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Interactive feedback on extended instruments

Realimentación interactiva en instrumentos extendidos

Carlos Gustavo Román
carroman@hotmail.com
Universidad San Martín

Timothy Schmele
t_schme@mad-ape.net

John O'Connell
johngerardoconnell@gmail.com

Universitat Pompeu Fabra
Barcelona - España

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Instrumentos extendidos; interacción; música en red; realimentación.

Abstract

This project aims at exploring interactivity in networked music by exploiting innovative mapping schemes to extend common musical instruments into acoustic controllers of digital sound. The sensors used were limited to only piezo element contact microphones, as they demonstrate a simple and cheap solution to retrieve an acoustic signal free of most environmental noise and crosstalk. The main idea was to employ the feedback that results from processing a particular system as a control signal, in a way that allows interaction with different musical systems by means of network communication. Another goal was to preserve the traditional techniques in which casual musicians play their instruments, so as to minimize the learning process that the creation of new interfaces require, and maximize the usability of the instruments' extensions. The extension itself is both reactive and transformative. We chose to extend the guitar and a djembe, as an example of a common ensemble of music in casual social contexts.

Resumen

Este proyecto explora la interactividad de la música *en red*, utilizando innovadores esquemas de mapeo para extender instrumentos musicales comunes y convertirlos en controladores acústicos de sonido digital. Los sensores empleados se limitaron a micrófonos de contacto, toda vez que ellos proveen una solución sencilla y barata para obtener una señal acústica libre de ruidos ambientales y diafonías. La idea central fue emplear la realimentación que resulta del procesamiento de un sistema particular, como una señal de control, de tal manera que permita la interacción con distintos sistemas musicales a través de redes de comunicación. Otro objetivo fue preservar las técnicas tradicionales que usan los músicos para tocar sus instrumentos, minimizando así el proceso de aprendizaje que se requiere en el proceso de creación de nuevas interfaces y maximizando la usabilidad de las extensiones de los instrumentos. La extensión, en sí misma, es a la vez reactiva y transformadora. Se seleccionó extender una guitarra y un *djembé*, como ejemplo de un ensamble musical común en un contexto social casual.

I. Introduction

This project, in its conception, explores categories that correspond to some well-known current research trends in music technology. The following fields were reviewed as conceptual foundations for the project:

» *Extended instruments.* The idea of taking any conventional music instrument and by means of specific techniques (which could be analog, digital or a combination of both), 'extend' it in a way that expands its timbral possibilities. For this project, a methodology that combines the acoustic sound and playing techniques of an instrument with processes of digital synthesis.

» *Music interaction.* Classic interaction among performers in small or large ensembles is currently being studied from cognitive and perceptive approaches. Also, network music has proven to be an active field of research, allowing the real-time interaction of performers located in distant geographic places.

» *Music Information Retrieval* (MIR). The usage of computational tools in order to extract relevant musical information and analyzing musical features in real-time performance allows also the transformation of these features into control signals, which could be employed in turn to modify the original signal.

II. On timbre, music interaction and extended instruments

Despite the fact that there is not yet a solid and universal definition of timbre (Sethares, 1997; O'Callaghan, 2007), this issue must be addressed, for one of the goals of the project involves the extension of the sound of a musical instrument. Some of the standardized definitions of timbre prove to be incomplete, either by trying to define timbre by what it is not (i.e. what distinguishes two sounds with the same pitch and loudness) , or by oversimplifying the concept until the point of misrepresentation (i.e. timbre as being exclusively defined by the waveform or a set of overtones). Timbre thus cannot be placed into a one-dimensional unit within a single classification method, where all possible timbres could be scaled and ordered. Instead, the most adequate approach to timbre description is multidimensional scaling (Sethares, 1997). In music, every phenomenon related to timbre is directly linked to the acoustic instrument producing the sound: timbre is determined by the physical properties of the instrument as well as the range of possibilities of producing sounds with a musical purpose. However, that description does not completely work when dealing with electronically produced sounds. Therefore, when designing an extended instrument, we intend to enlarge the regular timbre of it, but keeping it still attached to the physical source of sound and the perceptive connection that the listener creates between the sound and the object producing it.

