Composition Techniques for the Ilinx Vibrotactile Garment

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ABSTRACT

In 2014 the multi-sensory immersive experience Ilinx *was premiered at the TodaysArt 2014 festival in The Hague. A key element of this work was the creation of a full-body vibrotactile garment that provided haptic sensations, working in tandem with the visual and auditory elements of the piece.*

The tactile sensory channel is significantly different from the auditory channel, posing novel challenges from both the technical and conceptual perspectives. We describe our experiences in the addressing these challenges and focus particularly in the discussion of different techniques for the creation of tactile stimuli compositions in a multimedia work.

1. INTRODUCTION

This paper describes a full-body vibrotactile-enhanced garment, to be used in a composed immersive multimedia installation. We focus particularly on the compositional aspects of this new media and the repercussions of different approaches and their respective technical solutions. What are the properties this garment should contain in order to generate a wide variety of tactile stimuli? What kind of compositional tools would enable provide effective control over this stimuli? And how well are these tools able to convey the original vision of the composer?

We begin this paper with a description of the installation *Ilinx* before considering previous approaches to incorporating tactile sensations in multimedia compositions. We then address the main contributions of this paper – a description of the garments themselves, their control system, and compositional tools created during the course of the project.

1.1 Ilinx

The garment described herein was created by a multi-disciplinary collaborative team consisting of artists, clothing designers, engineers and scientific researchers. The initial conception was to leverage contemporary scientific research in haptic perception in order to create a flexible whole-body tactile display system to be used in a public multimedia artwork. This multimedia artwork was intended to create an intense bodily experience which blurs the senses of sight, sound and touch. A more complete description of this installation and its aesthetic and conceptual background is available in [1].

Before experiencing the piece visitors don the garments as well as a helmet equipped with a semi-opaque visor intended to limit their visual perception. They are then guided into an enclosed space containing several different systems to generate sound and light. Two different lighting systems are used: one consisting of RGB LED's which are very dimly lit and mounted in a large constellation in one half of the space and the other consisting of two strobe lights located in the middle of the room, facing away from the LED constellation. Two speaker different systems are used: a quadrophonic array of standard PA loudspeakers and two highly directional ultrasonic speakers mounted on robotic arms.

The work is structured into two sections. For the first section the visitors are seated. The piece begins with subtle vibration pulses and soft sounds and gradually new sonic and tactile material are introduced. A loud bell and the appearance of faint lights in the distance signals the beginning of the second section, in which visitors are able to stand and take hold of guide-ropes which allow them to safely explore the space. The piece then builds towards a final climax, with an increase of intensity in sound, light and vibrations.

2. UTILIZING THE TACTILE SENSE

Our tactile sense is very different than our auditory sense since we experience tactile sensation over our entire body. The complex system of mechanoreceptors located in our skin consists of four distinct types which respond to different forms of stimuli. These mechanoreceptors are also located in different parts of our body with widely varying densities. The most sensitive areas, such as our hands and arms, consist of up to 10000 mechanoreceptors per limb. An overview of these mechanoreceptors is available in [2].

2.1 The Challenges of a Tactile Display

The complexity of our tactile sense makes it difficult to create a tactile display with the same characteristics as an auditory display system, which are able to create stimuli over the full frequency and typical amplitude range of our hearing. A tactile reproduction system should be able to, in theory, recreate any typical tactile sensation which might experience in our daily lives. In practice, this would mean the ability to engage with all of the mechanoreceptors in our body, which vary widely in terms of amplitude and frequency perception, as well as in the types of tactile stimuli they are able to perceive. While the system we designed is able to engage a large proportion of the body it still falls significantly short of the theoretically ideal.

2.2 Previous Work

Much of the previous work on utilizing the haptic channel as a primary output modality for music has focused on tactile displays intended to allow deaf persons to experience music. Nanayakkara et. al created a chair equipped audio transducers located in the arm-rests, footrest, and back [3] . Audio signals from recorded music were used to directly drive these transducers. Karam et. al created a chair equipped with eight voice coils arranged in four rows of two [4]. Signals were generated to drive these voice coils by isolating discrete sounds from a musical recording in order to present them in discrete frequency bands. This chair was later expanded by moving to sixteen voice coils similarly arranged [5] [6].

Considering previous haptic garments [7] [8], the most relevant to our project was created by Gunther and O'Modhrain [9],consisting of 12 high-frequency transducers located on the legs, arms and shoulders, together with a single low-frequency transducer located on the back.

