The BodyHarp: Designing the Intersection Between the Instrument and the Body

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ABSTRACT

Mutualizing the body and the instrument offers a different way of thinking about designing embodied musical interfaces. This research presents the design of the BodyHarp, a wearable instrument that combines large body-based gestures with the fine control of hand-based instruments. This reflects a desire to create a single interface that both captures expressive, dance-like, body movement as well as nuanced gestural interactions. The BodyHarp was not designed as a separate artifact, but rather it was crafted as an augmentation to the human body. This fusion seeks to enhance the sense of intimacy between the player and the instrument and carries a different type of aesthetic — like playing a traditional instrument (the harp) but as part of the body. In other words, the BodyHarp aims to capture creative body movement and placing it in an instrumental context. In doing so, we aim to blur the transition between two gestural mediums (dance and playing an instrument) by mutualizing them — or, in a sense, by designing the interface as a part of the body.

1. INTRODUCTION

The musical instrument can be approached in two ways: as an object that the body plays, or as an extension of the body itself. Which of these two perspective one adopts can have profound influences on how the instrument is designed and how it is played. In this work, we explore possibility of combining these two notions, and designing a single instrument that simultaneously embodies both ways of thinking.

In this research, we propose a wearable instrument: the BodyHarp, which was designed to capture both body movements with two components. The first technique consists of four position sensing, variable length, pluckable strings drawn from a box placed at the foot of the player. The second technique is a sensor-augmented exoskeleton for the hand and forearm. In a sense, this is a harp-like string instrument extended to a wearable musical interface.

The BodyHarp operates between two modes, one of which projects a smaller instrument size (e.g., when the player is closer to the ground) and the other a fully extended version of the instrument that allows the player (e.g., while standing) to gesture within a larger space. Which mode the instrument is in at any given time has implications both on the gestures of the player as well as the timbre of the sound produced. Figure 1 shows the interface played in the first mode.

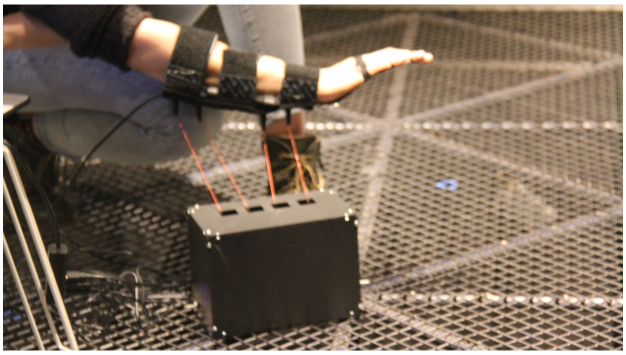

Figure 1. The BodyHarp, Mode 1.

The characteristics and playing techniques of the instrument are determined by the mode. The sound gradually diverges from the previous mode until it completely transforms to the present mode (Figure 2).

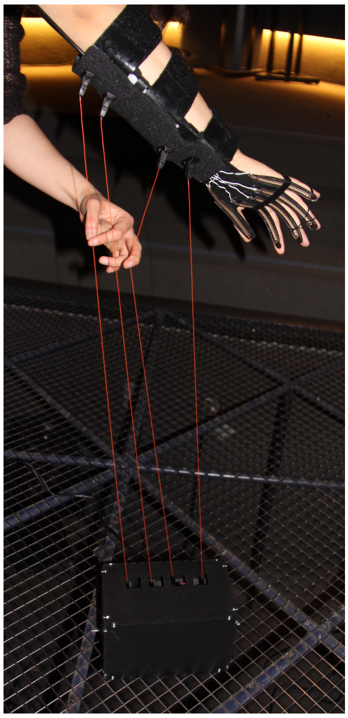

Figure 2. The BodyHarp, Mode 2.

This transition is supported by performer's movements. Depending on the mode of the instrument, the strings are played either by plucking and/or stretching. This way it retains some playing techniques of the classical stringed instrument while abstracting the notion of playing with large scale gestures and body movements.

