METRICAL STRENGTH AND CONTRADICTION IN TURKISH MAKAM MUSIC

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ABSTRACT

In this paper we investigate how note onsets in Turkish Makam music compositions are distributed, and in how far this distribution supports or contradicts the metrical structure of the pieces, the *usul*. We use MIDI data to derive the distributions in the form of onset histograms, and compare them with metrical weights that are applied to describe the *usul* in theory. We compute correlation and syncopation values to estimate the degrees of support and contradiction, respectively. While the concept of syncopation is rarely mentioned in the context of this music, we can gain interesting insight into the structure of a piece using such a measure. We show that metrical contradiction is systematically applied in some metrical structures. We will compare the differences between Western music and Turkish Makam music regarding metrical support and contradiction. Such a study can help avoiding pitfalls in later attempts to perform audio processing tasks such as beat tracking or rhythmic similarity measurements.

1. INTRODUCTION

The term rhythm is related to a grouping of unaccented events in relation to accented events in time [1]. As soon as we encounter a sound in which such events have a high regularity we are able to perceive one or more pulses at different periods. If those pulses are regular, and we are able to establish some relations between their periods, the encountered sound can be considered to have a metrical structure. In research both in the fields of musicology and Music Information Retrieval (MIR), the focus lied mostly on the analysis of music having a metrical structure. In Western music, this structure is assumed to be hierarchical, with regular pulses on each level and simple frequency relations between the levels, which was summed up by Lerdahl and Jackendoff [2] using well-formedness rules. There have been several studies which examined how compositions follow or contradict such structure, see *e.g.* [3,4].

In Makam music of Turkey, just as in other related Makam traditions, the metrical description of a piece is traditionally given by a verbal sequence that defines a series of strong and weaker intonations in time. In this paper, we will show some of these descriptions, which are referred to as *usul* in Turkish music tradition. It is apparent that many of these descriptions cannot be mapped into a well-formed hierarchical structure. Nevertheless, they form the metrical fundament for music in a huge cultural space, which contains apart from Turkey also *e.g.* Iran, Arabic countries and Northern Africa. We are going to examine how compositions following an *usul* support or contradict this underlying meter. While the findings show some consistencies with Western music, we find some important deviations. In particular we examine in how far note locations and note durations correlate with the meter, and if syncopation is systematically encountered in Makam music of Turkey.

Measuring note locations and durations is a straight forward task on the symbolic data of Turkish music we use in this paper. However the notion of syncopation should be clarified at this point. In the *New Harvard Dictionary of Music* it is defined as a temporary contradiction of the prevailing meter, and some computational approaches for measuring it on note sequences were proposed, see [5] for a summary. In this paper, we will apply an approach that was presented in [6] that is able to reliably detect syncopated events in symbolic data. This algorithm detects pauses on strong metrical units that are surrounded by note events on weaker metrical units, a combination which causes a temporary contradiction of the meter. While the notion of syncopation does usually not appear in literature on Makam music, we want to find out if it can be encountered and what the nature of this contradiction is.

Our motivation for the present study is twofold. First, the metrical properties of Makam compositions have never been systematically examined, and we want to contribute to a discussion about the nature of metrical structure in this music. We want to pose the question, if metrical descriptions that do not fit into a Western motivated hierarchical model still can be examined using methodology of Western musicology. And, secondly, by investigating the relation between compositions and meter, we want to give first guidelines which characteristics computational analysis of meter can rely on in Makam music. The author showed in a previous study that songs can be classified to a specific *usul* given only the knowledge of the contained periodicities in a sound [7]. In this paper, we will examine if a detailed knowledge of the alignment between a melody and its meter can provide us with additional information, namely the note positions, durations and contradictions in relation to the underlying meter.

The remainder of the paper is structured as follows; In Section 2 we provide the reader with some details about the *usul* in Makam music of Turkey, and describe the song collections used in this paper. Section 3 investigates the characteristics of note onsets and durations in relation to the meter. Section 4 measures syncopation to examine if we encounter metrical contradiction in a systematic way. Section 5 poses the question if note onset positions can be used to discriminate between *usul*, and Section 6 concludes the paper.

2. BACKGROUND

In Makam music of Turkey the meter of a composition is described by an *usul*, which is a rhythmic pattern of certain length that defines a sequence of intonations with varying weights. An example is shown in Figure 1: the *usul Aksak* has a length of nine beats. The notes on the upper line labeled *düm* have the strongest intonation while the notes on the low line denote weak intonations. While the weights of these intonations have never been evaluated experimentally, in available learning software [8] certain weights are applied such as weight 3 for the *düm* beats and 1 for the weakest beats.

