Controlling Physically Based Virtual Musical Instruments Using The Gloves

Stefania Serafin,
Department of Architecture,
Design and Media Technology
Aalborg University
Copenhagen
sts@create.aau.dk

Stefano Trento,
Department of Architecture,
Design and Media Technology
Aalborg University
Copenhagen
trento@create.aau.dk

Francesco Grani
Department of Architecture,
Design and Media Technology
Aalborg University
Copenhagen
fg@create.aau.dk

Hannah Perner-Wilson
Plusea
hannah@plusea.at

Sebastian Madgwick
Mechanical Engineering
Department
University of Bristol
s.madgwick@bris.ac.uk

Tom Mitchell
Department of Computer
Science and Creative
Technologies
UWE, Bristol
tom.mitchell@uwe.ac.uk

ABSTRACT

In this paper we propose an empirical method to develop mapping strategies between a gestural-based interface (the Gloves) and physically based sound synthesis models. An experiment was conducted to investigate which gestures listeners associate with sounds synthesised using physical models, corresponding to three categories of sound: sustained, iterative and impulsive. The results of the experiment show that listeners perform similar gestures when controlling sounds from the different categories. We used such gestures in order to create the mapping strategy between the Gloves and the physically based synthesis engine.

Keywords

physical models, gloves, mapping, gestural control.

1. INTRODUCTION

Several interfaces for musical expression and sound synthesis techniques have been developed in academia and industry. However, the issue of how to connect interfaces to sound synthesis, the so-called mapping problem, is still open. In this paper we are interested in understanding whether there exist a set of common sound producing gestures that people perform to control different physically based sound synthesis models. We are particularly interested in sound producing gestures which have been categorised by Cadoz into excitatory gestures, which are human movements made with the intention of transferring energy from the body to an instrument, and modulatory gestures, which are gestures that modify the resonant features of an instrument [4]. Classical musical instruments incorporate both categories of gesture, excitatory gestures such as hitting, blowing and bowing, as well as modulatory gestures such as the motion of the left hand of a bowed string instrument. In this paper we are interested in excitatory and modulatory gestures produced exclusively by both human hands.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, to republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.

NIME'14, June 30 – July 03, 2014, Goldsmiths, University of London, UK.

Copyright remains with the author(s).

2. RELATED WORK

The relationship between gesture and sound, and specifically which kind of gestures listeners and performers associate with specific sounds, is an active field of research [9, 13, 8, 21].

When the connection between gestures and sound is not predetermined, as is the case with digital musical systems, Leman proposes that mappings should be chosen using an approach based on embodied music cognition [15].

In [9], Godoy et al. document an experiment exploring the associations that listeners have between gestures and musical sounds. Listeners were asked to draw on an A4 Wacom tablet the gesture that they would ascribe to different categories of sound. This preliminary study showed some reoccurring gestures; for example, an ascending frequency was often represented as an ascending line.

In a similar study, participants were asked to move a rod in the air, pretending that the sound that could be heard was produced by the rod [18]. Canonic correlation analysis showed a strong correlation between vertical position and frequency. In [5], the authors hypothesise that the gestural response of participants was related to the ease with which the sound could be identified. In two experiments, subjects were exposed to sounds where the causing action was easily identified, and sounds where such action was not identified. It was found that gestures associated with causal sounds resemble the causing action, while gesture associated with non-causal sounds tended to follow the sound's acoustic contours.

The importance of mapping between gestures and sound is also an active field of research, especially in the new interfaces for musical expression community [23, 11, 22]. A relatively new book covering several contributions to this topic is [10].

Although bi-manuality is an important aspect of traditional musical instruments, the field of bi-manual coordination in new interfaces for musical expression has not been widely investigated. Some exceptions exist in the work described in [14, 7].

3. THE GLOVES

Gloves embedded with sensors have been widely adopted in the human-computer interaction and new interfaces for musical expression communities [20, 3]. A known example from the electronic music community are the gloves built by Laetitia Sonami in 1991.[1] In this paper we use the ArduIMU gloves developed by the team responsible of the research presented in [16, 17]. Such gloves have one bend sensor embedded in each finger, and are connected to one ArduiMU sensor board in each hand, which comes equipped with a MPU6000 combined triple-axis 2000 dps gyroscope and 16 g accelerometer (see Figure 1).

The gloves can be connected to a computer either wirelessly through Bluetooth LE or through USB. A custom software application called Glover receives the sensor data from the gloves and encapsulates a number of signal conditioning and posture recognition algorithms summarised in [17]. The resulting data are sent out as OSC messages, which are received within Max 6.