Interactive music systems based on MIDI messages have become a dime a dozen.

An early example that produces answers to musical gestures is a system called Cypher (Rowe, 1993). Cypher analyses input streams in the form of MIDI data to generate musical material. While MIDI is generally discrete and unambiguous, it lacks many expressive parameters employed by a skilled performer that go far beyond pitch and *discrete dynamics*. In the field of interactive music systems based on audio feature extraction, one of the first to implement a system was Cort Lippe (1993). He initially developed a system for an interactive clarinet performance within an early Max/MSP environment on an institutional system, using the available *rapid and accurate* pitch-detection algorithm. Evaluating the pitch material from the acoustic audio stream he tracks the score and creates events that influence the system. The research of William Hsu investigates the capabilities of a context free improvisational system based on timbre recognition and feature extraction in close collaboration with saxophonist John Butcher (Hsu, 2006). The system extracts and stores gestures and timbral contours for saxophone, which are then taken by the improvisation agent whenever needed. This way, the system generates phrases in collaboration with the human player which correspond to his playing.

'Hyperinstruments' has been a term particularly coined by the efforts undertaken in the research of Tod Machover (1992). The instruments are equipped with a series of sensors picking up several types of gestural movement possible that goes beyond the traditional way of interacting with a particular instrument. Gestures and movement that were intuitive and subconscious suddenly produce sounds directly and the instrumentalist has to adapt to a completely new style of playing. An important fact of Machover's Hyperinstruments is that the computerized sound plays a counterpart to the acoustic instrument.

In a recent talk, Miller Puckette (2011) pointed out the fact that in order to use a computer as a musical instrument, a new interface can be designed (which implies a long and extensive learning process) or a traditional instrument can be used for controlling the new instrument. While Puckette focuses on using instruments for controlling sound synthesis processes, we decided to create 'extended' instruments, that is, the idea of combining the acoustic sound of the original instrument with a processed digital extension of it. In that sense, the performer can intuitively play the instrument and the system will process his actions and translate them into new sound or musical expressions that will combine and complement acoustically the original sound of the instrument.

III. Characteristics

Rowe (1993) defined a classification scheme for live electronics, which became a common evaluation method used throughout the literature. It is a scale on three dimensions distinguishing:

1. The ability of a system to follow a score during a performance in comparison to merely reacting to recent events on perceptual measures

2. The way the system generates its output, either by controlling pre-recorded material based on measured metrics, transforming the live recording in real-time or generating new material automatically.
3. The paradigm, if a system is autonomous or merely reactive, which he calls either the instrument or systems paradigm. The instrument paradigm tries to create an extended or virtual instrument through electronic controls to create a single response, or additive to a musical gesture. A system paradigm on the other hand may act as an artificial player that plays autonomously, while listening to other input to which it adapts it generated output.

The electronics used in this project strictly follow the instrument paradigm. Following the philosophy that the piece should be based on the human element of the performance, it also implies that, even though the composition still has an electronic part, the electronics should contain that human element in every way possible. This, for one, is best done by using the real-time recording of the performers at the time of the performance, hence the usage of live input as a feedback source material, making it transformative (Rowe, 1993).

Taking inspiration from Kaija Saariaho, picking up the sound makes the body present in the electronics and, in turn, make the electronics part of the performer (Rijkonen, 2003). Transforming the actual sound of the performer captures every possible nuance inside the transformed output that even Music Information Retrieval (MIR) methods may never detect. Nevertheless, the way that the signal should be transformed is determined by a listener module that analyzes the input signal for features, which are mapped to parameters of the synthesis.

In order to preserve the spirit of spontaneity with which people jam at parties we chose to use affordable equipment, also to inspire and enable others to create their own low budget extended instruments. We are aware of the irony inherent in the labeling of this project as low budget when it requires one to several laptops. Nevertheless, this is also networked computer music and as such certain pre-requisites are expected to be fulfilled, one of which is laptop ownership.

