodology of Information Resource Management proved the effectiveness in real world moving IRM from an ART to SCIENCE.

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Table 1: Magnitude of IRM components Design Decisions

| IRM COMPONENT | AVERAGE NO. RESOURCES IN A VERAGE SIZE SYSTEM | NUMBER OF DESIGN DECISIONS | DECISIONS IN A VERAGE DESIGN |
|---|---|---|---|
| INFORMATIOW REQUIREMENT | 100 | 10 | 1,000 |
| FUNCTIONAL ENTITY | 30 | 5 | 150 |
| ORGANIZATIONAL ENTITY | 100 | 15 | 1,500 |
| SKILLS | 500 | 10 | 5,000 |
| PERSONNEL | 1,000 | 20 | 20,000 |
| SYSTEMS | 1 | 25 | 25 |
| SUB-SYSTEMS(business processes) | 15 | 25 | 375 |
| PROCEDURES(computer& administrative) | 40 | 30 | 1,200 |
| PROGRAMS | 75 | 30 | 2,250 |
| OPERATIONS(manual steps) | 125 | 10 | 1,250 |
| INPUTS(interactive or batch) | 50 | 15 | 750 |
| OUTPUTS(screens & reports) | 200 | 15 | 3,000 |
| FILES(logical & physical, computer & manual) | 100 | 30 | 3,000 |
| RECORDS (includes files structures, print maps, panels, input transactions, messages, etc.) | 1,000 | 30 | 30,000 |
| DATA ELEMENTS | 400 | 20 | 8,000 |
| TOTAL NUMBER | 3,736 | | 77,500 |

*NOTE：Decisions are design oriented only; they do not include Project Management related decisions(such as those associated with planning, estimating and scheduling).*

# Recommendation System of Shopping

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***Abstract*** - Recommending every customer the goods suitable for taste in recent years, in order to guide the purchase motive for every customer in the shop has been performed. In this research, the proposal about the recommendation systems by the mathematical programming model is made. The recommendation systems built the mathematical model by data-mining, the division by Analytic Hierarchy Process (AHP) and Conjoint analysis were applied, and the new technique about the basis of selection of recommendation candidate goods or presumption of goods taste evaluation has been proposed. This research is that proposed about the recommendation systems of the goods for having added the learning function to taste change of the customer.

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

## 1 INTRODUCTION

This research is that proposed a method that uses mathematical programming model to recommend goods in sales promotion that are suited to consumer tastes. Previous research applied a collaborative filtering method [1] and a contents analysis method [2] using purchase track record data. Although widely utilized in business, the method of recommending goods based on the similarity of purchase track record data for every customer requires a lot of the track record data.

These methods are not applicable to the recommendation of new goods. Moreover, a gap exists between the sales promoter's intuition and the recommendation made using the mathematical programming model that only depends on data analysis of each consumer's taste. 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 method, the taste degree of each consumer is quantified to include all individual goods contained in a commodity category.

A target customer usually has limited purchase track records for a set of goods, thus an evaluation value for goods without a track record will be presumed. 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 for the goods in the spot. If the amount of track record data in a specific period is relatively limited, the collaborative filtering method is applied, decreasing the presumed evaluation value gap and many of the resulting cases uniformly recommend non-purchased goods. The current paper proposes a new method of identifying recommendation goods [3] [4] [5].

## 2 METHOD FOR RECOMIDING 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.

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)" [6] 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 recommended 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.

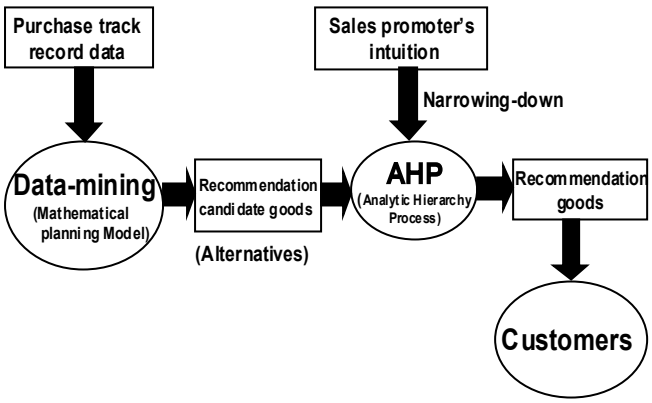



Figure1. The flow of recommendation goods selection

## 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 expression (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".

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 expression (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".

Table2. 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 Attachment to Attributes

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

The goods attribute taste degree matrix for all customers is defined as expression (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 track record 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 track record cannot be decided. "Collaborative Filtering" decides the undecided part-worth value using the purchase track record 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 track record 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 expression (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 track record 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 expression (9). This matrix is called "attribute relationship matrix".

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

Matrix $W$ is expressed with equation (10).

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

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).

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

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

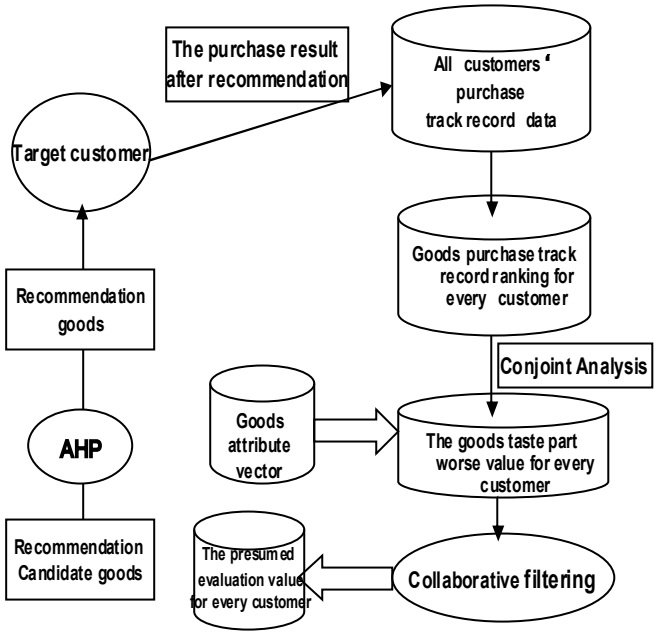



Figure2. The learning function of recommending goods

The difference between a presumed value and the purchase track record $d$ 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.

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

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 RECOMMENDATION 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 track record 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 track record 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 |
|---|---|---|---|---|---|---|---|---|---|
| gr1 | 0 | 4 | 0 | 3 | 0 | 2 | 0 | 1 | 10 |
| gr2 | 1 | 0 | 5 | 0 | 1 | 0 | 1 | 0 | 8 |
| gr3 | 0 | 1 | 0 | 3 | 0 | 2 | 0 | 1 | 7 |
| ... | | | | | | | | | |
| grk | 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.

Table4. 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 $C_i$ of "location-1, age-1, male, and genre-1" serves as equation (23).

$$C^T = (1,0,1,0,1,0,1,0) \tag{23}$$

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

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

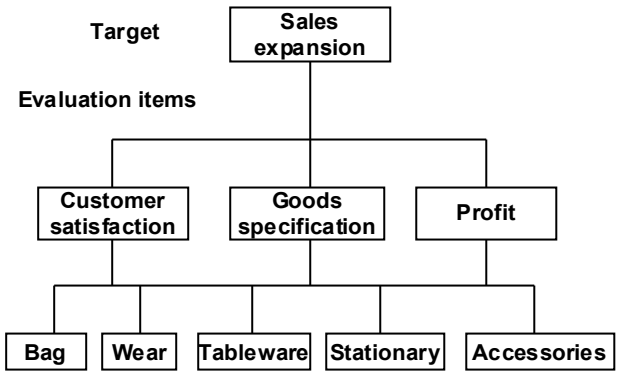
The taste evaluation value of the goods attributes in equation (24), "brand-1, type-1, specification-1, and price-1" is high. These goods attributes with high taste values are recommended out of the goods set.

### 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 dignity attachments 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.

Figure3. Example of recommendation 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.

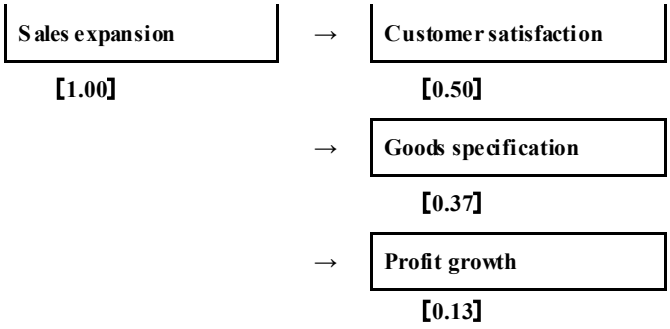



Figure 4.Example of the valuation-basis importance value for recommendation goods

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.

