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Analysis of psychoacoustic responses to digital music for enhancing autonomous creative systems

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ABSTRACT

In the present article the authors describe a psycho-acoustics study aimed at obtaining data for the enhancement of creative systems. Specifically, it is provided an analysis of the emotional responses provoked by fractal-generated music, establishing the link between input parameters from which a given musical piece is generated, and the emotion provoked. This analysis constitutes the basis to elevate computer-assisted creativity: Our ultimate goal is to create musical pieces by retrieving the right set of parameters associated to a target emotion. This paper contains the description of (i) a method to evaluate the emotional responses to fractal-generated music fragments, (ii) acoustic settings and protocol, (iii) analysis of the emotional responses given by human listeners. Even though similar experiments whose intention is to elucidate emotional responses from music have been reported, this study stands because a connection is appointed between fractal-generated music and emotional responses, all with the purpose of advancing in computer-assisted creativity.

1. Introduction

The perception of complex sounds provokes effects on emotions and mood. This process contributes to the construction of concepts that make up our reality. Music, being a complex sound itself, is used to enact emotion regulation, communicative expression, identity construction, and interpersonal coordination [1]. Music influences strongly on emotions and our cognitive system [2], indicating the involvement of the central nervous system through integration and interpretation together with peripheral auditory processing. However, it is not the physical sound parameters underlying music but the corresponding auditory qualities perceived by the auditory system that cause the effect on emotions. Hence the quantitative relations between the auditory stimuli and the perceived emotions are of particular importance for the realization of music [3]. Psychoacoustics is paramount to achieve this goal.

Emotions are defined as episodes of synchronized body responses, indicating the valuation of an event and leading to a series of reactions of limited duration [4]. Despite being difficult to characterize, they have been framed in several forms. The *Circumplex Model of Affect* (*CMoA*) developed by Rusell [5,6] classifies them according to two dimensions: Valence and Arousal. Valence refers to the degree of attractiveness or aversion that an individual feels towards, in this case, an emotion. Arousal measures to what extent an emotion leads to action or to physiological readiness for activity, thus defining a state in which bodily resources are mobilized, including the peripheral nervous system, the endocrine system, and the immune system [2].

Attempts to create music by computer systems abound. Some developments include the creation of musical pieces from the Mandelbrot set [7], non-linear models such as cellular automata [8,9], genetic algorithms [10,11], or swarm computing [12–14]. DNA-like data has been transformed into music [15]. Melodic sequences have been generated by using the Chua's circuit [16]. Our own work on computer assisted creativity is reported in [17,18].

However, whether musical pieces created by computers can lead to an emotional response is still an open question. If it is true that emotional reactions can be enacted by digitally created music, then it is attainable to find the link between the input data (used to create musical pieces) and emotions.

This article builds a bridge between acoustics and computer systems that assist in the creation of musical pieces. This bridge is built through obtaining, organizing, and analyzing data. Acoustics is applied successfully to obtain the emotional responses perceived when fractal music acts as auditory stimulus. Then, we proceed to find the relations between the input parameters on

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which fractal music is created, and the emotions actually felt. This is done through Knowledge Discovery in Databases (KDD).

As defined in [19], KDD is the nontrivial process of identifying valid, novel, useful, and understandable patterns in data. Clustering, in particular, is a technique that refers to the grouping of data instances into a unique collection of similar instances called *clusters*. K-Means is the algorithm used in this study, which is available in she WEKA platform [20]. In its original conception, the system that we developed did not possess any means to capture emotional responses. This statement is valid for most of the current computer systems aimed at creating musical pieces based on nonlinear models. Hence, the first step we took in order to unite emotions and computer algorithms consisted in developing an evaluation template based on the CMoA. This improvement permits to pair emotional responses with musical pieces in such a way that both, input data leading to musical pieces and output data pointing to emotions, are organized within a database. Knowledge, consequently, can be discovered by processing its contents.

This psychoacoustic study allowed us:

1. To obtain a pair of disjoint datasets by setting both, a controlled experiment and a random response study. Volunteers listened to musical fragments and then pointed out the emotion felt, and to what extent Valence and Arousal were perceived.
2. To analyze the volunteers's responses by executing the K-Means clustering algorithm using Valence and Arousal as main criteria.
3. To contrast the formation of clusters in both of the experiments.
4. To elucidate what Input Parameters might be obtained after KDD results are fused, should emotions of the CMoA were the criteria to clustering.

