CORRELATIONS BETWEEN MAKAM MELODY AND USUL USING SYMBOLIC SCORE DATA ANALYSIS

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ABSTRACT

In this research, we investigate the relationship between the melodic and the rhythmic dimensions of *makam* music. Leveraging a collection of 2200 .xml scores from the SymbTr database, we employ a systematic approach to extract notes and metadata, enabling systematic analysis of a selection of *usul* rhythmic patterns and musical forms. Our primary objective is to explore correlations between note count difference within pairs of beats and *usul* accents, hypothesizing that certain accents in *usul* may correspond to a higher mean value of that difference. Additionally, we also inspect the diachronic aspect of *makam* music, examining if these mean values evolve over the course of a composition. Through statistical analysis and visualization, we aim to deepen into the complex interplay between melody and rhythm in *makam* music, contributing to a deeper understanding of this rich musical tradition.

1. INTRODUCTION

Turkish music has a long and rich history, reflecting the diverse culture of its people over 1,500 years. While there are little written records, fragments of ancient songs have been found through archaeological discoveries and oral traditions. The core of Turkish music lies in its lyrics, which blend literature and melody to express emotions and cultural values. It follows a modal system that has evolved through different periods, while retaining its character.

Ottoman classical music is known not only for its rich modal but also for its rhythmic system. It features melodic modes called *makamlar* (pl. of *makam*) and rhythmic structures called *usular* (pl. of *usul*). textitUsular originated from Ottoman-Turkish music and poetry. Named after the duration and arrangement of their beats, textitusular define the rhythmic structure through a series of accents of varying intensity. These rhythmic patterns form the basis of compositions and provide a flexible framework for improvisation and emotional expression. To investigate Turkish classical music, we examine the connection between textitmakam melodies and textitusul rhythms. Using symbolic score data analysis, we aim to uncover how these crucial elements interact. [1]

Advances in technology have made the computational study of large collections of data, such as recordings and scores, available, allowing us to analyze them in large quantities. SymbTr is one of these collections. It contains a remarkably large library of Turkish music of 2200 .xml scores, which can be a useful tool for researchers who want to carry out work related to this music tradition. SymbTr is available on GitHub at `https://github.com/MTG/SymbTr`. Using SymbTr, we extract data from musical scores.

Our study begins with the hypothesis that there may be a correlation between the presence of a higher difference note onset within two consecutive beats and the presence of an accent that constitutes the underlying *usul* in the second of those beats. To simplify, we are calling this values density variation coefficients, in what follows, DVC.

Using mathematical and visual tools, we hope to uncover patterns and trends that show how the rhythmic contour of the melody and the rhythmic patterns work together in a complex way.

We also examine how *makam* music changes over time, focusing on how these correlations between notes and rhythmic patterns might evolve throughout a piece. This diachronic analysis can help us understand how melody is influenced by and contributes to *usul*.

All the code developed to conduct this research is publicly available in this GitHub repository `https://github.com/alexvilanovab/makam-amplab`.

2. RELATED WORK

As reported in a 2012 review of the state-of-the-art computational analysis of Turkish *makam* music, there is research on the topic which has highlighted the correlation between note durations and *usul* accents [1]. As Holzapfel and Bozkurt show, long note durations often coincide with highly stressed accents, a characteristic observed in both Western and Turkish music. Comparing duration with

[1] Available at: `http://www.turkishmusicportal.org` [Accessed: March 21, 2024]. The Turkish Music Portal belongs to the Turkish Cultural Foundation, an institution established on January 1, 2000, that aims to promote and preserve Turkish culture and heritage worldwide, support education for disadvantaged students in Turkey, facilitate research and publication in humanities related to Turkey, preserve Turkish cultural heritage abroad, and foster cultural bridges between Turkey and other countries for better understanding and appreciation of Turkish cultural heritage.

weight patterns further underscores this correlation, with duration information showing stronger correlation coefficients than onset frequency counts. This underscores the importance of considering both note position and duration in future music analysis tasks [2].

A posterior article by Holzapfel examines how the placement of notes within musical measures, the surface rhythm, matches with *usul*. It also uses analogue *usul* weight patterns to illustrate the hierarchical structure of the meter and compares them to typical meters like the 4/4 eurogenetic meter. Different weights to *usul* strokes reveal variations in emphasis patterns. The research aims to uncover how compositions interact with musical modes and create a sense of musical rhythm within particular *usul* contexts, deepening our understanding of their rhythmic foundations [3].

Our research also explores the link between surface rhythm and *usul* patterns in Turkish music but also uses a different method inspired by Holzapfel's surface rhythm concept. By calculating the note density rate for consecutive beat pairs (DVC), we quantify the distribution of notes within specific rhythmic intervals. This detailed analysis reveals how surface rhythm density changes in relation to *usul* patterns.

