TRACKING CHANGES IN HARMONIC INTERVAL STRUCTURES OF SVAN SONGS BASED ON COMPUTATIONAL ANALYSIS OF FIELD RECORDINGS FROM 1959-1971[1]

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Abstract. This study investigates the historical evolution of harmonic interval structures in Svan polyphonic songs using computational analysis of field recordings from 1959 to 1971. Svan songs, like other Georgian regional music, employ tuning systems that deviate from Western intonations, with the precise nature of these systems still debated. The audio archive of the Folklore Laboratory of the Tbilisi State Conservatoire holds an extensive collection of field recordings of authentically-performed Svan songs, offering a unique opportunity for in-depth analysis.

Traditional music information retrieval (MIR) techniques for fundamental frequency (F0) estimation are inadequate for these polyphonic recordings due to their reliance on monophonic sources. However, advances in deep learning now enable the estimation of multiple F0 frequency salience maps from single-channel polyphonic recordings.

We trained a deep learning model for multiple F0 estimation and applied it to 136 single-channel recordings of Svan songs from the Conservatoire's archive. The estimated harmonic intervals were used to construct statistical models of the interval distributions for each song. Employing hierarchical

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clustering based on the Wasserstein distance metric, we identified clusters of recordings with similar harmonic interval distributions.

Our analysis reveals distinct patterns of harmonic interval structures, providing insight into the tuning practices of Svan music within the past century. The clustering results indicate possible shifts in musical intonation, suggesting a dynamic evolution in the interval structures of Svan songs. This research contributes to the understanding of Svan musical heritage and demonstrates the efficacy of modern computational techniques in ethnomusicological studies.

Keywords: Computational ethnomusicology; music information retrieval; historical musicology; audio corpus analysis; tonal organization; cluster analysis;

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აბსტრაქტი. წინამდებარე კვლევა იძიებს სვანური პოლიფონიური სიმღერების ჰარმონიულ ინტერვალურ სტრუქტურათა ისტორიულ განვითარებას 1959-1971 წლების საველე ჩანაწერებზე გამოთვლითი ანალიზის გამოყენებით. სვანური სიმღერები, საქართველოს სხვა რეგიონული მუსიკის მსგავსად, დასავლური ინტონაციებისგან განსხვავებულ წყობებს იყენებს, რომელთა ზუსტი ბუნება ჯერ კიდევ მსჯელობის საგანია. თბილისის სახელმწიფო კონსერვატორიის ფოლკლორის ლაბორატორიის აუდიო არქივში ავთენტურად შესრულებული სვანური სიმღერების საველე ჩანაწერთა ვრცელი კოლექცია ინახება, რაც სიღრმისეული ანალიზის უნიკალურ შესაძლებლობას ქმნის.

ტრადიციული მუსიკალური ინფორმაციის ამოკრების (MIღ) მეთოდები, რომლებიც ფუნდამენტურ სიხშირეთა (F0) დადგენისთვის გამოიყენება, შეუსაბამოა ამ პოლიფონიური ჩანაწერებისთვის, რადგან ისინი მონოფონიურ წყაროებს მოითხოვს. თუმცა ღრმა დასწავლის სფეროს განვითარება ერთარხიანი პოლიფონიური ჩანაწერებიდან მრავალი F0-ს შემცველი ნიშანდობლიობის რუკების განსაზღვრას შესაძლებელს ხდის.

ჩვენ გავწვრთვენით ღრმა დასწავლის მოდელი მრავალი F0-ის დადგენისთვის და ის კონსერვატორიის არქივში დაცული სვანური სიმღერების 136 ერთარხიან ჩანაწერზე გამოვიყენეთ. თითოეული სიმღერის ნაანგარიშები ჰარმონიული ინტერვალები გამოვიყენეთ ინტერვალური დისტრიბუციის სტატისტიკურ მოდელთა შესაქმნელად. ვასერშტაინის მანძილის მეტრიკაზე დაყრდნობილი იერარქიული კლასტერინგის გამოყენებით გამოვავლინეთ მსგავსი ჰარმონიული ინტერვალური დისტრიბუციის მქონე ჩანაწერთა კლასტერები.

ჩვენმა ანალიზმა ჰარმონიული ინტერვალური სტრუქტურების მკაფიო კანონზომიერებები გამოავლინა. კლასტერინგის შედეგები მუსიკალური ინტონაციის შესაძლო ცვლილებაზე და სვანური სიმღერების ინტერვალურ სტრუქტურათა დინამიკურ განვითარებაზე მიუთითებს. ამ კვლევას წვლილი შეაქვს სვანური მუსიკალური მემკვიდრეობის გააზრების საქმეში და წარმოგვიჩენს ეთნომუსიკოლოგიურ კვლევებში თანამედროვე გამოთვლითი მეთოდთა გამოყენების ეფექტიანობას.

საკვანძო სიტყვები. გამოთვლითი ეთნომუსიკოლოგია, მუსიკალური ინფორმაციის ამოკრება, ისტორიული მუსიკოლოგია, აუდიო კორპუსის ანალიზი, ტონალური ორგანიზაცია, კლასტერების ანალიზი.

საკვანძო სიტყვები: გამოთვლითი ეთნომუსიკოლოგია; მუსიკალური ინფორმაციის მოძიება; ისტორიული მუსიკოლოგია; აუდიო კორპუსის ანალიზი; ტონალური ორგანიზაცია; კლასტერული ანალიზი;

Introduction

Research Problems

Scholars have long observed that the Georgian tuning system differs significantly from the equally tempered 12-tone system, spurring numerous studies aimed at uncovering its true nature. A primary challenge has been the separation of voices in multi-part vocal recordings, which is crucial for studying the polyphonic vocal music of Georgia. Analyzing historical archive materials, as old as the earliest audio recordings, allows researchers to observe changes in traditional singing practices and dynamically reveals their theoretical framework within the historical context and time span. However, extracting musical information pertaining to individual voices in old archival recordings has been a persistent challenge in ethnomusicological research. Historical recordings often suffer from poor audio quality, overlapping voices, and a lack of sophisticated recording techniques. Early efforts relied heavily on manual listening and transcribing, limited by the subjective nature of human hearing and the difficulty of acoustically analyzing individual voices in polyphonic textures.

