Adaptive Music Technology: History and Future Perspectives

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ABSTRACT

Computer music technology opens new possibilities in the design of new musical instruments for physically disabled musicians. The field of adaptive music technology has been relatively unexplored in the computer music literature.

In this paper, we provide an overview of existing work in this field, and describe in more detail two representative examples. Informed by this overview we propose a set of principles for how to work with a disabled participant to develop a new musical instrument. We hope that these principles will help stimulate and evolve future work in the field of adaptive music technology.

1. INTRODUCTION

The field of adaptive music technology has been growing since the late 1980s. Before that, advances in adaptive technology (such as electric wheelchairs) and music technology (such as the Theremin) laid the ground work for the field. The field is important because it provides a way for people with physical disabilities to play music they could not otherwise play [1]. It opens up music making to many people who would otherwise not be able to participate. Benefits of music making for the disabled can include increased self-awareness, increased agency, and increased control [2].

Because it is so important to develop new instruments that people with disabilities can play, it's key to develop a set of considerations to use when making a new instrument. This can be done by evaluating cases of pre-existing adaptive musical instruments and how they were developed, as well as by surveying some of the literature about adaptive music technology.

Adaptive music technology can be defined as the use of digital technologies to allow a person who cannot otherwise play a traditional musical instrument, to play music unaided. The term assistive music technology has been used in much literature [3], but the word 'assistance' implies an external source that provides aid to a person in need. In contrast, 'adaptive' implies a constant state of refinement, and an adjustment to the situation of the musician.

2. BACKGROUND

Robert Moog notes there are "three diverse deterninants of musical instrument design and musical instrument structure. The first is the sound generator; the second is the interface between the musician and the sound generator; the third is the... visual reality of the instrument [4]." It is useful to look at the technologies that have led up to the design of the adaptive musical instruments listed in Table 1.

Perhaps the single biggest development that has made adaptive music technology possible is the advent of MIDI in 1983. This allowed for rapid and simple transport of musical commands. Shortly after that development instruments such as the Soundbeam, which uses a sonar beam that triggers MIDI events when interrupted, and the Magic Flute, which triggers MIDI notes using a breath pressure sensor, began to be introduced. Other adaptive musical instruments that use MIDI include the Head=Space, the Doozaphone, the Jamboxx, the Yamaha WX5, the Canstrument, the Dimension Beam, the MidiCreator/MidiGesture/MidiSensor, the Optivideotone, the Synth-A-Beams, the Skoog and the AUMI.

The makers of the Soundbeam cite the Thereminovox as an ancestor and inspiration. Indeed, the idea of a no-touch instrument makes sense for many disabilities. Instruments such as Moog's Ethervox have evolved from both the Theremin and from MIDI.

Another important development for certain touchless sensors is sonar. This was developed to aid in underwater tracking and detection at large distances, and is used in many adaptive instruments because it is very robust.

Some touchless sensors, such as the Microsoft Kinect, use infrared light [5]. The Kinect contains an infrared transmitter and, right beside it on the camera, a receiver. When the light is emitted, it bounces off three-dimensional shapes, then returns to the sensor. The angle of refraction of the light allows the Kinect to compose a three-dimensional image of the world in its view.

Breath pressure sensors contain a membrane that has a pressure differential across it when blown into. The ones made for the use of disabled humans typically have a range of 0 to 1.5psi. Quadriplegics often lose lung capacity due to inactivity, so breath pressure sensors incorporated into instruments may actually increase lung capacity with use over time.

Touchless Sensor Musical Instruments	
Ethervox	A Theremin-like instrument that sends MIDI messages (1997)
Dimension Beam	An infrared light beam MIDI controller (1997)
I-Cube	A variety of body sensors that are attached to a MIDI "Digitizer" (1996)
MidiCreator/ MidiGesture/ MidiSensor	(2001-2006) Receives sound from many switches and outputs MIDI data.
EMS Soundbeam	(1989) Sonar at 50kHz forms a beam that, when interrupted, triggers MIDI events.
Microsoft Kinect	(2010) An infrared sensor that detects limb and joint positions and returns them as three-dimensional vectors.
Breath Pressure Sensor Musical Instruments	
Yamaha WX5	(1997) Similar to a clarinet, but outputs MIDI from breath pressure data.
Magic Flute	(2001) Breath sensor with gyroscope that allows the performer to make MIDI notes by moving the head up and down and blowing.
Jamboxx	A harmonica-like wind MIDI instrument.
Doozaphone	(2015) A prototype designed by Rolf Gehlhaar, the maker of the Head=Space.
Head=Space	(2000) Based on the Headmaster 2000, a breath-based interface using Max/MSP.
Biosensor Musical Instruments	
BioVolt (formerly BioMuse)	(1992) Bioelectrical signal controller.
Brain Machine (formerly IBVA)	(1998) EEG sensors attached to the head that create "interactive Mind Music."
Video-based Systems	
Mandala VR System	
Adaptive Use Musical Interface (AUMI)	(2007) Software that translates video from a webcam into motion that triggers MIDI events.
Very Nervous System	(1983-1990) A 3D interactive sound interface
Other Adaptive Musical Interfaces	
Skoog	(2008) A tactile cube with multicoloured buttons that when squeezed or pushed sends MIDI data.
Canstrument	(2014) A MIDI software app that uses the iPhone's accelerometer sensor.

