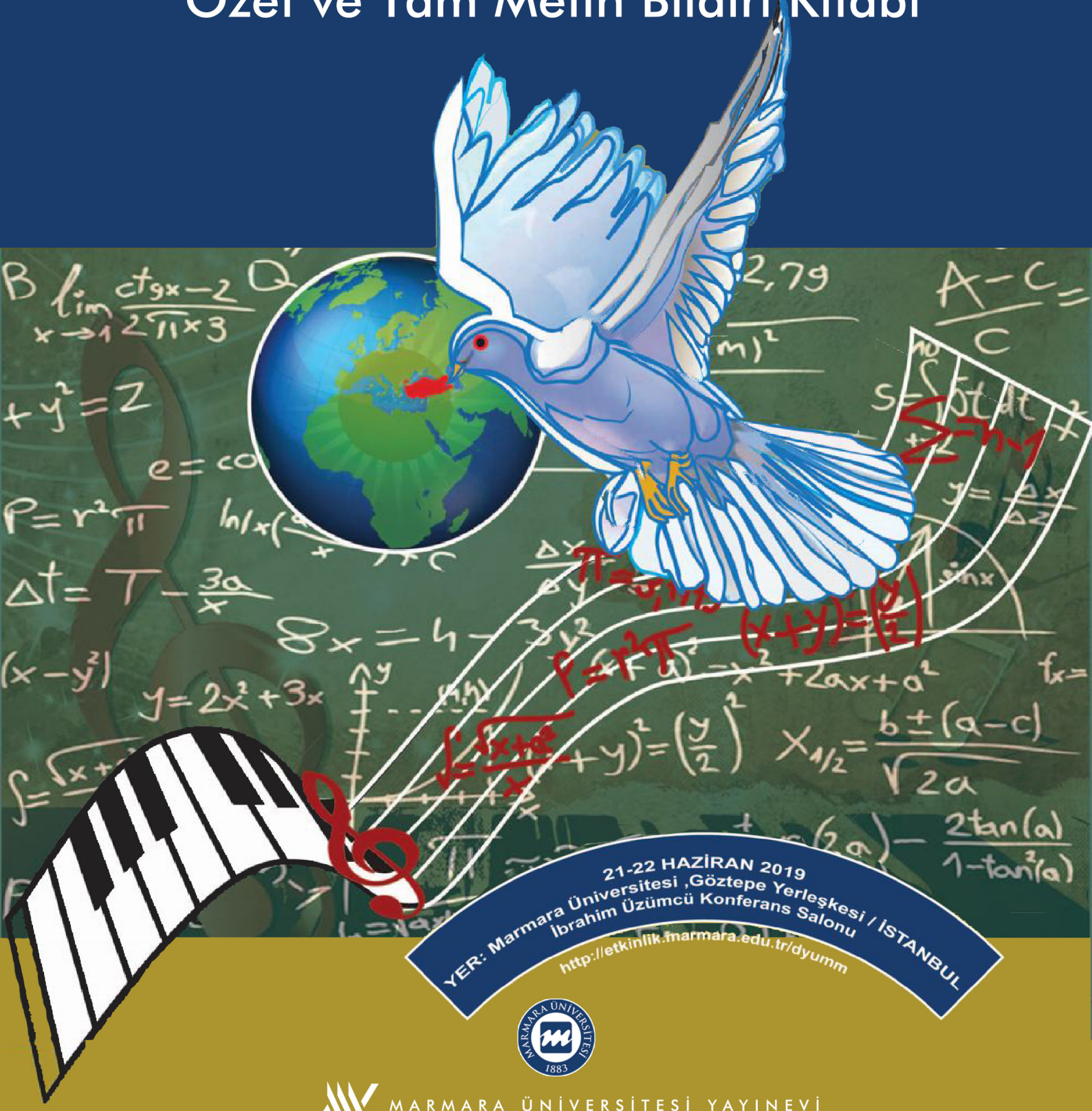
Disiplinlerarası Yaklaşımda Uluslararası