Research History

Past research on Georgian polyphony primarily focused on descriptive analysis and field recordings. Scholars such as Nadel (1933), Arakishvili (2010), Aslanishvili (2010), Chkhikvadze (2010), Chijavadze (1991), Akhobadze (1950; 1957), among others, laid the groundwork by documenting the musical practices and providing initial insights into the ethnographic, sociological and musicological aspects of Svan vocal repertoire, including its harmonic structures. However, the notated transcriptions of field recordings (i.e., Akhobadze, 1957) captured the essence of Svan polyphony but did not allow for in-depth acoustical analysis due to the five-staff notation system not being suitable for non-tempered music.

The advancement of technology and present achievements in computational sciences have significantly progressed studies in this direction. Recent studies have leveraged computational techniques to revisit these recordings with a new perspective. Work by a research group (Scherbaum et al., 2021; Scherbaum & Mzhavanadze, 2020; Mzhavanadze&Scherbaum, 2020; Scherbaum, 2016; Scherbaum et al., 2022) has demonstrated the potential of these methods in providing, among other aspects, more granular insights into the harmonic structure of Georgian, including Svan music.

This has enabled the documentation and study of the Svan repertoire in its current state. The research involves computational analysis using pitch detection algorithms to reveal patterns and structures in the music, including its harmonic interval analysis.

Importance of Harmonic Structure

Harmonic intervals are a core aspect of Georgian, and particularly Svan, musical vocabulary and grammar. Siegfrid Nadel noted:

> Finally, polyphony itself entails a change of tonal values of a different kind. For it demands, especially at the main and resting points of the melodic line, pure consonances, or it generally favors the major third; i.e., it demands simultaneous intervals which often do not coincide with the neutral or equal-distance ones of the melody. These simultaneous intervals must therefore be made possible by certain adjustments in intonation in the individual voices, which in turn can crisscross the intended melodic-tonal system..." (Nadel, 1933, p. 29).

Nearly 100 years later, during the fieldwork carried out within the GVM (Georgian Vocal Music) project in 2015-2016, Ruben Charkhviani, a singer from Ushguli/Svaneti, answered a question about what non-Georgian singers do differently when trying to sing traditional Georgian music by saying: “They always want to come to the end."This expression highlighted that traditional Georgian singing is not concerned with achieving something along a time axis (horizontally) but rather with respect to the other voices (vertically) (Scherbaum & Müller, 2023). This phenomenon, often referred to as “vertical musical thinking,” has been observed by other scholars as well (Chokhonelidze 2010; Akhobadze 1957; Mzhavanadze & Scherbaum 2020). The study of the harmonic/vertical musical inventory of the Svan repertoire, which is believed to be one of the oldest layers of Georgian musical heritage, can provide insight into the structural elements of traditional Georgian music as a whole. Conducting reliable and accurate studies of old archival recordings allows us to observe gradual, dynamic intonational and structural changes within songs.

Research data

The object of this study is a section of the audio archive of the Folklore Laboratory of the Tbilisi State Conservatoire consisting of field recordings of non-instrumental Svan polyphonic songs. In total, our subset consists of 136 audio tracks, representing a collection of multiple variants of 26 songs as well as 25 individual recordings of additional songs. The field recordings were made in 1959, 1960, 1967, 1968, and 1971 in both Upper and Lower Svaneti.

In total, about 61 different songs were recorded. Specifically, 25 of these songs were recorded in Lower Svaneti (Lentekhi communities) during the years 1967 and 1971. Additionally, recordings were made from 21 different groups, with 7 of these groups hailing from Lower Svaneti.

The computational analysis results provide a harmonic interval inventory, revealing the fundamental building blocks of the harmonic structures in these recordings and offering insights into this aspect of the musical language of the Svans.

Methods

The cornerstone of our analysis is the multiple F0 estimation model, which processes audio recordings and returns a salience map. Unlike the commonly-used single F0 estimation methods such as PYIN (Mauch & Dixon, 2014), which yield the F0 trajectory of a single voice, our model yields a salience map, a matrix *S[t,f]* with values ranging from 0 to 1, represents the estimated probability of the presence of a sung pitch at frequency f at time t.

Modern methods for multiple F0 estimation leverage convolutional neural networks (CNNs) to process frequency domain representations of audio signals. These methods treat the frequency domain slices of the input signal as images, utilizing CNNs to extract features that encode pitch salience information. During training, the models are fed datasets of multichannel recordings, where the input is the frequency domain representation of a sum of individual voice recordings, and the label is a salience map generated by applying PYIN to individual voice recordings and combining individual voice frequencies onto a grid.

DeepSalience (Bittner et al., 2017) uses CNN architecture to convert harmonic constant-Q transform (HCQT) magnitudes into salience maps. The Polyvocals architecture (Cuesta et al., 2020) builds on DeepSalience, applying an expanded DeepSalience-based architecture to vocal music. This architecture expands DeepSalience incorporating phase differentials as an additional input. The model concatenates magnitude and phase differential representations before applying the final CNN block. For data augmentation, reverb is applied to individual voice recording sums to better represent the domain of real polyphonic recordings.