Table 1. Adaptive Music Technology Instruments [6]. This list includes only instruments that have a digital component.

3. TWO CASE STUDIES: THE SOUNDBEAM AND THE MAGIC FLUTE

3.1 The EMS Soundbeam

The Soundbeam is a sonar beam that triggers MIDI events when the beam is obstructed [7]. The unit has a MIDI cable that plugs into its main device for sound synthesis. It was first introduced by composer Edward Williams at the Frankfurt International Music Fair in 1988 as Soundbeam 1. That version had a single sonar beam with the ability to add up to three more slave beams, and a menu of ten preset scales with the ability to store an up to 16-note pitch sequence in volatile memory.

Soundbeam 2 was released in 1998 and remained in use until 2010 when Soundbeam 5 came out. It had non-volatile memory and tactile switches (as foot pedals) to alter the sound, and could allow for up to four sensors to be connected to the main unit.

Soundbeam 5 was released in 2010 after many iterations of user experience and feedback. It incorporates an internal synthesizer and sampler, dispensing with the need for external modules and sound synthesizers. An important development with Soundbeam 5 is the ability to store preset melodies and harmonies. This makes possible a more methodical and progressive menu of presets (improvisations, tunes and themes) than was available with Soundbeam 2.

The Soundbeam 5 has a number of control parameters, which allow its range to be adjusted between 25 centimetres and 9 metres. This allows performers who have a relatively small range of motion to play a large range of notes, as the smaller range concentrates note information. There are also Mode settings which allow the player to adjust which notes are played (scales or arpeggios), how many notes can be played (from one to 64), and various parameters such as velocity and pitch bend.

When creating the Soundbeam, Tim Swingler kept in mind the importance of making the performer feel they can initiate something. That is, the idea of cause (the musician performing a gesture) and result (a pleasing musical sound) is central to the development of the Soundbeam.

One virtuosic performer of the Soundbeam is Ari Kinarthy of Victoria, British Columbia [8].

3.2 The Magic Flute

The Magic Flute is a breath pressure sensor that also triggers MIDI notes [9]. Inspired by a slide flute and the Yamaha WX5, it is the brainchild of Ruud van der Waal and David Whalen, who first envisioned the instrument in January 2006. In half a year, after being rejected by many universities, they had a prototype built by Brian Dillon from Unique Perspectives. The prototype was a breath sensor with a gyroscope that had 8 tone scales and a MIDI out.

The Magic Flute is mounted on a swiveling camera stand, and the performer moves it by holding the mouthpiece and moving their head up or down. The vertical position of the flute determines its pitch while the breath strength determines note amplitude. The unit plugs into a 'blue box' which in turn plugs into a synthesizer via MIDI cable.

The catalyst for change in the Magic Flute was Ruud's work with children at the Rijndam Institute in the Netherlands. From that he added a lot of new tone scales, a transpose function, switch behaviour, and the ability to change user settings.

The making of these two instruments shows the importance of iterative development and user feedback. In the next section, these will be qualified and explained further.

4. METHOD FOR FUTURE DEVELOPMENT OF ADAPTIVE MUSICAL INSTRUMENTS

This method is similar in many ways to what might be done to develop instruments for able-bodied people. The difference here is in the inputs to the process. It is often assumed in computer music and music in general that the performer has a standard set of abilities: four limbs, ten fingers, a working set of eyes, and a standard range of mobility. None of this can be assumed in adaptive music.

4.1 Introduce the Participant to the Technology

This is a necessary but often difficult first step. In most cases, the musician will have no or very little experience with computer music technology, and the strange hardware involved can often seem overwhelming. In a perfect world this step would be somewhere further down the list—after developing a relationship of trust with the participant as in step 5. But the need to use the technology in all subsequent steps is paramount, so the hurdle of using it must be overcome.

