A Ubiquitous Space User Interface (UUI) of Ubiquitous Fashionable Computer in a Ubiquitous Computing Environment, U-TOPIA

Ki-Woong Park, Jupuyung Lee, Jong-Woon Yoo, Seung-Ho Lim, Sung-Kyu Park, and Kyu-Ho Park
Computer Engineering Research Laboratory
School of Electrical Engineering and Computer Science
Korea Advanced Institute of Science and Technology
{woongbak,jplee, jwyoo,shlim,kpark}@core.kaist.ac.kr

Abstract

The interactive ubiquitous computing project, U-TOPIA, explores new possibilities for people working together in technology-rich spaces. Ubiquitous fashionable computers have more to do with form factor and usability than with computing. This paper focuses on our effort to overcome the challenges in a limited user interface of a wearable computer by providing a new interface, called Ubiquitous space User Interface (UUI) and its H/W platforms. Most portable devices like as a wearable computer have only small-sized display and limited input devices, which are definitely insufficient to interact with various peripheral modules, and send a user's intention to the other users. We attempt to resolve this problem by making full use of spatial resources inside the testbed room and mapping mouse operations to user's gesture. In the space based on UUI, a user can express one's intention easily and succeed to mouse device which is the most popular input device by using one's gesture. To explain the practical use of a wearable computer platform, UFC, and the user-friendly interaction based on the UUI, we implemented a ubiquitous testbed where multiple UFC users interact with various computing devices or other UFC users.

1 Introduction

The interactive ubiquitous computing project, U-TOPIA, started at KAIST in 2005 to investigate human interaction with smart places powered by ubiquitous computing technology, ranging from smart room and smart campus to smart city. We constructed several versions of our UFC prototype and smart places, created a software infrastructure for this environment, called U-TOPIA[1] [1, 2], and conducted experiments in human-computer interaction in the smart places. The evolution of UFC platforms are shown in Figure 1. We developed a bag-typed UFC and built-in type UFC with wired i-Throw device in 2005 and 2006 respectively. The new paradigm of wearable computer design has concentrated on the problems that arises when user has to put up with considerable inconvenience carrying around devices. Thus, the wearable computer platform should be light-weight, easy to carry, and washable. In 2007, deliberating on the requirements, we developed a reconfigurable type UFC and wireless i-Throw allowing users to construct their's own UFC platform to any kind of clothes. To achive it, UFC is designed to enable attachment to general clothe thanks to clip type case and stand-alone operation.

From the past couple of decades, personal computer users have gotten accustomed to using GUI with I/O devices like as a mouse and a monitor as described in Figure 2. In

	2005	2006	2007
Shape	Bag Type	Clothe Built-in Type	Reconfigurable (Clip Type or Stand Alone Mode)
Output	HMD	LCD	HMD / LCD
Input	Glove Type (Wired)	Ring Type (Wired)	Ring Type (Wireless)

Figure 1. Evolution of Ubiquitous Fashionable Computers (2005, 2006, and 2007)

[1] 'U' stands for 'ubiquitous' and 'TOPIA' stands for 'place' in Greek

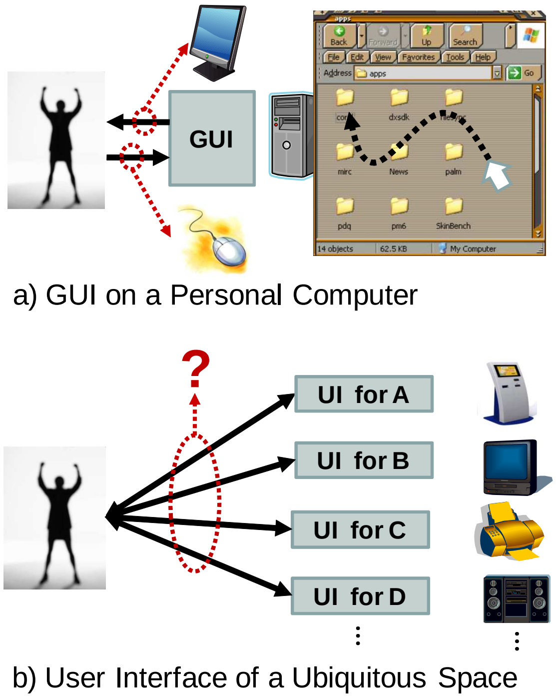


Figure 2. Comparison of User Interface between a personal computer and a ubiquitous space