As a digital musical instrument (DMI), the BodyHarp presents both a new way of playing (and thinking about playing) an instrument, while striving to meet a familiarity expectation—offering, as Morreale and McPherson described, "*an intuitive instrument based on traditional modes of interaction*", and whose evaluations have linked the success of DMIs to their familiarity [2]. In [1-3], researchers focused on learnability and playability of computer-mediated instruments. These aspects are even more difficult and less explored in body-movement-based wearable instruments. At the same time, there are advantages to body-based instruments. For example, Mainsbridge and Beilharz suggest that the dynamics of body movement bypasses conscious approaches to eliminate the artificiality of DMI's [1].

In this paper, wearable interfaces of various levels from minor-gestural interaction to full-body movements are covered with their strengths, weaknesses and some of the signature features (Section 2). Design motivation behind the BodyHarp is explained. The idea of combining some characteristics of traditional instruments and dance-like body movements is explored. Implementation details and performance aspects of such wearable instrument are given in the last sections (Section 3-4).

2. RELATED WORK

One of the primary motivations behind the BodyHarp is to make a computer-mediated musical instrument as an extension of the human body. Previous research stated that some designers directed their work towards creating traditional-instrument-based-controllers. Others made wearable gesture-based instruments [2]. Among many of these designs, some of the interfaces have developed unique performance practices over a long period time: Leatitia Sonami's Lady Glove [4] and Michel Waisvisz's The Hands [5]. One of the main findings from their research is that the design should include exclusive features specific to that DMI and support unique playing styles [2]. Some of the features such as familiarity, aesthetic, and simplicity of interaction support the initial motivation behind the current research.

BodyHarp is inspired by previous wearable gestural interaction designs. It focuses on adjusting its timbre by changing its size while it keeps familiarity and fidelity concerns, discussed in [3], in mind. In a similar instrument, the Fragment String, designers explore compositional and performance practices, investigating the strength and limitation of fragmented-strings based interaction and the sound output [6]. BoSSA discusses the sense of presence and intimacy of the interface [7]. Another similar design approach is observed in the Overtone Violin [8]. Similarly, it explores boundaries of the original violin techniques and sounds while extending the instrument with new techniques. Like in the Overtone Violin, BodyHarp also aims to keep conventional playing techniques.

In [2], Morreale and McPherson indicate the importance of expressive performance and audience engagement from their DMI evaluation survey. According to their questionnaire, designers reported the following self-evaluations:

> "for Manta, Snyder commented that *"it has a unique look and feel that sets it aside on stage"*, for the E-Recorder, it is expressed that "*it is nice to watch on stage*", and for The Talking Guitar: "*it requires large gestures which are easy to interpret for the audience*"" [2].

Previous wearable interface designs seem to focus on gestural interaction or full body movement [9,10,11]. In [9], Serafin et al. proposed an experimental design to investigate mapping strategies between gestural-based interfaces and physically based sound synthesis models. For this purpose, they used a glove interface with flex sensors for each finger. The results showed that users tend to map certain sounds with certain gestures. The other wearable instruments, Human Harp and Eclipse [10,11], focus more on full-body movement rather than gesture-based interaction. Even though they are designed to be wearable and used in expressive movement performances, these body-centric instruments are restricted by being examples of body motion sonifications. Since Human Harp needs to be attached to the bridge, it makes it difficult to consider the interface as a self-contained wearable instrument but more a site-specific installation. On the other hand, Eclipse has a significant amount of design and implementation resembling our design approach and on top of its artistic concerns. It is limited to a certain type of piece and performance so that it is hard to define it as a DMI. These interaction methods are designed to control virtual instruments or to synthesize sounds in new, interactive, and artistic ways [9,10,11].

Regarding the performance aspect of such designs, Lady's Glove and The Hands should be recalled. These instruments are well recognized and demonstrated the expertise of the creators in various expressive performances. In the BodyHarp, a similar hand instrument is designed combining larger scale gestures with fine hand-based control.

With all these evaluations, design considerations, and previous design approaches in mind, the BodyHarp is designed for music and expressive movement performances, like dance. It aims to leverage embodied experiences with gestures while keeping conventional instrument constraints. Since gesture based DMIs offer unlimited possibilities for sound mapping and abstraction [9], the BodyHarp focused on plucked and bowed string physical models. Yet, it still offers room for exploration of new sounds and improvisation techniques.

