Non-Conscious Control of Sound Spatialization

Mark T. Marshall Joseph Malloch Marcelo M. Wanderley
Input Devices and Music Interaction Laboratory, and
Centre for Interdisciplinary Research in Music Media and Technology,
McGill University, Montreal, QC, Canada
E-mail: {mark.marshall, joseph.malloch, marcelo.wanderley}@mcgill.ca

Abstract

This paper presents ongoing work into the design of interfaces for live musical performance using gesture controlled sound spatialization. In particular, we discuss the use of performer's gestures to allow them to manipulate spatialization parameters without their conscious control. A number of motion capture sessions involving a cello performer are described through which we determined a set of gesture parameters which are useful for this purpose. We also present our implementation of a wireless sensor system to allow control of spatialization parameters using cello performer gestures. Finally, we provide some guidelines for succesfully mapping gesture control to sound spatialization parameters.

1 Introduction

Musical performance intrinsically encompasses spatial elements, in the arrangement and directivity of musicians and instruments, the acoustics of performance and listening spaces, and the relative positioning of audience and performer. Sound spatialization effects have long been used by traditional composers and orchestras, but it is only since the advent of electric sound reinforcement and diffusion that the bulk of spatial parameters may be changed dynamically or be controlled in real-time. For a detailed review of the history of spatial music see [7].

As part of a project on the compositional uses of gesture controlled sound spatialization, we have been investigating possible performer roles and developing systems to explore the possibilities of this type of control [3]. The main aim of this work is to investigate and develop interfaces which can provide rich, intuitive control of compositionally interesting parameters in a sound spatialization system, and are above all compatible with expert musical performance.

Previously we have discussed the performance and mapping issues involved in implementing gesture control of spatialization parameters[2], with especial focus on resolution (of gesture, sensing, mapping, and subsequent control), integrality and separability, current vs. ballistic control strategies, and the *cognitive load* carried by a performing instrumental musician. This last issue addresses the concern that not all performers have spare attention for controlling something other than their instrument [1]. Taking this into account, we have divided performer control into three main approaches, one of which is the control of spatialization parameters by a performer's gestures *without their conscious control*.

If conscious control is desired, gestures must be chosen such that they can be performed without disturbing the instrumental performance, and it is assumed that the performer has spare attention for this task. For non-conscious control, the mapping relationships between performer movement and spatialization effect becomes an indirect compositional process rather than instrument augmentation or performer interpretation. Rather than asking the performer to deliberately manipulate spatial parameters, the composer or designer must plan instrumental movement with thought to the spatial effect as well as acoustic sound production.

This paper will focus on the third approach, specifically on explorations into non-conscious control of spatialization parameters using the movements of a performing cellist. An explanation of the process used to choose which movements to use for control will be given, followed by steps taken to move the chosen control systems from the lab to the concert hall. Finally, the implications of this type of control for composers, performers, and audience will be discussed, with insights into how to approach mapping gesture control to sound spatialization parameters successfully.

2 Aquiring Performer Gesture Data

In order to inform the choice of control strategies, it was necessary for us to make a number of recordings of performer gestures which could be analysed to extract useful data. To this end, we performed a number of mo-

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tion capture recording sessions using various technologies. These sessions focussed on recording and analysis of cello performer gestures.

2.1 Preliminary Motion Capture

The first capture session made use of a VICON motion capture system[1]. Markers were placed on the performer's body, concentrating on the upper body. The main goal of this recording was to identify movements useful for controlling spatialization which could later be captured using a more basic system suited for performance use. It was expected that the most useful data would be related to the bowing arm, but it was hoped that other useful data would also be discovered.

For this session, we recorded a number of performances with a single player. To allow us to examine a variety of material, she performed a number of simple scale excercises, followed by performances of 2 different pieces, each of which had a very different tempo.

As expected, we found that we could extract bowing data from the movements of the bowing arm in the axis perpendicular to the strings. This could give us information on bowing speed, position and energy. However, further analysis of the data indicated that the performer's center of mass might also prove a useful parameter. The recordings revealed a regular low-frequency oscillation in the performer's center of mass, the frequency of which appeared to be related to the piece being played. Figure 1 shows movement of the performer's center of mass in the forward/backward direction for the 2 recorded pieces. The second piece, which is faster than the first, shows a wider range of movement, more deviation from the neutral position and has additional high frequency movements not present in the recording of the slower piece. We also noticed a tendency for the performer to lean forward at the beginnings of musical phrases. Each of these artifacts might prove useful as controls in performance situations.