the advanced smart places, there are usually numerous controllable devices, each of which has different interface and different access control mechanism, making it a challenging issue to design and implement a unified interface for a smart place. Meanwhile, the functionality of a mobile device continues to grow so rapidly that today's mobile device can be actively utilized for various useful applications. However, as the complexity of a user device continues to grow, so does the difficulty in accessing various operation sets and resources of the device, which is an another challenging issue. No matter how plentiful computing resources of both external ubiquitous devices and internal user devices are, it means nothing from the perspective of a user if a user cannot access the resource easily via a well-organized user interface. User interface should be easy-to-learn, easy-to-use, user-friendly, and environment-friendly. To remedy these problems, in this paper, we present a new user interface, called Ubiquitous space User Interface (UUI). It makes full use of spatial resources inside the testbed room and mapping mouse operations to user's gesture.

The outline of this paper is listed as follows: Section 2 presents the motivation of UUI and Section 3 introduces U-TOPUA which consists of our testbed environment and UFC. In Section 4, a target application is presented and the conclusion is given in Section 5.

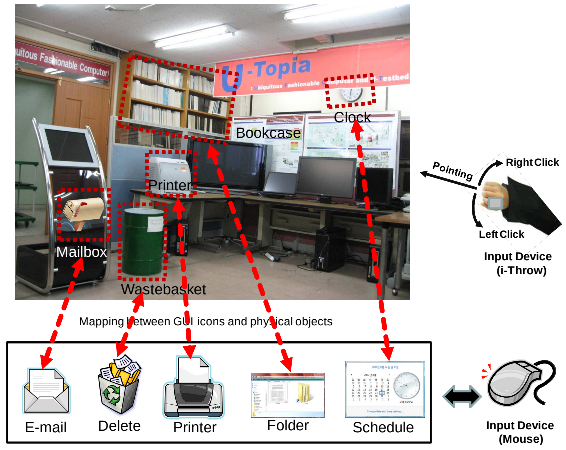


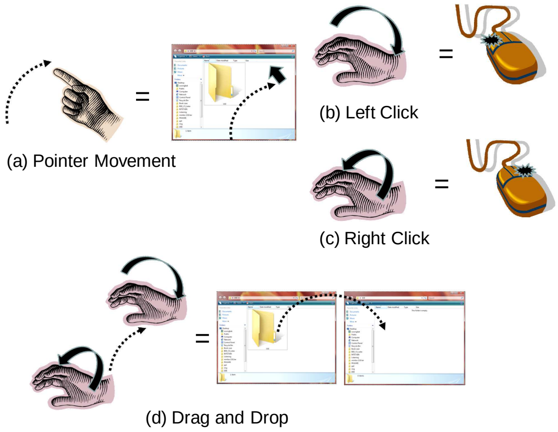
Figure 3. Concept diagram of Ubiquitous Ubiquitous space User Interface

2 Motivation of UUI

Most portable devices like as a wearable computer have only small-sized display and limited input devices, which are definitely insufficient to interact with various peripheral modules, control the modules, and send a user's intention to the other users.

Therefore, a novel user interface should be considered to minimize user's inconvenience while users access and utilize the system resource. The uncomfortable interface means that users should get training its function with burdensome input or output devices using wearable keyboard and mouse [3]. Thus, it is desired to develop comfortable and user friendly input devices and a novel user interface for wearable computing. The novel user interface is required to be simple, easy and intuitive by recognizing human friendly gestures, activities, or senses. Intuitive interface can be described as the mechanism of interactions with the devices in a ubiquitous environment by human friendly gestures which everyone can easily accept and recognize.

This problem is exacerbated when a wearable computer user tries to control various ubiquitous devices using one's platform: as the number of controllable ubiquitous devices increases, it becomes more inconvenient to find one among them and exchange information with it, due to the small-sized display and limited input devices. Efficient utilization of a small-sized display and intelligent mapping of various commands on the input buttons can partially solve this problem. However, such an approach usually makes it difficult to learn how to use the device, which degrades the usability of the UFC platform. One recent workshop underscored that usability is one of the primary challenges in a next-generation "smart" room, that is full of various ubiquitous devices[4].



