Composing for Hyperbow: A Collaboration Between MIT and the Royal Academy of Music

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ABSTRACT

In this paper we present progress of an ongoing collaboration between researchers at the MIT Media Laboratory and the Royal Academy of Music (RAM). The aim of this project is to further explore the expressive musical potential of the Hyperbow, a custom music controller first designed for use in violin performance. Through the creation of new repertoire, we hope to stimulate the evolution of this interface, advancing its usability and refining its capabilities. In preparation for this work, the Hyperbow system has been adapted for cello (acoustic and electric) performance. The structure of our collaboration is described, and two of the pieces currently in progress are presented. Feedback from the performers is also discussed, as well as future plans.

Keywords

Cello, bow, controller, electroacoustic music, composition.

1. INTRODUCTION

1.1 Background and Motivation

As the field of new music interfaces grows, great achievements are being made in the creation of controllers, as well as in composition and performance techniques featuring them. Alternative controllers, such as The Hands of Waisvisz [18], have been demonstrated to have truly virtuosic capabilities. Controllers inspired by traditional acoustic instruments, such as Tarabella's Imaginary Piano [16], Burtner's MetaSax [1], Scavone's Pipe [14], and the Hyper-Flute of Palacio-Quintin [9], extend the sonic possibilities, performance techniques, and metaphors of their counterparts. New string interfaces are a subset of these [2-4, 6-8, 11-12, 17].

All of the above interfaces represent many different approaches to sensor design, mapping, composition, and performance, yielding great musical and intellectual rewards. However, it is quite difficult to find cases of new music interfaces that have the benefits of a large associated repertoire and large group of dedicated players. Of course, these are not simple features to attain.

Often new interfaces are designed primarily for the use of the designer alone, or for a small number of select musicians. But even when the desire to disseminate is great, numerous practical issues, such as the robustness of the hardware and software involved, often interfere with the goal to make controllers available to more users. And, of course, it is often difficult to decide on the appropriate time in a new controller's development for feedback from a larger audience and user group, as the urge to iterate is ever-present.

Our controller, the Hyperbow [19], is one of the many that lack two of the basic characteristics, a large repertoire and large group of players, possessed by well-established instruments. The Hyperbow was built for use in real-time violin performance applications, such as required in Tod Machover's *Toy Symphony*, in which the Hyperbow made its debut. Given the rigorous demands bowed string players make on their instruments, as well as the impositions of a touring musical work, great care was taken to design the system with a high level of playability, usability, and robustness.

The Hyperbow performed well, achieving its task of an expressive new music controller that enables traditional violin technique. The Hyperbow system was successfully used in four public performances of Tod Machover's *ToySymphony* (2001-2002) by two different violinists. Later, it was featured in a performance of Michael Alcorn's *Crossing the Threshold* for the opening of SARC (2004).

However, although the Hyperbow had been used in performance by several players (who produced invaluable feedback concerning their experiences), it still cannot be considered in the same class as well-established acoustic and electric instruments. If the Hyperbow is ever to achieve the unqualified status of a real music instrument, it must not only provide wonderful new sonic possibilities, but must also be associated with a significant repertoire and have many players. Additionally, it must be easily maintained by these players, and ultimately, have its own performance practice.

In order to achieve these goals, it is essential that the Hyperbow be placed in the hands of more composers and performers. It is this belief that is the core motivation of this collaborative work.

2. HYPERBOW REVISIONS

The first Hyperbow system [20], a descendent of the original MIT Hyperstring Project [6], was designed to capture elements of violin bowing gesture for use in real-time performance applications. Installed on a commercial carbon fiber violin bow and electric violin, it features accelerometers on the frog, force sensors (composed of strain gauges) mounted on the bow stick, and an electric field position sensor that includes an antenna mounted behind the bridge of the violin. This last component of the sensor system is an adaptation of the position sensor first used in the Hypercello project [10].

The Hyperbow system is battery-powered and transmits its sensor data wirelessly via an RF communication module. An external electronics board receives the data and sends it to the computer via the serial/USB port.

In January 2005, when this collaboration officially began, the Hyperbow technology was already several years old. Though we could have significantly redesigned the hardware in preparation for this new work, we opted not to do this. Instead, we decided to postpone a major revision to a later date when the process could benefit from exposure to more composers and performers.