2.2 Subsequent Capture Sessions

Having determined that we could extract some useful data from the movement of the bowing arm, we began designing a system to allow us to record this data that could also be used in live performance. We decided to make use of accelerometers, as these are unobtrusive enough for performance use, but can be used to acquire both acceleration and rotation data.

Our design made use of ST Microelectronics LIS3L02AS4 3-axis accelerometers which were worn on the performer's forearms. These accelerometers were connected to the computer using a Teabox sensor interface from Electrotap[2], which recorded the accelerometer data at a sampling rate of 1 kHz and a resolution of 16 bits. This provided high-quality data for our analysis.

[1]http://www.vicon.com/

[2]http://www.electrotap.com/

Figure 2: The accelerometer-based capture system in use. The accelerometer board is being worn on the performers bowing arm.

Using this system, we recorded a large number of cello performance techniques, including different styles and speeds of bowing, pizzicato and extended techniques such as bowing on the bridge and on the body of the instrument. Figure 2 shows this system in use during the capture session.

From this session, we determined that the accelerometers could be used to measure most of the bowing parameters already identified. In addition to the bowing speed and energy, we found that we could determine which string was being bowed, from the angle of the bowing arm relative to the instrument. We also found it possible to determine a measure of the left-hand position on the fingerboard, using the angle of the fingering arm relative to the vertical plane.

A final motion capture session also took place, this time using 3-axis accelerometers together with a Bluetooth interface. This allowed wireless transmission of the data, which offers a distinct advantage for the performer, but at a slower update rate. In this final session, a number of recordings were made which measured the identified gestures to allow us to determine if the 200Hz update rate of the wireless sensors was sufficient for our purposes.

2.3 Features

Overall from these motion capture sessions we have discovered a number of gesture parameters which can be easily sensed and which may be useful for controlling spatialization. These parameters are:

- relative position of playing on the fingerboard, extracted from left arm rotation data

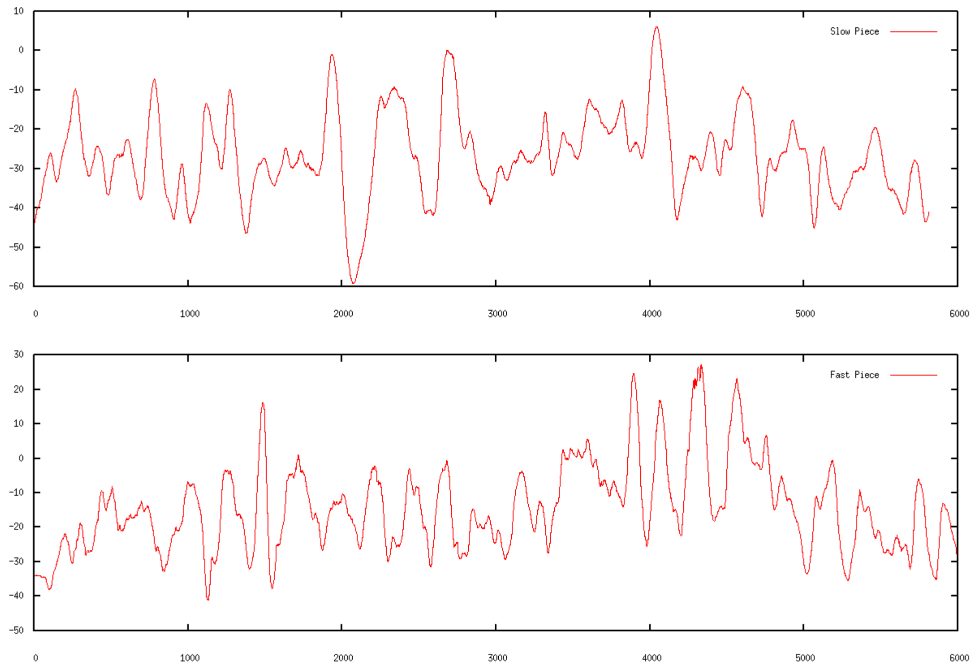

Figure 1: Center of mass movements in the forward/backward direction for the 2 recorded pieces. (a) Low tempo piece and (b) high tempo piece. Note the extra high frequency movements in the faster piece.

