FLEXIBILITY, SUBLTLETY AND SPONTANEITY IN NEW INSTRUMENT DESIGN: THE FEEDBACK JOYPAD

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ABSTRACT
This paper examines important issues around the instrumental approach to live electronic music, particularly design factors in the mapping stage affecting flexibility, spontaneity and subtlety in the control of new instruments. These elements are discussed in the context of the mapping layer in the author’s own Feedback Joypad instrument, highlighting ways in which design decisions can - intentionally and unintentionally - bias the instrument towards certain musical elements.

1. INTRODUCTION
The predominant approach to creating and performing electronic music has generally been through an engagement with individual sonic parameters. This can be traced from early instruments such as the theremin, through to synthesizers and on to digital systems such as Ableton Live and Pro Tools. This parametric approach is often at odds with established modes of musical performance, as noted by Chandabé [2], musicians generally prefer to be thinking about the music rather than the instrument (though arguably less so in some forms of composition and improvisation). Attempting to juggle individual sound parameters in a live performance can be difficult without sacrificing either spontaneity or subtlety, making it difficult to play alongside acoustic performers - particularly in improvised situations. This paper is concerned with approaches to electronic instrument design that attempt to address this problem and allow electronic sound worlds to be controlled with a higher level of flexibility, subtlety and spontaneity.

This three elements play a key role in determining how much depth an instrument has: the potential for mastery and range of expression available to be performed - particularly design factors in the mapping stage affecting flexibility, spontaneity and subtlety. These elements are discussed in the context of the mapping layer in the author’s own Feedback Joypad instrument, highlighting ways in which design decisions can - intentionally and unintentionally - bias the instrument towards certain musical elements.

2. REMOVING A LAYER OF THOUGHT THROUGH COMPLEXITY
Acoustic instruments rarely have straightforward relationships between input and output parameters. A reed instrument, for example, is not simply a set of individual controls for pitch, volume and timbre. The various aspects of the resultant sound are interconnected with the various input parameters in a complex web-like interweaving of parameters (see [1] and [6]) that is less intelligible in terms of individual settings, more intuitive in terms of performing complex musical gestures, and can provide a richer experience over time than a basic mapping could achieve [4]. Although the mapping is complex and the instrument can be confusing initially, it allows the performer to think directly about the sonic result of their physical gesture without having to concentrate on which control affects which parameter, enabling a more direct link between the bodily actions and sonic results. This relationship allows the sound world to be explored in an intuitive manner: an instrumental manner.

3. THE FEEDBACK JOYPAD
3.1. Sound Engine and Interface
The instrument is based around a feedback loop created in MaxMSP. The device has been used in performance in its current state since 2008, both for improvisation and for the realisation of a specific piece. A detailed look at some of the mappings is followed by an analysis of how the instrument’s design affects its proclivities for certain musical concerns.

These three elements play a key role in determining how much depth an instrument has: the potential for mastery and range of expression available to be mastered on the instrument.

The ‘instrumental’ model for live electronics that is explored in this paper looks to acoustic instruments for inspiration not in sound world or even in physical interface design but in the relationship between the two: to build instruments that have this scope for mastery, and - importantly - allow the electronic sound world to be explored in a more intuitive manner without the performer needing to think about the parameters involved in the software.

These issues are looked at below through a case study of the author’s Feedback Joypad instrument (see tom.mudd.co.uk/projects/joypad.htm for video and audio examples), a simple dual joystick game controller linked to a tuned, filtered feedback loop created in MaxMSP. Although all of the joypad’s controls are utilised, some parameters of the sound engine are controlled by a single input parameter. The second is the converse: a many-to-one mapping.

3.2. Mapping Examples
Two examples of different kinds of mappings utilised in the Feedback Joypad are described below. The first is an example of a one-to-many mapping where multiple parameters of the sound engine are controlled by a single input parameter. The second is the converse: a many-to-one mapping.

3.2.1 One-to-many mapping
Although all of the joypad’s controls are utilised, some are more powerful than others. For example, a single input parameter is used in the patch to alter multiple parameters within the feedback loop as shown in fig. 2. This links several aspects of the feedback loop together: the filter cutoff, the level (and method) of feedback and the balance between the band-pass filter output and the comb filter output. Together they form a complex entity which can affect the pitch, volume and timbre of the sound being produced. It also becomes a relatively impenetrable mapping from a performer’s perspective, forcing them to focus on the sonic result of the action.

3.2.2 Many-to-one mapping
Although pitch is ostensibly controlled by setting the feedback parameters which narrows the range of sonic possibilities available to the performer. This has been sacrificed in favour of subtlety, spontaneity and nuance of control over more limited sonic terrain.

