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Harmonygrams: A Graphical Notation System for Three-Voiced Music Facilitating the Perception of Harmonies

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Abstract

Georgian traditional polyphonic vocal music is known for its intricate interplay of melody and harmony. As has already been noted qualitatively by Nadel (1933), traditional Georgian singers often exhibit a remarkable ability to adjust their intonation vertically, particularly during specific intervals such as octaves, fifths, and primes, a phenomenon known as "vertical thinking". However, for those lacking extensive experience in this tradition, developing the capacity for "vertical thinking" is a formidable challenge. It requires recognizing the moments in a song where melodic precision should yield to harmonic cohesion across the ensemble. The Western 5-line staff notation, however, commonly used for transcribing Georgian vocal music, proves insufficient in intuitively capturing the harmonic structure. Deciphering harmonies remains a 'slow' process in the Kahnemann (2012) sense, even for most proficient score-readers. To overcome this challenge, a novel graphical notation for three-voiced music, named 'Harmonygram', is presented. This concept seamlessly integrates melodic and harmonic elements into a single, intuitively comprehensible plot. Individual voices are represented as note sequences in Global Notation (Killick, 2020). The vertical spaces between the individual voices are color-coded to indicate the corresponding harmonic intervals. The interval between the bass voice (which is always the lowest voice in the investigated corpus) and the highest voice is portrayed as a vertical mirror image, with the note trajectory of the bass voice serving as the reference curve. This system allows users with minimal training to grasp both individual melodies and harmonies more or less effortlessly. Harmonygrams offer several noteworthy features. First, they can be generated computationally from traditional musical scores. Second, they allow for algorithmic correction of some of the tuning system distortions happening during the transcription into Western notation. Third, the perception of the whole chord progression structure of a song becomes easily possible with Harmonygrams, even for lay people, since it all boils down to recognizing simple visual patterns. Fourth, the simplicity of Harmonygrams eliminates the need to read complex Western scores, making them an accessible yet information-rich tool for singing practice, providing a bridge for both novices and experts to appreciate and participate in this rich musical tradition.

Introduction

In the foreword to his book "Who asked the first question?" (Jordania, 2006), the Georgian ethnomusicologist Joseph Jordania recounts how he tried to teach the Georgian healing song *Batonebo* to a conference participant during a walk from Mount Mtatsminda through the old town of Tbilisi in the spring of 1977. His guest learned quickly and after a short time, they were walking through an empty street, singing the middle and upper parts of the song. Suddenly, from an apartment on the second floor, they heard a young man spontaneously adding the bass part of the song.

I read this anecdote, which demonstrates in a touching way that for Georgian singers a song is only complete when all three voices are present, long before I was able to experience it for myself through numerous encounters with singers in Georgia, but above all through my close collaboration and long-standing friendship with the singer and ethnomusicologist Nana Mzhavanadze, how much the polyphony of traditional Georgian songs characterizes this music and the people who sing it. Yes, traditional Georgian songs are polyphonic[1]! And yet this sentence means something completely different to me today than it did when I first read Joseph Jordania's book. Today, after ten years of intensive study of this music, I would like to add: Traditional Georgian songs are polyphonic, but they are definitely more than the set of three voices they are usually made up of!

On the one hand, there are the traditional Georgian tonal systems beyond major and minor, which are strange at first hearing and yet seem familiar in an archaic way. These can only be approximated imperfectly by the so-called '12-Tone Equal Temperament' (12-TET) system on which Western 5-line staff notation is based.

However, it is above all the harmonic structure, i.e. the 'vertical' intervals between the individual voices, which for me make up the special appeal of this music. Traditional Georgian singers often attach great importance to the intonation of the so-called 'pure' harmonic intervals (prime, octave, fifth, and fourth), but often take comparatively great liberties with the intonation of melodic phrases if these do not lead to pure harmonic intervals. This was already noticed qualitatively almost a hundred years ago by the ethnomusicologist Siegfried Nadel who noted in 1933, based on the analysis of phonograph recordings of Georgian singers recorded in prisoner-of-war camps in World War I (1914-1918):

"Finally, polyphony itself entails a change of tonal values of a different kind[2]. For it demands, especially at the main and resting points of the melodic line, pure consonances, or it generally favors the major third[3]; 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…[4]".

[1] The term ‚polyphony' is used here in its general sense and not restricted to ‚counterpoint polyphony'.
[2] Previously, Nadel had discussed differences of the perceived melodic tuning system with respect to Western-European "church modes".
[3] The presumed strong role of major thirds as a general feature of traditional Georgian singing has not been confirmed in more recent studies of Gurian and Svan songs, but it has been found in city songs (e.g., Scherbaum et al. 2022). However, it may exist in songs from other regions that Nadel has studied.
[4] Die Mehrstimmigkeit selbst bringt schließlich eine Änderung der Tonwerte von anderer Art mit sich. Denn sie fordert, vor allem an den Haupt- und Ruhepunkten der melodischen Linie, reine Zusammenklänge, oder sie bevorzugt ganz allgemein die große Terz; d. h. sie verlangt Simultanintervalle, die oft mit den neutralen oder distanzgleichen der Melodie nicht übereinstimmen. Diese Simultanintervalle müssen daher durch gewisse

What Nadel had noticed was that the intention of Georgian singers to maintain consistency of a melody with a fixed melodic scale was at times abandoned in favor of harmonic intonation adjustments to achieve certain intervals in particularly pure tuning. This behavior has recently been revisited in the context of a quantitative analysis of singer interaction in traditional Georgian vocal music by Scherbaum and Müller (2023), who found numerous examples for this phenomenon.

Trying to tackle the harmonic aspects of Georgian music in practice, one needs to know and take into account the vertical (harmonic) sound structure of a song as well as the melodic progressions of the individual voices. For traditional Georgian singers, the perception of the harmonic context of a song, sometimes referred to as 'vertical thinking', is an intuitive process which is favored through the mechanism of oral transmission, through many years of practice and continuous exposure to the music. For singers who are used to learning songs from Western 5-line staff notation, in particular for amateurs, recognizing chords requires solving several perceptual tasks. First of all, the exact pitches of the notes must first be deduced by memorizing the number and type of accidentals (# or b) of the key in which the song is notated. Only then can the harmonic intervals be derived from the vertical spacing of the notes involved.

