(5) Platform Technology for Ubiquitous Services

Toshiki Iso, Yoshinori Isoda, Kiyotaka Otsuji,
Hiroki Suzuki, Shoji Kurakake, and Toshiaki Sugimura

This article discusses platform technology that provides users with easy access to the services they require from the large number of services available in a ubiquitous environment, and platform technology that uses a sensor network to ascertain a user's context when the user accesses a service in order to allow the service to be used in the most convenient way.

1. Introduction

It is becoming possible to avail oneself of computing resources in all kinds of locations and situations these days. The appearance of these "ubiquitous" resources provides a basis for the development of new denominations of communication services such as ubiquitous networks and ubiquitous services. As a result, it should eventually become possible for anyone to use services provided by computer networks with the minimum of fuss at any time wherever they may be. There are basically two areas of technology that should be developed in order to make this concept a reality—technology for making services available on a diverse variety of networks and terminals [1], and technology for discovering services relating to ubiquitous computing resources and other machines and objects in the real world and making them available to users.

In this article we discuss our research into the latter of these two areas. In Chapter 2 we discuss the technology associated with platforms for the discovery and support of services from a wide variety of real-world objects and associated services in situations where users carry hand-held equipment with them. In Chapter 3 we discuss techniques for tailoring services to the user's context by gathering data from ubiquitous sensors situated in the environment. Finally, Chapter 4 concludes with a summary.

2. Ubiquitous Discovery Service Platform (UDSP)

2.1 Introduction

The development of mobile communication networks has made it even easier to connect to the world of telecommunications, and has made it possible to support a wider variety of services. This diversification of services goes beyond the scope of what can be offered in conventional fixed networks such as Ethernet networks. For example, mobile environments are being established to support all kinds of daily life activities. However, this diversification means that it is becoming harder to manipulate and manage the wide range of data needed by these diversified services. To realize ubiquitous services that provide mobile services to mobile users in an appropriate manner, it is essential to develop a platform for the management of diverse services (**Figure 1**).

As one of the constituent technologies of such a platform, DoCoMo is researching techniques for binding data with the real world.

In this article we describe the achievements of this study* relating to a Universal Object Identifier (UOI) that can be used to uniformly identify physical entities (e.g., clothing, food items, devices, household articles and buildings) and logical entities (e.g., places and events) in the real world, and a Ubiquitous Discovery Service Platform (UDSP) that extracts services from universal UOIs.

2.2 Trends in Related Technology

To implement a ubiquitous discovery service that associates objects in the real world with services on a network, at least the following functions are required:

- A function whereby real-world objects can be distinguished on a UDSP
- A function whereby it is possible to discover services on a network that relate to real-world objects

This means that it is necessary to prepare techniques ranging from the management of IDs for objects (including electronic content) to the management of services. However, although individual techniques have already been proposed in various forms and by various groups, they do not form a systematically comprehensive whole (see **Figure 2**). For example, although Auto-ID Center [2] provides a systematic platform for functions ranging from ID management to service management, it does this by introducing an independent ID format called ePC*1 which is incompatible with conventional IDs. Also, it does not prescribe a general-purpose service declaration for selecting services according to context or various types of service relationships.

* This research was carried out in a joint project by DoCoMo, Hewlett Packard Inc., and Hewlett-Packard Japan Inc.

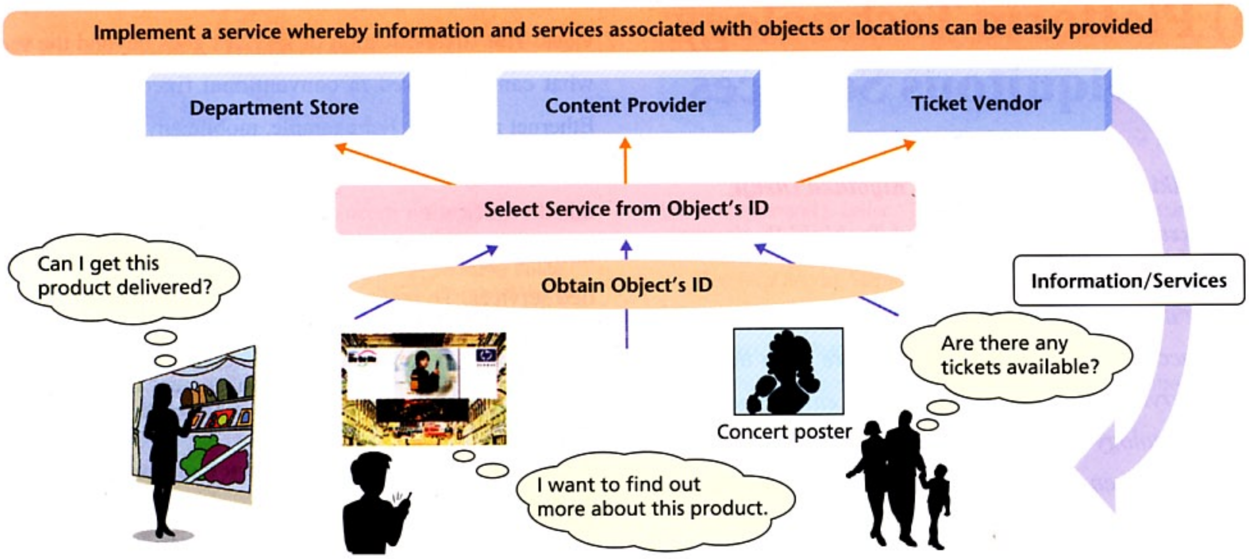
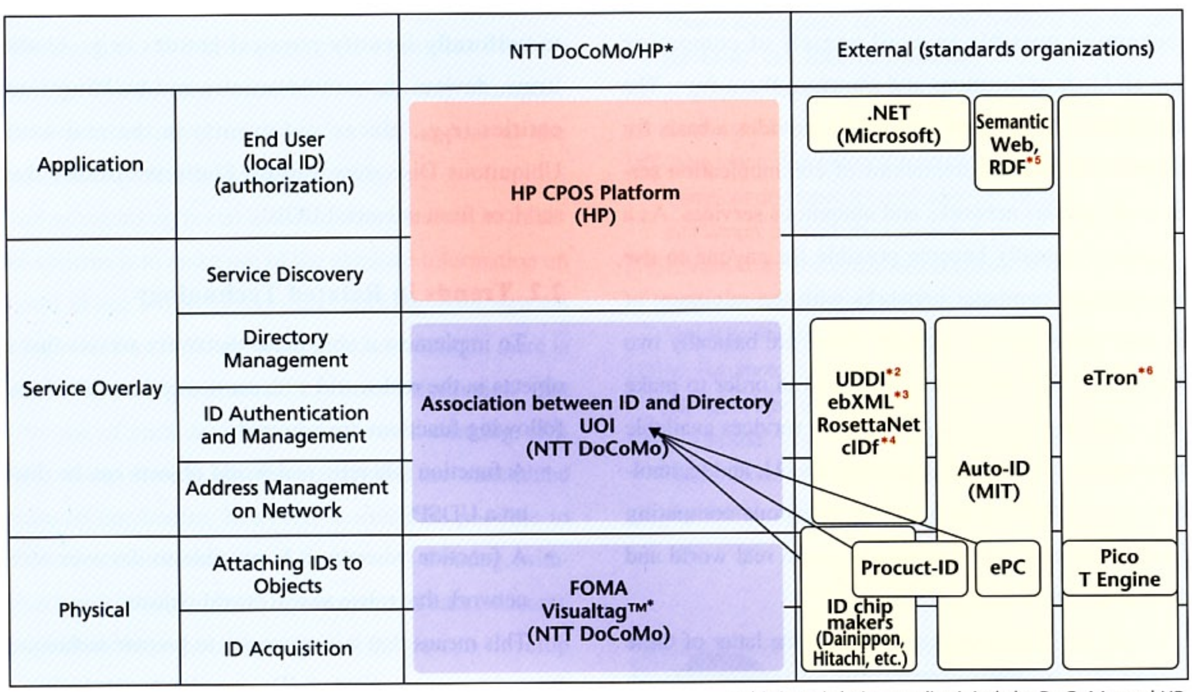


