ADAPTIVE BODY MOVEMENT SONIFICATION IN MUSIC AND THERAPY

Christian Bauman
Hochschule Fulda
christian.baumann@pg.hs-fulda.de

Johanna Friederike Baarlink
Musikschule Fulda
johanna.baarlink@gmail.com

Jan-Torsten Milde
Hochschule Fulda
milde@hs-fulda.de

ABSTRACT

In this paper we describe the ongoing research on the development of a body movement sonification system. High precision, high resolution wireless sensors are used to track the body movement and record muscle excitation. We are currently using 6 sensors. In the final version of the system full body tracking can be achieved. The recording system provides a web server including a simple REST API, which streams the recorded data in JSON format. An intermediate proxy server pre-processes the data and transmits it to the final sonification system. The sonification system is implemented using the web audio api. We are experimenting with a set of different sonification strategies and algorithms. Currently we are testing the system as part of an interactive, guided therapy, establishing additional acoustic feedback channels for the patient. In a second stage of the research we are going to use the system in a more musical and artistic way. More specifically we plan to use the system in cooperation with a violist, where the acoustic feedback channel will be integrated into the performance.

1. INTRODUCTION

Real time measurement of human body movement provides an excellent technical basis for a larger number of application and research scenarios. In this paper we describe the ongoing design and development of a real time sonification system for body movement data. Two application contexts for this system have been defined by us:

1. body movement sonification as an additional bio feedback channel as part of a physio therapy in multiple settings

2. body movement sonification as an additional channel as part of a musical performance, in our case playing the viola by our second co author, a trained musician and music teacher

So far, we focused on the first context, as we are still in the technical setup phase of our research.

Guided movements, which are body to body interactions between patient and therapist, are a central, important means for the treatment of a large number of human illnesses. The therapist is guiding the patient with her body movements and helps him, by giving language instructions, is controlling the tempo of the movement, controls the intensity of the patients movement and defines the rhythm of the movement. By holding the hand or touching the arm, a helpful supporting haptic feedback is given to the patient, who in turn, is reacting to the interaction and thus adapts and improves his body movements leading to a better recovery.

The similarity between therapy and musical performance or dance should be rather obvious now. In both cases we find the same pre conditions: dance consists of a body to body interaction, musical performance consists of a body to instrument interaction.

The integration of body movement and sound production is an integral part of the musical and artistic expression. Musician use body movements in multiple ways, obviously to create the sound in conjunction with their instruments, but also to intensify the musical effect, e.g. by synchronizing their body movements with the rhythm or the dynamic of the performed musical piece.

Body movements are also used to communicate during musical performance. Spoken language is often not to be used during a musical performance, giving posture, gesture, mimic and gaze a more important and prominent communicative function.

1.1 Bio feedback in therapy

Bio feedback training (BFB) is a powerful means to learn and re-learn body motion patterns. It is often used with patients suffering from neuro muscular disorders or pain symptoms of the motion apparatus. A positive effect through pallaestethic BFB can also be recognized for children with innate cerebral pareses ([1]). BFB is also used for patients with strokes and facial pareses ([3]; [8]; [2]). Current BFB systems are focusing on visual bio feedback (see [6]). These systems require the patient to visually focus an external source, quite often a monitor displaying some kind of visual stimulus. This is interfering with the patients ability to perceive their own body movements, which could be a very important source of information during therapy. It is currently not clear, whether audio based BFB systems provide better results for the therapy of motion limited or disabled patients, ([7]; [4]) And it is also unclear, how a satisfactory sonification process for body movement data could be implemented within the context of physio therapy ([5]).

2. THE MEASURING SYSTEM

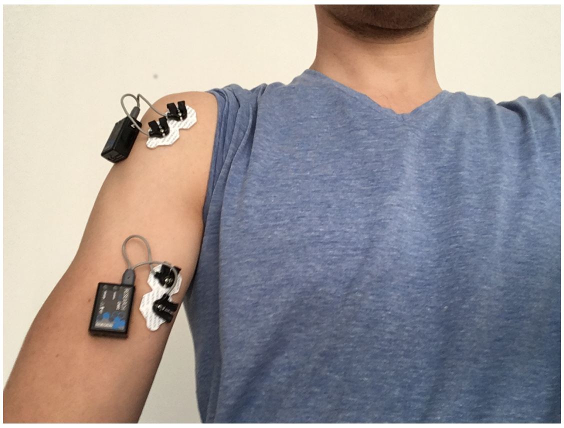

Figure 1. The experimental setup: sensors can be placed anywhere on the human body. In our case, we are interested in arm movements, either in a therapeutic context, in a later stage, measuring the arm movements of a violist.

