MyoSpat: A hand-gesture controlled system for sound and light projections manipulation

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ABSTRACT

We present MyoSpat, an interactive system that enables performers to control sound and light projections through hand-gestures. MyoSpat is designed and developed using the Myo armband as an input device and Pure Data (Pd) as an audio-visual engine. The system is built upon human-computer interaction (HCI) principles; specifically, tangible computing and embodied, sonic and music interaction design (MiXD). This paper covers a description of the system and its audio-visual feedback design. Finally, we evaluate the system and its potential use in exploring embodied, sonic and music interaction principles in different multimedia contexts.

1. INTRODUCTION

As noted by McNutt [1], performing with technology requires the development of new skills and flexibilities often at odds with musical techniques, with potential negative 'disruptive' effects. Our hypothesis is that a gesture-controlled electronic interaction system, in particular MyoSpat, can move towards overcoming the 'disruptive', 'highly complex' nature of live electronic processing experienced by many performers, providing them with an opportunity for new expressive ideas. Bullock et al. [2] identify that the lack of familiarity with highly complex systems can cause divergence between the performer and technology, which adversely affects the performer's experience. This can create a disassociation between the performer's gesture and the sonic result. Lippe [3] states the importance of allowing musicians' expressivity to extend to their control over any electronic part of a performance. Consequently, musicians must be able to interact confidently with technology in order to present a musical and expressive performance. With MyoSpat, we underline the importance of embodying music [4], allowing the performers' musical expression to be extended by their gestural control over any electronic part in performance.

Visual feedback can enhance the gesture-sound relationship, playing an important role in guiding the user's actions while using the system [5] and strengthening our perception of the auditory feedback [6]. MyoSpat affords musicians a greater sense of control over sound through a direct connection between movement and audio-visual feedback, whilst making the newly learnt as intuitive and complementary to instrumental technique as possible.

Motion tracking allows complex physical movements to be effectively captured and mapped to audio-visual responses. However, tracking both body motion and biodata, such as muscle activity, can create stronger action-sound relationships [7], leading to a better understanding of the dynamics and mechanisms embedded in these actions [8]. Over the last two decades many systems combining both motion with myograph data have emerged [9, 10]. Further developments over the past two years have seen the inclusion of the Myo armband in this area of work, demonstrating its reliability and appropriateness as an expressive gestural controller for musical applications [11, 12, 13]. The remainder of this paper is structured as follows: Section 2 outlines the MyoSpat system. Section 3 present our evaluation methodology and results are provided in Section 4. Conclusion and future works are presented in Section 5.

2. THE SYSTEM

MyoSpat is a interactive system that allows performers to manipulate sound and light projections through hand-gestures in a musical performance. Developed through an iterative design cycle, MyoSpat's design utilises context-based, activity-centred and emphatic design approaches: interactions between users and mediating tools are positioned within the motives, community, rules, history and culture of those users [14, 15].

The current version of the system (outlined in Figures 1 and 3) uses (i) the Myo armband as an input device to track hand-gestures; (ii) Myo Mapper [1] to extract and convert data from the Myo into Open Sound Control (OSC) messages; (iii) Wekinator [2] for the gesture recognition process; (iv) Pure Data (Pd) for the audio-visual signal elaboration and (v) Arduino for converting serial data into DMX signals. The simplicity of MyoSpat's audio engine allows the

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[1] http://www.balandinodidonato.com/myomapper/
[2] http://www.wekinator.org/

user to use a stereophonic or quadraphonic audio system without making changes to the code.
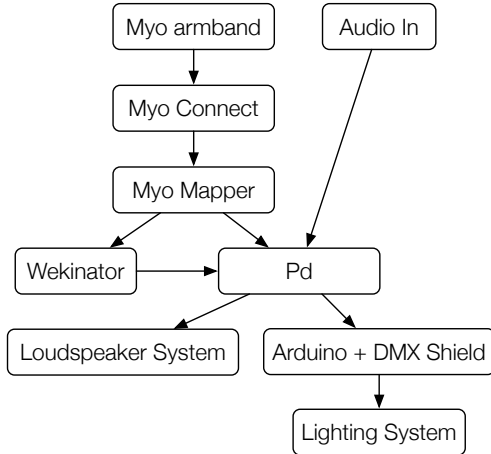

Figure 1. MyoSpat system structure.