Figure 1 Ubiquitous Services



*This item is being studies jointly by DoCoMo and HP.

Figure 2 Map of Related Technology

Therefore we propose a UDSP architecture that provides a systematic means of organizing and supporting functions for the issue and management of IDs, which is compatible with conventional ID codes and functions for reading IDs that can be used even in mobile environments, and which provides functions for the management of services associated with these IDs.

2.3 UDSP Overview

The UDSP is built around ID management techniques that allow it to support ubiquitous services whereby it is possible to find related services from a UOI (**Figure 3**) [3]. This UOI is a logical identifier that uniquely specifies an object in the real world. It can be generated from any code system—such as barcodes or Radio Frequency IDentification (RFID) codes—with guaranteed uniqueness.

This platform also includes service portals that allow it to offer a richer variety of ubiquitous services. The purpose of a service portal is to discover services suited to the context or the user's preference, and to connect the user to these services.

* Visualtag is a trademark of NTT DoCoMo, Inc. in Japan.

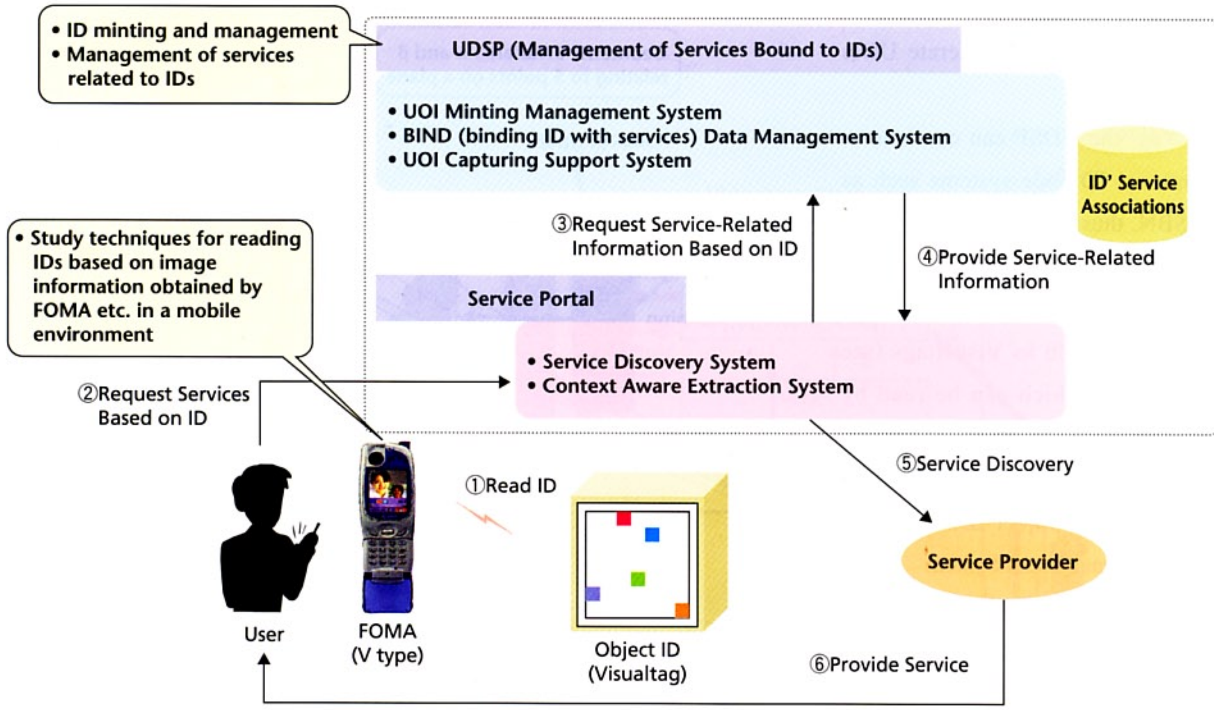


Figure 3 The UDSP

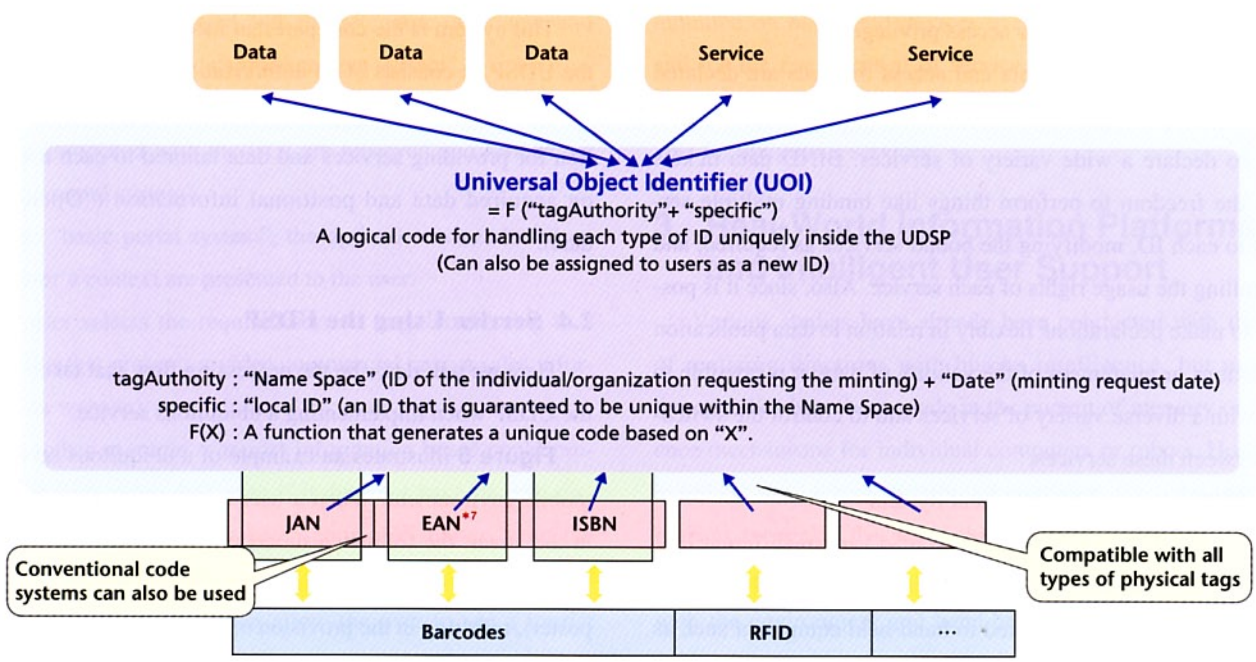


Figure 4 Technique for Deriving a Common ID from Individual ID Spaces

The UDSP is configured from the following technologies.

(1) UOI Minting and Management System

This system mints and manages logical ID codes for guaranteeing the uniqueness of all UOI based on conventional ID schemes or new ID schemes, as long as the codes are guaranteed to be unique within each code system. In principle, this UOI is a logical code that can be used to distinguish between a wide variety of code systems within the UDSP, but it is also possible to mint UOIs as new IDs (**Figure 