Enabling Sportive Games with a Do-It-Yourself Wearable Computing Platform

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Abstract

As advances are made in hardware design technology, the wearable computing platform is becoming widespread and comes with interesting and challenging issues. In an attempt to use wearable computing technology as a bodily game interface, this paper presents our experiences in realizing a wearable computing platform that enables users to perform bodily interactive games. First, we present our design and implementation of a Do-It-Yourself (DIY) wearable platform which is applicable to game platforms according to a usage goal. In order to promote physical activity, it provides computer games with a bodily interface, such as moving arms up and down, and pressing on-clothes buttons. Second, we present an interactive game called DanceToBe, which adds more active sportive-elements into the game in a manner that incorporates players' bodily actions with music and video based on the DIY wearable platform.

1. Introduction

With the rapid progress of mobile computing and communication technology, wearable computers are becoming more prevalent because computing devices worn on the body provide the potential for digital interaction in the real world [1, 4, 5, 6]. This creates a demand for more practical wearable computer designs that consider not only aesthetic appearance but also usability. The usability makes wearable computers more practical and cost-efficient because one well-designed wearable platform can be used in various areas according to usage goals. It offers the potential to achieve high usability while remaining cost-efficient and adaptable to a wide range of applications. For this potential to become realized, we need to develop wearable computing systems that have better flexibility and usability than domain specific wearable computer platforms such as

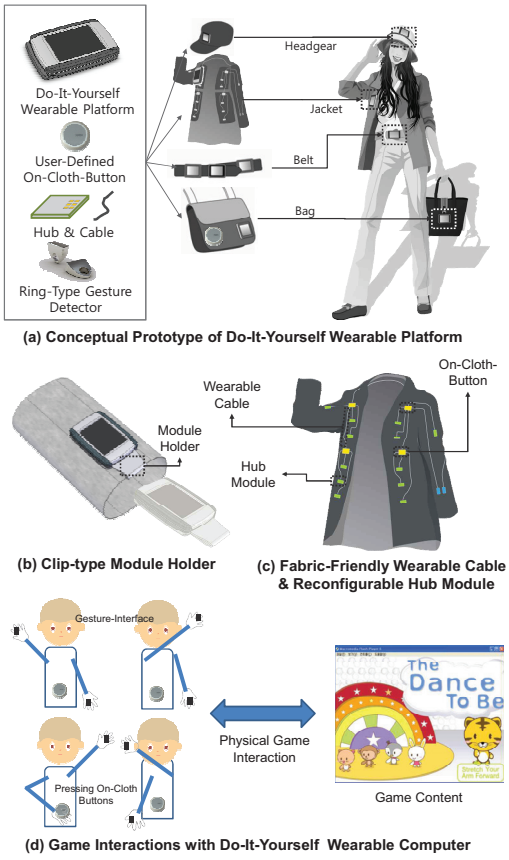

Figure 1. Prototype of Do-It-Yourself Wearable Platform and Game Interactions

those in [2, 3, 9, 11, 12, 13, 21]. To fulfill the requirements mentioned before and realize a practical wearable platform with usability and generality, we present our experiences in realizing a Do-It-Yourself (DIY) wearable platform that allows users to construct

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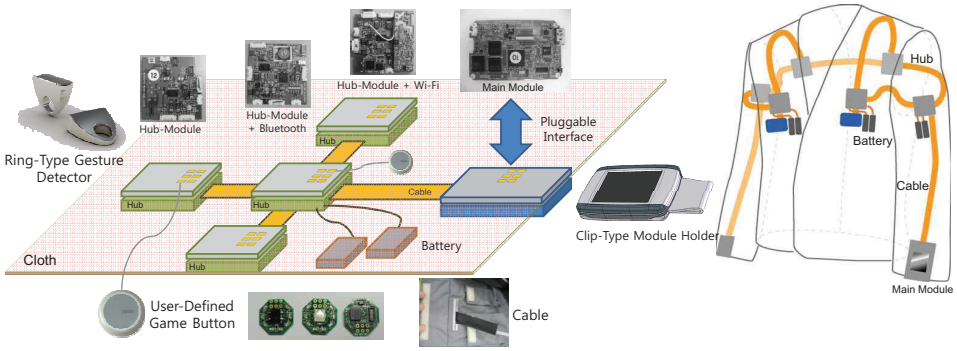
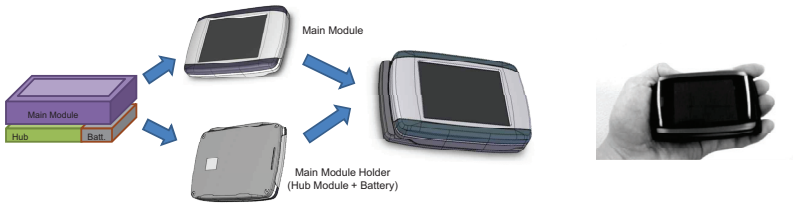