3. DATA COLLECTION AND PREPARATION

Our study of Ottoman classical music is based on the computational analysis of musical scores. Central to this research is the concept of *usul*, a rhythmic pattern defined by accents that serves as the framework within which the melody develops.

For our data collection, we focus on a collection of musical scores called SymbTr. This collection, curated by M. K. Karaosmanoglu, Burak Uyar, and Sertan Şentürk, contains 2200 musical scores, which include 155 *makamlar*, 88 *usular*, and 56 forms, and compositions from both Turkish classical and folk music traditions. [4]

To facilitate our analysis, we start extracting and organizing the data of .xml scores, so that it can be easily processed and filtered. Some information appears in the title of each .xml file, following the formula *makam–form–usul–lyrics–composer*, which is fully extracted. However, for a subsequent filtering by *usul* and *makam*, we rely on the expressions annotated in the score, which contain the same information but in the turkish spelling. To extract the data we use music21 python library.

The fields of the built DataFrame include path, *makam*, form, *usul*, lyrics, composer, poet, work title, bar count, time signature and DVC. The DVC, as previously mentioned, will serve as our primary resource for analysis. All these fields provide useful contextual and structural information for our investigation, some of which are used for different classification purposes. Changes in *usul* or *makam* during the composition are also retrieved in the DataFrame.

Since our main variable is the *usul*, for the statistical analysis we only consider the pieces that feature one single *usul* in the whole development. For this reason, we also incorporate this information into our DataFrame. Each measure has *usul* information in order to be easily filtered.

Although this is not an ideal solution, we have chosen it because in a subsequent analysis, we give importance to the temporal aspect, and therefore we do not calculate get the complications involved in having fragments in different *usul* in the context of a composition in development.

4. METHODOLOGY

In this section, we outline our systematic approach to analyzing the relationship between the melodic structure of *makam* music and the rhythmic patterns of *usul*. Our methodology involves a combination of computational procedures, statistical analysis and visualization techniques to showcase correlations and patterns within the musical data extracted from the SymbTr database.

4.1 Data selection

For the analysis, we filtered the database to compositions with six specific *usular* analyzed by Holzapfel and Bozkurt: *aksak*, *curcuna*, *düyek*, *semâî*, *sofyan* and *türk aksağı*. [2] This step ensures that we only consider music scores with these patterns. After this first step, 1034 pieces have been discarded. After creating a database of compositions, we organized based on their form. This initial step helps in choosing a smaller group of scores for more detailed study. The study focuses on *şarkı* and *türkü*, the two most common musical forms in the selection, as you can see in Figure 1. Although there is a significant difference in the number of *şarkılar* and *türkü* in the selection, both forms are still well-represented in the collection. Both are secular vocal forms. If the comparison shows statistically significant differences, other genres should be tested and compared as well.

4.2 DVC Analysis

4.2.1 *Calculation Process*

We explored the possible correlation between the difference in density of onsets for each beat with respect to the previous one, with the theoretical accent on the *usul*. Our hypothesis is that there may be large-scale correlations. Not only the number of onsets is taken into account, but the difference from the previous one also takes into account the cases in which we go from more rhythmic activity to less, so that the resulting value will be an entire number. We compute the density variation coefficient for each pair of adjacent beats for each measure in every piece in the filtered dataset. In computing this metric, we exclude grace notes.

4.2.2 *Barplots*

The barplot is an effective tool to visualize the data as it allows a direct comparison to be made with the representations of the *usul* taken as reference by Holzapfel and Bozkurt [2]. In Figure 3 you can see respectively the six selected *usular* models, in which the accents are defined at three levels of emphasis compared with average density differences computed for the score selection inf Figure 2.

4.3 DVC variation analysis

4.3.1 Calculation Process

At this point, we analyze the evolution of the descriptors obtained. The starting intuition is the following: as a piece develops, the melody can progressively emancipate itself from the *usul*. Such emancipation would translate into a 'softened' rhythmic texture, less conditioned by accents or, if not, into a slightly greater homogeneity in relation to rhythmic density.

For this purpose, we start from the selection of pieces, of the *türkü* and *şarki* forms, in the six *usular*.

Using a linear regression, we studied the tendency of the DVC for every particular beat of every piece in the score selection. The objective is to see if the DVC for a given beat tends to be higher or lower as the piece progresses. This trend is encoded in the slope obtained. A positive slope would mean that for the given beat, the variation of note density with respect to the previous beat is accentuated. A negative slope would mean an attenuation. A flat slope means that the change is not related to the development of the piece (null hypothesis). Figure 6 shows an example for the 7th beat DVC behavior in a *şarki* in *usul aksak*.

