Harnessing ancillary microgestures in piano technique: implementing microgestural control in to an expressive keyboard-based hyper-instrument

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Abstract

The chapter describes through the implementation of microgestural sound control, how performers can gain wide control over digital sound processing through their existing technique. By using radar millimeter waves to capture micromotions and microgestures, performers achieve high level of expression without the need to modify their instrument nor dev additional technique. This research builds upon existing instrumental technique and removes the steep learning curve typically found when performing digital or *augmented musical instruments. We present a case study that enables pianist to retain and focus on technical control and musical freedom resulting in a less disruptive experience.*

Introduction and Aims

Musicians spend a great deal of time practicing their instrument. As a result, they develop a unique set of microgestures that define their personal sound: their acoustic signature. This personal palette of gestures provides distinctive aspects of piano playing and varies from musician to musician, making their sound unique and enabling them to expressively convey their music. This chapter presents a case study investigating an innovative way of extending keyboard interfaces, drawing upon pianists' already learned instrumental technique. The research aims to extend the creative possibilities available on keyboard-based interfaces, stimulating the creation of new approaches into building new interfaces for musical expression, as well as exploring new ways of learning and playing digital instruments.

The ability of performers to communicate through their instrument depends on the fluency the performer has with the instrument itself (Tanaka 2000). Fluency, in this case, is seen as a combination of technical proficiency and expressive charisma, that are themselves dependent on the time spent practicing an instrument and ways of incorporating ancillary movements that are known to convey expressiveness in musical performance (Miranda and Wanderley 2006).

Pestova, a concert pianist, suggests that “the ability to be creative with phrasing, articulation and stylistically acceptable breathing or flexibility are just some of the elements that make for an expressive performance and create a satisfying experience for both the performer and the audience.” (Pestova 2008: 68)

The large kinetic vocabulary necessary to perform with an instrument is essential in order to operate an instrument. Thus, the aim of this research is to create a keyboard-based interface that enables processing of the piano sound utilizing the ancillary gestures that pianists already employs in performance so as not to ‘disrupt’ their piano technique. In this way, the digital instrument will not be seen and treated as a difficulty to be overcome as described by Rebelo (2006), but rather as an extension of the pianist’s known technique. In order to achieve this, we apply machine learning algorithms, specifically Random Forests classification algorithm, to enable us to accurately identify existing microgestures currently used and performed by the pianist and consequently freeing the performer from the difficulty of learning any new gestural language or technique that might be required. The learning curve of digital instruments can be the most challenging and disruptive element for a performer since it considerably limits any technical control or freedom (Nicolls 2011).

Focusing on user-centered and activity-centered interface design approach, we aim at creating a system that interfaces and allows performers to express their creativity and extend it through greater engagement with this innate microgestures in the activity of piano performance. An interface that removes or reduces the steepness of the learning curve when approaching it for the first time can also remove the creative barrier posed by a system designed without the end user in mind (Bullock, Michailidis, and Poyade 2016). For the purpose of this paper we consider microgestures as small movements that are part of the pianistic technique, but not necessarily related to the sound production. These movements revolve around the sound producing gestures are also called ancillary movements (Cadoz and Wanderley 2000).

The system, pertaining to the augmented instrument class (Newton and Marshall 2011), offers a creative environment to manipulate live piano sound. Google's Soli alpha sensor, a miniature radar based technology, was used to detect the pianist's hand movements (Lien et al. 2016). Through machine learning specific gestures are recognized which are then mapped to the frequency modulation algorithm parameters. Specifically, the acceleration and energy of the analyzed gesture are mapped and used to control the depth and speed of the vibrato effect.

Background

Since the development of aftertouch in the 1980s, keyboard-based digital instrument makers have had the opportunity to enhance features of the instrument by adding several layers of expressiveness, making effects and modulations possible that are not available to their acoustic counterparts.

