Ubiquitous Hands: Context-Aware Wearable Gloves with a RF Interaction Model

Jong Gon Kim, Byung Geun Kim, and Seongil Lee

[1] Sungkyunkwan University, Department of Industrial Engineering
Suwon, 440-749, Korea
gon0325@gmail.com, billkim@limeorange.com, silee@skku.edu

Abstract. In this paper, we describe the development of gloves that can be used in a ubiquitous computing environment. The ubiHand gloves were developed to access information devices in various wireless environments, including mobile computing, games, and in-vehicle telematic systems. The gloves are equipped with chording keyboard mechanism for flexible input and control of the wireless devices, an embedded RFID reader and a set of accelerator sensors for gathering information from the users' various hand gestures. The system configuration and keymaps for ubiquitous information access as well as the interface for input and control for the gloves are presented.

1 Introduction

For years, many research efforts have been made in designing ubiquitous technologies for smart environments. To make access and retrieve information efficiently, users need a convenient access tools and interfaces to give the users primary role to manage the information by themselves. This includes how portable their computing tools are to carry anywhere and anytime, and how suitable their computing tools and interfaces are for navigation and information presentation as well as data input.

Like many other emerging technologies, ubiquitous computing is characterized by being different from traditional computing methods in the physical appearance and the contexts in which it is used. This paper described our efforts of developing the ubiHand, a wearable ubiquitous device that can provide mobile users with accessibility and usability to various computing environments. Gloves equipped with a wireless communication module can be a good interactive device to many embedded computers since the hands and fingers are the most natural and dominantly used parts of the body. Many simple gestures of the hands reveal so many different contexts which the users deal with. Gloves equipped with a RFID reader also facilitates applications that are triggered by handling tagged physical objects, enabling the system be applied to context-aware mobile computing. Using hands, humans can naturally develop unique and effortless strategies for interacting with ubiquitous environment. In other words, hands do not have to hold and manipulate interfacing devices, but hands can be the interfacing devices themselves for ubiquitous environments to interpret.

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2 Background

Several types of glove-based devices recognizing hand gestures or contact gestures directly have been widely proposed as input devices to computers. These devices are well suited for use in a mobile environment because the gloves can be worn instead of just being used to hold a device, are lightweight and easy to store and carry. It is, however, difficult to recognize enough separate gestures to allow useful text input. Some glove-based input devices, though, have capabilities to make decent text input in addition to their intended functions of gesture recognition and space navigation. Pinch Gloves [3, 15] are glove-based input devices designed for use in virtual environments, mainly for 3D navigation, and N-fingers [7] is a finger-based interaction technique for wearable computers also utilizing finger pinching. Pinching is basically the motion of making a contact between the tip of thumb and a fingertip of the same hand. It uses lightweight gloves with conductive cloth on each fingertip that sense when two or more fingers are touching.

For use of many small portable electronic products, chord keyboards have also been proposed as input devices [5, 10, 11, 14]. A chord keyboard is a keyboard that takes simultaneous multiple key pressings at a time to form a character in the same way that a chord is made on a piano. In chord keyboards, the user presses multiple key combinations, mainly two-letter combinations, to enter an input instead of using one key for each character. Pressing combinations of keys in this way is called chording. Since chord keyboards require only a small number of keys, they do not need large space, nor the many keys of regular keyboards such as the QWERTY keyboard. For example, the Handkey Twiddler is a one-handed chord keyboard with only 12 keys for fingertips and a ring of control keys under the thumb, and the Microwriter with only 6 keys [14].

Rosenberg and Slater [12, 13] proposed a glove-based chording input device called the chording glove to combine the portability of a contact glove with the benefits of a chord keyboard. In their chording glove, the keys of a chord keyboard were mounted on the fingers of a glove and the characters were associated with all the chords, following a *keymap*. Their design of the keymap for the chording glove for Roman-alphabetic text input left room for improvement according to the experimental results. Pratt [11] also designed a device-independent input device and language code called “thumbcode” using chording gloves targeting for PDAs.

All the previous works on glove-based input devices were intended for usage with general computers, not targeted for mobile computing environments. The current works investigate the utilities, functionality, and usability of the chording gloves as a smart device for ubiquitous information access to mobile devices.

Recently, there has been research on wearable systems for detecting objects with RFID tags [4, 6, 8]. These systems mainly tried to design and implement a system for accessing contextual information using the wearable computer. The wearable computer came with a variety of forms, but the most common forms were gloves with a RFID tag.

