Taptop, Armtop, Blowtop: Evolving the Physical Laptop Instrument

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Figure 1: The soloist and the conductor in *Breeze in C*.

ABSTRACT

This research represents an evolution and evaluation of the embodied physical laptop instruments. Specifically, these are instruments that are physical in that they use bodily interaction, take advantage of the physical affordances of the laptop. They are embodied in the sense that instruments are played in such ways where the sound is embedded to be close to the instrument. Three distinct laptop instruments, Taptop, Armtop, and Blowtop, are introduced in this paper. We discuss the integrity of the design process with composing for laptop instruments and performing with them. In this process, our aim is to blur the boundaries of the composer and designer/engineer roles. How the physicality is achieved by leveraging musical gestures gained through traditional instrument practice is studied, as well as those inspired by body gestures. We aim to explore how using such interaction methods affects the communication between the ensemble and the audience. An aesthetic-first qualitative evaluation of these interfaces is discussed, through works and performances crafted specifically for these instruments and presented in the concert setting of the laptop orchestra. In so doing, we reflect on how such physical, embodied instrument design practices can inform a different kind of expressive and performance mindset.

Author Keywords

Laptop orchestra, physical laptop instrument, bodily interaction, design of digital musical instruments

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1. INTRODUCTION

Design of digital musical instruments can be approached in two ways: musicians' exploring new possibilities in composition and performance, and engineers' refining new technologies for new interfaces, but mostly a combination of two [15]. In this work, we introduce three embodied physical laptop instruments: Taptop, Armtop, and Blowtop, from design process to performance. The main motivation behind these laptop instruments lies in the exploration of the embodied physical laptop instruments. The embodied physical laptop instruments are physical in that they use bodily interaction, take advantage of the physical affordances of the laptop, and offer gestural expressions. They are embodied in the sense that they are played in such ways where the sound is embedded to be close to the instrument. Laptop orchestra instruments pose examples of embodied instruments with speakers in each station.

In laptop performances, the interactions between both performer-to-performer and performer-to-audience vary significantly based on the piece. Relatedly, the presence of laptops in an ensemble and non-obvious sound-to-gesture mapping create surprises and unfamiliarity for listeners. For example, instrument GUIs are rarely shared with the audience. Similarly, the sound generation and manipulation interfaces like keyboard, trackpad, or other frequently used controllers (e.g., Gametrak [12]) lack explicit visual cues [4]. This research aims to improve the transparency of the mapping and the performance by designing visually communicative instruments and adopting traditional ensemble settings and roles. We include musical gestures in laptop orchestra and more visible gesture-to-sound mapping. In the design process, composer and designer roles are interchangeable; the performers leverage existing software's flexibility; and have an increased control over their instruments. Yet, during the performance, the ensemble is crafted to present a familiar setting for the audience. For this purpose, the pieces include a conductor, accompaniment and a solo instrumentalist using a combination of laptop's built-in features.

The visual communication in the laptop orchestra performances does not necessarily draw only from the division of roles within the orchestra but also from our knowledge of the instruments. An instrument's sonic result is closely linked to a particular way that the instrument is played within a set of "musical" and "non-musical" gestures. As Godoy identifies such gestures as a motor-mimesis, they give information allowing us to mentally imagine the sound we listen to [7, 14]. This approach draws from the musical skills of acoustic instrument playing and transfers them into their digital counterparts. For example, Gotto presents a violin-like instrument where the instrument shape is loosely based on a violin and controlled certain granular synthesis parameters through violin playing techniques whereas the Bossa uses bowing gestures as one of the main interaction methods [9, 17, 16]. Laptop accordion emphasizes the metaphor for a traditional accordion by simulating the bellow movement with the opening and closing of a laptop's lid [11] while the BodyHarp is played with string plucking techniques along with its arm gestures [2]. The laptop instruments discussed in this paper take direct inspiration from the motor-mimetics-based approach from sound design to crafting the physical interaction.

