Working methods and instrument design for cross-adaptive sessions

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ABSTRACT

This paper explores working methods and instrument design for musical performance sessions (studio and live) where cross-adaptive techniques for audio processing are utilized. Cross-adaptive processing uses feature extraction methods and digital processing to allow the actions of one acoustic instrument to influence the timbre of another. Even though the physical interface for the musician is the familiar acoustic instrument, the musical dimensions controlled with the actions on the instrument have been expanded radically. For this reason, and when used in live performance, the cross-adaptive methods constitute new interfaces for musical expression. Not only do the musician control his or her own instrumental expression, but the instrumental actions directly influence the timbre of another instrument in the ensemble, while their own instrument's sound is modified by the actions of other musicians. In the present paper we illustrate and discuss some design issues relating to the *configuration and composition* of such tools for different musical situations. Such configurations include among other things the mapping of modulators, the choice of applied effects and processing methods.

Author Keywords

Live processing, instrument design, improvisation, modulation, processing, cross-adaptive

CCS Concepts

•**Applied computing** → **Performing arts;** *Arts and humanities; Sound and music computing;* •**Human-centered computing** → *Human computer interaction (HCI);*

1. INTRODUCTION

Introducing a new feature to an existing musical instrument changes the instrumental affordances, and as such deeply changes the way that a live musician can and will make music. If this change also influence the musical communication and interaction between performers, then the resulting impact on the music will be greater as it also impacts the collective music making. The sound of the instrument greatly informs and inspires the musician's performative decision making, thus allowing a "play on the sound". Similarly, electric and electronic musicians that can significantly change the timbre of their instrument will recognize that the choice of timbre and/or the choice of effect processing applied is deeply connected to *what* they can and will play.

With cross-adaptive techniques we can allow one musician to directly influence the timbre of another, also when the musicians play acoustic instruments. This is done by means of audio signal analysis and feature extraction, and subsequent electronic processing of the acoustic signal. The parameters of audio processing can be modulated by extracted features. The implications for this kind of signal interaction means that the expression of one performer modulates the sound of another performer's instrument, and as we have seen above, the sound of one's instrument deeply affects what one will play. In this manner, some radically new elements have been added to the affordances of musical interaction between live players. The *instrument* is no longer a private and personal interface to the creation of music, but rather a *collective entity* constituted by all instruments in the ensemble and the modulation mappings between them. This also connects crossadaptive performance to the larger field of collective instruments and interconnected musical networks [13, 3, 10]. The immediacy and intimacy of using an acoustic instrument both as a controller and simultaneously as a sound producer distinguishes crossadaptive performance from other forms of collective instruments.

The research presented here was done in the context of the project "Cross-adaptive processing as musical intervention", led by a group at the Norwegian University of Science and Technology, in collaboration with academic partners[1], and additional freelance researchers and musicians. A main objective of the project has been to explore cross-adaptive audio processing techniques as a means of creating interventions into the communication between music performers. The interventions are technologically based, but the most interesting part in our opinion is how this changes the human/human communication. The research method has been based on iterative practical experimentation done in studio sessions. Development of processing tools and composition of tentative interaction mappings has been refined on each iteration, and different performative strategies explored. Preliminary artistic results, reflections and experiences form the basis for further refinements of methods. Documentation in the format of multitrack audio and video recordings have been crucial in this respect, combined with short personal video interviews with the performers.

NIME'18, June 3-6, 2018, Blacksburg, Virginia, USA.

[1]De Montfort University, Maynooth University, Queen Mary University of London, Norwegian Academy of Music, University of California San Diego.