Within our system, the recording of the body movement is conducted using wireless sensors, that will be attached to specific body parts of the musician/patient. These sensors provide high quality readings with a high temporal resolution. The maximum sample rate of the sensors is at 3000 Hz, giving detailed information on the muscle excitation, the accelleration and the spatial alignment. The used Noraxon software provides the functionality to synchronize audio- and video streams with the recorded body movement data. In addition, a number of simple statistical steps can be computed by the software. It also visualizes the measurements in a live graph and is able to create a very simple auditory feedback, based on the definiton of threshold values for the parameters.

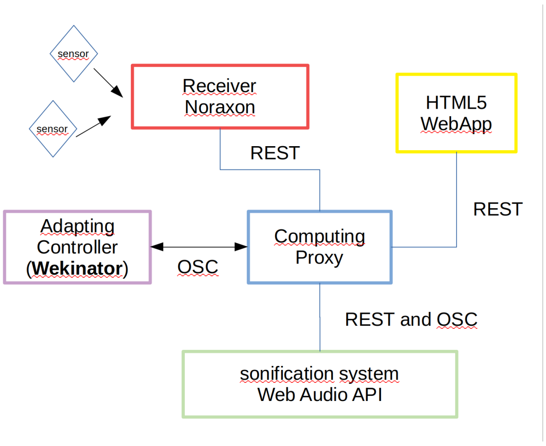

Figure 2. The system architecture: data is transmitted using a REST API. The computing proxy is preprocessing the incoming data and uses the wekinator to adapt the sonification parameters. The sonification process is implemented as a web audio based system running in the client browser (and also in SuperCollider).

In order to access the live data of a recording, the Noraxon software provides the user with a built-in web server that is implementing a simple REST API. The measurements are streamed as raw data and are encoded as a JSON compatible string. The blocksize of these data chunks is variable and depends on the request interval of the connected client system, in our case, the computing proxy system.

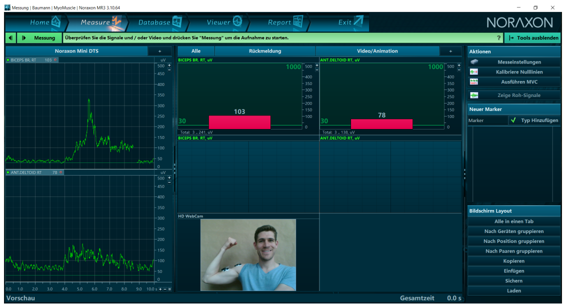

Figure 3. The Noraxon software is recording, audio data, video data and the body movement data in real time. Data is displayed as a live oscillogram.

The computing proxy system parses the data blocks and performs a set of pre-processing steps. It is implemented in python and uses powerful libraries to extract a number of key figures from the raw data. These include gliding average and standard deviation. It also integrates the signal and performs other standard statistical computations. Through these steps, the computing proxy reduces the amount of data, that is sent to the sonification system.

3. SONIFICATION WITH THE WEB AUDIO API

The sonification system has been implemented as a web based application using the web audio API for creating the sound [1]. The central component of the system is a 3 oscillator subtractive synthesizer. Its internal architecture is fixed (non modular) and follows the standard approach taken by most of the current analogue and digital synthesizers, consisting of a chain of VCO, VCF and VCA. In addition LFOs and an EG are provided to modulate a number of parameters of the main components (e.g. frequency, pulse width, filter cutoff frequency and filter resonance). In order to receive the movement data from the computing proxy, a simple timer creates GET requests in regular intervals. Depending on the selected sonifications strategy, the movement values are then mapped to control parameters of the synthesizer, eventually creating the perceived sound. For the creation of rhythmic patterns a simple web based drum machine has been implemented. A set of four pattern generators is used. These pattern generators function like a set of gears (see [9]), each producing a configurable repetitive rhythmic pattern. The gears could also be linked, thus being synchronized. For each gear up to two independent sounds could be selected with a pattern length between 1 and 17 beats for a single gear revolution. The sounds of the drum machine are produced by the described web audio synthesizer.

[1] A secondary simple sonification system has been implemented using SuperCollider. Here parameters are transmitted using OSC.

