

**ÇANKAYA UNIVERSITY  
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES  
ELECTRONIC AND COMMUNICATION ENGINEERING**

**MASTER THESIS**

**INVESTIGATION OF MAKAM CORRELATION BETWEEN TURKISH  
ART MUSIC AND TURKISH FOLK MUSIC**

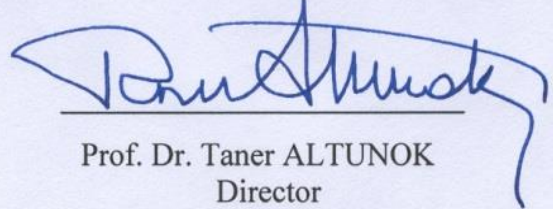
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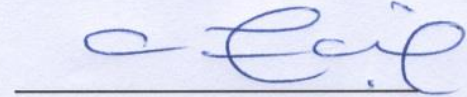
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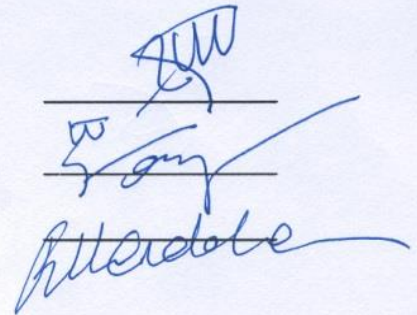
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## **ABSTRACT**

### **INVESTIGATION OF MAKAM CORRELATION BETWEEN TURKISH ART MUSIC AND TURKISH FOLK MUSIC**

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This thesis was made in order to understand makam concept mathematically with computer in Turkish music. The histogram and dynamic time warping (DTW) methods were used in this thesis. By using histogram method, similarities and dissimilarities of Hicaz makam art music songs and folk music songs, Acemkürdi makam art music songs, Kürdi makam art music songs, Muhayyerkürdi makam art music songs and sample seyirs of Hicaz makam were calculated. On the other hand,

by using dynamic time warping method, similarities of Hicaz makam art music songs and folk music songs, sample seyirs of Hicaz makam, behaviour of Hicaz makam according to time axis and the distinctiveness of Hicaz makam art music songs and folk music songs with Acemkürdi makam art music songs, Kürdi makam art music songs, Muhayyerkürdi makam art music songs according to time axis were revealed. The obtained results show that the investigation depends on time axis, it means that using a dynamic time warping (DTW) gives more explicit results than the investigation independent of the time axis, that is made according to histogram graphs. In brief, using a dynamic time warping method is a more reasonable approach in terms of obtaining better results in Turkish music.

**Keywords:** Turkish Music, Hicaz Makam Art Music Songs and Folk Music Songs, Acemkürdi Makam Art Music Songs, Kürdi Makam Art Music Songs, Muhayyerkürdi Makam Art Music Songs, Seyirs, Dynamic Time Warping, Histogram Graphs.

## ÖZ

### TÜRK SANAT MÜZİĞİ VE TÜRK HALK MÜZİĞİ ARASINDAKİ MAKAM KORELASYONUNUN ARAŞTIRILMASI

ŞENSES, Baturhan

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Bu çalışma, Türk Müziği'nde makam kavramını matematiksel olarak bilgisayar ortamında çözmeye yönelik olarak yapılmıştır. Çalışmada, histogram ve zaman eksenini katlama (dynamic time warping, DTW) yöntemi kullanılmıştır. Histogram yöntemi kullanılarak Hicaz makamı sanat müziği eserleri ve halk müziği eserleri, Hicaz makamına ait örnek seyirler, Acemkürdi makamı sanat müziği eserleri, Kürdi makamı sanat müziği eserleri, Muhayyerkürdi makamı sanat müziği ile olan

benzerlikleri hesaplanmış, öte yandan DTW kullanılarak Hicaz makamı sanat müziği eserleri ve halk müziği eserleri, Hicaz makamına ait örnek seyirler ile olan benzerliği, zaman eksenine göre davranışları, Acemkürdi makamı sanat müziği eserleri, Kürdi makamı sanat müziği eserleri, Muhayyerkürdi makamı sanat müziği eserleri ile olan ayırt ediciliği ortaya çıkartılmıştır. Elde edilen sonuçlar zaman eksenine bağlı olarak, yani DTW metodu kullanılarak yapılan bir irdelenmenin, zaman ekseninden bağımsız olarak, yani histogram grafiklerine göre yapılan bir irdelenmeden daha net sonuçlar verdiğini göstermektedir. Özet olarak, Türk Müziği'nde irdelenme yapılırken DTW metodunun kullanılmasının daha iyi sonuçlar elde edilmesi açısından daha doğru bir yaklaşım olduğu görülmüştür.

**Anahtar Kelimeler:** Türk Müziği, Hicaz Makamı Sanat Müziği Eserleri ve Halk Müziği Eserleri, Acemkürdi Makamı Sanat Müziği Eserleri, Kürdi Makamı Sanat Müziği Eserleri, Muhayyerkürdi Makamı Sanat Müziği Eserleri, Seyirler, Zaman Ekseni Katlam (Dynamic Time Warping), Histogram Grafikleri.

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## LIST OF ABBREVIATIONS

AK	Acemkürdi
AK <sub>AMS</sub>	Acemkürdi Art Music Songs
DTW	Dynamic Time Warping
EB	Erol Bingöl
H	Hicaz
H <sub>AMS</sub>	Hicaz Art Music Songs
H <sub>FMS</sub>	Hicaz Folk Music Songs
H <sub>TS</sub>	Hicaz Total Seyirs
K	Kürdi
K <sub>AMS</sub>	Kürdi Art Music Songs
MATLAB	Matrix Laboratory
MD	Main Diagonal
MIDI	Musical Instrument Digital Interface
MK	Muhayyerkürdi
MK <sub>AMS</sub>	Muhayyerkürdi Art Music Songs
RY	Rauf Yekta
ŞG	Şefik Gürmeriç
TRT	Turkish Radio and Television Corporation

## LIST OF SYMBOLS

$\sigma$	Scaled Autocorrelation and Crosscorrelation Coefficients for All Makams and Seyirs Obtained from the MD Regions of DTW Matrices
$\rho$	Correlation Value Based on Histogram Datas
$C_{min}$	Parameter of Cross Correlation
$C_{max}$	Parameter of Cross Correlation
$d_{i_1, i_2}$	Measured Distance Between $i_1$ st Note Value of $S_1$ and $i_2$ nd Note Value of $S_2$ .
DT45	Patterns of Lengths Tetrachord and Pentachord
$H^P_i$	Frequency of Usage of Individual Notes Located Between Min and Max and Covered by the Histogram
$H[S_H]$	Histogram Process
$i$	Indice of Common Time Decimation for $S$
$M$	Total Number of Songs
$N_m$	Length of $m^{\text{th}}$ Song
$P_H$	Probability Density Function
$S$	Similarity Ratio
$S_H$	End to End Added Form of MIDI Note Values in All the Songs
$s_i$	Decimal Note Value as MIDI
$S_{i_m}$	MIDI Value of Note of $i_m$ Order of $m^{\text{th}}$ Song



## CHAPTER 1

### 1. INTRODUCTION

In Turkish music, notes, sound system and makam concept is different from Classical Western music [1,2,3]. These differences were informed by masters, theorists and composers of Turkish music. Also, some of the informations related to these subjects were added to literature [1,7,8,9]. But, the large number of these detected differences are based on intuition of the human ear and analysis of human brain. However, the investigation of Turkish music as matemactical via computer is important for understanding the features of makams and musical pieces, correction of the detections made by masters, deviations of these detections, clarification of the issues that make out human senses and analysis. Understanding a makam in Turkish music is related to investigation of melodic seyir i.e., examination of the flow in time axis. Accordingly, determination of makam features can be provided with detection features of melodic seyir, determination of succesive notes which contribute to the formation of melodic seyir, discovery of note intervals, determination of the transitions and revealing the similarities of musical pieces along time axis. Besides, in melodic seyir, there is an order placement of pentochords and tetrachords which creates makam scale. According to TRT, there are 146 makams in Turkish music [1,2]. However, only a small part of these makams are used mostly in these days [3]. In this thesis, Hicaz makam, Acemkürdi makam, Kürdi makam and Muhayyerkürdi

makam have been selected for examination. As a requirement of the rules of statistics, in order to generalize about a makam, the number of pieces of examined makam must go to infinity or almost all of the musical pieces of a makam need to be examined to understand the features of makam. Hence, number of examined musical pieces was kept high in this study. Furthermore, some mathematical analysis methods have been developed to integrate the qualitative features of makams and express more quantitatively.

### **1.1 Introduction to Music**

Most basically, music is a substantive sounds stacks in nature created with specific order and harmony. Ancient civilizations used music as a most basic communication tool with some harmonic sounds and rhythms before speaking. Music most basically entered human life used as religious purposes such as requiem. After then, civilizations used music for entertainment, feasts, dinner, even for education or many other things.

### **1.2 Turkish Music**

Turkish Music is different from other music types in the world such as western music. After Turks settled in Anatolia, Turkish music was separated branches and was developed. Turkish music has own rules. There are several distinguishing factors for Turkish Traditional Music. But, makam structure and sound system are the distinguishing factors between Turkish Traditional Music and other music systems. Turkish Music system and its scales were found and developed by Turks. But, on the subject of rhythm, Turkish music's structure was effected from

Arab culture. At the same time, in Turkish Music, tempos vary from rhythm to placement combination of notes or etc. Moreover, Turkish Traditional Music divided into two main parts as Turkish Art Music and Turkish Folk Music. Turkish Art Music is more esthetic and literate. Turkish Folk Music is generated by folk poets and it reflects endemic features. There are some other differences between Turkish Folk Music and Turkish Art Music. Some of these differences include style, form, creation and development aspects.

### **1.2.1 History of Turkish Music**

Turkish Traditional Music is one of the most important music types on earth in respect to cultural history and prosperity. The Traditional Turkish Music rely on at least 5000 years historical and cultural background. Turks have spreaded to wide lands in the World, Turkish Music interacted with many different music types. As a result of this, Turkish music is rich in content. In history, Turkish Music started with Altai. In this period, Turkish Music was exposed to a lot of changes. The Huns started to use music for entertainment. Kok Turks increased sound numbers of Turkish music. Uighur Turks seperated music as palace music, folk music, city music and village music. Karakhanid used music for religious purposes. The Turkish Music interacted with many music cultures during the Gahznavids period. Especially, after the conquest of Anatolian, with Seljuks, Turkish Music became one of the most widespread and important music in the world. Then the makam concept emerged and Turkish music was seperated into two main parts as Turkish art music and Turkish folk music. In this period, Turkish Music was influenced from Byzantian palace music and with this interaction, Turkish Music embraced many difference makam.

In Ottoman period, music was the most important cultural item. Moreover, music became the highest level art. At that time, Turkish folk music gained quite importance. Many poets introduced a lot of Turkish folk music piece into the World and Turkish cultural arena. Some of the Ottoman sultans also contributed to Turkish music with many pieces and makams. Especially, since early years of Turkish republic, Turkish Music has gained a special importance and meaning for Turkish culture. With Turkish Republic period, new composers appeared who interpreted Turkish Music according to Western style and produce new pieces. Cemal Reşit Rey, Ahmet Adnan Saygun, Ulvi Cemal Ergin, Hasan Ferit Alnar, Necil Kazım Akses composed important pieces in this period. These people also known as Turkish fivesome. With these developments, the Arel-Ezgi system is adopted to Turkish music. In this system, the main scale is accepted as Çargah scale and unequal 24 interval and 25 pitch are obtained by taking advantage of this scale in one octave. As it is seen from above, the real source of Turkish music dates back to central Asia. Furthermore, when we examine the modern and historical period of Turkish Music, we can say Turkish Music has been exposed to important interactions. With these inventions and contributions, Turkish Music has developed reaching the current level.

### **1.3 Differences Between Turkish Music and Western Music**

There are many widespread music types in the world. But, differences and similarities of two types of musics are important for this study. The first one we consider is Turkish Music and second one is Western Music. The most important difference between Turkish Music and Western Music is tonal system difference.

In Western Music system, one octave is divided 12 equal sound. But, in Turkish Music, one octave comprises 24 unequal intervals. Besides, harmonic structure of Western Music is different from Turkish Music. While Western Music is tonal and polyphonic, Turkish Music is modal and monophonic. Western music is generated by all of the western countries. The most common and prominent example of modal music is Turkish music. Turkish music has also music system which depends on natural sounds. Turks developed this type of music during many years and explained it by using mathematical expressions. According to western music, the main frequency values of all of the Turkish music notes ( $f_0$ ) offset a bit. But, Dugah's (La,A4) frequency value ( $f_0=440$  Hz) is same with western music system. In Western music, one exact note interval is divided into 2 equal part. But, in Turkish music, one exact note interval is divided 9 equal koma interval. As it is seen in Table 2.2 in section 2.9, in the Western music, none of the these koma values are equal to flat and sharp positions. Especially, it is impossible to generate flat2 and sharp3 komas in piano which are used in Turkish Folk Music. In western music, there is no difference between octaves. It is supposed that octaves can be folded over one another for analyses. But, in Turkish music, this is meaningless. For this reason, most notes have different pitch names which are different from one octave to the other. For example, while G4 is known as Rast, one octave above note G5 is known as Gerdaniye. In Western Music, key signatures are the main elements to describe the major and minor scales. In Turkish Music, makam concept is not only described by key signature, melodic seyir and the chords in the melodic seyir are of equal importance.

