CONNECTED MUSICIANS - EXAMPLES OF NEW SUPPORTIVE TECHNOLOGIES FOR MUSICIANS' PERFORMANCE ANALYSIS AND DAILY ROUTINE

T. Grosshauser, D. Bannach, A. Calatroni and G. Tröster

Institute for Electronics
ETH Zurich
Switzerland
Grotobia|Calatron|Dbannach|Gerhartr@ethz.ch

ABSTRACT

Many technologies are used in musical instrument teaching and learning, starting with audio and video recordings, up to mobile phones equipped with several apps. In this paper, we try to show possibilities to integrate further technologies in musicians' daily routine up to performance research. We describe several body worn and musical instrument integrated sensor setups in combination with a new app for data recording, storage and server connectivity, server based data distribution, visualization and several possibilities for real-time feedback. The system is a further development of PART (Performing ARts Technologies) system including, but not limited to the following musical instruments: Stringed instruments, clarinet, trumpet, cornet, trombone, drums and piano, but setups for several more instruments are available or further developed continuously. In general, for nearly every musical instrument and problem statement a specific modular set of sensors can be developed, adapted or already exists. Till now, the measured parameters include mainly motion, force, pressure and posture. Beside the further developed PART setup, some applications for string instruments and trumpet are described in this paper.

1. INTRODUCTION

More and more technologies are added to the mainly audio and video based systems in musical instrument playing and performance research and analysis (see Ng et al. [1], Baader et al. [2], [3] and Grosshauser et al. [4]). In trumpet and trombone playing Bertsch et al. in [5], Mayer et al. in [6], Petiot in [7] and Grosshauser et al. in [8] introduced sensor based systems to measure lip pressure while playing. For PART[1] (see Grosshauser in [9]), the most important parameters are:

- unobtrusive measurements and fixation of the electronics to the musician or musical instrument,
- possibility to capture nearly all relevant parameters while music making,
- easy to use, adapt and individualize,
- stand alone operation mode and wireless app/server connectivity,
- server based data storage, sharing, visualization and analysis,
- app based real-time feedback and visualization.

Although the system still is in development, several components are finished and ready to use in daily musicians' routines like practicing, teaching or rehearsing (distributed by Bonsai Systems[2]). Further developments including several new sensors or combined sensor systems (stand alone or data streaming) are described in the following comprising wireless data transmission based on Bluetooth low energy (BLE), improved server- and app connectivity, data sharing, saving, visualization and real-time feedback.

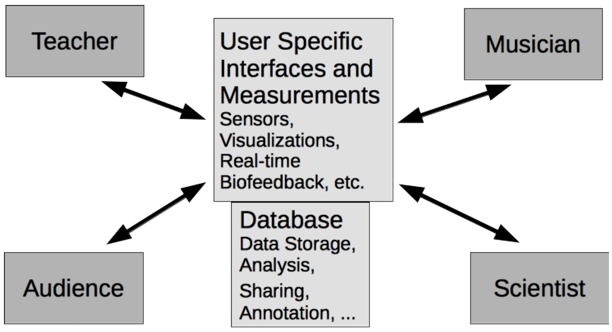

Figure 1: The central unit in the PART system is the user-centric (here musical instrument teacher, musician, scientist and audience or music enthusiasts) interface, including individually adaptable sensors, app and server connectivity providing data storage and visualization and several more features like data sharing and real-time feedback.

2. BASIC SETUP AND TECHNICAL DESCRIPTION OF THE FEATURES

Fig. 1 shows the underlaying idea of providing different kinds of data for audience, musicians, teachers and scientists. Server based online interfaces and apps allow the access to the recorded data. The data can be any sensor data, audio and video. The sensors (nearly any sensor can be integrated) can be used for motion capture, pressure and force measurement up to posture recognition. On the software side, the app allows adjustable individual real-time feedback, data visualization, recording, distribution, server up- and download and automatic sensor recognition and connectivity.