Our model architecture is based on the Polyvocals architecture. We replaced the stacked convolutional blocks with a residual network architecture to enhance feature extraction. Instead of applying reverb to artificial sum tracks, we perform room simulation using pyroomacoustics (Scheibler et al., 2018): we place individual recordings into a simulated room and use the simulated microphone signal as the sum recording. This approach better simulates the acoustic conditions of real polyphonic recordings, as source signals are not treated as a single point source. For training data, in addition to open datasets used for training polyvocals, we used a section of the GVM corpus.

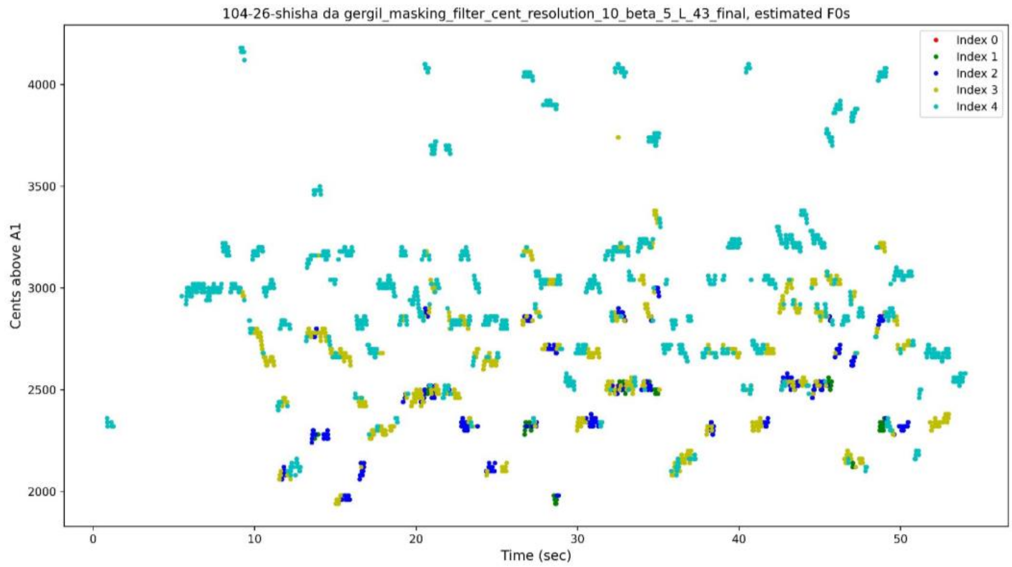

Figure 1: salience map of recording “104-26-shisha da gergil”. The horizontal axis represents time, while the vertical axis represents cents above A1.

Our automatic analysis pipeline begins by applying the trained model to all recordings in our corpus subsection, yielding salience maps. We then apply a filtering step to refine these maps by removing extreme frequencies (below 100 Hz and above 3000 Hz) and frequencies more than one octave above or below the mean frequency for each recording (manual analysis suggested that such intervals are beyond the ambitus of the songs in the corpus and were largely made up of estimation errors). The filtered data is converted to the cent domain, where we apply a masking filter (Rosenzweig et al., 2019) to retain only stable pitch regions.

For each time step in the processed salience map, we extract the cent differences between each detected frequency to determine harmonic intervals. Following Scherbaum's methodology (Scherbaum et al., 2017), we model the interval distribution for each recording by first using peak-finding of Kernel Density Estimation (KDE) of the input data to identify the number of peaks n. We then estimate the harmonic interval distribution using a Gaussian Mixture Model (GMM) with n components. The means of these components provide a synoptic scale of the harmonic intervals of the recording.

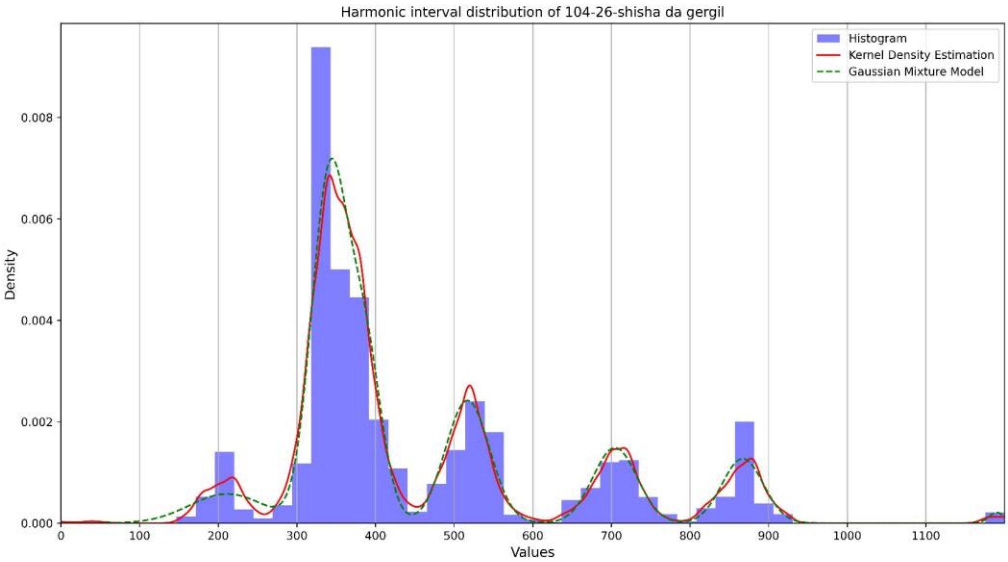

Figure 2: Harmonic interval distribution plot of recording “104-26-shisha da gergil”. The underlying histogram represents data extracted from the recording. The red line represents the probability density function of the estimated KDE (used for finding the number of peaks). The dotted green line represents the probability density function of the estimated Gaussian mixture.

Once the harmonic interval distribution models are established for each recording, we calculate the similarity between these distributions. We construct a distance matrix using the Wasserstein distance (Panaretos, 2018) metric to quantify the similarity between each pair of recordings' harmonic interval distributions. This matrix serves as the basis for further clustering analysis.

