Case Study of Human Computer Interaction Based on RFID and Context-Awareness in Ubiquitous Computing Environments

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Abstract. Context-awareness becomes the key technology in the human computer interaction of ubiquitous computing. The paper discusses the characteristic, significance as well as function of the context, and the properties of the human computer interaction in the ubiquitous environments where the physical space fuses with the information space. These characteristics bring new requirements, that is, mobility, tractability, predictably and personality. To satisfy the demands, we present a method to realize context-awareness and the wireless interaction by using the pervasive RFID tags to track the context and using Bluetooth as the contact-less communication measure. We also construct a prototype system composed of RFID tags, BTEnableReaders and Bluetooth-enable mobile terminals. One case of application scenario is given and the experimental results show that the performance and robustness of the device are suitable for ubiquitous applications and the interaction is experienced more positively by users than the conventional method. The devices we design also can be extended to other application areas such as wearable computing, health care, disable help, and road navigation.

Keywords: Human Computer Interaction, RFID, Context, Ubiquitous Computing.

1 Introduction

Ubiquitous Computing, which makes the user utilize the communication and computing ability more easily and merges the information space with physical space, has become one of the most active research areas. This mergence is an important foundation integrating the human and the computer naturally and makes the computing environments and the software resources available for user adapt to the related history situation and context. The context is an implicit intuition in human reasoning. It normally refers to the surrounding environments of interest center [1], such as providing the original information about Where, When, What, How and the direct comprehension about this information. Radio Frequency Identification (RFID) has

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become one of the most promising automatic identification technologies recently. Compared with other traditional identification technology, RFID has the advantages such as contact-less, multi-object recognition, non-line-of-sight, long distance, large store memory, programmability and penetrability. Especially, the most significant meaning embedded in the RFID technology is the fact that all the existing physical objects can enter the virtual world built by RFID networks by sticking a tag to the physical object as a unique entry. RFID is seen as a bridge between physical space and virtual reality [2] and can offer one of the foundations in the ubiquitous computing environments.

In these new ubiquitous computing environments where information access and service become pervasive, the human-computer interface differs from the WIMP (Windows, Icon, Menu and Pointer) graphic user interface. Owing to the heterogeneity of ubiquitous terminal communication devices in these environments, the interface must accommodate to variant devices of different users and provide different services based on the users' different locations, time, role and task. The context-awareness and the mobile computing interaction have become the key technology in the human-computer interaction. Since the RFID has the advantage of recording context information and Bluetooth has been embedded into many mobile terminals, such as mobile phone, PDA, notebook, digital camera, and MP3, this paper presents a case study of an implicit human computer interaction in ubiquitous computing based on RFID tags and Bluetooth enabled mobile devices.

The remainder of the paper is organized as follows. Section 2 introduces the focus point of HCI in ubiquitous computing environments and outlines our object. Section 3 presents our design concept. Section 4 details the approach and implementation of prototype system. The performance results of the original system in one application scenario are given in Section 5. The conclusions are drawn in the final section.

2 HCI in Ubiquitous Computing

Recent progress in mobile computing, signal processing and automatic recognition technologies has created a promising direction for human computer interaction research in the ubiquitous computing environments. Compared with the traditional research of the human computer interaction modalities which mainly focus on the multimode perception (e.g., speech, vision, pen, mouse, gesture, haptic), in the new environments the device is expected to possess sensation so that it can interact with the human in harmonious manner. This implicit interaction brings forward two demands; one is that humans prefer to communicate with computers socially rather than communicate by the passive and explicit input instruments; the other is that computers should communicate with humans nonverbally but intelligently which means they must be aware of the current scene situation and the context of interaction task to be capable of adapting to the current user with minimum instructions. These two demands are complementary for each other. If we make good use of the context, such as the location, temperature, time, light, noise, and people nearby, the interface will attract much less human's attention so that it will be more human-like, effective, recessive and adaptive.

The object of the human-computer interaction brought forward in this study is expected as follows: (1) Mobility, the ubiquitous environments contain heterogeneous mobile communication network infrastructures but the user can achieve accordant and transparent service no matter where he is among the ubiquitous environment. (2) Tractability, the user can inquire about internal situation and organized structure of background context process, the system should let user feel that the context is processed himself [3] and the interaction is in a natural and expressive modality. (3) Predictably, the computer should be able to understand the users' requests and future possible demands, the beforehand dispose of information does not need users' special attention and the user can even interact with the computer without training. (4) Personality, the services must be pushed according to the user's personal characters, because RFID tag has its unique ID, it has the innate advantage to identify users or computing objects.