Fig. 2 shows a possible data flow sequence and technical features. These start with the sensors, online and offline data storage on the sensor boards while recording, wireless data transmission to e.g. mobile phones (in streaming mode or offline after the recording), server connectivity, real-time feedback and several more possibilities.

A priority was to simplify the usage and to reduce set up time of the complete system for simple integration into daily

[1] https://www.fb.com/PerformingArtsTec

[2] http://www.Bonsai-Systems.com

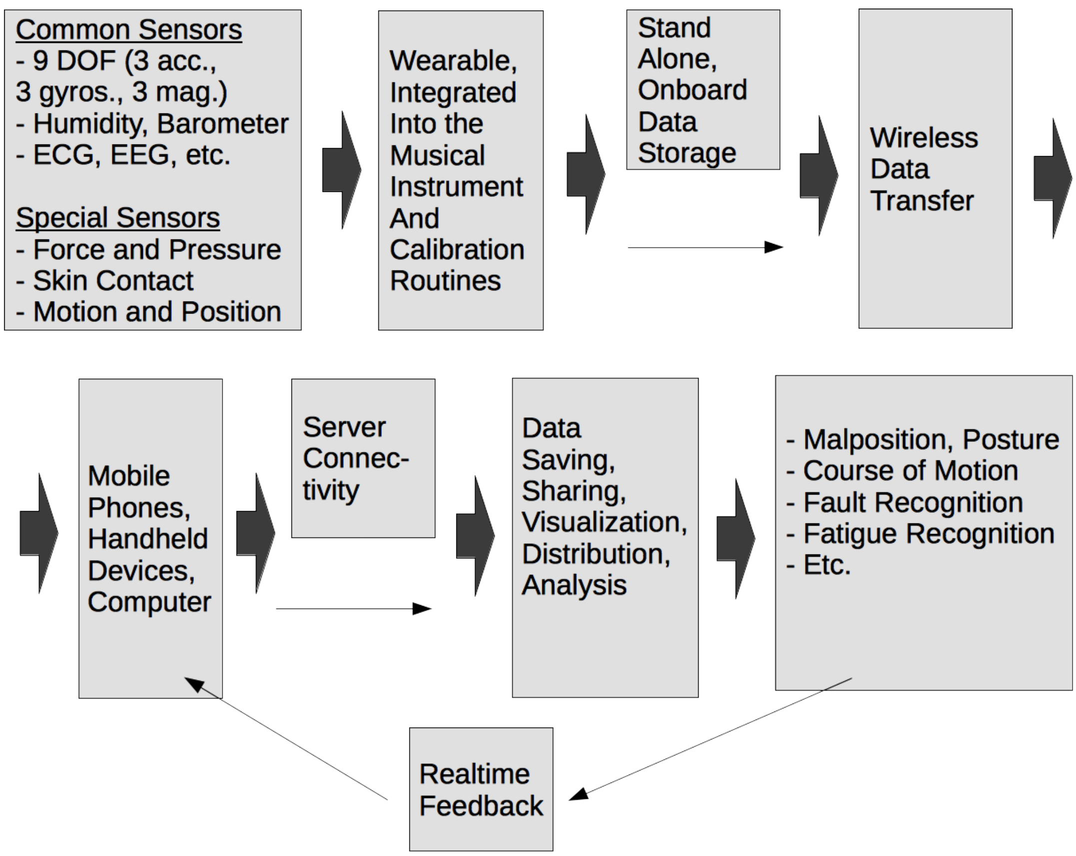

Figure 2: This figure shows the principle data flow from the sensors (motion and posture, pressure and force measurement and combination of all of these including calibration routines), the wireless data transfer including memory on the sensor nodes for stand alone use, app and server connectivity with versatile features including real-time biofeedback.

teaching and practicing scenarios. Beside daily usage, the precision of the sensors and possibilities of extensive data calculation on the sensor board, in the apps and on the server creates many possibilities in scientific experiments, on stage, or daily music making and teaching. Most relevant parameters (like force, motion and posture) can be captured of single musicians but also of music groups.