Detailed instructions for building such gloves are presented here:

http://theglovesproject.com/category/diy/

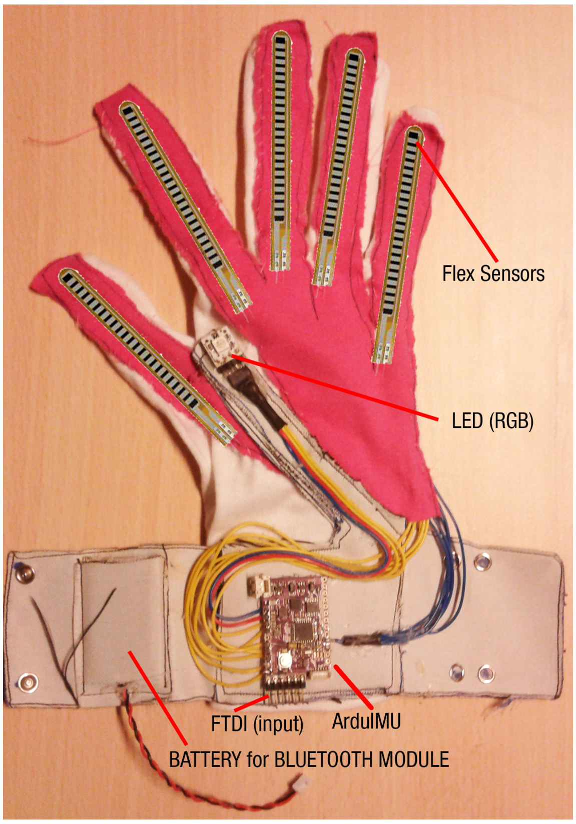

Figure 1: A photograph of the Gloves used in this paper.

4. PHYSICAL MODELS

As with previous studies [9, 1], we considered the three categories of objects proposed by Schaeffer: impulsive, iterative and sustained [19].

Based on those categories, we implemented several physics based sound synthesis models as external objects for the Max 6 environment.

4.1 Impulsive

For the categories of impulsive sonic objects, we implemented an extended plucked string Karplus-Strong physical model as described in [12]. The model allows to interact with a string with varying inharmonicity by simulating the act of plucking it. The control interface for the model is shown in Figure 2. The model is controlled by the duration of the excitation, the fundamental frequency of the string, inharmonicity factor and damping factor of the string.

4.2 Sustained

For the sustained excitation we adopted a friction model as described in [2], simulating continuous interaction between rubbed dry surfaces. The model is used to simulate the act of rubbing the rim of a tibetan singing bowl or bowing a musical saw. The musical saw example is shown in Figure 3. The interface includes control parameters for the resonating object (fundamental frequency and damping factor) as well as parameters for the exciter (in this case the bow), e.g., position, force and velocity of the bow.

4.3 Iterative

For the iterative excitation we implemented a physically informed stochastic model (PhiSM) proposed originally in [6]. This model is based on pseudo-random overlapping of grains of sounds according to predetermined physical rules. The control mechanism for such model is shown in Figure 4. The interface induces independent controls for five resonators, although for the purpose of the experiment we allowed only one of them to be modified; the others were adjusted according to the frequency ratio implemented.

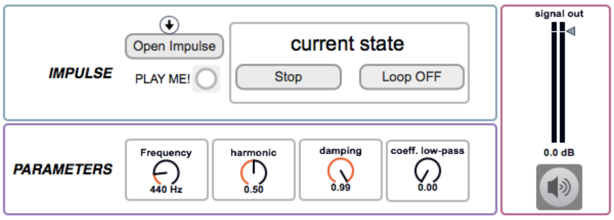

Figure 2: Control interface for the impulsive excitation model (plucked string).

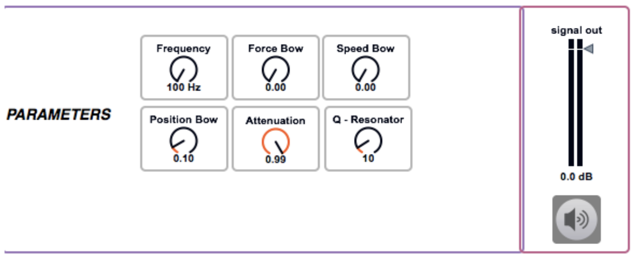

Figure 3: Control interface for the sustained excitation model (musical saw).

5. EXPERIMENTAL DESIGN

The goal of this experiment is to investigate whether there exists a recurring set of gestures that players would like to use to control the different synthesis models; we would then apply such gestures as mapping strategies between the gloves and the physical models.

