SABRe: The Augmented Bass Clarinet

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ABSTRACT

An augmented bass clarinet is developed in order to extend the performance and composition potential of the instrument. Four groups of sensors are added: key positions, inertial movement, mouth pressure and trigger switches. The instrument communicates wirelessly with a receiver setup which produces an OSC data stream, usable by any application on a host computer.

The SABRe projects intention is to be neither tied to its inventors nor to one single player but to offer a reference design for a larger community of bass clarinet players and composers. For this purpose, several instruments are made available and a number of composer residencies, workshops, presentations and concerts are organized. These serve for evaluation and improvement purposes in order to build a robust and user friendly extended musical instrument, that opens new playing modalities.

Keywords

augmented instrument, bass clarinet, sensors, air pressure, gesture, OSC

1. INTRODUCTION

Augmented instruments have been developed since electronic components were small enough to be added to a musical instrument: from grand piano[2] to the transverse flute[17, 14]. All these instruments have used specific approaches to add layers of control data to the acoustically produced sounds. With a specific focus on wind instruments, one can mention the following examples: finger pressure on keys[3], distance between the instrument and a fixed point[14] or between two instrument parts[6], key displacements [11, 17], DSP analysis of produced sound[3], knobs, sliders or touch-pads [7, 3] and the always effective trigger switches.

Depending on the degree of awareness necessary to control these additional layers, the instrumentalist may face a lack of mental resources necessary to play at the same time an acoustic instrument and a controller at a virtuoso level. Of course, practicing – over many years! – can partially remedy this problem, but it would sometimes be convenient to generate control data without the need to change the player's skills. This would shift the responsibility of processing of control data to the composer/programmer.

Furthermore, augmented instruments are often closely tied to their inventors, who are sometimes players as well as composers. This constrains the potential for feedback or collection of ideas and renders the dissemination of a potentially interesting product more difficult.

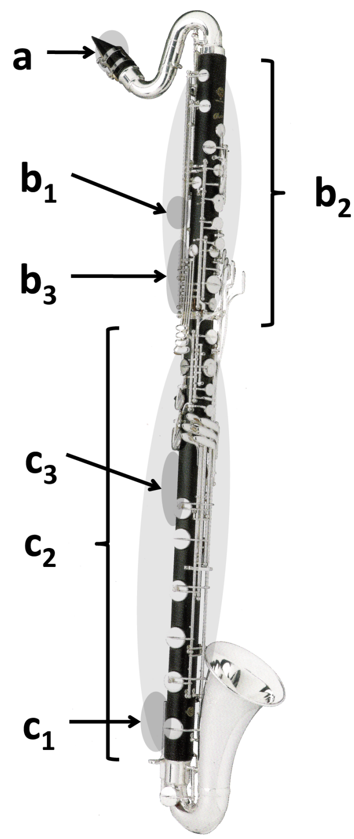

Figure 1: Schematic overview of the sensor groups, related to their PSU. a) airMEMS, b) left hand: switches (b_1), keys (b_2) and LH PSU (b_3), c) right hand: IMU (c_1), keys (c_2) and RH PSU (c_3).

For these reasons, the Sensor Augmented Bass clarinet Research (SABRe) project aims to build an augmented bass clarinet for professional musicians, permitting them to continue relying on their trained virtuoso skills, while developing new ways of expression. Through the project, several instruments are made available to a community of players and composers in workshops or residencies, in order to involve them in early development phases and be to able to evaluate weaknesses and more closely integrate the end-users' needs into the final design.

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2. HARDWARE

SABRe is made of four groups of sensors (Figure 1) which are connected to pre-processing & sending units (PSU). Each group measures a different gesture quality that occurs at a different level of instrumental awareness, while remaining ergonomically embedded in the instrument. These groups are: key sensors, thumb switches, inertial measurement unit (IMU) and air pressure sensor (airMEMS). They can be used independently from each other and – with the exception of one cable for supplying power between the lower and upper part of the clarinet – require no wiring.

