An Approach to Instrument Augmentation : the Electric Guitar

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ABSTRACT
In this paper we describe an ongoing research on augmented instruments, based on the specific case study of the electric guitar. The key question of the relationship between gesture, instrument and sound is approached via an analysis of the electric guitar's design, playing technique and interface characteristics. The study points out some inherent defaults in the guitar's current forms of acoustic-electric hybridation, as well as new perspectives for a better integration of the relationship between instrumental gesture and signal processing. These considerations motivate an augmented guitar project at the CICM, in which a gestural approach to augmentation is developed, emphasising the role of the instrumentist's repertoire of body movements as a source for new gesture-sound « contact points » in the guitar playing technique.

Keywords
Augmented instrument, electric guitar, gesture-sound relationship

1. INTRODUCTION
The current research field on augmented instruments is motivated by the assumption that the combination of traditional acoustic instruments with today's sound technology yields a high potential for the development of tomorrow's musical instruments. Integrating the tactile and expressive qualities of the traditional instruments with the sonic possibilities of today's digital audio techniques creates a promising perspective for instrument design. A substantial research effort has already been conducted in the field of instrument augmentation. Some projects, like the MIT hyperinstruments group [7] [5], the augmented violin of the IRCAM [3] [9], and research work at the STEIM [8], have attained emblematic status, establishing technological and methodological models in the research field of augmentation, such as the use of sensor technology and signal analysis techniques to « tap into » the insrumental gesture.

1.1. Electric guitar - precursor of augmentation
A short survey of the afore mentioned works on instrument augmentation shows that there has been a general tendency to work with acoustic instruments from the classical orchestra instrumentarium. In the research project presented here, we are working on a form of augmentation of the electric guitar, which distinguishes itself as already being an acoustic–electric hybrid instrument. Initially developed as an augmented instrument of its time, the electric guitar is intrinsically connected with technology. Over the decades, it has undergone extensive experimentation and development following the technological shifts from analogue electronics to MIDI, and to digital audio. The electric guitar incorporates key electronic live music issues in itself, such as signal processing, amplification, interface and control. Moreover, this « live electronic » praxis is, and has been, widely shared, tested, and discussed by a worldwide community of users, in a wide variety of musical styles and expressions. With all its effects, pedals, amplifiers, and more recently computers, the electric guitar stands out as a pioneer instrument in the area of acoustic–electronic hybridation.

Nevertheless, as we will try to demonstrate in this article, the solutions adopted by the electric guitar fall far from an ideal augmented instrument. In its current state, it offers a complex and often clumsy working environment, and much too often a stereotyped, reductive approach to the musical possibilities of signal processing and synthesis. For us, the actual point of interest lies in understanding the causes for the rather poor integration between the playing technique, the guitar and the electronics, as found in the current electric guitar set-ups. This leads us to question on a fundamental level the design of the gesture–sound relationship in an augmented instrument.

2. TECHNOLOGICAL EVOLUTION OF THE ELECTRIC GUITAR
The first electric guitar (Rickenbacker « frying pan », patent filed in 1934) was an amplified acoustic guitar, motivated by popular music's need for louder volume levels. Its qualities of timbre were poor compared to acoustic instruments and due to this it remained disregarded in its debuts [11]. From the 50's onward, technological progress and the rise of new popular music styles promoting the values of individuality and originality opened a demand for large scale experimentation of the sound possibilities offered by the new electric instrument. Starting with the development of guitars, microphones and amplifiers, the experimentation went on to signal processing with analog « effects », guitar driven analog synthesisers (Roland gr-500, 1977), creating bridges between audio and the MIDI protocol (guitar sythesiser, Roland GR-700, 1984), and adopting digital audio processing in the early 80's [10].

Currently, the electric guitar is following its development with the integration of the evermore powerful microprocessors, whether incorporated, like in the in the « many-guitars-in-one » modeling system proposed by Line6 (Variax), or on a PC with a « plug & play » environment like the « guitar rig » of Native Instruments. Other approaches are being explored (and commercialised), like the Gibson HD Digital Guitar featuring onboard analog-to-digital conversion and an ethernet connection which outputs an individual digital audio stream for each string.