In this paper, we introduce the motivation behind the embodied physical laptop instruments. It considers the aesthetic and technical issues relating to 1) their design and implementation, 2) composing and crafting the bodily interactions, and 3) performing with them in a laptop orchestra setting. We conclude with two case studies of pieces, *Breeze in C*, and *Harmony in the Wind*.

2. RELATED WORK

This work draws from three research traditions; physical laptop-based instrument design [6, 18, 11], embodied instrument design [16, 3, 19], and dual physical interaction that combines nuanced hand/finger gestures with larger, dance-like gestures [2].

One of the main motivations behind three laptop instruments, Taptop, Armtop, Blowtop, is creating expressive musical instruments for computer-mediated performances which are affordable to implement. Fiebrink et al. argue leveraging the laptop's native capabilities while designing instruments for group performance settings [6] as in laptop orchestras. In this work, built-in sensory controllers and devices, such as microphones, cameras, accelerometer, keyboards and trackpads of the "self-contained laptop" are discussed to craft instruments in innovative ways. Instruments relying on built-in components contribute to smooth functioning. Additionally, the software flexibility offers unexplored possibilities to strengthen the physical interaction. Earlier examples of physical laptop instruments can be found in the Princeton Laptop Orchestra, specifically, the use of blowing gesture was presented with Breathalyzer in the piece called "Unplugged" [6].

The iPhone "Ocarina" [18] also focuses on the concept of blowing into a mobile phone. "Ocarina" was designed to use exiting features embracing the iPhone's inherent capabilities and limitations without hardware add-ons. These built-in features, like the microphone for breath input, multi-touch sensing for finger interaction, and accelerometers to map expressive dimensions (such as vibrato rate and depth), in addition to iPhone's software capabilities, make possible to support certain physical interactions. Similarly, Laptop Accordion refers to the metaphor for a traditional accordion by simulating the bellow movement with opening and closing of a laptop's lid and the musical button board with the laptop keyboard [11].

As an embedded musical instrument, in the SqueezeVox project [3], Lisa allows sound of the instrument to be projected from the instrument itself by mounting two speakers inside an accordion. In Dan Trueman's BoSSA [16], a speaker array is implemented in the main instrument body to "place the sound source directly into the hands of the performer" in addition to taking advantage of spatial diffusion of the sound. BoSSA offers a more intimate relationship between the instrument and the performer [1]; firstly by embodying the sound source in the instrument body; secondly, by providing an instrumental presence; and finally, by receiving sonic feedback through gestural controllers (bowing gestures with the R-Bow and the Bonge [16]).

The dual physical interaction adopted by the physical laptop instruments is based on a combination of fine gestures, mainly borrowed from musical gestures like finger and hand control, and larger gestures which form the expressive and communicative gestures in performances[2, 8]. We adopted a similar approach to BodyHarp [2] incorporating varying qualities of gestures into laptop playing. BodyHarp is designed to introduce different forms of gestural interaction exchanging their roles in performance. While the nuanced finger gestures are part of the direct sound creation, the larger dance-like arm movements contribute to both sound modifying and communicative gestures. This notion of the dual physical interaction becomes essential in communication with the audience as well as with the other performers, dancers and musicians, as in the piece *Liriope* [2]. Either the gestures are purely musical (like pressing the piano keys or blowing gesture of a woodwind instrument), communicative (as conductor gestures), or expressive; the physicality amplifies both performer/instrument and performer/audience

Figure 2: The control interface of the Taptop for the conductor.

relationships. Specifically, the communication between the performers and the audience is described to be based on a set of conventional signifiers and cues similar to the language where the message is meant to be conveyed through a set of expressions [5, 8]. The physical laptop instruments take advantage of this design approach to present transparency and visual cues in the performance as the composition allows.

3. DESIGN AND IMPLEMENTATION

The common core mechanic at the center of the embodied physical laptop instruments (Taptops, Armtops, and Blowtops) is the use of native capabilities of the laptop to incorporate musical gestures with the existing hardware like trackpad, keyboard, or microphone. The instruments are designed to be interacted based on these built-in mechanics in each piece. For example, in *Breeze in C*, instruments are mainly combinations of trackpad and tethers, whereas, in *Harmony in the Wind*, they are constructed with laptop's microphone, trackpad, keyboard, and tethers. Again, in *Breeze in C*, the conductor's Taptop is designed to be played with the laptop trackpad by dividing it into grids and mapping to distinct instruments in the ensemble (Figure 2). Following subsections describe each instrument's design, implementation, and performance processes.

