Improvisatory Music and Painting Interface

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November 2001

Submitted to the Program in Media Arts and Sciences,
School of Architecture and Planning,
in partial fulfillment of the requirements for the degree of
Master of Science in Media Arts and Science at the
Massachusetts Institute of Technology
September 2004

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Abstract

Shaping collective free improvisations in order to obtain solid and succinct works with surprising and synchronized events is not an easy task. This thesis is a proposal towards that goal. It presents the theoretical, philosophical and technical framework of the Improvisatory Music and Painting Interface (IMPI) system: a new computer program for the creation of audiovisual improvisations performed in real time by ensembles of acoustic musicians. The coordination of these improvisations is obtained using a graphical language. This language is employed by one "conductor" in order to generate musical scores and abstract visual animations in real time. Doodling on a digital tablet following the syntax of the language allows both the creation of musical material with different levels of improvisatory participation from the ensemble and also the manipulation of the projected graphics in coordination with the music. The generated musical information is displayed in several formats on multiple computer screens that members of the ensemble play from. The digital graphics are also projected on a screen to be seen by an audience. This system is intended for a non-tonal, non-rhythmic, and texture-oriented musical style, which means that strong emphasis is put on the control of timbral qualities and continuum transitions. One of the main goals of the system is the translation of planned compositional elements (such as precise structure and synchronization between instruments) into the improvisatory domain. The graphics that IMPI generates are organic, fluid, vivid, dynamic, and unified with the music. The concept of controlled improvisation as well as the paradigm of the relationships between acoustic and visual material are both analyzed from an aesthetic point of view. The theoretical section is accompanied by descriptions of historic and contemporary works that have influenced IMPI.

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This work was supported by the TELMEX fellow program

Improvisatory Music and Painting Interface

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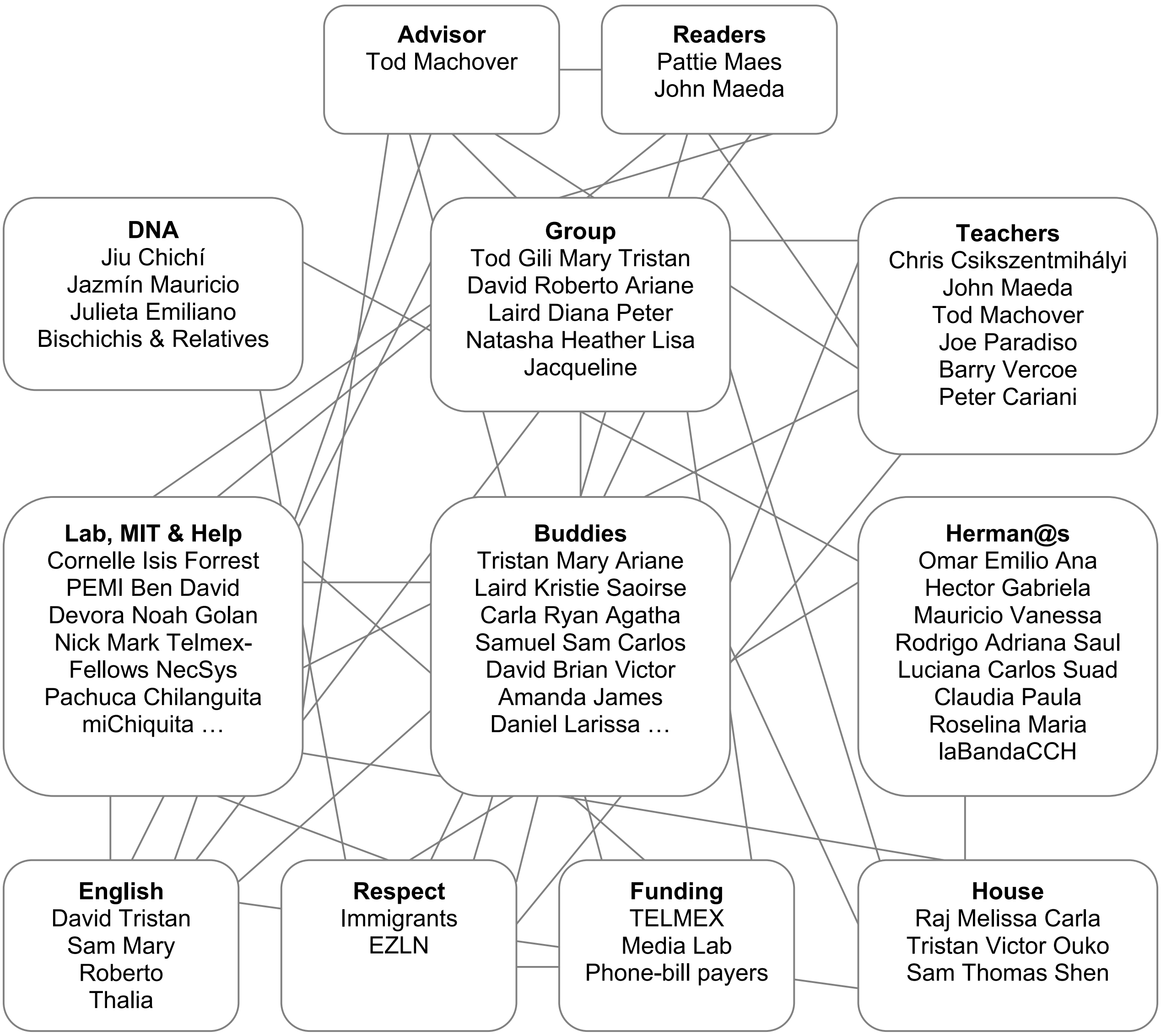
Improvisatory Music and Painting Interface

Acknowledgements

Special thanks to:



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Chapter 1

Introduction

"Uno por mulo…"

This chapter explains the motivations that led me to the development of the Improvisatory Music and Painting Interface (IMPI). It describes and evaluates the system and gives an overview of the challenges during its development. It also gives a general description of what is contained in each chapter of the thesis.

1.1 Motivation

The idea of creating an audiovisual system that could relate music improvisation using acoustic instruments and dynamic digital graphics is an old desire of mine. I was trained as a pianist performer and the experience of working with acoustic instruments has been important in creating my musical vision. I was also interested in the field of music composition and a part of my studies was focused in that direction. One of the most interesting activities that was developed as part of the music composition program at the Laboratory of Music Creation at the National School of Music in Mexico was the realization of imaginary sessions. During these two- hour sessions, students would close their eyes and try to verbally describe their creative fantasies. In most of the cases, the initial descriptions were vague and diffuse. Trying to influence as little as possible, the teacher tried to help the student to clarify and detail their ideas by asking questions about the events that the student was describing. During the session, the ideas became gradually more clear and precise. At the end of the experience, a short but accurate fantasy could be recovered and recreated by the students.

The combination of both areas, performance and composition, led me to the field of improvisation. For many years, I focused my attention mainly on the production of acoustic improvisation. Later, I was attracted to the use of electronics with the idea that new sounds and new technologies could expand my experience as an improviser. Therefore, I started to improvise with electronic devices, mainly commercial synthesizers and computer software.

At the same time, I started to have a deep interest in visual expression, more as a spectator than a creator. Nevertheless, the interest in the expressive possibilities of mixing music and painting led me to create the NICROM Trio in 2001 (see *Appendix*). This ensemble was composed of a painter, a wind player, and an electronic-device player (myself). The audiovisual material was completely improvised on stage by mixing the electro-acoustic sounds and the visual material. The paintings were created in real time and showed on the stage with the help of a projector. The relationships between the sound and the image were completely subjective and the interaction between the performers was non-deterministic. However, the audiovisual result was, in most of the cases, organic and unified.

When I entered the MIT Media Laboratory, I realized that a huge amount of works had been done in the field of audiovisual performance. I could study some of these works, interact with people concerned about the field, and become familiar with the technologies associated with this kind of expression. I also realized that the creative process could be extended beyond the use of available technology and reach the point where the creation of the tools becomes part of artistic development.

Within this context, it was natural to plan and develop a system where my interests -music performance, collective improvisation, and audiovisual creation- could be merged. The Improvisatory Music and Painting Interface (IMPI) was created during the second half of 2003, and the first six months of 2004.

1.2 Brief Description and Contributions

The Improvisatory Music and Painting Interface (IMPI) is a piece of software for the creation and guidance of audiovisual improvisations. By drawing into a digital tablet using a defined syntax, a conductor generates in real time both the music displayed in several formats on computer screens for the musicians, and dynamic graphics projected on the stage in synchronicity with the music. The kind of musical style this system is intended for is non-tonal, non-rhythmic, and texture-oriented, which means that strong emphasis is put on the control of timbral qualities and continuum transitions. One of the main goals of the system is the translation of planned compositional elements such as precise structure and synchronization between instruments into the improvisatory domain. The graphics that IMPI generates are organic, fluid, vivid, dynamic, and unified with the music.

Most of the audiovisual systems currently developed and most of the research in the field are focused on the exploration and creation of audiovisual systems with electronic sounds as audio output. This work, on the other hand, proposes the creation of an audiovisual system where the music is generated by acoustic instruments in real time.

Shaping collective free improvisations in order to obtain solid and succinct works with surprising and synchronized events is not an easy task. This thesis suggests an audiovisual system for obtaining these results.

There is not a unique and objective method for mapping acoustic and visual elements and several works has been created in the field of the audiovisual performance. With its own paradigm and techniques, IMPI is a contribution to the field.

IMPI is a project under development. Currently, three versions have been created, each one solving different technical and aesthetical challenges. What has been developed so far is an important step in the creation of a final version that integrates all the features and could generate the result that the system is intended for.

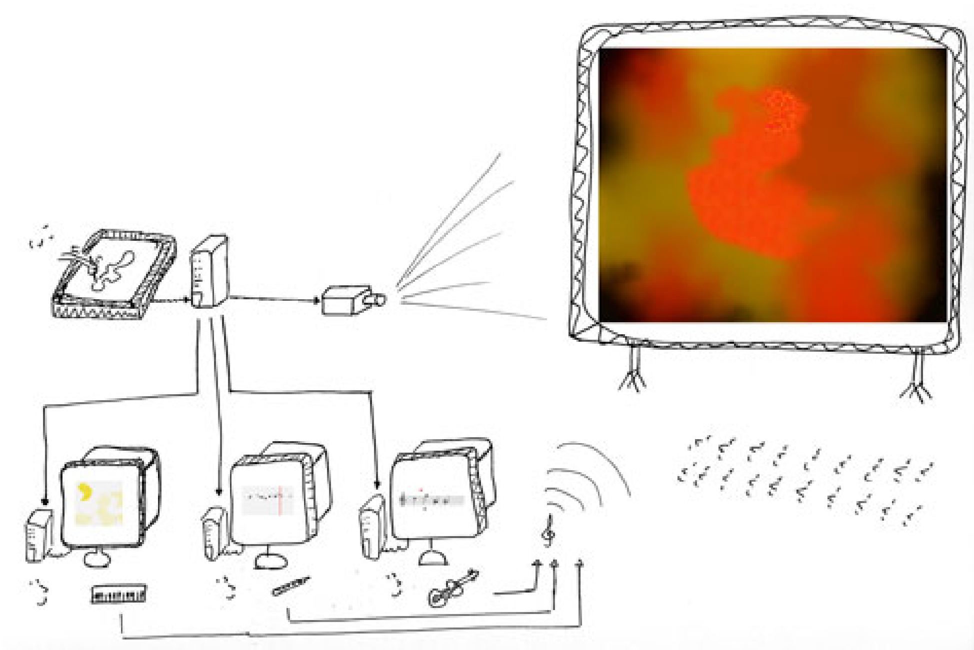

Figure 1-1 ***Improvisatory Music and Painting Interface***

1.3 Overview of the Thesis

The rest of the thesis is divided into five chapters. Each one covers a particular field related to IMPI. In Chapter 2, *Background: Musical Improvisation, Notation and Computer Music Systems* different aspects of the collective improvisation technique and the use of digital technologies in the creation of music improvisations are covered. In the first section, a definition about what is improvisation, an explanation about improvisation and structure, and comments about the technique from my experience as a performer are given. Later, characteristics of improvisatory ensembles such as roles of the players, methods of communication, and direction of the information are analyzed. A brief description about improvisation and music style is explained in order to understand that improvisation has a contextual meaning. In addition, aspects about the paradigm of notation in improvisatory music are covered. In order to contextualize IMPI, an analysis in the use of computers in music improvisation as well as a description of representative works and technologies are presented.

In Chapter 3, *Audiovisual Expression, Theoretical Background,* different aspects of audiovisual creation are covered. Particular emphasis is put on the aesthetical problems of merging music and image. In the opening section, fundamental elements that constitute the music and the visual expressions are described. A section is devoted to analyze the importance of imagination, form, and gesture in the audiovisual expression. Another section of the chapter is dedicated to analyzing important topics in the field such as representation of information, translation between domains, mapping and synchronizing issues. Finally, a series of works historically, aesthetically, or technologically related to IMPI is described.

The Improvisatory Music and Painting Interface is covered in detail in Chapter 4. First, a detailed description of what it is and how the system works is presented. The aesthetics behind the system are also exposed emphasizing not what was obtained but what is conceived as the ideal and finished system. Later, the role of imagination and the media employed are described. In another section, the technology used is presented, dividing the software and the hardware parts. A brief description of the technologies, libraries, and devices that IMPI uses is also presented. The rest of the chapter is devoted to showing in detail the evolution and development that took place during the creation of the three versions of IMPI. Each version is explained and analyzed, focusing on the features that were implemented and the features that had not yet been added. The technical challenges of each version as well as the elements that did not work as expected are also mentioned.

In Chapter 5, *Evaluation, Future Work, and Conclusions,* a general assessment of IMPI is given, emphasizing the knowledge that I obtained in both the technical and the aesthetic fields. Some of the potential paths that IMPI can take in both the near and far future are covered. In the last part, a general conclusion is presented about the experience of having created IMPI, and a personal evaluation about the audiovisual field is given.

At the end of the work, an appendix presents projects that I performed or developed and that strongly influence IMPI. *Siderales* is a piece for synthesizer and colored lights specifically composed for me by Mauricio Rodríguez. It was performed several times by me and was a practical experience in which I had to literally play both the music and the lights of the hall. NICROM was a trio for the improvisation of audiovisual material. A wind player, a painter on stage, and myself on digital instruments gave concerts where the audiovisual result was the product of human interaction between the performers. *GAB* is a system for the automatic reinterpretation of music during improvisatory piano performances. This system is composed of a MIDI controller with knobs and Java software, both designed by me. The program analyzes the material that the player improvises and generates new material according to the values of the controller. It was my first serious exploration in the field of improvisatory computer music. *Gestures* is a piece for acoustic ensemble and six electronic devices called “Shapers”. It is the result of a close collaboration between Natasha Sinha and myself. The compositional techniques involved drawing, producing graphics, and improvising. radioBANDA is a net project where the audience accesses a web page and plays with the graphics in order to modify the sound produced on a radio station. Multiple performers can improvise at the same time. *Siderales*, NICROM, and *GAB* were all realized before coming to MIT. *Gestures* and radioBANDA were developed as part of my master’s research at the MIT Media Laboratory.

Chapter 2

Background: Musical Improvisation, Notation, and Computer Music Systems

"Dos patada y coz…"

This chapter analyzes notions about collective musical improvisation, computer assisted composition, and musical notation. Theoretical background, historical references, and aesthetic thoughts are presented in each case. Special emphasis is put on their relationship with the audiovisual expression.

2.1 Musical Improvisation

2.1.1 Musical Improvisation, Background

Musical improvisation is one of the most antique artistic expressions of the human being. Before notation was created humans had the necessity to express themselves in the acoustic domain, and improvisation was one of the techniques employed. In fact, "there is scarcely a single field in music that has remained unaffected by improvisation, scarcely a single musical technique or form of composition that did not originate in improvisatory practice or was not essentially influenced by it. The hole history of the development of music is accompanied by manifestation for the drive to improvise" [Bai80].

Brunno Nettl defines improvisation as “The creation of a musical work, or the final form of a musical work, as it is being performed. It may involve the work's immediate composition by its performers, or the elaboration or adjustment of an existing framework, or anything in between. To some extent, every performance involves elements of improvisation, although its degree varies according to period and place, and to some extent, every improvisation rests on a series of conventions or implicit rules. The term ‘extemporization’ is used more or less interchangeably with ‘improvisation’. By its very nature – in that improvisation is essentially evanescent – it is one of the subjects least amenable to historical research” [Net04].

Improvising is learned with different methods according to the culture and musical style. It could be learned empirically by hearing, copying, and repeating material; or could be thought through in a carefully planned and systematized procedure. “Iranian musicians are told that memorization of the *radif*, a repertory of 250–300 short pieces, will automatically teach them the techniques of improvisation. Jazz musicians have a variety of learning techniques, including the notation and memorizing of outstanding solos” [Net04].

All kinds of improvisations are framed by the specific musical and cultural context that surrounds them, no matter if we talk about the improvisation of ornaments in the sixteenth century or the current experimental improvisations using laptops. There are also societies that do not have the notion of improvisation as it is defined in Western music because these societies do not separate composition from improvisation.

Improvisation has a connotation of spontaneity and liberty. Contrary to written music, improvisation offers performers the option of making their own decisions. The level of liberty is framed by the context and by how the improvisatory technique is used. Improvisatory techniques can be employed in different steps of the creative process and can influence the production of music in several ways. It could be, for example, the technique used to compose a score, or it could be the method used during a performance.

Even though it could be thought that improvisation is a field with no constraints, in reality in order to be able to improvise, one must master the language and techniques of the music being produced. In certain ways, improvisation is nothing but composition in real time. In some styles, the boundary between composition and improvisation is blurry especially because both fields take elements form each other. This situation creates one of the main paradoxes of the improvisatory language. For some creators, improvisation should emphasize its compositional quality, for others it should accent its own nature of real-time exploration. Nevertheless, it is accepted that collective free improvisation has its own musical form.

In Western music, the notion of *musical form* has been an important concern throughout history. Each historic period and musical style has created and expanded musical forms, and free improvisation has its own. The musical form in improvisatory materials is, in most cases, more diffuse and less structured than the form of compositional works. In addition, it takes longer to develop transitions and variations of the material. Usually, elements and ideas are much more spread out in time. The main reason for this is the difficulty of comprehending the material without a score, and the difficulty of synchronizing events in the case of collective improvisations.

Even if the free collective improvisatory style should not necessarily use the syntax of composed music, there are aspects of the latter that could acoustically enrich the expression in the improvisatory domain. Common elements in notated music such as synchronic events and sudden changes by the entire ensemble are hard to obtain with big ensembles. Several techniques have been created in order to import these elements into the improvisatory domain. The simpler one is to create hierarchic ensembles where one members guide the rest. Others, more complex, involves the creation of body language symbols, improvisatory scores, or implementations of computer systems.

The use of improvisatory techniques easily produces materials of extremely long duration. Besides the fact that improvisation is an exploration, and can be extended for as long as wanted, one of the reasons for the disproportion among duration and content is the difference in the perception of time between performers and listeners. In many cases, musicians have an accelerated perception of time. Some events that musicians produce as short are perceived longer for the audience. The phenomenon is not unique for improvisatory expressions, but it is more notorious due to the possibility of repeating and creating material in real time.

2.1.2 Collective Improvisation and Various Ensembles

Collective improvisation is an experience with particular characteristics. The activity of improvising with other musicians requires the same attention as the performance of written music. Attention must be given not only to the material that each member of the ensemble is producing but also to the final result.

According to the way the members of an ensemble interact, several kinds of ensembles can be designed. Each kind of organization offers advantages and disadvantages over the other configurations, and each one has characteristics that help to emphasize different elements. Some configurations offer more freedom and possibilities for interaction between the members, while others are better at creating well-organized materials. The basic models are:

- Centralized ensembles with one leader and unidirectional transmission of information between the leader and the rest of the ensemble (fig. 2-1 A).
- Centralized ensembles with one leader and bidirectional transmission of information between the leader and the rest of the ensemble (fig. 2-1 B).
- Hierarchic ensembles with group leaders and unidirectional transmission of information between the leaders and the rest of the sub-ensembles (fig. 2-1 C).
- Hierarchic ensembles with group leaders and bidirectional transmission of information between the leaders and the rest of the sub-ensembles (fig. 2-1 D).
- Centralized ensembles with one leader and communication between the leader and the rest of the ensemble, as well as communication between the members (fig. 2-1 E).
- Non-centralized ensembles with no communication among members (fig. 2-1 F).
- Non-centralized ensembles with communication among the members (fig. 2-1 G).

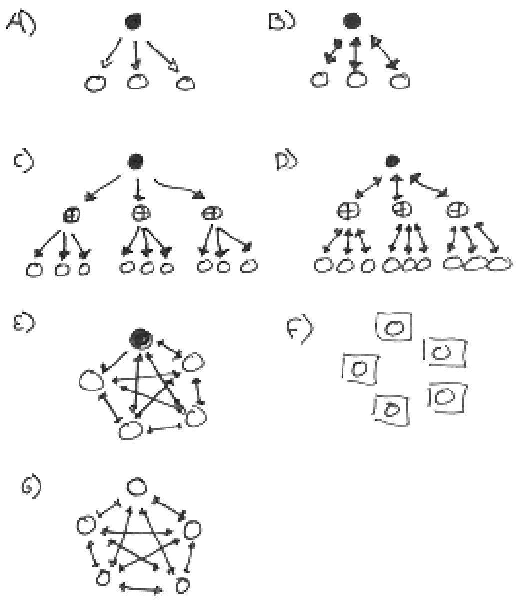

Figure 2-1 Different types of improvisatory ensembles

2.1.3 Notation and Improvisation

The creation of scores that allow certain ranges of variation have been present during the entire history of music notation. The *basso continuo* (fig. 2-2) [WL04] is, for example, one technique where the musicians improvise and complete certain aspects of a score that only presents the harmonic skeleton of the piece.

Figure 2-2 Kollman: A Second Practical Guide Thorough-bass (1807)

Currently, some styles of jazz have adopted the use of scores that must be completed by the performer. In this style, it is common that the score or *Standard* show only the basic melody and the harmonic structure. From these elements, the player can build the entire material. In this case, notation helps to preserve both the organization of the ensemble and the structure of the piece. The level of complexity in improvisatory symbols has increased over time. Several contemporary improvisatory scores help to create pieces of complex structure in real time.

2.1.4 Improvisation and Style

In modern Western music, improvisatory techniques for performance have had different levels of acceptance by the musicians depending on the musical style and kind of ensemble. Some improvisatory techniques are commonly used in popular styles such as blues, rock, and jazz. There are also ensembles and styles that are entirely based on improvising such as the performers of electronic improvisations. On the other hand, it is rare to see traditional ensembles such as orchestras, string quartets and brass quintets performing improvisatory concerts. From the entire range of improvisatory groups, I would like to describe two that have direct influence in IMPI.

- *Orchestral Improvisation with Conductor Leader*. In this kind of improvisatory ensemble the conductor stands in front of the entire orchestra and using traditional techniques for conducting, he or she leads the sonority of the orchestra. Around fifty to seventy musicians are usually involved in this kind of ensemble. Nevertheless, the conductor could control the loudness, the activity of events, and the sections that should or should not play, among other parameters. The level of previous agreement about the meaning of conductor's gestures varies.

- *Experimental and Free Improvisatory Ensembles*. These kinds of ensembles have their roots in the merging of jazz and the avant-garde music of the twentieth century. They are usually small, involving merely three to ten musicians. These groups performed entire concerts without any kind of musical constrains. Non-traditional instruments or custom sound devices are usually employed. When technology became popularized, these ensembles started to included computers and electronic devices in order to generate the sound.