2.1 Input device

We chose the Myo armband after carrying out a survey of commercial devices capable of reliably and wirelessly monitoring motion and muscle activity, without restricting or creating conflict with the movements required during instrumental performance. Due to a lack of reliable software to easily map and manage Myo data through a GUI, we developed the Myo Mapper software. Myo Mapper also features calibration and scaling functions in order to facilitate data management during musical performance; the calibration function helping to overcome issues linked to Myo's data drift [7].

2.2 Interaction design

MyoSpat's interaction design (IxD) draws on mimetic theories, embodied simulations [16] and metaphorical actions [17], directly connecting the audio-visual feedback produced by gestural interaction. MyoSpat approaches sound manipulation in a way that considers sound as a tangible entity to be grasped and shaped through continuous and tactile interactions [18].

The system's IxD was developed around three main objectives: to create a gesture vocabulary that enables interaction with the system through meaningful gestures for both performer and audience; to produce a clear, strong relationship between gestures and audio-visual feedback; and to enable musicians to use the system through natural interactions. The term natural here refers to the contextualised interaction, conditioned from previous knowledge, with physical and virtual objects [19, 20]. In this specific case we refer to previously acquired instrumental techniques.

MyoSpat allows the user to wear the Myo armband on either the left or right arm and retain the same level of interaction with the system. The following explanation of MyoSpat's interaction design considers the user to be wearing the Myo on the left arm.

The IxD comprises five *activation gestures* and one *modulating gesture*, allowing the sound and light to be manipulated in six different ways.
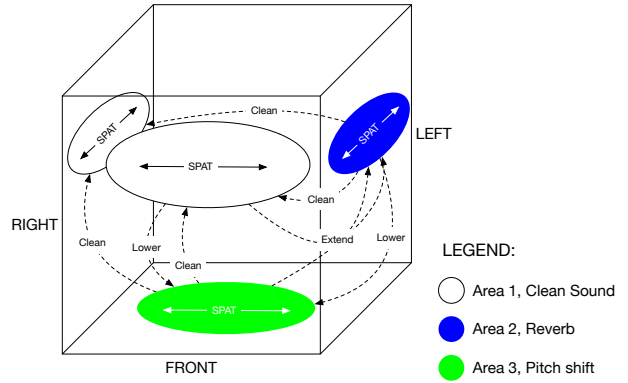

Figure 2. MyoSpat interactive areas.

The *clean* gesture is performed by orienting the arm towards the front of the body and/or inwards towards the chest (Figure 2, area 1). It allows users to obtain a clean sound and to set the lighting system colour to white.

The *extend* gesture is performed by orienting the arm outwards (Fugure 2, area 2), allowing users to process the sound through a long reverb with fixed parameters and to set the lights' colour to blue.

The *lower* gesture is performed by lowering the arm towards the ground (Figure 2, area 3). It enables the user to pitch shift the sound one octave lower, setting the lighting colour to green.

The *crumpling* gestures are performed by rapidly moving the fingers or performing a similar movement that engages the forearm's muscles and generates fluctuations in EMG data, as taken from previous experiments with sound design in mixed realities [21]. The sonic response allows the audio signal to pass through amplitude modulation (AM) and delay effects connected in series. AM gain and delay time are controlled by a direct mapping of Myo's EMG data.

The *throwing* gesture involves a rapid movement of the arm as if throwing an object, enabling the user to spatialise the sound through an automated trajectory. Duration and direction of the trajectory are respectively driven by direct mapping of Myo's EMG mean absolute value (MAV) [22], Myo yaw value and the moment at which the gesture is recognised by Wekinator. The brightness of each light adjusts relative to the spatial position of the sound as a consequence of the generated audio trajectory. The throwing gesture is inspired from previous works on approaches to visualising the spatial position of 'sound-objects' [23].

The *waving* gesture allows the user to pan the sound around the room; the spatial location of the sound is established through a direct mapping of the yaw data. The brightness of each light is adjusted relative to the spatial position of the sound.

The relationship between sound and gesture is built upon the metaphor and mimetic theories [24] embedded in the movements performed when the hand moves towards each of the three areas, and not the pose assumed by the hand once it has reached one of these areas. When performing the *extend* gesture, users move their arm outwards, thus extending the area that the body covers within the space. We try to represent the expansion of the body within the 3D space extending the sound with a long reverb. We associate

the *lower* gesture with a pitch shift one octave lower, as a result of lowering a part the arm.

