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MUSIC, MIND AND PROGRAMS

Ich bin von all Maschinenmusik, wozu ich auch Professors Spiel auf den Fluegel rechne, ordentlicht durchgewalkt und durchgeknetet, dass ich es in allen Gliedern fuehle und lange nicht verwinden werde.

(E.T.A. HOFFMANN, *Die Automate*).

In the novel *Die Automate* (Hoffmann, 1957 ed.), the German writer Ernst Theodor Amadeus Hoffmann (1776-1822) describes different kinds of musical automatons which play music with expression and musicality. The whole novel is based on the effect of the automatic performances on the feelings of the two personages and on the appearance of musical automatons which simulate, with their musical skill and expressiveness, the structures of the knowledge and feelings of human beings.

Such a theme is not surprising in that period. At the end of the 18th century, the representation of man as a machine was a featuring point of philosophical thought (La Mettrie, 1970; Cabanis 1960). But the relevant feature of the novel was representing the automatons not as devices which perform mechanical music but as

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machine-like entities which have internalized the competence of a musician.

Today, the computer is used to perform new and old music, to compose new types of sounds or musical pieces and to perform musical tasks that are not trivial. But relevant questions are still undefined in the field of computer application to music: how can the computer be a useful aid to represent our underlying musical knowledge? Is it possible to simulate a complex musical task such as the understanding of a musical compositon?

To answer these questions we can only rephrase them in the following statement: the computer can be used to help us formulate some hypotheses about our musical knowledge by testing musical theories regarding aspects of our musical competence, formalized and implemented in programs. In this sense, the automated tools play a crucial role in the field of musical cognition.

But what are che components of our musical competence? What kind of processes do they involve? In this paper I will represent musical cognition as composed of three properties which interact with each other: syntax, semantics and expression. In this theoretical framework I propose that each of these properties shares some processes with other human faculties, such as language and vision. In studying these musical properties, I propose a modular mental approach of the type described by Chomsky (1980) and Fodor (1983).

Thus we could represent the faculty of music divided into three different and interacting components:

i) The COMPUTATIONAL COMPONENT that rules the aspects forming syntactic construction;

ii) The CONCEPTUAL COMPONENT that involves a system of reference, musical beliefs and so called "associative relationships";

iii) The EXPRESSIVE COMPONENT that rules a system of musical semblance reference and some primitive expressive contours.

The last two may be considered as belonging to some faculty which provides "the common understanding" of the world.

By defining this theoretical approach, we point out that recently the study of music has been influenced and improved by concepts belonging to different disciplines that have introduced new and interesting theories about the structure of the human mind: linguistics (Chomsky 1965, 1975, 1980; Prince and Liberman 1977); artificial intelligence (Winston 1982; Minsky 1975); vision (Marr 1982) and for some ideas, the functionalism of the philosophy of mind (Fodor 1975, 1983; Block 1978; Lycan 1981). Furthermore, all these disciplines are related in some aspects to the utilization of automated tools, though with different approaches[1] and methodologies, and this indicates that, even if the different faculties of human cognition cannot be simulated by programs which model their processes and functions, their contribution will improve the empiric content of the formulated theories.

In the following section I will deal with the three musical properties of syntax, semantics and expression separately. In the concluding section I will briefly analyze how their components interact.

AN APPROACH TO MUSICAL SYNTAX

In his essay on the organic structure in sonata form, Schenker (1926) developed interesting concepts to demonstrate the motivic unity of this musical form. He introduced concepts such as "the improvisation-derived driving force (*Stegreif-Zug*)" and "the sweep of improvisation (*aus dem Stegreif*)" to illustrate how the musical genius achieve a work of art by means of the "composing-out (*Auskomponierung*)" process which rules the creative improvisation of the composer. The composing-out process unfolds the protostructure of the piece, formed by a few basic chords or the so called *Ursatz* (fundamental structure) by means of the system of *Verwechslung* (prolongation) which can be seen as a system of rules to be applied to the *Ursatz* (Schenker, 1935).

The concept of the improvisation derived from underlying processes (the prolongation techniques) resembles, in some aspects,

[1] See the philosophical debate about strong AI and weak AI following the article of Searle (1980).

the one that Lerdhal and Jackendoff (1983) call "the unconscious knowledge of an educated listener".