2.1.5 Computer Assisted Improvisation

The development of algorithms for leading improvisations is older than digital technology. However, computers are ideal devices for setting up systems in which the algorithms could be much more elaborate. Complexity in those algorithms does not necessarily mean that the aesthetic result is more interesting, but experimentation with intricate relationships is much easier, and the expressive possibilities can be extended. Graphical interfaces and hardware devices for the gestural input of information are also elements that have helped in the development of the field. For our analytical purpose, we could divide computer systems into two different branches: one that tries to emphasize the principle of spontaneity and liberty of improvisation, and one that tries to highlight the organization of the material.

2.1.6 Representative Works and Technologies

- *Historical References in Western Music*. Some referential points in the history of music improvisation are the numerous techniques that involve creation in real time, such as ornamentation, basso continuo, and cadenzas.

- *Improvisation and Composers of the 20th Century Music*. 20th century was the boom period for non-standard techniques, nomenclatures, and improvisatory techniques. An incredible number of composers have done explorations in the field, among others: John Cage, Karlheinz

Stockhausen, Luigi Nono (fig. 2-3) [Non88], La Monte Young, Terry Riley, Vinko Globokar, John Zorn, and George Lewis.

Figure 2-3 ***La lontanaza nostalgica utopica futura*** **by Luigi Nono**

- *Gestural Improvisation*. The works that Walter Thomson realizes with his orchestra deserve special attention because of the originality of his work. "*Soundpainting* was initially developed as a method of conducting and shaping improvisation during a performance" [Tho04]. Over many years, Thomson developed a vocabulary of hundreds of gestures. "Each player reads the conductor's hands for the style of the next sound, movement or utterance" and each movement has a different musical meaning. Some of them are simple, as, for example, "play loud" and some have a more detailed meaning, such as "long, loud, and high tone" (fig. 2-4). *Sparkler* [Mac01] by Tod Machover is another work where, sometimes during the piece, the conductor guides the improvisation of the entire orchestra. In parallel, a computer processes the music produced by the musicians.

Figure 2-4 Walter Thomson and the ***Soundpainting*** **orchestra**

- *Visual Computer Systems for Improvisatory or Collective Music Creation*. The possibilities for transmitting information over different locations, and the simplification of data manipulations using graphical representations has contributed to using computers as an excellent method for helping in collective composition and improvisation. Some computer systems that have been developed for are *FMOL* by Sergi Jordà (fig. 2-5) [Jor02]; *Auracle* by Max Neuhaus and others; *Webdrum* by Phil Burk.

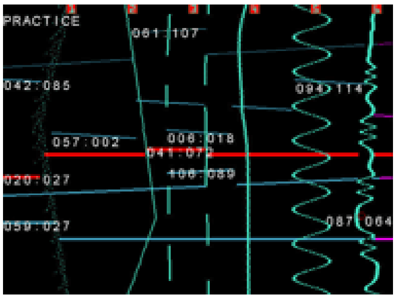

Figure 2-5 *Bamboo* screen, *FMOL* system by Sergi Jordà

2.2 Computer Assisted Composition

2.2.1 Computer Assisted Composition, Background

Computers are powerful instruments that can enrich some aspects of art. They have been used in many artistic contexts since they were created. In the field of computer-assisted composition, there has been a constant improvement of ideas and implementations.

Currently, the variety of approaches and techniques computers offer in the musical field is immense. Their possible uses can range from emulating techniques from the analog world, such as create a random collections of pitches, to the implementation of complex methods of artificial intelligence in order to, for example, automatically complete a musical phrase in the style of the input source.

Nowadays, the ability to create high quality digital audio, and the amount of techniques for synthesizing sounds, has made it so that most of the work in computer music is being focused on the production of digital audio. The situation is exciting because new sonorities are being created; however, the work with acoustic material should be also explored with the same intensity.

2.2.2 Representative Software and Technologies

In order to contextualize IMPI, some of the technologies that have been developed in the field of computer composition are described. Because the field is huge and numerous pieces of software have been developed, this section focuses only on transcendental works that have a direct relationship with the audiovisual domain or that have had historic impact on the field.

- *Historical References*. During the beginning of computer sciences there were some programs for the composition of music with graphical representations. Some of the important historic references are: The

GraphicI used by Max Mathews and L. Rosler and the *Unite Polyagogique Informatique de CEMAMu* designed by Iannis Xenakis [ccm04, Xen78]. The last one is particularly interesting since as an architect, mathematician, and composer, he proposed an extraordinary and original theory for approaching and visualizing musical material (fig. 2-6).

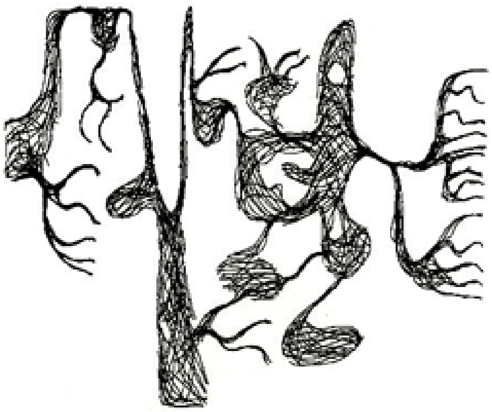

Figure 2-6 Upic-page from *Mycenes Alpha* (1978) by Xenakis

• *Visual Programming Environments*. There is a variety of music software for the analysis and creation of music elements. Nowadays, the majority of them have graphical interfaces and each one has its own visual paradigm. *Pure Data* by Miller Puckette; *Wire* by Phil Burk; *AudioSculpt* by Niels Bogaard and others, are some of them. *Open Music* by Gérard Assayag and Carlos Agon is particularly interesting in our context because it allows working with notated scores (fig. 2-7) [[Irc04].

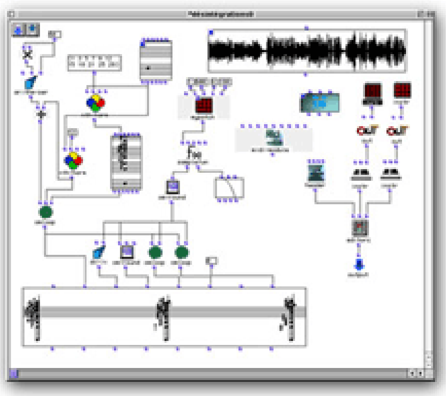

Figure 2-7 *Open Music* software

• *Graphical Interfaces for Generating Electronic Music*. There are also, a variety of programs that use graphical interfaces in order to create electronic music. In these systems, the graphic is not intended to be part of the final result but just a mechanism for representing the material that it wanted to be sonified. Two of these programs are *Metasynth* by Eric Wenger, and *Iannix* designed by La Kitchen (fig. 2-8) [Kit04].

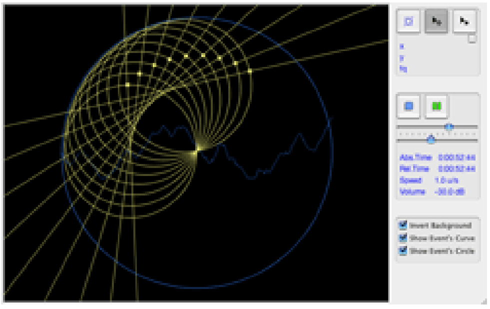

Figure 2-8 Example of a work with the *IanniX* system

- *Graphical Interfaces for Generating Acoustic Music*. Few programs are intended for creating music for acoustic ensembles. *Hyperscore* [Far01, Pas02] by Mary Farbood and Egon Pasztor is a piece of software that uses sketches of the user to generate music. The result can be exported as a MIDI file that can be easily edited in a score editor (fig. 2-9).

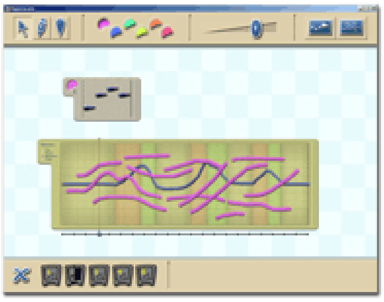

Figure 2-9 *Hyperscore* by Mary Farbood and Egon Pasztor

2.3 Musical Notation

2.3.1 Musical Notation, Background

Writing is one of the most important inventions in human history. It allows humans to preserve precise ideas for long periods of time without gradually altering the materials such as happens with oral transmission. In addition, writing permits going back and recovering, comparing, and modifying ideas generated at different times. In the musical field, the first attempts to notate music were around the fourth millennium BCE (fig. 2-10) [GH04]. From then to the present, there has been an extraordinary evolution of the written language that creates, by itself, an entire chapter in music history.

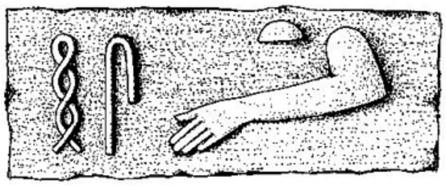

Figure 2-10 Symbols associated with music in ancient Egypt

With the evolution of musical ideas in Western music, musical creation became more complex and more idiomatic. Notation contributed to this evolution in at least two ways: First, the possibility of notating music helped to create and manipulate bigger and more complex materials. Second, the necessity of notating complex ideas generated better notations, and better notations made it possible to think of even more complex ideas. The feedback between the two different representations of the same idea has contributed enormously to the development of Western music.

Even if music notation has contributed greatly to the evolution of musical ideas, it is important to consider not only that many styles and music from different parts of the world are not written, but also that the actual notation system is far from a perfect method for writing music. A musical score is a graphical representation of the acoustic ideas of a composer. However, in order to keep the representation simple and easy, scores do not symbolize the musical events with extreme precision. There is an implicit acceptance of this “lossy” compression by the composer and the performers. In the past, the stylistic frame helps performers to reconstruct the acoustic idea, and currently recording helps performers to get the acoustic intentions of the work.

Because in most cases scores offer a margin for the interpretation of their content, there is a paradigm in Western musical tradition. For some performers, the score is just a guide that must be use as a medium for transmitting the performer’s ideas, while for others; the score must be followed with exhaustive precision with the intention of preserving the ideas of the composer with a minimum of alteration.

Another interesting situation is the displacement of music notation by new techniques for preserving acoustic material such as analog and digital recording. Since each day there is more music that cannot be notated with traditional techniques, since there is a deep interest in the exploration of new sounds, and since digital technology offers faster methods for creating, preserving, manipulating, and analyzing music, it seems that, at least conceptually, digital representation can be seen as the modern technique for notating music.

2.3.2 Notation and Computers

When computers were introduced in the musical world, the imitation of the possibilities of analog devices was the area that received the most development. In the field of music notation, most of the efforts have been focused on the representation of music as a traditional score instead of taking advantage of the new media and creating new representations.

However, several developers have taken the risk of pushing the digital media in order to create novel representations of music, and each day there are more people creating new representations that could present meaningful data in faster, cleaner, and more compressed ways. Some of these works are focused on creating representations that could change dynamically over time. Others are focused on showing information that is not presented in conventional scores.

2.3.3 Representative Software and Technologies

Representative technologies that have been developed for the notation of music are explained in this section.

- *Music Editors*. These pieces of software are tools for the creation of scores. They can be seen as word processors of music material. The user can insert and edit all the elements of a traditional score. Some of these pieces of software are confined to work with Standard Music Notation (SMN), while others allow the inclusion or creation of special symbols. Some of these programs are *SCORE* (fig. 2-11) [San03], *Igor Engraver* [Not04], *Turandot* [Spe04], *NoteEdit* [And04], *Finale* [Mak04], and *Sibelius* [Sib04].

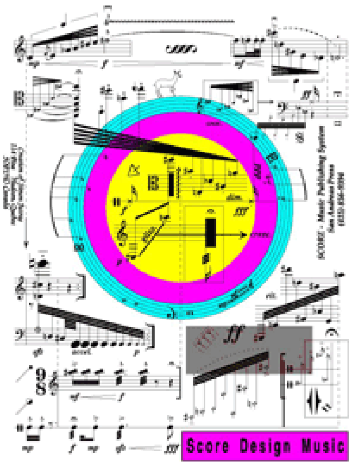

Figure 2-11 Music sheet created with *SCORE*

- *Music Screens*. These devices replace sheets of paper with digital screens. They are another approach to editing and preserving scores that is starting to be popularized. Even though, there are some advantages of such equipment, it will take some time to be accepted by musicians. *MusicPad* is one of these devices (fig. 2-12) [Fre03].

Figure 2-12 *MusicPad* by Freehands Inc.

- *Protocols and Standards*. The creation of a protocol for music notation in computers would help to the spread and transmission of music material. Some efforts have been done in the field. *MusicXML* [Rec04] is a “universal translator” between music notation programs. The *Unicode* standard [Uni04] has also some codes for musical symbols.

- *Score Packages for Computer Languages*. There are libraries and packages for many computer languages that create scores or graphical representations of music. These libraries can be used in the development of new software. In Java, for example, there are at least two packages for music score notation, *JScore* (fig. 2-13) [DB04] and *JMusic*.

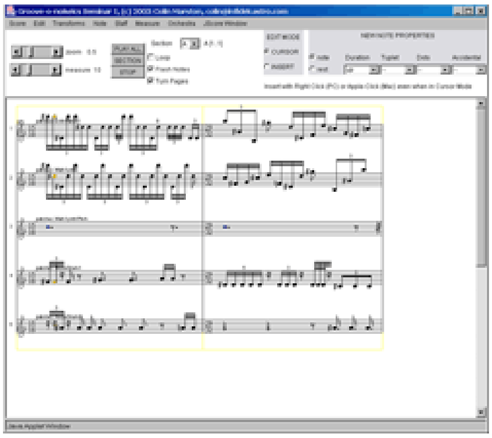

Figure 2-13 A score by Collin Marston using *JScore*

- *Programs for the Graphic Representation of Music Material*. There are many programs that represent music information in personalized graphics representations. These programs could be used for artistic purposes or for music analysis. Some of these programs show the material as an animation, and some as a static image. Each one has its own methodology and definition of the mappings between the music and the graphics. Some of them have mappings that are so interesting that the system could in fact be seen as an audiovisual system. Among some of the most interesting programs of graphic representation of music material we could mention: The works of Stephen Malinovsky [Mal04]; the *Acousmographe* developed at the Institut National de l’audiovisuel (fig. 2-14) [Ina03]; and *The Shape of Song* by Martin Wattenberg [Wat04].

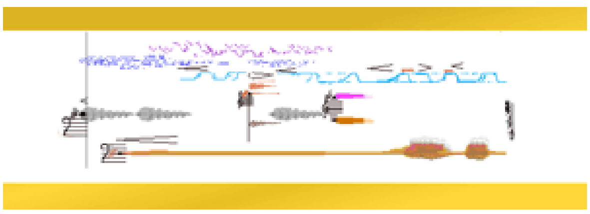

Figure 2-14 A *Portrait Polychrome* by Bernard Parmegiani (*Acousmaline*)

Chapter 3

Audiovisual Expression, Theoretical Background

"Tres hilitos rapiditos: uno, dos, tres…"

This chapter presents a theoretical background of the audiovisual expression. Basic elements of music and visual expression are described. The concepts of imagination, form, and gesture are covered. Different paradigms of the relationship between music and image are studied, and current and historic audiovisual works are analyzed.

3.1 Initial Observations

The intersection between image and sound is an area that has always been present in the mind of humans. Audiovisual stimuli are part of our daily lives and a huge amount of information is obtained from the unconscious analysis of the relationships between the visual and the acoustic elements of an audiovisual stimulus. Usually, both our visual and acoustic channels of perception run in synchrony. Any disassociation or unsolved relationship in the information of both channels creates tension and expectancy. Imagine, for example, witnessing a car crash in the street, and not receiving any corresponding acoustic stimuli; or hearing somebody whispering to your ear with nobody near you.

Throughout history a huge number of theories for analyzing musical and visual expressions have been developed. On the other hand, the number of techniques for analyzing audiovisual works is close to null and there is not yet a *grammar of audiovisual expression* that is comparable to the theories of harmony that exist in the musical domain. However, there has been a few important attempts as will be described in the *Historic References* section. It is interesting to follow the development of audiovisual thoughts throughout history, such as the concern of merging music and visuals using people in ballet; the introduction of cinema, which opened a new field for the relationship between music and graphics; the use of digital technologies that has popularized and widely spread out the audiovisual expression.

The audiovisual expression takes elements from the visual and the musical fields. The entire set of elements and behaviors of both domains are present in this merge. In addition, new kinds of components and relationships have been created. The new elements will be determined by several factors that will be described in the following sections.

3.2 Elements of Music, Basic Units and High-Level Structures

The smallest unit in the standard approach to music is the note. The elements of a note are intensity, duration, pitch, and timbre. These elements have a direct relationship to measurable acoustic components. The intensity is determined by the amplitude of the wave, the duration by the time of the sound, the pitch by the perceived fundamental frequency, and the timbre by the spectral content. Physical location and the acoustic conditions of the space where the note is produced are two elements that are external to the note, but influence the way the note is perceived. These parameters could remain unchanged during the production of the note, or they could continuously change over time, offering in both cases a huge amount of possibilities and combinations that together defined the characteristics of the acoustic stimuli.

Notes are combined over time, creating relationships between them. Notes that are created at the same time generate harmonic relationships and spread over time create rhythms. Harmony and rhythm are two of the most important elements in music. During history, there has been a constant exploration in both domains that has led to complex and intricate structures.

During the last century, alternative theories for explaining complex musical processes have been created. These theories search for methods that could coherently explain the relationships between all the musical elements among all levels of structure.

3.3 Elements of Visual Analysis, Basic Units and High-Level Structures

As in music, visual expression is created with minimal units and the relationship between such units. The analog to the note in the visual domain is the *shape*. Shapes have internal characteristics such as *form*, *color*, and *texture*. Shapes are affected by external factors such as *location* and *light*. In his book, *Visual Perception, a psychology of the creative eye* Rudolf Arnheim [Arn54] describes some elements that can be considered the high level structures of the visual domain. For Arnheim, shapes have *weight* and *direction*. These two elements generate the *balance* of the piece. The *space* is the three dimensional virtual space that is created by the relationships between shapes. Arnheim describes how the shapes share contours, how the figures and the ground interact, and how the levels of depth are created.

Arnheim also analyzes the concept of *movement* in two different contexts: first, as the physical displacement of objects in time, considering *speed* and *direction*; and also as an illusion in static works, produced by the "simulation of gravitatory effects" and the direction of the shapes. Finally, Arnheim analyzes *tension* as another perceptual element that is associated with the movement and the illusion of movement without motion.

Two other historic works that should be studied are the *Padagogisches Skizzenbuch* [Kle78] by Paul Klee, because of its fundamental ideas about the characteristics of the line, and *Punkt und linie zu fläche* by Wassily Kandinsky [Kan94], because of its details about composition and visual organization.

3.3.1 Paul Klee and Wassily Kandinsky

3.3.1.1 The Visual Analysis of Wassily Kandinsky

According to Kandinsky, the *point* is the basic visual element and it has static characteristics. The point can be conceived as an abstract concept without size, but also as an element with weight, color, limits, and even shape. It is possible to make an analogy between the point and the musical note. In fact, in *Punkt und linie zu fläche* there is an interesting analogy between the first notes of the fifth Beethoven's *symphony* and a collection of points of different sizes where the size corresponds to the duration of the note and the location to the pitch. Some other audiovisual relationships are also established; however, the level of precision is not particularly interesting because many of the concepts that are used are only empirical explanations of basic phenomena.

The painter establishes that the line is a secondary visual element extended from the point. This extension is the product of applying specific forces to the point. The characteristics of these forces determine the type of line. Thus, tension and direction are two characteristics of the line.

For example, if the line is horizontal, it appears simpler, rigid, static, with a blacker tendency. When vertical, it reaches the "clearest form of the infinite and warm possibility of movement," and has a whiter tendency. Finally, the diagonal ones keep characteristics of the two others, but are colder than the horizontal lines, and have a red, gray or green tendency. Other characteristics of basic lines are analyzed, for example the expressive quality of the angle formed by the intersection of two lines. In addition, the painter establishes that shapes have a natural relationship with color. The square would tend to feel red, the triangle yellow, and the circle blue.

The stroke of the line, and how its thickness changes, strongly defines the expressive qualities of the trace. The repetition of lines and their combinations, as well as the variations of their characteristics create rhythm and tensions. According to Kandinsky, the top of a canvas is more dynamic than the bottom, in the same way that the left is more active than the right.

Punkt und linie zu fläche was written in 1926. It is interesting to observe that many of the ideas that are described in the text are still valid, and intended to be systematic. Some of the concepts have a universal agreement because they are based upon fundamental principles of perception. On the other hand, many concepts were diffuse and lacked of a methodological approach. They did not reach the level of consistency that is required to create a solid theory of visual analysis. There are also concepts that would be much clearer and more precise if they were treated with a mathematical or physical approach.

3.3.1.2 The Visual Analysis of Paul Klee

In 1925, Paul Klee wrote *Padagogisches Skizzenbuch*. According to Klee, lines can be divided into three kinds: active lines, intermediate lines, and passive lines. He also explores *structures* based on repetitions, their variations, and the positions of certain objects in the plane, as well as structural materials present in nature, such as muscular structures, bone structures, and join structures. The aspects of dimension and bidimensionality are also studied. Like Kandinsky, Klee analyses the case of the horizontal line and the vertical line. However, he emphasizes the aspects of balance and equilibrium, which lead to a scheme about development and direction within a painting. He uses examples from the observation of his surroundings to describe physical phenomena such as acceleration, circular movement, spin rotation, pendulum movement, spiral movement, and free trajectory. Finally, as in the case of Kandinsky, Klee gives an interesting evaluation of color, and describes many physical phenomena with the approach of a practical painter.

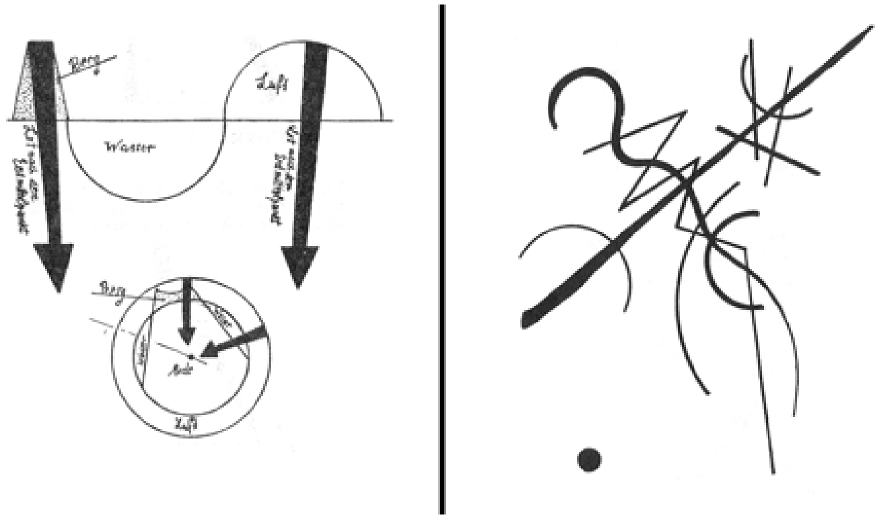

Figure 3-1 Illustrations from Klee and Kandinsky's visual analysis books

3.4 Imagination

As described in Chapter 1, the act of imagining is a fundamental element of the creative process and it is worth contextualizing it within the audiovisual framework. Imagination is “the act or power of forming a mental image of something not present to the senses or never before wholly perceived in reality” [Mer04]. In music, the development of an internal ear and the ability to combine, merge, and transform acoustic illusions is an ideal method for creating, or at least conceiving, the initial stages of a work. Acoustic illusions are not the only imaginative experiences that people have to compose music. Visual and kinetic illusions are often the initial seed for musical works. In these cases, the image is carefully analyzed and translated into the sound domain. Imagination in the visual domain deals with recreation of spaces, shapes, colors, and the relationships between them. In the case of dynamic graphics, where images are constantly changing, the time factor is also involved, and visual illusions share characteristics with the acoustic ones.