Matemetik ve Müzik Kongresi

Özet ve Tam Metin Bildiri Kitabı



21-22 HAZİRAN 2019
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İbrahim Üzümcü Konferans Salonu
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MARMARA ÜNİVERSİTESİ YAYINEVİ

Disiplinlerarası Yaklaşımda Uluslararası

Matematik ve Müzik Kongresi

Özet ve Tam Metin Bildiri Kitabı

Interdisciplinary International Mathematics and Music Congress
Conference Proceedings

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KONGRE PROGRAMI

21 HAZİRAN 2019 CUMA (1. GÜN)

09:30 - 10:30

- **Kayıt**

Marmara Üniversitesi Dr. İbrahim Üzümcü Konferans Salonu girişinde kurulacak masalarda kayıt yapılacaktır.

10:30 - 11:00

- **Açılış Konuşmaları**

Doç. Dr. Tülün MALKOÇ (Müzik Eğitimi)

Prof. Dr. Ahmet Ş. ÖZDEMİR (Dekan- Matematik Eğitimi)

Prof. Dr. Kamarsulu İBRAYEVA (Art Education)

Prof. Dr. Dalia KARATAJIENE (Art Education)

Sunum: Dr. Öğr. Üyesi Mehmet Şahin AKINCI

11:00 - 12:00

- **Konser**

Öğr. Gör. Aytaç RZAGULİYEVA

- Azerbaycan Bestecilerinin Eserlerinden Bir Demet

12:00 - 13:00

- **Açılış Kokteyli**

Marmara Üniversitesi Dr. İbrahim Üzümcü Konferans Salonu

13:00 - 14:00

- **Davetli Konuşmalar**

Prof. Filiz KAMACIOĞLU

- Tarihi Süreçte Doğu-Batı Ekseninde Müzik-Matematik İlişkisi ve Bu Bağlamda Günümüz Müzik Eğitimi için Öneriler

Prof. Dr. Kamarsulu İBRAYEVA

- Students' Intellectual Development by Means of Kazakh Traditional Music

Prof. Dr. Ayfer KOCABAŞ

- Disiplinlerarası Yaklaşımda Bir Model Önerisi: Müzikle Matematik Öğretimi

14:00 - 15:00

- **1. Oturum**

Arş. Gör. Volkan YALÇIN & Prof. Dr. Ahmet Ş. ÖZDEMİR

- Sayılar Teorisi Dersinde Sihirli Kare ve Müzik Notaları Kullanarak Şifreleme Oluşturma Etkinliği

Dr. Öğr. Üye. Özlem ÇEZİKTÜRK

- Müzikte Matematik Yapı: Beşliler Çemberi ve Pisagor Komaşı

Doç. Dr. Ceylan ÜNAL AKBULUT & Prof. Dr. Ece KARŞAL

- Matematik ve Müzik İlişkisi

Oturum Başkanı Dr. Öğr. Üyesi Oğuz KÖKLÜ

15:00 - 15:30

- **Kahve-Çay Molası**

15:30 - 16:30

- **Davetli Konuşmalar**

Prof. Dr. Nihan YAĞIŞAN

- İlkokul Matematik Derslerinde Müzik Destekli Öğretimin Başarı ve Kalıcılık Üzerine Etkisi

Prof. Dr. Dalia KARATAJIENE

- The Relationship Between Mathematics and Music in Visual Art: A Lithuanian Case

16:30 - 17:45

- **2. Oturum**

Ayşe VURAL, Prof. Dr. Ahmet Serkan ECE & Prof. Dr. Altay EREN

- Müzik Aracılığıyla İstem Dışı Hatırlanan/Zihinde Canlanan Anıların/Geleceğe Yönelik İmajların Matematik Ders Başarısı Üzerindeki Etkileri