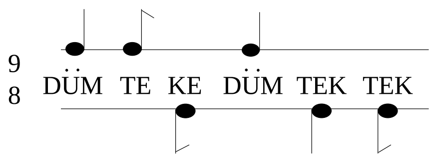


Figure 1: Symbolic description of the *usul Aksak*

Metrical structure in music is usually assumed to be hierarchical, with the strong beats on top of the hierarchy. A common representation for this hierarchy is given in Figure 2, showing the example of a $4/4$ meter; the strongest beat, referred to as the downbeat, is at the beginning of the depicted pattern. The next strongest beat is the half note level, and this results in an amplitude of 3 in the middle of the pattern. The amplitudes keep decreasing in steps of one until the level is reached which was chosen to be the fastest metrical level that we want to examine. As in many studies related to syncopation and meter [3,4], in this paper the fastest level is chosen to be the $16th$ note, which results in a histogram-like representation with 16 bins for the $4/4$ meter. We will refer to this representation as weight pattern in

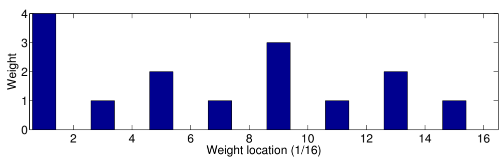


Figure 2: Metrical weight pattern for Western $4/4$

this paper. The regularity of the structure depicted in Figure 2 is caused by the fact that each pulse can be obtained from its ancestor in the hierarchy by doubling its tempo. The picture is different for the *usul* in general, as can be observed from the weight pattern for Aksak depicted in Figure 3a. This can partly attributed to the fact that the pattern of length 18 for a $9/8$ cannot be evenly subdivided into a hierarchy as a $4/4$. However, the weight patterns of the *usul* examined in this paper (Figure 3) are in general not as regular as for a $4/4$ meter in Western music.

In this paper we are going to examine the properties of a dataset of Turkish compositions, available in MIDI format. All compositions are vocal pieces of either *şarkı* or *türkü* form. These songs can be classified into six classes, which denote the type of *usul* they are composed in. The distribution of songs among the six usul classes and the number of notes in each class are depicted in the second and third columns of Table 1. The columns denoted as Beats and *Mertebe* define the time signature, in which the *usul* is usually notated, *e.g.* $4/4$ for *Sofyan*. The underlying weight patterns are given in Figure 3 using the weights as applied in Mus2Okur [8]. Using the miditoolbox [9] the onset times in beats of the notes contained in the melody are derived. The MIDI does not stem from real performances but has been generated from a score using mus2okur [8]. Therefor, the velocities contain no valuable information and could not be used to explore their importance in this study.

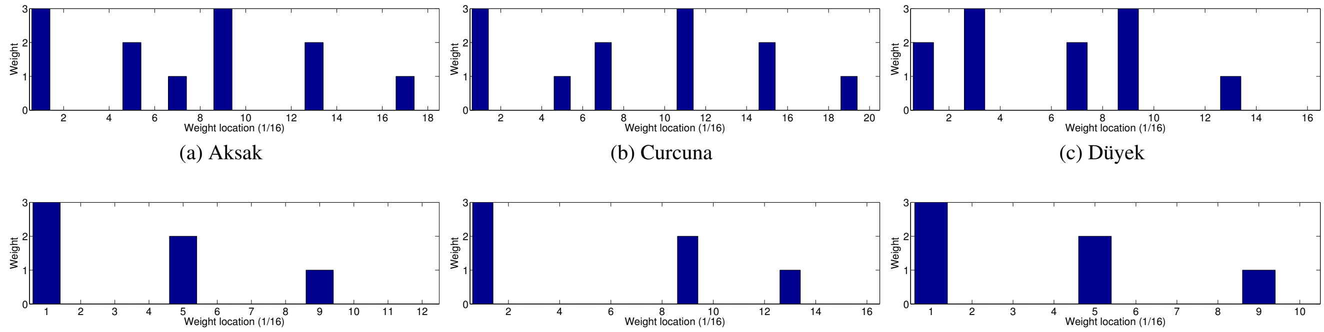
CLASS	N_{Songs}	N_{Notes}	Beats	*Mertebe*
AKSAK	64	28440	9	8
CURCUNA	57	23363	10	8
DÜYEK	47	17093	8	8
SEMAI	22	8376	3	4
SOFYAN	60	32139	4	4
TÜRK AKSAĞI	38	12972	5	8

Table 1: Data set

We are going to investigate in how far the Turkish compositions support their meter, and where they contradict it, and compare these properties with what is usually encountered in Western popular music. To this end, we will either use already published results from literature, or we examine a dataset of Western music. The subset of the RWC dataset [1] used in [6] is selected for that purpose. The RWC subset contains 32 songs in MIDI format, separated in channels containing onsets of the individual instruments of the composition (refer to [6] for a more detailed description).