3.1 Taptop

Taptop instruments in both pieces are played by orchestra members, conductor and as a part of the soloist's instrument. The main interaction mechanism of Taptops is built on the ability of the trackpad to track multitouch gestures. The capacitive grids in the trackpad allow detecting multiple finger touches [10]. It reports each finger's touch position, timestamp, X and Y velocity, finger blob size, and the angle of finger ellipsoid [13]. The information from the trackpad is detected by the Python's multitouch library, PyMT Library, and transmitted via OSC [23]. The data distributed via OSC again is mapped to the corresponding sound parameters in FaucK [21].

The sound of Taptops played by four musicians in this piece is produced by a combination of FM synthesis, a sinusoidal oscillator, and a pulsetrain generator. Instruments' timber is modified by changing the corner resonance frequency of the Moog Voltage Controlled Filter (VCF). The filter is implemented using Faust's effects library, the virtual analog filter effect (Figure 3). The role of the trackpad interface was again different in the conductor's station (Figure 2) than accompanying musicians'. It was divided according to the musicians in the ensemble to have direct control over their sound levels and timing. Musician's pitch selection or timbre of sound is only controlled by themselves independent of the conductor. This provided a particular relationship between the ensemble and the conductor in which the performer defines what to play but the conductor decides when it is played. By achieving unconventionally roles between the musicians and conductor, we aim to blur boundaries within the traditional roles in an ensemble. Hence, the trackpad in this piece serves not just as an interface to produce and modify the sound, but it also functions as a visualization of the interaction and a vehicle for communication for performers and the conductor.

Although the size of the trackpad limits the types of interaction, it offers a reliable, expressive interface for performers and flexible coding for designers. In both pieces, the trackpad is used by dividing it into grids while aiming different gestural interactions and sonic results. For example, in *Breeze in C*, each musician changes the timbre of the instrument by modifying the filter quality factor and cutoff frequency sliding and pinching gestures on the trackpad. Furthermore, Taptops include a level control slider on the right side of the trackpad separated by the filter control grid. This way, players could level their loudness with respect to the neighboring performers. Different from those played by orchestra members, the conductor's Taptop serves as a tool to guide the orchestra. It allows the conductor to control and visualize orchestra members' performance and sound levels (Figure 2).

Taptops are the main instruments for the ensemble members in both pieces in addition to their use as a complementary instrument coupled with other gestural interaction methods, like arm gestures in the *Armtop* (as the *Soloist* plays in *Breeze in C* see Figure 4) or blowing gestures of the *Blowtops*.

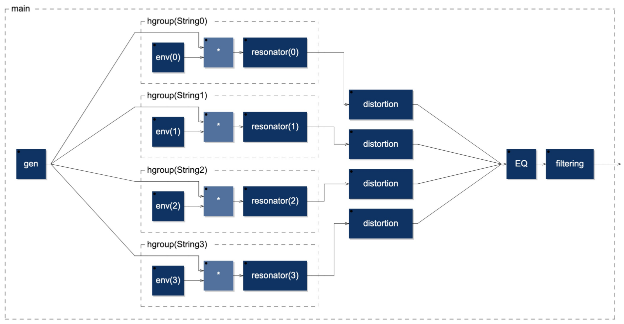

Figure 3: The Faust diagram for the Taptop instrument's sound design. For the filtering object, Faust's moog VCF filter is used.

3.2 Armtop

Armtops are integrated with tethers and trackpads. The trackpad use is inspired by Taptop instruments, and modified according to the musician's need. In the soloist's instrument, Armtop incorporates finger tapping on the trackpad as sound generating gestures with arm swings as accompanying gestures (gestures that contribute to the sound modification rather than direct sound generation [8]). The dual physical interaction inspired by BodyHarp's expressive movements [2] forms the main design consideration in Armtops. It appears as a combination of fine sound-producing gestures (creating the melodic line on the trackpad) and sound-facilitating and communicative gestures (modifying the dynamics and expressive features with the arm swings) (Figure 4) [8].