The creative mechanism that occurs in the visual and the acoustic domains can be combined when audiovisual illusions with the proper characteristics are created. These illusions belong to a field that, although merging the acoustic and the visual fields, is more than the sum of its parts. An integrated audiovisual illusion merges at several stages, and with several strategies, the acoustic and the visual elements: motives from one domain can be constantly plotted and reflected in the other; shared ideas can transmit organically among fields, blurring the boundaries between both domains.

Another phenomenon that is important to mention for its direct relationship with audiovisual creation is a physical experience called *synesthesia*. “Synesthesia (Greek, syn = together + aisthesis = perception) is the involuntary physical experience of a cross-modal association. That is, the stimulation of one sensory modality reliably causes a perception in one or more different senses. Its phenomenology clearly distinguishes it from metaphor, literary tropes, sound symbolism, and deliberate artistic contrivances that sometimes employ the term "synesthesia" to describe their multisensory joinings. An unexpected demographic and cognitive constellation co-occurs with synesthesia: females and non-right-handers predominate, the trait is familial, and memory is superior while math and spatial navigation suffer. Synesthesia appears to be a left-hemisphere function that is not cortical in the conventional sense. The hippocampus is critical for its experience. Five clinical features comprise its diagnosis. Synesthesia is "abnormal" only in being statistically rare. It is, in fact, a normal brain process that is prematurely displayed to consciousness in a minority of individuals” [Cyt95]. Because of its rare condition, and also because there is a high number of audiovisual works that have been created by people that do not have this physical experience, it seems that in praxis there are many other strategies that allow the creation of audiovisual experiences.

3.5 Form and Gesture

In the art theory, it is very common to refer to the concept of *form*. Music theory has been deeply concerned about the evolution of musical form throughout history, and it uses the concept to explain several elements of musical phenomenon. The form can be seen as a general map in which it is possible to track the development of elements and ideas. Different kinds of materials are traditionally associated with certain types of forms. Thus, the creation of an audiovisual language will necessarily create new kinds of forms that will probably share some elements from the musical field, and others form the visual field.

A gesture is “a movement of the body that expresses or emphasizes an idea, sentiment, or attitude” [Mer04]. No matter the media, the style, or the technique, a gesture is always a unit that, within the context, acts as a transmitter of expressive information. In the audiovisual domain, a gesture refers to an element or collection of acoustic and visual material that can be recognized as a single unit of expression with an identifiable meaning.

The audiovisual gesture is perceptually well delimited. In the case of digital materials, the medium offers the possibility for creating a huge range of gestures of different qualities and meanings. It is possible, for example, to create rigid, sharp, geometrically precise structures, mechanical and rigorous rhythms, as well as organic, plastic and malleable objects.

3.6 Characteristics of Systems for Audiovisual Performance

Several elements define the characteristics of an audiovisual system. Some elements correspond to its physical configuration and others to its internal implementation. One main element to consider is the type of materials that the system works with. A main distinction can be drawn between materials that are analog and digital. The audiovisual systems may or may not have dynamic transformations in the visual domain.

The flow of information is a fundamental element in the internal constitution of the system. In figure 3-2, this flow is depicted. In a first case, the gestural input determines the music and the image at the same time. In the second case, the gesture determines image and later on, the image determines the music. In the last case, the gesture determines the music and the music the image. The relationship between gestural input, audio, and image could be linear when the path is unidirectional (solid arrows) or could contain loop mechanisms in which there is feedback among the different components (dotted arrows).

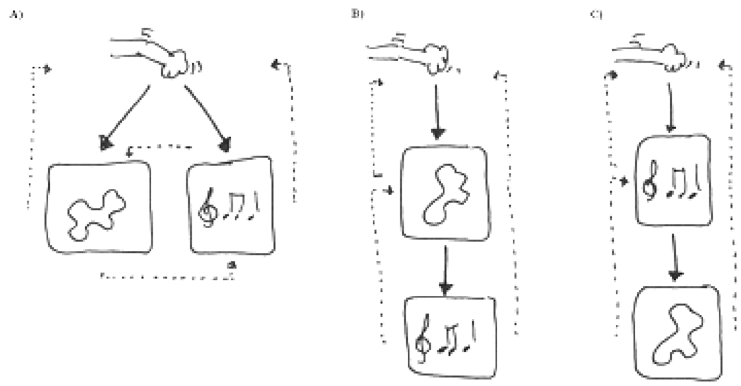

Figure 3-2 Different types of information paths

The type of mapping between image and sound, the flexibility, the degree of complexity, and the possibilities for creating dynamic vs. static mappings are, also, essential parameters that define the behaviors of an audiovisual system.

Franco, Griffith, and Fernstrom [FGF04] establish that the factors in interactive audiovisual systems are: Real-time (improvisatory) performance capabilities for the creation of images and sound, Compositional structures: events organization and modification, expressiveness, mapping flexibility between image and sound, modifiers, effects and filtering for audio and image, and learnability.

3.7 Mapping between Music and Graphics

How one creates expressive and coherent mappings between the visual and the acoustic components in audiovisual systems is the biggest unknown in the field. “There is no ‘objective’ mapping from sounds to image or vice versa” [FGF04]. Depending on how direct the relationship between both fields is, and how the basic structures of the languages are used in the mapping, the audiovisual relationship has a degree or *level*. If the mapping uses basic elements and/or easily recognizable perceptual structures, it is said that the relationship is of low level. Mapping, for example, the creation of a small circle in the canvas to the production of each musical note, and the location of the circle to the pitch of the note, indicates a low-level mapping.

Low-level mappings are easy to implement and easy to follow as an audience. However, their expressive potential is limited. As soon as the strategy is detected, which usually occurs almost immediately, the interest in the relationship is lost and either the music or the image becomes an ornament. On the other hand, low-level mappings are excellent methods for highlighting a relation between a musical and a graphical element.

High-level mappings involve relationships between the music and the graphic material that are complex and not easily recognizable. Instead of linking low-level units such as notes or color, these mappings merge higher structures such as relationships between colors, musical harmony, the contour of the musical phrase, and speed, velocity and trajectory in the movements. The list of possibilities and elements that can be taken into account in the creation of high-level mappings is infinite.

The decision of which elements should be considered, and how should they be interrelated, is part of the design and implementation of the system. Well-planned mappings are harder to conceive and implement, but they can offer richness and endlessness discourse. On the other hand, it is very easy to create abstract relationships that lose all perceptual meaning. An entire gamut of mappings, from the low-level mapping to the high-level, is available for exploration during the creation of audiovisual works.

3.8 Translation versus Mapping

The core essence of working with the audiovisual media is creating an expression with its own language where sound and image melt into a single unit, and where the boundary between both idioms becomes lost, or at least diffuse. The translation of information, ideas, and gestures between domains is a logical method for approaching both fields; however, there is not an objective or unique way to do it. The difference between mapping and translating elements is more conceptual than practical; however, highlighting the idea of "translating" units of information from one domain to the other instead of just mapping domains helps to bold the intention of treat the acoustic and the visual domains at the same hierarchic level.

3.9 The Paradigm of the Relationship between Musical Time and Visual Space

One of the most important paradigms in the audiovisual field is rooted in the different nature of the musical and the visual domains. The musical language is developed over time, while the graphical expression is created over space. Metaphors, abstract relationships, and even methodic mappings have been developed in order to merge both domains.

In the case of music and static images, the relationships tend to be more subjective, but at the same time they possess a subtlety that is lost with the use of dynamic graphics. On the other hand, in the case of dynamic graphics, the music and the image share the time element, which makes them much more related. The audiovisual expression that uses dynamic graphics is, therefore, more coherent and perceptually more understandable.

3.10 Synchronization of Audiovisual Events

Synchronization is another element that should be analyzed in order to have a better understanding of the relationship between music and dynamic graphics. In this area, both the music and the imagery use time for developing ideas. The variation in the level of synchronization is an ideal method for creating and shaping audiovisual structures.

Synchronic relationships are easy to perceive (fig. 3-3) and, probably because our sight and hearing senses perceive a huge amount of information in synchrony, they offer the sensation of stability and balance. On the other hand, asynchronous relationships divorce both fields and create tension with the disparity. The idea of synchronism can be metaphorically extrapolated to several levels of relationships in such way that we could think, for example, in terms of the synchronism between the level of the color's contrast and the musical pitch register.

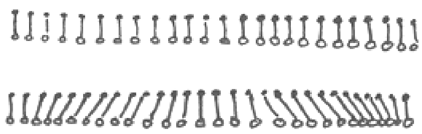

Figure 3-3 Tension caused by desynchronization

3.11 Representative Audiovisual Systems

3.11.1 Historic References

- *Color Instruments*. During the eighteen and nineteen centuries, several devices that merged sound with color were created. Most of them used traditional keyboards to trigger colors. This devices linked specific pitches with specific colors. However, each designer created different mappings. Numerous techniques were implemented and developed. The first one to be developed was the *Clavecin Oculaire* by Bertrand Castel in 1734 (fig. 3-4) [Col04].

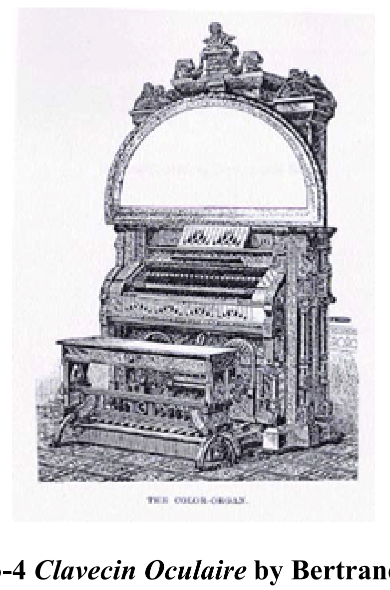

Figure 3-4 *Clavecin Oculaire* by Bertrand Castel

- *"The Total Artwork"*. In 1849, the composer Richard Wagner wrote an essay where he introduced the concept of *Gesamtkunstwerk* or *Total artwork*. "Wagner's description of the *Gesamtkunstwerk* is one of the first attempts in modern art to establish a practical, theoretical system for the comprehensive integration of the arts. Wagner sought the idealized union of all the arts through the "totalizing," or synthesizing, effect of music drama by the unification of music, song, dance, poetry, visual arts, and stagecraft" [Art00].

- *Moves and Animations*. In 1919, Viking Eggeling produced *Diagonal-Symphonie*, the first purely abstract film. Since then, this field has been an excellent territory to explore audiovisual relationships. Hans Richter (1888-1976) is an important figure in the field.

- *Audiovisual Relationships in Painting*. Several painters have done exploration with music. Some cases are well known. *Pictures from an Exhibition* by Modest Mussorgsky (1839-1881) is a piano work based on a subjective interpretation of a collection of paintings. The relationship between the Russian painter Wassily Kandinsky (1866-1944) and the Austrian composer Arnold Schoenberg (1874-1951) is also an interesting one in the history of audiovisual relationships. Interested in the works of the other, both creators influenced each other. The Swiss painter Paul Klee (1879-1940) is another painter who had a strong relationship with music. His life and his work show this strong influence (fig. 3-5) [Nin04].

Figure 3-5 *Fugue in Red*, Paul Klee 1921

- *Incursion of Music Composer in the Audiovisual Field*. During history, several composers have experimented and worked in projects that involved the use of light and color. "In 1913 Arnold Schonberg created his musical drama *Die Gluckliche Hand* which contained a light storm, created by projecting colored light. In 1911 Scriabin, the Russian composer, composed *Prometheus, the Poem of Fire*, for which he devised an accompaniment of changing colored lights" [Col04]. *The Omaggio a Emilio Vedova* by Luigi Nono, and some of the works between the composer and the painter Vedova, should also be pointed out. "In 1957 Jordon Belson collaborated with composer Henry Jacobs on the *Vortex Concerts* in which moving visual abstractions were projected on the dome of the Morrison Planetarium in San Francisco while electronic music was played" [Col04]. "In 1958 Edgar Varèse composed *Poéme Électronique* (fig. 3-6) [Zac04] to be part of a sound and light environment created in collaboration with the architect Le Corbusier, for demonstration at the Brussels World's Fair. Light images were projected on the walls of the pavilion while music moved in sweeping arcs through the pavilion. No attempt was made to synchronize the light and music"[Col04].

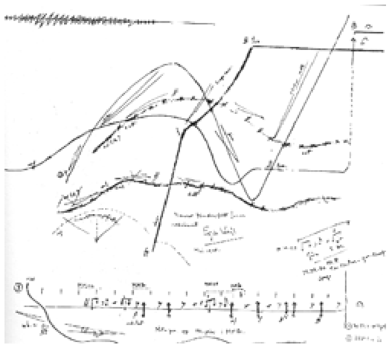

Figure 3-6 Score of *Poéme Électronique*, Edgar Varèse 1958

3.11.2 Audiovisual Systems in the Digital Era

The amount of audiovisual systems that have been developed so far is huge and some of them are described here. They were chosen because they are historically important, I had the opportunity to closely observe them, or they have similar characteristics to IMPI.

- "1974-1979 Laurie Spiegel at Bell Labs created VAMPIRE (Video and Music Program for Interactive Real-time Exploration/Experimentation), which included a few computer animation routines by Ken Knowlton as well as music routines from the GROOVE computer music system created by Max Mathews, et al" (fig. 3-7) [Col04] [Aud04].

Figure 3-7 GROOVE system

• During the last few years, diverse designers of operating systems and audio players have developed several applications that respond visually to acoustic events. They are worth mentioning as they have spread out within commercial operating systems, and have reached a huge number of potential users who will, in one way or another, become familiar with the language. Because there is a large variety of these programs, it is not easy to evaluate them precisely. However, their mapping is very crude and they are not particularly malleable (fig. 3-8) [Mic04].

Figure 3-8 Visualization of *WinMediaPlayer*

• From 1996 to 1998, Peter W. Rice developed at the MIT Media Laboratory *Stretchable Music: A Graphically Rich, Interactive Composition System* (fig. 3-9) [Ric98]. This environment allows the creation of audiovisual material. With a mouse, the user could grab and stretch different kinds of widgets. Each object is linked to a particular audio sequence. Considering the technical constrains of the moment, the system was a good contribution to the field. However, several limitations on the system that should be mentioned. The main lack in the system is that all the music is pre-composed. Even though this may guaranty a result without "errors", it also prevents the user from accessing basic elements of the material. Melodic or rhythmic patterns and instrumentation are not modifiable. Because the audio was rendered by a bank of sounds that tried to imitate analog instruments, the quality of the audio is low. The generated graphics are also too "heavy" to give a real impression of organic and malleable canvas.

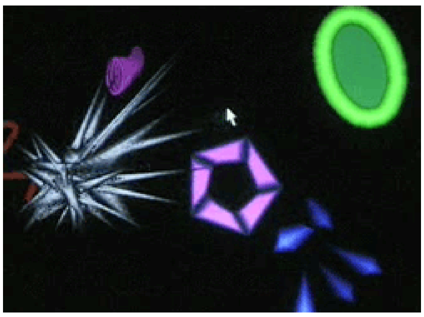

Figure 3-9 *Stretchable music* by Peter W. Rice

• From 1996 to 1998, Reed Kram developed at the MIT Media Laboratory *MidiVis* and *Transducer*; a series of audiovisual systems that "define new dynamic pictographic visual languages for describing interactive digital performance systems" (fig. 3-10) [Kra98]. The most attractive characteristic of these works is the three-dimensional representation of the audio space. However, these works tend to focus more on the graphical representation than on the creation of high-level sound-image relationships.

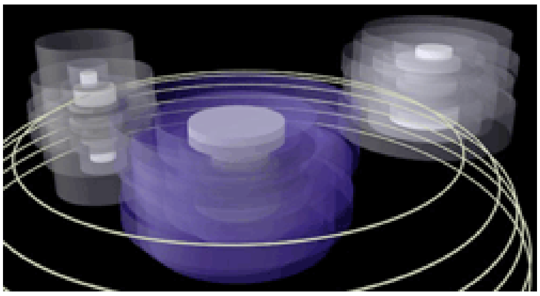

Figure 3-10 *Sound City* by Reed Kram

• From 1998 to 2000, Golan Levin developed at the MIT Media Laboratory *Yellowtail*, *Loom*, *Warbo*, *Aurora*, and *Floo* (fig. 3-11) [Lev00a, Lev00b]. All of these works generate synthetic sounds and animated graphics, each one using different algorithms to modify the audiovisual material. The works of Levin are organic and expressive, and the strategies used for relating the audio with the music are well designed. The sound is, however, less developed and less surprising.

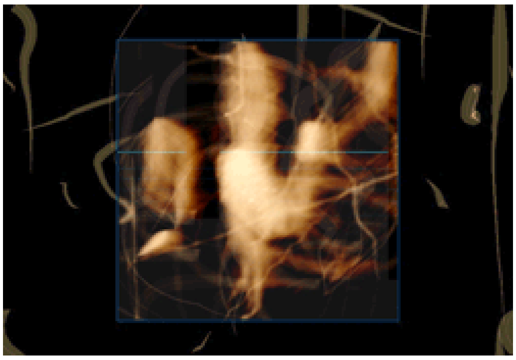

Figure 3-11 *Yellowtail* by Golan Levin

• *Small Fish Tale* by Masaki Fujihata, Kiyoshi Furukawa, and Wolfang Münch was presented in a concert in 2000. The production is a collection of audiovisual systems, each one with a different visual aesthetic, but all of them with similar audio results. On the screen, there are several objects; some of them remain static, and others are in constant movement. Each time that these movable objects hit a static object, they trigger a MIDI musical note. Individually, they are not particularly attractive. But as a whole, it is interesting to observe many ways to manipulate the material with the same algorithm [FFM00a, FFM00b] (fig. 3-12).

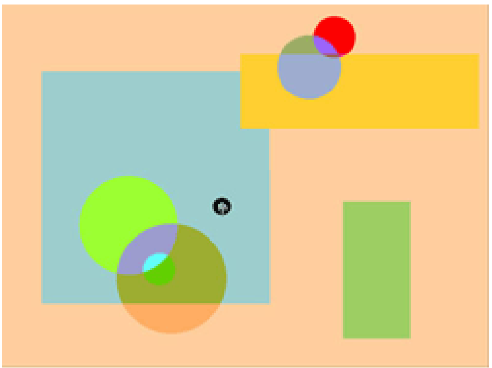

Figure 3-12 *Small Fish* by Masaki Fujihata et al

- The *AudioPad*, by James Patten and Ben Recht, is a system developed at the MIT Media Laboratory [PRI02]. A special tablet detects the physical location of some objects. The relationships between these objects launch and transform MIDI sequences. A projector presents an animation over the tablet where animated shapes show information of the music. Within the context of DJing, this system is a fabulous audiovisual proposal for allowing two players to improvise together. However, the interface is limited to a particular kind of music and aesthetic (fig. 3-13) [PB04].

Figure 3-13 *AudioPad* by James Patten and Ben Recht

- *ReacTable* is a project under development at the Interactive Sonic System at the Audiovisual Institute of the University Pompeu Fabra. Develped by Sergi Jorda et all [JKG04]. This system generates audiovisual material according to the positions that physical objects have on the tablet. “Unlike common visual programming languages for sound synthesis which conceptually separate the patch building process from the actual musical performance, the *reacTable* combines the construction and playing of the instrument in a unique way” [MGJ04]. The system is interesting because of its concern with dynamic patching, but the visual and the generated electronic sounds are not so interesting (fig. 3-14).

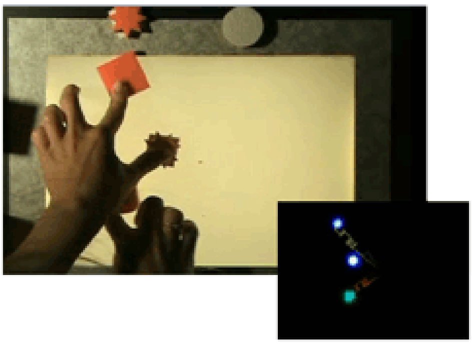

Figure 3-14 *ReacTable* by Interactive Sonic Systems UPF

- Amit Pitaru is currently working on the *Sonic wire sculptor* [Pit04]. This system uses a digital tablet to create audiovisual materials. The visuals are 3D animations, and the sound is synthesized in the computer. It has several constraints with the sound production, and the manipulation of the graphics is very limited. However, it has a particular method for mapping the sound to the three-dimensional figure which deserves attention (fig. 3-15).

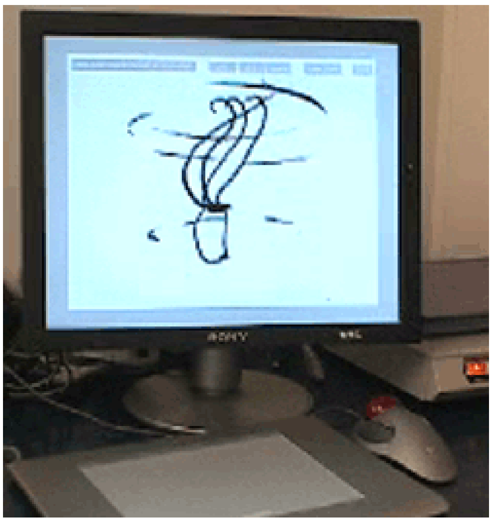

Figure 3-15 *Sonic wire sculptor* by Amil Pitaru

- *VJing (Video Jockey)* is a growing activity that has recently received much attention. It borrows its name from its DJ equivalent, well established in the music world since the turntable era. The new powerful and affordable equipment that can manipulate images and videos in real time quickly enabled its popularization. VJs focus exclusively on the “graphical performance,” and although they often perform together with DJs, the two activities have not come to a merge yet. However, it is highly probable that in the future a novel “VDJing” activity will emerge (fig. 3-16) [Liv04].

Figure 3-16 Livid Union VJing software

Chapter 4

Improvisatory Music and Painting Interface

"Cuatro Jamón te saco…"

In this chapter the Improvisatory Music and Painting Interface is fully described. The aesthetic behind the system, the technology employed, and its development are described. Special emphasis is put on the characteristics and challenges of each one of the three versions that were developed.

4.1 Introduction

Free musical improvisation is a fantastic domain. A teacher in composition once told me that improvising was similar to riding a bike without hands and no direction. "One of the typical components of improvisation is *risk*: that is, the need to make musical decisions on the spur of the moment, or moving into unexplored musical territory" [Net04]. The idea of creating a system that could help shaping these risky explorations in the audiovisual domain is, in essence, the goal of my work.

As soon as I started studying music, I became excited about improvisation and multimedia. In 1999, I performed Siderales, a piece for lights and electronic sound (see *Appendix* part A). In 2001, I created and played with the NICROM Trio, an ensemble for electro-acoustic improvisations with action-painting (see *Appendix* part B). That same year, I developed *GAB,* a system for the reinterpretation of improvisatory piano performances (see *Appendix* part C). Finally, during my research at the MIT Media Laboratory, two important projects were developed. I collaborated on the composition of *Gestures,* a piece in which drawing and improvising were fundamental to its creation (see *Appendix* part D); and I collaborated on the creation of *radioBANDA*, a radio-net project where people manipulate graphics in the computer to alter the sound of a radio station (see *Appendix* part E).

In chapters two and three, several examples and systems–some in the music improvisation domain, others in the audiovisual domain–were presented, not only because they are interesting or important, but also because I learned from each one of them. These examples have influenced my own work; from some I learned certain aspects of music or visual expression, from others methods for creating collaboration among people, or again aspects of technology. Nevertheless, none of these works have fully and completely satisfied my expectations, or aesthetic requirements, and this is probably the reason for my motivation in creating IMPI.

Both, my own work and my approach to the works described in chapters two and three strongly influenced and led towards the development of the Improvisatory Music and Painting Interface (IMPI).

