SENSOR FUSION AND MULTI-MODAL FEEDBACK FOR MUSICAL INSTRUMENT LEARNING AND TEACHING

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ABSTRACT

Pressure, motion, gesture and the coordination of all these parameters is an important task in musical instrument playing, exercising and teaching. New sensing and feedback technologies provide many possibilities to support the teacher and the student in the complex learning scenarios. In this paper we show with some practical examples the application of our current sensing technologies to teaching and everyday self exercising of violin. This starts from a left hand and chin pressure sensing method for coordination and position change analysis, a setup for force measurement and the weight allocation between the chin and left hand while playing, and a left and right hand thumb position and bending measurement method.

Different individually adapted feedback methods allow assisted teaching in teacher-to-student tuition and also efficient training in single exercising situations at home without a teacher. But also in combination with audio, video, and gesture recording, our setup is useful for accurate offline music sheet alignment and analysis.

Especially studies of complex movements as well as finger position and force distribution changes can benefit from this approach. We discuss the practical applications regarding the recognition of inaccuracy, cramping, and malposition.

1. INTRODUCTION

In numerous papers and articles about sensing technologies applied to musical instruments, here especially the violin, different methods and strategies are introduced and developed. E.g. Rasamimanana et al. [1] and Maestre [2] in his thesis about bowing gestures, interesting approaches about gesture recognition and especially bowing gestures have been developed and realized. The mainly used measuring methods in case of pressure are one or more foil strains placed in the middle of the bow. Another pressure measure method is described by Demoucron et al. [3] where the overall pressure of the bow hair is measured near the frog. McMillen [4] measures the first finger pressure, integrated into the commercially available K-Bow, which is a complete bow and does not allow to use the existing bow of the violinist. Other frequently used sensors and technologies are radio frequency transmission, gyroscopes, acceleration, and force resistive sensors, integrated into smallest PCBs, which are fixed on the frog. Beginning with the work of Bevilaqua et al. [5], meanwhile several similar setups exist.

These are just the most recent developments – the "history of violin sensing" goes back for many more years and approaches. There are other technologies, that allow sensor-based motion and gesture tracking in 3D and video or VICON-based systems, e.g. the one described by Ng [6], which are different to our approach and are not described here and would extend the list.

Figure 1: Example of the bow mounted sensors, (here pressure sensors) after ca. 3000 played bowing samples.

Beginning with the measurements of the relations of the pressure of each finger (see Fig. 1) and especially the changes of it during one bow stroke (see Fig. 4), we ad new aspects to this subject regarding different coordination issues and pressure allocations e.g. chin versus left hand. Conclusions and measurements regarding cramping, faults, bow position, and different types of bow strokes, just to name a few, are thereby made possible. In general, the fixation of the sensors is easy. The basic module usually contains 3 axis accelerometer and gyroscope, in this paper we emphasize the "FSR" (force sensitive resistor) sensors. In section 4 we demonstrate some typical violin teaching scenarios with the implementation of real-time feedback.

2. TECHNICAL SETUP AND DESCRIPTION

The used sensing method was introduced at WSEAS 2007 and NIME08 by Grosshauser [8]. First results of pressure and position measurements as well as applications for teaching, recognition of bowing type and quality and first composition examples have been shown.

In this study, we introduce several improvements and extensions, including a left hand sensor and a chin rest sensor.

The modularity of our setup allows a flexible number of sensors to be fixed on the bow or violin, depending on the needs of the student, teacher or performer. Data transmission is possible either to a computer via Bluetooth or directly to sound synthesizers or other modules via the serial port, OSC or MIDI. All sensor data are recorded, sometimes with additional audio and video recording, but most importantly real-time feedback can be composed and given directly onboard the PCBs.

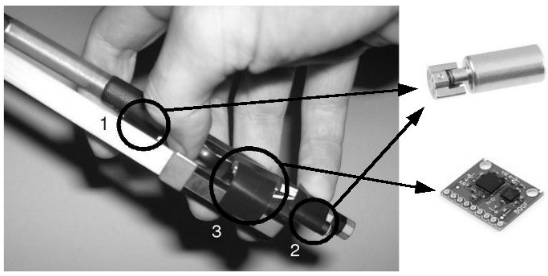

Figure 2: Sensor board (3) and 2 vibration motors (1 and 2) attached to the frog of the violin bow.

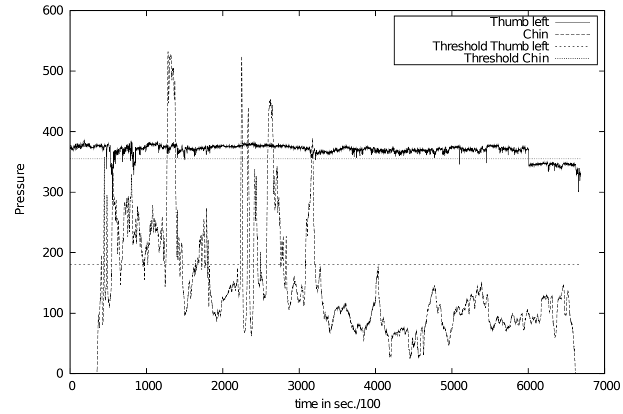

Figure 3: Chin and left hand weight/pressure allocation with adjusted threshold lines.