However, because of the different range of bowing movement required by the cello and the fact that we would be using acoustic cellos, some small but critical revisions of the existing hardware were required. Specifically, the electric field position sensor was adapted to produce a signal with greater amplitude emitting from the bow (so that it could be detected by the original receiver from the greater bow-bridge distance of the cello).

When used for violin performance, the position antenna was mounted directly on the solid body of a Jensen electric violin by means of a simple screw and right angle bracket. Obviously, such a scheme was not possible for our work with acoustic cello, so the antenna was fixed to a threaded rod, which was then mounted on the underside of the tailpiece by means of a plastic clamp. (This was a variation of an arrangement used in the Digital Stradivarius controller [15].)

Figure 1:Hyperbow and acoustic acoustic cello (© Roberto Aimi).

Interestingly, although the antenna mounting just described was functional, the musicians determined that it was easier and more convenient to attach the antenna to the strings with tape (behind the bridge). Also, they sometimes found it useful to shift the location of the antenna with respect to the center of the bridge, as pictured in Figure 1. These improvisations arose as the participants experimented with the Hyperbow and were taken as positive indications of increasing comfort with and ownership of the technology.

3. A NEW COLLABORATION

3.1 Structure

This project includes researchers from the MIT Media Laboratory, whose primary role is that of interface design, and composers and cellists from the Royal Academy of Music.

Two Hyperbows for cello were built at MIT and then transferred to the RAM's permanent instrument collection. Though we were interested in an equal exchange of information and ideas, one of our intentions was for the artists at RAM to create, rehearse, and perform without any need for outside technology support, and to be able to freely develop their own individual work processes.

3.2 Schedule

This collaboration began in January 2005, at which time the collaborators from MIT traveled to London for a week long workshop. Two Hyperbows (slightly revised, as described below) were presented to the colleagues at RAM, and the week began by imparting technical knowledge of the Hyperbow system and related software such as Max/MSP.

After these introductory exercises, each composer/cellist team began the work of creating the first compositional sketches of the project. These evolved throughout the week, and on the last working day we made a presentation to the RAM community.

The composers continued to independently develop their pieces through the spring of 2005, and in June 2005, the group met again, this time in Boston. After another week of concentrated work together, we presented the progress at MIT.

In November 2005 during the Association Européenne des Conservatoires Congress 2005 at Birmingham Conservatoire, the first performance for the outside community was given of two of the works in development, Patrick Nunn's *Gaia Sketches*, and Artem Vassiliev's *MODES*. These two pieces were performed again a month later at RAM for the third research seminar on the Hyperbow collaboration entitled "New Tools, New Uses", and are described below by their composers.

4. COMPOSING FOR HYPERBOW

As described above, there have been four public presentations of new works for Hyperbow and cello to date.

During the last two events (Novemeber and December 2005), two new compositions were performed. *Gaia Sketches*, by Patrick Nunn, incorporates the Hyperbow with acoustic cello, while *MODES*, by Artem Vassiliev, features an electric cello. Below, the composers discuss their works.

4.1 *Gaia Sketches*, by Patrick Nunn

4.1.1 Approach

As part of my own research, my intention was to explore ways of extending the timbre of the acoustic cello in a manner that would feel natural to the player without the need to change their existing technique. By applying a method of direct mapping of bow gesture data to control parameters, the incoming audio signal from the acoustic cello could be coloured and transformed.

This particular approach stems from a desire to create a closer relationship between the performance gesture and audio processing. This method of design permits the player to actively feel and control the electronic processing, rather like an extension of his/her own instrument.

The decision to use acoustic cello as opposed to the electric cello was made on aesthetic and conceptual grounds. The greater range of sonorities and resulting range of expression obtained from the acoustic cello provided a wider contrast to the sounds produced after the signal was processed. In addition, the score requires the cellists sound to be localized to their position in performance without the need for separate amplification.