Table5. Example alternatives weight values for recommendation 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.

(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 recomendation 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 recomendation method was "○", the sales promoter was recommended the tableware to the customer, that did not purchase.

Table6. Recommendation result in the model shop

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

## 5 CONCLUSIONS

The proposed method of recommending goods in the spot has the following advantages:

(1) The various functions of goods, performance, brand,price, etc., which influence consumer interest, are identified;

(2) The goods that suit customer tastes are recommended, including new products;

(3) The strength of the correlation between the attributes of both goods and a customer in the "attribute relationship matrix" is defined. If this "attribute relationship matrix" is used, the goods can be recommended to the customer with the particular characteristics, and the target customer can be identified for the goods with particular characteristics; and,

(4) The target and valuation basis utilized by the evaluator of the spot are set up using AHP, which computes an evaluation weight value, and selects recommendation goods with validity.

The conclusion and subject of future is described below about the application examination by shop.

(1) The rate of purchase of each recommending method by application was compared with the rate comparison table 7 of purchase of each recommending method. This application result to the attribute relationship matrix method had the rate of purchase higher than the method and the collaborative filtering method which are enforced by shop.

Table7. Rate of goods recommending method purchase

| Recommending Method | Rate of Purchase(%) |
|---|---|
| Currently method at the shop | 56 |
| Collaborative filtering method | 67 |
| Attribute relationship matrix method | 77 |

The attribute relationship matrix method could recommend goods which suit customer's taste from these results, and many new products were included. More enough satisfaction was obtained from the promoter.

(2) Effect of application

a. Recommendation of the new goods which do not have a purchase track record by having used the effect goods attribute and customer attribute by the technique using an attribute is possible. According to the attribute relationship matrix method, dignity attachment of the relationship between the customer characteristic and the goods characteristic is known, and extraction of the recommendation candidate goods to a customer is easy.

b. On the spot, since a problem has only the recommending-according to subjectivity of the spot method, only the recommending method for presuming recommendation goods by the mathematical technique can utilize the goods recommending method with which the result of data-mining and the subjectivity of the spot are united, and can harness experience and the feeling of conviction of the spot.

## 6. The next research subject

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

(1) Fashion changes may impact the observations in the real shop, indicating a sharp dynamic change in customer's tastes, which are changing continuously, and
are summarized in an attribute relationship matrix . Dynamic optimization of should be studied.

(2) Corresponding to the needs in the shop at the time of applying a technique, a future subject is listed to below.

a. The application of goods recommendation;
Recommendation of goods to a target customer is repeated, the employment method for improvement in the rate of purchase is studied based on real alms giving and the goods recommendation result data for every customer, and application of the method of goods recommending to a target customer is advanced to it.

b. Correspondence to a dynamic change;
Since the taste evaluation value by the mathematical technique is presumed using the past purchase track record 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.

c. Taking in of the combination of goods, and a purchase order;
An attribute vector is generated about a user's purchase action pattern. For example, the combination of goods and a purchase order (at the time series sequence) are classified. By this, the order of recommendation of set goods or goods recommendation is taken in from a single article.

d. The recommendation method corresponding to the goods life cycle;
The selling life cycle of new goods is 2～3 months, is divided into three steps, an initial stage, a middle stage, and the final stage, from sale of new goods, and evaluates a user's taste attribute at the target shop this time. It finds to which timing from now on, it should recommend after a new goods sale start.
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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# Session 3: Networking

# Local Pipelining for Reprogramming Wireless Sensor Networks

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***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]. 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. The pipelining method, which quickly distributes bulk data to the entire network has been proposed in some studies[3][4][5]. 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.

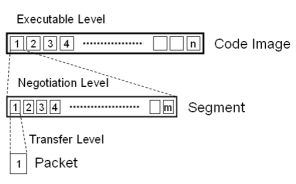



Figure 1: Structure of segment

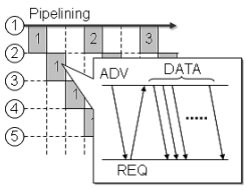



Figure 2: Handshake

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. 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 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 [6]. 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.

## 2 Related Issues

### 2.1 Pipelining

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

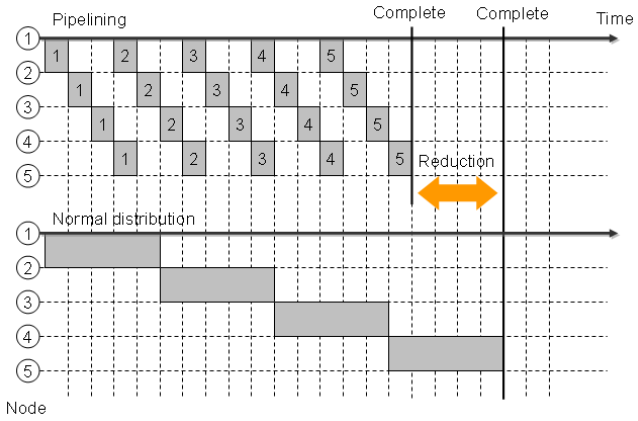



Figure 3: Pipelining

- **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 [2]. The latest

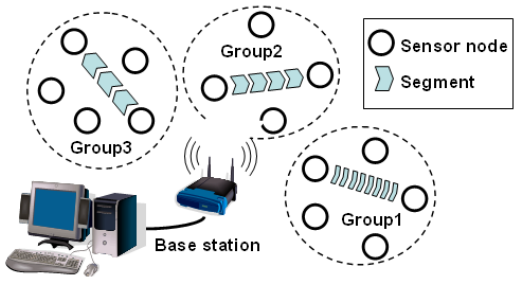



Figure 4: Local pipelining

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 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 [3] and MNP [4] 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.

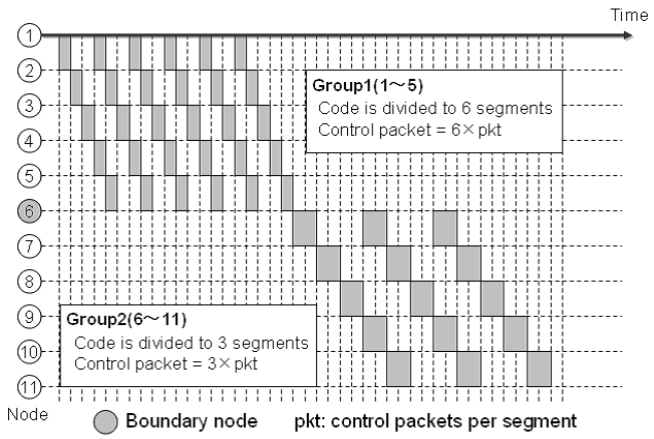



Figure 5: Distribution of Local pipelining

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 handked 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.

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

## 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 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.

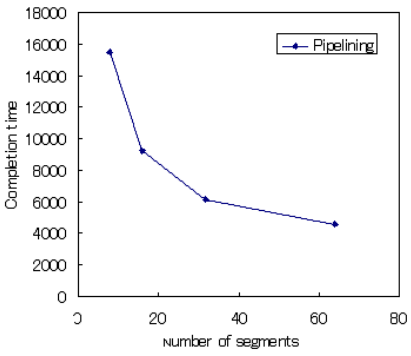



Figure 7: Completion time of normal pipelining

# 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 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. 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.

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

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.

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

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.