4**). When generating UOIs from conventional IDs such as JAN codes*8 or ISBN (International Standard Book Number) codes, the UOI includes a "tagAuthority" defined by a "Name Space" element that represents the code system of the ID (e.g., JAN, ISBN or the email address of the individual or organization requesting the minting) and a "Date" element (the minting request date). The "tagAuthority" can then be combined with IDs local to each system—whose uniqueness is guaranteed within the name space—to generate UOIs (Figure. 4).

In this way, the UDSP can continue to use conventional ID code systems such as JAN and ISBN, thus making it highly compatible with conventional systems.

It is also possible to mint and manage new types of ID—such as Visualtags (see below for details) which can be read by portable cameras—as new codes within the UOI.

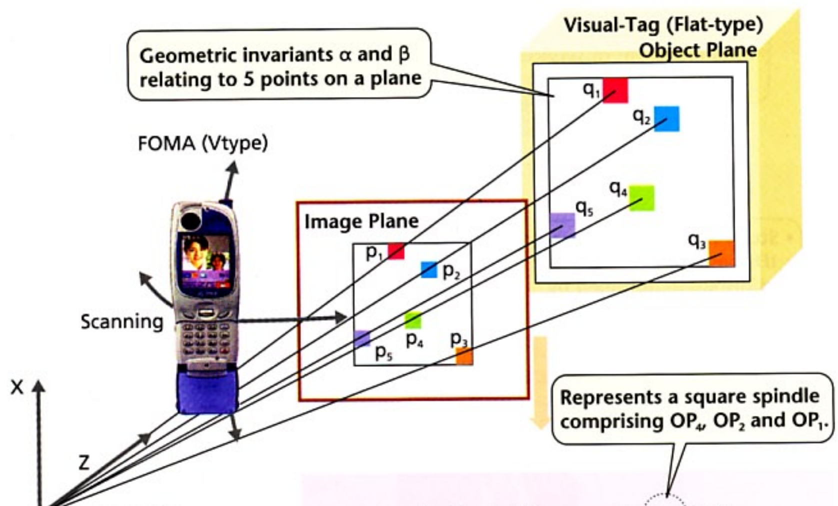
(2) BIND[*9] (Binding object IDs with services) Data Management System

This system is based on the "BIND data ticket" service declaration scheme whereby it is possible to express a wide variety of information about an object. This is a data set that can declare information on services associated with an ID, methods for accessing these services, and other data such as access privileges.

In particular, service data and access methods are declared by means of pointers to the actual data or methods, so it is possible to declare a wide variety of services. BIND data tickets offer the freedom to perform things like binding multiple services to each ID, modifying the bound services as required, and controlling the usage rights of each service. Also, since it is possible to make declarations flexibly in relation to data publication restrictions or guarantees of the validity of data, it is possible to deal with a diverse variety of services and to control the switching between these services.

