Platform Technology for Ubiquitous Services

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Abstract

This article introduces platform technology that i) makes it easy for users to access the services they want among numerous services available everywhere in a ubiquitous environment and ii) uses a sensor network to ascertain a user's context when the user accesses a service and allows the service to be used in the most convenient way.

1. Introduction

Over the last few years there has been a growing need for computer networks that allow services to be used comfortably at any time, anywhere, and by anyone. To achieve this, it is essential to develop services that can be made available to users in a form suited to their context by automatically discovering services related to ubiquitous real-world computing resources and other equipment and objects.

In this article we discuss our research on technology associated with platforms for discovering and supporting services from a wide variety of real-world objects and associated services in situations where users carry hand-held equipment with them. We also discuss techniques for tailoring services to the user's context by gathering data from ubiquitous sensors situated in the environment.

2. Ubiquitous discovery service platform (UDSP)

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

- A function that enables real-world objects to be distinguished on a UDSP
- A function that lets one 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 been proposed in various forms and by various groups, they do not form a comprehensive system. For example, although Auto-ID Center provides a systematic platform for functions ranging from ID management to service management, it does this by introducing an independent ID format called ePC, which is incompatible with conventional IDs. Moreover, it does not prescribe a general-purpose service declaration for selecting services according to context or various types of service relationships.

Therefore in this article we propose a UDSP architecture that provides a systematic means of organizing and supporting functions for minting and managing 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 managing services associated with these IDs.

Figure 1 shows a service platform that links real-world objects and services on the network. It therefore lies at the core of ubiquitous services. The UDS mainly consists of the following key technologies.

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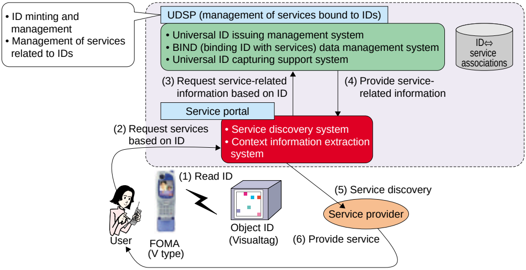


Fig. 1. UDS platform.

2.1 Identification of objects in mobile environments

To allow objects to be identified wherever they are, they are labeled with Visualtag [1] markers representing their ID codes based on geometric invariants that do not depend on the viewing direction. Compared with conventional ID-tags such as barcodes, these markers have fewer constraints in terms of viewing distance and angle. As a result they allow objects to be identified easily by using a camera built into a mobile terminal. By processing the images of these tags to take account of different lighting conditions, it is possible to extract their features stably, even from images captured with the sort of camera in mobile terminals. As a result, there is no need for a separate reading device (Fig. 2).

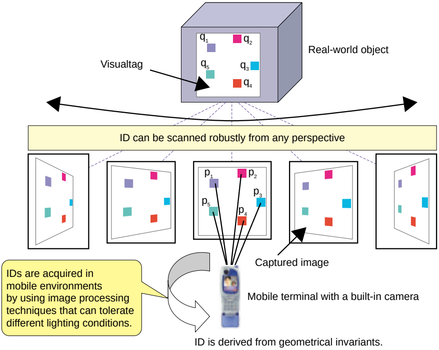


Fig. 2. Object recognition with Visualtag.

2.2 Management and use of universal IDs

By introducing an ID management scheme that can perform integrated management encompassing the existing ID code system of “universal IDs”, the platform can also handle existing barcodes and RF-IDs in their original form.

2.3 Management of services associated with IDs

We have proposed a “BIND*1 data ticket” service scheme that allows a wide variety of information to be associated with all kinds of objects, thereby offering the freedom to do things such as linking together multiple services, presenting services according to a user’s preferences or circumstances (e.g., location), and placing restrictions on the use of each service.

3. Example of a ubiquitous service using the UDS platform

Here we describe the process that takes place in the UDSP when it is used to support a ubiquitous service. Figure 3 shows 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.