3. FEEDBACK TYPES

3.1. Tactile feedback

The vibrotactile feedback are short rhythmic bursts between 40Hz and 800Hz, which is the sensitive range of the mechanoreceptors in the fingers. The distance between the two motors is big enough for easy identification which one is vibrating. The amplitude and frequency can be varied. This allows to evoke a controlled level of attention by increasing and decreasing of the vibration level and by using different combinations between the motors. For example (1) all motors on, (2) only the indicating motor on, (3) one motor high frequency, other low frequency, and so on. The vibrotactile motors are attached directly to the bow, as depicted in Fig. 2 near the thumb and fingers. As described in Grosshauser et al. [10] the touch-sense feedback channel is extended and the awareness of the vibrotactile feedback is increased and trained (see video BowHapticFB at [7]). The feedback reacts if the fingers are in incorrect position or if the applied pressure is too strong.

3.2. Auditory feedback by Sonification

We use sonification, the non-speech auditory display of information as real-time auditory feedback. Sonification, as described in [11] 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. Even more, sound 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.

Sonification allows short and long-term unobtrusive monitoring and feedback of many parameters to the musical instrument player in real-time. 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. Particularly in the latter situation, attention is concentrated to other demands and in turn sometimes even basic skills are neglected and cause a significant loss in sound or performance quality. A sonification example is given, evaluated and published in [12] by the authors Grosshauser and Hermann.

3.3. Visual feedback

The simplest and mostly used visual setup in every-day teaching and practising is a mirror. Gesture, posture and angle detection are observed easily and without delay. The key advantage of the before mentioned direct vibrotactile feedback is, that it is given at the exact position, where it refers to. This is also possible with visual feedback, small "displays" e.g. LED lights or other small devices, which are very lightweight and can be attached to the observed position, where the feedback is needed and expected.

The visual feedback used here is adjusted and attached according to the observed position or problem. This means for example a LED at the chin rest and a second one at the neck of the violin. For standard displays, real-time plotting and simple graphical displays are sometimes useful after an adaptation phase. A demonstration can be seen in the video VisFB at [7].

4. STUDIES AND EXEMPLARY TEACHING SCENARIOS

In the following part, some examples for complex motion, posture and position scenarios in violin teaching and playing are described. All motion and force data of the experiments including the real-time multi-modal feedback are recorded for later data analysis and real-time plotting.

4.1. Force allocation between left hand and chin

Problem: Student applies too much pressure to the chin rest and the neck of the violin.

Pedagogical aspect: Understanding and getting a feeling of the violin's weight allocation between the pressure from the chin on the chin rest and the weight and the force in the left hand.

Real-time feedback: Indicating lights (LEDs) near the left hand and on the chin rest during the exercise. The lights are switched on, when a certain threshold is exceeded. In the graph (see Fig. 3) the thresholds are the straight lines "Threshold Thumb Left" and "Threshold Thumb Right".

Results: The student is able to apply the appropriate pressure herself to the chin rest during the first bowings, although she started with the wrong pressure. See 0-35 sec., "Chin" value, applied chin pressure and "Thumb left",

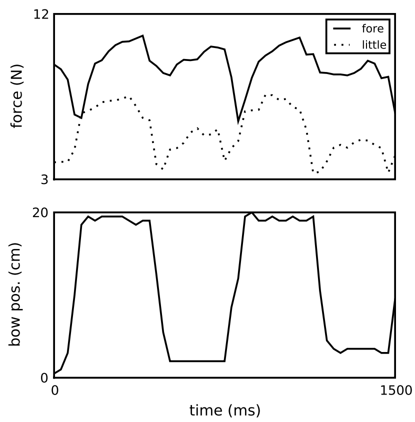

Figure 4: Plot of pressure of fore- and little finger and bow position, Martele up- and down-bow strokes.

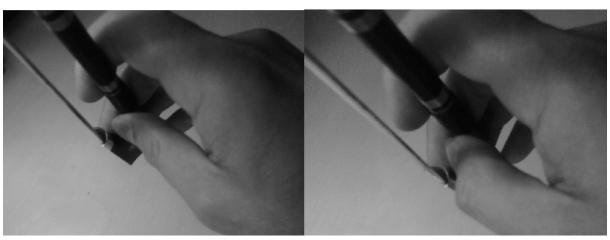

Figure 5: Wrong (a) and correct (b) thumb position on the bow.

0-60 sec., applied force of the left hand thumb (also Fig. 3).

4.2. Right hand thumb position

Problem: Student starts playing with inaccurate right hand posture.

Pedagogical aspect: Learning to keep the correct bending of the right hand thumb.

Real-time feedback: Vibrotactile feedback (see video BowHapticFB at [7]) gives a correction signal. The correction signal is given by the vibrotactile channel, directly near the thumb and indicates the student to change the thumb position.