A direct comparison of the Western popular music contained in these songs with the Turkish compositions might appear out of place. However, the forms contained in the RWC subset are partly known for their extensive usage of syncopation. By showing up the differences we can gain insight into how syncopation is applied in the two cultural contexts.

[1] http://staff.aist.go.jp/m.goto/RWC-MDB/



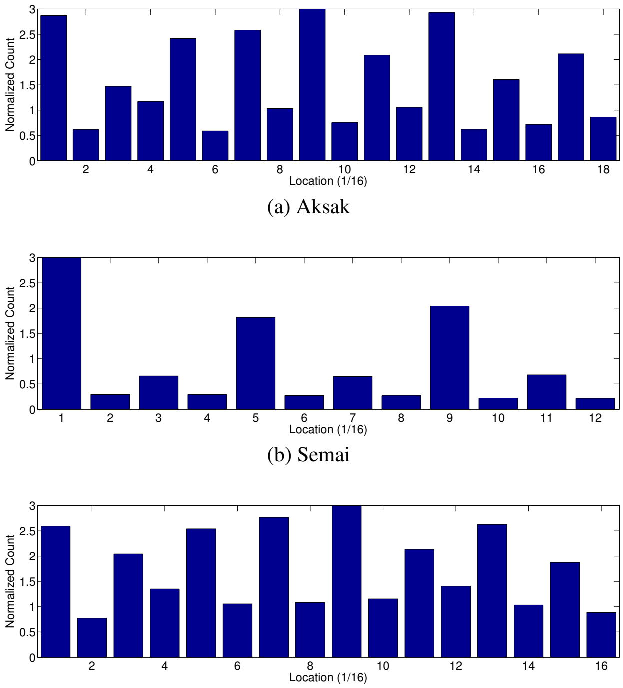
(a) Aksak (b) Curcuna (c) Düyek

(d) Semai (e) Sofyan (f) Türk Aksaği

Figure 3: Weight patterns according to theory for the six *usul* in the dataset

3. NOTE LOCATION AND DURATION

In order to determine how much the note onsets in a composition support the underlying meter we follow the experimental setup proposed by Palmer and Krumhansl [3]. We count the frequency of note onsets in each location of a weight pattern. We attribute each note to the temporal bin where it starts, and neglect annotated durations of the notes and rests in our analysis.



(a) Aksak

(b) Semai

(c) Sofyan

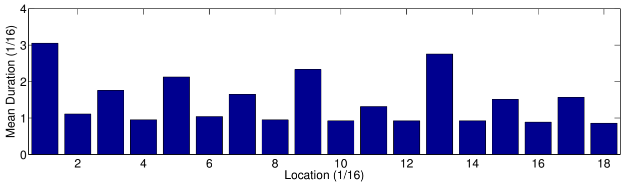
Figure 4: Frequency count histograms for three *usul* in the dataset

In Figures 4a to 4c we show the frequency count histograms for three *usul*. The frequency counts were normalized so that the highest value takes the maximum weight of the related weight pattern. We can observe that at those bins where the weight patterns are non-zero, high peaks in the frequency count histograms of the *usul* appear. However, their magnitudes are not as strongly related as observed in [3] for Western music. We observed that in most cases the metrical positions different from the strongest according to theory obtain more weight in the count histograms than would be expected from theory. This can be seen *e.g.* for *Sofyan* in Figure 4c, where the peaks at 9 and 13 are higher than the theoretical ones, while the peak at 1 is even lower. Furthermore, many note onsets appear where there is no weight defined by theory. This should not surprise as the *usul* are more sparse than *e.g.* the metrical weights assumed for a Western $4/4$ meter. The sparseness of the theoretical description, however, does not imply that note onsets cannot appear in the absence of a theoretical weight. It appears more reasonable to interpret the theoretical descriptions as guidelines to which metrical positions high stress should be given.