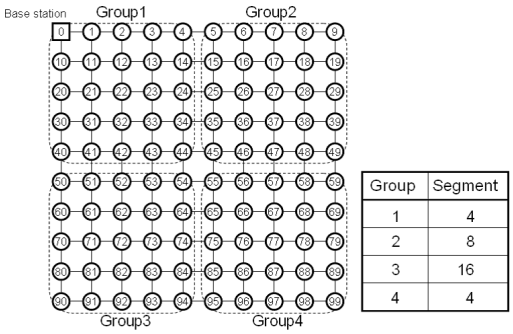
$$C_{lp} = \sum_{i=1}^{k} n_i \cdot m_i \cdot (N_{adv} + N_{req}) \tag{5}$$

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 [7]). The




| Group | Segment |
|---|---|
| 1 | 4 |
| 2 | 8 |
| 3 | 16 |
| 4 | 4 |

Figure 8: Sensor node deployment

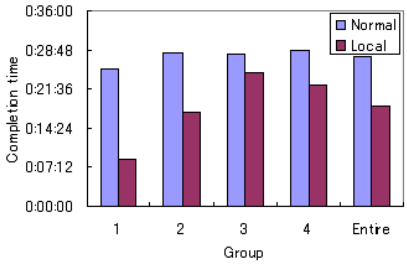



Figure 9: Average completion time of each node

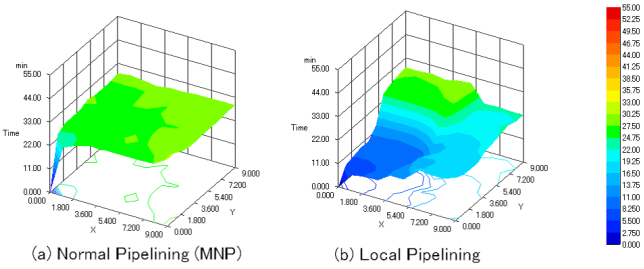



Figure 10: Propagation

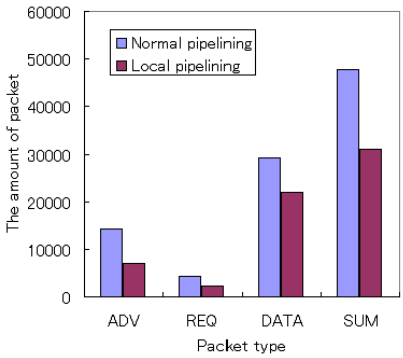



Figure 11: Number of packets

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.

First, we describe the implementation of local pipelining on TinyOS. The implementation was based on MNP [4] 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 $5 \times 5$ 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.

## 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, 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, 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 pipelin-

ing, 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).

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# A Prototype of Brain Model Hyper Communication Mechanisms

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***Abstract*** - It is known that conventional audio and video communication for cooperative work causes a lack of seriousness in remote cooperative work. The author believes that this condition depends on a lack of "awareness". Thus a new communication model should be developed that treats the five senses for awareness. We proposed a new communication mechanism, which refers to the brain mechanism, named the brain model hyper communication mechanism and developed an initial prototype system based upon it. The prototype system has a detection system of a subject's condition and environmental situation for awareness. The prototype system sends finger touch resistance information, mouse-grasping pressure information, pulse information, body temperature information, surrounding noise information, environmental illumination information, and CO gas information. The prototype was applied to an experiment. The results of experiments show that a partner's condition or environmental situation was somewhat understood and the awareness was increased using the prototype system.

***Keywords***: brain model, five senses, sensors, cooperative work, awareness.

## 1 INTRODUCTION

Communication is a very important part of cooperative work. A real-time system for cooperative work, which requires high and complex technology, has been studied in recent years. MUDs (Multi User Dungeon or Multi User Dimension) or MOOs (MUD Object Oriented) which have 3-D (three-dimension) environments have been intensively developed [1], [2]. 3-D representation has been very highly regarded in entertainment applications or games. But some reports have suggested that the video and audio communication channel was not adequate for high efficiency [3], [4]. It is known that conventional audio and video communication for cooperative work causes a lack of seriousness in remote cooperative work [5]. The author believes that this condition depends on a lack of "awareness". The term "awareness" means "become aware of a partner's atmosphere". An atmosphere consists of a partner's condition and environmental situation. Thus a new communication model should be developed that treats the five senses for awareness.

New communication models using the five senses have been studied. The Japanese government has a plan to realize five senses information communication [6]. Many playthings that stimulate the sense of touch, for example Tangible Bits [3], have been developed. Ota et al. developed a system, which shares smell via the Internet [4].

We propose "hyper communication" based on five senses communication. Hyper communication is not realistic sensation communication, but it sends an emphatic atmosphere from remote places. If people communicate between remote places, they feel like they are communicating with one another in the same place by using the hyper communication technique.

The author has devoted attention to human brain processing. The human brain integrates and processes many kinds of information in a moment. Upon this was modeled the brain processing mechanism, especially the vision mechanism to establish hyper communication. The vision mechanism of our model is basically based on Hubel and Wiesel's hierarchical model of area V1 neurons [7]. The author proposes a new communication technique, which is called brain model hyper communication [8]. It sends almost all kinds of environmental data i.e. information of the five senses at the transmitter part, and integrates and processes the data selectively at the receiver part [9]. Fukushima indicated that if one wanted to realize universal information processing, which was adapted to the environmental situation, detailed processing in the retina was not a good strategy. One should send data to the cortex as it is like a higher animal at present [10]. Brain model hyper communication is also based on Fukushima's view.

Conventional neural computing mimics the brain mechanism as a centralized data processing system, yet our mechanism mimics the brain mechanism as a transmitter and a receiver. The author wishes to apply the brain mechanism to communication between distributed systems.

The concept of hyper communication was realized as a brain model hyper communication mechanism based on the vision mechanism of the vertebrae brain processing. The vertebrate processes most environmental information in vision. The author developed an initial prototype system based on the brain model hyper communication mechanisms and evaluated the mechanisms for awareness using the prototype system.

In this paper the concept of the brain model hyper communication mechanism and the application and the evaluation of the prototype system based on it is presented.

## 2 CONCEPTS OF BRAIN MODEL HYPER COMMUNICATION MECHANISMS

The items required of the brain model hyper communication mechanism are as follows. The mechanism consists of a transmitter part and a receiver part.

-Transmitter part: The mechanism analyzes and divides almost all kinds of environmental data into parameters, but some kinds of data are not sent to the receiving part.

-Receiver part: The mechanism integrates and processes the adequate data selectively and hierarchically corresponding to the goal. But some kinds of data are processed directly. A feedback mechanism exists from the receiving part to the sending part.

## 3 BRAIN MODEL HYPER COMMUNICATION MECHANISM

(1) Retina: Sensor (Analog/Digital transducer)

Information of the outside world is transformed to analog signals in the retina. The ganglion cell is located at the output of the retina. The ganglion cell transforms analog signals into digital signals. The number of ganglion cells is said to be $10^6$. More than video and audio signals, the information of smell, touch, temperature, humidity, terrestrial magnetism, atmospheric pressure, and so on that are detected by sensors or measuring devices will have been used in the communication of the cooperative systems [3],[4]. When a cooperative system transmits the data in the network, analog data are transformed into digital data and submitted. This processing part is similar to the role of the retina and the ganglion cell.

(2) Lateral Geniculate Nucleus (LGN): Adding some pre-processing to data and sending to the visual cortex (V1 area)

The LGN cells basically receive the visual information from one or several retinal ganglion cells and relay the data to the visual cortex cells. However, inhibitory inter-neurons exist in LGN. Cortico-geniculate pathways from the V1 area are also said to exist [10]. An LGN cell is not only a relay cell, but it also controls the flow of visual information and so on.

(3) V1 area: Receiving, integrating and re-submitting data

The neurons of the V1 area integrate the information sent from the LGN. Cortico-geniculate pathways from the V1 area are also said to exist [10]. This mechanism may apply the information processing of the agent. The term agent means the autonomous processing program. Hubel and Wiesel proposed in their model that the LGN, simple cells, complex cells and hyper complex cells are connected sequentially [7]. If the light stimulation covers the on-centers of LGN cells, the simple cell corresponding to the slant is discharged. Their model seems to be familiar with the hierarchic structure of agents.

(4) V2 area

Information of pattern, color, and movement are analyzed and integrated explicitly and repeatedly. This mechanism may also correspond to the hierarchy mechanism of the agents.

Equations must be center aligned, and recommended that they be preceded and followed by one line of white space.

## 4 BRAIN MODEL HYPER COMMUNICATION MECHANISM

The brain model hyper communication mechanism mimics the brain mechanism as a transmitter and a receiver (Figure 1).

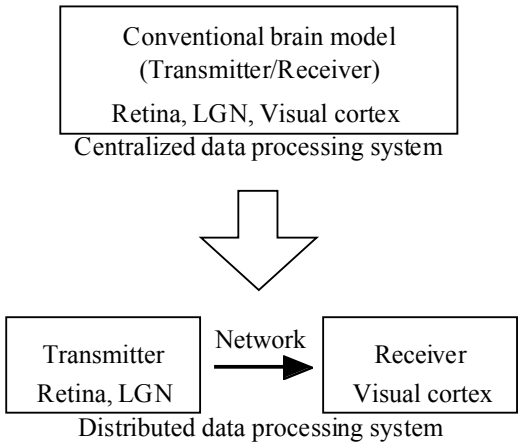


Figure 1: Concept of brain model hyper communication.

