Tooka: Explorations of Two Person Instruments

Sidney Fels, Florian Vogt
Human Communications Technology Laboratory
Department of Electrical and Computer Engineering
University of British Columbia
Vancouver, BC, Canada, V6T 1Z4
{ssfels, fvogt}@ece.ubc.ca

ABSTRACT

In this paper we describe three new music controllers, each designed to be played by two players. As the intimacy between two people increases so does their ability to anticipate and predict the other's actions. We hypothesize that this intimacy between two people can be used as a basis for new controllers for musical expression. Looking at ways people communicate non-verbally, we are developing three new instruments based on different communication channels. The *Tooka* is a hollow tube with a pressure sensor and buttons for each player. Players place opposite ends in their mouths and modulate the pressure in the tube with their tongues and lungs, controlling sound. Coordinated button presses control the music as well. The *Pushka*, yet to be built, is a semi-rigid rod with strain gauges and position sensors to track the rod's position. Each player holds opposite ends of the rod and manipulates it together. Bend, end point position, velocity and acceleration and torque are mapped to musical parameters. The *Pullka*, yet to be built, is simply a string attached at both ends with two bridges. Tension is measured with strain gauges. Players manipulate the string tension at each end together to modulate sound. We are looking at different musical mappings appropriate for two players.

Keywords

Two person musical instruments, intimacy, human-human communication, cooperative music, passive haptic interface

INTRODUCTION

As two people interact with each other they begin to anticipate and predict each other's responses. As the ability to predict each other's responses grows, intimacy builds [4]. This intimacy allows people to have close, meaningful and expressive bonds. The complex interplay between stimulus/response, action/reaction provides an ever growing level of expression capabilities. We are seeking to create new musical controllers that tap into the intimacy between two people to create new forms of expression through sound.

We differentiate our approach from a duet. An intimate connection may be achieved in these situations; however, the feedback is mostly through the acoustic signal or the visual channel. In our approach, we also connect people through a *physical* channel, providing haptic feedback. The interaction of one player is *felt* by the other. This interaction is directly sensed and transformed into control parameters of a music synthesis engine. We also differentiate between our two-person instrument from other instruments that have multiple players through the balance of control. In our approach, two (or more) players share the same medium and have equal control. This does not mean they have the same control, but rather have the capacity to participate equally in the production of music and expression. In contrast, with an instrument such as the early version of the hurdy-gurdy [6] that had one person turning the crank and the other playing the keys, the cranking had only some effect on the sound quality while the keys played the melody. Specifically, cranking the wheel faster allows one of the drone strings to vibrate to provide accompaniment to the melody being played on the strings.

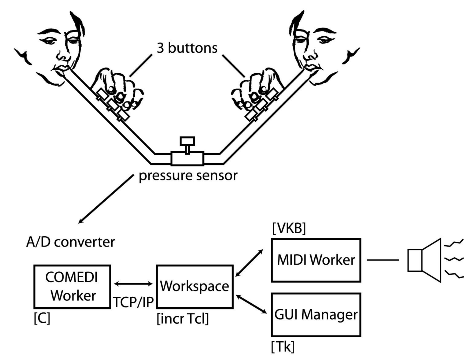

Figure 1: System diagram for the Tooka.

Our exploration begins by considering two distinct, easily measured, haptic channels that people may use to communicate with each other. The two ways are through breath and force to the hand. For breath, we connect two players breathing through a tube allowing coordinated modulation of pressure as shown in Figure1 Buttons are added to the tube to allow for coordinated button presses. This device is called a *Tooka*. For hand forces we consider two different modes of connecting the two players: 1) a semi-rigid rod and 2) a string. The semi-rigid rod is called the *Pushka* and the string instrument is called the *Pullka*. Oakley et. al. [9] also explores using haptic channels (hands) to communicate emotion however he is not looking at mapping the control to musical expression.