2.3 Gesture recognition

The gesture recognition process was implemented using Wekinator. The *clean*, *extend*, *lower* and *crumpling* gesture were recognised using the Neural Network Model, which is an implementation of Weka's [3] Multilayer Perceptron class. These four models were trained using Myo's yaw, pitch and EMG MAV data. These models were trained with 5476 samples. The *clean*, *extend*, *lower* and *crumpling* gesture models were built using respectively 1, 1, 2 and 3 hidden layers.

We observed that the throwing gesture is better recognised through a gestural data analysis over time. For this reason, the relative model was created using dynamic time warping. It was trained using Myo's acceleration and gyro data. This was trained with 50 samples.

2.4 Audio and light projection processing

The Pure Data (Pd) programming environment was used to develop the engine behind audio manipulations and light projections, with data sent from Wekinator and Myo data changing the parameters of each component. The Pd patches used in Integra Live's [4] Pitch Shifter and Reverb modules were implemented in the MyoSpat Pd patch to control pitch shift and reverb respectively. MyoSpat's spatialiser has three components: gain control, a high-pass filter and a delay line. Gain factor, filter cut-off frequency, and delay time are controlled by a direct mapping of the Myo yaw value. Data from the throwing gesture model triggers an automated sound spatialisation trajectory. A direct mapping of the Myo EMG data determines the duration for which this effect is applied to the audio signal.

Data from Wekinator controls the light colour, with the Myo yaw value independently adjusting the brightness of each light depending on the sound's spatial placement. Pd then rescales the Myo and Wekinator data, transmitting it via serial connection to an Arduino with a Tinkerkit DMX Master Shield. A perfect white light was not obtained due to the low resolution of the DMX lights used in the user study (Section 3); higher resolution lights capable of producing a pure white light may improve visual feedback.

The audio system was formed using a quadraphonic audio system of four Genelecs 8050A speakers. The lighting consisted of four RGB LED light sources placed next to each speaker.

3. EVALUATION

The gesture recognition evaluation was carried out adopting a direct evaluation approach [25].

A user study was conducted to evaluate the gesture recognition models, reliability, learnability, as well as the participants' perception of the audio-visual feedback and their user experience, and the ease of use. 11 participants took part in the study: 9 musicians and 2 non-musicians. The musicians were 1 harpist, 2 keyboardists, 2 saxophonists, 1 percussionist (snare drum), 1 singer, 2 guitarists,

[3] http://www.cs.waikato.ac.nz/ml/weka/
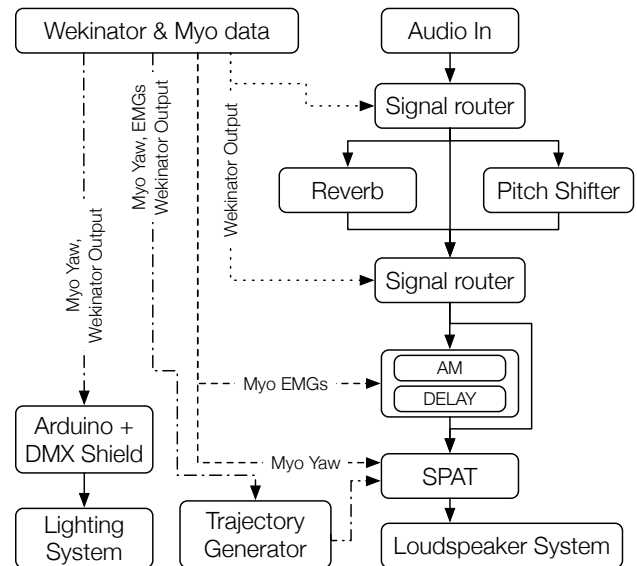[4] http://integra.io/integralive/

Figure 3. System implementation.

1 engineer and 1 visual artist. Of the musicians 6 were conservatoire-trained, with most actively using or having used technology in their professional practice.

The user study was divided into four stages: (i) structured interview, (ii) training, (iii) qualitative evaluation/interview and (iv) user experience questionnaire (UEQ) [26]. Participants were first asked questions about their musical background and experience with technology through a structured interview. During the training stage participants were instructed about the MyoSpat system, and the interaction design and audio-visual feedback they should expect to experience. This was followed by a practice period lasting for a maximum of 10 minutes. After this training period, a qualitative evaluation was conducted. Participants were asked to perform each of the recognised gestures 5 times with visual feedback and 5 times without. An audio file containing the sound of water flowing was used during this part of the study, with participants manipulating it with the recognised gestures. With every successful gesture and pose recognised by the system, we asked the participants if they positively perceived a change in the audio manipulation mapped to each gesture. Direct evaluation of the second machine learning model was also conducted. This was done by tracking how many times out of 5 Wekinator correctly recognised the gestures. During the qualitative evaluation data about the system and each user's experience was gathered through an informal, semi-structured interview. Lastly, participants were asked to complete a UEQ.