Figure 4: The Soloist in *Breeze in C*.

Soloist plays the melodic line on the trackpad as part of her main instrument. Because the trackpad does not offer visual feedback, a simplified interface is printed on the terminal following and visualizing the finger location on the trackpad (Figure 5). The lower part visualizes the finger location on the trackpad and how close it is to the next note. Each grid is assigned to a pitch value. This setting can be customized by the designer. The upper-left part depicts where the tether is with respect to its resting location; hence, it gives a visual cue about how much vibrato and tremolo applied. The upper-right part shows the gain level controlled by the height of the tether. This interface was only for performer's use and it was only shared with the audience after the performance. The expressive features like vibrato and tremolo are played by stretching and extending the tether forward. Soloist is also able to control the level of her instrument independent of the conductor by controlling the length of the tether. Consequently, adding vibrato by arm extensions puts emphasis on played notes by slight volume increase. Merging expressive features and dynamics control on the same interaction mechanism helps the soloist to develop an unconventional gestural vocabulary.

The sound synthesis for soloist's Armtop uses a combination of a triangle and a sinusoidal generators with both tremolo and vibrato capabilities. The sound synthesis is followed by a cubic distortion. The distortion is applied to enrich the harmonic spectrum of the Armtop which is later tamed by a filter based on the Moog Voltage Controlled Filter (VCF). Different than Taptops, filter parameters are kept fixed, vibrato and tremolo are available for the soloist.

The conductor in *Harmony in the Wind* wears Gametrak tethers on his hands to conduct the tempo and instrument gain levels. The tempo is controlled by the conductor's hand gestures with the tether. The downward and upward motion triggers the quantization and transmits periodic pulses via OSC. Any changes in the tempo detected by the tether are smoothly reached over a short period of time. Apart from leveraging the network communication to augment the degree of control, the conductor performed other traditional conducting roles such as changing the dynamics, cueing, and unifying performers. Similar to soloist's Armtop in *Breeze in C*, the use of the Gametrak tether both provides automated control; furthermore, it operates as a visual communication tool for performer and the audience. Still, some of these messages are only delivered through conducting gestures which is discussed in the following section in more detail.

3.3 Blowtop

In Blowtop instruments from *Harmony in the Wind*, the main mechanism is based on signal detection on the laptop microphone. The breath pressure is picked up by the microphone and followed by an amplitude follower. The detected level is used to amplify the synthesized flute sound. The instrument is also sensitive to the tilt motion using the Sudden Motion Sensor (SMS). This sensing mechanism is normally used to protect hard drives by the motion-detecting hardware in the form of a triaxial accelerometer that can detect movement in three axes or directions. The amount of up and down motion data is mapped to the tremolo and vibrato parameters via SMS inputted as an Human Interface Device (HID) in ChucK [20]. Hence, the combination of two sensing systems requires the performers to blow into the laptop microphone which is on the upper left corner of the control panel and select the pitch using the trackpad and the keyboard simultaneously (Figure 6). The location of the microphone forces the performers to play their laptops in an orientation such that it resembles a traverse flute playing.

The lower part of the trackpad is assigned to 3 chords for easiness of playing in tilted position. The set of three chords are selected using the "\", "enter/return", and "right shift" keys (Figure 6). Those control keys are selected since the right hand can still interact with them easily while supporting the laptop. In this piece, the orchestra members play the Blowtops with this mapping whereas the Blowtop soloist uses a mapping with the trackpad divided into nine tones to play the melodic line. Three keys on the right side of the keyboard are devoted to octave selection.