Preparation and Setup of PART

First, regarding to the specific problem statement, the relevant sensors or complete sensor setups are chosen. After doing so, all sensors are connected with the data logging app. After the app is started, all available BLE sensors in a range of around 20 m are shown. The individual set of sensors chosen for experimentation or measurements is composed by tapping on their icons shown in the app. The wireless connection is established automatically. In a second step, different visualizations can be selected and if necessary, thresholds for real-time feedback can be adjusted. All data of each selected sensor can be recorded and saved in *.csv file format to allow further calculations in standard statistic programs. Additionally, sharing and saving the recorded data via email, online storage service providers or automatic server upload is possible. If the server upload is used, a web based interface provides multi-modal online data management, visualization, alignment, analysis and annotation.

2.1. Application Scenarios

In the following chapters, some basic applications for the complete system and several sensor systems are described.

2.1.1. *String Instruments: Miniatur- IMU Based Right Hand Measurements*

The measured and calculated parameters in the following examples are all based on 9 DOF (9 degree of freedom) IMUs (inertial measurement units) measurements. The measured parameters are:

- Bow position
- String level
- Bow rotation
- Bow to string angle

String Level and Bow Position

Several sensor based bow position measurement methods exist like in Demoucron et al. in [10], but mostly additional sensors have to be attached to the bow with a certain influence while playing, like shortening the playable overall length of the bow hair.

In our scenario, a 9 DOF IMU (see fig. 3) is fixed on the upper half of the forearm (see sensor nr. 1 in fig. 4) to reduce the influence of the wrist movement on the bow position measurement. After the sensors are fixed, a short calibration routine

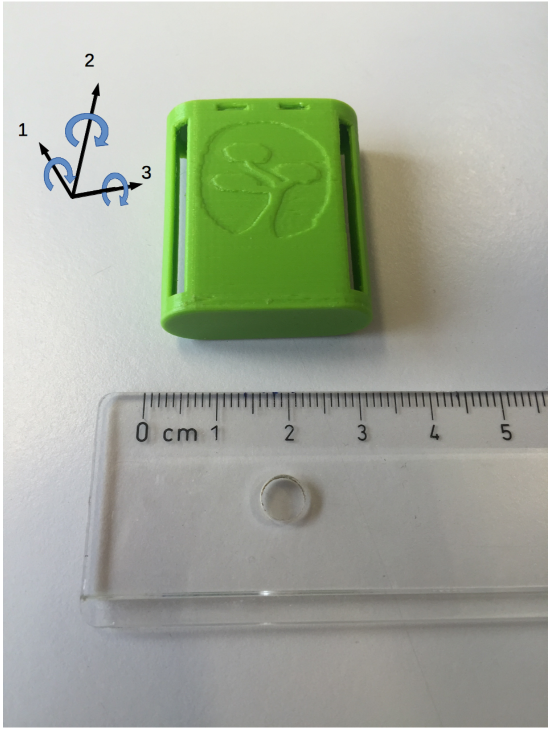

Figure 3: This figure shows the 9 DOF IMU, dimension is 10 x 29 x 33 mm, weight is 9 gr including rechargeable battery (chargeable via micro USB connector) providing yaw, pitch, roll (arrows 1, 2, and 3), w, x, y, z quaternions and raw data of the three axes accelerometer, three axes gyroscopes and three axes magnetometer. Different casings are available for several situational fixation possibilities.