IV. System overview

The system is built on the premise that each instrument is used with the respective musicians laptop, using the built-in single input sound cards. In this particular example the guitar and djembe audio signals are picked up by piezo elements and routed to 2 different laptops where they are analyzed for features. The guitar audio signal is processed and used as the raw sonic material for extending the two instruments. Both instruments act on the transformation of the guitar signal, making the instrument extension a collaborative effort. Figure 1 shows the overall system designed.

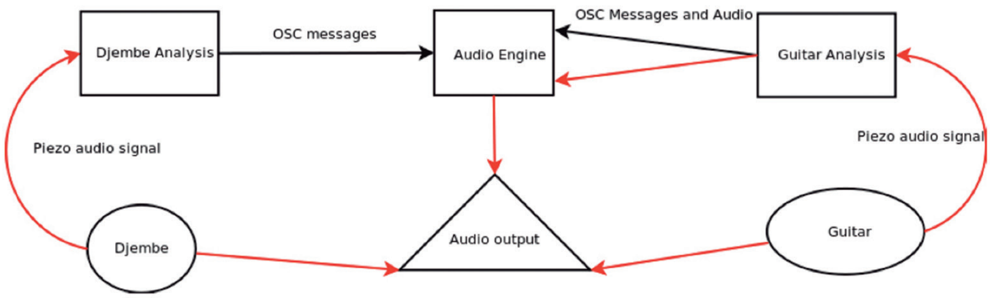

Figure 1. System overview for the extended djembe and guitar interactive feedback processes

As it can be seen from Figure 1, the final audio output is made from both the acoustic sound coming from the instruments and the digitally processed information coming from the instrument analysis which in turn affects the digital audio. Now we refer to the main components of the implemented system.

A) Contact microphones

Using contact microphones in acoustic instruments enables us to analyze and manipulate the signals in real time. The large advantage of contact microphones is the relatively high isolation from outside noises and crosstalk between different instruments in the ensemble. Recording only what is transmitted through the surface with which it is in contact with. A contact microphone is made of thin piezoelectric ceramic, which picks up vibrations when in contact with a surface and translates them into voltage signals. Hence, we accomplish the transduction of physical acoustic attributes of the instrument (such as vibration and resonance of the body of the instrument) into electrical signals, which can be subsequently processed digitally using specialized software. As the signal created by the contact microphones is analog, it contains plenty of information regarding the musician's gestures and performance details, which otherwise would not be available. Piezoelectric elements are cheap and easily constructed from scratch.

The disadvantage of this approach is that the piezos are more fragile and the soldered connections can be easily broken. To this end, we attached the piezos securely to the instruments using masking tape as shown in Figure 2 and Figure 3. Furthermore, the frequency response of piezoelectric elements suffers greatly as they display an unavoidable resonance peak depending on their design and a sharp drop-off in the higher frequency register. While high quality recordings using these contact microphones is discouraged, their use to capture sound material for synthesis is completely validated, if the aimed for result considers and compensates for these flaws.

Figure 2. Securing the piezo to the djembe

Figure 3. Securing the piezo to the guitar

B) Sound Synthesis

As already discussed in the preceding sections, our goal for the sound synthesis was to create a timbral extension to an acoustic instrument. Hence the resulting sonorities should not depart too far from the original sound material, while adding acoustic qualities instead of perceptually copying the input signal. The instrument should allow to be explored in new ways and still preserve its traditional means of interaction. As the extension does not happen in the addition to new physical gestures but merely in timbral additives, the project explores possibilities to use primarily MIR techniques to strictly bind the behavior of the system to the musical playing of the respective performer.

The chosen synthesis module is primarily an enhanced delay module. We implemented a ping pong delay that uses a low-pass filter on the feedback signal. Next to the parameters of the delay module, this opened up new points of control in both the cut-off frequency and Q-value of the filter(s). It is also possible to experiment using different filters on each half of the delay chain.

Additionally, we recorded a predefined length of the guitar signal into a live ring-buffer and had the reading head move in opposite direction to the writing one. What was currently played by the guitar could then be repeated, but in reverse giving an unusual echo effect to the overall sound. As we mainly controlled this synthesis module with the percussive instrument, we controlled both the envelope and and playback speed of the reverse playback, still maintaining coherence with the original input while alienating the synthesis to a degree to separate the reverse echo enough to be perceivable as such.

