AUDIO FEATURE EXTRACTION FOR EXPLORING TURKISH MAKAM MUSIC

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ABSTRACT

For Turkish makam music, there exist several analysis tools which generally use only the audio as the input to extract the features of the audio. This study aims at extending such approach by using additional features such as scores, editorial metadata and the knowledge about the music. In this paper, the existing algorithms for similar research, the improvements we apply to the existing audio feature extraction tools and some potential topics for audio feature extraction of Turkish makam music are explained. For the improvements, we make use of the Turkish makam music corpus and the culture specific knowledge. We also present a web-based platform, Dunya, where the output of our research, such as pitch histograms, melodic progressions and segmentation information will be used to explore a collection of audio recordings of Turkish makam music.

1. Introduction

To gain an analytical understanding about a music tradition and the relations between its descriptive attributes, it is useful and practical to get the help of the computational methods. Taking the advantage of the improvements in information retrieval and signal processing areas, we can organize large amount of data, navigate through large collections and discover the music genres, etc. By using the computational methods, more data can be processed in less time compared with the manual research methods. What is more, music exploration systems can be designed specifically for different traditions according to their specificities.

A definition for an exploration system is “a platform that provides new technologies, interfaces and navigation methods to browse through collections from specific music cultures” (Porter et al 101). A music exploration system allows users to reach the musical content in a structured way or provides tools to analyze the attributes of the music. This structure can be designed according to the aim of the system and can be organized in many different approaches. Currently, there are several examples for the music exploration systems. One of them is Sonic Visualiser(Cannam et al 324), which is an exploration system that visualise low-level and mid-level features from the uploaded audio recording. Another music exploration system is Musicsun(Pampalk and Goto 101), designed for artist recommendation.

Our study is the Turkish makam music branch of the CompMusic project (Serra 151). In the CompMusic project, our aim is to explore music cultures other than the Western popular by taking advantage of the advancement in Music Information Retrieval. We work on extracting musically meaningful descriptions from audio recordings by using research tools and support these descriptions with additional information, such as *music scores* or *editorial metadata*. Besides this, we develop an application “*Dunya”*(Porter et al 101), where we can evaluate our research results from a user perspective. Dunya is a web-based exploration system that users can reach our research results easily.

For this kind of research and studies, there is a need for a corpus which should mainly include audio recordings. By analyzing the audio recordings using computational methods, different aspects of a music tradition can be understood. In addition to the audio recordings, it is beneficial to have related supportive information from the music tradition (e.g. *culture-specific knowledge*). This information helps studies to be multi-directional and understand the connections between them. At the same time, the corpus should contain data as much as possible with a high degree of diversity in order to represent the tradition well enough for research. For these reasons, we use Turkish makam music corpus (Uyar et al 57) in our research. This corpus includes audio recordings, music scores and editorial metadata. By using the different data types in this corpus we are able to conduct our experiments based on the features we are interested in.

In the context of music, features give semantic information of the analysed material. In our methodologies, we use features and other relevant information (e.g. *metadata, music scores and culture-specific knowledge*) to understand the characteristics of Turkish makam music. Because the features are our main focus in our study, we have created a feature list to decide and classify the attributes we plan to extract from the corpus to discover Turkish makam music tradition. By using this list, we can prioritize and follow-up our experiments in a structured way. While developing our methodologies, we examine the existing studies on similar problems and, if available, we modify the best-practices aptly to our case. In this paper, we present the extracted features and the features we plan to extract for Turkish makam music to include in Dunya. Moreover, we explain new methodologies for extracting the predominant melody and pitch distribution.

The paper is structured as follows: In Section 2, we briefly explain the key attributes and characteristics of Turkish makam music. In Section 3, we describe the corpus we are using for our research. In Section 4, our music exploration platform, *Dunya*, is presented. In Section 5, we explain the features related to our study and in Section 5, finalize the paper with a brief conclusion.

2. Turkish makam music

In Turkish makam music, there are three main concepts to explain the main attributes of the pieces. These concepts are *makam, usul* and *form*. *Makams* mainly constitute the melodic aspects and are modal structures which have initial, dominant and final tones. The melodic progression starts around the initial tone, moves around to the dominant and goes to the final tone in the end, which is also called as *tonic*. These tones and the melodic progression are used to describe a certain makam. *Usuls* include strokes with different velocities to describe the rhythmic structure. Usuls can be very basic with one strong and one weak stroke or a specific usul can include the combination of multiple usuls.

