Pattern Recognition Letters 000 (2017) 1–9

Contents lists available at ScienceDirect

Pattern Recognition Letters

journal homepage: www.elsevier.com/locate/patrec

Modeling perceptual categories of parametric musical systems

Iván Paz, Àngela Nebot*, Francisco Mugica, Enrique Romero

Computer Science Department BarcelonaTech, C/ Jordi Girona 1-3. Omega 005, Barcelona 08034, Spain

ARTICLE INFO

Article history:
Available online xxx

MSC:
41A05
41A10
65D05
65D17

Keywords:
Musical system
Modeling
Classification
Rule base system

ABSTRACT

In computer music fields, such as algorithmic composition and live coding, the aural exploration of parameter combinations is the process through which systems' capabilities are learned and the material for different musical tasks is selected and classified. Despite its importance, few models of this process have been proposed. Here, a rule extraction algorithm is presented. It works with data obtained during a user auditory exploration of parameters, in which specific perceptual categories are searched. The extracted rules express complex, but general relationships, among parameter values and categories. Its formation is controlled by functions that govern the data grouping. These are given by the user through heuristic considerations. The rules are used to build two more general models: a set of "extended or Inference Rules" and a fuzzy classifier which allow the user to infer unheard combinations of parameters consistent with the preselected categories from the extended rules and between the limits of the explored parameter space, respectively. To evaluate the models, user tests were performed. The constructed models allow to reduce complexity in operating the systems, by providing a set of "presets" for different categories, and extend compositional capacities through the inferred combinations, alongside a structured representation of the information.

1. Introduction

Computer music is the application of computer technology in music composition [10], either to program computers that create music automatically, like algorithmic composition [20], or to help human composers to program music in real time, as is the case in live coding [6,16,28]. In these activities, parametric systems capable of generating different types of musical material are used [2,25]. Examples of parametric musical systems include sound synthesizers and signal processors, as well as melodic or rhythmic sequence generators. To develop a clearer idea of the wide range of possible parametrical musical systems, and therefore motivate the need for a methodology that creates a structured model of their capabilities, let us consider a couple of examples: In the first one, McCormack et al. [18] discuss the granular synthesis system "Chaos-Synth", developed by Miranda [19] for wind instruments. It consists of a bank of oscillators, whose individual frequencies and durations are controlled by the arithmetic mean of groups of cells taken from a cellular automata. In this case, the granular synthesis engine is parameterized by the cell states. The control parameters of the system, once the set of rules for the automata is written, are the cells, and the parameter space is the set of initial conditions with which the automata can be initialized. As a second example, consider a simple synthesis system based on two oscillators controlled by directly changing the values of their parameters. Suppose the system has two parameters: frequency 1 and frequency 2 both in Hz, with values ranging from a to b. In this case the system has an $[a, b]$ x $[a, b]$ space of possibilities, controlled by parameters frequency 1 and frequency 2. Even though these constructions can be framed in general structures (e.g, in additive or granular synthesis), they may have small changes or particular characteristics that modify their response. For example, they could have a different number of oscillators or envelope types, as well as different ranges in their parameters. Therefore, although there is a general idea of the behavior of the different architectures, it is necessary to test a new system to explore its possibilities.

By changing their parameters, the musician interacts with the parametric musical systems. Therefore, in all cases, the exploration of the different combinations of parameter values is the process through which the system's capabilities are learned, and the selection and classification of the musical material is performed. In [11] the commercial and cultural roles that specific parameter settings (called "presets") have had when they become sound "standards" is analyzed. Examples of presets include the classic configurations of an equalizer labeled as "Funk, Rock or Classical", digital plug-ins that mimic iconic instruments and new programs for the automatic audio mastering of a song depending on its genre. In a

* Corresponding author.
E-mail addresses: ivanpaz@cs.upc.edu (I. Paz), angela@cs.upc.edu (À. Nebot).

http://dx.doi.org/10.1016/j.patrec.2017.07.005
0167-8655/© 2017 Published by Elsevier B.V.

similar way, in algorithmic composition and live coding the selection of parameter configurations has to do with selecting settings that produce musical material with specific perceptual categories. Examples of this selection process are: given a system with two variable-frequency oscillators, to find all the frequency combinations that produce a consonant output (in acoustics a sound with harmonic partials), or a sound with "rough" quality. Although the exploration of parameter combinations in search of perceptual categories is a common activity in computer music, there have been few attempts to formalize the information produced during this process with the aim of using it for different musical tasks, such as the automatic creation of variations within a part of a piece while playing in front of an audience (live performance), or the execution of generative music algorithms [2].

Nonetheless, there are excellent examples of methods for finding sets of parameters that successfully produce entities with specific perceptual properties. For example, Collins [4], 5], Dahlstedt [8] applied interactive evolution [9], which uses human evaluation as the fitness function of a genetic algorithm for system parameter optimization. In [8], this technique was applied to sound synthesis and pattern generation tasks, while in [4,5], it was used for searching successful sets of arguments controlling algorithmic routines for audio cut procedures.

