The Quantitative Laws of Musical Discourse: Models and Applications

It is intuitively obvious that music is neither “regular” nor random or chaotic. Rather, it seems to keep a delicate balance between predictability and surprise that clearly attracts our attention (even if we are well aware of the musical piece). Not much research has unveiled the fundamentals of this situation. In fact, the systematic mathematical study of these properties is just starting to take place [1].

In this project, we propose a comprehensive characterization of the structure of musical discourse from the perspective of statistics, nonlinear time-series analysis, network theory, and complex-systems science. Both, audio databases and symbolic scores in electronic form (such as MIDI) will considered to perform a large-scale big-data study, encompassing classical, jazz, and modern pop music (among others). Several sorts of models will be tried in order to reproduce the empirical findings from which important applications can also arise. Indeed, knowledge of the basic fundamental laws guiding music creation and perception can deeply foster music-related software and applications (e.g., by facilitating music organization, enhancing music recommendations for end users, or assisting playlist generation).

The first key pattern to investigate is the so called Zipf’s law, well known for the repetitions of words in texts, the population of cities, the distribution of richness, etc., and which has been recently shown to appear in basic audio timbral codings [2] and in the harmonic content of pop music [3]. More in-depth analyses are needed, in particular addressing classical music but also considering different definitions of the elementary units with musical content (we need “musical words” related to different musical aspects such as tonality, timbre, loudness, rhythm, etc.). A second target in this framework is to quantify the returns of musical words or phrases, in order to characterize long-range correlations. It is expected that these patterns may help to identify plagiarism, improve near-duplicate detection algorithms, and the recognition of musical “keywords”. Major transitions on the history of music can be reproduced as a corollary of the present study.

As a next step, the transition rules between the different musical words need to be investigated. From the simple perspective of a Markov process, these transitions define a network, whose properties can be analyzed by means of modern complex-network theory [3]. But one has to take into account the dynamic nature of the network (where links are not frozen in time), which enforces the redefinition of many concepts and tools in network theory. In fact, this is a fundamental issue in current research on the mathematics of networks. The knowledge of these properties should facilitate the development of models, and from them the “prediction” of musical pieces, inferring the most likely musical word given the previous history of the piece, as well as the design of programs able to generate artificial but “realistic” music. Moreover, tools from the theory of stochastic processes will be necessary to apply and develop.

The ideal candidate should have a good academic record, a natural curiosity to raise and explore new issues, and high motivation to do cross-disciplinary research. Good computer programming skills are compulsory. Some knowledge of music will be appreciated but it is not necessary to start the project.

[1] D. Zanette. *Playing by Numbers.* Nature 453, 988 (2008).

[2] M. Haro, J. Serrà, P. Herrera, and A. Corral. *Zipf's law in short-time timbral codings of speech, music, and environmental sound signals.* PLoS ONE 7(3), e33993 (2012).

[3] J. Serrà, A. Corral, M. Boguñá, M. Haro, and J. Ll. Arcos, *Measuring the Evolution of Contemporary Western Popular Music,* Scientific Reports 2, 521 (2012).

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