In the practice of Turkish makam music, musicians have large room for interpreting a music score and may add many ornaments while playing. With this concept, Turkish makam music is more of an oral tradition. On the other hand, this tradition has been represented by using a modified Western notation for the last century. The scores include the main melodies and musicians interpret the scores with their own approaches. The most accepted theory is Arel-Ezgi-Uzdilek(AEU) (Arel) . This theory approximates to the 24 tones in an octave by using the 53-TET system, which divides a whole tone into 9 equal pieces.

Another characteristic of Turkish makam music is *heterophony*. In the performances the musicians play the melody in the register of their instruments or vocal range. However, each musician applies their own interpretation to the melody by adding embellishments, expressive timings and various intonations. The musicians might adjust tuning of the instruments among each other according to the makam, or personal taste. The tonic frequency is also not definite as it may be adjusted to a number of different transpositions, any of which could be favored over others due to instrument/vocal range or aesthetic concerns.

3. Turkish makam music corpus

Within the scope of the CompMusic project, one of the most important tasks is to create music corpora, which represent the music traditions to be studied. The aim of preparing such corpora is to facilitate research on the music traditions by providing well-structured and representative data. These corpora are tailored considering the criteria of purpose, coverage, completeness, quality and reusability (Serra 1).

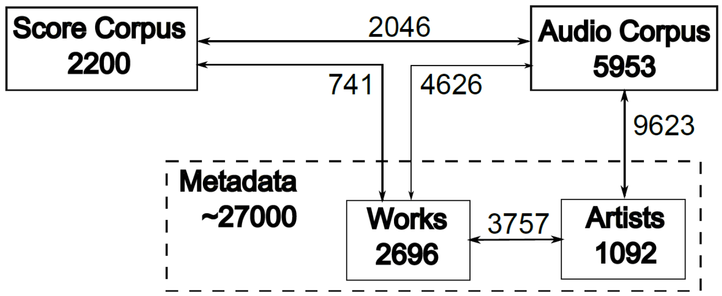

Figure 1: Numbers of entities in each data type of corpus and the relations between them.

In the Turkish makam music corpus (Uyar et al 57), there are three main types of data: *audio recordings, music scores* and *editorial metadata*. There are 5953 audio recordings in the corpus, which consist of commercial/non-commercial releases as well as bootleg concert recordings. 150 distinct makams, 88 usuls and 120 forms are performed in the audio recordings. In the score corpus, there are 2200 machine-readable score files from 157 makams, 82 usuls and 64 forms. The main source for the metadata is MusicBrainz and there are ~27000 entries related to the corpus. These entries include all available information about the entities such as album cover information, biographies, lyricists and makams. These relationships allow the researchers to use different types of data sources or combine them for a specific study or experiment. Some of the possible studies are explained in Section 5.

To easily access the data sources and the relationships, we make use of a simple database which stores the audio recording path, related score file's path, MBID[1] of the recording, MBID of the related work on MusicBrainz and the related culture-specific metadata, (i.e. *makam, usul, form*). By using MBIDs, the metadata on the album covers and the detailed information of the metadata can be accessed as well, (e.g. *biography of the artist*).

4. Dunya

Dunya is planned to be a platform where the outcomes of the research in scope of the CompMusic project are going to be presented. By using the data provided on Dunya, a user who wants to learn Indian or Turkish makam music tradition briefly can reach to the basic information or a more experienced user can use the research results to explore the analytic structure of this music tradition. Mainly, the data provided on Dunya represents the *melodic, rhythmic* and *structural* properties of the records. With this information, a user can improve his/her understanding of that certain music tradition in an analytical approach.

