THE SONIFIED MUSIC STAND – AN INTERACTIVE SONIFICATION SYSTEM FOR MUSICIANS

Tobias Grosshauser
Ambient Intelligence Group
CITEC – Center of Excellence in Cognitive Interaction Technology
Bielefeld University, Bielefeld, Germany
tgrossha@techfak.uni-bielefeld.de

Thomas Hermann
Ambient Intelligence Group
CITEC – Center of Excellence in Cognitive Interaction Technology
Bielefeld University, Bielefeld, Germany
thermann@techfak.uni-bielefeld.de

ABSTRACT

This paper presents *the sonified music stand*, a novel interface for musicians that provides real-time feedback for professional musicians in an auditory form by means of interactive sonification. Sonifications convey information by using non-speech sound and are a promising means for musicians since they (a) leave the visual sense unoccupied, (b) address the sense of hearing which is already used and in this way further trained, (c) allow to relate feedback information in the same acoustic medium as the musical output, so that dependencies between action and reaction can be better understood. This paper presents a prototype system together with demonstrations of applications that support violinists during musical instrument learning. For that a pair of portable active loudspeaker has been designed for the music stand and a small motion sensor box has been developed to be attached to the bow, hand or hand wrist. The data are sonified in real-time according to different training objectives. We sketch several sonification ideas with sound examples and give a qualitative description of using the system.

1. INTRODUCTION

Musical instrument learning is a complex multi-modal real-time activity that involves processes from low-level coordinated motor control, auditory perception up to automation and complex cognitive processes such as understanding and learning. It is representative for the larger class of human activity where expression and behavior shape and develop during practice towards a specific goal, such as in dance and sports. Due to its richness and complexity, novices tend to allocate their attention on the closed-loop interaction so that they comply with a coarse level of control, for example to produce the accurate frequency or to generate the accurate rhythm, and this strong focus on primary objectives induces a neglecting of other important aspects such as a good body posture and alike that become relevant at later stages. Particularly, wrong coordination and posture can even cause physical problems for musicians and lead to a lot of effort to be relearned. Therefore techniques that can actively shift the player's focus of attention during practice in a early learning phase are highly motivated. As second aspect, the training of the hearing abilities and the reaction to acoustic events is one of the core abilities in learning musical instruments and singing. Sonification supports learning, by providing additional information in real-time acoustically and helps the students to use and train their ears with less visual distraction, compared to visual feedback.

SMC 2009, July 23-25, Porto, Portugal

In this paper we present an approach that uses sonification[1], the non-speech auditory display of information as real-time feedback for the musician. Sonification, as described in [1] addresses our highly developed yet often neglected sense of listening. Indeed, compared to visual display, sound does not demand the user to visually attend a specific display location, sound is processed over a larger range of frequencies (typically the useful pitch range 50Hz to 5000Hz exceeds the visual 'one octave' from red to blue, and in the range from 0.1 to 10 Hz we perceive temporal structure and rhythm), and is highly capable to direct and alter the human's focus of attention. Furthermore, we are capable to attend to even subtle cues in complex sounds simultaneously and perceive the sound as a whole at the same time. Concerning coordinated rhythmical activity, by listening we are capable of discovering even faint changes in rhythm as well as coordination problems.
With this motivation, the idea is to measure the player's motor activity and to reflect specific properties of his/her

[1]See www.sonification.de/main-def.shtml for a definition.

performance as an task-specific and unobtrusive interactive sonification, so that on the one hand, the musician can still focus on the musical sounds but, without change of media, receives additional information to keep awareness on relevant aspects of the physical execution. To be successful, a careful selection of sensing technology, an appropriate and well-defined task, a suitable feature extraction process by means of data mining techniques and a sonification design which combines well with the musical signal need to come together, so that a system will be acceptable to musicians and helpful for long-term use.

The *sonified music stand* is our approach to integrate the essential technology into a tool that is typically in use anyway for musicians. It represents a first principled approach towards better closed-loop auditory interaction systems, here developed and optimized for a specific user group and application, but conceptually reaching beyond this case towards general sonification-based interaction support. The paper continues with a description of design aspects and a presentation of the technology. This is followed by a section on the selection of movements and requirements for the application of violin learning support. In turn, sensor data of bow strokes are shown and features are extracted. Section 5 presents our first interactive sonifications implemented in SuperCollider and projected via the sonified music stand. Finally we discuss our first experiences and our plans for continuation of this research.