Mouse Operations	Mapped Gesture
(a) Pointer Movement	Movement of finger's direction
(b) Right Click	Tilt hand to right-side and return
(c) Left Click	Tilt hand to left-side and return
(d) Drag and Drop	Pointing & Tilt hand to right-side

Figure 4. UUI Interface mapped to mouse operations

We attempt to resolve this problem by making full use of spatial resources inside the testbed room and mapping mouse operations to user's gesture. We named it to ubiquitous space user interface (UUI). In the space based on UUI, a user can express one's intention easily and succeed to mouse operations which is the most popular input device by using one's gesture. For example, icons of GUI like as a folder, scheduler software, and e-mail software are mapped to physical objects as described in Figure 3. And all of the mouse operations are mapped to users' gestures. Figure 4 shows the mapping between mouse operation and users' gesture. From the perspective of the user, the most natural way of pointing an icon of GUI is moving and pointing his/her finger at the mapped physical objects. In this way, several mouse operations like as a right click, left click, and drag & drop can be mapped to user's gestures.

3 Interactive Ubiquitous Space, U-TOPIA based on UUI

In order to realize U-TOPIA, we developed a wearable computer, UFC, that allows people to exploit ubiquitous computing environment as described in Section 1 and security infrastructure for secure ubiquitous services based on our testbed and middleware technology. Since our ubiquitous environment aims for a intuitive interaction with physical objects and UFC users, it is essential to build an intelligent testbed which various services can be operated. Three important components of U-TOPIA are a communication infrastructure, a location-tracking infrastructure, and a middleware with a security server.

- **Communication Infrastructure:** Communication infrastructure lays the groundwork for ubiquitous computing. Two well-known standards are used to support anytime and anywhere wireless communication services; IEEE 802.11 (WLAN) [5] and IEEE 802.15.4 (ZigBee) [6] We installed an enough number of ZigBee sensor nodes and WLAN access points in a wide mesh manner. In this environment, communication could be done via multi-hop sensor nodes for low speed data transmission and WLAN for high speed data transmission.

- **Location-tracking infrastructure:** Location-tracking infrastructure is necessary for location-based services such as the intuitive spatial pointing of *i-Throw*. The ZigBee sensor nodes are also used for location tracking. Every nodes periodically broadcast beacon signals, which uses 2.4GHz band as a physical channel. A moving user receives beacon signals from the ZigBee communication interface. When the user receives multiple beacons from the multiple sensor nodes, the users who have received the beacons can identify his location by calculating each Received Signal Strength Indicator(RSSI) value from each sensor node [7]. During the measurement, however, we found that the resolution of location sensing using this mechanism was not sufficient for our target application. Thus, we also utilized a UWB-based location tracking device [8] whose typical accuracy is 6 inches(15cm). Due to the high cost of this solution, the UWB-based location tracking device have installed in only two rooms inside the testbed.

- **Middleware and Security Server:** In this testbed, we assume a situation where thousands of users move here and there, interact with each other or a location-based service environment, share information with authorized other users, access to diverse devices for diverse purposes, and run various location-based applications. In this situation, an extensible middleware and security framework is necessary to keep up with highly variable dynamic and secure environment. Therefore, we developed a middleware, called μ-ware [9] and a security infrastructure, called pKASSO [10]. As described in Figure 5, μ-ware is composed of light-weight service discovery protocol, distributed information sharing, context manager and instance service loader, all of which are useful to manage dynamic data and to develop new application that utilizes various ubiquitous resources. Like other mobile devices, UFC is a battery-powered device. Because users carry and uti-