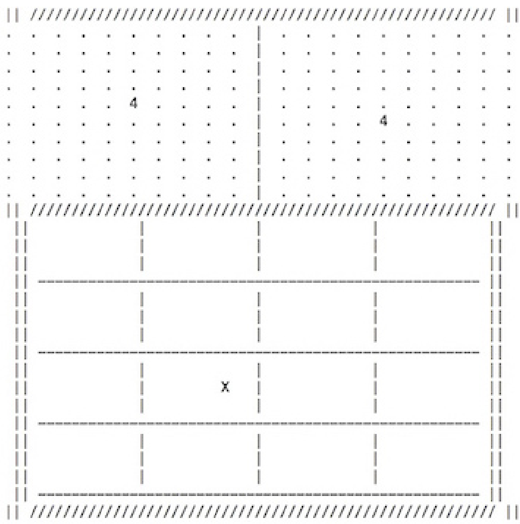

Figure 5: The interface of the soloist's instrument in *Breeze in C*.

The design of Taptops, Armtop, and Blowtops focuses on the sound quality and gestural interaction with the existing traditional instruments. Soloist's Armtop is designed to sound like a cello playing expressive features, like vibrato and tremolo, with the accompanying gestures such as arm swings and extensions. In Blowtops, we adopt the main playing mechanism of a flute including holding position, effective gestures of blowing into the instrument and the accompanying gestures of tilting the instrument up and down. On the other hand, in Taptops, the sound is the primary focus which uses the metaphor of a string instrument extending the techniques with the touchpad.

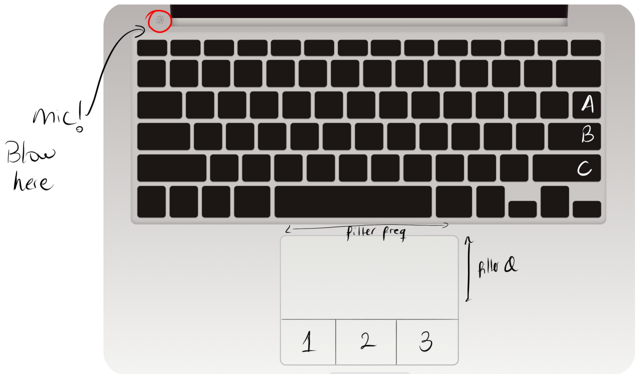

Figure 6: The interface of the Blowtop is provided as a part of the score. The performers blow into the microphone while they select the pitch from the trackpad. The octave range is adjusted using the keys labeled.

4. AESTHETIC EVALUATION

As Dahl emphasized how complexity increases when composing music for a laptop ensemble, the tasks of composition and instrument design interlace into a single one [4]. The composer/designer is required to compose not only the pieces but also the instruments, interactions, and performance. The fact that composers and designers are required to work simultaneously in multiple tasks blurs boundaries between the roles of the orchestra members during the design process. This quality is used as the primary principle in both of the compositions, *Breeze in C* and *Harmony in the Wind*. The pieces are supported with the several gestural cues for enhanced transparency for each instrument. Auditory and visual cues from the physical interaction and well-defined roles of the ensemble members helps the audience, as well as the performers, enjoy the musical performance and the technology. It draws better transparency without worrying about the details of the mapping behind the instruments as reported by the audience members. Thus, we felt that the most honest way to evaluate these instruments is a music-first, aesthetic evaluation. In other words, can we make music with it, and communicate this to an audience in the performance? As such, we wrote music specifically for these instruments and performed them in public laptop orchestra concerts.

In *Breeze in C*, the dual physical interaction, the nuanced interaction of the finger on the laptop trackpad and large-gestural interaction as arm swings or conducting gestures, shows itself in the Armtop performance the most. From soloist's perspective playing the Armtop, the performer's expressive intentions begin with the finger-based trackpad interactions, and are then amplified using large arm-based gestures, affording a nuanced control over pitch, and precise expressive control over each note. From the audience perspective, the virtue of the Armtop is that it visually amplifies the musical gesture, expanding from the limited size and visual context of a laptop. The instrument is designed to be seen. Nothing is hidden, the focus is on the physical gestures and their correspondence with the sound. This, in a sense, reclaims a kind of physical aesthetic that is often difficult to communicate in laptop performance (including laptop orchestra).