To overcome this problem, I have developed the Harmonygram toolbox[5], which implements a graphical visualization scheme for digital scores of three-part music (in musicXML format) that makes it possible to display the entire melodic and harmonic content of a three-part song in a single, intuitively understandable diagram, a Harmonygram. It also allows the partial correction of scores for the distortions of the tuning system during the transcription into Western 5-line staff notation. An additional advantage (especially for amateur singers) of the Harmonygram concept is the fact that it completely eliminates the need to be able to read musical score notation.

Intonationsänderungen in den einzelnen Stimmen ermöglicht werden, die ihrerseits das intendierte melodisch-tonartliche System durchkreuzen können… (Nadel, 1933, p.29).

[5] Programmed in Mathematica, Wolfram Research, Inc., Champaign, IL, USA.

Melodic representation of three-voiced songs

Using the example of the Gurian song 'Batonebo', which presumably gave rise to Joseph Jordania's anecdote above, Fig. 1 shows the pitch trajectories of the three voices in 'Global Notation' (Killick, 2020).

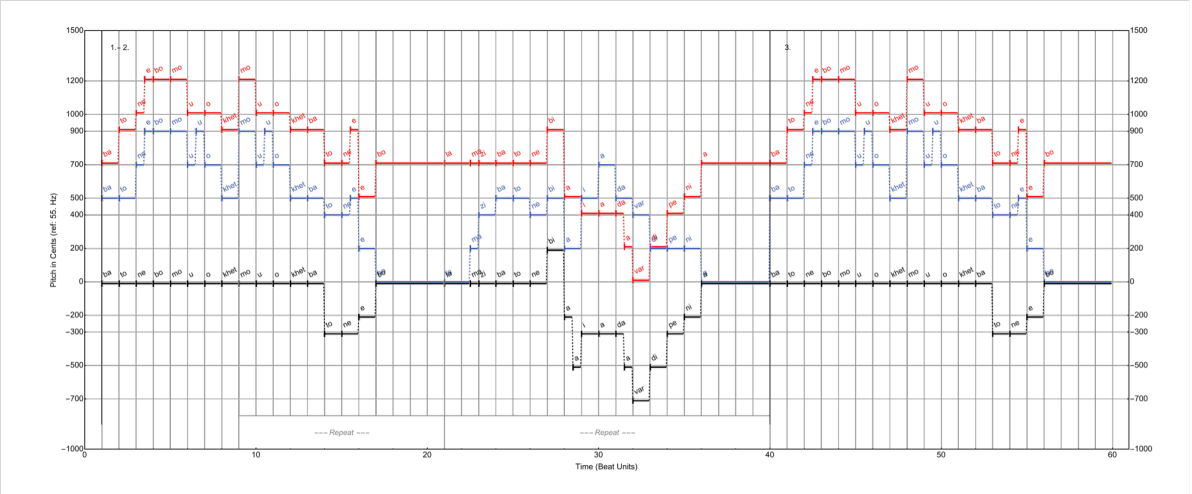

Fig. 1 Pitch trajectories of the upper-, middle-, and bass voice of the song *Batonebo* in red, blue, and black, respectively[6].

The lyrics are shown above the notes in the color of the corresponding voice. One can see that in this song all the voices start at the same time, which is not always the case[7]. One can also see that the largest pitch difference, the so-called ambitus of the song, is 1900 cents in total (from -700 to 1200). As 100 cents correspond to a semitone step (and 1200 cents to an octave), this corresponds to around 1 ½ octaves. It is also immediately apparent that the bass voice moves less than the two upper voices and remains on the same note, which is also the final note, for a long time. This tone therefore represents a kind of 'reference tone' in this song and was therefore chosen as the zero point of the pitch axis and all other pitches were calculated relative to it. The horizontal pitch grid is chosen so that all pitches occurring in the song lie on a grid line. The vertical spacing of the lines in this example (since it is in 12 TET tuning) is either 100 or 200 cents apart, i.e. a half step or a whole step. All this and more can already be recognized directly from the melody-contour-representation, which – in the present context and in analogy to the term seismogram in seismology - will be referred to in the following as a *Melodygram*.

[6] Since the pitch trajectories of the two top voices in traditional Georgian songs do cross sometimes, e.g. in the central part of *Batonebo*, the terms "upper voice", "middle voice", and "bass voice" refer to individual singers, while the terms "highest voice", "intermediate voice", and "lowest voice" refer to the pitches of a voice at a particular instance of time, e.g. in a particular chord.

[7] In other Georgian folk songs often the middle voice starts the song with a monophonic introduction.

Harmonygram: melodic and harmonic representation of three-voiced songs

To represent the harmonic interval structure of the song, the vertical spaces (between the staves of the individual voices) are color-coded according to the size of their (vertical) pitch differences, i.e. their harmonic intervals, and superimposed on the melodygram. This is shown in Fig. 2a) for the intervals between the lowest and the intermediate voice and above it for the intervals between the intermediate and the highest voice. Please note that in case of voice crossings, what is referred to here as upper voice (shown in red), may not always be the highest voice in terms of pitch. Fig. 2b) shows the intervals between the lowest voice, which is always the bass voice, and the highest voice.