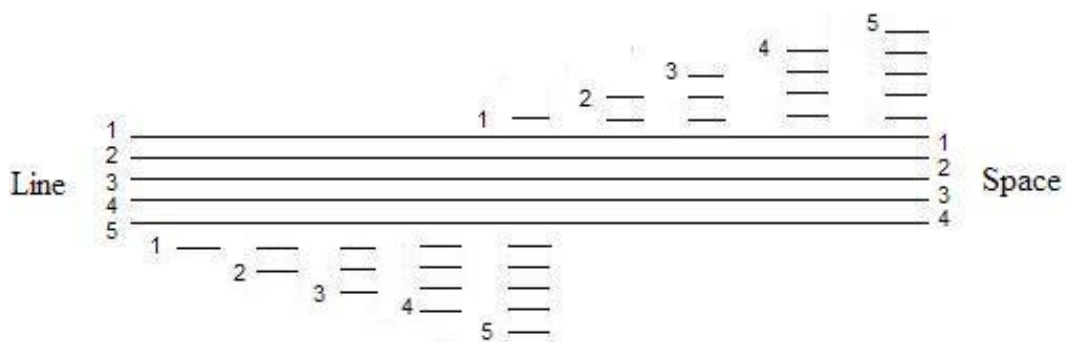
## CHAPTER 2

### 2. SOME EXPRESSIONS RELATED TO MUSIC

Some details related to the understanding of music are explained below.

#### 2.1 Staff and Additional Lines

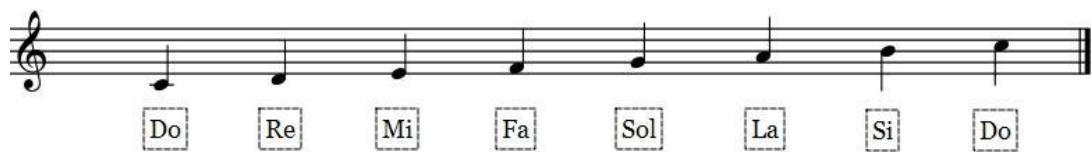
Staff is a system consist of five lines and four spaces. The notes are written on staff system. And also other things about the sound and note are written on this system such as accidentals and articulations. We can only write eleven notes on one staff. Thus, additional lines have to be drawn for writing more notes on one staff. These lines and spaces are shown in Figure 2.1.



**Figure 2.1.** Staff and additional lines

## 2.2 Note

Note is a specific sign which is used for reading and writing the sounds. Just as we use specific letters to convert from speaking language to writing language, we use specific signs to convert from musical sounds to writing. There are seven notes and these are La, Si, Do, Re, Mi, Fa, Sol. If the notes are ranged as Figure 2.2, this is called octave. The octave is an interval between one pitch.



**Figure 2.2.** Notes

Moreover, we express notes with letters in Table 2.1.

**Table 2.1.** Letter names of notes

Note	Letter
Do	C
Re	D
Mi	E
Fa	F
Sol	G
La	A
Si	B

When the range of notes Do to Si, it is named as C Major. If you read the notes La to Do, it is named as La Minor.

### 2.3 Values of Notes and Rests

There are eight types of signs used to specify note duration as shown in Figure 2.3. These are whole note, half note, quarter note, eighth note, 16th note, 32nd note, 64th note and 128th note. Note value is related to note duration.



**Figure 2.3.** Values of notes

Each note duration has corresponding rest value. But, rest values are inversely proportional to their own note duration values. The rest values are shown in Figure 2.4.

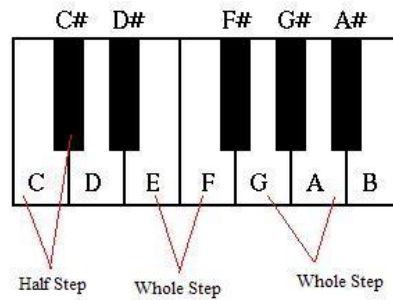


**Figure 2.4.** Values of rests

### 2.4 Whole and Half Step

In Western music system, there are specific distances between notes. Some notes distances are whole step and some notes distances are half step. The distances between Do-Re, Re-Mi, Fa-Sol, Sol-La, La-Si are whole steps. But, the distances between Mi-Fa, Si-Do are half steps as shown in Figure 2.5. A half step is a  $\frac{1}{12}$  of an octave, or 1 semitone and a whole step is a  $\frac{1}{6}$  of an octave, or 2 semitones.





**Figure 2.5.** Whole and half step

## 2.5 Low and High Pitched Concept

In music pitch is defined as frequency. Bass sounds are low pitched (low frequency) and thin sounds are high pitched (high frequency). Low pitched sounds are comprised a few numbered and heavy vibrations. High pitched sounds are comprised numerous vibrations. Notes express the low or high pitched situation of sounds according to placements on staff. The notes which are placed in the underside of staff are more lower pitched than the notes which are placed in the upperside of the staff. Similarly, the notes which are placed upperside of staff are more higher pitched than the notes which are placed underside of the staff.

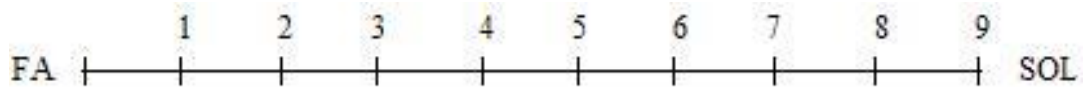
## 2.6 Form

Form is comprised of equal and unequal specific hits. These specific hits named as heavy and poor hits. These hits are merged and they create some patterns. Also these specific patterns are called as “form”. Forms are separated into two groups according to structures and times. Structural forms are also separated into 2 groups. These are simple forms and unified forms. Simple forms are 2 or 3 times. There is no different form in structure of simple forms. This type of forms are used to

make other forms. Examples of simple forms are Nim Sofyan and Semai. Unified forms comprise of two or more forms. Durational forms are also separated 2 groups. These are minor forms and major forms. Minor forms times vary from 2-15. Song, Yürük Semai, instrumental semai, folk song pieces are composed with minor forms. Major forms times must be at least 16 times or more. Ağır semai, peşrev and some of the religious music pieces are composed with major forms.

## 2.7 Koma

In Turkish music, one octave is divided into unequal 24 intervals, while one whole step is divided into 9 equal parts. Each of the 9 equal parts is named as koma. The komas are shown in below.



**Figure 2.6.** Komias

In Western music, because of one whole step's dividing 2 equal parts, half step is 4,5 komas. In Turkish music, there are 9 komas in whole steps, whereas in half steps (E-F, B-C), there are 4 komas in Western music. Thus, in Turkish music, there are 53 komas in one octave.

## 2.8 Accidental Signs

Accidental signs are used to increase or decrease the pitch between two notes. These signs are usually placed in front of the note. In Western music system, these

are sharp and flat. But, in Turkish Music system, this situation is different. Because, one octave is divided 24 unequal intervals. So, to define these sounds, special accidental signs are used. These accidental signs are labelled as title of komas. These accidental signs of Western music are as follows.



**Figure 2.7.** Accidental signs

### **2.8.1 Sharp**

This sign increases the note half tone or make the note high pitched. It is shown with # sign.

### **2.8.2 Flat**

This sign decreases the note half tone or make the note low pitched. It is shown with b sign.

### **2.8.3 Natural**

This sign makes the notes natural which is deformed by sharp and flat. It cancels the accidental changes. It is shown as ♮ sign.

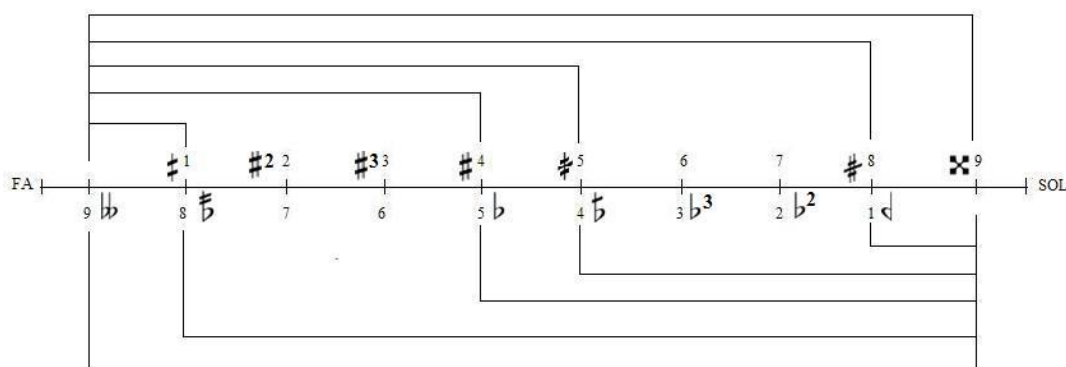
## **2.9 Accidental Signs in Turkish Music**

While in Western music, only 1 sharp and 1 flat are used as accidental signs, in Turkish music, there are 4 sharps and 4 flats are used as accidental signs. The abbreviations, values, names and figures of these accidental signs are shown below in Table 2.2.

**Table 2.2.** Names, figures, koma values and abbreviations of accidental signs in Turkish music

Name of sign	Figure of sign	Koma value of sign	Abbreviation of sign
Koma sharp	#	1 koma	F
Koma flat	♭	1 koma	F
Sharp2	# <sup>2</sup>	2 koma	-
Flat2	♭ <sup>2</sup>	2 koma	-
Sharp3	# <sup>3</sup>	3 koma	-
Flat3	♭ <sup>3</sup>	3 koma	-
Bakiyye sharp	#	4 koma	B
Bakiyye flat	♭	4 koma	B
Minor müccennep sharp	#	5 koma	S
Minor müccennep flat	♭	5 koma	S
Major müccennep sharp	#	8 koma	K
Major müccennep flat	♭	8 koma	K
Tanini sharp	✕	9 koma	T
Tanini flat	♭	9 koma	T

The koma values of intervals can be calculated easily from Table 2.2. Figure 2.8 also shows sharps and flats which are used in whole step in Turkish music.



**Figure 2.8.** Koma values of intervals according to accidental signs

## 2.10 Intervals

Interval concept can be described as frequency difference between two sounds. In other words, it can be described as low pitch and high pitch difference between two sounds.

### 2.10.1 Harmony and Melody Interval

If the sounds that compose interval are heard simultaneously, this is harmony interval. If the sounds that compose interval are heard consecutively, this is melody interval. In polyphonic Western Music system, harmony intervals and correspondances are important. But, in monophonic Turkish Music system, melody intervals are important. The example of harmony and melody interval is shown below.



Figure 2.9. Harmony and melody interval

### 2.10.2 Upper and Lower Interval

If the first sound which composes interval is low pitched and second sound which also composes interval is high pitched, this is an upper interval. If first one of the sounds that compose interval is high pitched and second one is low pitched, this is lower interval. The example of upper and lower interval is shown below.



**Figure 2.10.** Upper and lower interval

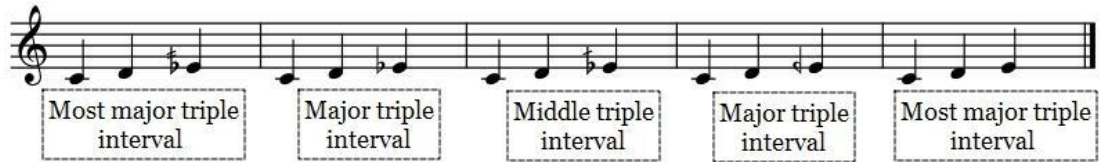
## 2.11 Intervals in Turkish music

The concept of interval is different in Turkish music from Western music. These different intervals are explained in below.

### 2.11.1 Dual interval

Dual interval is the smallest interval that are used in Turkish music. There are 6 kinds of dual intervals in Turkish music. These can be ranged as koma interval, diminished bakiyye interval, bakiyye interval, minor mücennep interval, major mücennep interval and tanini interval. The examples of dual interval are shown in Figure 2.11.





**Figure 2.12.** Triple intervals

### 2.11.3 Tetrachord interval

If the interval is generated from 2 tanini intervals and 1 bakiyye intervals, it is complete tetrachord interval and its koma value is 22 (9+9+4) koma. If interval koma value is more than 22 koma, it is excess tetrachord interval. If interval koma value is less than 22 koma, then it is incomplete tetrachord interval. And, the examples of these are shown in Figure 2.13.



**Figure 2.13.** Tetrachord intervals

### 2.11.4 Pentachord interval

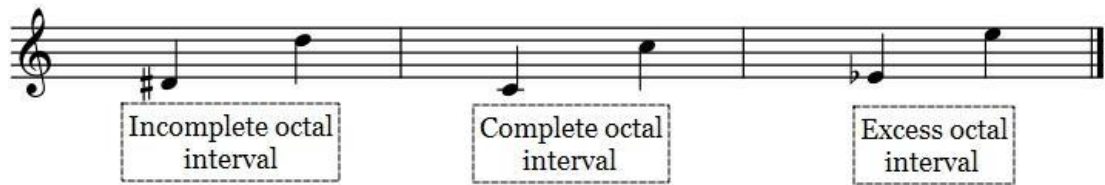
When 3 tanini intervals are added to 1 bakiyye interval, this is called complete pentachord interval and its koma value is 31 komas. Complete pentachord interval is also obtained by adding complete tetrachord interval to 1 tanini interval. If interval koma value is more than 31 koma, then it is excess pentachord interval. If interval koma is value less than 31 koma, then it is incomplete pentachord interval. The examples of pentachord interval are shown in Figure 2.14.