2. THE SONIFIED MUSIC STAND – IDEA, OBJECTIVES AND DESIGN

The closed-loop audio feedback supports students in learning and performing situations, similar to the AcouMotion system in [2]. Complex movements are divided into several simple ones. Audio feedback supports the active learning phase by significant acoustic events for instruction in real-time. In this paper, scenarios of violin learning and teaching are shown, but other possibilities in the area of instrumental teaching in general and learning of movements, gestures and postures are possible.
A pair of self-made and developed three-cornered active stereo speakers is assembled on the left and right side of a conventional music stand. It is connected with the audio out of a laptop computer. The computer receives data from a 5 DOF sensor and generates audio out via SuperCollider. The sensor data are processed and several levels of difficulty allow user-adapted feedback, new experimental learning scenarios and a controlled learning effect. The evaluation process includes sensor-based motion capturing, evaluated on music instrument learning based scenarios and audio feedback.

Figure 1. The sonified music stand

2.1. Sensor Hardware

Similar to the carbon K-Bow form Keith McMillen [3] and the used technologies from [4] and [5], acceleration and gyroscope sensor data were measured.
In our exemplary use cases, 5 degrees of freedom, acceleration sensors for x-, y-, and z-axis and 2 gyroscopes are analyzed. The data from the sensor are transmitted via radio frequency. A small Lithium polymer (Lipo) battery is directly attached for power supply. This small and light-weight, about 20 gr. sensor-module can be used as a standalone tool, just for movement learning or clipped to a bow of a string instrument.

2.1.1. The Gyroscope

A IDG-300 dual-axis angular rate sensor from InvenSense is used. This allows the measurement of the rotation of the x- and y-axis of the bow stroke (see fig. 2). The x-axis rotation is an additional compensating motion for e.g. soft bowing starts. The y-axis rotation is besides other functions relevant for pressure transfer onto the bow and to balance and change articulation and volume.

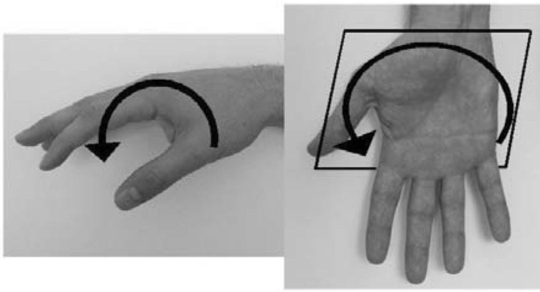

Figure 2. X-axis (left) and y-axis (right) rotation of the hand

2.1.2. The Accelerometer

The ADXL330 from InvenSense sensor is used, a small, thin, low power, complete x-, y-, and z-axis accelerometer. According to the description of the test cases in Sec. 3.1, every axis is important and has it's own defined plane, in which the movement is performed. Thinking in planes and rotations helps to learn complex movements, especially when the movement takes place beside your body and you the player hardly see it or control it visually.

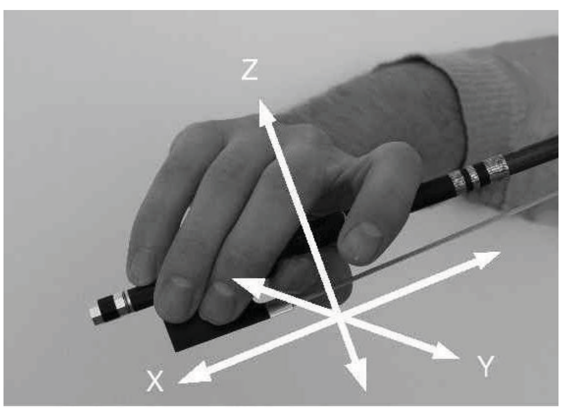

Figure 3. Motion coordinate system, x-, y-, and z-axis

2.2. Loudspeaker Design

For the sonified music stand, we developed a new design of an active loudspeaker, which offers many advantages:
the new developed active loudspeaker is easy to use and can be attached very flexible to manifold things and surfaces. The exceptional shape, the good sounding and energy-efficient amplifier allows many other uses. The introduced cases below will show simple sonification

