On making and playing an electronically-augmented saxophone

Sébastien Schiesser
Laboratoire d'informatique, acoustique et musique (LIAM)
Faculté de musique, Université de Montréal
200, avenue Vincent d'Indy
Montréal (Québec), H3C 2J7
Canada
sebastien.schiesser@a3.epfl.ch

Caroline Traube
Laboratoire d'informatique, acoustique et musique (LIAM)
Faculté de musique, Université de Montréal
200, avenue Vincent d'Indy
Montréal (Québec), H3C 2J7
Canada
caroline.traube@umontreal.ca

ABSTRACT

A low-tech electronically-augmented saxophone has been developed with a modular palette of sensors and their corresponding control interfaces. This paper describes the modules and proposes mapping strategies derived from a reflection on the various uses of live-electronics and an analysis of the functions of gestures applied to the saxophone. It also discusses the functional mutation of the performer's gesture induced by the electronic augmentation of an acoustic instrument.

Keywords

saxophone, augmented instrument, live electronics, performance, gestural control

1. INTRODUCTION

A plethora of new interfaces and gestural controllers have been presented these last years, as the high quantity of papers and conferences on this subject tends to show. Nevertheless, the amount of musical works written for these new instruments remains dramatically low in comparison. Many of these new instruments will never overcome the prototype stage. In fact, there is generally a wide gap between the invention of an instrument and its acceptance from a broader audience, depending on many technical and socio-economical factors. For example, the saxophone – which first appeared in public in 1842 and was lauded by Berlioz [10] – has become one of the most popular instruments in jazz and entertainment music, although it is still maverick in classical and contemporary music.

The current project was based on the idea to develop a simple (*low-tech* and *low-costs*) electronically-augmented saxophone (as defined in [16]) and to exploit its potential to compose and perform music. Comments and ideas from composers have influenced the development of this project from its very beginning. Similar to J. Impett's Meta-Trumpet [9], M. Burtner's Metasaxophone [4] or C. Palacio-Quintin's Hyper-Flute [12], this saxophone is augmented with sensors, where each device may be used independently from one another. Since this work is still in progress and only few experiences have been collected in concert situations, this paper prepares the ground for new compositions and further performances outcomes.

The long-range goal of this project is to develop a toolbox with many *modules* – *i.e.* sensors and their corresponding control programs – and play pieces from this young and growing repertoire for saxophone and live-electronics. According to the needs of the composition and the performance (gestures, staging, ability of the performer), the best combination of modules should be found for each piece. We also plan to develop a completely portable system (wireless microphone and interface) which will allow us to explore some interesting staging possibilities made possible by the greater freedom of movement that will be gained.

In the next section, as a starting point for the description of our electronically-augmented saxophone, we define the gesture parameters on an acoustic saxophone. Then, in section 3, we describe the configurable set of sensors that can be added to the saxophone and we provide some examples of mapping. Before concluding with an overview of potential and further developments of this instrument, section 4 proposes a general reflection on the various issues and mutations in the performer's control and practice induced by the electronic augmentation of a traditional acoustic instrument.

2. ON PLAYING AN ACOUSTIC SAXOPHONE

2.1 Functional levels of gestures

The performer's gestures can be categorized in three functional levels [5] [7]:

- *Effective* or *instrumental gestures* – necessary to produce the sound, *e.g.* blowing into the mouthpiece, closing and opening keys, etc. The initial conditions of these gestures (*e.g.* pressure exerted on the reed before blowing) may be considered as *biasing gestures* [16].
- *Accompanist* or *ancillary gestures* – body movements associated with effective gestures, e.g. inclining the instrument;
- *Figurative* or *sonic gestures* – perceived by the audience, but without any clear correspondence to a

physical movement.

The instrumental gestures can be sub-categorized in three functions:

- *Excitation gestures* – that provides the energy, *e.g.* plucking a string;
- *Modification gestures* – related to the modification of the instrument's properties, *e.g.* modulating the air flow to produce a vibrato;
- *Selection gestures* – choosing among multiple similar elements in an instrument, *e.g.* choosing a fingering to produce a given pitch.

Performers always aim to refine the gestural control of their instrument. After years of practice, they generally loose awareness of some movements that have become reflexes. Many tactile or kinaesthetic perception – touch sensitivity of the skin, position and orientation of limbs and other parts of the human body, etc. [3] – are so deeply internalized that any change in an instrument has to be domesticated through hours of practice. For example, changing from the alto to the baritone saxophone requires hours of adaptation, although these two instruments have the same mechanism.