Then we compute the t-statistic and, finally, we aggregate the means of the t-statistics for all the pieces for a beat. Determining the significance of each beat of the pattern separately is essential because they occupy unique positions in the *usul*, and may behave differently over the course of the pieces.

4.3.2 Boxplot visualization

The boxplot visualization shows the distribution of t-statistics for each beat and part, as well as the aggregate mean. Figure 7 shows a boxplot with DVC variation means slope values distribution for each beat in *usul aksak*. Since the overall results do not show a significant behavior, boxplots for every *usul* are not discussed, but they are publicly available at the project's repository.

5. RESULTS

5.1 DVC

The results show that, in general, there is a clear relationship between changes in rhythmic density. In the six *usul* analyzed, we found the maximum increase in rhythmic density in the first beat. In general, it is observed that there is an increase in rhythmic activity coinciding with the accents of the theoretical models. However, it is interesting to observe how this correlation is subordinated to an increase in activity that precedes the more emphasized accents. Specifically, in *semâî* there is a dramatic decrease in activity in the second accent, while it increases in the third, which could be understood as an announcement or anticipation of the new first beat. The same phenomenon occurs in *türk aksağı*. Although the decrease in activity is much more pronounced in the fourth accent, which indicates that the absolute activity of the fifth accent should be lower than in the third, there is a greater increase than in the third accent, which in relative terms one can discuss what effect it has on the listener.

In *curcuna*, the positive values are in perfect agreement with the theoretical model, and that the emphasis on the third pulse stands out, even though it is a less emphasized accent, it significantly increases its rhythmic activity as a preview of the fourth pulse. This fact finds parallels in the peak of variation in *düyek*'s fourth beat, which anticipates a strong accent.

5.1.1 Makam Breakdown Analysis

The six most present *makam* and their number of appearances in the selection of pieces in the six selected *usul* are *hicaz*, 90, *nihâvent*, 84, ussak, 69, *hüzzam*, 63, *rast*, 58 and *mâhur*, 51. A comprehensive figure of the results is provided in the appendix (see Figure 4).

This breakdown analysis shows the consistency of the indicator studied in relation to the *makam*, although there are some exceptions that deserve comment. The behavior of the *makam hüzzam* in *usul sofyan* is practically reversed. A more detailed analysis and a larger sample would be necessary to contrast this trend and to see if it can be correlated with other characteristics, such as type of composition or tempo.

For the *makam hüzzam*, the high value for the last beat also stands out in relation to the value close to 0 for the first beat, which means that there is hardly any change in rhythmic density. In this case, there is also a somewhat larger sample of 21 works.

The overall consistency of the results still needs to be evaluated, as does the significance of the magnitude of the values obtained, which is beyond the scope of the work at this stage. But the contour remains consistent, with a remarkably constant sign ratio for the values, so that *makam* effects seem to be, if anything, minor.

5.1.2 Form Breakdown Analysis

An analysis of the *şarki* and *türkü* forms shows differences in the sign of the DVC means in the last beats of the *makam semâî* and *şarki* (see Figure 5). A positive variation means more note density, which can be interpreted as a reactivation of the rhythm and a more anachrusic value for the *şarki* form.

The greater coincidence of activity increments with major accents in the results for *türkü* indicates more defined rhythmic contours. We obtain fewer beats with a positive sign for DVC in the *makam semâî*, *türk aksağı* and *sofyan*, the latter with a sample of 73 scores. In the case of the *şarki*, the last beat for the *makam semâî* and *türk aksağı* shows a medium increase in note density while for the *sofyan* it shows a slight increase in beats 2 and 3.

For the *makam curcuna* the increase is also slightly more concentrated in the accents when it comes to pieces of the *türkü* form.

5.2 DVC variation

The analysis of the DVC variations for each beat and part shows a general trend of decreasing coefficients. The example in Figure 6 is one of many cases where the t-statistic shows the variation to be significant (p-value > 0.05). However, we are talking about the behavior on specific beats for specific parts. While the aggregation of the t-statistic means also shows a trend toward values less than 0, the result is not considered significant for any of the means for any *usul*.

The result shown in Figure 7 is very similar in practically all cases, obtaining slope averages with negative sign and close to 0. For the means of the t-statistics, a p-value < 0.05 is always obtained, which is not sufficient to speak of a significant relationship. On the other hand, the values of all the means have a negative sign, suggesting a regularity.

From these results, we can say that the general behavior does show a trend, but too subtle to be significant. A more detailed study might uncover significant results for some sub-selections.

6. CONCLUSION

Compositions have distinct sections, being *şarkılar* often divided into different *hane* or sections. Of particular relevance to the present study, *türkü* and *şarki* forms often include instrumental sections, such as *saz* and *aranağme*, which may feature rhythmic texture changes. A subsequent analytical step could involve extracting similar information while distinguishing between different types of sections, especially if the information obtained from the analysis could be better encoded in a combination of factors, on the one hand, the same information extracted from these parts and, on the other hand, an analysis of how the *saz* and *aranağme* evolve within the *şarki*.