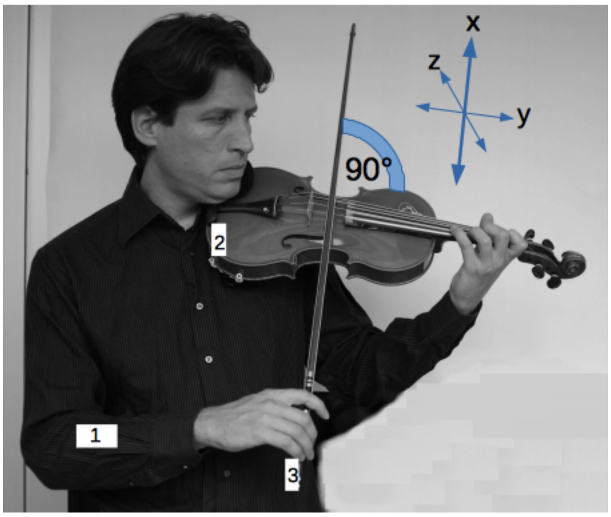

Figure 4: This figure shows the placement of three 9 DOF IMUs on the violin and the body. The first is on the fore arm, the second on the violin and the third is on the frog of the bow. Each 9 DOF IMU transfers the data to the app on a mobile device. Due to this topology, each node can act autonomously (battery, processor unit and onboard memory) and can be added or removed without disturbing the other sensors.

is done, first a defined starting position e.g. bow position frog on the g-string and a second posture like bow position frog on the e-string. The IMU measurement resolution is 0.1°angular degree, sampling frequency is up to 80 Hz.

With the z-axis rotation data of sensor 1 (see fig. 4) the bow position of 4 bow strokes from frog to tip on G, D, A and E string with a stop every 5cm (see blue line in fig. 5) is measured. The accuracy of position capturing is 1 cm with little body movements. Strong body movements while playing decreased the accuracy, but it is sufficient for stable middle, upper and lower bow half recognition (the most used terms regarding bow position in daily string instrument playing). The red line in fig. 5 represents the 4 string layers. Especially for beginners learning legato bowing these measurement method and data are useful.

Body movements mainly change the orientation data, which are not used in this setup, although a certain influence remains. To decrease this, a second sensor (see sensor nr. 2 in fig. 4) is fixed on the violin to measure the movement of the musician and the instrument relative to the forearm. By doing so, the accuracy is increased even with larger body movements.

Bow to String Angle Measurement and Bow Rotation

Sensor nr. 2 and 3 (see fig. 4) is used for bow to string angle detection.

First the sensors are calibrated both together in a fixed position, e.g. on the bow or the violin. Sensor nr. 2 is fixed on the violin, sensor nr. 3 on the bow. After the calibration, the two sensors measure the deviation of the orientation of each sensor to each other in the z-axis (orientation). If the bow and the sensor nr. 2 is parallel it is a 90° bow to string/violin angle. As soon as bow to string angle changes, the positive or negative difference of the sensors alias the deviation to the 90° angle is shown. Fig. 6 shows the string to bow angle changes during several bow strokes. Further the rotation of the bow and the string levels (see red line in fig. 5) are measured and clearly recognizable.

Fig. 7 shows the rotation of the bow along the bow stick. This is a further parameter measured with IMU nr. 3 (see fig. 4), an additional parameter to describe the full motion of a bow while playing.

2.1.2. Brass Instruments: Trumpet and Cornet

In this section the PART system is used for lip pressure measurement in trumpet and cornet playing (see fig. 8), introduced by Grosshauser et al. in [11]. The setup consists of two modules, one (see no. 2 in fig. 9) with three miniature load cells and a 9 DOF IMU with 3 axes accelerometer, 3 axes gyroscopes, 3 axes magnetometer, (providing yaw, pitch roll and w, x, y, z quaternions) the other one (see no. 1 in fig. 9) with three adjustable screws to secure the force closure between mouth piece and instrument. The intersection between the mouthpiece and the trumpet is sealed with a silicone tube, part no. 3 (all parts in the following description see fig. 9). The three screws no. 4 are inserted into part no. 1. These screws push part no. 1 and 2 apart from each other by touching the tip of the miniature load cells. By doing so, the mouthpiece is pushed around 1 mm out of the trumpet and the lip pressure is transmitted to the load cells directly via the screws (no. 4), which are tightly fixed on the instrument (part no. 1).