In the past, both the Haken Continuum Fingerboard (Haken, Abdullah, and Smart 1992) and The Rolky Asproyd (Johnstone 1985) had approached the issue with two different methods. The first approach consisted in a continuous surface where a classical keyboard was drawn, and the independent tracking of the x-y-z coordinates of up to 10 different fingers enabled single note pitch and amplitude control. The second approach consisted of a transparent surface using light detection to determine the position of each finger and enable single key pitch modulation. Both these interfaces had a limited amount of tactile information regarding the location of the fingers, and didn’t manage to provide an intuitive way to provide polyphonic pitch-bending capacity while also enabling effective tuned playing (Lamb and Robertson 2011). In addition, the Haken Continuum Fingerboard does not have moving keys, with the Rolky Asproyd being a touch controller and not specifically a keyboard based instrument. Both interfaces present the pianist with a level of unfamiliarity that requires adaption or the learning of new skills.

More recently, innovative keyboard interface development are mainly represented by ROLI Seaboard (Lamb and Robertson 2011) and Andrew McPherson’s TouchKeys (McPherson 2012). Once again, the common thread between these two interfaces is that they both require users to alter or adapt their technique to accommodate a new gestural vocabulary built to work with their systems.

The ROLI Seaboard, as described by its creator Roland Lamb “is a new musical instrument which enables real-time continuous polyphonic control of pitch, amplitude and timbral variation.” (Lamb and Robertson 2011: 503) This is achieved by transforming the classical keyboard interface into a silicon continuous slate where the fingers’ position, pressure, and movement can all be tracked and mapped to control individual parameters through the provided software.

Similarly, Andrew McPherson's TouchKeys coats a standard electronic keyboard, or acoustic piano, with a touch capacitive sleeve that enables the individual detection of the fingers along the length of the keys, enabling the control of different parameters. Both interfaces take what is known as the pianistic technique and enhance it by implementing individual note pitch bending capabilities and other sound modulations, all taking information from the fingers of the pianist. However, these two interfaces disassemble a familiar pianistic technique into various time dependent gestures. They extrapolate only the sound producing gesture, the vertical movement of the finger when pressing a key, and build a new set of gestures or technique to control the new sound modulation parameters. Whilst we acknowledge the cutting-edge technology implemented in these innovative interfaces our research aims to address the steep learning curve that is inherently proposed towards the 'classically' trained performer, that already has mastered his or her piano technique.

Lower Degree of Invasiveness

Traditionally, instruments are built and designed to achieve a certain sound, the physical properties of their construction defining their timbral identity. For example, the organ or the double bass need to be shaped in the way we know and occupy a certain amount of volume in order to produce their unique tonal qualities. The shape of the acoustic instrument determines the gestural interaction and technique required to play the instruments as well as determining the sonic characteristic and any haptic feedback. Musicians spend years working within these limitations refining their own command of the instrument to achieve a certain sonic result, a certain acoustic signature (Chadefaux et al. 2010). The amount of time spent on the instrument itself refining its performative technique is also justified by the fact that the interface of acoustic instruments is embedded into a well-established musical culture with a long history: one that charts a steady evolution in instrument design and technique. The combination of years of practice and technique development create a unique relationship between the instrumentalist and the instrument.

This concept could be also explained with Heidegger's' concept of tools considered 'ready-at-hand' (Dourish 2004). Acoustic instruments, being embedded into musical culture, become embodiment of the sound the performer wants to produce with them, thus falling into Heidegger's' category of tool that can become *ready-to-hand*. A *ready-to-hand* tool is one that a user can act through: in this case, the musical instrument becomes an extension of the performer's hands and arms to play music. However, the morphing nature of the musical instrument considered as a tool, doesn't usually apply to digital interfaces which gestural interaction and timbral identity are not defined by their physical properties. On the contrary, digital instruments are versatile with no fixed properties on how they produce sound. This is the reason why Norman, in a more pragmatic way defines digital interfaces problematic because of their own nature. "The real problem with the interface is that it is an interface. Interfaces get in the way. I don't want to focus my energies on an interface. I want to focus on the job." (Norman 1990: 210)

The problem with digital interfaces lies in the intrinsic fact that they are interfaces. They interface the user with something else. When this concept is applied to musicianship, an instrument is also an interface but through years of practicing instrument/interface is no longer disruptive but becomes a tool. However, a digital interface posed between the musician and the sound produced is an added step that is not present in its everyday practice, thus being seen as disruptive, or with a higher degree of invasiveness. Interfacing between the performer-instrument relationship can often become invasive and disruptive from a performer’s view. Grandhi, Joue and Mittelberg (2011) propose the significance of naturalness in interfaces. When an interface is defined as unnatural, the definition usually is attributed to the system itself. Instead it should be noted that the unnaturalness of a system, or the interaction with it, is the result of bad design and implementation.