Brain model hyper communication requires two mechanisms. One mechanism analyzes and divides all environmental data, and the other integrates and processes the data selectively and hierarchically corresponding to the goal. The data contains five senses (Figure 2).

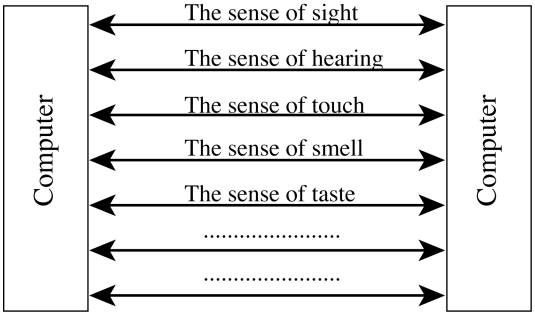


Figure 2: Parameters of the brain model hyper communication.

Figure 3: The experimental system.

Figure 3 shows the experimental system of the brain model hyper communication mechanism. The author developed an initial prototype system for the brain model hyper communication mechanism. The prototype system consists of the five senses information detection system and the five senses information processing system. Table 1 shows an example of the parameters in a target application. Figure 4 shows an example of the parameters for processing. We explain the brain model hyper communication mechanism using the prototype system.

Table 1: Example of parameters

| Parameters |
|---|
| No.1 Finger touch resistance |
| No.2 Mouse-grasping pressure |
| No.3 Pulse |
| No.4 Body temperature |
| No.5 Surrounding noise |
| No.6 Environmental illumination |
| No.7 CO gas |

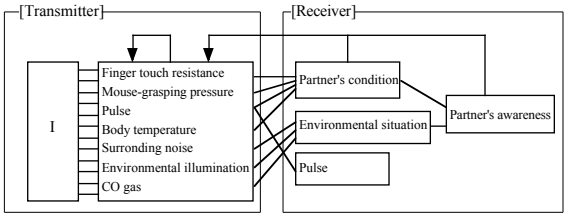


Figure 4: Example of parameters of processing.

# 5 EXPERIMENTS

## 5.1 Procedure of experiments

We have developed an initial prototype system of the brain model hyper communication mechanism. The prototype system has seven parameters for communication, i.e. touch resistance of subject's finger, subject's mouse-grasping pressure, subject's pulse, subject's body temperature, surrounding noise, environmental illumination, and CO gas (Figure 4).

The touch resistance detector is made by copper foil around the mouse. The fluctuation of the resistance is measured. If a subject is excited and begins sweating, the resistance of his finger becomes low. The pressure detector is placed between the mouse and copper foil. The subject grabs the mouse, and if excited, he grasps the mouse tightly and the resistance of the pressure sensor becomes low. The pulse detector is installed on the mouse. If a subject is excited, his pulse rate becomes high. The temperature detector is also installed on the mouse. If a subject catches a cold, his temperature becomes high. The detector measures hand temperature, which is somewhat lower than the body temperature. The noise detector, which is set up around the subject, can show whether a subject is in a noisy situation or not. The illumination detector, which is also set up around the subject, can reveal whether a subject is in a well-lit room or not. The CO detector is also set up around the subject. This can indicate whether or not a subject is safe.

The experimental system consists of a target application (ex. a Web Browser), a five senses information detection system, and a five senses information processing system. The five senses information detection system is shown in Figure 5. The copper foil was used for measuring resistance of a subject's finger. We used sensors on the market except the touch resistance sensor. The goal of the system is to transmit the awareness information.

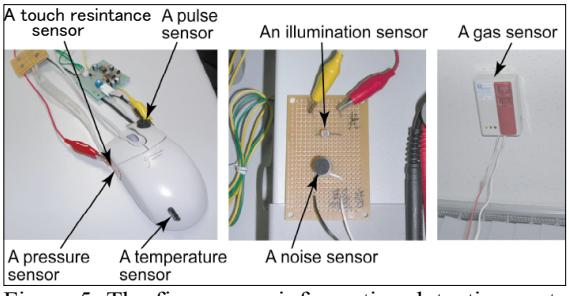


Figure 5: The five senses information detection system.

Examples of the screen of the experimental system are shown in Figure 6 (bar graph presentation) and Figure 7 (time-series graph representation). The time-series graph representation consists of fifty data which are sampled at

every 0.5 seconds. We can choose some graphs in the time-series graph presentation (presentation/ no presentation function), as well as detailed information (detail presentation function).

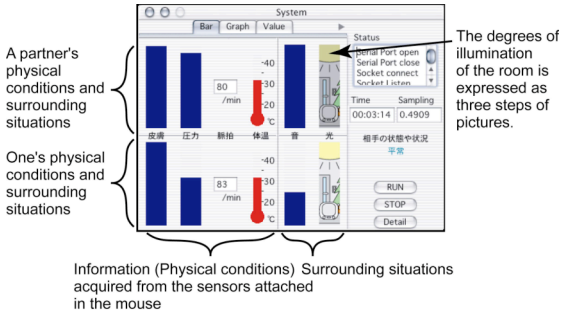


Figure 6: Bar graph presentation of the five senses information processing system.

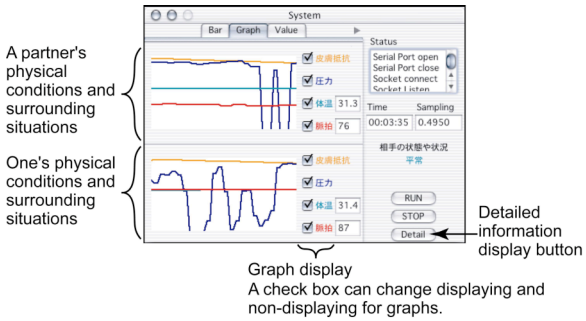


Figure 7: Time-series graph representation of the five senses information processing system.

The target application is a mouse-driven application, ex. a Web browser. The experiment was performed in a room at our university for about one hour. Two Macintosh computers (Apple) and a 100 Base-T network were used. Seven students participated in the experiment. Experiments were performed by two subjects. One used the five senses information detection system, while the other (observer) watched his partner's operation via the network. All experiments involved performing the original experiment at first and then the extended presentation experiment using the presentation / no presentation function and the detailed presentation function. Observers sometimes watched the screen of the system. The five senses information processing system has the following functions:

(1) If a subject's pulse is over 100 times/minute, then the system represents it as "pulse is high".
(2) If a subject's pulse is over 110 times/minute, then the system represents it as "pulse is very high".
(3) If a subject's finger temperature is over 33°C, then the system represents it as "temperature is high".
(4) If the CO sensor detects CO gas, the system represents it as "the CO gas is leaked".

The value was decided by fourteen subjects.

## 5.2 Results and discussion

The experimental system requires about 3 Kbps for transmitting seven kinds of data. After the experiments, we administered a questionnaire, which had a 5-point scale (with answers "1; very bad", "2: bad", "3: neutral", "4: good" and "5: very good") to evaluate each item.

Table 2 shows the results of the 5-point questionnaire. The "no using" means the graph representation without extended functions (presentation/no presentation, detailed presentation). The "using" means the graph representation with extended functions.

Next are shown the content of the results.

[Overall]
- I understood the condition of my partner, seriousness or exciting vaguely.
- I could understand that my partner became calm.
- I could understand that my partner was sitting.
- I could understand that my partner grasped the mouse.
- The graphs reflect the conditions very well.
- Judging the received information is difficult for me.
- I could select the graphs. That was good for deciding condition or situation.
- The partner's condition should be presented to be understood at a glance.

[Individual]
[Pressure]
I could understand that my partner became sleepy.
[Pulse]
I could understand that my partner's condition was stable, because the pulse did not change seriously.
I could understand that my partner became stable.
I could understand my partner's condition by "pulse" and "body temperature".
[Surrounding noise]
I could understand that my partner was in a noisy space.
[Illumination]
I could understand that my partner was in a well-lit room.

The "pressure" or "pulse" was highly evaluated. The "pulse" and "body temperature" may indicate the condition of the partner from the questionnaire. From the content of the results and Table 2 (1), a subject recognizes a partner's condition or situation well by the prototype system. From Table 2 (2), the selection of the graphs is highly evaluated. Those are the results of dividing many sending parameters and selecting data. They indicate that the concept of transmitter part and the concept of the receiver part of the brain model hyper communication mechanism are adequate.