Seven participants (five professional musicians and two non musicians) were asked to wear the gloves and listen to different sound stimuli, produced using the physical models. Each participant was instructed to use their left hand to control the parameters of the resonator, e.g., fundamental frequency and damping factor, and the right hand to control the parameters of the excitation mechanism. After

[1]More details on Sonami's gloves can be found here here:http://www.sonami.net/lady_glove2.htm

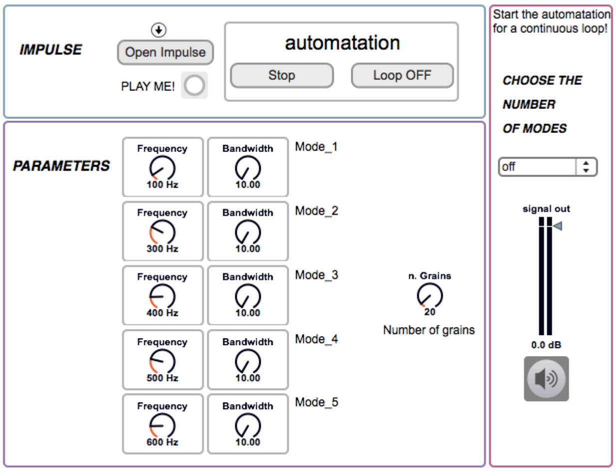

Figure 4: Control interface for the iterative excitation model (physically informed stochastic model (PhISM)).

listening to each stimulus, participants were asked to produce a gesture with both hands that would represent the control strategy for the sound heard.

The test set was comprised from 11 sounds in total, which included all categories of iterative, sustained and impulsive sounds. The experiment was video recorded for further analysis.

5.1 Results

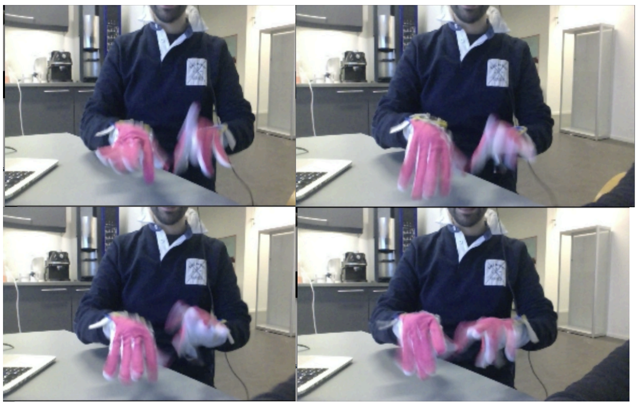

Figure 5: Video capture from the experiment. Playing the PhISM algorithm.

The video recordings where analysed using qualitative observations by the authors of the paper. They revealed the common control procedures described in the following.

5.2 Left hand

- Six out of seven participants used an up and down movement of the left hand as frequency control. Specifically, participants responded to increases in frequency by raising the left hand upwards, and viceversa (see Figure 6).
- The last participant was moving the hand horizontally to control the frequency.

5.3 Right hand

- During the control of impulsive sounds, the right hand was simply used for hitting. The length of the gesture corresponded to the duration of the plucked sound: short damped pluck sounds were controlled by short gestures, while longer sustained plucked sounds were controlled by longer gestures.

Figure 6: Video capture from the experiment. Controlling changes in frequency by moving vertically the left hand.

- The same happened for the control of sustained sounds: the right hand was used for starting and sustaining the excitation, is a way similar to how bowed string players perform bow strokes. As in the case of an impulsive excitation, the length of the gesture corresponded to the duration of the sound.
- The iterative sounds represented by the physically informed stochastic model had a very specific control gesture: six out of seven participants moved alternatively up and down the fingers of the right hand, at a frequency corresponding to the variations of the particles.
- The last participant was hitting on the table to control the iterative sounds.
- For both sustained and impulsive sounds, all subjects performed control gestures whose length was the same as the amplitude envelope of the corresponding sound, e.g., longer sounds were reproduced using longer arm gestures, and shorter sounds were reproduced using shorter hand gestures.

This preliminary experiment, despite the small number of participants, showed that there exist some common gestures that listeners associate with specific sounds. We therefore adapted those gestures to create the mapping strategy between synthesis models and the Gloves, as described in the following section.

5.4 Mapping strategies

The results of the experiment described in the previous section allowed us to design the mapping strategies between the sound synthesis models and the Gloves.

For all models, we used the left hand to control the parameters of the resonator (e.g., fundamental frequency and damping factor). As seen in the experiment, the vertical position of the left hand was used to control the fundamental frequency. Specifically, a continuous upwards and downwards vertical motion of the left hand implied a continuous increase and decrease of the fundamental frequency. This position was tracked by integrating twice the value of the accelerometer embedded in the left hand glove.

The right hand was used to control the parameters of the excitation. For the impulsive and sustained gestures, we used the accelerometer embedded in the glove to control the excitation. For the iterative excitation, the rate of variations for the value of the bend sensors of the fingers was used to control the physically based stochastic synthesis algorithm.