**Figure 2.14.** Pentachord intervals

### 2.11.5 Octal intervals

Octal interval can be generated from 2 bakiyye interval and 5 tanini interval or 1 complete tetrachord interval and 1 complete pentachord interval and its koma value is 53 koma. If interval koma value is more than 53 koma, then it is an excess octal interval. If interval koma value is less than 53 koma, then it is incomplete octal interval. The examples of octal interval can be seen in Figure 2.15.



**Figure 2.15.** Octal intervals

### 2.12 Tetrachords and Pentachords

Generally, tetrachords and pentachords are used to constitute fundamental makams, i.e., makams are obtained from combination of tetrachords and pentachords in Turkish music. Sometimes, tetrachords are in the low pitched side and pentachords are in the high pitched side. Or, this can be opposite. However, in some makams, tetrachords and pentachords can be nested.



### 2.12.1 Exact tetrachords and exact pentachords

Exact tetrachords are 22 komas and exact pentachords are 31 komas. There are six exact tetrachords and six exact pentachords which are used to constitute the fundamental makam scales. These tetrachords and pentachords are shown in Table 2.3.

**Table 2.3.** Exact tetrachords and exact pentachords

Exact tetrachords	Exact pentachords
Çargah	Çargah
Buselik	Buselik
Kürdi	Kürdi
Rast	Rast
Uşşak	Hüseyni
Hicaz	Hicaz

If 1 tanini is added to tetrachords, the pentachords are obtained. As it is seen above, only name of tetrachords of Uşşak changes. When 1 tanini is added to tetrachord of Uşşak, it changes to pentachord.

### 2.12.2 Other tetrachords and pentachords

Aside from exact tetrachords and exact pentachords, there are some other tetrachords and pentachords in Turkish music. These are Saba tetrachord, Segah pentachord, Hüzzam pentachord, Nikriz pentachord, Pençgah pentachord, Ferahnak pentachord, Müstear pentachord, Nişabur pentachord.

## **2.13 Makam**

Makam is a melodic structure which has certain rules and is used with combination of more than one sound. Makam is also composed of various sound forms. Makam concept is used in Turkish music. Generally, Makam is specified with durak, güçlü and yeden sounds and it has a specific melodic seyir. When makam is examined in historical process, we can see evolutions and convergence. For example, there are more than 500 makams in Turkish music but, 60 or 70 makams are used these days.

### **2.13.1 Durak pitch**

Durak is the first sound of the scale of makam features and scale of makam. Durak is also the last sound of the song. The seyir finishes with this sound. The other name of this pitch is karar pitch. Durak is also most low pitched sound of the scale. Durak can change from makam to makam. Furthermore, durak is the most important pitch for makam and scale.

### **2.13.2 Güçlü pitch**

Güçlü pitch is the sound which combines the tetrachord and pentachord or pentachord and tetrachord in main makams. Generally, temporary hangings are made around this pitch. While the song progresses, we sustain around this pitch temporarily. Güçlü pitch is as important as durak pitch.

### 2.13.3 Yeden pitch

Yeden pitch takes song to the final stage. It is a sub sound of the durak pitch. Yeden pitch fortifies the durak pitch.

### 2.13.4 Suspension decision pitch

Suspension decision pitch is a temporary decision pitch. But, the real decision pitch is conserved. It changes from makam to makam. Sometimes, it is not obvious which pitch is suspension decision pitch. It can be more than one for some makams.

### 2.13.5 Scale

In the scale, 8 notes or octaves are generally ranged as successively according to pitch level and according to specific rules. An example of the scale is shown in Figure 2.16.



Figure 2.16. Scale

### 2.13.6 Seyir

Seyir can be described as the progress of notes of makam scales along time axis. Seyir is used to identify the characteristic features of makams. In the progress of seyir, makam rules are important. In terms of the pitch direction, there are 3 types of seyirs.

#### **2.13.6.1 Ascendant seyirs**

In this seyir, song begins in durak pitch and advances around low pitch region. Then, temporarily, song hangs around in güçlü pitch and subsequently moves on to high pitch region. Lastly, song comes back to on low pitch region and terminates at karar pitch.

#### **2.13.6.2 Descendant seyirs**

In this seyir, song begins in high pitch region of durak pitch and advances on to low pitch region. Temporarily, song hangs around in güçlü pitch and moves on to low pitch region. Eventually, song terminates at karar pitch.

#### **2.13.6.3 Ascendant – Descendant seyirs**

In this seyir, song begins with güçlü pitch and advances on to low pitch and high pitch regions of scale. Temporarily, song hangs around in güçlü pitch and song moves back to low pitch and high pitch region. Eventually, song terminates around karar pitch.

### **2.14 Turkish music makams**

Turkish music makams can be examined under 3 main headings. These are main makams, şed makams and unified makams.

#### **2.14.1 Main makams**

These are obtained by adding exact tetrachord to exact pentachord or adding exact pentachord to exact tetrachord. Main makams are shown with an octave. The fusing

note of exact tetrachord and exact pentachord or exact pentachord and exact tetrachord is güçlü pitch. The accidental sign can not added to first note of scale. According to makams, scales are started from 3 pitches. These are çargah pitch, rast pitch and düğah pitch. There are 13 main makams. These are listed in the first column of Table 2.4.

### 2.14.2 Şed makams

If some of the start up pitch of main makams scales are modified, then şed makams are obtained. Some of the şed makams are listed in the second column of Table 2.4.

**Table 2.4.** Main makams, şed makams and unified makams

Main makams	Şed makams	Unified makams
Çargah	Acemaşiran	Hüzzam
Buselik	Mahur	Segah
Kürdi	Sultan-ı yegah	Nikriz
Rast	Ruhnevaz	Nev-eser
Basit Süz-nak	Nihavend	Saba
Uşşak	Ferahnüma	Irak
Hüseyni	Aşkefza	Eviç
Karcıgar	Kürdilihiczkar	Ferahnak
Neva	Şedaraban	Nişaburek
Hümayun	Süz-i dil	Acem
Hicaz	Evcara	Acemkürdi
Uzzal	Hicazkar	Muhayyerkürdi
Zirgüleli Hicaz	Zirgüleli Süz-nak	Sazkar
		Gerdaniye
		Gülizar
		Şehnaz
		Ferahfeza
		Bestenigar
		Bayatiaraban
		Isfahan
		Zavil

### **2.14.3 Unified makams**

Unified makams are obtained by adding and revising some of the main makam scales or other makam scales. Some of the unified makams are listed in the third column of Table 2.4.

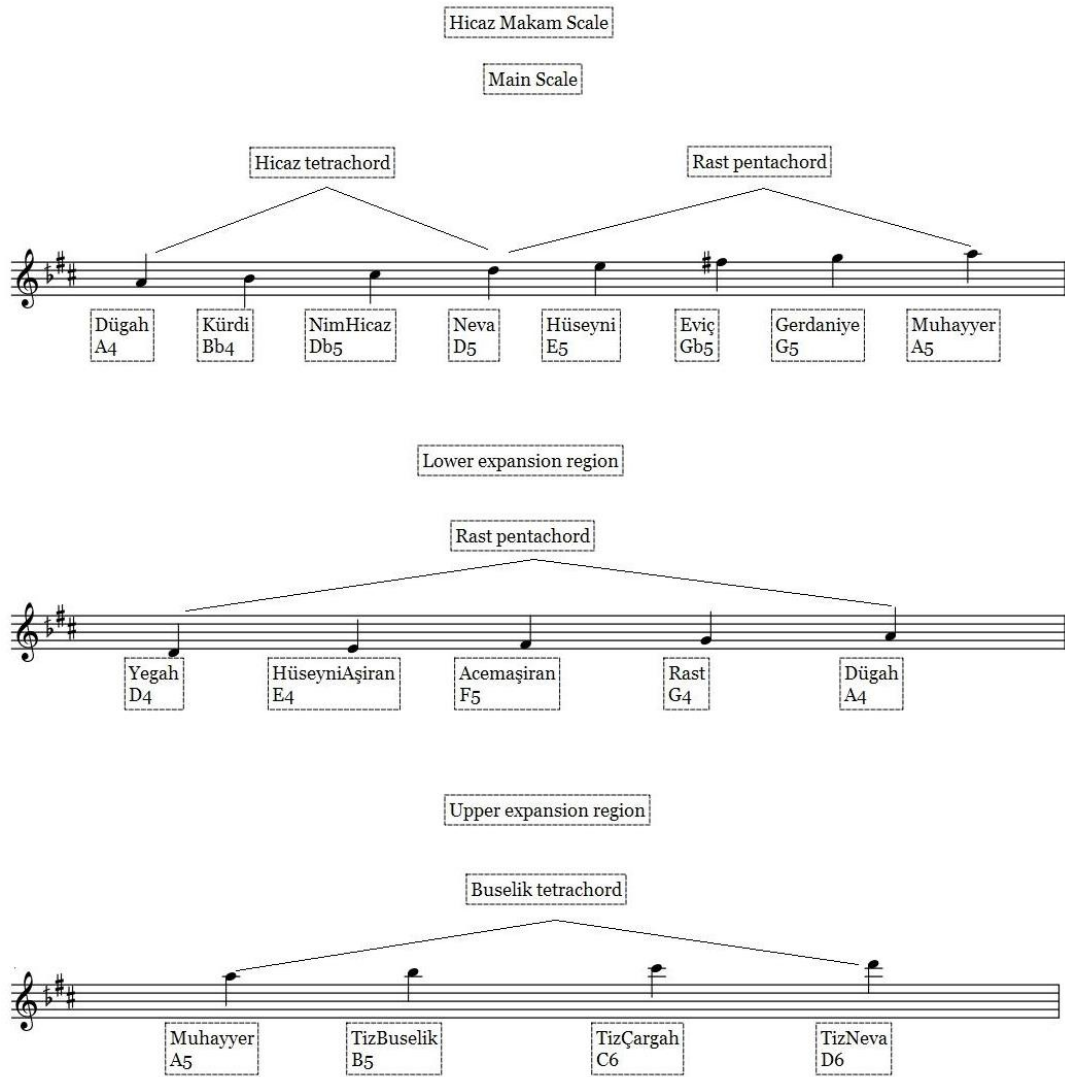
### **2.15 Makams Used in This Thesis**

There are four makams that we used in this thesis. These are Hicaz makam, Acemkürdi makam, Kürdi makam and Muhayyerkürdi makam. These makams are explained in the followings.

#### **2.15.1 Hicaz Makam**

Nowadays, hicaz makam is one of the most used makams and it is one of the oldest makams in the Turkish traditional music. From past to present, hicaz makam is described by Rauf Yekta, Hüseyin Sadettin Arel, Suphi Ezgi, Abdulkadir Töre, Ekrem Karadeniz and many other composers. Hicaz makam is a main makam. General features of Hicaz makam are as follows: Its durak pitch is Dügah pitch, güçlü pitch is Neva pitch, yeden pitch is Rast pitch. Hicaz makam has a ascendant-descendant seyir. The notes of Hicaz scale from low pitch to high pitch are Dügah, Kürdi, Nim Hicaz, Neva, Hüseyini, Eviç, Gerdaniye and Muhayyer. Main scale is obtained by adding hicaz tetrachord in Dügah to Rast pentachord in Neva. The expansion to the lower region (low pitched) is obtained by Rast pentachord. The expansion to the upper region (high pitched) is obtained by Buselik tetrachord. The main scale and expansion regions of Hicaz makam are shown in Figure 2.17 with Turkish music pitch names and converged approximated note names to the Western

music [3]. Generally, in literature, Hicaz makam seyir is started with Hicaz tetrachord by using A4 or D5 notes. Firstly, moving on disordered in scale. After, switching to the Rast pentachord which is in the upper region of scale, it makes temporary hangings there. If needed, it moves on to expansion regions, making suspensions there. Lastly, moving on to Buselik tetrachord, it comes back to Hicaz tetrachord and terminates at A4.



**Figure 2.17.** Hicaz makam scale

### **2.15.2 Acemkürdi Makam**

Acemkürdi makam is one of the most used makams and it is almost 100 years old. The Acemkürdi makam is a unified makam. It is obtained by combining Kürdi tetrachord with shifted Buselik pentachord. General features of Acemkürdi makam as follows: Its durak pitch is Dügah pitch, güçlü pitch is Acem pitch, yeden pitch is Hüseyनियाşiran pitch. Acemkürdi makam has a ascendant-descendant seyir. The pitches of Acemkürdi scale from high pitch to low pitch are Dügah, Kürdi, Çargah, Neva, Hüseyni, Acem, Gerdaniye, Muhayyer, Sümbüle and Tiz Çargah. According to the literature of Turkish music, the melodic seyir of Acemkürdi makam starts with shifted Buselik pentachord of the core region and begining note is generally F5 [1,7]. The seyir continues with shifted Buselik pentachord and Çargah pentachord of the expansion region. Then, seyir continues to Kürdi pentachord with the C5 or A4 notes. Eventually, seyir ends around A4. The common core region and expansion region of Acemkürdi makam are shown in Figure 2.18 with Turkish music pitch names and converged approximated note names to the Western music.