A digital interface may be portrayed as badly designed if it requires performers to relearn a familiar technique. When an interface is built around the designer’s idea instead of the user’s needs, it often results in fabricating a new type of hybrid performer that combines the creator of the interface, the composer and the performer (Michailidis 2016). These design-centered, not user-centered, interfaces are not necessarily intuitive to performers other than the creator.

Utilizing a user-centered approach to the development of expressive digital interfaces, our system focuses on the importance of touch-free gesture recognition characterized by a low degree of invasiveness. This is inspired by the work of Dobrian and Koppelman (2006) who highlight the importance of developing systems enabling artists to reach the level of sophistication achieved in other specialties with traditional instruments (jazz, classical, etc.). We focus on developing strategies for better mapping and gesture recognition utilizing existing virtuosity and developing new repertoire for piano performances.

Radar-Based Detection

Here we provide an overview of the capabilities of Google's Soli Alpha Dev Kit (Soli hereafter) sensor, outlining our motives for choosing the device. A thorough technical description of the Soli examining its hardware, software and design is given by Lien et al. (2016). Soli is capable of using millimeter-wave radar to detect fine grain and microscopic gestures with modulated pulses emitted at frequencies between 1-10 kHz. The strength of a radar based signal lies in its ability to offer a high temporal resolution, the ability to work through certain materials such as cloth and plastic, and to perform independently of environmental lighting conditions (Arner, Batchelor, and Bernardo 2017). One significant feature is the highly optimized hardware and software devoted to the prioritization of motion over spatial or static poses. In addition, the compact size makes it a good choice for musical purposes that require a low degree of invasiveness from the system.

Other systems are also able of identifying gestures. This includes color detection from 2D RGB cameras (Erol et al. 2007) to 3D sensing arrays of cameras, such as Microsoft's Kinect (Han et al. 2013). Researchers have developed other means of sensing gestures such as IR technology mainly represented by Leap Motion (Han and Gold 2014). However, such technologies often lack in precision when aimed for fine grain gesture detection. Other devices that enable gestural input using radar-like detection are the

SideSwipe, that analyses disturbances of GSM signals (Zhao et al. 2014) and the WiSee that analyze existing WiFi signals and their perturbances in order to recognize human gestures (Pu et al. 2013).

The devices mentioned above are unable to capture microgestures with a high level of accuracy. Current devices using radar waves or wireless signals similar to Soli work with lower frequency bands typically under 5 GHz. Soli uses high frequency radar of 60 GHz that considerable increases the device's level of accuracy, making it suitable for fine-grain gesture sensing (Wang et al. 2016).

The System

Figure 1 shows an overview of the system design and components. Data received from Soli are managed and visualized by OpenFrameworks. The Random Forests classification algorithm determines whether the gesture is being performed or not. This binary outcome is then used as a gate to forward or block the actual data directly mapped to the pitch shifting algorithm.

<<FIGURE 1>>

Figure 1. Overview of the system design and components.

Google provides several existing wrappers and examples for Project Soli, including OpenFrameworks, a C++ wrapper specifically designed for creative applications. Nick Gillian's "Random Forests Classification Algorithm" from the GRT (Gillian and Paradiso 2014) was chosen as initial test algorithm, as it is already implemented as part of the Soli framework, and during the initial prototyping phase of this research it proved to be a valuable tool due to its ease of use and implementation.

