Introduction

Over the past years many audio and gesture parameters have already been investigated with sensors, audio and video analysis in the fields of exercising, teaching and performing of musical instruments. In numerous recent papers and articles of e.g. Rasamimanana et al. [6] and Maestre [4], several approaches about gesture measurement and recognition, especially bowing gestures have been developed and realized. Beside the first finger pressure measurement possibility with the K-Bow from Keith A. McMillen, which is a complete bow and does not allow violinists' to play with their own bow they are used to, developments of Bevilaqua et al. [1], also partly used by the before mentioned authors are the first developments. This means mainly radio frequency data transmission, gyroscopes and acceleration sensors integrated into small PCBs fixed on the frog of the bow. These are just the most important developments – the "history of violin sensing" goes back for many more years and approaches. All video or VICON based systems, e.g. the one described by Ng [5] are not further mentioned here and would extend the list. The systems allow sensor-based motion and gesture tracking in 3D, overall bow pressure and many more parameters. The method described here includes Grosshauser's approach [2], to additionally measure the pressure of each finger on the bow.

Technical Setup

The general idea is optical tracking with emitters (LEDs) on the bows and receivers (photoresistors) on the violin. The setup works also the other way round with emitters on the violin and receivers on the bow. But the emitters fixed on the bow simplify the setup, due to easy installation, meaning no additional electronics on the frog or wrist. The SMD (surface mounted device) LEDs (light emitting diodes) need a power supply, only, which is a small battery fixed on the frog and thin copper wire connections to the LEDs. A ring of the LEDs is fixed on the bow every 8 cm (see Fig. 1). In the simplest implementation they are switched on continuously. In a more complex design, certain blinking patterns or color changes improve the measurement parameters and increase accuracy.

Figure 1: Every 8 cm a ring of SMD LEDs is fixed on the bow. Thin copper wires are used for electrical connection to the battery on the frog.

This means, at least 8 rings are necessary to capture the whole length of the bow (more rings increase the accuracy). The setup is very lightweight, especially very light electronics on the curved wood rod, crucial for unhindered professional bowing techniques. For the simplest design, no data connection between bow and violin is needed, meaning no additional cables fixed on the musician's arm and no further PCB for wireless data transfer or processing has to be fixed on the frog. Two different LED setups are tested: The first consists of IR SMD LEDs only (setup 1), 6 or more LED rings, 2 to 4 LEDs each, fixed on the bow every 8 cm (or less, if more rings are used). In the second further colored SMD LEDs are added (setup 2), 6 or more LED rings each with a different color, each ring consisting of 2 to 4 LEDs, fixed on the bow at least every 8 cm.

The receivers are placed under the strings between the bridge and the fingerboard. The placement below the strings allows unhindered playing without influencing the musician or the sound of the violin. In setup 1, 4 IR photoresistors are used to measure the motion of the IR emitters on the bow (see number 1 in Fig. 2). In setup 2, additionally at least one color sensor is used to capture the LED's color moving near the sensor (see number 2 in Fig. 2).

Figure 2: 4 IR photoresistors (1) and color sensor (2) is fixed under the strings. The IR photoresistors are used to capture bow speed, bow to bridge distance and up- and down bowing, the color sensing photoresistor is used to detect the position of the bow (frog, tip or middle).

With setup 1 the bow speed, direction (up and down bowing), bow to string angle and contact point on the string between bridge and fingerboard is measured. In setup 2, additionally the bow position between tip and frog is measured. The emitters on the bow and receivers on the violin can be fixed the other way round to decrease the influence of ambient light.

Measurements and First Results

Several hundred bow strokes of different style and from different violinists were recorded with the described setup fixed on their bows and violins. The violinists all confirmed the unobtrusiveness of the emitters and receivers fixed to their instruments. Until now, only the legato strokes are analyzed.

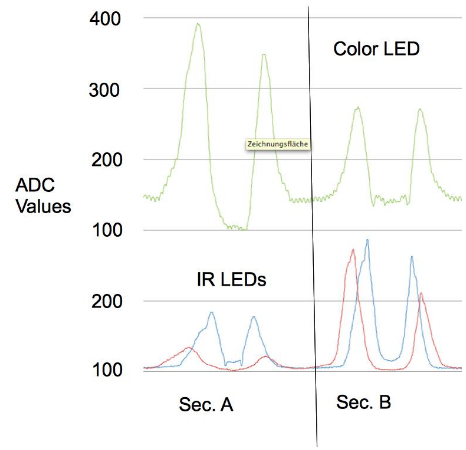

Figure 3: Sec. A shows a legato bow stroke (around 10 cm linear bow movement) close to the bridge, sec. B in the middle between bridge and fingerboard with incorrect bow to string angle.

These first measurements show the following results:

- The up and down bowing recognition is robust.
- The accuracy of longitudinal bow position recognition is around, but not limited to 2 cm. No calibration necessary, no influence of bow rotation.
- The accuracy of bow to string contact position measurement is around 0.5 cm.
- The bowing speed measurement has an imprecision

of around 20% but can be refined with better detection algorithms. The recognition works independent of bow pressure.
- Bow to string angle measurement is robust.

Outlook and Future Work

The setup shows robust detection of up and down bowing, bow position, speed, bow to string contact point and angle. The combination of these parameters, maybe additionally with finger pressure and bow rotation measurement methods of previous works are useful parameters for performance analysis and realtime applications like augmented instruments for new musical expression. The sensor setup can be combined with specific audio descriptors as described in Grosshauser et al. [3] and other sensors, like e.g. the standard 9 DOF (degree of freedom, meaning 3 axes acceleration, 3 axes gyroscopes and 3 axes magnetometer) or 10 DOF sensor boards fixed on the frog to make further investigations in bowing and sound analysis. Further experiments with optical flow sensing with improved spatial resolution are currently conducted. All technologies will be combined and integrated into our system and by doing so, covering the most important bowing and sound parameters in string instrument playing.

References

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