Tuğçem KAR & Aziz Murat ASLAN

- Batı Müziği ve Türk Müziğinde Basit Dizi ve Makamların Analitik İncelenmesi

Dr. Filiz YAĞCI, Doç. Dr. R. Erol DEMİRBATIR, Prof. Dr. Rıdvan EZENTAŞ & Hülya BOZYOKUŞ

- Matematiksel Kodlama Yoluyla J. S. Bach II Viyolensel Suiti Prelud Bölümünün Geometrik Modellemesi

Sümeyye BAKIM & Prof. Dr. Seyit YÖRE

- Mathematical Proportions in Music

Oturum Başkanı Doç. Dr. Ceylan ÜNAL AKBULUT

19:00 - 23:55

- **Sosyal Etkinlik: Boğazda Tekne Turu & Akşam Yemeği**

Boğazda hususi tekne ile tur, akşam yemeği ve müzik dinletisi.

- Not: Tekne turuna katılmayı düşünen katılımcıların isimlerini 19. 06. 2019 a kadar Kongre Düzenleme Kurulu Dr. Oğuz Köklü'ye yazdırmaları ve 18:00'de Göztepe Yerleşkesi Dr. İbrahim Üzümcü Konferans salonu girişinde hazır bulunmaları gerekmektedir.

22 HAZİRAN 2019 CUMARTESİ (2. GÜN)

09:30 - 10:00

- **Davetli Konuşma**

Doç. Dr. M. Kemal KARAOSMANOĞLU

- Pür Matematikten Uygulamalı Matematiğe Müzik

10:00 - 11:00

- **3. Oturum**

Arş. Gör. Cenk Önder ÖZEN, Dr. Öğr. Üyesi Zühal DİNÇ ALTUN & Dr. Öğr. Üyesi Yalçın YILDIZ

- Müziğin Matematik Öğretiminde Kullanılmasına İlişkin Okul Öncesi ve Sınıf Öğretmeni Görüşleri

Dr. Alper GÖNEN, Prof. Dr. Metin ARIK

- Sesler Arası Uyumun Gönen-Arik Fonksiyonu ile Belirlenmesi

Gökhan DERİN & Prof. Dr. Ahmet Ş. ÖZDEMİR

- Matematik ve Müzik

Dr. Öğr. Üyesi Özlem ÇEZİKTÜRK

- Çok Sesli Müzik (Polifonik Müzik) ile Matematik İlişkisi

Oturum Başkanı Doç. Dr. Hatice AKKOÇ

11:00 - 11:30

- **Kahve-Çay Molası**

11:30 - 12:30

- **4. Oturum**

Perihan SARIGÖZ & Zeynep Eylül ÜÇER

- Gitar Yapımındaki Matematik: Disiplinler Arası Bir Ders Planı

Dr. Öğr. Üyesi Mehmet Şahin AKINCI

- Matematik ve Müzik-Oyun-Drama İlişkisinde Yapılmış Tez ve Makale Çalışmalarının Çeşitli Değişkenler Açısından İncelenmesi

Dr. Alp ÖZEREN

- Müzik ve Matematik Etkileşiminin Toplumsal Yaşam Kalitesinin Artışına Katkı Sağlama Potansiyeli Odaklı, İşlevsel Örnekler ve Öneriler

Sercan BAYRİ

- 5-9 Yaş Aralığındaki Çocukların Müzik ve Matematik ile İlişkileri

Oturum Başkanı Dr. Öğr. Üyesi Mehmet Şahin AKINCI

12:30 - 13:30

- **Öğle Yemeği**

Marmara Üniversitesi Göztepe Yerleşkesinde Öğle Yemeği

13:30 - 14:30

- **5. Oturum**

Doç. Dr. R. Erol DEMİRBATIR, Prof. Dr. Rıdvan EZENTAŞ, Dr. Filiz YAĞCI & Hülya BOZYOKUŞ