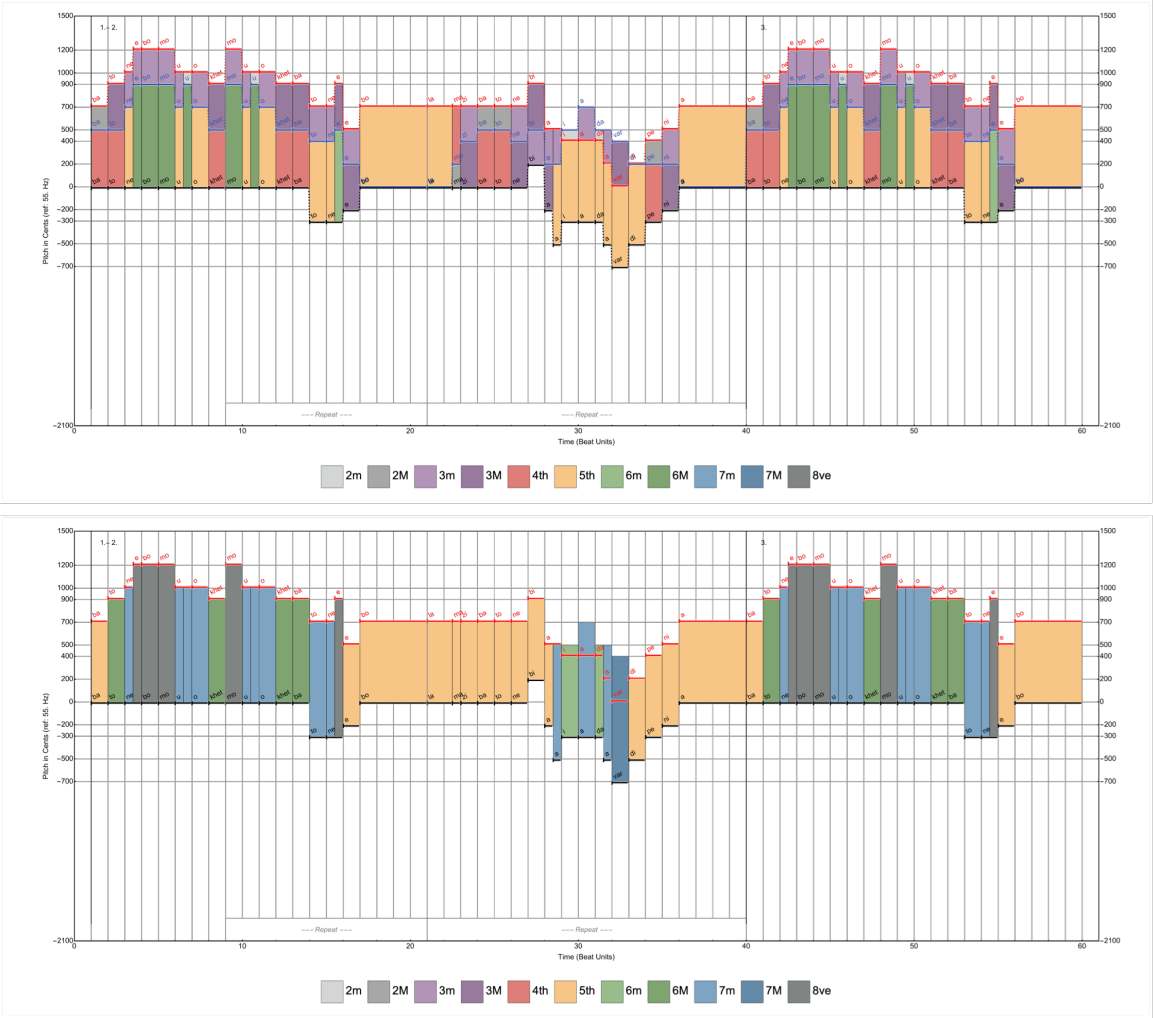

Fig. 2 Harmonic intervals between the lowest (bass) voice and the intermediate voice, and between the intermediate and the highest voice (a), as well as between the lowest (bass) and the highest voice (b). The colors for minor and major non-pure intervals, i.e. second, third, sixth, and seventh, each marked with a lower case m or upper case M, are deliberately kept very similar, since their pitches differ much less in traditional Georgian tuning than the transcriptions into a Western notation system, from which the illustrations produced here were calculated, would suggest.

Due to the dominance of the 'sand color' in Fig. 2, it can be readily observed that the most prevalent harmonic interval throughout the entire song is the fifth. This is particularly

evident in the bass voice (shown in black) and the upper voice (shown in red), which predominantly move in parallel fifths throughout the central section. At the beginning and end of the song, the distance between the bass and the upper voice increases, eventually reaching an octave. The intervals between the bass and the middle voice, as well as between the middle and the upper voice, present a slightly different pattern. While fifths reoccur, the visually most prominent intervals in the score, and therefore also in Fig. 2, are major and minor thirds between the middle and the upper voice. Note also that the middle and the upper voice cross two times in the central section so that temporarily the middle voice becomes the highest voice and the upper voice the second highest.

The song commences with the characteristic 1-4-5 chord progression commonly found in Georgian music. In this progression, the bass voice forms a fourth with the middle voice, and a fifth with the upper voice. As a byproduct, a major second arises between the middle and upper voice. In the context of Western perception, a highly dissonant interval, the major second, coincides with the generally as consonant perceived perfect fifth and a fourth[8], creating both 'tension' and 'resolution' for Western ears. These brief considerations illustrate the wealth of interesting information that can be derived from a simple visual examination of the melodic-harmonic representation.

A drawback of depicting harmonic intervals as two separate images in Fig. 2 is that the intervals between individual voices are challenging to perceive 'at a glance.' Since Georgian songs, with few exceptions, are practically always three-voiced music, the two interval representations can be easily combined. This is achieved by shifting the 'interval columns' for the lowest-to-highest voice intervals beneath the melody line of the bass voice (which is always the lowest voice). This corresponds to the vertical mirroring of each lowest-to-highest voice interval column at the bass melody. The transition from Fig. 3a) to Fig. 3c) illustrates this process. Fig. 3c) displays the mirrored interval columns for the lowest-to-highest voice intervals derived from Fig. 3a). The fact that these are mirrored intervals is additionally indicated by cross-hatching the mirrored interval columns. Now, the space between the lowest and highest voice is freed up and can be utilized to show the combination of lowest-to-second-lowest voice intervals and the second-lowest-to-highest voice ones, as displayed in Fig. 3d). The whole process leads to the representation of all three harmonic intervals in a single figure, referred to hereafter as a *Harmonygram*.

