Composing Music with Case-Based Reasoning

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Abstract

Music is one of the most intriguing and joyful domain of research and analysis. Driven by this insatiable curiosity, Musical Analysis has emerged to formally understand and structure music and its intrinsic intention and causality. Each complete analysis of a piece points to issues that go far beyond the normal graphical music representation. A better analysis is important not only to a better interpretation, but also to a more perfect composition. An exceptional composer is indeed an exceptional analyst.

This paper presents a computational approach to music composition through the use and exploration of musical analysis. Centered on Case-Based Reasoning and Planning techniques, it consists on creating new solutions by keeping, transforming and extrapolating knowledge from already expert-made music analysis. For our approach, each analysis is represented as a precisely structured Case, divisible into all of its components.

The process of composition we adopt is progressive, left-to-right, and top-to-bottom and has some similarities with (Wallas' 1926) theory for creative production (Macedo et al. 1996a) which we adapted for this specifically structured and complex domain.

The resulting implemented program has already generated several different musical pieces, which were examined and analyzed by experts, bringing up precious questions and advice.

Introduction

To compose a music, to write a story, to design a chair are acts of what we call by "creative production". Associated with "ethereal" concepts like inspiration, mood, will, the creative production is also, and definitely strongly, dependent on structure and knowledge representation (Holyoak and Thagard 1995).

As they say, the potential for creativity in a domain is constrained by the way in which one structures and represents knowledge.

A more creative knowledge representation must have, among others, flexibility, be dynamic and open (Carey and Flower 1989).

The knowledge representation by itself is not enough. A process to use it adequately is also a key issue. There are several different proposals for answers on "how do we create?". Wallas, for example, considers a process divided into four sequential stages: preparation, incubation, illumination and verification. In this paper, we present an approach to compose music, using a highly structured knowledge representation and an adaptation of Wallas' model for creative production.

In the base, our approach has emerged from a combination of Case-Based Reasoning, Planning, Creativity and Musical Analysis. For us, each analysis of a musical piece is a case, hierarchically divided into actions and operators (Ferreira and Costa 1994). Each case can thus be considered as a plan. The process of generation of new solutions, based on the Wallas' model, creates new plans by using pre-existing cases in the library. This approach can be extended far beyond musical creation, namely to any equally structured domain, like story plot creation, design tasks, etc. (Macedo et al. 1996a).

Initially, in section 1 we'll make a brief introduction and description of the main issues of Music Analysis.
Section 2 will be dedicated to some already done work on the subject of "Making Music".
The approach will be presented in section 3. Its results and expert evaluation are discussed in section 4.
Finally, section 5 is dedicated to conclusions and further work.

1. Music Analysis

From the most simple lullaby to the complicated Shöenberg piano pieces, structure and logic is present. Each music has its harmonic line, rhythmic cells, motives, phrases. Consciously or not, the composer builds a structure, with internal antecedent-consequent relations, according to some kind of structured thought. A music analysis extracts this structure, its internal relations and subtleties and permits musicologists to infer the structured thought of musicians. This brings up the notion of style, which we won't discuss here, since we would need more than an entire paper. Style, according to the analyst's point of view, is associated to a set of typical structures, relations and procedures, also related to the historical, aesthetical and social context.
The historical reference we have chosen for experience was the baroque age. We have selected three pieces from the Portuguese composer Carlos Seixas, a well-known harpsichord composer, which followed a similar style to Domenico Scarlatti's (they were contemporaneous and friends), and obtained from expert analysts the detailed analysis of each one. An analysis divides a musical piece according to the following hierarchy:

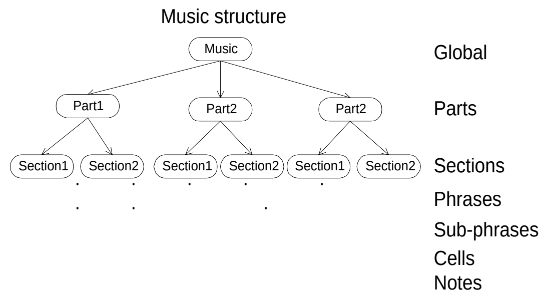

Figure 1

There may be relations between any two of these components. For example:

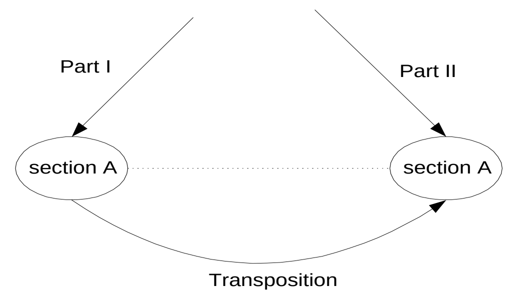

Figure 2

is a common situation. This means that section A of Part2 is the same as Section A of Part 1, but transposed. Moreover, there is also an harmonic, rhythmic and melodic line associated to this structure. In this approach, each of these tree-like structures, with interrelated components is a case, to be explored later in the retrieval process. The ability of CBR to explore past cases, keeping subtleties, and of Planning to deal with time and causality (Macedo et al. 1996b), becomes precious to accomplish the task we proposed ourselves.

2. Making Music

Plenty of work has already been made on the subject of composition and A.I.. Here, a book of reference is, indeed, A Generative Theory of Tonal Music (Lerdhal and Jackendoff, 1983). This work presents a fundamental point of view to those who work on this subject: Music is a Language, and as any other languages, can be expressed and generated by grammars. This idea based excellent work from other people like (Cope, 1992), (Blevis et al,1992), (Bell and Kippen, 1992). In these works, also, the musical analysis is an important issue. There are other important developments like (Balaban, 1992), (Smaill et al. 1993), also dealing with structure and analysis. In our approach, we tried to look for the subject from other point of view. Why not see a musical piece as a case, instead of inferring grammars from it? The use of generative grammars, although keeping style and coherence, doesn't allow a simplified way of generating much different music from the original (i.e. when using a grammar for a style, we can't produce much different music). The use of CBR allows, as we will show bellow, the creation of much different solutions.

3. Our Approach

Finally, in this section, we will describe our approach in some detail. Its computational implementation has been given the name "SICOM", which means, in English, Musical Composition Intelligent System.

First of all, it is important to discuss and present our case representation.

Case Representation

As said before, a good representation must be flexible, dynamic, open. A complicated, and yet completely unsolved, problem comes to us: how to represent music with all of its relations, time associated and hierarchical structure, having flexibility and being dynamic and open? Of course, the perfect solution doesn't exist and we have to balance carefully all of its features. Our representation can be described as having two simple properties: tree-like structure and divisibility.

Each case is composed of a hierarchy of temporal objects, to which we call by "case-nodes".

The case-node

A case-node is a prolog fact with the following form:

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case_node(Case_Name,
          Node_Name,
          Temporal_Position,
          Constraints,
          Atributes,
          Antecedents,
          Consequents).
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Where Case_Name identifies the case name which the node belongs to; Node_Name is the node´s name; Temporal_Position is a kind of pseudo-date (Pereira et al. 1996) that shows the temporal and hierarchical position the node occupies in the tree; Constraints are features that must be in accordance to the context (tonality, metric, etc.) in order to be introduced in a new structure; Attributes are the features of the node (its inherent characteristics, e.g. melodic patterns); Antecedents are relations with hierarchically superior nodes or with a previous occurrence in time; Consequents are relations with hierarchically inferior nodes or with a former occurrence in time.

Structure

Each of these case-nodes is stored in the library, and represents an object from the musical analysis. The analysis of a case is thus represented by a set of case-nodes and relations. With this, we achieved a structure that is coherent with the analysis and is also divisible in all of its components.

Interrelation

These links, represented in the antecedent and consequent lists, allow the connection of causality that is so typical in music (and of everything else…). With this, it's possible to relate any two nodes in any way.

Divisibility

We think the flexibility of a representation is proportionally related to its possibility to decompose itself into smaller and independent parts. With this idea in mind, we think we achieved a degree of flexibility that enables us to treat knowledge easily.

Some dynamism and openness in our representation is achieved with the use of links that, in the analysis, are considered as causal relations/explanations and in the process of composition are treated as suggestions and context transformation operators.

