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A non-homogeneous beat-based harmony Markov model

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ABSTRACT

In this paper, a novel probabilistic model of harmonic progressions and a generation scheme based on such model are presented. On the basis of the large amount of publications that show the stochastic nature of the music and the possibility of modelling it by means of statistical processes, this paper shows how to create a non-homogeneous Markov chain to automatically generate harmonic progressions by building a temporal reference of the internal beat structure of music to guide the progressions. Thus, this new model develops on the classic transition matrix to include a beat-dependent / temporal layer to model the residency time.

The method for the automatic creation of harmonic progressions based on the model developed is presented after the model. The harmonic progressions generated by our scheme are coherent with the style of the training data employed and, thanks to the specific temporal layer designed, the musical mid-term and long-term dependencies that lead to a natural and logic cadence are taken into account. The model developed is usable for the automatic generation of harmonic patterns that can be used to enlarge the flexibility and creativity of pattern-based computational music composers.

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1. Introduction

The statistical nature of music has been proven in multiple works on music analysis, perception and cognition [1, 2]; more specifically, the long-term musical dependencies can be successfully accounted for when modelling music in a probabilistic way [2]. Commonly used Markov models can be adequate for dealing with the short-term dependencies but, additionally, context, such as melody [3] or chord roots [4], is required to properly consider the long-term ones.

Looking into chords, the fact that one of the main features of tonal music is its organization around chord progressions is unveiled. This concept does not only imply that a chord is simply followed by another one, but also that their progression is controlled, ordered and related to the global musical structure [5].

Recall that in typical tonal music, the duration of every single chord is an integer multiple of the shortest chord length [2] and most chord progressions are repeated in an approximately cyclic fashion in which chord changes occur at fixed time intervals [6]. This structure builds harmony as a high-level descriptor closer to the description of music than to the low-level signal-based descriptors commonly used in Music Information Retrieval (MIR) [7], which are unintelligible and can not be presented to non-technical users. Instead, as stated in [2], notes comprising a chord act as central polarities for the choice of notes at a given moment in a musical piece. Thus, from a probabilistic point of view, the chord progression can be considered a sequence of symbols that can be modelled by using probabilistic models; at the same time, such symbols can be seen as a latent variables that condition the probabilities of choosing particular notes in the melody and accompaniment.

Within this context built on music, harmony and probability, the purpose of this manuscript is to propose a novel probabilistic model of musical harmonic progression and a scheme, based on this model, for the automatic generation of such progressions. Note that the outcomes of this model not only complement the melody generation scheme described in [8] but also can be used as basis for other automatic melody generation schemes and, furthermore, as inspiration and starting point for the creative process of human composers to create new musical melodies.

The proposed scheme to model the chord progression makes use of a modified non-homogeneous Markov structure designed to focus on both the chord itself, which defines the short-term dependencies learned during the training stage, and the beat position of each chord within both the measure and the whole composition in order to model the influence of the temporal context. Thus, our model comprises two different sources of information: the chord

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transitions related to the beat position in the measure and the residency time of each chord, i.e. the number of beats the chord was maintained.

In order to simplify the model, some constraints are added taking into account that the final purpose of this work is to provide an automatic melody composer, like the one presented in [8], with the ability of generating new harmonic progressions: melody or chord roots will not be used to define context for the generation of harmonic progressions since the chord progression is selected previously to melody and rhythm.

This paper is organized in four sections: after this introduction, which next contains a brief review on chord progression modelling, in Section 2, a detailed description of the proposed model and the statistical and music theory basis on which this work is based are presented; in this section, both the analysis and the generation processes are depicted. In Section 3, the process for validating the devised model is explained and the results obtained are drawn. Finally, the last section presents the conclusions coming out from this work.

1.1. Background on chord progression modelling

Previous research has been carried out for chord progression modelling or, more specifically, the analysis and specification of transition schemes between chords, which has led to the description of different methods for harmony generation.

In [9], the approach adopted consists on modelling the harmonic movement through Natural Language Processing (NLP). In this case, the sequence of chords conforms a coherent 'sentence' which defines by itself the long-term dependencies needed for the proper generation of chord progressions. Within the same framework, Yoshii et al. [10] model chord progressions by using a Bayesian n-gram scheme oriented toward chord recognition; Eigenfeldt and Pasquier [11] propose a variable-order Markov model controlled by expert user choices based on heuristics to generate chord sequences; Paiement et al. [4] propose the usage of graphical models as an alternative to the utilization of hidden Markov models (HMM) [12].