Even if these concepts are formulated in a different manner, they share the belief of representing the surface musical activity, of the composer or of the composer/listener,[2] as ruled by a system composed by finite elements (rules), which can be applied recursively and which can analyze (in the case of the listener) or compose a musical piece by means of the process of reduction in a hierarchical structure. The structure should be inferred by the application of the system of rules.

In this sense the component which rules the applications of the well-formed rules to infer that the underlying structure of the piece should by modeled as a system which performs a sort of computation, as in the case of language and vision but with different properties.

But what are these properties? As far as the parallel between language and music is concerned we could say that constituents, like noun groups, verb groups and so on, do not exist in music. Even if we explain some aspects of the structure of a piece referring to tonal categories,[3] these are quite different from the constituents in language syntax.

I believe that representing our musical knowledge in a theory of music means to develop, as in Lerdahl and Jackendoff's theory, different systems of rules, each one referring to an aspect of the musical structure, which should have these characteristics: those entailing different kinds of representation from the others,[4] conveying and sharing information with each other, being divided into subsystems or subagencies.

I propose here, following Lerdahl and Jackendoff's theory, that,

[2] The concept of the "educated listener" entails a more theoretical clarification since the composer can be defined as the first listener of his music.

[3] In this case I mean the categories of Tonic Prolongation, Tonic Completion and Dominant Prolongation developed by Keiler. Even if they can explain the domain, and the hierarchy in that domain, of a particular tonal area and the complexity of the nesting of these tonal areas they do not have a close likeness to the verb and noun groups of language.

[4] Some studies on musical learning have pointed out that in defining different aspects of musical structure children use different kinds of representation and that they play an important role in the completion of the musical sense (Bamberger, 1976).

our musical knowledge being formed by four systems concerning the grouping subdivision, metrical structure, pitch stability and reduction, and the movements of tension and relation, each of these systems or, for a better definition, rule systems can be seen as an agent or a homunculus. In that way I hypothesize the formulation of a "homuncular theory" of musical syntax features, in order to model in a computational paradigm our underlying musical knowledge.

Following this paradigm (Dennett, 1978; Lycan, 1981) the musical listener is viewed as a sort of corporate entity, divided into subpersonal agencies (homunculi) which have access to each other by means of many routes to cooperate in carrying out the purpose, in this case, of analyzing a piece of music. Each homunculus has internalized a rule system which allows it to process the musical structure submitted to it only for the aspect which it is specialized for.

To show roughly how an analysis could be performed, representing the listening activity in that way, I will use four homunculi; GH, dealing with grouping structure; MH, dealing with the metric structure, RH, dealing with pitch reduction and thus with pitch stability and hierarchy; and PH, dealing with the so-called prolongational reduction concept concerning the tension and relaxation of a piece. The piece could be analyzed as follows: the one specialized in the recognition of the grouping structure starts segmenting the piece into subgroups, groups, phrases, periods and so on. To do this, it sets up its subsystems such as the groups delimiter and groups recognizer, and its rule system which allows it to build up the hierarchy of the parts of the composition. Then it sends all the information to the MH which assigns the metrical weight and hierarchy. The assignment of the metric stress is carried out by the bar subdivider and the duration recognizer, subagents of subsystems of MH which, in performing their work, refer to the information worked out by GH.

After having received the information from both GH and MH, the reduction homunculus RH begins the reduction of the piece by starting its harmonic degree and motion parser, its cadence recognizer, all of which are subagents. Taking into account the metrical position of single pitches and chords and referring to the group segmentation RH builds up the hierarchy of the tonal struc-

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ture of the piece. Finally PH, the homunculus concerned with the subdivision of the piece in zones of tension and relaxation, stores all the information received by the other homunculi and starts its task. By means of parsing bass motion, defining voice leading and recognizing the harmonic degrees which support the different piece parts and chord progressions, it completes the information about the piece. When all the information is assessed, the structure of the whole piece is computed.

After we have briefly outlined this theory modeled on an artificial intelligence paradigm a question arises: what are the benefits in using this kind of "homuncular theory of music"?

To conclude this section I summarize the motivations which make this model suitable to explain how we process musical structures:

i) Being forced to develop some systems by means of a set of rules and discovery procedures which represent the homunculi of internalized musical competence;

ii) The possibility to translate these systems into computational terms, that is, to implement them into programs;[5]

iii) The different structure of these systems which means a different kind of representation for each one and the possibility of studying the exchange of information among systems.

