Detection of Historical Period in Symbolic Music Text

Michele Della Ventura

***Abstract*—Despite the various studies on computer-aided musical analysis, there have been relatively few attempts at trying to locate, by means of analysis, a given melody in a certain stylistic period (Baroque, Classical, Romantic or Contemporary). The main problem is that a compositional style of a certain historic period is difficult to formalize. This study presents a model of analysis based on the theories of Warren Weaver and Claude Elwood Shannon, able to progressively explore the symbolic level of a melody, identifying the historic period on the basis of the information that it carries. The concept of information has already been used for several years now in linguistic analysis and it has also been applied to musical language. This approach was dealt with on the melodic level, omitting concepts like tonality, modulation and moreover rhythm. The efficiency of the model was verified by analyzing a series of melodies by different authors and from different times (trying to range through the different compositional techniques by means of a unique analysis methodology) emphasizing both the strong points and the weak points of the approach.**

***Index Terms*—Information theory, musical surface, historical analysis, segmentation, entropy.**

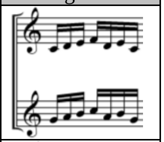
I. Introduction

Simulating the human intellect with the help of information and computer systems is a research area that continues to engage scholars in the field of musical analysis: melodic, rhythmic and harmonic analysis.

In all these cases we are dealing with analyses that allow, a posteriori, a formalization of the analysis tools, i.e. is the development of the instruments required in order to describe in mathematical terms, the musical functions extensively exploited by composers (see Table I) [1]: functions as the transposition (the process of moving a sequence of notes up or down in pitch by a number of semitones (which represent the transposition degree *x*) while keeping constant the relative distance between its composing notes), the inversion (the process through which a melody is transformed by inverting the direction of its single intervals in relation to the initial note, so that every ascending interval becomes descendent and vice versa.) or the retrogradation (the process that consists in representing the melody backwards, from the last to the first note) of a melodic or rhythmic cell [2].

These musical functions are used in the segmentation algorithms of a musical piece in order to identify the significant melodic and rhythmic cells and in many cases the final choice of the segment is performed by comparing every single identified fragment to a previously compiled list of rules [3]: rules that may go well for a certain musical piece and not for some other musical piece depending also on the compositional style that changes in accordance with the historical time period [4]. The latter is one of the aspects that are rather difficultly taken into consideration in computer-aided musical analysis, because of the lack of well-defined parameters that would allow its formalization.

TABLE I: An Example of the Main Musical Function for Melodic Analysis

Musical Function	Mathematical Operator	Musical Segment
Melodic Transposition	$Tx(h) = h + x$	
Melodic Inversion	$I_i(h) = I - (h - I) = 2i - h$	
Melodic Retrogradation	R(h) h $R(wh) = hR(w)$	

This article will present a model of melodic analysis able to explore the symbolic level of the musical text, identifying the historical period on the basis of the information that it carries.

This paper is organized as follows.

Section II describes the characteristics of the historical periods. Section III describes the information theory. Section IV describes the analysis of the musical message. Section V shows some experimental tests that illustrate the effectiveness of the proposed method. Finally, conclusions are drawn in Section V.

II. Characteristics of Historical Time Period

The style of a certain epoch, of a school, of a composer, of a musical work does not emerge accidentally, they are not casual products and manifestations of artistic will. On the contrary, they are based on the laws of becoming, development and decay of an organic nature. Music is an organism, a multitude of organisms that by means of their variable relationships and interdependencies make up an entirety [5].

The evolution of music may be seen as a sufficiently continuous, uninterrupted, phenomenon, nurtured by listening to music from the past and motivated by a desire to improve it [5]. Tonality, for instance, is a language the maturation of which was very slow and did not cease to develop for several

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centuries, before reaching its breaking point in the early ’900.

This evolution was achieved by virtue of a continuous culture and experience, enriched by means of written and oral communication forms.

May we hope to find models that include the style and the rules typical to every epoch?

A fundamental fact emerges from a macroscopic analysis of the musical text of pieces belonging to different historical time periods and different composers:

A progressive increase, in the various historical periods, of the diversity of intervals between various sounds that make up the melody (see Fig. 1) [6]: there is a gradual transition from the intervals of second, third and fourth (an interval that becomes a fifth if inverted) of the Baroque period to wider intervals, as the sixth, the seventh and the ninth (along with an increased use of dissonance) in the Romantic period up to even wider intervals in the Contemporary period.

In the Romantic period, melody also displays some other characteristics (still on a melodic level) as [6]:

- the presence of chromaticism;
- the (expressive) use of note repeats.