3 System Configuration

The design of the ubiHand chording gloves and its controller began with the arrangement of the sensors on the gloves which function as control keys. The interface of the system is based on the human-friendly nature of finger movements, particularly finger flexion. All the operations by the chording gloves consist of either a series of finger tapping on a hard surface with ground levels or finger contacts between the fingers with silicon inks. The ubiHand glove also contains a RFID reader so that it can sense what touches and where it is by reading RF tags providing such information.

3.1 General Structure

The ubiHand chording gloves developed in the study which use finger tapping to make various types of input is shown in Fig. 1. An input can be made by contacts between the keys on the fingertips and either the thumb or hard surface. Chording is possible by making simultaneous tapping with multiple fingertips to the thumb or hard surfaces. Four keys are placed on the fingertips and phalanges of the index and middle on the palm side of leather gloves. The keys are made of conductible silicon ink applied to the fingertips with the rectangle of 1.5 cm by 1.3 cm. The keys become “pressed” once the voltage through the silicon ink rises above 3.5 V with contact with the thumb or any hard surfaces. The voltage outputs of chord gloves are connected to an embedded controller that translates chord information into its corresponding character. The corresponding finger force to generate 3.5 V is set to 3.50 N to avoid unwanted activations with light contact between the fingers and driving wheel. The glove with the RF reader and controller on weighs approximately 55.0 g and the right-hand glove with only keys weighs 28.5 g.

3.2 Control and Communication

The 16F874 microprocessor is used for controlling and analyzing the signals from the chording gloves. The controller also works for functions of converting the signals to text codes and sending them to PC or PDA through a Bluetooth 1.1 (aircode) wireless adapter. The controller works with a 9V battery.

Fig. 1. The UbiHand Glove. The thumb acts as a ground to conduct electricity to the keys on the fingers made of silicon ink. It also contains an RFID reader so that it can sense and record what it touches or where it is.

The voltage outputs of chording gloves are sent to an embedded system that translates chord information into its corresponding code, character, or number. The chord glove-based input device can be used in connection with computers or PDAs directly as a portable keyboard. The voltage outputs of chording gloves are sent to an embedded system that translates chord information into its corresponding code, number, or signals. The controller transmits signals from the gloves to the PDA, mobile phones, and other telematic systems with a Bluetooth module to control them.

One in the pair of the ubiHand chording gloves are also equipped with a RFID reader.

4 Ubiquitous Access

4.1 Access to In-Vehicle Transport Telematics

Multimedia and telematic systems have become important parts to automobiles. A substantial amount of effort has been invested in transport telematics and in-vehicle multimedia systems over the last decade. The increase in use of smart electronic products such as navigation systems, wireless internet, mobile phones, and other audio/video devices in automobiles provide mobile information accessibility and convenient and pleasant driving conditions. Automobile infotainment systems for today's luxury cars provide noise-compensation and surround sound technology, communication systems with telematics and hands-free digital phone, navigation systems are equipped with DVD-based programs including maps and precise audio/visual directions [1, 2, 9]. Control or manipulation of each device, however, requires human attention and inevitably distracts driver's attention from driving tasks, resulting in degrades in driving performance and potential danger of accidents. Emerging concept for central control of these multimedia devices suggests for needs of interface design that can provide straightforward, effortless, and logical activation and manipulation without driver's performance degrade in the main task of driving.

The traditional display screen-keyboard interaction model is inappropriate for this ubiquitous information access capability in in-vehicle multimedia interface, and new interaction paradigms need to be investigated in multimodalities using speech or haptic input and output.

The ubiHand chording gloves we developed can provide drivers with safe, all-in-one telematics control functions with an integrated and wireless wearable multimedia interface. Gloves equipped with a WPAN-based wireless communication module can be a good controller to multimedia systems inside automobiles since the hands and fingers are the most dominantly used parts of the body. Therefore, drivers can naturally develop unique and effortless strategies for interfacing with multimedia and telematics in the car without moving their hands away from the driving wheel. In addition, the drivers do not have to move their eye gazes to control the devices while driving, which serves as a very important factor for safe driving. Control input can be made by simple tapping or chorded tapping of the fingers on the hard surface of driving wheel. The i-PAQ PDA with a Bluetooth module is working as a server for other in-vehicle information devices that are wired and as an access point for the wirelessly connected devices in our system (Fig. 2).