In order to obtain a clean audio signal from the acoustic cello and to eliminate maximum external audio pollution, a Fisherman C-100 cello pickup was attached to the bridge

4.1.2 Concept

Gaia Sketches were inspired by Rachel Rosenthal's poem titled *Gaia mon amour* – a passionate portrayal of humanities infliction upon the Earth and the retaliation of the spirit of Earth through environmental events [13]. The cellist (representing the human spirit) is positioned at the centre point between four surrounding speakers (representing Gaia – Mother Earth).

In the early stages of testing, small composition sketches were written to test the effectiveness of the seven parameters when mapped onto audio processes. These sketches were developed with the addition of feedback delays, reverberations and twelve sequentially triggered samples that act as an accompanying landscape to the seven-minute composition.

Gaia sketches comprises essentially of a series of statements constructed from variants of a four-note motif. Each statement is subjected to transforming timbral states and colourations that explore the interaction between the players bowing gesture and the possibilities inherent in the chosen mapping configurations.

The accompanying samples serve as an additional layer of sonorities that encompass and surround the soloist. A series of sequential modes (triggered by pitch recognition) change the configuration of colouration of the incoming audio signal and is further added to the accompanying samples.

4.1.3 Challenges

The interface for *Gaia Sketches* was programmed in Max/MSP and allows for initial calibration of the bow. Visual references are given to incoming bow data and pitch values of the acoustic cello. Further control is given to mode selection and signal values in and out of the attached audio interface.

The mapping of raw data from the bow often produced inconsistent effects in practice due to natural variations in the cellist's gesture or variations between different performers. A calibration procedure was introduced before each performance which scales the extremes of incoming gesture data to a set of maximum and minimum values.

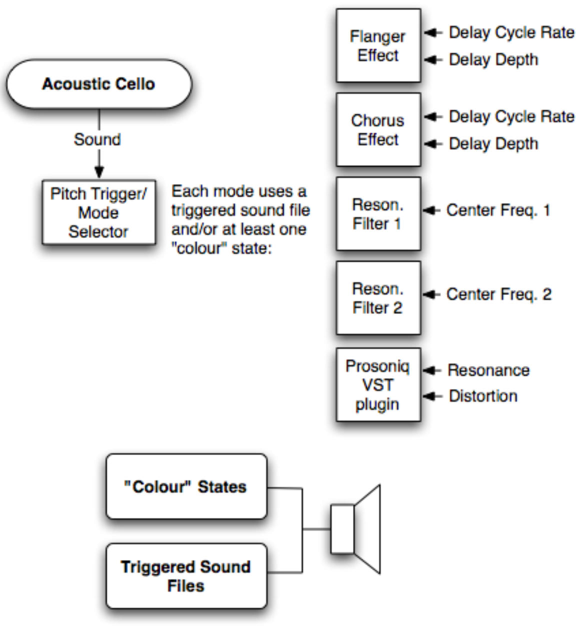

Figure 2: *Gaia Sketches* uses pitch recognition to trigger combinations of "colour" states and stored sound files.

Although the Hyperbow controller offers seven parameters of gesture data, the challenge was to find combinations of bow parameters that were responsive enough for the player to experience effectively for real-time manipulation of audio processing.

Five coloration states transform the incoming audio signal from the acoustic cello through a combination of bow gesture to sound processing parameter mappings. These include two comb filters, two resonant filters and a Prosoniq Northpole VST plugin.

The two comb filters are independently set with different feedforward and feedback coefficients to produce both flanger and chorus type colourations of the signal. The bow velocity, obtained from the rate of change in bow position between frog and tip data, is directly mapped to the rate of the filter. The downward force bow parameter is directly mapped to the depth of the effect.

The first of the resonant filters directly maps the z-acceleration (normal to the string) of the bow to the centre frequency of the filter, exciting the sound during passages involving techniques such as spiccato. The second maps the bow position (obtained from frog and tip values) to the centre frequency of the filter.

The final colouration is achieved through the use of a Prosoniq Northpole VST plugin in which two simultaneous mappings occur. The first directly maps the downward force data to distortion level of the incoming cello signal. The second directly maps bow velocity to the cutoff frequency creating a 'wah-wah' effect.