(3) UOI Reading and Management System

This system makes it possible to read various different IDs. Conventional IDs such as barcodes and RFIDs can be read in with cameras or scanners fitted to hand-held equipment such as digital cellphones (PDC: Personal Digital Cellular) and hand-held terminals (PDA: Personal Digital Assistant), and can then be used by the UDSP. This functionality is achieved through the use of a Visualtags reading scheme [4] based on geometric invariants, which allows the IDs of objects to be identified even in mobile environments (**Figure 5**). This involves the use of ID codes based on geometric invariants determined by the relational position of feature points with five colors (called Visualtags) that do not depend on the camera viewpoint. This makes it easy to identify the IDs of objects with a hand-held camera with less-



$$\alpha=\frac{\det P_{431}\cdot\det P_{521}}{\det P_{421}\cdot\det P_{532}},\quad \beta=\frac{\det P_{421}\cdot\det P_{531}}{\det P_{432}\cdot\det P_{521}}$$

Figure 5 Reading Visualtags

er constraints on the reading distance or reading angle than with conventional ID tags such as barcodes.

(4) Basic Service Portal

This system is the core part that mediates between users and the UDSP. It consists of an authorization function that operates based on the user's equipment identification data, and a function for providing services and data tailored to each user based on acquired data and positional information ("Open i-area" data).

2.4 Service Using the UDSP

Here we will describe the processing flow that takes place in the UDSP when implementing a ubiquitous service.

Figure 6 illustrates an example of a ubiquitous service in a mobile environment. When a user notices an interesting poster in the street, the following procedure shows how it is possible for information to be obtained from a real-world object (the poster), resulting in the provision of a related service:

① The user uses a camera mounted on a hand-held device to read in a Visualtag that has been added to the poster, and sends this image data to the UDSP.

② The "basic portal system" in the UDSP acquires the user's context data ("i-area" position data, etc.), and sends the image data to the "UOI reading management system".

③ In the "UOI reading management system", the geometric invariants are analyzed from the image data and are sent to the "UOI minting management system".

④ In the "UOI minting management system", a UOI is extract-

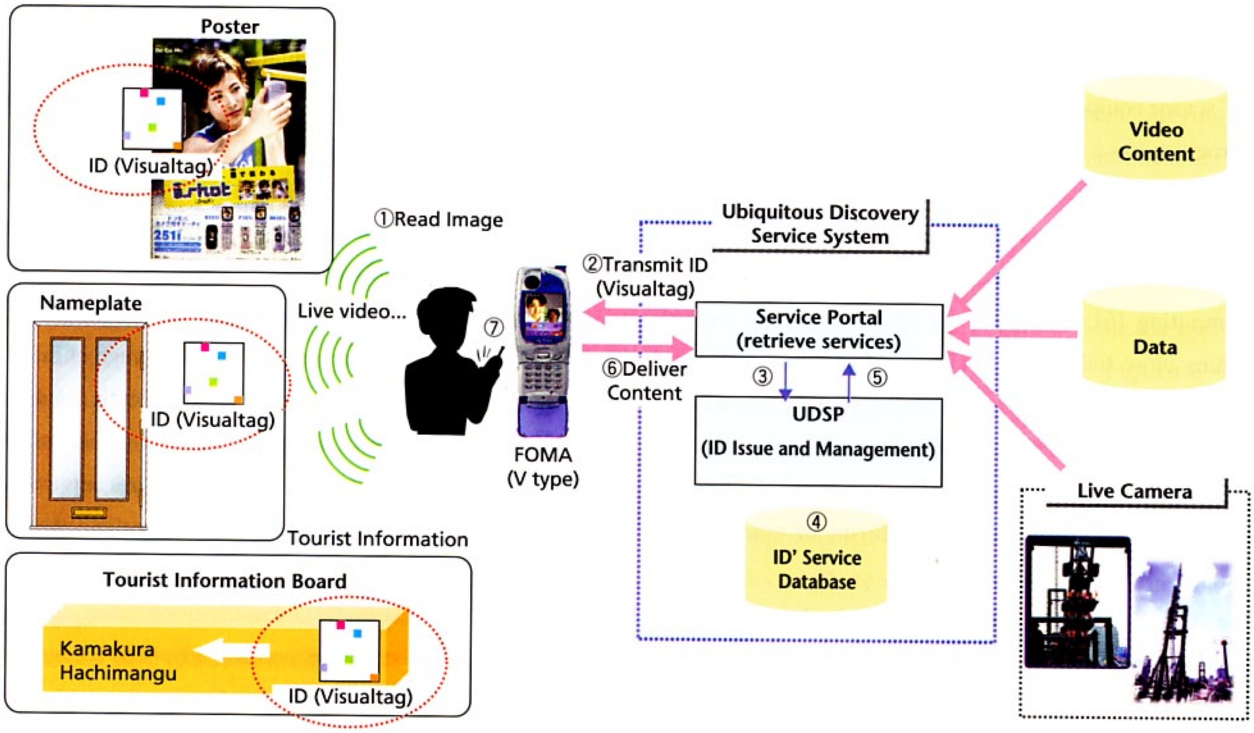


Figure 6 Ubiquitous Services

ed as the code associated with the geometric invariants, and is sent to the "BIND data management system".

⑤ In the "BIND data management system", the various services associated with the UOI are retrieved and sent to the "basic portal system".

⑥ In the "basic portal system", the optimal services based on the user's context are presented to the user.

⑦ The user selects the required service (e.g., connecting to a website that presents a video commercial or to a sales information website).

As another example, a tourist information board could provide users with video data even if it does not have its own display device. In this case, a user scans a Visualtag from the board with a camera built into a hand-held device and sends it to the UDSP, which can then allow the user to see a tourist information video or a live video image of a particular destination.