[1] MusicBrainz Identifier

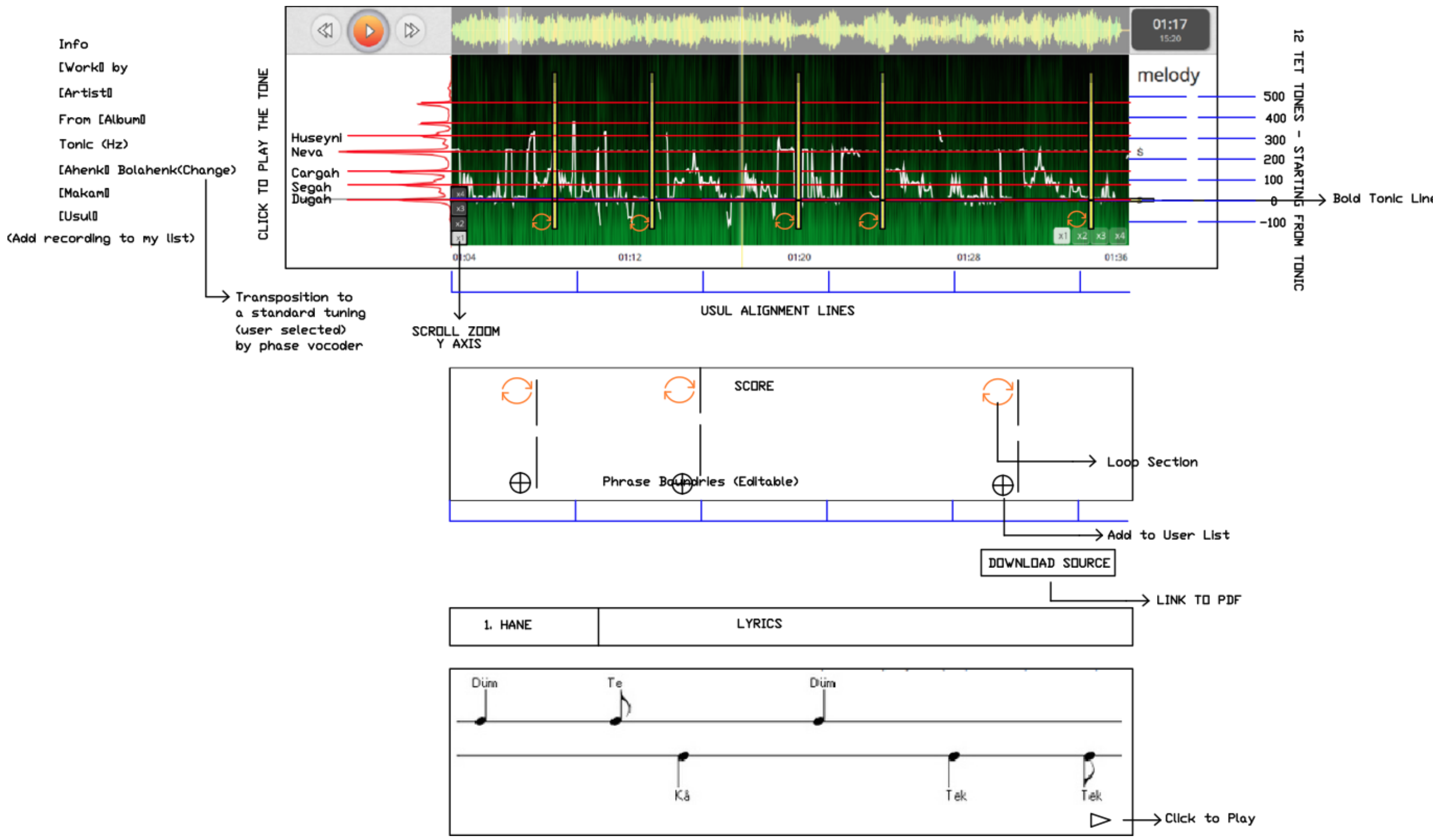

Figure 2: Dunya-Makam mock-up

For Turkish makam music version of Dunya, a mock-up for the recording page is provided in Figure 2. Recording page is the main interface for this tradition because recordings are the main entities in Turkish makam music. On a recording page, the *melodic, rhythmic* and *structural* features of the recording are presented. In this context, the interface can be examined under three parts. In the topmost part, *pitch distribution, predominant melody* and *the tonic* of a certain recording are presented, which are related to the melodic attributes. For the rhythmic attributes, the *beat/downbeat* information with *usul* cycles are displayed on the topmost part. In addition to the rhythmic analysis of the recording, the related *usul* is presented in the lowest part, where user can listen and see the strokes. In the middle, there are the *score* and *lyrics* of the piece, which are computationally aligned with the audio and include the *section* and *phrase* information. Section and phrase information are related with the structural attributes of the audio. These features of a recording are helpful to understand a piece and the related makam and usul as well.