The process

As we referred before, the cognitive modeling foundation of SICOM is the Wallas' model for creative production.
This model consists on 4 sequential stages:
1) Preparation. This phase includes: (i) a formulation of the problem in the sense of knowing what is to be solved; (ii) an accumulation or assimilation of knowledge, to which we call background knowledge, necessary to create something.
2) Incubation. This phase corresponds to the generation and formulation of possible solutions. This process can be unconscious or partially conscious. During this phase, the problem is being unconsciously pursued and the flexibly organized background knowledge, acquired during the anterior phase, is being restructured into new schemata, i.e., new mental structures are created by recombinations and reorderings of the original knowledge (Armbruster, 1989).
3) Illumination. At this stage the solution is consciously proposed.
4) Verification. In this stage the creative properties (novelty, usefulness, etc.) of the solution are tested and some revisions and adaptations are made when necessary. If the solution is still considered as a non-creative product then it may be refused and all the sequence may be repeated from the beginning, trying to find a new knowledge recombination.

We adapted this idea to the domain of musical composition, taking into account that it has structure, causality and time.

For SICOM, the process is divided (also) in 4 parts:
1) preparation: This is the phase in which the cases are loaded into memory (or their indexes) and when the problem to solve is defined. This "problem to solve" corresponds to the case-node of the new music to be created next.
2) incubation: Here, the CBR mechanism of SICOM is activated and, for each node of the new music, the retrieving mechanism proceeds as following:

- Evaluates the expected context characteristics of this new hypothetical object.
- Searches the memory for nodes with the pretended contextual similarities.
- Eliminates those whose constraints get in conflict with the actual context.
- Orders the resulting nodes according to user-defined criteria.

3) Illumination - Having the ordered list of candidate nodes for the actual position, SICOM tries to adapt the first node to the new composition. If not possible, then try the second, etc. After finding the new solutions, the cycle needs to be restarted through a recursive call to the preparation phase.
Now, once more in the preparation phase, a new problem to solve is determined, and this process follows all over again.
This process is repeated iteratively left-to-right and top-to-bottom:

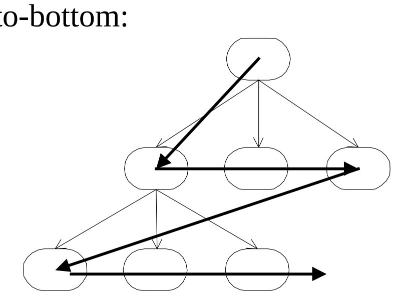

Figure 3

It finishes the cycle when achieved and completed the deepest level.
4) Verification - After constructing an entirely new structure, the verification is started. At the moment, this phase is entirely performed by

musical analysts. Their task is to evaluate the new composition according to the style in question, the originality and structure correctness. With this data, we intend to build a module of correction and advice to support the illumination and verification phases.

The Role of Links in the Process

In the above described scheme of generation of solutions there was no emphasized reference to the relations in music. They are very important, if not determinant on the act of composing. Links have two important roles in the process:

- Transforming the context. By way of illustration:

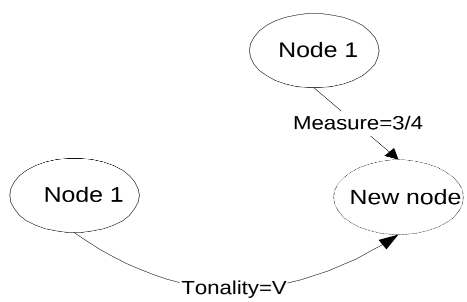

Figure 4

For the position determined by "new node", new values for context are defined (its tonality and its metric measure).

- Giving suggestions. In figure 2, it is given an example of a causal relation between two objects of the analysis (section A of part 1 and section A of part 2). When in the process of generating new structures, these relations may be broken and become suggestions. For example:

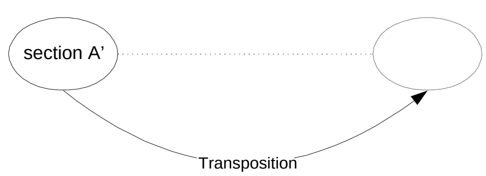

Figure 5

The first node of figure 1 has been used and transformed to "section A'". As a result of its placement on the new structure, a suggestion of "Transposition" appears. Of course, if this suggestion is accepted, a new object would be created (the transposition of A'). This is how SICOM creates new ideas (suppose that instead of transposition, it was "inversion" or "mirror").

There is a degree of importance for each link. According to expert analysts, there are strong, methodological, according to style, causal relations and there are inspiration, soft, subtle relations. The mechanism for choice of solutions weights also this property of the links.