Similar techniques can be used to implement personalized "info-attachment" services such as binding rail pass IDs to timetable data, or binding the IDs of gift message cards to an audio greeting.

2.5 Future Development

In the future, we aim to extend the functionality of basic techniques—e.g., for reliably reading in IDs with cameras mounted on hand-held devices even in mobile environments, and for the fast retrieval of services. We will also subject the UDSP to technical verification and we will check that it is suitable for ubiquitous services.

3. Real-World Information Platforms and Intelligent User Support

Various studies have already been conducted with the aim of realizing functions with human intelligence, but most of these studies have been made in the pursuit of memory or inference mechanisms for individual computers or robots. However, based on the idea of distributed cognition (i.e., the idea that humans recognize the world through their interaction with the environment [5]), it is important to encourage users to interact with the environment and hand-held terminals instead of producing hand-held terminals with more memory and processing power. Also, to achieve smooth interaction, it is essential to gather and utilize detailed data on the user's activity.

In this Chapter we discuss an approach to a system for adapting services to the user's context based on interactions between the environment, hand-held terminal and the user, and a prototype system in which this approach is being embodied.

3.1 Real-World Information Platform

While the Internet has already become an extensive and indispensable information platform, it is still considered a cyber world separated from the real world. However, these days all kinds of sensor equipment such as cameras can be connected to the Internet, and as a result there is a growing trend towards the incorporation of real-world information into the Internet. Steps are also being taken toward making computer resources and sensors available throughout the environment, such as in ubiquitous computing [6]. Consequently, there is a trend towards establishing close links to the real world from the cyber world that was once separate from it. Although cyber worlds are also important in current society, the ability for real-world information to flow into the cyber world in real time on the Internet should result in the formation of platforms of even greater value.

Meanwhile, current hand-held terminals are already equipped with functions for interacting with the environment, such as phone, email and internet access capabilities. By adding short-range radio communication functions to allow these terminals to talk to other equipment and sensors in the vicinity, it will be possible to implement various types of interaction, such as operating peripheral equipment. Also, by using sensors built into hand-held terminals, such as microphones and cameras, it is possible to use these terminals to capture diverse information. This information is closely associated with the user's activity, and it should be possible to utilize it in various ways by storing it on a server via the network. By capturing this sort of information, conventional Internet platforms may develop into real-world information platforms, which incorporate information on interactions with users and information on the environment relating to the abovementioned real world. **Figure 7** shows how intelligent user support can be provided by using a real-world platform of this sort. The symbiotic agent platform in this figure is closely associated with the user's everyday activities, and is formed from the long-term gathering and storage of information on interactions specific to each user by symbiotic hand-held terminals. These hand-held terminals not only gather information on the user's activities but also provide various services and act as a medium of interaction between the user and the environment. The environment platform is formed by information equipment and sensors situated in the surrounding environment, and in particular the sensors perform advanced recognition processing by distributed or coordinated processing.

In the future, as the research and development of both platforms continues, it is expected that the real-world platform will become more advanced and that the scope of its use will expand. It is also expected that intelligent user support functions will become available.

3.2 User Support System

NTT DoCoMo is developing a prototype system to support

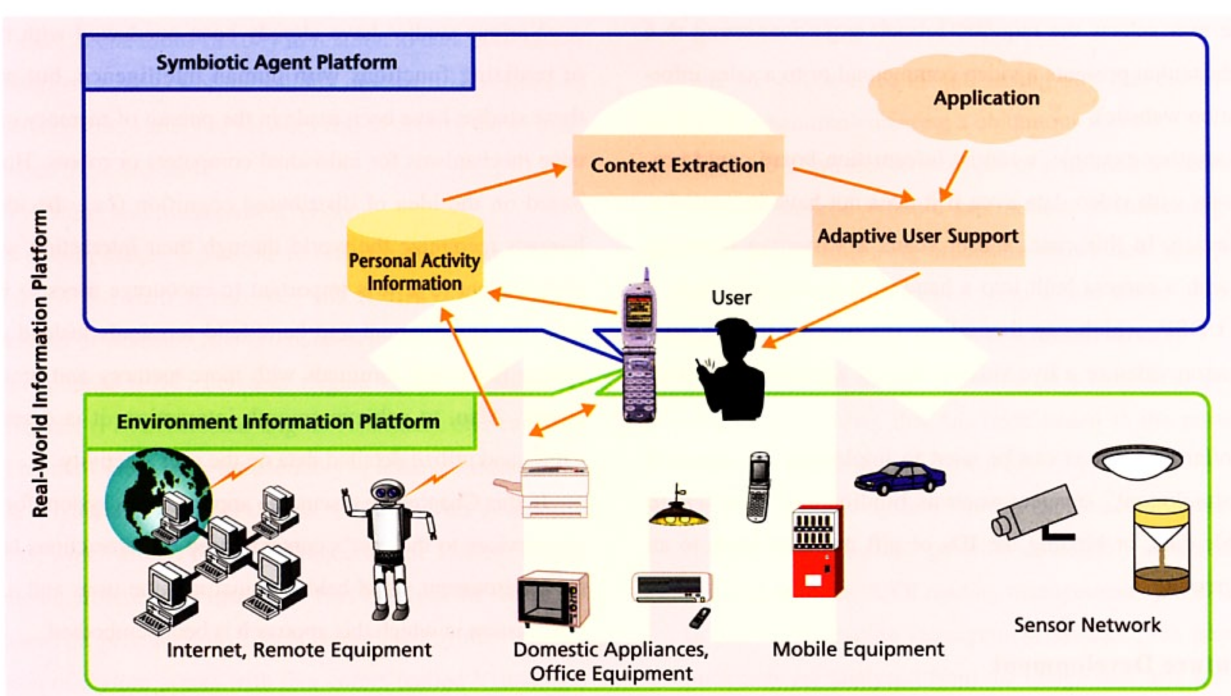


Figure 7 A Real-World Information Platform

humans in various daily life activities through the cooperative operation of an ubiquitous environment with hand-held data processing terminals (here in after referred to as hand-held terminals) made by expanding the capabilities of current cellphones. In this system, the hand-held terminals support users in various ways such as by offering customized services and providing guidance information suited to individual user context.