4.2 Description

IMPI is an audiovisual system with two main goals first, to assist ensembles of acoustic musicians in the creation of organic improvisations where elements of the compositional technique, such as synchronization between instruments and abrupt changes of the material, could be created. Second, to create a dynamic graphical expression that, in conjunction with the music, produces a coherent and malleable audiovisual work with perceptual meaning between all the elements.

In the versions that have been developed, a “conductor” is in charge of shaping the improvisations and creating the visual material by drawing with a specific syntax on a digital tablet. With the objective of recognizing the gesture of the stroke, several elements such as speed, pressure, location, and duration are analyzed. In the versions developed, the musical elements that the “conductor” can control are the level of participation and activity of each member of the ensemble, the general contour of the improvisation, the levels of intensity, and the pitch regions of the music. The visual elements that can be controlled by the conductor are the shape, the location, and the color of the objects. The rest of the functions are automated using functions explained in the *Versions and Evolution* section.

The musical information generated by the conductor is distributed and sent to the ensemble by a computer network. Ideally, each musician should have a computer to read from, substituting for the traditional paper score. On the screen, each musician receives the material that the conductor is creating for him or her. The information is represented with several degrees of abstraction, and musicians are free to choose which representation to follow. Standard Music Notation (SMN) is one of the possible representations, and should be sight-read while it is scrolling through the window. Dynamic shapes that represent musical content is another type of symbology. In this case, the player has the potential for greater freedom; however, the shape of the improvisation is preserved.

The visual information is also generated by the drawings of the conductor. The gestures used in the drawings produce dynamic images that should be projected on the stage with the music. In the implemented versions, the traces created by the conductor are directly mapped to the shape of the object created in the main visual output. Dynamic filters and transformations are then applied to the image to generate blurring and merging among the shapes.

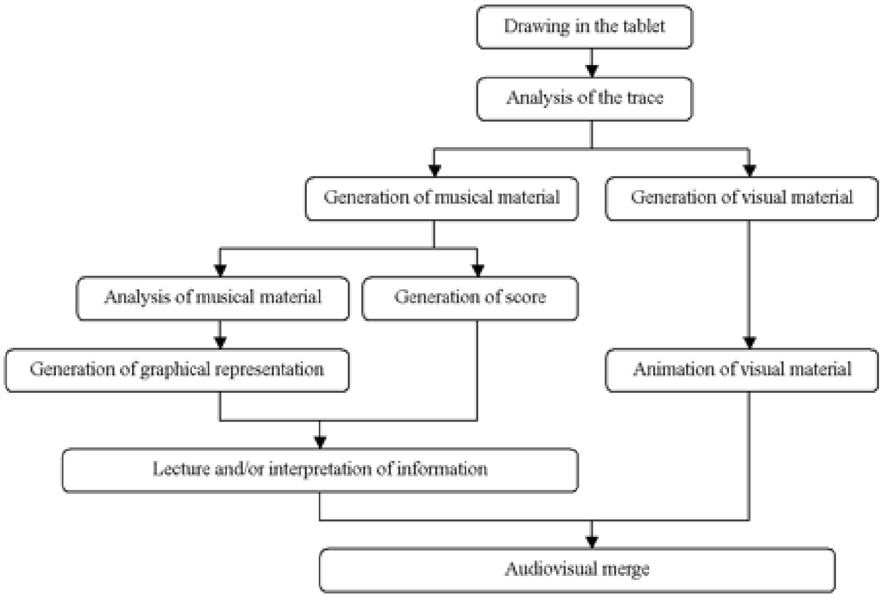

Figure 4-1 Diagram of IMPI's functions

The kind of music that the system should ideally generate is non-tonal, non-rhythmic, and pattern oriented, which means that strong emphasis should be put on the control of timbral qualities and global textures. Because the interface is for acoustic instruments and there is particular interest in the timbre element, the instruments should use all their resources. Extended techniques are ideal resources to represent the intention. In order to create the sensation of continuum transformations in the pitch domain, intervals smaller than the semitone should be employed. If the instrument allows glissandi, they should also be used.

In order to create the sensation of movement over space in the musical domain, IMPI should use fundamental transformations in pitch and intensity. In order to create the sensation of continuum transformation in the time domain, the synchronicity of events and the use of regular pulses or clear rhythmic patterns should be carefully employed. *Politempis*, irregular rhythmic patterns, and avoidance of repetitions should also be considered.

Ideally, the graphics in the systems should be extremely malleable and organic. Shapes should constantly change in shape and size in a vivid manner. The details of this ideal are described in the following section.

4.3 The Aesthetics behind the System

IMPI is a system that shapes and materializes kinetic fantasies with certain characteristics. The core elements that integrate these “archetypical” illusions beyond the media to represent them are:

- *Free Movement of Objects*. I want to create the illusion that objects that are part of the work can fly and move around the space in all direction. A good analogy from the natural world would be the flight of a fly.

- *Clouds of Objects*. I imagine collections of objects that form big clouds that can be expanded and collapsed over time, moving organically, similar to the way that flocks of birds do.

- *Gradual Transformations*. I am interested in slow but constant transformations of the material. The subtle continuum changes that are imperceptible from one point to the next but that at the bigger scope create obvious modifications have particular interest to me. Many physical and biological events have this quality in their way of evolving. To me, some of the most interesting dynamic systems are the movement of fluids, smoke, and clouds.

- *Organic Shape and Texture*. No matter if it is an acoustic or visual event, its shape and texture quality should be granular or fibrous.

The elements described above should necessarily materialize into physical and measurable musical elements. There is not an objective translation of these illusions into the musical or graphical world, and the techniques and procedures to create such translation are indeed part of the creative process. IMPI has its own paradigm in the way it creates the translation of these ideas into acoustic and visual materials.

4.4 Technology

4.4.1 Software

4.4.1.1 Java

IMPI was developed using the Java 1.4 language. Java is a nice language that offers a balance between low-level and high-level languages [Sun04]. It is also much simpler than C and C++. In addition, Java is, at least theoretically, cross platform, which means that the code written in pure Java can run on any platform. The idea of running the same code in a Windows, a Macintosh, a Linux, or a PDA system without having to change the code is an attractive feature. Another nice feature of Java is the huge number of libraries that have been created for it. People have created specific packages for a big number of tasks such as audio and MIDI, 2D graphics, 3D graphics, and video manipulations. Networking protocols, hardware control, and communication with other languages are other features that make it a powerful language.

On the other hand, Java requires a virtual machine that works as a bridge between the operating system and the Java code, which makes it slow, especially for multimedia processing. One solution that has emerged to deal with this situation is the creation of libraries in C that are then used by Java. Jsyn for example, uses an audio engine that is a C library to deal with the audio hardware. The audio core is hidden from the user; however, it is possible to call it from within Java. As long as the library is present in the system, the code should still be cross-platform.

With the increase of computer speed over the years, the problem of the Java performance has been solved little by little in a natural way. What was not possible two or three years ago, can now be easily executed in a computer of regular characteristics. IMPI uses a complex graphical rendering for the visual part of the interface. The filters and the algorithms that create the animation consume almost the entire CPU of current powerful computer. However, IMPI is a system that uses one computer for each performer, which means that at least the rendering of the score and graphics of each performer are calculated in a separate CPU.

4.4.1.2 JMSL

The Java Music Specification Language (JMSL) was crated by Nick Didkovsky and Phil Burk as an evolutionary successor of the Hierarchical Music Specification Language (HMSL) created by Phil Burk, Larry Polansky, and David Rosenboom. JMSL is a "Java-based development tool for experiments in algorithmic composition, live performance, and intelligent instrument design" [DB04].

JMSL is a excellent package for the creation of algorithmic music. Its concepts of hierarchical organizations, musical tasks, and parallel and sequential collections, are entirely natural to the way music is organized no matter what kind of structures and elements create the musical language.

In addition, JMSL is well integrated with JSyn. It "uses native methods written in 'C' to provide real-time audio synthesis for Java programmers. JSyn can be used to generate sound effects, audio environments, or music. JSyn is based on the traditional model of unit generators which can be connected together to form complex sounds" [DB04]. This means that if, in the future, IMPI grows to integrate the production and manipulation of electronic and/or electro-acoustic music, the extension will be easy to integrate.

The current version of JMSL (101) offers the ability to render scores in real time. The first version of IMPI uses its own score rendering, as will be seen in the section *Versions and Evolution*; during the process of improving the system, the option of using the JMSL's score package seemed much more logical. The score package of JMSL is a Java package totally integrated with the rest of JMSL, and allows the creation and transformation of scores written with Standard Music Notation. The method of creating, modifying, or transforming the score is entirely open to the choice of the programmer and can be done entirely in real time. In addition, the JMSL's scores can be saved as musicXML scores which means that the final file can be opened into music editors such as Finale, Turandot, and Igor Engraver, among others.

4.4.2 Hardware

IMPI uses a computer network to transmit the information among musicians. These days, networks of computers are easy to set up, protocols have been spread out, and the required hardware is not as expensive as it used to be. In addition, the option of creating fast wireless networks seems to be a nice solution for easily setting up systems during live situations.

The ideal configuration for using the IMPI system is a wireless network of laptops where each musician has his or her own computer. All the computers must be fast enough to render the graphic animations and the score. They should have a wireless LAN connection. The conductor also needs a computer with a digital tablet connected. The video output of the conductor's computer must be connected to the projector that exhibits the main graphics. For the networking transmission, a wireless router is required. The current communications protocol is the 802.11b.

4.4.2.1 The Digital Tablet

IMPI uses a 12 * 12 Intuos2 digital tablet by Wacom [Wac04]. This device registers all the movements of a special pen that are created on the surface of the tablet. The parameters that are captured with a maximum rate of 200 points per second are:

- *Location*. The tablet registers the X and Y coordinates of the pen with a resolution of 2540 points per inch. It also senses whether the pen is touching the surface or is just above it.
- *Pressure*. The tablet registers the pressure applied with the pen into the tablet surface with a resolution of 1024 levels.
- *Angle*. The tablet registers the direction at which the user is holding the pen.
- *Tilt*. The tablet senses the tilt at which the user is holding the pen.
- *Buttons and direction employed*. The device registers if any of the three buttons of the pen are pressed. It also registers which end of the pen is being used.

Taking advantage of the many parameters that can be sensed with this device, IMPI uses some of them in order to create an audiovisual instrument with several features. The way these parameters have been used varies between different versions of the system, but some of them have been preserved and are the core strategies of the interface.

- *Location*. IMPI tracks the location of the pen in order to register the shape of the stroke created by the player. The values are scaled to the normal values employed with a mouse.
- *Speed*. Measuring the location and the time allows getting the speed of the trace at every moment. Speed of the gesture is one of the most important elements for understanding the kind of trace the player is performing. The range is scaled as a decimal number between 0.0 and 1.0. The fastest speed was calculated based on the fastest average speed that could be meaningful for the performance of the system. If a stroke is created with a faster speed, a limiting value is applied.
- *Pressure*. The pressure of the pen also contains meaningful information that helps to understand the kind of gesture the player is creating. The value is scaled as a decimal number between 0.0 and 1.0.
- *Position*. The angle and the tilt of the pen are merged together into a single value that represents how far toward the front or back of the tablet the outer end of the pen is in relation to the end of the pen that is touching the tablet. Imagine examining the tilt along the Y axis in a joystick without taking the X axis into consideration. The decision of merging both values was made with the idea that the back-front movement is a natural movement with an intuitive meaning. The merging was created by multiplying both values. The value is also scaled as a decimal number between 0.0 and 1.0.

4.5 Versions and Evolution

The creation of IMPI has been a long process. Several prototypes and versions were planned, sketched, designed, or implemented. Some of these versions were just ideas that never came out as a piece of code because the ideas and systems were too vague or too ambitious. On the other hand, three versions were thoroughly implemented. The evolution of IMPI progressed in parallel with my learning of the technologies employed and the audiovisual ideas that IMPI integrates. The development of IMPI was not a straight line of constant progress, but an exploration with ups and downs better described as a spiral. During the creation of IMPI, some technologies were created and later discarded. Some libraries and packages by other creators were imported and implemented at some stage of the development. Some of them were later discarded or changed by other solutions. IMPI is not finished, and a lot of work can be made in order to improve it. However, the current version is the most aesthetically balanced among all of the implemented ones.

It is important to notice that although there are changes in the way performers interact with the system, and although there were changes in the used technologies between versions, there has been an aesthetic constant during the entire process. The kind of acoustical intention and the essence of the visual material have been the same among versions. A detail explanation of this aesthetic search is described at the beginning of this chapter.

4.5.1 Original Idea

The original idea was to replace the figure of the traditional conductor of chamber music with a musician-painter that could guide the performance with his or her painting. Musicians would just have a narrow range for modifying the acoustic material because they would receive the score on the screen of their computers. The drawings that the conductor would create would be used to define musical parameters in the scores.

In this initial idea, neither the graphics nor the relationships between music and image were well defined, just the intention of developing a frame that could create the audiovisual materials following the intended aesthetic. The first written description of the system, described in the proposal of the thesis, establishes that “the graphical language allows hierarchical control of musical material. First, graphical primitives (geometrical shapes) control the microscopic musical level such as pitch, duration, timbre, and intensity of a note. Then, actions over the graphical objects (dissolving, moving, rotating) allow the modification of musical elements such as rhythmic, melodic, and dynamic contours of phrases. Finally, the overall modification of the graphics (freezing, rotating, blurring) controls the macro elements of the music such as dynamic range, pitch range, and climax” [Sol03b].

4.5.2 First Implementation

Based on the initial idea and as an exploration of the technologies that would be employed the first implementation was created. At that moment, the focus of the research was more on solving the computational challenges than on the aesthetical result. Although usable, the digital tablet was not implemented in this version and all the code was developed for the use of a mouse.

In this version, the musicians just have a window on their screens with the score. The painter has a window where he or she could draw lines with the mouse, and a small window with a pallet of different colors where the color can be chosen with the click of the mouse.

Even though it was technically possible to have multiple painters and multiple musicians on the net, this version was conceived as a system where only one painter creates the material for multiple musicians (fig. 4-2). Because in practice, this version sends the same information to all the musicians and the audiovisual relations were not artistically planned, this is not a useful system in real musical situations.

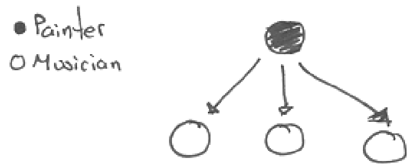

Figure 4-2 Characteristics of the ensemble

4.5.2.1 The Painter

The painter's side of the system consists of a color pallet and a black canvas (fig. 4-3). The player uses the mouse in order to draw lines in the selected color. There are no kinds of mappings, filters, or transformations of the input, and the screen shows the exact movement of the mouse. The lines that the user creates disappear gradually over time by becoming darker and darker. There is no relationship between this animation process and the music created. The elements for creating the music part are all taken from the moment that the gesture is generated.

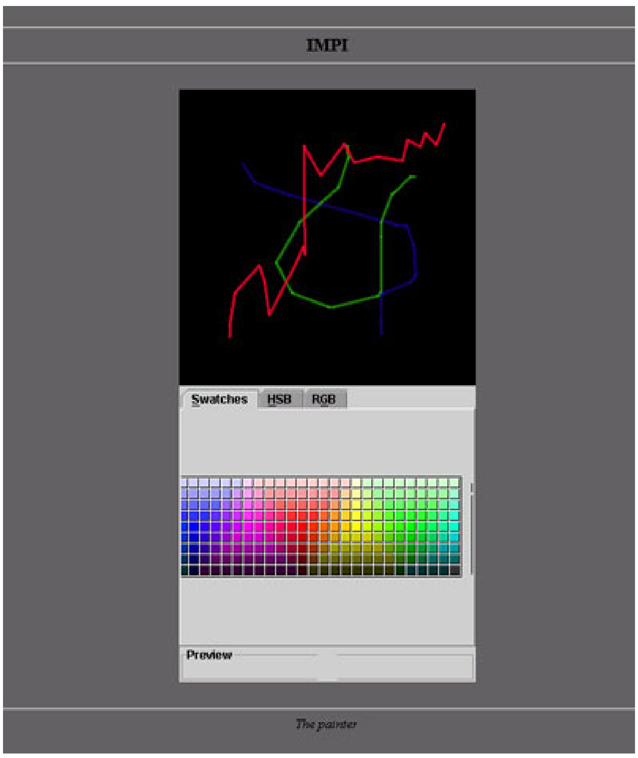

Figure 4-3 Painter window, first version

4.5.2.2 The Players

The musicians have in their screen only one window where the score is rendered (fig. 4-4). The computer role in the musician's part is limited only to provide a score that could be created in real time.

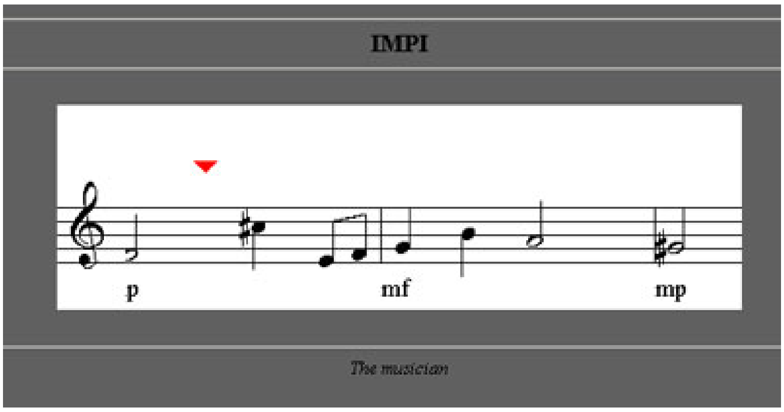

Figure 4-4 Player window, first version

4.5.2.3 Audiovisual Mapping

The mapping between the musical and the visual part in this version was not deeply explored; however, some interesting elements of this version were taken into account for later versions.

When the user draws a line with the mouse in the canvas, the following elements are taking into account in order to generate the music:

- *Color*. The current color of the line is used to determine the intensity of the musical phrase. The red, green, and blue values of the color are added together and the result is scaled in a range between one and four. If the value is one (obtained with dark colors) the intensity of the phrase is mf. While the color becomes brighter, the range of possible dynamics, from which dynamics are chosen at random also become bigger. If the value of the color is four (white color) the dynamics of the musical phrase could be *pp*, *p*, *mp*, *mf*, *f*, *ff*, or *fff*.
- *Length*. The length is obtained by measuring and adding the distance between all the points of the line. The length of the line is used to determine the number of notes that each measure in the musical phrase will have. Reasonable values are set as the minimum and maximum value for the length. Limiters are applied if the line is out of the range. The value is scaled in a range between one and four. If the value is one (short lines) the measures are created with three notes. As the length of the stroke becomes bigger, the range of the possible number of notes, from which the final number of notes is chosen randomly, also becomes bigger, going from one to four. If the value is four the measure could have between one note (white note or rest) and four notes of different values. The length of the line only sets the number of notes per measure, not the duration of these notes.

- *Duration*. The time that it takes to create a line is used to set the kind of rhythmic pattern for each measure. Reasonable values are set as the minimum and maximum values for the duration. Limiters are applied if the duration is out of the reasonable range. The value is scaled in a range between one and four. If the value is one, the measure has just one kind of rhythmic pattern, taking into account the number of notes. As the duration in the creation of the line becomes bigger, the possible rhythmic patterns randomly chosen also becomes bigger. If the number of notes in the measure is one, the duration value will not have any effect, since there is just one way to fill the measure with one note. On the other hand, if the number of notes in the measure is four, a long duration would allow many different patterns. The possible patterns are taken from the table described in the Score Render section.

- *Curvature*. A basic algorithm for measuring the curvature of the line is used to set the kinds of pitches for the musical phrase. All the angles created with the segments formed between adjacent points are measured (fig. 4-5). If the angle is close to 180^{o}, that section of the line is almost straight, and a tag of small value is added to a counter. If the angle is around 90^{o} a tag of medium value is added. If the angle is close to 0^{o} that means that in that section of the line there is a big change of direction and a big value is added to the counter. The final value of the counter gives a sense of how wavy the line is.

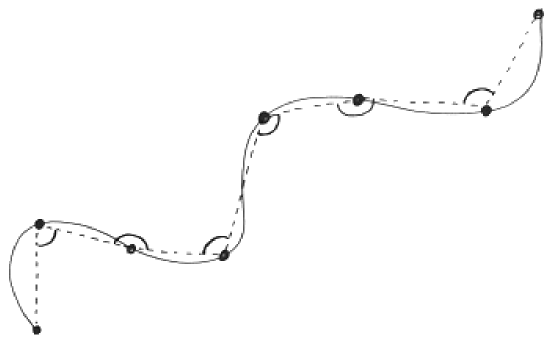

Figure 4-5 Method used to measure the curve of the line

The value is scaled between one and four. If the value is one, all the notes of the phrase are C one octave above middle C. As long as the value increases, the range of possible notes to be randomly chosen from is also increased. For testing purposes, the range was set to fit in the range of the staff without additional lines.

- *Speed*. With the total duration of the stroke and the final length of the line, the average speed at which the line was created can be calculated. This value is used to determine the tempo of the music. The range goes from 60 to 240 BPM. The tempo value is reflected in the speed at which the score scrolls in the screen.

4.5.2.4 The Score Render

The main contribution of this version was the development of the real-time score-rendering library. Using the graphics capabilities of Java 2D, and the free *Toccata* and *Fughetta* fonts [Hod03], a score that constantly scrolls from right to left over the screen was implemented. At the top right corner of the clef, a triangle shows the current position within the score.

A table of integers defines the possible rhythmic formulas that the score can render (fig. 4-6). Basic patterns were selected for testing purposes but it could be easily extended to implement other rhythmical cells of higher complexity.

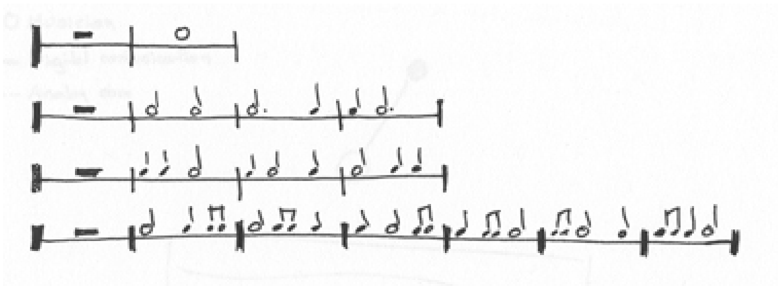

Figure 4-6 Table of possible rhythms

4.5.2.5 Observations on this Version

In the technical field, the main contribution of this version was the implementation of the score rendering and the implementation of the initial stage of the network engine. It helped also to understand many of the graphical functions of Java. In the aesthetic domain, this version helped to see that most of the direct mapping between the graphical and the visual field were too direct to have a significant value. The experience in the development of this version contributed to the implementation of the second version.

4.5.3 Second Implementation

Based on the experience of having designed the first version, and after seriously considering which would be the best direction for the evolution of the system, I worked on a second version that had several similarities with the first one, but also significant changes. Some of the code that was employed in the first version was, if not recycled, at least taken as starting point. This version is more elaborated than the previous one, both technically and musically and it was used during a workshop with John Zorn as is described in the Chapter 5.

4.5.3.1 Ensemble Configuration

This version preserves the configuration of having just one painter that leads a group of musicians (fig. 4-7). Musicians can receive data but they do not have technical capability of communicating with the rest of the ensemble. They have, however, the option of creating music without necessarily following the score, as will be explained in the *Players* section.

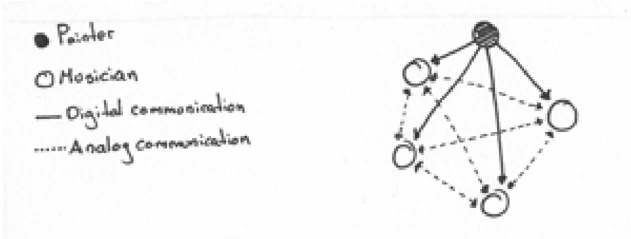

Figure 4-7 Ensemble configuration

4.5.3.2 The Painter

In this version, the conductor can use several features for guiding the improvisation. The conductor's window (fig. 4-8) is divided into four sections; each one has a particular function in the system.

