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On the modeling of musical solos as complex networks

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ABSTRACT

Notes in a musical piece are building blocks employed in non-random ways to create melodies. It is the "interaction" among a limited amount of notes that allows constructing the variety of musical compositions that have been written in centuries and within different cultures. Networks are a modeling tool that is commonly employed to represent a set of entities interacting in some way. Thus, notes composing a melody can be seen as nodes of a network that are connected whenever these are played in sequence. The outcome of such a process results in a directed graph. By using complex network theory, some main metrics of musical graphs can be measured, which characterize the related musical pieces. In this paper, we define a framework to represent melodies as networks. Then, we provide an analysis on a set of guitar solos performed by main musicians. Results of this study indicate that the presented model can have an impact on audio and multimedia applications such as music classification, identification, e-learning, automatic music generation, multimedia entertainment.

1. Introduction

Nowadays, there is a common trend in research to model everything as a network, i.e., systems or data which can be represented by graphs. In particular, complex network theory is a mathematical tool that connects the real world with theoretical research, and is employed in many fields. Networks are employed across a multitude of disciplines ranging from natural and physical sciences to social sciences and humanities [11,30].

Technological, biological, economic systems, disease pathologies, protein-protein interactions, can be modeled in the same way. Focusing on multimedia contents, it has been proved that language, for instance, can be seen as a system that can be represented as a complex network [10,13,15,20,32]. As human language has a non-random structure, since it is used by humans to construct sentences from a limited amount of discrete units (words), also music is created by combining notes played by a set of instruments. In this paper, we show that musical pieces can be treated as complex networks as well (we will focus on melodic lines played by a single instrument).

When dealing with audio, the main concern has been on the issue of digitalizing it, in the most efficient way, or to synthesize, represent, reproduce sounds, by employing a variety of sound generation techniques. Attention has been paid on transmitting, indexing, classifying, clustering, summarizing music [7,19,23,27,33,37,39,42]. However, the idea of capturing some general characteristics of a melody (and harmony) is somehow an overlook aspect. In literature, there are works in the field of computer science that focus on musical scores [34,41]. There are studies on the development of digital libraries and on human interaction with musical scores and more general notational/instructional information objects [41]. Other

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works are on the automatic transcription of the melody and harmony [36]. As concerns music information retrieval, a goal is to devise automatic measurements of the similarity between two musical recordings, based on the analysis of audio contents. Techniques worthy of mention are acoustic-based similarity measures [9], compression-based classification methods [14], statistical analyses and artificial neural networks [26]. Finally, artificial intelligence techniques have been employed to capture statistical proportions of music attributes, such as pitch, duration, melodic intervals, harmonic intervals, etc. [26]; outcomes confirm that several essential aspects of music aesthetics can be modeled through power law distributions.

Studies on music can be based on symbolic data (music score sheets) or on audio recordings. Symbolic music data eases the analysis in several music application domains. For example, finding the notes of a melody in an audio file can be a difficult task, while with symbolic music, notes are the starting point for the analysis. Thus, in general traditional musicological concepts such as melodic and harmonic structure are easier to investigate in the symbolic domain, and usually more successful [22].

In this paper, we develop a model that allows capturing some essential features of a musical performance (a music track). We will focus on melodies, and specifically on musical "solos", which are a part of a song where a performer plays (often improvises) a melody with accompaniment from the other instruments [17]. It is quite common in music theory asserting that solos performed by musicians are bound to their technical and artistic skills. Indeed, musicians are recognized for their own "style" in playing a solo over a music piece, that identifies a sort of musical "language", typical of that musician. It is not by chance that an artist can be recognized from others, and that we can classify artists in categories and hierarchies. Moreover, since during a solo a player (quite often) improvises and creates a melody "in real time", he employs typical patterns (licks) he is used to utilize. The goal of this work is to make a step further toward the identification of the rules and characteristics of the music style of a certain performer. If a music line is conceived of as a complex network of musical units (notes, rests) and their relations, it is expected to exhibit emergent properties due to the interactions between such system elements. Complex networks provide appropriate modeling for music as a complex system and powerful quantitative measures for capturing the essence of its complexity.

As a proof of concept, we retrieved and analyzed different solos of some main guitar players. Namely, the artists are Eric Clapton, David Gilmour, Jimi Hendrix, Allan Holdsworth, B.B. King, Pat Metheny, Steve Vai, Eddie Van Halen. The selection of guitar as instrument and these particular artists is motivated by the fact that there is a quite active community of guitar enthusiasts that share musical scores on the Web. Scores are published and formatted, usually, by employing description schemes that are alternative, easier and more intuitive to read with respect to the classic musical sheets. These schemes are based on guitar tablatures, and there is a wide list of software applications and libraries to handle digital representations of such scores. The considered artists are prominent musicians; thus, several scores of their music are available online. This simplified the creation of the database.

It is worth mentioning that a previous work was published in [24], presenting a methodological approach that is similar to that presented in this work. Nonetheless, the use of the model and the application were different to those considered in this work. In [24], complete scores of classic and Chinese music are considered. Networks are concatenations of a number of different music pieces by the same author, having the same style, to reach 18K notes per composer. Using these aggregate networks, they find scale-free properties, small-world phenomenon, mean shortest distances around 3 and clustering coefficients around 0.3. The application approach followed in this work is different. In fact, the analysis is on solos rather than aggregate music pieces. The focus on solos has the specific goal to eliminate repetitions typical of the main melodies of contemporary pop/rock/blues songs, the main theme of jazz compositions, and above all the rhythmic parts. In any case, following the approach employed in [24], in the last part of Section 6 an analysis is performed of concatenated solos of each artist. Obtained results are comparable with those obtained in [24], i.e., networks are small worlds, with a mean shortest distances around 3 and clustering coefficients around 0.3. However, we show that results obtained for concatenated networks are different to the average results for separate solos.

The presented analysis provides novel results and promotes novel applications in the artificial intelligence, didactics and multimedia domains. In particular, the contributions of this work are the following:

- It is proposed to represent a melodic track as a network (but this can be extended to a whole instrumental music track); this provides a representation of the entire track and allows calculating some general measures that characterize it. Such a representation provides novel insights into understanding the music composition process and fosters novel applications in this domain.
- We show how complex network theory can be profitably employed in a novel application scenario.
- The proposed representation network model has been applied to a set of guitar solos. We show that networks associated to different solos do have different topologies; this allows discriminating among different music solos and music styles of different artists, in general. An accurate analysis of such tracks can lead to the extrapolation of general characteristics of a given performer.
- We calculate different measures, typical of complex network theory, on the considered networks, and present some aggregate results to characterize these performers. We measure the length of solos, the dimensions of the networks, the degree distribution, distance metrics, clustering coefficient, centrality measures (betweenness and eigenvector centralities) and, finally, we identify that the network representation of certain solos are small worlds. The paper discusses how these metrics are related to the "style" of the performer.