Each of these instruments provides different techniques for measuring the interaction between two people and mapping it to musical parameters. We are in the process of exploring different mapping strategies for each type of control. We are optimistic that controllers built specifically for two people will provide new means for musical expression. By maintaining a direct mapping the instruments' expressive capabilities should mirror those of the two people playing it. Thus, as their intimacy grows, so should the space of expressive possibilities. The instruments afford different performance styles which should further enhance the expressive capabilities. In addition to the Tooka providing a new type of expressive musical controller, it may have potential to be used in the reverse direction. That is, the music that is heard as people learn to play music together may facilitate the development of intimacy between the players. This characteristic suggests that the Tooka may also be a new human communication device between two people instead of between performer and audience.

In the discussions that follow, we describe some of the instruments we have either built or are building. So far, our efforts are towards two-person musical instruments, however, we see this being extended to multiple people.

In the following sections we describe each new controller and how two-person interaction maps to sound.

TOOKA: BREATH

The current version of the Tooka is a hollow flexible tube with three buttons at each end. A pressure sensor in the center measures the air pressure in the tube. The instrument is shown in Figure 2. Two people demonstrating how to play the Tooka are shown in Figure 3. To play the Tooka, each player puts their mouth over opposite ends forming a sealed tube. The players collectively modulate the tube pressure to control sound. Each player has three buttons that may be used to control mode changes, such as pitch.

Figure 1 shows a block diagram of the Tooka. The overall architecture uses a *Workspace* model to connect all the computational elements called *managers* and *workers*. The Workspace is implemented as a Tcl/Tk [10] process that workers and managers attach to and do the work in. Effectively, the Workspace is a common interpreter environment where workers and managers execute Tcl/Tk commands.

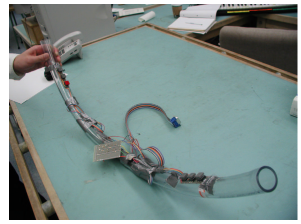

Figure 2: A picture of the Tooka.

Figure 3: Two people demonstrating how to play the Tooka.

The workers and managers attach either through a TCP/IP connection or are embedded in the Tcl/Tk workspace using dynamically linked libraries.

For Tooka, there is one manager and two workers. The manager is the graphical user interface (GUI) that controls data flow and configuration of the data acquisition and music production via the workers. The data acquisition worker is responsible for reading data from the instruments buttons and pressure sensor. It runs as a separate process written in C and uses the Comedi libraries [8] for reading/writing to the data acquisition board. It attaches to the workspace using a TCP/IP connection. The second worker is the MIDI Music worker. It is responsible for mapping data inputs to MIDI notes. It has been implemented as a dynamically loadable music module. It was created by modifying the virtual keyboard (VKB) [7]. Currently, all the processes run on a single processor machine running Linux.

Players can modulate the pressure in the tube using either their tongue, pharynx, or lungs. Each mechanism has different precision as well as feedback providing a diverse control and feedback space. This property of the Tooka suggests that with a well designed mapping from air pressure to sound it should become an expressive instrument.

The Tooka's pressure sensor is a NovaSensor 410-015G3L that detects medium range pressures. The pressure sensor is connected to an instrumentation amplifier and the signal is passed to a National Instruments A/D converter (PCI-MIO-16E-4). The buttons are also connected to the digital inputs

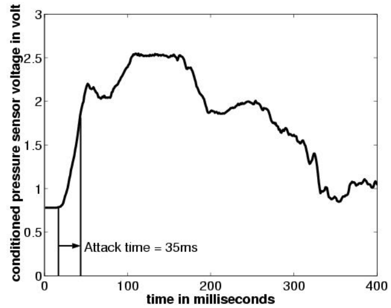

Figure 4: Pressure profile over time of a person blowing into the Tooka. The other end is sealed. The player is increasing the pressure and then modulating it.

of the A/D converter. All the information from the A/D converter is available to our application through a Tcl/Tk [10] interface. All the music code for mapping sensor data to MIDI is performed using Tcl/Tk. The actual MIDI output comes from the MIDI worker.

In order to achieve full dynamic range for the pressure sensor we included both hardware and software calibration in our configuration. First we matched the dynamic range of the pressure sensor to the analog-to-digital converter input voltage range. This was achieved by setting the gain of the instrument amplifier(Linear Technology LT1920) to 500 based on pressure range measurments. Further we configured the sampling frequency to trade-off between low sensor data rate and high signal quality. We have also investigated pressure profiles for attacks and modulation that players are capable of making. A typical pressure profile is shown in Figure 4.

