Modeling an Air Percussion for Composition and Performance

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ABSTRACT
This paper presents a project involving a percussionist playing on a virtual percussion. Both artistic and technical aspects of the project are developed. Especially, a method for strike recognition using the Flock of Birds is presented, as well as its use for artistic purpose.

Keywords
Gesture analysis, virtual percussion, strike recognition.

1. INTRODUCTION
To collect, through the gesture of the musician, his musical intention and to incarnate it in a sound matter, such is generally the role of a musical instrument, whether it is acoustic or electronic. From this point of view the SCRIME developed a research project for a virtual percussion instrument using electromagnetic sensors that are fixed at the end of drums sticks. To our knowledge, this work is the first attemp to gesture modeling of percussionists playing with drums sticks. We started from a model of the basic strikes and measurements taken on a musician in order to obtain a modeling of its play. A device of air percussion thus was implemented, including a system of sensors connected to a computer which analyzes and recognizes the gestures of the percussionist, a system of graphic edition of the instruments and visualization of the trajectories of the strikes, and modules of sound synthesis.

First section of this paper presents the artistic project called *Metamorphoses* which motivates this work. Second section enumerates existing similar works and actual disposals among which we had to choose. Then, in third section, we give some technical details about strike recognition, including the limits of the actual algorithm and material. Last section describes how the air percussion can be used for composition and performance.

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2. *METAMORPHOSES* ARTISTIC PROJECT
For a few years the first author has worked out, within the project *metamorphoses*, a musical writing for electronic instruments through a succession of works of chamber music joining together from 2 to 4 musicians. Each one of them plays, with its own mechanical and auditory reflexes, with sensors adapted to its instrument of origin. With the difference from traditional writing, the partition consists of various environments of reactions to the instrumental requests, environments programmed in patches using the Max/MSP software. The work is then defined by the general form suggested in the instrumentalists, the environments and the associated modes of play, and the manufacturing of it electronic sounds. Wishing to improve the original instrumental device (guitar midi, saxophone midi and theremin) with a percussion instrument, the composer imagined to develop a system for collecting the percussionist gestures. The already existing solution of the MIDI drums was quickly excluded because this system generates parasitic noises of shock; moreover they allow only starting of sounds whereas the percussion in general is rich in play modes according to the sound object used, modes of play which require the recognition of a gesture and not only of one striking - for example the shaken maracas or a rubbed cymbal. The ambition of such a project would be then, starting from the modeling of peculiar gestural of the percussionist, to be able to collect in real time, i.e. with the constraints of a play in concert possibly virtuoso, musical intentions of the instrumentalist to apply them to an electronic instrument by the intermediary of an air instrumental device, i.e. without presence of sounding body.

Modeling of the Strikes
In this study, we first were interested in the recognition of the strikes, which are probably the most frequent gestures of the percussionist. A first question that one can put about such a device is the capacity of a percussionist to play without the return of striking on the instrument. Actually, apart from one type of sequence that uses the rebound on the head, the strikes of percussion can be carried out without instrumental support, for what makes sound is the energy of the gesture transmitted to the sounding body, and this trans-

mission is maximum when the impact is very short and does not crush resonance. It was thus modeled 3 types of strikes:
• *down* : the stick in high position goes down then goes up in low position
• *up* : the stick in low position goes down then goes up in high position
• *piston* : the stick goes down then goes up with the same position (normal-strike).

At the time of the play with two mallets, these strikes can be sequenced in various manners to form the following figures :
• the roll : the sticks alternate the following cycle symmetrically: down, up
• the single stroke : the sticks alternate the following cycle symmetrically: up-down
• the flam : the sticks alternate the following cycle asymmetrically: down, up with start on a up.

Among these three sequences, only the roll uses the rebound on the head for the sequence of both strikes with the same stick. This technique will thus not be usable with an air percussion.

