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A Graph-Theoretical Approach to the Harmonic Analysis of Georgian Vocal Polyphonic Music

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A GRAPH-THEORETICAL APPROACH TO THE HARMONIC ANALYSIS OF GEORGIAN VOCAL POLYPHONIC MUSIC

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1. INTRODUCTION

The present paper proposes a computational approach to the comparative analysis and visualization of the harmonic structure of three-voiced vocal music. The dataset which has been used in this study is the same as in Scherbaum et al. (2015), a corpus of polyphonic songs from Svaneti (Akhobadze, 1957). Similar to the earlier work, a song is treated as a discrete temporal process in which harmonic or melodic states change according to unknown rules which are implicitely contained in the song itself. In contrast to the prior study, however, there are no assumptions regarding their probabilistic or deterministic nature.

2. METHODOLOGICAL FRAMEWORK

In the preprocessing phase of the analysis described in Scherbaum et al. (2015), each score was analysed for its mode type. It turned out that 99% of the usable songs where in mode La (75%), Sol (21%), and Re (3%). These modes differ only in the size of the 3rds and 6ths being sung as minor or major. Based on the observation of recent recordings of authentic Svan singers (Scherbaum, 2016) which suggest that 3rds and 6ths in traditional Svan music are neither sung as minor nor as major intervals, it was concluded that the separation of the Akhobadze corpus into different modes is not sufficiently supported by the data. For the subsequent analysis it was therefore provisionally assumed that all songs belong to a single 7-step mode in which the distinction between minor and major intervals is dropped, but for which the particular scale does not have to be specified.

In the main part of the analysis, each song is represented as a directed graph (e. g. Chartrand, 1985) G=={V,E} which consists of a set of vertices V (representing the harmonic states of a song) and a set of edges E which represent all the chord transitions in a song (Figure 1). Fig. 1 shows the harmonic structure of the song "Tamar Mepla" in a very efficient graphical way, which also contains some statistical information regarding the harmonic structure of the song. Fig. 1b) for example shows the number of times chords - the positions of which correspond to the positions of the edges in Fig. 1a) - are used. It can be seen that the most common chord is VI_3^5 which is used 10 times, followed in frequency by the chords VII_4^5 (the starting chord), V_5^7, and VII_1^3 each of which are used 8 times. From the edge thicknesses in Fig. 1a) one can see for example that the sequence $V_5^7, VI_3^5\ VII_1^3$ is the most often used chord progression in the whole song.

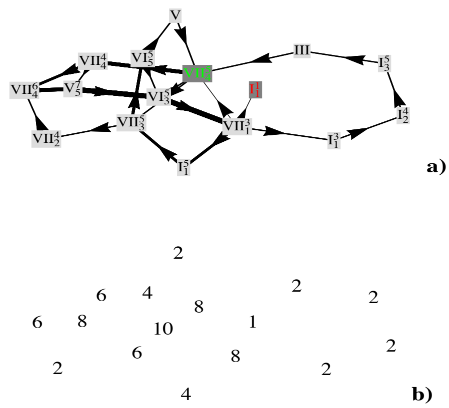

Figure 1. Graph representation of the song "Tamar Mepla" in which the line thickness of each edge indicates how many times the corresponding chord progression is used in the song. The vertex positions in the graph are calculated such that the number of edge crossings of the graph is minimized (Tutte embedding). Fig. 1. a) shows the graph while Fig. 1. b) shows the number of times the corresponding chord is used in the song.

Within the graphical framework, an individual song is simply a "path" (called "song path") in a "landscape of chords" which will be referred to as "chordscape". The thickness of the individual segments of a song path reflects how often the particular segment is "travelled". The interpretation of songs as directed graphs might require some training on the side of a musicologist but its advantages become obvious in the context of analysing a whole set of songs together. Naturally, the concept of song paths is easily expanded to a larger group of songs by simply adding new chords (as vertices) to the chordscape and recalculating their optimum positions so that the number of path crossings of all song paths is minimized, using the principle of Tutte embedding. This is illustrated in Fig. 2 for the combination of two songs (Akhobadze song number 5 "Mgzavruli" Fig. 2a with Akhobadze song number 9 "Tamar Mepla" Fig. 2b.