Another way to develop the work would be to consider the *seyir*for each *makam*. In this case, it would be interesting to contrast the statistically significant differences obtained in the results of the DVC for each *makam* in order to find an explanation for them in the theoretical framework of the *seyir*.

During the "data selection" phase, the statistics for the note density difference are calculated for the *usular* without taking into account the distinction of the time signature denominator. For our purposes, we didn't deepen the analysis in this direction, but it might be interesting to consider it. The analysis of the presence and distribution of grace notes is an interesting research that could complement the work done.

In the "DVC analysis", the results derived from the calculation of the density variation coefficients in the rhythmic activity show congruence with the theoretical accent models of *usular*. While the interpretation of these parallels may be complex, they underscore the importance of this metric as a useful indicator for characterizing the relationship between melodic and rhythmic dimensions. Its utility may also extend to serving as a descriptive feature within machine learning frameworks.

Regarding the "DVC Variation Analysis", as *türkü* form seems to be a wide definition that includes compositions in several genres, information obtained from it might be less useful as a descriptor, something that should eventually be explored in a later phase of research. While counting and comparing notes seems to have a musicological meaning, a more subtle analysis could be made by considering the different durations of the notes. Thinking about the effect of different duration distributions could lead to more complex, but perhaps more meaningful, descriptors. Future research should consider extending analogous analyses to instrumental compositions, such as *saz semâîsi*. Given their frequent changes in usage, adjustments to the processing methodology would be necessary. Investigating the variation slope of density across different forms with a sufficient number of scores could provide valuable insights.

The results obtained should be evaluated with caution. Its possible usefulness as an identifying descriptor of a *usul* through melody is subsidiary to whether it provides information that is not already somehow included in the rhythmic analyses performed by Holzapfel and Bozkurt. At the same time, the different categories of metadata could be used as criteria for expanding the analysis in different directions.

While the DVC is congruent and sufficiently consistent, the DVC variation does not seem to provide significant information. A category search for a different breakdown of results could show whether it makes sense to extract this descriptor in limited contexts.

7. REFERENCES

[1] B. Bozkurt, R. Ayangil, and A. Holzapfel, "Computational analysis of turkish makam music: Review of state-of-the-art and challenges," *Journal of New Music Research*, vol. 43, no. 1, pp. 3–23, 2014.

[2] A. Holzapfel and B. Bozkurt, "Metrical strength and contradiction in turkish makam music," in *Serra X, Rao P, Murthy H, Bozkurt B, editors. Proceedings of the 2nd CompMusic Workshop; 2012 Jul 12-13; Istanbul, Turkey. Barcelona: Universitat Pompeu Fabra; 2012. p. 79-84*. Universitat Pompeu Fabra, 2012.

[3] A. Holzapfel, "Relation between surface rhythm and rhythmic modes in turkish makam music," *Journal of New Music Research*, vol. 44, no. 1, pp. 25–38, 2015.

[4] M. K. Karaosmanoğlu, "A turkish makam music symbolic database for music information retrieval: Symbtr," in *Proceedings of 13th International Society for Music Information Retrieval Conference; 2012 October 8-12; Porto, Portugal. Porto: ISMIR, 2012. p. 223–228.* International Society for Music Information Retrieval (ISMIR), 2012.