Table 2: Results of 5-point questionnaire.

| 5-point evaluation | No using | Using |
|---|---|---|
| (1) Did you recognize a partner's condition or situation? | 3.9 | 4.1 |
| (2) Was the presentation/no presentation function useful for finding important information? | - | 4.0 |
| (3) Was the "touch register" useful for recognizing a partner's condition or situation? | 3.0 | 3.3 |
| (4) Was the "pressure" useful for recognizing a partner's condition or situation? | 3.7 | 3.9 |
| (5) Was the "pulse" useful for recognizing a partner's condition or situation? | 3.9 | 4.0 |
| (6) Was the "body temperature" useful for recognizing a partner's condition or situation? | 3.0 | 3.1 |
| (7) Was the "surrounding noise" useful for recognizing a partner's condition or situation? | 2.6 | 3.4 |
| (8) Was the "environmental illumination" useful for recognizing a partner's condition or situation? | 3.1 | 3.9 |
| (9) Was the "gas detection" useful for recognizing a partner's condition or situation? | 1.7 | 1.9 |

## 6 CONCLUSION

We proposed a new communication mechanism, which refers to the brain mechanism, named the brain model hyper communication mechanism and developed an initial prototype system based upon it. The prototype system has the detection system of a subject's condition and environmental situation for awareness. The prototype system sends finger touch resistance information, mouse-grasping pressure information, pulse information, body temperature information, surrounding noise information, environmental illumination information, and CO gas information. The prototype was applied to the experiment. The results show that a partner's condition or environmental situation was somewhat understood and the awareness was increased using the prototype system.

In the future, we would like to modify the prototype and increase the number of sending parameters. We also would like to add a feedback function, thinned function, autonomous judgment function, and hierarchical function to approximate the brain model hyper communication mechanism.

## ACKNOWLEDGEMENTS

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# Heterogeneous Network Convergence: Towards An Advanced Infrastructure Management

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***Abstract*** - Energy consumption has been increasing remarked over the past half century. Even though ultra-low power consumption appliances are developing, the amount of energy consumption in home is increasing because of various lots of appliances appear to realize the ubiquitous smart infrastructure. In this paper, we propose an advanced infrastructure management system for control the home energy consumption that can be realized by the convergence of heterogeneous networks. The system goes far beyond traditional AMR systems that offer only limited meter-reading functionality and provides a smart infrastructure management system that brings new features and benefits to every aspect of our utility's operations.

***Keywords***: Heterogeneous Network Convergence, Advanced Infrastructure Management

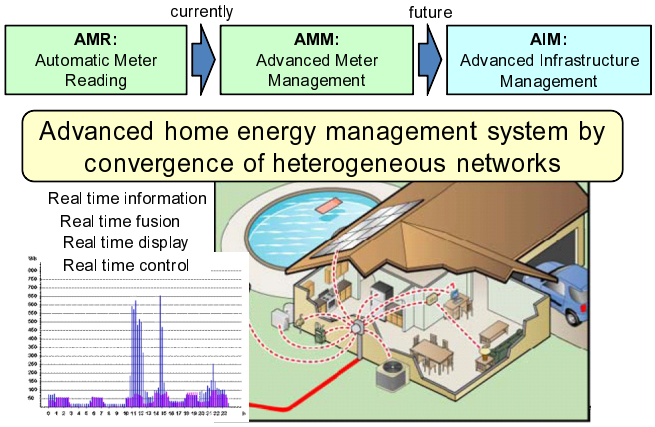


Figure 1: Overview of advanced home energy management.

## 1 Introduction

Recently, energy consumption has been increasing remarked over the past half century mainly due to increasing population and economic development in the world [1]. Although the development of new low consumption appliances, high efficient heat pump system, such as Ecocute, and hybrid vehicles for consumer use are contributing in no small part to reduce the emission of greenhouse gases in home, it's important thing to remember the recent rapid growth for ubiquitous comfortable services everywhere are becoming the main power hunger in our life.

On the horizon, there may be more various lots of appliances coming soon to our convenience life to realize the ubiquitous smart infrastructure than there are now. Even though each appliance is ultra-low power consumer electronics, the amount of energy consumption in home will increase because of the number of themselves. We have to consider the power consumption and power supply trouble is becoming more serious problem than now.

In this paper, we propose an advanced infrastructure management system for control the home energy consumption that can be realized by the convergence of heterogeneous networks. Figure 1 outlines the overview of our system. We assume the future appliances have its own battery or be attached to the UPS (Uninterruptible Power Supply system) and can be controlled through the converged heterogeneous networks, such as PLC (Power Line Communications), Wi-Fi networks, broadband next generation networks, cellular networks, future sensor networks and so on. PLC has been used to network indoors and homes, AMR (Automatic Metering Reading), remote control and monitoring system [2]–[4].

There are several researches in the field of home energy management system [5]–[7], the key feature of our proposed system is distributed power supply shifting among appliances. Each appliance charges the midnight power in the UPS and supplies charged power to the other appliances through the power line that is temporarily disconnected from the commercial power supply. If the system can adjust the power supply shifting appropriately, the peak power consumption in home will be reduced dramatically.

The rest of the paper is organized as follows. Section II outlines the heterogeneous network convergence as related work. In Section III, we describe the features of proposed advanced infrastructure management system in more detail. Section V ends the paper with a brief summary and some concluding remarks.

## 2 Heterogeneous Network Convergence

IP Multimedia Subsystem (IMS) and Fixed Mobile Convergence (FMC) are expected to allow service providers to deliver any service to any customer over any device at any location. Since the IP realize the horizontal integration of control mechanism between heterogeneous networks, its extensions, heterogeneous network convergence, would provide a tremendous opportunities for future advanced infrastructure management. In this section, we discuss related work that en-

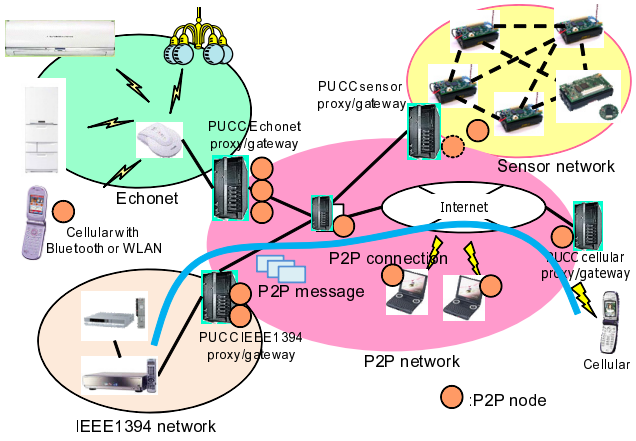


Figure 2: PUCC architecture.

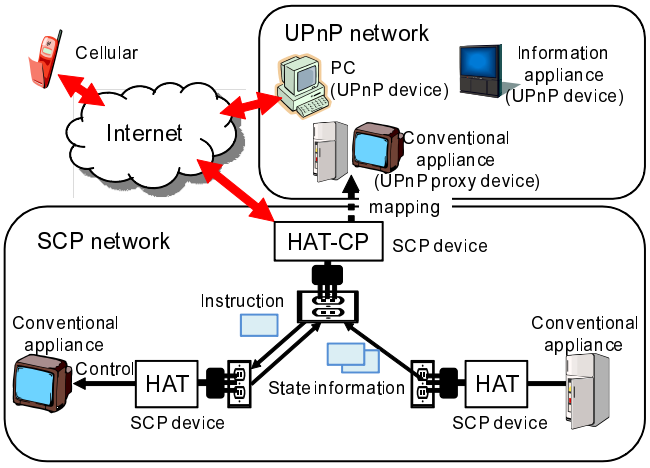


Figure 3: HAT architecture.

ables us to achieve the heterogeneous network convergence.

## 2.1 PUCC: Peer-to-Peer Universal Computing Consortium

Peer-to-peer Universal Computing Consortium (PUCC) was established in 2005 to develop a peer-to-peer networking platform for realizing applications in ubiquitous networking environment. The PUCC architecture is shown in Figure 2. In the architecture, bidirectional communication entities, called peer-to-peer nodes, construct a peer-to-peer network by establishing peer-to-peer connection among them. The peer-to-peer nodes communicate one another using the peer-to-peer connections. The architecture has elements as described below [8].