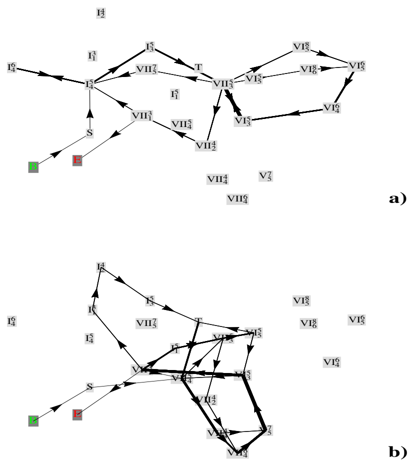

Figure 2. Chordscape and song paths for the combination of two songs, a) "Mgzavruli" and b) "Tamar Mepla".

3. RESULTS

The representation of songs as song paths in a chordscape offers interesting ways of graphically analysing the harmonic organization of songs and their relationships. Due to the space constraints in this abstract, the potential of this framework can only be highlighted through some selected features. If for example one displays all song paths in a single graph on the full chordscape of the whole corpus (Fig. 3), the chords in the outer locations of the chordscape reveal those chords which are less often used (maybe even only once) while the most used chords in the whole corpus are found in the center of the cluster.

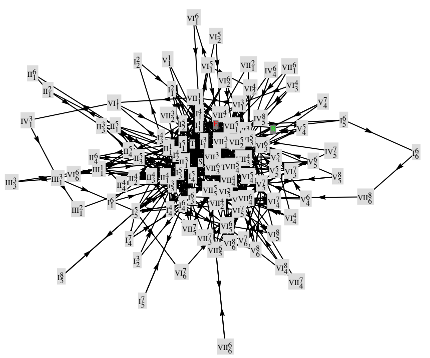

Figure 3. Joint song paths for all songs in the corpus plotted on top of the chordscape for the complete corpus. The complete chordscape consists of a total of 102 different chords.

One can now also quantitatively calculate the relationship of songs in terms of their harmonic organisation, e. g. by calculating the Sammon´s map (Sammon, 1969) for the song path images (Fig. 4), just to mention another example.

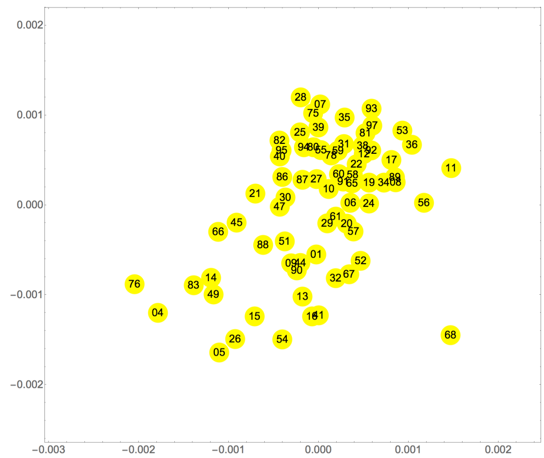

Figure 4. Sammon´s map for the song paths images of all analysed songs. The two-dimensional mutual distances between the individual points, each representing a song, are reasonably good approximations of the mutual distances of the dissimilarity of the corresponding song paths.

4. CONCLUSIONS

The representation of songs as directed graphs allows the quantitative analysis of the harmonic organization of individual songs in a graphical, transparent and reproducible way. It also provides a framework to quantitatively compare the similarity of songs in a whole corpus e. g. by using techniques such as Sammon´s maps. The resulting neighborhood relations from the latter analysis can be displayed in ways which can be used for further musicological studies even by non-mathematically inclined analysts.

5. REFERENCES

Akhobadze, Vladimer. (1957). *Collection of Georgian (Svan) Folk Songs*. Tbilisi: Shroma da Teknika. (In Georgian. Foreward in Georgian and Russian).

Chartrand, G. (1985). "Directed Graphs as Mathematical Models." §1.5 in *Introductory Graph Theory*. New York: Dover, pp. 16-19.

Scherbaum, F., Arom, S., & Kane, F. (2015). "On the feasibility of Markov Model based analysis of Georgian vocal polyphonic music". In *Proceedings of the 5th International Workshop on Folk Music Analysis, June 10-12, 2015, University Pierre and Marie Curie, Paris, France* (pp. 94–98).

Scherbaum, F. (2016). "On the benefit of Larynx-microphone field recordings for the documentation and analysis of polyphonic vocal music". In *Proceedings of the 6th International Workshop on Folk Music Analysis, June 15-17, Dublin, 2016 (accepted).*

Sammon, J. W. (1969). „A nonlinear mapping for data structure analysis". *IEEE Transactions on Computers*, *C-18*(5), 401–409.