Again in the same piece, Taptops emphasize the notion of embodied performance. Taptop's control of the finger position on the trackpad allows each musician to modify the sound quality of her instrument. Because laptop orchestras are performed with sound sources in each station, the overall soundscape is kept balanced by the conductor. Similarly, the individual timbral changes in musicians' instruments both enrich the harmony and perform well with the nuanced finger interaction. What we observed is that the balance between individualized instruments and conductor-led performance reflected to the audience appreciation of the musical interaction. The communication goes beyond the performer and audience but also addresses a kind of performer-to-performer communication. It emphasizes how the performer relates to her instrument. Is the instrument an object to be played? Or, is it a natural extension of the body, and thereby, an extension of how the performer thinks?

In *Harmony in the Wind*, the fine gestural interaction with the Blowtops is satisfied by leveraging previously obtained instrumental skills. The microphone senses breath above a certain threshold and parameters are modified by the direct microphone input tracked by an envelope follower. The dependence of the sound generation on continuous variables of the breath poses some challenges for the performer such as practice, time commitment, and certain skill levels. Such requirements are not necessarily part of the DMI or laptop instrument learning process when musicians usually expect to achieve a certain level in short periods [22]. Although Blowtops seem to have a steeper learning curve, after sufficient practice, the musicians can adopt prior musical skills easily. The timbral correspondence of the laptop instruments with their acoustic counterparts further enhances the intimacy between the instrument and the performer. As a result, it advances the learning progress. A similar, yet relatively less demanding requirement can be observed in Taptops in *Harmony in the Wind*. Taptop players pick a bar long rhythm and play it for the next four bars. The rhythms are variations of a simple arpeggiation (Figure 7). When each percussionist simultaneously plays a different variation with Taptops, it creates a more complex and richer rhythmic section. It also allows each member to improvise in these sections. The musicians performing with Taptops as the percussion instruments take advantage of the prior experience of the piano playing techniques.

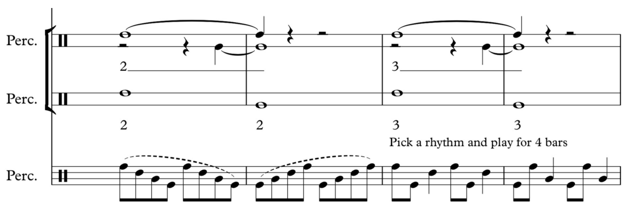

Figure 7: The score for section B for the Taptop instruments. In section B, percussion players pick a bar long rhythm and improvise within the set of rhythms as provided in the score.

In both performances, all members are given the opportunity to engage in the musical output. The balance in the participation of each member is made possible by the nature of the composition; although there is a written score for the pieces, it is intended to aid the performance and to provide room for improvisation. The first piece, *Breeze in C*, is fully improvised within three sections. Similarly, in *Harmony in the Wind*, each orchestra member is given chances to improvise and have direct control over the sound quality of their instruments. The presence of a conductor in both pieces directing the musical flow is only required due to the design constraints, such as skill level, interaction, visual communication, and available rehearsal time. The division between the roles or the presence of the conductor does not pose a hierarchical organization, instead, it is intended to provide visual communication available to performers and the audience. The presence of the conductor also does not divide the interlaced roles between designer, composer, and performer.

5. CONCLUSIONS

In this paper, the evolution and evaluation of the embodied physical laptop instruments are presented through two case study pieces. We focus on the physicality of the interaction methods such that performers can leverage their existing knowledge of musical gestures gained through years of traditional instrument practice. Our efforts make use of the core components of the laptop to offer flexibility and expressive control to the composers/designers. We describe the design, implementation, and composition process as a whole. A music-first aesthetic evaluation of these interfaces is presented, through works and performances crafted specifically for these instruments. We believe that this approach amplifying physicality and transparency can help to create an intimate performer/instrument and performer/audience relationships as well as it can offer physical aesthetics that is often difficult to communicate in laptop performances.

6. LINKS

Performance with laptop instruments in *Breeze in C* can be viewed here: `https://youtu.be/6S80_X23dOc`, and in *Harmony in the Wind*, here: `https://youtu.be/qqCg971_s_E`.

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