3. ACTUAL DISPOSALS

There are currently several artistic projects which use devices of percussions, and let us present some of them below. Most of them are interested to detect the point of striking to carry out the play of samples, but little of them approach the gesture in a more total way, and there even exists for the moment very few data on dynamics of the gesture itself.
• **Max Mathews radio baton**[1] [6] is the oldest device, to our knowledge, which tracks the motion of the tip of 2 sticks in a 3 dimensional space. Max Mathews had not developed this product for the percussion, but it allowed us, before being directed toward such or such technological choice, to carry out a first series of measurements with a percussionist thanks to a pleasant collaboration with the LMA of Marseille. Its rather reduced dimensions were not appropriate however for the project. The **digital baton** [5] probaly could have been used as well for that purpose, but we did not have the chance to try it.
• **Lightning**[2] is a MIDI controller developed by Don Buchla that detects the position and movement of handled sticks. Based on principles of the optical triangulation, Lightning gathers its information by tracking tiny infrared transmitters that are built into sticks and provides the horizontal and vertical position of each hand. It can be used to detect strikes of a percussionist or to follow the beat of a conductor, but its perception in a two-dimensional space limits its use for a complete analysis of the gesture.
• **Video camera** : Another alternative for the capture of the instrumental gesture is the use of video cameras that allows, with an appropriate image analysis, to detect the movement of the hand of the instrumentalist. One can quote among other that projects of the GMEM[3] of Marseille, which consists in graphically defining areas around the instrumentalist, areas in which a movement will trigger the synthesis of an electronic sound using VNS.

[1]http://ccrma-www.stanford.edu/CCRMA/Courses/252/sensors/node27.html
[2]http://www.buchla.com/lightning/index.html
[3]http://www.gmem.org/

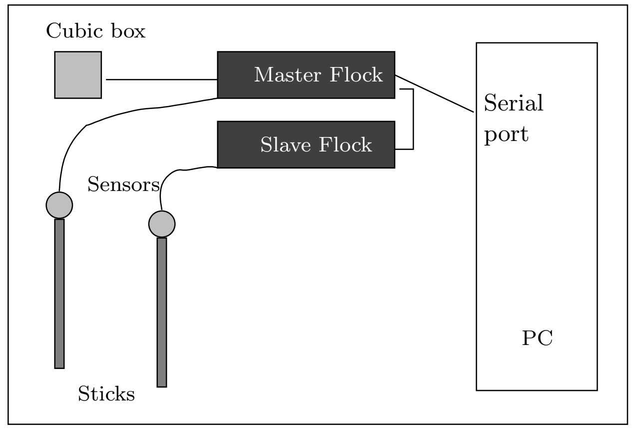

Figure 1: System Architecture for recording and analyze inputs coming from the FOB

• **Flock of Birds**[4] are widely used in the context of virtual reality. They are constituted of a cubic box emitting an electromagnetic field and sensors, which are called Birds, receiving electromagnetic waves within a spheric area around the cubic box. Sampling rate of this material is in theory 100 samples per second. This technical specification especially turned us to choose this material for our percussion. Each sample contains 3D position of a sensor and its orientation (3 angular values) with a spatial accuracy of 1.8mm RMS and angular accuracy of 0.5 degrees RMS.

4. STRIKES RECOGNITION

In this section, we present studies we performed for strikes recognition. We precise peripherals characteristics and the whole system architecture we used for recording and analyzing inputs coming from peripherals. Then, we present results and limits of our detection, due to material drawbacks.

4.1 System Architecture

System architecture for preliminary studies is constituted of a PC running the libflock library, and the FOB peripherals, whose Flock master is connected to a serial port of the PC (see figure 1). Moreover, each sensor is placed at the extremity of a drum stick.

The libflock library aims at the management of FOB peripherals, and runs under GNU/Linux. This library is under GNU Public License and is published on the SCRIME web site (www.scrime.u-bordeaux.fr). It is constituted of the following modules :
• The "flockOutput" program outputs the bird's records as text.
• The "flockNoise" program detects the noise level in measurements of the bird's positions.
• The "flockOSC" program sends flock events to a remote host by using UDP datagrams that comply to CNMAT's OpenSound Control protocol.