[8] In western perception, the fourths is sometimes interpreted as consonant and sometimes as dissonant.

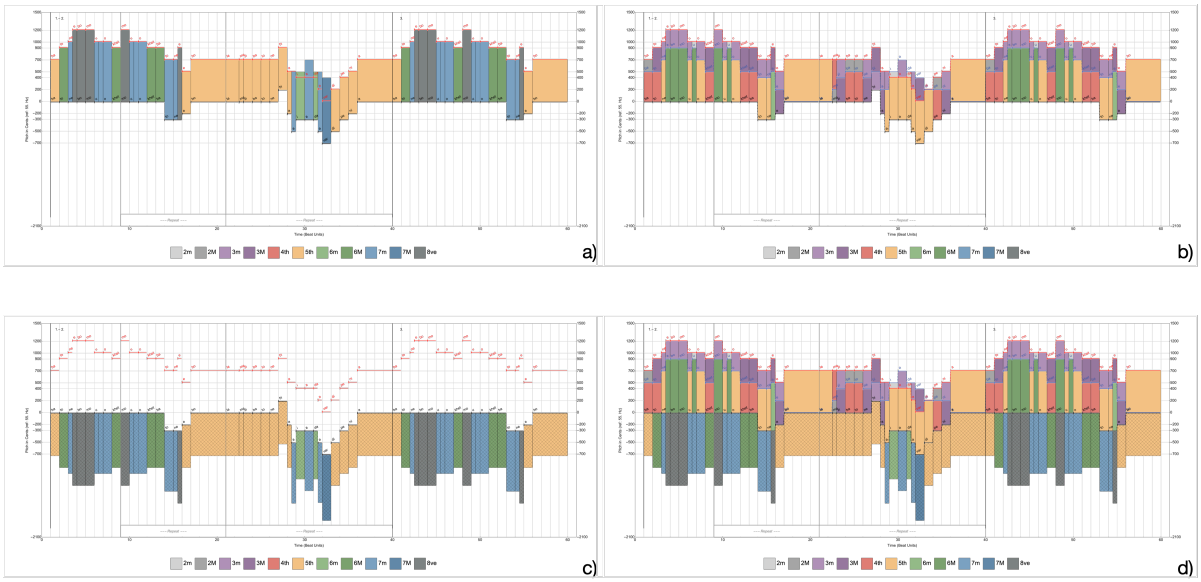

Fig. 3 Steps involved in the generation of the Harmonygram of the song *Batonebo*. The mirrored interval columns of the lowest-to-highest voice intervals (Fig. 3c) are combined with the interval columns for the lowest-to-intermediate voice intervals and the intermediate-to-highest voice (Fig. 3b).

Subsequently, in Fig. 4, the Harmonygram (Fig. 3 d) is presented again on an enlarged scale.

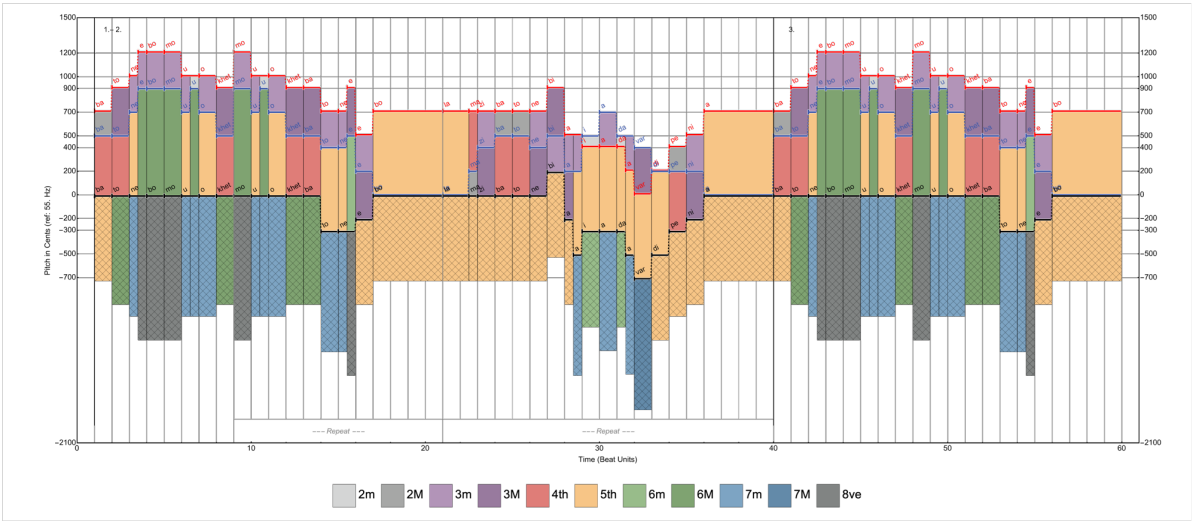

Fig. 4 Harmonygram of the song *Batonebo*.

In the event that the explanations regarding the generation of Harmonygrams have not already made this clear, I would like to explicitly emphasize that Harmonygrams encode the entire melodic and harmonic information of a three-part song, as present in the sheet music from which they were derived to such an extent that, if one were to forego bar lines, most of the essential aspects of musical notation could be reconstructed from this representation (if one were so inclined).

One significant advantage of this admittedly unconventional representation lies in the intuitively understandable nature of Melodygrams and Harmonygrams compared to traditional sheet music. In classical notation, the exact pitches of notes must be deduced

through 'reflection' on the number and type of accidentals used in the key in which a piece is notated, and then memorized. In contrast, Melodygrams allow these pitches to be 'seen' immediately based on the vertical position. Recognizing the harmonic context is even more challenging in classical notation. And even if you are very skilled at recognizing a single chord from its components in a score, it becomes a perceptionally more demanding time-consuming, sequential process to grasp chord progression sequences, not to mention the entire harmonic structure of a song. In contrast, in a Harmonygram, both individual chords and the harmonic structure of an entire song can be perceived instantly via color perception, bypassing the need for "slow thinking" as defined by Kahneman (Kahneman, 2011).