3 Design Concept

The perceptions of the intelligent human-computer interface in ubiquitous computing environments emphasize the natural interaction between users and services embedded in the environment or available through mobile devices. In these environments the physical and virtual worlds seamlessly gear into each other. The bottleneck in reaching these scenarios appears in the natural mapping between the physical objects and their virtual counterparts [4]. The emergence of RFID opens possibilities for implementing novel user interface and enhances this mapping. The low-cost and obscure tags can be used to identify all the objects in the really world include computing device and daily commodities. It can be used as the carrier of context information needed for the human computer interaction. This context is the characteristic description of entity [3]. The entity may be the person, space or any other object related to the human computer interface, even the user or application itself. The context can be classified according to

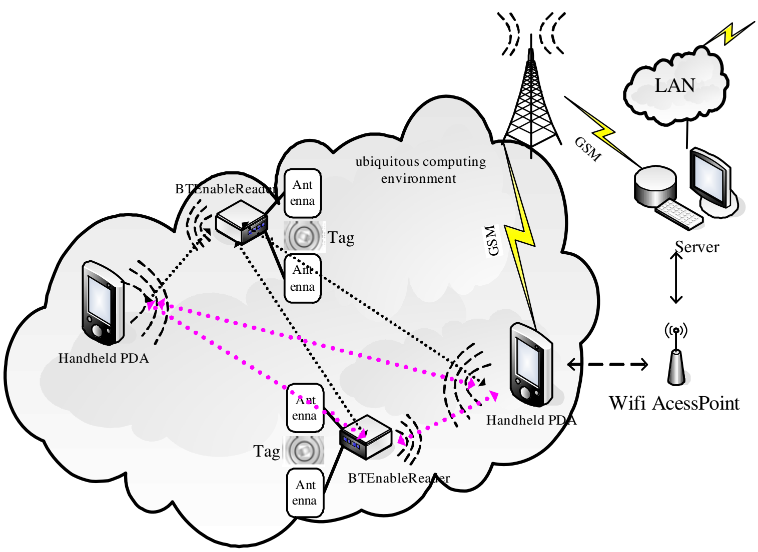

Fig. 1. Application scenario in ubiquitous computing environments

function or conception. From the functional point of view, the context's categorization is related to how the context is obtained, modeled and processed. For instance, it can be classify as low-level context with high-level context or active context with passive context. From the conceptual point of view, the context's categorization is related to how the context is cognized. For instance, it can be classify as user context, physical context and computing context. In this study we acquired the data in RFID tags through wireless mobile terminal shown in Figure 1. These pervasive tags are viewed as aggregation of context and resources or container of the URI that link to the needed context or resources, By using the information stored on RFID tags, the context of users and the state of computation objects and environments can be determined collaboratively. This context information can be used to associate interaction partners [5]. Based on the analysis of the data acquired from the tags, the system will push to users the services which agree with the current situation of interaction and the interaction will become more efficient.

The ubiquitous computing environment consists of different mobile computing devices that supply the interface for users. Because the users' situation is changing continuously, mobile computing is one of the important and broad application areas of context-awareness. When a nomadic user comes into a new environment and wants to understand his current status, the best way is to analyze the history and current context. Since the physical devices that provide available resource for user are normally in the space nearby, the PAN (Personal Area Network) is adaptive to these application scenarios very much. As one of the standards of WPAN (Wireless Personal Area Network) operating in the 2.4G ISM band [6], Bluetooth has the advantages like low-cost, opening, small-size and security. Because Bluetooth has been embedded into numerous kinds of mobile device and has become easily available, it can play an important role in the deployment of ubiquitous computing environments [7], [8]. For the communication between mobile device and computing space, we adopt Bluetooth in the environment connection layer.

4 Approach and Implementation of Prototype

Since more and more computers designed for mobile usages and the human-computer interface is expected to support the user's intentions and be aware of context, we elaborate on the implementation of an early prototype system which supports WPAN

