Ubiquitous Computing Technologies for Ubiquitous Learning

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Abstract

Ubiquitous computing is a new information and communication technology that utilize a large number of cooperative small nodes with computing and/or communication capabilities such as handheld terminals, smart mobile phones, sensor network nodes, contactless smart cards, RFIDs (Radio Frequency IDentification), and so on. This paper proposes the concept of ubiquitous learning that enables anyone to learn at anytime and anywhere by fully utilizing ubiquitous computing technologies. As the pilot system of the ubiquitous learning, this paper briefly introduces Digital Ubiquitous Museum that makes our daily living environments learning materials.

1. Introduction

Ubiquitous computing is a new trend of information and communication technologies, in which we embed a huge number of tiny computers into an invisible part of the fabric of everyday life. Especially, these computers are equipped with sensors and/or actuators that interact with our living environment, and with communication functions for exchanging their data. Concretely, RFIDs, contactless smart cards, sensor network nodes, and tiny mobile devices are among them. Using these cooperative tiny computers, ubiquitous computing provides computing for all: access to anything, by anyone, at anytime and anywhere.

We had been continuing the ubiquitous computing research for more than 20 years since 1984 [1]. Current status of our ubiquitous computing research is no longer the phase of basic research, but the phase of practical use. We should make technology standards, establish business models, and explore various commercial applications. Moreover, we are planning to build a new technological and social infrastructure for ubiquitous computing all over the world. For the purpose, University of Tokyo, YRP Ubiquitous Networking Laboratory[1], and many IT companies have launched an international forum for creation and deployment of ubiquitous computing technologies, *Ubiquitous ID Center*[2]. Currently, the number of forum members is about 500 from world wide. We are cooperating with these member companies in terms of R&D, standardization, and establishing and/or managing the ubiquitous computing infrastructure (called, *Ubiquitous ID Infrastructure*) [2,3,4].

Especially, the following two nation-wide projects are very important: *food traceability project* and *location-aware computing projec*[3]. The former project embeds RFIDs onto all foods, and increases the visibility of total food chains. The latter project puts enormous RFIDs and active tags onto all places of the Japan land as the national infrastructure. These tags will be used for the support of the efficient and smooth transportation. Both projects are cooperative projects with Japanese government. By advancing these projects, we will establish a new general infrastructure for ubiquitous computing that serves for various application fields.

This paper proposes a novel learning style, *ubiquitous learning*, in which we learn *anything* at *anytime* and *anywhere* utilizing ubiquitous computing technology and infrastructure. For example, while having a supper, we learn everything about vegetables on a dish if we are interested in it. When and where was this vegetable grown up? How was it transported? What is the cooking method? What is the history of this food? Moreover, when, after the supper, we walk on the street of the town and have a sudden squall, we learn the characteristics of squall of this area, then we can predict how long this squall will continue. This is just the *ubiquitous learning*.

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[1] http://www.ubin.jp/
[2] http://www.uidcenter.org/
[3] Official name of the project is *autonomous movement support project*. http://www.jiritsu-project.jp/

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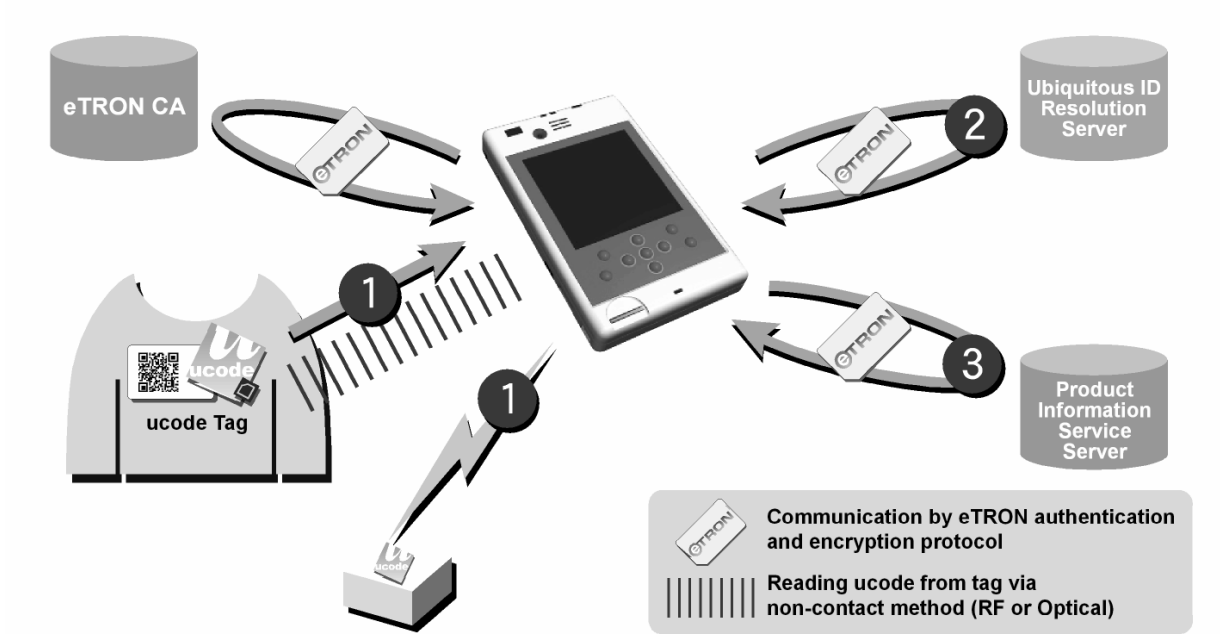