The greatest degree of control is from the tongue. Players can form a completely closed tube with their mouths, tongues and pharynx to block any air flow into their lungs or out their nose. Keeping the back of their tongue against their pharnyx creates an air tight seal. Players move the front of their tongue to adjust the volume of air in their mouths providing a very precise pressure controller. As their mouth and tongue is forming the seal any pressure changes made by either player are immediately felt by each of them, providing excellent feedback as to the state of the instrument as well as an indication of what the other is doing. Air pressure changes using just the tongue can be quite substantial. During this type of interaction, each player can breathe at the same time as modulating the tube pressure.

Players can control their pharynx to allow air to flow through their nose. This ability allows each player to be able to quickly change and/or modulate the tube pressure by adjusting the amount of air that flows through their nose. Generally speaking, this mechanism only allows for one player to lower the tube pressure to 0 without going negative. Further, this control allows a continuous stream of air for the duration of one player's breath.

In contrast, a player may use their lungs to adjust the air pressure. While this control is fairly coarse grained, it does allow players to create large negative and positive pressures in the tube. For a rush of air to pass through the tube, one player has to allow the air to pass into their own mouth while the other is blowing. This is reversed to have air flow the other way. We do not currently measure air flow velocity though. While the use of lungs to play the instrument provides coarser control of the air pressure, visually it provides a clearer image of what the players are doing. This is helpful both for the other player and audience to make the instrument's mapping more transparent. Note though, the second player typically uses the high fidelity sensing of the air pressure to understand the effort and intentions of the other player.

We experimented with several tube types. One tube had a large compliance. The large compliance meant that changes in pressure caused the tube to expand making pressure changes small and slow. With only tongue control, it was difficult to have significant pressure changes and players had to use their lungs to get fast and large changes. When one player uses their lungs excessively the other player often find it disturbing and interferes with the interaction. Thus, we use a hard, non-compliant tube as shown in Figure 2.

We are somewhat concerned about how sanitary the Tooka is. Our objective is to make the instrument as intimate as possible for the two players; thus, we allow airflow between them. In our testing, this feature has the desired effect. Just the thought of the instrument has emotional impact between the two people planning to play it. We may create a second version that has a latex membrane that allows pressure to be transferred but not the actual air. It will not be as intimate nor will it allow the exploration of air flow, however, novice players may feel more comfortable with it.

Finally, an interesting feature of the instrument is that it can be played continuously. Players do not have to stop playing to breathe if they do not want to. This is because if they are playing with their tongues, then they can be breathing at the same time. This opens some new performance and expressive possibilities.

Sound Mapping with the Tooka

We are exploring different types of musical mappings with the Tooka. The first mapping we have pursued is the most obvious. We are using the metaphor of the recorder to constrain the way air pressure and button presses affect the sound. In the mapping, each button combination corresponds to a pitch change. In our first prototype, we used six buttons limiting the number of discrete pitches to $2^6 = 64$; the full mapping is shown in tables 1 and 2. Each player has 3 buttons. The players' index finger controls a button (B2) to change octaves. The players' middle and ring fingers control buttons B1 and B0, respectively, to change the interval in the current octave. We use coordinated button presses to move up the pitch scale to maintain consistency with our goal of exploring two person interaction to provide the basis for an expressive instrument.

As can be seen in table 2, we chose to map each player's top button to shift the pitch by one octave (in our current implementation, the four combinations correspond to a base note of C2, C3, C4 and C5). We use the other two buttons that a player has for semitone offsets from the current octave. There are 16 different positions which we map to 14 semitones above the base note and 2 notes below. Identical finger positions between the two players look synchronized from an audience's perspective making them visually appealing, so, we have mapped them to notes I, III, IV and V. The other notes follow a Gray code pattern alternating between players so that each player only changes one button between semitones. This mapping has yet to be fully explored, thus, further work on the mapping is in progress. For the second prototype, we have added another button for each player that is controlled by his or her pinkie. This extends the tonal range of the instrument. Finally, air pressure is mapped to the loudness of the sound approximating an effort-to-sound level map that a player experiences with a recorder.