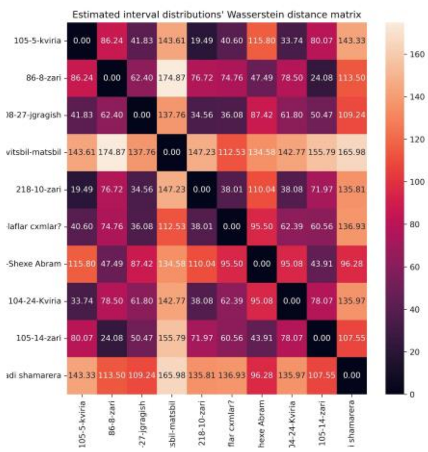

Figure 3: Distance matrix heatmap generated from a subset of 10 recordings.

Using the distance matrix, we perform agglomerative hierarchical clustering (Nielsen, 2016) to identify groupings of recordings with similar harmonic interval distributions. The resulting tree structure is represented as a dendrogram, where the x-axis represents the Wasserstein distance. Each split point in the dendrogram signifies a potential clustering, with early splits forming small clusters of highly similar recordings and later splits forming larger clusters of relatively less similar recordings.

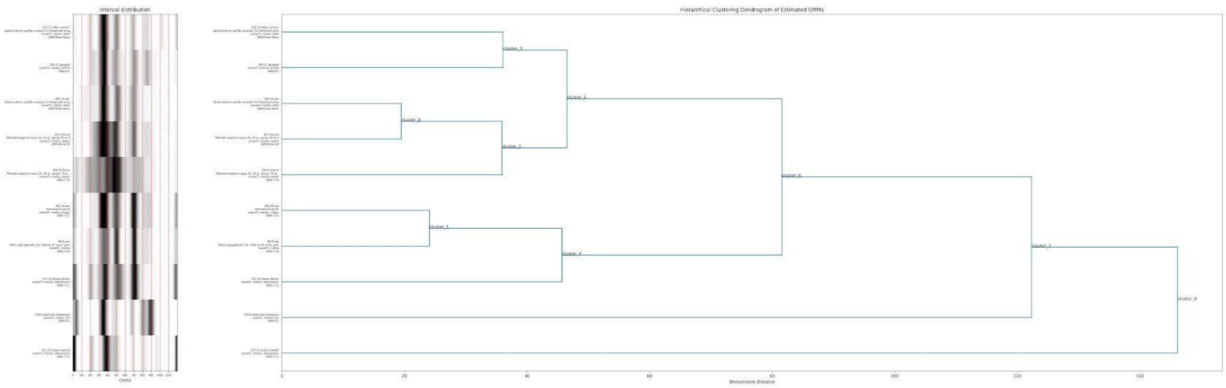

Figure 4: Dendrogram generated from distance matrix demonstrated in Figure 3. To the left of the dendrogram. To the left of the dendrogram, the black-and-white mesh representation of the harmonic interval distribution of each recording is shown.

For each cluster, we generate an average harmonic interval distribution. The means of the average GMM are used as the synoptic scale of the cluster.

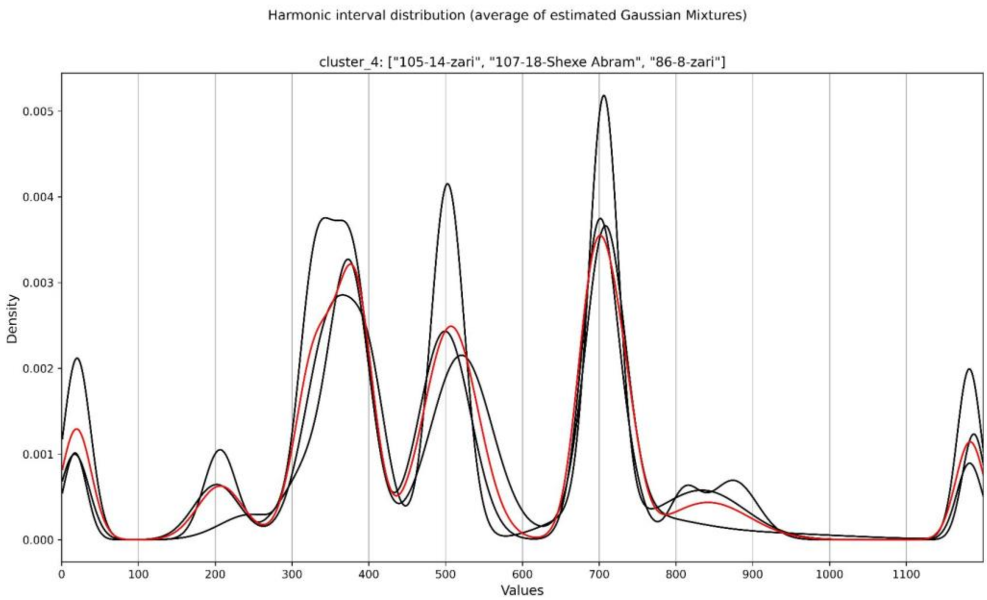

Figure 5: Harmonic interval distribution cluster consisting of three recordings. Black lines show probability density functions of estimated GMMs of individual recordings, while the red line shows the probability density function of the average GMM.

Results

Applying our multiple F0 estimation method to the recordings in our corpus, we obtained harmonic interval distributions for each recording. These distributions were used to generate synoptic scales, summarizing the prominent harmonic intervals in each recording.