(a) Baroque (J.S. Bach, invention BWV 772).

(b) Romantic (F. Chopin, Nocturne op. 9 n. 2).

(c) Contemporary (B. Bettinelli, Prelude for piano).

Fig. 1. Examples of melodies belonging to the time periods.

Fig. 1 Esempi di melodie appartenenti rispettiv amente al periodo Barocco (J. S. Bach ….), Romantico (….) e Contemporaneo (….).

An analysis of this kind requires well-defined musical knowledge. The “average” listener (this expression is used to mean a person who lacks specific knowledge of musical grammar) manages nevertheless to comprehend, by simply listening to various musical fragments, more or less ample and belonging to the same epoch or to different epochs, a stylistic difference and though not managing to identify the related historical time period, he is able to perform a cataloguing based on personal schemata (reminding, in this regard, that one's past experiences and own culture may influence perception) [7].

In the listener's perception it is not only the presence of certain types of intervals, but also the way in which these intervals follow one another that define this cataloguing. In fact, it is the structure of the musical text that supplies precise information to the listener in this regard [8].

By means of the quantification of the information contained in the musical message it will be possible to identify the historical time period and, therefore, define potential rules of analysis.

III. Information Theory

The analysis based on information theory sees music as a linear process supported by syntax of its own [9]. Nevertheless we are dealing with a syntax formulated not on the basis of grammar rules, but on the basis of the probabilities of occurrence of every single element of the musical message in relation their preceding element [10].

The fact that music is equated to a message transmitted by a sender to a receiver, or that “information” is dealt with may give the impression of an analytical approach of a hermeneutic kind, interested in the meanings of communication [11]. In fact, here, the interest goes exclusively to the manner in which the expectations of the receiver are stimulated, satisfied or disappointed.

From the definition of “message” being a chain of discontinuous “units of meaning” follows that the musical “units of meaning” correspond to the minimal events of a composition: usually isolated notes, chords.

Any event of such a chain demands a prevision about the event that will follow: there is information transmission when the prevision is disregarded, there is no information transmission when it is confirmed. Besides, the fact that the events of a composition are organized modularly brings forward the possibility to calculate using a formula, or to express with an “index” the total amount of information transmitted by a certain musical segment [12].

In a communication that occurs by means of a given alphabet of symbols, information is associated to every single transmitted symbol. Hence, the information may be defined as *the reduction of uncertainty that might a priori have existed in the transmitted symbol* [10].

The wider the message range that the source can transmit is (and the greater the uncertainty of the receiver with respect to the possible message), the larger the quantity of transmitted information and along with it its measure: the entropy.

In the information theory [8], entropy is a positive value as opposed to its original negative counterpart in physics. Mathematically, the measure of the content of a piece of information (I) is obtained with Shannon's formula:

$$I = \log_2 \frac{p'}{p} \tag{1}$$

where p is the probability of the message to be transmitted, p' is connected to the use that the observer makes of the message and corresponds to the probability for the content of the information expected by the latter to be fulfilled after the transmission of the message.

For every symbol (of a message) that we transmit we have a certain quantity of information associated to that symbol.

In most practical applications of information theory a choice must be made among the messages of a set, every single one having its own probability of being transmitted.

Shannon gave a definition of the entropy of such a set, identifying it with the information content that the choice of one of the messages will transmit. If every single message has the probability pi of being transmitted, the entropy is obtained as the sum of all the set of functions $p_i \log_2 p_i$, every single one related to a message, that is:

$$H(X) = E[I(x_i)] = \sum_{i=1}^{n} I(x_i) \bullet P(x_i) = \sum_{i=1}^{n} P(x_i) \bullet \log_2 \frac{1}{P(x_i)} \quad (2)$$

The term entropy, borrowed from thermodynamics, designates therefore the average information content of a message.

In the light of what has been said so far, the musical message may be defined as a sequence of signals organized according to a code.

IV. Analysis of the Musical Message

Given a melodic segment, the identification of the historical time period may be performed by means of two distinct analyses which are consecutive and complement each other:

Analytical analysis: through the identification of the intervals and the probabilities for a certain type of interval to resolve to another type of interval;

Quantitative analysis: through the identification of the information contained in the melodic segment.

A. Analytical Analysis

To calculate the entropy and therefore quantify information, one must refer to a specific alphabet: in the case of musical language, the classification of the various melodic intervals as symbols of the alphabet was considered.

The classification of an interval consists in the denomination (generic indication) and in the qualification (specific indication) [13].