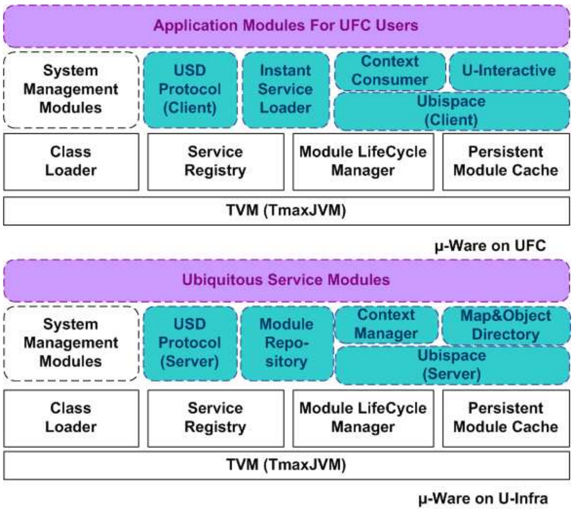


Figure 5. μ**-ware Architecture on UFC and infrastructures**

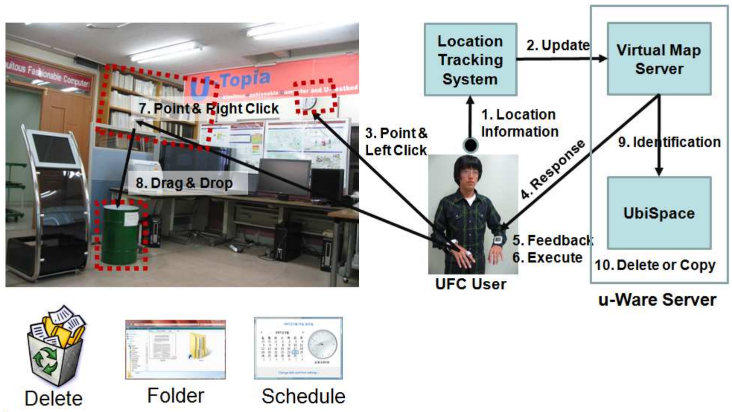


Figure 6. A sequence of UUI operations

lize UFC during most of a day, its energy consumption is a critical point. Besides, the users want to take advantage of new ubiquitous services around various places. Meanwhile, on the part of the U-Infra room server, the administrator wants to simultaneously execute server threads for a variety of ubiquitous services and to manage and control them at the remote place. Based on these design issues, we have designed and implemented an energy-efficient and extensible middleware framework for both the UFC and the infrastructure. This framework, μ-ware, supplies a private computing environment to users as well as enables users to interact with user-centric services from various infrastructure service areas with low energy cost.

In order to provide a full-fledged security solution especially tailored for our testbed environment, wherein numerous devices and sensors with severe resource-constraints interact with each other, we developed an computationally efficient PKI-based security infrastructure, pKASSO enhanced with single sign-on and delegation technology. It enables a cost-effective but uncompromisingly secure development of UFC. The delegation mechanism of pKASSO makes it possible to offloads complex cryptography operations from UFC to server-side so that it significantly improves authentication latency as well. According to the performance evaluation, the authentication latency (Avg. 0.082sec) is much shorter than a contact type smart card (Avg. 4.31sec) and a conventional PKI-based authentication latency (Avg. 5.01sec) [10].

4 Target Application of UUI

In this paper, we take 'UUI-based user-friendly interaction with ubiquitous space and physical objects' as a target application. To execute this application, we have implemented a ubiquitous testbed room where multiple UFC users interact with various ubiquitous devices or other UFC users. Figure3 illustrates the concept of the ubiquitous testbed room which present a practical application that runs upon the UFC platform and the ubiquitous devices based on UUI, which makes it possible to interact with the various objects and control ubiquitous devices very easily.

In order to explain the components necessary to realize the UUI-Based interaction in the ubiquitous testbed room, we will take the following scenario: there is one UFC users, the user executes the scheduler application mapped to the clock (physical object) by pointing and left click. After that, the user opens folder mapped to the bookcase (physical object) and selects the files in the folder. Finally, the user deletes them by drag and drop to the wastebasket (physical object). A sequence of interactive operations necessary to realize the scenario is shown in Figure 6. In the figure, each operation is denoted by the number and each operation corresponding to each number will be detailed below.

1. The UFC user's location is recognized by the *location tracking system*. We utilized UWB-based location tracking device[8] whose typical accuracy is 6 inches (15cm).

2. The location information of the UFC user estimated by the location tracking device is sent to the *virtual map server* of the μ-ware server. Based on the location information, the *virtual map server* of the μ-ware updates the virtual map of the ubiquitous testbed room.

3. The user points and left click the clock (physical object) using the i-Throw.

4. On recognizing the 'pointing' gesture, the *virtual map server* of the μ-ware responds the information of the pointing object to the UFC platform of the user.

5. On receiving the information, it appears on the LCD screen of the user in the form of graphical feedback so that the user can identify the currently selected target device.