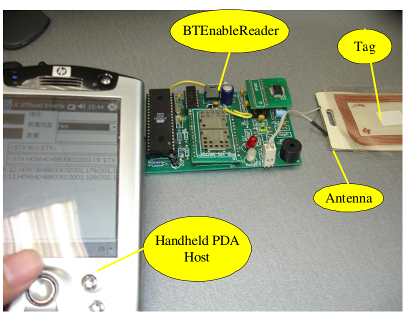

Fig. 2. Illustration of handheld host and RFID tag with reader

and is capable of associating RFID with context to trace the users' intentions in this section. Figure 2 presents the main devices for experimentation including handheld host, RFID reader, antenna and tag. The RFID reader named BTEnableReader is not only responsible for read and write of tags but also furnishes host control interface for upper layer mobile terminal's application and can be controlled by mobile host (as shown in Figure 2). Its design details are shown in Figure 3: (1) RF read/write module contains the transceiver IC S6700 [9] which handle protocol ISO/IEC 15693 communicates with responders that operate in the 13.56MHz band. (2) Real-time Clock Module is controlled by I2C bus to get time data for synchronization. (3) Memory Module is 24LC256 256K bit CMOS serial EEPROM controlled by I2C bus and used for store context history data for later query. (4) Communication Module here is equipped with an Ericsson ROK 101 007 Bluetooth chip [10] together with an onboard antenna. (5) Microprocessor Control Unit here is the 8-bit microcontroller with 8K Bytes Flash AT89C52, it also controls two LEDs for debugging purposes. In addition, the experimental responder we use is the smart-tag named "Tag-it" and supplied by TI.

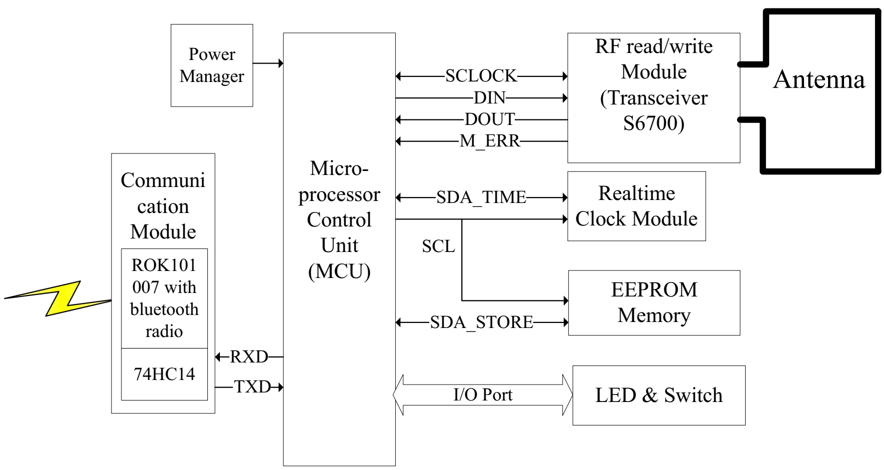

Fig. 3. Schematic diagram of BTEnableReader

As shown in Figure 4, in the physical bus drive layer we use the UART to connect the MCU with the Bluetooth hardware and set the baud rate to 57600bps. The host controller interface (HCI) defines a suit of functions to access underlying layers and Bluetooth hardware, such as baseboard, link manager, status register and event register. It hides the realization of link manager layer and supplies a uniform interface for upper application layer. The Bluetooth host can send the HCI command packet to the Bluetooth hardware and the Bluetooth hardware returns HCI event packet as the response, HCI data packet, which is classified as ACL (Asynchronous Connection-Less) or SCO (Synchronous Connection-Oriented) packet, is used for the data exchange between the Bluetooth host and Bluetooth hardware. In the BTEnableReader we design, only the ACL HCI data packet is used for context data communication in respect that SCO is more suitable for voice transmission.

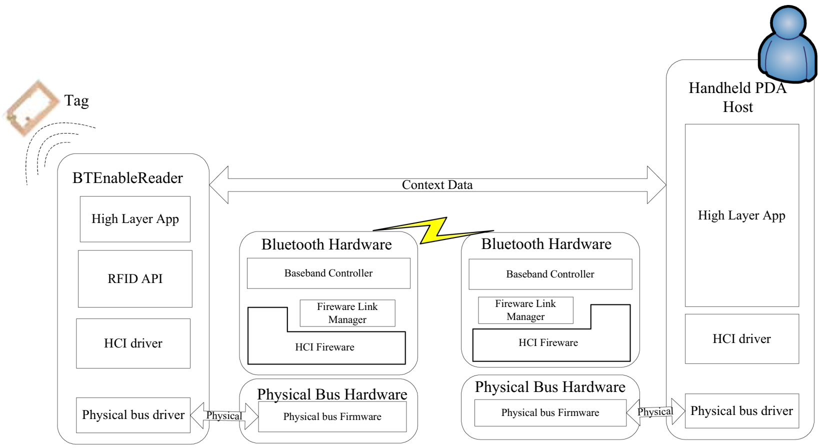

Fig. 4. Implement of software stack

5 Analysis of Interaction in Application Scenario

We present an exhibition hall as one ubiquitous computing space and use the RFID tags instead of passport barcode. The exhibition information management system consists of server center, booth reader sub-system, and mobile terminal sub-system; the whole exhibition hall is considered as one ubiquitous computing space (Figure 5 outlines the basic interaction between different partners in the space). The contexts we pay attention to include the visitor's identity, age, job, location and the nearby exhibitors. Each of visitors and the exhibitors gets one and only one RFID tag for passport identification before exhibition opening and each of gates and booths installs one BTEnableReader.