(a) Wearable Platform with DIY Mode: Main Module + 4 Hub Modules + Two-Cell Battery + User-Defined Buttons



(b) Wearable Platform with Standalone Mode: Main Module + Hub Module + One-Cell Battery

Figure 2. Do-It-Yourself Wearable Platform Architecture

their own wearable platform on general clothes. We achieve this by attaching the main module and I/O peripherals such as a gesture detector and on-clothes buttons, onto the user's clothes as shown in Fig. 1-a. The main module is designed to be attached to general clothes by a clip type module holder (Fig. 1-b), fabric-friendly wearable cable, and a reconfigurable hub module (Fig. 1-c). With the DIY wearable platform, new forms of user interaction can be utilized widely through the use of a gesture detector or on-cloth buttons that are attached to the user's clothes in a user friendly manner. This innovation could lead to a change in the way users interact with not only mobile office [8, 9] or health-care services [12] but also game interaction with wearable computing technology as shown in Fig. 1-d.

To exploit the wearable platform as a game input device, a player uses a gesture detection module and on-clothes buttons that can be attached to the player's clothes. Several bodily interface games can be built using the motion detection feature and on-cloth buttons in the DIY-wearable platform. When the player's arm movement or pressing the buttons is detected, the platform sends a detected input signals to the host game platform. Over the past years, several reports [14, 15, 16] have discussed the benefits of being physically active in life from health and socioeconomic aspects [17]. This DIY-wearable computer-based game can improve the players' health by involving them in physical activities. Using our wearable platform instead of using directional keys or joysticks, the player can control the games through arms' movements or pressing on-cloth buttons.

Therefore, as our next step, we present a bodily interactive game called *DanceToBe*, which is an attempt to add more active sportive-elements into games in a manner that incorporates players' actions with music and video based on the DIY wearable platform. In order to promote physical activity, it provides computer games with a bodily interface, such as moving arms up and down, and pressing on-clothes buttons.

This paper is organized as follows. We outline our proposed architecture for a DIY wearable computing platform targeted for general purpose which is applicable to various areas in accordance with usage goals in Section 2 and 3. Section 4 then presents a bodily interactive game, called *DanceToBe* as our realized service based on a DIY wearable computing platform. The conclusion is presented in Section 5.

2. Do-It-Yourself Wearable Platform

In our effort to realize a practical wearable computing platform, we made the main design concept of the platform usability, modularity and transformability. We tried to find the solution to fulfill the requirements by repeating the prototype with body storming. Our objective was to segment the overall system into

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reconfigurable sub-components, which makes it possible to combine components with each other to construct a customized wearable platform. Fig. 2 shows the proposed architecture for a DIY wearable computing platform. It consists of several module parts: the main module including the CPU and Memory, hub modules including various communication and button interfaces, and user interface modules with I/O interfaces. Each module can be distributed on a garment, considering the distribution of weight and aesthetic design. Moreover, each module can be easily attached to and detached from a garment, allowing users to construct their own wearable platform.

Fig. 2-(a) is configured for a general purpose wearable platform that is applicable to various designs of clothes. A number of hub modules and I/O peripherals can be composed in several layouts to fit the clothes and to meet the user's demand. When this construction is used as a game input device, a user uses the gesture detection module and on-clothes buttons. Several bodily interface games can be built using the motion detection feature and on-cloth buttons in the DIY-wearable platform.