Figure 1. Ubiquitous ID Architecture

One of the ultimate goals of "learning" is to increase the quality of our daily life. Thus, essential subject for learning exists in our daily living environment, but not in classrooms or textbooks. Conventionally, it is very difficult to learn from our daily living environment because we had no methodology to obtain learning information from the real objects or places. On the other hands, recent advance of ubiquitous computing enables us to learn in our daily living environment.

The rest of this paper firstly introduces the concept of ubiquitous learning and describes our innovative pilot projects of the ubiquitous learning. The first example is the *ubiquitous learning* using our daily objects such as foods and medicines. The second example is to learn from places. This paper also introduces ubiquitous computing technologies for the efficient and effective ubiquitous learning such as *real-world bookmark* system, *learning navigation system*, and *exhibition capsules* [5,6,7].

2. Background of our Ubiquitous Computing Research Project

Ubiquitous computing is a new trend of information and communication technologies, in which we embed tiny computers into an invisible part of the fabric of everyday life. Especially, these computers are equipped with sensors for obtaining context of the real world environment and/or actuators for making effects in real world. They are also equipped with computer networks for cooperating with each other.

We have started a research project of ubiquitous computing technologies, called *TRON* (The Realtime Operating system Nucleus) *Project*[4], in 1984 [1]. In the project, we have already developed a group of realtime operating systems for ubiquitous computing environments, *ITRON* (*Industrial TRON*), *JTRON* (*Java TRON*), *BTRON* (*Business TRON*), *CTRON* (*Communication and Control TRON*), and so on. These operating systems have already been used in the industries of embedded and ubiquitous computing systems, such as mobile phones, electronic dictionaries, digital cameras, automobile controls, and digital home appliances. Today, market share of these operating systems in the Japanese computerized embedded systems is more than 50%. As a more innovative experiment, we have built TRON Smart House in Tokyo in 1991, that is a pilot house which fully utilizes ubiquitous computing technologies. It contained a thousand of sensors, actuators, and computers.

In 2003, we have started a new ubiquitous computing R&D project, *Ubiquitous ID Project*[5], to establish a new information and communication infrastructure of ubiquitous computing for the 21st century. The main purpose of this project is to develop

[4] http://www.tron.org/
[5] http://www.uidcenter.org/

and to deploy the new ubiquitous computing architecture, *Ubiquitous ID Architecture* [2,3,4], that enables various context-aware information services at anytime and anywhere. Ubiquitous ID Architecture includes many RFIDs (Figure 2) and/or sensor network nodes (Figure 3) that are embedded in our living environment and hold semantic information of various things and environmental information. This information is used by other embedded computers controlling the environment, hand-held mobile computers, robots, and so on. Using the information, they provide various information services and manage our living environments.

Figure 1 illustrates the basic system structure based on the Ubiquitous ID Architecture. We allocate unique identifier called *ubiquitous code* (*ucode*) for an object and/or a place in the real world. To attach ucode, we use ucode tags such as RFIDs, barcodes, QR codes, and active tags. High-end ucode tags with large non-volatile memories store not only identifier ucode but also attribute information of the object and/or place. If the tags do not have enough memories for the attribute information, it would be stored in the remote databases that are accessed via computer networks. Hand-held mobile computers obtaining context information from ucode tags and remote database are *Ubiquitous Communicators* (*UCs*) (Figure 4, 5). A UC firstly gets ucode from a ucode tag, then it retrieves main information with the ucode from the remote database. In the practical ubiquitous computing environment, there are enormous ucode tags and information servers. This makes it difficult to find proper servers only from obtained ucode. To solve this problem, Ubiquitous ID Architecture provides large-scale distributed directory servers, *ucode Resolution Servers*, that manages a collection of the relations between ucode and information sever addresses.