3. SOUND AND GESTURE RELATIONSHIP IN THE ELECTRIC GUITAR

3.1. The gesture – string – signal continuum

The basis of the electric guitar is a transduction of the of the vibrating strings' mechanical energy into electricity by a microphone. The electromagnetic pick-up converts the vibration of the string directly into voltage, thus creating an immediate causal relationship between the instrumental gesture providing the initial energy, the string, and the electric signal produced. Thus the basis of the electric guitar preserves the fundamental characteristic of the acoustic instruments, the connection between gesture and sound, through direct energy transduction as described by Claude Cadoz [4]. This intimacy ensures a high quality instrumental relationship between the player and the guitar, a fact that has certainly contributed to the success of the electric guitar among other experimental instruments. Players experience an immediate response, multimodal (haptic, aural, and, to a lesser degree, visual) feedback, a sense of « connectedness » to the instrument.

3.2. A cumulative model of augmentation

While the basis of the electric guitar is a genuine « electrified » acoustic instrument, its hybrid quality becomes more abstruce with the addition of various sound shaping modules or « effects », essential in creating the instrument's tone. These analog or digital extensions are powered by electricity and have no direct energy connection to the initial playing gesture, and therefore alternative strategies for their control must be conceived. This makes up for a second « level » of the hybrid instrument, where the gesture – sound relationship has to be designed solely by means of creating correspondencies between acquired gesture data and sound processing parameters. The design of the « electric » level of the hybrid instrument is a central question of instrument augmentation, all the more challenging as the electric « implant » should integrate and enhance the instrument without hindering the acoustic level's sonic possibilities and playing technique.

In the case of the electric guitar, the question of coexistence between the acoustic and electric levels of the instrument has been addressed with a cumulative model of augmentation. In this process, the electric level is conceived as an extension of the initial acoustic instrument, leaving the latter relatively intact. Thus the core of the electric guitar does not vary much from the acoustic one's : both hands are involved in the initial sound production, working on the mechanical properties of the strings. The augmented part of the instrument is grafted « on top » of this core by adding various sound processing modules and their individual control interfaces. The consequences of this cumulative process of augmentation are twofold :

1) The playing environment becomes more complex as interfaces are added, each new module requiring a separate means of control. Moreover, as both hands work mainly on the initial sound production, the control of the augmented level needs to be relegated to the periphery of the playing technique, using the little free « space » that can be found in between the existing hand gestures or in other parts of the body like the feet. Due to this marginal position, the control of signal processing seems very limited and qualitatively poor in regard to the sonic possibilities offered by the technologies used.

2) The instrument undergoes spatial extension, going from a single object to a collection of interconnected modules. A common electric guitar playing environment comprises a guitar, a set of « effect » pedals and an amplifier, adding up to form an environment which may easily expand beyond a single person's physical capacities of simultaneous control.

It appears to us that the cumulative approach to « electrification » and augmentation adopted by the electric guitar carries inherent problems for the signal processing control which lead to downgrading its sonic and expressive possibilities. Nevertheless, the established modular set-up of the electric guitar is currently undergoing a profound transformation with the advent of digital audio computing within the guitar itself or with PC plug-and-play environments. This development could offer an opportunity to redesign the electric guitar by efficiently integrating the signal processing with the player's gestures, and connecting the electronic graft to the instrument and to its playing technique on a fundamental level.

4. « CONTACT POINTS » : AN ANALYSIS OF THE GESTURE-SOUND RELATIONSHIP :

The augmentation project we have undertaken has its basis in the observation that a musical instrument is not simply an object, but a meeting point between a gesture and an object, the result of this encounter being the sound which is produced. For us, a musical instrument loses its essence when taken out of its context, i.e. the relationship with the human body. In this « gestural » approach of the instrument, the central question is to find ways of understanding the link between the body, the object and the sound produced. The nature of the continuum between gesture and sound, mediated by the instrument, is a key factor for the expressive and musical qualities of an instrument. A highly functional continuum enables the player to gradually embody the instrument in a process where the musician's proprioception extends to the instrument, resulting in an experience of englobing the instrument and playing directly with the sound [2]. Through observation of how the musician connects to the instrument, it appears that the body manipulates the instrument with a repertory of very precisely defined movements. Each part of the body connecting to the instrument has its own « vocabulary » of gestures adapted to its task and to the constraints of the object. This repertory forms the « instrumental technique » where constituants of the corporal « vocabulary » are combined in real time to form an instrumental discourse. Each movement and combination of movements has its caracteristic sonic result. We use the term « contact points » to signify these convergencies between gesture and object which result in the production or modification of a sound. It allows us to think in terms of a continuum between these three elements and to establish a « map » of their relationships in the playing environment.