The use of Harmonygrams can also support the perception of the voices of the co-singers, as a singer can constantly "see" which harmonic intervals he or she is currently contributing to and tune the attention towards recognizing them. This can be especially helpful at key positions of a song, where, for instance, one's voice contributes to the formation of harmonic fifths or octaves. It allows singers to check, correct if necessary, or simply appreciate the beauty of pure harmonic intervals. There are ample opportunities for this, as many Georgian songs feature extended sequences of, for example, parallel fifths or octaves.

Two additional aspects of scientific practice are worth mentioning. Harmonygrams lend themselves very well to the analysis of songs, as structural relationships can be easily discerned. This efficiency arises from our evolutionary development, making us adept at perceiving visual patterns. For example, in Fig. 4, one can immediately observe that the harmonic patterns at the beginning and end of the song are identical. Examples of using Harmonygrams in musicological structural analysis can be found in Mzhavanadze and Scherbaum (2020). Another positive aspect is that a similar plot to Harmonygrams can be computed from audio signals, enabling visual structural comparisons of field recordings of songs (Scherbaum and Mzhavanadze, 2020).

Regarding the limitations of the Harmonygram concept, it is the restriction to three-part music that needs to be mentioned. This, however, is not a significant constraint in traditional Georgian music since most of the songs meet that condition.

Documentation of Non-Western Music in Western notation

A hitherto unaddressed issue, which can now elegantly be addressed through the Harmonygram concept, pertains to distortions arising when traditional Georgian music and, more broadly, non-Western music, is transcribed into Western staff notation. For the purpose of this discussion, 'Western music' is casually defined as music whose scales are based on the premise that the pitches of all involved notes occur at intervals of integer multiples of a semi-tone, in other words, integer multiples of 100 cents. Consequently, an octave comprises 12 equally spaced intervals of 100 cents each, giving rise to the term "12-tone equal-tempered system" or 12-TET system. This system underlies Western musical notation and the generation of sound from instruments such as the piano.

Among most ethnomusicologists specializing in traditional Georgian music, there is consensus that traditional Georgian vocal music can NOT be accurately represented by the 12-TET system. However, there has been a very controversial debate over several decades as to what would be an appropriate alternative Georgian tuning systems. An overview of this discussion, which is difficult to evaluate due to the lack of detailed information on the data sets and methods used, can be found, for example, in Scherbaum et al. (2020) and more recently in Jordania (2022). New methods of analysis and the availability of larger data sets, both of historical and recent (field) recordings, have made it recently possible to contribute to this discourse in a new way, using large amounts of objectively verifiable pitch measurements from audio data.

All recent acoustical analyses of traditional Georgian vocal music recordings conducted by Tsereteli and Veshapidze (2014, 2015) and Scherbaum et al. (2020, 2022) consistently note that, on average, the melodic scales in traditional Georgian music predominantly feature approximately evenly spaced intervals. Fig. 5 shows the synoptic model derived by Scherbaum et al. (2020, 2022). In extensive datasets, such as the Erkomaishvili dataset (Rosenzweig et al. 2020; Scherbaum et al. 2020), the interval between the fourth and fifth scale degree above the last bass note frequently aligns with a whole tone step (200 cents), while - on average - the other intervals typically measure around 5/6 of a whole tone (167 cents). The size of the melodic second, the most common melodic step size in these songs, exhibits considerable variability, centering around an average of approximately 170 cents. In contrast, the mean value of the harmonic second is notably larger, namely close to 200 cents (Fig. 5). This may be attributed, in part, to the influence of the widely used 1-4-5 chord in Georgian music, where a fourth and a fifth are simultaneously intoned as pure intervals above

a fundamental. Discrepancies between the findings of Tsereteli and Veshapidze (2014, 2015), which indicate a pure unitonic scale with a step size of 6/7 of a whole tone (171 cents), and those of Scherbaum et al. (2020, 2022), which suggest a scale model involving a combination of a whole tone step and six equally sized intervals with a step size of approximately 5/6 of a whole tone (167 cents), likely stem from differences in dataset sizes.

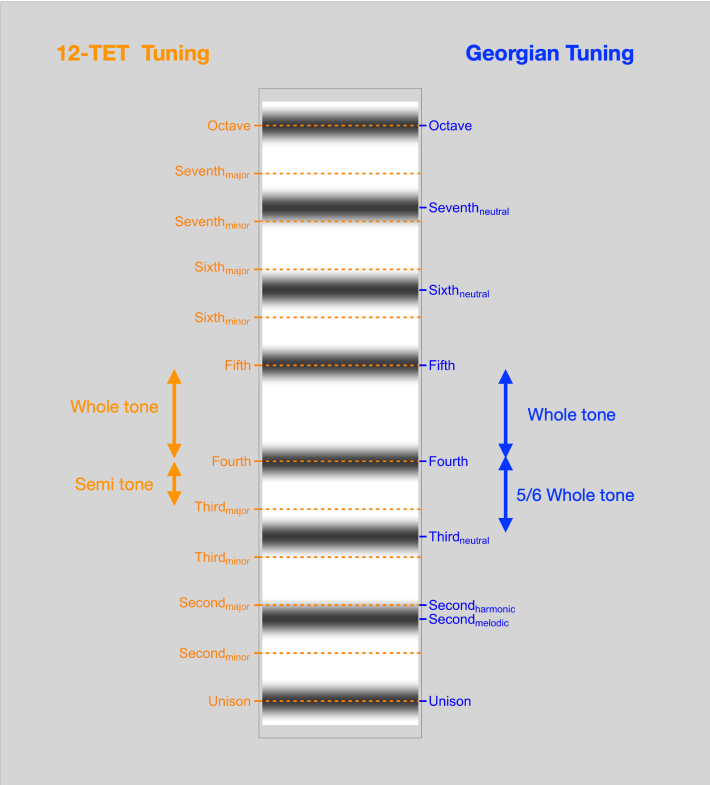

Fig. 5 Comparison of the key elements of the 12-TET tuning system (orange labels) with the essential characteristics of the observed tuning systems in traditional Georgian vocal music based on the work of Scherbaum et al. (2020, 2022) (blue labels). The generic synoptic pitch distribution shown as density plot in the middle was generated by combining the key elements of the average scale models derived from the Erkomaishvili dataset (Rosenzweig et al., 2020; Scherbaum et al. 2020) with the average tuning systems obtained from all Svan ensembles (Scherbaum et al., 2022).