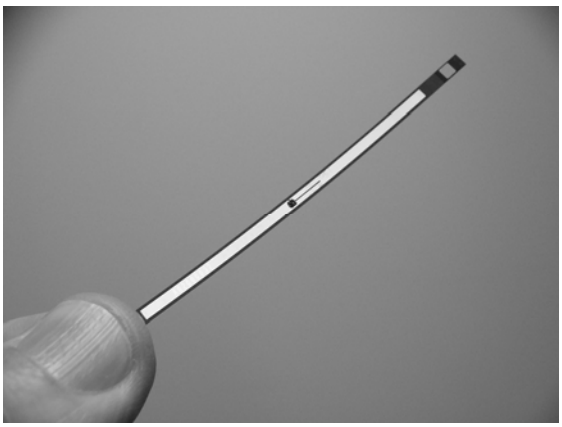


Figure 2. Passive RFID

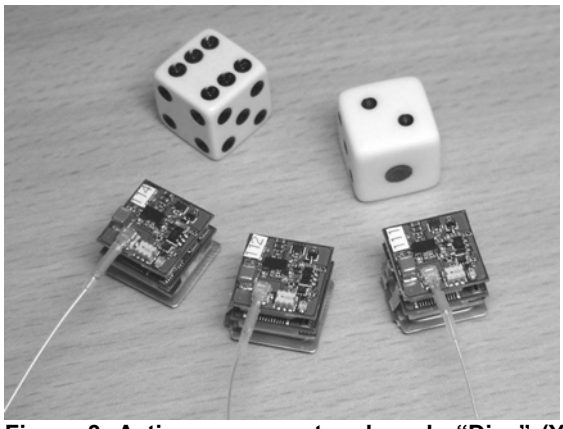


Figure 3. Active sensor network node "Dice" (YRP Ubiquitous Networking Laboratory)

Figure 4. Ubiquitous communicator (PDA type)

Figure 5. Ubiquitous communicator (mobile phone type)

3. Ubiquitous Learning

3.1 Definition

Recently, we are proposing a novel learning style, *ubiquitous learning*, in which we learn about *anything* at *anytime*, *anywhere* utilizing ubiquitous computing technology and infrastructure. One of the ultimate goals of learning is to increase the quality of our daily

life. Thus, essential subject for learning exist in our daily living environment, but not in classrooms or textbooks. Conventionally, it is very difficult to learn from our daily environment because we had no methodology for it. Recently, the deployment of ubiquitous computing technologies enables us to share information and to communicate effortlessly, constantly and continuously throughout the day.

3.2 Conventional Methods of Real World Learning

Conventionally, we have several learning methods using real objects and/or in the real field. First, we have several facilities for learning from real objects or real lives: museums, zoos, aquariums, botanical garden, and so on. The limitation of these facilities is that they cannot store everything because of physical reasons, such as its size, and several social reasons. For example, they cannot preserve pyramids in Egypt, the Pompei ruin in Italy simply because it is impossible to move them. Second, field work is another learning method. Conventional field work requires advanced skills for the learners or supervisors because no information facility is provided for supporting field works in the real field. In ubiquitous learning, we consider that the every aspect of our daily life is considered as the field work for learning. To enable this, we need the help of information and communication technologies. For this purpose, we use ubiquitous computing technologies.

3.3 Learning from Old Buildings: Typical Scenarios of Ubiquitous Learning

An elementary school student "Bob" from UK is now living in Tokyo, Japan. On Sunday, he was going to the house of his friend. On the way, he passed by "Kaminari-Mon" (Thunder Gate) at the Asakusa area (Figure 6). "Kaminari-Mon" is a very old and traditional gate, and one of the most famous sightseeing spots. Bob was impressed very strongly by the shape and vivid color of "Kaminari-Mon". He found an ID tag plate beside "Kaminari-Mon", which includes an RFID with its *ucode*. Bob has read the *ucode* from the plate using his mobile phone with an RFID interface, and retrieved information of "Kaminari-Mon" from remote information server via mobile phone networks. He registered his language preference "English" into mobile phone, so that the information server has selected English contents for children automatically. "Bob" has read only the first page of the contents, and he hurried to the house of his friend. Arriving at the house, Bob has talked his friend about "Kaminari-Mon", and gave the *ucode*. The Japanese friend has also retrieved the information. In this case, personal profile of his computer was set that language preference is Japanese and explanation level is the elementary school student level. His friend got Japanese contents for children.