1) Guitar effects and Mapping

The guitar signal is fed into the ping-pong delay while features control certain parameters of the plugin as shown in Figure 6. The features are extracted using the Max fiddle object as described by Puckette, Apel, y Zicarelli (1998). The pitch of the guitar determines the cut-off frequency while the dynamics control the Q-value of the filter. The pitch tracking allows the synthesis sound to follow the harmonic center of the currently played section. To smooth the movement across the frequency spectrum, the effect is averaged in time with a variable window size, allowing for fast or slower movement in the instrument.

Instead of increasing intensity through a one-to-one loudness correspondence, the effect is rather intensified by modulating the resonance of the low-pass filter. While low Q values with a smooth drop-off cause the effect to slowly fade away, high Q values provoke a resonance peak that is transferred and intensified in every loop of the ping pong delay. Effectively, the signal is not just intensified across the whole spectrum, as it would be if one were to increase the gain of the filter, but rather the frequency band that corresponds with the spectral center of the current harmony or melody is brought out, making the effect come forth behind the acoustic instrument when pushed to the extreme.

The resulting sound can be heard as a clear, pristine, drone-like sound that moves with the overall envelope of the melody/harmony. It pulsates with the intensity of the articulations of the performer, also maintaining the actual sounds: No matter if harmonics are played on the strings or the body of the instrument is tapped, the sound of the articulation is kept as the input signal itself is used to extend the overall sound.

In this sense it acts somewhere in-between an effect and a indistinguishable fusion with the guitar timbre. Although it can psychoacoustically separate itself from the timbre of the guitar, due to it sonic extension in time beyond the physical capabilities of the instrument, it reacts actively to the extracted features, making it more part of the instrument and the musician him/herself than a regular, static effect. Our module, in effect, is therefore truly interactive, as it changes its properties and state automatically and reactively as opposed to a simple delay pedal, taking the definition of interactivity by Jordà (2003) into account.

2) Djembe effects and Mapping

Additionally to the above mentioned ping pong delay effect, the guitar is also recorded into a circular buffer for further processing using analysis information from the djembe signal. The rhythm of the djembe was supposed to be included in the sound synthesis. For this, we connected the reverse playback of the circular buffer to the detected onsets of the percussion instrument. Together with a corresponding envelope, the result was a cross correlated effect, being tied to the djembe temporally and partly timbrally, but using the guitar signal as source.