2. CROSS-ADAPTIVE AUDIO PROCESSING

In cross-adaptive performance, the audio signal (often from an acoustic instrument) is used as the sole interface to exerting expressive control over timbral modulations of another audio signal. Feature extraction (based on well known MIR techniques) is used to create control vectors, and these are then mapped to sound modulating parameters via OSC or MIDI. Any audio processing techniques that can be parametrized can be used as the modulation destination. The techniques we use are based on extensions of the well researched field of adaptive digital audio effects (ADAFx) as described by Verfaille and others [12, 4, 8]. Using audio features as control signals performatively has also been explored by [9, 11] and performer-instrument-designers like Stefano Fasciani [2] and Hans Leeouw [5]. The use of audio features as control signals in electroacoustic composition has been explored by Phillippe Manoury in collaboration with Miller Puckette [6]. Common to all of these methods is the immediate use of a feature from one sound to control some parameter of modulation, where processing is applied to the same sound or another sound.

2.1 Signal modulation and performative interactions

All of these modulation techniques fall under the general term *adaptive* processing. When the processing is applied to another sound we can call it *cross-adaptive*, signifying that some features of one signal has been enabled to cross over from one sound to another. In our project, we apply these kind of modulations in a live performance setting, analyzing live signals and applying the modulators to another live signal. The term cross-adaptive in this context also relates to the *performative aspects* of how the affected live performers then interact musically. When the actions of one performer is allowed to influence the *sound* of another performer's instrument, this changes the conditions of musical expression for the other performer. The cross-adaptive performance situation thus affect the ensemble interaction, with the potential of creating complex networks of signal modulations as well as performative interactions. Later in this paper, when we write about *modulator to parameter mappings*, we refer to the signal interaction created by using one extracted feature as a control vector to modulate a parameter of effects processing.

2.2 Custom tools

As a necessary part of the project we have developed tools for signal analysis, feature extraction and modulation mapping. The tools are implemented as VST plugins, and the source is available online at[2], an early version of these tools were also described in [1]. The reason for making VST plugins instead of building a dedicated processing environment is that we wanted to be able to integrate these techniques in a regular audio production toolchain (DAW). Routing of modulations signals is done via OSC and MIDI, and the functionality of the DAW is then used to allow parameter modulation within the production environment. This allows for using any off-the-shelf software effect processors to modulate the sound, and thus relieves the need to develop audio effect processors specifically for the project. It also allows other potential users and instrument designers to reconfigure and appropriate our technology for other use cases, including their existing favourite audio effects.

The signal analysis methods have partly been based on The Timbre Toolbox [7], as well as custom methods developed for this project. The scope of this paper prevents a thorough treatment of the details of feature extraction, but we'll mention some of the analysis methods briefly as a means to understand what kind of expressive and perceptual features we have been working with.

- Amplitude envelope: the smoothed instantaneous signal level. Used directly, and also for transient detection.
- Envelope crest: The ratio betwewen peak and average amplitude. Can be used as a measure of "percussiveness", as it relates to staccato/legato playing.
- Transient density: Number of transients per second, as a simple measure of rhythmic activity.
- Spectral flatness: Ratio of the geometrical mean to arithmetical mean of the spectrum. A flatter spectrum indicates a more noisy sound.
- Spectral crest: Ratio of maximum value to arithmetical mean of the spectrum. A low ratio indicates noisy sound as for spectral flatness, but since the method is different, it may respond differently to different spectra.
- Spectral flux: Represents the amount of variation of the spectrum over time, namely how much it changes from frame to frame. This also correlates with noisy or tonal sounds, where a high flux may indicate a noisy sound.
- Pitch: Pitch tracking (several different methods available in the analyzer).

As a means to familiarize the performers with the relationship between instrumental gestures and the corresponding analysis features, we have used some visualization methods. Some of these show the instantaneous values, while other methods plot statistical or temporal behaviour of analysis vectors.

