Full Title*

Subtitle†

ANONYMOUS AUTHOR(S)

Transformations and musical patterns -> Haskell ->

Additional Key Words and Phrases: transformation, edit distance, musical patterns, evaluation, clustering, ...

1 INTRODUCTION

Musical patterns are hard to define. Musical patterns are generated by composers [], employed by performers [], perceived by listeners [], and help us better understand and communicate about music. However, in music theory and music information retrieval (MIR), the definition of "musical pattern" has been elusive. For example, one can argue a musical pattern can be "an excerpt of special importance", "a salient fragment", "a prominent unit", etc.. In addition, in different corpora, experts use terminologies such as "lick", "riff", "sequence", etc.. The variability in the definition poses difficulties on designing and evaluating automated computational systems to extract musical patterns.

Musical patterns are useful but hard to extract. Patterns in music are relevant in many musical activities: created by composers [], used by performers [] and perceived by listeners [], people conceptualise [], comprehend [] and communicate meaningful patterns in the context of music. One could try a data-driven way and define musical patterns as the data generated by such activities. Nevertheless, another challenge emerge: the subjectivity and ambiguity give rise to a demand is personalised data, therefore induce the curse of high dimensionality. This also contribute to the vicious loop going from the complexity of the task to a lack of annotations datasets in the field and back. Therefore, with a wide potential for various applications, the automation of musical pattern analysis and discovery is an important and difficult task. The challenge is: How do we leverage the limited data and theory to design and evaluate a pattern discovery system?

MIREX. Previous research has addressed the challenge to a certain extent. Historically, algorithms have been tested on unassociated datasets with disparate metrics [**?**]. One attempt to standardise the evaluation of algorithms is the MIREX Discovery of Repeated Themes & Sections task initiated in 2014. In the task, a pattern is defined as a set of time-pitch pairs that occurs at least twice in a piece of music and the JKU-PDD dataset was introduced [**?**]. According to the evaluation metrics in this task, the state-of-the-art algorithms perform acceptably well in precision, recall, and F1-scores, although they cannot reproduce the human-annotated patterns yet. Another pattern annotation dataset which has been used for evaluating the algorithms is the MTC-ANN Dutch Folk Song dataset [**?**]: human-annotations have been compared with algorithmically extracted patterns by their performance in a classification task [**?**] showing the annotated patterns perform better. Furthermore, a large disagreement between annotated and computationally extracted patterns has been shown in both the JKU-PDD and MTC-ANN dataset in [**??**].

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Existing algorithms. The algorithms submitted to MIREX use different models and methods from geometry [],information theory [] and machine learning []. Often, the algorithms provide pattern candidates instead of a definitive and simple answer on why the algorithms identifies the output patterns.

Our Methods. In this paper, we encode well-defined, music and computationally relevant transformations to investigate the output of pattern discovery algorithms, human annotations and random passages. The implementation in the functional programming language Haskell gives a clean representation of the pattern comparison and extraction process.

Contributions. - Implementation in Haskell - Analysis on MTC-ANN and MIREX - Detection and query

2 MUSICAL PATTERNS AND MODELLING

Repetitions and Variations. Musical patterns and variations are closely related. Variation, in the generic sense of a change or slight difference, can be local or global in music: ornaments such as trills and turns are local, form and thematic variations are global.

"variation is a formal technique where material is repeated in an altered form. The changes may involve melody, rhythm, harmony, counterpoint, timbre, orchestration or any combination of these." – wikipedia

Prototype and transformations. Irrelevant to which type of variation it is, there must be an original material whence the variations are developed and can be related back to. We refer the original materials as the prototype patterns; we name the processes of going from the original materials to the variations as a morphing processes using operators to perform transformations.

Different types of transformations can be coded as functions $f : A- > B$, where $A \in Prototypes$, $B \in Variations$.

For example, one simple transformation is chromatic (real) transposition, where $f(x) = x + n, n \in allowedpitchshifts$. Evidence in cognitive science confirms that this is a natural equivlance relationship except for people with absolute/perfect pitch.

3 DOMAIN SPECIFIC LANGUAGE IN HASKELL

Haskell. Combinator DSL.

Functors.

Contravariant functors.

Computationally combine viewpoints and transformations. With modified input, stream computation in a mathematically found way.

A spectrum of modifications using diff and edit distance.

Pattern discovery and querying system.

3.1 Transformations

- Edit distance: modelling using diff, fuzziness modelled with one parameter

4 MUSIC MATERIALS AND PATTERNS IN MUSIC

We use the MTC-ANN Dutch Folk Song dataset [**?**], which contains an exceptionally large number of annotated patterns and is therefore suitable for a classification experiment. In this section, we examine groups of patterns, random passages, and their features in this dataset.

4.1 Pattern groups in MTC-ANN

Annotated patterns During the making of MTC-ANN, three experts have been asked to annotate the prominent patterns in each song which best classify the song into one of 26 tune families. *Tune family* is a concept in ethnomusicology that groups together tunes sharing the same ancestor in the process of oral transmission [**?**]. The dataset consists of 360 Dutch folk songs with 1657 annotated pattern occurrences. In an annotation study on what influences human judgements when categorising melodies belonging to the same tune family, repeated patterns turned out to play the most important role [**?**]. It is, therefore, reasonable to use repeated pattern discovery algorithms on this dataset.

Patterns from algorithms We use the six pattern discovery algorithms and extract the patterns from the MTC-ANN dataset using the same setup as in [**??**]. The extracted patterns from each algorithm form a subgroup under the umbrella of the extracted pattern group. The seven algorithms were submitted to the MIREX task during 2014-2017: SIATECCompress - TLP (**SIAP**), SIATECCompress - TLF1 (**SIAF1**), SIATECCompress - TLR (**SIAR**) [**?**], **VM** & **VM2** [**?**], SYMCHM (**SC**) [**?**], and SIARCT-CFP (**SIACFP**) [**?**].

We compare annotated and extracted patterns with randomly sampled passages as a baseline in order to potentially support or refuse the significance of musical patterns. In more detail, taking the annotated patterns from MTC-ANN, random passages are sampled with the following procedures: for each annotated pattern, we find the corresponding song where the annotation appears. We then find a random starting point and take an excerpt of the same length as the pattern to construct a candidate excerpt. Finally, we repeat the sampling procedures five times to prevent accidental results.

5 RESULTS

5.1 Patterns Explained by Transformations

5.2 Comparing Algorithms

Different profiles in different datasets.

5.3 Pattern querying and discovery

6 DISCUSSION

Future work: Polyphonic

A APPENDIX

Text of appendix …