Musical Expression

exploring a virtual analogy of interactive performance

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Introduction

Introduction

A virtual analogy of skilled musical performance

> *Man tries to make for himself in the fashion that suits him best a simplified and intelligible picture of the world. He then tries to some extent to substitute this cosmos of his for the world of experience, and thus to overcome it (...) He makes this cosmos and its construction the pivot of his emotional life in order to find in this way the peace and serenity which he cannot find in the narrow whirlpool of personal experience (…) The supreme task is to arrive at those universal elementary laws from which the cosmos can be built up by pure deduction. There is no logical path to these laws; only intuition, resting on sympathetic understanding of experience, can reach them (…)*
>
> *"Principles of Research", address by Albert Einstein (1918)*

As part of the evolution of computer music, the human-machine paradigm has found a solid popularity base and become a breeding ground for experimentation. Interactive music systems have a particular place in this context in that they explore some highly specific compositional techniques, while at the same time that they create a novel and engaging form of interaction between humans and computers [Rowe, 1999]. There have been numerous creative developments in this field of expertise in which the interaction between the computer and the performer has taken on a multitude of diverse forms and shades.

Looking at a rough outline of interactive systems, one could differentiate between two general types of interaction: (1) the computer as an expansion of the performer's instrument (computer-as-extension) and (2) the computer as an additional musical entity (computer-as-musician) in a musical environment. In many of the interactive implementations of a computer-as-musician, the generative principles of the electronics have been confined to the realm of pure compositional thought. Although this is to some extent to be expected – the conception of music is evidently assigned to composition – one should in my opinion not overlook the importance of the performer's contribution to musical creation and expression. If a composition remains unperformed, it will probably never fully crystallize into its actual musical existence. Even though we might be able to imagine music simply by reading a score as a result of our experience and knowledge, the score itself remains a mere representation of the composition and not an expression of the music itself – it is as representational of the actual music as a recording is of a concert.

This obviously has a number of implications on the way we deal with the creation and analysis of these processes. It is necessary to realize that the generative and expressive elements of music take place on many more levels then those of composition and performance alone – they are all-pervasive in the concept of music. In developing musically interactive computer systems I believe that this realization will have a significant impact on how we deal with the design and implementation of such systems and could potentially improve the expressive sensibility, functioning and coherence of such systems in arrangement with human performers. As noted by Robert Rowe: "I believe that any application involving computers and music (…) would be improved by having the program know about the music it treats" [Rowe, 1996]. It is in this context that our knowledge and understanding of the music we are dealing with will be translated into some algorithmic implementation in the computer domain.

In my own development of real-time electronics, the aim has been to devise a musically interactive system that can achieve autonomous interplay with a live performer as part of a more traditional concept of performance by functioning as a meta-performer implemented within the computer domain. The understanding of musical creation and expression is of particular importance within this field. Because a human performer has been trained to possess specific musical knowledge and conventions, one has to account for the presence of this knowledge in order to develop fruitful interrelation. By accounting for this knowledge one can develop a mutual understanding of the musical environment in which both human and machine musician move. It is through this understanding that we could benefit from traditional performance practice by observing the conventions and knowledge that are a part of the development of musical expressivity.

In traditional musical performance practice one rarely comes into direct contact with the question "What is musical expression?" therefore an understanding of this concept remains rather elusive. Expression is not taught or seen as present as a definite skill.

Rather it is dealt with as an unconscious process that is the result of many other teachings – through focused training of explicit skills, one simply enables musical expression to happen. In many situations this method has proven to be relatively successful. However, in machine musicianship we are not dealing with a being that has unconscious processes and implicit learning capabilities. We are dealing with a computer that only represents our limited (algorithmic) knowledge of these musical concepts. Musical expression in this field thus becomes something that needs to be implemented or enabled in the computer environment. Therefore I cannot but attempt to open up one of music's impossible and subjective questions: What is musical expression? It is an unknown yet its true conception pervades the entirety of music.

In my thesis this question will not function as a conventional central issue but rather as an entrance into the rabbit's hole through which to explore the extent and makeup of the matter. To do justice to this question and any of its subsequent issues is patently beyond the scope of this thesis, or probably any other writing [Garnett, 2001]. I do however hope to give an approximation of some relevant topics of particular significance and interest in the field of developing the computer as a meta-performer.

At the outset I will take a look at some of the metaphysical and ontological issues involved in musically expressive and interactive systems and from that starting point attempt to outline a large-scale conceptual framework for relevant concerns. I will discuss some of the conceptual barriers of musical expressivity, devising a potential context in which to work, while subsequently defining some limitations to its interpretation. While doing this I will take a closer look at issues such as music-as-language, musical gestures and performance interactivity, as well as exploring some considerations derived from traditional performance practice.

In the following section I will move towards more specific areas of consideration in relation to the computer-as-musician. The human performer here poses a vast potential source of inspiration, this despite the fact that the human performer is unfortunately lacking in a transparent disclosure of its construction as a musical entity. Within this conceptual constraint, I propose a metaphoric or poetic strategy of observation in devising a computer implementation of skilled musical performance – a virtual analogy of expressive musicianship.

In the last section I will propose a possible translation of the thoughts and concepts as presented in the previous sections, to form a theoretical computer implementation. I will introduce the application of a planetary simulation model as a metaphor within the context of the generative and expressive capabilities of a machine musician, as well as describe an extended interpretation of computer "listening" and mapping strategies in the development of a meta-performer.

In dealing with the issues involved and building on concepts, my main goal in this thesis will not be to give a purely scientific or extensive philosophical elucidation of the matters that I am dealing with. Nor will I attempt to provide objective justification for my ideas and their implementations. Rather I am attempting to develop an intuitive understanding of the subjects at hand from an artistic point of view on the notion that we are essentially dealing with music. I do not wish to exclude science and philosophy from being a part of the argument, in fact on many occasions my line of reasoning is largely constructed upon them. My aim is to allow the personal and the subjective to become part of viable arguments in dealing with expressive skilled performance, the design of an autonomous musically interactive system and ultimately music.

Conservative Anarchism

Conservative Anarchism

A conceptual framework for the development of an expressive system

> *"I can well imagine an atheist's last words: "White, white! L-L-Love! My God!"-and the deathbed leap of faith. Whereas the agnostic, if he stays true to his reasonable self, if he stays beholden to dry, yeastless factuality, might try to explain the warm light bathing him by saying, "Possibly a f-f-failing oxygenation of the b-b-brain," and to the very end, lack imagination and miss the better story."*
>
> *"Life of Pi", chapter 22, by Yann Martel*

Tearing down the walls

When progressing towards a model in which a live performer and a computer can expressively interact as individual autonomous musical entities, an innumerable number of factors have to be taken into account. We have to study and implement our conceptions and ideas about what it is to be interactive, expressive and a musical entity. In most cases in this process however, we tend to look at isolated parts of the processes in music in order to come up with viable concepts of how they function within the whole. As described by the Oxford Dictionary "to study" is "a detailed investigation and analysis of a subject or situation". In this context it is theoretically impossible to study the whole at once. Our common concept of study is based on the notion that one can build a house when one knows what a brick is – with what we have learned about the detailed, we are able to understand the bigger picture. However, given that at any time in musical performance the whole is at work, one might question the validity of such study, or at least question the extent of its validity.

When dealing with music, one can ultimately only deal with the whole. In the experience of a concert one would probably not focus on every single element present in the music at any given time, e.g. its timbre evolution, its rhythmic manifestation, its visual presence. The primary focus would most likely even shift over the course of the event, possibly guided by the composer's intent. The essence of the matter however is the potential one has to drive one's main focus through the entire scope of the music at any given time, as even elements that are not in focus are still perceived. This to the extent that even the lack of one of music's elements, for example the absence of a visual presence, becomes an inadvertent quality of the music.

Whilst looking at the central question of my thesis "What is musical expression?" it is evident that the scope of the question manifests itself through the creation, performance and perception of music. It is a ubiquitous part of music. What I would like to argue against is the popular notion that musical expression is a mere part of the music one can isolate and study. When attempting to isolate this phenomenon in order to be able to study it, one will soon find one's self in an impasse, as musical expression exists through the totality of music. It is present in all elements of music. Coming from this idea music, and subsequently musical expression, do not function as such when any single element is taken out of the totality. Nor does a single element function as musical expression without its total musical context.

Parts of or in a whole

When studying isolated elements in music, you can of course still learn about these particular elements. Looking at pitch space only for instance, you can also clearly observe harmony or timbre. But as soon as you want to make a valid statement on the nature of this element in the context of music, you have to place it back within the whole. You have to link the element back to the construct of music and look at how it combines with all the other parts of a musical work. The meaning of the texture of a musical phrase for instance, is inadvertently only of musical and expressive value when placed back within its original context of rhythm, articulation and all other aspects of the music. Studying musical expression thus becomes a study of the interplay and combination of all elements.

In this sense musical expression functions as a dome, covering a multitude of factors that interact and merge in its conception – it transcends the level of the detailed and moves to the point of intersection thereof. Isolating a single element and discussing it outside of the dome will make it lose its musical value and eventually its relevance. Therefore I cannot but discuss musical expression as a dome in its entirety. Since the whole is too large of a concept to conceive of, I would like to propose to put spotlights on parts of particular personal interest and discuss their effects on the totality of what we call musical expression. In light of this I would like to elaborate on the impact musical expression has on a number of select regions of the whole that might help us acquire a deeper insight and intuitive understanding of what it is to be musically expressive.

At this point the central question "What is musical expression?" is more present as a context in which I would like to discuss a number of factors at work in the interaction between humans and machines as performers, rather than a central question. It represents the potential to gain knowledge about the notion of musical expression by looking at the impact it has on more contained elements. From this point of view I am also not interested in giving an answer to this question, but to develop understanding of its effects in music.

What is musical expression?

Since musical expression only exist as an intersection of elements, it is almost impossible to say anything less generic then that: it is an amalgamation of parts out of which a whole is formed. This however is a rather broad statement. I would therefore like to suggest taking a brief look at some common interpretations of musical expressiveness, what it possibly constitutes, implies and encompasses and what it might not.

On what it might not…

A widespread, but problematic understanding of musical expression is that of a mere nuance of the musical material. This viewpoint is here illustrated by Bob Snyder in his work on music and memory. It follows on the notion that in perception and memory, music is divided into discrete objects or categories such as the twelve tones of an octave.

> *The patterns of rhythm, melodies, and so on that we are able to remember from music consist of sequences of musical categories. Each occurrence of a category, however, is shaded in a particular way by its nuance, which constitutes the expressive aspects of the music. Unlike categories, which are discrete, expressive nuances are continuous variations in the pitch or rhythm of a musical event. (Snyder, 2000)*

The expressive qualities are here portrayed as sheer inflections on other musical parameters, breaking the discretization of perception into the continuous. This point of view however diminishes the expressive qualities of music to residual information of the music's categorization. Even though the categorization of the music in perception and memory might be a very plausible process, it does not imply the later to be true. It makes the unfortunate assumption that the perceptual categorization of music is the actual representation of the musical domain. It is however not the category which is shaded with nuance, but the nuance that has been reduced into categories.

The expression lies in the continuous, or what Trevor Wishart has referred to as the "dynamic morphology" [Wishart, 1996], but does in this respect not exclude categories – one would certainly not wish to deny the expressive capabilities of a composition utilizing a traditional score. It is solely to stress that even though the traditional score might possibly make use of the parametric categorization of music, it remains to be a mere hegemonic convention and reduction of what it is trying to describe. This angle on musical expression thus leads us nowhere, other than to the observation that musical expression takes place in the continuous domain – the dynamic morphology.

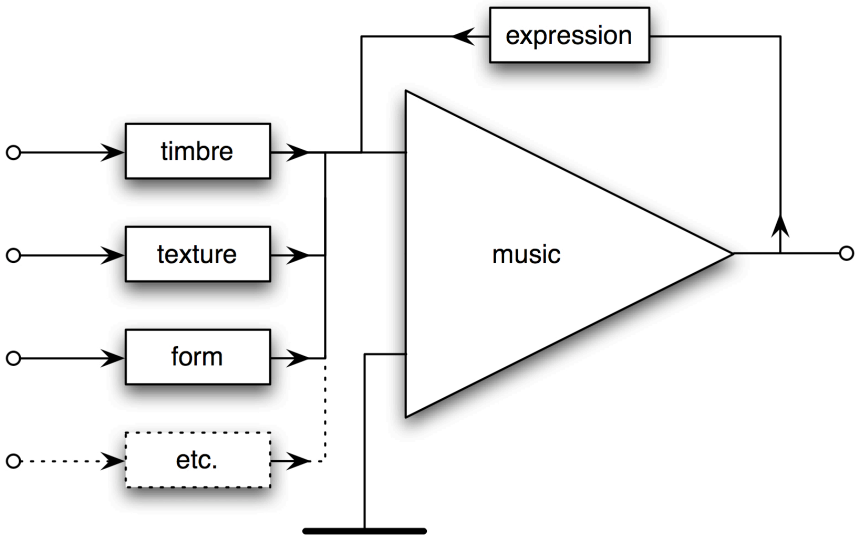


Figure 1: A poetical diagram of musical expression, in which the expression is not depicted as a mere additional element to the sum of parts that makes up music, but as a feedback loop of the undivided dynamic morphology on the level of music. It here affects not just the individual elements of music, but shapes the sum thereof in its entirety.

The self-expression, arousal or possession of emotion

Now to look at the issue of expression from a more philosophical angle, let us start by stating that to express involves conveying or communicating something, whether thought, feeling or something of an entirely different scope. From this perspective, musical expression involves conveying or communicating something within the framework of music. But what does the nature of this message being conveyed possibly encompass? What is it that is being expressed?

Commonly found definitions of expression in music oftentimes deal with (1) emotion and (2) gesture, although not entirely unrelated. Peter Kivy, in his inquiry into the views of Johan Mattheson on the subject of musical expression, has illustrated three possible interpretations pertaining to what it means to express in music [Kivy, 2002]. They all however are based on the inference that to express in music, is to express emotion.

The first option is that expression takes place in the literal sense of the word, here defined as follows; when one experiences a certain emotion, one can *express* this emotional state by wearing a certain *expression* on ones face. Thus the expression of a certain emotional state in music would be the result of the creator who expresses his emotional being through the music. Kivy referred to this as the "self-expression" theory. From this point of view however, it would be a necessary condition for the composer or performer of the music to be in a certain emotional state in order to be able to literally express this emotion. A composer would have to be sad and anguished in order to literally *express* anguished sadness in his music. This view would gravely limit the muse in musical composition and performance, as one would unfortunately have to wait for the appropriate emotions to occur in order to start working. Not to mention, it is historically inaccurate and does not apply to our experience with music.

The second construal mentioned by Kivy is that the emotion expressed in the music is not a literal expression of the creator's emotional state, but the arousal of this emotion in the listener. It is not the composer's anguished sadness, which is expressed in the music, but rather the composition that has been fashioned in such a way as to, in the appropriate circumstances, make its auditors sad and anguished. For obvious reasons Kivy refers to this as the "arousal" theory. It seems however to be very unlikely that a listener would actively seek to become sad and anguished by listening to a particular piece of music. These are unpleasant emotional states, which we assiduously try to avoid in most other circumstances. Furthermore, there is also no support for this actually being the case; a concert hall would most likely be a very different place if it were.

The remaining notion, and also the most plausible one according to Kivy, is the one in which musical expression relates neither to the creator's emotions, nor the listener's. Rather, music possesses such emotions as phenomenological properties. This is described much in the same way a weeping willow is seen to be sad in spite of the obvious fact that the weeping willow cannot be feeling sad. This expressiveness is parasitic of human "expression-behavior" and bears likeness to its appearance. It does so in virtue of resembling the appropriate expression of human voice, gesture, countenance, posture and gait. Hence Kivy called this the "possession" theory of musical expression.

Mattheson's possession of the lively spirits

With the "possession" theory being the most likely candidate for describing musical expression, I would like to take a closer look at Kivy's interpretation of Mattheson's view on the subject as articulated in the magnum opus "Der volkommene Capelmeister". Mattheson, as a prisoner of his time, had formulated his views within the Cartesian theory of the *esprit animaux*, which Kivy elucidates as follows.

> *These refined corpuscles were imagined by Descartes, in his influential* Passions of the Soul *(1649), to be diffused throughout the body and, by their particular motions, to be the efficient cause of the emotions: that is to say, of the "passions of the soul." They were not, of course, observable entities but "theoretical constructs," if you will, whose operation and character could be inferred from what* was *observable: the "feel" that the affections were experienced as having, in introspection, and the behavioral outcome of these subjective sates in the form of observable human expression. (Kivy, 2002)*

Kivy then construed the following concept on musical expression based on Mattheson's writing.

> *If one wished to write music expressive of this or that emotion, then, according to Mattheson, one was obliged to make it conform to the particular motion and disposition of the vital spirits as manifested in their arousal of this or that emotion in human beings.*
>
> *(…)*
>
> *It is worthy of some note, in this regard, that the relationship of the vital spirits and the actual emotions they were supposed to cause was thought to be so close and intimate as to make it all one to Mattheson whether he was talking about the vital spirits, or just the emotions themselves.*
>
> *(…)*
>
> *The impression we are left with is that music expressive, say, of love and sadness merely in virtue of it representing the particular motions and dispositions of the vital spirits associated with those emotions; and, as we have just seen,* that *is sometimes thought tantamount to representing the emotions themselves. Thus it would appear, Mattheson is maintaining here not that we* feel *the love and sadness that the music*

> *might somehow embody, but that we* recognize *the love and sadness that the music represents. (Kivy, 2002)*

In the continuation of this idea it is not stated that the music cannot move the listener, but that the emotions being expressed do not necessarily move the listener to experience these particular emotions. It simply moves the listener to recognize the representation of emotions and can as a consequence of this still be exciting. How these emotions are then represented and in what form they are recognized becomes, in my opinion, a rather personal or subjective matter. This even to the extent that the shape and motion of the emotions as represented by the creator might mean something of entirely different matter to the listener, without this forming an impediment to what is being expressed. I will thus not further look into this aspect of expression. But the idea that the music contains shape and motion regardless of what it might represent is an aspect of expression worthy of further thought. Moreover, this is also where the concept of gesture might start playing a role in musical expression.

This line of thought has largely followed the expressive qualities in the creation and experience of the music and has accounted for what it is we mean by music as an expressive medium. I would now like to continue by taking a look at what possible implications communicational processes and the shape and motion of music have on the expression thereof.

A communicational paradigm

Communication is an important aspect of the act of expressive performance, but the implications thereof are not as clear. I would like to briefly discuss some of communication's artifacts in combination with the common but problematic analogy of music as language. First of all, even though music might resemble a language, it is not literally a language. The analogy of music as a language is one that might come quite naturally though. Both share a number of similar properties and communalities in their vocabulary such as sentences, phrases and punctuation. This does however not imply that they are the same. The analogy functions only as a means to understand certain of the artifacts present in its manifestation, but that is also where the similarity ends.

> *Music points to true language in the sense that content is apparent in it, but it does so at the cost of unambiguous meaning, which has migrated to the languages of intentionality. (Adorno, 1956)*

This thought points towards the idea of music as a non-intentional language, a language that is deprived of definite semantics. The meaning of music does not lie in the recognition of a particular emotion, but the recognition of its presence. What remains is the structure, design or form.

> *Form can only be the form of a content. The specific necessity, the immanent logic, evaporates: it becomes a mere game in which everything could literally be something else. In reality, however, musical content is the profusion of things which obey the rules of musical grammar and syntax. Every musical phenomenon points to something beyond itself by reminding us of something, contrasting itself with something or arousing our expectations. The summation of such a transcendence of particulars constitutes the content; it is what happens in music. (…) It does not just embrace the content from outside; it is the thought process by which content is defined. Music becomes meaningful the more perfectly it defines itself in this sense - and not because its particular elements express something symbolically. (Adorno, 1956)*

From this line of reasoning you can conclude that even though music as a language has no definite semantics, it does have content. This content however is not a representational one, but one that is referential. It is defined by the very act that made it come into existence. A traditional I-IV-V-I cadenza certainly does not, and cannot have the same meaning now, as it had in the time of Beethoven. This is simply because the library of referential material today is a completely different one then that of Beethoven's time. At the same time as being contextual, music is structured and follows a syntax and morphology with inner logic. However, the syntax and morphology of musical expression, becomes fluid at this point. It can change its design in its entirety as long as it upholds uniformity in its own context.

Throughout history, the syntax and morphology of music and with it music's gestures, have changed shape continually and they will continue to do so in the future. However, music has and always should be consistent within its own style or idiom. A unifying or universal description of this musical consistency is not achievable and effectively goes directly against its nature. This is because of its fluidity and the continually changing socio-historical context. With the ambition of developing a musically expressive and interactive system it is therefore not fundamental to analyze and model the existing grammar of any particular idiom. Rather one will develop one's own syntax and morphology, possibly rooted in preexisting idioms, but more importantly, one which will maintain consistency within itself.

A musical gesture

The application of the notion of musical gesture is a widespread phenomenon, but its definition is almost as elusive as that of musical expression. I would first like to state that within this context I am using gesture to refer to a metaphorical gesture and not a physical one. A musical gesture is the unfolding over time of that which is the substance of musical expression. It is a gesture in the conceptual domain. Much like a painting, which takes shape and comes into existence as a conglomeration of individual brush strokes, it is the totality of musical gestures that makes up expression.

In this context gesture becomes part of the syntax of music. Its relevance does not lie in the possible emotional state it might represent, but in its dynamic morphological qualities. It serves a structural function rather than a semantic one, where its content is defined by the idiom in which it is set. That is where the gesture obtains its functionality.

An expressive system in music

I would like to propose that the extent to which any musically expressive system is relevant in its practice, is constrained by the idiom in which its musical gestures have been developed. This however does not necessarily have to imply a limitation to the system, but rather implies a limit to what it means to express in music. In the case of a human performer it might be limited to the idioms and styles in which the performer has acquired experience and training. A classically trained and skilled performer is proficient within his own idiom, but can prove rather inept when asked to play jazz. The same holds true vice versa for a jazz musician trained in the Bebop style. In the case of an autonomous computer performer the system is limited by the idiom in which it is implemented, the technological constraints and the programmer's insight into the manner of its application. It probably won't play jazz, it probably won't play Brahms, but it might prove very capable of playing within its own uniquely defined idiom.