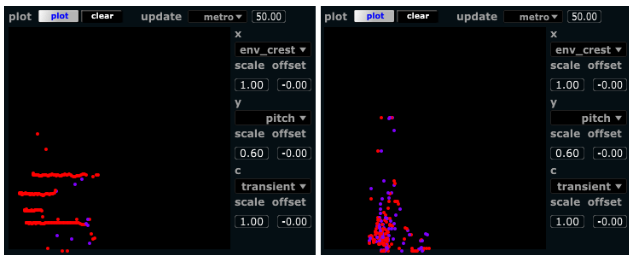

Figure 1: *Analyzer screenshot, plotting of legato (left) vs. staccato (right). The plots have the usual Cartesian coordinates for X and Y, while colour represents a third dimension (from red for low values, via green, to blue)*

3. THREE APPROACHES

Due to practical circumstances, the activities in the research project has been carried out in different locations, by different subgroupings of the workers in the project. By design, we did not adapt a common methodology, aesthetic, artistic, or experimental approach. The field of cross-adaptive performance is still relatively uncharted territory, and we wanted to keep things open. Thus, we developed slightly different "experimental cultures" in the different cities where sessions were carried out. This also led to different decisions regarding instrument design, mapping and processing. In particular, we see differences in the complexity of mapping, and in the choice of radical effects or more "traditional" processing. There are also differences in group composition, in

[2] `https://github.com/Oeyvind/featexmod`

whether we worked with new performers each time, or one steady group of throughout all sessions. The following paragraphs gives an outline of these approaches.

3.1 The Trondheim model

The Trondheim team did several sessions with different student groups, and also some sessions with members of the T-EMP[3] ensemble at NTNU. The approach was similar in all sessions, but with subtle differences between sessions with students and the T-EMP ensemble. The majority of sessions was conducted in a sound studio to get good separation between instrument and clear monitoring of the processed sound.

3.1.1 Studio sessions with students

The student groups consisted of approximately 10 students each, with a wide variety of instrumentation. Since many of the performers had limited experience with live electronics in general, it was decided to introduce the cross adaptive systems gradually during the sessions in order to build experience incrementally. Simple audio analysis methods (like e.g. envelope followers and transient detectors) and mappings were chosen to make the connection between musical input and sensation of control as clear as possible. The chronology of work and mapping strategies more or less followed the same procedure in these sessions:

1. Start each session with individual instruments trying different effects through live processing and decide together with the performer which effects were most suitable to add to their instrument (detachment from the direct sound of the performers instrument).
2. Introduce the analyzer and decide, based on input from the performers, which methods are best suited for controlling effect parameters from their instruments.
3. Introduce one-way cross-adaptive processing where one performer is controlling the effects on the other, and then repeat vice versa (being in control/being controlled).
4. Use bidirectional cross-adaptive processing where all previous choices and mappings are activated for both performers (being in control/being controlled at the same time)
5. Discussion and reflection within the group.

3.1.2 Studio sessions with T-EMP ensemble

All sessions with members from T-EMP were carried out with Tone Åse on vocals and Carl Haakon Waadeland on drums and percussion. Both performers with extensive experience within live electronics. Since previous student sessions had been carried out with the most common analysis strategies, exploration of two novel analysis methods were investigated: Rhythmic consonance and rhythmic irregularity. The methods of rhythm analysis that we used are described in more detail online at[4], and also in source code[5]

An initial familiarization with the analysis methods was done by trying different instrumental gestures and at the same time receiving a visual feedback from the software on a large monitor in the recording room. The performers thus achieved an understanding of how the analysis output corresponded to different instrumental gesures. With this experience the group tried and discussed different effects that would fit well with their playing style, and then mapped control data to chosen effect parameters. This process was in many ways similar to the five-step model used for the students.

3.1.3 Live performance with T-EMP ensemble

For a live performance, the group was expanded with an extra musician resulting in an ensemble of vocals, drums and electric guitar. Development of analysis and mapping strategies followed the same procedure as described above. Since microphone bleed can be an issue in a live context, the simplest and most robust analysis methods were used. Microphone bleed will not only cause bleed of the signal to be processed but also affect the analysis and subsequent mapping. The concert was freely improvised, but with some prepared "interaction scenes" based on experiences with various modulation mappings. These scenes were then used as a temporal framework, so that the dynamic switching of mappings created a precomposed dramaturgy for the improvisation. A recording of the live performance followed by reflections from the musicians and questions from the audience is available at[6].