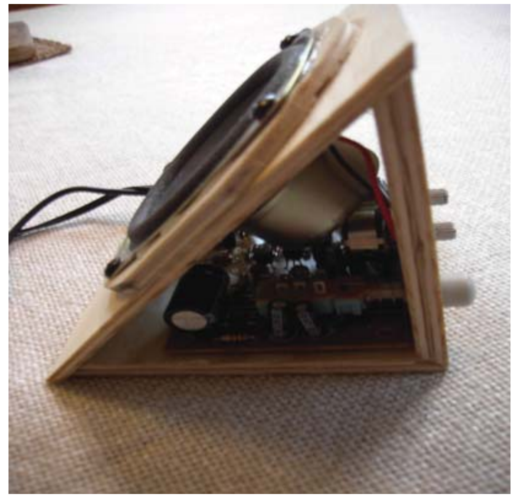

Figure 4. Loudspeaker without lateral housing

methods, where the loudspeaker can be used fixed to the music stand or stand-alone on a table or other surface.

2.2.1. The Three-Cornered Design

The side view of the speaker shows the three-cornered shape. It allows an 45° angular, right angular and a parallel mounting of the loudspeakers. In the case of just putting them on a table, the sound 45° propagation is easy adaptable to the listener's ears for best audio quality results. In the other case of mounting them parallel to a screen or the music stand, the sound propagation is right-angled and in the direction of the user sitting or standing in front of a monitor or the music stand.
The three-cornered design diminishes standing waves compared to quadratic boxes because of the non-parallel walls. Furthermore, the robust construction of the cabinet reduces the transmission of the inter-casing wave propagation and vibration. These two advantages, besides the integrated amplifier, lead to good sound quality. The practical form-factor allows safe transportation of speaker pairs in cube-form putting them together membrane to membrane.

2.2.2. Amplification, Low Energy Consumption and Battery

The active loudspeaker design allows simple usage with all audio sources such as laptop computers and mp3 players. For amplification, a digital chip is used, which provides high energy-efficiency and good sound quality.

The mounting of the loudspeaker is done with clamps or hook-and-loop fasteners, depending on the surface and thickness of the music stand, monitors or other surfaces. Only a power and stereo cable is attached to the stereo amplifier housed in one loudspeaker, the other one is directly powered via one cable. This design allows the use of only one power cable for two speakers.

3. PERFORMANCE ASPECTS IN VIOLIN PLAYING

3.1. Methodical and systematical learning scenarios for complex motor skills

The following scenarios are basic extractions of beginners' violin lessons. Depending on the age of the pupil or student, different approaches exist. One of these is the breakdown and fragmentation of a movement into several simpler action units, based on the ideas of Conrad von der Goltz [6] . In our scenarios, a simple bow-stroke is decomposed in 4 cases, where the last one is the "recomposition" of the stroke. This is not only a beginner's problem, this is even trained from time to time by advanced students and professionals to develop their skills and physical awareness. The sensor and the real-time sonification gives us the possibility to train these simplified movements and adding step by step more and more complexity. In other words, this means the combination of simplified movements to more complex ones. The single and combined movements in the following cases can be performed simultaneously or successively, with or without instrument.

Case 1:
Problem: Movement of the hand in the x/y-plane (see fig. 4), with zero deviation in the z-axis.
Pedagogical aspect: Understanding the different planes of the bowing movement.
Idea: Drawing a line on a plane, for example on a virtual table. The pencil would draw a curve, accelerating in the x- and y-axis, but the plane surface of the table gives a constant zero-acceleration of the z-axis. The x-plane itself has different horizontal angles, but they don't change during one stroke. This is the so-called "string-plane", the elbow and upper arm don't change their height, just the forearm and hand move sidewards.
Result: The student gets an idea of the arm movement in one plane and the so-called "string-planes".

Case 2:
Problem: Adding a second plane, the y-plane with zero deviation of the y-axis to the exercise, drawing a virtual straight line.
Pedagogical aspect: Understanding the "virtual straight line" of bowing movement.
Idea: If you move your hand exactly along one direction so that you draw a perfect line into the air beside your body, complex compensating movements of the hands and arms are necessary. If you try this with a pupil the first time, it is not only hard to understand the movement without seeing your hands, also practicing in front of a mirror is difficult, because every change has to be side-inverted.
Result: Students learn to move the hand on defined straight lines, without looking to it.