In initial experiments, players were able to play melodies with the buttons. This is not too surprising as the buttons provide relatively easy control of pitch. It also appears that expression was possible through the control of the air pressure in the tube. The breath pressure to volume gain had to be adjusted to provide fast response to changes in pressure. For both control of the pitch (buttons) and volume (breath), coordination between partner requires practice. This is the result we had hoped: individually, the instrument does not really make sound, but with practice, two players can play well together. Furthermore, the test subjects reported that they indeed felt a link between each other but found it difficult to articulate the feeling. We are looking forward to having musicians play the Tooka for extended periods to evaluate it better.

Based on these promising results, we are investigating how to map the nuances of pressure changes to more expressive control of the sound. For example, mapping pitch bend as a non-linear function of air pressure would approximate a recorder as well. Further, pressure exceeding a threshold may be mapped to a shift in register. We have built a graphical user interface (GUI) to facilitate exploring non-linear mapping between breath pressure and amplitude/pitch variations.

	Player 1		Player 2	
Note offset	B1	B0	B1	B0
-2	1	0	0	0
-1	0	0	1	0
0	0	0	0	0
1	0	0	0	1
2	0	1	0	1
3	0	1	1	1
4	1	1	1	1
5	1	1	1	0
6	0	1	1	0
7	1	0	1	0
8	1	0	1	1
9	1	0	0	1
10	1	1	0	1
11	0	1	0	0
12	0	0	1	1
13	1	1	0	0

Table 1: Table of Button Presses to Note Offsets for the Tooka

	Player 1	Player 2
Octave	B2	B2
0	0	0
1	0	1
2	1	1
3	1	0

Table 2: Table of Button Presses to Octaves for the Tooka

The recorder metaphor is only one way to start the exploration of the expressive possibilities of the Tooka. We plan to add additional sensors to measure air flow speed and direction so that further mechanisms of control can be introduced allowing new means of expression for two people.

PUSHKA: PUSHING AND PULLING

We are currently building a second two-person instrument to see the effect of different feedback and form has on expression and experience. The current version of the Pushka is a semi-rigid rod held by each player. Strain gauges are placed on the rod to measure the flex in the rod as well as the torque on the rod. As well, the ends of the rod are tracked using a magnetic tracker. These sensors provide position, velocity and acceleration of the rod's ends. A diagram of the instrument is in Figure 5. To play the Pushka, each player holds

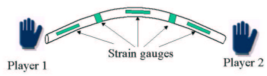

Figure 5: A diagram of the Pushka.

the ends of the rod in their hands. The semi-rigid rod connects the two players directly. Collectively, they pull, push, move and twist the rod to control music. By coordinating their movements in opposing direction they can provide effectively an isometric force controller. By coordinating in the same direction they have an isotonic controller allowing position, velocity and acceleration to control the music. The coordinated interplay between the players provides a large degree of control over the musical spaces. The instrument has many desirable features:

- it affords a large musical mapping space;
- it provides force feedback to each player through the rod itself;
- control of the instrument is easily visible for each player as well as the audience.

Note that the metaphor of a connected rod provides a warm and intimate communication channel. We make our rod out of wood as well to enhance the warm connection between players. Another direction for the Pushka would be to make the rod distributed as in Intouch [3] or HandJive [5]. Using the Pushka remotely as in InTouch would prevent using the rod in isotonic mode until better force feedback devices are available.

Actually, all the two person-instruments described in this paper could be made distributed with the appropriate feedback added to the remote device. This is another aspect to investigate to see if it enhances intimacy between people at remote locations.

We are in the process of building this device. Technically, building the hardware is relatively straightforward. Experimentation with the mapping and determining whether the Pushka can be used by two-people effectively remains to be done.

PULLKA: STRING TENSION

While the Pushka allows push and pull forces to be exchanged between players, we envision a third type of two-person instrument that uses only pull forces called the Pullka. The current vision of the Pullka is a single string (or more) held under tension with a bridge about 1/5 of the way from each end of the string. A picture of the instrument is in Figure 6. A strain gauge measures the tension in the string. To play the Pullka, each player pushes on the string behind the bridge at each end. The string connects the two players directly through the tension on the string. The string we are currently using is not meant to be plucked or strummed; however, this is a simple variation which we intend to explore. Collectively, players push on the string to control music. The coordinated interplay between the players provides a large degree of control over the musical spaces. This instrument highly constrains the control space. We do this to explore a reduced control space to see how much expression is possible with only a single parameter. The string does provide direct feedback between players suggesting the possibility for an expressive controller.