- Matematiksel Kodlama Yoluyla A. Adnan Saygun'un Op. 31 "Partita" adlı Solo Viyolonsel Eserinin Geometrik Modellemesi

Dr. Muhammed Recai ÇİFTÇİ, Prof. Dr. Safa YEPREM

- Mabed Müziğine Yönelik Bir Hesaplamalı Müzikoloji Tecrübesi

Dr. Öğr. Üyesi Ebru SELÇİOĞLU DEMİRSÖZ

- Sınıf Öğretmenliği Öğretmen Adaylarının Müzik ve Matematik İlişkisine Dair Metaforik Algıları

Güldane EVGİNER

- Özel Yetenekli Müzik Öğrencilerinin Matematik ve Müzik Arasındaki İlişkiye İlişkin Görüşlerinin İncelenmesi

Oturum Başkanı Dr. Öğr. Üyesi Özlem ÇEZİKTÜRK

14:30 - 15:30

- **6. Oturum**

Prof. Dr. Ozan YARMAN, Prof. Dr. William A. SETHARES, Doç. Dr. M. Kemal KARAOSMANOĞLU, Dr. Öğr. Gör. Mehtap DEMİR & Prof. Dr. Tolga YARMAN

- An Investigation of the Role of Diatonic Functions in the Seyir Phenomenon of Turkish Makam Music: Case of 'Hicaz Family'

Doç. Dr. Ekin ÇORAKLI

- Müzik Felsefesinde Matematik

Dr. Öğr. Üyesi Ferda ÖZTÜRK KÖMLEKSİZ

- Müzik Dersi Öğretim Programının Disiplinlerarası Yaklaşımla Matematik-Müzik İlişkisi Bağlamında İncelenmesi

Doç. Dr. Tülün MALKOÇ

- Okul Öncesi Dönemde Matematik Kavramları ile Şarkı Söylemenin Önemi

Oturum Başkanı Prof. Dr. Serkan ECE

15:30 - 16:00

- **Kapanış Paneli**

DAVETLİ KONUŞMACILAR

Prof. Dr. Ayfer KOCABAŞ

Dokuz Eylül Üniversitesi, Türkiye

- Disiplinlerarası Yaklaşımda bir Model Önerisi: Müzikle Matematik Öğretimi

Prof. Filiz KAMACIOĞLU

Marmara Üniversitesi, Türkiye

- Tarihi Süreçte Doğu-Batı Ekseninde Müzik-Matematik İlişkisi

Dr. Alper GÖNEN

Kocaeli Üniversitesi Güzel Sanatlar Fakültesi Müzik Bölümü Emekli Öğretim Görevlisi, Türkiye

- Sesi Sayılarla Duymak

Prof. Dr. Dalia KARATAJIENE

Academy of Art in Vilnius, Litvanya

- The Relationships between Mathematics and Music in Visual Art: A Lithuanian Case

Prof. Dr. Nihan YAĞIŞAN

Akdeniz Üniversitesi, Türkiye

- Müzik ve Matematik

Prof. Dr. Kamarsulu İBRAYEVA

Abai Kazakh National Pedagogical University, Kazakistan

- Intellectual Development by Means of Kazakh Traditional Music

Doç. Dr. M. Kemal KARAOSMANOĞLU

Ankara Müzik ve Güzel Sanatlar Üniversitesi, Türkiye

- Pür Matematikten Uygulamalı Matematiğe Müzik

AN INVESTIGATION OF THE ROLE OF DIATONIC FUNCTIONS IN THE SEYIR OF TURKISH MAKAM MUSIC: CASE OF 'HICAZ FAMILY'*

Ozan YARMAN**
William SETHARES***
M. Kemal KARAOSMANOĞLU****
Mehtap DEMİR*****
Tolga YARMAN******