4. MUSICAL PROCLIVITIES IN THE FEEDBACK JOYPAD
The interlinking of parameters as described above affects flexibility, subtlety and spontaneity in different ways. Multiple methods of controlling pitch provides a level of nuance by allowing for not only the fine-tuning of the pitch, but also for many different approaches to slipping, sliding, shifting, fading or jumping between pitches. This also provides a flexibility of sorts by providing a range of approaches to articulation, phrasing and polyphony. Flexibility is limited in other ways by this approach however. The one-to-many mapping described in fig. 2 prevents the possibility of individual manipulation of feedback parameters which narrows the range of sonic possibilities available to the performer. This has been sacrificed in favour of subtlety, spontaneity and nuance of control over more limited sonic terrain.

4.1. Built-in Bias
Many new instruments are developed for specific performances or specific compositions. In these situations an intimate level of control is perhaps not so important and elements such as flexibility and...
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1. INTRODUCTION

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2. REMOVING A LAYER OF THOUGHT THROUGH COMPLEXITY

Acoustic instruments rarely have straightforward relationships between input and output parameters. A reed instrument, for example, is not simply a set of individual controls for pitch, volume and timbre. The various aspects of the resultant sound are interconnected with the various input parameters in a complex web-like interweaving of parameters (see [1] and [6]) that is less intelligible in terms of individual settings, more intuitive in terms of performing complex musical gestures, and can provide a richer experience over time than a basic mapping could achieve [4]. Although the mapping is complex and the instrument can be confusing initially, it allows the performer to think directly about the sonic result of their physical gesture without having to concentrate on which control affects which parameter, enabling a more direct link between the bodily actions and sonic results. This relationship allows the sound world to be explored in an intuitive manner: an instrumental manner.

3. THE FEEDBACK JOYPAD

3.1. Sound Engine and Interface

The instrument is based around a feedback loop within the software, triggered by a short fragment of noise and then sustained as long as is required by keeping the feedback level above a certain threshold. The loop passes through filters of various kinds as shown in fig. 1, which help to control the pitch, volume and timbre of the feedback.

The band-pass filter bank and the comb filter bank each consist of three separate filters that can be given a specific pitch from the controller. In the case of the band-pass filters there are in fact up to 24 filters, as each of the three patches can have up to 8 partials. The interaction between these filter banks and the 2-pole filter that is placed after the delay unit is a key element as the manipulation of the cutoff frequencies can cause different partials to come through at different strengths. Since the audio is in a constant feedback loop, the louder a particular frequency is, the more it will increase in volume over time, so the system generally tends towards a clear tone. The user can upset this progression by altering the pitches of the band-pass and comb filters, by cutting off different frequencies with the 2-pole filter or by having two frequencies interfere with each other (e.g. two very similar frequencies).

A dual-analog joystick is used as a physical controller to handle the various parameters within the patch. This was deemed appropriate due to the mixture of discreet and continuous controls, and for various other reasons, but the issues around interface design are too numerous to be included here (see the archives of the New Interfaces for Musical Expression conference for research on this).

3.2. Mapping Examples

Two examples of different kinds of mappings utilised in the Feedback Joypad are described below. The first is an example of a one-to-many mapping where multiple parameters of the sound engine are controlled by a single input parameter. The second is the converse: a many-to-one mapping.

3.2.1. One-to-many mapping

Although all of the joypad’s controls are utilised, some are more powerful than others. For example, a single input parameter is used in the patch to alter multiple parameters within the feedback loop as shown in fig. 2. This links several aspects of the feedback loop together: the filter cutoff, the level (and method) of feedback and the balance between the band-pass filter output and the comb filter output. Together they form a complex entity which can affect the pitch, volume and timbre of the sound being produced. It also becomes a relatively impenetrable mapping from a performer’s perspective, forcing them to focus on the sonic result of the action.

3.2.2. Many-to-one mapping

Although pitch is ostensibly controlled by setting the band-pass and comb filter frequencies, there are many other factors that contribute towards the pitch of the final sound. For example, if the 2-pole frequency is filtering out the fundamental, then a higher harmonic may be heard instead; or, if the three filter pitches as described in 3.1 are set to differing values, the frequencies may compete for dominance in the feedback loop. The list of parameters that affect pitch is lengthy: band-pass and comb filter pitch controls, pitch bend controls, the 2-pole cutoff frequency and filter type, the resonance of the band-pass filters, the number of overtones present in each filter bank, the level of feedback b) (see fig. 1); in short, almost any parameter affecting the feedback loop can potentially have a large-scale effect on the pitch of the resultant sound.