The 9DOF IMU allows conclusions about the position and orientation and the acceleration of the instrument in all 3 dimensions while playing. The sampling frequency is up to 80 Hz. The final force resolution is below 1 gr, or below 0.01 N. A LiPo Battery is used for power supply, rechargeable via a micro USB adapter. The overall weight of the complete setup is 50 gr.

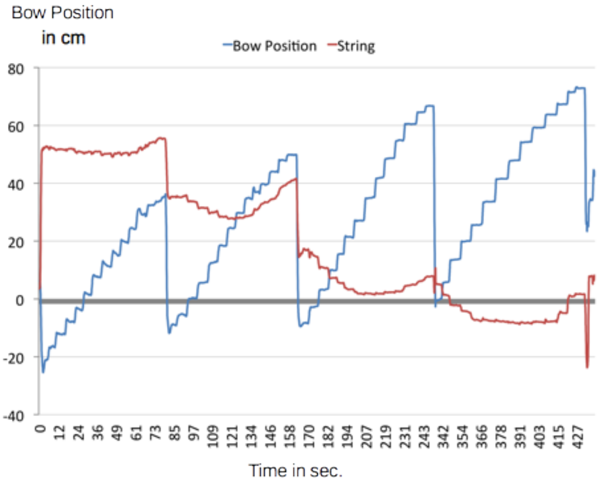

Figure 5: This figure shows a bow stroke on G, D, A and E string. The 9 DOF IMU is fixed on the forearm, the blue line are the roll data "bow position", showing a bow stroke with a stop every 5cm. IMU pitch data "string" show the bow level on each string from left to right according to the strings G, D, A and E (red line).

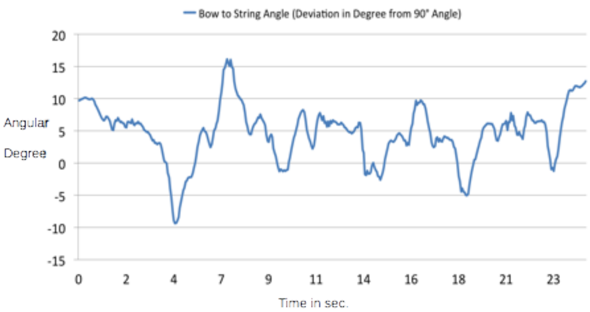

Figure 6: This figure shows the deviation of the 90° angle angle during a bow stroke on the E string. One 9 DOF IMU is fixed on the bow, the other one on the violin.

3. CONCLUSIONS AND FUTURE WORK

The basic work flow and usage of the extended PART system is demonstrated with several examples. It shows, that these additional technologies could be applied in daily teaching, practicing and performance science. Based on a plug-and-play process to use the sensors needed by simply adding them into an existing setup, the ease of integration into daily work- and practicing flow is shown. It is demonstrated with string instrument and trumpet scenarios. The main application fields right now are teaching, practicing, learning and performance research but also many experiments could be carried out in music medicine and physiology, and last but not least new possibilities for writing and composing music for completely new and augment musical instruments are given.

4. ACKNOWLEDGMENTS

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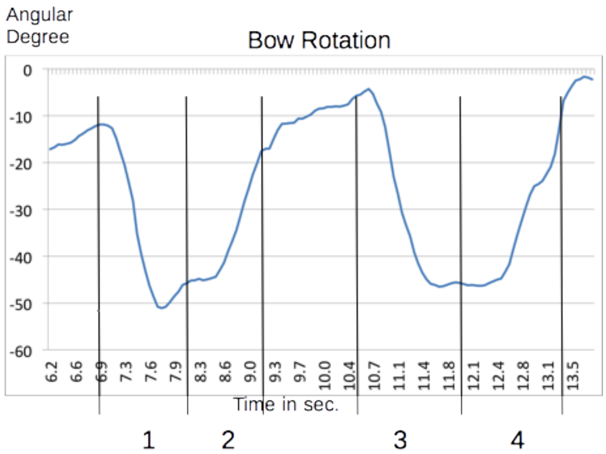

Figure 7: This figure shows the bow rotation of 4 up- and down legato bow strokes around the x-axis. Nr. 1 and 3 are down bows, 2 and 4 up bows.