Abstract

This paper presents a novel mathematical approach – originally framed by the first co-author and systematized afterwards by the second and last co-authors – that extracts sets of features related to diatonic functions out of a large collection of pieces in Turkish music. Pitch histograms, which are so far commonly used as a surrogate for the "perde" (variable pitch), customarily represent the proportion of time that a melody rests on each visited frequency. Contour histograms, introduced herein as a surrogate for the "seyir" (thematic flow), display the proportion of time the melody is "ascending" (e.g., Do-Re-Mi), reaches a "peak" (e.g., Re-Fa-Re), is "descending" (e.g., Sol-Fa-Mi), or remains in a "valley" (e.g., La-Do-Mi). It is possible to conceive these sets of mathematical properties in terms of a scale-degree vector analysis of a trigram chain of musical notes that demarcates both perde and seyir elements of Turkish makam scales. Using such computational surrogates, it becomes viable to examine the balance between the two elements (perde vs seyir) in a different light, and to identify, with

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respect to the established Arel-Ezgi-Uzdilek (AEU) theory, the prominent features of makam scale degrees that other pitches 'gravitate towards'. The proposed method is first concretized by the popular children's song commonly known as "*Twinkle Twinkle Little Star*" to show, in a familiar context, some of the interpretations that are suitable. The approach is then applied to a collection of monophonic pieces belonging – for this study – to "*Hicaz* (*Hijaz*) family" makams transcribed at 53-commas to the octave from the SymbTr database of the third co-author. This allows a comparison between the actual function of scale degrees and the *de facto* theoretical diatonic functions of standard AEU theory, and helps to highlight new information that can be extracted from the pitch and contour histograms. All "peaks", "valleys", "ascents" and "descents" in Hicaz, Hümayûn, Uzzal and Zengûle pieces are then juxtaposed to yield summary contour histograms that display commonalities and differences among the makam classes. Specifically, comparing the Kullback-Leibler divergences of 4 art and 4 folk music pieces (a total of 8 files) in Hicaz-family makams from those (a total of 418 files) in four unrelated makams communicates how closely the pieces under consideration align with the given makam type. In particular, said divergences reveal very close proximity of the chosen 8 Hijaz-family pieces to the Hijaz-kind (i.e., Hicaz, Hümayûn, Uzzal, Zengûle) instead of Buselik, Nihavend, Uşşak and Rast. To this end, cumulative contour histograms for all pieces in respectively Hicaz (158 files), Hümayûn (38 files), Uzzal (13 files) and Zengûle (9 files) are contrasted with the cumulative contour histograms for all pieces in respectively Buselik (59 files), Uşşak (118 files), Nihavent (130 files) and Rast (111 files) from the SymbTr database in order to quantitatively exhibit the generalized seyir behavior for each makam.

Keywords: Diatonic Function, Histogram, Melodic Contour, Seyir, Makam

Öz

Bu makale, Türk müziği'ne özgü geniş bir eserler seçkisi içinden diyatonik fonksiyonlarla ilgili unsurları ayıklamaya dönük – ilkin birinci eşyazar tarafından önerilip daha sonra ikinci ve son eşyazarlar tarafından sistematize edilmiş – özgün bir matematiksel yaklaşım ileri sürmektedir. Günümüze kadar genellikle "perde"nin (sabit olmayan seslerin) mübadili olarak kullanılan perde histogramları, alışıldık biçimde, bir ezginin her uğranılan frekans üzerinde geçirdiği bağıl süreyi temsil eder. Burada "seyir" (tematik akış) mübadili olarak sunulan kontur histogramları ise, bir ezginin "yükseldiği" (örneğin Do-Re-Mi), "zirve yaptığı" (örneğin Re-Fa-Re), "alçaldığı" (örneğin Sol-Fa-Mi), yahut "vadide kaldığı" (örneğin La-Do-Mi) durumların bağıl süresini gösterir. Sözkonusu matematiksel özellikler kümelerini – Türk makam dizilerinin hem perde hem seyir öğelerini ayırdetmeye dönük – üçerli üçerli zincirlenmiş notaların bir müzik dizisi derecesi vektör analizi yoluyla kavrayabilmek mümkündür. Bu tür hesaplamalı mübadilleri kullandığımızda, adı geçen iki öğe (perde ve seyir) arasındaki dengeyi farklı bir bakışla inceleyebilmenin ve diğer perdelerin "üzerlerine doğru cezbolduğu" makam dizi derecelerinin öne çıkan ana hatlarını – yürürlükteki Arel-Ezgi-Uzdilek (AEU) kuramına kıyasla – saptamanın, yolu açılmaktadır. Önerilen metod, öncelikle, alışıldık bir bağlamda uygun yorumları göz önüne serebilmek adına, yaygın olarak "*Daha dün annemizin kollarında yaşarken*" diye bilinen popüler çocuk şarkısı ile somutlaştırılmıştır. Yaklaşımımız daha sonra,