4. MUSICAL PROCULIVITIES IN THE FEEDBACK JOYPAD

The interlinking of parameters as described above affects flexibility, subtlety and spontaneity in different ways. Multiple methods of controlling pitch provides a level of nuance by allowing for not only the fine tuning of the pitch, but also for many different approaches to slipping, sliding, shifting, fading or jumping between pitches. This also provides a versatility of sorts by providing a range of approaches to articulation, phrasing and polyphony. Flexibility is limited in other ways by this approach however. The one-to-many mapping described in fig. 2 prevents the possibility of individual manipulation of feedback parameters which narrows the range of sonic possibilities available to the performer. This has been sacriﬁced in favour of subtlety, spontaneity and nuance of control over more limited sonic terrain.

4.1. Built-in Bias

Many new instruments are developed for specific performances or specific compositions. In these situations an intimate level of control is perhaps not so important and elements such as flexibility and
that a violin has more scope for varied expression than a piano. From a control perspective, it is difficult to separate the physical model is used, it brings its own cross mappings into play. A particular strength of the physical model is used, it brings its own cross mappings into play. A particular strength of the instrument is not a straightforward task either. Below is a (by no means exhaustive) list of limitations in which the feedback loop can influence the music in some way. So are some musical instruments can still find endless variety within a particular sound world as long as they're flexible enough to really explore the material they are limited to. Constraints and Coherence

The musical predilections inherent in instruments can be seen as the embedding of the compositional process within the design process, and many performers embrace this. David Wessel states that in his work, "the most important act of composition is the design of the computer. The instrument" [8] and Michel Waisvisz had a similar outlook [7].

The issue of flexibility remains, however. Both Wessel and Waisvisz have used their instruments in a variety of contexts, both solo and in improvisations with other electronic and acoustic musicians. Given their penchant for improvisation with their instruments, they must still be concerned with building-in flexibility at the design stage to allow them the freedom to make significant musical decisions during a performance and to react to the playing of other musicians. With improvisation, the limits of the instrument are border-definition and must shape the improvisers approach to playing. So how can electronic instrument design address this problem of flexibility and limits? The word flexibility is used throughout this paper to describe the potential scope of an instrument's use: the instrument is not limited to reproducing a single aesthetic and can be used to perform meaningfully distinct pieces or improvisations. With electronic music, the design is there to have a button that changes the instrument completely, from one sound world to another and potentially from one control paradigm to another. It can even be several instruments at once or a whole orchestra of sounds controlled by one performer using a single interface. Such approaches distance themselves from the instrumental model of live electronic performance as they lack sonic coherence and identity - as Croft notes, the limits of an instrument are essential to its being perceived as an instrument at all" [3]. Feedback is a good example of a coherent sound world as it has a set of rules that guides the sonic development even when simulated in software. The nature of the attack, sustain and decay all follow specific rules that contribute towards a sonic identity, just as physical rules dictate the sonic identity of acoustic instruments.

Placing restrictions on the sound world obviously limits the range of sonic options available to a performer, but this doesn't mean that the musical possibilities are necessarily limited in the same way. An analogy can be drawn between limits of this kind and a set of numbers. For example, if the set of real numbers is restricted to numbers between 0 and 1, there are still an infinite amount of numbers and interrelationships between numbers that can be found in this tiny fraction of the complete set. In the same way, musical instruments can still find endless variety within a particular sound world as long as they're flexible enough to really explore the material they are limited to.

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5. CONCLUSION

The instrumental approach to live electronics can potentially offer a way to explore electronic sound worlds away from the abstractions of numbers and parameters. The Feedback Joypad utilises creative cross-mappings and conditional controls based on the characteristics of the computer-generated sound to help to provide the instrument with sonic depth, the potential for spontaneity, and control over the finer nuances of the sound. Various limitations and musical predilections are put into place through the combination of sound engine and mapping strategies. The degree to which flexibility is an important factor will depend on the purpose of the instrument - whether it is intended as a tool for realising a fixed composition, whether room needs to be left for interpretation or whether it needs to be able to adapt to varied situations.

6. REFERENCES

that a violin has more scope for varied expression than a possible musical dimensions, and will therefore its player” that “A good instrument should not impose its music to embedded that they go undetected. Sergi Jorda states deviate from equal tempered pitches or to interfere with complex counterpoint harmonies. The piano is unable to bending. Bagpipes lend themselves well to music based the pitch will only glide up and down and cannot jump perhaps desirable in the situations described above for this way will tend to bias the musical output. This is spontaneous are not pressing concerns. The software can therefore be built to prioritise certain musical elements which are significant to that particular event or composition. The piece may only require a particular scale for instance or may require very slow, smooth glissandi or the ability to accurately play quarter tones. These elements can be considered at the design stage and a mapping can be set up that makes controlling such elements more straightforward. To take an example, slow glissandi would be easier to achieve with an interface that allows for smooth continuous movements on a particular axis and a mapping that smooths the user input to avoid sharp changes in pitch.