### **2.15.3 Kürdi Makam**

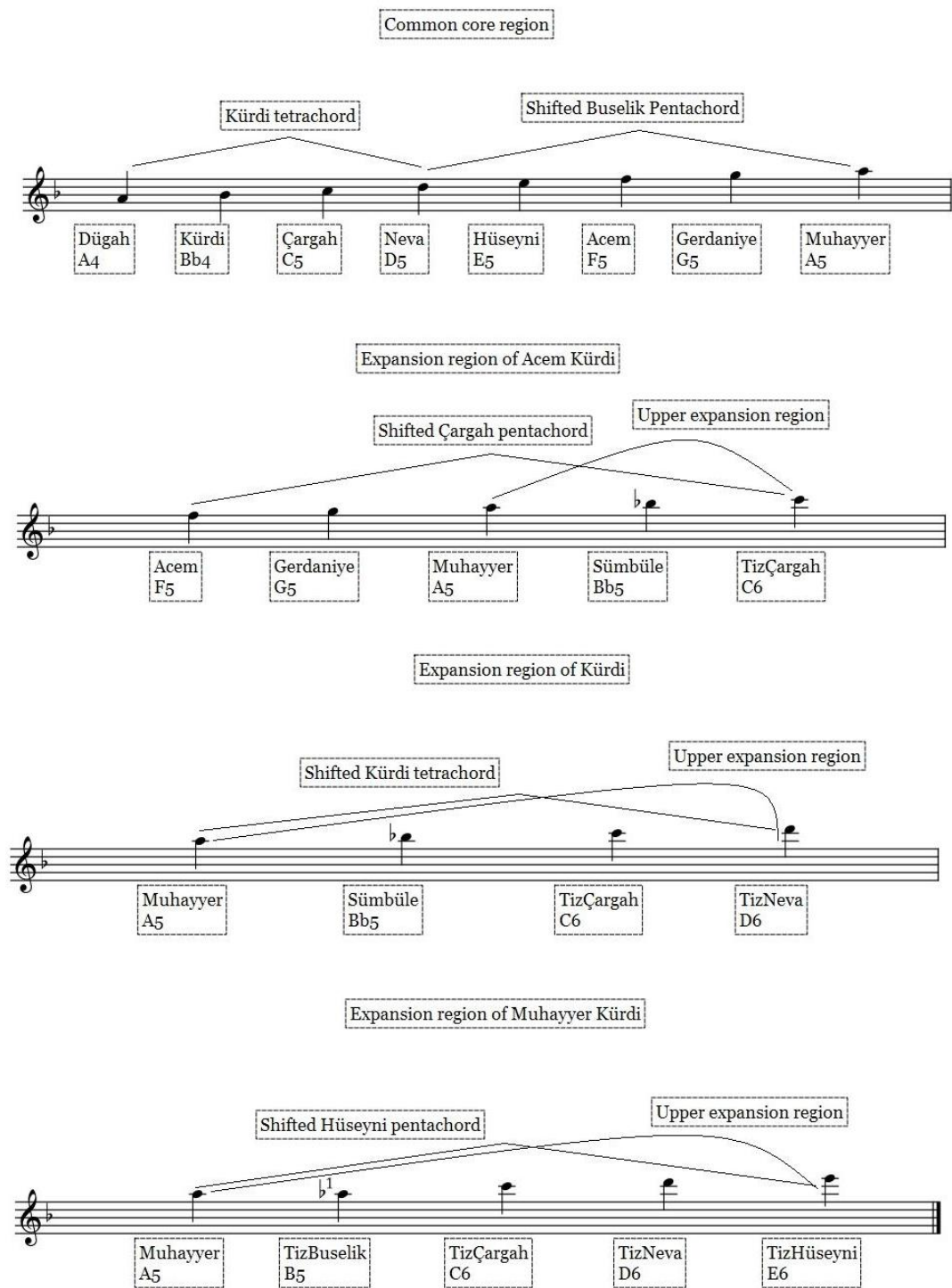
Although Kürdi makam is one of the oldest makams, it has only been used recently. Furthermore, şed and unified makams of Kürdi are more demanded than Kürdi. The Kürdi makam is a main makam. General features of Kürdi makam as follows. Its durak pitch is Dügah pitch, güçlü pitch is Neva pitch, yeden pitch is Rast pitch. Its seyir is generally descendant. But, sometimes it is used in ascendant-descendant form. The pitches of Kürdi scale from high pitch to low pitch are Dügah,



Kürdi, Çargah, Neva, Hüseyini, Acem, Gerdaniye and Muhayyer. Kürdi makam starts the seyir with Kürdi tetrachord using A4 or D5. The seyir continues with Buselik pentachord. Then, melodic seyir is finished around A4 by using Kürdi tetrachord. The common core region and expansion region of Kürdi makam are shown in Figure 2.18 with Turkish music pitch names and converged approximated note names to the Western music.

#### **2.15.4 Muhayyerkürdi Makam**

Muhayyerkürdi makam has been used with big interest for one and a half centuries in Turkish traditional music. The Muhayyerkürdi makam is a unified makam. It is obtained by mixing Muhayyer makam scale and Kürdi tetrachord. General features of Muhayyerkürdi makam as follows. Its durak pitch is Dügah pitch, güçlü pitch is Muhayyer and Hüseyini pitches, yeden pitch is Rast pitch. Acemkürdi makam has a descendant seyir. The pitches of Muhayyerkürdi scale from low pitch to high pitch are Dügah, Kürdi or Segah, Çargah, Neva, Hüseyini, Eviç or Acem, Gerdaniye and Muhayyer. The melodic seyir of Muhayyerkürdi starts with Buselik pentachord around A5 and it advances to upper expansion region of shifted Hüseyini pentachord. Then, it moves on Kürdi tetrachord with D5 note. At last, it ends around A4. The common core region and expansion region of Muhayyerkürdi makams are shown in Figure 2.18 with Turkish music pitch names and converged approximated note names to the Western music.



**Figure 2.18.** Acemkürdi makam, Kürdi makam and Muhayyerkürdi makam scales

## CHAPTER 3

### 3. ANALYSIS

#### 3.1 Transferring Data to The Digital Medium

The study contains Turkish Art music compositions of TRT repertory. 40 Hicaz art music songs, 40 Hicaz folk music songs, 40 Acemkürdi art music songs, 40 Kürdi art music songs, 40 Muhayyerkürdi art music songs of TRT repertory and 3 Hicaz seyirs were chosen for analysis. Before analysis, firstly, the notes of these compositions were transferred to the digital medium and correction of these transferred compositions were made by human ear. While transferring these compositions to the digital medium, the Finale has been used, which is professional musical notation program. Some screenshots related to the Finale and compositions are shown in Figure 3.1. Secondly, in the Finale, these written and checked compositions were recorded in MIDI file format where note names and durations are in binary format. Lastly, MIDI file formatted compositions were transferred to the MATLAB interface software program that enabled analysis. Screenshot of MATLAB can be seen in Figure 3.2. MIDI file format is also acceptable in MATLAB. So, the Finale was convenient during these processes.

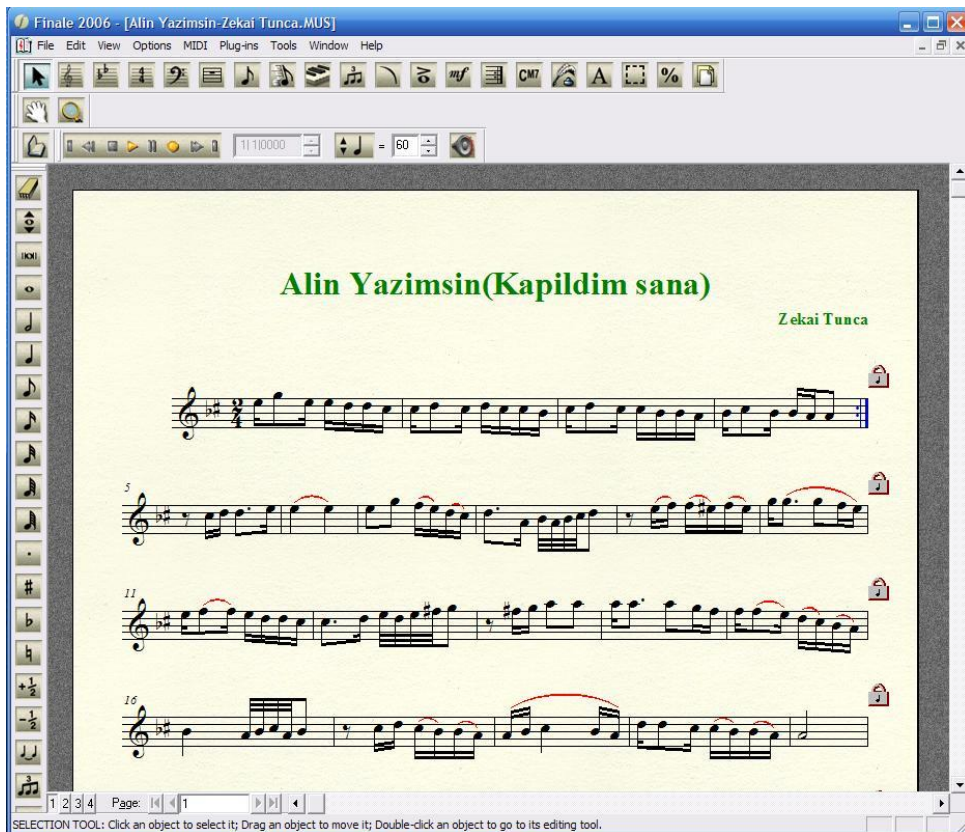


Figure 3.1. Snapshot of Finale

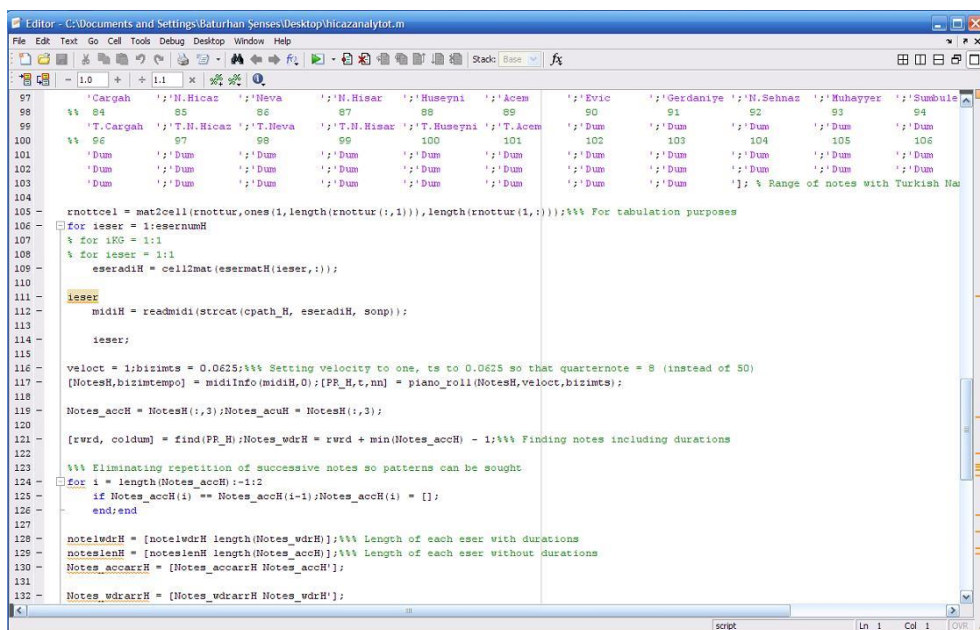


Figure 3.2. Snapshot of MATLAB

### 3.2 Histogram Based Analysis

Properties of major and minor scales in Western Classical music which are associated with makam concept in Turkish music can be understood from corresponding histogram graphs [10]. Histogram graphs were constructed by calculating note usage rates of the full duration songs and seyirs, where scales were used. In this part, there is only detection of pitches like Güçlü, Durak and so on. Information of which notes or note groups are in which duration zone of the song, is entirely omitted. The chosen and written 40 Hicaz art music songs, 40 Hicaz folk music songs, 40 Acemkürdi art music songs, 40 Kürdi art music songs, 40 Muhayyerkürdi art music songs and 3 Hicaz seyirs examined with the MATLAB codes and the obtained results were compiled. The Hicaz seyirs used in the analysis belong to Rauf Yekta, Şefik Gürmeriç and Erol Bingöl. According to notes usage densities, the histogram graphs that are obtained from these songs are shown in Figure 3.3a, Figure 3.3b, Figure 3.3g, Figure 3.3h, Figure 3.3i. Histogram graphs of 3 seyirs and all of the seyirs also can be seen in Figure 3.3c, Figure 3.3d, Figure 3.3e and Figure 3.3f. In the histogram graphs, while horizontal axis stands for notes and pitches in Turkish music, vertical axis stands for density of usage of notes and pitches in terms of percentage. According to these histogram graphs, note variety in Şefik Gürmeriç's seyir is more than Rauf Yekta and Erol Bingöl's seyirs. Besides, these results were gained by taking into account of the values in Table 3.1. Hence, when all songs and seyirs are taken into account, most used notes are generally as the makams rules require. In addition, it can be seen that songs also widen expansions zones. Calculations of correlations between songs and seyirs, shown in Table 3.2,

were made by the method mentioned below. Formulations of calculations are shown for Hicaz songs and Erol Bingöl's seyir, however it is the same for other songs and seyirs.