The hierarchical clustering process resulted in a dendrogram illustrating the relationships between recordings based on the similarity of their harmonic interval distributions (see Appendix 1). We observed that most clusters formed splits at a Wasserstein distance of 60 units or less. Beyond a distance of 80 units, additional large-cluster splits occurred after approximately 30 more distance units. This pattern indicates that around 60 distance units, several large clusters emerge that are internally consistent yet distinct from each other. We identified three primary clusters at this level:

Cluster index	Number of recordings	Synoptic scale
129	85	0, 219, 333, 385, 503, 703, 853, 966, 1200
130	36	0, 211, 287, 337, 385, 473, 524, 702, 868, 1200
131	13	0, 207, 329, 377, 500, 706, 873, 1000, and 1200

Table 1: Clusters split above distance 80.

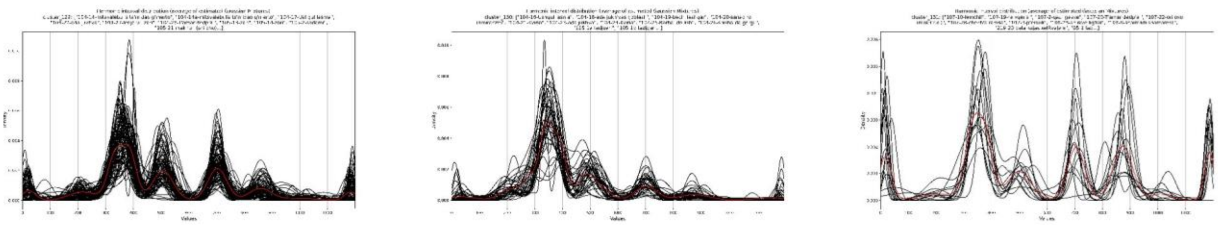

Figure 5: Harmonic interval distributions of clusters 129, 130, and 131

Cluster index	Number of recordings	Synoptic scale
15	8	0, 318, 367, 486, 688, 777, 924, and 1200
126	79	0, 220, 361, 503, 702, 845, 949, and 1200

Table 2: Sub-clusters of cluster 129, split around distance 75.

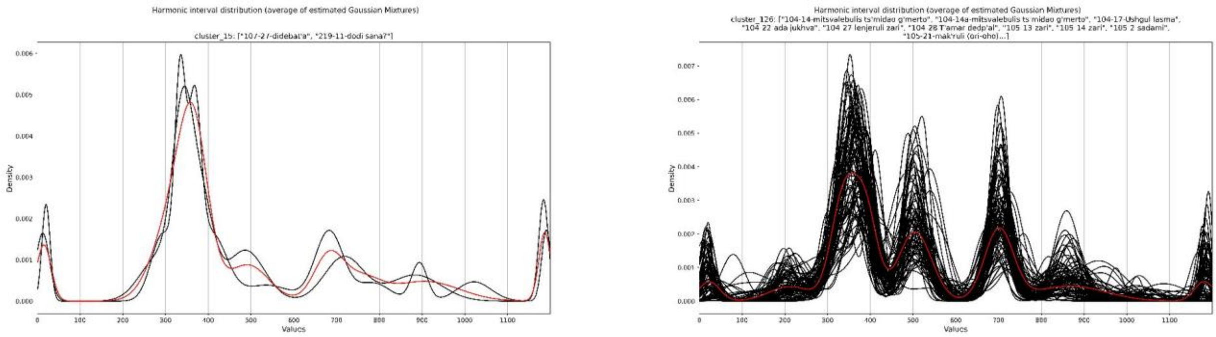

Figure 6: Harmonic interval distributions of clusters 15 and 126.

(Figures showing the synoptic scales of Clusters 15 and 126)

At a Wasserstein distance of 65 units, Cluster 126 subdivides further into Clusters 118 and 121:

Cluster index	Number of recordings	Synoptic scale
118	52	0, 223, 332, 383, 479, 530, 704, 869, 1200
121	27	0, 202, 295, 343, 388, 480, 529, 693, 724, 873, 1200

Table 3: sub-clusters of cluster 126, split around distance 65.

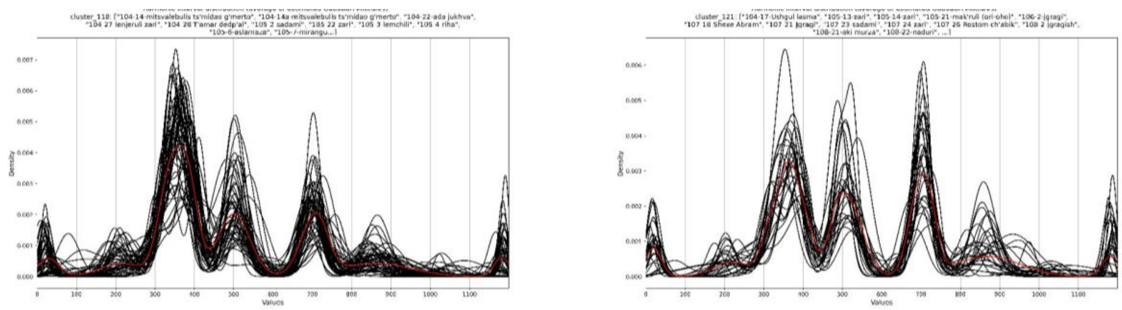

Figure 7: Harmonic interval distributions of clusters 118 and 121.

Below the 65 distance units threshold, clusters continue to subdivide frequently with each increment of around 10 distance units. These subdivisions reflect smaller variations in harmonic interval distributions, suggesting that the large clusters identified above are robust and consistent with the underlying data. The finer subdivisions provide insights into the nuanced variations within these large clusters, highlighting the rich diversity of harmonic practices in Svan polyphonic songs.