Results: The student changes the bending of the thumb to the correct posture (see Fig. 5b), although she started with the wrong posture.

4.3. Left hand thumb position

Problem: Student starts playing with inaccurate left hand thumb position.

Pedagogical aspect: Learning to keep the correct position of the left hand thumb.

Real-time feedback: Visual feedback (see video VisFB at [7]) gives a correction signal. The correction signal given, directly near the left hand thumb, indicates the student to change the thumb position.

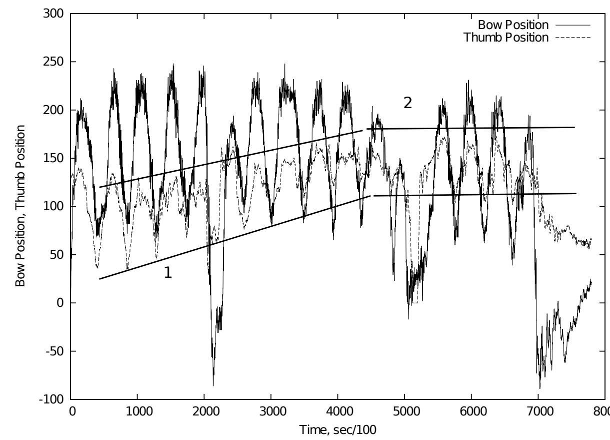

Figure 6: Self correction (phase 1) of the student during playing (with visual real-time feedback) and corrected position (phase 2).

Exercise and Results: In this scenario, the student plays a simple scale and tries to correct the thumb position. The range itself was adjusted during a short supervised gesture and posture preparation phase. The student begins playing with wrong thumb posture and changes the position of the left hand thumb (see Fig. 5b and Fig. 6, phase 1), and after some bow-strokes, the position is changed to the correct range (see Fig. 6, phase 2).

4.4. Left hand and chin coordination during stage shift

In this example, we are interested in the left/right hand synchronization and left hand pressures itself. Left hand sensing for string instruments is underrepresented compared to right hand research. A recent article from Kinoshita et al. [9] shows one possibility to measure the left hand finger pressure at different volumes, tempi, and bowings on one single position on the fingerboard. We observe our coordination demand while playing any notes and music pieces and record the left and right hand parameters simultaneously (similar to [8]). This means, finger pressure compared to bowings, speed, volume, and with different types of vibrato and double stops.

In this study, pressure sensors are fixed on the chin rest and on the neck of the violin, where thumb and the side of the first finger are in contact.

Problem: Student learns to shift the stages or to coordinate difficult stage shifts within a piece.

Pedagogical aspect: Supporting the understanding of the weight allocation between chin and left hand (and bowing) during a stage shift.

Real-time feedback: In this case we use visual feedback, meaning real-time plotting of the pressure graphs, to explain visually the force allocation during the stage shifts.

Exercise and Results: The student plays a simple scale and tries to optimize the transition between the left hand and chin (data shown in Fig. 7). The recording of position shifts shows the coordinated reduction of the finger pressure, here of the thumb and of one of the fingers 1-4, the increase of the chin pressure during the shifting phase and the increase of the pressure of the new position. These data allow a precise analysis, especially of

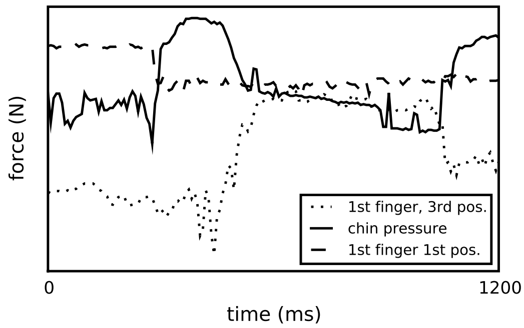

Figure 7: Typical real-time visual display of a transition between first and third position.

the timing between finger and chin rest, which is one of the most complex movements to learn and execute for beginners and to optimize for advanced students. The analysis can help the student to better understand the coherences of the correct timing and weight allocations between chin and left hand. The teacher sees, beside the latter mentioned coherences, the pressure and effort the student applies. Beside other parameters, this indicates a lot about the smoothness and well-being of the student.

5. CONCLUSION

The full potential of sensing and feedback supported violin tuition is only tapped in this article. We currently work on more, easier to use and cheaper sensors and we will extend the above mentioned possibilities. More advanced feedback methods and stand-alone solutions will bring new possibilities and simplification. The practical evaluation is going on and we find more and more useful teaching situation, where this technology is applied. Other instruments like string instruments in general, piano and wind instruments are considered as well.

The combination of the mentioned methods and setups with advanced data mining techniques is a further promising way of recognition of different playing styles, left/right coordination, cramping detection, and many more possibilities. This may open up useful tools for every-day exercising and teaching. Especially the pressure and force sensors offer many more possibilities for new music compositions in combination with simplified real-time interaction within electronic music environments.

6. ACKNOWLEDGMENTS

The work has been supported by CITEC – Center of Excellence in Cognitive Interaction Technology.

Special thanks to my violin students Stefanie Schirmer and Fabian Hanter.

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