ADAPTING POLYPHONIC PICKUP TECHNOLOGY FOR SPATIAL MUSIC PERFORMANCE

Enda Bates   *Dermot Furlong*   *Donnacha Dennehy*

Dept. of Electronic and Electrical Eng.
Trinity College Dublin

ABSTRACT

This paper describes how polyphonic pickup technology can be adapted for the spatialization of electric stringed instruments such as the violin, cello and guitar. It is proposed that mapping the individual strings to different spatial locations integrates the spatial diffusion process with the standard musical gestures of the performer. The development of polyphonic guitar processing is discussed and a method of adapting MIDI guitar technology for this purpose is presented. The compositional and technical stratagies used with various augmented instruments is presented along with an analysis of three compositions by the author for spatialized hexaphonic guitar.

1. INTRODUCTION

1.1. Background and Motivation

Space is often used as an explicit compositional parameter in electroacoustic music. Many performances of acousmatic music, i.e. music without any live instrumental performers, are presented using pre-diffused multi-track compositions and a loudspeaker array or through the live diffusion of a stereo track to a loudspeaker orchestra.

The addition of live performers introduces a number of difficulties in the performance of spatial music. The spatial distribution of performers around the audience can be very effective but is logistically challenging and also highly dependent on the specific layout of the performance space. Compositions for live performers on stage and spatialized audio are particularly challenging as the static location of the live performers provides a frontally-biased visual and audible focus which can conflict with the non-visual and surrounding spatialized audio. Linking the musical gestures of the instrumental performer with the spatial gestures of the electronic part is a significant challenge, as the spatialization process is often not related to the musical instrument in any obvious way. In addition it is rarely practical or possible for a single performer to concurrently play and diffuse a musical instrument.

While various new musical interfaces have been developed which feature some form of spatial control, the idiosyncratic nature of these devices mean they are unlikely to become widely adopted. Augmented instruments, i.e. traditional musical instruments featuring additional hardware or sensors present a possible solution to this problem, as they can potentially combine existing and sophisticated instrumental practice with spatial or timbral processing algorithms. One form of augmentation specific to stringed instruments is the use of polyphonic pickups which produce a separate audio signal for each string. The discrete multi-channel output of these instruments would seem to be very suitable for spatialization to a multi-channel loudspeaker array. By linking the spatial location to the choice of string, the spatialization process could be synchronized to the physical performance of the instrument. In addition, spatialization algorithms and other processes could be applied to each individual string as required.

This signal processing approach to instrument augmentation has the advantage that the performer does not need to learn any new gestures or instrumental techniques. In addition, the necessary hardware has become widely available, particularly for electric guitar, and can often be retrofitted non-destructively to an existing instrument.

2. POLYPHONIC PICKUPS

Polyphonic pickups (also called divided or split pickups) are used to generate a separate audio signal for each string in instruments such as the guitar, violin and cello. They have been widely used over the past three decades to detect and convert the pitch coming from individual strings into MIDI messages. The majority of these systems however do not provide split signals for external processing, preferring instead to multiplex the signals into a single cable which can then be easily connected to a MIDI converter. This emphasis on MIDI capability is changing however and more devices are becoming available which allow for the individual processing of each string, in particular for the electric guitar.

2.1. Polyphonic Pickups for the Electric Guitar

Polyphonic pickups (hexaphonic in the case of a guitar) have been used since the seventies to provide seperate audio signals for conversion to MIDI. Recently however some dedicated systems such as the Gibson HD.6X-Pro have been developed specifically for polyphonic processing. The initial prototyping of the instrument was carried
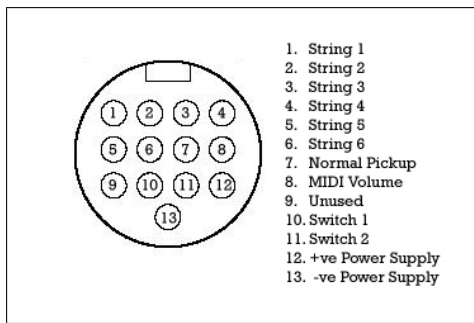
Figure 1. Roland 13-pin Wiring Diagram

Figure 2. 13-pin Breakout Box Schematic[4]

out by Adrian Freed and the Guitar Innovation Group at UC Berkeley's Center for New Music and Audio Technologies (CNMAT) [1]. Further research has since been carried out at CNMAT on polyphonic guitar effects based on vocal-tract modeling, frequency localized distortion and coordinated equalization [2].