The intervals used in Georgian tuning (blue in Figure 5) generally fall between the small and large intervals utilized in Western tempered tuning (orange in Figure 5). What implications does this hold for traditionally Georgian songs notated in Western musical notation? Specifically, when using Western score notation for traditional Georgian music, and the derived melodic-harmonic representations, artificial semi-tones arise which do not reflect traditional performance practices. However, Figure 5 also reveals that the differences between traditional Georgian tuning and the tempered tuning on which Western musical notation is based are comparatively small for pure intervals (fourth, fifth, octave, prime).

Since in traditional Georgian performance practices, harmonic semi-tone-intervals occur only very rarely if at all, major and minor thirds are not fundamentally distinguished by singers when they sing in Georgian tuning; instead, their thirds usually vary around an average of

350 cents, sometimes referred to as a neutral third. The same applies to other non-pure intervals, such as the sixth and seventh.

Therefore, it seems unjustified to attempt to interpret traditional Georgian songs or individual chords within the major and minor schemes of Western music. The same applies to attempts to interpret this music according to Western church modes, since these modes differ not in the used pitch inventory but only in how the two semi-tone-intervals of the 12-TET system (which presumably are not part of traditional Georgian tuning systems) are arranged in relation to the lowest note of the scale[9].

Using the example of the Svan song *Elia Lrde* shown in Figure 6, it is illustrated below how, within the framework of the Harmonygram concept, one can address and partially compensate for this problem.

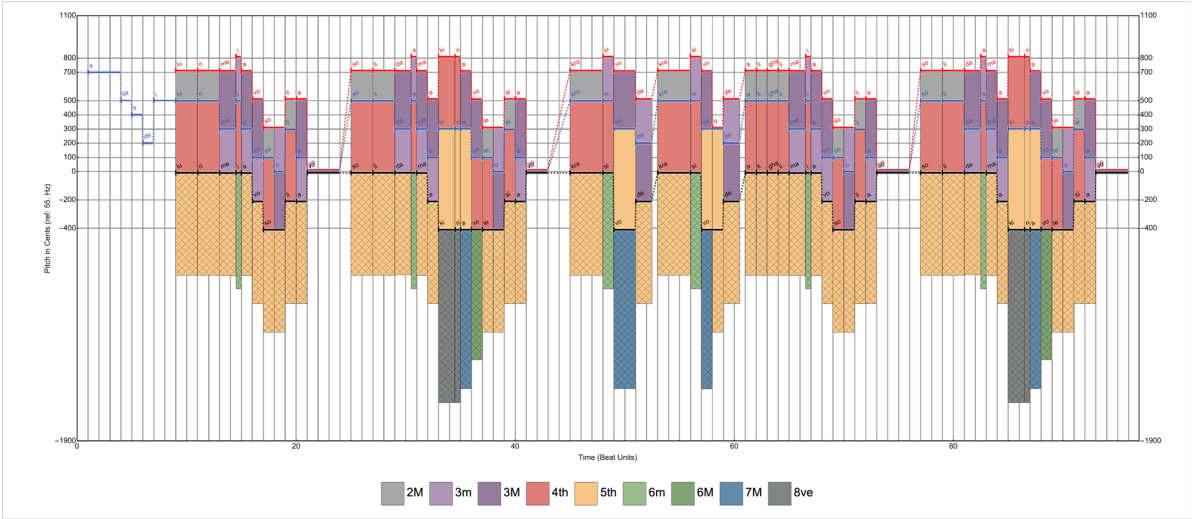

Fig. 6 Harmonygram of the Svan song *Elia Lrde*.

As depicted in Figure 6, this song is harmonically composed primarily of pure intervals. Following a monophonic introduction, the polyphonic section begins with the aforementioned 1-4-5 chord, followed by a chord progression where the bass voice and the upper voice move in parallel fifths. The middle and upper voice move in intervals of thirds until the first unison at beat 21 (except where another 1-4-5 chord occurs), which, when notated in Western notation, appears as a sequence of major and minor chords. One should be aware that this is a distortion introduced by Western musical notation, as neutral intervals cannot be easily[10] represented within this system.

[9] The seven Western European church modes can all be derived conceptually from the white keys of a keyboard by starting with different tones and adding the tones of the seven white keys arranged above them. For the Ionian mode for example one starts with a C while for the Mixolydian mode with a G.

[10] As a workaround, some transcribers have used arrows or other graphical signs attached to particular notes for this purpose.

Within the Harmonygram concept, two straightforward approaches present themselves for addressing this issue, first transformation of all pitches into scale degree indices (SDIs) and second, the approximative transformation of all pitches into a chosen (Georgian) tuning system. The technical details of the implementation of these mathematical transformations are omitted here, but are described in detail in Scherbaum et al. (2023 b).

Transformation of pitches into Scale Degree Indices (SDIs)

In essence, this approach involves replacing the absolute pitches (in cents) by the number of scale degrees that a note differs from the chosen reference note, in our case from the last note of the bass voice melody. This assigned number is referred to as the Scale Degree Index (SDI), starting at 0 for the reference note. A note with an SDI of 2 is therefore positioned 2 scale degrees above the reference note, and correspondingly below if marked with a negative sign. Figure 7 illustrates the song *Elia Lrde* in this tuning-system-independent representation, where the specifics of the tuning system, i.e., the concrete interval sizes that occur, are not considered. The use of this representation somewhat aligns with the chironomic practice of some choir directors, who approximate pitch levels by the position of their hands or by associating a note with a finger of one hand. In Figure 7, the color scale of the interval columns shows all non-pure intervals as neutral ones, indicating that there is no longer a distinction between major and minor intervals, thereby resolving this issue.