4. RESULTS

The *clean*, *extend* and *lower* gesture were recognised with an accuracy of 100%; the *crumpling* gesture achieved 97% accuracy and the *throwing* was recognised only 75% of the time (Figure 5).

Data from the interview and the qualitative evaluation were collated and statistically analysed; the UEQ Analysis Tool was used to tabulate and analyse this data [26]. A

Grounded Theory approach, also used in [27], was adopted to analyse qualitative data gathered through the informal semi-structured interview.

Results from the qualitative evaluation, indicate that the MyoSpat system is easy to learn, and with practice can adapt to the instrumental technique required for the instruments used during the test. MyoSpat's flexibility in allowing the user to wear the Myo armband on either the right or left arm partly facilitates this. Participants felt confident using the system, with an average training time of 04'55" (min 2'30", max 10'18"). We believe that this is a very short time for learning how to use a new interactive system to control audio-visual feedback. However, when comparing data from the UEQ collected from the user study and from a workshop at Cardiff Metropolitan University, where 13 participants used the system for an average of 2'30" each, it emerged that goal-directed tasks were more difficult to perform, suggesting that improvising with the system offers a better user experience than composing. Attractiveness and hedonic qualities scored similarly on the UEQ, as can be seen in Figure 4.
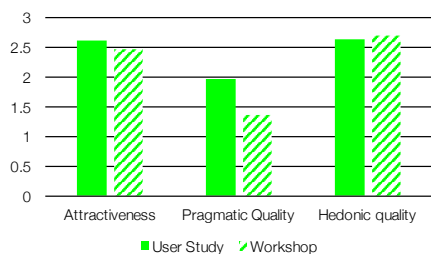

Figure 4. User experience questionnaire results from data collected during the user study and a workshop delivered using MyoSpat.

As discussed in [28], audio feedback can be meaningful to the user for exploring the system when fulfilling sound-oriented tasks. However, the completion of the task is improved when using visual feedback and the IxD-auditory feedback relationship becomes stronger.

Most participants initially interacted with the system through the *crumpling* gesture. When using it to manipulate a pre-recorded audio file containing a flowing water sound, their interaction appeared natural and embodied. The lower gesture created an underwater sound, resulting in participants interacting with it as if they were submerging their hand in a tub filled with water. Other gestures included splashing and swirling water, [5] demonstrating MyoSpat's potential to explore embodied interaction with sonic objects, in line with similar research [29, 28]. When using their instruments with the system, these embodied gestures were further explored by creating vibrato and tremolo effects through the periodic waving of the hand similar to the vibrato technique on a string instrument; this in turn modulated MyoSpat's amplitude modulation and delay effects. Interestingly, the same gesture was performed not only by guitarists but also by keyboard and saxophone players. [6] This way of interacting with the system was non-previously considered to us. As stated in [30], it is clear that non-obvious gestures and the sound

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[5] https://vimeo.com/209717708
[6] https://vimeo.com/202150793

such interactions produce [31] are relevant for informing the designing natural and embodied music interactions.

All participants considered the *lower*, *clean* and *waving* gestures easy to learn and perform, being intuitive, natural and highly related to the audio manipulations associated with each gesture. Participants considered the relationship between the *throwing* gesture and its related audio-visual response to be the weakest. This is most likely attributed to a lower accuracy (75%) of the gesture recognition model by the machine learning algorithm. Only in the case of one participant, the *throwing* gesture was recognised correctly by the system and perceived correctly by the participant 100% of the time. Participants were able to perceive the *throwing* gesture's audio response better and use it creatively, when interacting with the system using their instrument instead of the flowing water audio file. [7] Detailed data about gesture recognition performance and the participants' perception of the audio-visual feedback are reported in Figure 5.
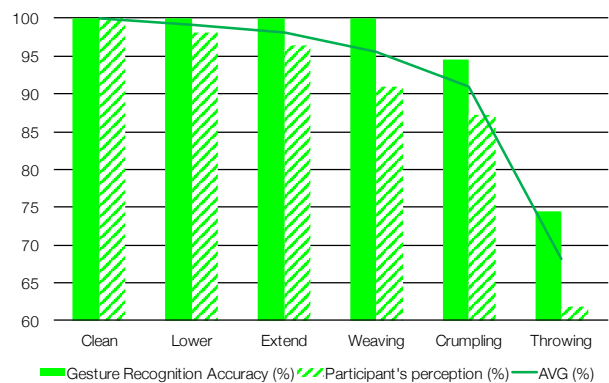

Figure 5. Gesture recognition and participants' perception of the audio-visual feedback perception, calculated in percentages.

