THE MCGILL DIGITAL ORCHESTRA: INTERDISCIPLINARITY IN DIGITAL MUSICAL INSTRUMENT DESIGN

Ferguson, Sean, Centre for Interdisciplinary Research in Music Media and Technology, Digital Composition Studios, Schulich School of Music of McGill University, Canada, sean.ferguson@mcgill.ca
Wanderley, Marcelo, Centre for Interdisciplinary Research in Music Media and Technology, Input Devices and Music Interaction Laboratory, Schulich School of Music of McGill University, Canada, marcelo.wanderley@mcgill.ca

ABSTRACT

Background in Gestural Musical Controllers

The McGill Digital Orchestra was a three-year research/creation project that involved the development of a number of novel digital musical instruments. It included the composition and concert performance of several new musical works, for example during the 2008 MusiMarch Festival of Contemporary Music in Montreal. A digital musical instrument comprises a gestural control surface that controls the parameters of a digital synthesis algorithm in real time. In the Digital Orchestra Project, the synthesis engine was hosted on a general-purpose computer, while the gestural control surfaces were new hardware devices created specifically for the project. The mapping between gestural data and synthesis parameters was carried out through the use of custom-written software called The Mapper.

Background in Musical Performance

From a performance perspective, a successful digital musical instrument should allow the performer to feel that he or she has expressive control of the musical material. This sensation results from a number of different factors, including the responsiveness of the instrument (low, consistent latency), haptic feedback, the mapping strategies used, and the reproducibility of musical ideas, among others.

Aims

The aim of the Digital Orchestra Project was to create a number of new digital musical instruments with expressive musical potential comparable to that of existing acoustic musical instruments. Interdisciplinary teams of music technologists, performers and composers participated in the design and creation of the instruments, which were then used in the composition and concert performance of a number of new musical works. An important goal was to leverage the expertise of elite performers on traditional orchestral instruments to provide ongoing feedback to the instrument designers. We also wanted to address the issue of reproducibility in the performance of digital musical instruments by developing appropriate notation methods.

Main Contribution

The Digital Orchestra resulted in the design of a number of new digital musical instruments. In the early stages of the project a large number of prototypes were developed. Those judged to have the greatest musical potential were then refined to become viable musical instruments. The composers who participated in the project composed new works for small ensembles that included these instruments. These works were performed in various concerts. A new approach to musical notation based on dynamic visual elements displayed on a computer screen was developed. Software for easily mapping between performance gestures and synthesis parameters (The Mapper) was also created.

All members learned to work in an intensive long-term multidisciplinary project. In this model, composers and performers are able to influence aspects of the instrument design from the very earliest stages. The project notably included three years of intensive training on these instruments by performers who had already achieved a high level of expertise on traditional acoustic musical instruments.

Implications

The McGill Digital Orchestra presents a number of paradigms for the design, creation and performance of digital musical instruments in the context of a long-term interdisciplinary, collaborative environment. Issues related to mapping strategies, notation, the relationship of physical and musical gestures, robustness, responsiveness, and haptic feedback arose during the course of the project. As well, we devised new methods for communication of performance instruments to the players of the instruments. Furthermore, the Mapper software continues to be used in other contexts.

Based on our experience, we propose that one effective measure for the evaluation of a digital musical instrument is its ability to reproduce a performance of a particular piece, either by the same performer or by different performers. This involves the ability to realize a piece based on a notated score, whether on paper or using software-based visual feedback in a graphical environment. We suggest that this may aid in ensuring the viability and longevity of a novel digital musical instrument.

The results of this long-term, multidisciplinary approach to digital musical instrument design include interfaces that have been proven in high-profile professional performance contexts and that are still being used actively by several performers world-wide.

1. INTRODUCTION

The McGill Digital Orchestra was a three-year research/creation project that included the development of a number of novel digital musical instruments and the composition and concert performance of several new musical works written for these instruments. The Digital Orchestra Project originated from a series of interdisciplinary seminars given at McGill University by Marcelo Wanderley, Sean Ferguson and D'Arcy Philip Gray.

A DMI comprises a gestural control surface that controls the parameters of a digital synthesis algorithm in real time. In the Digital Orchestra Project, the synthesis engine was hosted on a general-purpose computer, while the gestural control surfaces were new hardware devices created specifically for the project. The mapping between gestural data and synthesis parameters was carried out through the use of custom-written software called *The Mapper*.