In the in-vehicle telematics mode, the glove for the left-hand basically works as a device selection keypad. The thumb, together with the thumb of the right hand, works for the power on/off of the entire unit. That means the system can be turned on or off only with the "thumb + thumb" chord tapping. The index finger selects the mobile phone, while the middle finger selects the navigator on the PDA. Once a device is selected, the interface changes to the control mode for the selected device until the other device is selected with the left-hand fingertip tapping. With the thumb excluded, a total of 6 devices can be selected from single finger tapping and two-finger chord tapping combinations. Pilot experiments showed that users could easily memorize and activate devices with chording combinations of adjacent fingers such as "index + middle" fingers, but had hard time to memorize and activate the functions assigned to the chords with "the other hand" chording.

Fig. 2. Use of chording gloves in an in-vehicle infomatics and telematics environment

4.2 Access to Wireless Internet

Users can access to information from the wireless internet either by the explorer program installed on the PDA or by the wireless internet services provided on the mobile phone's carrier company inside the car. Since the ubiHand chording gloves can control the PDA's operating system (Windows CE) as well as application programs, users can select internet navigation browser program and then type in the URL addresses in the text mode to access the information on the internet.

The other way to access information on the wireless internet is to use the wireless internet services provided by mobile phone's communication services carriers. The mobile phones equipped with a Bluetooth module can be controlled by the chording gloves, and a corresponding service function buttons can be activated by chording. In this way, text messages (SMS) or emails transmitted to the internet services on mobile phones can be accessed by the chording gloves. The accessed internet information, however, is not displayed on the LCD on the back of the left hand, but presented only on the mobile phone's display.

4.3 Access to Home Network

The ubiHand gloves can also be used for wireless access to and control of home network systems. A PC with an access point connected to an iPAQ serves as a server for the home network. The gloves can work in the same way with the in-vehicle system. The specific keymaps and wireless network protocols were not yet finalized in this area using the chording gloves. User can always carry a PDA and the gloves as a set, and select the appropriate mode and then activate the corresponding keymap. Future studies on situation-awareness can help the system be more efficiently used in many different environments.

5 RF Interactions for Context-Aware Computing

5.1 Experiments in a Classroom Domain

We performed an experiment in a classroom domain how useful the ubiHand gloves can be for context aware wearable devices. Since the ubiHand gloves are equipped with a RFID reader, it can sense the RFID tags in the surrounding environment, and hence can change the status of modes automatically based upon the context it infers. We set up a classroom with many relevant objects equipped with an RFID tag in a laboratory. A student and a teacher who is wearing the ubiHand on one hand simulated class acts such as lecturing and discussion on a whiteboard. The experimental set-up is described in Fig. 3. The concept of a wearable RFID-tag reader or wireless wearables for detecting objects have well been explored in other studies [####].

We also developed a matrix-based context-aware model for the ubiHand gloves application in the same domain. The matrix can describe the interactions between the RFID tags of the objects and also of the users and RFID readers of the ubiHand gloves. The model can extract data on context of each users by analyzing the RFID interactions on the matrix, and can change mode of operation of the gloves and computers. This process of context-aware model is described in Fig. 4, from the primary context data gathering by the ubiHands, to matrix-based operation of fusion context extraction, and the final context inference. The final context contains the data on why the user did such an action and how it is done at a certain time within the classroom.

Such objects as the whiteboard, student's chairs, podium, chalks, pencils were tagged with a small RFID. The teacher and the student were also attached with a RFID tag. The final context results were categorized into 5 contexts: student's attendance, teacher's attendance, lecturing, discussion on the whiteboard, end of class. The ubiHand changes its mode according to the context inferred. For example, the teacher's ubiHand glove changes its mode to a presentation pointing device when its context aware system recognizes it in a lecturing state, and to a communication or other controller mode when the class is over. The RFID tagging data was logged into a main computer every second for 12 minutes of experiment. At the end, the accuracy of correct context inference was measured at around 69.7%, with the analysis of video frame data.