Fig. 2-(b) is configured to a stand-alone mode so that users can carry the device in their hands as a general mobile device, such as a private game console, music/video player, or electronic dictionary. As depicted in Fig. 2, modularity is achieved by separating a centralized computing device into a variable number of sub modules such as main module, hub modules, and I/O peripherals. They are connected by wearable cables. Each hub module may have multiple connections to the adjacent hub modules or the main module so that transformability is also achieved. The four major components of our architecture are listed as follows:

- **Main module:** It includes CPU, Memory, and LCD to control the sub modules. The bottom side of the main module can be combined with a clip type module holder for attachment to general clothes or other objects such as shoulder-bag, hat, belt, etc. It is an *ARM*-based *Intel XScale*™ processor: the *PXA270*™. The main features of this processor include clock scaling and dynamic voltage scaling up to 624MHz. With this, power management of the wearable computer can prolong the lifetime of the platform. The operating system running on this module is a GNU/embedded Linux kernel 2.6 with an *ARM* processor that shows a performance that allows it to be used as a game platform. A computationally efficient gesture detection module and game interface modules are implemented inside to provide various bodily game interfaces with low overhead and low power.
- **Gesture Detector:** It is a ring-type wearable device which is small enough to be worn on a user's finger. It has a three-axis accelerometer [18] and a three-axis magnetic sensor [19] for recognizing a user's gesture and the direction of the finger to allow the use of motion and gestures as user input. It also has a *ZigBee* transceiver [20] for informing the recognition results to the main module. The gesture recognition algorithm is designed to be simple enough to run on a micro-controller inside the gesture detector by extracting the minimum set of the required features and using threshold-based simple features.

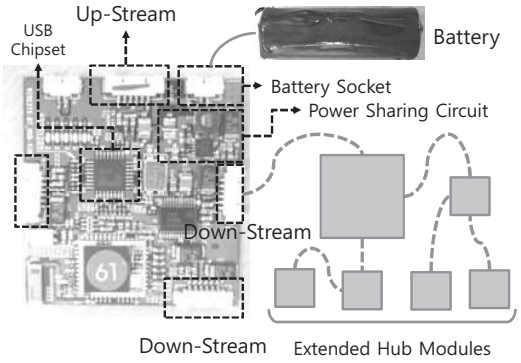

Figure 3. Implemented Hub Module

- **Hub module and Wearable Cable:** Several hub modules can be distributed on a garment, considering the distribution of weight and aesthetic design. We used a standard USB protocol to communicate among the sub modules. The logical composition of the hub module, as shown in Fig. 3, comprises a USB chipset, an interface for external peripheral devices, battery sockets and up-and-down stream sockets. The up-and-down stream sockets provide a four-direction extensibility of the hub module allowing a reconfigurable topology. Each hub module is in charge of a hub from one upstream to three down-stream sockets. The advantage of the interface is that the wiring of the hub modules allows the user to construct a customized wearable platform. With the multiple battery sockets and power sharing circuit, the user can scale the battery capacity up and down on demand. The hub module can include various communication interfaces such as Wi-Fi or Bluetooth.
- **I/O peripheral:** It includes input buttons, camera, storage, and communication modules. Each I/O peripheral can be easily attached to and detached from the hub modules, allowing users to construct their own wearable platform to meet their demands. Among the I/O peripherals, the on-clothes button can be exploited as a game interaction. We designed it in the form of a button because that is one of the easiest ways to dock with clothes. With button-type

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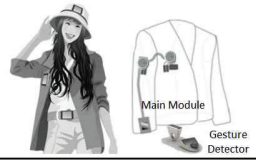
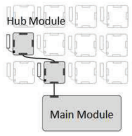
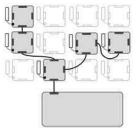
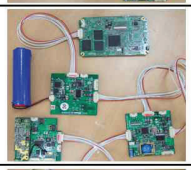
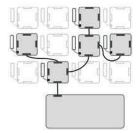
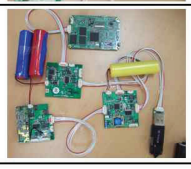
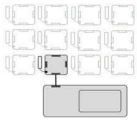
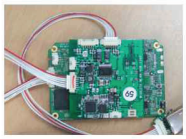
Table1. Transformation Roadmap