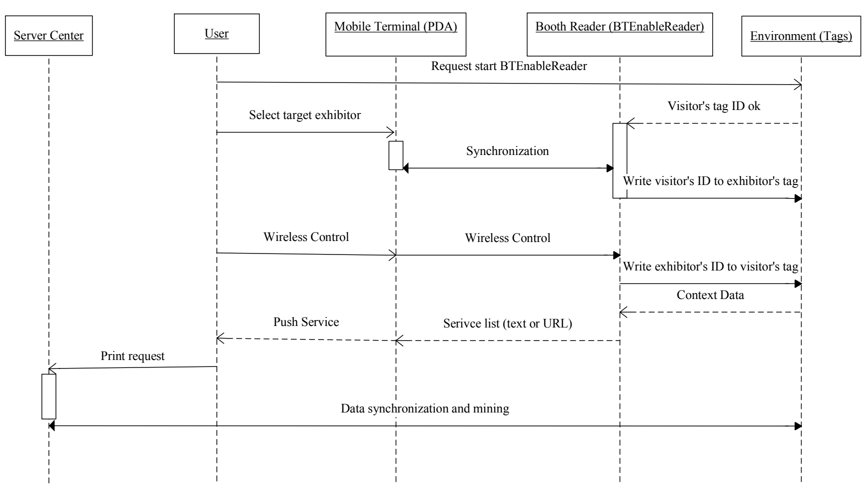

Fig. 5. Basic interaction in the scenario

The exhibitor puts his tag in the read/write range of his own booth reader. Thus when one visitor passes the booth, he can control the BTEnableReader to read the exhibitor's tag and get the context information of this exhibitor using Bluetooth-enable mobile phone or PDA (HP iPAQ5460, Pocket PC 2002, as shown in Figure 2). The context here maybe one URL of the exhibitor's introduction stored in tag and the visitor can navigate it on web through PDA or mobile phone. We measure throughput on point-to-point connection between Bluetooth-enable PDA and BTEnableReader. As shown in Figure 6, via experiments we observed that the throughput decreases as spatial distance between master (iPAQ 5460) and slave (BTEnableReader) increases. However for a given spatial distance, throughput remains stable regardless of the size of the context data.

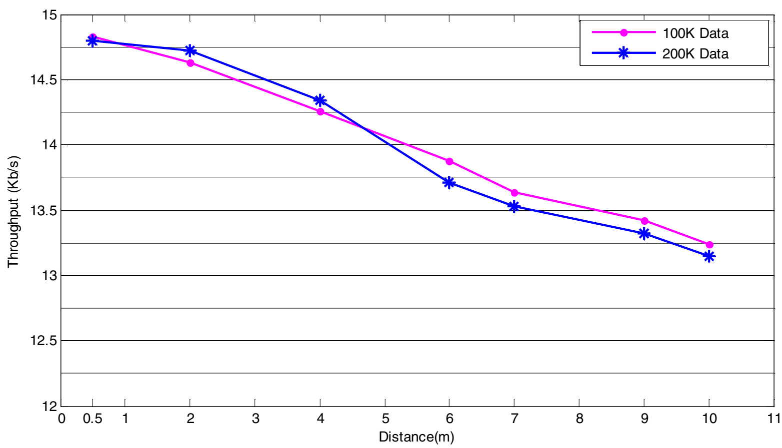

Fig. 6. Throughput of master to slave

If the visitor is interested in this booth, he can let the booth reader read his tag and the UID of his tag will be write into exhibitor's tag and vice versa. When the booth reader has known the visitor's identity, age or job, it pushes the service list in the form of text or URL to his PDA according to what he may be interested in. Since the readers are also installed at the exit, if the visitor leaves the exhibition hall, he will be reminded through the mobile device to print the stored exhibitor list. He can only use his tag to print by the self-help server center. Because the booth's location is fixed, we can know each visitor's path in a certain period of time and exhibition's host can analyze the feedback and interest of different type of visitor to different exhibitor. The exhibitor can also print all the visitors who are interested in his company or product on the self-help server center by his tag. Owing to the implicit interactions among this scenario, the users can feel that the interface base on RFID and mobile terminal compared with traditional method based on barcode is more easy-used and human-oriented.

6 Conclusion

One of the characteristics of this paper is that RFID is used to extend the way of acquirement and representation of context. The other is that we invent an embedded mobile device for test platform and this Bluetooth-enabled test bed can be applied to many real scenes and even the wearable computing. We advocated that the context sensed by RFID is an effective modality to enable a pervasive and consistent user interaction with computers across a full range of devices, and has the potential to provide a natural user interaction model.

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