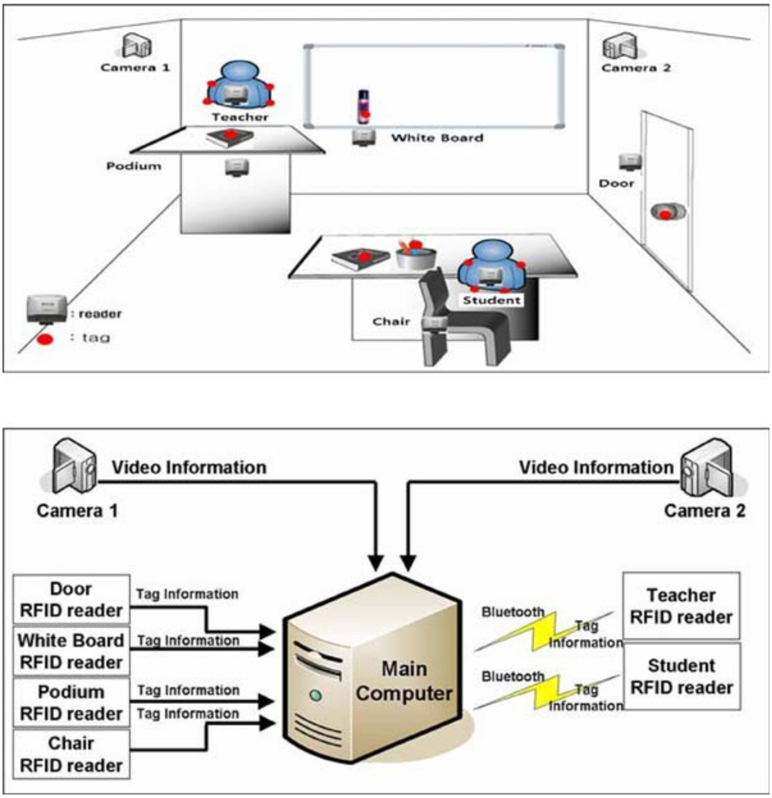

Fig. 3. Configuration of the ubiHand gloves experiments. A teacher and a student wearing the ubiHand gloves simulated class acts while touching and being near the classroom objects with a RFID tag. All the data along with the video frames are sent to a main computer to log the RFID tagging at every second.

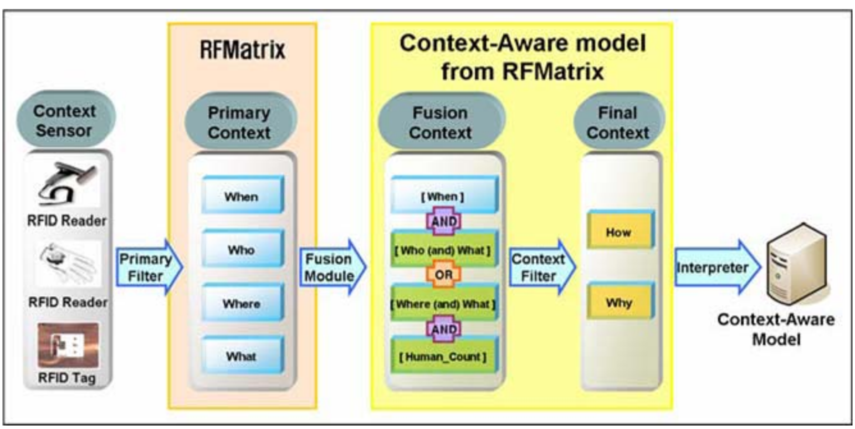

Fig. 4. A concept diagram of the context-aware model developed for the ubiHand application in the classroom domain

6 Conclusion

Our goal was to make a wearable controller for mobile computers capable of sensing the users and their current state, exploiting context information to significantly reduce demands on human attention. We came up with a glove-based context-aware computing system with a wireless communication module and a RFID reader. The ubiHand glove was supplemented with a RF interaction matrix to infer context data for it to adjust its function mode to its user's situation and states. Even though the accuracy of the RF interaction matrix-based context-aware system in a classroom test domain, it still shows possibility to be used as a ubiquitous controller for a context-aware mobile computing system.

We first tested the ubiHand gloves in various environments such as vehicles and homes, and then developed an appropriate context-aware computing model for the wearable controller that can be used in environments with many objects tagged with RFIDs. We developed a model that infer the context out of the information from multiple RF tags to define the tag and reader relationship based on a matrix that define the primary context (When, Who, Where, What) into Fusion context (Primary context with operators of AND and OR) to infer the final context of Why and How, using the ubiHand gloves. By combining a context-aware computing model with a wearable controller, we have been able to design and implement a user-friendly ubiquitous input device and controller. Even though the RF interaction matrix was not accurate enough to support the user's context in highly reliable fashion, it was still a powerful and useful system.

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