How to Choose a Good Solution?

By now, there is nothing described above that a computer can't do. The process described and the knowledge representation are plausible and computationally acceptable. What to tell about the choice of solutions? Does a computer have any kind of aesthetic judgment capability, or some good musical taste? Of course, not directly, i.e., one can model and structure thought, teach a neural network, but we're still too far away from that "computer with personality" moment.

As described above, SICOM uses a similarity metric to classify nodes and orders them according to a user-defined criterion. We based these criteria on a simple idea: A less similar solution is potentially a more creative one. So, we established criteria according to reorderings of the candidate list dependent on its degree of similarity. SICOM orders the node list in a descendant order of similarity, and then applies the criteria(e.g. criterion 2 - reverses the first 40% nodes of the list and places them on the end). The metric counts similarities between contexts, temporal addresses, attributes, links/suggestions.

This is the solution we found. Other ideas may emerge to solve this problem of "solution choice", but we think this can be a good starting point.

4. Results and Expert Evaluation

SICOM has created more than 20 different pieces of music with the initial case library of three cases. The output of the system is, at the moment, a MIDI file with two tracks, corresponding to soprano and bass line.

We presented these results to expert musicologists. They concluded the following:

- SICOM compositions are comparable to young student's with the first degree of Analysis and Composition.
- Its capability of generating new ideas, although very interesting, is not enough, since there are sets of compositions with the same ideas.
- Sometimes, there is some lack of logic or sequence of reasoning.
- The bass line is just for harmonic purposes, so its value in the compositions is minimal.

The first point, being important as a kind of benchmark for the program, shows the point in which SICOM is, in terms of musical composition. We think this could be very much improved through the use of a greater case library.

The second point reflects also the problem of having a short case library, since there are situations that SICOM can solve in only a short number of ways.

The third point is very important. It reflects the efficiency of the retrieval mechanism. As the experts say, it sometimes doesn't achieve consequent solutions. Obviously, it varies according to user-defined criteria. The more different is the criterion, the more strange the solution is. Despite this fact, experts also said that even the more odd solutions were acceptable. This means that our constraint verification mechanism is working properly.

The final remark was already expected. Due to implementation priorities, and mainly to the fact that the analysis centered only on one voice, we decided to concentrate on one soprano melodic line, leaving the bass line as a satellite harmonic support. According to these experts, the system would improve exponentially with a multiple voice treatment and more varied solutions.

Apart from these points given by the evaluation of the experts, we asked them for a more deep analysis of each musical piece. With the results we expect to build a new module for SICOM. It is expected to be a case-failure and advice module to support the illumination and verification phase.

5. Conclusions and further work

This paper presented SICOM, a musical composer based on CBR, Planning, Creativity and Musical Analysis. This kind of hybrid system gathers from CBR its ability to use and explore experience and from Planning a simple way of dealing with causality and time. Creativity and Cognitive Science gave us the opportunity to try and test already established models. Although the model we chose for SICOM, the Wallas' model for creative production, is rather out-dated in terms of state-of-the-art on Cognitive Science, we proved it is computationally valuable. In future, we intend to test other models rather than Wallas' like (Guilford 1967), (Holyoak and Thagard 1995). The process of generation, although based on the Wallas' model, is a result of an adaptation to CBR and Planning, so it has a retrieval engine, reasons according to time, causality, hierarchy, and frequently makes recursive calls. This process uses Musical Analysis as a starting point to Composition. By considering a Musical Analysis as a case divisible into small objects (case-nodes) interrelated, it constructs progressively a new structure, gathering and transforming objects from the old analysis and adapting them to the new composition. By now, SICOM generates music using a case-library of three cases. With a representation based on divisibility and structure, it is possible to explore and create new ideas using a small number of cases, since each case splits into several case-nodes. It has already generated a number of pieces of music, which were heard by experts. They evaluated these new creations and gave some important advice on further work to do. At the moment, SICOM generates one independent soprano melodic line, having the Bass line the function of harmonic support. This happens because the three analysis in the library concern mainly with the melodic line of the soprano. Having deep and complete analysis of a music is not only very complicated, but also very time consuming. With this in mind, we believe it would be very important to develop an automatic analyzer with attention to counterpoint and multiple-voice relations. It would also be interesting to use in the library cases from different composer and different ages. Would a new concept of music appear?…

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