6. Then, the scheduler application mapped to the clock (physical object) is executed in the UFC platform.

7. The user points and right click the bookcase (physical object) using the i-Throw. Then, the folder mapped to the bookcase is opened and selected in a similar way of previous phase.

8. The user drags and drops the selected files to the wastebasket (physical object).

9. On recognizing the 'drag' gesture, the *virtual map server* of the μ-ware responds the information of the pointing object to the *UbiSpace* of the μ-ware server to identify the files.

10. On recognizing the 'drop' gesture, the *UbiSpace* of the μ-ware server deletes the files in case that the pointing location is the wastebasket. If the pointing location is the other bookcase, it copies the files to the other bookcase.

5 Conclusion

In this paper, we present a novel user interfaces, UUI, have been developed and integrated with the UFC to help the intuitive use of it in our wearable computer system. In the space based on UUI, a user can express one's intention easily and succeed to mouse operations which is the most popular input device by using one's gesture. In this way, several mouse operations like as a pointer movement, right click, left click, and drag & drop can be mapped to user's gestures. From the perspective of the user, the most natural way of pointing an icon of GUI is moving and pointing his/her finger at the mapped physical objects. To explain the practical use of a wearable computer platform, UFC, and the user-friendly interaction based on the UUI, we implemented a ubiquitous testbed where multiple UFC users interact with various computing devices or other UFC users.

References

[1] K.H. Park, J.P. Lee, J.W. Yoo, S.H Lim, K.W Park, H.J Choi,and K.Wohn "U-TOPIA: Campus-wide Advanced Ubiquitous Computing Environmen," Proceedings of Conference on Next Generation Computing, Vol. 3, No.3, pp. 5-16, June 2007.

[2] KAIST UFC Project, http://core.kaist.ac.kr/UFC

[3] Matias Corporation halfkeyboard products, http://www.halfkeyboard.com/products/whkbinfo.html

[4] M.Back, S.Lahlow, R.Ballagas, S.Letsithichai, M.Inagaki, K.Horikira and J.Huang, "Usable Ubiquitous Computing in Next-genration Conference Rooms: Design, Evaluation, and Architecture," In Proc. UbiComp 2006 Workshop, Sep. 2006.

[5] IEEE 802.11 Specification, "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications," IEEE Specifications, June 1997.

[6] IEEE 802.15.4 Specification, "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (LR-WPANs)," IEEE Specifications, October 2003.

[7] H.Cho, M.Kang, J.Park, B.Park, H.Kim, "Performance Analysis of Location Estimation Algorithm in ZigBee Networks Using Received Signal Strength," 21st International Conference on Advanced Information Networking and Applications Workshops (AINAW'07), pp. 302-306, 2007.

[8] Ubisense, http://www.ubisense.net

[9] Y.Song, S.Moon, G.Shim and D.Park, "Mu-ware: A Middleware Framework for Wearable Computer and Ubiquitous Computing Environment," In Proc. 5th Conference on Pervasive Computing & Communications(PerCom 2007), Mar. 2007.

[10] K.W Park, H.C Seok, and K.H Park, "pKASSO: Towards Seamless Authentication providing Non-Repudiation on Resource-Constrained Devices," In Proc. 21st IEEE Symposium on Pervasive Computing and Ad Hoc Communications, Vol. 2, pp. 105-112, May 2007.

[11] T.Starner, "The challenges of wearable computing: Part 1.", In Proc. IEEE Micro, pp. 44-52, Jul. 2001.

[12] Hoysniemi, J., Hamalainen, P., Turkki, L., and Rouvi, T., "Children's intuitive gestures in vision-based action games," In Proc. ACM Communications, vol. 48, pp. 44-50, Jan. 2005.

[13] J.Lee, S.H Lim, J.W Yoo, K.W Park, H.J Choi, K.H Park, "A Ubiquitous Fashionable Computer with an i-Throw Device on a Location-Based Service Environment," In Proc. 21st IEEE Symposium on Pervasive Computing and Ad Hoc Communications, Vol. 2, pp. 59-65, May 2007.

[14] M.Kang, J.Chong, H.Hyun, S.Kim, B.Jung and D.Sung, "Adaptive Interference-Aware Multi-Channel Clustering Algorithm in a ZigBee Network in the presence of WLAN Interference," In Proc. IEEE International Symposium on Wireless Pervasive Computing, Puerto Rice, Feb. 2007.