2. THE DIGITAL ORCHESTRA PROJECT

The goal of the Digital Orchestra Project was to create a number of new digital musical instruments with expressive musical potential comparable to that of existing acoustic musical instruments. Our approach centered on the formation of interdisciplinary teams of music technologists, performers and composers. These teams participated in the design and creation of new instruments, which were then used in the composition and concert performance of a number of original musical works. An important goal was to leverage the expertise of elite performers on traditional orchestral instruments to provide ongoing feedback to the instrument designers. We also wanted to address the issue of reproducibility in the performance of digital musical instruments by developing appropriate notation methods.

Our focus on interdisciplinary collaboration resulted from our desire to create instruments that would remain viable and in use following the tenure of the project. One risk in an approach in which a single person working alone fulfills all the roles of instrument designer, composer and performer is that the resulting instrument – though possibly of interest in various ways – is only ever used by its inventor. The current scene is peppered with unique and fascinating digital instruments with a performer base of one. In the Digital Orchestra, we hoped to develop a methodology for the process of creating DMIs that would increase the likelihood of their being adopted by performers other than the instrument's designer.

The project was planned to take part in three distinct phases. In year one, teams of music technologists freely experimented with various sensing technologies and together with composers created a large number of prototypes of hardware and software tools. Performers of orchestral instruments carried out testing of these prototypes, as well as practiced on prototypes previously developed at the interdisciplinary seminars mentioned above. Their impressions of the novel prototypes provided valuable feedback for iterative development to the instruments.

In year two, three teams – each of which included performers, composers, and music technologists – created new gestural controllers, synthesis engines and digital signal processing and analysis tools based on the prototypes from year one. At the end of this year, the goal was to finalize the tools of the Digital Orchestra to prepare for concert use in the following year, including documentation. At the end of this year, the composers began preliminary work on new compositions using the resources of the Digital Orchestra.

In the third year, the composers completed new works for concert performance during the 2008 MusiMarch Festival in Montreal at end of year. During this year, the role of the music technologists shifted from a strictly developmental one, to include support for the technical requirements of each of the works composed for this concert.

While the above planned structure was largely maintained, some alterations did occur. One of the most significant was that the number of concert works that were composed went far beyond the pieces that were performed during the MusiMarch Festival. The three composers who participated – Sean Ferguson, D. Andrew Stewart and Heather Hindman – composed a total of eight pieces, which received eighteen performances in all during the duration of the project, including performances in Canada, France and Brazil.

3. BACKGROUND – THE DMI SEMINARS

In March 2002, the two authors (a composer and a researcher in music technology, respectively) and percussionist D'Arcy Philip Gray first discussed the need for an interdisciplinary seminar that could be taken by students in music technology, composition and performance. The initial impetus came from Wanderley, then recently hired at McGill, who brought the DMI research to McGill's Faculty of Music from his earlier work at IRCAM [Wanderley and Battier, 2000]. The idea was to move from the design of gestural controller prototypes into fully-fledged DMIs, i.e. instruments that could be used in performances anywhere, anytime, not only in controlled research laboratory settings. The seminar "Digital Musical Instruments: Technology, Performance and Composition" was first given in January, 2003. During the course of the seminar, students formed into groups consisting of at least one representative from each of the three areas. In conjunction with lectures given by the professors, students worked on the joint creation of new gestural controllers for digital synthesis engines. This included the design and construction of the new devices (including both hardware and in many cases software for digital synthesis), the development of playing techniques for the instrument and the composition and performance of new works in an end of term class recital.

The seminar was repeated on two other occasions, in the Winter 2004 and in the Winter 2006. Such seminars were designed to allow students to actively collaborate during an academic term (13 weeks) on the design, performance and composition of pieces for novel digital musical instruments (DMIs). Despite the fact that, in the three opportunities when this seminar was offered excellent work came out of it (for instance, the *T-Stick* [Malloch and Wanderley, 2006]), we felt that such a limited duration for this exercise did not allow for a complete, high-level design—composition— performance cycle. In fact, in many opportunities, there was not enough time to fully develop novel DMIs. When development time was enough, many times performance time was minimal, i.e. performers were only able to begin working with the final version of the instrument shortly before the concert.

Figure 1. Students in the DMI seminar (technologist Eileen TenCate, composer Heather Hindman and performer Jonathan Davis) discussing the Tralf, by composer Geof Holbrook.