Resurrecting a coat rack

In light of enabling musically expressive interaction during combined human and machine performance, one might now assume that there are no conceptual constraints to the grammar, gestures or idioms applied in expressive systems. Musical expression has after all been described as referential and everything could literally be anything else. One might thus suggest that one can do anything, as long as one remains consistent within the context of the work. Even though this might hold theoretical value, I do not believe this to be literally valid. Music as a language might be referential in its nature and its consistency might be contained within itself, but it is also in a socio-historical context. It is not a solely self-referential system.

Aesthetical contemplations

In the creation of purely electronic music, the implications of a non-self-referential syntax and morphology are possibly not obviously present. In this context the main musically expressive interaction in its creation occurs between the composer and the work. There are essentially no other human counterparts present in the process of its conception. The conceptual restraints will then only manifest themselves in the creative ideas of the composer herself and her inner dialogue with the work. In this environment there are no apparent indications to a composer that the musical expression of the work is not a self-referential one, since the work is still referential to the composer's self. The composer, however, in spite of his creativity, is still under the influence of his own socio-historical context. It will lead him to particular inclinations or even to react and reflect upon them. The margins of the work's expressive capabilities might then only reveal themselves when placing the work in a performance situation. In this situation the composer's socio-historical context embedded in the piece will now have the opportunity to interplay with that of her audience. Through the work there is now an expressive dialogue between the composer and her audience.

Considerations on a performer

However, while working with human performers in the context of a newly created work, the constraints of the socio-historical context become readily apparent from the moment you engage in interaction with your performers. Skilled performers have still been trained and educated and have acquired extensive experience in the socio-historical context of their relevance. They have obtained their own referential library to which they allude when performing and interpreting music. Even performers specializing in free-improvisation have a multitude of gestures and experiences in their possibly custom-made idiom. With this they still have constructed a reference library, albeit a more personalized one.

This of course does not mean that these libraries cannot be expanded. Moreover, I believe that one of the ambitions of art is to continually expand these libraries. Looking at the historical development of musical styles and idioms, it is apparent that there is an incessant creative progression taking place with an expanding, continuous and counteractive character. It is however not commonly a hop-skip evolution of ideas opening up widespread, discontinuous, random new territories of artistry. All inevitable artistic extensions and explorations take place in the context and reflection of their own creative moment.

A mutual creative understanding

What I would now like to propose is that in light of enabling inter-performer musical expressivity, one should take the performer's referential libraries into account in the creation of a musically expressive interactive system. The performance gestures should to some extent be cognizable or recognizable to the performer; he must be able to put his mind around them in some way [Garnett, 2001]. This should however not constrain or interfere with the artistic direction and exploration of the creator, quite the contrary. When taking account of the performer, one should only strive to provide a familiar foundation within the musically expressive environment, one in which the performer feels more at ease and therefore more enticed to explore the environment's newly acquired territories of musical expressivity as shaped and created by the composer. It is a search to open up conventional and pre-established channels of performance interactivity in order to improve mutual expressive understanding.

Conventional channels of interaction

In order to explore some of the already established channels of musical expression, I would like to take a closer look at musical interactivity. As the word suggests, there is an action in between. It is the capability of multiple musical entities to influence each other. In the context of human-machine interaction, Guy Garnett has described the interaction as follows.

> *Interaction has two aspects: either the performer's actions affect the computer's output, or the computer's actions affect the performer's output. These can occur at fairly simple levels or at more complex levels, and they can be combined in various ways. (Garnett, 2001)*

There are thus two possible directions of influence. In this context I would however like to add that the act of effecting is not simply one directional, but that effecting can take place in both directions at any time. Even on the simplest level of interaction this bi-directionality can easily be overlooked. When hitting a key on a piano for instance, you would most likely review the result of your action through some sort of feedback from the piano and react appropriately. Even when the keystroke came as a semi-unconscious act and no obvious reaction was expected, if the piano refrains from giving you the expected sonic feedback, you would most likely be disturbed. There is an implied feedback loop of some sort present in the interaction [Lippe, 2002]. It is a continual loop of information on some level within the process.

A subdivision of interactive roles

This brings me to the next issue arising out of Garnett's description of interactivity. What do these different levels of interaction represent? In writing about real time interaction in computer systems Cort Lippe proposes a subdivision of interacting roles.

> *A composer can assign a variety of roles to a computer in an interactive music environment. The computer can be given the role of instrument, performer, conductor, and/or composer. These roles can exist simultaneously and/or change continually, and it is not necessary to conceive of this continuum horizontally. (Lippe, 2002)*

The divisions of these interactive roles are used in this context to ascribe certain qualities to the machine. Rather I would propose that these qualities are present at all times in any environment of musical interactivity. I do not necessarily mean this in the traditional and literal way - in which these roles are assigned to individual people (e.g. composer, performer) - but rather as an emblem of what each role represents. The instrument as representing the sound source; the performer as the one who operates the instrument; the composer as the designer of the rule system in which the performer operates his instrument; and finally the conductor as the one who gives direction to the former. In the literal sense some of these roles overlap – a performer can take some liberty in its musical direction, a conductor might devise additional compositional rules, etc. The value of these subdivisions lies in that they represent traditionally established channels of interaction in a musical environment.

The interrelation of levels

This brings me to the subsequent consideration derived from Garnett's statement. In what arrangements could these roles of interaction interconnect? The way a performer interacts with an instrument is not the same as the way in which two performers interact with each other. In the former situation there is a disparate interaction between two different levels of interactivity, namely instrument and performer. George Lewis has also well described this as acting according to a stimulus/response setup (fig. 2). In the latter situation, that of two performers, the interaction takes place on an equal level (fig. 3). This would thus suggest a non-hierarchical, subject-subject model of discourse [Lewis, 2000]. The content of the interaction in this situation is not of a different substance, but shares a common origin. This approach provides the opportunity to develop heterarchical musical correspondence between two musical entities in an interactive environment.

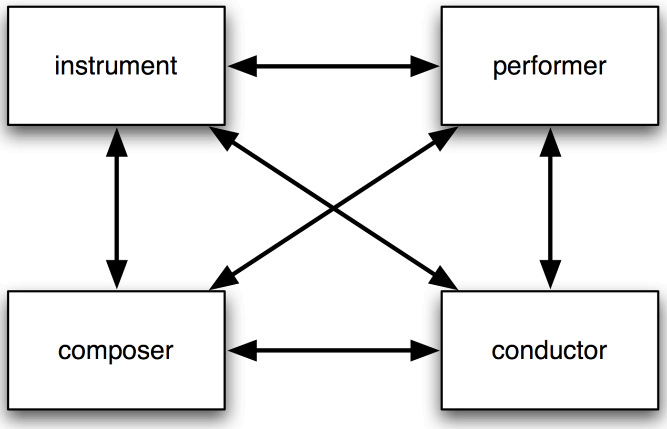


Figure 2: Interconnections in a stimulus/response setup of interaction.

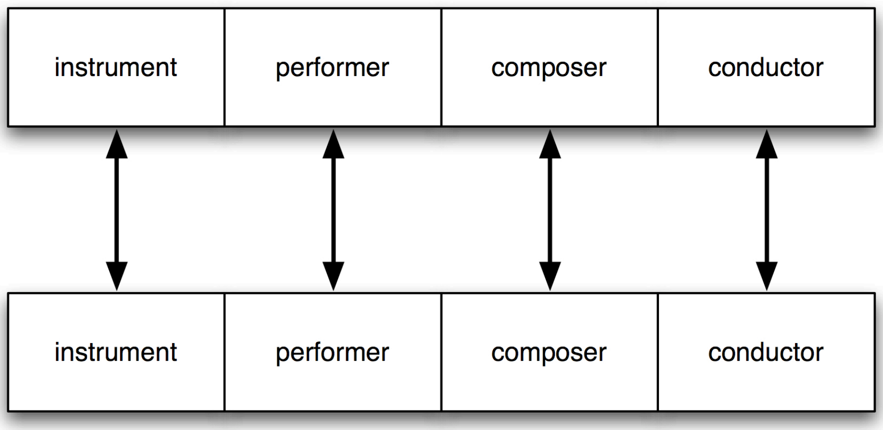


Figure 3: Interrelations of a subject-subject model of discourse.

Falter in novelty

These subdivisions and interrelations present in a musical environment are however not present as apparent divisions in the setting of an interactive computer system. It is evident that the computer has not been constructed on the logic of musical convention. The subdivided roles would have to be superimposed and implemented into this setting and thus would have to in some way become part of the structure formed by the composer. In addition one could argue that a computer system preeminently provides the opportunity for the composer to explore alternative and innovative arrangements of interactivity due to this apparent lack of conventions. As valid an objective as this might be, the absolute implementation of this notion could significantly undermine the performer's cognitive comprehension of the expressive environment. A performer will always initially interpret the feedback received from a musical system as moving along the known and pre-established channels (fig. 4). This is simply what she has trained herself to do for many years and is comprised of the experiences she has collected. Learning a novel system from scratch would then require an additional extensive amount of effort and time. When challenging a live performer in this manner, one may consequently very well jeopardize the overall quality of the expressive capabilities of the work. If the performer has no perception of how the acquired feedback relates back to his initial actions, the feedback loop is broken and the expressivity of the whole lost (fig. 5). With regard to the objective of improving mutual expressive understanding, I would therefore like to suggest that one should at least employ or illuminate some of the traditionally established aspects of interactivity within the computer environment (fig. 6) – this in order to provide the live performer with some identifiable underpinnings within the atypical musical environment and functioning at the very least as a possible aid, preventing the performer from getting lost in the environment's novelty.

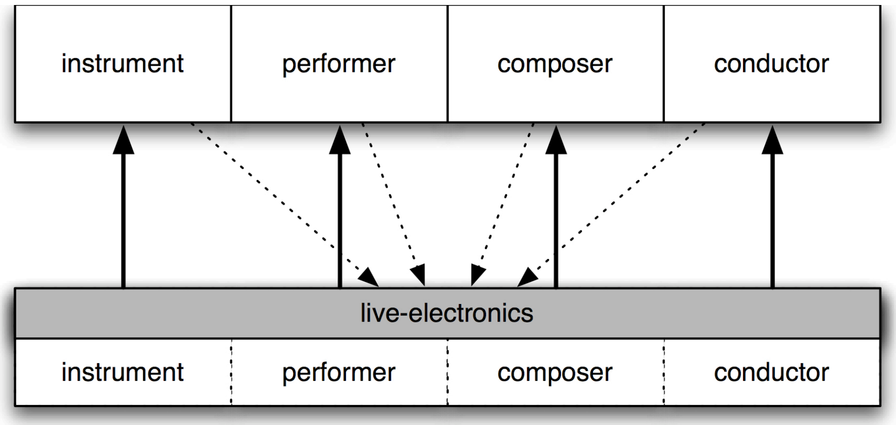


Figure 4: In the interaction between a human and a machine performer in which the computer is utilizing novel methods of interaction, the performer will nonetheless interpret the feedback of such a system as coming over the conventional channels.

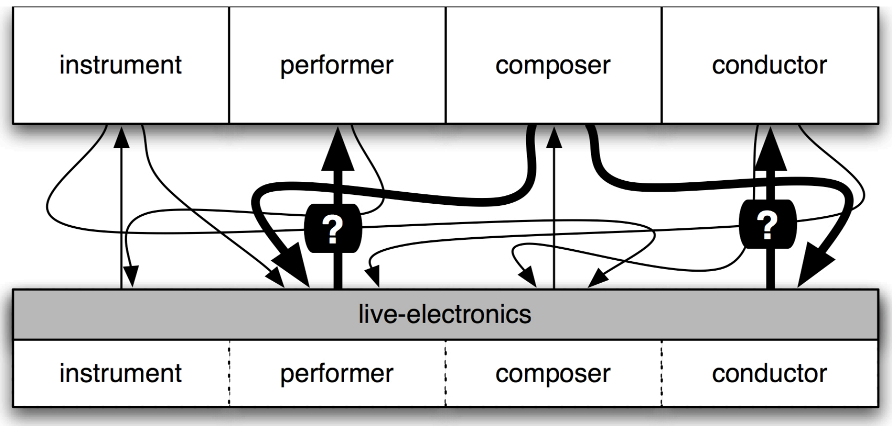


Figure 5: When due to the lack of consideration of these pre-established channels of interaction, the feedback the performer receives from the computer is seemingly unrelated to the performer's input, the notion of origin of the feedback information then becomes garbled and the interaction gets lost.

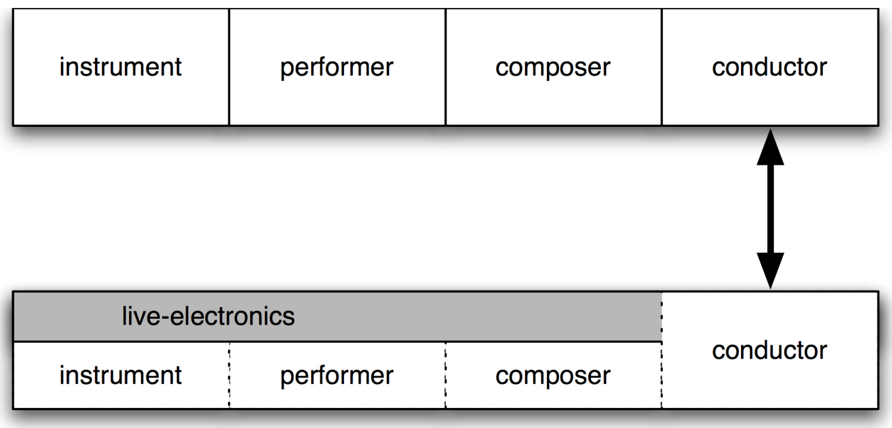


Figure 6: Explicitly utilizing or illuminating even a single traditional level of interaction, could potentially greatly improve the cognition of the system for the performer therewith enabling and enticing the exploration of this innovative musical environment.

An expressive director

In light of enabling musical expressivity it is at the level of the conductor that I find the traditionally established aspects of interactivity most suitable to explore. It is this level that seems to bear the strongest relation to musical expression. Looking at the role of the conductor in musical interaction, it would be a common misconception to state that this role is defined by merely stating the pulse and/or keeping the music together. This would diminish the role of the conductor to that of a mere metronome. This does however outline some element of the conductor's functionality. The conductor role operates on a level of communication of musical direction. It provides a means to unify the processes of musical expression amongst all present musical entities, while at the same time imposing the derived expressiveness onto the entirety of the compositional matter. Thereby the conductor compels and induces the expressive qualities of the music. In the traditional conception of "rubato", for instance, it would appear that there is not a re-composing of the compositional rules of time, but an effective directing of its content.

Where in the context of a traditional orchestra this process is evidently transparent, as the conducting roles of interactivity have been centralized into the actual conductor, the process of conducting is equally present in for instance a string quartet. Here, however, we will find the four conducting roles of four individual performers coalesce into a singular direction of ensemble playing through the communication of music. In interaction, the act of conducting becomes the substance of performance communication - the exchange and unification of the direction of its musical matter.

Having formerly depicted the musical gesture as the evolution of the substance of expression, one could now deduce that musical direction is the driving force behind musical gesture and it is this musical direction, which has been formerly attributed to the conductor. Musical direction in this manner obtains a differential relation to the expressive gesture. The conductor level of interaction operates as the power that unifyingly moves the dynamical systems of musical expression.

Methodical Shambles

Methodical Shambles

A metaphorical layout of an interactive meta-performer

> *Clouds represented a side of nature that the mainstream of physics had passed by, a side that was at once fuzzy and detailed, structured and unpredictable. (…) Where chaos begins, classical science stops. For as long as the world has had physicists inquiring into the laws of nature, it has suffered a special ignorance about disorder in the atmosphere, in the turbulent sea, in the fluctuations of wildlife populations, in the oscillations of the heart and the brain. The irregular side of nature, the discontinuous and erratic side – these have been puzzles to science, or worse, monstrosities.*
>
> *"Chaos: Making a New Science", by James Gleick*

Pragmatic analysis of the unknown

At this point we have a conceptual framework in which to possibly found the conception of a computer model where a live performer and a computer can interact as individual musical entities - a subject-subject model of discourse utilizing a conductor level of interaction. This framework provides an appealing opening in which to explore, develop and possibly enable bi-directional musical expression in a human-machine environment.

While attempting to develop possible implementations of interactive processes, I would like to suggest a look into a musical environment from an initial improvisational point of view – this in order to maintain a certain level of transparency and clarity in the materials that we are trying to work with. If the performer and machine are to be treated as equal in an interactive environment, one could argue that the performer should be offered a similar variety of roles [Lippe, 2002]. From this perspective, the different interactive roles that we will have to deal with will not only be fully present in the performer, but also in the computer environment.

Dissecting a conductor

Looking deeper into the matter of the conductor role in interaction and at the unification process of musical direction, one immediately comes across a number of theoretical obstacles. I would like to take a brief look at some of the obstacles I have discovered as part of my dissection procedure of the conductor's role. There are creative dichotomies in the nature of analysis and externalization of musical direction.

Creative analysis?

The field of music psychology has provided many inquiries into the realm of musical expression, direction and creation and has opted for many possible conclusions. In my opinion, none of these seem to describe the above concepts in a particularly convincing way, not to mention their use in creative potential. I therefore have a possible annotation on the value and application of these kinds of conclusions in the realm of creativity as formerly indicated by Robert Rowe.

> *Researchers in music cognition carry an additional burden in the design of musically capable programs – they must ensure that the output of the algorithm correlates significantly with the behavior of human subjects performing the same task. While we are concerned with emulating human performance as well, we do not face the methodological requirements of reproducing the experimental data produced by human subjects. (Rowe, 2001)*

It is one of the objectives of music psychology to provide an analysis of these subjects and an analytical understanding of the matters of music. As much as this is a valid objective, which might teach us about what it is we call human, it does not necessarily teach us about what it is we call the creation of art. From my point of view, art does not exist as an analysis of itself; it is the synthesis thereof. Where synthesis deals foremost with the creation of what is to come, even when potentially rooted in what is already there, analysis primarily deals with the study of what is already there and only might make possible predictions on what is to come. I believe that this vast difference in the nature of these two fields greatly affects the value of literal information derived by one, intended for use in the field of the other.

The analytical conclusions might provide valuable insights for an understanding of art, but does not provide an accurate aid to its creation. It is this that I believe to be one of the main constraints on the value of music psychology in the creative arts. I do not wish to negate the relevance of psychological studies in the field of art. There are certainly many cognitive processes at work in the realm of music making and in most circumstances while dealing with a computer performer we depend on them. It is the perspective we have on these artifacts that determines the way we use and interpret the meaning of the concepts and ideas derived from these studies. I would therefore like to note the intentions of the creative arts versus those of psychology and the subsequent constraints because of this on their interchangeability of knowledge. As noted by Werner Heisenberg who wrote on how science reveals the world to us: "We have to remember that what we observe is not nature in itself, but nature exposed to our method of questioning" [Lindley, 2007].

Abstract understanding

When challenged to give a description of musical expression and direction, one must externalize the courses of action involved and in some way describe their functioning. We must in some way try to grasp the processes involved, usually so easily and intuitively understood by the people who work with them. Note that the term "understanding" here metaphorically refers to a process that takes place "underneath" the conscious mind – in the subconscious [Snyder, 2000]. The act of externalizing consequently contains a number of conceptual predicaments as illustrated by Axel Cleeremans in a paper about conscious and unconscious processes in cognition.

> *Most native speakers of a language are unable to articulate the grammatical rules they nevertheless follow when uttering expressions of the language. Likewise, expertise in domains such as medical diagnosis or chess, as well as social or aesthetic judgments, all involve intuitive knowledge that one seems to have little introspective access to. We also often seem to tell more than we can know. In a classic article, social psychologists*

Nisbett and Wilson (1977) reported on many experimental demonstrations of the fact that accounts of our own behavior frequently reflect reconstructive and interpretative processes rather than genuine introspection. (Cleeremans, 2001)

The text here exemplifies how when placed in a situation where one must externalize a given process, the act of introspection regularly turns out to be nothing of the sort – it becomes a reconstruction or interpretation thereof rather than an actualization. When performing music, the expressive qualities are not regularly part of conscious thought in their totality. As musical expression deals with the entirety of music, one does simply not have the cognitive capability to move all these processes into conscious focus at a single time. They exist as implicit processes and are accessed through intuitive understanding. When attempting to describe the musical processes involved, one is thus more likely to provide a reconstruction or interpretation, rather then an externalization of the actual account.

Dialectics of intuition

I would however like to note that in this context, the meaning of intuition is not one of instinctive feeling or the like. Rather, it is used to describe unconscious processes that deal with large quantities of data, nonetheless based on previously acquired experience and knowledge. Through rehearsal and acquisition of knowledge one builds neural pathways of expertise that provide tools of recognition and response to particular circumstances. Even though these processes might take place outside of conscious reasoning, they are implicitly present and represent vast amounts of implicit and explicit teachings and experiences within their field. Conducting in this context is thus best described as an intuitive, intrinsically non-verbalized implicit skill developed over many years of practice and experience. Even when inherently it cannot be accurately described in words, it is not vague. It signifies the convergence or intersection of singly acquired skills making up the dome that is musical expression.

Observing the mind observe

Having identified musical direction and conducting as an intuitive skill, we have thus stumbled upon another hurdle. Since we are discussing an intrinsically non-verbalized and implicit skill, how do we find a model that could accurately represent musical direction? In order to exemplify the problem I would like to make an allegory with quantum physics. When attempting to describe the quantum world,

> *(…) the act of measurement defines the thing being measured, or, the thing measured and the thing doing the measurement are inextricably intertwined. (…) It is the statement that learning one kind fact about the world will very often preclude forever our knowing some other kind fact. (Lindley, 2007)*

Based on this concept one could assert that trying to conceive of a concept of musical expression would therefore be impossible since it only exists as a whole. It is thus that any knowing of one kind fact of musical expression will prohibit us from knowing another. Werner Heisenberg however implies the following.