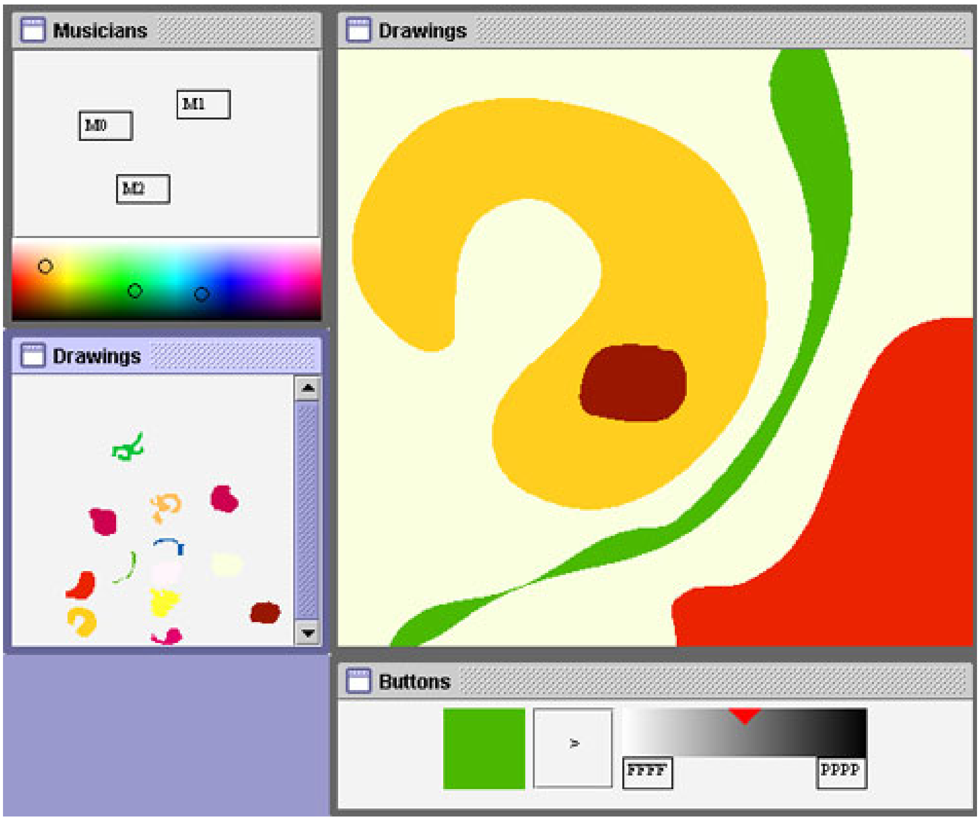

Figure 4-8 Painter's interface

4.5.3.2.1 The Canvas Window

The principal window is the canvas (fig. 4-9). In it, the conductor can draw the shapes that generate the musical objects and can see the graphical result that is projected for the audience. When the performance starts, this canvas is a rectangular white area. Contrary to the first version, this one uses shapes instead of lines as the basic graphic unit. The player must create a shape by drawing its contour. While the shape is being created, just a slight black line is shown. As soon as the drawing of the line is finished, the ends of the line are connected by a straight line, and the shape gets the current color. According to the time that it took to draw the contour, the shape gradually appears and disappears on the screen. Although the animation technique is simple, it offers smooth transitions and creates a basic but continuous discourse.

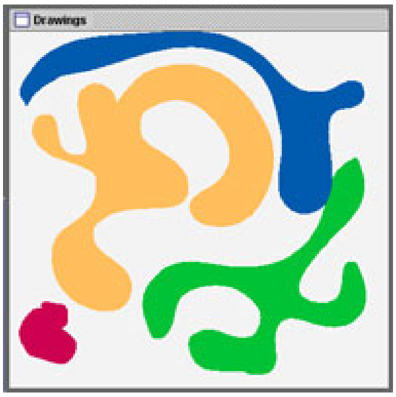

Figure 4-9 Canvas window

4.5.3.2.2 The Collection of Ensembles Window

The conductor's interface has also a small window (fig. 4-10) that is subdivided into two sections. The top one is a rectangular white area where all the musicians currently online are represented as small rectangles. Each time that a new musician logs onto the system, a small rectangle with a number that increases sequentially is created in the center of the area. The rectangles can be displaced freely around the area with the intention that the conductor could geographically organize the musicians in any particular way. The location on the screen could, for example, indicate the physical location of the musicians on stage, or on the other hand could mean importance or order of appearance. That choice is intentionally left to the performer's requirements. As soon as a musician logs out or disconnects from the system, the rectangle that represent him or her is erased.

The bottom section is a rectangular area that shows the entire gamut of colors. The values of the color are organized in such a way that a continuum of color similar to a rainbow is created in the X axis. On the Y axis, variations with major or minor values of black and white are presented, creating also a gradual continuum.

The bottom section is used to create combinations of musicians or sub-ensembles. Each sub-ensemble is represented by a small circle over the colors. To create a sub-ensemble, the user clicks in the top window above all the musicians that are to be part of the ensemble. Once all of them are selected, the user clicks on the bottom section on the color that is wanted to represent that particular sub-ensemble. At that moment, a new circle is created over the color that was chosen. Each time that the cursor is above a circle, all the musicians that make up that ensemble are highlighted with the particular color of that ensemble.

As in the case of the musicians, the sub-ensembles can be freely moved around the area. However, in this case there is an effect because, the movement modifies the color of the ensemble and also sets the current color for painting, as will be described in the *Mapping and Interaction* section.

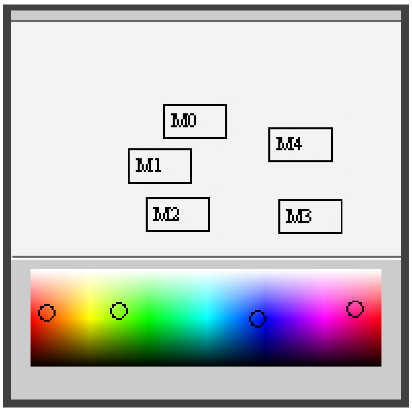

Figure 4-10 Ensembles window

4.5.3.2.3 The Collection of Objects Window

The interface of the painter also has a small window (fig. 4-11) where all the objects are collected and organized. This window is below the collection of ensembles window, and is a white rectangle. Each time that a shape is finished in the canvas window, a scaled version of the shape is created in the collection of objects window. By default, each new shape is added in the center below the previous ones. However, once created, it can be freely moved around the window to fit the particular requirements of the player. They could, for example, be organized by shape, color, or the order in which they to be replayed.

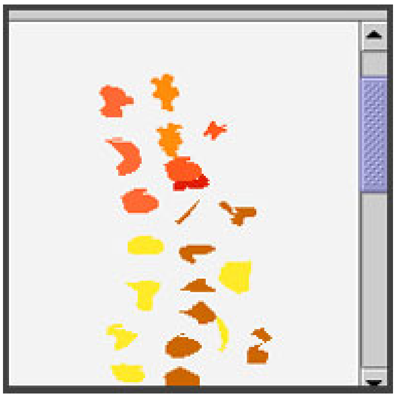

Figure 4-11 Window with objects

If a player selects the object, a new window is created (fig. 4-12). In the window a copy of the object is presented. Around the entire contour several little circles are shown. These circles represent the end and control points of the Bezier curves that compose the shape. More of this is explained later in this section.

All the points can be dragged and moved around the window, which causes a transformation of the original shape. Once the user is pleased with the variation, the window can be closed and the new object is automatically added into the collection of objects. Originally, this transformation would be the method used to create graphic and visual variations. However, this was not implemented for reasons that will be explained on the section *Observations on this Version*.

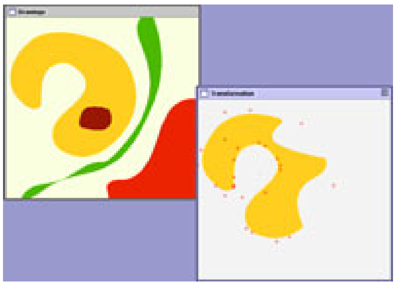

Figure 4-12 Transformation of shape

4.5.3.2.4 The Control Panel Window

In the lower part of the painter's interface there is another section (fig. 4-13) that corresponds to the control panel. It is composed of several different elements. At the left there is a square that constantly shows the current color that will be use to paint, and therefore the ensemble that has been selected. At the left of the square is the play button that is used to send to the musicians the information that has been collected since the previous press of the button. At the left there is a second button that was not assigned.

Finally, at the right, an object sets the transparency of the shape and the intensity of the musical phrase. This object is composed of two linked elements. At the top it has a rectangular area with a gradient that goes from white to black. Above the gradient there is a red triangle that indicates the current transparency. At the bottom, there are two movable rectangles. One rectangle indicates the softer dynamics *pppp* and the other the high dynamics *ffff*. With the mouse or tablet it is possible to modify the location of the triangle and the rectangles. By moving the triangle, a new transparency for drawing the shapes is selected. By moving the rectangles a different map of dynamics is selected.

As a default, there is a linear mapping between the transparency of the drawing and the intensity of the musical phrase. If the object is almost transparent the musical phrase is as soft as possible. While the draw becomes darker the intensity increases. By moving the rectangles this linear map can be modified and even inverted. Dark strokes could imply piano, while transparency could imply loud sound.

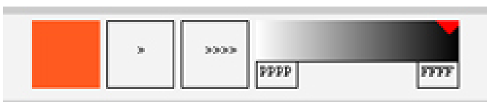

Figure 4-13 Control panel

4.5.3.3 The Players

The musician interface (fig. 4-14) is made of five windows, each one with different characteristics,; however, all the windows that are currently implemented display the musical information with a particular kind of graphical representation.

Once that the musician launches the program there is nothing to set or modify, and the connection to the server is done automatically. This version does not allow any kind of input by the musicians; therefore, the computer is used only as a display. However, special emphasis was put in finding alternative representations of the music.

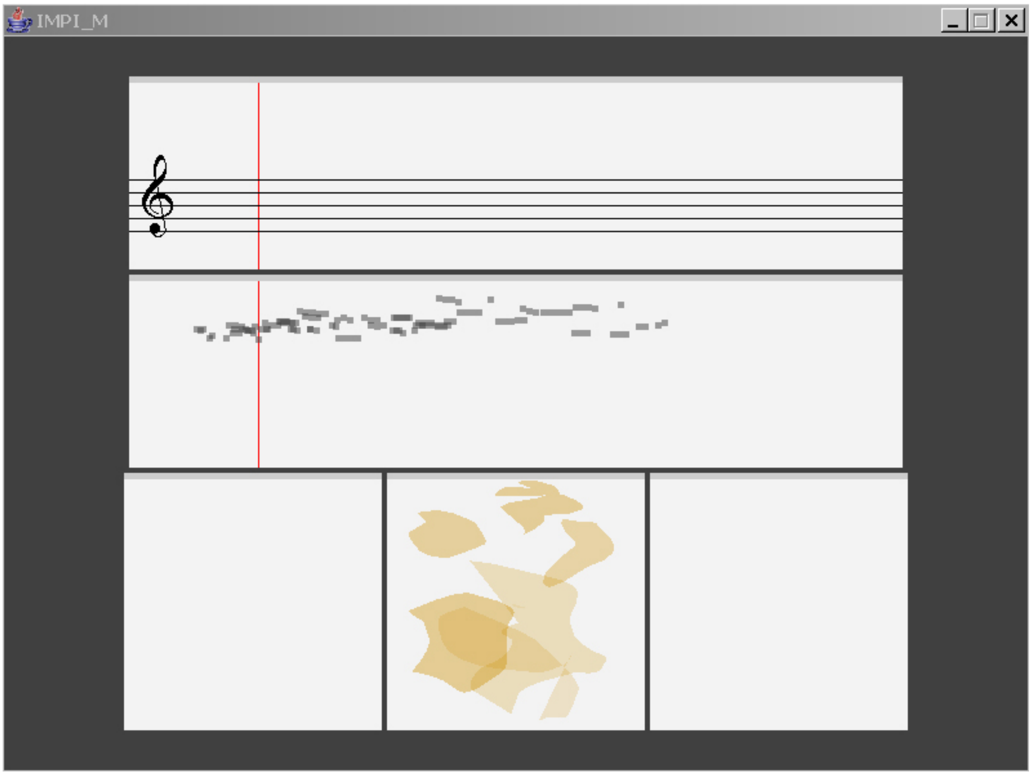

Figure 4-14 Screen for the musicians

4.5.3.3.1 Different Ways of Representing the Music: a Natural Way of Creating Interactivity

While working in the second version of the system, I started to think that if musicians would not have a digital "pipe" to feed information into the system, they should at least be able to have some options of modifying the information they received from the painter. However, the traditional notated score that was used on the first version did not seem to be the appropriate method. Music scores do not give a lot of space for variation. Different possibilities were considered trying to solve the situation. One of the solutions was to create different kinds of musical representations. Each representation would give to the musician a different level of independence, ranging from the determinism of the Standard Music Notation, to letting the musicians create their own interpretations of graphical shapes. In addition, the possibility of creating scores for musicians that do not know how to read music seemed to be a nice option for inviting all kind of musicians to interact with the system.

Because musicians have the option of altering or modifying the information they receive or even generate a personal line of music, a natural interaction occurs. Since in this version musicians are not necessarily constrained to what is presented in the notated score, they can interact with the same conditions that traditional free collective improvisation offers. Musicians can choose among the different musical representations according to their wishes and abilities, and they can voluntary switch among windows. The musical representations on this version are:

- *The Score Window*. The top window of the interface shows the material that is sent by the painter in the Standard Music Notation style. This window would correspond to the window of the first version of IMPI; however, it was not fully implemented when the I decided to work on the next version. The musicians should know how to read scores, and he or she can not alter the information received.

- *The Sketch Window*. Below the score window there is another representation of the musical material. It was designed to preserve the musical intention and structure of the improvisation, but musicians are not required to know how to read music and they have a bigger frame for developing personal ideas. This representation of the music is, in many ways, comparable to the piano rolls; however, it also preserves similarities to the scroll window. Musical notes are represented with rectangles. The length of the rectangle represents the length in time, and its darkness represents the intensity of the note. Almost white rectangles represent soft notes and black rectangles represent louder notes. Notes are constantly scrolling from right to left, as occurs in the score window. The position of the rectangle in the Y-axis represents the pitch of the note. The lower part of the window indicates the lowest register of the instrument, and the high section of the window indicates the highest register of the instrument. Information runs from right to left.

- *The Drawing Windows*. Below the sketch window, between other two square windows, there is a white square area where the musicians receive only the graphical information that was intended to be directed to them. Musicians do not receive the final animation, but only the objects that were sent to the sub-ensembles they belong to. Musicians should use this graphical information in order to create a subjective acoustic representation of the visuals. Of all the representations, this is the one that offers almost complete independence to the musicians. Even with all the liberty that this option offers, it is expected that at least a slight intention of the structure defined by the conductor is still preserved.

- *The Messages Window*. In this window, the musician can receive information that does not necessarily have a symbolic notation, such as text. This window was not implemented when the I decided to stop working on this version.

- *The Animation Window*. At the right of the drawing window, there is another square white area where the final version of the graphics is presented. Its function is only to help the musician to see the development of the visual section in case they do not have easy access to the projection. This window was not fully implemented when the I decided to stop working on this version.

4.5.3.4 Audiovisual Mapping

In this second version, the relationships between the visual and the audio material started to be seriously studied. Taking some elements from the first version, discarding others, and trying to create complex but coherent audiovisual combinations resulted in the following mapping. As in the first version, all the information is created by the painter. One of the premises in building this version was the idea that the action of creating a drawing has a lot of expressive content that could be easily translated into the acoustic domain. Special interest was put in the analysis of the speed, pressure, and kind of shape.

- *Speed*. The speed and the changes in the speed while doing a trace have a lot of physical meaning, and a lot of gestural content. In music, rhythm is probably the element that is most directly associated with the movement of the body. Because of this similarity, this version of IMPI uses the speed and the changes in the speed when the drawing is created in order to construct the rhythm of the musical phrase. If the trace is slow, long notes are created; if the trace is fast, many short notes are created. Therefore, if the speed is constant a regular pulse is created; on the other hand, if there are changes in the speed, irregular pulses are created. The calibration of values for this parameter was a long exploration.

- *Color*. As explained in the previous section, the color is mapped to the sub-groups that share a musical idea. When the painter creates a sub-group, a color is assigned to it. Each time the conductor chooses to paint with that color, he is also sending information to the particular sub-group that owns that color.

- *Transparency*. As explained in the previous section, the transparency of the shape can be modified by a slider. The transparency of the shape determines the intensity of the musical phrase. The transparency can be dynamically modified with the pressure value of the pen, as will be explained in the next point.

- *Pressure*. It was at the end of the development of this version that the digital tablet was implemented. Before its implementation, visual transparency and therefore the intensity of the musical phrase were obtained by assigning the value in the slider. However, once the system had the option of using pressure as an input parameter, it was decided to use it with this intention. For this reason there are two ways to modify the transparency-intensity: directly on the slider, or changing the pressure of the pen over the digital tablet.

- *Trajectory*. The trajectory of the stroke is used to derive the pitches that constitute the musical phrase in conjunction with the rhythm from the speed and the dynamics from the pressure. The intention in this version was to avoid mappings that could be too obvious, too complex to perceive, or that do not offer the same result with the same input. A simple but potentially interesting algorithm, explained in the section 4.5.3.5*,* was developed.

- *Duration*. Initially, the time that it takes to create the shape was used as the total duration of the musical phrase. However, after some tests it was clear that the ratio should be modified because it was extremely hard for the painter to create enough strokes to keep enough musical material running in the system. The ratio was then multiplied by ten. Therefore, the time that it takes to create the stroke generates a musical phrase ten times longer.

4.5.3.5 Technology

4.5.3.5.1 The Calculation of the Pitches

For the creation of the pitches in each musical phrase, the contour of the stroke was employed. The contour of each stroke can be seen as a collection of sequential points (fig. 4-15). Each time that a new note is created the center of gravity of the current shape is calculated. The center of gravity is the point where it would be required to balance a surface on just one point. Some symmetrical shapes such as circles, ellipses, squares, etc. have their center of gravity exactly in the center. Irregular shapes could have this point inside or outside them. Getting the average of the X and Y values of all the points that creates the contour's shape gives the center of gravity. It is important to notice that this technique is not mathematically correct although it works for our practical implementation.

Each time that a new note was created, a distance was measured with the current center of gravity and the current location. The value of this distance was used to calculate a pitch. If the current location was close to the center of gravity, the pitch of the note was middle C; the farther the point was from the center of gravity, the farther the note was chromatically from middle C.

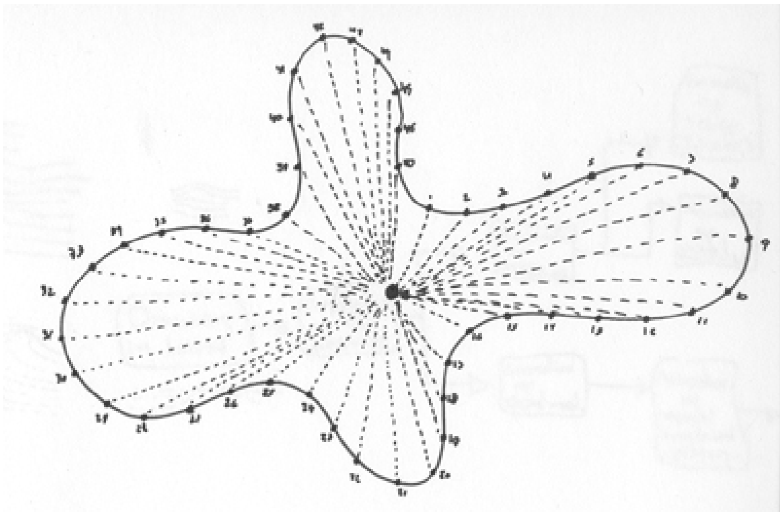

Figure 4-15 Center of gravity and distance from the contour

Even if in practice this algorithm did not seem to be effective enough, the idea of creating the pitches based on the shape of the figures seemed to be an interesting method for creating a link that is not as direct as other methods, such as using absolute values of the points.

4.5.3.5.2 Graphic Tools

4.5.3.5.2.1 Smoother

When a shape is drawn with the mouse or with the digital tablet an internal clock is constantly updating the current location of the device. All the points are in storage in an array, and then connected with straight lines. For many applications, the time resolution is good enough for creating the required amount of points in order to produce the illusion of a continuum. Nevertheless, if the drawing is created at high speeds, the velocity of the clock is not high enough, and the straight lines are observable. Since the clock speed is a limitation of the operating system, there is no easy way to modify it.

There are, however, some techniques for smoothing the strokes. Based on the work of Robert Sentinella [Sen04a] (fig. 4-16) who developed a java smoother, a method that corrects fast drawings was implemented in this version. This method analyses the distance between the points and instead of connecting them with straight lines it calculates Bezier curves. The control points for each curve are set according to the distance of the points. Because the math involved is not computationally expensive, the method does not consume CPU and can be used in real time.

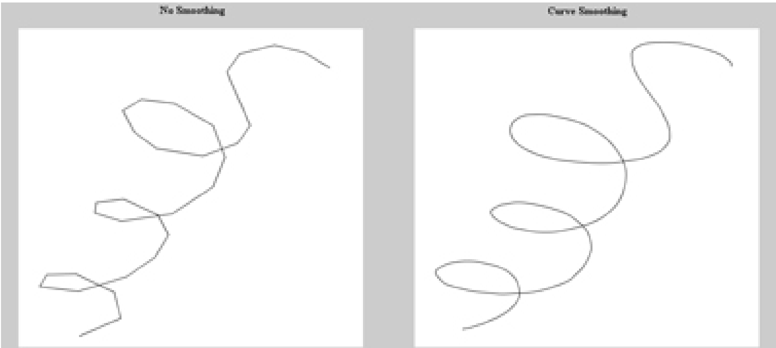

Figure 4-16 Smoother

4.5.3.5.2.2 Shape Analyzer

When the idea that transforming graphical objects could generate musical transformations was defined, the problem of how to analyze the drawing emerged. The amount of points that a graphical shape is composed of could be in the order of thousands. The shape needed to be vectorized in order to transform the collection of points into something more manageable.

By using the *Newton Raphson method*, a Delph program by Nils Haeck [Hae04] approximates an array of points and converts it into a collection of Bezier curves permitting the transformation of images (fig. 4-17). The code was translated into Java by Carlos Rocha and myself and implemented in the system. The method allows setting the desired level of approximation and the smoothness of the curves.

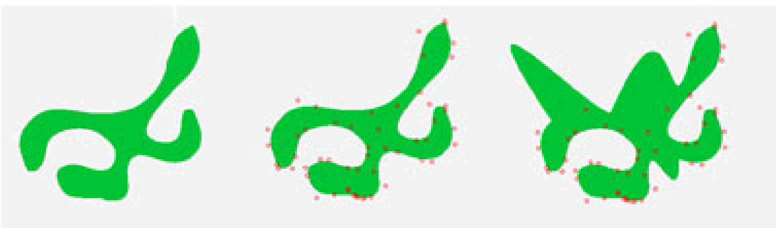

Figure 4-17 Vectorization and transformation of a shape

4.5.3.5.3 Cleaning Techniques

The signal generated by the input device, and some of the data used during the analysis of the information needed to be cleaned and smoothed in order to have meaningful value. Information such as speed and pressure of the pen over the tablet were passed over a first order low-pass filter.