3. INSTRUMENT DESIGN AND IMPLEMENTATION

The design process involves two components of interaction. The first part is a small box with four gametrak strings and the computer connection [13]. The second part consists of hand gestures and arm rotation interaction. It is made out of the hand exoskeleton with five flex sensors, the arm extension with adjustable straps, and the control board with an accelerometer. The parameter control is mostly provided in the skeleton part of the interface. The hand skeleton is analyzed and tested on piano players to satisfy sufficient flexibility and playability with individual finger bends. Moreover, the restriction of being physically attached to an instrument and being able to extend the playing techniques provide passive haptic feedback.

3.1 Exoskeleton

This part of the interface can be considered as the most common one in the previous literature. As in [4,5,9], researchers made gloves, hand-controlled instruments, or other wearables. Yet, in our design, the choice of an exoskeleton is intentional in order to emphasize embodying instrument and making it an extension of the body. The same design motivation is the idea of attaching strings to the connectors on the exoskeleton. The exoskeleton extending from the fingers to the forearm is made out of flex sensors. Flex sensor which has a nominal impedance around 10 Kohm increases its impedance gradually with the amount of bending. The stretched position of fingers is used for parameter control of physical models used in each mode. Flex sensors are mounted on a flexible wooden surface. The choice of material was crucial since it needed to be stretchable, durable and strong. Softwood fit well for all those needs and kept the sensors steady in the initial position when not excited.

Gametraks have two gloves with male connectors. The connectors have their female counterparts on the string end. The male connectors are disassembled from the gloves and screwed to the arm band. The arm skeleton consists of two layers. The control circuitry is mounted in between of two layers of the arm band. The first layer has three straps wrapping around the arm. The outer layer is again attached to the inner layer through the same double-sided stick-on straps. Figure 3 shows the three layers of the wearable part.

3.2 4-String Box

As presented in [13], gametrak controllers are widely used as a controller themselves. However, their parts, like gloves, pulleys, and spool chasings, are also included in the interface designs. Some of the applications involve various methods of exploring its spatial positioning feedback such as direct mapping, counterweighting, combining, gearing, dividing, and dismantling [13]. In this design, the 4-string box consists of gametrak string pulleys disassembled from two gametraks. One of the main reasons why there are four strings used in the design is to retain the familiarity of the interface to classical polyphonic stringed instruments.

4-string box consists of gametrak string pulleys disassembled from two gametraks. As shown in Figure 4, each spool-chasing is removed from the Gametrak and from their pulleys. The joysticks are directly attached to the chasings which is connected to the laser cut box through a steel rod.

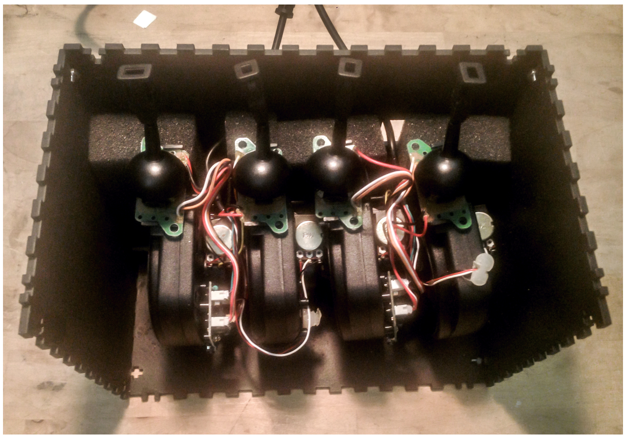

Figure 4. Reassembled spool chasings and joysticks.

Since the interaction with the strings requires plucking

Figure 3. a.) Hand skeleton, b.) Outer layer with string attachments, c.) Inner layer of the armband showing the circuit board and sensor connections.

and stretching them, the box needs to be fixed to its position. It is immobilized through steel weight plates on two sides of the box while the spools are damped with spongy isolation material.

3.3 Playing the BodyHarp

The instrument is originally designed to be played stationary sitting on the ground or a higher surface. Most of the gestural interaction comes from the wearable interface like finger gestures, string manipulation, and arm movement. As a result of the mode selection, the size of the instrument can be fixed or interactively modified depending on the composition. This brings up the compositional concerns and performance aspect of the design. In [14], Cook emphasizes a way to design instruments by working backwards from an envisioned piece rather than designing the controller itself in a top-down manner. We adapted a similar approach in this research with a focus to co-design the interface with an envisioned composition and performance, which simplified sound creation and the action-to-sound mappings.