For this sort of system to provide appropriate user support, it must be able to gather, store and analyze the activity of individuals over long periods and to utilize the results. A number of other systems have been proposed for monitoring the activity of humans [7],[8], but the system we are aiming to develop in this study differs in the following two respects.

First, as mentioned above, a ubiquitous sensor network is provided as part of the environment so that data can be gathered both from hand-held terminals and from the environmental sensor network.

Second, the system is designed based on the maxim that interaction between users and the environment is fundamental to providing user support, rather than simply enhancing the data storage or processing abilities of the hand-held terminals. This makes it possible to utilize many different types of information in the ubiquitous environment, and should make it easier to ascertain a user's context when providing support.

3.3 A Ubiquitous Experimental House

As a trial implementation environment of this system, NTT DoCoMo has been installing equipment and sensors in an experimental house as shown in **Figure 8**, and we have been conducting tests in this house [9],[10]. The users in the experimental house move around indoors while carrying sensor-equipped notebook PCs or cellphones as hand-held terminals. A visual sensor network on the environment side tracks the user positions and saves images. To promote close interaction between users and the environment, Visualtags are disposed in the environment to enable the control of domestic appliances or the provision of various types of guidance. **Figure 9** shows the overall system configuration.

(1) Visual Sensor Network

The positions of multiple users in the house are tracked by 16 cameras installed in the ceilings of rooms on the first and second floors. These ceiling cameras incorporate conical mirrors that allow them to take pictures over a wider angle than ordinary cameras. As **Figure 10** shows, the users are detected in the resulting images by performing differential processing on the images, whereby the location of the feet in the fan-shaped region where a user is detected are assumed to be position of the user on the floor. When combining the user positions detected by multiple ceiling cameras, the detected position at which a user exists within a fixed range of the user position inferred in the previously detected frame is assumed to correspond to the same user, and the final user position is determined by calculating the center of gravity of the detected positions.

We also installed 25 omnidirectional visual sensors with a 360° field of view in the first floor walls. User activity data is obtained by taking pictures with the omnidirectional visual sen-