Some Issues on Musical Semantics

As far as the musical meaning, and thus the musical semantics, is concerned I would like to answer a first objection that could arise: why separate musical semantics from musical expression? Musical expression evokes meaning (extramusical meaning) one could ob-

[5] Regarding the implementation of a theory in a program, Dennett (1978) pointed out that "the demands of program writing force into the open any incoherencies, gaps or unanswered questions in a theory; it keeps the theoretician honest. Second, once a theory is thus incorporated in a working, debugged program, its implications can be quickly determined and assessed". Dennet also believes that the simulation can be an "experience-generator". A simulation program can produce thousands of results of the theory to scrutinize for implausibility or worse.

ject. But I believe that differences exist between these components of music; the relevant one, I think, is that musical semantics is concerned with sintactic features more than musical expression. Moreover, the separate study of these two components of music can allow a clear definition of the problems and an attempt to discover the processes underlying them.

As a starting point I propose the definition of A. and J. Becker (1979) who classify four aspects of musical activity from which the performer/listener/composer can derive musical meaning. These are the following:

i) structural meaning; the meaning derived from the structural relationships among the various musical elements.

ii) stylistic reference meaning; one derived from the relationships between a piece of music and the history of its genre.

iii) situation meaning; that referring to the context in which the piece is performed.

iv) extramusical meaning; one that bears on all the non-musical events which enter into relation with the musical piece.

After defining these four possible derivations of meaning from musical events, we must determine the area to which each one belongs. The area of belonging marks the definition of the content conveyed by the meaning, i.e., if it is referred to structural or to expressive aspects. In this sense I propose that the component regarding musical semantics mediates the information between musical syntax and musical expression. Following this assumption, I classify the first two definitions of meaning as belonging to musical syntax and the others as belonging to musical expression.

Structural meaning can be compared to the logic form in language (Chomsky 1977), that is, those aspects of semantic interpretation which are strictly determined by syntactic features. In other words, we have a semantic representation which is not concerned with extramusical events (Camilleri, in press).

The question concerning the stylistic reference meaning, related to the history of a musical genre, calls for a more complex answer. The explanation of this facet entails the representation of our musical experience that I call here the amount of our "musical beliefs". The lack of this assumption has given rise to many misunderstandings of this kind of musical meaning; the relevant one is to see this

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type of musical meaning as an active part of our musical syntactic competence (Minsky, 1982).[6] On the contrary, I believe that it is only partially concerned with the syntactic construction of music. It is concerned with the information yielded by our musical beliefs by means of the system of reference. The system of reference carries out the comparison between structural features of the piece and stylistic features of the musical genre.

But the explanation of the role played by the system of reference and our amount of musical beliefs requires a more precise definition of these. Thus, they are in turn divided into two distinct parts. For example, when I listen to a *Requiem* I activate in my mind the processes which search for all the musical information to compare the stylistic features of a *Requiem*. But I also start all the processes which are related to the emotional and expressive values and to the concepts[7] referred to this kind of music.

In this sense the meaning of points iii) and iv) clearly refers to musical expression since it connotes the representation of emotion/expressive values and extramusical concepts.

If we take this subdivision as correct, two more questions may arise: are the musical beliefs and the system of reference linked to other human faculties? How is their computational representation possible? My answer to the first question is that I consider our musical beliefs as a part of our system of beliefs and experiences. The exchange of information between expressive and structural values should be mediated by this system.

The computational representation of these aspects of musical meaning could again be organized in homunculi or agents each containing a protocol of information in which a structural feature is referred to a structural/stylistic and an emotional/expressive values with a certain degree of stability. The protocol should continu-

[6] Regarding this aspect Minsky writes "But neither could one remember Beethoven's Fifth Symphony entire, from a single hearing. But neither could one ever hear again those first four notes! Once but a tiny scrap of sound; it is now a known thing, a locus in the web of all the other things we know, whose meanings and significance depend on one another". Despite his correct formulation of this facet Minsky fails in assigning syntactic values to it. The "four notes" of the Fifth Symphony belong to our musical beliefs.

[7] Boiles (1967) presents a kind of relationship between musical elements and extramusical concepts. Boiles' article deals with the songs of Tepehua, a tribe of Mexico, in which each musical element represents a well-defined concept, such as death or birth.

ously be increased to represent musical beliefs and should contain a network of interrelations between the structural aspects and the expressive significance related to each of them.