2.1 Keys sensors

Each independently movable key of the clarinet is equipped with the pair of a permanent magnet and a linear Hall Effect sensor, which permits to measure the key position very accurately. The magnet is coupled to the key movement by a bracket with several degrees of freedom, which enables the precise adjustment of its position and the physical optimization of sensing amplitude (see Figure 2). Opposite to it, a Hall Effect sensor is attached to the clarinet body and connected to one PSU.

The *Selmer Privilège* bass clarinet has 25 independently movable and non-redundant keys, divided into thirteen on the upper and twelve on the lower part. On each section of the instrument, the Hall Effect sensor output of all keys are multiplexed to one ten-bit analog-to-digital converter and sequentially polled by the PSU.

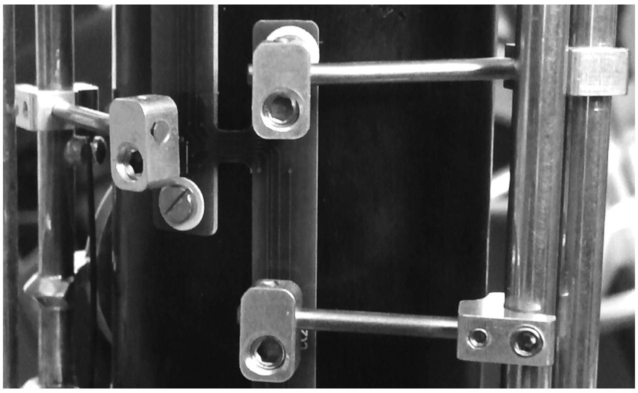

Figure 2: Magnet brackets with several degrees of freedom, clamped to the key axes and positioned above the Hall effect sensors.

2.2 Thumb switches

Just below the left thumb key, three small switches are placed on a platform in such a way as to let the player activate them while pressing the thumb or the octave key. Since the buttons remain somewhat difficult to use while playing, their main purpose is the triggering of "low-frequency events" such as scene changes or slow cue sequences and by no means that of virtuoso playing.

2.3 Inertial Measurement Unit

The inertial measurement unit (IMU) is placed as low as possible on the bass clarinets body, where the movement amplitude is at a maximum when playing with a neck belt. It is made of an accelerometer, a gyroscope and a magnetometer, each with three measurement axes and at least thirteen bits of resolution. It delivers information about rotation, linear displacement, inclination and orientation of the instrument. An Attitude Heading Reference System (AHRS) will be implemented with the data of these sensors[10] in order to get the absolute position of the instrument in space.

2.4 Pre-Processing & Sending Unit

The three sensor groups mentioned above are connected to two pre-processing & sending units (PSU): the upper one serving for the thirteen left hand keys and three thumb switches (LH PSU), the lower one for the twelve right hand keys and the IMU (RH PSU). On both halves, the PSUs are centered along the instrument body and connected to the different sensors with flat printed circuits (FPC), as shown on Figure 3. Each PSU is responsible for polling, processing and packaging sensors data for later transmission, and manages the communication sequences with the receiver.

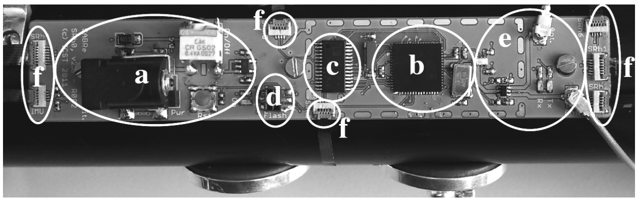

Figure 3: Right hand PSU with power supply (a), RF micro-controller (b), multiplexer to the ADC (c), programming connector (d), radio control with antennae connectors (e) and FPC to the sensors (f).

Power is supplied by a 3.7 V Li-ion battery with a capacity of 1000 mAh, mounted below the RH PSU. Power for the upper part of the clarinet is transferred through a short cable plugged across the clarinet articulation, in order to conserve the instruments disassembly capability.

The battery is mounted in a holder and can either be removed and charged separately by the user or charged in place with a standard cell phone charger through a Micro-USB plug.