Discussion

The results of the computational analysis allow us to compile a list of harmonic intervals used within Svan songs, identify the fundamental components of harmonic structures in these recordings, and gain insight into this aspect of the Svans' musical language. Although various trends are observed, we have selected only a few to consider what conclusions can be drawn from the results of this study, given the historical context of the repertoire under consideration. These include: a) the complete list of harmonic intervals and their hierarchical use; b) the classification of song groups according to their harmonic structure and its significance for understanding Svan songs; c) the phenomenon of the so-called "national trichord" and its representation in the Svan repertoire at this historical stage.

Harmonic Intervals inventory:

The total inventory of harmonic intervals, as other studies have already shown, includes (conventionally, we use classical Western musicological terminology) the interval spectrum from prima to octave. However, the most stable intervals are prime, fifth (700 cents), fourth (500 cents), and octave (1200 cents), with the degree of deviation gradually increasing hierarchically in the following order: second (200 cents), sixth (about 900 cents), third (between 300 and 400 cents), and seventh (about 1100 cents).

The most commonly used interval groups (as seen in the Gaussian mixture model image) (in the descending hierarchical order) are: thirds, primes, fifths, fourths, sixths, octaves, and seconds.

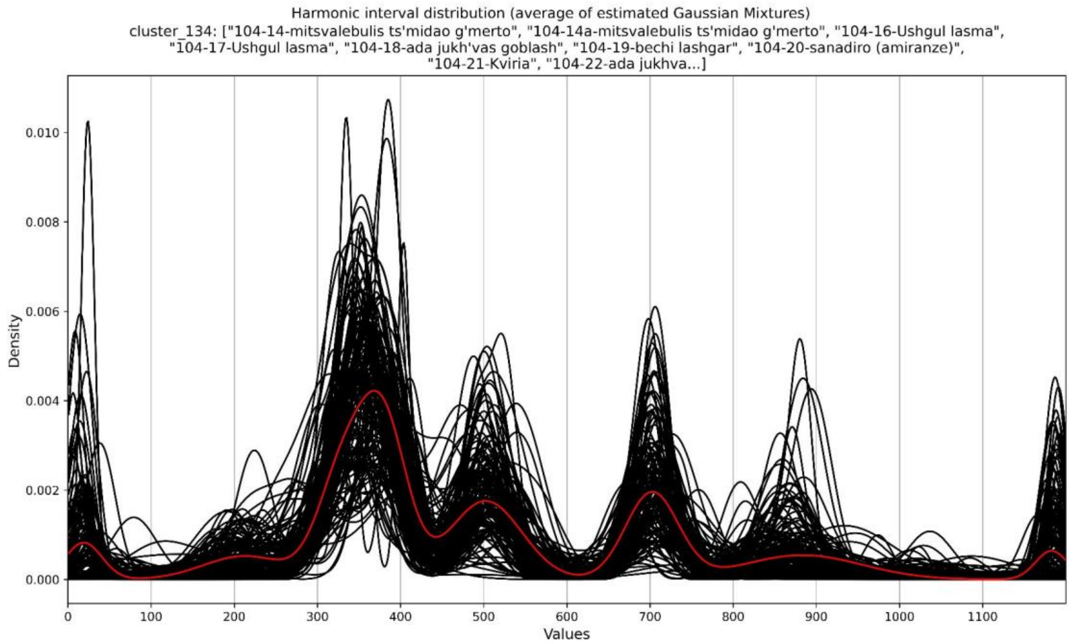

Figure 8: Harmonic interval distributions of cluster 134, consisting of all recordings

Classification of the song groups:

The clustering method allows comparative observation from different perspectives of the individual songs of the field recordings. However, considering the limitations of the given format, we select only a few of them to draw the reader's attention, namely:

1. On the one hand, it can be seen that the interval landscape ("chord landscape") of individual groups of songs is more or less the same. In particular, it can be seen that across genres, across geography and performance contexts, and across groups of performers, the distribution of harmonic intervals of different songs is often close to each other. For example: Cluster 7 ['108-22-naduri', '86-1-lile', '86-2-lile'] shows that the work song 'Naduri' (recorded in Upper Svaneti, Tsvirmi village) and the ritual hymn type song 'Lile' (recorded in Upper Svaneti, Lenjeri village) share a common harmonic vertical interval inventory and hierarchical redistribution. This also applies to the songs "Riho" (recorded in Upper Svaneti, Lendjeri community) and "Dala Koja" (recorded in the village of Kheled in Lower Svaneti), whose chord vertical (interval inventory and hierarchical redistribution) is also similar.

2. On the other hand, there are songs whose vertical inventory, despite deep differences in other aspects, is identical. Namely, repertoires of the same genre, but different purposes, are exactly the same. For example, the interval composition, distribution and hierarchical arrangement of the hymn-type songs "Saddam" (ritual wedding hymn) and "Zari" (ritual funeral chant) are almost identical. However, it should be noted that both songs are sung by the same group (recorded in 1960, probably in Lower Bal region in Upper Svaneti, Etseri community).

