Wearable Haptic Gaming Using Vibrotactile Arrays

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Abstract

In this paper we describe the design process of expanding vibrotactile displays from single channels devices to multichannel vibrotactile displays. The purpose for this exploration is to add simple, interactive visual and vibro-tactile patterning with button arrays to wearable gaming devices intended for young children. We examined how arrays of various configurations affect gameplay and how they can be used to convey information about device dynamics and expected user interactions.

**Key words:** haptic gaming, vibrotactile arrays, wearable devices, multi-sensory

H.5.2Information interfaces and presentation (e.g., HCI)User Interfaces.

Haptics, Gaming, Wearable

## 1 Introduction

Vibrotactile displays allow for a variety of information communication scenarios, most compelling for use are those where the user can receive information without having to look at the signifying device.

The research questions we address in this paper concern whether it is possible to create wearable gaming experiences that involve visual and vibrotactile spatial and temporal patterns.

Our approach is to explore the simplest of patterns and study their affordances. The patterns involve some kind of order that is apparent either visually or tactilely. The patterns generated may involve movement and may have directionality. These patterns may be useful in the conveyance of some information, such as the state of a game, a device or the gamer. The pattern may also be a signalling device within a game device to inform the gamer about some situation within her gaming or external environment.

Using simple components such as buttons, lights and vibrating motors a a device will have certain affordances. This paper explores what those affordances are and what their potential application might be.

Our demo experiences focus on an attempt to make the interactions very simple, such that they convey information in a way that presents few cognitive demands on the user and which the user would tend to find enjoyable and engaging, even if they were not participating in a mobile game.

## 2 Related Work

Ruspini provides a useful introduction to the concepts and history of haptics, the basics of haptic psychophysics and haptic devices past and present [6].

Bronner notes that a sense of touch is basic to human processes of testing, expressing reality and meaning. Often people must both see with their own eyes as well as touch with their own hands to believe in a phenomenon[1]. He also notes that people surround themselves with particular, touchable objects to reinforce their own feelings and identities.

MacLean [4] discusses the potential benefits of haptic feedback as an ambient notification system. Unlike visual information, which can be obtrusive while completing a task, or sound, which can be obnoxious in a public environment, haptic feedback is usually experienced only by the user and does not directly interfere with the task at hand.

In Profita (2013) [5] researchers reveal the results of studies completed in the United States and South Korea on the social acceptability of interacting with on-body controllers in which participants ranked factors such as ‘awkwardness‘ and ‘coolness‘ of the exhibited interactions as actors performed them. This article is helpful for providing insight on social acceptability of wearable positioning as it relates to gender and culture.

Oliveira and Maciel propose a network of haptic actuators that use a set of patterns to express elements of an environment that has obstacles and free paths and demonstrates the use of a haptic language that helps users navigate and consists of vibrotactile signs to complement or replace their vision. [2]

De Jesus Oliveira and Maciel [2] present research towards building a hand-mounted array of haptic actuators intended to help the wearer perform a variety of tasks including orientation.

Such haptic systems could help visually impaired users navigate. They would also enable fully sighted users to perform certain tasks without being distracted by personal technologies (i.e. using a smartphone to check a map).

[3]HandJive is a handheld device used for communication and play between people. Researchers found that participants were able to successfully replicate purely haptic patterns at increasing levels of difficulty in a gameplay situation, and enjoyed improvising their own patterns. These findings suggest that haptic feedback can be incorporated as an enjoyable and meaningful way of conveying game information.

[7]Williams, Amanda and Scott present Damage, a smart bracelet for interactions between groups of users. Damage emerged as the result of participants’ responses to another project, the social media application Slam. With Slam, participants liked the app and the feeling of being always connected to their social circle, but found the frequent vibrational alerts from their phones as a result of a message being sent or received frustrating. Though at the time of writing still a work-in-progress, Damage would allow users to send coded messages in the form of flashing LEDs embedded in the bracelet to the group by opening and closing snap closures. Though the sender can choose whether to send a red, blue or green LED, ultimately it is up for the users to decide/interpret what each message means. This allows for potentially rich information to be transmitted by the simple device, in a manner that is convenient and unobtrusive to monitor.