3.1.4 Cross adaptive setup for T-EMP ensemble

On the drums, we used a pitch shift and a convolution reverb. The parameters exposed for control was the effects send level for each of the two effects. On the vocal we used a delay, exposing the delay time parameter for control. On the guitar we used a pitch shift. The pitch shift amount was exposed for control. Table 1 shows the mappings used.

Map	**Vocal feature**	**Drum parameter**
1)	Amplitude	+ Pitch shift send
Map	**Guitar Feature**	**Drum parameter**
2)	Amplitude	- Reverb send
Map	**Drum feature**	**Vocal parameter**
3)	Transient density	+ Delay time
Map	**Vocal feature**	**Guitar parameter**
4)	Amplitude	+ Pitch shift

The musical purposes of these mappings: 1) Vocal activity (amplitude) will dynamically adjust the amount of down-pitched drums. 2) Louder guitar will dry up the amount of reverb on the drums. 3) Faster drum playing will create a more dense delay pattern on vocal. 4) Louder vocals will increase the upwards pitch shift for the guitar.

Table 1: Mapping table for the ensemble

3.1.5 Student sessions vs T-EMP sessions

The sessions with students gave valuable feedback from a large number of performers into the concept of cross adaptive processing. Naturally, it is beneficial for the sensation of control to use more time with performers in order to construct a meaningful and understandable collective instrument. Using more time enables deeper understanding, but also opens possibilities for more subtle and dynamic changes in the software setup during sessions. The experienced live electronic performers adapted faster to the situation, even though the concept of cross adaptive processing was unfamiliar. In this context it enabled them to interact with a larger degree of control earlier in the process.

3.2 The Oslo model

The Oslo based group consisted of Bjørnar Habbestad (flute), Gyrid N. Kaldestad (voice) and Bernt Isak Wærstad (guitar). As most of the sessions in the other cities had changing constellations, it was decided that the Oslo group

[3] https://www.researchcatalogue.net/view/48123/48124

[4] https://wp.me/p7UOyo-5F

[5] https://github.com/Oeyvind/featexmod

[6] http://wp.me/p7UOyo-hD/#Trondheim

should explore cross adaptive techniques in the context of a fixed ensemble. This made it possible to spend more time developing ideas for cross adaptive implementations, tailored for a specific set of performers. The goal of this approach was to resemble a “real life” application of the cross-adaptive tools and techniques, with the performers gaining increased intimacy with the techniques over time.

All three participants had extensive experience with live electronics, which gave them an advantage in that everyone participated in both technical and musical discussions. This democratic approach made everyone invest in the process, creating an organic group effort. Most of the first session was spent discussing how to learn the analysis and mapping tools and collectively decide upon an instrument design and mapping strategy. Remaining sessions focused on refining mappings after further discussions and tests. Recording followed by listening and reflection became an important part of this process.

3.2.1 Instrument design

The Oslo group’s cross-adaptive instrument is a collaborative instrument bespoke to the three performers and their individual acoustic instruments. The instrument design was based on analysis of selected individual sound material, in order to accommodate and extend existing improvisation and performance practices. A network of complex cross adaptive mappings where used to make the new instrument responsive to individual sounds and gestures, trying to obtain the same level of nuanced expression as in acoustic performance.