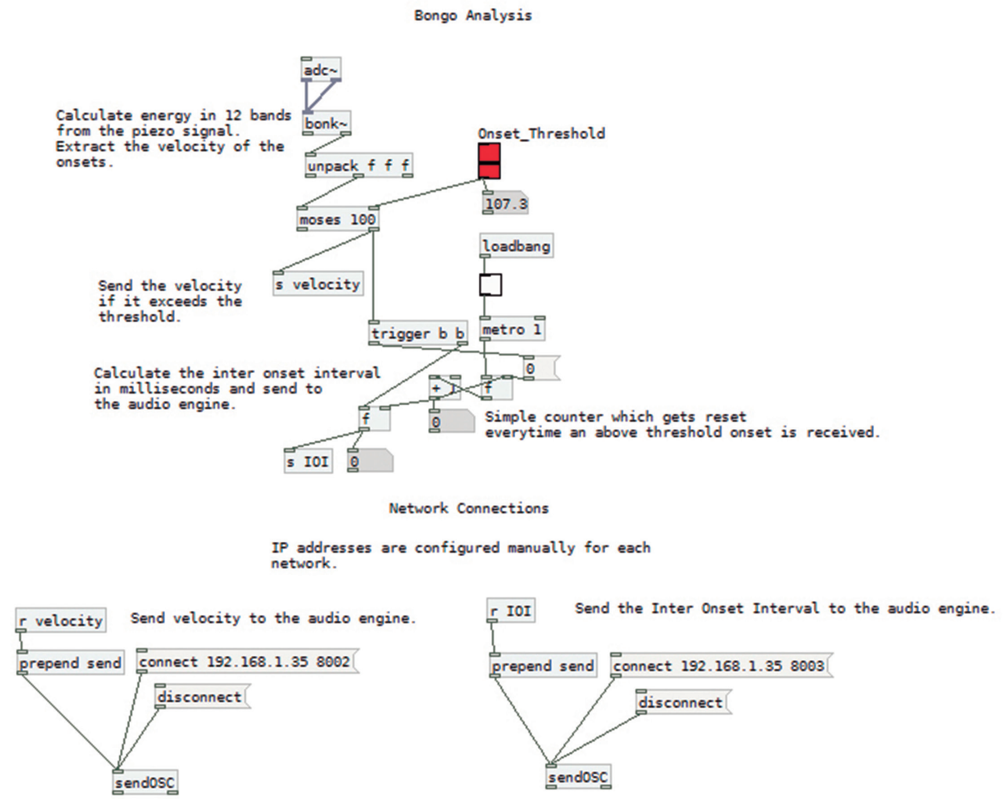

Figure 4. The PD patch analyzing the djembe signal for onsets among other features to control the transformation signal of the guitar

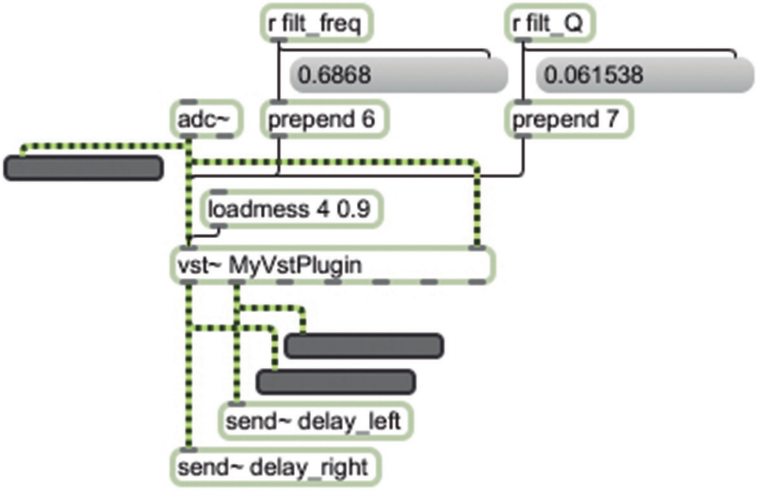

Figure 5. The vst~ object comes standard with modern versions of Max/MSP and can be easily included in a patch as shown above

In the Pure Data patch shown in Figure 4, the object bonk~, as presented by Puckette et al., (1998), is used to extract onsets as picked up by the piezo microphone on the djembe. A velocity threshold for onset transmission is configurable in the patch, allowing for sparser usage of the effect in only *heated* situations, as the effects prominence called for artifact, or garnishing use in specific places of the jam only. Onsets above this threshold are then sent to the audio engine, which playbacks part of the buffer in reverse, departing from the current position of the recording. The speed of the playback is determined by the intensity of the measured onset, creating a corresponding perceptual intensity not through loudness, but through suggested feeling of speed. Furthermore, a louder onset also causes the length of the playback to increase. The actual loudness is normed to the volume of the guitar itself again.

A counter is used to calculate the inter onset interval in milliseconds. The interval between onsets is also mapped to the ping pong filter in the audio engine. Short inter-onset periods produce a brief jump to a Q-value corresponding to the length of the interval. This results in either a crystalline or bubbling sound, depending on the frequency as played, in turn, by the guitar. The listener can relate this to a fast drum roll, for example. While a short *appoggiatura* can produce a single corresponding breakout of the dense drone, a roll creates a texture in the electronics that corresponds rhythmically and is transported in the delay line into infinity. The patch controlling this behavior is shown in figure 6.