In our research, we compute and analyze the relevant features of the elements in our corpus to understand the tradition. This helps us to discover both high and low level attributes of the music tradition and the relations between different elements in it (e.g. *makams, usuls*). A similar design for Carnatic and Hindustani music traditions has already been implemented and can be seen on Dunya[2].

[2] http://dunya.compmusic.upf.edu/carnatic

5. Features

In the CompMusic project, we mainly focus on the extraction of melodic, rhythmic and structural aspects of the studied music traditions (Serra 151). For Turkish makam music, we use the audio recordings, music scores, related metadata available in the corpus and the knowledge provided by the masters of this music tradition.

In Table 1, we present a list of features for Turkish makam music. This list consists of the features that we have already extracted by running relevant algorithms on the Turkish makam music corpus and those we aim to reach within the scope of the CompMusic project. They have been classified under three categories as melodic, rhythmic and structural. In the rest of this section we explain these categories in detail.

5.1. Melodic Features

In our studies we extract the features such as predominant melody, pitch distribution, tonic and makam. Using these features, we can analyze the melodic progressions, the similarity between makams or the style of a certain performer or composer etc.

5.1.1. Predominant Melody

In the analysis of eurogenetic musics, chroma features are typically used due to their ability to represent harmonic content and their robustness to noise and changes in timbre, dynamics and octave-errors (Gómez). On the other hand, predominant melody is preferred to study the melodic characteristics of Turkish makam music due to its heterophonic nature (Bozkurt et al 3). (Gedik and Bozkurt 1049) uses YIN (De Cheveign et al 1917) to estimate the fundamental pitch and then post-processing step to correct octave errors and short erroneous jumps. While YIN outputs accurate pitch estimations for monophonic recordings, in (Şentürk et al 57) it is observed that it does not output reliable estimations for heterophonic recordings.

(Şentürk et al 34) uses the methodology proposed by (Salamon and Gomez 1759) to extract predominant melody. Figure 3 shows the steps followed to compute the predominant melody. Note that the methodology proposed by (Salamon and Gomez 1759) is optimized for popular musics with a predominant melody and accompaniment such as Western pop and jazz. The methodology assumes that there is no predominant melody in time intervals where the peaks of the pitch saliences are below a certain magnitude with respect to the mean of all the peaks. Moreover, it eliminates pitch contours, which are considered as belonging to the accompaniment. Since time intervals without predominant melody are rare in Turkish makam music, the methodology with default parameters erroneously discards a substantial number of pitch contours in Turkish makam performances. (Şentürk et al 34) changes some parameters according to the specificities of Turkish makam music to overcome this problem. In the structure-level audio-score alignment experiments, predominant melody computed with modified parameters yield better results compared to YIN and chroma features.

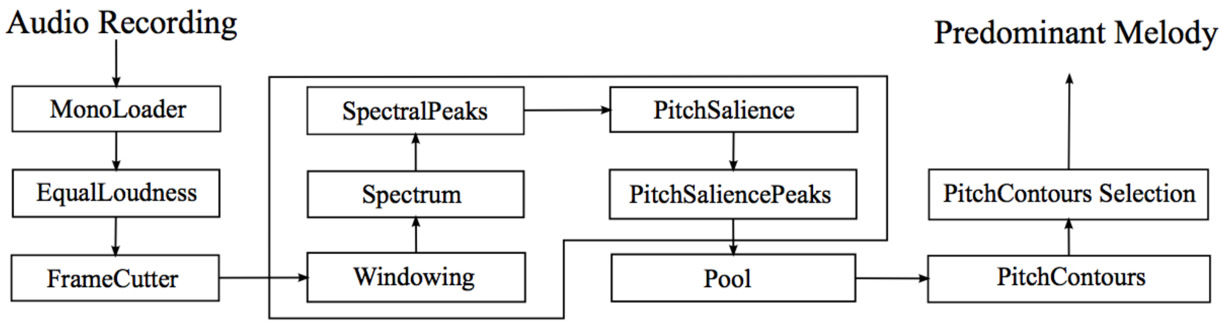

Figure 3: Flow diagram of predominant melody computation using the methodology proposed by (Salamon and Gomez 1759). The names in blocks refer to the corresponding functions in Essentia.