The main achievement of these seminars was perhaps the forming of a working method for interdisciplinary, collaborative development of new digital musical instruments. One of the main goals of the digital orchestra project was to apply this methodology on a larger scale by spreading the activities over a more appropriate, longer time span.

Figure 2. Percussionist Kristi Ibrahim with a notated score for glove controller by Joseph Malloch.

4. CRITERIA FOR EVALUATION OF DIGITAL MUSICAL INSTRUMENTS

Over the years, a number of criteria have emerged to evaluate digital musical instruments from multiple viewpoints.

4.1. Reproducibility

Musical instruments that allow a performer to be expressive must permit an artist to imagine a musical idea and be able to reproduce it consistently. If a gesture has an indeterminate musical result, one cannot say that the performer is in expressive control of the instrument. Traditional musical instruments may be ranked according to their ability to provide the performer with precise control. For example, according to this definition wind chimes could be said to have less expressive potential than the cello, since the performer has less continuous control over the musical result. In digital musical instruments, the equivalent of a wind chime might be the use of a single gesture to trigger a dense sequence of random events. We avoid designs whose purpose is solely to initiate sequences, whether random or pre-composed. Our goal is to provide the performer with consistent, reliable and continuous control throughout the sonic life of a musical idea.

One of the ways in which we attempt to ensure reproducibility is to maintain a consistent mapping between a gesture and its sonic result. Originally, our goal was to maintain a single mapping for each instrument. As we progressed, we changed this approach to one that requires a consistent approach within a particular mapping, with the possibility of different mappings on the same instrument used, for example, in different movements or sections of a piece.

Our emphasis on reproducibility is intended to contribute to the potential for the adoption of an instrument by other performers. We feel it is important to ensure that a given instrument can allow the same piece to be played by the same performer on different days, or by different performers in different locations.

4.2. Reliability

In the presentation of a new instrument in a scientific context, such as a talk during a conference, it is not unusual for unexpected problems to arise. This experience is sometimes referred to as the "demo effect." In the context of a conference, most members of the audience will be sympathetic, and the instrument can be demonstrated in other ways, such as a video recording. In the context of a live performance, however, any failure of an instrument to function exactly as expected, no matter how slight, can be catastrophic. Even minute changes can have a devastating effect on the artistic result, whether they are explicitly noticed by the audience or not. If they are aware of any problems, the listeners in a concert setting cannot be relied upon to have similar scientific experience to that of the designers of the instrument, and they may therefore not exhibit the same degree of sympathy to the plight of the performer. If the demo effect can cause embarrassment to a researcher, the failure of an instrument to function properly during concert can cause stress and humiliation for the performer, and existential crisis for the composer.

All instruments – even traditional orchestral ones – have a risk of failure, such as broken strings, dropped mallets and stuck keys. Nevertheless, we attempted to minimize this risk in a number of ways, including: (1) freezing the addition of new features to an instrument well in advance of the concert; (2) giving performers extensive access to the instruments for explorations and rehearsal; and (3) having the composers write small etudes that acted as proving grounds for their musical ideas, means for performers to learn the instruments, and technological test beds.

4.3. Expressive Potential

Many definitions exist for musical expression.[1] An informal explanation from a performance point of view is that an instrument should permit unconscious control of the musical result. Consider the scenario of an instrumental lesson in which a teacher attempts to influence a student's performance not by providing explicit instructions about which gestures to use, but by using an evocative metaphor or image (such as imagining that one is in a flower-filled meadow on a sunny afternoon). An instrument with expressive potential will react to the minute adjustments that this mental image causes in the performance gestures of the student to alter the musical result in the desired fashion.

This expressive relationship between a performer and his or her instrument is a result of both the design of an instrument and of a highly developed performance practice. On any instrument, musical expression is a result of the development of advanced playing technique over a long period of study. One result of this criterion is that the creation of an instrument that could be easily mastered by a performer within a short period of time was not an objective of the Digital Orchestra.

5. INTERDISCIPLINARY PERSPECTIVES

In this section we discuss the contributions of each of the disciplines to the overall goals of the project.

5.1. Music Technology

The design of novel DMIs has been the focus of much attention in recent years, most notably through the NIME Conferences (New Interfaces for Musical Expression). NIME started as a workshop during the ACM CHI 2001

[1] See, for example, the discussion of "expressivity" in [Malloch et al, 2006]

Conference in Seattle, becaming a fully fledged conference in 2002 with NIME02, held in Dublin. Although before NIME a (very!) large body of work had already been developed in this field (see Wanderley and Battier, 2002 for a comprehensive review), NIME definitively helped in focusing the field as a research community.