Case 3:
Problem: Starting the movement of case 2 with a short acceleration phase, followed by constant speed without any acceleration and deceleration at the end of the movement.
Pedagogical aspect: The recognition of a constant low or high acceleration and constant speed of a movement in 3d-space is very difficult.
Idea:. Acceleration, the constant moving speed and deceleration in one single move influence the produced sound. These three aspects are realized, learned and trained in this exercise, supported by sonification.
Result: The student gets an idea of the 3 phases of a bow stroke and its' influence to sound generation, the acceleration phase, the constant bow speed phase and the deceleration phase.

Case 4:
Problem: Adding a defined rotation of some degrees at the beginning of the movement, as described in the cases before to the x-axis.
Pedagogical aspect: Learning and understanding the movement according to playing in reality with more or less bow-hairs influencing the attack and volume.
Idea: The data from the gyroscope and sonification allow an easier evaluation of this matter. Practicing in front of a mirror is difficult, because the posture and movement changes are very small and hard to see. The fine grain solution of the sensors allows detecting them and augmenting them for rendering sonified feedback.

3.2. Sonification for short- and long-term monitoring

Sonification allows short and long-term unobtrusive monitoring and feedback of many parameters to the musical instrument player in real-time. The above described cases 1 - 4 demonstrate a short-term observation. But long-term use allows the recognition of mistakes or symptoms of fatigue while exercising a completely other problem or playing a long piece en bloc. In these cases, attention is concentrated to other demands and sometimes even basic skills are neglected and cause a significant loss in sound or performance quality. The sonified music stand is easy to set up and on this account it can support students in every day practicing.

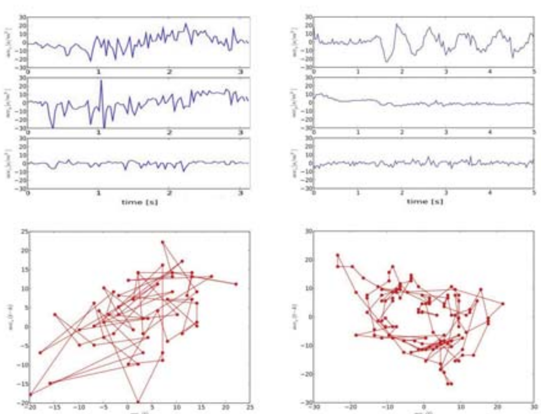

Figure 5. Left column incorrect bowing, right column correct bowing, time series of accelerations along the , x-, y-, z-axis and below Takens embedding, plotting accelerations against their delayed values.

4. FEATURE EXTRACTION FOR BOW MOVEMENT SONIFICATION

There are many sonification designs that use the raw measured sensor readings for mapping sonification. Sometimes (see for example [7] and [8]) also the audio signal of the instrument, played by the musician is used to render and calculate the audio-feedback and visualization with defined audio descriptors. In this paper, we use the sensor data for the sonifications, which allows a flexible set-up and learning scenarios with and without a musical instrument. However, we believe that sonification can profit a lot from the definition of task-oriented defined features which emphasize the movement structure of interest. For that we here present our first steps towards using data mining techniques as plug-in for mapping-based sonification. Since, however, the described cases are already quite straight-forward characterized by the cartesian axes of the sensors, a mixture of such raw sensors and derived features comes ideally to application. We depict the sensor readings and a Takens-embedding (plot of y(t) against y(t-k)) for the case 2 in fig. 5. It can be seen that the correct execution is a circle-shaped figure, so that the deviation of that circle radian as well as the phase are promising features to be used for parameter mapping sonification.

5. INTERACTIVE SONIFICATION DESIGN AND EXAMPLES

The sonifications are programmed in SuperCollider. For the first versions, the sensor data are mapped to different acoustic synthesis parameters and used to create acoustic events, as explained in the following. This 4 cases can all be exercised with and without instrument and bow and are at beginners' level. An example video can be seen at: http://www.sonification.de/publications/GrosshauserHermann2009-TSM/ . The first video shows 4 strokes of a bow, where the first two are executions within the x/y-plane, so that only the violin sound can be heard, in the following two strokes a salient noise sound can be heard that is the result of the deviation from the ideal movement. Obviously, the noisy sonification does not or only marginally interfere with the perception of the musical sound signal, yet it efficiently keeps the player's attention aligned to the task.

Concerning case 1, the frequency of a certain tone changes according to the deviation of the z-plane. If the deviation is bigger than a given gain, a second sound appears, according to the contact of another string in real life scenarios.

In the 2. case, first, the spatial panning in the stereo position changes according to the deviation of the given y-plane. Then the panorama and a second sound is played, the latter according to the deviation of the z-plane.