By adding each Hicaz songs to the end of the other, the following formulation is obtained.

$$S_H = \sum_{m=1}^{M_H} \sum_{i_m=1}^{N_m} S_{i_m} \quad (1)$$

In here,  $M_H$  is the total number of Hicaz songs,  $N_m$  is the length of  $m^{\text{th}}$  song,  $S_{i_m}$  is the MIDI value of note of  $i_m$  order of  $m^{\text{th}}$  song. Hence,  $S_H$  is a end to end array of MIDI note values in all the songs. If the histogram operator ( $\mathbf{H}[S_H]$ ) is applied to  $S_H$ , the following formula is obtained.

$$\mathbf{H}[S_H] = P_H = \sum_{i=H_{\min}}^{H_{\max}} P_i \quad (2)$$

The  $P_H$  is a probability density function which gives us histogram function.  $P_i$  also gives us a frequency of usage of individual notes located between  $H_{\min}$  and  $H_{\max}$  and covered by the histogram. In order to make possible the calculation of cross correlation between songs and seyirs, horizontal axes of histograms should be in the same note range. For this cross correlation, two parameters are needed like  $C_{\min}$  and  $C_{\max}$ . If cross correlation between Hicaz songs and the seyir that belongs to Erol Bingöl is to be calculated,  $C_{\min}$  and  $C_{\max}$  are

$$C_{\min} = \min(H_{\min}^H, H_{\min}^{EB}), C_{\max} = \max(H_{\max}^H, H_{\max}^{EB}) \quad (3)$$

The similarity ratio between Hicaz songs and seyir that belongs to Erol Bingöl is also named as cross correlation coefficient and given by

$$\rho_{HEB} = \frac{\sigma_{HEB}}{\sigma_H \sigma_{EB}} \quad (4)$$

The terms in Eq. (4) can be calculated as shown below.

$$\begin{aligned} \sigma_{HEB} &= \sum_{i=C_{\min}}^{C_{\max}} ({}_H P_i - m_H)({}_{EB} P_i - m_{EB}) , \\ \sigma_H &= \sqrt{\sum_{i=C_{\min}}^{C_{\max}} ({}_H P_i - m_H)^2} \quad , \quad \sigma_{EB} = \sqrt{\sum_{i=C_{\min}}^{C_{\max}} ({}_{EB} P_i - m_{EB})^2} \end{aligned} \quad (5)$$

In Eq. (5),  $m_H$  and  $m_{EB}$  show the average of histograms of Hicaz songs and seyir that belongs to Erol Bingöl.

As can be seen from the Table 3.2, by using the static informations, the similarity ratios between Hicaz songs, Hicaz seyirs, Acemkürdi songs, Kürdi songs and Muhayyerkürdi songs come out be too high. It is known that in the calculation of similarity or distinctiveness between makams, the histogram method is not valid since it is composed of static information which is independent of time axis [4]. The next section describes how time information can be added to the analysis.