DMI design was at the core of the Digital Orchestra Project, and music technologists at McGill performed several tasks in this direction: the study and development of novel pressure and position sensors based on paper [Koehly et al 2006], the use of a variety of sensors available for commercial applications [Wanderley et al. 2005 – SensorWiki] and the evaluation of the choice of sensors that best fit a musical application [Marshall and Wanderley, 2006]. The design of novel devices was also carried out by technologists, but with the indispensable help of composers and performers, e.g. the T-Stick, [Malloch and Wanderley 2006], the Gyrotyre [Sinyor and Wanderley, 2005] and the Rulers [Malloch et al. 2006]. Another use of sensors and technology in the project was the development of tools for gestural control of sound spatialization [Marshall, Malloch and Wanderley, 2007], using both existing gesture capture devices as well as novel designs.

But apart form the extensive evaluation and testing of a variety of sensors and their use in the design of novel DMIs, the music technologists also developed tools for mapping the sensor outputs to sound synthesis control inputs. This was an interesting, initially unexpected, outcome of the project. In fact, in practice, the development of mapping strategies by an interdisciplinary group of people is not an obvious task for the following reasons: a) people do not all have the same technical knowledge to approach mapping strategies (i.e. good programming experience with Max/MSP in that case), and b) in a group, the opportunity to easily create and destroy mappings on the fly simultaneously by different people playing versions of the same controller is essential (contrary to the case of a single instrument designer). The solution to this issue is called *the Mapper* [Malloch, Sinclair and Wanderley, 2008].

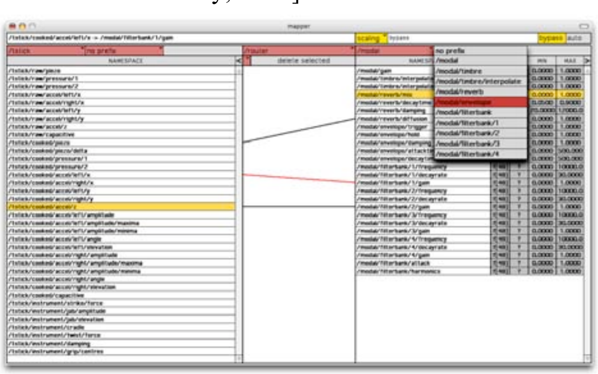

Figure 3. The initial graphical interface for the Mapper.

Another software tool that proved essential in the project was the *Digital Orchestra Toolbox*, a large collection of Max/MSP objects that help the design of novel DMIs by providing tools for data conditioning and processing.

5.2. Composition

An important requirement for the longevity of an instrument is the existence of a compelling repertoire of works that serves to motivate future performances. One of the principal goals of including composers in the development process and including performances in a professional context was thus to attempt to create viable works of art with value beyond simply demonstrating the capabilities of the instruments.

In order to create a corpus of music, it became apparent that the development of an appropriate system of notation was crucial. In our experience, three different approaches are used: (1) a graphic representation of the type of gesture desired; (2) a metaphorical representation of the resulting sound; or, (3) a symbolic system with no obvious links to either gesture or sonic result. In practice, the type of notation that we have used includes a combination of traditional musical notation with the addition of new graphical elements representing any or all of the above three approaches: see Figures 4 and 5. In addition, composer D. Andrew Stewart developed a dynamic graphical interface that is displayed on a computer screen and used by the performer during the performance of a piece: see Figure 6.

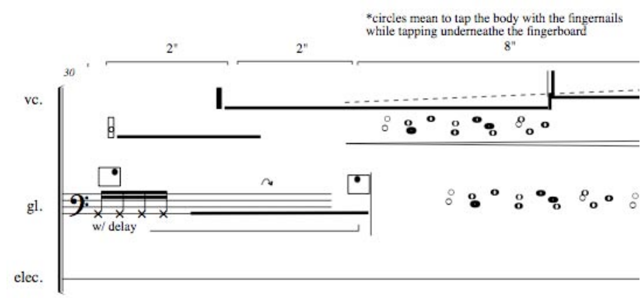

Figure 4. An excerpt of the score for *The Long and the Short of It*, for cello and two digital musical instruments, by Heather Hindman.