For instance, mapping « contact points » on the electric guitar results in a precise repertory of the gestural vocabulary comprised in the playing technique in relationship with each gesture's corresponding interface and sonic result. We can thus establish a typology of initial sound producing « contact points » (left and right hand techniques on the strings) and of the gesture-interface couples which control the instrument's electric level (potentiometers, switches, pedals etc. and their corresponding gestures). This allows for a comprehensive articulation of the instrumental environment in the scope of establishing strategies for further and/or alternative augmentations.

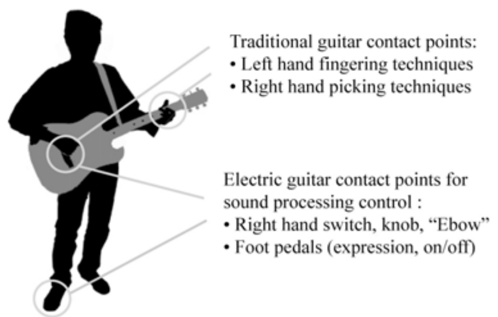

Figure 1. Mapping « contact points » on the electric guitar (gesture-specific detail not included here).

In the perspective of instrument augmentation, there is a dual interest in the mapping of « contact points ». On the one side, breaking down the complexities of instrumental playing into a set of « meta-gestures » and their corresponding sonorities allows us to focus on strategies of « tapping into » the gestures of the standard instrumental technique, motivated by an intimate knowledge of gesture and medium. The gesture data acquisition can thus be adapted to the instrument according to its technical and playing specificities, using both direct and indirect acquisition techniques [13]. On the other side, a map of contact points allows for the articulation of the instrument according to a typology of « active zones » participating in the sound production, and of « silent zones » : convergencies of gestures and localisations which have no role in the production of sound. From this « map » of « active » and « passive » regions of the instrumental environment, we may go on to find ways of « activating » the silent zones, creating new contact points and new gestures.

5. THE AUGMENTED GUITAR PROJECT

We are currently developing an augmented guitar at the CICM motivated by the considerations exposed in this article. The project is based on simultaneous and crossover use of direct and indirect gesture data acquisition (i.e. sensors and signal analysis) [13], as well as, both existing and new « contact points ». The technological platform is made up of a standard Fender Stratocaster electric guitar equipped with an additional piezoelectric pickup and a selection of sensors (tilt, touch, pressure). The 2-channel audio and multichannel MIDI sensor data output is routed to a PC performing a series of signal analysis operations : perceptive feature extraction from the audio signal (attacks, amplitude, spectrum related data) [5], and gesture recognition on the sensor data. The resulting data is mapped to the audio engine, providing information for a dynamic control of signal processing. The project is developped in the Max/Msp environment.

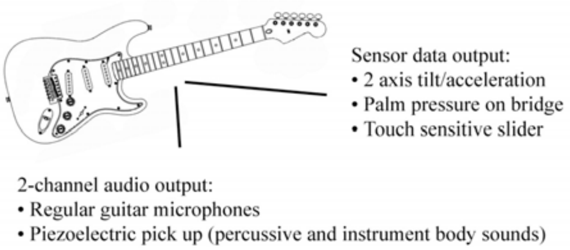

Figure 2. The CICM augmented electric guitar set-up

In our augmentation project we have adopted a gesture-based methodology which proceeds by an initial mapping of the « contact points » comprised in the guitar's basic playing technique. The augmentation potential of each gesture is evaluated in relationship with the available aquisition and sound processing/synthesis techniques. In parallel, we study the musician's body in the playing context, looking for potential « ancillary » [12] gestures not included in the conventional playing technique. We then look for ways of tapping into these gestures with an adapted gesture acquisition system (sensors or signal analysis), thus activating a new « contact point ». Following is a selection of augmentations we are working on. Audio and video material of the augmented guitar and its related *MAA* music project can be found at : www. myspace.com/maamusique