.

$$y_t = c * x_t + (1 - c) * y_{t-1}$$

Where *t* is current time; and *c* a coefficient between 0 and 1

If we had not applied this filter, the input would have been very unstable, and there would not have been accuracy in the performances.

4.5.3.5.4 Scaling Techniques

Some of the values that were registered from the tablet were too linear to have a significant meaning. In order to make these values significant for the system, a curve scale was applied to the input.

$$y = \left(\frac{x - in_1}{in_2 - in_1} \right)^c * \left(out_2 - out_1 \right) + out_1$$

Where *c* is a coefficient between 0 and 1

The factor of the curve was calculated by a trial and error method and is open to be tuned in the future while the system evolves and is tested by more players.

4.5.3.5.5 Digital Tablet

A digital tablet was also implemented in this version and the interface works both with a mouse and the tablet. In order to have the tablet working with Java, a complete set of methods and classes were programmed. This tablet library is based on the library JWinTab by Jun Rekimoto [Rek04] developed at Sony Computer Science Laboratories, Inc. The library extends the Rekimoto's functionality and allows dealing with the tablet information in the same way that Java deals with mouse information; that is, using tablet events and listeners.

4.5.3.5.6 Networking

This version re-implements the network engine developed for the former version; however, there is now the possibility of sending information to particular subgroups and insolated members of the ensemble.

4.5.3.6 Observations on this Version

This version has several improvements compare to the first one. The coding of this version was a laborious process that involved the acquisition of new concepts and techniques. There are however several observations that can be made.

With the experience of Zorn's workshop (see Chapter 5) it was clear that the system had many features that, although interesting, were implemented in such a way that it took too much time to access them. IMPI is intended to be an interface to be used in a real-time context. There is no time to open windows and drag small elements if the intention is to have control over the material.

Another element that should be considered is the capacity of the system to distribute and develop the musical material for the ensemble. Although musicians have the option to create their own music, the system also covers the possibility of creating the music for all the members of the ensemble. This means that one person guides the entire ensemble. The input of a singe person should be enough to create the music for many instruments. If composing music is a process that requires diligence and calmness, composing music for many musicians in real time seems to be a complicated challenge. If coherently improvising as a player is, in most cases, a complex procedure, creating interesting improvisations for many musicians is even much more difficult.

IMPI does not try to be an algorithmic music generator; however, with the development of this version it was clear that future versions would require mechanisms for creating more material than what was produced in this and the previous versions.

The visual part of this version, however, is much more rich and interesting than in the previous versions. The use of shapes instead of lines, the gradual fade in and fade out of the shapes, the possibility of creating shapes with different level of transparency, and the possibility of queuing events in order to launch them simultaneously, were good improvements that makes the visuals potentially much more interesting.

4.5.4 Third Implementation

The experience of having developed the first and second versions, and having tested the second one with an ensemble of musicians in a workshop, strongly helped to define the characteristics of the third version. This version is closer to the ideal one, although there are still many features that should be implemented, rethought, or completely modified.

The most important change in this version was the approach to the visual and acoustic material. One of the important objectives in creating IMPI is the development of an interface with the fewer possible preconceived or pre-establish definitions. Therefore, IMPI tries to automate as few parameters as possible. However, the experience of the previous work has shown that it is very hard to create music for many instruments and a visual animation in real time defining only the basic and low-level structures. This version sacrifices some of this "complete control" of the material and predefines some relations and procedures. The details are explained in the *Audiovisual Language* section (4.5.4.4).

From the previous experience it was clear that creating phrases of the duration of the trace itself was not very efficient because the system consumed the material in a faster time than the painter could generated it, creating in this way bigger sections of silence. In this version, each trace generates a phrase with duration in proportion to the time that took to create but multiplied by a factor. The creation of longer sections of music implies the auto-generation of musical material. The way these materials are developed is determined by the "sculptures" created with two new windows.

Another important modification is the change in the procedure for generating the link between the audio and the visual elements. Whereas the previous versions uses elements of the graphical domain such as color or transparency of the shape in order to create the music, in this version the audio and the graphics both share a common element to merge them. These changes result in a system where none of the media are dependent on the other. Each media has its own set of techniques and procedures for development. It could be said that this relation results in the lost of comprehensible mappings, however because this technique also offers the option of low level mapping, the modifications are for the good of the final result.

This version simplifies many of the methods that the second version showed to be too complex for real-time situations. A significant addition was the creation of a window that represents information using a three dimensional representation. There are fewer windows, and the hand that was not employed in the previous versions controls some keys of the computer.

The audiovisual result is much closer to the ideal of the system. In the graphic part, filters and textures were implemented, and there has been more care in the way colors are generated. The music also follows transformations that are more organic.

In the technical aspect, many part of the code were modified for a better use of computer resources. All the techniques that were learned during the development of the former versions, such as filters and smoothers, have been implemented. In addition, the size of the windows with graphical renderings was reduced in order to allow the use of much more expensive graphic algorithms.

In addition, JSML [DB04] was now implemented in the code because it showed to be of transcendental value. JScore also substituted the score renderer that was used in the previous versions. This library is integrated in JMSL and offers most of the features that IMPI requires.

Finally, it is important to mention that this third version is a work in progress, and many changes are still under development. Before moving to another version, the current one must be finished.

4.5.4.1 Ensemble Configuration

The ensemble configuration of this version is essentially equal to that of the second version in the sense that only one painter is conducting the entire ensemble. Interaction between musicians is only obtained by acoustic methods outside the system. The flow of information in the system is unidirectional. There is no information send from the musicians to the conductor. The code that handles the net functionality from the previous version is essentially preserved (fig. 4-6).

4.5.4.2 The Painter

The painter interface suffered several modifications. In the previous versions, the window where the painter created the drawing was the same window that had the final graphical material. The initial hypothesis of having the current draw and the former graphical material in the same window is not applicable in this version. The levels of disassociation than can be reach between the trace of the gesture and the graphical rendering now can be so high that for this version it is much more coherent to have one window for tracking the original material and one where the result is rendered.

In the previous versions, the space of the digital tablet corresponded to the entire screen of the conductor. This means that the tablet was subdivided according to the distributions of the different windows of the interface. The configuration did not seem to be very efficient. When the user was working with one particular window, the potential space of the rest of the windows was wasted. On this version, some keys of the computer’s keyboard are used to select the desired window to be used, and the total space of the digital tablet is mapped to that particular window. In this way, the entire space of the tablet is always mapped to the active window.

4.5.4.2.1 The Graphics Window

The painter has a window with the final graphic material on the screen. This window (fig. 4-18) shows the animated graphic material that should also be projected during the performance. The player does not have control over it.

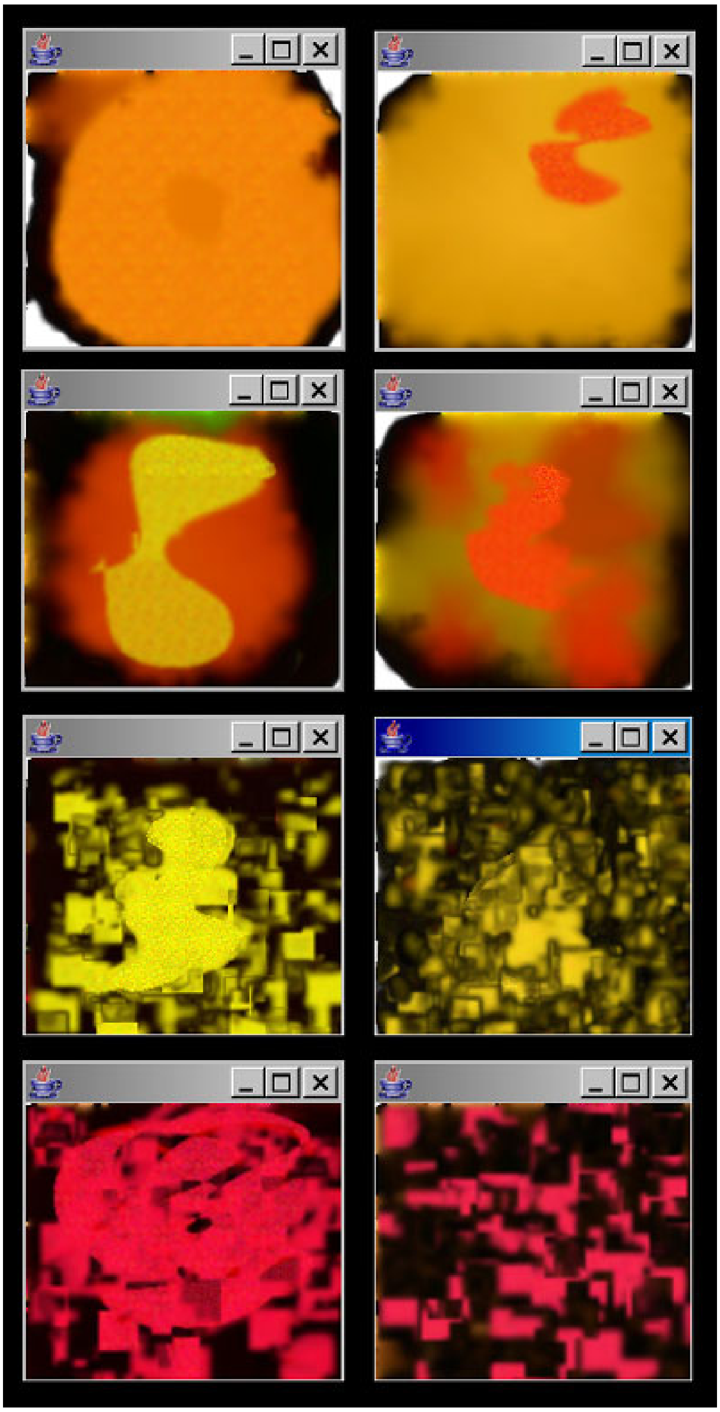

Figure 4-18 Snapshots of the graphic window

4.5.4.2.2 The Canvas Window

The canvas window is a small white area (fig. 4-19). Each time that the painter starts a new trace, the window is clean. When the drawing is being created, the trajectory is shown on the window with a thin black line. There is no need to have a cursor that shows the position of the pen because the total size of the window corresponds to the size of the tablet. It is selected by pressing F1 on the keyboard.

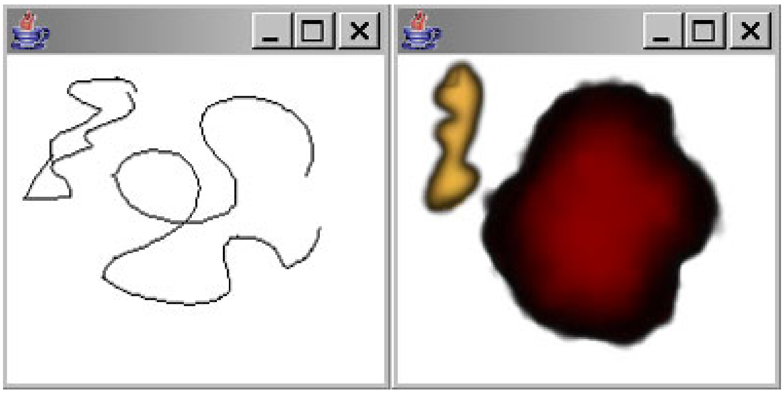

Figure 4-19 Canvas window and the result of the trace

4.5.4.2.3 The Ensemble Window

This version does not map the current selected color to a particular sub-ensemble. The relationship between color and instrumentation was not efficient. The technique for choosing the musicians that receive the information also changed. The user has to surround or at least touch the musicians' rectangles with a stroke. All the rectangles can be moved into any part of the window to create sections according to the requirements of the conductor. When a musician is selected, it is highlighted. A sub-ensemble remains active until the user re-activates the window. If no sub-ensemble is selected, the information is sent to the entire ensemble.

In a similar way to the first version, each time that a musician runs the program in his or her computer, a movable rectangle appears in the ensemble window. As soon as the musician closes the program the rectangle disappears from the window. This window is selected with the F2 key. This window is not currently implemented

4.5.4.2.4 The Regions Windows

Clicking on objects was a technique implemented on the former versions. However, drawing is the natural function of the digital tablet, and clicking was against the natural functionality of the interface. Instead of clicking, this version preserved the technique of drawing shapes to modify the parameters that determine the music and the visual material. These windows are used to define the visual and the acoustic regions. On these windows, the user draws three-dimensional shapes. The details about the notion of space regions are explained in the *Audiovisual Language* section (4.5.4.4). The window for defining the acoustic region is activated by pressing the F3 key. The window for defining the visual region is activated by pressing the F4 key. Currently, these windows are not fully implemented.

4.5.4.2.5 The Color Pallet Window

For purposes of testing, this version preserves the color window that was part of the collection of ensembles in the former version (see the color panel of the ensemble window in the second version). However, now it is not directly associated with any musical parameter, and is used only to define the main color for the creation of the drawing. The current color is preserved until a new one is defined. This window becomes active by pressing the F5 key. It is highly probable that the window will be removed when color becomes one of the transformation spaces controlled with one of the regions window.

4.5.4.3 The Players

The player's window preserves the strategy of representing the information in several formats to allow the user to choose and interpolate among them. However, these representations have suffered significant changes.

- *The Scored Representation*. On this version, the score render previously developed has been replaced by the Jscore package of JMSL [DB04]. The score does not scroll from right to left as it did. Now the note that is currently being played is highlighted by a yellow cursor. The cursor is the one that scrolls from left to right. As soon as the cursor reaches the end of the window, new material is created in the window and the scroller is rewound to the beginning of the score material (fig. 4-20).

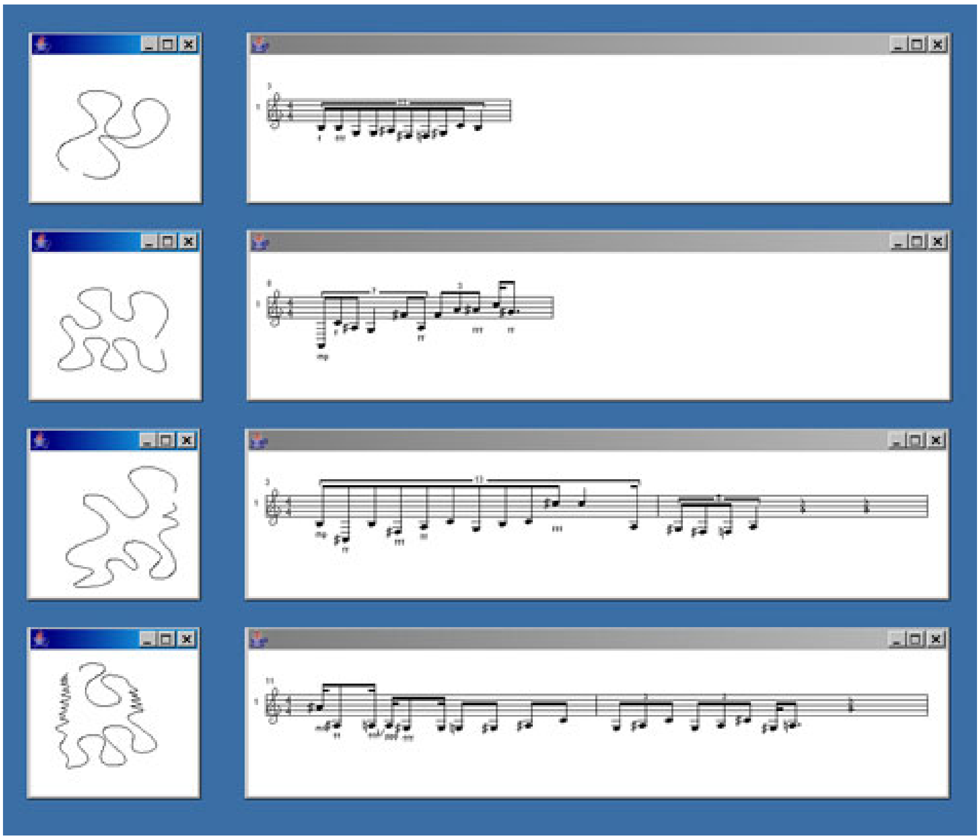

Figure 4-20 Score windows with their generative traces

- *The Personalized Graphics Window*. In this window, the musician receives a graphical representation of the information that is directed to him or her. Multiple musicians could receive the same information if they belong to the same sub-ensemble. However, because these sub-ensembles are constantly changing, each musician ends with different graphics.

- *The Main Graphical Material Window*. The musician has in the screen a small window where the main graphical material is presented, just in case he or she does not have access to the projection.

4.5.4.4 Audiovisual Language

There are several decisions that still have to be made about the audiovisual language and the mapping that will be finally used in the version under development. However, important characteristics are already defined and should be pointed out. The most important change is the disassociation of direct mappings between the audio and the visual material. In the previous versions, some musical elements were subordinated to graphical parameters, and none of the musical elements affected the graphic expression in any way. Direct relations were discarded with the belief that each media should evolve without interfering with the other in the low level mapping. The audiovisual dialog between the visuals and the music should come for the creation of tension and relaxation of bigger structures in time. The level of recognizable synchronicity between events of both domains is the main aesthetic goal and the field of research.

The digital tablet is still the method for inputting information into the system. This means that the information generated at the moment of creating the strokes continues as a fundamental part of the algorithm that generates the information. However, in this version, the tablet is not used only to generate new material but also to transform the information that is already present in the system. This is obtained by a new and more complex paradigm for the creation of the audiovisual material that involved the use of two windows with different functionality. The hypothesis is that the control of low-level relationships with the canvas window was extended by the control of high-level relationships with the regions window, and would allow the creation of coherent and interesting material at the same time such that both audience and performers could understand the audiovisual language.

4.5.4.4.1 Low level Structures and the Canvas Window

The canvas window preserves many of the characteristics of the previous version. There are also some modifications. The parameters generated by the digital tablet are mapped as follows:

- *Speed*. This parameter is kept from the former version. If the trace is slow, long notes are created; if the trace is fast, many short notes are created. Therefore, if the speed is constant a regular pulse is created; on the other hand, if there are changes in the speed, irregular pulses are created.

- *Duration*. The duration of the trace defines the duration of the musical object. In the future, this object will be repeated with gradual morphologic transformation based on the three-dimensional structure of the *regions window*.

- *Trajectory*. This parameter is kept from the former version. The trajectory set the pitches to be used. However, the value of the trajectory is now combined with the tilt to create the final pitch. The code was improved. The center of gravity is not the average of the previous points at particular moment, but the average point of the entire collection of points.

- *Pressure*. This parameter is preserved from the former version. It defines the intensity of the gesture.

- *Tilt*. The tilt value is used to define the register of the note to be generated. The trajectory defines the note (C, D, E, F, etc.) but the tilt assigns the region (C2, C3, C4, etc.).

4.5.4.4.2 The Medium Level Structures and the Regions Windows

The regions windows and its features have not yet been implemented. However because they were conceived when this version was designed, they should be described. A region refers to a segment of the total space represented in the window. The meaning of this space is different for the visual and the acoustic domain, but in both cases this window will represent a three dimensional space. The region will be defined with the digital tablet. These windows will define the region that will be affected by the trace created on the canvas window. Because the intention of these windows is to set the behavior of high-level relationships that work over long periods of time, ephemeral information such as speed will not be employed on this window. Location and pressure of the pen are the only two parameters that will be employed to create the regions. The location will set the x and y values. The pressure will set the z value of the specific point. Drawing on the tablet will generate a 3D map. Ideally, the system would interpolate between points in order to create smooth shapes. The regions would be visualized as three-dimensional sculptures. They can be seen as the macro-controllers of the material already created, and also as the material that is created with each new trace (fig. 5-2).

4.5.4.5 Graphic Textures and Filters

The use of textures and filters was implemented in these versions (fig. 4-21). They were shown to be interesting and expressive methods of generating organic and smooth transformations of the image. Reapplying the same filter repeatedly to an image in regular periods of time helped bring life to the graphical material and break with the static geometry of the previous versions.

Textures are easy to implement with the Java2D API. Filters, on the other hand, require more programming steps and should be carefully designed if they are to be used in animated images because they use a lot of the CPU time. Initially, the filter library of JH Labs [Hux04] was employed. However, for exploratory reasons and because of slight incompatibility with the new paradigm of image processing in Java, I decided to create the filters from scratch.

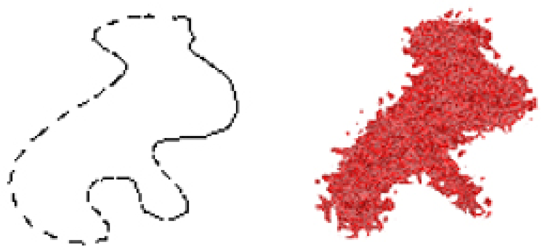

Figure 4-21 Shape with texture and filter

4.5.4.6 Observations on this Version

The most important observation of this version is that it should be completely finished and tested if a real judgment is to be made about it. First, the idea of using 3D maps as macro-controllers has to be explored and tested. In the case that this strategy was shown to be a malleable method for creating and manipulating information; then, its behavior should be further extended to new domains: color in the visual domain, and instrumentation in the acoustic domain. Dynamics maps where the meaning of the dimension could be interchangeable should also be tested. If it is true that the “sculptures” help to visualize and manipulate big musical and visual structures, then perhaps the sculptures should be treated as objects in the space and it would be interesting to be able to rotate, transform, and displace them. However this exploration is, at the moment, out of the scope of this thesis.

In the near future, it is important to find an interesting method that allows the inclusion of the color variable and the sub-ensemble combinations as part of the dynamic spaces. Currently, it seems that these two windows remain without aesthetical justification. Removing these windows and embedding the values that they produce into the some of the region windows would be beneficial, not only practically but also conceptually.

In the technical aspect, it is important to implement some features that are not necessary in a research context, but that will be indispensable for the use in a real performance. First, the window with the graphic material should be redirected to an alternative graphical context that could be sent to an auxiliary video output. This second video context should be rendered in a full-screen configuration in order to project it without disturbing frames.

There are also slight additions that could make the system a much more robust piece of software. Details such as indicator of which is the current active window, and routings that automatically detect the resolution and size of the screen, are factors that are required if we want to create a stand –alone application. Other details that should be implemented are the right use of clef in the scores, and other notation elements of the score in the score window of the players.

Chapter 5

Evaluation, Future Work, and Conclusions

"Cinco desde aquí te brinco…"

In this chapter, a general evaluation of the Improvisatory Music and Painting Interface highlighting its qualities and defects is presented. An evaluation of its use during a workshop is also described, and possible future paths that the system can take are analyzed. Finally, a conclusion that includes thoughts about the entire experience of creating, implementing, and working with the system closes the thesis.

5.1 Evaluation of IMPI

IMPI is a musical interface for improvising music with an ensemble of acoustic musicians, thus, the only real method of evaluating the system is in a musical context such as a concert or presentation. Currently, only the second version of the system has been tested as will be described later. As soon as the third version is finished, it will also be tested and a new evaluation done. In the previous chapter, each version is evaluated separately in relation to the other versions. On the other hand, in this section, several aspects of IMPI are evaluated taking the entire process of designing, implementing, and testing the system as a unit.

5.1.1 Development

IMPI has been developed over the period of a year. Of that year, the last six months were intensely devoted to the project. The creation of the first version helped to improve the Java programming. It also helped in learning some of the packages and libraries, and the IDE that were used to create IMPI. During the creation of the second version more graphic techniques and the networking packages were learned. In the last version advanced graphic techniques and strategies for optimizing the program were developed. In general terms, there has been an significant degree of progress in the design of the system observable if we compare the results between the first and the last versions. In addition, the acquisition of technical knowledge used in the realized work will help for future development of the project.