3.1 Adaptive Sonification

The processing proxy performs the central analytic part of the current systems. Basically it reduces the vast amount of sensor readings to a set of relevant control parameters.

This transformation process is also parameterized and can thus be dynamically adapted to body movements. This is achieved by integrating the wekinator (see [10]). The wekinator is connected via Open Sound Control (OSC) and is able to learn a mapping function for given parameters.

In order to create a dynamic mapping, fixed values of control parameters are paired with certain postures of the human body. After presenting the system just a couple of relevant examples, the wekinator is able the create an interpolation model for this parameter.

This approach makes it relatively simple to adapt to the specific movement abilities of a system's user.

4. FIRST EXPERIMENTS

A set of different sonification strategies has been implemented. Parameters on a number of musical levels and sound levels are controlled by the preprocessed movement measurements.

- pitch
- volume
- rhythm
- complexity of tonal clusters (filter parameters of noise)
- chord selection
- melody structure
- position in the stereo field
- position in a spatial field

The simplest way to sonify value changes is a direct mapping from movement to pitch. In our case, we experimented with speed and acceleration of the arm movement. While speed leads to smaller, less abrupt changes in pitch, acceleration creates a sound impression, that can be compared to a theremin. We also tried out to simultaneously sonifiy different sensors with different sounds (and also positioned them in the stereo field). While the sound became more interesting in a musical sense, the bio feedback seemed to be too complex. It became quite complicated to map the perceived sound back to the movement control of the arm. The second experiment tried to keep the pitch of the sonification steady. This allowed for a better control of the harmonic structure of the auditory feedback. Instead the volume of the sound was mapped to the arm movements. It turned out, that a better speed control of the arm movement could be realized by the participants. On the other hand, it became relatively complicated to get an adequate feedback for fine grained arm movements. The differences in auditory feedback were barely noticeable, even though, the volume mapping used a logarithmic scale. In our experiment on rhythmic structure we followed ideas inspired by Toussaint ([9]). A rhythm machine was implemented by means of geometrical descriptions. Here we (conceptually) used gears of different sizes to create rhythmic patterns of different length and speed. The arm movements were mapped to these parameters, thus changing the overall speed of the rhythm, as well its internal structure. Participants liked this kind of feedback. It gave them a good control about the temporal course of their movements. Even slight variations of movement speed were easily detected. On the other hand, variations in the movement measurement needed to be smoothed out more. For the next experiment we tried to provide as little musical structure as possible. Instead, multi band filtered pink, white and brown noise was used to create a non disturbing pleasant background hiss, comparable to an ocean noise on the seaside. The filter cutoff frequencies were modulated by a set of slowly moving LFOs, which in turn were controlled by the arm movement data. Here the acoustic feedback was perceived as delayed, not directly connected to the arm movement. Nevertheless, participants kind of liked it, as it provided a means of a slow moody change. They realized something went wrong a little time ago, moved back to a previous position and repeated the movement, hoping to get no further negative acoustic feedback.

The experiment on chord selection was based on a variation of a Tonnetz by Euler. Instead of moving through the network in a circular way, a given central chord was chosen, and the arm movements were mapped to a distance value, thus moving away from the central chord to select more distant chords. Once the arm movement was back on track, closer chords were chosen again. Most of the participants liked to stay within a close range to the central chord, thus mainly producing simple (musically rather dull) cadences of tonica, dominante and sub-dominante. Still some also enjoyed the more complex structure of the distant chords. The perceived musical structure led to a stronger distraction of the participants, as they rather tried to get back to the central chord, than concentrating onto the correct arm movement. In a sense, the participants used the sonification system for a musical performance. The final three sonification strategies have not yet been under experimental testing. If accepted to the conference, we hope to be able to present all of our results as part of a poster/demo presentation.

5. CONCLUSIONS

In this paper we present the early stage of our research on the development of a web audio based sonification system for body movement data. So far, we have been able to design and implement a first version of the system. This prototype is fully based on current web technology. We developed a set of sonification strategies and conducted a number of experiments to pre test our hypotheses. The results are quite promising. Within the context of physiotherapy we expect to achieve positive effects on the rehabilitation of patients by integrating auditory bio feedback into the therapy. In a second strand of research, we would like to use the system in a more musical way. More specifically, we would like to use the system to capture and analyse the arm and body movements of a violist (our second co author) and use the incoming body movement data to control the sonification system in a musical and esthetic way. As the violist is also teaching viola playing to younger children, one might also use our system in a didactic setting.

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