As we will see in section 4, the electronic extension of an acoustic instrument such as the saxophone induces a redefinition and a functional mutation of some types of gestures.

2.2 Case study: the saxophone

Analyzing gestures on a saxophone is a difficult task given that gesture parameters within and across functional levels are often strongly interdependent. Here is a non-exhaustive list of gestural parameters involved in saxophone playing :

Embouchure – *excitation, modification*
The embouchure – here defined as the vertical jaw pressure combined with the round-shaped lip pressure on the mouthpiece – is one of the necessary parameters to produce tone[1]. It also plays an important role as a modification parameter in the production of vibrato and timbral nuances, from sub-tones[2] to very bright sounds.

Tongue – *excitation, modification*
The position and movements of the tongue play a role in the excitation and the modification of a saxophone tone. The position of the tongue in the mouth influences timbre and its back-and-forth movements can be used to modulate the air flow in order to produce a vibrato.

Throat – *excitation, modification, selection*
The degree of opening of the throat and larynx directly determine how the air flows to the instrument, enabling sound production, as well as affecting timbre and selecting pitch. The influence on pitch selection is demonstrated by the possibility to play partials of a given note, without changing fingering but rather by modifying the air flow.

Breath pressure – *excitation, modification*
Besides its role in the excitation gesture, the breath pressure can be varied to produce vibrato, in the same manner as for the flute. Any lack of stability will also cause intonation problems, particularly in the upper register.

Fingering – *modification, selection, accompanist*
On the saxophone, fingering mainly determines the pitch of the note and is thus considered as a selection gesture. But since each fingering also induces structural and timbral changes in the instrument, it can be seen as a modification gesture as well [8]. The accompanist function is not obvious, but is sometimes specified on the score by composers, who can ask, for example, to use the right hand (instead of the left hand) to play on the upper part of the instrument[3] or making demonstratively large finger movements.

Body movements – *modification, accompanist*
The sensation of the body's center of gravity is directly linked to the stability of breath pressure and therefore influences sound parameters. Accompanist gestures are composed of all the expressive movements made by a performer while playing, as well as some parasitic movements due to tensions in the upper part of the body, such as shoulder or elbow twitches. The performer is not always aware of these movements and does not usually control them precisely. Nevertheless, some specific controlled accompanist gestures are sometimes required by composers to affect the perception level of a performance[4].

3. ON MAKING AN AUGMENTED SAXOPHONE

In this section, we present the toolbox of sensors we have developed for the saxophone. Sensors are classified in terms of output modalities.

3.1 Interface and control patches

We built a simple microcontroller-based interface to read signals from digital and/or analog sensors and send them to a computer[5] (see Figure 1). The current version of this interface reads up to six analog channels on 10 bits (1024 values), communicates to the computer *via* USB and is recognized as a six degrees of freedom (DOF) joystick. It can be used in Max/MSP 4.5 with the *hi* (human interface) object. Further improvements will include the addition of digital ports in order to make the analog ports available for continuous signals. We are also planning to implement wireless communication to the computer.

A collection of Max/MSP patches were programmed to process the data generated by each type of sensor. All sensor/patch units – from now on called *modules* – are autonomous and independent. They can be used or not in

[1]If an embouchure is required to produce tone, it does not obligatory play a role to produce sound, since percussion or squealing effects can also be produced without any embouchure.

[2]Sub-tones are defined here as mellow tones containing very few partials above the fundamental frequency.

[3]In Luciano Berio's *Sequenza VIIb* for soprano saxophone, some left-hand trills are proposed by Claude Delangle with the right hand, first to play faster, but in a acting way as well.

[4]Karlheinz Stockhausen's *In Freundschaft* defines three melodic levels, emphasized by three body positions of the performer. It also requires back and forth movements while playing.

[5]For more information on the AVR-HID, please see the project web-page at `http://www.music.mcgill.ca/~marshall/projects/avr-hid/`