The process carried out for this study is depicted in Fig. 1. We must highlight, however, that the evaluations are due to increase as new musical pieces get evaluated by users. Nevertheless, the organization of the data and its subsequent treatment will remain as presented in this article.

The paper is organized as follows. Section 2 presents similar experiments that elucidate emotional responses to music. The explanation of the relevant Input Parameters is given in Section 3. The acoustic settings for conducting the experiments are detailed in Section 4. The results of applying KDD on the dataset of the controlled experimental design are presented in Section 5. After this controlled experiment, we describe a protocol in which volunteers were allowed to select what auditory stimuli, among a large pool of musical fragments, to evaluate (Section 6). Knowledge Discovery for such dataset is described in Sections 6.1 and 6.2. Finally, conclusions and future work are delineated.

2. Related work

2.1. Emotions as a parameter to recommend music

Mood has been used as a basic feature in music recommender and retrieval systems [21]. A listening experiment was carried out establishing ratings for moods, valence and arousal. 288 songs over 12 musical genres from popular music where evaluated. However, in [4] it is stated that emotions are not the same as mood.

A method for creating automatic music mood annotation is presented in [22], where a database of 1000 songs was employed. Also, tests of different classification methods, configurations and optimizations have been conducted, showing that Support Vector Machines perform best. However, the researchers restrict the study to four broad emotional categories: happiness, sadness, anger, and relaxation. They argue that those categories reflect basic emotions covering the four quadrants of the 2D representation from Russell. Nonetheless, it is said that six are the basic human emotions conventionally accepted [4].

A personalized affective music player (AMP) that selects music for mood enhancement is described in [23]. They employ bio-signals to measure listeners' personal emotional reactions as input for affective user models. Regression and kernel density estimation are applied to model the physiological changes the music elicits. Using these models, personalized music selections based on an affective goal state were made.

MEMSA (Mining Emerging Melody Structure Algorithm), is proposed to discover a new kind of pattern, called Emerging Melody Structure (EMS) [24]. It is argued that customization of on-line music experiences will improve with the application of this technique.

An evaluation of seven multi-label classification algorithms was performed in order to rank and classify 593 songs according to emotional evaluations [25]. The study was conducted to enhance music information retrieval systems that will use a target emotion as the most important parameter to retrieve music from large collections.

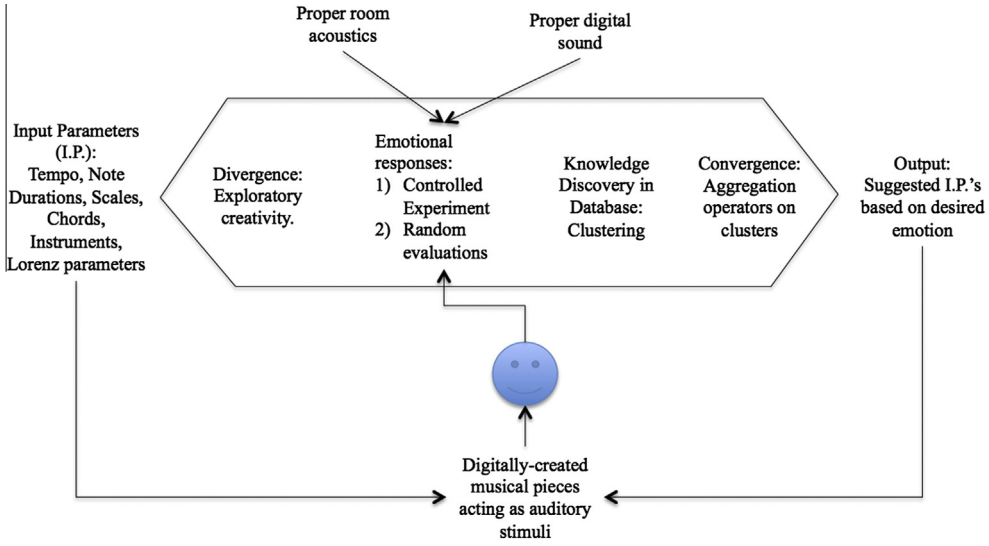

Fig. 1. Process of the psychoacoustics study.