External Appearance	Topology		Specification	Usage Goal
			• Battery : 1100mAh • Communication: - Wi-Fi • Peripherals: - Gesture Detectors (Max. 6) - On-Clothes Buttons (Max. 5)	• **Bodily Game** • Mobile Office • Mobile Phone
			• Battery : 2200mAh • Communication: -Wi-Fi, Bluetooth • Peripherals: - Gesture Detectors (Max. 6) - On-Clothes Buttons (Max. 11) - Storage Module	
			• Battery : 2200mAh • Communication: - Wi-Fi, Bluetooth, ZigBee • Peripherals: - Gesture Detectors (Max. 6) - On-Clothes Buttons (Max. 11) - Camera, Storage Module	
Stand Alone Mode 			• Battery : 800mAh • Communication: - Wi-Fi • Peripheral - Storage Module - 4 Embedded Buttons	• **Console Game** • Media Player • Mobile Phone

I/O modules, the DIY wearable platform extends I/O functionalities to fit a game's interface requirement. For games with musical instruments like *RockBand* [10], we can deploy several buttons on the player's clothes in a way that resembles real music instruments.

3. Transformability Evaluation

The mechanisms described in the previous section for reconfigurable topology have ramifications for the physical design of the system. The structure of the topology needs to be able to support variable numbers and combinations of various hub modules. The transformation roadmap of our design is illustrated in Table 1. Since modules are fully placed and routed internally at deployment phase into the user's clothes, the configurations of our design are repositionable within the fabric.

For the transformability aspect, one of the advantages of having a reconfigurable topology is that the electronic modules can be plugged in anywhere, and users can construct user-defined wearable platforms according to their usage requirements in terms of interface specifications (the number of input buttons and required sensing devices), battery life time, and so on. Another way in which the DIY wearable platform enhances transformability is its ability to incorporate multiple modules. Various kinds of sensors for like touch, acceleration, or orientation can be assembled into a wearable computer in a way inherent to our reconfigurable topological design (Table 1, rows1-3). Then, a harmonic combination of those sensors attached to the user's clothes might act as a single interface. For instance, we can attach buttons on some impact spots over the clothes and gesture detectors on sleeves so that the combination of them can detect various upper-body poses and motions such as contact of a hand or arm with the tummy, the orientation of both arms, and even waving of arms for recreational active movements. Given that some modules, such as the accelerometer and the attachable buttons, may require multiple input channels, all input ports can be fully occupied. The DIY wearable platform supports multiple connections up to 64 input/output devices onto the platform by tree-type hub topology.

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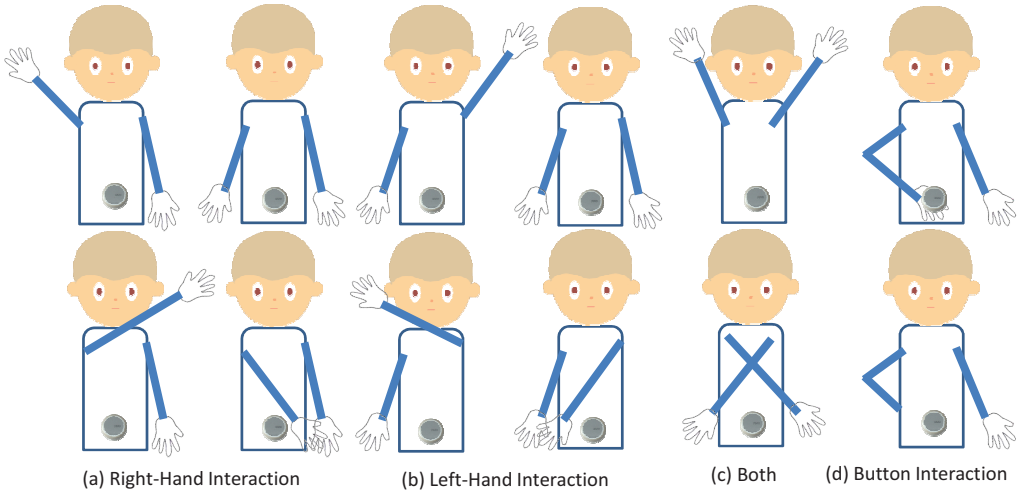