- current string being bowed, measured from bowing-arm rotation data
- overall bowing energy
- performer center of mass

It may also be possible to extract more data from the performer's gestures, including the recognition of certain playing techniques based on combinations of the other data.

3 Moving Towards Performance

In order to make use of these gestures in performance we needed to develop reliable, robust methods of sensing the necessary movements. With this in mind and based on the results of our motion capture sessions, we implemented a system which measures acceleration and rotation data from which we can extract the required bowing and fingering gesture parameters. The final performance system makes use of an Xsens Technologies Xbus kit wireless motion capture system, which provides drift-free calibrated acceleration and orientation data.

The data from the wireless sensors is read using a patch in the Max/MSP graphical programming language, which performs recording and analysis of the incoming signals. Signals are recorded into multichannel audio files which allow for easy processing in software such as Matlab. It should also be noted that this patch offers the possiblity of loading previously saved gesture data to allow for simulations based on recordings of real gestures.

Currently, the patch extracts bowing speed, bowing energy, the number of the string being bowed, and left-hand position on the fingerboard, but is easily expandable for other data. Communication between the patch and the spatialization system occurs using OpenSound-Control (OSC) messages[6] which are sent over the network. This allows us to peform the gesture capture on one computer, while running the spatialization on another, thus spreading the processing load across machines.

For the performer center of mass measurement, we decided to build a pressure-sensitive floor. A 1m by 1m plywood floor was built with 4 evenly-spaced force sensing resistors (FSRs) attached to the underside. The outputs from these FSRs are converted to digital values and sent over a USB connection to the computer. By measuring the difference in signal across the FSRs it is possible to estimate the center of mass of a performer standing on this floor.

We initially tested this floor with a number of different users in standing positions and the output proved reliable. However, some complications arise in the case of a seated performer (such as our cello player). Depending on the type of chair used by the performer, the performer's mass can be distributed more or less evenly. This requires some calibration of the system to allow for such differences. Another possible option would be to embed the FSRs in the chair, rather than on the floor underneath it, as described in [4].

Data is read using a patch in Max/MSP, which incorporates both a visual and numeric representation of the center of mass estimated from the pressure sensors. We once again use OSC for the communication between this patch and the spatialization system.

4 Discussion

The ultimate aim of this work is practical: to provide knowledge and tools for composers who wish to use gesture control of spatial effects within their pieces. The solutions and systems are not intended to directly shape the aesthetic effect of the works, but rather to enable composers to produce the acoustic and performative impact they desire. Without presuming to label approaches to an artistic work as "right" or "wrong," our experiences with multiple composers, performers, systems and venues have yielded suggested guidelines which may minimize performer distraction and maximize mapping success when making use of non-conscious performer control of spatialization parameters.

Map resting body states to neutral spatialization states. If resting body states are mapped to dramatic or obvious spatialization effects, the performer is likely to become distressed, as they will be unable to "stop" performing. The field of digital musical instruments has shown that the ability to *stop* sounds and processes is essential for a feeling of being in control[5].

Use non-conscious control for high-level spatialization control. High-level spatialization parameters, such as system changeability, the flocking behaviours of clouds of sound sources, or control over other algorithmic behaviours, may be successfully controlled using ancilliary performer movements. If the mapping relationships are obscure enough, the performer will be less likely to be tempted to try to "take control."

Use non-conscious control for subtle spatialization control. Similarly, subtle effects, such as sound spread or diffusion in the space or boundary reflectivity, may be less distracting for the performer than direct source position or volume.

Avoid changing mapping relationships dynamically. If the audience is intended or permitted to perceive the nature of gesture control, this effect may be confused or destroyed by changing scaling or transfer functions. In the case of very subtle effects this may not be an issue, since it is unlikely that the audience will understand the mapping relationship.

5 Conclusion

This paper described an approach to the use of performance gestures for controlling parameters of a sound spatialization system. Using motion capture systems we have identified parameters of a cello performer's gestures which can be detected and used for such control. Testing has indicated that such control can prove useful to allow interactive sound spatialization without placing much additional load on the performer. There now exists the opportunity to make use of this system in live performance and a number of such performances are planned, beginning with a performance as part of Enactive/07.

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