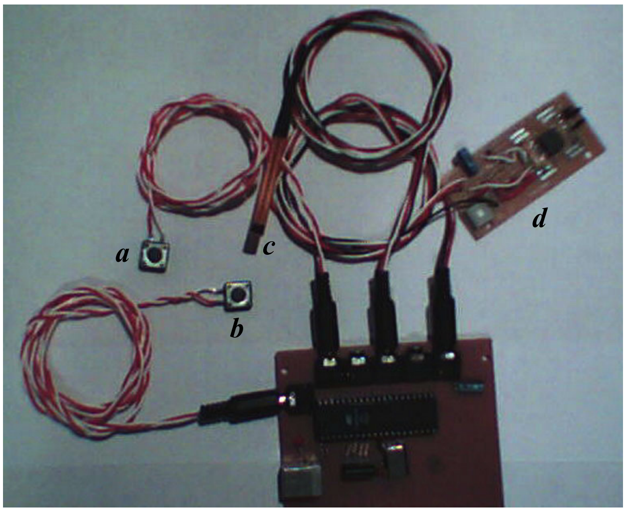

Figure 1: Microcontroller-based interface with different sensors: *a), b)* push-buttons, *c)* FSR, and *d)* inclinometer with scale adjustment electronic and low-pass filter.

a particular set-up, depending on the specific needs of the piece to be played.

Each module comes with a specification chart (see Figure 3) which defines the hardware and software parts, the number and the type of usable parameters, as well as the range, name and type of inputs and outputs for an implementation in a higher-level Max/MSP patch. Figure 4 shows a Max/MSP patch for video-tracking with a webcam as input.

3.2 Sensors and mappings

The sensors used with the interface previously described can be categorized by output modalities – *i.e.* the ways humans physically control things [3] – rather than by the physical energy they measure. In the present case, two modalities are used:

- *Muscle action* – movements or pressures induced by body parts (see Figure 2)
- *Sound production* – acoustic parameters of the emitted sound

Muscle actions can be detected by various types of sensors since they can produce changes in many different physical quantities, such as kinetic energy, light, sound or electricity. The coordinated muscle actions involved in sound production result in pressure changes only, which can be captured by microphones.

3.2.1 Muscle actions

Isometric actions

For muscle actions inducing variable pressure with no large-scale movement, two types of sensors are used :

- *Push-buttons.* Two triggers have been placed under both thumb-rest pads of the saxophone. These allow some event-triggering without movement and constitute a good alternative to foot pedals which are not always easy to use and might disrupt the flow of the performance. Any kind of triggering action can be made with these buttons: launching pre-recorded sound samples, enabling an effect, switching on or off some light or video projection.

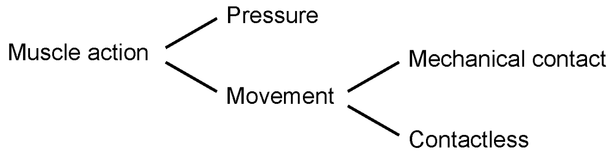

Figure 2: Sub-categorization of muscle action output modalities (after [3]).

- *Force-sensing resistors.* Next to the thumb triggers, two force-sensing resistors (FSRs) can be used to control continuous values such as the amount of harmonic distortion in the signal. A third FSR is mounted under the octave-key, where the cork comes in contact with the body of the saxophone. Since the octave-key is used for a wide pitch range on the saxophone and is not sensitive to small opening changes, continuous values can also be controlled while simultaneously playing and slightly changing the thumb pressure on the octave-key.

  It should be noted that pressing with a finger on an FSR does not generate a very accurate control signal. This should be taken into consideration when determining the mapping.

Movements with mechanical contact

- *Slide potentiometers.* This type of sensor can be placed on the left side of the saxophone bell to control continuous values such as the cut-off frequency of a filter. New instrumental gestures such as "stroking the bell" can be exploited to control effects.
- *Foot pedals.* If needed by the composition or to spare other sensor channels, MIDI foot pedals are added to the set-up (here we use a Behringer FCB1010 with ten triggers and two expression pedals). They can serve to trigger events or to control the main volume of the P.A. system of a concert room.

Contactless movements

Muscle actions inducing contactless movements are captured using three types of sensors which have complementary functions:

- *Inclinometer.* Mounted on the saxophone bell, a one-dimensional accelerometer is used as an inclinometer that generates a continuous value analog to the angle between the instrument axis and the floor. The accompanist gesture associated with the inclinometer output could be mapped to several processing control parameters, such as the amount of pitch-shifting and the reverberation level.
- *Ultrasonic distance sensor.* The distance to a reflecting surface (*e.g.* a metallic instrument) can be derived from the delay between the time a short ultrasonic pulse train is emitted and the time its reflection on the surface is received. From the distance values generated by three synchronized ultrasonic emitter/receiver devices placed at different points on the