> *The conception of objective reality of the elementary particles has thus evaporated not into the cloud of some obscure new reality concept but into the transparent clarity of a mathematics that represents no longer the behavior of particles but rather our knowledge of this behavior. (Heisenberg, 1958)*

In line with this statement one could deduce the fact that it is not impossible to envisage a conception of musical expression, but that what that conception represents changes. It is not a representation of an actual event, but a description of what we know about it through the tools of our measuring. One could potentially conclude that it is simply the tools that determine the difference between psychological and artistic knowledge. Where the field of music psychology utilizes tools such as empirical data and theoretical analysis, art makes use of different tools. The tools of art might then consist of poetical and personal elements. My own works often encompass tools such as metaphors and analogies represented by algorithms subsequently implemented into the computer environment. These algorithms simply represent a different aspect of our knowledge of the behavior of musical expression, but nonetheless consist of an equal amount of transparent clarity.

This is the mangle of practice as proposed by Andrew Pickering in describing the sociology of science [Pickering, 1993]. He refers to the mangle as a convenient and suggestive shorthand for the dialectics of the resistance and accommodation in agency and emergence of scientific models.

> *(…) Modeling is an open-ended process with no determinate destination: a given model does not prescribe the form of its own extension. (…) Modeling, then, is the link between existing culture and the future states that are the goals of scientific practice, but the link is not a causal or mechanical one: the choice of any particular model opens up an indefinite space of different goals. (…) Practical goals are [subsequently] constructed in a temporally emergent cultural field, and their detailed substance is itself emergently constructed in that field. (Pickering, 1993)*

It is the notion that the knowledge and understanding of the substance of our study becomes emergently transformed and delineated through the mangle of our practice. It is the mangle that defines the scientific or the artistic.

A metaphorical musical space

In utilizing the personal and the artistic as our essential tools, we now have devised a general strategy with which to implement the conceptual framework of an interactive meta-performer. It is the exploration of metaphorically formulated algorithms unfolding the inner workings of an autonomous and interactive virtual performer – a poetic analogy of expressive musical performance. I would like to begin by taking a look at the basic building blocks of an artificial musical system by identifying a chain of possible stages and processes in the context of a player-paradigm system.

A rudimentary musical analogy

In devising a computer musician, looking at a human performer may well provide us with a basic understanding of the rudimentary processes involved in interacting musicianship. The human performer certainly gives us a starting point for any of our knowledge about such systems. Through this understanding we could begin constructing an abstraction of a human performer, to be used as an analogous underlying framework of a machine musician.

In general, one could assert that in a subject-subject model of musical discourse there is an interdependent feedback loop of expressive interaction between performers in a musical setting, whether human or machine based. In addition one might assume a human performer to put their experience, knowledge and skill into practice as a hidden generative element of the model. Accordingly, one could expect the machine musician to do the same. This provides us with a basic model in which any single one of the musical entities present in a musical environment behaves in relation to all other entities in that environment and its own hidden musical background and vice versa. For purpose of transparency in representation, it might be favorable to presume "all other entities" to be a single skilled musical performer (fig. 7).

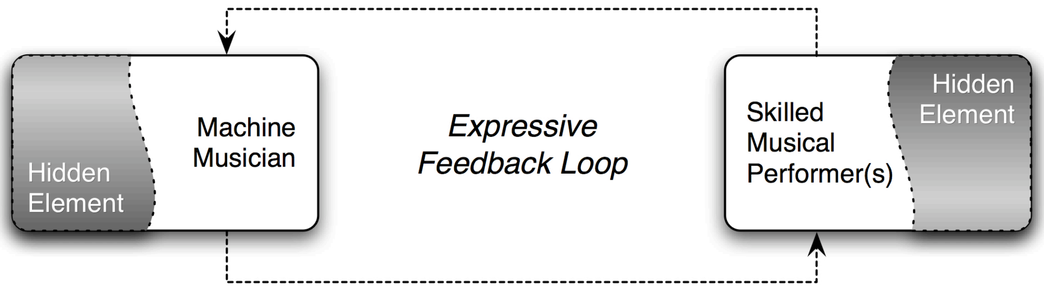


Figure 7: A basic interdependent feedback-loop of musical expression between a machine musician and skilled musical performer(s). Each here contains its own hidden generative element as part of its makeup with which it influences and shapes the direction and expression of the musical material.

A chain of processes

The next step would be to define how such a musical entity embeds itself in the musical environment. What are the essential processes involved in developing interdependent performance? In general terms Robert Rowe has laid out the following flow of processes in the context of an interactive computer.

> *The processing chain of interactive computer music systems can be conceptualized in three stages. First is the* sensing *stage, when data is collected from controllers reading gestural or audio information from the other performers. Second is the* processing *stage, in which a computer reads and interprets information coming from the sensors, and prepares data for the third, or* response *stage, when the computer and some collection of sound producing devices share in realizing a musical output. (Rowe, 1996)*

It should however be noted that this chain of processes was originally intended for application in the domain of the MIDI standard. When utilizing this line of thought in an audio driven computer environment, some interpretation or generalization on what these processes represent is necessary.

The sensing stage

This stage could be well represented by a microphone and possibly an AD converter. Given, however, that the MIDI standard abstracts away from the acoustic signal level of music up to a representation based on notes, comprising a pitch and velocity, that go on and off [Rowe, 1996], the *sensing* stage could equally well be preceded by an internal data representation of the musical material based on some feature extraction processes of the sonic material. Consequently, this stage could function as some form of computer listening deriving relevant musical information from input. In pursuit of musical direction or conducting qualities of the music, this stage could pose as the process in which to explore the directive aspects of the sonic input.

The processing stage

At this stage we will perhaps find the most important aspects of the system. The computer will here perform a generative process in correlation with the data acquired by "interpretative listening". This is where the *machine musician* affectively puts its autonomous expressive capabilities into effect. The computer generates the abstract expressive gestures of its musical output under incessant influence of what it is "listening" to. This is where the metaphorically formulated algorithms will become most important in the implementation – the description of the hidden generative elements of musical performance in interaction with the conductor role of the other musical entity in the environment.

The response stage

At this point the abstract expressive gestures are once again interpreted to be transformed into the actual audio output through the application of a computer instrument containing some form of digital sound processing or synthesis. The generative processes are metaphorically given "physical handles on phantom models" [Ryan, 1991]. All previous stages thus function as an expressive control structure or internal performer and interface over the response of the DSP or synthesis models. Here we find the interpretative actualization of expressive gestures into sonic output.

Inner unfoldment

With this line of thought we have illustrated a chain of rudimentary processes namely interpretive listening, generative processing and internally interpretive responding. Subsequently, these processes disclose the intermediate stages representing the material to be processed. At the outset we will find the perceptual data derived from some basic feature extraction process. This data is then interpreted into its conducting direction. The direction then collides with the generative hidden elements of the machine musician to form the expressive gestures of the machine, followed by a further actualization of this abstract data into musical matter (fig. 8).

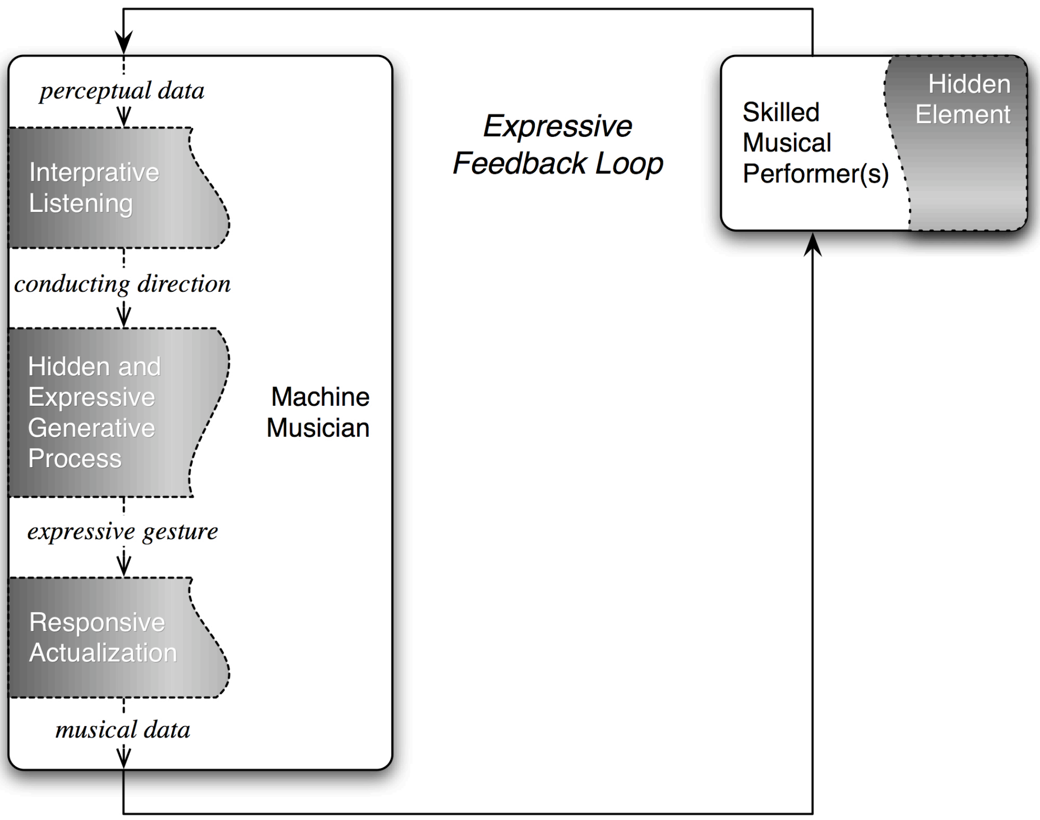


Figure 8: The unfolding of the machine musician into its internal processes and its consequent intermediate stages.

The structure of these intermediate stages is not as straightforward as it might seem, since they represent rather different phases in the process of performance and thereby symbolize dissimilar spaces. Guy E. Garnett and Camille Goudeseune exemplify this notion through the development of instrumental performance interfaces.

> *We consider the family of sounds produced by a musical instrument as lying in a Euclidean space. The axes of this perceptual Euclidean space are given by parameters such as pitch, loudness, and various psychoacoustic measures of spectral content. A similar space is given by the control parameters of the instrument (which may be both more numerous and more difficult to deal with abstractly). The mapping from this control space to the timbral space can also be analyzed: continuity, monotonicity, hysteresis and other mathematical properties affect the simplicity of the performer's mental model of the instrument. In the case of synthetic instruments, a third space is given by the parameters which the synthesis algorithm accepts as inputs. (Garnett and Goudeseune, 1999)*

In instrument modeling they roughly consider a triptych of spaces, consisting of a perceptual space, a control space and a timbral space. The axes of these spaces are then given by the parameters that make up these spaces. A similar interpretation can be made of the intermediate stages in the musical environment of a computer. These stages would here respectively allocate a perceptual space, a conducting space, an expressive gesture space and an instrument space, each constructed out of an n number of dimensions.

The consideration of representing the individual parameters as lying in Euclidean space here serves as a means to illustrate the vision that the individual parameters are fully interconnected and are not separable without consequence. As formerly argued, the parameters represent a unique location or object within the dimensions of a particular space. The question however remains open on what number of dimensions these particular spaces posses and what these dimensions represent.

Dimensionality of musical spaces

We are thus initially looking for the basic building blocks of some particular musical spaces – the parameters that accurately describe the various characteristics of a specific phase in the musical process. When observing a musical space, however, there is an indistinctness to the number of dimensions or parameters that make up this space. Given any arbitrary musical space, one cannot definitively state a fixed number of dimensions that would accurately represent this space. This ambiguity of dimensionality is exemplified by the following example of a violinist's hand in performance.

A performer's hand paradigm

When performing an inquiry into the dimensionality of a violinist's hand for example, one could deduce a number of divergent dimensionalities that would accurately depict the space the hand occupies. The distinction of these spaces is in this case greatly dependent on the performer's point of view in unfolding the dimensionality of his hand, e.g. physically, while practicing or in performance. Each of these angles will provide us with a different number of dimensions accurately describing some aspect of the same musical space.

A physical stance

When giving a description of the physical manifestation of the hand e.g. its position or placement on the instrument, a performer is most likely to make use of the three dimensions that regularly describe physical space. The three dimensional representation then becomes most appropriate to illustrate the physical materialization of the hand as an object (fig. 9). However, when practicing a particularly difficult passage or technique the three-dimensional space might prove insufficient.

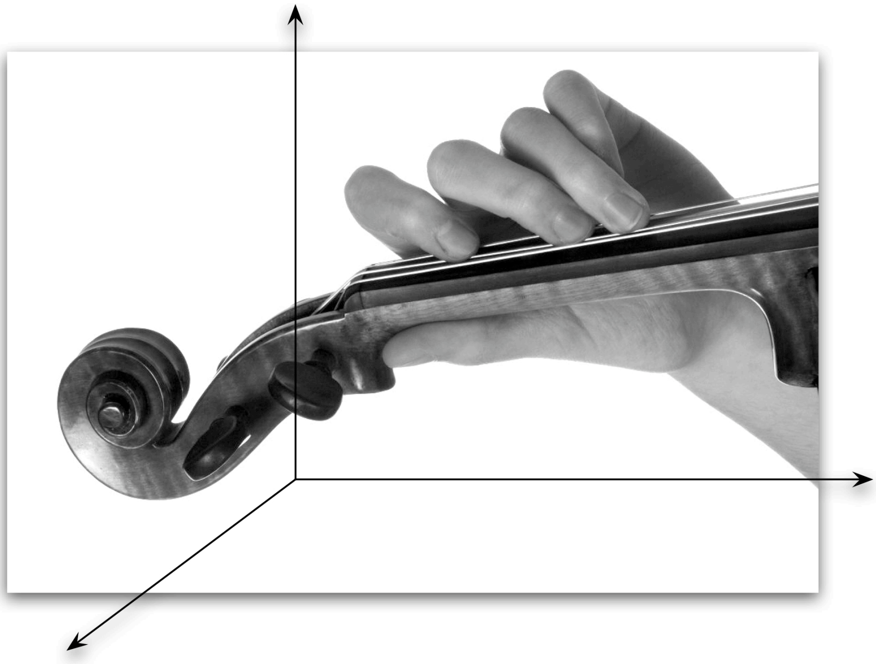


Figure 9: The violinist's hand as a three-dimensional manifestation in common space.

Manifold in practice

Whilst practicing, the violinist's hand could also be accurately represented by the numerous axes describing the individual phalanges, tendons and muscles and the consequent forces being exerted by them. In the act of practicing, a performer focuses on specific tasks the individual parts of the hand are performing in order to improve their dexterity. A performer thus has the potential ability to zoom into the excess of dimensions that make up this space of the corporal hand – a multidimensional manifold of dimensions, unfolding and enfolding space in focusing on specific skills (fig. 10). This manifold of space is however not likely to generally hold in performance as there are other, more significant parameters at work at that time. In basic terms, there would be too many dimensions to be able to conceive of consciously.

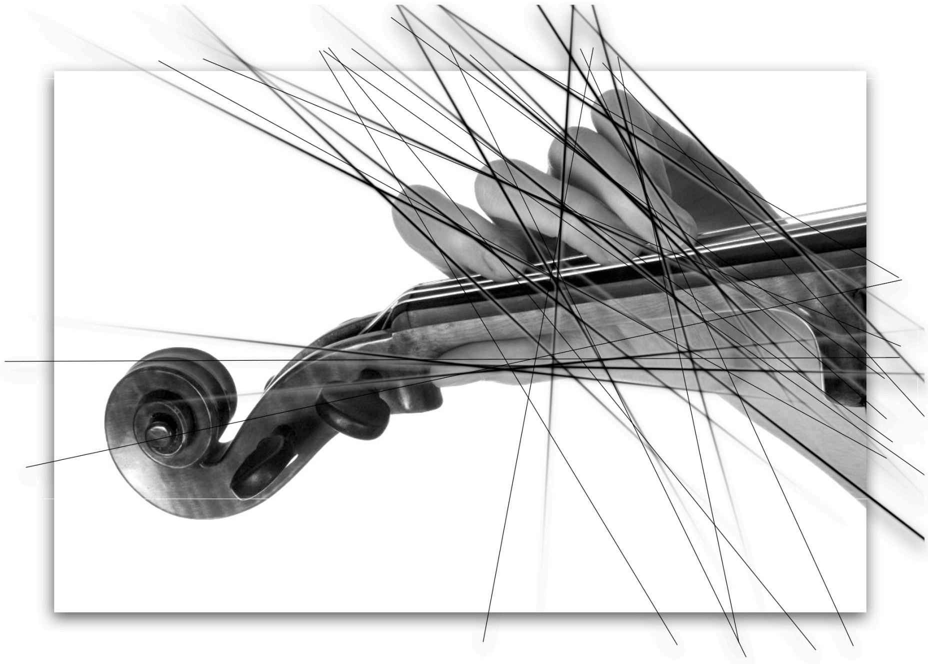


Figure 10: The violinist's hand as a manifold of n-dimensions describing all corporeal traits.

Performance singularity

Whilst a performer performs, he still upholds dependence on the physical skills acquired during practice in the corporal space. The significance is however that, given the limitations of our consciousness, he is no longer carrying out procedures on the direct axes of that space. It is in this context that the performer can evidently equally well represent her hand by means of a convergence of the multi-dimensional manifold into a singularity – the musical thought as directly dispersing through the execution of dexterity. The hand here thus becomes a singular object of musical continuity as represented by a one-dimensional space (fig. 11).

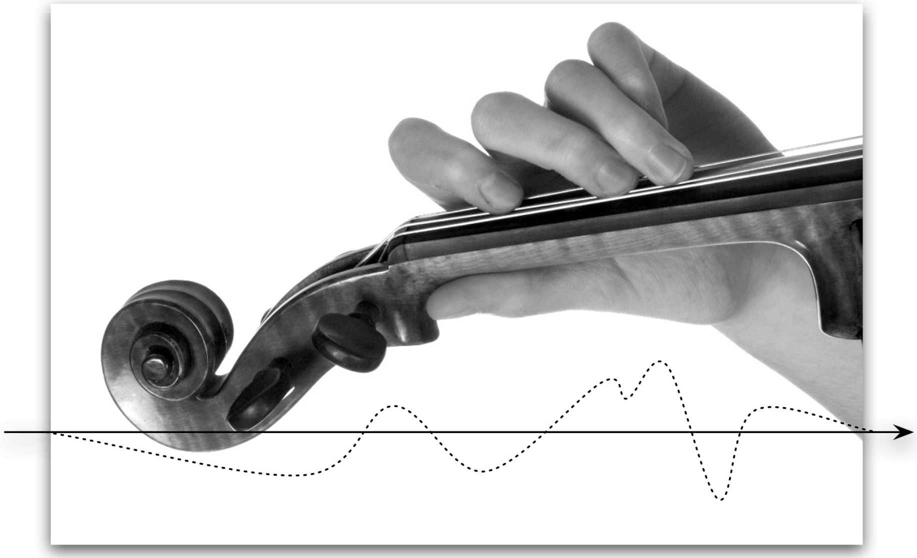


Figure 11: The violinist's hand as a one-dimensional expression of performance continuity.

We now have three possible spaces with which to describe the hand of a violinist, each dependent on the practical context in which it was conceived. There exists no conclusive representation of this space or dimensionality. The required spaces come forth as part of a pragmatic effort to define the dimensions suitable for describing the processes at hand.

The computer's box

To extend the concept of interchangeable dimensionalities into the domain of computer music, the matter is well illustrated by Julius O. Smith in dealing with digital sound synthesis.

> *Since it takes millions of samples to make a sound, nobody has the time to type in every sample of sound for a musical piece. Therefore, sound samples must be synthesized algorithmically, or derived from recordings of natural phenomena. In any case, a large number of samples must be specified or manipulated according a much smaller set of numbers. This implies a great sacrifice of generality.*

> *The fundamental difficulty of digital synthesis is finding the smallest collection of synthesis techniques that span the gamut of musically desirable sounds with minimum redundancy. (Smith, 1991)*

In the creative use of parameter space, one will have to enfold or reduce a potentially unlimited dimensionality into a finite number that is most useful in its application. I would like to argue, however, that in doing so no great sacrifice is being made. By creating a system based on a certain dimensional interpretation and not another, one is able to exert particular interest. It is here that a composer is given the option of focusing and zooming into a level of compositional and personal creative interest – it is not a sacrifice, but an indispensable compositional choice.

Given this notion, defining the dimensionality of a computer performer becomes directly interconnected with the intentions of the composer. The axes of the system have to disclose an accurate representation of the space the machine needs to perform in, rather than an accurate illustration of what it endeavors to model.

A poetic foundation of musical space

Whilst looking at the intermediate stages in the musical environment of a machine musician, the unlimited dimensionality previously mentioned is initially present in the performer's sonic output used as input for the computer. In defining the dimensionality of the intermediate stages we will at this point first have to define a parameter space enfolding this unlimited number of dimensions into the functional.

Starting at the final stage, the dimensions of musical matter could here be defined by the parameters that make up the DSP or synthesis models in use. Evidently, they depend on the programmer's choice of sound processes, but also become rather transparent after implementation, thus they are in need of no further clarification.

The former stages of conducting direction and expressive gesture contain somewhat less transparency, but are flexible nonetheless. As these stages represent an abstraction of and not an actual musical space, they consequently contain a high level of plasticity. In determining their dimensionality I have once again utilized a pragmatic attitude and delineated their dimensionality in a corollary of perceptual space. Though possibly not directly representative of the actual parameters, this proved sufficient in a metaphorical sense.

The initial perceptual space here symbolizes the perceptual data of the computer performer as formerly discussed, and establishes our first contact with the computer's space. In order to define this space we could once again begin by taking a look at the cognitive structure of a human performer.

> *Feature extraction: A basic process of perception. This happens very early in the perception process, during the persistence of echoic memory. Different features are believed to be extracted by various special-purpose feature detectors. (…) This process must happen before higher-level coding and recognition can take place. (Snyder, 2000)*

The features extracted by this process, however, remain elusive and are open to numerous divergent interpretations. Many music psychologists and computer musicians alike have devised a multitude of accounts for the essential aspects being extracted. A general guideline in defining the dimensionality of the object of music might nonetheless be established as proposed by Daniel J. Levitin, capturing a multitude of commonly found qualities and potential subsequent re-interpretations thereof.

> *A performance of music contains the following seven perceptual attributes: pitch, rhythm, tempo, contour, timbre, loudness, and spatial location (one might also add reverberant environment as an eighth). Technically speaking, pitch and loudness are psychological constructs that relate to the physical properties of frequency and amplitude. (Levitin, 1999)*

Having here delineated seven potential parameters in the makeup of the perceptual space, we could now render a musical entity as an object moving within this seven dimensional space – a musical object which subsists and evolves at the intersection of its individual parameters. Though possibly not the definitive space, this dimensionality will provide me with a poetic starting point for the implementation of musical dimensionality in a virtual meta-performer.