2.5 airMEMS

Air pressure used to produce sounds in wind instruments has been widely modeled[8, 1, 5, 12, 15] or investigated in laboratory situations[9, 4], as well as used for performance practice in commercial products like the EWI[1] and WX5[2] saxophone-like controllers, as well as the BCA3 breath controller[3] and a hybrid saxophone patented by Yamaha in 2006[13]. The laboratory systems on the one hand are not usable for stage situations and the performance-based wind controllers on the other hand block the air flow in order to measure the mouthpiece pressure or do not make any use of it for sound production.

In the case of an augmented instrument, the use of air pressure as an expressive control value makes only sense if the instruments acoustic characteristics remain completely undisturbed. For SABRe, a modified mouthpiece has been developed, that measures the pressure directly in the player's mouth, at the tip of the mouthpiece (see Figure 4), without altering its acoustic properties.

The airMEMS sensor-platform has its own PSU, which manages data polling, packaging and communication. It also has a smaller, separate battery and can thus be used independently on other non-SABRe instruments. This will

[1] `http://www.akaipro.com/ewiusb`, accessed on April 20, 2012

[2] `http://usa.yamaha.com/products/music-production/midi-controllers/wx5/`, accessed on April 20, 2012

[3] `http://usa.yamaha.com/products/music-production/accessories/breathcontrollers/bc3a/?mode=model`, accessed on April 20, 2012

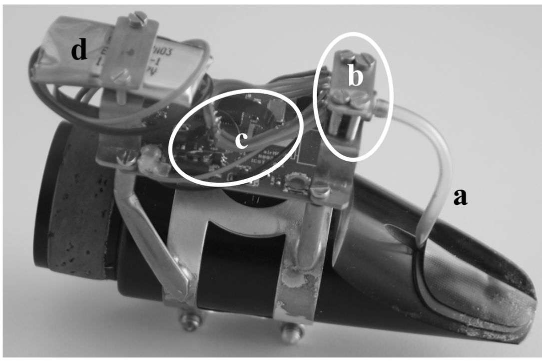

Figure 4: airMEMS-modified mouthpiece, with flexible hose (a), pressure sensor (b), RF electronics (c) and battery (d).

enable the separate development of airMEMS sensors for e.g. pedagogical applications on other clarinet or saxophone mouthpieces.

2.6 Receiver

The receiver manages registration and synchronization of the PSUs, as well as data forwarding from the radio transceiver to the USB port of a host computer at the highest possible data rate. It consists of an USB flash drive-like device with a radio transceiver and a USB module, which is automatically enumerated as a virtual serial port.

After having developed a first working prototype of the receiver, it was decided to work with a commercially available device, which is already packaged, optimized against electro-magnetic interferences, meets security specifications and costs only €35.-.

3. COMMUNICATION

SABRe communication takes place in a dedicated low-latency wireless network. PSUs send their data to the receiver, which is connected to a USB port of a host computer and forwards them to the SABRe-server. This application parses them to a human-readable OSC address space on a specific port, which can be read by any application supporting the protocol. Figure 5 shows an overview of a communication sequence.

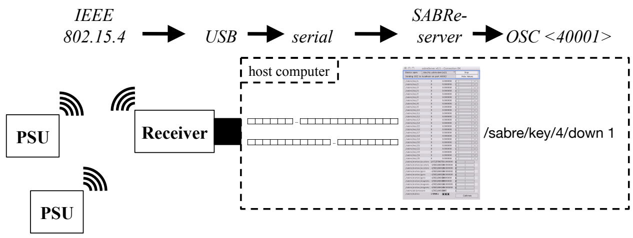

Figure 5: Overview of a SABRe communication sequence.

3.1 Network

All SABRe wireless devices communicate on a IEEE 802.15.4 network[16] in a star mode, where the receiver acts as coordinator and the PSUs as end devices. The network is configured in an automatic registration mode, which allows each PSU to enter into the network at any time, announce itself and get registered by the receiver. In order to coordinate the communication between all PSUs and avoid data collision, the receiver calls each registered PSU sequentially for data transmission. If the called device does not respond until a timeout limit, it gets bypassed until the next turn. After several bypassed turns, the device is considered dead and is deregistered, until it announces itself again in the network.