Module name:	**VIDEO-TRACKING**
Sensor:	Webcam
Patcher:	jit.videotrack
Communication:	USB
# parameters:	2
Kind of values:	continuous
Resolution:	320 x 240
Accuracy:	medium*
Range:	0.1 – 10 m^2
INs:	- Video ON/OFF (toggle)
	- Open / close video stream (toggle)
	- Get video devices list (bang)
	- Selected device (string)
	- Get input mode list (bang)
	- Selected input (text)
	- Min. RGB value to track (3 x integer)
	- Max RGB value to track (3 x integer)
OUTs:	- Monitor window (jitter matrix)
	- Devices list (string)
	- Input mode list (string)
	- Tracking window (jitter matrix)
	- X coordinate (0 – 1 float)
	- Y coordinate (0 – 1 float)

* Accuracy changes depending on the light conditions and color contrast of the background. Obscurity: very good; daylight: poor

Figure 3: Specification chart for the webcam video-tracking module.

stage, the absolute position of the reflecting surface is calculated by triangulation in a Max/MSP patch. The module would typically deliver the X-Y coordinates of the performer on stage. The most intuitive mapping for this sensor is probably to link the balance between the stereo speakers left and right channels to the X (horizontal left-right) axis and the volume control to the Y (horizontal front-back) axis.

- *Video-tracking.* The color-tracking module is composed of a commercial webcam and a Max-jitter patch as shown on Figure 4. It can follow a LED placed on the performer or a spot light projected on a vertical surface in the X-Z plane (width and height of the stage). We use a one-by-one square meter plate as a projection surface for a laser pointer. The surface is divided in several invisible zones, which can trigger some pre-recorded sound events for example.

3.2.2 *Sound production*

Four acoustic parameters can be extracted from the sounds produced on the saxophone and used as distinct control values.

- *Intensity level.* An envelope follower generates a continuous control signal that can be used to modulate an effect or automatically adapt the volume of any pre-recorded sound event to the instrument's dynamic level. Coupled with some adjustable threshold detection, it also allows conditional triggering of an effect, switching on and off according to the specified thresholds.

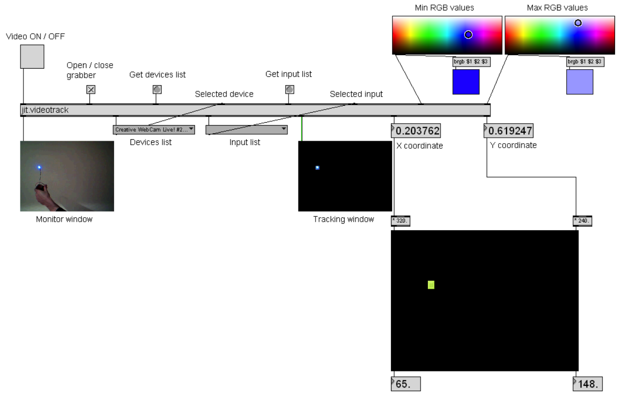

Figure 4: *jit.videotrack* patch with a webcam as input.

- *Attack detection.* Attacks are detected by monitoring sudden level increase in a given time period. The level difference and the time period – which also defines the shortest time between two attacks – are both adjustable parameters. Such a control signal allows quick repetitions and can be used to trigger randomized and short events (*e.g.* grains of a granular synthesis for example or impulses of a strobe light[6]).

- *Pitch estimation.* The pitch is extracted using the *fiddle˜* object in Max/MSP. This signal can be coupled with the attack detection module for more reliability in the triggering signal.

- *Zero-crossing.* The number of times a waveform crosses the zero line provides a measure of the sound noisiness (since a noisy waveform crosses the zero line much more frequently compared to a periodic waveform). An adaptive processing of the saxophone tone could be based on this control signal.

4. ON PLAYING AN AUGMENTED SAXOPHONE

4.1 Functional reconfiguration of gestures

The addition of several buttons or movement sensors on an instrument indubitably affects the way the performer interacts with it. The functional levels of gesture (instrumental, accompanist and figurative) can be greatly affected by the electronic extension, by either adding new types of gestures of reconfiguring the functional levels themselves.

At the instrumental level, on an electronically-augmented instrument, excitation gestures not only include blowing into the mouthpiece but also triggering actions, such as pushing a button or moving in front of a video-tracking system. Modification gestures can be pressing on a FSR or moving a slider. The produced sound itself can be used as a control signal. For example, the trigger signal from an attack detection can enable some sound effect.

[6]The input sound is converted into a trigger signal (bang), which is sent through a Virtual COM Port [14] to a USB-to-DMX signal converter [13], then to the strobe as a standard DMX command.