3.2.2 Performer analysis

The process started by recording different improvisational techniques and feeding them through the analyzer. This functioned as a familiarization stage to find out how the analysis methods responded to different sounds. Focusing on the timbral quality of these sounds, the output of the spectral analysis techniques where plotted (similar to figure 1), interpreted and summarized. Due to space limitations, only one simplified example is shown here (see table 2). The reading and recording of these analysis results where refined over several iterations. A more complete overview can be found online[7]

Sound	Flatness	Flux	Crest
Pure tones	Mid to High	Low	Low to High
Multiphonics	Mid	Mid	Mid
Air sounds	High to Mid	Low to Mid	Low to Mid
Pitch, vocal, flutter	Mid	Low	Low to Mid

Table 2: Flute analysis

3.2.3 Processing

Before starting the mapping process, the group decided upon a selection of classic processing techniques; ring modulation, filtering, reverb, compression/distortion, delay, reverse, and tremolo. The choices were based on the following criteria:

1. Already well known to the performers.
2. Simple, clear and easily recognizable.
3. Fitting to their individual and collective aesthetics.

Using quite simple and familiar effects, would make it easier to navigate a complex mapping setup and thus for the performers to decode and understand how the system responded to different musical input.

3.2.4 Mapping Strategy

The basic premise for the Oslo group’s mapping strategy was to use the individual performers’ sounds as a starting point rather than a specific analysis technique. By using the analysis results as seen in table 2 and the list of processing techniques described in the last section, they could map sounds and musical gestures to different processing parameters. This made it easier to make “musical mappings”. For example, the vocalist singing a pure tone would introduce ring modulation on the flute (see fig. 3) which would create an open space for the voice since the flute would gradually loose its fundamental and be somewhat distributed up and down the spectrum. To achieve a complex network of mappings and give a feel of multidimensionality for the performers, it was decided that each performer should affect processing parameters in both other players.

Due to space constraints, only a simplified version of the vocal mappings are shown here. All the mappings in greater details can be found at[8] with an accompanying live peformance at[9]

Map	Vocal feature	Flute parameter
1)	Spectral flatness	+ Compression mix
2)	Spectral flux	+ Reverb size and mix
3)	Spectral crest	+ Ring modulation mix and frequency
Map	**Vocal feature**	**Guitar parameter**
4)	Spectral flatness	+ Tremolo mix and rate
5)	Spectral flux	+ Reverb size and mix
6)	Spectral crest	+ Reverse

Table 3: Mapping table signals from Vocal

3.2.5 Learning experiences

Since the instrument was designed around the performers’ sounds and musical gestures, it was perceived as an “intelligent” instrument which listened and responded musically to their input. This reduced the need for being in full control and, being experienced live electronics performers, made them feel liberated by not having to focus on controls separate from their acoustic instrument and focus more on listening. The performers also commented that the interplay experience felt similar to working acoustically.

3.3 The San Diego model

A number of sessions was conducted in San Diego during the period August 2016 to June 2017. The sessions was done with a small group of musicians[10], working iteratively in various combinations. Some of the sessions were rehearsal room explorations, other were studio sessions, and again others were live concerts. The following paragraph will attempt to summarize some methodical characteristics across these sessions over the time span that they were conducted. Due to space limitations, only one specific example of a mapping will be treated.

Upon meeting each of the musicians, the first session consisted of testing how the analyzer would respond to this specific instrumental signal. As an example, *spectral flux* could quite reliably be used to measure the balance between tonal

[7] `http://wp.me/p7UOyo-cf`

[8] `https://tinyurl.com/y8wr3ukv`

[9] `http://wp.me/p7UOyo-hD/#oslo`

[10] Kyle Motl: double bass; Jordan Sand: double bass and vocal; Kjell Nordeson: drums; Miller Puckette: electric guitar; Steven Leffue: saxophone

and noisy signals on some instruments, but it would respond quite differently on others. For some instruments, spectral flatness and/or spectral crest would need to be combined to achieve a similar effect. When a sufficient correspondence between perceptual features and analysis vectors had been achieved, the connection between musical intention and timbral result was explored.

3.3.1 Mapping strategy

The design of mapping scenarios developed from very simple and intuitive mappings in early sessions, to more complex mappings. The aim was to produce a collective instrument that was rich enough in interaction potential that it could last for an extended performance without becoming too obvious. It was thought that very simple mappings would somehow "wear out" and become too predictable after a while, and that a richer mapping would enable the musicians to continue exploring new modes of interaction during extended interplay. The specific mappings were designed with a particular musical effect or gesture in mind, to enable a particular kind of interaction.