The data chosen to control the pitch shifting algorithm is extracted from two core features coming from the soli SDK: the energy, and the velocity of the gesture analyzed. Using the Open Sound Control protocol, data are passed to the Pure Data programming environment, where it is directly mapped to a pitch shifting effect, the range and amplitude of the effect being controlled by gesture intensity. The intensity of the effect is also affected by the amount of audio signal incoming from the acoustic instrument, thus giving complete control to the performer regarding not only quantity of modulation but also volume.

Testing - Initial Case Study

The first prototype of the system was used during a performance at the Beyond Borders conference, held at Birmingham City University in July 2017. The performance in front of live audience was a good opportunity to identify any limitations and constrains as well as examine potential applications of microgestures of the system before the formal usability test.

<<FIGURE 2>>

Figure 2. Lateral swaying of the hands after the key had been pressed. Sequential snapshot of the vibrato gesture.

The prototype system presented recognized only one gesture: lateral swaying of the hands after the key had been pressed, as shown in Figure 2.

To demonstrate the system a simple piano piece was composed in the key of D major exploring the soundscape of the tonal key itself through chords, voicings and different melodic lines superimposed upon one another. The use of the pedal was essential in this piece both to create an extended and continuous bedrock of sound that would fill the room with harmonics. It was also aimed to give enough ‘room’ to the pitch-shifting effect to be heard and noticed. The composition and the performance were tailored to audience without any musical background to get as much constructive feedback as possible. The piece was divided into three parts, to underline the differences of gestures and gestural nuances in piano playing. During the first part the pianist use different sizes of wooden sticks allowing the playing of chords otherwise impossible to play. This section underlines the non-expressive elements of performance, by limiting the abilities of the musician to a mechanic motion: note-on, note-off. By pressing the piano keys with a wooden board instead of the finger, it resulted in a ‘binary’ playing that lacked expression and musicality.

The second part bridges the purely ‘binary’ playing of the first part, seeing the pianist slowly abandoning the wooden contraptions he had been using until that moment to play, and moving towards a hand driven exploration of the keys. With the hands on the keyboard, but still performing a binary movement, the system didn’t activate and the machine learning algorithm wasn’t able to recognize any ancillary movements revolving around the piano technique: the playing was still not expressive. This lead us to the third part of the piece where the pianist makes extensive use his pianistic technique enhanced by layers of sound modulation.

The third part the pianist explores chords sounds modulating sounds and playing with the sound effect driven by the sensor. The gesture recognition is tailored to the unique hand gestures of the performer. Naturally, the microgestural approach changes depending on the expressive articulations within the score. The piece finishes with a chord struck with one of the sticks from the first part.

The feedback from this initial performance were mostly positive. Mapping the gesture to a frequency modulation effect, gave the illusion to the performer that the acoustic piano could produce a vibrato effect on the notes played. The system turned out to be stable throughout the performance. The majority of the audience when asked felt that the gestures produced an organic sound modulation and, even if the speaker was visibly placed under the piano, couldn't distinguish the different sound provenance of the acoustic and electronic textures. The recognized gesture by the system took place as if it was always there. The pianist said that took no time to be able to control the vibrato and trigger the vibrato and that it felt natural and non-invasive (Granieri 2017)[1].

This turned out to be a really intuitive pair of gesture-modulation to implement, as one of the pianists from the user testing said: "*It's helpful to know what a vibrato is so you can try and fit a technique to what you'd imagine it. Or if you'd imagine a string player doing vibrato and copy that shape that was kind of what was going through my head*." The lateral movement of a hand associated with slight pitch modulation is something that both musicians and audiences can easily relate to the gesture due of the familiarity that vibrato effect has with string instruments. The performer found interesting the control of sound modulations through microgestures, he also mentioned: *"it was very easy to connect with the audience and increase or decrease the amount of the modulation depending on the section of the piece that was being played. This was also due to the piece being very free in its form and composed to accommodate the modulation of the system and the gesture recognized."*

User Testing

A formative, informal method of user testing was chosen as described by Martens (2016) in order to test and assess interaction in a task based scenario. This method was chosen due to the early stage of the research and the ongoing development of the prototype system. A formal user testing method including error counting and timed tasks would have been less useful for the further development of the system. Moreover, not having any previous reference, a simple empirical test followed by an interview to gather experiences and impressions from the users on the system was the best approach.