Both Gunther and O'Modhrain as well as Baijal et. al created their systems with the intention of supporting composing for the tactile channel, by playing sequences of tactile stimuli in parallel to audio and video stimuli.

3. DESIGN OF THE GARMENT

The garments consist of a jacket and two leggings containing a total of 30 vibrotactile actuators split into five body segments: arms, legs and torso. Each segment consists of six actuators as well the electronics necessary to create the signals to drive them. These electronics are connected via Cat-5 cable to a central control unit located in a pocket on the front of the torso. This central control unit, as seen in figure 2, consists of a BeagleBone Black, a custom shield containing RJ45 jacks for cables connected to the body segments, and a commercial USB battery pack. The garments themselves were produced by designers with extensive knowledge in the field of wearables, providing a consistent high-quality finish, both mechanically and aesthetically.

The intended use of the garment in an immersive multimedia installation led to criteria which drove its design. The garments needed to be:

Figure 1. The Ilinx garment.

- Wireless in order to not restrict the movement of the visitors.
- Whole-body in order to afford a wide range of tactile effects.
- Able to be constructed in quantity in order to support use by multiple participants.
- Robust enough to withstand use by large numbers of participants.
- Aesthetically compatible with the intended artistic vision.

3.1 Transducer technologies

We evaluated several different kinds of actuators to use in this project, including eccentric mass (ERM) rotating motors, linear resonant actuators and tactile transducers. Our primary concerns for choosing an actuator were ease of implementation, price and size. In particular we looked closely at utilizing voice coils driven by an audio signals, but we chose to utilize ERM motors instead, due to the need of implementing a large array of actuators, facilitating the "Cutaneous Rabbit" sensation, in which tapping sequentially on two close-by locations can lead to the sensation of the tap moving continuously between points [10].

4. COMPOSING FOR THE HAPTIC CHANNEL

Much like visual and auditory stimuli, we found that individual haptic stimuli are most effective when implemented as part of a sequence or pattern of events. Based on our research into tactile perception we created several different haptic effects utilizing different combinations and patterns of vibration. These included two different categories of effects: discrete and continuous.

Discrete effects are perceived as occurring at a single identifiable location on the body. Depending on the number, length, shape, and intensity of the vibrations this may be felt as a *poke*, *buzz*, or *sparkle*. The first two effects are achieved through a simple activation of one or more spatially close

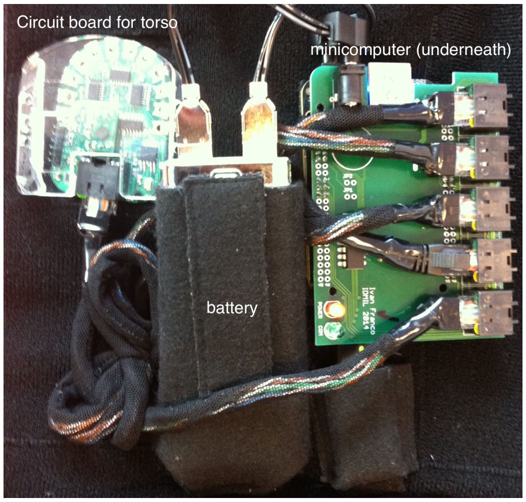

Figure 2. Electronics in the garment.

motors. A poke is implemented sending a sharper envelope message, while a Buzz-envelope has longer attack and decay times. The Sparkles effects consist of random actuation of actuator all over the body, or limited to one specified limb.

A continuous effect is one which seems to move on the body and is not restricted to a single location. One example of such an effect is a *snake*, in which adjacent motors are activated such that the vibration seems to move from one to the other. This effect can move through the length of one limb or may be implemented such that it seems to move from one part of the body to another.

4.1 Tools for composing with Haptic Effects

The definition of a haptic effect will determine the number of parameters exposed to the composer. A poke effect, for example, would include parameters for location and amplitude, whereas a snake effect would include parameters for starting and stopping points, amplitude, and duration. A series of tools were created drawing upon these haptic effects to assist in composing for the vibrotactile-enhanced garment.

4.1.1 Abstractions for Generating Haptic Effects

A series of abstractions were created to create the specific haptic effects described above. These abstractions were intended to provide a way to create variations on these effects with a minimum of input parameters. These input parameters are then used to generate the envelopes, order, and timing of the individual motors.

An example of the use of a higher level parameter to control multiple lower-level parameters occurs in the abstraction used to create the *Sparkle* effect. The input parameters for this abstraction are *position* (selecting individual limbs or the whole body), *time* (the overall length of the haptic effect), *intensity* (overall amplitude of motor vibration, able to be modulated continuously), and *length*. This last parameter determines several different lower-level parameters, including the length of each individual motor activation, the envelope of the motor (in which the attack and decay are a fixed fraction of the total overall length), and the speed at which subsequent motor activations occur.