First, the user uses a camera mounted on a hand-held device to read in a Visualtag that has been added to the poster and transmits this image data to the UDSP. A service portal system in the UDSP acquires the user’s context data (user location, user preference, etc.), and sends the image data to a universal ID reading management system located within the UDS. The universal ID reading management system analyzes and extracts the geometrical invariants from the image data and transmits them to a universal ID issuing management system in the UDS. The universal ID issuing management system then extracts a universal ID as the code associated with these geometrical invariants, and transmits it to a BIND data management system in the UDS. The BIND data management system retrieves the various services associated with the universal ID and transmits them to the service portal. In the service portal, the optimal services based on the user’s context are presented to the user, allowing the user to select 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 sign could be made to provide users with video data even if it does not have its own display device. Instead, the user uses a hand-held device with a built-in camera to read in a Visualtag from the sign and transmit it to the UDSP, which allows 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 linking the ID of a rail pass to an electronic timetable, or the ID of a gift card to an online audio greeting.

*1 BIND: binding ID with services

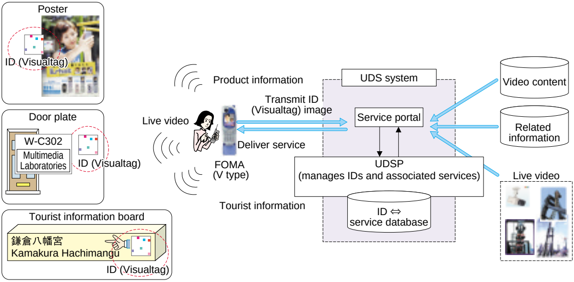


Fig. 3. Examples of ubiquitous services based on the UDS platform.

4. Real-world information platforms and intelligent user support

Although the Internet has become an indispensable information platform for human activity, it is still considered a virtual world that exists separately from the real world. On the other hand, there is a growing trend towards connecting cellphones and sensor equipment such as cameras to the Internet, making it possible to incorporate data that is closely related to human activities. Furthermore, there is growing activity aimed at making computer resources and sensors ubiquitously available throughout the environment, as in ubiquitous computing for example. It is thus likely that in the future the Internet will develop into a real-world platform incorporating information on the diverse activities engaged in by humans in the real world (Fig. 4). This real-world platform should make it possible to provide intelligent user support, such as providing services tailored to the user's context.

5. Experimental house and user support system

To create a system that supports users intelligently, it will probably be necessary to promote interaction between the environment, mobile terminals, and humans rather than simply enhancing the ability of mobile terminals or environment-side systems. Also, to achieve smooth interaction it is essential 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, but the system we are aiming to develop in this study differs in the following two respects.

First, a ubiquitous sensor network is provided as part of the environment so that information can be gathered both from mobile 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 mobile 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.

We have therefore built and started trials of a prototype system aimed at supporting users intelligently based on cooperation between mobile terminals and environment-side systems. This system is installed in an experimental house [2]. Users of the experimental house move around indoors while carrying sensor-equipped notebook PCs or cellphones (both of which are referred to below as mobile terminals). These mobile terminals provide the users with services tai-

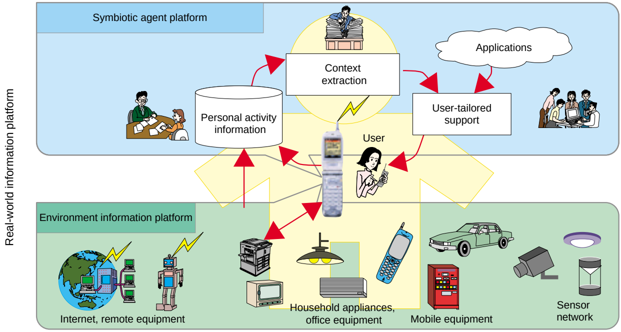


Fig. 4. Real-world information platform.

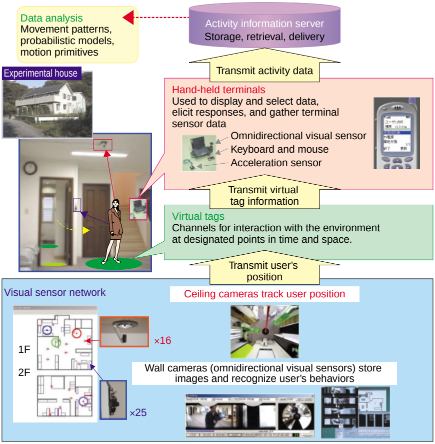


Fig. 5. User support system.

lored to their context (Fig. 5).