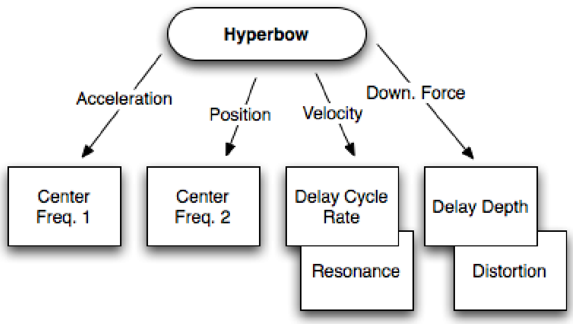

Figure 3: In *Gaia Sketches* the Hyperbow is used to control at least one parameter in each of the "colour" states.

4.1.4 Thoughts on the Outcome of Gaia Sketches

The realization of *Gaia Sketches* can be seen as an initial exploratory step in the collaborative development between designer, composer and musician. Working with new tools such as the Hyperbow generates a unique set of possibilities and challenges both musically and technically for a composer. The most common issue experienced by all composers was one of balance between the processes of learning the required new skills, design, programming, composition and testing.

Perhaps the most exciting of opportunities lies in the potential for creating an intuitive link between the performer and the sound processing through successful mapping strategies. In *Gaia Sketches*, these mappings are independent one-to-one types although the higher- level controls used in the Prosoniq Northpole VST plugin are indeed lower-level parameters that have been cross-coupled. Although these simple mappings were successful in attaining a reasonable amount of intuitive control for the performer, the range of timbral diversity was rather limited and would certainly benefit from further experimentation into more complex mapping strategies.

By far, the most fundamental part of the composition process involved a thorough understanding of the relationship between the gestural data and the perceived sound from the player's instrument. The seven parameters of the Hyperbow, although a little daunting at first, provide a composer with a multitude of gestural information about the performer. Through innovative design of sound synthesis and processing and efficient mapping schemes, it is possible to find suitable combinations that are not only musically interesting but effective in their response.

With the possibility of future performances in mind, one aim was to make the electronic processing as automated as possible. This was achieved through the use of sequential mode selection triggered by pitch recognition using Tristan Jehan's pitch~ object [5]. It is feasible that certain bow parameters could have been used but at the expense of the integrity of the composition. Similarly, the coordination of specific pitches within the composition with the triggering of electronic events can pose further challenges for the composer. However, the pitch tracking method proved to be reliable on most occasions although further improvements are required to ensure complete autonomy.

Future plans include more sketches exploring the interaction and relationships between gesture mapping and sound processing culminating in a larger work for string orchestra and cello with Hyperbow.

4.2 *MODES for electric cello, Hyperbow and computer interaction*, by Artem Vassiliev

As this is my first piece involving live electronic interaction, the proportion between computer-generated musical events and episodes of unaccompanied cello was chosen with the emphasis on the solo instrument. It is a more familiar medium for me as a composer; therefore this approach allowed me to explore the new technology without a danger for this work to become a purely technological study rather than a piece of music. It consists of three sections called *MODES*, 2 interludes, prelude and postlude. Live electronics appear only in *MODES* and their compositional function here can be seen mostly as ornamentation and distorted reflection of the main solo. The musical implication was to create an atmosphere of a meditative self-reflection, for which the timbre of an electric cello was the most productive sound source to explore. (Although initially this piece was intended for an acoustic cello, it was transformed later during our collaboration with Peter Gregson.)

While working on the electronic component of my composition, I aimed to produce a result, which can at the same time sound predictable enough to become a part of a 'stable' composition and flexibly follow all the nuances of the soloist's behavior, which inevitably varies with every new performance, on stage. This was achieved by means of Max/MSP and Logic software with inclusion of two VST plug-ins. The Max patch is a result of my collaborative work with Philippe Kocher, Mike Fabio and Patrick Nunn.

In the MODE 1 the amplitude of incoming cello sound triggers one of the three delay lines (as show in Figure 4), so an echoed version of the original sound is being transformed and distorted in three different ways.