The electronic extension of an acoustic instrument usually causes an important reconfiguration of the functional levels. For example, with an acoustic saxophone, inclination of the instrument as well as circular or eight-shape movements of the bell are accompanist gestures which do not need to be tightly controlled since they have a very subtle influence on the sound [15]. But if the instrument is equipped with a motion tracking device, these gestures become instrumental when they are mapped to directly produce sound events or modify them. As a result, the performer needs to consciously and precisely control this type of gesture, which was mostly uncontrolled when playing the non-extended acoustic instrument. Integrating this functional mutation (from accompanist to instrumental level) is not obvious to the performer and will requires many hours of practice. The performer also has to think of all uncontrolled movements that could interfere with some event-producing gestures. For example, elbow movements could lead to some pressure changes on the thumb, thus interfere with an FSR control.

4.2 Playing one or two instruments

The mapping strategies have an important impact on how the instrument will be played and on how the audience will perceive the performance.

Some carefully designed mappings will allow a good integration of both acoustic and electronic components of the performance, resulting in one single instrument: an electronically-augmented acoustic instrument. In this case, the electronics is used to extend the timbral palette of the acoustic instrument by transcending its physical limitations. The electric guitar is a good illustration of an electric extension of an acoustic instrument. It is in fact a hard task to identify the conditions under which an acoustic instrument can be electronically augmented without loosing coherence with its original acoustic characteristics.

In some other cases, the performer of an electronically-augmented instrument may seem to play two instruments, one acoustic and one electronic [6]. From the performer's standpoint, the instrument is split in two parts being played simultaneously: a "standard" acoustic instrument and a controller driving other events (sound effects, electronic accompaniment of the solo acoustic instrument, video images, ...). It is as if the performer had to play alone in a duet formation, controlling two instruments at the same time. This situation generally leads to an increased cognitive load and requires more practice to achieve accurate control.

4.3 Choosing sensors and mappings

In section 3, we have suggested some mapping possibilities for the various sensors.

The advantage of a fixed mapping is that the performer does not need to relearn each time how to play his instrument. The wah-wah effect on an electric guitar sound is a good example of fixed mapping. It is always controlled by an expression pedal. In the case of this project, the system has been conceived to be flexible and adaptable to the pieces to be performed. Although the system is flexible, it is important to determine mappings which are intuitive to the performer and that take into account electronic, acoustic, ergonomic and cognitive limitations (accuracy, resolution and response time of sensors, added cognitive load corresponding to the type of sensors, player's technical ability, etc.).

In order to decide on a particular setup, many questions need to be answered:

- How many parameters is the performer able to simultaneously control?
- What are the constraints on movements induced by the added sensors?
- How to evaluate the cognitive load of the electronic extension?
- Are they strategies to reduce this cognitive load?
- Which sensors and mappings are more intuitive to the performer?
- How long does the performer need to practice to become comfortable with a particular set-up?

4.4 New ways to practice

Performers should probably invent new ways to practice, learn how to use their feet, body movements or fingers independently. Solutions to this problem could be borrowed from dance or theater domains. Some basic exercises using the various sensors of a set-up – similar to the common scale drills on acoustic instruments – could be developed to get more comfortable with the electronically-augmented instrument. Appreciating this reality and playing with its limits will help to improve the instrument's capabilities, as the extended techniques[7] did some decades ago.

In the design of new instruments, we could question the tendency to reduce learning time and performer's needed skills [1][11]. The instruments that have the highest musical potential are not always the ones which are the easiest to use or to learn. In fact, the investment required in learning to play an instrument and the intimacy derived from that process are worthwhile and essential in the evolution of an instrument. Citing Berio, technical and intellectual virtuosity "may also count as the celebration of a particular understanding between composer and performer, and bear witness to a human situation" [2].

4.5 Interacting with the composer

With a flexible and configurable augmented saxophone, the performer can either play an existing piece for saxophone and electronics (which generally needs some porting and rewriting of code), compose and improvise on the instrument or collaborate with a composer to create new works. In this last situation, the compositional process can adopt a *bottom-up* or a *top-down* approach.

A bottom-up approach refers to the development of compositional ideas according to the possibilities and limitations of a given instrument. The performer explores a particular set-up and feeds the composer with informations on the various capabilities of the instrument and its controls. The composer can also select a set of modules and their gestures and use it as a canvas to work from. With a bottom-up approach, we run a higher risk that technology becomes the main justification of the whole composition.