Figure 4. *DanceToBe* Interface based on DIY Wearable Platform

4. Application: *DanceToBe* with DIY Wearable Platform

To respond to the user's desire to experience an electronic game not only just sitting and clicking but also moving, running or even dancing, we take advantage of our DIY wearable computing platform as a mobile full-body interface for such a game. As a concept-proof model, we developed a bodily-action game, *DanceToBe*, which exploits the user's upper-body gesture like a hand up or down as depicted in Fig. 4. Based on those pre-defined upper-body gestures, users mimick or learn some kinds of dances, combinatorial sequences of the gestures, from the teacher in the game for the sake of their corresponding avatars. These interfaces allow players to perform dance movements by moving their arms in up, down, left and right directions (Fig. 4-a, b) or pressing on-cloth buttons located in back and forth (Fig. 4-c). To score well, a player must translate visual cues into actions by moving their arms or pressing profit buttons on their clothes and perform them at the appropriate time and in rhythm.

In order to realize the designed game interaction with the DIY wearable computing platform, we equipped the wearable computer with two on-clothes buttons and two gesture detection modules to sense the players' actions and gestures as summarized and illustrated in Fig. 5. The gesture detector captures the acceleration of a player's motions and translates the measured sensed data into gesture information, which is sent immediately to the main module. It is a bodily interface game that uses the player's physical arm movement to control the character in the game. Given that the wearable platform is equipped with a gesture detection module and buttons on the suit, several motions, such as moving a hand (up, down, left, and right) or pressing the buttons can be detected to incorporate the player's gestures with music.

The main synopsis is like this; the leading character *Ho-Rang* (tiger) teaches the dance to the rest of characters like *Peng* (penguin), *Nabi* (cat), *Mong* (monkey) and *Rang* (rabbit) who are eager to win the dance festival for fame and money, which are not the options to escape themselves from confinement in the zoo under ownership of some villain. There are four stages and two difficulty levels. A stage represents each

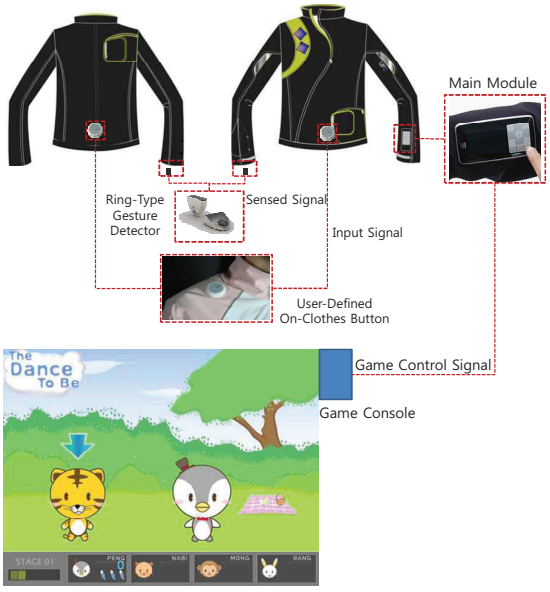

Fig 5. Configured DIY Wearable Platform and Interaction with *DanceToBe*

Figure 6. Screen Shot of *DanceToBe*

season and the complexity of a dance is quite escalating in every next stage. The easy and hard levels are a pre-defined sequence of gestures and a random sequence of gestures, respectively. Actually, it is very hard to remember and follow a sequence of gestures, which can be composed of even more than 10 in winter. To alleviate such an agony (To be or Not to be), we adopt an auditory cue in addition to the visual one for a gesture, that is, a specific sound is played whenever a gesture is represented graphically by an avatar. So users can remember a sequence of gestures with a rhythm of both bodily actions and musical notes. We demonstrated the *DanceToBe* game enhanced with our DIY wearable platform as shown in Fig. 7.

5. Conclusion

The task here was to use wearable computing technology as a bodily game interface. This paper presents our experiences in realizing a wearable computing platform enabling users to perform bodily interactive games. To accomplish this task, we present our experiences in realizing the DIY wearable platform allowing users to construct their own wearable platform to any kind of clothes. The wearable platform is designed to enable attachment to general clothes by a clip type module holder, fabric friendly wearable cable, and a reconfigurable hub module. Using the DIY wearable computing platform, we present a bodily interactive game called *DanceToBe*, which adds more active sportive-elements into a game in a manner that incorporates players' actions with music and video based on the DIY wearable platform.

Fig 7. *DanceToBe* User Experience

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