5.1.2 Technology

Of the technical domain, several observations should be pointed out. First, Java turned out to be efficient and versatile, the language and its libraries worked as expected. In addition, it offered the possibility of easily expanding the system. However, as will be described in the section *Future of IMPI*, several technologies could be considered in future implementations of IMPI, for improvements with speed, scalability, etc. Second, the digital tablet proved to have expressive potential once the user mastered it, which is a fairly natural process considering that drawing is a common activity for humans. However, it was also clear that the tablet is not the ideal method to generate gestural information, especially if there are intentions to create three-dimensional information. Third, during the John Zorn's workshop there was some loss of information between computers which shows that the networking engine still needs to be improved.

5.1.3 Aesthetics

Obtaining interesting aesthetic results is the most complicated part of a project such as IMPI. It is only the rest of the problems have been solved that a creator can really start the process of calibrating the subtle behaviors of the system and see if all the planned hypotheses are indeed correct. After all, the entire work has the final goal of creating an experience that could expand the perception of the person that receives the aesthetic message.

In the first version of IMPI there were no aesthetic intentions. It was a prototype to solve technical challenges. The second version tried to create meaningful results. After being finished, and after testing the version during the John Zorn's workshop, we could see that some of the premises were right and worked nicely, while others did not work as expected. Some sections of the material created during the workshop do cross the line between being a technical experiment and being a work with meaning. Unfortunately, the brief moments that were interesting did not reach the consistency to create an organic work. The third version has much more content and meaning in the ideas transmitted. Even if this version has not been tested and is not completely finished, we can observe from what has been developed until now that the flow of the ideas that can be created is deeper and could create more expressive audiovisual material.

It is also important to emphasize that IMPI is an interface that has its own syntactic rules and techniques of performance. The possibilities and the limits of these have to be learned, mastered, and finality assimilated into a personal language in order to seriously evaluate the aesthetic capabilities of IMPI. Until now, nobody has done this and it will not happen until a robust version can be use on a professional basis.

The workshop with John Zorn has been the only experience until now where IMPI has been tested in a real musical context. Without considering the technical limitations of the version and independent of the absence of knowledge of the interface, aesthetically speaking, the experience was an extraordinary context to see the effects on the audiovisual relationships. The most important observation is that the graphics (which still need to be improved) must match the level of complexity that an ensemble of improvisers could generate in the musical domain. There is an inconsistency between the two domains that does affect the appreciation of the work.

5.1.4 Use of IMPI at John Zorn's Workshop

At the end of March 2004, the Media Laboratory hosted the visit of the composer and improviser John Zorn. During the visit a colloquium and workshop with the *Performance with Experimental Musical Instruments* team were realized. In the workshop each member played the instrument that he had designed and several collective improvisations were developed and recorded. The experience was guided by Zorn who contributed constant comments and suggestions to help to improve the improvisations.

On the last day of the workshop, the second version of IMPI was tested with the entire ensemble of six musicians and myself as the conductor. Each of us had a computer so that the musicians could read the scores and I could generate them by drawing with the mouse and the digital tablet. Once the system was set up I explained to the musicians how they should read and interpret the different representations that they had available on the screen. Most of the musicians did not know how to read traditional scores, so it was not a problem that the score window was not fully implemented at the moment. At the same time, this helped to test IMPI as a shaper of form and guider of ideas more than a creator of finished music.

Several improvisations were performed using IMPI. In the first one, most of the musicians decided to follow the sketch window which caused a low-density improvisation. Musicians produced an insolated note for each rectangle that appeared on the screen. Their concern for catching the next rectangle on time made them forget about other musical elements such as intensity and pitch. As for my part, I did not have enough time to feed the information at the speed it was being consumed. In order to maintain a good speed in the generation of information I stopped changing ensembles which meant all the musicians were getting the same information. In addition, I was so concerned about generating information to fill the sound space that I did not pay attention to the structure of the improvisation or in the subtlety of the graphical result.

After the first improvisation, we had a discussion and agreed that the musicians should put more attention into the draw window and expand the dynamic range because they were not completely precise with the information about the intensity. We concluded also that I should be more aware of the general shape of the improvisation.

After the discussion, other improvisations were performed with gradually better results. Since musicians created musical ideas based on the drawings instead of notes according to the sketch, IMPI worked more as a shaper of form than as a generator of musical content. It was interesting to see that during the performance, the improvisatory language was preserved at the same time that some moments of silence and solo sections were easily created.

At the end of the improvisations, a discussion took place where John Zorn and all the musicians gave their impressions. Zorn said that given the audiovisual systems for live music applications he was familiar with, IMPI posed one of the most interesting musical paradigms due to the multi-representation of the musical content. The musicians of the ensemble described in detail their impressions. The general agreement was that the graphics reduced their attention to the performance of other musicians, which is something fairly common when musicians work with scores that they do not know in detail. The discussion helped to point out that some of the mappings were in fact, interesting and potentially expressive, and some parts of the design of the musicians' and the conductor's interfaces should be modified. It also showed that the system requires careful study by the conductor and musicians in order to generate coherent results, such as consistent interactions between musicians and stronger relations between audio and visuals.

Figure 5-1 Musicians during the workshop

5.2 Future of IMPI

The creation of audiovisual systems for performance is an unlimited exploration which means that IMPI could be extended and modified indefinitely. Currently, IMPI has interesting features and a unique way to approach the audiovisual creation. However, IMPI is not a finished system, many details could be modified, many features improved, and new options implemented. In the first subsections of this part, isolated and objective possibilities are analyzed; the last sub-section refers to an ideal but feasible system.

5.2.1 Interactivity

IMPI is an improvisatory system that coordinates an ensemble of performers in order to create a final audiovisual work; however, in all the implemented versions just one person has control over the rest of the ensemble. A contradiction in this situation must be analyzed. Musicians could not influence other musicians with the tools of the interface and they do not have control over the visual part. In a future version, it would be interesting to modify this kind of interaction within the members of the ensemble. In Chapter 2, the configuration of different kinds of ensembles was presented. The implementation of some of these configurations, or the creation of a system that allows free transitions between those configurations should be considered for future version of IMPI.

5.2.2 Static versus Dynamic Role of the Performers

One of the possibilities that was seriously considered was the option to make dynamic roles in the ensemble. In this configuration all the members of the ensemble would be able to voluntarily switch between playing the role of musician or painter during the piece. The final result would be a product of the constant interaction between all of the members of the ensemble.

5.2.3 Representation of the Music Information

The first version of IMPI presents the information that the conductor sends to the musicians as a traditional score. The second version offers them four representations: score, sketch, drawing, and text. All four representations are available at the same time for the musicians. In the last version the material is represented as a score and also as a personalized drawing simultaneously.

For future versions of the system, other kinds of data representations for the performers should be considered. There is no doubt that Standard Music Notation is an efficient method to represent musical material and probably should be preserved in future versions. It is also true that most professional musicians usually have the training required to read scores. However, there is information that is better transmitted with other kinds of representations. It would be interesting to take further the current idea of representing the musical data as sketches and drawings and to take full advantage of the graphical capabilities of the computers to generate meaningful, compact, and understandable representations. 3D maps are one possibility to consider.

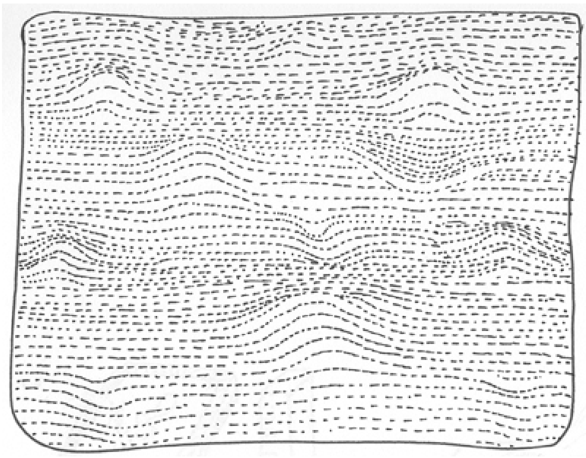

Figure 5-2 Sketch of a 3D map

Another element that should be carefully designed for future versions of IMPI is the accessibility of the different representations. Whether or not the different representations should appear at the same time on the score of the musicians might seem like a trivial issue; however, the decision about how to show the representations is important not only for design reasons, but also for the possibility of creating subjective interpolations between representations.

5.2.4 Audiovisual Relations and Processes

IMPI has a set of audiovisual relationships that control its behavior. These relationships were created and lead by an intuitive process of trial and error. There was of course a systematical study and organization of the ideas; however, the decisions regarding which parameters should be mapped to others, the presets values, the ranges, the morphing algorithms, the kinds of graphic filters for many other elements were determined by experimentation.

In the last version, an exploration of the use of three-dimensional structures was initiated. If three-dimensional objects and the manipulations of the “sculptures” are comprehensible metaphors for manipulating high-level structures of the audiovisual language, these representations should be deeply analyzed and extended. In addition, a deeper exploration about how to manipulate the information should be done. Traditional techniques such as Markov processes could also be investigated.

5.2.5 Different Audio Results

IMPI is a system that merges two different kinds of materials. On one hand it creates digital graphics; on the other it works with acoustic instruments. The situation leads to some observations.

Currently, IMPI works with acoustic instruments, and this is one of the nicer qualities of the system. While most computer systems work with electronic sound, IMPI is creating music with acoustic instruments. However, the possibility to include real-time processing of the instruments is a temping option. Including the sound pallet of electro-acoustic music into IMPI could be an interesting exploration and could help to create organic relations between the sound and the digital graphics.

Another option to consider for future versions is the inclusion of a third category of performers that could work entirely with electronic sounds. These performers and noise players would use computers to design, process, and launch synthetic sounds or prerecord samples.

5.2.6 Different Visual Results

Although digital media offers the option to generate animated material in an easy way, the option of creating static digital paints should also be considered. The audience would see how the paint is being created in the analog way that a real painting is developed. However, there would not be any temporal transformation of the graphical objects already displayed on the canvas. Eliminating the time dimension in the graphical domain would necessarily lead to a different kind of relationship between the graphics and the music.

Without the dialog in the time domain the relationship between the graphic and the audio domains would be more subjective or at least would exist only in higher levels of correspondence. If the gesture for creating the drawing would be lost just after the object is created perhaps the relationships should be based more in the content and meaning of the drawing than in the gesture of its creation.

Modifying the graphical output of the system and creating not a digital rendering but a real painting is another option to consider. The hardware challenges to create a system that could create paintings in real time are large and there are many approaches to the idea. I could imagine, for example, a big plotter that could spread oil paint over a canvas, or a robotic arm that could hold a spray-paint tube and move it around a wall.

5.2.7 Different Kind of Inputs

Even though a digital tablet is a powerful interface, another kind of input could be explored. An attractive alternative is the *Phantom* “haptic” device by SensAble Technologies (fig. 5-3) [Sen04b]. This device allows the generation of 3D information with an input arm that could apply dynamic resistance to the movement which means that virtual sculptures could be shaped. Alternatively, other kinds of 3D input devices could be tried such as the *Digital Baton* by Teresa Marrin [Mar96].

Figure 5-3 *Phantom* device by SensAble Technologies

Another possible modification in the input of IMPI is to track the activity of an analog painter instead of using a digital device. The technical challenges for these kinds of systems are not trivial. One possibility for solving this would be the use of motion tracking technologies. Painting on a transparent surface such as glass or acrylic and installing a digital camera on the opposite side from where the performer is applying the paint could be an option. A computer should be constantly analyzing the digital image obtained from the camera and creating meaningful information such as speed of the trace, color, or kind of shape.

5.2.8 Other Languages

During the development of IMPI, the latest version of Java was employed for all the reasons presented in Chapter 4. However, special care had to be taken in order to deal with the speed limitations of the language, especially in the graphics domain. The alternative of developing the system using C++, Pure Data [Puc04] & Graphics Environment for Multimedia [Dan03], or Cocoa should be considered. For faster rendering of more complex graphics the alternative of using OpenGL should also be taken into account.

While IMPI was being developed, Java underwent many improvements that could help for future implementations. Java now has the option to create full-screen applications; it has direct access to native graphic methods of the system, and version 1.5 (currently in Beta stage) offers support for hardware-accelerated rendering using OpenGL.

5.3 Conclusions

Important conclusions can be reached from the creation of IMPI. Some of these conclusions are only from this particular system and others are generalizations of the audiovisual language derived from my involvement with such a language. In both cases these conclusions are not intended to be “absolutes”; rather, they are based on my own experience, observation, and aesthetical principles. I hope that future creators and performers of audiovisual and/or improvisatory systems could take some of these conclusions (and also the rest of this document) in order to expand or reaffirm their own ideas.

This thesis presented some principles of the improvisatory collective musical language and the paradigm of musical notation of such a language. It gave a summarized theoretical framework for musical and graphical creation, and it related the production of acoustical musical material to the creation of digital animation in a search for a unified audiovisual expression. By describing the different stages and versions of IMPI, the thesis also illustrated technical challenges that were presented during its creation. IMPI is not finished and several options for its future development were described. Much of the work entailed generalizing musical and graphical ideas and searching for the aesthetical meaning of the technical decisions.

I consider, after having developed this system, that the artistic explorations that try to push the available technologies into unexplored regions should always place the artistic intention first. It is, believe it or not, the hardest task to do in the art-technology paradigm.

Even though audiovisual expression has a long history and many people have worked in the field, a system that relates the material in the way IMPI does has not yet been successfully developed. However, it is highly probable that with the continuing expansion of the available technologies, the popularization of computer languages and libraries, with the work of many musicians and computer scientists, several systems that relate collective improvisation, abstract visual animation, and alternative input devices will emerge. IMPI will be part of this work. Let us hope that each artistic proposal will be unique and transcend the stamp of its technique.

As a creator and as a spectator, I am still looking and working towards an audiovisual experience where the integration of the acoustical and visual elements are indeed aesthetically meaningful; where a group of musicians could freely improvise to create an organic work full of surprising events, gradual transformations that reach an end, textures that converge and diverge in a dancing manner, timbres that melt into other timbres; where the visuals mimic a constant fluid of vivid objects that could be inactive and suddenly sparkle, where sharp movements gradually become a delicate undulating gesture.

On a personal level, the experience of having conceived IMPI, having performed the research in the theoretical and technical fields, having learned some of the knowledge that is required to create digital art, and finally having started the system and reached its final state was a rich and invaluable experience that will significantly influence my future work.

Appendix: Previous Work

"Seis otra vez.
Siete martillo y machete.
Ocho te lo pico y te lo remocho.
Nueve copita de nieve sabor a…
Diez lávate los pies.
Once caballito de bronce.
Doce la viejita tose.
Trece el rabo te crece.
Catorce la viejita cose.
Quince el diablo te trinche."

As described in Chapter 1, the idea of creating IMPI is the product of mixing several interests that I have had for a long period of time. Some of these interests have been musical, some visual, and some technological. On this section, different works and projects that led and influenced the IMPI system are chronologically described.

A *Siderales* Performance

My first experience in the audiovisual domain was as a performer. In 1999, the composer Mauricio Rodriguez wrote the piece *Siderales* for light and electronics [Rod01]. In this piece, one single performer uses a synthesizer for playing the electronic audio material at the same time that he or she controls four lights that are located around the public and also a couple of stroboscopic lights. With the keyboard section the player triggers the samples that make up the piece; with the sliders of the keyboard, the performer graduates the intensity of the lights and triggers the stroboscopic lights. For appreciation of the visual part, the hall must be in total darkness.

The score (fig. A-1) has one additional staff for the light information, and it is possible to observe and analyze the level of integration between both domains. Among the most interesting ideas of the work is the piece's conclusion with 30 seconds of light material without sound. In this section the audio memory of the listener would resonate with the help of the lights. Whether this intention is obtained or not is arguable; however, the composer's search for an integrated language is remarkable.

This project influenced IMPI in the idea of searching for methods where different types of information could be integrated and manipulated as a whole.

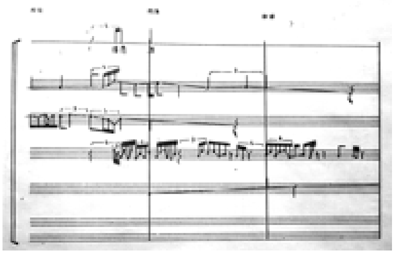

Figure A-1 *Siderales* score by Mauricio Rodríguez

B NICROM

One of the most important contributions to the creation of IMPI came from the experience of having worked with the trio NICROM. In 2001, I founded and played in a trio for improvising electro-acoustic music with action-painting. We were two musicians and one painter. Rodrigo Garibay played wind instruments, I played synthesizers and effects processors, and Mauricio Zárate experimented with watercolor and oil.

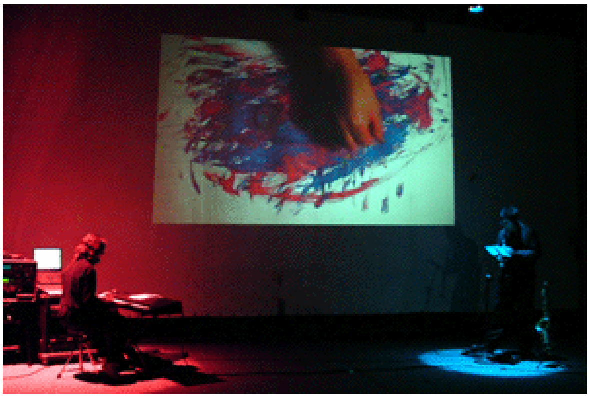

Figure B-1 NICROM presentation

The concerts consisted of a one hour-long free improvisation session with a projection on stage of the material that the painter was creating in real time (fig. B-1) [Sol04b]. The relationship between the audio and the visual material was subjective and based solely on the human perception of the members. It was, in this way, a human feedback between both mediums: The painter listened to the acoustic material and used it to continue the painting; the musicians looked at the painting and used it as a base from which to generate music.

The kind of graphic language that the painter created was abstract and a lot of emphasis was put in the use of color (fig. B-2) [Sol04a]. The *gesture* used in the creation of a stroke was an important criteria in relating the visual element with the music. This relationship got lost as soon as the stroke was finished but the final painting preserved at least in a subjective way the acoustic intention.

The music that was produce was, in general, non-tonal material with a strong emphasis on the timbral quality of the music. Many parts were also noisy with irregular and inconstant rhythmic patterns. The clarinet and the saxophone were digitally processed in conjunction with the electronic material created with the synthesizers and the computer.

Because there were no agreements before the performance and all the decisions were made during the concerts by a subjective interpretation of the material, the level and type of interactions between the members varied freely over time. There were not assigned roles. At any moment one member could be leading the improvisation, and later on be guided by other members. Sometimes there was no clear leader, creating in this way a segment consisting of three independent lines.

Figure B-2 Four paintings by Mauricio Zárate during a NICROM concert

During a concert, between 15 and 20 paintings were created and about 10 musical ideas developed. Some moments of the performance used to be solid and coherent but there were also segments where there was not any recognizable idea. Even though the transitions between segments were smooth and fluid, the general shape of the improvisation was on many occasions uninteresting. It was this lack of control over the big structures that made me think of the idea of creating a system that could help in creating better-structured audiovisual improvisation.

C GAB

GAB is an electronic system that allows the reinterpretation of musical material in real time by a pianist improviser [Sol01]. GAB was the first main system in which many of the technologies that IMPI used were explored. Some of the contributions of GAB to IMPI are in the technical field, because of the exploration of JMSL [DB04], and others are in the improvisatory field, because of the research in the algorithms for the transformation of the music.

Figure C-1 Interface and controller of the GAB system

GAB was designed to be used by a pianist during the performance of musical improvisations. The system consists of a computer program written in Java that performs all the mathematical calculations required to produce the reinterpreted material, and a small controller enabling the pianist to modify the variables of the system (fig. C-1). GAB attempts to combine the design and use of musical instruments with improvisation as a creative means of expression.

i) Characteristics

GAB is composed of a software program and a hardware device. The software is a Java program that reads the input data in MIDI format; analyzes this information; creates new material according to some algorithms; and finally outputs the new material on several MIDI channels. The algorithms create the new material based on a set of modifiable values that are established in real time with the controller.

The controller is a device designed to manipulate and control the software of the system. It uses a *BasicStamp* microcontroller in order to read the values of the different potentiometers and convert them into a digital signal formatted according to the MIDI specification. It contains eight knobs and eight ¼ inch plug-ins to connect variable controllers such as dynamic pedals, pressure sensors, light sensors, etc. It sends 16 signals containing continuous MIDI messages in a fixed channel.

The objective of the system was to create a tool that enriches the pallet of possibilities that a pianist performer could have when an improvisation is developed. The intention was that the acoustical result would be completely dependent of the material of the input material. In this way, the system would expand the particular language that the musician would be using. The intention was not to create a random generator with autonomous processes, but more an accompanying device. GAB can be thought as an ensemble of virtual pianists that can create variations of the original material.

D Gestures[1]

Gestures is a piece written for two trumpets, two violas, two trombones, double bass, and six electronic devices called "Shapers." It was performed as part of the Toy Symphony concerts in April and May of 2003. The piece is the result of a close collaboration between Natasha Sinha, a 13-year-old composer and myself.

Creating Gestures was a four-month project, and the piece was finished just before starting IMPI. The process of carefully planning a score where improvisation and interaction between members is crucial had a serious influence on the way IMPI was designed.

The compositional process of Gestures involved the use of graphics to represent acoustic ideas. Searching for ways to graphically represent acoustic images was also an element that was reanalyzed in IMPI.

i) Toy Symphony

Toy Symphony, a project directed and developed by Tod Machover and the Opera of the Future Group at the MIT Media Laboratory [Mac03a], is an educational project that employs new technologies as a vehicle to teach music to children of different ages and different levels of musical skill. "The Toy Symphony project [Mac03b] provided an integrated series of activities as an alternative entry for children into music. Rather than develop new tools and technologies in isolation, we imagined Toy Symphony as a program of on-line and on-site workshops, conceived as collaborations between our Media Lab team and international symphony orchestras. A major public concert was the medium term goal of each Toy Symphony event, while various activities could also be made available on a longer term basis to local children" [Mac04]. As of August 2004, Toy Symphony has toured in Berlin, Dublin, Glasgow, Boston, and New York. In each city, the first stage of the project consists of workshops and open-house sessions where children and audience members are able to try out a variety of Music Toys: specially designed hardware and software, such as Shapers, used by children to perform and compose music. This week-long series of intensive workshops is followed by a final orchestra concert where children involved in the workshops perform with professional musicians using the Music Toys.

ii) Shapers

Shapers are MIDI devices developed by the Opera of the Future Group mainly by Roberto Aimi, Margaret Orth and Gil Weinberg [Wei00, Wei01, Wei03]]. They are soft, spherical musical instruments made of a squeezable material, five inches in diameter, covered with bright fabric, and decorated with attractive embroidery (fig. D-1). By squeezing the instrument with both hands, children can alter sounds in a way that allows them to access high-level musical parameters such as contour, timbre, density, and structure. The mapping of these values to musical ideas is produce by Max/MSP [Cyc04] software running on a Macintosh.

The Shapers have been used in different roles in two pieces. In *Nature Suite* by Jean-Pascal Beintus, the Shapers are employed to play different sound effects corresponding to different seasons of the year.

[1] With some changes, this section was presented as a paper in the "III Encuentro Internacional de Música Electroacústica" in Brasilia University. November 2003 [Sol03a].

The Shapers are versatile instruments that can be programmed to control a diverse spectrum of musical elements. In *Gestures*, the idea was to use the instrument in a context that better exploited its malleable and gestural nature.

Figure D-1 Music Shaper

iii) Characteristics of the Piece

Gestures is intended to be a piece where children could collaborate without being worried about technical issues with professional musicians in a performance setting. Children would not only learn and realize the importance of listening carefully to other players during a performance, but also become conscious of how their own decisions could influence the general evolution of the musical material. The piece was inspired in this way, at least in its conception, by Luigi Nono's *La Lontanaza nostalgica utopica futura* for violin and eight audio channels. From Nono's work originated the idea of composing a work where musical thoughts were only suggested and where volume and sound density were never going to exceed the threshold of the semi-darkness and distance.

