Set-class surface analysis: a hierarchical multi-scale approach

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Abstract. This work presents a methodology for hierarchical multi-scale set-class analysis of music pieces, based upon a systematic approach to the segmentation, description and representation stages. This is done by combining existing systematic approaches to segmentation and representation with a set-class description domain. The method benefits from the representation completeness, the compromise between generalisation and discrimination of the set-class spaces, and the access to hierarchical relations of analytical interest. A set of data structures are derived from the method, and exploited in varied music information retrieval applications.

1 Introduction

The representation of the musical surface is a critical element in analysis, as it conditions the observation of musical objects of analytical interest. Proper music information representations and interfacing techniques can free the analyst from the most systematic, time consuming and prone to errors tasks, and assist them in finding and testing material of analytical pertinence.

Pitch-class set theory [1] forms part of the regular music analysis practice since decades. The systematic and objective nature of the theory, together with the compactness of the basic representations, constitutes a systematic and flexible descriptive framework, suited for the analysis of any music based on fixed temperaments. This description domain is thus purposeful for several music information retrieval (MIR) applications, such as structural analysis, similarity, pattern finding or classification.

Among the most systematic approaches to tonal content description, [4] has proposed a hierarchical multi-scale representation of tonal center (key). Systematic (but not hierarchical) pitch-class set analysis methods have been also proposed [2]. In this work, we combine the comprehensive segmentation and representation methods in [4] with the powerful description domain in [2]. The resulting framework [3], benefits from the systematisation of the three stages, providing the analyst with rich and flexible surface material.

2 Method

The input to the system is a sequence of MIDI events of any rhythmic or polyphonic complexity. A comprehensive segmentation defines every possible (different) segment. Each segment is then described, by mapping its pitch-class set content to a set-class space. The three most common class-equivalences are used: interval vector, transposition, and transpostion/inversion. The general representation, named *class-scape*, indexes each segment by the temporal position of its centre, its duration (time-scale), and the class it belongs to.

The class-scapes provide a bird's-eye view of the complete piece, as they represent every possible segment of music in terms of every possible class-sonority. They allow the localisation of every segment belonging to any class, or the visualisation of every segment in terms of the distance to a reference class. Different inter-class measures allow the visualisation of varied tonal relationships.

A first dimensional reduction, named *class-matrix*, consists of projecting the class-scape to the time versus class plane. A class-matrix is a multidimensional time series which represents the existence of every class over time. This data structure is invariant to time-scale, as well as to the transformation which defines the particular class-equivalence.

A more compact representation, named *class-vector*, consists of quantifying the temporal presence of every possible class, relative to the total duration of the piece. This piece-wise summary preserves the integrity of the class-space, while retaining relevant temporal information.

3 Applications

The class-scape has been designed for interactive exploration of music pieces. It can be used as an index for navigating the piece, for inspecting the properties of every possible segment, and for testing by listening. It can also be filtered in varied ways, by substituting the complete set-class space, the inter-class measures, or by selecting a set of cardinalities. The class-scape can be interfaced with the corresponding class vector, from which class references can be chosen, facilitating the exploration of the actual sonorities in the piece.

The class-matrices can be combined with the simplest recurrence finding methods, such as plain self-similarity matrices, in order to find repetitions under different transformations. A case study analyses the large-scale structure of a challenging (serial) piece, in which the main material is restated under different transpositions, inversions and harmonisations.

The class-matrices can also be filtered for hierarchical analysis of the subclass content under any sonority of interest. This is done by first isolating the existing segments belonging to the chosen class, and building a *subclass-matrix* and the corresponding *subclass-vector*. A case study compares the diatonicism in two contrasting (but related) corpora, revealing differences in the contrapuntal writing.

Datasets of class-vectors can be queried for finding music containing specific sonorities, or any combination of (existing or non-existing) sonorities. The contextual approach of the general framework, deviating from the usual event-based methods, allows the localisation of any pitch aggregate (or combinations), whether appearing as melodic, chordal or scalar patterns. The usage of class-vectors as content-based metadata points to advanced applications related with music similarity.

Supplemental material

The interactive potential of the methods discussed in this work can be tested with our multi-scale set-class analysis prototype for Matlab, freely available from `http://agustin-martorell.weebly.com/set-class-analysis.html`. A detailed manual of the tool, a comprehensive table of set-classes, and a (growing) dataset of 16000+ class-vectors, are also available at this site.

References

1. Forte, A.: A Theory of Set-Complexes for Music, *Journal of Music Theory* **8(2)**, pp. 136–183 (1964).
2. Huovinen, E, Tenkanen, A.: Bird's-Eye Views of the Musical Surface: Methods for Systematic Pitch-Class Set Analysis, *Music Analysis* **26(1–2)**, pp. 159–214 (2007).
3. Martorell, A., Gómez, E.: Hierarchical Multi-Scale Set-Class Analysis, *Journal of Mathematics and Music*, Online, pp. 1–14 (2014).
4. Sapp, C. S.: Visual Hierarchical Key Analysis, *Computers in Entertainment* **4(4)**, pp. 1–9 (2005).