## 3 Prototypes and Case Studies

### 3.1 Simon Says Wristband

Description: this is a wearable version of the traditional *Simon Says* game mounted into a velcro and felt wristband. It is sewn onto a flexible felt band. Conductive thread connects components, which aids wearability. The game is controlled by four push buttons, each with a corresponding LED light. This forms a 2x2 button and light matrix. The LEDs flash in a random pattern to begin a game session.

A single vibration motor signals the beginning of a new game. To play the game the wearer repeats the pattern as flashed by the LEDs by pressing the buttons directly adjacent to each LED. The button and light array affords simple gaming possibilities. The components are low profile and are integrated into a device that is lightweight and comfortable to wear.

### 3.2 Rubber vibration band version 1

This wrist band with a thick rubber band has vibrating motors and LED lights. Vibrating motors and lights are arranged linearly with motors alternating with lights. It is connected to and controlled by an Arduino Mega board. The activation pattern of the lights and vibrators is linear and sequential; that is, they activate each in sequence to the end of the line and then repeat from the beginning. This sequential activation gives the band a simple haptic rhythm. Other types of haptic patterns are conceivable, such as rhythmic pulses, flashes and sequences with more complex rhythms.

The device is very thick and can? t be worn (some components come out the back of the device). It is also hard-wired to an Arduino board, which also prevents wearability. The device has no input buttons or other input devices. The device makes a repetitive rhythmic sound by nature of its simple looping activation pattern. Other activation patterns could be programmed using the same components. These rhythms can be enjoyed in their own right as simple proto-musical patterns. Rhythmic, haptic patterns could also convey certain types of information, such as game mode, beginning of new sessions, ends of a session, arrival into a new playing zone, etc.

### 3.3 Rubber vibration band version 2

This band is similar to the first band nut instead of a linear pattern, there is 3x8 array of buttons, lights and vibrating motors. Each row of this array has one button, one light and one vibrator. The buttons are programmed to activate the other two components in their row, to activate patterns across the whole array, (such as all the lights flashing at once, all vibrators at once, all red lights in sequence, all top vibrators in sequence, etc.), and to create interactive buttons games like *Simon Says*.

It is not possible to wear in its current configuration due to the connection to its controlling Arduino board and thickness of its components. The 3x8 matrix starts to afford some interesting possibilities for user interaction. Modal play becomes possible since there are so many types of signals possible. For instance, all red lights could flash to indicate entering into a certain game mode. Therefore, some plausible use cases for the wristband could involve a simple wearable game involving button pushing; it could become the target device for authoring of light and vibration patterns, or it could be signalling device (if connected to wireless components) when in proximity to people or objects.

The prototypes consist of simple arrays of vibrating motors and LED lights. Later prototypes add buttons to these components. What patterns can be created when using these components? The simplest are non-directional ones, such as flashing patterns [all on, then all off]. Other simulate movement using 1D and 2D transformations.

### 3.4 Development of prototypes

Prototypes began as the simplest and least refined expression of a wearable or functional haptic device. The first prototype has simple linear arrangement of LED light and mobile phone type vibrating motors. When the connected to an Arduino micro-controller this band emits a rhythmic and visual sequential pattern that could conceivably could be used to notify band wearers of others in their vicinity.

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## 4 Discussion

This paper has demonstrated a number of interfaces that provide wrist based vibrotactile displays. Our work has shown that providing a vibrotactile array instead of a simple vibration motor provides user with a many more pathways of receiving and perceiving information.

### 4.1 Component Patterns vs. Dynamic Interactive Patterns

Two types of patterns involved int the devices prototyped: there are the simple grids of the components themselves, and then there are the patterns which can generated using these simple components. When lights and vibrating motors can actuate in a dynamic way, then the dynamics that can be designed, such as flashes, waves and very low resolution visual images, can produce very interesting effects.

## 5 Future Work

Next steps in this research are: [*a*)] 1. Explore various configuration of low-resolution haptic patterns that include 6, 4, 2, and 1 vibrating motors 2. conduct more involved user studies into the affordances that such haptic arrays provide both as gaming platforms and as information displays 3. explore other types of rhythm and memory games suitable for such devices 4. study appropriate spatial resolutions for haptic actuators such we can determine whether there is an optimal number suitable for both entertaining gameplay and useful informational interaction with wearers.

## 6 Conclusion

Vibrotactile arrays present new possibilities for information display to users through their body. We have demonstrated the use of a wearable multichannel vibrotactile display intended for gaming in order to explore the uses and affordances in a non-critical usage scenario.

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