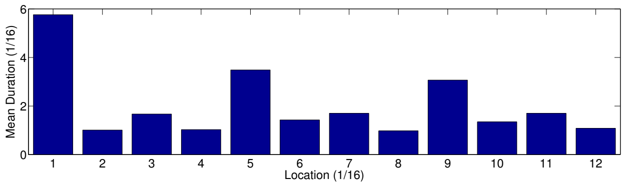
CLASS	r_o	r_d
AKSAK	0.859	0.903
CURCUNA	0.826	0.883
DÜYEK	0.762	0.792
SEMAI	0.943	0.969
SOFYAN	0.572	0.818
TÜRK AKSAĞI	0.819	0.749

Table 2: Correlation coefficients between patterns and onset frequency counts (r_o), and between patterns and durations (r_d)

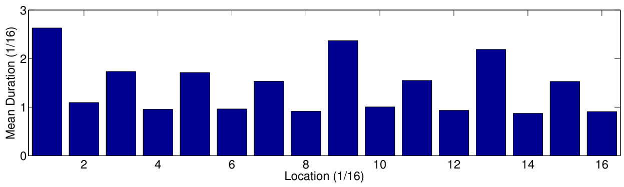
The varying amount of correlation between theory and onset frequency is reflected by the correlation coefficients, r_o, given in Table 2. All shown correlations are significant at 95% confidence, with the very low correlation value for *Sofyan* being at the border with a p-value of 0.02. The related frequency count histogram shown in Figure 4c shows indeed the smallest amount of similarity for all six examined *usul*. It is worth to point out that the observed correlations for Western music are much higher, with a correlation coefficient of 0.96 for $4/4$ meter [3]. It might be assumed that the cause of this is the sparseness of the theoretical description. In order to evaluate for the effect of having a more detailed description, we used an alternative *usul* description which is referred to as *velveleli*. This description, which could be translated to English as *raucous*, contains more dense rhythmic patterns than the simple *usul* patterns. However, no consistent increase in the correlation



(a) Aksak



(b) Semai



(c) Sofyan

Figure 5: Duration histograms for the three *usul* depicted in Figure 4

coefficients was observed.

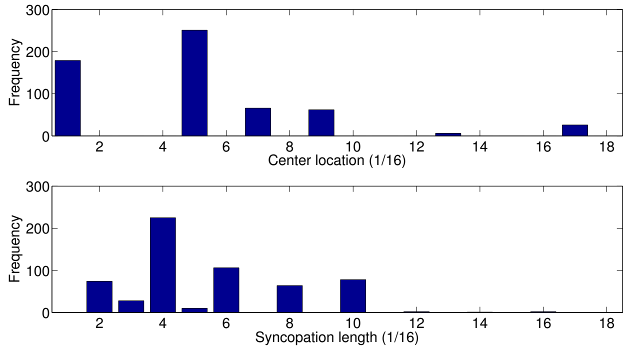
The weight histograms obtained from onset frequencies completely disregard the importance of note durations. As has been observed *e.g.* in [10], in Western music long note durations tend to occur more often at high metrical levels. Indeed this phenomenon is very strong in Turkish songs as well, as can be seen by comparing the duration histograms in Figure 5 with the related weight patterns in Figure 3. The depicted duration histograms show the mean note duration encountered at every location of the underlying *usul*-pattern. In fact, the correlation coefficients, r_d, between these duration histograms and the weight patterns are even larger in most cases than the coefficients r_o obtained for the onset frequency counts, as it is depicted in Table 2.

This emphasizes the importance of note position and duration information for determining an *usul* in future music information retrieval tasks. As shown by Temperley [11] these information can be combined by using a probabilistic model of note combinations. However, it should be pointed out that the estimation of such models poses significant problems for audio signals where the note onsets are not given.

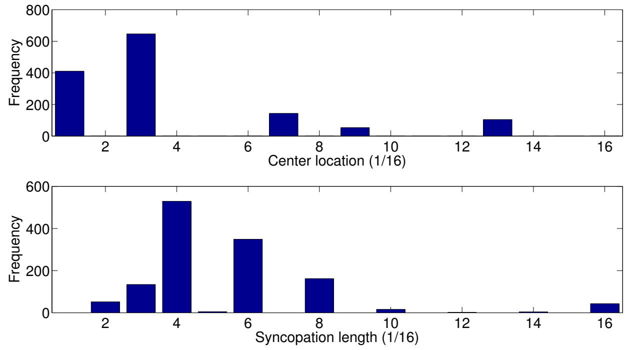
4. SYNCOPATION

For the detection of syncopated events we use the NLHL-p method [6]. It will not be attempted to draw conclusions about the strength of the syncopation in the detected events, but we rather concentrate our analysis to the positions in the meter where they occur. This way we want to gain some insight into if and in which way pieces contradict the underlying meter, and if there is anything systematic in the way this contradiction appears.