The most important consideration at this early stage is to simply introduce the technology as part of a human relationship with the participant, and move on to the next step, as opposed to dwelling on it and explaining its features in detail. Let the musician discover how wonderful this new technology is for themselves instead of explaining it before they've had a chance to experience it.

4.2 Determine the Range of Motion of the Participant

This is a key second step and absolutely must be done as soon as possible to ensure success. This can be done using the instrument itself, or with another motion capture device such as the Microsoft Kinect camera. In any case, a baseline of measurements of which body parts the participant can move and how far they can move them is important.

Note that the participant must be observed closely in this step, and their input into the process is crucial. There is a difference between being able to move in a direction, and feeling comfortable moving in a direction. This takes careful consideration, as many disabled participants will feel strained moving at all, so a threshold for what movement can be done repeatedly, versus what can barely be accomplished one time, must be determined.

The best way to determine which movements are acceptable is to know the participant and their responses. Normally if there is a lot of strain on the participant's face the movement is too strenuous and should not be included in calculations.

Note that the progression of all these steps is cyclical, so a perfect result at stage two is not needed. It is better to find a few movements the performer can do well and consistently then quickly move on to step three.

4.3 Make Sound Quickly

Come up with a program that will allow the participant to make sound quickly to keep their interest. Normally the first two steps can be accomplished in one or two meetings. After it is determined that the participant likes the idea of the technology enough to give it a try, and they have some ability to move that can be translated into sound by the technology, it is paramount to get them making a sound a soon as possible.

Perhaps the most obvious is a MIDI scale that increases in pitch as the performer moves up or forward, and decreases in pitch as the performer moves down or back. This gives a quick introduction to the potential of the instrument, and gets the main goal of the exercise, to make music, into the foreground as rapidly as possible.

In the experience of the authors, this step provides a turning point in the process, where theory becomes reality, and can be a catalyst for future developments.

4.4 Develop a System for Activating Sounds that is Reproducible for the Performer

After some sound is made and the performer is excited about the potential of the instrument, it's time to actually create the instrument interface. That is, the performer must be able to enact a gesture, and have the system respond in the same way every time. This is the most difficult step and the one that takes the most time to master. In considering how to set up the interface, the following should be decided:

How will sound be triggered? How will sound be turned on and off? How much control over the sound will the performer have, and how much of the process will be determined by the instrument? What type of music does the performer want to play? Are they open to new sound experiences? It may be helpful at this stage to stick to tonal, Western, easily accessible sounds at first until the performer gets a better feel for the instrument.

4.5 Evolve a Relationship with the Participant that Extends Beyond Music

Of course this will be happening at every step but it's an essential component and must be highlighted. The relationship needed to go into the unknown and develop a new instrument is one of immense trust. Neither the researcher nor the participant knows where the process will end up, so it is important to be unified and take the journey together. Further, there are many frustrations when dealing with new musical interfaces, and these can only be overcome with mutual understanding and respect. This is true in any musical endeavour, but much more so when dealing with disability and developing something new.

4.6 Make Improvements Incrementally

Allow the participant to try the new prototype at each stage in development. This is a collaborative process, and the more participation from the musician, the better. Of course, one must put in enough programming work to make each session fruitful, and to keep the participant encouraged. But too much work in between sessions runs the risk of making assumptions about what the participant wants and can potentially alienate them.

4.7 Evolve a Set of Exercises the Performer can do to Increase Mastery of the Instrument

This is the final step and should not be undertaken until all the others are substantially completed. However, it is important for the participant to be able to advance with the instrument. The creators of the Soundbeam place this as the forefront of instrument design: the musical device must be able to increase in difficulty as the performer progresses, and mastery of the instrument must be possible.

5. FUTURE WORK

One sensor that has demonstrated immense potential for adaptive music technology applications is the Microsoft Kinect. Its SDK for Windows is robust, and allows for joint and limb detection of a musician in an electric wheelchair. The iPhone and the iPad also continue to be used in adaptive music applications, and hold many possibilities for future innovations.

6. CONCLUSIONS

The field of adaptive music technology has developed alongside computer music. It is hoped that with a set of parameters with which to approach developing an instrument, more researchers will take on this rewarding task.

In the words of David Whalen, the maker of the Jamboxx and the Magic Flute, "If you have a disability of any kind, the point is that with the resources we have today, there might be a solution for you. New technology and computers are opening many doors for us."

Acknowledgments

A big thank you to Tim Swingler and Ruud van der Waal who were so gracious to answer my questions about the Soundbeam and the Magic Flute, respectively, by email.

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