The denomination corresponds to the number of degrees that the interval includes, calculated from the low one to the high one; it may be of a 2nd, a 3rd, 4th, 5th, and so on.; the qualification is deduced from the number of tones and semi-tones that the interval contains; it may be: perfect (G), major (M), minor (m), augmented (A), diminished (d), more than augmented (A+), more than diminished (d+), exceeding (E), deficient (df).

For every single musical piece, or part of it, a table representing its own alphabet is compiled, considering also for every interval its ascending or descending evolution (Table II).

Determining an alphabet is not enough to calculate the entropy of a musical segment: the way in which the intervals follow one another within the musical piece must be taken into consideration.

To do so the Markov process (or Markov stochastic process) is used: the choice was made to acquire the probability of transition that determines the passage from one state of the system to the next uniquely from the immediately preceding state (Table III).

Please note the way in which the configuration of the statistic values in the table is a visual indicator of the probability of the intervals alphabet of the musical piece and, therefore, of the redundancy of the melodic articulations.

B. Quantitative Analysis

The data identified by means of analytical analysis (alphabet and matrix of transitions) allow the quantification of the information contained in the musical message calculating its entropy value on the basis of the formula specified in paragraph 3:

$$H(X) = E[I(x_i)] = \sum_{i=1}^{n} I(x_i) \bullet P(x_i) = \sum_{i=1}^{n} P(x_i) \bullet \log_2 \frac{1}{P(x_i)} \quad (3)$$

TABLE II: Example of an Alphabet Related to the Musical Segment of Fig. 1A

Interval	Direction	Semi-Tones	N°
Concordant		0	
2° m	ascending	1	3
	descending	-1	3
2° M	ascending	2	8
	descending	-2	9
3° m	ascending	3	2
	descending	-3	3
3° M	ascending	4	2
	descending	-4	2
4 G	ascending	5	3
	descending	-5	
4° A / 5° d	ascending	6	
	descending	-6	
5° G	ascending	7	2
	descending	-7	1
6° m	ascending	8	
	descending	-8	
6° M	ascending	9	
	descending	-9	
7° m	ascending	10	
	descending	-10	
7° M	ascending	11	
	descending	-11	
8° G	ascending	12	
	descending	-12	

The first column indicates the denomination of the interval (classification), the second column displays the ascending or descending movement, and the third column presents the number of semi-tones that make up the interval (qualification) while the fourth column shows the number of semi-tones of that specific type identified in the musical piece.

TABLE III: Example of a Final Matrix of Transitions Related to the Musical Segment of Fig. 1A

Interval			2m		2M		3m		3M		4G		4A / 5d		5G		6m		6M		7m		7M		8G		concordant
	semi-tones		1		2		3		4		5		6		7		8		9		10		11		12		
			a	d	a	d	a	d	a	d	a	d	a	d	a	d	a	d	a	d	a	d	a	d	a	d	
2m	1	a		1	2																						
		d				2					1																
2M	2	a	1		2	1		2								1											
		d		1		3	2		1		2																
3m	3	a		1		2																					
		d	2		1	1																					
3M	4	a				1																					
		d			2																						
4G	5	a						1							2												
		d																									
4A / 5d	6	a																									
		d																									
5G	7	a								2																	
		d			1																						
6m	8	a																									
		d																									
6M	9	a																									
		d																									
7m	10	a																									
		d																									
7M	11	a																									
		d																									
8G	12	a																									
		d																									
concordant																											

The historical time period is identified on the basis of the entropy value of the musical segment (that may be represented by a phrase or by an entire composition).

This kind of analysis allows the presentation of the results in statistic tables (which are easily convertible in diagrams so as to increase their comprehensibility) [11] with an immediate identification of the result, unlike analytical analysis where the result may be identified only by means of an interpretation of the final matrix of transitions (see Table III): an interpretation that presupposes specific musical knowledge.

V. The Results Obtained

The model of analysis proposed in this article was verified by realizing an algorithm the structure of which takes in consideration each and every single aspect described above:

The algorithm does not provide any limitation with respect to the dimensions of the table representing the alphabet and the matrix of transitions that will be automatically dimensioned in every single analysis on the basis of the characteristics of the analyzed musical piece. This allows conferring generality to the algorithm and specificity to every single analysis (Strength), due to the statistics on the type of intervals being present: every formal expectation with respect to the intervals expected to be significant might have limited the analysis to musical pieces of a certain time period.