A. APPENDIX

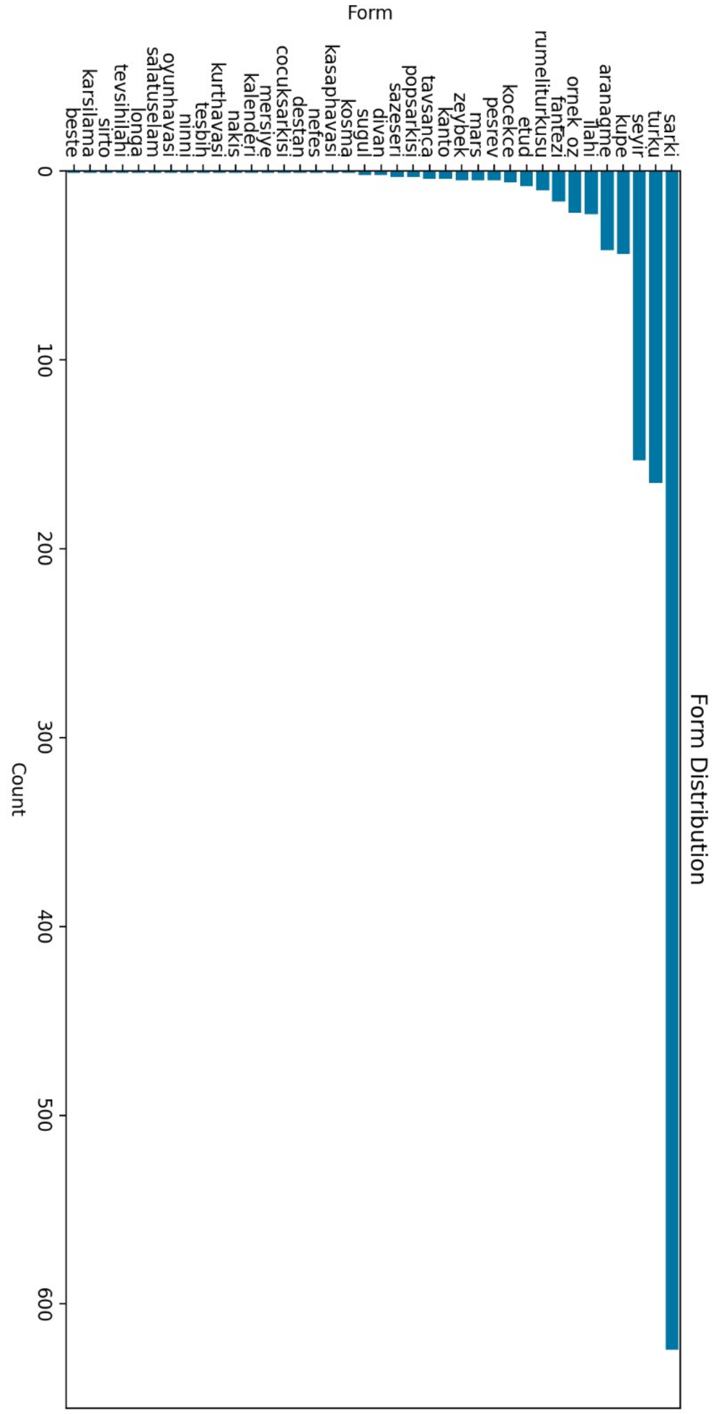


Figure 1: Form distribution in filtered score collection.