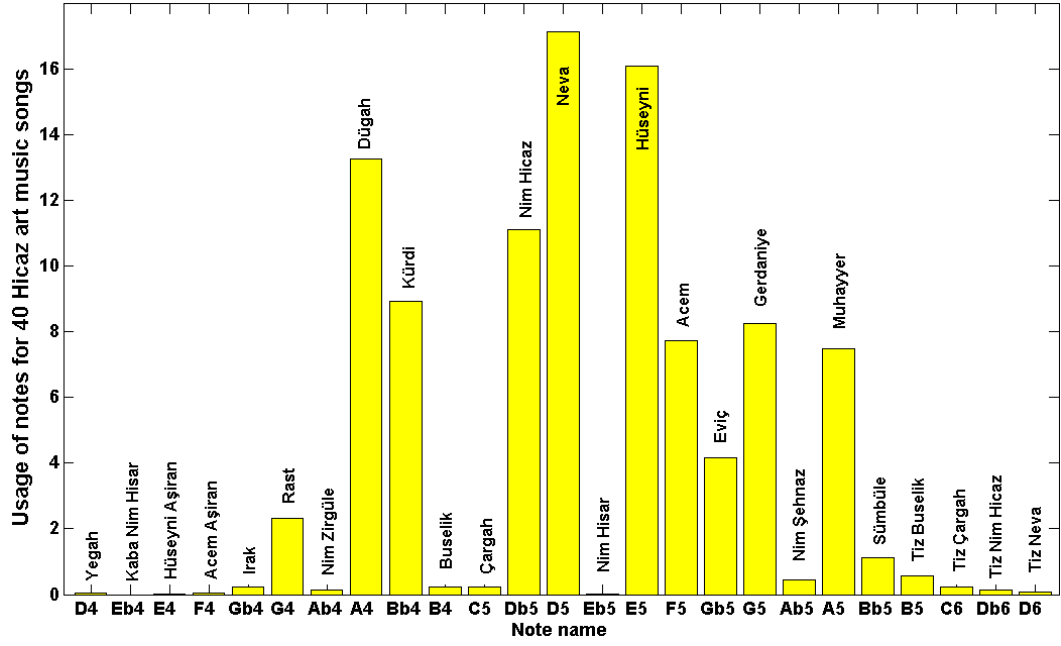


Figure 3.3a. Usage of Notes for 40 Hicaz Art Music Songs

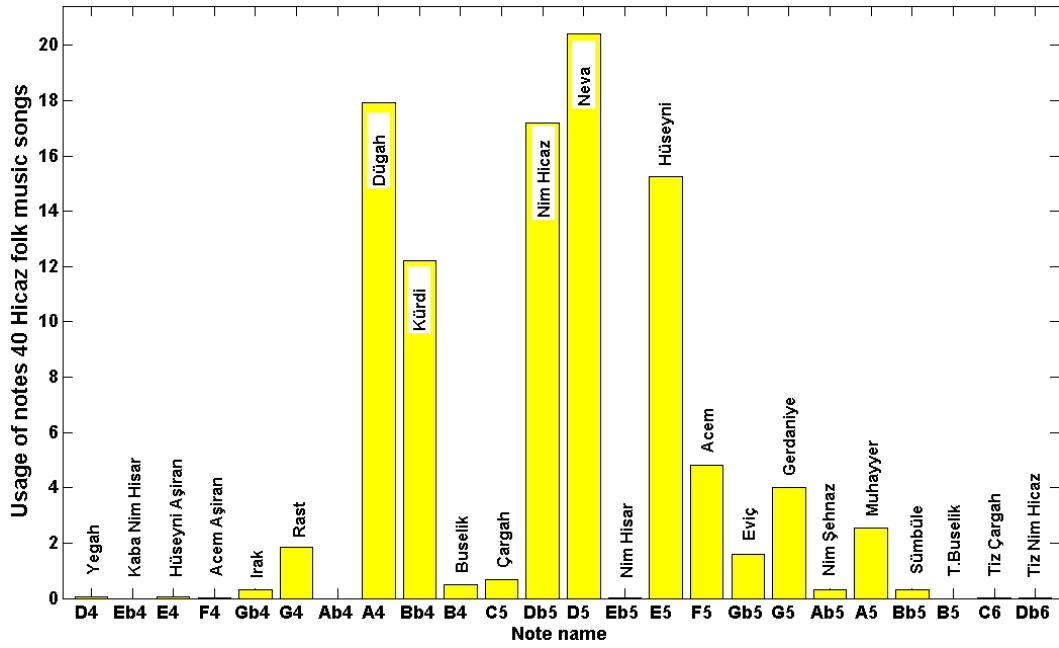


Figure 3.3b. Usage of Notes for 40 Hicaz Folk Music Songs



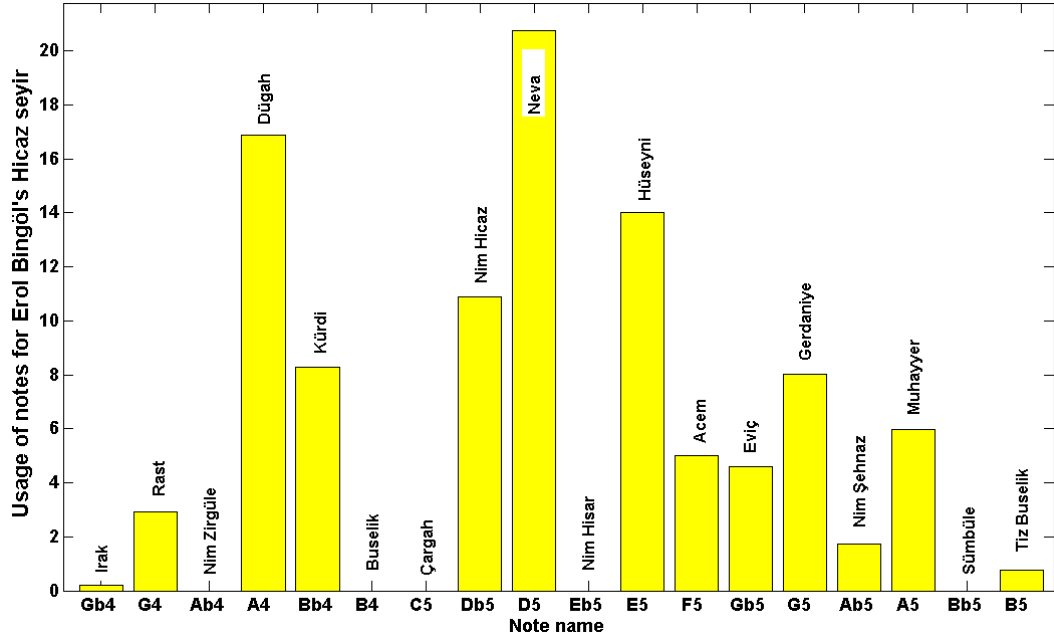


Figure 3.3c. Usage of Notes for Erol Bingöl's Hicaz Seyir

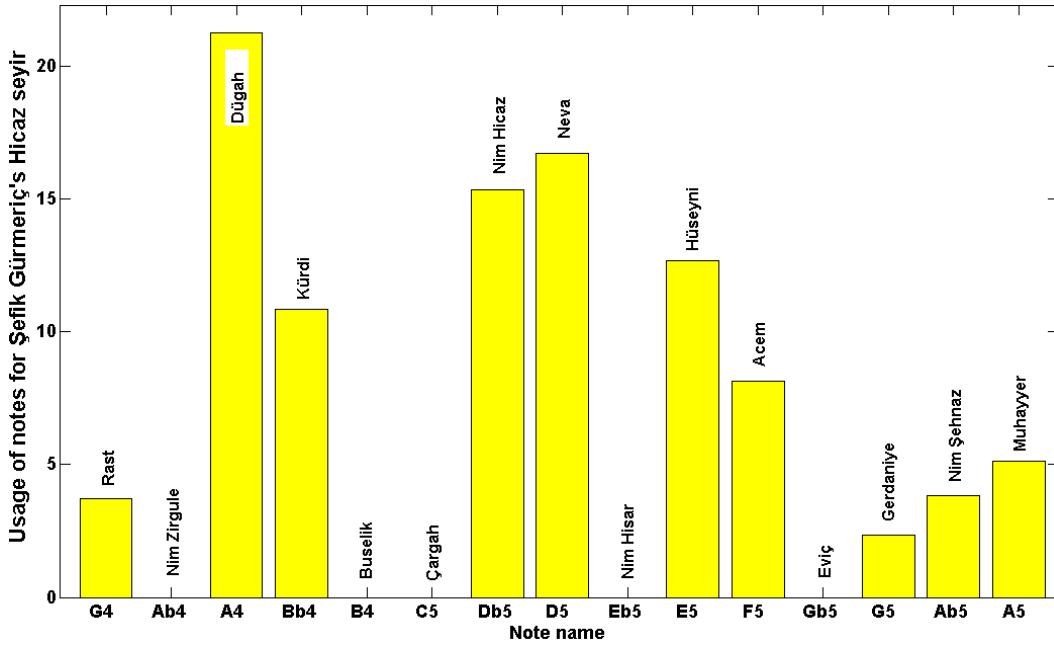


Figure 3.3d. Usage of Notes for Şefik Gürmeriç's Hicaz Seyir

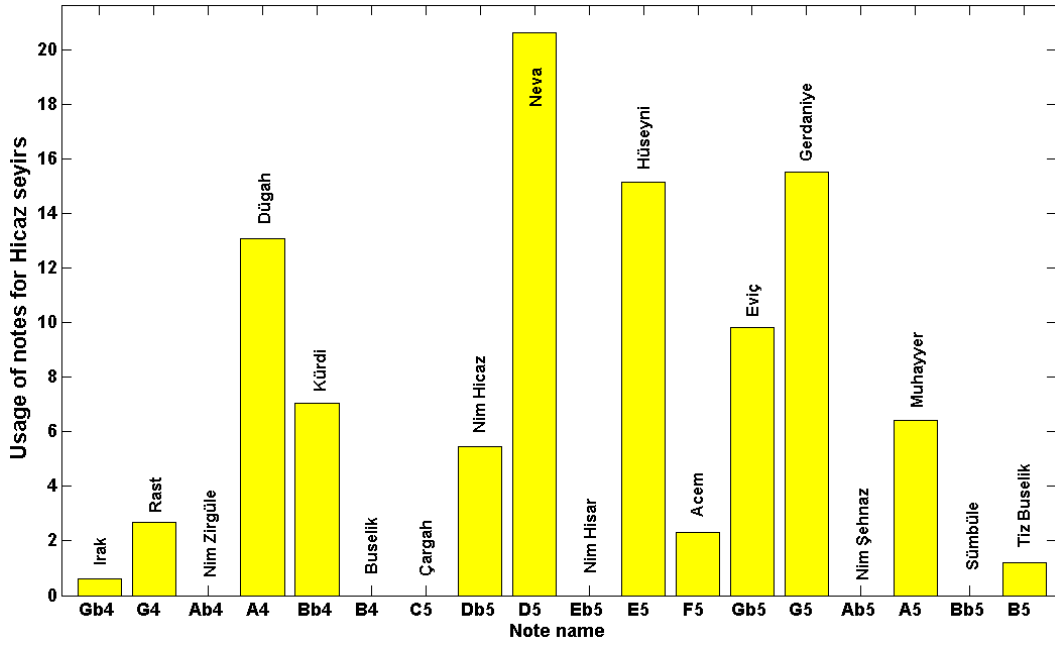


Figure 3.3e. Usage of Notes for Rauf Yekta's Hicaz Seyir

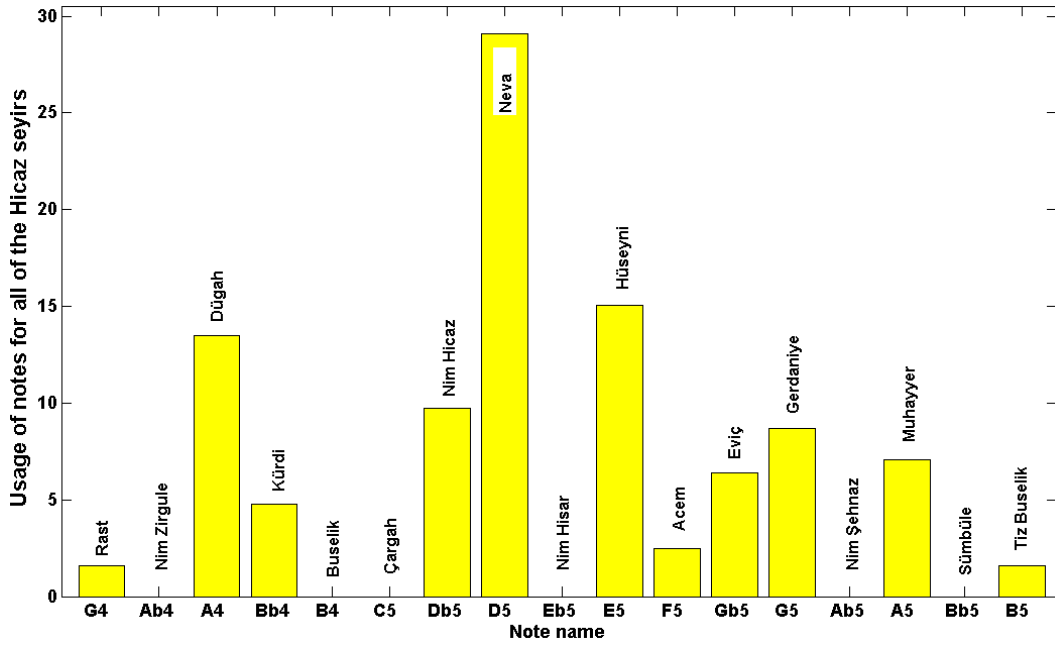


Figure 3.3f. Usage of Notes for all of the Hicaz Seyir

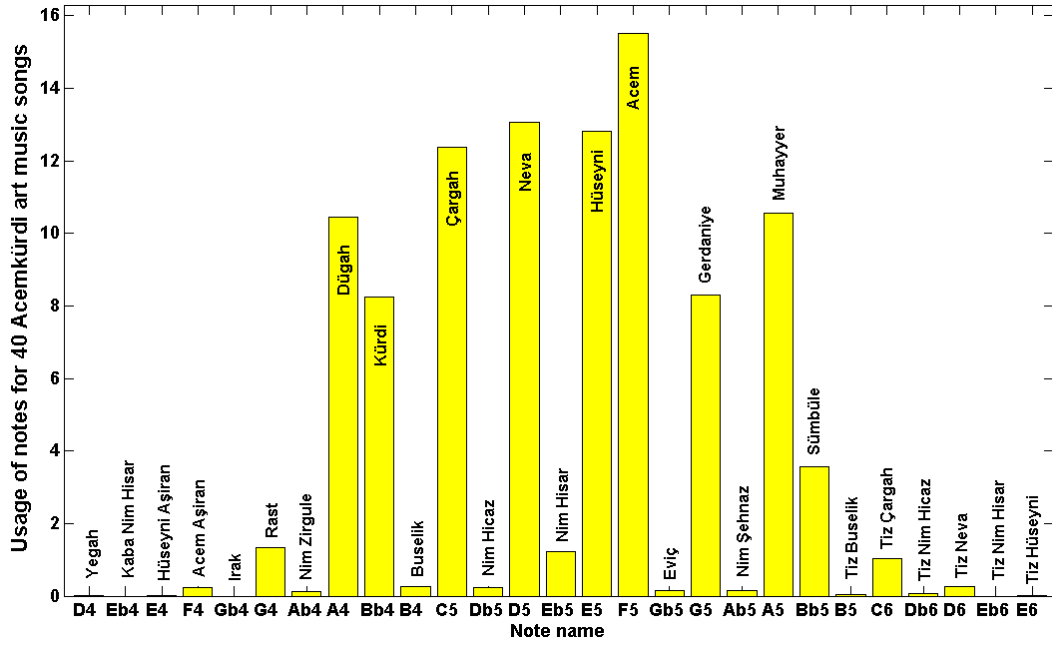


Figure 3.3g. Usage of Notes for 40 Acemkürdi Art Music Songs

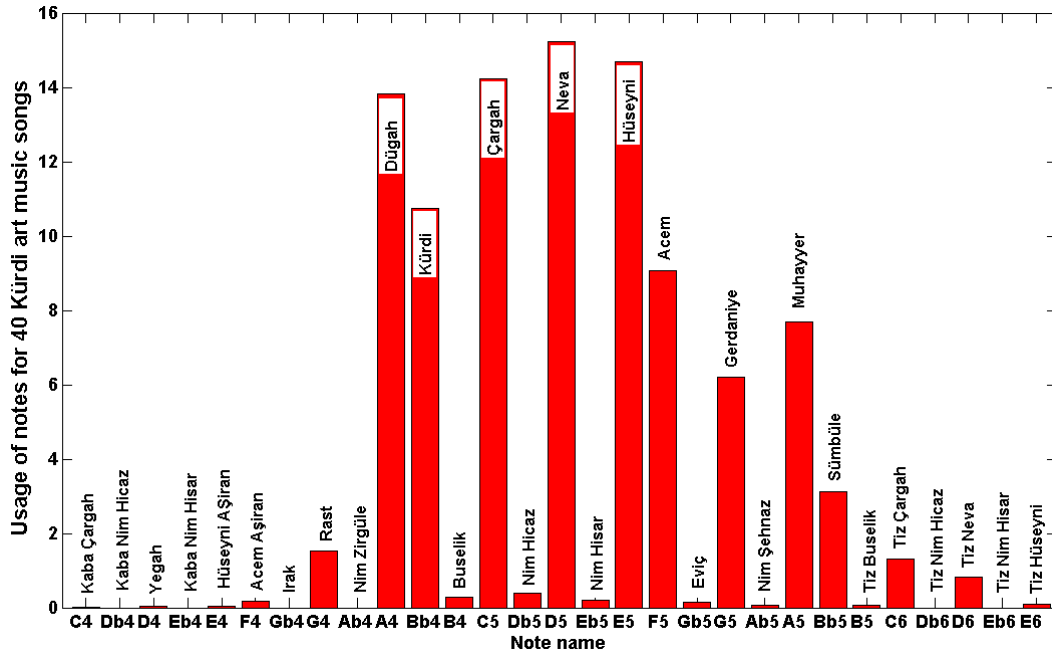
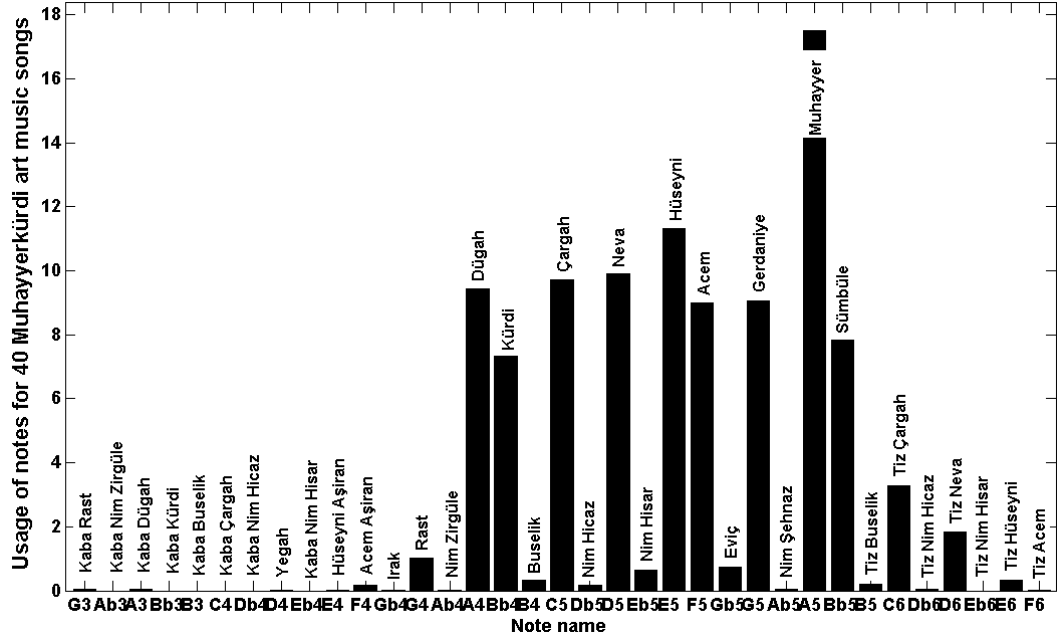


Figure 3.3h. Usage of Notes for 40 Kürdi Art Music Songs



**Figure 3.3i.** Usage of Notes for 40 Muhayyerkürdi Art Music Songs

**Table 3.1.** Frequency of Note Usage Values for Hicaz Art Music Songs, Hicaz Folk Music Songs, Acemkürdi Art Music Songs, Kürdi Art Music Songs, Muhayyerkürdi Art Music Songs, and 3 Hicaz Seyirs

Note Name	Hicaz Art Songs %	Hicaz Folk Songs %	Erol Bingöl's Hicaz Seyir %	Rauf Yekta's Hicaz Seyir %	Şefik Gürmeriç's Hicaz Seyir %	All of Hicaz Seyirs %	A.kürdi Art songs %	Kürdi Art Songs %	M.Kürdi Art Songs %
G3 K.rast	0	0	0	0	0	0	0	0	0.0354
Ab3 K.Zirgüle	0	0	0	0	0	0	0	0	0
A3 K.Dügah	0	0	0	0	0	0	0	0	0.0354
Bb3 K.Kürdi	0	0	0	0	0	0	0	0	0
B3 K.Buselik	0	0	0	0	0	0	0	0	0
C4 K.Çargah	0	0	0	0	0	0	0	0.0108	0
Db4 K.Hicaz	0.0058	0	0	0	0	0	0	0	0
D4 Yegah	0.0663	0.0445	0	0	0	0	0.00421	0.0504	0.00537
Eb4 K.Bayati	0	0	0	0	0	0	0	0	0
E4 H.Aşiran	0.039	0.0574	0	0	0	0	0.0232	0.0459	0.0107
F4 A.Aşiran	0.0904	0.00556	0	0	0	0	0.224	0.168	0.161
Gb4 Irak	0.151	0.319	0	0	0.607	0.197	0	0	0.0172
G4 Rast	1.88	1.84	3.73	1.6	2.67	2.91	1.33	1.53	1.02
Ab4 Zirgüle	0.201	0	0	0	0	0	0.113	0	0.00644
A4 Dügah	13.2	17.9	21.2	13.5	13.1	16.9	10.4	13.8	9.44
Bb4 Kürdi	8.6	12.2	10.8	4.79	7.04	8.26	8.23	10.7	7.32
B4 Buselik	0.176	0.478	0	0	0	0	0.26	0.285	0.322
C5 Çargah	0.192	0.66	0	0	0	0	12.4	14.2	9.73
Db5 Hicaz	11.5	17.2	15.4	9.75	5.46	10.9	0.229	0.388	0.185
D5 Neva	17.4	20.4	16.7	29.1	20.6	20.7	13.1	15.2	9.89
Eb5 Bayati	0.00498	0.0148	0	0	0	0	1.24	0.207	0.637
E5 Hüseyni	16	15.2	12.7	15.1	15.2	14	12.8	14.7	11.3

