Of Music, Mind, and Machines: Towards an Integrative Musicology

Kevin Dahan
Laboratoire LISAA - EA 4120
Equipe CCAMAN
Université Paris-Est Marne-La-Vallée
5, Boulevard Descartes,
Champs-sur-Marne, France
Email: kevin.dahan@univ-mlv.fr

***Abstract*—Music has always been a particular aspect of human culture. It is the first art form that deals directly with time- how it is shaped through vibrations and how these vibrations are organized. Numerous theories have been developed to understand how the organization of sounds intimately works, each proposing interesting views on music, albeit very diverse and apparently difficult to conciliate. However it has been shown that two opposite forces are at work whenever music is described: physical resistance and symbolic obfuscation. For the most part, the study of music (musicology) has a vested interest in abstraction and symbols; however recent technological developments make reasoning on (or about) music more difficult, as the well-defined frontier between data and symbol is getting thinner. We present a review of the different aspects of time in music and musicology, proposing a categorization of both musical times and related disciplines, then describe the recent conceptual and technological developments that should be taken into account when studying music. Finally we show that musicology has a potentiality for acting as a merger for coordinating up to a certain extent several aspects of music research.**

I. Introduction

When our minds are confronted to music, be it at the perception and cognition levels, we react in a number of different ways, at different levels (e.g. psychological, emotional or physiological). Various strategies have been used to characterize what exactly happens when subjected to music, most of them strongly tied to the concurrent existing paradigms in other disciplines, notably linguistics and artificial intelligence, fields that are mainly dealing with symbolic manipulations. While numerous advances are made in many related disciplines (from digital signal processing to psychoacoustics and music cognition), few actually address the problems of the musical mind in music-oriented (or musicological) perspectives.

Musicology is defined as ”the study of music”. Throughout history, this discipline have been redefined a number of time: during medieval times music was taught as part of the *Quadrivium* (on par with arithmetic, geometry and astronomy), then its teaching moved away from mathematics, and is now commonly found in the Humanities departments of most universities. However, recent technological developments led to a flourishment of novel subfields, each dealing with a particular aspect of the music phenomenon (music and mind, music and machines, music and physics, . . .). However musicology did not redefine itself.

We believe the study of music could benefit from unifying these multiple approaches by using a framework based on musicology and music theory. Instead of arbitrary defining a musicological-only framework, we propose to take into account several aspects of music rarely explored by musicology, from psychology to engineering. In this discussion we will describe how music and musicology deals with time, then how technology changes our relations to music; finally we will describe how technology can help in redefining musicology, and how musicology can integrate the numerous fields of music-related researches.

II. Aspects of Time in Music and Musicology

While music has been traditionally (at least since Kant) defined as being ”the art of time” [1], the concept of time have been considered consubstantial to music, and consequently it has seldom been addressed in music theory and musicology[1]. It can be noted that absolute time-measured notation in Western music appeared quite late in history, at the turn of the 17th century, and for the most part, other musical traditions relay on variable (i.e. complex) rhythmic relations instead of fixed (i.e. measured) ones. Regarding musicology, though *rhythm* is an aspect of music that is commonly addressed, does different traditions question the notion of *time*?

A. Traditional approaches to Musicology

There are a number of ”traditional” approaches to music analysis and musicology. Depending on a number of factors, these approaches are mixed to a certain extent, and for the most part, studies use concepts, tools and methods drawn from several of the subfields we describe below.

1) Historical Musicology: Historical musicology originated towards the end of the 18th century. It primarily deals with contextual information surrounding the creation of a musical works. Such information is used to inform a transformation model of music, ultimately describing an *evolution of musical language(s)* (in relation to history). While there is, obviously, a

[1] We assume for the rest of this article that musicology addresses first and foremost Western classical music tradition. It is used in this sense, unless otherwise noted.

relation to time, historical musicology is not interested in using (or even describing) *musical time* as an explanation criterion, and therefore this approach have little interest for our goals.

2) Analytical Musicology: Analytical musicology centers on the object, that is the musical work, and tries to explain it in a self-referential fashion. Most methods are strongly related to a particular musical idiom or language. On of the oldest tool used is the functional analysis, which describes tonal music as a succession of tensions with associated releases. There are numerous methods and tools that have been developed in order to provide the analyst with functional approaches which have been developed for the most part during the 20th century.

This tendency towards sequencing can also be found in these more modern approaches, such as in Schenkerian analysis. [19], which follows a reductive approach of these tensions/releases episodes, resulting in a graph subjected to interpretation. Interestingly, time is considered in Schenkerian analysis as a ”surface aspect”, and describing the music composition process as essentially arythmic.

Further developments of analytical methods pertaining to non-tonal idioms include pitch-class set analysis [7] and set-theory. One of the interesting aspect of pcs analysis is to provide a non-linear approach to pitch grouping, thus permitting to describe both simultaneous and separate events as pertaining to the same grouping. This particular effect of pcs would allow the description and analysis of rhythmic patterns, but is as only seldom been addressed *per se* in set-theory literature [16], and particularly when dealing with specific cases of procedural music in which rhythm is the prominent compositional aspect [3].