In terms of playing technique, we focused on plucking the strings with the motivation of its similarity to contemporary string playing techniques. The sound associated with each mode is controlled by four basic triggering mechanisms: exciting the physical model of each mode, stretching the strings, plucking strings, and finally controlling the parameters with finger gestures. In the first mode, the instrument is restricted to a certain height. In this mode, a banded waveguide model is selected for bowed string sounds [16]. In the second mode, plucked-string model is used [17,18]. Plucking the strings is controlled by the differentiation of x and y axis over time. It gives a discrete control of the string positions. In this mode, as an extension of plucking technique, a chorus effect can be played by stretching one or more strings. This method of using single technique with different gestures allows performer to explore the interface and new possible techniques.

4. PERFORMANCE

BodyHarp explores expressive performance of musician as a part of the instrument. Meanwhile, it aims to augment the instrument into human body. The first performance with BodyHarp happened on CCRMA Stage at Stanford Univeristy (Figure 5). It showed that larger scale gestures, different than full-body-motion sonification [10,11] or single gesture focused controllers [4,5,9], provided haptic feedback engaging the performer with the instrument.

The BodyHarp relates to the composition with its design. It gives flexibility in sound design but preserves the gestural interaction and playing techniques. The instrument fits well into performances which involve movement in their narratives. The instrument was also performed in a site-specific retelling which involves narrative dance and improvisational music performances (Figure 6). BodyHarp, electric cello and the trumpet improvised Risset-like spectral music. For this performance, the technical focus was carried to the plucking techniques, where each string is mapped to multiple pitches adjustable with the length. Along with the narrative of the performance, in two separate acts, the music was switched back and forth between plucked and sustained sounds. Pitch adjustment by varying the string length allowed to express the arm motion as in common dance techniques. The instrument created a relation between the dancers and the musicians with its dance-like nature.

Figure 5: Improvisation with BodyHarp.

Despite the restriction of the interface in terms of physical limitations, it creates a meaningful interaction between gestures and the sound. It requires the performer to be more intentional about her gestures and movements during the performance. The haptic feedback provided from the arm-string attachment necessitates an active listening to synch the motion with the composition. In a way, body motion shapes the sound and in turn, gesture resulting from playing the instrument naturally exudes a dance-like quality.

Figure 6: Performance with dancers in *Liriope*.

5. CONCLUSION

The BodyHarp is part of an ongoing project motivated by attaching DMIs to a wearable interface. Body movement forms an important part of this instrument. It is not limited to gestures, but it couples the instrument with hand and arm movement to simultaneously work with motion at two different scales. For example, the BodyHarp allows you to make small gestures, e.g., plucking with your finger to articulate the sounds and large-scale gestures, e.g. arm movement to both express the sounds as well as to provide a different, almost dance-like visual aesthetic.

However, we observed a limitation in the relation of gestural interaction and sound creation of wearable interfaces. BodyHarp extended this constraint in two ways. It created a passive feedback from the strings being attached to the arm and to the body of the instrument. Actuating the strings at the arm connection point with the arm movements as well as triggering different modes by changing the size of the instrument gives a certain degree of freedom in movement. On the other hand, it made it hard to meet repeatable expectations as each movement varies from one another. The learning process of BodyHarp required the musician to overcome the unfamiliar feeling of being attached to an interface.

There will be future developments to ease this adjustment period of wearing the instrument as a part of the body. In the later developments, a design which offers an easy-to-wear interface is planned to be adopted. One of main solution is to explore other gestures and to couple them with new DMIs. Hence, we plan to explore the relation of different types gestures and performance with new wearable instruments. There are other technical improvements to BodyHarp: 1) mounting stereo speakers around the 4-string box for a self-contained, more embodied sound source, 2) deducing the wire dependence with wireless communication with two controllers, 3) lighter and smaller embodied wearable parts.

The BodyHarp is an exploration in the gestural space between small nuanced hand-based gestures, e.g. playing a harp, and larger body-based movements, e.g., dance. We think of this larger scale gesture in a scale that somehow distinct from these two extremes. This offers an interesting link between dancers and musicians as a new way of thinking and playing instruments that involve different scales of gestures.

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