A top-down approach rather refers to the development of compositional ideas without any regard for instrumentation[8]. The composer first writes the piece without con-

[7]The extended techniques allow to produce unconventional sounds, like flutter tongue, slap tongue or multiphonics. A quite complete list of these techniques for the saxophone can be found at `http://www.jayeaston.com/Composers/sax_techniques.html`.

[8]From Bach's *Kunst der Fuge* to Stockhausen's *Solo*, there are many works written without specific instrument designation.

straints induced by the instrument. Then the best sensors and mappings are chosen to fit the needs of the composition. Ideally, the flow of information between the performer and the composer should run in both directions. This can lead to interesting and new types of work dynamics between composers, performers and engineers.

5. CONCLUSION

In this paper we presented a modular low-tech electronically-augmented saxophone. Modules from the toolbox we developed are selected and added to the saxophone to best fit the needs of a composition. The selection of modules in a particular set-up can also serve as a compositional canvas.

Several on-going musical projects with contemporary composers currently explore the capabilities of this electronically-augmented saxophone. The modular toolbox also makes possible the recreation of older works for saxophone and electronics (for which the technologies does not exist anymore) by choosing the appropriate sensors, mappings and signal processing algorithms.

As the electronic augmentation of an acoustic instrument reorganises the functional level of gestures applied on the instrument, performers have to become more conscious of their movements and need to find new practice methods to become comfortable with the transformed instrument.

6. ACKNOWLEDGMENTS

We are grateful to Prof. Marcelo Wanderley from the Input Devices & Music Interaction Lab (IDMIL – McGill University) for the access to his laboratory, as well as the whole IDMIL crew for sharing their knowledge and infrastructure.

Thanks to Mark Marshall who designed the AVR-HID microcontroller interface and spent a lot of time helping and debugging, as well as to Kris Covlin for corrections, suggestions and exciting exchanges about the saxophone.

Very special thanks to Sonia Paço-Rocchia for fruitful conversations, tips in programming and all the energy you gave during this time.

7. REFERENCES

[1] A. Baumann and R. Sanchez. Interdisciplinary applications of new instruments. In *NIME-02 Proceedings*, 2002.

[2] L. Berio. *Sequenzas*. Deutsche Grammophon, 1998. Booklet of the CD *Sequenzas* by the Ensemble Intercontemporain.

[3] B. Bongers. Physical interfaces in the electronic arts. In *Trends in Gestural Control of Music*. M. M. Wanderley and M. Battiez, 2000.

[4] M. Burtner. The metasaxphone: Concept, implementation, and mapping strategies for a new computer music instrument. *Organized Sound*, 7(2), 2002.

[5] M. Cadoz and M. M. Wanderley. Gesture - music. In *Trends in Gestural Control of Music*. M. M. Wanderley and M. Battiez, 2000.

[6] C. Cox. Interactive technologies in music composition: Towards a theory of interactivity. In R. H. M. Ewans and J. A. Phillips, editors, *Music Research: New Directions for a New Century*. Cambridge Scholars Press Titles, 2004.

[7] F. Delalande. La gestique de gould: éléments pour une sémiologie du geste musical. In G. Guertin, editor, *Glenn Gould, Pluriel*, pages 83 – 111. Louise Courteau Editrice Inc., 1988.

[8] K. Demers. Acoustique de la clarinette et exploration de nouvelles possibilités timbrales au moyen de l' électroacoustique. Rapport. Laboratoire d'informatique, acoustique et musique, Université de Montréal, 2005.

[9] J. Impett. A meta-trumpet(er). In *ICMC Proceedings*, 1994.

[10] T. Liley. Invention and development. In R. Ingham, editor, *The Cambridge Companion to the Saxophone*. Cambridge University Press, 1998.

[11] K. Ng. Interactive gesture music performance interface. In *NIME-02 Proceedings*, 2002.

[12] C. Palacio-Quintin. The hyper-flute. In *NIME-03 Proceedings*, 2003.

[13] ENTTEC. *Open DMX USB*. `http://www.enttec.com/dmxusb.php`.

[14] FDTI Chip. *Virtual COM Port*. `http://www.ftdichip.com/Drivers/VCP.htm`.

[15] M. M. Wanderley. Non-obvious performer gestures in instrumental music. In *Gesture-Based Communication in Human-Computer Interaction: International Gesture Workshop*. Springer Berlin, 1999.

[16] M. M. Wanderley. Gestural control of music. In *Proceedings of the International Workshop on Human Supervision and Control in Engineering and Music*, pages 101–130, Kassel, Germany, 2002.