The specific question of *time* and its subdivisions (i.e. rhythms) is very difficult to address from a purely musicological standpoint: albeit at the very heart of music, little specific literature is available on that subject. Jonathan Kramer pioneered an approach that has yet to be explored [10], defining multiple temporalities (absolute, virtual, vertical, . . .) and opposing linear and nonlinear time, that all relates to post-modernism philosophy and reminds heavily of the Deleuzian concepts of repetition and differences [5]. While this discussion is important and vital to our field, it however lacks informed commentary originating from other fields of music research, which would give quantitative information to this analysis; this is one of the key point that needs to be addressed.

B. Recent Approaches

More recent approaches to musicology tries to apprehend the musical fact in a transitional fashion: by making music not only the object of study but also a experimental object that can be modified through the course of analysis. Such an approach can be found in computational musicology, whose methodology is that of computer modeling: through series of abstraction, models of musical pieces are generated and ”evaluated” through situational studies and/or traditional musical analysis [2]. Most of the time, these studies are restricted to specific cases of music, and are generally limited to the western tonal music tradition [13] [14]. More complex methods, such as cognitive musicology for example, tries to conciliate psychological approaches to music perception with musical analysis explanations [11]: such a research plan requires careful studies on music perception in order to gather meaningful data to be mapped on traditional musical analysis.

Interestingly, time is rarely a central concept to these new approaches, who however frequently use discrete subdivisions of physical time, e.g. studies on *timing* in performances [6]. Instead of exploring the complex topic of musical time, current musicological approaches often prefer to relay on cognitive information (that are dealing with multiple temporalities) and computational manipulation (that also has to deal with multiple coexisting subdivisions of time), without confronting the main topic of time(s).

III. How Music Changes

Processes of time and arrangements thereof form the basis of music, and the study of any music should first and foremost be the study of how time is (or is perceived to be) manipulated. We described in the previous part how musicology has a strong tendency towards segmenting musical works into different structural levels. We can analyze this tendency towards the *discretization* of musical parameters as a mirror of the technologies that are available to the musician: from early digital signal processing (an example of which can be found in most DSP textbooks [20]) to modern music information retrieval techniques (which sort of can be viewed as DSP enhanced by artificial intelligence findings [9]), methods for the manipulation of digital audio signals have been following the same path of exploiting smaller elements, that is: finer time resolutions.

A. Levels of Time: 5P model

A rough categorization of the different levels of time found in music is presented below. It is not intended to be complete, nor to be completely accurate, but rather to serve as a basis from which to build further thoughts and refinements. We refer to this categorization as the 5P classification model of musical time.

1) Physical: The basic level of musical time is that of vibration. This particular level has interesting properties in that, *perceptually*, different manifestations of time coexist: pitch can be thought as essentially (really!) fast regular rhythm, while timbre may represent an arrangement of polyrhythms played together (really fast too. . .)[2].

2) Poietic: Poietic time refers to the creative moment of music, be it composed or improvised. This level is related to Xenakis' descriptions of *inside time* and *outside time* [22], and does not include performance issues.

[2]It reminds of the *vertical time* concept developed by [10], albeit enclosed in a smaller time fragment.

3) Performative: Performance issues form a very complex subfield of music research. For the most part, studies are interested in examining motor control at work in musical instrument performers. Due to technology, however, it is possible to redefine this particular time by including issues in computer environments used in music performance.

4) Psychological: Psychological time is the time of emotions[3]. This level represents a number of elements, ranging from immediate physiological manifestations [18] and longer term memory issues [8].

5) Protective: Protective time can be understood as the particular format (and *size*) a musical data needs for storage (in digital (e.g. audio files), physical (e.g. printed score), or mental (e.g. memory) form). Exploitation of such archive formats form an entire subfield of music research: to a certain extent, traditional music analysis is the exploration of archival time through physical format.

The 5P classification provides also a means for categorizing musical-related research: for example, a study of classical musician articulations could be classified as **Pe**-**Ps**-**Po**, denoting a strong interest in performative time, and lesser interest in psychological and poietic aspects; similarly some MIR results could be described as **Pr**-**Ph**, expressing findings in the archival and physical data representation domain. (Subjective) variations of quantitative importance in the related aspects could also be indicated (e.g 0.7 **Ph**-0.2 **Po**-0.1 **Pr**).

B. Technologies of Time

Thus any analysis of the musical fact is by ways an analysis of how time levels can be related to other time levels or other manifestations: for example, signal processing explores physical time through studying the relations of music to physics, psychoacoustics explores emotive time by describing the effects of music on subjective perception, and so on. At these intersections, models are produced, that can help explain a particular set of relationships from and to music. However most of the time these models work in unilateraly: musicological models are either *productive* or *analytical*. We believe models of music should instead be bidirectional: a working model for analysis should also be a correct model for production. Models used in music performance simulation (**Pe**-**Ph**-**Po**) should work backwards and be useful in music performance analysis (**Pe**-**Ps**).