Pandemonium in space

One of the most important questions still remains to be dealt with. What might a skilled musical performer possibly be doing within this space? Given the fact that there exist a multitude of styles, idioms and personal expressions, a singular answer clearly would not suffice. One could nonetheless still discern a number of characteristics portraying the performer's behavior.

In general terms one could state that each performance contains (1) some element of order and (2) some element of unpredictability, such is the coherence and the complexity of music. There exists nevertheless a discrepancy about the origins of this order and unpredictability as exemplified by the following analogy to the scientific practice of physics.

> *Traditionally, when physicists saw complex results, they looked for complex causes. When they saw a random relationship between what goes into a system and what comes out, they would have to build randomness into any realistic theory, by artificially adding noise or error. (Gleick, 1988)*

The principle of adding noise to account for complexity and unpredictability is one that has been well incorporated into the domain of electronic music. Here we will frequently find systems that in addition to stable or static parameters make use of random deviation or jitter to "liven up" the musical output (fig. 12). This notion might be considered to be a similar mistake to that of expression as mere inflections of categorical perception. The complexity and potential random relationships imparted by a performer do not necessarily come forth from a mere addition to the model, but from the very nucleus that created the complex output. In stating this however, I do not wish to negate the relevance of stochastic processes as an artistic or aesthetic choice, but only to question their application in achievement of particular objectives: the use of random deviation to provide complexity.

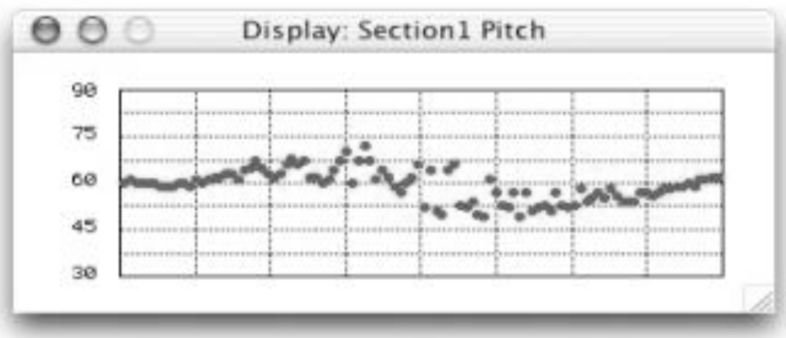


Figure 12: An illustration of a recognizable stable defined mean and random deviation around the mean. This picture has been taken from the tutorial examples accompanying the popular AC Toolbox programming environment.

Systematic randomness

When one is faced with a lack of intricacy in the sounding output of a certain computer model, the addition of some type of noise might indeed initially enrich the sounding result. Nonetheless, I do not believe any musical process to be contingent upon randomness. Even though we might often not fully comprehend what the source of complexity and sophistication comprises of, it is in my opinion most likely not arbitrariness and indeterminacy. Music remains an intentional act of human expression. Although a performer may exert unpredictable behavior, this behavior might still very well be the result of a systemic process. Systems containing such order and unpredictability are also commonly described as containing unstable aperiodic behavior in deterministic nonlinear dynamical systems or in short as *chaos* [Kellert, 1993].

> *This unpredictability results from the feature of all chaotic systems known as sensitive dependence on initial condition. This feature means that two systems that start very close together may eventually move very far apart, much the same way that two paper*

cups floating next to each other at the top of a waterfall may well end up yards away from each other at the bottom. (Kellert, 1993)

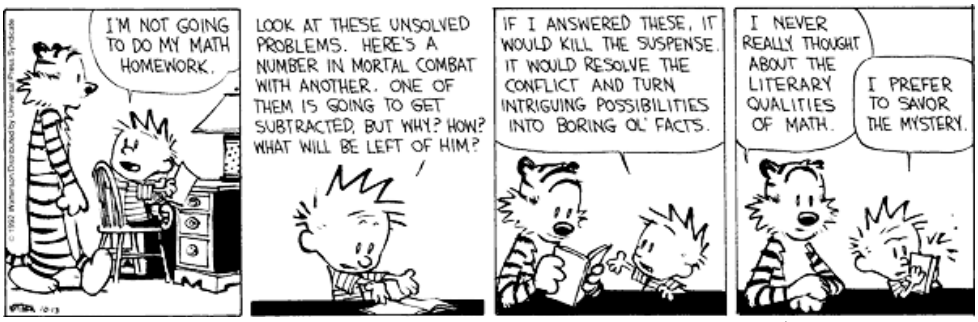
It is through this notion that musical processes point toward chaotic phenomena. The minute differences in initial conditions between any given musical performance and another can potentially greatly drive apart the resultant output of the musical entities involved, through the incessant feedback-loop of musical expression. The system of musical expression here is the nonlinear dynamical system, which exerts unstable aperiodic behavior. This behavior might be intrinsically unpredictable, it is nonetheless deterministic in its origin as it arises out of an intentional artistic act.

By exploring chaotic models in the context of a machine musician, we could devise a metaphorical representation of the hidden and unconscious processes in musical performance. It will be in using the metaphor of chaos as unpredictable order that I would like to propose bringing together objectivity and subjectivity, conscious and unconscious, ordered and disordered and finally form and expression in musical performance.

Technician’s Poetry

Technician’s Poetry

On the implementation of an autonomous interactive musical system



from “Calvin & Hobbes” (1992)

Conceptual rendition

The full scope of implications on the implementation of an autonomous and musically interactive meta-performer as formerly described, has been too great to consider as part of a single research project. Regardless of this fact, I would at this point like to transfer a number of these concepts and propositions I have previously discussed to a computer model dealing with an expressive musical environment. It is an implementation, exploration and musical actualization of the metaphysical concepts of performance practice as previously outlined, devising a computer model of an expressive meta-performer.

My current work in this field has made use of the MaxMSP programming environment. In spite of this, I would like to move away from any platform specific representations in order to focus on the more conceptual and theoretical aspects of the inner workings of the machine performer. I have therefore decided to make use of a mathematical representation in relating to a more general computer implementation. The purpose of this representation is not to form a mathematical model accurately describing the concepts of musical expressivity, but to form a bridge and common language between the domains of the conceptual and the technical. The notions and considerations on expressive performance might initially become mangled by this process only to ultimately be assembled to form a machine musician out of the mathematical metaphors – the building blocks resulting in a poetic computer implementation of a meta-performer.

I have already described a rudimentary chain of processes that make up an interactive system, comprised of some listening, generating and responding functions. The generative processes here perhaps present us with the most significant elements for enabling a computer model's expressive capabilities, after all the generative processes account for the emergence of the computer's expressive gestures. For the sake of clarity I have decided to describe the processes at hand in order of chronology, rather than in order of the significance of their expressivity. In line with Blackwell and Young [2004] I would like to begin by formalizing or translating the rudimentary chain of processes in an expressive feedback-loop to a more schematic representation. With this I would like to outline the successive processes and stages of the computer implementation of a meta-performer, as well as provide more concise future reference to the elements that make up a musically expressive system.

A chain of functions

Let us begin by asserting a *skilled musical performer* and a *machine musician* to be some sort of function, processing or transforming some kind of input into some kind of output.

$$B: \; X_A \xrightarrow{B(X,h_B)} Y_B$$

The *skilled musical performer* is represented by the function B and produces output Y, based on a sonic input X as produced by a *machine musician* A, and a hidden function h_B. In this situation the hidden function symbolizes the musical entity's contextual and generative input to the model and X here indicates B's dependence on the other musical entity in the environment.

$$A:\ Y_B \xrightarrow{A(Y,h_A)} X_A$$

The *machine musician* as function A, when upholding to a certain level of similarity in the subject-subject model of discourse, would be best represented by an inverse to the function B, thereby completing the feedback loop in music (fig. 13).

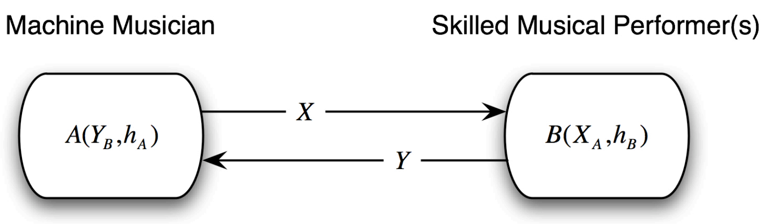


Figure 13: A schematic representation of an interdependent feedback loop in an expressive and interactive musical environment. The machine musician and skilled musical performer are here respectively represented as functions $A(Y_B,h_A)$ and $B(X_A,h_B)$, where X_A denotes the output of function A as input to function B and Y_B denotes the output of B as input to A. The hidden generative functions of the individual performers are here indicated by h_A and h_B

Internal processes and intermediate stages

As function B, representing the human performer, is implied as part of the model, it needs no further elucidation and operates adequately in its current form. Function A, the *machine musician*, still remains to be unfolded into its separate processes and intermediate stages.

$$I_L(y):\ Y_B \Rightarrow y_A \longrightarrow c$$

Here the sonic output Y_B, as derived from *performer* B, serves as input to *machine musician* A with an internal representation y_A of basic perceptual features. Some interpretative listening function $I_L(y)$ dependent on y_A then further processes this into an intermediate state c. At this point c symbolizes the abstract internal representation of the extracted relevant musical features, namely the sonically defined conducting elements of the Y_B.

$$G(c,h_A):\ c \longrightarrow e$$

In the above, the generative processes are represented by $G(c,h_A)$ as a function of c and h_A. This function does thus not merely transform c into e, but amalgamates it with the hidden process h_A. Here c and e respectively represent the intermediate stages of the extracted musical direction and the internal representation of the computer generated abstract expressive gestures. Then h_A represents the external hidden aspects of the model, signifying A's potential independence from external input and the experience, knowledge and skill of its implementation.

$$I_R(e):\ e \longrightarrow x_A \Rightarrow X_A$$

The expressive gestures e are here processed through some interpretative response function $I_R(e)$ into x_A, transforming the generated abstract gestures into a musical mode. The internal representation x_A can then be finalized in the actual sonic output X_A and through the "humanly" defined and implied function $B:\ X_A \xrightarrow{B(X,h_B)} Y_B$ complete the feedback loop containing the musical environment (fig. 14).

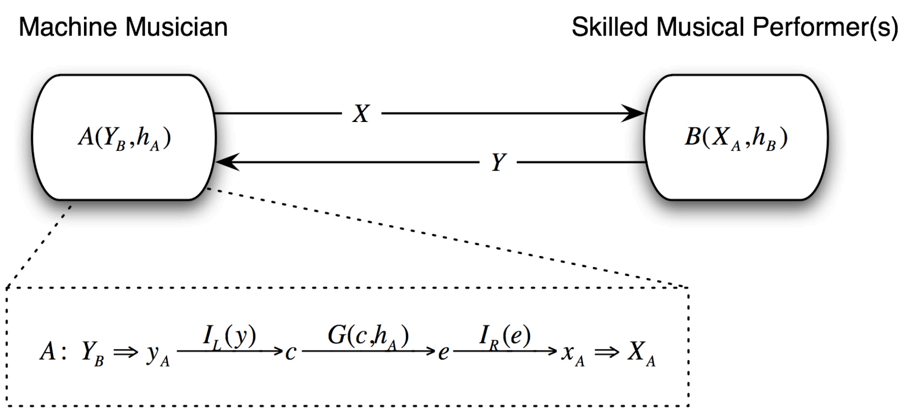


Figure 14: An extended schematic representation in which the function B of the human performer is implied as part of the model and the machine musician's processes A are expanded into its internal intermediate stages and corresponding functions illustrating the machine's listening, generative processing *and* responding *procedures.*

Interpretive listening

When in first contact with any audio-driven environment we have to deal with how the computer will make sense out of its environment. This is the process whereby the computer assesses and construes the environment in which it is operating.

$$I_L(y):\ Y_B \Rightarrow y_A \longrightarrow c$$

As we have seen, there is a twofold process at hand in which low level perceptual cues are extracted and subsequently interpreted into the musically relevant data, namely conducting qualities.

Low level cues

In general terms we have previously asserted that perceptual space may occupy seven dimensions namely pitch, rhythm, tempo, contour, timbre, loudness, and spatial location. I have used this parameterization as a poetic starting point in delineating the number of dimensions defining an abstract musical space, rather than as a conclusive classification of the actual dimensions of perceptual space. Many alternative diverging auditory models have been formulated, such as the IPEM toolbox for perception-based music analysis by Marc Leman et al. [2001] and the MaxMSP implemented analyzer~ by Tristan Jehan and Schoner [2001]. Subsequently, a multitude of perceptual parameter subsets have been successfully utilized in search of musical expression such as sets comprised of roughness, cochlear filter-bank centroid, sound level range, duration, articulation, number of notes and residual spectral ratios, as employed by Mion and De Poli [2004], or interonset duration, relative articulation, peak sound level, attack velocity, and spectral ratio, as used by Friberg et al. [2002].

With the objectives of devising an expressive meta-performer and allowing it to function skillfully within its own musical space or idiom, we are dealing with a creative process. The idiom of the machine musician is one that needs to be composed as part of the implementation process, as exemplified by Agostino Di Scipio in dealing with the design and implementation of his interactive systems.

This idea is motivated with a notion of 'interaction' as a means, not an end in itself, i.e. a prerequisite for something like a 'system' to emerge. Therefore, 'interaction' should be the object of design (hence, composition), and more precisely the by-product of carefully planned-out interdependencies among system components. The overall system behavior (dynamics) should be born of those interactions, in turn born of lower-level interconnections.

This is a move from 'interactive performance', or 'interactive composing' (…) to 'performing the interaction', or 'composing the interaction'. In the latter approach, one designs, implements and maintains a network system whose emergent behavior in sound one calls music. (Di Scipio, 2003)

With this notion, the selection of the particular cues to be extracted becomes determinative of the compositional significance the computer performer exerts on its input. When for instance the selected subset of cues includes a predominant number of loudness related qualities – i.e. sound level range, peak sound level, spectral ratio, etc. – the machine musician will subsequently respond to these aspects of the performance to a higher degree. In an expressive feedback-loop with another performer, the development of loudness related elements would consequently gain compositional and ultimately expressive significance in the course of a performance. The selection of parameters to be extracted hence becomes a compositional act and consequently makes the utilized perceptual subsets dependant on specific pieces, computer implementations and performance explorations. Many of my current implementations include parameters such as sound level, inter-onset duration, event density, spectral ratio, noisiness and pitch as dimensions of the perceptual space. The only compositional constant or guideline I generally uphold is my interest in the interplay of loudness and density.

A conceptual vector delineation

After having formerly denoted a compositionally defined perceptual space constructed out of some seven dimensions, we have an object y_A in this space defining a metaphorical location of this analysis data. The expressive gestures of the music could subsequently be envisaged as the movements of this multi-dimensional object in the perceptual space, i.e. the dynamic morphology of object y_A. With an implied notion of movement we can denote this object as a vector $\vec{y}_A$ representative of the perceptual disposition of the musical input.

$$\vec{y}_A = (y_1, y_2, \ldots, y_7)$$

The components of vector $\vec{y}_A$ are logically derived from the individual parameters of the perceptual analysis data.

Interpreting direction

We now have to further transform the perceptual object $\vec{y}_A$ through function $I_L(y)$ into a conducting object $\vec{c}$. From the behavior of $\vec{y}_A$ we should in some way interpret the directive qualities of the expressive gestures in order to instigate a unification of musical direction in interaction between the *machine musician* and the *skilled musical performer*. Having formerly established a differential relation between the musical gesture and the musical direction, I suggest a similar strategy in the current transformation to be appropriate.

Velocity of a perceptual object

Whilst observing the conducting aspects of the perceptual object, we are thus looking at the rate of change or in other words, the velocity of the musical content. We can define the average velocity of object $\vec{y}_A$ as the displacement Δy_A in a time interval Δt.

$$\vec{c} = \frac{\Delta \vec{y}_A}{\Delta t}$$

When writing the vector in component form, the above yields:

$$\vec{c} = (c_1, c_2, \ldots, c_7) = \left(\frac{\Delta y_1}{\Delta t}, \frac{\Delta y_2}{\Delta t}, \ldots, \frac{\Delta y_7}{\Delta t} \right)$$

Objects in time

Since we are working within the multilayered domain of a musical environment, the time interval Δt needs to be defined. When observing time scales of musical gestures it is apparent that they cover a multitude of different time intervals. Jeff Pressing has classified a number of these musical time scales with reference to distinctive musical phenomena (tab. 1) that potentially provide insight into the significant time scales of a musical gesture [Pressing, 1993].

Table 1: Musical time scales

Phenomenon	*Typical time scale*
Single waveform	.00005-.05 sec
Envelope attack component	.0005-10 sec
Single note	.001-10 sec
Steady note production	.05-10 sec
Vibrato/tremolo	.1-.5 sec
Tempo/pulse	.1-5 sec
Motif	.5-5 sec
Phrase	3-30 sec
Melody	5-100 sec
Movement	30-1000 sec
Piece	30-30000 sec

One could here assume a musical gesture to be a quintessential component of the time scales motif, phrase, melody and movement. In my personal work I have generally worked with these four time scales or a smaller subset thereof.

$$\vec{c}_1 = \frac{\Delta \vec{y}_A}{\Delta t_1} \qquad \vec{c}_2 = \frac{\Delta \vec{y}_A}{\Delta t_2} \qquad \ldots \qquad \vec{c}_7 = \frac{\Delta \vec{y}_A}{\Delta t_7}$$

With this we have defined four vectors describing some directive qualities in four different time scales of musical input. These vectors now need to be combined in some way to describe the total direction of the expressive gesture.

Cartesian or polar considerations

The vector $\vec{c}$ is at this point still constructed out of its Cartesian components. This has so far been conceptually consistent with what it represents in perceptual space – the direction of the perceptual object constructed out of its individual parameters. When however placing $\vec{c}$ within a conducting space, a conceptual or poetic conversion could be effective. The musical conductor is here more convincingly described as giving a particular direction with a certain magnitude to the music, i.e. a coordinate conversion of vector $\vec{c}$ into its Polar coordinate representation $\vec{C}$.

$$\vec{C} = (\rho, \phi, \ldots, \theta)$$

Here ρ denotes the total magnitude of the rate of change and $\phi, \ldots, \theta$ a list of angles stating the direction thereof. The vector $\vec{C}$ at this point upholds a more viable poetic relation to what it is attempting to symbolize (fig. 15). In addition, the modified representation allows us to perform alternate permutations on the numbers of its makeup.

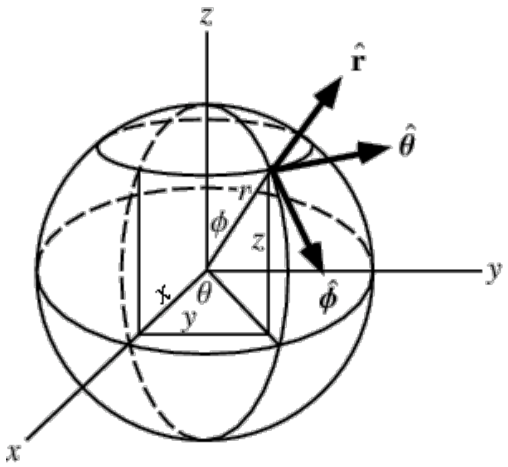


Figure 15: An illustration of a Cartesian and Polar coordinate representation of a vector in three dimensions, poetically presenting us with two possible viewpoints in describing a single line.

Motivated by computations with complex numbers, as present in the domain of FFT related processes, I would like to propose a convolution inspired process in unifying the vectors of the different time scales. As in a complex number multiplication, the individual magnitudes of the four vectors would here be multiplied with each other and the corresponding phases added.

$$\vec{C} = \vec{C}_1 \circ \vec{C}_2 \circ \ldots \circ \vec{C}_4$$ *(where $\circ$ symbolizes a complex number inspired multiplication)*

where the individual vector components are combine in the following:

$$\rho = \rho_1 \cdot \rho_2 \cdot \ldots \cdot \rho_4 \qquad and \qquad \phi = \phi_1 \cdot \phi_2 \cdot \ldots \cdot \phi_4$$

$$\ldots$$

$$\theta = \theta_1 \cdot \theta_2 \cdot \ldots \cdot \theta_4$$

Through these kinds of transformations we have induced an initial conversion of the material from the intrinsically analytical space of perception, into the more abstract creative space of a meta-performer – a poetic extraction of the compositionally relevant expressive musical direction.

Generative processes

Having arrived at an abstracted account of the conducting elements in a musical environment, we can continue to deal with the potentially most significant and intangible processes of a musically expressive system – the intuitive, unconscious and emergent qualities that make up the generative principles.

$$G(c, h_A): \ c \longrightarrow e$$

At this stage we will find the chaotic system metaphorically rendering the hidden functions of a meta-performer, as previously discussed. Furthermore, it will be this element of the system that will eventually autonomously perform the computer's expressive gestures under the incessant influence of the conducting aspects.

The composition of a chaotic gesture

At the core of this process lies the act of devising a metaphorical representation of generative performance. With this understanding, we have become fully immersed in the intrinsically hidden creative space. We can consequently allow the generative musical environment to function as a complete abstraction of a potential musical space – an instantiation of the unconscious and expressive level of creative performance. The objects in this space thus no longer represent actual particulars of music, but a metaphorical notion of the chaotic dynamics of musical morphology. The emergence of the expressive gesture here constitutes a compositional undertaking in formulating the machine musician's idiom of musical expression – the composition of a meta-performer.

A gravitational object

In my personal inquiries into chaotic systems I have implemented and explored a planetary simulation model as a metaphor for chaotic musical thought. In this model a space is defined in which one can place a number of objects that will interact with each other when given a certain mass. Each object here exerts a gravitational force of attraction on every other object within the space, this being contingent on the respective masses and distances between the objects (fig. 16).

$$F = G\frac{m_k \cdot m_l}{r^2}$$

Given only one object in the space, nothing would occur (there are after all no other objects to interact with). When two objects are placed in the model, they will simply attract each other and collide. Though when the model is provided with three objects, interesting chaotic behavior begins to emerge as the collision trajectories of any two objects begins to interact with the gravitational pull of the other.