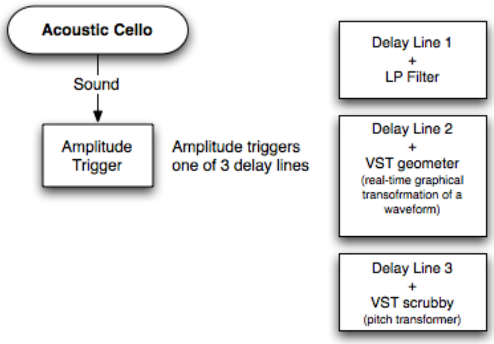

Figure 4: MODE 1 uses a variable delay. The amplitude of the cello sound triggers one of the 3 delay lines.

The next two MODES in this composition require the use of the Hyperbow. Among the multiple possibilities offered by this powerful performer's tool, the one that interested me as a composer was to use it as a flexible trigger and the controller for the electronic accompaniment in this piece. Thus, in the MODE 2 the incoming pitch from the cello is analyzed by the software (using FFT) and replicated with random octave transpositions. The pitches are also mapped according to the three predetermined harmonies. The fast acceleration of the bow switches the programme to the next chord. In order to prevent very rapid changes, the software was set to react on this parameter every five seconds. The tempo of resulting accompanying arpeggiated patterns is regulated by the bow pressure (the stronger the pressure, the slower the tempo). Transposed cello pitches are also doubled by the sine wave synthesizer, which creates an additional layer of texture in a higher register. Its amplitude envelope follows the amplitude of the incoming audio signal from the cello.

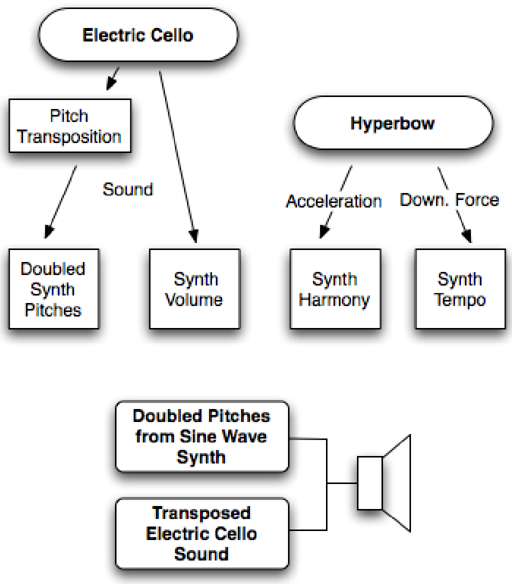

Figure 5: MODE 2 uses a sine wave synth to double transposed pitches produced by the electric cello.

The MODE 3 is similar to the MODE 2, but instead of the transposed cello sound and the sine wave synthesizer, two other physical modeling software synthesizers were used in this section. The performer can switch between them by playing either closer to the tip of the bow or to the frog. The harmony and the tempo are controlled in the same way as in

MODE 2 (fast bow movement will switch the programme to the next chord and the bow pressure determines the tempo).

Although all sound events in the electronic part of my composition are generated in realtime, they can be controlled in order to match harmonically and rhythmically the solo cello part. This flexibility is mainly achieved by use of the Hyperbow. Our practical experience demonstrated, however, that such an approach to the bow as a trigger increases responsibility and demands an additional effort from the performer. This is the one of the problems that I am going to explore further and possibly to solve in my next composition for cello with the Hyperbow and string orchestra.

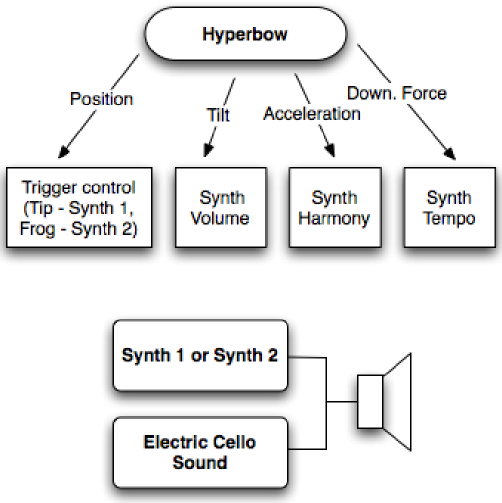

Figure 6: MODE 3 is similar to MODE 2, but uses two external software synths (instead of a sine wave synth).