An abstraction to create a *snake* effect utilizes length and speed, implemented in the same way, while a preset parameter is used to trigger previously defined sequences of motor operation.

In the two abstractions described above the envelope of each individual motor actuation are a fixed ratio to the overall length of the motor actuation. Individual abstractions for simple haptic effects such as *buzz* or *poke* with the intention that a single message in the motor envelope format described above would be utilized, requiring the specification of individual envelope parameters directly. One scenario we envisioned but did not implement is the location of a discrete event on a part of the body between two motor locations, requiring an interpolation of motor amplitude from the adjacent motors.

4.1.2 DrawOSC

An iPad app was created in which the user is able to draw trajectories of vibration on a representation of the body. A starting point is chosen by placing a finger upon a location on the body, and the finger is dragged upon that body part or to a different body part to create a continuous trajectory. An example is shown in figure 3. When creating the trajectory the variable speed of the drawing motion is recorded and used to drive the trajectory's subsequent playback. Once trajectories are created multiple instances can be recalled simultaneously.

In DrawOSC the overall intensity is determined by an independent slider. The movement of the slider is recorded in real-time and associated with the trajectory in a similar way to the drawing speed. The actual envelopes are intended to be determined independently of the trajectories created by DrawOSC.

4.1.3 Pattern Player

An additional tool for generating and playing back patterns similar to the tools described above was created. The unique characteristic of the pattern player is that amplitude envelopes are created independently of the motor sequence, and the entire envelope, not just the intensity, is able to be modulated continuously. In addition a pulse mode was implemented in which all of the motors in a sequence would be activated simultaneously at a fixed rate.

4.2 The Tactile Composition of Ilinx

In the discussions which resulted in the systems described above it was clear to us that restricting compositional access to predefined haptic effects could serve to limit compositional freedom. In the final composition of the vibrotactile element of Ilinx a variety of approaches to generating tactile events were utilized. These approaches include: discrete events tightly linked to visual and auditory stimuli, events sequenced using the previously described compositional tools,

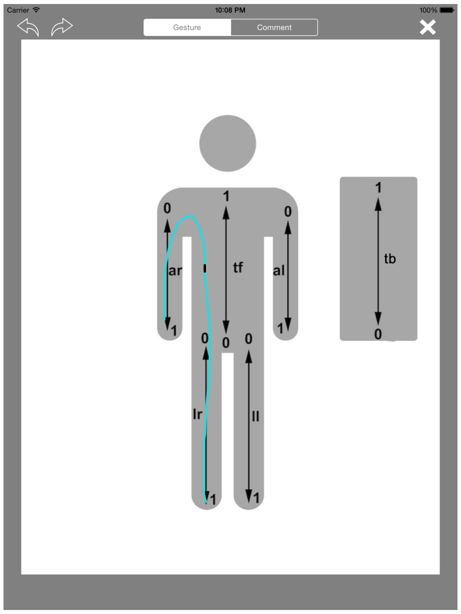

Figure 3. A trajectory created in drawOSC.

and several new continuous haptic effects created by the composers.

The first of these new haptic effects is the linear addition of motors, in which new motor actuations are continuously added to a predefined sequence. The second consists of a burst of desynchronizing motors in which motors are initially fired simultaneously and then gradually start to drift temporally.

As we expected, the final work consisted of a mixture of predefined haptic effects and new effects conceived of during the compositional process. As the haptic effects were not the sole focus of the piece the abstractions allowed for the creation of sequences within the work without dealing with lower-level parameters. The ability to create individual motor messages as well as new effects consisting of sequences of these messages, however, also proved to be important to the work's creation.

5. CONCLUSION

This paper presents vibrotactile-enhanced garments, a system for controlling the garments, and software tools created for the creation of a multisensory artwork utilizing the garments. We described both our conception and implementation of several haptic effects, and discussed the ways in which tactile stimuli were used in the final composition of the artwork.

More than 300 people visited *Ilinx* in its premier exhibition at TodaysArt 2014. Since then it has also been also presented at CTM/Transmediale 2015 in Berlin. The garments we developed have proven to be reliable and robust, and the tactile effects they produce an essential element of the work's success.

Acknowledgments

This project was funded by the Canada Council for the Arts. Additional thanks to Olof von Winden and Remco Schuurbiers from Todays Art.

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