Figure 6. Kaminari-Mon at Asakusa Area in Tokyo

3.4 Ubiquitous ID Mechanism for Ubiquitous Learning

In ubiquitous learning, we learn what we are seeing and what we are touching just-in-time. Each object and place is allocated an ID number in 128 bits, ucode, stored in RFIDs. In the above example, the RFID is embedded in the tag plate beside "Kaminari-Mon" and the explanation data of "Kaminari-Mon" is retrieved from remote servers via computer networks. The information is described in the *uContens* format that is a standard semantic data format in the Ubiquitous ID Architecture and is based on the RDF/XML format. Ubiquitous communicator obtained by Bob recognizes the ucode by interfacing with the RFID, retrieves the data from the remote server, and shows them. As shown above, we can build ubiquitous learning environment easily by only attaching ucode tags to objects and places and providing the information and communication environment for retrieving the contents.

3.5 Authoring by Public

An important point of the ubiquitous learning is the cost of information authoring. Because our Ubiquitous ID Architecture is an open architecture, we can expect that many people can participate for the authoring of these learning contents. This is very similar to *Wikipedia*[6]. Wilkipedia is a new digital encyclopedia on the Internet. Authors of Wikipedia are anonymous internet users. Wikipedia is a collection of contents

[6] http://www.wikipedia.org/

written by anonymous internet users. However, its mechanism is restricted to the digital world. Ubiquitous ID Architecture connects the digital information and objects and places in the real world.

3.6 Ubiquitous ID Architecture as a General ICT Infrastructure

Another point of ubiquitous learning is the cost for the information and communication system. In terms of economical view, it is impossible to prepare ubiquitous learning system that can be used only for ubiquitous learning. The most important point is that the ubiquitous computing infrastructure is very general that can be used for various applications. RFID tags onto foods are used for making SCM (Supply Chain Management) of foods more efficiently, and for accomplish the traceability of foods that contributes increasing the food security. RFID tags onto several places are used for automatic navigation system for handicapped users, ITS (Intelligent Transport System), sight seeing, supply chain management.

4. Learning at Everywhere

An important ubiquitous computing project including the ubiquitous learning concept is *location-aware computing project*. Technologies of this project are based on our Ubiquitous ID Architecture. The goal is to deploy an information and communication infrastructure that identifies physical location automatically and to provide location-aware information services. We have already made several location-aware information service experiments in several places in Japan such as Kobe, Tsuwano, Sapporo, Aomori, Asakusa, and Nagoya Expo. Concretely, in this project, we embed innumerable RFIDs and sensor network nodes all over the Japan land for the automatic location identification. This is a general infrastructure used by human navigation, transportation support, sightseeing, supply chain management, electronic commerce, and also ubiquitous learning.

Figure 7 shows our experiment in Tsuwano, a famous resort area in Japan. We have put many ucode tags at sightseeing places, which enable visitors to obtain rich information such as cultures, histories, geographical information. Figure 8 shows another experiment, held in Asakusa in Tokyo, which is a very popular place for foreign tourists in Tokyo. In this experiment, we have put many RFIDs and active tags with infrared (IR) and/or radio frequency (RF) communication functions in front of the gift shops. Foreign tourists can get information about gifts such as traditional foods using their mobile terminals. Both examples are an application of ubiquitous learning for tourists.

Figure 7. Showing information of historical house in Tsuwano (Location-aware computing project)

Figure 8. Showing information of Japanese traditional food in Asakusa (Location-aware computing project)

5. Learning from Everything

Another important project is *food traceability project*. The main purpose of the project is to increase the visibility of total food chain, such as production, circulation, sales, and consumption, by managing information of the food. For this purpose, we put RFIDs or printing tags such as barcode and QR code onto the food package, which keep the correspondence between the food and its information in databases. Usually, the database contains the record how the food was produced and circulated. This information is mainly used for food safety management, supply chain management, and information disclosure for consumers.

This system contains all information of the food, which can be obtained at anytime in anywhere. Thus, this mechanism can be used for ubiquitous learning only if we put additional information for food study. Figure 9 shows that a user is reading the ucode from the food, and retrieving the data about the food. Using the same system, we have also realized drug traceability, which is useful for ubiquitous learning of drugs (Figure 10).