One unexpected development that took place during the Digital Orchestra Project, was the role taken by composers in the mapping of gestures to the parameters of the digital synthesis algorithms that served as the voices of the instruments. In our original conception, mapping was placed within the domain of the technologists. In practice, however, the technologists created powerful tools for mapping (e.g. The Mapper), but the responsibility for the actual implementation came to rest on the composers. We thus came to see mapping ultimately as being primarily an artistic, rather than technological, activity.

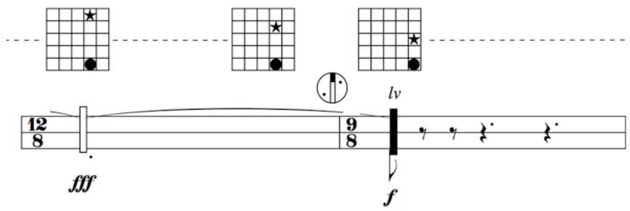

Figure 5. Notation of the t-stick part for *Catching Air and the Superman*.

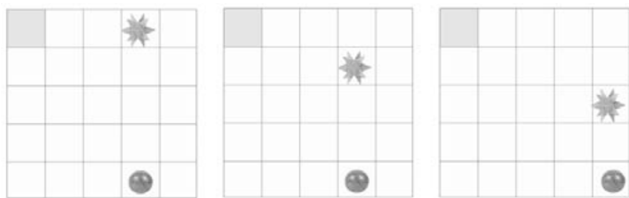

Figure 6. Examples of the dynamic graphical user interface for t-stick notation developed by D. Andrew Stewart for his work *Catching Air and the Superman*.

5.3. Performance

In order to evaluate DMIs for their expressive potential, it was crucial to have input from advanced artists who had already experienced a degree of artistic symbiosis with their own instruments, whether it be cello, piano, percussion or any other instrument. The performers involved in the Digital Orchestra provided constant feedback to the instrument designers and composers throughout the entire three-year period. Since the instruments were not designed to be based on existing acoustic instruments, many different types of performers were involved (e.g. piano, percussion, cello, etc.). Furthermore, performers were not necessarily required to have had previous experience with gestural controllers.

Their contributions took a number of different forms. They evaluated the physical aspects of the instruments, such as size and weight. At one point, for example, concern over possible injury to performers due to the heavy weight of one instrument caused it to be rejected for future use in the Digital Orchestra. They also evaluated the "feel" of the materials of the instruments and helped in the fine-tuning of the tactile feedback that the instruments provided. The performers were particularly vociferous in their demands for low and consistent latency between gestures and their sonic results.

The composers also benefitted from the performers' expertise. The instrumentalists worked closely on the development of the notation for the instruments and of idiomatic playing techniques. Another important area of collaboration was the appropriateness of physical gestures to musical material.

Figure 7. D. Andrew Stewart demonstrating two different playing techniques on the T-stick: tapping (left) and jabbing.

Since our goal was to design instruments that had the potential to be performed by many different artists, we felt it would be valuable to observe the process of the adoption of a new instrument by a performer who had not participated in its development. At the end of the second year of the project, cellist Erika Donald joined the Digital Orchestra to perform the soprano t-stick in Heather Hindman's piece *The Long and the Short of It.* Ms. Donald was asked to document her experience in learning this new instrument. Her contributions were particularly valuable, since they gave the point of view of a performer approaching a new DMI for the first time. She was given approximately a year to develop expertise on the instrument before performing in concert.

6. CONCLUSION

The McGill Digital Orchestra presents a number of paradigms for the design, creation and performance of digital musical instruments in the context of a long-term interdisciplinary, collaborative environment. Issues related to mapping strategies, notation, the relationship of physical and musical gestures, robustness, responsiveness, and haptic feedback arose during the course of the project. As well, we devised new methods for communication of performance instruments to the players of the instruments. Furthermore, the Mapper software continues to be used in other contexts.

Based on our experience, we propose that one effective measure for the evaluation of a digital musical instrument is its ability to reproduce a performance of a particular piece, either by the same performer or by different performers. This involves the ability to realize a piece based on a notated score, whether on paper or using software-based visual feedback in a graphical environment. We suggest that this may aid in ensuring the viability and longevity of a novel digital musical instrument.

The results of this long-term, multidisciplinary approach to digital musical instrument design include interfaces that have been proven in high-profile professional performance contexts and that are still being used actively by several performers world-wide.

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