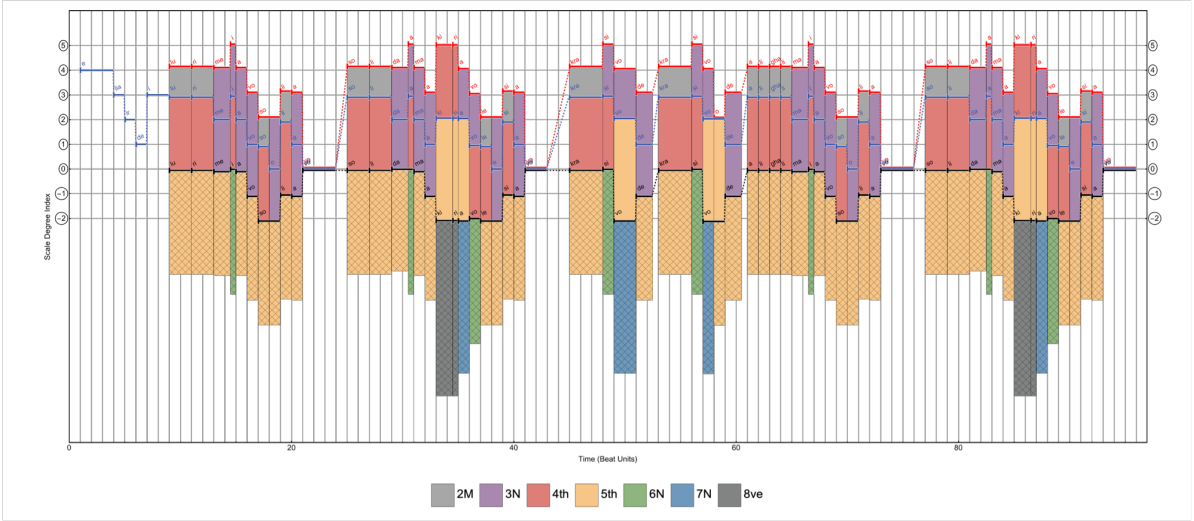

Fig. 7 Harmonygram of the song *Elia Lrde* in Scale Degree Index (SDI) notation.

Transformation of pitches into a chosen heptatonic tuning system

For practical application using the SDI notation (Figure 7) in singing practice, the tuning system of the song must be already internalized, for instance, through listening to the repeated singing of the teacher or to audio recordings. This requirement can be bypassed somewhat by the second approach, namely by using a specific chosen heptatonic (7-interval) tuning system, here as example the SMRM23 system described by Scherbaum et al. (2023). The resulting Harmonygram is shown in Fig. 8. In this case, the absolute positions on the Harmonygram can be interpreted again as absolute pitches. As can be seen in Fig. 8, similar to the case of SDI notation, all non-pure intervals, except for the second, now appear as neutral ones and can no longer be misinterpreted as building blocks of major or minor chords. An assumption behind the SMRM23 model is that the harmonic fourths and fifths appear as pure intervals (498 and 702 cents, respectively). This is accommodated during the transformation into this model via a dynamic intonation adjustment model for those note pitches which contribute to a pure harmonic interval[11]. All the seconds in this song are now shown as major intervals since they only appear as a byproduct of a pure fourth and a fifth.

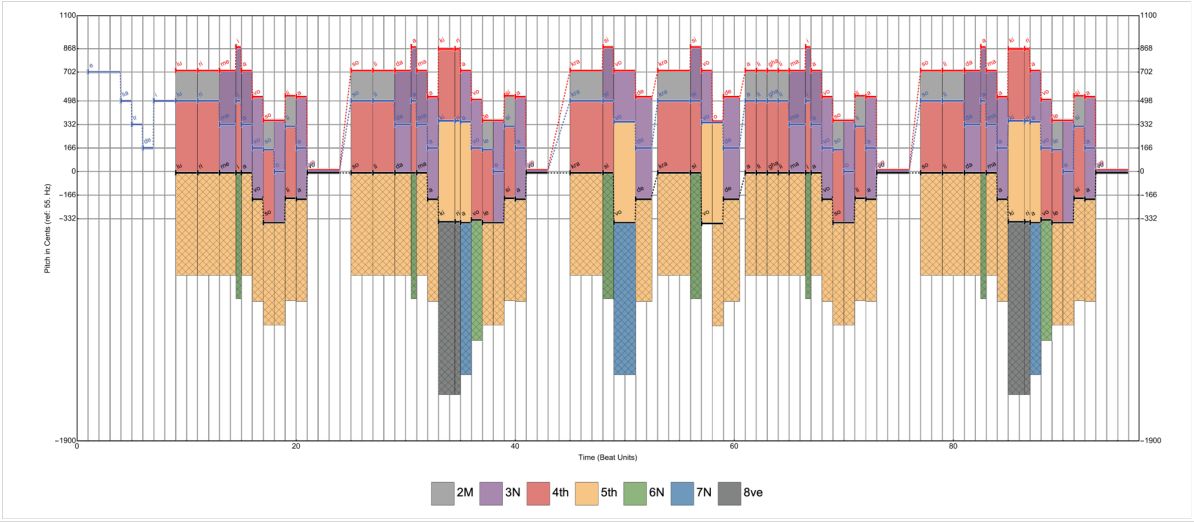

Fig. 8 Harmonygram of the song *Elia Lrde* represented in the SMRM23 tuning system.

[11] Mathematically this is a non-unique problem for which several solutions exist. In Fig. 8, the solution which results in the smallest total adjustment was chosen. An equally justifiable adjustment model could be to leave individual voices unadjusted. A more detailed discussion of this problem, however, is beyond the scope of the present paper.