When a PSU is called, it transmits data to the receiver, starts a sensor polling sequence and, when done, waits for the next receiver call. On the receiver side, captured data is immediately forwarded to the USB chip in order to be processed by the SABRe-server.

3.2 SABRe-Server

On the host computer, the low-CPU-demand multi-threaded SABRe-server continuously reads the serial port and parses data along the specific SABRe address and message format. Once parsed, data is processed to produce higher-level information like scaled sensor data, key-codes (e.g. MIDI notes) retrieved from a fingering table, heading and tilt calculated from the IMU sensors, as well as a system timestamp for synchronization purposes. The data is subsequently transmitted via UDP to a given port, in order to be captured by any OSC-capable host application.

4. PERFORMANCES

The performance evaluation of the first SABRe prototype delivered results, which will determine the necessary improvement of the next versions. First significant results are shown in the next sections.

4.1 Latency

The total amount of transmitted data, including overhead, checksum, temperatures and timestamp is about 100 bytes. Since the radio transmission takes place at a non-IEEE-standard theoretical speed of 2 Mbps[4], the whole data load is transferred from the PSUs to the receiver after about one millisecond, leading to a theoretical sampling rates close to 1 kHz.

Notwithstanding, on the most current Mac OS X 10.x, the highest built-in speed for USB as virtual serial port is 115'200 bps, which causes a total forwarding latency of about 9 ms. In order to overcome this problem, higher USB data rates as well as more efficient data packaging are planned for later versions.

4.2 Keys sampling rate

To be efficient, the key sampling rate has to be fast enough to capture key positions in a binary (open/close) mode. If one considers a slightly exaggerated maximum playing speed of four sixteenths notes at 240 beat per minute (i.e. 4 beat per second), the minimum binary sampling rate for each key, including a Nyquist factor of 2, would be 32 Hz. The current waiting time due to slow USB speed permits a sampling rate of about 110 Hz, which is enough for binary values. But if additional continuous data have to be acquired, such as key press and release speed, higher rates will have to be achieved, in order to get a sufficiently high number of samples necessary to calculate speed values.

4.3 Battery life

The first evaluations of the battery life for both PSUs show promising durations of more than six hours at full transmission power and maximum polling speed, which appears to

[4]The actual communication speed is lower than 2 Mbps, due to header sequences that take place at the standard speed of 250 kbps.

be long enough for normal performance-based uses. In order to save discharge cycles during longer uses phases such as rehearsals, it remains possible to play instrument while plugged into a charger.

4.4 airMEMS

The development of airMEMS is still in an early stage but delivers some interesting results such as a first apparent relationship between played dynamics and mouth pressure, pressure ranges on a completely closed mouthpiece, and the potential for slap detection.

Even though the battery for the airMEMS-unit is small, and has not been properly specified yet, it appears to last longer than the large main battery on the instrument body.

5. COMPOSITIONS

As mentioned in Section 1, SABRe shall be made available for a large community in the form of a hardware and software package that can be mounted on any bass clarinet. In order to spark interest in this new instrument, an effort is made to foster content generation by inviting composers for residencies and offering them the opportunity to discover new means of expression. In return, the SABRe-team can profit from these demanding test persons, improve the instrument performance and at the same time produce materials for presentations, demos or concerts.

As of this writing, one commissioned piece by the Swiss composer Katharina Rosenberger – *nodes* – has been premiered already and two residencies are in progress to be premiered in the fall of 2012. Publications specifically concerned with the content-creation part of the SABRe-project will follow in short order.

6. CONCLUSION

SABRe aims to provide a robust, user friendly and broadly available augmented instrument, which extends the bass clarinets performance and composition potential.

After a first engineering phase on hardware and communications, the SABRe project has entered into an evaluation and composition phase. Composers are invited for residencies for them to explore the instruments potential, generate new dedicated content, simultaneously help the developers to identify general users needs and detect weaknesses.

After this evaluation phase, an upgraded version of SABRe will be available. Regularly updated information can be found under: `http://www.icst.net/research/current-projects/sabre/`.

7. ACKNOWLEDGMENT

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Martin Suter and his company "Das Blashaus" (`www.blashaus.ch`) conceived and realized the magnet brackets as well as the mounting system for the electronics.

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