Discovering Hidden Themes in Symbolic Music Text

Michele Della Ventura

Abstract—The algorithm proposed in this article, in order to identify the (“concealed”) motif hidden among the notes of a musical composition represents, a revision of a previous algorithm (by Michele Della Ventura), based on the concept of “structural similarity”: the motif, though being hidden among melodic figurations, maintained the rhythmic and melodic structure unaltered (even if it was subjected to transposition). The current algorithm dealt with the issue of identifying the melody hidden among the melodic figurations which change its structural characteristics, thus making its identification very complex. The comparison between a melodic segment and the melody taken as a “model” will be made by constructing the Trellis Diagram. The new algorithm works out correctly even in case of analysis of the same set of scores analyzed by the previous algorithm.

Index Terms—Musical surface, segmentation, similarity matrix, motif, trellis, musical variation.

I. INTRODUCTION

The growing number of music files on the web, from MIDI files to scores written in text format (as, for instance, Lilypond), makes it necessary to further improve the tools used for their search and retrieval (*Music Information Retrieval* - MIR). A key issue that makes the design and creation of these tools difficult is the lack of structural information about the musical data to be analyzed [1]. MIR is based mainly on the concept of *similarity* for the identification of a melody (or a motif) within a musical composition existing in a Database: a similarity that may be analyzed (from different perspectives [2]) either considering only the melodic aspect (succession of the intervals between various sounds) or considering both the melodic and the rhythmic aspect (distribution of the intervals in time) [3].

This latter methodology is the fulcrum of the system proposed in this article: a motif, may in fact be subject, within the course of a musical piece, to variations, due to the use of melodic figurations such as the passing tones, turns, escape tones, retardations or anticipations which alter its structure. Therefore, the following possibilities may be noted:

- a motif, within the musical composition, is identified every single time it presents itself unaltered, that is without variations in the interval (and rhythmic) structure even if it is subject to transposition or retrograde and non retrograde inversion (see Fig. 1) [4].
- the motif can present itself hidden by melodic figurations, yet maintaining its own interval and rhythmic structure unchanged (see Fig. 2) [5], [6].

Fig. 1. Bach's Two-Voice Invention in C Major, BWV 772.

The sequence of notes (beat 1) is represented on the first staff, its transposition is represented on the second staff (beat 2) and its inversion on the third staff (beat 3).

Fig. 2. A melodic passage excerpted from “Knecht Ruprecht” belonging to R. Schumann's Album for the Young.

- the motif may present itself hidden by melodic figurations, which though maintaining its interval structure unaltered, do modify its rhythmic structure making it difficult to identify the motif (see Fig. 3).

Fig. 3. Theme of Mozart's Sonata in A Major KV331 and the first variation of the theme.

This paper is organized as follows. Section II presents the concept of rhythm. Section III describes melodic figurations. Section IV describes the structure of melody. Section V shows some experimental tests that illustrate the effectiveness of the proposed method. Finally, conclusions are drawn in Section VI.

II. RHYTHM, SUBDIVISION AND ACCENTS

The composer makes his thoughts comprehensible by coordinating sounds in time, i.e. by means of rhythm.

Musical rhythm is the orderly motion of sounds [7], i.e. a motion performed on the basis of certain time units having the following requisites: equality of duration (isochronism); susceptibility to divide exactly into elements of lower value or to add up to other of higher value; possibility to

Manuscript received March 26, 2014; revised August 4, 2014.

Della Ventura Michele is with the Music Academy “Studio Musica” Department of Music Technology, 31100 Treviso, Italy (e-mail: michele.dellaventura@tin.it).

differentiate from one another by different accentuation (weak accent, strong accent) (Fig. 4) [8].

However, time units alone are not enough to express the musical idea and they would lead, in certain cases, to an inevitable rhythmic monotony (Fig. 5) [9]. To comply with this necessity to vary the rhythm, time units are often subdivided into lower time values or added up so as to constitute a unit of a higher value.

Fig. 4. The first two beats of "Frère Jacques" with the subdivision of the accents (F = strong, D = weak, mF = medium strong).

Fig. 5. Excerpt from the score of "Bolero" by Ravel.

The initial notes of the theme are represented on the first staff, without any indication of rhythm; the same notes with the rhythm assigned by the composer are represented on the second staff.

Dividing a time unit, for example into groups of two or three, means assigning an accent to certain movements in preference to some others: create a hierarchy by virtue of which some must be considered strong movements (more accentuated) and some others weak movements (less accentuated). The terms weak and strong do not have, in this context, anything in common with the lower or higher intensity of the sound that is identified with that specific movement. Here it is about a lower or higher rhythmic importance which, accidentally and not necessarily, may coincide with the sonorous intensity.