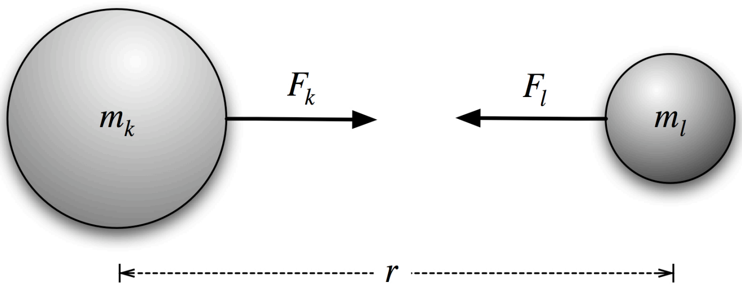


Figure 16: An illustration of gravitational forces as exerted by two point masses on each other. Here the magnitude of F_k and F_l will always be equal, regardless of the masses or distance.

In addition, one can exert external forces upon the objects within the model, making an object responsive to its surroundings. The forces working on an object k could then be defined as follows.

$$F_k = F_{gravitation,k} + F_{conducting}$$

The external forces have logically been defined as the conducting force of the musical environment. The disposition update of k over computation time interval n can then be computed by proceeding in the following way:

$$a_k(n) = \frac{F_k(n)}{m_k}$$

$$v_k(n) = v_k(n-1) + a_k(n)$$

$$x_k(n) = x_k(n-1) + v_k(n)$$

This set of functions then has to be applied to all objects in the model's space and repeated for all subsequent dimensions thereof.

I have worked with this particular physical model as it satisfied a number of fundamental attributes of the conceptual framework. At the outset, it upholds the statement of a musical object as a singular entity – an object representation of musical thought. In addition, this singular entity exerts chaotic gestures such as the dislocation, velocity and acceleration of the object interrelated with all other objects within the space and more importantly in interaction with the music's conducting elements as derived from the sonic input. Most importantly, I found it to be an interesting model to explore within the compositional context of emergent musical gestures.

Some implementation pragmatism

In addition to the rudimentary formulas of a gravitational model as stated above, I have inserted a number of supplementary rules. This has been a necessary step in providing some limitations and stability to the behavior of the model and has subsequently put forth a number of parameters that could be used in configuring the space and thus its composition.

Spatial perimeter

First of all a spatial perimeter is defined in order to contain the space in which the objects move. In this model I have defined the boundaries as additional forces to the object.

These forces work in an opposite direction to the object and exponentially increase in approaching some upper and lower bound.

$$F_{lower\_perimiter,k} = s^{(lowerBound - x_k)} \qquad where\ s \geq 1$$

$$F_{upper\_perimiter,k} = -s^{(x_k - upperBound)}$$

Here s signifies the stiffness of the boundary and can be denoted as a variable when working with the model. This function has been very effective in creating some limits to the physical model without yielding a multitude of unwanted side effects.

Object slingshots and orbits

Another feature of the planetary simulation model is the appearance of slingshots. This effect takes place when two objects come very close together. As the distance r between them becomes smaller (being a dividing factor) the forces consequently increase rapidly causing a colossal acceleration. This behavior is idiosyncratic to the model and therefore a potentially interesting compositional feature. The magnitudes of these accelerations, however, can grossly spiral out of control. In order to somewhat constrain this feature I have included two supplementary functions. The first function transforms the object's distance to other objects to include some kind of imaginary bubble around its center point.

$$r = x_k - x_l$$

$$r_k = \frac{b_k}{r} + r \qquad where\ r \neq 0$$

This function effectively envisions the other object as promptly becoming very distant when it passes within its perimeter, instantly reducing the gravitational forces (fig 17). Here b implies some outer limit of the object and can be defined as another variable in the model.

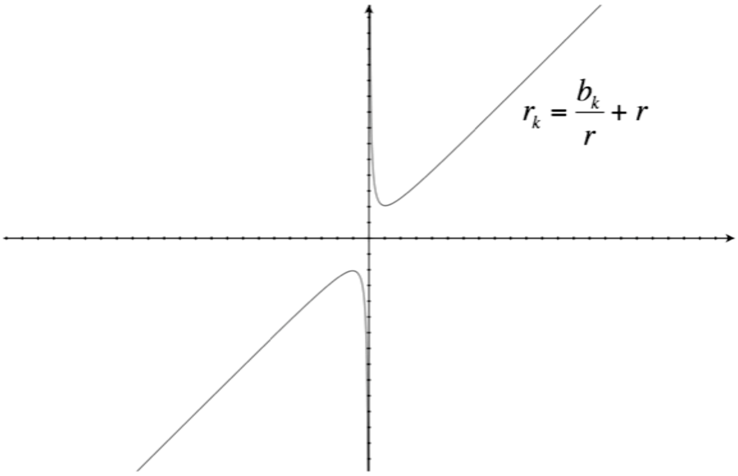


Figure 17: A graph plotting the "bubble" function with the actual distance r on the x-axis and the imagined distance r_k on the y-axis.

As this alone is not enough to reduce the excessive forces in the model while maintaining the model's idiosyncratic slingshot behavior, I have applied a basic limiting function to the velocity of the object.

$$v_{new,k} = v_{max} \arctan\left(\frac{v_{old,k}}{v_{max}}\right)$$

Here the velocity has been regulated to constrain its acceleration when exceeding v_{max}, at this point an additional variable in the model as well.

The object's drag

Additionally, I have incorporated friction into the model, effectively filling the space the objects move in with some kind of liquid or gas. In adding friction the model is provided with a means of slowing itself down, allowing it to incorporate static moments as part of its behavior. This drag force is defined as an inverse dependent on the velocity of the object.

$$F_{friction,k} = -dv_k$$

Here d delineates the general viscosity of the liquid or gas and presents us with the ability to shift and alter the dynamic qualities as exhibited by object k.

Altering the warping of space

Finally, I have mildly adapted the original gravitational function to exclude G (as this is a constant with no direct behavioral relation to the model) and denoted the power of the radius as a variable.

$$F_{gravitation,k} = \frac{m_k \cdot m_l}{r^w}$$

By adjusting w, one is presented with a means of altering the manner in which an object's gravitational field warps the abstract space in some elementary way and consequently modifies the inter-object attraction, making the space either more smooth or more angular.

The model's baton

Having accounted for the "hidden" function of the model which provides it with some autonomous behavior, we still need to define $F_{conducting}$, stating the machine's interaction. In the former stage of interpreting direction we have denoted the vector $\vec{C}$, where the angles $\phi,\ldots,\theta$ of the vector state the direction of the musical input and the magnitude ρ represents the total rate of change. The magnitude of the vector could here be viewed as a scalar of speed. Since we need to define a force given to the object, I would suggest differentiating this magnitude so as to derive the force (as acceleration with mass 1.), while preserving the angles of the music's direction.

$$\vec{F}_{conducting} = \left(\frac{\Delta\rho}{\Delta n},\phi,\ldots,\theta\right)$$

This vector then becomes representative of the force of the total rate of change in the musical environment, whilst maintaining the conducting direction therein.

With these additional rules and considerations I have implemented the model into the computer environment. We can now manipulate the planetary model's final behavior by configuring the variables s, b, v_{max}, w and d and by providing the objects with some external force $F_{conducting}$. This set of variables has provided me with a fruitful collection of parameters to explore in devising an idiom for the machine musician's expressive gestures. Later, I would like to discuss some strategies in setting up the model for use in either a compositional or an improvisational context.

Expressive responding

The machine musician's expressive gestures as result of the generative principles of the model now have to be transformed into some kind of musical output. The planetary simulation model here serves as a control structure for a more traditionally defined computer instrument, the objects in expressive space being metaphorical "physical handles on phantom models" [Ryan, 1991].

$$I_R(e):\ e \longrightarrow x_A \Rightarrow X_A$$

There is again a twofold process at work. The expressive gestures have to be interpreted and mapped onto some synthesis or processing algorithms, i.e. sound objects (here used to indicate a generality of processes), where they will subsequently be finalized into the actual sonic output of the system.

Phase space interpretations

Firstly, we have to decode the expressive gesture e as coming from the generative principles of the machine musician. As this process is again interpretive in nature, although now in emergent response to the input, rather than analysis, I believe this stage could benefit from a similar approach to the one applied in deriving the musical direction. This would lead us to monitor the location of the objects placed in the planetary simulation model, as well as its velocity and acceleration in all dimensions and would in fact configure e as the model's phase space. Here all axes required to specify the state of the system define the dimensionality of the phase space.

From the computations of the model most of the object's phase space values are straightforward and can be obtained directly. These values are the dimension's realization at an instant in time and are represented by scalars of dislocation, velocity and acceleration per axis.

$$\vec{a}_k = (a_1, a_2, \ldots, a_7)$$

$$\vec{v}_k = (v_1, v_2, \ldots, v_7)$$

$$\vec{x}_k = (x_1, x_2, \ldots, x_7)$$

In addition, one can derive the object's scalars of total velocity and acceleration through the following:

$$a_{total,k} = \sqrt{(a_1^{\ 2} + a_2^{\ 2} + \ldots + a_7^{\ 2})}$$

$$v_{total,k} = \sqrt{(v_1^{\ 2} + v_2^{\ 2} + \ldots + v_7^{\ 2})}$$

As well as interpretations of the total activity in the model:

$$a_{total} = a_{total,k} + a_{total,l} + \ldots + a_{total,m}$$

$$v_{total} = v_{total,k} + v_{total,l} + \ldots + v_{total,m}$$

In deriving these quantities I have so far neglected the direction of the vectors, which could once again be represented by the angles of the objects in relation to their axes. These angles become quite garbled in the conversion from Cartesian to Polar coordinates due to the periodic wrapping of the rotation. Previously, this did not pose a problem as we were observing conducting qualities in the abstract, but in the context of gestural control over sonic objects angles turn out to be rather incomprehensible.

From the parameters monitored up to this point we could extract some rhythmic triggers by tracking the zero-crossings of the velocity in selected dimensions, as well as tracking other possible thresholds being passed by one or more of the object's parameter values.

Connecting the wires

The phase space containing the expressive gestures of the machine performer now has to be connected to the sonic objects. I would at this point like to draw attention to the strong similarity between this process and more "conventional" computer instrument mapping strategies. The planetary simulation model could essentially be viewed as the performer of the computer instrument. The mapping strategies could consequently benefit from more widespread and established methods as formulated by many others. In general one could classify the following tactics.

- *One-to-One Mapping: Each independent gestural output is assigned to one musical parameter (…). This is the simplest mapping scheme, but usually the least expressive. (…)*
- *Divergent Mapping: One gestural output is used to control more than one simultaneous musical parameter. Although it might provide a macro-level expressivity control, this approach nevertheless may prove limited when applied alone (…).*
- *Convergent Mapping: In this case many gestures are coupled to produce one musical parameter. (…) Although harder to master, it proves far more expressive than the simpler unity mapping.*
  (Rovan, et al, 1997)

In addition one could apply a combination of these tactics, which could be described as many-to-many mapping. A full report on gesture mapping falls outside of the scope of this thesis, as it could itself be a unique area of expertise. For a more detailed account I would therefore like to refer the reader to other writings on the matter, such as Goudeseune [2003], Hunt et al. [2000], Fenza et al. [2005] and Wanderley [2001], in which more extensive accounts of mapping strategies in developing expressive gestural control over computer instruments have been given. There is one aspect I wish to address as being specifically related to the planetary simulation model.

Object or dimension

When dealing with multiple objects in the generative expressive space of the system, there exists a dichotomy in the relation between the objects and the individual dimensions. On the one hand, one could assert that all values that make up a single multidimensional object can connect with a single distinct DSP process. On the other hand, it would be equally viable to map the values of all objects in a single dimension to control an individual DSP process.

As both these descriptions seem equally persuasive in my opinion, I do not wish to resolve this conceptual conflict. Rather, I propose to use a combination of both approaches. Moreover, honoring the explicit and subconscious processes discussed previously, I would like to suggest the use of one's skills of intuition and creativity, as built upon experimentation, exploration and trial-and-error with the system in order to connect the wires in a musically appealing manner.

Conflicting sonic objects

In my own work, the sonic objects have largely consisted of various processing algorithms, e.g. spectral modifications, harmonizing, delay and granular re-synthesis, performing some transformation on the sound input. In general I have chosen to use transformational processes rather than sound synthesis as it provides me with a richness of basic sound material that is difficult to equal in computer models. In addition, I believe that the use of the musical environment's own sounds provides ways to effectively blend the machine musician within the whole.

One could however find a conflict between the pursuit of autonomy in a computer performer and the dependence of the computer on a human musician's input for sound production, even though the objective of autonomy is on the level of expressivity, not sound. When observing for instance two violists, it is apparent that they share a similar sound space without this affecting their expressive independence. Therefore I find that this conflict exists on an artistic level and not on a conceptual. On this level it can serve as a potential source of inspiration, rather than a conceptual inconsistency.

Customized configurations

At this point we have outlined the theoretical implementations of a machine musician in dealing with a number of subjects as derived from the discussion on musical expressivity in autonomous and interactive systems. I have proposed the use of a planetary simulation model as a metaphor for the chaotic, explicit and intuitive processes of generative musical performance. I would here like to conclude with a brief illustration of two variations of potential arrangements in setting up the model with regards to either a compositional or improvisational intention, alluding to some of the conceptual distinctions between the two.

A compositional arrangement

In a compositional context I have defined twofold gravitational objects as part of the planetary simulation model, namely *chaotic particles* and *preference points*. These two types of objects are descriptive of two distinct elements in the musical environment.

- *Chaotic particles*: are the dynamic and chaotic objects in the generative space as presented above. They are the metaphorical "physical handles" that ultimately control the sound objects within the emergent context of chaotic expression.
- *Preference points*: are additional static objects in generative space, signifying more traditionally known presets of specific sound objects. They are defined as points in the generative space whose Cartesian coordinates are delineated by preferred parameter settings.

Having assigned certain masses to the *preference points* in the model, they become gravitational attractors to the *chaotic particles*, which in turn will move around these points and potentially plot chaotic interpolations between them. The traditional presets are expanded with the phase space of the *chaotic particles*, effectively generating inflections in the sound objects' control. It should be noted that the expressive inflections are not mere added nuance to the categorically defined presets, but come forth out of the entire emergent chaotic behavior of the model.

In interaction with the external musical environment the *chaotic particles* can be submitted to the conducting forces of the sonic input. With this, the model's gestures will in some degree exercise inclination towards certain areas of the space or specific *preference points*, making the *chaotic particles* responsive to the musical environment in which they move (fig. 18).

In a timeline one can define a route for the *preference points* as a compositional path through space, changing the locations and weights of these points. Additionally, one can specify the properties of the space as a consequence of altering the behavior of the *chaotic* *particles* contained in it. As a result one can compose the general notion of the expressive gestures and define a distinct area of control values over the sonic object – a generative compositional space interrelated with a human performer on a conducting level of interaction.

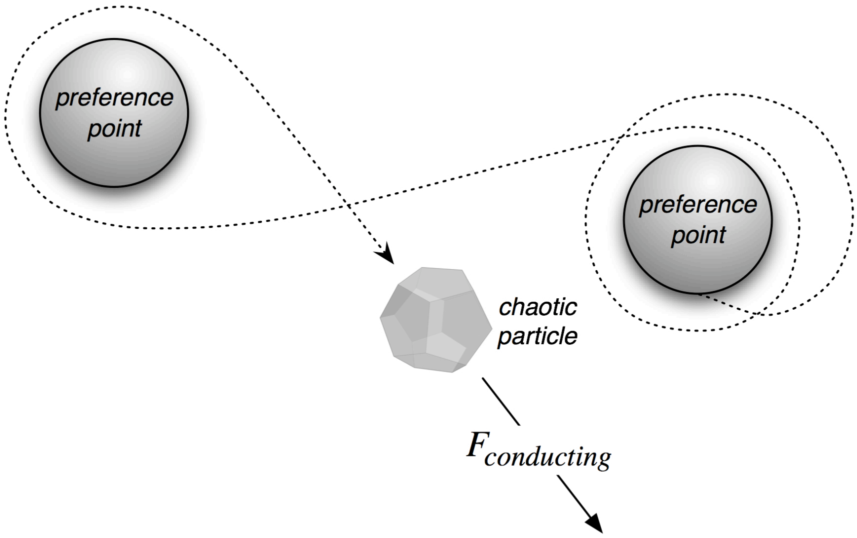


Figure 18: An illustration of a reduced planetary model's space in which the chaotic particle *interacts with the* preference points *under the influence of a conducting force exerting an inclination to the right preference point rather than the left.*

An improvisational course of action

In an improvisational context I would like to propose a similar construct to the one used in a compositional context, but in a modified arrangement. In view of the fact that in improvisation there is no predefined timeline, I would suggest the location of the *preference points* and the properties of the space become dynamically outlined over the course of a performance. This, however, implies a loss in the urge for predilection during the model's conception. Nonetheless, there remain certain areas of particular preference within the generative space that one might wish to address outside the instance of a performance. They are the intrinsic tendencies of sound objects to perform more adequately at certain settings than others, as well as the exertion of personal preference as composed into the process of a machine musician. Given this notion, I would like to propose a third object type to be used in the planetary simulation model namely, *hidden preference points*.

- *Hidden preference points*: are static objects in the generative space, preliminarily defined to more gently warp the space to incline towards particular points of attraction in particular sound objects.

With the addition of the *hidden preference points*, the now dynamically shaped orbits of the *preference points* will be drawn toward certain areas of the generative space.

Furthermore, the final trajectories of the *preference points* in improvisation are conceptually developed in a way that is interrelated with the emergent musical environment. This would imply a further rearrangement of the system to associate the conducting force with the *preference points*, rather than the *chaotic particles*. As a result the *chaotic particles* become free moving objects in interaction with the *preference points* whose trajectories in turn are now fabricated under the influence of the conducting elements and the precursory warping of space through the *hidden preference point(s)* (fig. 19).

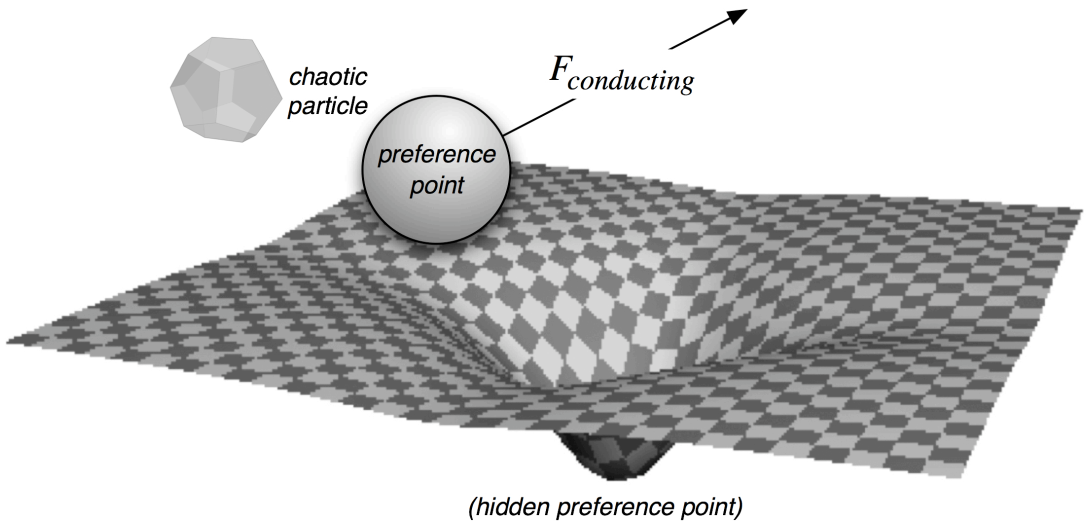


Figure 19: A graphic representation of the elements that make up the planetary simulation model for possible use in an improvisational context. Here the chaotic particle *moves around the* preference point, *which in turn moves in the warped space of the* hidden preference point *under the influence of the conducting force.*

Voyage through the universe

As part of my research I have implemented a collection of software modules labeled APICS (Autonomous Planetary Interactive Compositional Systems) containing some of the essential procedures as discussed in this thesis. The modules have been implemented in the MaxMSP environment as Max externals written in the C programming language and include the following items.

- *rb_APICS:* a module containing a single object in a planetary simulation model's space, incorporating all additional features as previously discussed. One can denote the object to move in up to seven dimensions and to be connected to up to twelve additional objects in the space, as well as adjust all variables of the supplementary functions.

- *rb_APICS_forces:* a multi-dimensional Polar to Cartesian coordinate converter applying an expansion of the following:

  $$(\rho, \phi, \ldots, \theta) \longrightarrow (x, y, \ldots, z)$$

  $$x = S\sin\theta$$

  $$y = S\cos\theta \qquad (where\ S = \rho\sin\phi)$$

  $$z = \rho\cos\phi$$

  This module directly connects to rb_APICS to provide external force to the selected object in space.

- *rb_APICS_vector:* a multi-dimensional Cartesian to Polar coordinate converter yielding an extension of the following:

$$(x, y, \ldots, z) \longrightarrow (\rho, \phi, \ldots, \theta)$$

$$\rho = \sqrt{(x^2 + y^2 + \ldots + z^2)}$$

$$\phi = \tan^{-1}\frac{z}{S} \qquad (where\ S = \rho \sin\phi \sqrt{x^2 + y^2})$$

$$\theta = \tan^{-1}\frac{y}{x}$$

- *rb_APICS_obtodim:* a basic I/O matrix for lists. Here the individual lists containing the coordinates of all objects are recombined to produce lists holding the locations of all objects in the individual dimensions.

In the appendix you will find a copy of this collection of Max externals, including help files and source codes (the externals have however at this point only been tested and used in MaxMSP 4.5 on a Macintosh PPC computer).

Additionally, the appendix includes a number of pieces and recordings, illustrating the artistic explorations of the thoughts, concepts and considerations as presented in this thesis. These works represent the origin, evolution and actualization of issues and ideas in expressive performance as presented in their purest form, music.

Conclusion

Conclusion

A virtual analogy of skilled musical performance

> *Total predictability becomes boring, but so does total unpredictability. So you have to have a range - I'm looking for plausibility, and that's a compositional thing. I'm composing a kind of musical space within which we improvise.*
>
> *George Lewis, in an interview by Lawrence Casserley*

Musical expression continues to be an elusive area of interest whose scope extends through the invention, performance and experience of music. It potentially signifies the quintessential human side of the artistic and musical endeavor. In this thesis I have attempted to illuminate some of the artifacts of expression within the context of its effects on the development of an autonomous interactive machine musician – a virtual analogy of skilled musical performance.