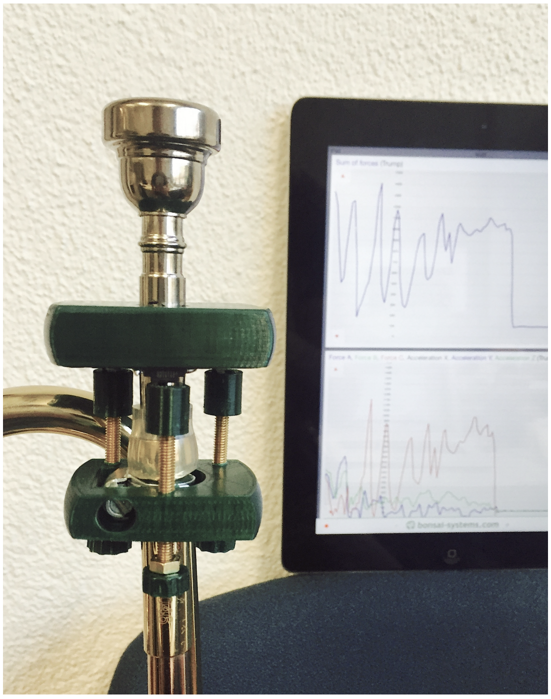

Figure 8: This figure shows the lip pressure sensor fixed on a trumpet and real-time data visualization with the logging app. The first row shows the sum of the 3 pressure sensors, the second row data of each sensor.

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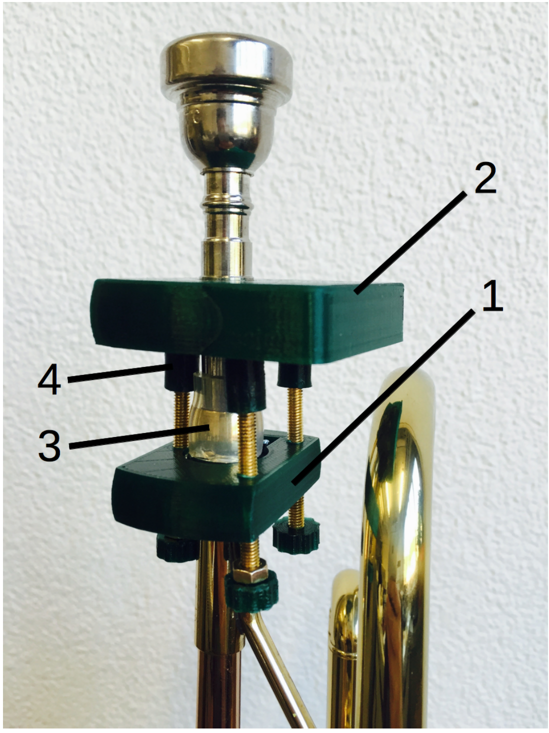

Figure 9: This figure shows the sensor module for lip pressure measurement fixed on a trumpet. Part 1 is the lower fixation part housing the three adjustable screws (4), touching the three load cells placed in part 2. These are the 3 contact points for force transmission from mouth piece to instrument. Between mouthpiece and trumpet there is a 1 mm gap (the mouthpiece is pulled around 1 mm out of the trumpet from the normal fixed position), sealed with a silicon tube (3). Module 2 includes the PCB with three miniature load cells, a 9 DOF IMU (providing yaw, pitch roll, w, x, y, z quaternions and raw data of the 3 axes accelerometer, 3 axes gyroscopes, 3 axes magnetometer), a BLE module and a rechargeable battery, chargeable via USB micro connector.

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