It is to be noted that this effect does, in fact, most significantly break away from the *traditional* sonorities of a casual, acoustic jam session. Because techniques inspired by *musique concrete* and similar trends in electronic music are still rather unusual to more popular and radio appropriate styles of music, the perception of this overlay may

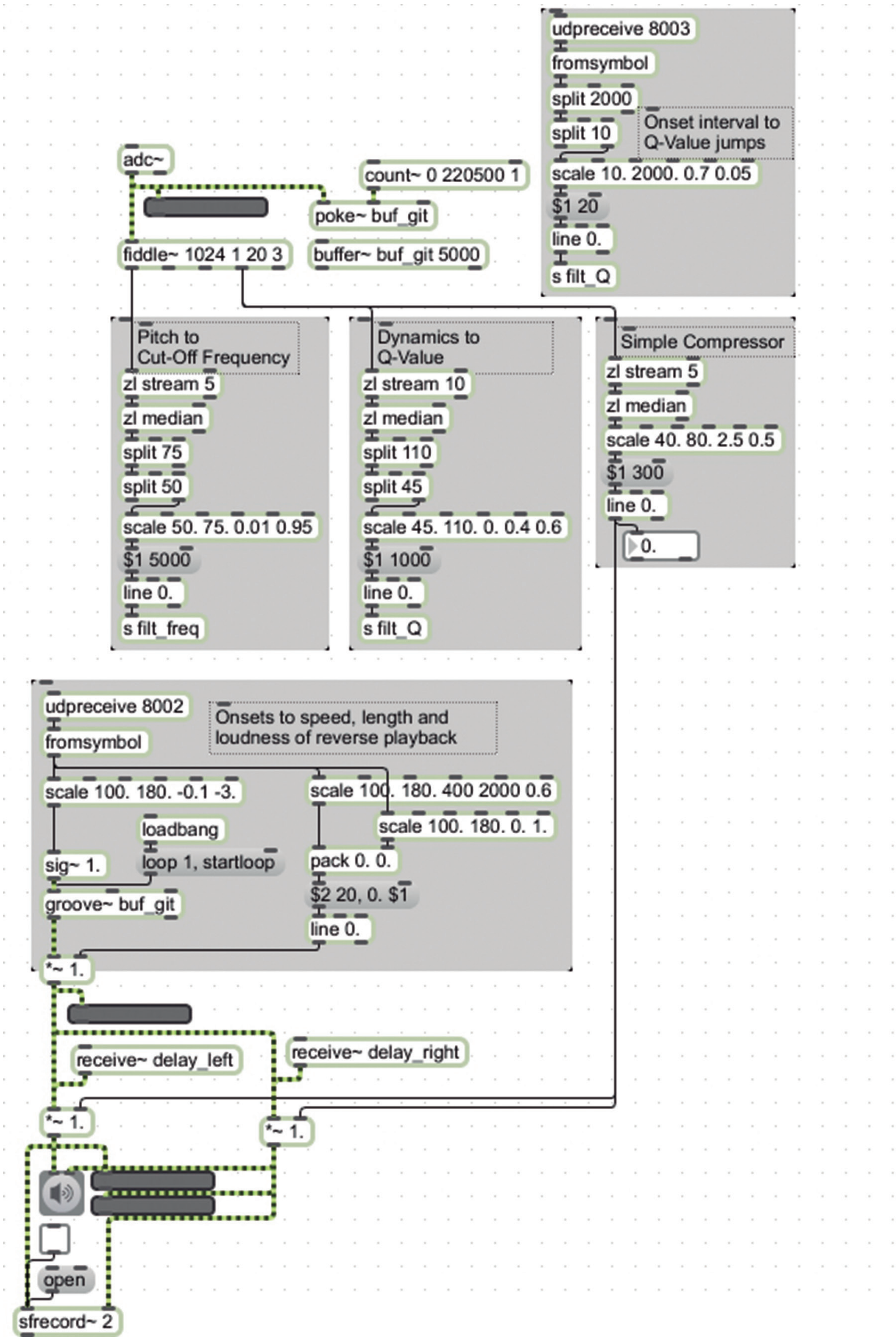

Figure 6. Here we see how the OSC messages from the Djembe Analysis machine are analyzed and mapped in order to sequence reversed segments of guitar from the circular buffer and also how the guitar is analyzed in order to control parameters of the effect.

disturb the unfamiliar listener. Nevertheless, this does not result in the refusal of this timbres produced as we are creating electronic music after all. In fact, it transforms the djembe into a pitch based instrument, as the percussionist can tamper with the melodies proposed by the guitarist and may (more or less intentionally) suggest new melodic lines, which the guitarist may pick up and close the interactive feedback loop by means of the jointly produced electronic extensions.