As explained in [12] it is an open question to which position to assign a syncopation as it is always constituted by two note events and one intermediate pause which overlaps with a metrical weight that is higher than the weights of the adjacent notes. We decided to assign the syncopation to the pause with the highest metrical weight that occurs between the initial and the closing note of the syncopation. This way we can examine in which metrical positions notes are missing and a metrical contradiction is caused by this absence of a note onset. Furthermore, we depict the length distributions of the syncopations as the time span in $1/16$ notes from the initial to the closing note.



(a) Aksak



(b) Düyek

Figure 6: Syncopation localizations and lengths for *usul Aksak* and *Düyek*

In Figure 6 we show the locations and lengths of syncopations for two *usul*. The depicted metrical contradiction is exemplary also for the *usul Curcuna* and *Sofyan* for which we do not include Figures. This behavior is characterized by a stronger appearance of syncopated events in the first half of the rhythmic cycle, and by durations with a maximum at quarter notes.

In Table 3, the percentages of two-note combinations forming a syncopation is given for all *usul*. The *usul* with the most sparse occurrence of metrical contradiction are *Semai* and *Türk Aksaği*. These are also the only *usul* which to some extent contradict the above cited behavior of metrical contradiction. On the other hand, the *Düyek usul* makes a stronger use of metrical contradiction than the others, which is interesting as this specific *usul* is known as *Tsifteteli* in Greek music and is known in Western cultures as *belly dance* rhythm. This can be seen as another evidence that metrical contradiction in Turkish music does

USUL	Perc. of Syncopated Events
AKSAK	2.01
CURCUNA	2.59
DÜYEK	7.98
SEMAI	0.53
SOFYAN	2.33
TÜRK AKSAĞI	1.21
RWC subset	15.33

Table 3: Percentage of syncopated note couples in short *usul*

not appear randomly, but follows certain rules related to the metrical structure.

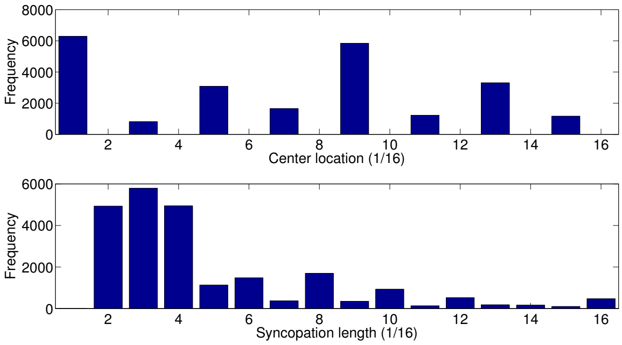


Figure 7: Syncopation localizations and lengths for the RWC subset

In Figure 7 we depict syncopation locations and durations encountered in the RWC subset. It is apparent that syncopations in these compositions follow a different scheme. While here the syncopations follow the metrical weights very strongly, also the durations of the encountered syncopations tend to be shorter. The durations go down to the minimum possible length of a note-pause-note combination at the resolution of 16-th notes, which is the eighth note ($2/16$ in Figure 7). This indicates that syncopation in Western music might to some extent be captured by calculating the *off-beatness* of a signal, while this might not be the case for Turkish music with its metrical contradictions having larger durations. It is not astonishing that the measured percentage of syncopated note-pause-note combinations is much higher for the RWC subset than for all *usul*, with 15.33% as depicted in the last line of Table 3. Finally, syncopation is a term that is mainly used in the context of Western popular music, and the compositions in the RWC subset contain genres of popular music that make a frequent use of syncopation, such as Jazz and Funk. However, while being less frequent in Turkish music, metrical contradiction seems to be systematically applied to strong beats in the first half of the metrical pattern, and is not as rare as should be assumed keeping in mind that the term syncopation is usually not applied in the context of this music.

5. DISCRIMINATION

In the previous sections we showed that there is a strong correlation between note onsets and the theoretical weights of the meter in an *usul*. In this Section we conduct a preliminary study if this factor can also be used to discriminate between *usul*. Discrimination using syncopation will not be attempted, because it was observed in Section 4 that metrical contradiction appears systematically only in four of the six *usul*. Furthermore, it is our final goal to propose methods to differentiate between *usul* when using audio signals, and the accurate calculation of syncopation on audio is a highly complex task [6].