As my first work for live electronics, *MODES* has achieved its goal. It gave me enough practical experience and inspiration for the new project in which the involvement of live electronics component is going to be more substantial. My first excitement of working with the Hyperbow is now leading me towards serious exploration in a broader area of compositional interests and research activities. Thus, in the new project I am going to try using only those parameters that will not interfere with interpretive ideas of the performer. In other words, I see the Hyperbow in my next piece more as a controller rather than a trigger. The ideal situation for such a performance would be when the complexity and variety of functions of the Hyperbow will become almost unnoticeable for the player, but at the same time all the events in the electronic part will be accurately synchronized with the solo instrument and the orchestra, leaving enough space for an interpretation and for an improvisation if it is required.

Apart from offering endless opportunities for an experiment, the Hyperbow is continuing to develop over the period of our ongoing collaboration. I see this fact as a great advantage for me as a composer. It motivates me to continue working on this project because certain improvements in software and hardware components can be made even according to the needs of one individual composition. Thus, the composer can be as precise as possible in his/her compositional demands. On the other hand, every new composition written specifically for the Hyperbow extends its repertoire and potentially increases chances for this outstanding invention to become one day an industrial standard in contemporary music making and performance practice.

5. PERFORMING WITH THE HYPERBOW

In this project, we are extremely fortunate to have the participation of highly skilled, classically trained, adventurous cellists. To date, four such players, Philip Sheppard, Shu-Wei-Tseng, Alexander Holladay, and Peter Gregson, have performed the various new works with Hyperbow composed throughout this collaboration.

Figure 7: Shu-Wei Tseng with Hyperbow and cello (© Roberto Aimi).

Not surprisingly, the expectations, impressions, and experiences of each individual cellist regarding the Hyperbow vary considerably. Previous experiences, such as whether or not the player has performed with an electric or amplified acoustic cello before, and the degree of familiarity with studio equipment, computers, or technology in general, are important factors. Also, the amount of time spent with the Hyperbow, in collaboration with the composers and in rehearsal, is of course critical.

Both Shu-Wei Tseng and Peter Gregson, who recently performed *Gaia Sketches* and *MODES*, respectively, took a keen interest in the technical capabilities of the Hyperbow. However, in reaction to various aspects of the experience, their impressions varied. Tseng remarks, “I was immediately put into a position where I have to be fully aware of what and how I do things. This is wonderful…” Gregson observes that producing the gesture data to produce the desired sound “came down simply to feel.” Of course, their perceived ability to control the sound output of the system was also dependent on the mapping in place.

On the issue of the weight and ergonomics of the Hyperbow, feedback also differed. One player stated that the increased weight of the Hyperbow was of no concern, while another disagreed. Interestingly, criticisms regarding the carbon fiber bow itself were also expressed, as Tseng observed that it produced sound louder than usual, and Gregson noted that he found the frog to be too low.

Though the number of cellists who have played with the Hyperbow is still quite small, the feedback gained from them has been extremely helpful. Perhaps the most encouraging piece of feedback received thus far was the suggestion by two of the cellists to conduct a training session on the maintenance and upkeep of the Hyperbow interface for the performing cellists in the group. Such a session would include instructions on when and how to change batteries, remove the electronics board to enable rehairing of the bow, debug potential problems in the operation of the electronics, etc. Imparting these skills to Hyperbow performers is essential to ensure the success of the interface, as we hope that it will one day be entirely under the care of its users and truly “gig-worthy”.

Though the number of performers who have played the Hyperbow is still quite small, the benefits we have gained from their contributions are great. As our collaboration grows and the Hyperbow develops, we will continue to enlist the essential help of these and other performers.

6. SUMMARY

We are greatly encouraged by the progress we have achieved in the past year of our Hyperbow collaboration. The successful deployment of the Hyperbow within a new community of users, performances of new compositions, and the enthusiasm of both composers and performers for this work of art and research, are all positive results.

As we continue, we plan to further increase the number of participants (composers and cellists) involved in the project, in order to create a greater repertoire for the Hyperbow and a larger body of knowledge regarding its performance applications. It is our hope that through such work we may soon be able to produce a significantly improved and refined Hyperbow that will be useful to many other musicians.

7. ACKNOWLEDGMENTS

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