At the outset I have discussed how musical expressivity commonly refers to the emotional content and gesture of music. Within this domain, rather than residing as a mere element of musical artifacts, expression operates on a lateral level and has embedded itself throughout the entirety of a musical manifestation. I have presented the expressive qualities in their context as being contained by the music itself. This is in opposition to alternative interpretations, such as the literal communication of a composer's intent or the arousal of certain emotions in one's audience, that seem to give rise to more harm than insight. Being embedded within the music, the substance of musical expression as conveyed by the music is representative of emotional content in mimicking the movements thereof, albeit without a fixed interpretation of the meaning of this content.

As expression refers to a communicational process of conveying content, I have addressed the common but problematic analogy of music as language. The analogy however, only serves music as a non-intentional language, as proposed by Adorno [1956] and indicates the syntax and dynamic morphology of music. The expressive content of music here excludes any definite semantics, becoming fluid in what it represents, rather than dogmatic in unambiguously symbolizing particular emotions. The dynamic morphology, as put forth by musical (i.e. non-physical) gesture, is subsequently interpreted in line with the idiom in which a composition has been created, whether this is a preexisting idiom or a newly defined one. This opens up the possibility of devising a machine musician that induces a compositionally defined idiom into a musical environment through expressive interaction with a live performer.

The paradigm of interactivity has produced a multitude of diverse strategies in developing computer musicianship. Within this context Cort Lippe has proposed a number of traditional subdivisions of interaction, consisting of an instrument, a performer, a composer and a conductor role [Lippe, 2002]. These traditional roles can subsequently serve to open up conventional channels of interaction both vertically as well as horizontally, providing a certain transparency to the interaction with a live performer. In the development of the computer as a meta-performer, a horizontal notion of interaction has proven to be most appropriate in striving for equality of roles in an interactive environment. Furthermore, the conducting role offers significant insight into the expressive content of a musical environment. In this role description, a conductor not only states the pulse of the music, but also utters the musical direction. With the notion of expressive movement, I have proposed a differential relationship between a musical gesture and its subsequent directing with a conductor role giving expressive direction to the musical gesture.

In analyzing these concepts with the objective of computer implementation, a number of methodical constraints have appeared. As music and expression deal with many inaccessible subjective and intuitive processes, there exists a dichotomy in the emergence of concepts. The study of these hidden procedures is either conducted with an analytical or creative intent. Both intents will consequently mangle our knowledge of these implicit processes through the tools of their practice. The analytic or creative nature of our tools should be addressed when implementing our knowledge into the domain of a computer application. As creative tools of my practice, I have oftentimes put forward the poetic and metaphorical understanding of the hidden musical processes of expressive performance.

Through the extension of Robert Rowe's processing chain in interactive music [Rowe, 1996] I have described interpretive listening, generative processing and responsive actualization as the elementary processes of a musician in an expressive feedback-loop.

The generative processing stage here possibly presents us with the most significant expressive capabilities of a musical entity. I have proposed a concept of chaos (i.e. deterministic nonlinear dynamical systems) as a poetic metaphor to account for the expressive musical emergence of a machine musician. With a view of musical emergence as chaos, musical thought as represented by a singular object and musical expression as gesture, I have implemented and explored a planetary simulation model as an expressive algorithm within the domain of real-time electronics.

In addition, I have discussed computer "listening" procedures that have been expanded to include some further interpretation function. The conventional perceptual analysis data is in this process transformed to reveal the conducting qualities of the musical input, effectively constructing a bridge between the analytic space of perception and the creative space of expressive emergence. Furthermore I have described how the individual processes of an expressive feedback-loop can be interconnected in the context of a theoretical computer implementation, as well as how these processes could be configured with respect to a compositional or improvisational environment.

When dealing with an expressive machine musician, we are essentially speaking about an analogy of human performance. Any implementation of such a system is only as valid as the extent to which the metaphors, from which the analogy has been constructed, are convincing. With the thoughts and ideas that I have presented in this thesis, I have attempted to consolidate my experience and knowledge of performance, composition and real-time electronics, into a viable concept of expressive musical performance. through this effort, I have attempted to provide a breeding ground for incessant exploration and inspiration within the intangible realm of music.

Acknowledgments

First of all I would like to thank my mentors Paul Berg and Joel Ryan. Their critique, discussion and continuous support and guidance have been a source of inspiration over the last two years.

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I'm eternally indebted to Emlyn Stam, for his critical notes and for being the finest editor one could wish for. I would like to thank many friends and colleagues, in particular Justin Christensen, Federico Reuben, Dganit Elyakim, Martijn Tellinga, Andrea Young, Ángel Faraldo and Billy Bultheel. With them I've had countless precious conversations and shared much fruitful contemplation over many liters of good (and bad) coffee.

I would like to thank my partner, Ofer Marmur, for the eternal hours of listening and his comments on my ideas and writing, as well as his everlasting patience and love. And not to forget, my parents Peter and Manuela, my sister Lisa and her partner Gaico, who have given me their unconditional love and support throughout in every sense of the word.

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Appendixes

Appendix I: synopses of pieces

Lullaby for a troubled boy [2006]

This work has been the first to be completed as part of my Master's degree, but concludes an earlier exploration within the domain of an interactive machine musician. The interaction in the real-time electronics largely takes place on a compositional level rather than a conducting one. Moreover, the electronics do not contain a generative structure as discussed in this thesis.

The piece should be performed by two instruments that represent the mid/low range within their instrument family such as viola, bassoon or bass clarinet. This piece does not have a written score, but exists as a guided improvisation in which the musical form is orally communicated to the performers as well as through listening to an example recording. One of the most important instructions of the oral score refers to the stretching and warping of time and anticipation through a number of subsequent phases.

Frames [2007]

This piece was the first to explore the expressive generative capabilities of the planetary simulation model APICS. However, the model was here implemented without external interaction and made use of synthesis models as its sound objects rather than processing. The composition is performed by APICS through the interpolation of a preset sequence governing the model's configuration. The sound of the piece was in part projected over an installation of metal plates (transferred onto the plates through loudspeaker cones and solenoids) and amplified over a quadraphonic speaker setup with the aid of contact microphones positioned on the plates. In addition, a visual projection of the model's behavior was beamed onto the installation of metal and Plexiglas plates.

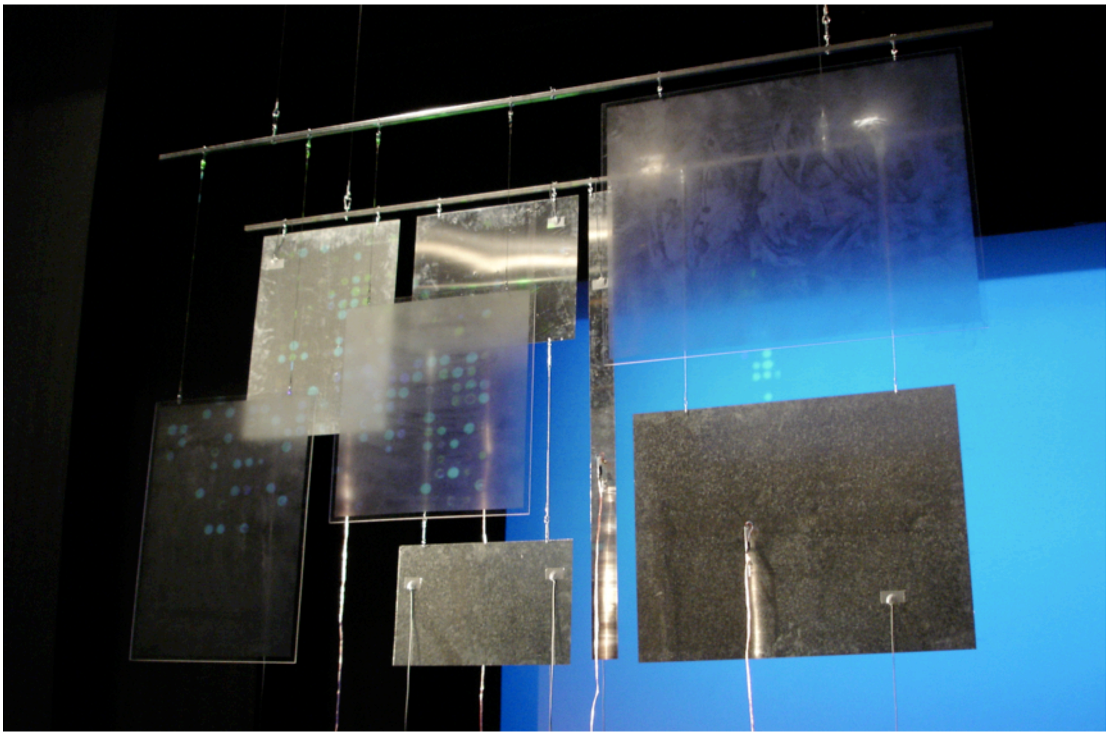


Figure 20: A photograph of the plate construction for "Frames".

Instill [2007]

This piece is a reworking of a former piece called "Distillation" and was presented at the Next Generation Festival at ZKM, Karlsruhe. It is a guided improvisation duet for viola and APICS driven electronics. In this work I have explored some aspects of the conducting qualities interacting with the planetary simulation model. Although the conducting features of the live electronics were implemented without a Cartesian to Polar conversion as described in this thesis, it served an interesting exploration of a compositional configuration of the APICS model. The chaotic gestures of the live-electronics were in this setup directed to take place in certain areas of the sonic objects' space, effectively conducting tendencies in the response of the machine musician.

Viewpoints of a Mechanical Mind [2008]

This work was originally composed for the MAE ensemble in collaboration with the visual artists Judith van Oostrum and Zoe Reddy and was premiered at the Korzo Theater as part of the "Haagse Hemelbestormers". In this piece I have explored the interrelation of composition, guided improvisation and free improvisation, respectively represented by a concertante pianist, four musicians in boxes and an invisible APICS driven machine musician. Many of the concepts and strategies I have discussed in this thesis have been utilized in this implementation of the meta-performer. In addition, the pianist's score has been generated with the aid of the APICS model to form a conceptual link between the compositional part and the free improvisation. The guided improvisation in the piece initially comments on the pianist's part, only to eventually take over the leading role. The improvising musicians have been placed in boxes in order to investigate and illustrate the intentional absence of visual communication in the musical interaction between a human and a machine musician as explored in my work.

Figure 21: An overview of the stage setup of "Viewpoints of a Mechanical Mind".

Appendix II.a: CD

Appendix II.a: CD

Mixed Audio and Data CD

Audio content

track 1	"Lullaby for a troubled boy" [2006] performed by Emlyn Stam and Ronald Boersen	[09'16"]
track 2	"Instill" [2007] performed by Ronald Boersen	[07'39"]
track 3	"Viewpoints of a Mechanical Mind" [2008] performed by the MAE at Korzo	[10'14]

Data content

rb_APICS_collection
- put content into init
    - rb_APICS-objectlist.txt
- rb_APICS-helpfiles
    - rb_APICS.help
    - rb_APICS_vector.help
    - rb_APICS_forces.help
    - rb_APICS_obtodim.help
- rb_APICS-maxobjects
    - rb_APICS.mxo
    - rb_APICS_vector. mxo
    - rb_APICS_forces. mxo
    - rb_APICS_obtodim. mxo
- rb_APICS-source
    - rb_APICS
        - rb_apics.c
        - rb_apics.xcodeproj
    - rb_APICS_vector
        - rb_apics_vector.c
        - rb_apics_ vector.xcodeproj
    - rb_APICS_forces
        - rb_apics_forces.c
        - rb_apics_forces.xcodeproj
    - rb_APICS_obtodim
        - rb_apics_obtodim.c
        - rb_apics_obtodim.xcodeproj

Appendix II.b: help file printouts

rb_APICS.help

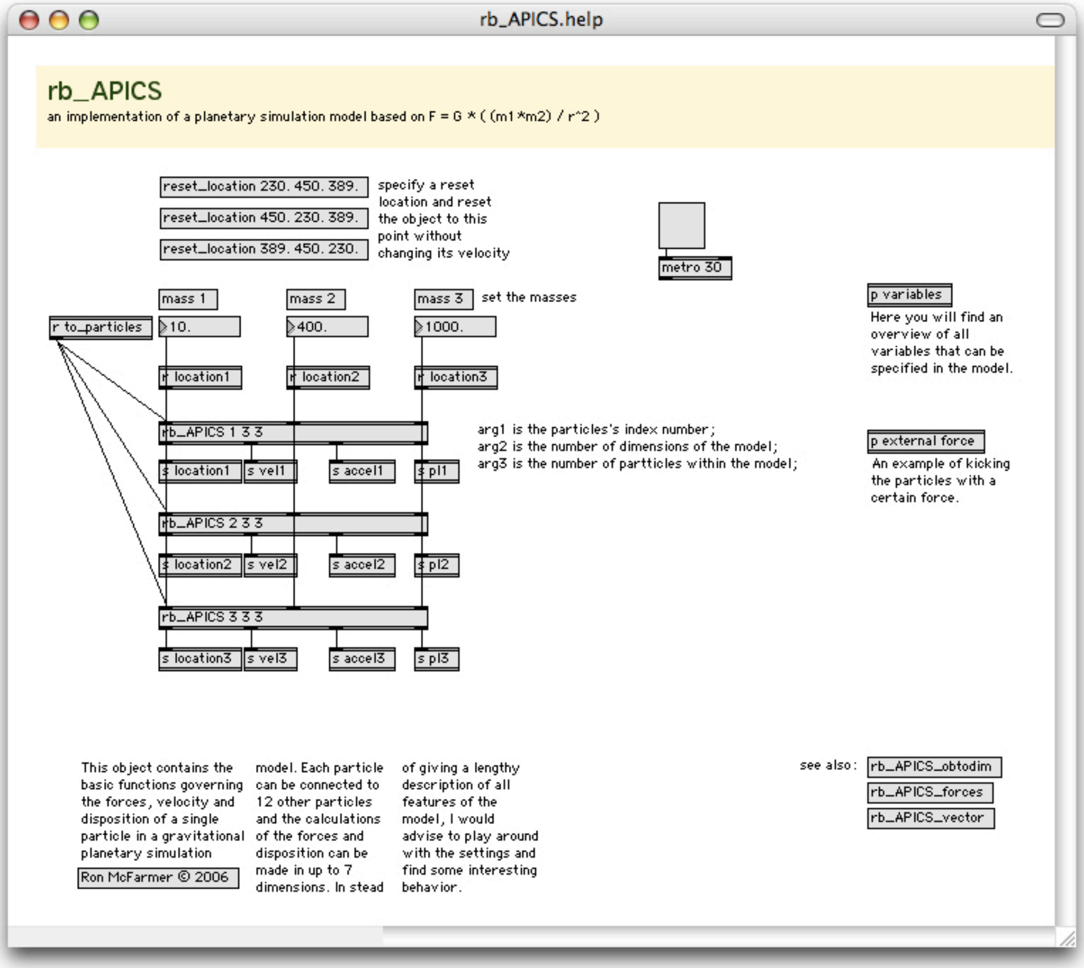


Figure 22: A screenshot of the main MaxMSP helpfile of object rb_APICS providing an example of a configuration of a three dimensional space containing three associated particles and reference to the accompanying MaxMSP objects of the rb_APICS collection.

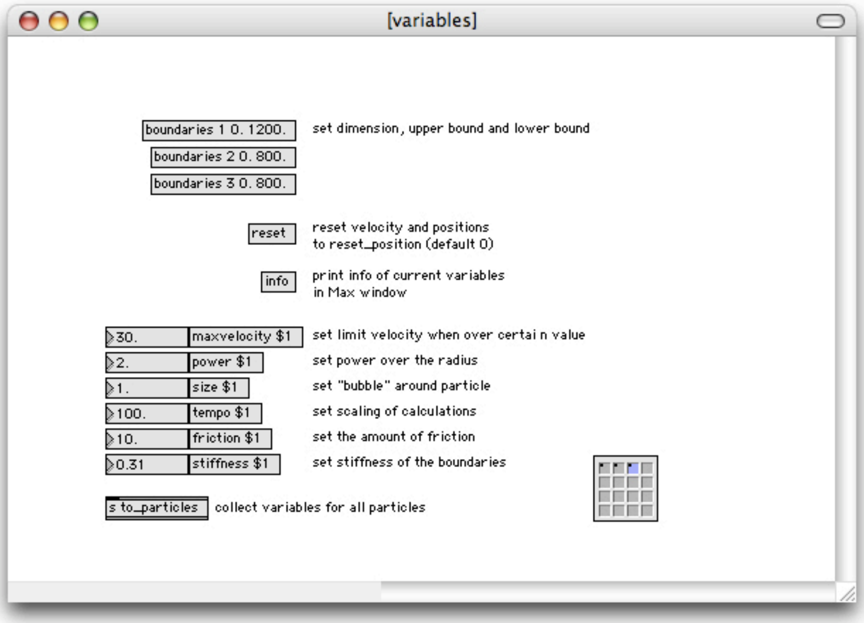


Figure 22.a: A sub-window containing an overview of the rb_APICS variables as well as three presets from which one can experiment

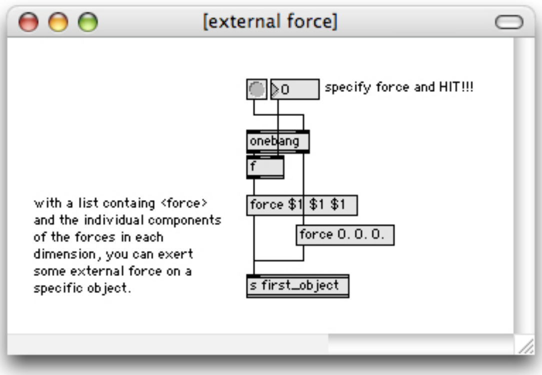


Figure 22.b: A sub-window of rb_APICS providing an example of exerting external force on a specific particle in the modeled space.

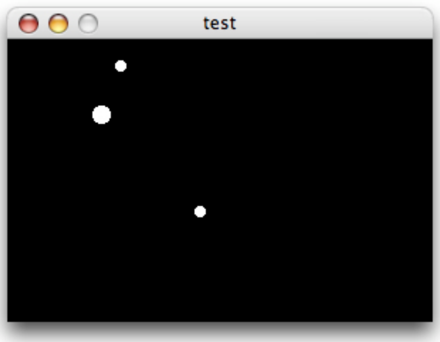


Figure 22.c: The accompanying window of rb_APICS.help providing visual feedback of the particle behavior in the model.

rb_APICS_vector.help and rb_APICS_forces.help

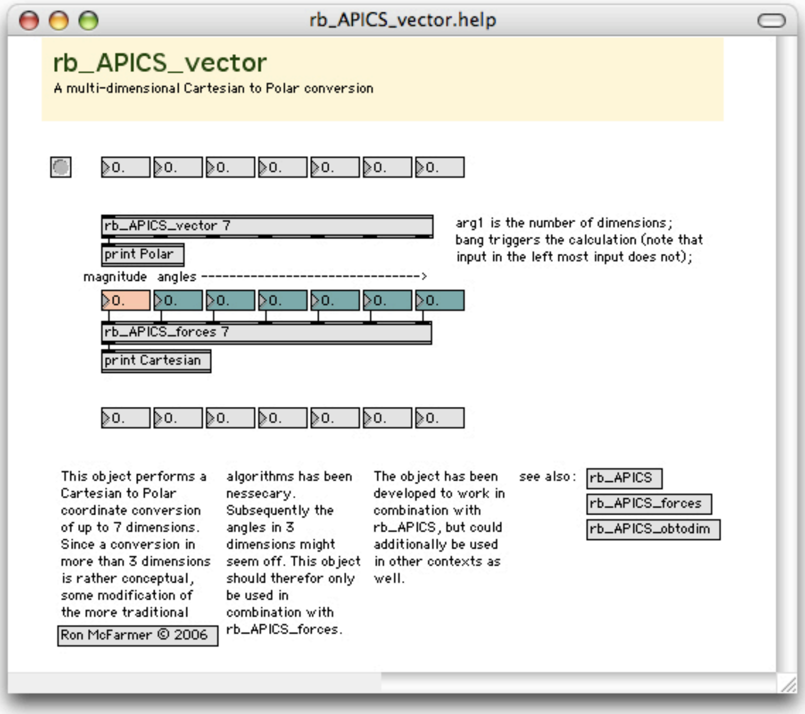


Figure 23: A screenshot of the rb_APICS_vestor heldfile giving an example of a 7-dimensional interpretation of a Cartesian to Polar conversion. As the objects rb_APICS_forces is the reverse of this conversion, it is included in this helpfile.

rb_APICS_obtodim.help

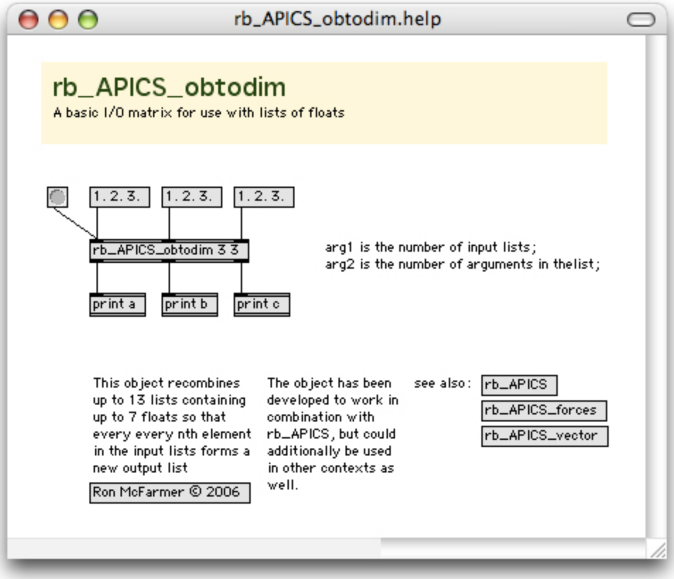


Figure 24: A screenshot of the helpfile accompanying rb_APICS_obtodim.