The mapping that was used for Miller Puckette (guitar) and Steven Leffue (sax) is given in tables 4 and 5.

A basic premise for the San Diego approach is that we wanted the effects to be an integral part of the instrumental gesture, meaning that we searched for effects that would have clearly audible, even dramatic, changes in sound when a parameter was adjusted. As an example, controlling the reverb time (room size and reflectivity) is a dramatic and clearly audible effect. One could say it is a musically unnatural thing to do, but because of this, it also stands out and make a very clear gesture. Similarly, we used a spectral delay, which also can shape the sound in a distinctively "processed" manner. Other effects like the filter and spectral shifter on the sax provides less dramatic shaping, especially because the acoustic signal can camouflage the filtered signal. As such, there is a range from distinctive effects on to more subtle ones.

On the guitar, we used a spectral delay effect with control over effect send level, delay time, feedback, and spectral delay shaping. On the saxophone, we used a resonant lowpass filter, spectral shift, and reverb.

Map	Sax feature	Guitar parameter
1)	Envelope crest	- Delay send
2)	Transient density	+ Delay time
3)	Amplitude	Gate mapping 2) above
4)	Pitch	+ Spectral delay shaping
5)	Spectral flux	+ Delay feedback

The musical purpose of the mappings: 1) Dynamic playing will "dry up" the effect, but long notes will open the delay send. 2) Fast playing give more distinct repetitions. 3) Must play loud ***and*** *fast to affect delay time. 4) Crazier effect when playing high notes. 5) Noisy playing give more delay repetitions.*

Table 4: Mapping table Sax to Guitar

Map	Guitar feature	Sax parameter
1)	Envelope crest	+ Reverb time
2)	Transient density	+ Hipass cutoff **and** - Lowpass cutoff for Reverb
3)	Transient density	- Spectral shift
4)	Spectral flux	+ Resonant lowpass c.freq

The musical purpose of these mappings: 1) Dynamic playing give a big room. 2) Fast playing give less full sounding reverb. 3) and 4) Animation and variation.

Table 5: Mapping table Guitar to Sax

The mapping seen in table 4 and 5 was used for a session documented in the project blog at[11], where one can also find videos with interviews of the performers. They are discussing how it feels to play in this situation and reflects on on monitoring issues and preferences. The details of the mapping from features to modulators signals and how they influence the affordances of performance are also discussed.

3.4 Similarities and differences

As we have seen, an iterative approach has been taken in all three locations where sessions have been carried out. After an initial design, this has been tested in practical experimentation, and adjustments have been made to try to solve apparent problems. The Oslo sessions has been done by a steady group of musicians, working together over a longer time span. This allowed for an incremental approach both in system design and also in the performers' understanding of the cross-adaptive method. In Trondheim, various constellations where used, producing feedback from a wide variety of performers and personalities. In San Diego, we worked iteratively with several different constellations, allowing for a combination of the qualities from the Trondheim and the Oslo methodologies.

The three cities also had different approaches for their instrument design. Trondheim used a pedagogical approach, striving for mappings that would be intuitive and easy to understand for the performers. This was reinforced by using clearly audible audio processing that could be used gesturally and structurally to radically shape the resultant musical statement. With new performers coming in at a steady rate, this approach was valuable as a manner of getting started quickly.

The Oslo group had an instrumental approach focusing on individual expressiveness. The mappings where relatively complex, and we also see three-way networked mappings as opposed to the bilateral approach of Trondheim and San Diego. In terms of effects, Oslo chose to work with finer nuances of traditional processing, exploring how the cross-adaptive situation could enhance and strengthen the natural interplay of the group. The complexity here can be seen as a holistic approach to creating a performance environment where the musicians could explore different traits of the collective instrument by means of improvised collective actions. This means that not all of the potential of the processing scenario is actually used, but that one can leave uncharted territories for further exploration later.