On the other hand the predominant melody computed with modified parameters still produces substantial amount of errors when the music is played softer than the rest of the piece. This becomes a noticeable problem in the end of the melodic phrases, where musicians choose to play softer. For this reason we decided to optimize the methodology of (Salamon and Gómez 1759) step by step. We first estimate the pitch contours and then use a simpler pitch contour selection methodology, which does not consider accompaniment, to obtain the predominant melody. We utilize Essentia (Bogdanov et al 493) to compute pitch contours[3]. The implementations of this methodology and the one used in (Şentürk et al 34) are available in pycompmusic[4] library.

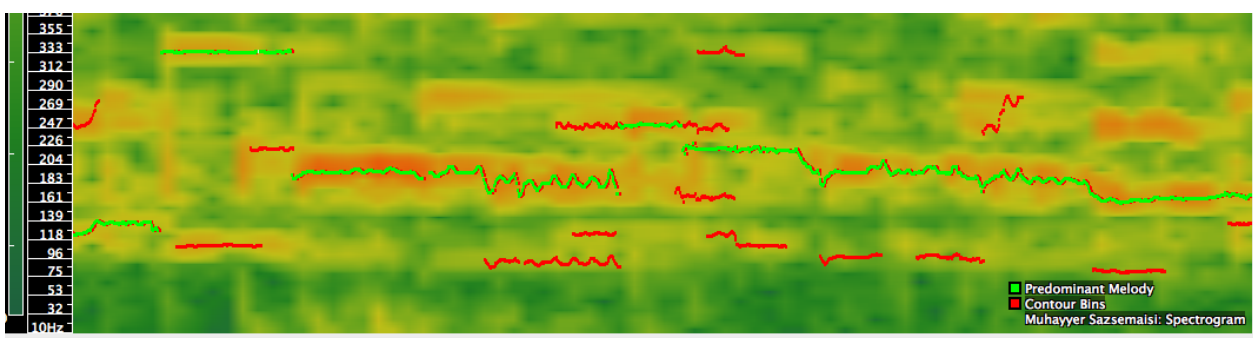

Figure 4: Contour bins and predominant melody

In the computation of the pitch salience function[5] we select the bin resolution as 7.5 cents instead of 10 cents. 7.5 cents approximately corresponds to the smallest noticeable change (⅓ Hc) in makam music (Bozkurt 13). In the computation of pitch salience peaks, we experimented on different values of the peak distribution threshold parameter to get a satisfactory pitch contour length. Currently, we lack the ground truth to empirically find an optimal value for this parameter. Hence, we decided to set the *peakDistributionTreshold* parameter as 1.4, instead of using the default parameter "0.9" to get and observe longer pitch contours (Figure 4).

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3 http://essentia.upf.edu/documentation/reference/std_PitchContours.html
4 https://github.com/MTG/pycompmusic
5 http://essentia.upf.edu/documentation/reference/std_PitchSalienceFunction.html

Once the pitch contours are obtained, we order the pitch contours according to their length and start with selecting the longest one. Then, we remove all portions of pitch contours which overlap with the selected pitch contour (Figure 4). We carry the same process for the next longest pitch contour, and so forth. By repeating the process for all pitch contours, we obtain the predominant melody of the audio recording (Figure 4). Some predominant melodies might contain octave errors because of the heterophony of Turkish makam music. In the future we will implement the postprocessing step used in (Gedik and Bozkurt 1049)[6].

Apart from the predominant melody estimation in audio recordings, we also extract a synthetic predominant melody from the notes and their durations given the in music scores. This feature may be synthesized either according to the theoretical pitches (e.g. *according to AEU theory*) or according to a tuning obtained from one or multiple audio recordings (Şentürk et al 95) (Bozkurt 43). This feature is currently used in audio-score alignment (e.g. Şentürk et al 43 and Şentürk et al 57). We will also use this feature to playback the music scores in Dunya.