4.2 Strikes Analysis

[4]http://www.ascension-tech.com/

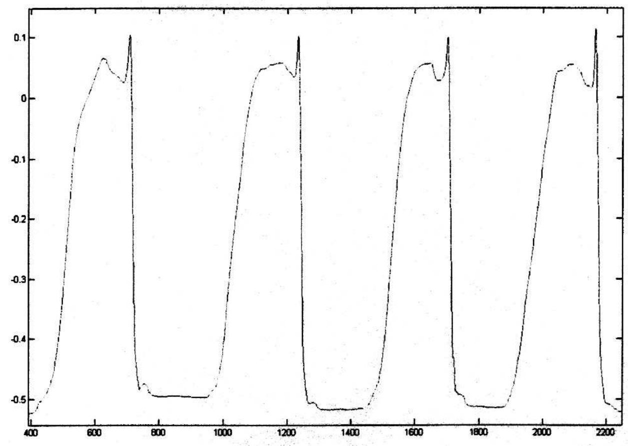

Figure 2: Trajectory of four up strikes

The aim of this work is to detect strikes and to classify them according to one of the types: *down*, *up* and *piston*. In this paper, we limit our study to the simple detection of strikes.

Of course detection of a strike could have been decided each time the trajectory of a sensor crosses a threshold in the Z axis. But such a detection depends only on the absolute level of the threshold and represents a strong constraint for the musician. We preferred to detect each strike wherever in the space, according to any of the three dimensions. Such an objective requires to analyze input samples to predict strikes with a latency as low as possible. As a matter of fact, the system is to be used in real time and played at a very high speed. This study has been performed according to the Z axis, to get a maximal speed from the musician, and then the detection algorithm we obtained was generalized to the 3 dimensions.

We recorded several sequences of elementary strikes (*up*, *down* and *piston*), played with several kinds of nuances and tempo. Then, we observed with Matlab the curves of the 3D trajectories. Some trajectories are displayed respectively on figures 2, 3 and 4, where the Z axis is oriented upward and the time axis from left to right. Thanks to the fixed sample rate, speed and acceleration can be easily computed and plotted with the trajectory. Those curves shown several drawbacks that are presented in subsection 4.3. Nevertheless, correction was applied to the curves in order to be able to analyze them.

Several parameters were extracted from a temporal window of 200ms preceding each impact : abscissa and amplitudes of strike and speed peaks, duration between two peaks (strike or speed). Statistical analysis were performed with those variables (mean, standard deviation, correlation). This analysis showed that the amplitude of the speed peak preceding a strike is highly related to the duration between them, as well as a negative peak of the speed along the X axis. In consequence, two thresholds were introduced in this first detection algorithm, for the two derivatives along Z and X axis. Moreover, in order to avoid detection errors due to unintentional movements, we decided to apply a delay threshold between two strikes. This delay was extracted from the recorded data.

