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CHAOTIC MELODY GENERATION AND STATISTICAL CHARACTERIZATION

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Automatic music composition by using chaotic systems has triggered much interests for the last decades [2]. Chaotic music has its origin in the analysis carried out on the fractal structures presented in classical music and experiments realized in self-similar music [1]. Due to the relationship between fractal geometry and chaotic attractor, in the late 1980's, some researchers had begun to explore the musical potential of nonlinear dynamical systems, especially chaotic systems [3]. The main feature of chaotic music is the possibility to obtain large quantity of different musical fragments with slight changes in initial conditions of the systems.

We firstly present an algorithm of automatic composition of melodies by using chaotic dynamical systems. The proposed algorithm permits to work with a large number of different scales and modes [4]. So, it has advantage to cover a large part of the musical space.

Then, we characterize chaotic music in a comprehensive way, consisting of three perspectives: musical discrimination, influence and perception. For the first perspective, the coherence between the generated chaotic melodies (continuous as well as discrete chaotic melodies) and a set of classical reference melodies are characterized by statistical descriptors and melodic measures [5]. The significant differences among the three types of melodies are determined by discriminant analysis. Regarding on the second perspective, it is determined the influence of dynamical features of chaotic attractors, such as Lyapunov Exponent, Hurst Coefficient, and Correlation Dimension, to melodies by canonical correlation analysis. The last perspective concerns the perception of originality, complexity and degree of melodiousness (Euler's "gradus suavitatis") of chaotic and classical melodies by using the Mann-Whitney U test. The results of these analysis leads to propose a comprehensive and deeper characterization on chaotic music from the view points of statistical features and dynamical influential factors.

1. ALGORITHM OF CHAOTIC MELODY COMPOSITION

The algorithm starts by using the numerical solution of a nonlinear dynamical system consisting of three variables $x(t)$, $y(t)$, and $z(t)$. The first variable $x(t)$ is assigned to the extraction of musical pitches (frequencies and MIDI notes), the second variable $y(t)$ is attributed to the duration of each musical note (in seconds or in time units), and the third variable $z(t)$ is the musical velocity (intensity and musical dynamics). Each pair of variables can be unconditionally exchanged in musical property representation.

The whole melody generating process by using the chaotic system is summarized by Fig.1. The figure 2 presents the melody generated by using Chen's chaotic model (Eq. 1) with parameters $a = 35$, $b = 3$, $c = 28$.

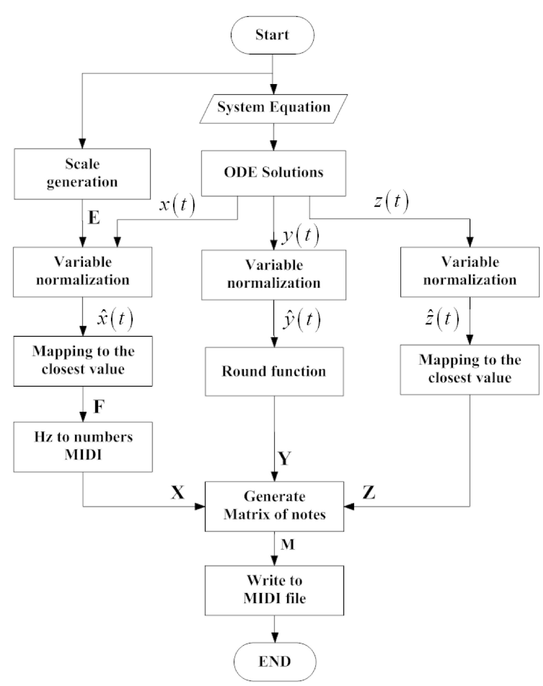

Figure 1 – Flow chart of the proposed algorithm for chaotic melody composition

$$
\begin{aligned}
\dot{x} &= a\,(x-y) \\
\dot{y} &= (c-a)\,x - xz + cy \\
\dot{z} &= xy - bz
\end{aligned}
\tag{1}
$$

Figure 2 – Melody generated by Chen's model.

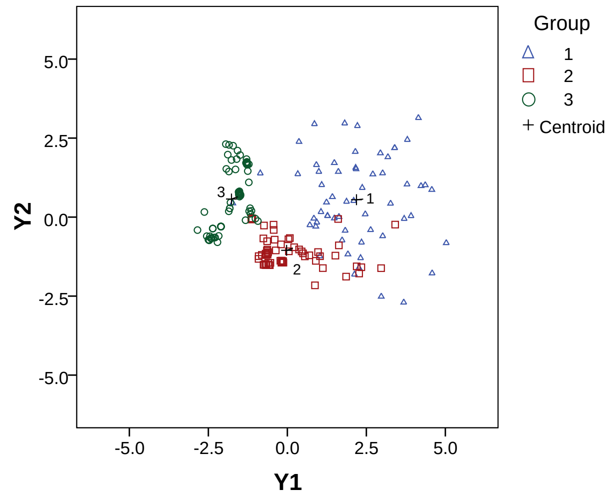

Figure 3 – Discriminant functions.

2. STATISTICAL ANALYSIS OF MELODIES

In this paper, we introduce a set of objective (Pitch Variety V_t, Key Centered C_t, Dissonant Intervals I_d, Melodic Contour Stability in Direction E_c, Movements by Step M_p, Leap Returns S_r, Climax Strength I_c) [5] and subjective melody measures (Melodic Originality, Expectancy-Based Model of Melodic Complexity and Degree of Melodiousness).

We also apply discriminant analysis [6] to classify and find the relevant variables for the following melodic groups: group of classic melodies (Group 1), group of melodies generated by continuous chaotic systems (Group 2) and group of melodies generated by discrete chaotic systems (Group 3). For Group 1, a database of 59 classical melodies are used serving as reference, selected within each of the different music epochs since Renaissance to the contemporary period. For Group 2, 10 melodies are generated by each of the 7 continuous chaotic systems. For Group 3, 12 melodies are generated by each of the 6 discrete chaotic maps. Therefore, there are 70 observations for Group 2 and 72 observations for Group 3. Totally, there are 201 observations. We find that the three groups of melodies have distinct features and thus they can be classified as shown by Fig. 3.

Also in this paper, we have determined the influence of dynamical features of chaotic attractors, such as Lyapunov Exponent, Hurst Coefficient, and Correlation Dimension, to melodic features by canonical correlation analysis.

3. CONCLUSIONS AND DISCUSSIONS

By comparing the melodic features described by statistical descriptors, it is found that the chaotic music is different from classical music and continuous chaotic music is significantly different to its discrete counterpart. A fundamental difference between classical and chaotic music is represented by the distribution of their respective intervals. Through discriminant analysis, it is determined that continuous chaotic melodies tend to be shaped by a few dissonant intervals and smooth melodic curves without conjunct movements, which leads to a high tendency in development of melodic contour.

Discrete chaotic melodies contain more skips and a few conjunct intervals. At last, classical melodies have a predominant melodic curves with conjunct diatonic intervals, moderate dissonant intervals and melodic contour with middle trend. By comparing the melodic features described subjective measures, we find that classical music is more smooth, less complex and more melodically original than chaotic melodies.

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