5.1.2. Pitch and Pitch Class Distributions

Pitch distributions and the "octave-wrapped" pitch-class distributions are the features commonly used for tuning analysis (Bozkurt et al 45), tonic identification and makam recognition (Gedik and Bozkurt 1049). These distributions typically have a high pitch resolution to capture the tuning characteristics specific to the Turkish makam music. The pitch distributions are useful to capture the tuning characteristics of a recording or a set of recordings (e.g. in the same makam) spanning to several octaves, whereas pitch-class distributions are more desirable for tasks which would suffer from octave errors. These distributions are typically computed from predominant melody. There are two common methods to count the number of samples in the predominant melody that fall into each bin, (histogram) (Gedik and Bozkurt 1049) and kernel-density estimation (Chordia and Şentürk 82).

For each audio recording we use the predominant melody explained in Section 5.1.1 to compute the four possible combinations; namely pitch histogram, pitch-class histogram, pitch kernel-density estimate and pitch-class kernel-density estimate. The bin size is kept as the same as the pitch resolution of the predominant melody (7.5 cents) resulting in a resolution of 160 bins per octave.

We use the intonation library[7] to compute the kernel-density estimates. We select a normal distribution with a standard deviation (kernel width) of 15 cents as the kernel. In (Şentürk et al 175), this value was empirically found to be optimal for the score-informed tonic identification task. Next, we will select the appropriate distribution and optimize the parameters for other computational tasks and also for the visualizations in Dunya. The code to extract the pitch and the pitch-class distributions are also available in pycompmusic[8] library.

We also use the peaks observed in the pitch (and pitch-class) distributions to obtain the tuning. We use "slope" method in the "GetPeaks" algorithm which is included in pypeaks library[9]. We will use this information for adaptive tuning as explained in (Bozkurt 43).

[6] http://essentia.upf.edu/documentation/reference/std_PitchFilterMakam.html
[7] https://github.com/gopalkoduri/intonation
[8] https://github.com/MTG/pycompmusic
[9] https://github.com/gopalkoduri/pypeaks

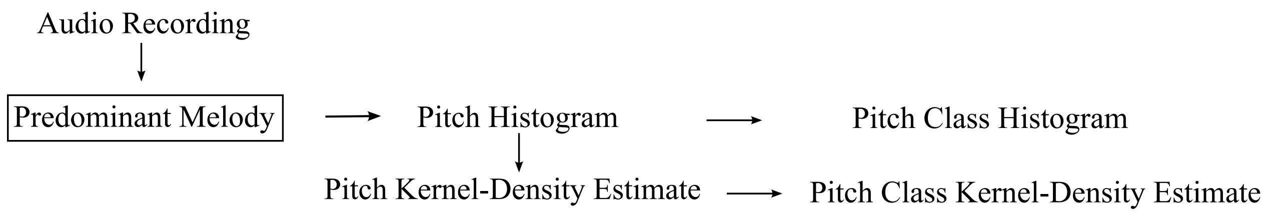

Figure 5: Flow diagram of pitch histogram calculations

5.1.3. Tonic and Makam

Bozkurt finds the tonic frequency by estimating the frequency of the last note in a recording (Bozkurt 1). Nevertheless, this method is prone to the quality of the predominant melody and impractical for the recordings which do not end in the tonic frequency (e.g. recordings ending with fade-out or applause).

Another approach is comparing the pitch distribution computed from an audio recording and the template pitch distribution of several makams (Gedik and Bozkurt 1049). The audio pitch distribution is pitch-shifted and a similarity score is computed according to each template distribution for each of these shifts. Assuming that the highest score would be observed between the audio pitch distribution and the template of the "true" makam when the shifted tonic and the tonic in the template are matched, the tonic frequency and the makam of the audio recording are jointly estimated.

When a machine-readable score of the performed composition in an audio recording is available, the symbolic melody information can be used to assist the tonic identification task. (Şentürk 175) extract a predominant melody from the audio recording and compute a pitch- class kernel-density estimate. Then the peaks of the estimate is picked as possible tonic candidates. Assuming each candidate is the tonic, the predominant melody is normalized such that the candidate tonic is assigned to zero cents. Then for each candidate the score and the audio recording are partially aligned to each other. The tonic is estimated as the candidate which yields the most "confident" alignment. This method outperforms (Gedik and Bozkurt 1049). However, this method cannot be applied to all audio recordings since it requires the score of the performance to be available.