bu çalışma özelinde, oktavda 53-komma ayrıntısında notalandırılmış ve üçüncü eşyazarın SymbTr veriüssünden edinilmiş "*Hicaz* ailesi" makamlarındaki teksesli eserler demetine uygulanmıştır. Böylelikle, dizi derecelerinin asıl işlevleri ile standartlaşmış AEU kuramının *defakto* diyatonik fonksiyonları arasında karşılaştırma olanağı sağlanabilmekte, ayrıca, perde ve kontur histogramlarından çıkarsanabilecek yeni bilgileri aydınlatabilmenin önü açılmaktadır. Daha sonra, Hicaz, Hümayûn, Uzzal ve Zengûle makamlarındaki parçaların tüm "zirveleri", "vadileri", "çıkışları" ve "inişleri" üstüste geçirilerek, muhtelif makam sınıflarında ortak yanlar ile farklılıkları göstermeye dönük olarak, özet kontur histogramları oluşturulmuştur. Ayrıntıya girecek olursak, Hicaz ailesi makamlarındaki 4 sanat ve 4 halk müziği parçasının (toplamda 8 dosyanın) Kullback-Leibler sapmalarını, bunlara ilişkisi uzak dört makamdakilerle (toplamda 418 dosyayla) karşılaştırmamız sonucunda, ele alınan parçaların herhangi bir makam örneği ile örtüşme yakınlığı ortaya çıkmaktadır. Sözkonusu sapmalara bakıldığında, seçili 8 Hicaz-ailesi parçasının – Buselik, Nihavend, Uşşak veya Rast yerine – özellikle Hicaz türüne (yani Hicaz, Hümayûn, Uzzal, Zengûle makamlarına) çok yakın düştüğü açığa çıkmaktadır. Bu doğrultuda, her makamın genelleştirilmiş seyir davranışını nicel olarak belirtebilmek üzere, SymbTr veriüssünden sırasıyla Hicaz (158 dosya), Hümayûn (38 dosya), Uzzal (13 dosya) ve Zengûle (9 dosya) makamlarındaki bütün parçaların kümülatif kontur histogramları, sırasıyla Buselik (59 dosya), Uşşak (118 dosya), Nihavent (130 dosya) ve Rast (111 dosya) makamlarındaki kümülatif kontur histogramlarıyla karşıt kılınmıştır.