In the 3. case, more or less attack or crunchiness of the sound is rendered according to different high acceleration changes. Changes in the “constant speed” phase are augmented with overdone volume changes. Also the ending of the bow, the deceleration phase is overdone with abrupt volume decrease or even combined with a crunchiness sound, to point out the importance of this matter.

Simple ticking sounds point to a missing or too strong rotation of the hand. In a certain range of rotation, similar to the 1. case, the volume is raised or reduced.

6. DISCUSSION

The possibilities of sonification will show in an intuitive way, that every change of the movement induces and influences a sound or changes certain parameters of an existing sound. This helps to understand intuitively, how a special movement, in this case the bowing on a stringed instrument works. The closed-loop auditory feedback supports the learning and the optimization of the movement, only by hearing. Hearing, the most important feedback channel for musicians, can't be trained enough by music students and pupils.

Our first impression is that the continuous mapping sonifications described above for case 1 and 2 work great and are quite efficient to direct the attention to improper executions. A comparison of strategies in their ability to induce better execution needs psychophysical studies. Also the age-related reactions and adapted sonifications are tested.

7. CONCLUSION AND NEXT STEPS

This paper has introduced the *sonified music stand* as a portable, integrated, versatile, interactive sonification system for musicians. The system combines sensor technology, real-time sonification, and new ideas on integrating multi-channel audio projection into a standard music stand into a usable every day system. The presented application has been specifically selected and optimized for the task of violin learning and the sonification examples demonstrate that the sound conveys useful information. This prototype system is still in a quite early state and we plan to conduct long-term user studies after we arrived at a couple of competitive and useful sonification approaches. We hope that our sonified music stand can make a positive contribution to better pedagogic approaches and methodical understanding, exercising-productivity rising methods and ultimately to the development of more healthy practices for musicians.

Future scenarios provide a highly compact multi-channel loudspeaker array, which can also be fixed to other displays such as computer monitors or other surfaces.

The next step is the development of a at least 8 + 1channel portable speaker setup for better sound localization in 3D sound scenarios and for complete loudspeaker arrays around surfaces, monitors, displays etc.. A high-power battery supply for off-the-line usage and several attachment features allow simple usage and fixing on and beside nearly every surface, monitors, stands, walls etc.. Also audio radio frequency transmission from the computer to the speaker is considered.

Finally, we are very convinced that we can easily adapt the system to other musical instrument playing problems and even to other fields such as movement training in sports and dance, where sonification can help to better learn and perform complex movements.

8.ACKNOWLEDGEMENT

The work has been supported by CITEC – Center of Excellence in Cognitive Interaction Technology. Thanks to Till Bovermann and Florian Grond for their help with SuperCollider programming.

9. REFERENCES

[1] Hermann, T. A*n introduction to interactive sonification* (guest editors' introduction). *IEEE MultiMedia*, 12(2):20–24, 04 2005

[2] T. Hermann, T. *AcouMotion - an interactive sonification system for acoustic motion control.* In S. Gibet, N. Courty, and J.-F. Kamp, editors, Gesture in Human-Computer Interaction and Simulation: 6th International Gesture Workshop, GW 2005, Berder Island, France, May 18-20, 2005, Revised Selected Papers, volume 3881/2006 of Lecture Notes in Computer Science, pages 312–323, Springer, Berlin, Heidelberg, 2006

[3] McMillen, K. *Stage-Worthy Sensor Bows for Stringed Instruments*, Casa Paganini, NIME 2008

[4] Bevilacqua, F. *The augmented violin project: research, composition and performance report*, NIME06, Paris, France, 2006

[5] Young, D. *Wireless sensor system for measurment of violin bowing parameters*, Music Acoustics Conference, Stockholm, 2003

[6] Goltz, v. d. C. *Orientierungsmodelle fur den Instrumentalunterricht*, G. Bosse Verlag, ISBN 978-3764925826, 1974

[7] Ferguson, S. *Learning Musical Instrument Skills Through Interactive Sonification,* Proceedings of the 2006 International Conference on New Interfaces for Musical Expression (NIME06), Paris, France, 2006

[8] Grosshauser, T. *Seeing the Inaudible. Descriptors Used for Generating Objective and Reproducible Data in Real-Time for Musical Instrument Playing Standard Situations*, AES Convention, Amsterdam, Netherlands, 2008