5.2. Rhythmic Features

(Srinivasamurthy et al 94) have been working on rhythmic feature extraction, including Turkish makam music and Indian art music. In their study, they define 3 rhythm related tasks, beat tracking, meter estimation and beat/downbeat detection. For Turkish makam music, currently we are planning to include beat/downbeat analysis for the audio recordings. By using the output of this analysis, the usul structures and the relations between different usuls can be understood deeper.

5.3. Structural Features

In the score corpus, section information of 2200 compositions are available in our machine-readable file formats (e.g. 1.Hane, Teslim). Additionally, for the compositions with vocals, each phrase of the vocal line is marked by space character in SymbTr[10]. Moreover, in (Karaosmanoğlu et al 10), 899 of the scores from this collection have been segmented into approximately 30000

[10] https://github.com/MTG/SymbTr

phrases by three Turkish makam music experts. These annotations have been used for (Bozkurt et al 1) study.

(Şentürk et al 57) uses the section information given in the SymbTr-scores to link each section to the time-intervals they are performed in the audio recordings. Next, each section and the time intervals are aligned in the note-level (Şentürk 57). We plan to use the alignment results to estimate the average and local tempo, to automatically retrieve the performances of a selected part from a composition and also to study the tuning and intonation characteristics. By using the lyrics information in the SymbTr-scores, lyrics-to-audio alignment is also studied by (Dzambazov 61).

6. Conclusion

In this paper we have presented a music exploration system for Turkish makam music, *Dunya*, and the feature extraction methodologies for this music tradition. We have provided the musically descriptive features, which will be computationally extracted from Turkish makam music corpus and will be presented in Dunya. We have presented a mock-up for Dunya-Turkish makam music, explaining how it includes the extracted features. For the existing features, we have provided brief information and references. As being the new methodologies we implemented, flow diagrams and calculations are explained for the predominant melody extraction and the pitch histogram calculation in Section 5.1.1. and Section 5.1.2., respectively. We also provide a list of the musically descriptive features of Turkish makam music. We expect these studies facilitates academic research in several fields such as music information retrieval and computational musicology.

7. Acknowledgements

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Feature	Source	Data Type(s)	Input	Type	Explanation
Pitch Salience	Recording	Audio	Audio	M	Extraction of pitch contours from an audio recording by the methodology of (Salamon and Gómez 1759)
Predominant Melody	Recording	Audio	Pitch Salience	M	Predominant melody estimation by the methodology in Section4.1.1
Synthesized Predominant Melody		Score	Score	M	Synthesized Predominant Melody with by methodology of (Şentürk et al 57)
Corrected Predominant Melody	Recording	Audio + Score	Predominant Melody + Synthesized Score	M	Correction of predominant melody by related synthesized predominant melody with the methodology in Section 4.1.1
Pitch Histogram	Recording	Audio	Predominant Melody	M	Pitch histograms computations by the methodology in Section 4.1.2
Tonic	Histogram	Audio	Histogram	M	Tonic frequency identification by the methodology of histogram matching (Bozkurt 1)
	Last Note	Audio	Predominant Melody	M	Tonic frequency identification by the methodology of last note (Bozkurt 1)
	Score Info	Audio + Score	Predominant Melody + Synthesized Score	M	Score informed tonic identification by the methodology of (Şentürk et al 95)
Adaptive Tuning	Histogram	Audio + Score	Predominant Melody + Histogram Peaks	M	The tuning is obtained from an audio file by using the histogram and the related score is synthesized according to the frequencies in that tuning.
Phrase	Annotations	Score	Score	S	This data is used to understand the melodic phrases in the Turkish makam music tradition. (Karaosmanoğlu 10)
Audio-Score Alignment	Synthesized Score	Audio + Score		M+S	Alignment of score with related audio recording by the methodology of (Şentürk et al 34)
Beat/Downbeat		Audio + Metadata	Spectrogram	R	Beat/Downbeat analysis of Turkish makam music by the methodology of (Srinivasamurthy et al 94)
Section Linking	Synthesized Score	Audio + Score		S	Score sections linking with related audio recording
Audio-Lyrics Alignment		Audio + Lyrics		S	Lyrics alignment with related audio recording by the methodology of (Dzhambazov et al 61)

Table 1: Some of the features to be extracted from the corpus by computational methodologies. M, S and R denotes melodic, rhythmic and structural, respectively.

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