6. CONCLUSIONS

In this paper, we presented a preliminary experiment whose goal was to investigate whether there exists some common sound producing gestures that listeners perform when played a range of musical sounds, from sustained, to iterative to impulsive. We were particularly interested in investigating such gestures in the context of bi-manual control of physically based sound synthesis models, by instructing listeners to control the parameters of the excitation with the right hand and the parameters of the resonator with the left hand. Despite the low number of participants, the experiment indicated that a common set of sound producing gestures might indeed exists. These common gestures allowed us to empirically design the mapping strategy between the Gloves and the different sound synthesis models.

Until now, the adopted mapping strategies have been informally tested by few performers that found it rather intuitive after some limited training. Further studies are needed in order to assess the playability of the connection between the Gloves and different sound synthesis models, in such a way that they can be utilised in performances.

7. REFERENCES

[1] A. Altavilla, B. Caramiaux, and A. Tanaka. Towards gestural sonic affordances. In *Proceedings of the 2013 conference on New interfaces for musical expression.*

[2] F. Avanzini, S. Serafin, and D. Rocchesso. Interactive simulation of rigid body interaction with friction-induced sound generation. *Speech and Audio Processing, IEEE Transactions on*, 13(5):1073–1081, 2005.

[3] B. Bongers. Physical interfaces in the electronic arts. *Trends in gestural control of music*, pages 41–70, 2000.

[4] C. Cadoz. Musique, geste, technologie. *Les nouveaux gestes de la musique*, pages 47–92, 1999.

[5] B. Caramiaux, F. Bevilacqua, T. Bianco, N. Schnell, O. Houix, and P. Susini. The role of sound source perception in gestural sound description. *ACM Trans. on Applied Perception (in review)*, 2013.

[6] P. R. Cook. Physically informed sonic modeling (phism): Synthesis of percussive sounds. *Computer Music Journal*, 21(3):38–49, 1997.

[7] N. dÕAlessandro and T. Dutoit. Handsketch: bi-manual control of voice quality dimensions and long term practice issues. *Quarterly Progress Scientific Report*, page 59.

[8] R. I. Godøy. Gestural affordances of musical sound. *Musical gestures: Sound, movement, and meaning*, pages 103–125, 2010.

[9] R. I. Godøy, E. Haga, and A. R. Jensenius. Exploring music-related gestures by sound-tracing: A preliminary study. 2006.

[10] R. I. Godøy and M. Leman. *Musical gestures: Sound, movement, and meaning.* Routledge, 2009.

[11] A. Hunt, M. M. Wanderley, and M. Paradis. The importance of parameter mapping in electronic instrument design. *Journal of New Music Research*, 32(4):429–440, 2003.

[12] D. A. Jaffe and J. O. Smith. Extensions of the karplus-strong plucked-string algorithm. *Computer Music Journal*, 7(2):56–69, 1983.

[13] A. R. Jensenius, M. M. Wanderley, R. I. Godøy, and M. Leman. Musical gestures. *Musical Gestures: Sound, Movement, and Meaning*, page 12, 2009.

[14] L. Kessous and D. Arfib. Bimanuality in alternate musical instruments. In *Proceedings of the 2003 conference on New interfaces for musical expression*, pages 140–145. National University of Singapore, 2003.

[15] M. Leman. *Embodied Music: Cognition and Mediation Technology.* The MIT Press, 2008.

[16] T. J. Mitchell and I. Heap. Soundgrasp: A gestural interface for the performance of live music. 2011.

[17] T. J. Mitchell, S. Madgwick, and I. Heap. Musical interaction with hand posture and orientation: A toolbox of gestural control mechanisms. 2012.

[18] K. Nymoen, B. Caramiaux, M. Kozak, and J. Torresen. Analyzing sound tracings: a multimodal approach to music information retrieval. In *Proceedings of the 1st international ACM workshop on Music information retrieval with user-centered and multimodal strategies*, pages 39–44. ACM, 2011.

[19] P. Schaeffer. *Traité des objets musicaux: essai interdisciplines.* Seuil, 1977.

[20] D. J. Sturman and D. Zeltzer. A survey of glove-based input. *Computer Graphics and Applications, IEEE*, 14(1):30–39, 1994.

[21] D. Van Nort. Instrumental listening: sonic gesture as design principle. *Organised sound*, 14(02):177–187, 2009.

[22] D. Wessel and M. Wright. Problems and prospects for intimate musical control of computers. *Computer Music Journal*, 26(3):11–22, 2002.

[23] T. Winkler. Making motion musical: Gesture mapping strategies for interactive computer music. In *ICMC Proceedings*, pages 261–264, 1995.