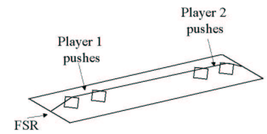

Figure 6: A diagram of the Pullka.

RELATED WORKS

Two person and multi-person musical environments have been explored throughout history. As mentioned in introduction, the hurdy-gurdy was originally played with two players. The control of the instrument was not balanced. We can only speculate how much haptic feedback was involved between the two players to determine when to spin the wheel faster. The instrument itself is not so sensitive to small variations of the spinning wheel, thus, it is not clear how integrated the two players are.

Another style of multi-player music is the symphony. “The hub” [2] and the earlier “The League of Automatic Music Composers,” [1] extend the idea of the symphony into an electronic version. Each person plays their own instrumented interface/musical instrument which feeds into a centralized music generation system. The system is able to use the coordinated actions of the players to modify the musical output allowing multiple players an opportunity to make new sounds not possible with only a single instrument. Like a jazz ensemble, the players communicate through sight and sound. The physical medium of the instrument is still controlled individually so the physical actions of one player are not felt by the other. In the instruments introduced here we focus on letting players feel each other’s actions.

SUMMARY

We have begun building and experimenting with electronic two-person instruments. Each instrument provides a physical channel between the two players providing haptic feedback so that each person knows what the other is doing. Of course, each player also has visual and auditory feedback much like normal two player or multi-player situations. The physical channel allows the players to form a physical link enhancing intimacy with each other. We are looking to exploit this intimacy by mapping player interaction to musical forms.

The Tooka provides feedback through breath. This is extremely intimate as initial experiments have revealed. We believe this instrument has the capacity to be very expressive but more work needs to be done to verify this and optimise the sound mapping. Interestingly, the instrument may be used to facilitate the formation of relationship between two people rather than being used as a musical instrument. The Pushka and Pullka used physical forces on the players hands to provide feedback. These have not been built yet but we plan to do so.

All of the instruments can be extended to include more than two players. For example, adding a three way hollow pipe that three tubes connect into would allow the Tooka to be played with three players. One can imagine a pipe junction box having many ports that can be connected or disconnected for multiple players to come and go on the fly. For the Pushka to be made multi-person requires extending the rigid structure to have multiple sticks extending from a rigid junction with the appropriate sensors added to each protrusion held by each player. Though, having a central junction is not absolutely necessary as any instrumented rigid structure allowing multiple people to pull and push it could be used. Finally, extending the Pullka for multiple players is more complicated. Multiple strings would need to be spliced at strategic locations to form multiple leads attached to each other centrally and extended out to bridges for each player. The tension to sound mapping would be much more complex and interesting to explore. The effect may be something like a complex distributed Biwa bridge. Also, all of the instruments can be made to be distributed. This would allow for intimate musical experiences over a network. These directions are yet to be explored.

We expect the two-person instruments that we are exploring to be used in two context. First, one of our goals is to create a highly expressive musical instrument that requires two people to play it. By carefully addressing the human interfacing issues as well as the physical nature of performance we hope that our instruments (and other two or multi-player) will become part of the core of accepted musical literature. We would like to compose pieces for the unique possibilities offered by the coordination of players activities. Further, we expect that the intimate nature of the instrument will lend itself to both visually and cognitively meaningful performances for audiences. Virtuosity with a two-person instrument, such as the Tooka, will emerge from two players.

Electronic two person instruments provide an excellent platform for exploring the musical expression gained by exploiting the complex relationships that form between two people. We expect new forms of relationship protocols to develop with the two-person instruments we are building in addition to typical turn-taking behaviour. This opens the door for exploring novel collaborative and communicative performance and interaction. Using the two-person instruments, players' intimacy, if mapped to sound effectively, may provide an exciting, expressive performance.

ACKNOWLEDGEMENTS

We thank Edgar Flores and Kuang Tien for their help building the electronics. Further we thank Paula Wirth for the design of the Tooka system Illustration.

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