In order to recognize the usul of a song, we calculate its frequency count histogram and measure its correlation factor with the *usul* pattern of each *usul*. As the *usul* have varying length we determine the least common multiple of two different *usul* lengths, and repeat both histogram and pattern accordingly. If *e.g.* an *Semai* histogram (length 12) is to be compared with the *Sofyan* pattern (length 16), we will repeat the *Semai* histogram 4 times and the *Sofyan* pattern 3 times, in order to obtain a common length of 48. Then we determine the correlation coefficient for each pattern and assign a song to the class with the maximum correlation coefficient.

As a descriptor for a class, we apply the theoretical weight patterns shown in Figure 3 as well as metrical weights learned from data. When trying to classify a song we learn the reference histogram from all samples of the same *usul* except of the sample to be classified, *i.e.* we do not use the test songs for training the model.

5.1 Results

In Tables 4 and 5 we depict the results from the classification experiments using theoretical weight patterns and measured frequency count histograms, respectively. While the accuracy is quite high ($74, 7\%$) when using the theoretical patterns, there is a high confusion for *Sofyan*. When using the frequency count histograms as a metrical description, this particular confusion is much lower and almost only with the only other *usul* of same length, *Düyek*. This indicates that while the theoretical patterns serve as a basis for composition and study of rhythm in Makam music, they do not describe fully the probabilities of note onsets in each metrical position. The obtained accuracies show that correlation between observed onsets in a song and the metrical weights obtained by accumulating histograms from a larger dataset represent a promising starting point for a later *usul* classification system. The accuracy obtained when using measured histograms (85.4%) is slightly higher than the best reported accuracy in [7] (82.3%), which indicates that descriptors that incorporate the metrical structure are more discriminative than those based only on periodicities contained in the signal.

6. CONCLUSIONS

In this paper we addressed the question of how songs of Turkish Makam music support or contradict their metrical structure. While high correlations between the theoretical

	Aks.	Cur.	Düy.	Sem.	Sof.	Tür.
Aks.	63	0	0	1	0	0
Cur.	0	51	0	0	0	6
Düy.	0	4	37	1	5	0
Sem.	0	0	0	22	0	0
Sof.	6	6	26	16	6	0
Tür.	1	1	0	0	0	36

Table 4: Classification using patterns from theory: Mean accuracy 74.7%

	Aks.	Cur.	Düy.	Sem.	Sof.	Tür.
Aks.	63	0	1	0	0	0
Cur.	0	54	0	0	0	3
Düy.	0	0	37	0	10	0
Sem.	0	0	0	21	1	0
Sof.	0	3	16	4	37	0
Tür.	0	2	1	1	0	34

Table 5: Classification using measured histograms: Mean accuracy 85.4%

weights and note frequency count histograms exist, they are lower than the correlations reported for Western music. This can be attributed to the fact that onsets tend to appear more often on the weaker weights than implied by the theoretical model. As this model was never evaluated in experiments, it can be concluded that the weights should be adjusted accordingly. Furthermore, the weaker correlation can be also attributed to the fact that the *usul* pattern are more sparse than the metrical description applied for Western music. This is caused by the fact that they only define some degree of emphasis at positions that are important to learn the *usul* as a sequential description in musical practice. We were also able to show that durations play an important role in supporting the meter in Turkish Makam music, with correlations even higher than for the note onset positions.

Apart from supporting the meter, also contradicting it seems to play an important role for some *usul*. Syncopations were found to be located more frequently in the first half of those *usul*, which is quite different from Western popular music where syncopation was shown to tightly follow the metrical weights. The strong appearance of metrical contradiction in the *usul Düyek* might indicate the existence of a relation between syncopation and groove, as this *usul* is the pattern that has the strongest relation to dance movements.

In a preliminary *usul* classification experiment we evaluated note onset positions for their discriminative power. Results are promising especially when using onset count histograms learnt from data instead of the theoretical patterns. Summing up the findings we can state that the discriminative power of a system for *usul* recognition that works on audio can profit from using information regarding note onsets, note durations and the location of pauses on strong metrical pulses. Such a system can be considered a complementary system to the one presented by the author in [7] for the case when an underlying pulse can be reliably estimated using some beat tracking algorithm.

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