The degree of freedom imposed by the physical requirements of playing a musical instrument, coupled with the movement limitations imposed by the hand gestures of the interaction design, allows performers to explore new postures and ancillary gestures. 6 participants interpreted these limitations as potentially having a restrictive effect on their musical performance, and as a result may impose certain body postures and instrumental techniques.

Participant 1 (guitar player) said, "*when you play a fast passage you contract the muscles, and you might not want to trigger the delay effect. In that case you don't have control of the effect. To play that kind style (musical style) might be difficult. But the more you practice you will be able to play.*"

Participant 9 (guitar player) said, "*when you are doing bar chords, the muscles naturally tense. So you cannot really control the effect. The more you go down (closer to the guitar's bridge), the muscles tense a lot more and more, so you cannot control the effect at all.*"

At the same time, some of the participants interpreted these restrictions as something with which they could explore new creative possibilities as well. Participant 11 (saxophone player) said, "*When the fingers are moving, it causes certain things to happen, and I'm one who doesn't*

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[7] https://vimeo.com/209730610

move much, so in this case the system imposes a performing style that you don't necessarily want, but exploring the three spaces is very interesting. However, I would like to have a smoother transition between the effects, for the reason that I like to get to the spaces in between. Because the three spaces are so well defined, apart from the drop in pitch, the reverb, the delay and the trajectories there is not much. But it's a good sign because you can easily understand and control what you want to do. But by the way I perform, the places in between would be the interesting spaces that I want to get to, but I can't. My approach to electronic systems is to have something very limited, which then gets incorporated with other things. The saxophone is very limited, it's a metal tube, and actually it does one thing, part of the fun is to find out where the boundaries are. With three effects it's enough, there is interesting stuff there and you can also start to test where the edges are, where breaking points are, to test the misbehaviour."

Many gestures and poses used by participants to trigger audio manipulations were not anticipated by the authors, demonstrating the system's potential to allow new ways to approach bodily exploration during musical performance. Participants felt that visual feedback from the light projections helped to guide and improve the accuracy of their interaction with the system, improving their ability to identify the audio manipulations associated with each gesture. It also provided an extra layer of interaction to explore, enhancing the level of immersiveness participants felt. Though visual feedback was noted to enhance the user experience, it also had the potential to distract the user, shifting their focus from auditory to visual.

MyoSpat was considered by all participants in the user study as an engaging and stimulating creative tool for musical performance. Despite UEQ results suggesting MyoSpat offers a better user experience when improvising, one participant used the system to compose *The Wood and the Water*, a work for harp and electronics [32]. Although a pre-composed work, the composer did note that recreating each performance exactly was not possible, highlighting that an improvisatory element existed in the work. These types of "misbehaviours" of the system also allow a reciprocal sonic interaction between the performer and the machine, making the live electronics as interactive electronics within an compositional context [33]. A video of participants improvising using MyoSpat can be found here. [8] In addition to musical performance applications, one participant (amateur dancer) saw a potential use of the system to recognise dance movements and map them to audio-visual responses. [9] Interestingly, systems for extending other form of interactive dance performances have been recently developed [34, 35].

5. CONCLUSIONS

We have presented MyoSpat, an interactive hand-gesture controlled system for creative audio manipulation in musical performance. Machine learning was successfully incorporated to recognise a number of physical gestures, enabling audio-visual manipulations to be mapped to each

one of them. Results from the user study demonstrate that the system can be used for improvisation and composition [32], allowing users to explore a novel range of embodied physical interactions during the music making process. Results demonstrate that the use of a prosthetic gestural controller that does not restrict the user's movements has potential applications beyond purely musical ones.

Suggestions from user study participants form the basis for future work on MyoSpat. These include developing (i) stronger audio-visual elaborations, (ii) smoother transitions between audio and visual effects, (iii) a wider palette of gestures and (iv) ways to manipulate sound and light projections, (v) better panning curves, and (vi) a more coherent colour mapping of the lighting system. One participant suggested using the primary colours red, green and blue for the three areas. Another participant, who also composed and performed using MyoSpat, requested the development of a MyoSpat standalone application, allowing any performer to use MyoSpat without any previous knowledge.

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