Appendix III: DVD

Appendix III: DVD

DVD content	
“Viewpoints of a Mechanical Mind” [2008] performed by the MAE at Korzo	10'06"
“Frames” [2007] performed at the KvB Hall, Royal Conservatoire The Hague	10'23"
Bonus track*	
“Solid Movement” [2005] performed at the KvB Hall, Royal Conservatoire The Hague	08'56"

** It should be noted that this piece has NOT been part of my Master’s Degree. Nonetheless, I have decided to include it on the DVD as it signifies some original inspiration of many of the topics discussed in this Thesis. In this piece I have explored the interaction between dance and music through an early interpretation of a directing strategy interfacing the dancer and a generative physical model.*

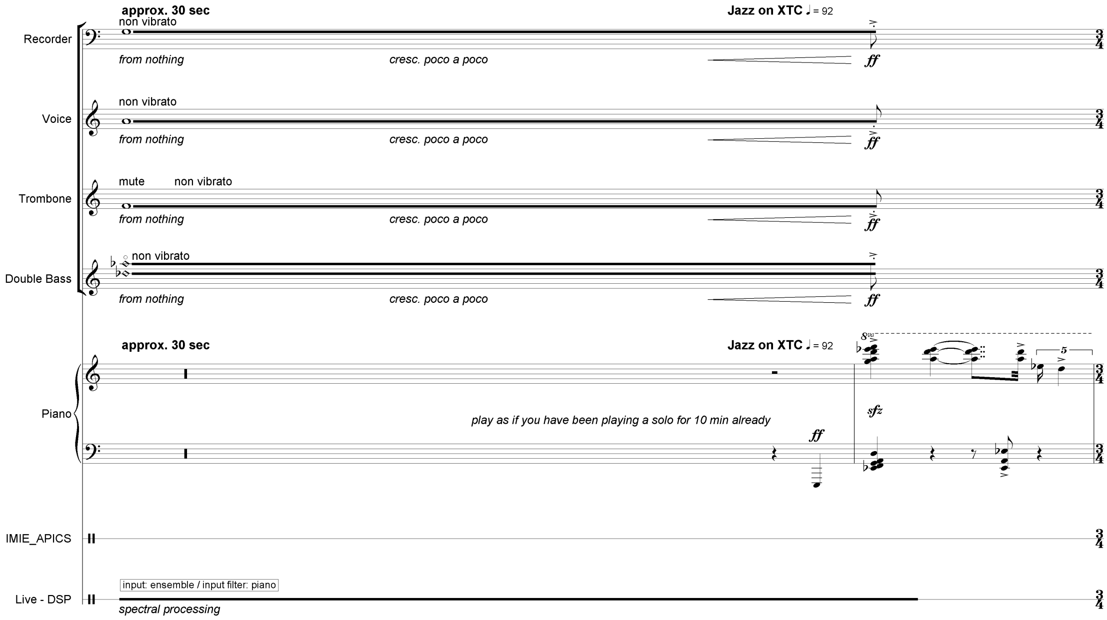
Appendix IV: Score

Viewpoints of a Mechanical Mind [2008]

Viewpoints of a Mechanical Mind

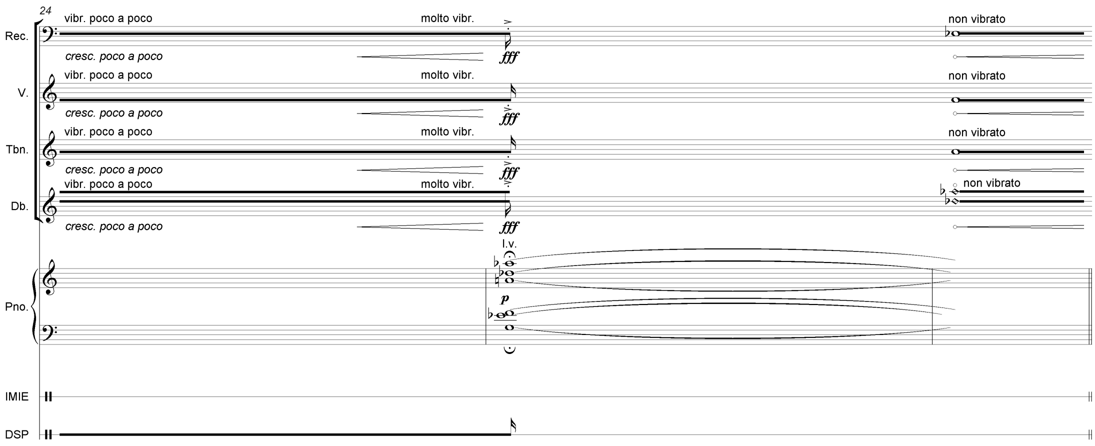
dedicated to Ofer Marmur

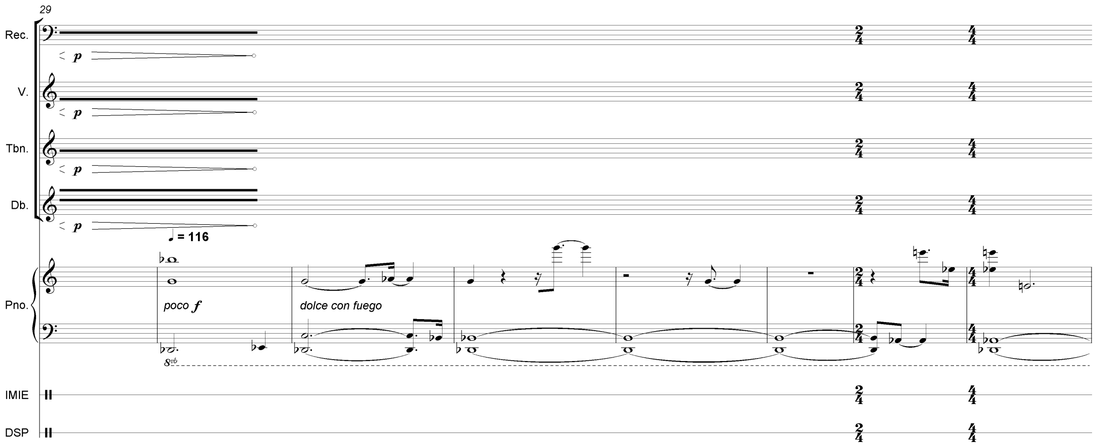
Ronald Boersen



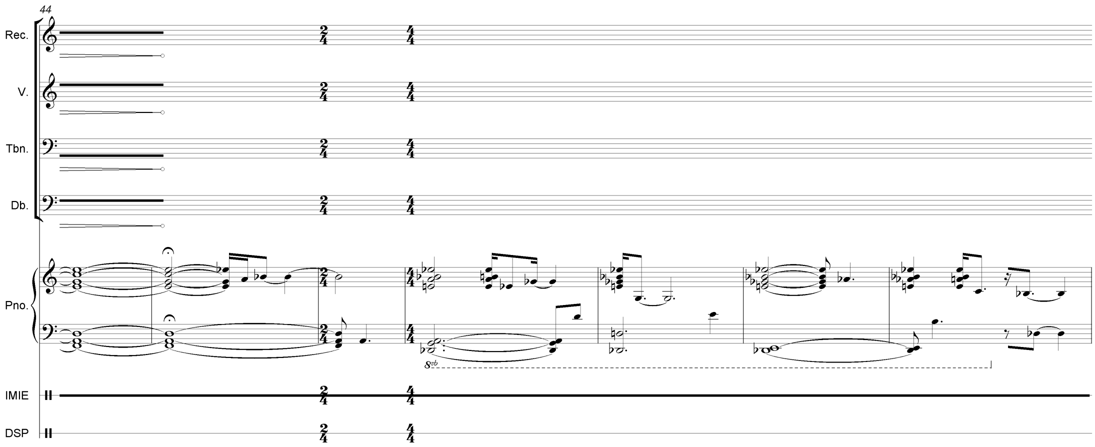

8
Rec.
V.
Tbn.
Db.
Pno.
IMIE
DSP
13
Rec.
V.
Tbn.
Db.
Pno.
IMIE
DSP


18
Rec.
V.
Tbn.
Db.
Pno.
IMIE
DSP
non vibrato
from nothing
non vibrato
from nothing
non vibrato
from nothing
non vibrato
from nothing
input: ensemble / input filter: piano
spectral processing

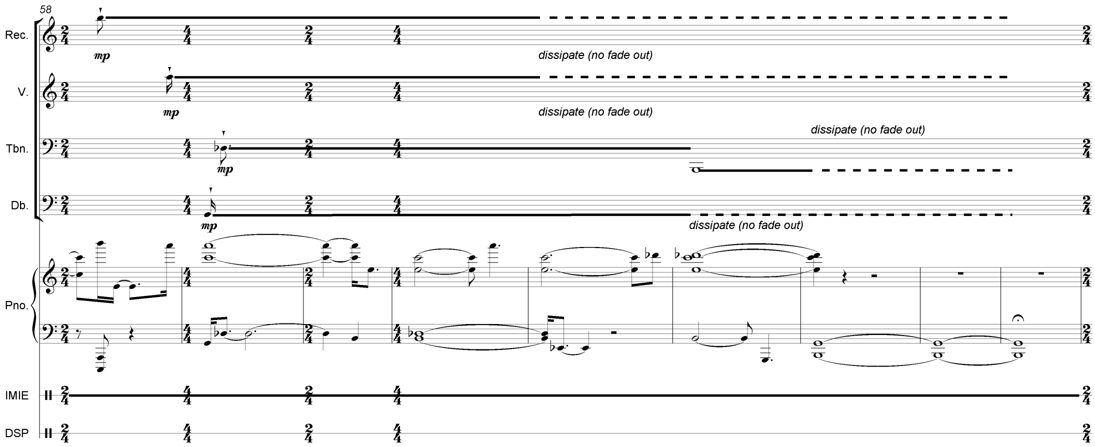

24
Rec.
V.
Tbn.
Db.
Pno.
IMIE
DSP
vibr. poco a poco
molto vibr.
cresc. poco a poco
fff
non vibrato
vibr. poco a poco
molto vibr.
cresc. poco a poco
fff
non vibrato
vibr. poco a poco
molto vibr.
cresc. poco a poco
fff
non vibrato
vibr. poco a poco
molto vibr.
cresc. poco a poco
fff
non vibrato
l.v.
p


29
Rec.
V.
Tbn.
Db.
p
♩ = 116
poco f
dolce con fuego
Pno.
IMIE
DSP

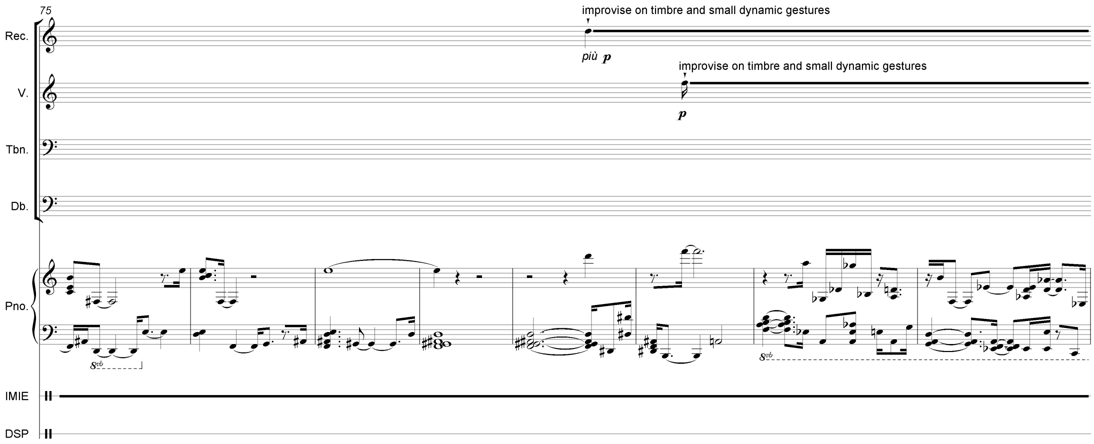

37
Rec.
V.
Tbn.
Db.
mf
Pno.
input: piano
IMIE
DSP

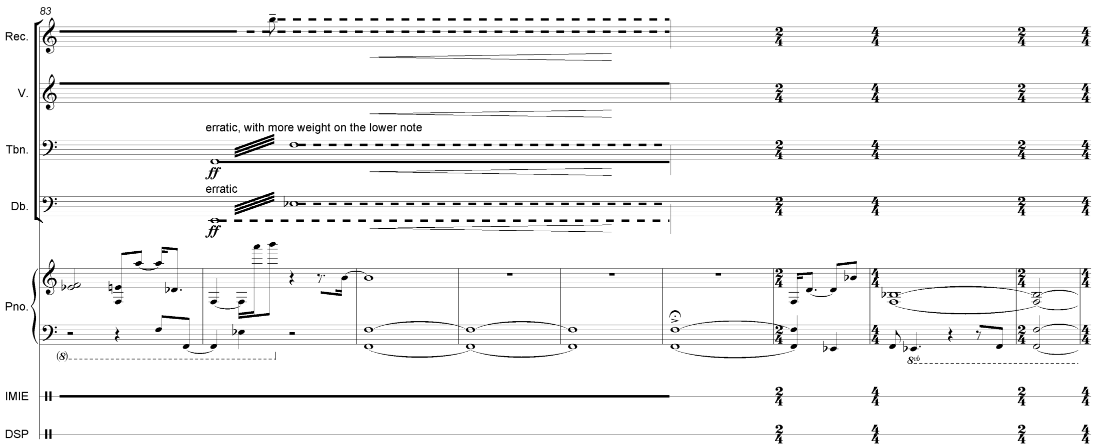

44
Rec.
V.
Tbn.
Db.
Pno.
8vb
IMIE
DSP


51
Rec.
pp
sf
V.
Tbn.
Db.
pp
sf
Pno.
IMIE
DSP


58
Rec.
V.
Tbn.
Db.
Pno.
IMIE
DSP
mp
mp
mp
mp
dissipate (no fade out)
dissipate (no fade out)
dissipate (no fade out)
dissipate (no fade out)

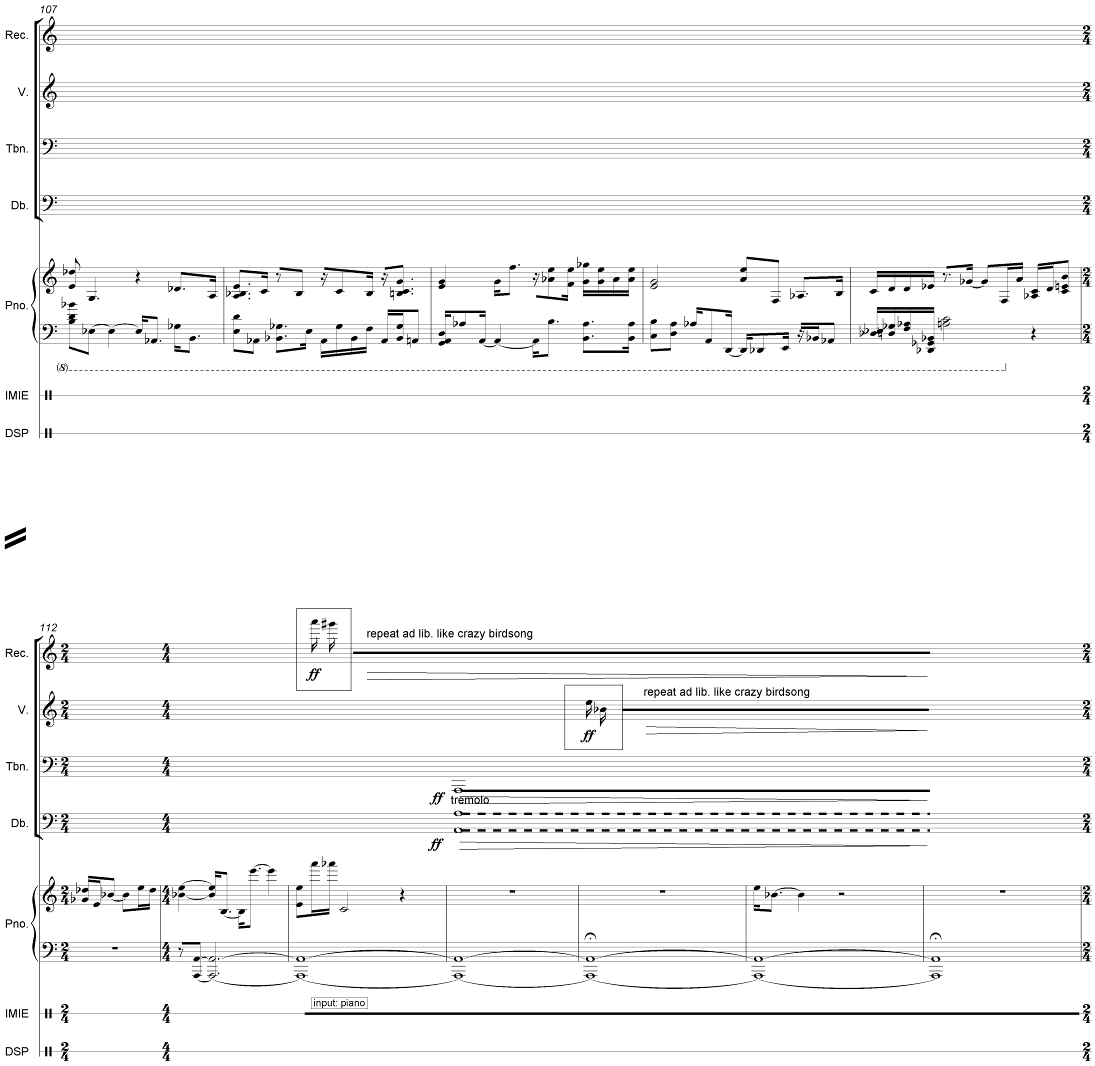

67
Rec.
V.
Tbn.
Db.
Pno.
IMIE
DSP

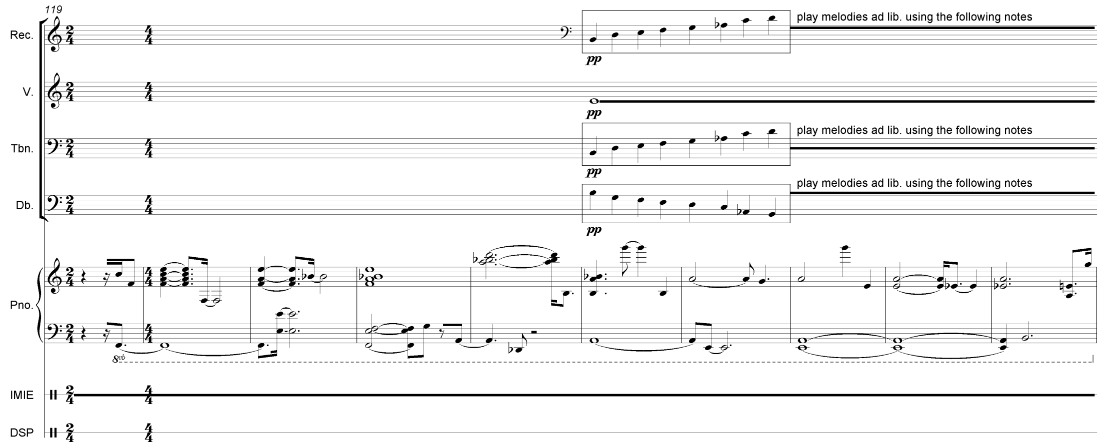

75
Rec.
V.
Tbn.
Db.
Pno.
IMIE
DSP
improvise on timbre and small dynamic gestures
più p
improvise on timbre and small dynamic gestures
p