Peer-to-peer node is an independent bidirectional communication entity. In the architecture, it can be a mobile device, a PDA, a personal computer, a server, a workstation, or any of a variety of devices. Each node has a unique ID and communicates using the ID independent from the physical networks. Peer-to-peer network is a logical collection of peer-to-peer nodes those have a common interest and obey a common set of policies. The connection between peer-to-peer nodes is established on mutual trust. Each peer-to-peer node can enter or depart the peer-to-peer network at its convenience. Messages are sent from one peer-to-peer nodes to another directly or via some intermediary peer-to-peer nodes. Routing information is discovered by broadcasting an inquiry message to the network. Peer-to-peer message is data object that is sent and received between peer-to-peer nodes. The message is a basic unit for exchanging data and it has a unique ID. Peer-to-peer connection is a communication channel established between peer-to-peer nodes. The messages are transmitted along the peer-to-peer connection.

The peer-to-peer communication is one of the most important and suitable networking technologies for communicating among various heterogeneous devices since it effectively supports one-to-one communication. The free, extensible distribution of resources and the distributed search mechanisms needs to handle the enormous resources on the Internet. The peer-to-peer communication has the ability to link heterogeneous network in a cross-sectional manner such as the Internet, ad-hoc networks, and home networks. It can realize seamless connection between various devices via various networks and handle the enormous resources as an overlay network.

## 2.2 HAT: Home Appliance Translator

We developed a HAT (home appliance translator) and a HAT-CP (HAT control point) to enable conventional appliances without telecommunication capabilities to connect to home networks [9]. The architecture of a home network, including the conventional appliances that contain HATs and a HAT-CP, is shown in Figure 3.

The HATs and HAT-CP communicate through power lines and construct a SCP (Simple Control Protocol) network [10] automatically. The SCP is a control protocol for intelligent lightweight devices formulated by the Microsoft Co. The protocol provides autonomous communication and a high compatibility with UPnP.

An SCP device supports one or more services. A service has a group of properties and actions. The properties describe the state of the service, and the actions change the state of the service. An SCP device communicates with its own services, namely, the services 'properties and actions to other SCP devices on the network. An SCP device can construct a relationship called a subscription with its own properties and the communicated properties of other devices. A subscription is a relationship established between an SCP device called the publisher and another SCP device called the subscriber. When a property of the publisher is changed, the publisher notifies the subscriber of that change by using a PropertyChanged message. In addition, an SCP device can initiate an action in another SCP device by sending an InvokeAction message to the device.

The user does not need information appliances, new communication wire, and complex settings for the network, they only have to insert the HATs and HAT-CP into outlets. A

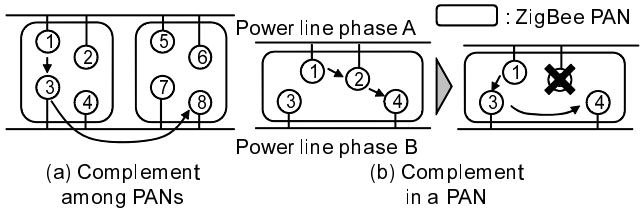


Figure 4: Mutual complementary home network.

HAT is inserted between a conventional appliance's plug and an outlet. The HAT transmits state information about the connected appliance when it receives an operation instruction from the HAT-CP. A HAT-CP is a control point device for HATs. When a HAT-CP discovers a new HAT on the network, the HAT-CP automatically begins communicating with the new HAT. A HAT-CP collects information about the connected appliances from HATs and infers the state of the appliances. The HAT-CP transmits operation instructions to HATs. In addition, a HAT-CP functions as a gateway between the SCP network and other networks. Users can remotely control conventional appliances from areas not connected to power lines by accessing the HAT-CP. Especially, a HAT-CP functions as a SCP/UPnP bridge gateway and can map a conventional appliance connected with HAT into the UPnP network as an UPnP proxy device. Home networks, including conventional appliances with HATs and HAT-CP, can coexist with an UPnP network, which is the most common home network that includes information appliances.

The HATs and HAT-CPs can automatically communicate with each other using existing power lines. This allows users to construct a home network easily, cheaply, and without the need for information appliances, new communication infrastructures, or complex settings. In addition, this system enables interoperation between information appliances and conventional appliances.

## 2.3 Mutual Complementary Network

While a home network needs to maintain the communication infrastructure, wiring new cables costs a lot of money. Therefore, the best way to make a home network is to use existing cables in a home. Electric power lines are wired throughout houses, and most appliances are connected to outlets: thus power lines are a suitable for home network medium. The power line communications (PLC) signals, however, are attenuated by different phases and appliances that exist between communicating equipment may decrease the arrival rate.

We have gotten results of an investigation on the arrival rates for all combinations of outlets that can be used for PLC in a three-story house and a university building in a real environment. The result was that the arrival rate of PLC was characteristically either 100% or 0%. In contrast, wireless communication standards, 802.11b/a/g/n, Bluetooth, ZigBee and UWB (Ultra Wide Band), are applicable to a home network. It is likely that some sensors in the wireless network will be placed where they cannot get power: therefore it is preferable that the power consumption of the communications is low. So the ZigBee is suitable for controlling home network appliances and sensor networks. In ZigBee, however, communication quality is degraded by obstacles, transmission distance, and noise.

To solve these problems, we have proposed a mutual complementary network environment that improves arrival rate by using PLC and ZigBee, and study communication methods that improve reachability and efficiently [11]. The mutual complementary network complements these places where nodes can't communicate through only one interface. Figure 4 shows a model of the mutual complementary network. Two phases exist in the electric power line and the arrival rate of PLC decreases significantly in communications between different phases. Figure 4 (a) depicts the situation of connecting between different ZigBee PANs by PLC through a node 3 at the time of the message transmission from node 1 to 8. Figure 4 (b) depicts the situation of complementing with PLC through a node 3 at the time of the message transmission from node 1 to 4.

# 3 Advanced Infrastructure Management

## 3.1 Overview

Figure 5 outlines the architecture for our proposed advanced infrastructure management system. This advanced infrastructure management system control the home energy consumption through converged heterogeneous networks, such as PLC, Wi-Fi, NGN (Next Generation Network), Echonet, DLNA (Digital Living Network Alliance), cellular, sensor networks and so on. Especially, the right side of Figure 5 depicts the distributed power supply shifting function. The function provides the AIM service and is connected into the other PUCC peer-to-peer nodes through the PUCC proxy/gateway node so that consumer can subscribe the AIM service and cooperate with other heterogeneous PUCC network services.

In the PUCC architecture, peer-to-peer network is established among peer-to-peer nodes. If the peer-to-peer node acts as a proxy/gateway of other domain network, the peer-to-peer network takes the heterogeneous network into itself and allows PUCC peer-to-peer nodes to access the connected network. The peer-to-peer node and proxy/gateway node have a metadata that is used to describe the information of published service. If the proxy/gateway node has several devices/nodes under connected other domain network, the proxy/gateway might describe several services into either a metadata or several metadata.

## 3.2 Metadata Model

The metadata model is shown in Figure 6. Device is a unit to describe an appliance or node as a PUCC peer-to-peer node. It can describe several sub-devices as primitive devices so that the proxy/gateway may provide several services, such as publishing temperature, power consumption, location,

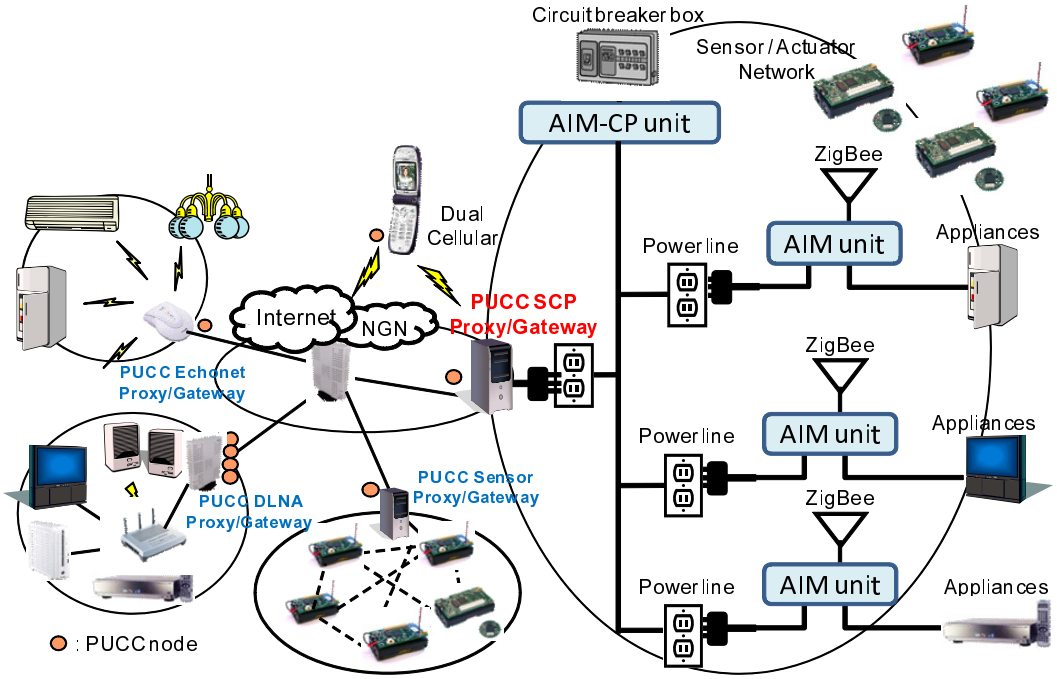


Figure 5: Advanced infrastructure management system.