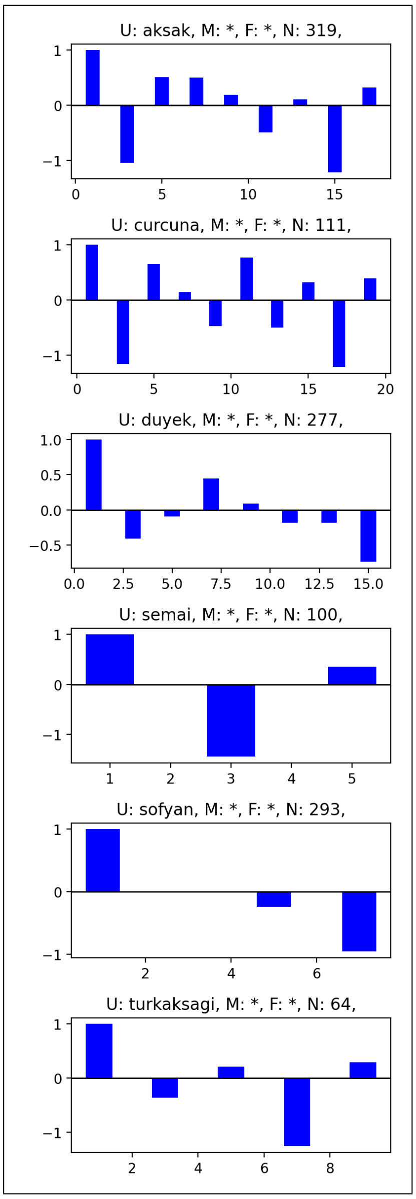


Figure 2: DVC means by *usul* for score selection

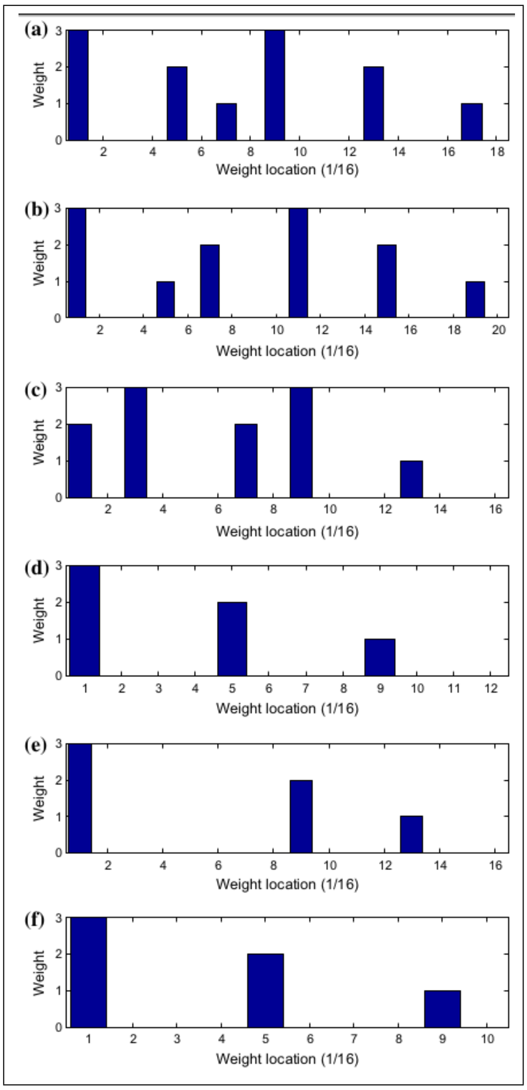
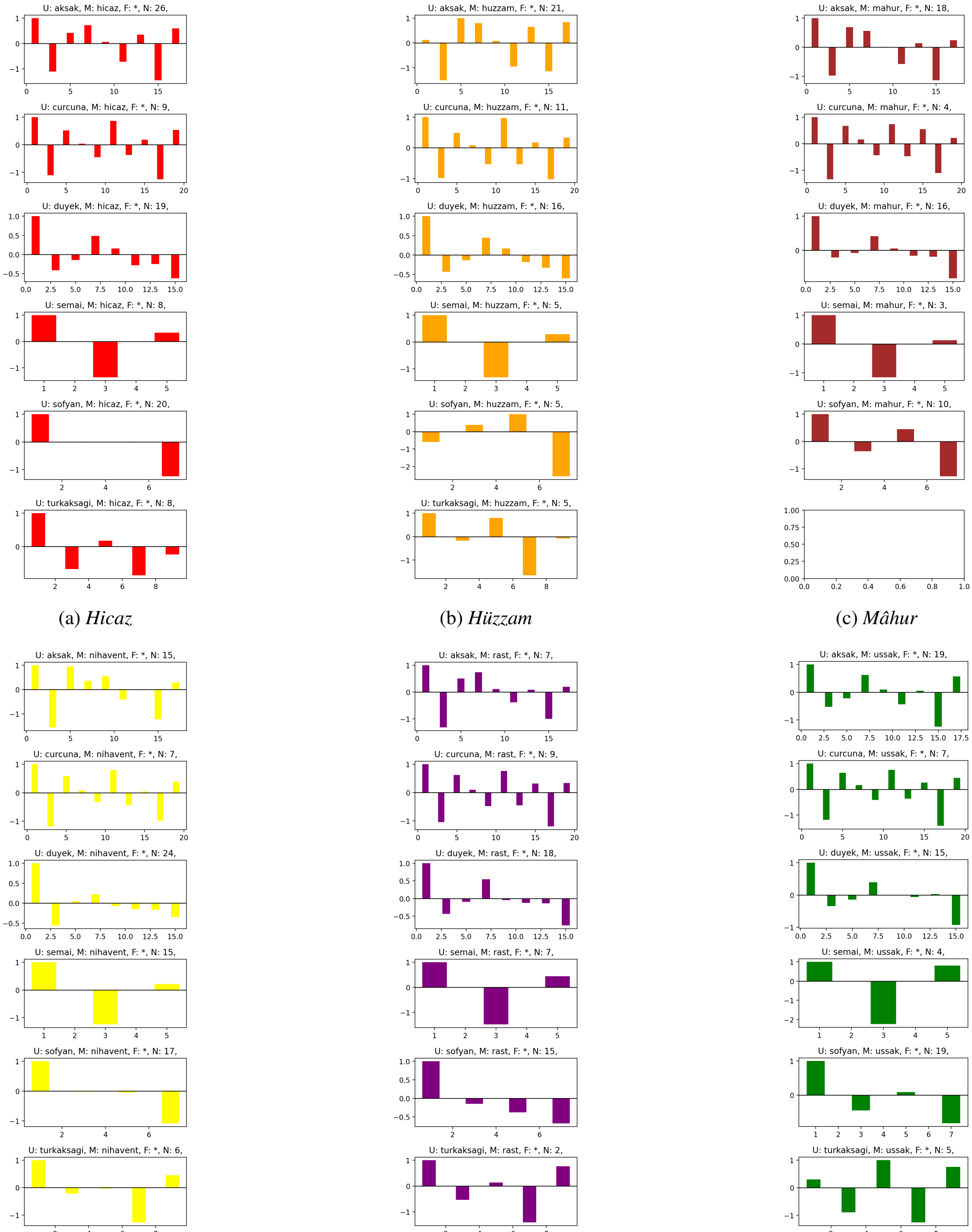