The San Diego approach to analysis was subtly different than the Oslo approach. Where Oslo recorded instrumental gestures and observed which analysis dimensions could be useful, San Diego would experiment to find the analysis methods that corresponded better to a given intentional expressive dimension. The mappings where relatively complex and designed for specific musical purposes. Specific actions were mapped to distinctly audible timbral gestures, and the expectation was that a more intentional performative approach would be applied. As in Trondheim, the type of processing effects was selected to be clearly audible and with a compelling sonic impact.

A complicating factor in the familiarization process of a cross-adaptive session, is the fact that one contributes modulation to another musician's instrument. The Trondheim group used simple mappings and distinct processing methods in an attempt to help this process and saw performers being able to expressively apply a modulation with a reasonable level of accuracy after some initial exploration. In San Diego, familiarization was accompanied by adaption of the

[11] `http://wp.me/p7UOyo-fw/#miller-steven/`

analysis methods to the perceptual expressive dimensions of each signal. The Oslo group didn't have the same imminent need for a familiarization process, as the mappings where already based on musical gestures and musically meaningful connections between them. This led to a quite coherent and predictable sounding result, but somewhat pacified the musicians in exploring the cross-adaptive aspects of the instrument and the use of intentional modulation control was less apparent as a tool for musical intervention.

In all cases, we saw a profound change in performance practise where the performers have to play, listen and think of how to affect the processing of the other musicians while producing something aesthetically pleasing. In most cases, it proved too demanding to maintain this multi-layered focus over time, and the performers would sometimes fall back into their habitual improvisational patterns. We believe this is mainly due to lack of training and that this is a truly new performance skill which needs to be properly learned through a fair amount of rehearsal. We can also envision an intentional exchange between engagement and disengagement as yet another expressive dimension of group improvisation.

Even with a full mastery of the relationship between instrumental gesture and analyzer response, the actual sounding result will depend on what the other musician is actually playing at that precise moment in time, so the timbral modulation may not always have the expected effect. In this lies one of the deep challenges of cross-adaptive performance, and also the biggest potential for impacting how music is made and played with these techniques. As with other forms of improvised interplay, a certain level of prediction of what the other musicians will be playing is needed, and the negotiation between desire, prediction and actual events consist some of the driving force. Even more so in the cross-adaptive setting.

4. CONCLUSIONS

We have presented some working methods and instrument design considerations for cross-adaptive performances. The use of both changing and constant groups, enabled us to both get an overview on how different musicians and instruments respond and function in a cross-adaptive environment, while also getting an in depth view from a specific set of performers and instruments.

Furthermore, we have presented different approaches to complexity of the controller mapping and choice of processing in the collective instrument. In all cases, the performative aspect of the mapping are closely tied to *which features are analyzed* and of course also *what is being controlled*. Thus, the selection of effects for the processing have also greatly influenced the affordances of the resulting instruments.

Within the working methods are also contained different methodologies for how to familiarize performers with the cross-adaptive situation and the specific mappings used in that session.

It is clear that we have barely scratched the surface of the universe of possible approaches for this kind of work. We see the potential for even more novel modes of musical interaction and interplay. Performers may refine the crossadaptive sensitivity, and the analysis, mapping and processing could be developed much further. Still, the work done in the three cities show some distinctively different methodologies and aesthetics, and as such represent an initial attempt at a broad exploration. Hopefully others will take on the challenge of using cross-adaptive techniques in wildly different aesthetics and performative approaches.

5. ACKNOWLEDGMENTS

The project "Cross-adaptive processing as musical intervention", was partially funded by the Norwegian Artistic Research Programme. In addition to our collaborating academic partners, we'd like to thank the performing musicians taking part in our practical experimental sessions for their generous efforts.

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