Of course, each musical time subdivision also implies a correspondent representational system, which are largely dissimilar. However, from the physical (e.g. measurable) time to the archival (e.g. digital) time, from the poietic (e.g. improvisation) time to the emotive (e.g. listeners) time, and from another poietic (e.g. designing) time to a performative (e.g. electronic interaction) time, many musical works imply using simultaneously these different levels.These different representational systems are therefore placed in interaction with each others, constituting complex networks of times and related representations, with multiple contact points and cross-references.

Musicology should be the study of these particular interactions, through their manifestations in the different structuring levels of musical works. The whole musicology field should therefore be described by the complete sequence **Ph**-**Po**-**Pe**-**Ps**-**Pr**.

IV. Evolving Musicology: Crossing the Representational Barrier

As such, we believe musicology should integrate novelties from the many disciplines and approaches that exist outside it and that esthetical consideration should be taken into account when developing specialized tools and techniques for use in music. We are now at the threshold of enormous possibilities in manipulation of musical information, thanks to advances in the fields of cognitive science, digital signal processing, hardware and software engineering; but what is needed is a more integrated agenda for coordinating researches in those fields with respect to music.

A. Symbols

Computing - or more largely machines - redefined how we routinely deal with *symbols*. To a certain extent, what technology allow is the manipulation and transformation of *representamens*, as defined in the peircean tradition [17]. Such ease in the manipulation of musical information (unprecedented in history), finally permits to explore music beyond the traditional parametric approach to the music phenomenon: pitch, rhythm, dynamic, timbre, note, melody, harmony, form, structure, process, …, can all be represented by similar symbols and handled by similar manipulations: through representamens we manipulate musical time (or rather, the multiple levels of musical time) [4]. Such a possibility calls for a radical rethinking of musicology.

B. Integrative Musicology

Therefore what we propose is a new definition of musicology, one that articulates different disciplines, in particular findings in embodied cognition [21], neurodynamics [12], music information retrieval [15], and more traditional fields (such as computer music, psychoacoustics, human-computer interaction). We call this particular approach of music *Integrative Musicology*, as it does not limit its investigations to specific idioms or genres of music, nor to subfields of music research: rather, it seeks to integrate findings in different music researches within a common framework, which articulates around the notion of time levels.

A tentative agenda for integrative musicology is described in three propositions:

1) Proposition 1: To define and characterize the different levels of time that are at work in music; to describe as accurately as possible the multiple interactions of these levels in order to provide a theoretical framework of musical time. This essentially develops the categorizations developed above.

[3] While it can also be termed *subjective*, we prefer to use *emotive* as a label, which unambiguously includes both ends: receiver and producer.

2) Proposition 2: To articulate and coordinate findings in music-related research according to the framework described in proposition 1; to inform findings in music-related research with signifying musicological models (obtained through analysis of musical works). This ensures collaboration to various levels according to the 5P sequence (**Ph**-**Po**-**Pe**-**Ps**-**Pr**).

3) Proposition 3: To develop a cohesive environment for music analysis and production, pertaining to advances made in proposition 1 and proposition 2. This completes the 5P sequence with a 0.2 factor for each aspect (**Ph=Po=Pe=Ps=Pr**).

Music production and analysis are essentially the same activity: a construction/deconstruction of structures that articulate different levels of time according to specific rules. Technological tools are essentially providing facilities to interpret and manipulate these rules and structures. This is why it is important to relate musicology to music-related researches in psychology, computing and technology.

V. Conclusion

Throughout history, music theory has developed concepts to deal with smaller and smaller time units, hand-in-hand with music technology. Since the digital revolution, numerous possibilities have been made available for music manipulation; we are almost able to cross the representational barrier, allowing to handle musical time through symbolic representation without mediation (which was not the case in earlier music periods). This approach has consequences on how we consider musicology.

More than being just a discipline that uses tools and methods developed in "more technical" fields, musicology should inform research in these fields, as well as deriving concepts from them. An algorithm for finding perceptual similarities in an audio signal (**Ph**-**Ps**) will be made more efficient if it can rely on musicological data that describe what musical characteristics are more salient than others in a given musical work (**Po**-**Ph**-**Ps**): for now, such data is not available, for lack of a cohesive framework for exploiting musicological concepts. Similarly a musicological theory for electroacoustic music analysis (**Pr**-**Po**) should take into account data gathered in music perception research (**Pr**-**Ph**-**Po**): otherwise it risks to function only in a circular fashion. Unfortunately, these situations are becoming more and more frequent nowadays.

In order to be able to work in music-related research in a more cohesive manner, we presented a proposal into what musicology could evolve in the next few years. By exploring the possibility of a common framework grounded in a shared analysis of musical time levels, integrative musicology follows the evolution of music theory, music psychology and music technology towards control over the smallest and most important element of music: time itself.

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