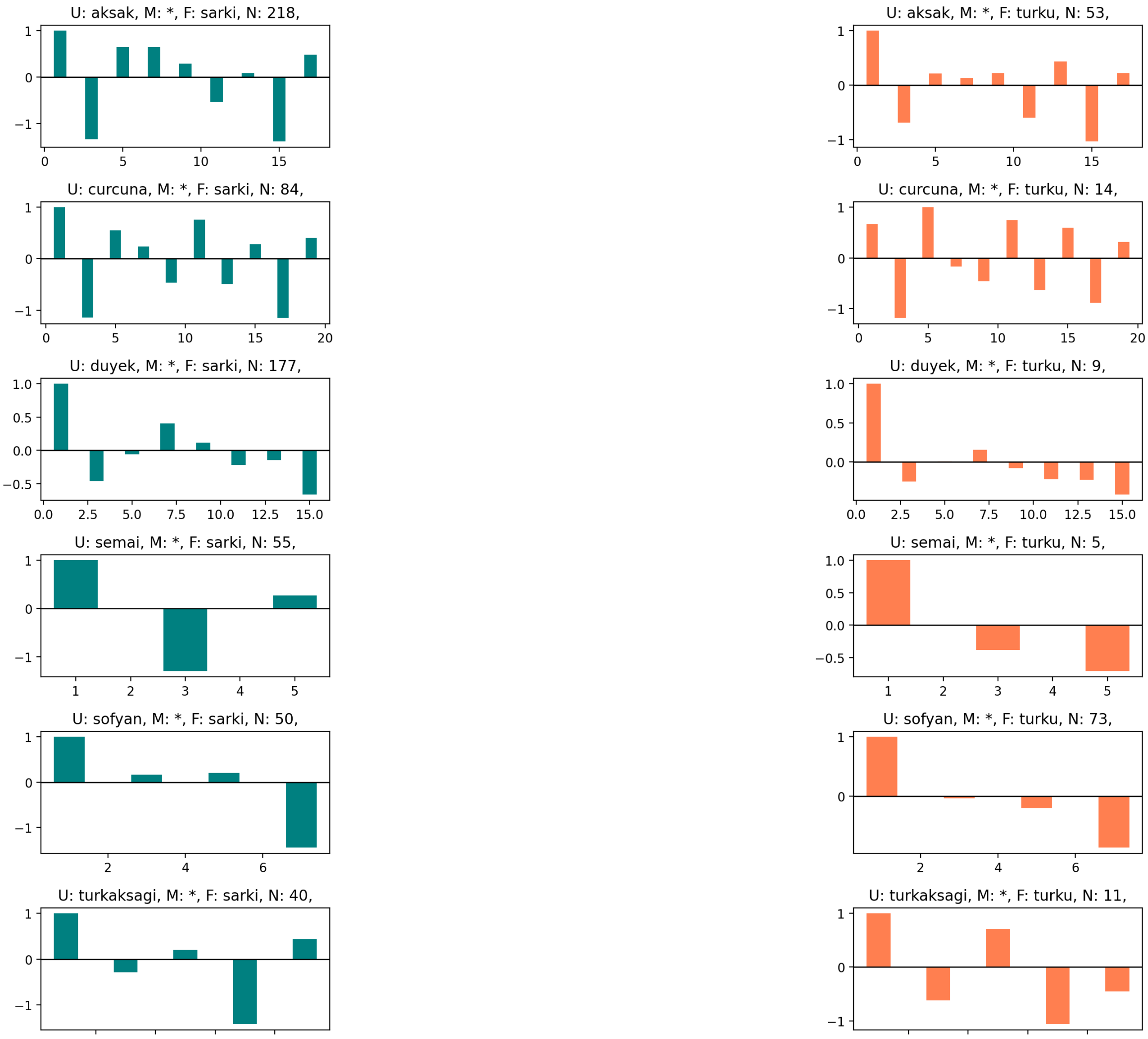
Figure 3: Theoretical accent model for six target *usular*. Figure by Holzapfel and Bozkurt. [2]



(a) *Hicaz* (b) *Hüzzam* (c) *Mâhur*

(d) *Nihâvent* (e) *Rast* (f) Ussak

Figure 4: DVC means for six most frequent *makamlar* in the selection.



(a) *Şarkı*　　　　(b) *Türkü*

Figure 5: DVC for *şarki* and *türkü* forms.