5.1 Visual sensor network

Two types of camera have been installed inside the house. The ceilings are fitted with 16 cameras incorporating conical mirrors that allow them to take pictures over a wider angle than ordinary cameras. The pictures taken by these ceiling cameras are subjected to differential processing to extract the regions occupied by humans and thereby detect the user positions. The positions of multiple users can then be tracked in real time by combining the user position data obtained from multiple cameras. The walls are fitted with 25 cameras called omnidirectional visual sensors that can take pictures over a range of 360° in the horizontal direction. Of these cameras, the one closest to the position of each user (as detected by the ceiling cameras) is selected to provide a function for saving images as user activity monitoring information and a function for recognizing the behaviors of users indoors, such as standing and sitting.

5.2 Virtual tags

To allow users to interact with the environment in a variety of ways depending on their locations and the time, virtual tags can be set inside the house. These virtual tags are set by each user on a server in a "5W1H" format (when, where, by who, for who, what, and how). Information that matches these conditions is provided to the mobile terminal of the same user or to other users. For example, it is possible to deliver *reminder data* in the form of memoranda (e.g., a reminder to take one's medicine or bring an umbrella), or *recommendation data* in the form of suggested information (e.g., weather forecasts or train timetables). Interfaces to electrical equipment inside the experimental house, such as the TV, can also be provided as recommendation data. Furthermore, it is possible to provide users with information by way of interaction between users and the environment in the form of *communication data*. It is envisaged that this interactive information can be used to extract information about the user's characteristics, although this is not directly linked to supporting users.

5.3 Hand-held terminals

When a user carries a notebook PC around in the experimental house, the PC acquires various types of information—omnidirectional images from a built-in camera, movement data from an acceleration sensor, and data input via the mouse and keyboard—and transmits it to an activity information server via a wireless LAN (11 Mbit/s). If the user's terminal is a cellphone, it uses an "*i*-application" to display recommendation information in the form of a list. The user can access all kinds of information and control domestic appliances by making selections from this list. For the PC user, reminder information is displayed in the form of a pop-up window, while for the cellphone user it is delivered as a text message.

Communication data is only supported when the user has a notebook PC. This allows the user to interact with the environment by choosing a preset response phrase or inputting any text response when presented with an interactive phrase in a pop-up window. This interaction information is stored on the activity information server as user activity information along with the sensor information obtained from the environment sensors and the hand-held terminals.

5.4 Activity information server

Data transmitted from each user is stored on the activity information server in XML format. The activity information server also supports a function for delivering data in response to user requests for accessing the activity information.

6. Applications

Sometimes a user may wish to access information about his or her own activities or the activities of other users. For this purpose, we have implemented an awareness communication application whereby the activity information for each user recorded in the experimental house can be retrieved by the corresponding user or by other users. This application allows the previous or current data for a user to be accessed by inputting the name of the target user, the time range, and a keyword (Fig. 6). Since it is important to consider the privacy of users in such cases, the delivery of data in this system is controlled by defin-

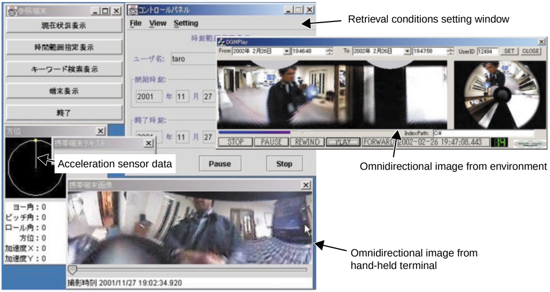
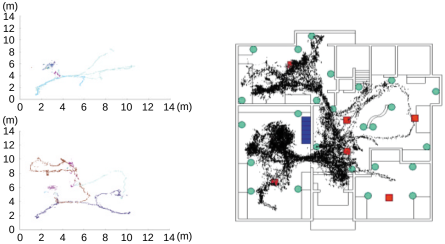


Fig. 6. Retrieval and access of user activity information.



(a) Movement traces over a 10-minute period (b) Movement traces over a whole day (7 hours)

Fig. 7. User movement traces.

ing a protocol that specifies the users who may access the information, and parameters such as the types of data that can be disclosed and their playback rates.

We are also conducting experiments to gather and analyze the activity information of users over long periods to optimize applications that use virtual tags to deliver information to them. Figure 7(a) shows the movements of an individual user during a 10-minute period, and Fig. 7(b) shows the movements of multiple users over a 7-hour period. Based on the results of these experiments, we are using techniques such as probability models to express the behavior patterns that are common to all users and the behavior patterns characteristic to each individual user.

7. Conclusion

We have introduced two types of research we are performing to enable 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 status-dependent service discovery and management, and context-sensitive service customization.

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