**Table 3.1 cont.** Frequency of Note Usage Values for Hicaz Art Music Songs, Hicaz Folk Music Songs, Acemkürdi Art Music Songs, Kürdi Art Music Songs, Muhayyerkürdi Art Music Songs, and 3 Hicaz Seyirs

Note Name	Hicaz Art Songs %	Hicaz Folk Songs %	Erol Bingöl's Hicaz Seyir %	Rauf Yekta's Hicaz Seyir %	Şefik Gürmeriç's Hicaz Seyir %	All of Hicaz Seyirs %	A.kürdi Art Songs %	Kürdi Art Songs %	M.Kürdi Art Songs %
F5 Acem	7.94	4.83	8.15	2.48	2.31	5	15.5	9.08	8.99
Gb5 Eviç	4.03	1.59	0	6.38	9.83	4.6	0.158	0.154	0.725
G5 Gerdaniye	8.08	4	2.34	8.69	15.5	8.03	8.3	6.21	9.06
Ab5 Şehnaz	0.503	0.3	3.82	0	0	1.73	0.145	0.0603	0.0548
A5 Muhayyer	7.67	2.54	5.12	7.09	6.43	5.98	10.5	7.68	17.5
Bb5 Sümbüle	1.21	0.322	0	0	0	0	3.57	3.12	7.82
B5 T.Buselik	0.551	0	0	1.6	1.21	0.748	0.0474	0.0612	0.216
C6 T.Çargah	0.195	0.0111	0	0	0	0	1.02	1.3	3.29
Db6 T.Hicaz	0.176	0.0185	0	0	0	0	0.0653	0	0.0365
D6 T.Neva	0.128	0	0	0	0	0	0.25	0.826	1.84
Eb6 T.N.Hisar	0	0	0	0	0	0	0	0	0
E6 T.Hüseyini	0	0	0	0	0	0	0.0274	0.106	0.33
F6 T.Acem	0	0	0	0	0	0	0	0	0.00644

**Table 3.2.** Cross Correlation Coefficients Based on Histogram Datas

$\rho_{H_{AMS}H_{TS}}$	$\rho_{H_{AMS}H_{EB}}$	$\rho_{H_{AMS}H_{SG}}$	$\rho_{H_{AMS}H_{RY}}$	$\rho_{H_{AMS}AK_{AMS}}$	$\rho_{H_{AMS}K_{AMS}}$
0.9747	0.9087	0.9027	0.9164	0.7468	0.7628
$\rho_{H_{AMS}MK_{AMS}}$	$\rho_{H_{FMS}H_{AMS}}$	$\rho_{H_{FMS}H_{TS}}$	$\rho_{H_{FMS}H_{EB}}$	$\rho_{H_{FMS}H_{SG}}$	$\rho_{H_{FMS}H_{RY}}$
0.6926	0.9379	0.9531	0.9630	0.7891	0.8721
$\rho_{H_{FMS}AK_{AMS}}$	$\rho_{H_{FMS}K_{AMS}}$	$\rho_{H_{FMS}MK_{AMS}}$	$\rho_{AK_{AMS}K_{AMS}}$	$\rho_{AK_{AMS}MK_{AMS}}$	$\rho_{K_{AMS}MK_{AMS}}$
0.7627	0.7843	0.7163	0.9723	0.9421	0.9106

### 3.3 Dynamic Time Warping Based Analysis

It is known that dynamic time warping (DTW) method is one of the best methods to measure similarities and dissimilarities of two functions, which can be referred as arrays, have different time durations and unequal length [8-16]. In this method, the distances between all elements of both arrays are calculated and these calculated values are placed in a matrix. While this calculation is performed, the route from upper left corner to lower right corner is desired to be minimum in terms of the sum of these distances. The emerging diagonal curve and intermediate values on this diagonal curve show the similarities between two objects along the time axis. Total length is also accepted as a criterion of total similarity between compared two objects. While this method was functioning in healthy manner for events that occupy less space on the time axis, for the musical pieces under investigation, it was observed that values were quickly reached saturation. So, whichever two songs are selected, it becomes impossible to obtain meaningful results. Instead of this conventional understanding, differences and similarities are calculated by taking the area between the main diagonals of DTW matrix. Thus, much more reliable results are obtained. This method is summarized below.

Let  $S_1$  and  $S_2$  be two songs belonging to different makams or seyirs belonging to different makams.

$$S_1 = \sum_{i_1=1}^{N_1} s_{i_1} \quad , \quad S_2 = \sum_{i_2=1}^{N_2} s_{i_2} \quad (6)$$

Here,  $i_1$  and  $i_2$  indices indicate common time decimations for  $S_1$  and  $S_2$ .  $s_{i_1}$  and  $s_{i_2}$

are decimal notes values as MIDI. From Eq. (6),  $N_1$  and  $N_2$  are lengths of 1<sup>st</sup> and 2<sup>nd</sup> songs, DTW distance matrix  $D$  is constructed as shown in Figure 3.4 whose elements are calculated with the help of Eq. (7).

$$d_{i_1, i_2} = (s_{i_1} - s_{i_2})^2 \quad (7)$$

$d_{i_1, i_2}$  indicates the measured distance between  $i_1$  st note value of  $S_1$  and  $i_2$  nd note value of  $S_2$ .

Under the condition of  $N_1 \leq N_2$ , it is possible to make the following reviews by taking into account the view of Figure 3.4 in DTW matrix.

As an alternative to trying to find the shortest route from 1,1 to corner of  $N_1, N_2$ , we can perform calculation in the region between the diagonals 1,1 to  $N_2, N_2$  and  $N_1 - N_2 + 1, 1$  to  $N_1, N_2$ , called main diagonals (MD) region. The aim in here is to utilize the vast majority of scaled simultaneously similarities between  $S_1$  and  $S_2$  which are confined to the main diagonal region. If needed, main diagonal region can be expanded, as shown in Figure 3.4, to the lower left and upper right corners of the  $D$  matrix with an amount of  $cN_2$ , where  $c$  is a fractional multiplier smaller than unity.

Simultaneous similarities in the main diagonal region are revealed in the form of diagonal consecutive zeros. In this context, singular zeros and  $d_{i_1, i_2} > 0$  values do not carry any information. Diagonal consecutive zeros in areas outside the main diagonal express the similarities of asynchronous spans of the musical pieces. However, these are not considered in this study.

As a result, the similarity between  $S_1$  and  $S_2$  bounded with the region of MD can be calculated by a correlation coefficient as defined in Eq. (8).



$$\sigma_s = \frac{\text{Number of selected zeros in selected diagonal region of } D}{\text{Total number of elements in selected diagonal region of } D} = \frac{\sum_{i_2=1}^{N_1} \sum_{i_1=i_2}^{N_1-N_2+i_2} (d_{i_1, i_2} = 0)}{N_2 (N_1 - N_2 + 1)} \quad (8)$$

Benefiting from Eq. (8), Eq. (9) and Eq. (10) are used for finding the consecutive notes scales of tetrachord and pentachord.

$${}_{DT4}\sigma_{HH} = \frac{\sum_{m_1=1}^{M_H} \sum_{m_2=1}^{M_H} \sum_{i_2=1}^{N_{m_2}} \sum_{i_1=i_2}^{N_{m_1}-N_{m_2}+i_2} \frac{{}_{DT4}(d_{i_1, i_2} = 0)}{N_{m_2} (N_{m_1} - N_{m_2} + 1)}}{M_H^2} \quad (9)$$

$${}_{DT5}\sigma_{HH} = \frac{\sum_{m_1=1}^{M_H} \sum_{m_2=1}^{M_H} \sum_{i_2=1}^{N_{m_2}} \sum_{i_1=i_2}^{N_{m_1}-N_{m_2}+i_2} \frac{{}_{DT4}(d_{i_1, i_2} = 0)}{N_{m_2} (N_{m_1} - N_{m_2} + 1)}}{M_H^2} \quad (10)$$

In these expressions  $M_H$  represents total number of Hicaz songs.

Eq. (9) and Eq. (10) are written for the Hicaz art music songs. At the same time, these equations can be applied to 3 seyirs of Hicaz makam, 40 Hicaz folk music songs, 40 Acemkürdi art music songs, 40 Kürdi art music songs, 40 Muhayyerkürdi art music songs. Thus, calculated autocorrelation and crosscorrelation values are presented as in Table 3.3.

It is seen that the highest correlation value will be between the hicaz songs. This is also shown in the Table 3.3 as 0.3383 and it is expressed as %100 in Table 3.4. In tables, DT45 indicates the patterns of lengths tetrachord and pentachord. In the same way, calculation and expressing of other correlation values as percentage are based on this value. Table 3.3 shows the similarities and dissimilarities of inside and outside of makam for tetrachord and pentachord consecutive note scales. When other note scales are tried, the obtained correlation coefficients were found to be worse than Table 3.3. In these respects, it is concluded that the similarities and differences

of inside and outside of makam can be revealed by taking mostly tetrachord and pentachord notes.

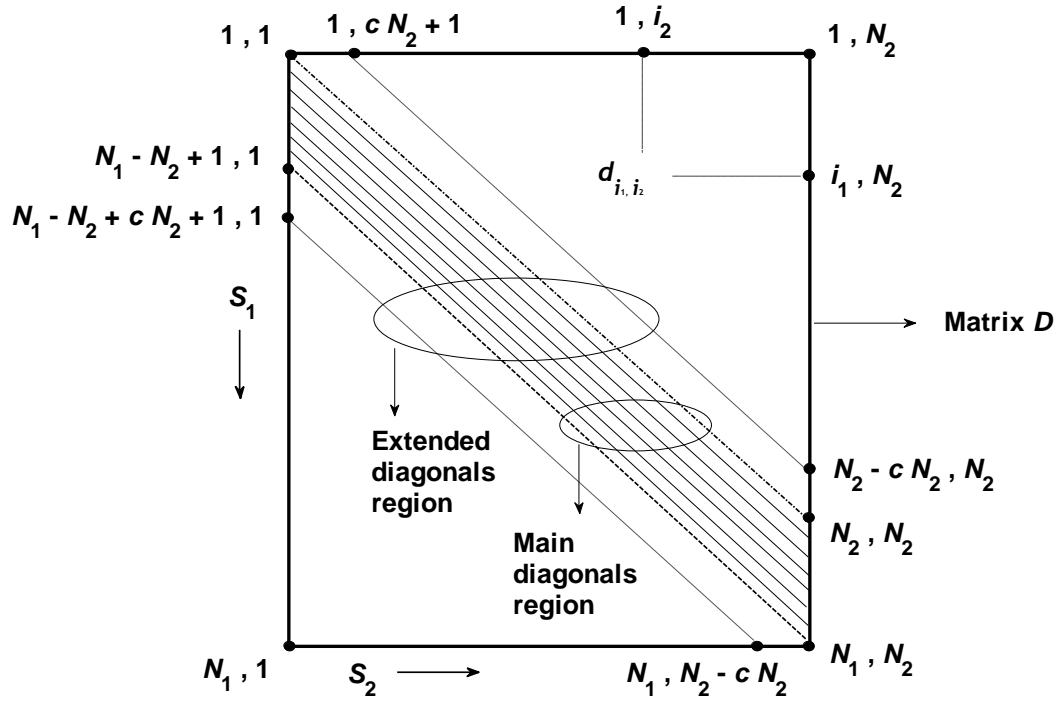


Figure 3.4. DTW D Distance Matrix and Its Important Features

Table 3.3. Scaled Autocorrelation and Crosscorrelation Coefficients for All Makams and Seyirs Obtained from the MD Regions of DTW Matrices

$DT45\sigma_{H_{AMS}H_{AMS}}$	$DT45\sigma_{H_{AMS}H_{EB}}$	$DT45\sigma_{H_{AMS}H_{SG}}$	$DT45\sigma_{H_{AMS}H_{RY}}$
0.3383	0.3353	0.3353	0.3292
$DT45\sigma_{H_{AMS}AK_{AMS}}$	$DT45\sigma_{H_{AMS}K_{AMS}}$	$DT45\sigma_{H_{AMS}MK_{AMS}}$	$DT45\sigma_{H_{FMS}H_{FMS}}$
0.0043	0.0045	0.0044	0.3520
$DT45\sigma_{H_{FMS}H_{AMS}}$	$DT45\sigma_{H_{FMS}H_{EB}}$	$DT45\sigma_{H_{FMS}H_{SG}}$	$DT45\sigma_{H_{FMS}H_{RY}}$
0.3142	0.3248	0.3051	0.3193
$DT45\sigma_{H_{FMS}AK_{AMS}}$	$DT45\sigma_{H_{FMS}K_{AMS}}$	$DT45\sigma_{H_{FMS}MK_{AMS}}$	$DT45\sigma_{AK_{AMS}K_{AMS}}$
0.0068	0.0067	0.0054	0.0145
$DT45\sigma_{AK_{AMS}MK_{AMS}}$	$DT45\sigma_{K_{AMS}MK_{AMS}}$		
0.0128	0.0122		