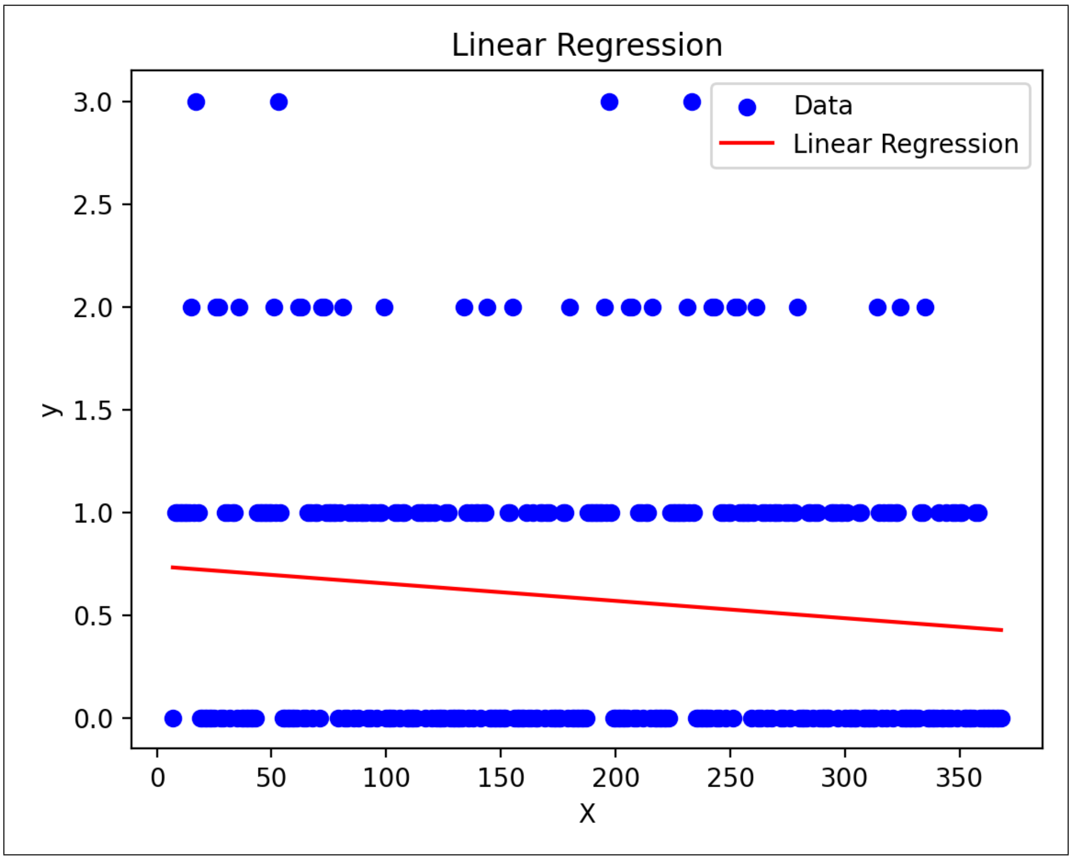


Figure 6: Linear regression for the 7th beat for a particular *şarki* composition in the collection in *usul aksak*.

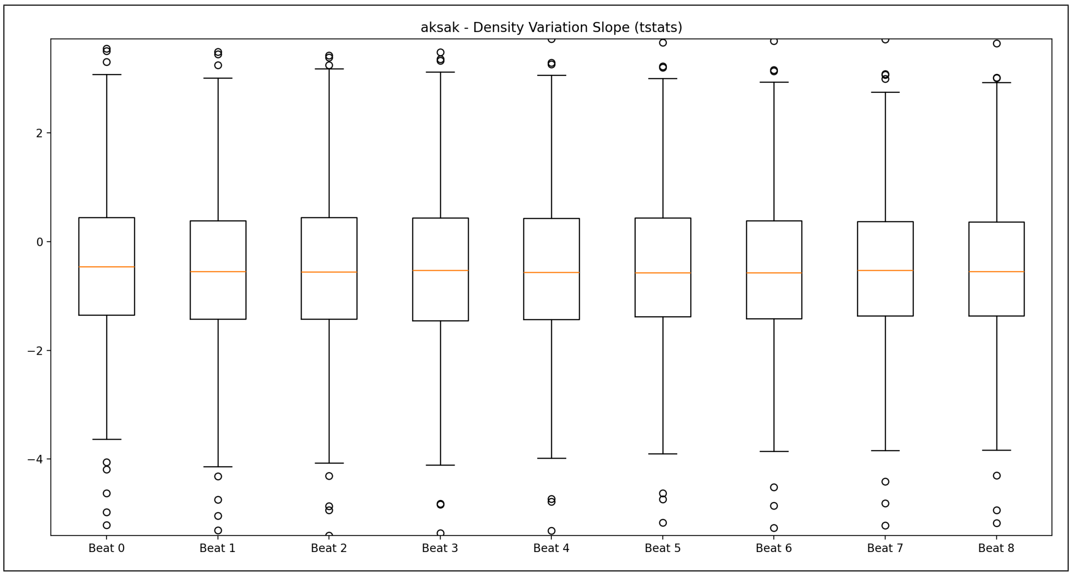


Figure 7: DVC variation slope means for each beat in *usul aksak*.