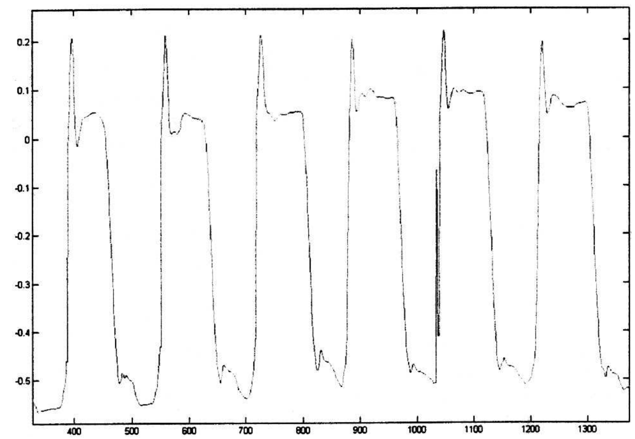

Figure 3: Trajectory of six down strikes

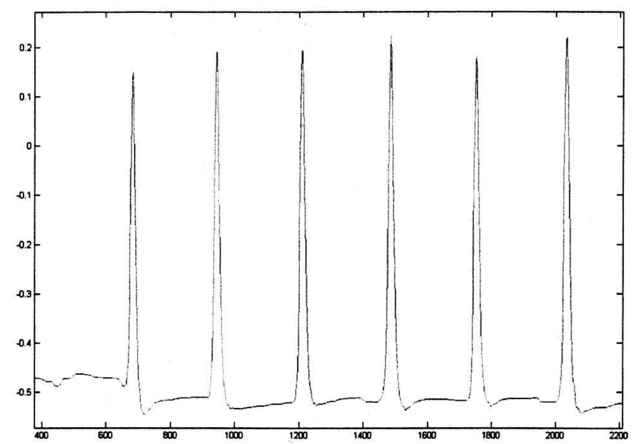

Figure 4: Trajectory of six piston strikes

4.3 Material Limits

Several drawbacks were shown by the curves of the trajectories of the sticks. First of all, the material has to be used far from metallic objects, to get aware of electromagnetic interferences. But other problems were observed, probably related to a too high speed:
• Several successive points were sometimes superimposed, especially when the speed was very high during the downward phase.
• Some points were sometimes completely out of the trajectory. They were especially situated during the rising phase.

Such errors of the material generates several kinds of detection errors. Nevertheless, within the whole percussion simulation, as it is described in section 5, most of those errors disappear, because only the strikes hitting a part of the virtual percussion are filtered.

5. USING THE AIR PERCUSSION

We developed a 3D editor for the composer to define an air percussion within the sphere around the emitting cubic box. The objective is to split the space into several areas which have different properties for sound synthesis. Shapes of those areas are elementary so that the area corresponding to the position of the strike can be detected easily and fast. An area is defined by the following parameters.

• A shape : sphere, box or cylinder;
• Geometrical parameters (center position, size);
• Percussive sound synthesis : six binary values indicating whether or not the area detects each of the six kinds of strikes and strikes sequences (*up*, *down*, *piston*, *roll*, *single-stroke* and *flam*);
• Continuous sound synthesis : raw coordinates of the position of the sensors can be used for sound synthesis in this area.

We designed an architecture for the disposal in order to be able to use it during performance. In particular, the composer uses its own compositional environment on the MAX platform. So the architecture which is presented on figure 1 is augmented with a MacIntosh running MAX and connected to the PC using UDP datagrams. Moreover, the PC runs a program implementing strike detection, augmented with a spatial analysis of the position of the sensors. It sends an event to the MacIntosh which is constituted of several fields (type of event, number of the stick, number of the current area, coordinates, speeds according to the three dimensions). Simultaneously, the PC displays a representation of the air percussion including the real time position of the sensors.

The current device was used in concert by the composer, within his cycle of *metamorphoses*, in duet with a midi saxophone. Two types of percussion instruments were defined, using the graphical interface, each one corresponding to a different type of synthesis. One consists of a keyboard of 20 keys, horizontally laid out on 2 lines of 10, each key triggering the play of a sample of sound. The strike speed information makes it possible to control the sound volume, and the information of angular position according to the y-axis is used to modify the timbre by means of a filter. The other instrument consists of a parallelepiped inside which the displacement of the stick controls a module of granular synthesis. Again, information of angles and position is used to control the various parameters of the synthesis (position and loop size, volume, pitch), but moreover detection of strikes according to any axis allows to produce accentuations of the sound. If the definition of the instrumental areas is common to both mallets, on the other hand the sound result obtained may be differentiated by the use of various samples and synthesis modules.

6. CONCLUSION

The results currently obtained are sufficiently satisfactory to allow its use in concert. Except certain errors of detection probably related to the defects observed on the sensors, the device answers the requests of the instrumentalist well, thus allowing him certain virtuosity. The reduction of the delay between visual and auditory perception by the use of methods of prediction should make it possible to improve comfort of playing of the instrumentalist and the spectacular effect of the instrument. Then, when strike detection will be completely accurate, we shall perform strikes classification (*up*, *down*, *piston*), and strikes sequences classification (*roll*, *single-stroke* and *flam*) leading to a model of the percussive gestures thus providing a wider musical control to the instrumentalist.

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