The co-director of CNMAT, David Wessel has conducted research on augmented instrument design and interactive computer music with a particular focus on the live performance of improvised computer music. Wessel had used polyphonic pickups in performances such as "Situated Trio", an interactive live performance for a hexaphonic guitarist and two computer musicians with expressive controllers [3]. In this piece, the polyphonic guitar signal is processed by the two computer musicans using various algorithms such as granulation, looping, cross-synthesis and spatialization. The polyphonic guitar signal is also converted to MIDI to provide a high level discrete event representation of the guitarist's performance for triggering automated computer based processes.

2.2. Adapting MIDI Guitar Systems for Polyphonic Processing

The adaptation of existing MIDI guitar systems is an alternative and cost effective method for deriving a polyphonic signal from an electric guitar. Popular MIDI guitar systems by Roland, RMC and AXON use a 13-pin connector which carries six individual signals from the hexaphonic transducer, a mono audio feed from the guitar's normal electrics, and some controls specific to the Roland system.

As we can see from the wiring diagram in Fig.1, the individual string signals from the 13-pin connector can be accessed simply by wiring the approproate pins to several 1/4 inch jack connectors. A schematic for such a breakout box is shown in Fig.2 [4]. The specific implementation of this breakout box for two of the more popular MIDI guitar systems is detailed as follows.

2.2.1. RMC Pickups

RMC produce high quality hexaphonic pickups based on piezo-electric elements mounted under the individual string saddles at the bridge and can be found in Godin and Brian Moore guitars. The pickup is fed into an on-board pre-

amplifier and routed to a standard 13-pin connector. As the RMC pickup uses an onboard power source, the simple schematic shown in Fig.2 is all that's required to obtain the individual string signals. RMC also produce a commercial breakout box that splits the polyphonic signal into six seperate audio channels along with some additional features (www.rmcpickup.com).

2.2.2. Roland GK-2 and GK-2A Pickups

The Roland GK-2 (single coil) and GK-2A (humbucker) consist of an electromagnetic hexaphonic pickup mounted at the guitar bridge. This system is available in various "Roland Ready" electric guitars but can also be mounted externally on an existing instrument. Due to its low cost and nondestructive installation, the Roland GK range has become one of the most widely available and popular MIDI guitar systems. The simple breakout box shown in Fig.2 will however not be sufficient to derive the split audio signals as these pickups are designed to be powered by an external MIDI convertor device. A simple circuit using two PP3 9V batteries must therefore be incorporated into the breakout box design when using the Roland GK system.

3. POLYPHONIC STRINGS

The use of traditional instruments to control or generate synthetized sounds is a recurring theme in electroacoustic compositional research. Much of this research has focused on developing traditional instruments augmented with additional sensors. The mapping of musical gestures to electronic processes is a critical issue in the design of any augmented instrument. The composer David Wessel suggests that "musical control intimacy and virtuosity require both spatial and temporal precision in the sensing of gestures (Control intimacy refers to a tight connection between a body movement and change in an auditory feature)" [5]. The mapping of individual strings to spatial location would seem to be a suitable approach in this regard.

The electronic violin developed by Max Mathews and the Hyperinstruments developed by Todd Machover are two examples of augmented stringed instruments which incorporate polyphonic pickup technology. As we shall

see, the polyphonic output of these instruments was used extensively by the composers who wrote for them. As many manufacturers now produce electric instruments with polyphonic outputs, this approach represents a viable and generalised solution to stringed instrument augmentation that is not tied to specific hardware.