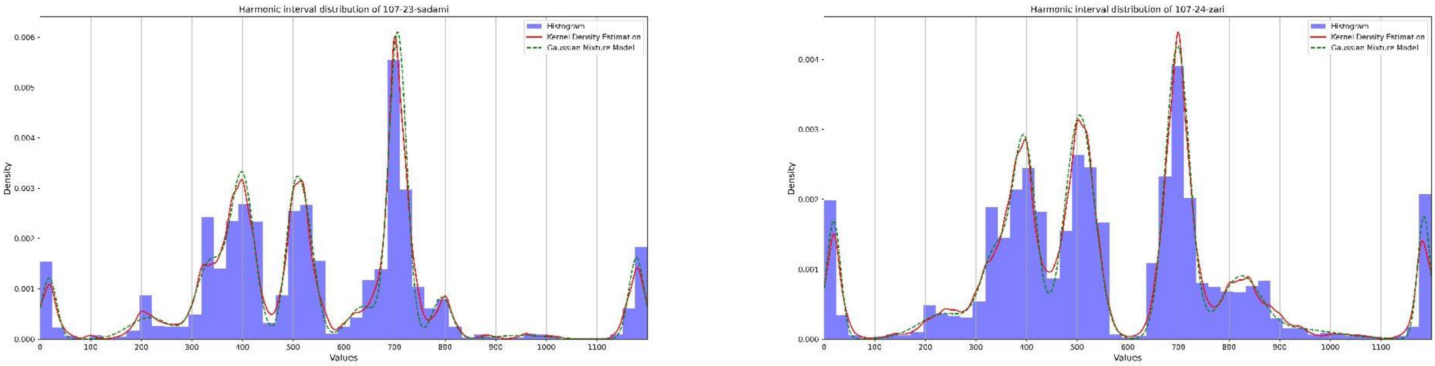

Figure 9: Harmonic interval distributions of recordings within cluster 10 (“107-23-sadam" and “107-24-zari”)

On the dendrogram these two hymns were grouped side by side, separated by a very small Wasserstein distance.

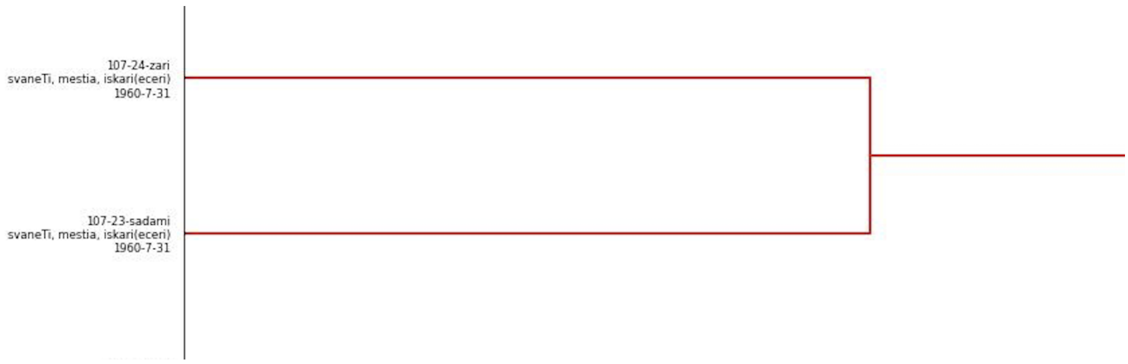

Figure 10: Section of the dendrogram representing cluster 10

We wondered how another recording of "Sadam" [85-2], made from a performance by other performers in 1959 in Mestia (Upper Svaneti), fared in this case. According to the classification given on the dendrogram, it turned out that these hymns of the same genre, title and purpose did not fall into related groups in this classification. For clarity, see the image of its harmonic interval distribution.

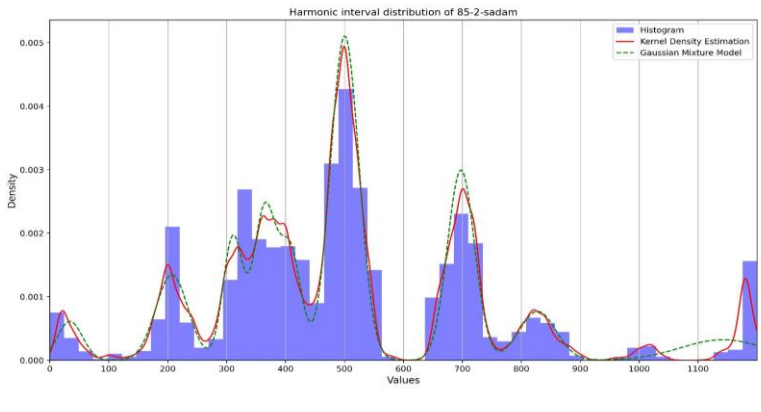

Figure 11: Harmonic interval distribution of “85-2-sadam”.

As can be seen in the dendrogram below, the song "Adrekila" recorded on Latali village (Upper Bal in Upper Svaneti) in 1968 [218-16] and "Ga" recorded on Pari village (lower Bal in Upper Svaneti) in 1960 [107-29] are closely related recordings of the mentioned hymn (Sadam).

Figure 12: Dendrogram section corresponding to recordings grouped closely with 85-2-sadam

National trichord (do-fa-sol/1-4-5):

As previously noted, within the historical context of studying the Svan repertoire, D. Arakishvili emphasized the significance of the 1-4-5 chord at the outset of his research into Svan vocal practices. He attributed to this chord the same qualities as the triad, considering it one of the most stable harmonic supports within the complete harmonic interval inventory. In response to objections raised by B. Steinpress—who argued that, given the chord's universal application and nature, it could not be an independent harmonic unit but rather served as a transitional chord —Arakishvili stated: "The Georgian trichord is interesting because, being a dissonant combination, it plays the role of a kind of consonance. In Georgian folk music, [this] trichord is a favored consonance, and very often, a song begins with it (like many other Georgian songs such as Gurian "Sabodisho", Svan "Elia Lrde" etc). In practice, it is the same consonance as the triad" (Arakishvili, 1952, p. 43). Arakishvili supported this argument by citing a notated transcription of the Svan song "Jgragish," which concludes with a 1-4-5 chord (he also mentions a Gurian song, "Indi-Mindi," which also ends with this chord) (Figure 13, from ibid., p. 44):