5.1. « Tilt – Sustain » augmentation

This augmentation is motivated by a double observation : 1) the upper body movements that characterise the performance of many guitarists remain disconnected from the actual sound. They carry an untapped expressive potential. 2) the sound of the guitar has a very limited duration, which keeps it from employing long, sustained sounds. The development of the guitar can be seen as a long search for this sustained quality [6]. The electric guitar with distortion and feedback effectively attains that but only with a very distinct « overdriven » tone and high volume levels. The idea of our augmentation is to create a sustainer controlled by the tilt of the guitar and of the player's torso : the more the guitar is vertical, the more sustain. The augmentation is developped with a 2-axis tilt sensor attached to the guitar, mapped to a realtime granular synthesis engine which records the guitar sound and recycles it into a synthesised sustain. The tilt–sustain augmentation activates a new « contact point » in the electric guitar playing technique, incorporating torso movements into sound creation.

5.2. « Golpe » : The percussive electric guitar

Acoustic guitar allows for the possibility of using percussive techniques played on the instruments body. Due to its microphone design, the electric guitar has lost this ability . The percussive augmentation we're working on aims to restore a percussive dimension to the electric guitar, thus reactivating a traditional « contact point » which remains unused. In order to tap into the sounds of the guitar's body, we have proceeded with the installation of a piezo microphone, detecting the percussive attacks and then analysing the signal's spectral content. When hit, different parts of the instrument resonate with specific spectra, thus allowing us to build up a set of localisation–sound couples. The analysed signal drives a sampler where the piezo output is convolved with prerecorded percussive sounds, inspired by Roberto Aimi's approach in his work for augmented percussions [1].

5.3. « Bend » : an integrated « wah-wah » effect

The left hand fingers operating on the fretboard have an essential role of producing intonations with horizontal and vertical movements which range from a minute vibrato to an extended four semi-tone « bends ». This technique is widely used on the electric guitar, allowing the player to work in the doman of continuous pitch variations as opposed to the semi-tone divisions of the fretboard. The « bend » technique is often used to enhance the expressiveness of the playing, giving the guitar a « vocal » quality. The motive of this augmentation is to extend the inflexion gesture's effect on the sound from a variation of the pitch to a double variation of both pitch and timbre. In our system, we use attack detection and pitch following to match the note's evolution compared to its initial pitch. The resulting pitch variation data is mapped to a filter section, emulating the behavior of the classic « wah-wah » effect. We find that controlling the filter through an expressive playing gesture incorporates the effect into the musical discourse in a subtle manner compared to the expression pedal used traditionally for this type of effect.

5.4. « Palm muting » : an augmented effect switch

A popular playing technique on the electric guitar consists of muting the strings with the picking hand's palm, thus producing a characteristic, short, muffled sound. Our augmentation is based on the detection of the muting gesture by an analysis of the spectral content of the guitar's signal : a loss of energy in the upper zones of the spectrum, regardless of which string(s) is(are) being played. Our system tests the incoming signal with a « model » spectrum, interpreting closely matching signals as the result of a muted attack. The aquired « muting on/off » data is used in our guitar as a haptic augmentation of an effect pedal's on/off switch, allowing to add a desired timbre quality (« effect ») to the sound simply by playing in muted mode.

6. CONCLUSION AND FUTURE WORK

The augmented guitar project is currently evolving at a steady pace, exploring new augmentations and sound–gesture relationships. Two different directions seem to emerge from this work : one is refining the traditional electric guitar working environment by finding ways of replacing the poorly integrated effect modules with signal processing control systems more closely connected to the guitar's playing technique. The other direction points towards more radical augmentations of the guitar's soundscape ; associated with the will of expanding the guitar's melodically and harmonically oriented musical environment towards novel possibilities of working with timbre and sound texture. A central factor in this research is the establishment of an interactive working relationship between technological innovation and music. Live playing experience provides high quality feedback on our augmentations, and it bears a central role in (in)validating our work. As the augmentations stabilize and become more refined, we are looking forward to conduct a series of user evaluations which could provide useful insight for further developement of the augmented guitar.

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