3.1. Augmented Strings

The electronic violin developed by Max Mathews in 1986 was an attempt to use the considerable dynamic, expressive timbral range and highly evolved instrumental technique of the violin as the musical source, modifier, and controller of various real-time performance networks [6].

The electronic violin used four contact microphones inserted into the bridge to pickup the signal. Mathews noticed that when the outputs from the four strings were combined and passed through a single amplifier and speaker, nonlinearities resulted in unpleasant combination tones [6]. To eliminate this problem, Matthews used a separate amplifier and loudspeaker for each string. When the composer Richard Boulanger later came to compose a piece for the instrument, he commented that the discrete four-channel output of the instrument significantly directed the composition in a number of ways", specifically toward a composed spatial component. In the resulting piece, "Three Chapters from the book of Dreams", Boulanger supports and contrasts the linear counterpoint and compound melody with a concurrent spatial counterpoint. He comments "By assigning the output of each string to a separate speaker, the audience is given the unique sense that they are seated within the violin body. This spatial component is based on the inherent design of the instrument and its antiphonal treatment is at the same time quite old and quite new." [6]

The Hyperinstrument group at MIT Media Lab have been researching and developing augmented instruments since the late eighties. The first of these, the Hypercello was completed in 1991 and combined an electroacoustic cello with additional sensors to provide data on various performance parameters such as bow position, placement and pressure, string and finger position and pitch tracking. The composer Tod Machover worked with the reknowned cellist Yo-Yo Ma to create "Begin Again Again....", an interactive composition in which different playing techniques such as tremolo, bow bounce, pizzicato and legato are mapped to various electronic processes including spatial movement [7].

4. COMPOSING FOR THE HEXAPHONIC GUITAR

Writing for a hexaphonic guitar in which each string is individually spatialized requires the composer to carefully consider which strings will be used to produce the chosen pitches. In this scenario, the routing and particular spatialization method used will inform the composition in a very real and tangible way. In the compositions discussed
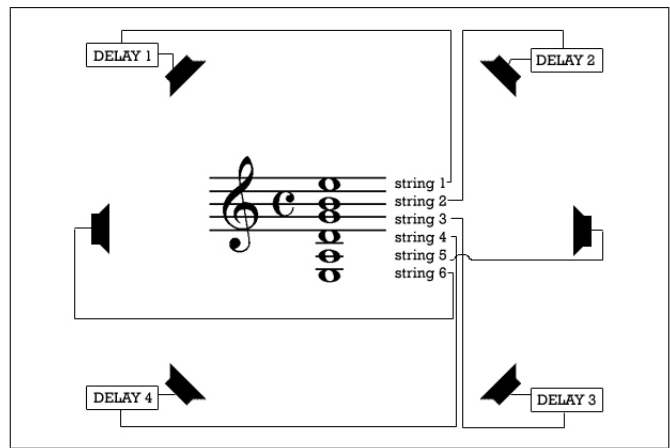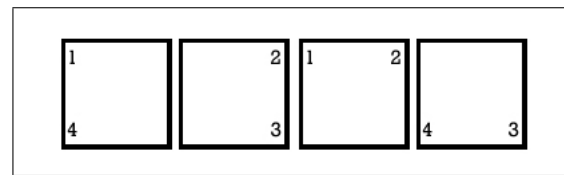

Figure 3. Routing for Etude No. 1

Figure 4. Spatial sequence to Etude No. 1

here, the six strings are routed to individual loudspeakers as this reduced the localization issues relating to virtual images in a performance setting [8]. Static sources were generally used as it was found that dynamic trajectories were not percieved well due to the relatively short sustain of plucked notes on a guitar.

The compositions were realised using a Godin LGXT electric guitar prefitted with a RMC piezo-electric hexaphonic pickup and heavy gauge electric guitar strings. The 13-pin guitar output was connected to a MOTU 828 multi-channel souncard via a breakout box (see Fig.2) which routed pins 1 to 6 of the 13-pin cable to six 1/4 inch analog connectors. The multiple signals were processed in the Max MSP environment and routed to a loudspeaker array. [1]

4.1. Etude No. 1 for Hexaphonic Guitar

In this piece the hexaphonic guitar output is routed to a six-channel loudspeaker array via four synchronized tape delay effects as shown in Fig.3.