The present work is inspired by the methodologies of [5,8], and further focuses on structuring the information that is produced during the exploration process to build tools intended for the following objectives:

1. To provide a structured representation of how the values of the parameters are related with the user-selected perceptual categories.
2. To reduce the cognitive and operational complexity of the algorithms by providing a set of organized "presets" for the different preselected categories which can be used to automate some musical tasks, such as live coding.
3. To extend the compositional capacities by inferring new unheard (unexplored) parameter combinations consistent with the perceptual categories.

In this research, a methodology based on rules is developed for the modeling of perceptual properties. Our particular interest in a rule-based model relies on its interpretability. Rule models, in contrast with subsymbolic approaches (like neural net classifiers), are human readable information, which make them especially attractive for applications in the context of computer music. In addition, a rule-based model naturally functions as a set of presets, by encoding user associations (between parameter configurations and perceptual category). Furthermore, it is possible to extend this model to explore new regions of the space consistent with the assigned classes of the rules. An early version of the methodology can be found in [22].

The proposed methodology consists of four parts, shown in Fig. 1, together with their respective evaluation processes. The methodology has a data acquisition stage which is performed through a parametric exploration of a musical system, while searching for predefined perceptual categories (see # 1 in Fig. 1). During this process, the parameter combinations are labeled with their respective perceptual categories. Then, the data is grouped according to specific patterns, as explained in detail in Section 2. The resulting structures are called "Strict Rules" (see # 2 in Fig. 1). These rules are used to build a more general model, which extends the validity of the Strict Rules from points in the space to intervals. The result of this process, described in Section 3, is a set of "Inference Rules" (see # 3 in Fig. 1). Then, a next level generalization based on the set of Inference Rules is made through the design of a fuzzy classifier (# 4 in Fig. 1). This classifier covers the complete explored space and is presented in depth in Section 3.

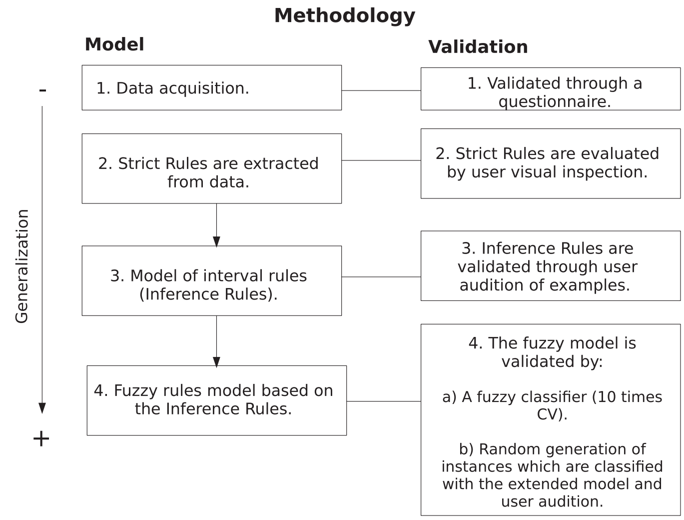

Fig. 1. General methodology.

Sections 4 and 5 describe, respectively, the model evaluation process and the experiments performed to validate the different models. Section 5 also describes in detail the data acquisition process and the user interface used for the parametric exploration. Finally, Sections 6 and 7 present, in turn, the discussion followed by the conclusions and further work.

2. Strict Rules extraction

2.1. Algorithm design considerations

The Strict Rules extraction algorithm was designed to identify complex but general relationships among the values in the system parameters and the perceptual categories assigned by the user. The idea is to reorder the data to make visible specific patterns. In this way, it produces a "structured" and interpretable representation of the input data. In Section 3, this representation is used to infer new combinations of parameters consistent with any of the user-defined perceptual categories. The algorithm was inspired by a rule extraction algorithm developed by Castro et al. [3]. However, it has two fundamental differences. First, the result does not depend on the order of the data. Second, the algorithm can create rules requiring fewer conditions. These are discussed in Section 2.3.

The input data are organized as data pairs (parameter values, perceptual category), which are seen as deterministic input-output relations. In these data, the algorithm searches iteratively for patterns. Specifically, it looks for combinations of parameters with the same category that differ only in one parameter value (let us say p_j). In that case, if the absolute difference of the p_j values that differ is less than a certain threshold (t), the combinations are grouped together into one structure. This structure has the same values of the grouped combinations in all its parameters, the same category and a *set* in p_j that contains the values that differ. Before presenting the algorithm let us define the function that calculates the thresholds.

2.1.1. Threshold function

The thresholds are calculated through functions that are declared in advance by the user. These are based on heuristic considerations, i.e. on a priori knowledge of the variables that the parameters represent. For example, the frequency or the number of upper harmonics added to a signal. Some ideas on how to automate this process are presented in Section 7. For each parameter p_j a threshold function $t_{p_j}(x)$ is declared. It assigns a threshold to

Please cite this article as: I. Paz et al., Modeling perceptual categories of parametric musical systems, Pattern Recognition Letters (2017), http://dx.doi.org/10.1016/j.patrec.2017.07.005