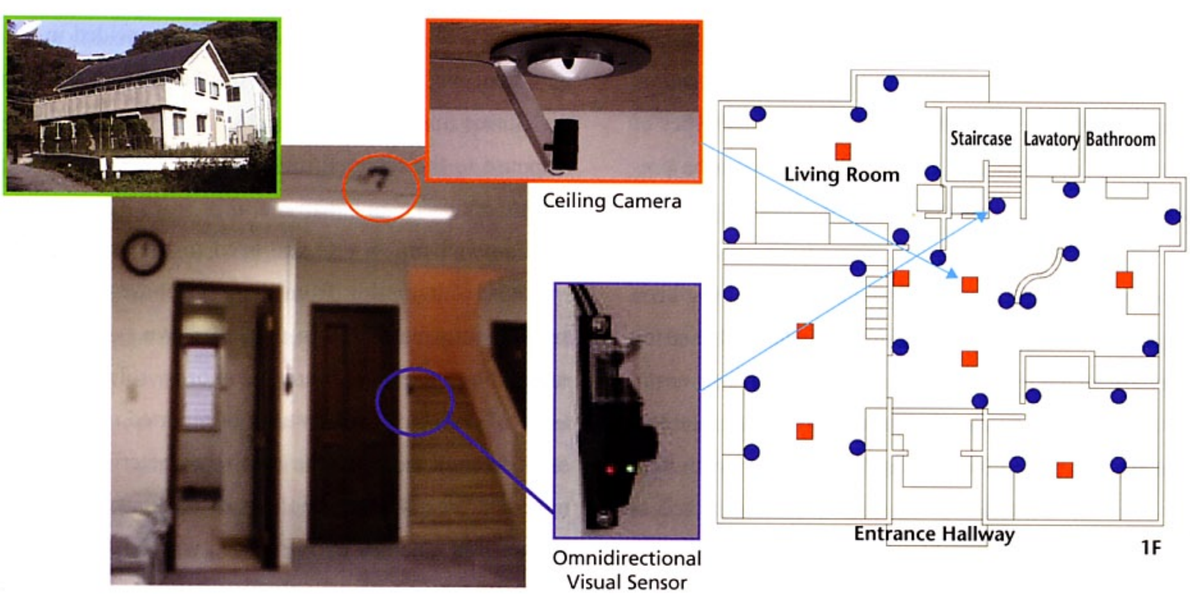


Figure 8 Ubiquitous Experimental House

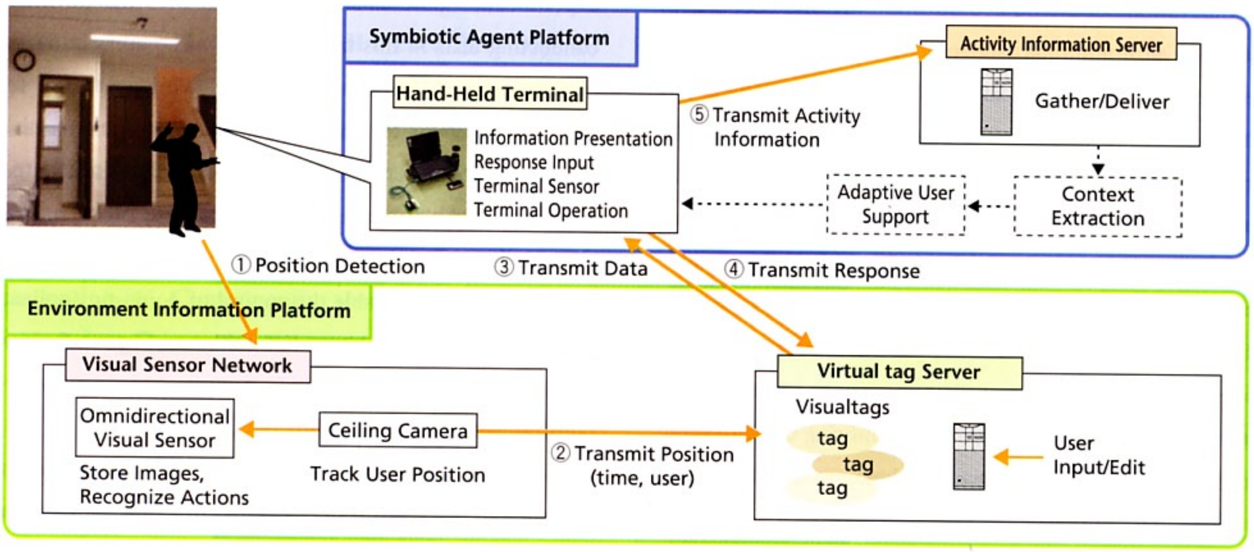
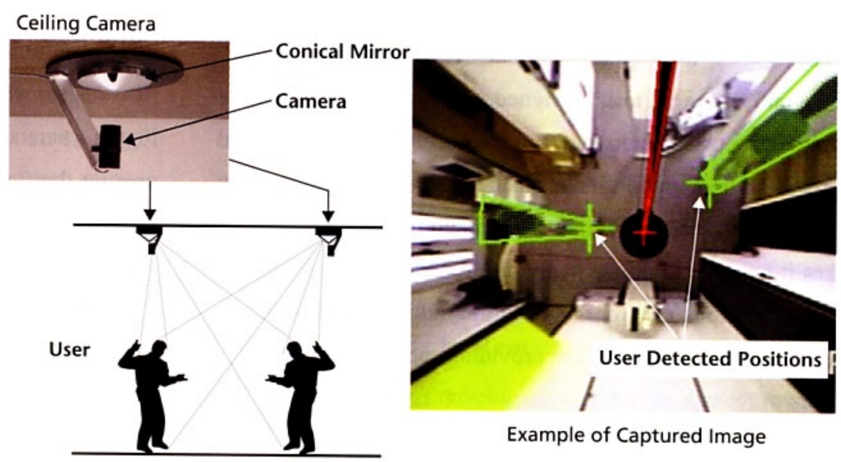


Figure 9 System Configuration

sor closest to the position of each user based on the user position detected by the ceiling cameras. We are currently implementing functions for recognizing the behaviors of users indoors, such as standing and sitting.

(2) Visualtags

In the experimental house, tags that exist virtually in time and space are setup, and by communicating with the user's hand-held terminal, the user is provided with various types of guidance information and a means of controlling domestic appliances. The users can set Visualtags in 5W1H format ("when", "where", "by who", "for who", "what", and "how") by using a graphical user interface (GUI). Tags whose conditions have been met communicate with the hand-held terminal of the corresponding user. With these Visualtags, three types of tags—*Recommend, Remind and Communication*—can be prepared. These differ in terms of how the information is provided to the user.



Example of Captured Image

Figure 10 Detection of User Positions with Ceiling Cameras

With *Recommend* tags, the tags whose conditions have been met are displayed as a list on the hand-held terminal, and by selecting a tag from the list, the user is able to control domestic appliances or is provided with data such as train timetables. Although changes to the list with the user position or with time are not actively reported to the user, the user is able to access the desired information with a single click.

A *Remind* tag actively reports information to the user. When the hand-held terminal is a notebook PC, the information is provided in the form of a pop-up window and audible message, while on a cellphone the information is provided in the form of an e-mail message. These tags can be used to set ordinary "to do" items and the like, and the user can also send back a response to the reported information such as "report again" or "delete notice".

Communication tags are used to provide information on redundant interaction from the environment rather than user support information as in the other two types. The user can respond by inputting arbitrary text or by selecting options such as "yes" and "no" from a series of reported conversation phrases. It is envisaged that the user's characteristics can be ascertained indirectly from this sort of response information. The information obtained by interaction with Visualtags in this way is all stored in an activity information server as described below.

(3) Hand-Held Terminals

User activity information is acquired from an omnidirectional visual sensors and an accelerometer sensors fitted to notebook PCs carried by the users, and text information input from a keyboard and mouse position information is also obtained. This information is transmitted via wireless LAN (11 Mbit/s) to the activity information server. Also, information on the selection and responses to information presented by Visualtags, and information on the control of domestic appliances is also transmitted along with the time of each action. **Figure 11** shows the screen of a cellphone and a notebook PC used as a hand-held terminal.

(4) Activity Information Server

The activity information server stores the activity information transmitted from each hand-held terminal in XML[*10] (Extensible Markup Language) format. It also has a function for controlling the delivery of activity information from this user or from other users in response to delivery requests.