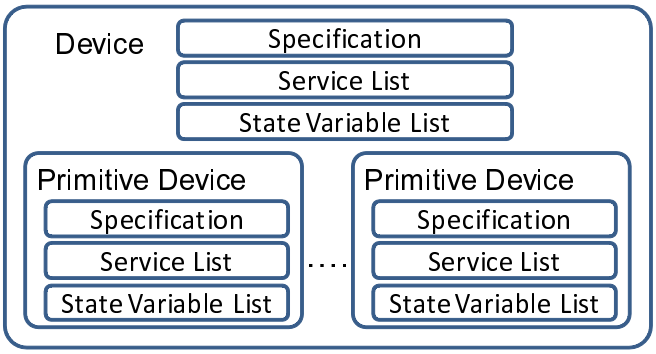


Figure 6: Metadata model.

turning on/off control. Service is an abstracted function provided by the device. State variable is a value representing the state of device and used for notifying a message. The metadata is written in XML and includes specification, service list, state variable list and event list. The specification declares device information, such as model name, manufacturer information and capability. The service list is a set of service that the device provides.

### 3.3 Power Supply Shifting

The key feature of the proposed system is distributed power supply shifting among appliances. Each appliance stores the midnight power in the UPS and supplies charged power to the other appliances through the power line that is temporarily disconnected from the commercial power supply.

As shown in the right side of Figure 5, each appliance is attached by AIM (Advanced Infrastructure Management) unit to provide power supply shifting function. The function is published to the PUCC peer-to-peer network as a PUCC service by PUCC SCP proxy/gateway node. The AIM unit consists of UPS, PLC and ZigBee communication modules and their control software. The UPS control module selects the power supply method either commercial power or charged power of UPS. AIM unit attached to the breaker disconnects the commercial power supply so that the other AIM unit can run the charged power to the in-house power lines. The AIM unit communicates each other by using mutual communication protocol with PLC and ZigBee so as communication among AIM units to get high reliability. The AIM software, upper layer of AIM unit, is a main module to adjust the power supply shifting appropriately.

The UPS control module monitors its own charged power in UPS periodically and broadcasts the state information to AIM-CP unit attached to the breaker. The AIM-CP unit is a control point for safety power supply shifting and transmits operation instructions to AIM units. Of course, users can remotely monitor and control AIM units from areas not connected to power lines by accessing the PUCC SCP proxy/gateway. The AIM-CP creates the other AIM units table and makes records of their power consumption and soared power regularly. AIM-CP selects the AIM unit that has maximal charged power continuously. Although each UPS has small capacity and supply power for a short time, peak shift can be achieved by adequate power supply shifting continuously.

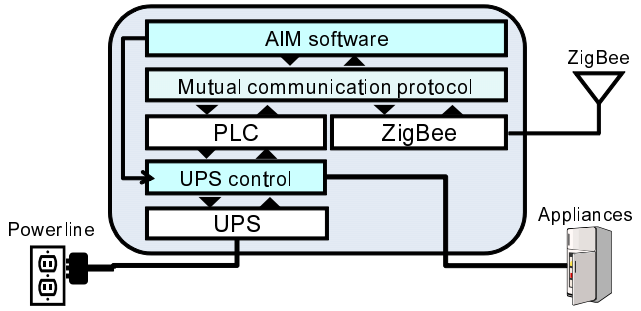


Figure 7: Architecture of AIM unit.

### 3.4 UPS Communication Protocol

There are several UPS communication protocols. Although almost protocol depends on the UPS product, the protocol provides features to allow the user to:

1. Monitor charger status.
2. Monitor battery status and condition.
3. Monitor inverter status.
4. Monitor UPS status.
5. Monitor the utility status.
6. Shut off power to the UPS load.
7. Turn off power to the UPS load and allow the power to return after a user-selected amount of time.

The connected AIM unit controls information exchange through a query command. Writable variables may be edited on higher end equipment like APC's Smart-UPS models for local customizations. The UPS responds with information or a specific action takes place without a serial response. Some data/functions are different depending on whether the UPS is a standby or on-line. In the case of RS-232C cable, UPS data is provided at a rate of 2400 baud and consist of 8 data bits, 1 stop bit, and no parity bit. All the information is provided in ASCII format. UPS responds to inverter shut down and output shut down after a specified delay and for specified time. They also permit cancellation of the shut down sequence.

AIM unit communicates its connected UPS by using UPS communication protocol and send the information to AIM-CP through power line by using SCP. AIM-CP unit collects the UPS information for control the home energy consumption.

## 4 Conclustion

We discussed the advanced infrastructure management (AIM) system for control the home energy consumption that can be realized by the convergence of heterogeneous networks. With its open, bi-directional, and extensible infrastructure, AIM system enables a comprehensive range of utility applications. It goes far beyond traditional AMR systems, which offer only limited meter-reading functionality over proprietary, often one-way communication modules retrofitted to conventional electricity meters. Instead, the AIM system provides a state-of-the-art, future-proof smart infrastructure management system that brings new features and benefits to every aspect of our utility's operations. We have plans in place to implement the AIM system and evaluate the reduction of in-home energy consumption.

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# Adaptation to small building with Mutual Complement Communication system by Wired and Wireless

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**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.

**Keyword:** 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".

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

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 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.

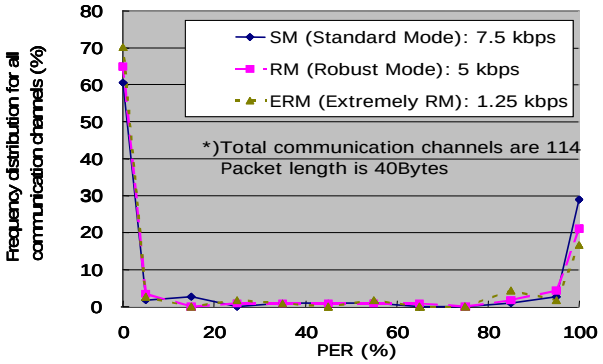


**Fig.1 Testing result of PLC (100kHz–400kHz) in typical Japanese home**

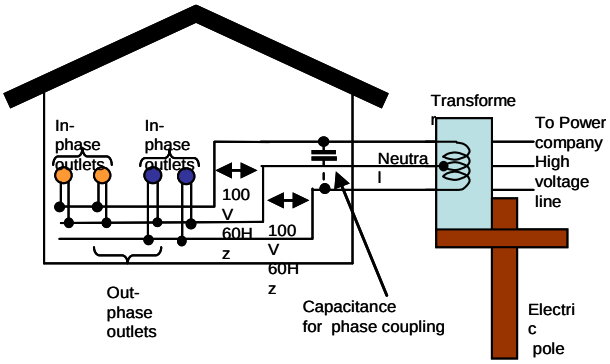


**Fig.2. Power line of Normal home**

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 (20K-bps 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.