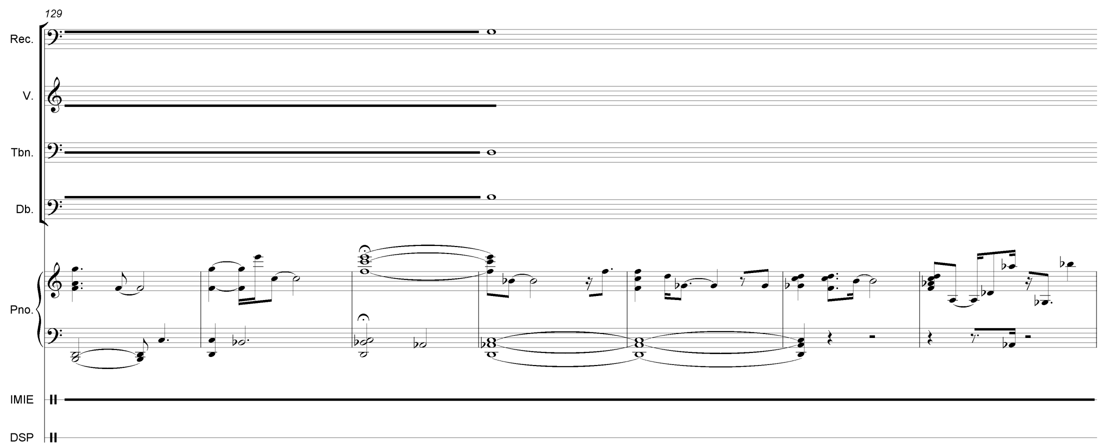

83
Rec.
V.
Tbn.
Db.
Pno.
IMIE
DSP
erratic, with more weight on the lower note
ff
erratic
ff

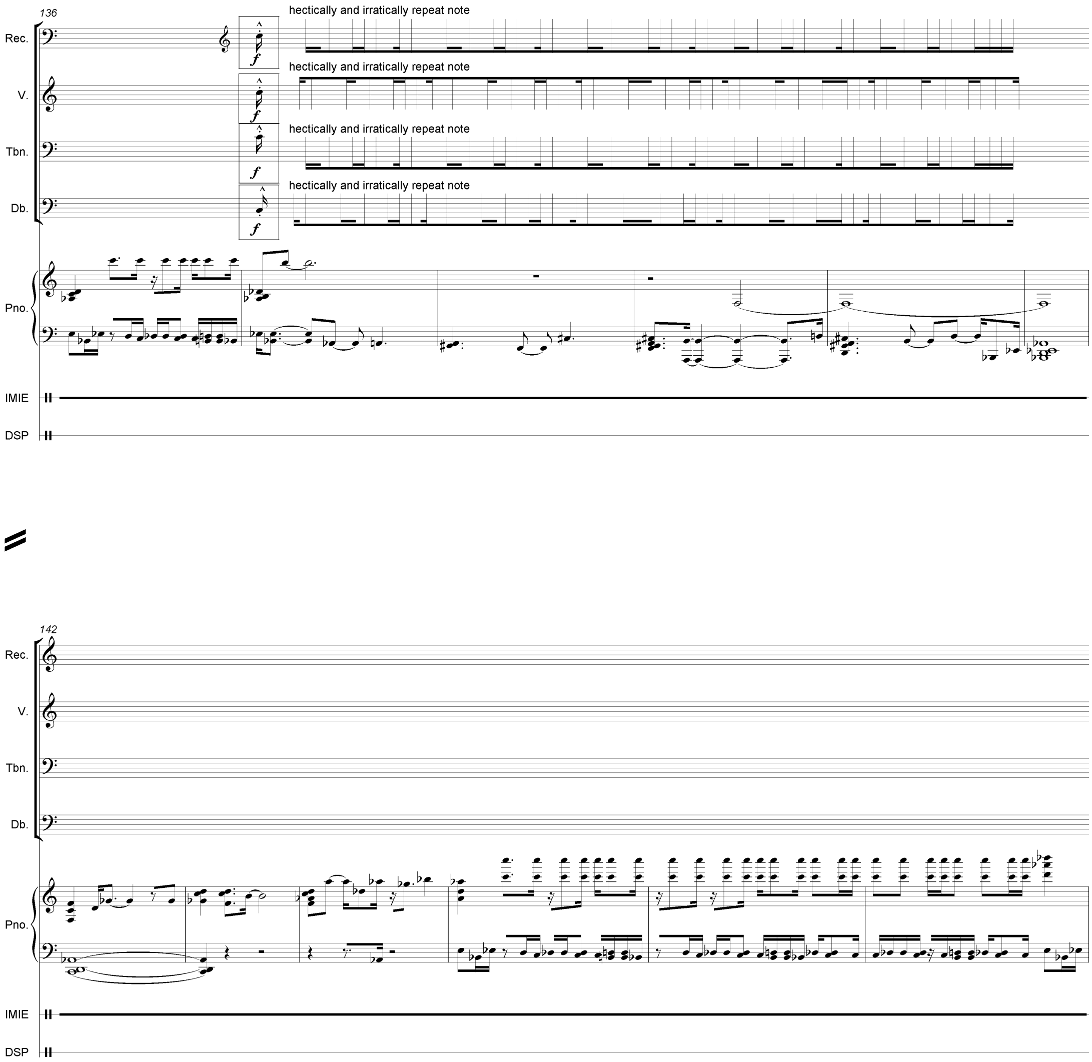

92
Rec.
V.
Tbn.
Db.
Pno.
(8)
IMIE
DSP

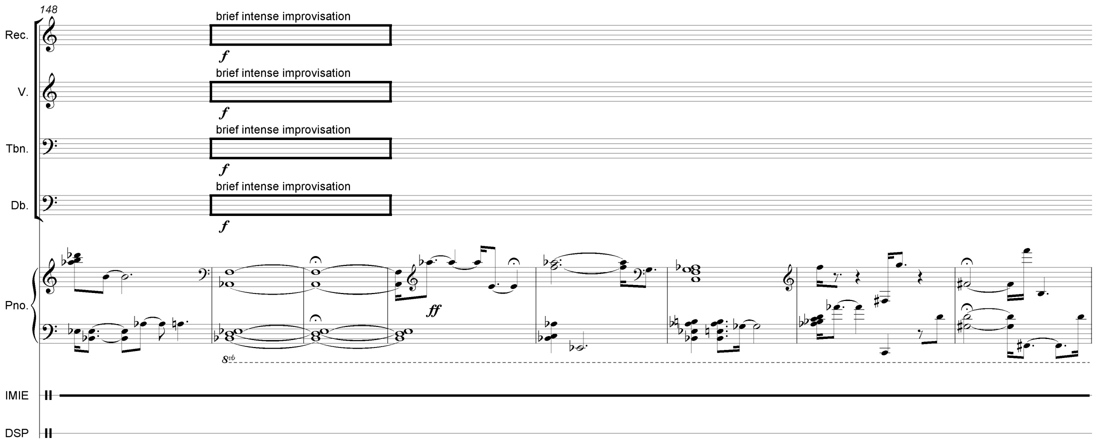

99
Rec.
V.
Tbn.
Db.
Pno.
(8)
IMIE
DSP

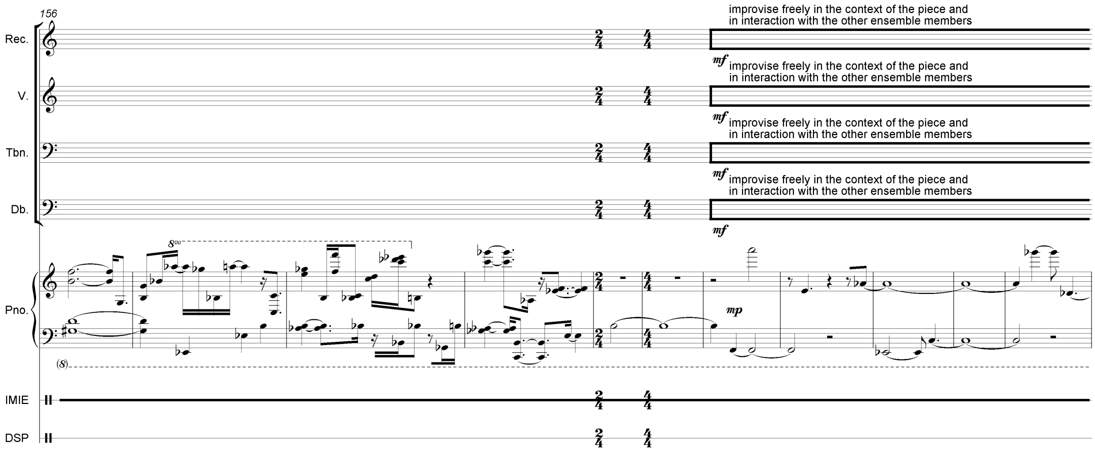

107
Rec.
V.
Tbn.
Db.
Pno.
IMIE
DSP
112
repeat ad lib. like crazy birdsong
ff
repeat ad lib. like crazy birdsong
ff
ff
tremolo
ff
input: piano

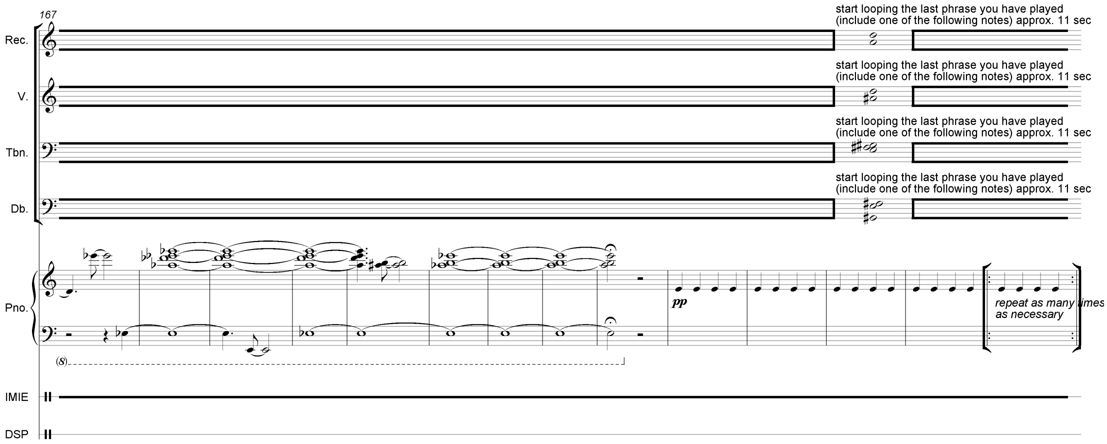

119
Rec.
V.
Tbn.
Db.
Pno.
IMIE
DSP
pp
play melodies ad lib. using the following notes
pp
pp
play melodies ad lib. using the following notes
pp
play melodies ad lib. using the following notes

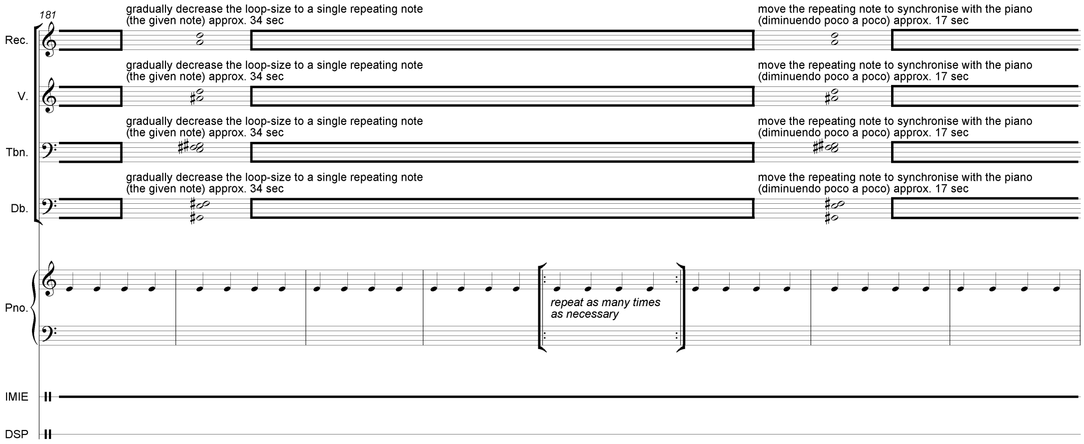

129
Rec.
V.
Tbn.
Db.
Pno.
IMIE
DSP


136
Rec.
V.
Tbn.
Db.
hectically and irratically repeat note
hectically and irratically repeat note
hectically and irratically repeat note
hectically and irratically repeat note
Pno.
IMIE
DSP
142
Rec.
V.
Tbn.
Db.
Pno.
IMIE
DSP

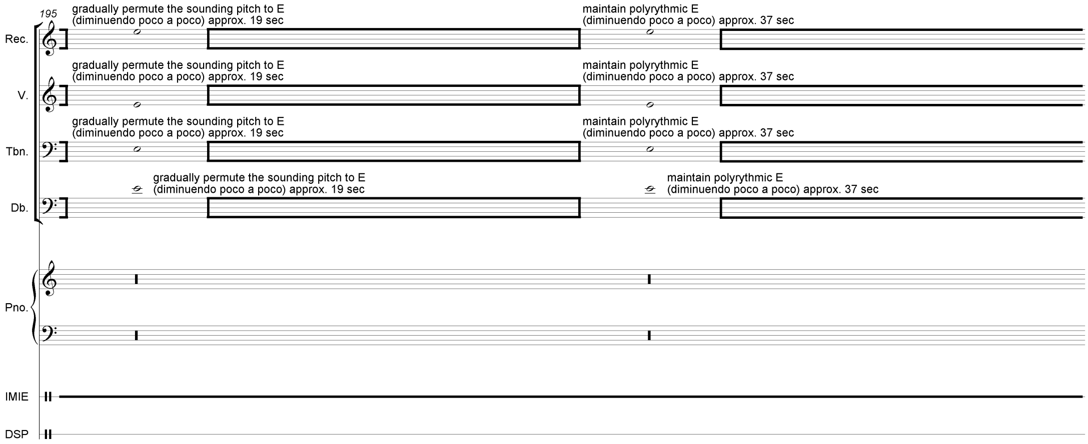

148
Rec.
V.
Tbn.
Db.
brief intense improvisation
f
brief intense improvisation
f
brief intense improvisation
f
brief intense improvisation
f
Pno.
ff
IMIE
DSP

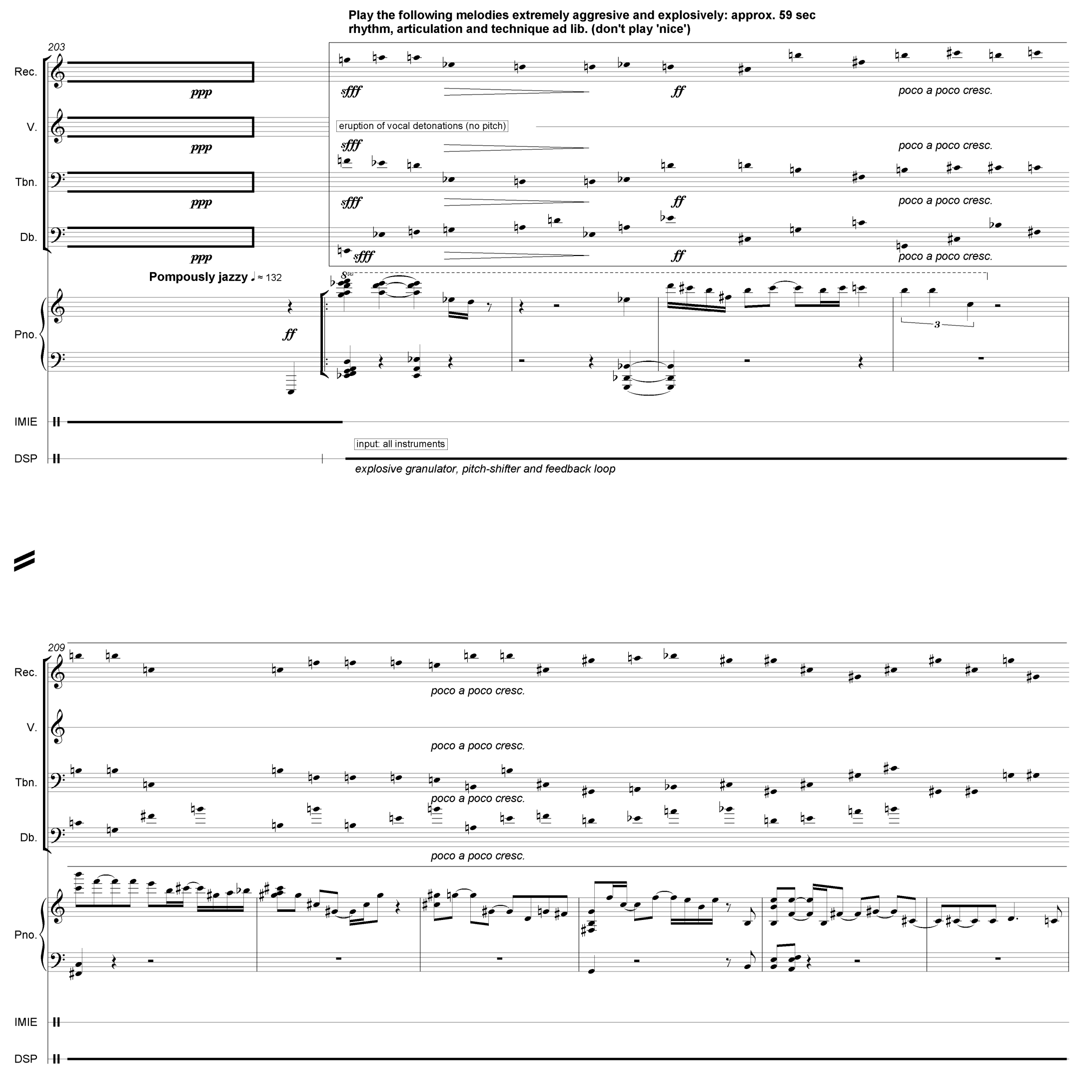

156
Rec.
V.
Tbn.
Db.
improvise freely in the context of the piece and
in interaction with the other ensemble members
mf
improvise freely in the context of the piece and
in interaction with the other ensemble members
mf
improvise freely in the context of the piece and
in interaction with the other ensemble members
mf
improvise freely in the context of the piece and
in interaction with the other ensemble members
mf
Pno.
mp
IMIE
DSP

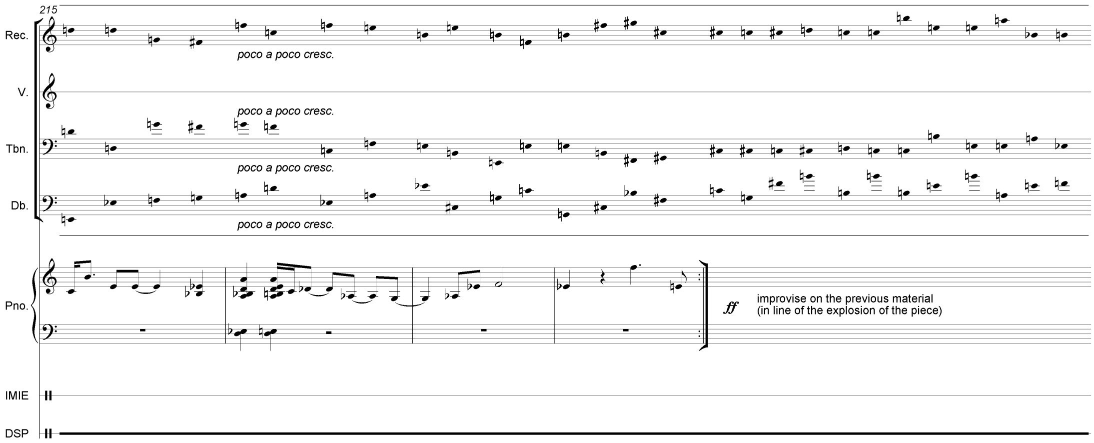

167
Rec.
V.
Tbn.
Db.
Pno.
IMIE
DSP
start looping the last phrase you have played
(include one of the following notes) approx. 11 sec
start looping the last phrase you have played
(include one of the following notes) approx. 11 sec
start looping the last phrase you have played
(include one of the following notes) approx. 11 sec
start looping the last phrase you have played
(include one of the following notes) approx. 11 sec
pp
repeat as many times
as necessary

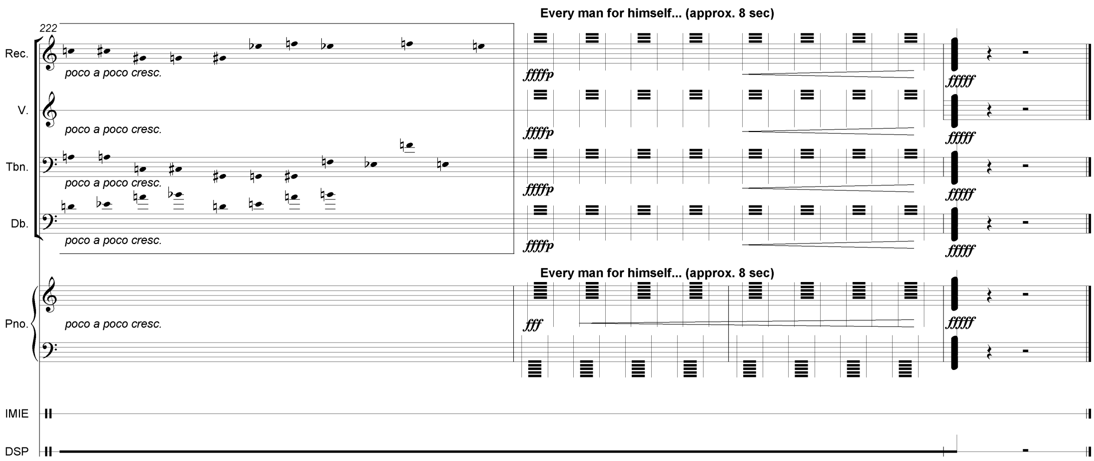

181
Rec.
V.
Tbn.
Db.
Pno.
IMIE
DSP
gradually decrease the loop-size to a single repeating note
(the given note) approx. 34 sec
gradually decrease the loop-size to a single repeating note
(the given note) approx. 34 sec
gradually decrease the loop-size to a single repeating note
(the given note) approx. 34 sec
gradually decrease the loop-size to a single repeating note
(the given note) approx. 34 sec
move the repeating note to synchronise with the piano
(diminuendo poco a poco) approx. 17 sec
move the repeating note to synchronise with the piano
(diminuendo poco a poco) approx. 17 sec
move the repeating note to synchronise with the piano
(diminuendo poco a poco) approx. 17 sec
move the repeating note to synchronise with the piano
(diminuendo poco a poco) approx. 17 sec
repeat as many times
as necessary


189
Rec.
V.
Tbn.
Db.
Pno.
IMIE
DSP
gradually diverge into multiple individual metres
(diminuendo poco a poco) approx. 13 sec
gradually diverge into multiple individual metres
(diminuendo poco a poco) approx. 13 sec
gradually diverge into multiple individual metres
(diminuendo poco a poco) approx. 13 sec
gradually diverge into multiple individual metres
(diminuendo poco a poco) approx. 13 sec
p
p
p
p
repeat as many times
as necessary
l.v.


195
Rec.
V.
Tbn.
Db.
Pno.
IMIE
DSP
gradually permute the sounding pitch to E
(diminuendo poco a poco) approx. 19 sec
maintain polyrythmic E
(diminuendo poco a poco) approx. 37 sec
gradually permute the sounding pitch to E
(diminuendo poco a poco) approx. 19 sec
maintain polyrythmic E
(diminuendo poco a poco) approx. 37 sec
gradually permute the sounding pitch to E
(diminuendo poco a poco) approx. 19 sec
maintain polyrythmic E
(diminuendo poco a poco) approx. 37 sec
gradually permute the sounding pitch to E
(diminuendo poco a poco) approx. 19 sec
maintain polyrythmic E
(diminuendo poco a poco) approx. 37 sec


Play the following melodies extremely aggresive and explosively: approx. 59 sec
rhythm, articulation and technique ad lib. (don't play 'nice')
203
Rec.
V.
Tbn.
Db.
ppp
sfff
ff
poco a poco cresc.
eruption of vocal detonations (no pitch)
Pompously jazzy ♩≈ 132
Pno.
IMIE
DSP
input: all instruments
explosive granulator, pitch-shifter and feedback loop
209


215
Rec.
V.
Tbn.
Db.
poco a poco cresc.
poco a poco cresc.
poco a poco cresc.
poco a poco cresc.
Pno.
ff
improvise on the previous material
(in line of the explosion of the piece)
IMIE
DSP


222
Every man for himself... (approx. 8 sec)
Rec.
V.
Tbn.
Db.
poco a poco cresc.
poco a poco cresc.
poco a poco cresc.
poco a poco cresc.
ffffp
fffff
Every man for himself... (approx. 8 sec)
Pno.
poco a poco cresc.
fff
fffff
IMIE
DSP