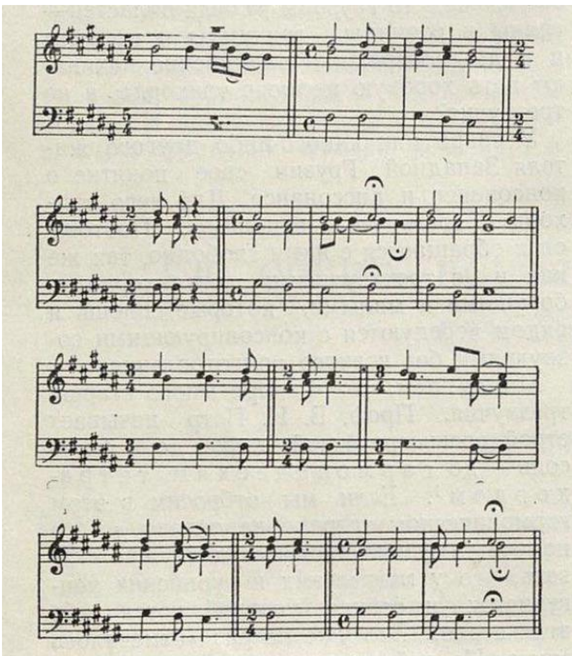

Figure 13: Arakishvili's cited transcription of "Jgragish", concluding with a 1-4-5 chord.

This brief overview of early musicologists' appreciation of the 1-4-5 trichord, supported by citations of audio and sound recordings, underscores their view of the 1-4-5 trichord as an embodiment of the ancient musical identity of the Georgians. While the focus is not on making an in-depth comparison between the old repertoire and the corpus studied in this research, it allows us to observe a general historical trend. This approach provides insight into the journey of the 1-4-5 trichord from the early 20th century to the time of recording the repertoire in our field of study.

Observation of the analysis results of the complete repertoire, as demonstrated in the final analysis, shows the relatively rare use of the second interval, while the fourth interval appears to be more active. This observation suggests that two-part cadence segments often utilize the fourth as an important cadence function.

In general, a comparative overview of the full repertoire reveals relatively few instances of the 1-4-5 trichord, as shown in the clustering of all the songs.

However, some results allow us to observe more specific trends. For instance, very few songs lack a 1-4-5 trichord. Among these are "Shairebi" (recorded in Upper Svaneti in 1959), as well as "Mirangula," "Iav Kalti," "Dodisana," and "Simghera Gablianze" (all recorded from two mixed groups in Lower Svaneti in 1971). "Shairebi" is the only song recorded in Upper Svaneti that doesn't employ the 1-4-5 trichord. This can be explained by its hybrid nature, influenced by other musical dialects of Georgia (Mzhavanadze, 2018). Regarding other songs, several correlations can be observed:

"Simghera Gablianze" and "Dodisana" are relatively new songs. Due to the influence of other (new) musical styles, especially in Lower Svaneti, which has been geographically more accessible compared to Upper Svaneti (which used to be blocked for half the year due to severe climate conditions), the import of new waves of popular music in the area was easier. Consequently, the movement of parallel thirds, as seen in these songs, was more likely to take over, and triads could more easily replace the 1-4-5 trichord. Although "Mirangula" belongs to the old traditional repertoire, parallel thirds could have penetrated it as well. It is worth noting here that men from the same group employed the 1-4-5 trichord when singing traditional ritual hymns such as "Lile" and "Lagusheda."

Apart from this, we could not detect any major consistency between singer groups and the use of the 1-4-5 trichord, meaning that one group can sing one song with more 1-4-5 trichords while using very few in other songs. For example, the singers from Tsvirmi (Upper Svaneti) use very few 1- 4-5 trichords in "Lemchil" but many more in "Shishada Gergil" and "Jgragish."

Furthermore, it appears that the same song can be sung with more 1-4-5 trichords in one case and with much fewer in another. For example, "Adrekila" sung by the Latali group in 1968 (recording 218-16) has many more 1-4-5 trichords than "Adrekila" recorded in Pari (Lower Bal Svaneti) in 1960 (recording 108-3) or in Lower Svaneti in 1971 (recording 219-1), both of which have extremely few 1-4-5 trichords. Moreover, two versions of the same song, such as "Jgragish" performed by the Latali singers in 1968, show marked differences in the predominance of the second interval.

Conclusion

The comprehensive analysis of the Svan musical repertoire, focusing on harmonic intervals, reveals significant insights into the structural components and historical trends of this unique musical tradition. The study identifies the most stable harmonic intervals—prime, fifth, fourth, and octave—while highlighting the prominence of neutral thirds (which deviate significantly from thirds in western tuning systems), primes, fifths, and fourths in the harmonic landscape (chordscape). Despite the general consistency in the interval structures across different songs and genres, notable variations are observed in the use of the fourth-fifth chord, particularly in its historical and contemporary contexts. The findings suggest that the use of this chord varies, influenced by the introduction of new musical styles and the geographic accessibility of Lower Svaneti. The analysis also reveals inconsistencies in the use of the 1-4-5 chord among different singer groups and across various renditions of the same song, indicating a dynamic and evolving musical practices. In conclusion, this research offers insights into the harmonic structures of Svan music, shedding light on the influence of historical, cultural, and geographic factors on its development.

However, we can also conclude that mapping and exploring the harmonic interval inventories of the repertoire cannot be used as the sole criterion for fully uncovering its essence or classifying song groups by genre. For instance, as we observed, songs from radically different genres may sometimes share the same harmonic interval inventory. The database resulting from computational research gives us the possibility to further deepen such research. Therefore, a multidisciplinary study that incorporates deeper historical, ethnographic, linguistic, and contextual analyses, as well as other musicological aspects including melodic intervals, modal structure, compositional form, and rhythm, should be conducted.

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Appendix

Appendix 1: Hierarchical Clustering Dendrogram

Exported dendrogram is hosted at the project's GitHub appendix directory: https://github.com/lshug/pypolyphonicanalysis_data/blob/main/HAE_appendix/svaneti_subset_hierarchical_clustering_dendrogram_of_estimated_gmms.jpg