Discussion and conclusions

As Siegfried Nadel observed nearly 100 years ago, the tonal organization in traditional Georgian vocal music defies description through a rigid scale system with a fixed interval structure. Melodic and harmonic constraints interact, leading to, in Nadel's words, a demand for "pure harmonies at the main and resting points of the melodic line." Additionally, considering that the tonal system of traditional Georgian vocal music significantly differs from the 12-TET system, it becomes evident once again how challenging the representation of this music is within a Western notation system. Nevertheless, western score notations of traditional Georgian vocal music are in heavy use by non-Georgian and Georgian musicians alike. Does this mean that all users of Western score notation believe that the music should be performed in tempered tuning? From discussions with Georgian singers and ensemble leaders like Malkhaz Erkvanidze I know that this is not the case. Instead, some of the experienced singers and choir leaders can mentally adjust for the differences between Western notation and the tuning system which they believe to be the appropriate one. For the 'mortals' among us who can not, I believe that the Harmonygram concept may offer an elegant workaround which eliminates the need for a mental correction. It also eliminates the need to learn how to read Western score notation. The biggest advantage, however, in my opinion, is that the harmonic content of a song can be perceived in a similar way to the melodic content, reducing the focus on the melodic aspects of a song that underlies many Western song learning practices. In other words, it allows us to recognize the harmonic structure of a chord or the whole song as quickly and as intuitively as the melodic content while Western score notation still requires a thinking process to derive the harmonic structure of a song from the score. And even if this can be sped by training to some degree, it is impossible to perceive the whole chord progression structure, including repetitions or variations of chord progression patterns of a whole song in a single glance. This, however, becomes easily possibly with Harmonygrams, even for lay people, since it all boils down to recognizing simple visual patterns.

Finally, how could one possibly visualize how the importance of melodic and harmonic constraints changes in the course of a song? One idea that suggested itself in this context from a Harmonygram perspective, and which is presented in Fig. 9, again for the song *Elia Lrde*, not as a final answer but as a stimulus for discussion, was to reduce the display of the interval

columns of the Harmonygram to only those which belong to pure intervals and their byproducts[12].

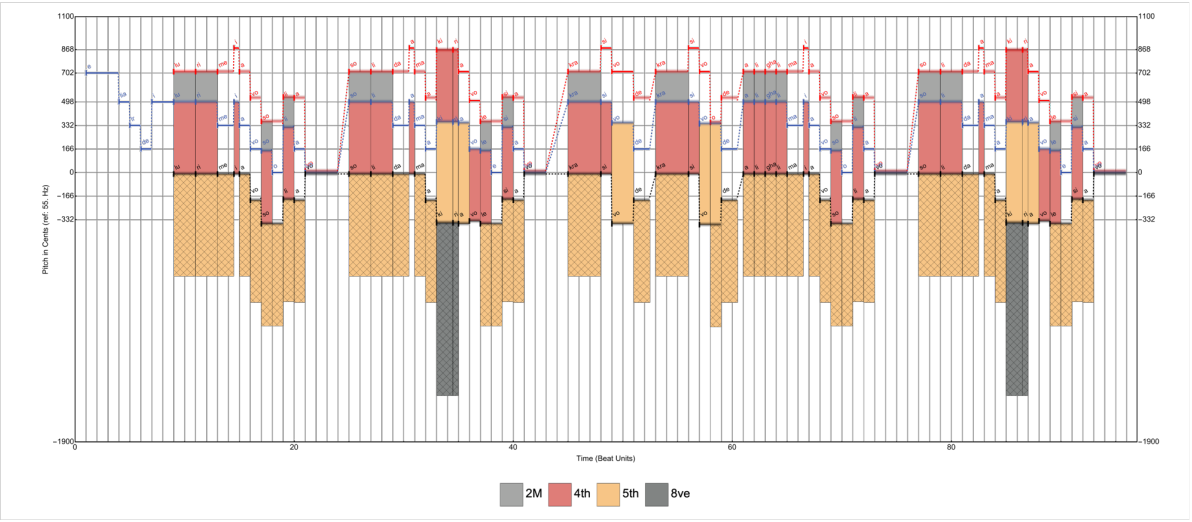

Fig. 9 Harmonygram of the song *Elia Lrde* represented in the SMRM23 tuning system with the restriction on pure intervals and their byproducts. The stems of the note symbols in Global Notation for those notes which contribute to a pure interval are blurred to indicate that these notes might be subject to harmonic intonation adjustments.

To further illustrate the potential benefit of the combined use of Global Notation (Killick, 2020) and the Harmonygram concept, the stems of the note symbols in Global Notation for those notes which contribute to a pure interval are blurred. This is supposed to illustrate that singers might accommodate the pure harmonic intervals (wherever they appear in the song) by harmonic intonation adjustments[13] (indicated by the blurring of the note stem). In contrast, the notes shown as unblurred symbols are not subject to such harmonic constraints. For a singer, the blurring of a note stem might therefore indicate places in a song, where it becomes particularly important to carefully listen to the other voices and potentially adjust the tuning or to identify places where one can easily check if one is still in tune[14].

The British statistician George Box is credited with the quote that all models are wrong, but some are useful ("All models are wrong, some are useful"). This also applies to musical notation systems. I don't believe that Harmonygrams are "the only right way" to represent traditional Georgian vocal music. Instead, I see them as an information-rich tool that might help to better document the complex interplay of melodic and harmonic aspects of Georgian traditional vocal music (and other three-voiced music), and as such provide a bridge for both

[12] A typical byproduct is e.g. the major second which appears between the intermediate and highest voice as a consequence of the bass and intermediate voice singing a pure fourth while the bass and highest voice sing a pure fifth.
[13] This is a conjecture based on the results of the analysis of singer interaction in Scherbaum and Müller (2023) which should be further investigated.
[14] From my own experience as a amateur bass voice singer, this is particularly helpful in cases where the interval with one of the upper voices becomes a fifth or an octave.

novices and experts to better understand, appreciate and participate in this rich musical tradition[15].

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[15] Singers, in particular ensemble leaders, who would like to experiment with the use of Harmonygrams in practice, feel free to contact me for material at fs@geo.uni-potsdam.de.

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