Two types of rhythmic accents can be distinguished in music, for every single time unit:

- the *primary accents*: strong, medium strong and weak;
- the *secondary accents*: accents that fall on the subdivisions of every movement (Fig. 6).

Primary accents F D mF D
Secondary accents d d

Fig. 6. Distribution of the primary and secondary accents.

III. ORNAMENTAL NOTES

The subdivision of a movement into several notes contributes to the enhancement and at the same time variation of the melody by inserting ornamental notes [5], [10]. The sounds of a melodic line, therefore, may belong to the harmonic construction or may be extraneous to it. The first ones, that fall in the chordal component, are called real, while the others, that belong to the horizontal dimension, take the name of melodic figurations (passing tones, turns or escape tones, anticipations and retardations). They are complementary additional elements of the basic melodic material that lean directly or indirectly on real notes and also

resolve on them [11].

The use of melodic figurations, therefore, allows achieving greater freedom of the melody, bestowing upon it a better profile, yet at the same time making it hardly recognizable and, consequently, difficult to identify (Fig. 7).

Fig. 7. Beginning of the theme and of the first variation of Mozart's Sonata in A Major KV331.

The melodic figurations may alter the melody but not its internal structure [10], making it therefore still recognizable: these modifications are intended to bring about in-depth interpretation, the clearest enlightenment and the renewal of the pre-existing fact (melody or motif) through an intensive valorization of all the resources.

The recognizability of the melody is the "*conditio sine qua non*" that must constantly inform the act (of modification) that otherwise could not be considered as such [12].

IV. THE STRUCTURE OF THE MELODY

As mentioned in the preceding paragraph, there is always a connection between a melody and the same melody varied by means of melodic figurations: both have the same internal structure.

In order to identify this structure, it is necessary first of all to confront the two melodic segments (melody and varied melody) so as to identify and eliminate the non-common sounds. Every single melodic segment is represented by a matrix ($A_{x,y}$) that takes into consideration its two constitutive elements: the melody and the rhythm (Fig. 8) [5].

$$A_{9,2} = \begin{bmatrix} 0 & 0 \\ -5 & 4 \\ -3 & 8 \\ -5 & 12 \\ -8 & 16 \\ -7 & 18 \\ -5 & 20 \\ -3 & 22 \\ -5 & 24 \end{bmatrix} \quad B_{9,2} = \begin{bmatrix} 0 & 0 \\ -5 & 4 \\ -3 & 8 \\ -5 & 12 \\ -8 & 16 \\ -10 & 17 \\ -8 & 18 \\ -7 & 19 \\ -5 & 20 \\ -7 & 21 \\ -5 & 22 \\ -3 & 23 \\ -5 & 24 \end{bmatrix}$$

Fig. 8. Example of a melody and one of its variations with the corresponding matrices.

The data considered to construct the matrixes represent the coordinates of a point in the Cartesian plane [5], where the

first sound will have the coordinates 0, 0 and the following sounds will be respectively:

- x the value corresponding to the number of semi-tones from the i -th note to the preceding one (value that is respectively positive or negative based on the note being higher or lower than the preceding one);
- y the value corresponding to the duration from the i -th note and the preceding one to the origin. Since it is a score that must be analyzed, the duration of the sound will not be expressed in seconds but calculated (automatically by the algorithm) as a function of the musical sign (be it either a sound or a rest) having the smallest duration existing in the musical piece. The duration of every sign will therefore be a number (an integer) directly proportional to the smallest duration.

It is possible to represent the melodic segments in a diagram that takes into consideration the pitch of the sounds and the corresponding durations on the basis of the movements and their subdivisions (Fig. 9): this is the main point that improves the operational logic of the preceding version of the algorithm [5], where it was not the duration of the sounds within the ambit of the movements and subdivisions that taken into consideration, but only the initial attack point of every single sound.

Fig. 9. Graphic representation of the theme (black lines) and of its variation (gray lines) shown in Fig. 9.

By eliminating the non-common notes existing in the varied melody compared to the model (identifiable by means of the gray lines that in the diagram do not overlap the black lines), one can easily note the presence, in every single subdivision, of sounds that, compared to the next, have the same interval distance existing in the model, even though the attack points are in different instants (Fig. 10).

Fig. 10. Graphic representation after the elimination of the non-common notes.

It is therefore possible to represent the internal structure of the model melody and of its variation, through the *Trellis Diagram*. From a conceptual perspective it is simply a two-dimensional expansion of the transitions diagram [13] along an axis of times.

The states are represented in correspondence of every instant and the transitions are shown as arcs from the

departure state at the instant t , to the arrival state at the next instant $t+1$.

The transitions diagram, in the case of musical analysis, is obtained by considering the way in which the intervals follow one another within the melody (Fig. 11) [13].