Conclusiones

One of the intentions behind the live electronics for this project is that the performance should remain literally in the hands of the performers, regardless of their knowledge on the digital processes underlying this particular system. This is the reason why a tape part was avoided. Similar to the opinion of composer George Benjamin (1985), we require the human aspect in the music. For the example provided, we created compositions that evoke the familiar blues-based progressions of classic and contemporary popular music and we also wished to preserve the sound of casual musicians jamming together and their feelings of musical interaction as they feed back off each other. We believe that the live electronics should listen to the performer and be a supplement to his performance. The extensions increase the interactivity of the performance, as they are non-linear and hence not easily predictable. Because the extensions also contribute to the interaction without detracting from the human element of the performance, the performance itself is, therefore, heightened by another dimension of interactivity and sonic experience. S&T

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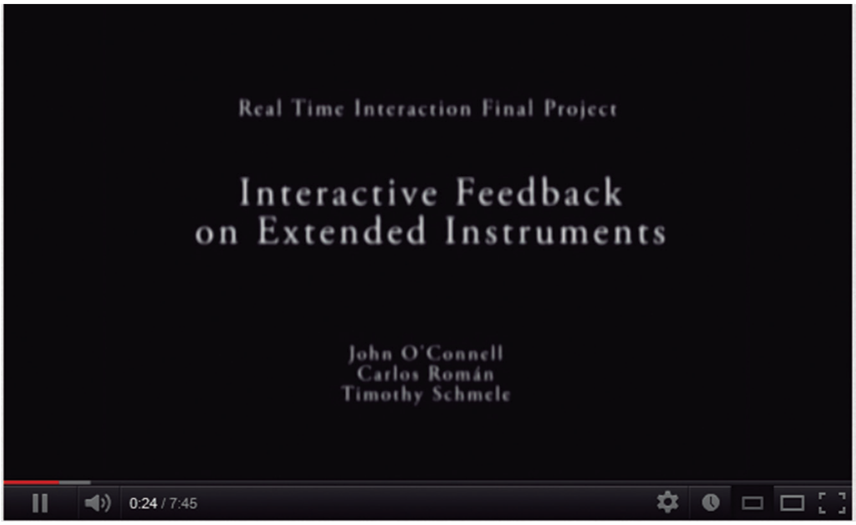
Anexo 1

Video 1 is aimed to explain this project in the context of a live performance using these extended instruments.



Video 1. Interactive feedback on extended instruments

Currículum vitae

Carlos Gustavo Román Echeverri

M. Sc. in Sound and Music Computing, Universitat Pompeu Fabra. Electronic Engineer, Universidad de los Andes. Teacher and researcher for Fundación Universitaria San Martín, Bogotá. He has presented papers at international conferences in New York University, UCLA, Universidade de São Paulo, among others, in topics of music, aesthetics and technology. He has been a member of the Barcelona Laptop Orchestra.

Timothy Schemele

M. Sc. in Sound and Music Computing, Universitat Pompeu Fabra. Composer and researcher in audio technology. He currently works for the Barcelona Media foundation, researching in the 3D audio, sonification and ultrasound fields. He is a member of the Barcelona Laptop Orchestra. His composition "The Common Perkins Scream" recently won the prestigious Luigi Russolo award.

John O'Connell

M. Sc. in Sound and Music Computing, Universitat Pompeu Fabra. Programmer and musician. He has worked for Reactable Systems. His current interests are music interaction and mosaicing. He is a member of the Barcelona Laptop Orchestra. Originally from Hibernia, he currently lives in Catalonia.