Gestures is a five-minute piece composed in collaboration with Natasha Sinha, a 13-year-old composer. It was originally conceived for six shapers, two trumpets, two violas, trombone, bassoon, and double bass. However, due to acoustic and logistical reasons, the bassoon was replaced by a second trombone. Since the six Shapers were supposed to be played by children without musical training, we did not want to create a score that specified when or what they had to play. We wanted to create an acoustic experience where children were free to play whatever and whenever they wanted without any constraints during the entire piece. However there were some options and rules all the performers, children included, had to respect in order to allow the piece to flow smoothly and maintain a coherent structure even with the freedom of the Shaper parts. After the initial trials with children, we realized that total freedom for children so young (6-7 years old) was unrealistic for the amount rehearsal time we would have for the piece. In addition, the score was more complex to coordinate than expected. For these reasons we decided to create a score where Shaper parts were described as opposed to completely undirected. Furthermore, we decided to use a conductor to coordinate the acoustic and Shaper players.

For the performance, Shaper players are located on stage in a single row with the double bass in the middle. The rest of the acoustic instruments are arranged in the audience space in a pre-established configuration. As the performance of the piece progresses, the musicians move around following fixed routes defined in the score. The hall must be dimmed enough to leave the off-stage musicians in semi-darkness, and the stage must be illuminated but not too bright to the point of breaking the atmosphere of the hall.

Although the double bass was not conceived of as a solo instrument, it is naturally highlighted due to its fixed onstage presence. The sounds produced by the Shapers are electronic variations of acoustic instruments used in the piece. These variations, realized in the studio, are traditional processes such as reverb, delay, flange, granular synthesis, pitch-shifting, time stretching, etc. Two Shapers produce electronic variations of trumpet sounds, two others produce viola sounds, and the last two produce trombone sounds. During the performance these sounds are morphed in real time according to how they are squeezed by the children. Amplitude, density, and quality of the texture are some of the parameters children may manipulate with the Shapers.

iv) Collaborating with a Young Composer

Natasha Sinha was invited to collaborate in the Toy Symphony project in November 2002. Natasha was a 12-year-old composer who started playing the piano at age five and composing at age seven. She has won prestigious awards such as the ASCAP Foundation Award, and now has a considerable creative output that includes solo pieces and music for small and large ensembles, all of them written in traditional forms using established techniques; it is important to note that none of her pieces prior to the collaboration employed electronics.

The main task of this pedagogical project was to teach Natasha new perspectives and techniques, both acoustic and electronic, without dampening the freshness of her perspective. During the first meetings, I realized that although Natasha had had many years of musical training and guidance, she had not been exposed to contemporary music.

v) The First Sessions and Initial Exercises

We spent a few sessions listening to and commenting on pieces composed by interesting contemporary composers that had some bearing on the project. The listening sessions were always done with the score in hand because notation was an important issue we had to deal with. Of particular interest were Berio's Secuencias for trombone, viola, and voice and Luigi Nono's *Lontanaza nostalgica utopica futura*. Berio's piece presented an extraordinary exploration of extended instrumental techniques and methods of notating them. Nono's piece offered an original solution to the interaction of acoustics and electronics. We also examined other composers because of their historic relevance or because they had works related to our exploration; Ligeti, Stockhausen, Subotnick, Nancarrow, Xenakis were some of the composers studied.

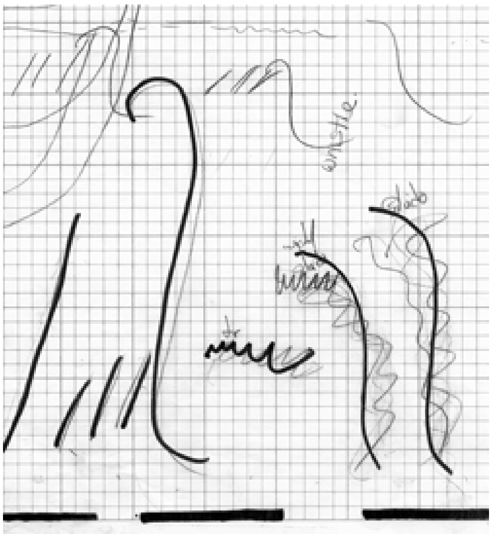

Figure D-2 Sketch of an audio gesture

The listening sessions were complemented with different kinds of sound explorations, most of them vocal experiments. Exercises of "vocal imitation" were induced by questions such as: "Please recreate with your voice the sounds that are in your room just before you go to bed" or "What is the soundscape of your kitchen at breakfast time?" Natasha would first recreate the various sounds in the environment described. I would then ask her to focus attention on one particular sound, for example: "Can you reproduce with more detail the sounds of the blender?" or "Can you layer this blender sound? How does it change when you speed it up? What does the movement of the blades sound like? What do the tomatoes sounds like while being chopped? How does the sound change as they liquefy?" We did additional experiments where we were not worried about the precision of the exact reproduction but used the question as a pretext for generating and developing abstract sounds. These "acoustic fantasies" were induced by questions such as "Sing the sound of the color red, then change it to blue gradually" or "What is the sound of a sunflower?"

I also wanted Natasha to seriously question the paradigm of music notation. My opinion is that traditional music notation, despite its long history and evolution, is just a low-resolution guide that requires a trained person not only to perform what is written in the score, but to provide an interpretation for what is omitted. However, the exploration of new musical notation systems is not a new field and it is possible for individual composers to come up with their own solutions. However, in working with Natasha, I did not want to suggest solutions that twentieth-century composers had developed as part of the general evolution of standard notation. I wanted her think through the problem and come up with her own ideas through personal experimentation.

In one of our "vocal imitation" exercises I asked Natasha to write down what she had previously sung. It was the imitation of a bunch of house keys; her vocal performance was interesting and filled with delicate details. She took out some staff paper, drew the clef and the bar lines, and started to write down quarter notes and eighth notes. Her inability to use a different kind of notation system, more appropriate to the sounds she was producing, was not result of inaptitude, but rather the way she conceived the musical process and the way music has been taught to her.

In addition, Natasha was asked to notate pieces written by other composers which either had no score (were purely electronic) or had a nontraditional score (e.g., music by Jonty Harrison, Subotnick, and Berio). Once Natasha realized the difficultly of employing traditional notation, she discovered many interesting, personal, diverse, and original methods of notation. Sometimes she used colors, sometimes lines and curves (fig. D-2); sometimes she used the x-axis for temporal evolution and sometimes she avoided this convention. She distinguished between layers, phrases, and directions, and all these elements were in one way or another represented in the drawings.

vi) Form and Instrumentation

It is important to note that one main interest Natasha and myself had when writing the piece was the exploration of spatialized sound. The intention of exploring "surround" sound was the main factor in defining the form, structure, and instrumentation of the piece. For technical reasons spatialization was not implemented for the Shapers; this effect is created only by the acoustic instruments. The excellent sound projection, ample dynamic range, and easy portability (i.e. it is possible to walk while playing) made brass instruments the best candidates for spatialization. Mobility was the reason for choosing two trumpets and two trombones. Later we decided to complement the ensemble with instruments that would enrich the sound palette. In spite of the difference in dynamic range we decided to use two violas and one double bass. The double bass would be the only instrument on stage and would play a distinguished role during the piece not only because of its fixed location but also because of its low pitch range.

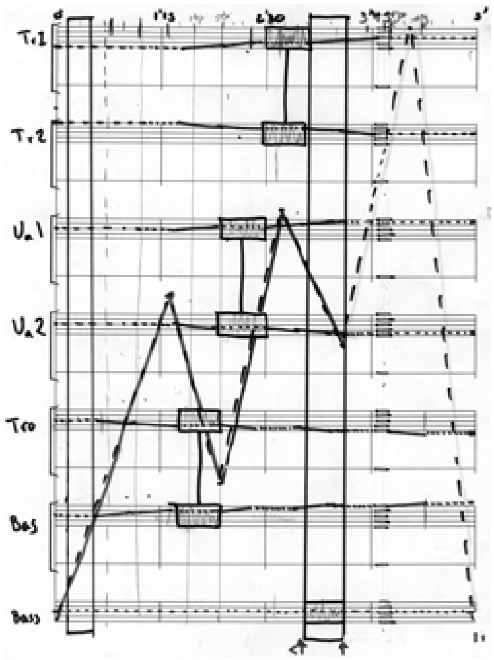

Figure D-3 Sketch of form and map of musicians' movement

Seven acoustic instruments and six shapers seemed to be a manageable and balanced ensemble to work with. We started to work on the main shape of the piece. We wanted musicians to walk around the hall in a way similar to the displacement of musicians used in Xenakis' *Persephassa*. We sketched routes that were interesting, surprising, and balanced. On these "maps" we defined moments where musicians should stand at fixed points reading the score and also moments where musicians should be walking while they improvised within some constrains such as: “While walking to point B, improvise based on the sounds that the other acoustic instruments are playing.” The flow of when and which musicians were walking and improvising carefully defined the structure of the piece (fig. D-3).

vii) Writing the Main Graphic Score

The next step was the formalization of a notation system that would allow us to preserve the freedom of the earlier experimental attempts while also being able to understand the evolution and form of the piece. We reduced our variables for sound manipulation to the following categories: general pitch range, dynamic intensity, density of orchestration, and speed of event changes. We decided to graph these parameters using a well-known system. On a long roll of paper where the x-axis was time and the y-axis the value of the parameter, we drew one color-coded line for each parameter. Based on our map of the instrumentalists’ physical movements, we created regions and transitions for each parameter. These values—only one for the entire acoustic ensemble—represented the combination or sum of the individual values for each instrument (fig. D-4).

Several discussion sessions were necessary in order to complete this graph, from which the individual instrumental parts would later be derived. Shapers were not included in the graph because of the free-form improvisatory nature of their parts. The intent was for the children to respond to what they were hearing in the score in an unscripted way.

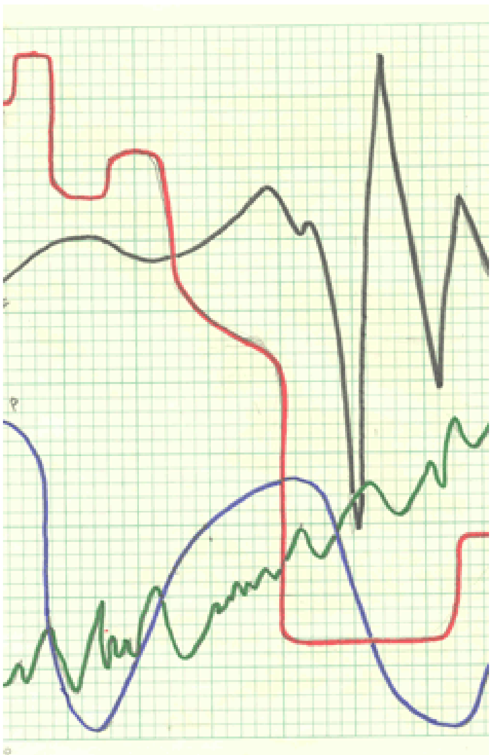

Figure D-4 Fragment of the graphical score

viii) Creating the Individual Scores

Once we had finished the graphical score, we had to find a way to derive the individual parts. We approached this problem by improvising with our voices based on the score. Using a multi-track recorder, we created an audio rendition of the piece; we first started with a vocal imitation of the bass part, then layered the other parts on top of it. We recorded them in pairs: trombones first, trumpets next, and violas last. The technique of recording pairs of similar instruments together—each improviser on a different channel—was particularly interesting because it allowed us to create contrapuntal and imitative interactions between the instrumental lines.

Listening, muting, redoing and rerecording material was an extremely natural and intuitive method for modeling and shaping the piece. During the improvisation we did not worry about intonation or pitch registers because we only wanted to indicate the gestures, motivic relationships, and motivic evolution.

When we finished the improvisation it was necessary to transcribe this vocal version into individual scores for each instrument (fig. D-5) [SS03]. We decided to employ proportional notation where the length of a line that extends from a note indicates its duration. The slope of a line would mean a gradual change in pitch (glissando). The frequency resolution employed for all the instruments was a quartertone and the dynamic range was *pppp* to *fffff*.

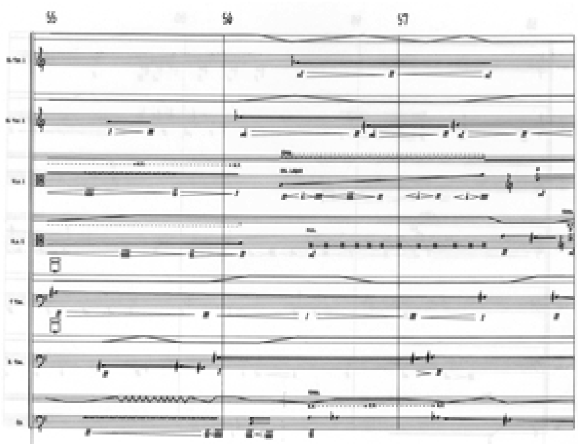

Figure D-5 Fragment of *Gestures* score

During the transcription process, the ranges and physical possibilities of each instrument were studied in order to decide the final pitches. However, the intentions and gestures of the vocal version were preserved as much as possible. The process of listening to the vocal recording carefully, adjusting and deciding the pitches and timbral effects (e.g., muting, string techniques, amount of vibrato, etc.) took several sessions. Nevertheless, we finished with a score that preserved much of the original intentions and acoustic ideas.

ix) The Electronic Part

The realization of the electronic parts of the piece was done in parallel with the development of the acoustic sections. At first, we were not sure how to relate the acoustic instruments to the Shapers. After analyzing different possibilities we decided to implement electronic variations of the sounds produced by the acoustic instruments. We individually recorded members of the MIT

Symphony Orchestra and asked them to play an extensive range of sounds. In addition to recording normal notes and scales at different pitches and intensities, we asked the musicians to make an exploration of instrumental techniques such as flutter tonguing, glissandos, harmonics, multiphonics, noise, etc. The trombone player, for example, suggested putting water in his instrument; the double bass player created interesting glissando improvisations; the trumpet player developed surprising rhythmic patterns. All of this material would be the basis from which electronic textures would be derived.

When the recording sessions were finished, we started the procedure of manipulating and processing the sounds. Natasha did not know anything about digital audio processing, therefore this task was realized slowly, requiring myself to explain basic concepts and techniques. The different techniques employed included time stretching and reversing, pitch shifting; convolving and mixing sounds, adding reverb, flangers, and delays; special emphasis was placed on granular synthesis.

Once we had the source material for the Shapers, we needed to develop some interesting strategy for how the children would use them. We developed a system with Max/MSP [Cyc04] where the children could manipulate the sounds in a free-form intuitive manner without altering the structure of the piece. The process of implementing the Max/MSP patch was also slow because Natasha did not know the basics of the programming language.

In an initial version, the system allowed the children to modify an extended set of parameters with a wide range of variation—intensity, pitch, and reverberation among others. However during one workshop at the Boston Children's Museum, we realized that in order to clarify the interactions and procedures we had to limit and reduce these ranges and parameters. We also observed that our initial intention of giving children total freedom in playing whenever and whatever they wanted was hard to accomplish in a few rehearsals. We decided to create another version with a more rigid structure and fewer Shaper parameters (limited to pitch and intensity). In this version, the sounds produced by the Shapers depend on the current section in the piece. In order to facilitate this, a very simple score indicating sections was added. The changes of sound were performed by a person sitting at the computer and following the score. These modifications gave the piece a more stable structure without completely eliminating the free style of the first version. Although the Shaper parts were simple, a conductor was still required to guide the children. The addition of the conductor was extremely helpful because he also helped to synchronize the musicians.

x) Conclusion of the Work in *Gestures*

The importance of this project, independent from the final acoustic result, was the learning process experienced by Natasha during the months we worked together. Finding a balance between teaching her diverse techniques, tools and concepts and preserving her personal ideas and acoustic imagination was not easy at all. I tried to limit himself to being a guide for Natasha's own exploration. Suggesting, proposing, showing possibilities and options, discussing and arguing, comparing situations and giving examples, listening to previous works and teaching the principles that give substance to the digital technologies were the principles on which the piece was built. In this way, the principal goal of the project was reached successfully.

However, some elements did not work as well. The piece fails on the level of musical direction and discourse. The notation, which was intended to simplify the performance, became a difficulty for the ensemble, and there were problems with dynamic balance between brass, strings, and electronic instruments. Another problem was the lack of experience in creating music on the part of the young children. Some pedagogical elements were also not completely controlled or investigated.

The principal value of the project was the collaboration with Natasha. I wonder if this experience is or is not the first time that a child has composed a piece for electronics and ensemble. In addition, the experience of having developed a work where the use of drawing and graphics, and where the concerns of creating organic results even if some parts are improvised was very important in the following works.

E radioBANDA

During March and part of April 2004, I created in collaboration with Tristan Jehan an interactive project oriented to reach new way to make an interactive experience with the radio medium. Although radioBANDA deals with electronic sounds it has certain relation with IMPI because it generates acoustic transformations base on the modification of a graphical interface.

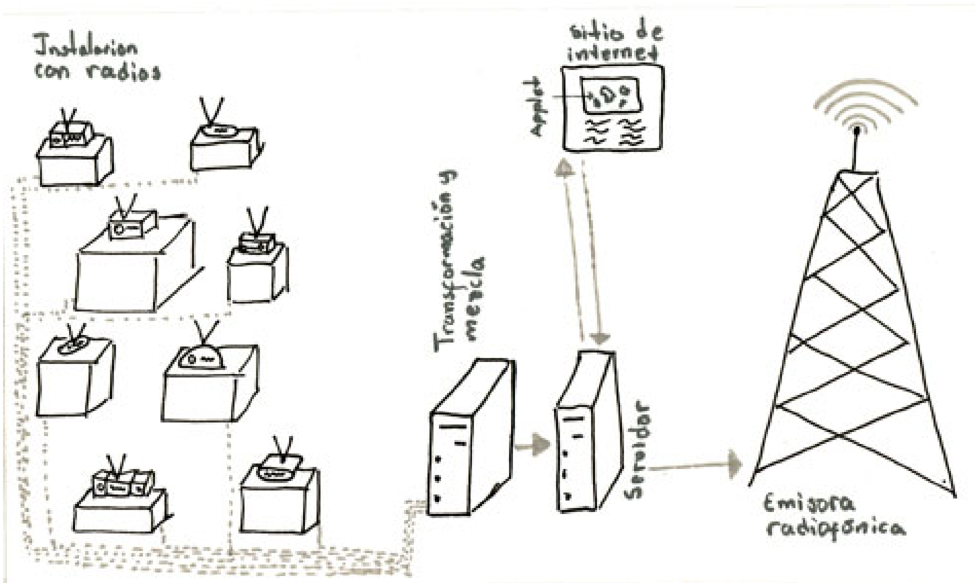

Figure E-1 Initial sketch of radioBANDA project

Even though the radio has one of the most interesting and long histories within all the massive mediums of communication, one must inevitably admit its centralized and unidirectional nature. However, over the history of the radio, many experiments and solutions have been designed in order to create bi-directional bridges between the radio station and the audience, and also between the different listeners [Kun04]. radioBANDA belongs to this class of experiments in which a clear and direct interaction between listeners, with a direct participation and collaboration of each of them, is intended. Because of its interactive expectations, and because of its audiovisual component, the project is briefly explained in this thesis.

radioBANDA is a multimedia project with the objective that a radio station recreates, intervenes and transforms all the information broadcasted within the entire spectrum of the radio band in which this radio station is broadcasted (fig. E-1). This intervention is produced with the direct collaboration of the listeners. For this purpose, an Internet page with an interactive applet is use to generate in real time the transformations of the radio stations. The signals of all the radio stations are retrieved with a collection of analog radios that constituted an installation. The signals of this collection are modified in real time by the changes produced in the interactive applet.

Conceptually, this project had many goals allow the audience to take direct control over what is transmitted over the radio, create an acoustic bridge between all the listeners, and become a mechanism that allows the radio to listen to its audience. At the same time, there is the intention that each one of the parts that constitutes the entire project could be an aesthetic work that alone could talk directly or indirectly about the radio.

i) Operation

Figure E-2 Installation of analog radios

radioBANDA is composed of the following parts: an installation of analog radios (fig. E-2); an internet server with a web page that the users access in order to modify the signals produced by the installation, and a traditional radio broadcasting emitter that returns to the audience the material that they are modifying on the web page.

The installation of radios is a collection of analog radios of different characteristics; each one tunes in to a different station than the others, trying the spread the entire spectra among all the radios. Ideally, the installation should be located in a place that has some relation to the radio, or in a public space such as the lobby of a radio station or a public library, or cultural institution. The different signals of all the radios are sent in a multichannel format to a computer that will create the acoustic transformations based on the information received from the web page.

On the address www.radioBANDA.net the radio listener could access the graphic applet that controls the parameters for the transformation of the audio (fig. E-3). The animated graphic is composed of several "objects". Each of these objects represent one physical radios, which also means that it represents one radio station. Clicking each of these objects and moving it within the window, the listener is modifying in real time the original material of the station. A radio station can be modified by just one listener at a given moment, but one listener could modify several stations at the same time. If more than one listener is connected to the server, the modifications that each listener is creating on his or her computer are reflected in the computers of the other listeners. In this way, all the listener are aware of the activity of the rest of the "players" creating the possibility of creating dialogs, direct communication, and interaction between all the listeners. In the case that there would be more listeners than radio stations already under the control of a listener, the rest of the listeners could follow the interaction of the “active listeners” and wait for one of them to liberate one of the stations.

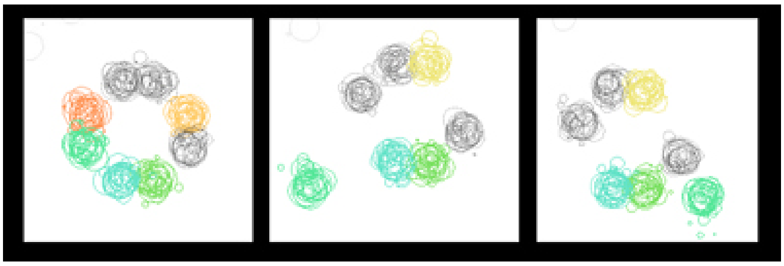

Figure E-2 Three snapshots of the graphical interface

The result, a product of the interaction and manipulation of the listeners, is injected into a stereo mix and transmitted by the radio emitter. If the computer is not located in the same physical place as the radio emitter, the latter could access the audio through the address www.radioBANDA.net/audio.html. Even though it would be simple and easy for the audience to access the audio by Internet, this is not the intention of the project, and the address would not be accessible by a human listener. The intention of the project is that the listener would ordinarily use a normal radio and tune it into the specific frequency.

ii) Technical Details

The installation is created with eight radios of different characteristics, some are portable, others are old radios, and some are car radios. The intention of this heterodoxy collection is to emphasize that the radio is accessible easily in different contexts such as the street, the car, at work, etc. A Macintosh computer that has a multi-channel audio card receives the signals from these radios. Each radio is sent to one different channel. A Max/MSP [Cyc04] patch is responsible for processing the audio in real time. Granular synthesis is the process employed [Wol04], even though it is computational expensive, because the process offers a big range of variations while preserving the original sonority.

The applet was developed with Processing [FR04], as a way to ensure that most of the platforms and systems could access the interactive page. The server was developed in Java to facilitate compatibility. The graphics modified the audio with these direct mappings: the intensity of the audio is based on the distance between an object and its original location; the amount of granularity and the change in frequency are based on the angle created between an imaginary horizontal line that intersects the center of the applet and the location of the object. This configuration allows to the listener to have an intuitive and simple but variable control over the station. Finally, for delivering the final audio over the Internet, a Shoutcast server [Nul04] and a library for audio transmission [Mat04] over the net are used.

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"Dieciséis todos los niños a correr." A Julieta