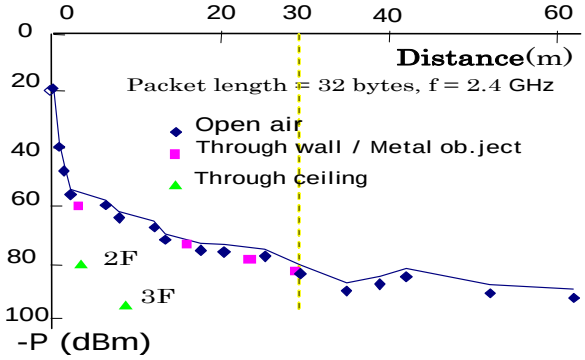


**Fig.3. Distance vs electric(dBm)**

## 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 | Not Truth |

As for the frequency of Fig.1 to ? truth ?, a 'imitation' makes ? truth ?? 20% 10% 70%. 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 'fake'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 70% and 82% improve to 94.6% and makes 'truth ?'- 'truth ?' 'truth'

**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.

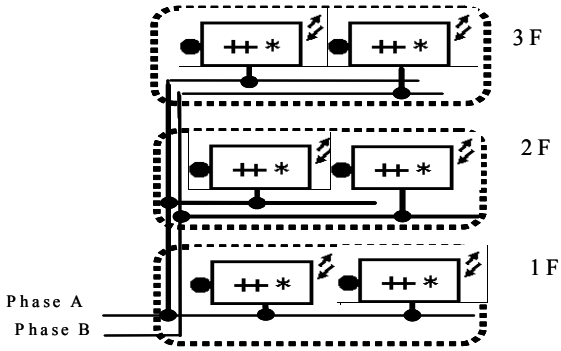


**Fig.4. An actual check of the power distribution condition.**

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 reception | | |
|---|---|---|---|---|
| | | 1F | 2F | 3F |
| Floor of transmission | 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.

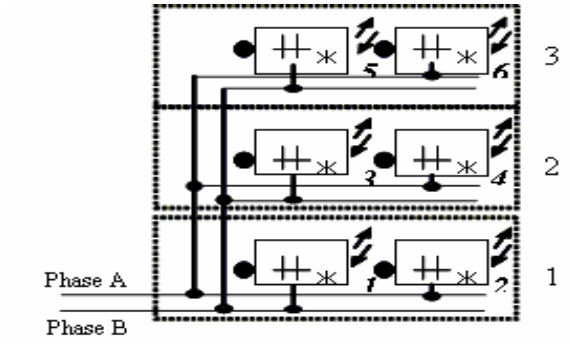


**Fig.5. Routing node example at three-story house**

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**

| | | Receiving node No. | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| Sending node No. | 1 | — | Z | P | × | P | × |
| | 2 | Z | — | × | P | × | P |
| | 3 | P | × | — | Z | P | × |
| | 4 | × | P | Z | — | × | P |
| | 5 | P | × | P | × | — | Z |
| | 6 | × | P | × | 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 | — | — |

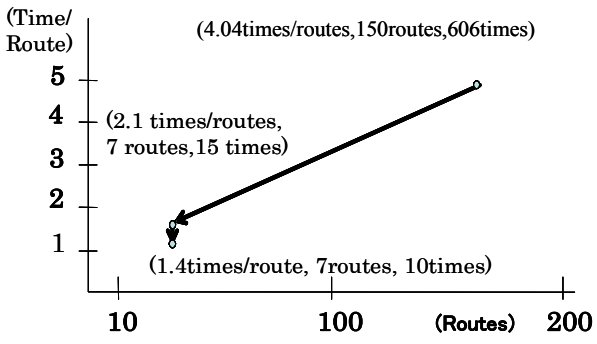


**Fig.6. Number-of-times reduction of routing**

## 4. Communication performance evaluation at a small scale 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 1586m$^2$ floor, B is the university building with 5365m$^2$ floor and C is the graduate school building with 1920m$^2$ 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.4. Mutual complement network performance evaluation of each building**

**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**

| Building name | Summary | Number of Tr | Communication performance | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | PLC | | Zigbee | | | MCN |
| | | | Tr | | Same room | Same floor | Dif floor | |
| | | | Com | Dif | | | | |
| A | 1586.4m² B1～7F | 1 | a | - | a | d | x | b |
| B | 5365m² B1～4F | 3 | b | x | a | c | c | a |
| C | 1920m² B1～4F | 3 | c | x | a | c | c | a |

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.

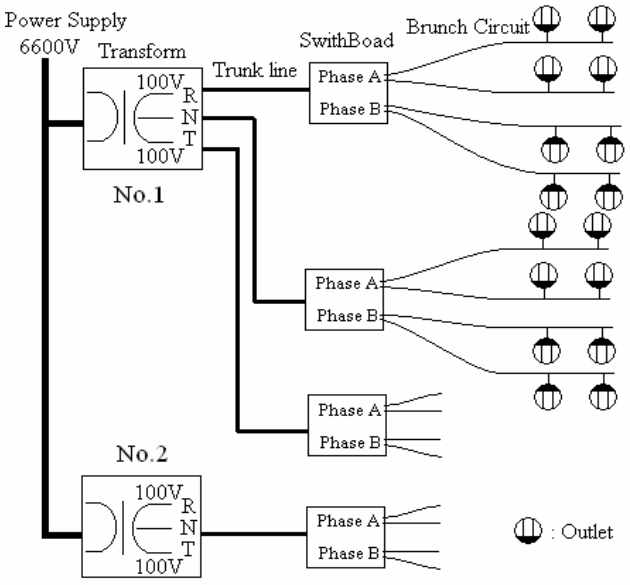


**Fig.7 The power line routing diagram in C building.**

**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 transformer 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（%）**

**PC：Computer room / Server room**

**- : it dose not evaluate**

| 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 | | |

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**

**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**

| 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 | — | — | — |

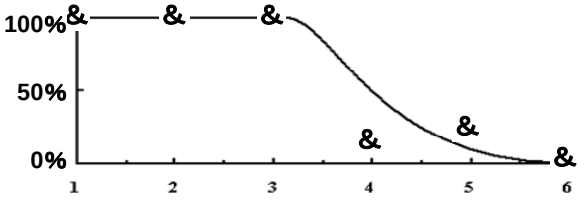


**Fig.8. Relation between the communication load level and a communication performance. "&" mark is an actual measurement.**

**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.

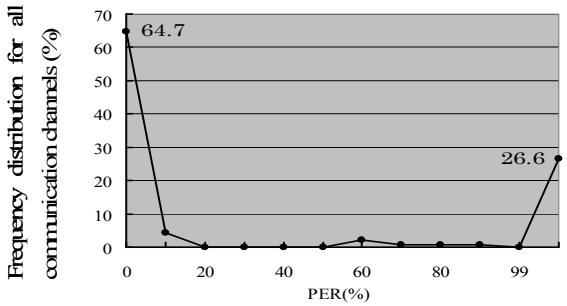


**Fig.11. The PLC experiment result at 3 small buildings with total 139 case.**

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.**

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

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

## 5.2 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.

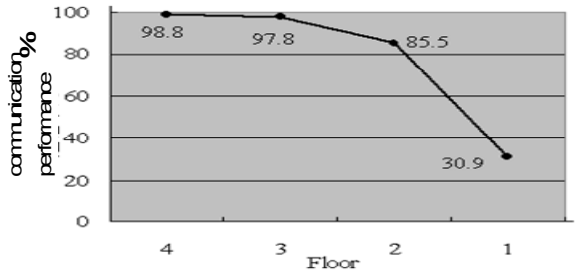


**Fig.10. The ZigBee communication success rate from 4th floor to other floors at B building.**
**Near stair place, the communication perforance is still OK even between 2 floors distance.**

### 4.2 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.

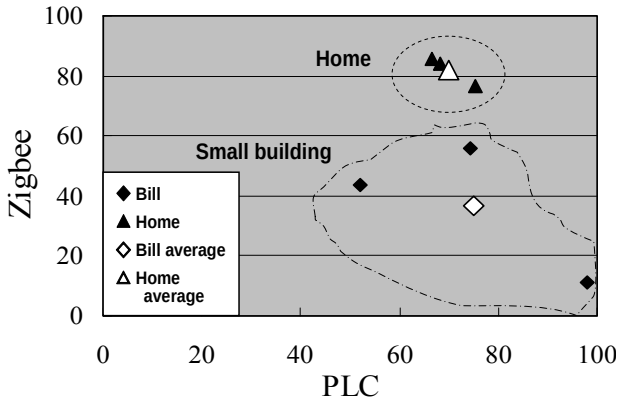


**Fig.11 The difference in the communication (PLC and Zigbee) performance of a small building and a home.**
**A small building has the large distribution of a communication performance.**

## 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 points;

1point;

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.

2 point;

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.

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