The opening section consists of a sequence of two-note chords on the four high strings which mark out the spatial boundaries of the piece as shown in Fig.4. Each of the two iterations of the four chords is followed by a six-note coda which introduces the two lower strings and their associated spatial locations.

The main body of the piece consists of six voicings of a six-note chord based on a quartal harmony. Each chord is played as a repetitive two note pattern on the two low strings accompanied by single delayed notes which cycle

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[1] Selected binaural recordings and scores are available at www.endabates.net.
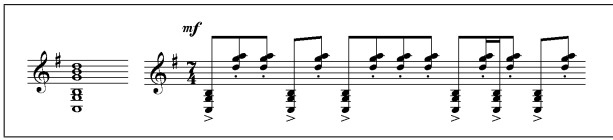
Figure 5. Etude No. 2, Tuning and Rhythmic Pattern

sequentially through the four high strings. The four delay effects are synchronized and set to repeat at eight note intervals. The piece ends with a shorter iteration of the initial section to complete the ABA structure.

4.2. Etude No. 2 for Hexaphonic Guitar and Electronics

In this work-in-progress the three high strings are routed to the back of the array while the three low strings are routed to the front. The opening and closing sections of the ABA structure is based on the rhythmic development of a patteren (Fig.5) of rapid alternating staccato triads which are seperated in terms of space and pitch.

The longer middle section incorporates a multichannel tape part of granulated and time-stetched guitar notes spatialized using the Vector Base Amplitude Panning externals for Max MSP [9]. The guitarist triggers the various granulated notes using a MIDI foot controller which also alters the spatial location of the guitar strings. In each case the granulated note is preceded by a played note from the same spatial location, in this way, the tape part is percieved to originate from the plucked guitar notes and gradually expands spatially across the array.

4.3. Etude No. 3 for Hexaphonic Guitar and Electronics

In this work dynamically spatialized drones are contrasted with more rhythmical passages performed using various extended playing techniques. The strings are consecutively routed in pairs through three instances of Ambience, the freeware reverb VST plugin by Smartelectronix (Fig.6). Each plucked interval is sustained using the reverb hold function which is triggered using a MIDI foot controller. After each of three three intervals has been layered a number of times in this way, the combined drone is is dynamically routed to a spatialization algorithm which chaotically pans the drone around the entire array. This entire process is repeated three times with increasing intensity, culminating in a loud crescendo.

5. SUMMARY

In this paper we have described how polyphonic pickup technology has been used in augmented stringed instruments. The routing of individual strings to a loudspeaker array has been suggested as a method of mapping the spatialization process to the gestures of the performer. The implementation of MIDI guitar technology for polyphonic
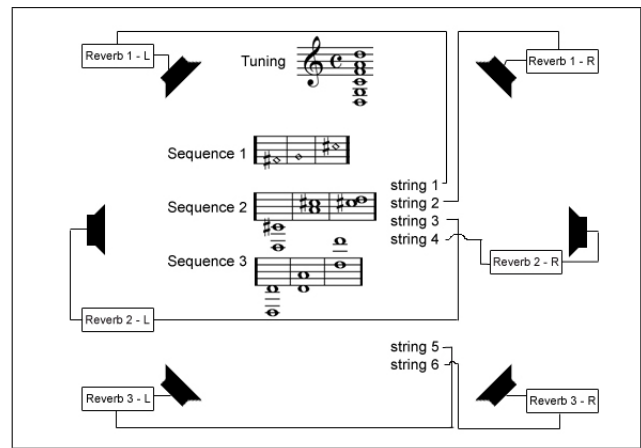

Figure 6. Etude No. 3, Tuning and Interval Sequence

processing is described and three compositions for spatialized polyphonic guitar are presented.

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