Therefore, the conceptual component operates as a system in which the homunculi work to represent high level structural features and to refer micro and macro form characteristics (large forms or single melodic or harmonic lines) to expressive values. In this last case, the information worked out by the expressive component and in the former case the representation build-up by the computational component is needed.

In that way I define as musical semantics the aspect which is concerned with various levels of significance from the structural to the expressive/emotional ones.

Remarks on Musical Expression

In Thomas Hardy's *Jude the Obscure* (Hardy, 1951 ed.) we find an interesting description of the effect of music on the human being. Hardy writes, "as they all sang it (the piece) over and over again its harmonies grew upon Jude, and moved him exceedingly". This description stresses the fundamental point of musical expression; the relation between structural contour (in this case the harmonies) and emotional stimuli.

When we think of musical expression, we consider it as the representation of emotions and feelings of the composer translated into musical terms. Another definition is that musical expression deals with the aspect of music which rouses emotions and moves the listener. These explanations of the expressive content of music have been defined by Kivy (1979, 1984) as "self-expression" theory and "arousal" theory. Kivy's remarks on this broad definition of expression in music are that music does not express or give rise to emotions. The emotions belong to the music itself as a property of it. Nevertheless, Kivy develops two complementary theories; the contour theory based upon the resemblance between the features of music and those of human behavior, and the convention theory referring to the function of the customary association of certain musical features with certain emotive ones.

When all these assertions are summed up, it seems to me that we need the answer to one more question: what are the relationships between structural and expressive features? In fact, denying either that music does not express the composer's emotions or that music does not arouse emotion in the listener,[8] and following the convention and contour theories it does not only entail the development of a theory which relates structural content with emotional content and associates some features of music to expressive ones. We need the formulation of a theory which explains the processes which rule the expressive/emotional properties of music.

In this sense I postulate two different systems which are related, in some aspects, to Kivy's theory and to research in musical expression carried out by Clynes (1983). The systems is that of musical/-emotional semblances in which the mutual relation between musical and expressive features is carried out by rules which activate two processes: the one which searches for structural likeness between the two features and the other which refers to the musical beliefs related to this expression. The other system entails the definition of primitive contours (the essential forms postulated by Clynes) representing emotional features. The primitive contours should be translated into structural musical terms so as to define a rule system which explains the contours in terms of their expressive content. The task of abstracting emotional values in music should consist in being able to recognize the features of emotional structures in musical ones and to relate them to the system of semblance. Nevertheless, the system of semblance can be thought of as dynamic. In that way each new relationship between emotional and structural features due, for example, to a stylistic change, is added in a proper way to it.

But after these definitions we need to elucidate two aspects regarding the structural features yielding emotional contour and whether these associations are linked to the surface or to a deeper level.

As musical features which are particularly related to expressive

[8] We can exclude that the composer should be in a particular emotive state to compose a piece with a particular expressive characteristic. For a composer whose works were commissioned it might be a problem. On the other hand, the listener would avoid all the pieces whose content is related to emotive states like anguish, sadness and so on.

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properties we can refer to phrasing, the line of melodic contour, chord progression and rhythmic articulation.[9] For the other aspect, saying that music represents emotion implies that representing means the possibility to abstract relevant features by means of a sort of computation. The other step should be referring them to our amount of musical/emotional features. The representation should be highly constrained and the comparison carried out only in terms of relevant/primitive features which are not the ones of the surface piece.

Conclusion

As a conclusion, I would like to summarize briefly some relevant points concerning the approach to the music theory I have sketched out.

The first one is the assertion of studying the faculty of music as composed of three interacting components, each one in turn subdivided into systems and subsystems, or in highly specialized homunculi which work together to compute the representation of a particular musical task.

This assertion calls for the realization of a theoretical framework in which the musical properties, syntactic, semantic or expressive, can be simulated or represented by programs functioning as a test of the theories and as the experience generator scrutinize some aspects of our musical behavior.

Furthermore, I stress the importance of referring to the studies of other human faculties so as to introduce new and useful concepts in music theory, concepts which point out the processes shared by the different faculties of our mind and serve to build a theory of music explaining the mental structures underlying it.

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[9] Tarasti (1983) has developed an interesting concept about musical expression and musical interpretation based on the categories of "being" and "making" related to certain expressive modalities.

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