A closely related topic to modelling harmonic progressions is the harmonisation of melodies. Despite the fact that this task is not directly applicable to the composition architecture followed in this work, the generation of chord progressions that fit a particular melodic line must be taken into account. This approach requires solving two problems: first of all, to find a proper chord progression that fits the melodic line and, then, to find the note evolution of each voice in order to avoid dissonances and bad harmonisation issues.

In [13] and [14], Phon-Amnuaisuk, Tuson and Wiggins solve the harmonisation problem by following two different approaches: on the one hand, a rule-based scheme related to musical theory rules is applied; on the other hand, a genetic algorithm is employed to find a chord progression that fits the melodic line. In the case of the rule-based approach, the theoretical methods are applied backwards; thus, the cadences will be respected and the long-term dependencies will be taken into account; however, this method is more time consuming that genetic algorithms. The genetic algorithm approach is formulated to find a solution of the chord progression via genetic operations that depend on a fitness function. This function penalises certain theoretical concepts such as dissonant chords. Nevertheless, according to the conclusions of the comparison, the solution proposed by the genetic method was not optimal and further knowledge (reproduction operators) makes the process excessively computationally expensive.

In [15], rules and probabilities are employed for automatic harmonization generation, however, neither the overall musical structure nor strong/weak beats are considered.

A different approach is followed by Allan and Williams in [3] where a harmoniser based on a Viterbi decoder is presented. This method decodes the most likely harmonisation of the melodic line where the hidden states correspond to the intervals created between the voices.

2. Proposed harmony model

As described in Section 1, the goal of the model that we propose is aimed at generating harmonic progressions automatically, i.e. the outcome is a sequence of harmonic symbols. Particularly, the output of this scheme complements the functionality of the music composer presented in [8]; consequently, since the melody generator follows a composition structure based on four-measure phrases, the training data and the generated structures are created accordingly. Note that this four-measure structure is very common in pop and classical music.

On the other hand, recall that Paiement et al. [4], Temperley [1] and Yoshii et al. [10], among others, consider that music can be successfully modelled by means of statistical processes; according to this, the model chosen is purely statistical.

Diverse both scientific [4, 16], and music theory [17] publications related to the automatic generation of harmonic sequences with both short-term and the long-term dependencies can be found. These musical dependencies are due to the fact that a musical melody is not just a simple sequence of symbols, instead, all the symbols are inter-related according to a Musical Form [6] in which melody evolution, harmony and structure can be modelled using a statistical process. Nevertheless, it should be kept in mind that what differentiates music from other common statistical processes is the goal of a musical piece, i.e. whatever decision is taken during the composition process, it is aimed at accomplishing a musical objective. Particularly, when defining a chord sequence, it is very important to cope with the creation of harmonic tensions and relaxations. It is quite simple to create a sequence of symbols for both intervals or chord sequences; however, the real challenge resides on modelling harmonic sequences with musical sense and a conclusive ending.

To this end, the proposed statistical model decidedly takes into consideration both the short-term dependencies (first-order chord transitions) and long-term ones (harmonic preparation for the cadence) [18].

Now, after the general musical requirements for the creation of chord sequences with musical sense have been stated, the proposed method will be presented and the design decisions will be accounted for in terms of the exposed requirements.

Regarding the cadence preparation, two different temporal zones are identified: the free-transition zone and the cadential zone. In the first one, the system is designed to generate a sequence of chords relying only on short-term dependencies. This is a simple generation of symbols according to the statistical model created during the training process without any kind of additional manipulation due to any long-term musical structure.

In the second zone, following the cadence preparation principle [18], the model is wrapped in a temporal layer designed to define a conclusive harmonic transition at the end of the musical piece, i.e. a V - I transition. This cadential zone model wrapping adds the long-term dependencies needed to create a natural and logic harmonic sequence.

The cadential preparation zone consists of a predefined number of measures before the end of the musical piece. From a musical point of view, in this zone, the objective of the composer is to define the proper chord path for attaining the desired tension at the end of the composition. It is a decision of the composer to keep some tension, a kind of feeling of incompleteness which is achieved by means of the Deceptive Cadence (V - iv) or the Half

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