**Table 3.4.** Smilarity Rates of All Makams and Seyirs Obtained from the MD Regions of DTW Matrices as a Percentage

$DT45\sigma_{H_{AMS}H_{AMS}}$	$DT45\sigma_{H_{AMS}H_{EB}}$	$DT45\sigma_{H_{AMS}H_{SG}}$	$DT45\sigma_{H_{AMS}H_{RY}}$
100	99	99	97
$DT45\sigma_{H_{AMS}AK_{AMS}}$	$DT45\sigma_{H_{AMS}K_{AMS}}$	$DT45\sigma_{H_{AMS}MK_{AMS}}$	$DT45\sigma_{H_{FMS}H_{FMS}}$
1.2	1.3	1.3	95.1
$DT45\sigma_{H_{FMS}H_{AMS}}$	$DT45\sigma_{H_{FMS}H_{EB}}$	$DT45\sigma_{H_{FMS}H_{SG}}$	$DT45\sigma_{H_{FMS}H_{RY}}$
92.8	96	90.1	94.3
$DT45\sigma_{H_{FMS}AK_{AMS}}$	$DT45\sigma_{H_{FMS}K_{AMS}}$	$DT45\sigma_{H_{FMS}MK_{AMS}}$	$DT45\sigma_{AK_{AMS}K_{AMS}}$
2.01	1.98	1.59	4.28
$DT45\sigma_{AK_{AMS}MK_{AMS}}$	$DT45\sigma_{K_{AMS}MK_{AMS}}$		
3.78	3.60		

## CHAPTER 4

### 4. CONCLUSION

This study was conducted to examine the mathematically makam concept in Turkish music. 4 Turkish music makams and 3 Hicaz makam seyirs are examined. These are Hicaz makam, Acemkürdi makam, Kürdi makam, Muhayyerkürdi makam, Erol Bingöl's Hicaz makam seyir, Şefik Gürmeriç's Hicaz makam seyir and Rauf Yekta's Hicaz makam seyir. The study includes time dependent and time independent analysis. From the results, we see that time dependent analysis gives more reliable results than the time independent analysis. For example, in terms of correlation coefficients values obtained from histograms, while the similarity between Hicaz makam and Acemkürdi makam is 0.7468 this value drops to 0.0043 in DTW based analysis. So, the analysis based on dynamic time warping (DTW) method gives better results than the analysis based on histogram graphs method. From the results obtained in the analysis, it is seen that the songs belongs to makams were followed predefined seyirs. By taking tetrachord and pentachord notes (DT45), the differences and similarities between makams were determined better. Besides, autocorrelation coefficients and cross correlation coefficients were found to be useful in finding similarities and dissimilarities between investigated makams and seyirs.

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## APPENDIX A

### LIST OF SONGS AND SEYİRS USED IN THE THESIS

<b>Hicaz Art Songs</b>	<b>Hicaz Folk Songs</b>	<b>Acemkürdi Songs</b>	<b>Kürdi Songs</b>	<b>Muhayyerkürdi Songs</b>
Açık bırak pencereni	Ağasarin Balini	Ağlasam faydası yok	Ask rüyadır	Adım adım ümit
Adalardan bir yar gelir bizlere	Ahleyar	Ah bu gönülde sen olmasaydın	Aşkın tadına vardık	Al Gülün Dalında
Ağlamışım gülmüşüm kırılıp dökülmüşüm	Ankaranın ortasında kurulu pazar	Akşamı getiren sesleri dinle	Aynı bedende can gibiyiz	Aşkımınla oynama kumar değildir
Alın yazımsın	Aşka düştüm ezelden gönlüm geçmez güzelden	Al git al git beni sevda rüzgarı	Bakma sen gözlerimden akan yaşlara	Aşkınla yana yana
Anladım sevmeyeceksin beni sen nazlı çiçek	Ayrılık	Alev alev yanıyorum	Bana kollarını uzatsan biraz	Bakarım yollarına nerdesin sevgilim
Aşkını seninle tattı hicranla yandı	Bağa Girdim Üzüme	Artık gelecek sanma	Bana sevgiyi anlat	Bakisi çağırır beni uzaktan
Bana yardım vaz geç derler gönül senden vaz geçer mi	Bağa Gittim Nar İçin	Artık yanımda kal	Bilsen neler	Bir kızıl goncaya benzer dudağın
Ben ne ettim sana bilmem ah felek	Bahçelerde saz olur gül açılır yaz olur	Aşka gel tenhada olsun	Bir hayal	Bunca güzel içinde birisi var ki
Benim yarım gelişinden bellidir	Ben Senu Sevduğumi	Aşkımı bir anlasan	Bir sevda geldi başıma	Duydum ki unutmuşsun gözlerimin rengini
Bir kere baktın kalbimi yaktın yalnız bıraktın kalpsiz	Dane Dane Benleri Var	Aşkın gözü görmez ki	Çiçekler bile gonca iken sevilir	Elbet bir gün buluşacağız

Bir nigah et ne olur halime ey gonce dehen	Değme Felek	Aşkın ile gece gündüz	Denizlerin birincisi	Gençliğe Veda
Bu ne acı bu ne keder sus kalbim sus artık yeter	Değmen Benim Gamlı Yaslı Gönlüme	Aşkın kanununu yazsam yeniden	Dudağında şarkı	Gözlerinin rengi deniz mavisi
Çerkez kızı	Dirvana vurdim uçdi	Ay geçer yıl geçer	Dudaklarında arzu	Gözyaşım şarap olsa
Çıksam şu dağların yücelerine	Entarisi ala benziyor	Ayırma gözlerini	Dün akşam yine benim	Hala sözümdeyim unuttum sanma
Değdi saçlarıma bahar gülleri	Eşimden Ayrıldım Göz Yaşım Durmaz	Ayrılsakta kalbim sana	Gel bahardan zevk alalım	İçin için yanıyor
Dil yaresini andıracak yare bulunmaz	Esmerim Biçim Biçim	Bahar olur benim kışım	Gelemezsin kara	İste hepsi o kadar
Gölgesinde mevsimler boyu oturduğumuz	Etek Sarı	Bahar senden almış	Gül goncası nazende	Kapın her çalındıkça
Görmedim ömrümün asude gecen bir demini	Evlerinin onu bulgur sıkusu	Baharla hazan birleşemez	Hani ayrılık	Karlı dağlar yıldızı
Hançer-i aşkınla ey yar gönlüm üzre vurma hiç	Fincanı taştan oyarlar	Bak bahta da ikbale	Hiç tatmadım böyle duyguyu	Kime derdim söyleyeyim halden bilmezse
Hüsrana olacaksa bu aşkın sonu	Gemilerde talim var	Bak yine geçti bahar	İçindeki duygularla	Mevsimler yas tutup çöller ağlasın
Körfezdeki üç beş güzel söylesinler şarki gazel	Gidem dedim aman yarenlerim darıldı	Bana aşkın şarabını	İlkbahara bekle beni demiştim	Nakış nakış isledim sevdanı
Muhabbet bağına girdim bu gece	Gine Yeşillendi Niğde Bağları	Bari felek ben	Karlı dağlar	Ne çıkar bahtımıza ayrılık varsa yârin



Nasıl geçti habersiz o güzelim yıllarım	Girdim Yarın Bahçesine	Bende mazide kalan	Nasıl geçer	Ne olursun güzelim sevsen beni
Ne gelen ne soran var acı geçti günlerim	Gurbette ömrüm geçecek	Beni reddetse	Nasıl Unuturuz gecen günleri	O beni bir bahar akşamı terkedip gitti
Pencerenin perdesini aç bana göster yüzünü	Hisardan İnmem Diyor	Bilir misin a sevdiğim	Ne ask kaldı	Rüzgar söylüyor şimdi o yerlerde
Sen beni bir buseye ettin feda	Karanfil oylum oylum	Bir bahar akşamında	Neşeler bulurum	Sarmaşık gülleri
Sevgimizin aşkımızın üstünden sene geçti	Kozan Dağı Çatal Matal	Bir başka eda	O ceylana	Sarsam seni gül dudaklım
Sevmiyorum seni artık gözlerimi geri ver	Mektebin Bacaları	Bir gün bana	Onun olmaya hakkım yok	Sen benimsin
Terk et beni artık yetişir sende vefa yok	Necibemin ikidir kürkü	Bir sevda geldi başıma	Öyle bir göz süzdün	Sen gül dalında gonca
Yeşil gözlerinden muhabbet kaptım	Nefesim Nefesine	Canan bilirim sen beni	Sakın dönme	Sen ne kadar saklasan gönlündekini
Yine neşe-i muhabbet dil u canımı etti şeyda	Seherde indim ben bağa	Ebedi bir yolculuk	Senelerce beklettin	Sen nişansın daha
Af eyle suçum	Şu gelen atlı mıdır yavrum sorun Bağdatlı mıdır	Fikrimin ince gülü	Seni andım bu gece	Sen uzakta bir yıldız
Akşam olur sabaha olur yar gelmez	Su Gelir Bulanarak	Geceler hiç bitmiyor	Senin sevdan rüya bana	Seni ilk gördüğüm anda
Apansız uyanırsan	Tabancamın Sapını	Kır atıma bineyim	Seninle tattım	Servet gibi bir aşkı bir kurşuna sen sattın

Bir gün karşılaşırsak ayrıldığımız yerde	Urfa Divan Ayağı	Ruhum şu gelen yılda bile maziyi andı	Sevdiysen hiç bekletme	Sevgilim benim yanımda olsan
Boğaziçi şen gönüller yatağı	Yazımı Kışa Çevirdin	Sana eller ne güzelsin demesin kıskanırım	Sevgi yağmuruna	Şimdi hasret bu gönül
Bu yara başka yara	Yeşil Başlı Telli Turnam	Sen kalbimin mehtabısın	Susadım gülüşüne	Sürmeyi kastan alır
Bülbülün çilesi yanmakmış güle	Yiğidim Aslanım	Seviyorum özlüyorum	Uçurumlar	Tekrar bana dönsen yine beni sevsen
Çatılmış kaşlarınla kime düşman gibisin	Yol Üstüne Kurdum Kara Kazanı	Yollarda kalan gözlere	Yaşamaya bak	Viran olan kalbimde sevgilimi özlerim
Eğilmez başın gibi	Yürü dilber yürü ömrümün varı	Zehretme hayatı	Yine menekşelerde	Yine bahar oldu coştı yüreğim

## APPENDIX B

### 25 PITCHES OF TURKISH MUSIC SYSTEM

PITCH NAME	FLAT	SHARP	PITCH NAME	FLAT	SHARP
Kaba Çârgâh	♭	♭	Çârgâh	♭	♭
Kaba Nim Hicaz	♭	♯	Nim Hicaz	♭	♯
Kaba Hicaz	♭	♯	Hicaz	♭	♯
Kaba Dik Hicaz	♭	♯	Dik Hicaz	♭	♯
Yegâh	♭	♭	Neva	♭	♭
Kaba Nim Hisar	♭	♯	Nim Hisar	♭	♯
Kaba Hisar	♭	♯	Hisar	♭	♯
Kaba Dik Hisar	♭	♯	Dik Hisar	♭	♯
Hüseynî Aşîrân	♭	♭	Hüseynî	♭	♭
Acemaşîrân	♭	♭	Acem	♭	♭
Dik Acemaşîrân	♭	♯	Dik Acem	♭	♯
Irak	♭	♯	Eviç	♭	♯
Geveşt	♭	♯	Mahur	♭	♯
Dik Geveşt	♭	♯	Dik Mahur	♭	♯
Rast	♭	♭	Gerdaniye	♭	♭
Nim Zîrgüle	♭	♯	Nim Şehnaz	♭	♯
Zîrgüle	♭	♯	Şehnaz	♭	♯
Dik Zîrgüle	♭	♯	Dik Şehnaz	♭	♯
Dügâh	♭	♭	Muhayyer	♭	♭
Kürdî	♭	♯	Sümbüle	♭	♯
Dik Kürdî	♭	♯	Dik Sümbüle	♭	♯
Segâh	♭	♯	Tiz Segâh	♭	♯
Bûselik	♭	♭	Tiz Buselik	♭	♭
Dik Bûselik	♭	♯	Tiz Dik Bûselik	♭	♯
Çârgâh	♭	♭	Tiz Çârgâh	♭	♭
	♭	♯	Tiz Neva	♭	♯

**APPENDIX C**  
**CIRRICULUM VITAE**

**PERSONAL INFORMATION**

Surname, Name: Şenses, Baturhan

Citizenship: Republic of Turkey

Date and Place of Birth: 29 May 1988, Ankara

Marital Status: Single

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**EDUCATION**

Degree	Institution	Year of Graduation
M.Sc.	Çankaya Univ. Electronics and Communication Engineering	2013
B.Sc.	Çankaya Univ. Electronics and Communication Engineering	2011
High School	Arı Private Science High School, Ankara	2005

**FOREIGN LANGUAGES**

Advanced English

**PUBLICATIONS**

1. Şenses B., Eyyuboğlu H.T. and Yüceer M. “ Uydulararası Optik Link Tasarımı”, Çankaya Üniversitesi 4. Mühendislik ve Teknoloji Sempozyumu Bildiriler Kitabı, 4(28-29), 318-322 (2011)