Fig. 11. Trellis diagram relative to the interval structure of the melody Fig. 8.

V. THE RESULTS OBTAINED

The model of analysis exposed in this article was tested by realizing an algorithm on a set of scores for pianoforte. the algorithm does not provide any limitation with respect to the dimensions of the matrix representing the melody (that will be automatically dimensioned on the basis of the characteristics of every single segment) and similarly, it does not provide any minimal preset value with respect to the duration of every rhythmic subdivision, that will be defined automatically on the basis of the smallest duration existing in every single composition.

The results of the analysis relative to the melody excerpted from the Theme of Mozart's Sonata in A Major KV331 (Fig. 12), compared to the first two variations excerpted from the same Sonata, are illustrated below.

The result is similar also for the comparison between the melody and the following variations existing in the Sonata.

Fig. 12. Theme (A) is represented in A^1 . The simultaneous analysis of melody (A) and of the first variation (B) is represented in B^1 . The simultaneous analysis of melody (A) and of the second variation (C) is represented in C^1 .

In all cases an equal Trellis Diagram is obtained (Fig. 13), which means that the two segments are similar inasmuch as they have the same internal (interval) structure.

Fig. 13. Trellis Diagram relative to the simultaneous analysis of the melody and of the first and second variation.

VI. CONCLUSION

This article contemplated the concept of motif and how it can be varied by means of instruments that the musical grammar provides the composer with. The criteria for its identification within the score were, therefore, examined in depth.

This new approach allowed the development, on the basis of a previous version, of an algorithm that is able to identify a melodic model within the musical composition, even if this model includes various degrees of variation/transformation.

Even if the results obtained are satisfying, it is necessary to perform a more complete and rigorous experimental analysis in order to verify the solidity of the algorithm. Further research is needed in order to improve the current version and to demonstrate its full potential.

REFERENCES

- [1] M. Fingerhut, "Music information retrieval or how to search for (and maybe find) music and do away with incipits," in *Proc. IAML-IASA Congress*, 2004.
- [2] E. Cambouropoulos, "How similar is similar?" *Musicae Scientiae*, Discussion Forum 4B, pp. 7-24, 2009.
- [3] M. D. Ventura, "Evaluation of musical similarity on the symbolic level of the musical text," presented at the 15th International Conference on Artificial Intelligence, 2013.
- [4] M. D. Ventura, "Analysis of algorithms' implementation for melodic operators in symbolical textual segmentation and connected evaluation of musical entropy," presented at the International Conference on Models and Methods in Applied Sciences, 2010.
- [5] M. D. Ventura, "The concealed motif: Analysis and identification," presented at the 12th International Conference on Artificial Intelligence, Knowledge Engineering and Data Bases, 2013.
- [6] E. Sams, *The Clara-Theme*, Analogon, 2010.
- [7] E. Cambouropoulos, "Musical rhythm: Inferring accentuation and metrical structure from grouping structure, in music, gestalt and computing - studies in systematic and cognitive musicology," M. Leman (ed.), pp. 277-293, Berlin: Springer, 1997.
- [8] N. Sofia, *Treatise of Music Theory*, Berben, 1990.
- [9] C. Orff, *Schulwerk, Elementare Musik*, Hans Schneider, Tutzing, 1976.
- [10] B. Coltro, *Lessons of Complementary Harmony*, Zanibon, 1997.
- [11] S. Ahlback, "Melody beyond notes: A study of melodic cognition," Ph.D. thesis, Goteborgs Universitet, Sweden, 2004.
- [12] R. Nielsen, *Musical forms*, Bongiovanni Editore, 1961.
- [13] T. M. Cover and J. A. Thomas, *Elements of Information Theory*, New York: Wiley-Interscience, 2006.

Michele Della Ventura brilliantly graduated in pianoforte under the guidance of Francesco Bencivenga. Concurrently to the music studies he graduated in technology disciplines with the highest honors and distinction, obtaining a scholarship followed by a II level master's degree in e-learning (e-learning: methods, techniques and applications) at the University of Rome "Tor Vergata". He was valedictorian of his class with his master's thesis "Learning and new technologies".

His research interests include correlation between music and mathematics with a particular emphasis on artificial intelligence research in the field of computer-aided analysis of tonal music, use of web technologies for teaching.

He is the author of several articles published in international science magazines and high school textbooks (also featured at the International Book Salon of Turin in 2012). He proofreads articles and is a member of Scientific Committees in International Conferences. He was invited as a lecturer to international conferences in Italy, Canada, China, France, Germany, Hong Kong, Japan, UK, Romania, Singapore, Spain, USA (Baltimore and Harvard). He teaches music informatics in university courses and musical technologies in Music High Schools.