Twelve piano students from Royal Birmingham Conservatoire, split equally by gender, participated in the user testing. The tests include students from different stages in their studies varying in ages. Musical focus was equally split between classical and jazz trained pianists.

The user tests were conducted in a recording studio using a Yamaha upright piano at Royal Birmingham Conservatoire. The sound was captured by an Audio Technica AT4040 cardioid microphone. The system was controlled by a MacbookPro11,4 and the effects were emitted via a single Behringer B2031A Active Studio Monitor placed on the floor of the studio. The microgestures were analyzed using the Soli sensor as described earlier. The system detects the lateral swaying of the hands as shown in Figure 2, mapped to the pitch shifting effect of half a tone. Real time audio analysis allows us to introduce a threshold for to detection of involuntary triggering of the system.

Each test lasted approximately 40 minutes per participant. Subjects were briefly interviewed about their pianistic background and current knowledge and experience with electronic music and digital instruments. After the interview and a brief explanation of the system, the users were given 10 minutes to try the system and get comfortable with the effected sound coming from the speaker. During that time, we calibrate the system adjusting to the gesture technique of the pianist. Subjects were then asked to perform a series of simple tasks to assess the precision and reliability of the system. These tasks were the following: play a note, play a chord, play a scale. All tasks were performed twice; the first run users try not to activate the system and the second time purposely trying to activate it. This was done to make users aware about the threshold and how the gestures trigger the audio processing. Subjects were asked to either perform a piece we provide or perform one from their own repertoire.[2] We then asked them to perform the pieces twice with and without the system active as a mean of comparison. Two users chose to perform a piece from the provided repertoire, both were coming from a classical background. Finally, they were asked if they were willing to improvise, and then were asked to fill in a User Experience Questionnaire (UEQ) (Schrepp, Hinderks and

Thomaschewski, 2017). Each subject was then asked in a brief final interview about the experience and the system.

1.1. Discussion

The musical background and level of the pianist appeared not to have a major effect on the result of the test itself. Both classical and jazz pianists were able to perform with the system and saw it as a useful interface that they would happily use in their own personal performances. For example, during discussion one user said "*this is very diverse, can be applied to classical, jazz, anybody who plays the piano. It can be for anyone*". He continued, "*it was really interesting to play on a real piano, in its natural form being able to effect sound is not something is possible without controls and effects"* (referring to knobs and effects on his keyboard). The results from the questionnaire were all positive with higher marks given to the systems attractiveness and hedonic quality, with lower but still positive marks in the pragmatic section, as seen in Figure 3. This section concerned the responsiveness and reliability of the system. This was expected from the system being in prototyping stage. During the analysis of interviews, a connection emerged between the piece performed and the feedback given. When performed one of the proposed pieces the users tended to be more willing to adapt the composition to their imagination, and bend the tempo in order to accommodate sound modulation through the system. The listed pieces were chosen together with a piano teacher from the Royal Birmingham Conservatoire because of their loose tempo signatures and long ringing chords, something that we believe encourages the pianists to take advantage of the system. When users chose to play a piece from his or her personal repertoire, the comments were less encouraging. The users seemed to be less likely to feel the need to add this expressive layer on a consolidated piece that he or she already knew how to play expressively in order to convey a certain emotion. This can be related to what previously noticed by McNutt (McNutt 2004) stating that performers need to have a reasonable idea of what sounds they will hear, and in this specific case, what sound their hands will produce. This link between the pieces and the comments given was also confirmed by the most noticed comment on the system throughout the user testing. All users said that the system was eliminating or at least reducing the learning curve of typical interactive systems, but that the strain had shifted to the ability of predicting and expecting the sound of the instrument. Five users underlined that the hardest element to get accustomed to in the system was not the gestures it involved, but was the sound of it. "*(...) In this case I heard something I wasn't expecting, before I played I knew how the sound (of the acoustic piano) should have been, and when I played now I was like 'wow what is this' because it's something new, and I don't like the sound to be different to what I hear before*".