Biasing the control towards certain musical areas in this way will tend to bias the musical output. This is perhaps desirable in the situations described above for specific compositions, but will limit the range of possibilities on the instrument. In the glissandi example, the pitch will only glide up and down and cannot jump (as is the case in the theremin for example). This is not an issue that is unique to electronic instruments either. Zithers such as the guzheng or the koto tend to emphasise a particular scale and a reliance on pitch bending. Bagpipes lend themselves well to music based around a drone note, but are not able to produce complex counterpoint harmonies. The piano is unable to deviate from equal tempered pitches or to interfere with the development of a note that has been sounded other than by stopping it or by combining it with others (discounting for the moment the possibility of touching the piano strings). These musical biases are often so strongly embedded that they go undetected. Sergo Jordas states that “A good instrument should not impose its music to its player” [5], but it is clear that however an instrument is designed, it cannot provide equal control of all possible musical dimensions, and will therefore influence the music in some way. So are some instruments more flexible than others? Few would argue that a violin has more scope for varied expression than a triangle, but it is a difficult thing to quantify and beyond the scope of this paper to do so.

4.2. Bias in the Feedback Joypad

Identifying the bias in a particular instrument is not a straightforward task either. Below is a (by no means exhaustive) list (though I would emphasise that a feedback Joypad can influence - if not impose - the music it produces)

1. Long sustained phrases are very easy to produce, whereas more fragmented phrases are relatively difficult.
2. Slowly evolving sounds are often easier to produce than more static, constant sounds.
3. Staccato sounds are possible, but it is comparatively difficult to play quick, precise sequences of notes of varying pitch.
4. Beat patterns can be pronounced and are easy to control.
5. It very easy to shift sounds up and down the harmonic series which can end up imposing a particular harmonic approach.
6. Rudimentary polyphony is possible, but it favours either leaving certain pitches static (drones), or keeping fixed intervals between notes.

It is difficult to isolate a particular part of the design that is responsible for these predictions. With the exception of the sixth item, they all seem to be a result of a combination of the particular mappings chosen and the behaviour of the feedback model. Beat patterns, for example, are an interesting area to play with as they can be controlled with ease and accuracy due to the mapping, and can be more pronounced due to the purity of the feedback tones. The fact that the harmonic series is favoured is partly due to the control mapping being set up in a similar way to the 2-pole filter that makes it easy to emphasise different harmonics.

From a control perspective, it is difficult to separate the mapping from the feedback engine, and this is perhaps a false distinction. When the sound engine is a deterministic additive model the separation is much clearer, but when something more akin to a physical model is used, it brings its own cross mappings into play. A particular strength of the Feedback Joypad is that it has a complex and chaotic system at the heart of it which dictates many of the mappings itself in a similar manner to the reed instruments described by Backus [1].

4.3. Constraints and Coherence

The musical predications inherent in instruments can be seen as the embedding of the compositional process within the design process, and many performers embrace this. David Wessel states that in his work, “the most important act of composition is the design of the control structure itself” [8] and Michel Waisvisz had a similar outlook [7].

The issue of flexibility remains, however. Both Wessel and Waisvisz have used their instruments in a variety of contexts, both solo and in improvisations with other electronic and acoustic musicians. Given their participation in improvisations with their instruments, they must still be concerned with building-in flexibility at the design stage to allow them the freedom to make significant musical decisions during a performance and to react to the playing of other musicians. With improvisation, the limits of the instrument are border-defining and must shape the improvisors approach to playing. So how can electronic instrument design address this problem of flexibility and limits?

The word flexibility is used throughout this paper to describe the potential scope of an instrument’s use: the instrument is not limited to reproducing a single aesthetic and can be used to perform meaningfully distinct pieces or improvisations. With electronic music, the question is there to have a button that changes the instrument completely, from one sound world to another and potentially from one control paradigm to another. It can even be several instruments at once or a whole orchestra of sounds controlled by one performer using a single interface. Such approaches distance themselves from the instrumental model of live electronic performance as they lack sonic coherence and identity - as Croft notes, “the limits of an instrument are essential to its being perceived as an instrument at all” [3]. Feedback is a good example of a coherent sound world as it has a set of rules that guides the sonic development even when simulated in software. The nature of the attack, sustain and decay all follow specific rules that contribute towards a sonic identity, just as physical rules dictate the sonic identity of acoustic instruments.

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