Figure 9. Learning vegetables (Food Traceability Project)

Figure 10. Drugs with an RFID (left), and its information is referred by UC (right) (Drug Traceability Project)

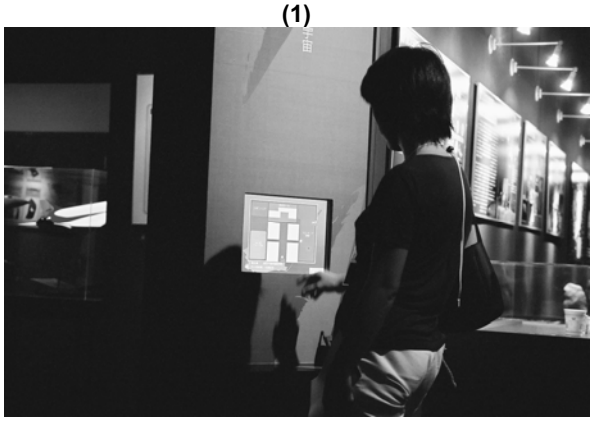
6. Ubiquitous Museum: ICT System for Ubiquitous Learning

In this section, we introduce *Digital Ubiquitous Museum* that is an example system realizing ubiquitous learning. For about ten years, we have been introducing digital technology into museums to advance their function. We call this concept *Digital Museum* [5]. Digital *Ubiquitous* Museum is more advanced framework that enables ubiquitous learning in Digital Museum. In Digital Ubiquitous Museum, exhibitions are distributed over the town. Exhibition materials are exhibited at several places. To support this kind of exhibition, we have developed several technologies [6,7].

Figure 12 shows the system for personalized museum. A visitor always brings his id card containing his personal profiles such as his/her preferred languages for explanations, knowledge levels, personal interests and learning history logs. In viewing information, he/she put the card on kiosk terminals. The kiosk terminal adapts information according to the personal profiles. After that, it will guide the visitor to the next exhibition place according to the interests and learning history logs (Figure 11). Using the id card, personalized museum system provides real world bookmark function. Bookmark is a popular mechanism to record preferred and interesting information in the Web. In our system, it is possible to make bookmark for the information of exhibited materials. If you are interested in the exhibited material and like to record the information, you can make a bookmark by only clicking bookmark button on the screen of the kiosk terminal. After you go back to your home, you can see your own personalized web pages that consist of contents you have bookmarked in the Digital Ubiquitous Museum.

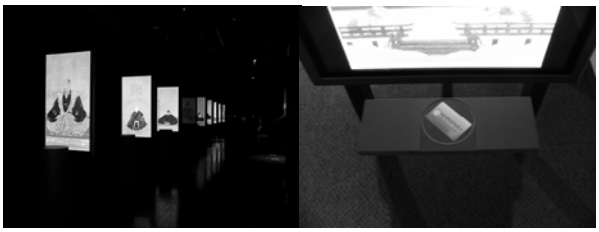
Second, we have developed a special module that safely preserves exhibited materials with kiosk terminal and computer network facilities (Figure 13). We call this the minimum museum or exhibition capsule. If we use this capsule, we can build the minimum museum anywhere.

(1)

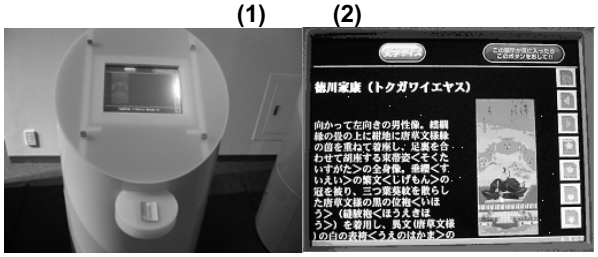


(2)

Figure 11. Guiding visitors to the next spot
(1) using ubiquitous communicator, (2) using kiosk terminal



(1) (2)



(3) (4)

Figure 12. Real world bookmarking
(1) Exhibition of old painting (digital replica)
(2) Getting the paintings in the id card (bookmarking)
(3) Putting the id card on the Kiosk terminal
(4) Getting the information of bookmarks

Figure 13. Exhibition capsule

7. Summary

In this paper, we have proposed a novel learning style, "ubiquitous learning", in which we learn anything at anytime in anywhere utilizing ubiquitous computing technology and infrastructure. For ubiquitous learning, ubiquitous computing infrastructure is necessary. Recently, ubiquitous computing technologies are about to be introduced for various fields such as transportation and supply chain management. This movement is a very good condition for ubiquitous learning because this will establish a

general purpose ubiquitous computing infrastructure. This infrastructure will enable ubiquitous learning. The most important point is that the system for ubiquitous learning should not the special system only for ubiquitous learning, but that it should be general system which can be used for general applications. This is like the Internet. Today, the Internet is a very popular tool for learning and education, but the Internet is not a special system for learning and education. Similarly, ubiquitous computing infrastructure is a next generation ICT infrastructure for general purpose. Ubiquitous learning is a new learning style fully utilizing the ubiquitous computing infrastructure.

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