When asked if they had to change their piano technique to take advantage of the system one user said *"The technique that's needed is the listening, as we say we pedal with our ears. It's really what it's about."*

Three out of twelve users pointed out that they would have needed some time to practice the system, to learn what their pianistic gestures would correspond to from a sonic point of view. This is closely tied to the previous statements related to the piece performed during the testing: the fact that the user couldn’t predict what the system would have sounded like, meant that the system would have felt invasive from a sonic point of view in contrast to a performance of an already known piece.

The following section of the test was optional, and consisted of a short improvisation with the system. This enable us to assess if within the relatively short time of using the system subjects were able to improvise and to what extent. This section was aimed mainly towards jazz pianists however one classical pianist asked to try and improvise with it. The results had many similarities with the previous part. During the improvisation, users were keen to unexpected sounds and timbres, and willing to explore new sonic environment with their technique. When asked to compare the experiences of playing a repertoire piece or improvising, one user said: *I’d say they were different, I wouldn’t say one was better than the other. The theme was less spontaneous so you knew what was coming up, so I was able to pre-empt. Whereas the improvisation is spontaneous so I would have to be actively putting it and using it.*” Another user said “*I guess someone could be inspired, and write a piece for it, or someone could use it to aid a performance. Not so sure about pre-existing composition, I am sure that for me if I wrote something I wouldn’t want to mess around and perform it in a manner that’s adding something that’s not in the original scripting of my writing.”*

Before the final interview process, the users were asked to complete a UEQ that enabled us to evaluate the system about its efficiency, perspicuity, dependability as well as aspects of the user experience such as originality and stimulation.

Figure 3 shows the average values from the twelve users with a breakdown of the different aspects analyzed thanks to the UEQ. On the left, the average of each individual parameter showing maximum and minimum score on the Y axis. On the right, the same parameters grouped under three macro categories, showing a reduced average of the Pragmatic qualities something that we believe is due to the low score around dependability.

With exceptionally high values of 2.4 and 2.17, attractiveness and hedonic quality were the categories that reached the highest score in the test. We believe that the high values were due to the non-invasive character of the system that gave users an additional sonic element with minimum learning curve. The weakest, but still positive, aspect of the system was identified in its pragmatic area. Whilst nine users found the system to be innovative and exciting to play with, three users did not feel completely in control of the system and felt that the system was not responsive enough resulting in mistriggering.

The users that felt in control of the system were able to control the triggering of the audio effects in an expressive way through their playing. One user said, *"Yeah I felt mostly in control at some points maybe I was worried I wasn't doing it right. But especially once I got used to it, it felt a lot easier to control. There were a couple of points where I really was thinking If I was performing the gesture correctly, but I don't see it as a long-term issue because I played for a total of 15 minutes."*

The comments and feedback as well as the results from the questionnaire were expected at this stage of the research. During in lab test the prototyping system was sometimes lacking consistency in providing the data output.

<<FIGURE 3>>

Figure 3. On the left, the average of each individual parameter on a scale from -3 to +3. On the right, the same parameters grouped under three macro categories.

Conclusions

From our initial research, the approach we have adopted for developing new interfaces for musical expression has helped to elucidate a number of factors that musicians face when using digital instruments. By creating interfaces that are non-invasive and build on existing instrumental technique, we can move towards creating less disruptive experiences for performers using technology in performance. We have shown how musicians and pianists in particular may benefit from such interfaces. The choice of technologies we have used has allowed us to achieve this. The findings gathered from both the development of the prototype and the usability testing showed positive and encouraging outcomes. The user testing showed how user are keen to adapt and accept such a system which builds upon their own existing technique.

With the development of new technologies and devices available perhaps we need to think about a new communication protocol in instrumental performances that can explore further the potentials presented through microgestures and open new horizons to composers and musician alike.

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[1] The performance can be seen on Vimeo: https://vimeo.com/226180524.

[2] Piano pieces: September Chorale by Gabriel Jackson, Nocturne I by Sadie Harrison, Nocturne II by Sadie Harrison, Utrecht Chimes by Elena Lange, Bells by Simon Bainbridge, Yvaropera 5 by Michael Finnissy.