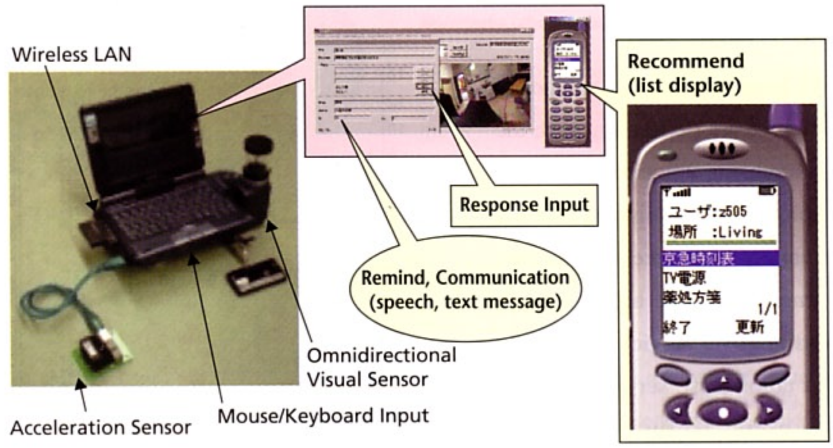


Figure 11 Experimental Hand-Held Terminals

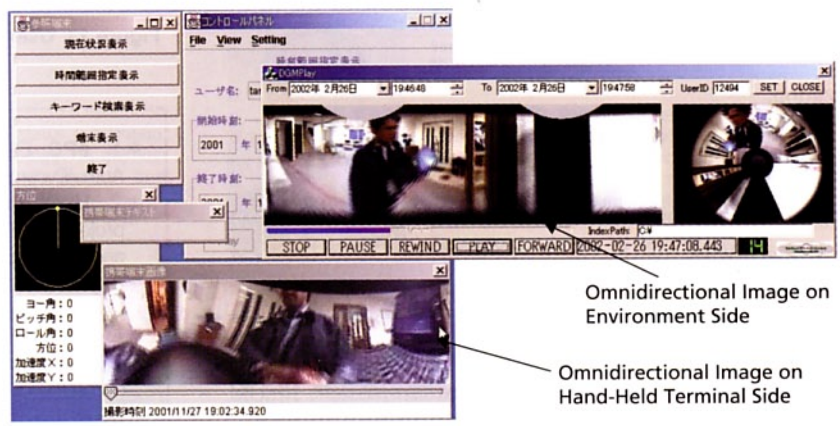


Figure 12 Activity Information Reference Images

3.4 Awareness Communication

In this section we discuss an awareness communication application implemented to utilize a real-world information platform in an ubiquitous environment.

Users may sometimes want to refer to their own previous actions or to the current status of other users. Here, applications that support this type of function are said to be "awareness communication". In such cases, if it is possible to access the sensor data on the user's hand-held terminal, the terminal's operation data, and the sensor data from the environment, then it is easy to confirm the user's past actions and ascertain the current context of other users. This system can retrieve and access each type of sensor data and the operating data of hand-held terminals based on the name of the user whose data is to be accessed, the time range, and keywords input with a keyboard (**Figure 12**). The activity information can be accessed not only from information stored in the server, but also in real time by extending direct links to the hand-held terminals of other users. When data is accessed from other users, it is essential to deal with privacy issues. Therefore, in this system the disclosure of information is controlled by using a protocol in which data types and playback rates are defined corresponding to the user to which information is disclosed.

3.5 Analysis of User Activity Information

To analyze the activity information collected by this system, NTT DoCOMo is looking into ways of extracting activity patterns based on where users go and how frequently they are in certain designated areas. **Figure 13** shows the movement of individual users during a 10-minute period and the combined movements of multiple users over a 7-hour period. Here is can be seen that the places where users are most likely to be found depend the structure of the house. In the future we will attempt to extract movement patterns specific to individual and specific time ranges (e.g., morning and evenings) in the form of models. We will also analyze how these patterns change according to the presence or absence of Visualtags.

4. Conclusion

We have introduced two types of research we are performing with the aim of realizing ubiquitous services. In a ubiquitous environment where a wide variety of services are present, it is important to be able to search for and discover services efficiently and to tailor these services to individual users. To further enhance these services, topics for further study include context-dependent service discovery and management, and context-sensitive service customization.

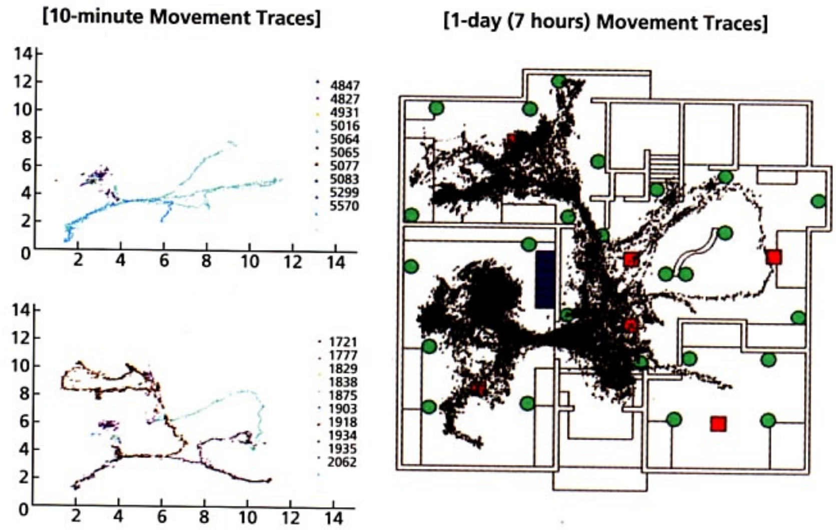


Figure 13 User Activity Traces

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*1 **ePC**: Electronic Product Code (article IDs used by the Auto–ID center)
*2 **UDDI**: Universal Description, Discovery, and Integration (a project which designs XML-based open standard specifications and which operates a registry)
*3 **ebXML**: Electronic business XML (an XML-based business transaction standard)
*4 **cIDf**: Contents ID Forum
*5 **RDF**: Resource Description Framework (a language specification for managing documents written in XML or HTML)
*6 **eTron**: Entity and Economy TRON (this can be used to implement a mechanism whereby real items whose authenticity needs to be guaranteed — such as certificates, sales vouchers, seals, keys, money and tickets — can be managed as electronic data and moved (transferred) across insecure networks).
*7 **EAN**: European Article Number (a barcode system used in Europe)
*8 **JAN**: Japan Article Number (a type of barcode system)
*9 **BIND**: Binding object IDs with services
*10 **XML**: Extensible Markup Language (a markup language that allows tags to be independently defined)

Glossary

FOMA: Freedom Of Mobile multimedia Access (3rd generation cellphones)
GUI: Graphical User Interface
ISBN: International Standard Book Number
LAN: Local Area Network
PDA: Personal Digital Assistant (a hand-held data terminal)
PDC: Personal Digital Cellular (a type of digital cellphone)
RFID: Radio Frequency IDentification
UDDI: Universal Description, Discovery, and Integration
UDSP: Ubiquitous Discovery Service Platform
UOI: Universal Object Identifier
XML: eXtensible Markup Language