For a superior precision of the result the choice was made to submit to analysis not entire musical pieces but only parts of every one of these: in particular, a standard length segment made up of 40 musical notes starting from the beginning of the musical piece was taken into consideration. This choice was made for two reasons:

1) the beginning of every musical piece contains the pre-thematic elements, i.e. the elements that will characterize the entire musical piece;
2) the longer the segment, the larger the number of intervals considered in the analysis, therefore more probabilities for a certain situation to occur, that is for a certain interval to resolve to another interval: this reduces the degree of uncertainty and thus diminishes the value of the information (see paragraph 3).

For the definition of entropy described in the preceding paragraphs we deduce that there will not be values above zero, but, on the contrary, very small values, therefore it is important to evaluate the number of decimals that may influence, albeit slightly, the interpretation of the segments (Weakness): the bigger the number of decimals and the higher the accuracy of the analysis.

TABLE IV: Table Summarizing Some Elements of Musical Pieces Analyzed with the Indication of the Related Entropy Value (Column 3)

Author	Title	Entropy
J.S. Bach	Allemanda	0,000000000013002
D. Scarlatti	Sonata L413 K9	0,000000000000191
F. Couperin	Preludio	0,000000000001608
A. Vivaldi	Primavera	0,000000000000098
…	…	…
F. Chopin	Mazurka op. 69 n. 2	0,000001872379605
F. Schubert	Momento Musicale n. 1	0,000001872379605
F. Schubert	Valzer op. 50 n. 11	0,000000002506347
F. Mendelsshon	Romanza op. 53 n. 2	0,000000001836063
R. Schumann	Arabesque op. 18	0,000000898651929
...	...	…
A. Schonberg	Klavierstuke op. 19 n. 1	0,00317076873789
G. Petrassi	Petite Piece (1950)	0,015682496448
B. Bettinelli	Preludio (1984)	0,425593113228291
…	…	…

Baroque Romantic Contemporary

Musical pieces by different authors and of different epochs were subject to analysis. Table IV illustrates some of the representative results of the analysis performed, divided into historical time periods.

As it can easily be seen, for every historical time period, the Entropy values of the segments are placed inside specific intervals which are clearly different from one another (Strength): this allows us to obtain indexes (equal to the maximum values) in order to delimit every single historical time period.

The graphic representation (Fig. 2) of these results may help understand their meaning.

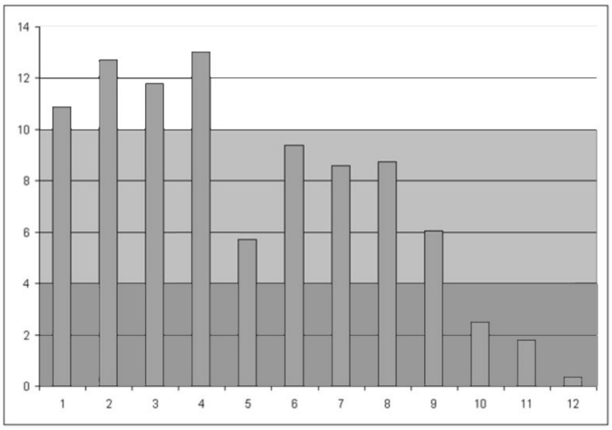

Fig. 2. Graphic representation of the information conveyed by the various segments analyzed (Table IV). The scale used for the diagram is the logarithmic scale that allows the representation of both very small values and very large values.

In spite of the fact that the results achieved are satisfactory, the artistic part of the author, that may lead to a result differing from the expected one, still remains to be considered (Weakness): for instance there are musical pieces composed by Bach in the Baroque period that display certain characteristics which are typical of the Classic style and sometimes of the Romantic style; Beethoven with his Great Fugue (op. 133) tries to surpass the concept of Tonality using, therefore, intervals which are typical to the contemporary period.

VI. Conclusion

The tools presented in this article, developed on the basis of specifically musical objectives, represent a means of support for the melodic analysis within the field of automatic segmentation of a musical piece: we are dealing with an a priori analysis that allows the identification of the body of rules to be used at a later stage, in the field of melodic segmentation of the musical piece.

The extension of this methodology to rhythmic analysis of a musical piece might help acquire greater accuracy in identifying the historical time period.

The high degree of complexity of musical phenomena imposes certain forms of achievement that must be adequate and that, for completeness' sake, must cope with the problems under a sufficiently large number of angles. Thus, even from a theoretical - musical point of view, the possibility to integrate different approaches appears as a precursory way of interesting developments. And it is really thanks to the new techniques of artificial intelligence that such forms of integration and verification of the results become achievable.

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