Anahtar Kelimeler: Diyatonik Fonksiyon, Histogram, Melodik Kontur, Seyir, Makam

1. Background

By the 18th Century, Ottoman, Safavid and Mughal realms, who for the most part can be said to have shared a similar Islamic cultural background, were becoming increasingly subjected to the brunt of European imperialism and colonialism. This led to a demand for officially sanctioned reforms in the Orient from the 19th Century onward, with subsequent renovations and revolutions in many areas of life [Kinross, pp. 417-530]. Especially in the Ottoman Empire, the effects were noticeable in the unrelenting transformation of traditional musical aesthetics. Soon enough, following the overthrow of the insurgent Janissary Corps in 1826, the time-honored *Mehter* was replaced by a Eurogeneric Imperial Military Band by the name of '*Miziqay-i Humayun*' [Öztuna Vol I., pp. 170,216,237 & Vol. II, pp. 22-23,30]. Orchestral instruments and staff notation were thereby adopted, and microtonal features of *maqamat* (pl. of maqam/makam) were abandoned in favor of Western keys and triadic harmony. This soon led to a cultural conflict lasting two centuries in the land known as the *Alla Turca – Alla Franca strife* [Yarman, pp. 8-21]. Not long after this date, attempts were made to identify makams in terms of kindred European tonalities. For example, Haşim Bey wrote in 1864: "… while this makam (*Neveser*) is not present in *Alla Franca* (music), it is called G minor." [Yalçın 2013]

This was but part of a long history of Europeanization. On the one hand, the French Campaign to Egypt and Syria spearheaded by Napoleon Bonaparte in 1798 motivated Orientalists such as Guillaume A. Villoteau [1826] of the *Commission des Sciences et des Arts* to take an account of native settings from an Enlightenment perspective[1]. On the other hand, this, in turn, influenced the Arab world to incorporate and ratify 24-equal divisions of the octave (first clearly formulated at the beginning of the 19th Century by Mikha'il Mishaqah of Lebanon [D'Erlanger, pp. 23,27,29,34,37,40,42,47, Maalouf]) as the principal tuning grid of Levantine and Maghribi music-making at the 'Cairo Congress of Arab Music' held in 1932 [Farmer].

As a reaction to the 'synthetic' quarter-tones being so openly embraced by Arabs – and in view of the increasing animosity by the revolutionary Kemalist intelligentsia of the young Republic of Turkey toward this musical interval (and thus, every 'non-rural' performance tradition incidentally associated with it) as the presumed 'artificial product' of Byzantines and their Arab/Ottoman contemporaries [cf. Yarman] – the conservative Turkish faction led by Rauf Yekta, Saadettin Arel, Suphi Ezgi and Salih Murat Uzdilek defended, much to the detriment of established praxis, a 24-tone rival theoretical model based strictly on Pythagorean pitches that entailed only 3-limit musical ratios, insofar as shunning outright the usage of quarter-tone alterations on the surface [Yekta, Arel, Ezgi, Uzdilek].

As Westernization came to dominate the official parlance via growing its sphere of influence into public and private niches, so too were the old ways of calligraphically describing music on drawn-out manuscripts gradually superseded with tonality-inspired theoretic frameworks. What would later become the 'accepted theory' of Classical Turkish music, the now-ubiquitous Arel-Ezgi-Uzdilek (AEU) system, was forged in such a setting. Even in early efforts to preserve makam microtonality via staff notation using special accidentals, said trend was apparent – as exemplified by the distinctively commatic 'quartal harmonization' method proposed during 1940s by İlerici [1981] based on his novel and highly innovative understanding/restructuring of the diatonic function of each perde (variable pitch) of a given makam scale [cf. Yalçın 2012].

In this regard, late 19th to early 20th Centuries saw such figures as Notacı (Notator) Emin Bey [Yalçın 2014], Muallim (Tutor) İsmail Hakkı Bey [Kaygusuz], Ali Rıfat Çağatay and Mildan Niyazi Ayomak (cf. Girgin [2006, pp. 197-205]) – next to Yekta, Arel, Ezgi and Uzdilek. The former four used staff notation with supplementary yet haphazard microtonal sharps &

1 Villoteau specifically mentions '1/3rd tones' on page 16 of his *De l'État Actuel de l'Art Musical en Égypte*: "…l'echelle musicale divisee en tiers de ton…" – therefore accounting for 17 tones to the octave on pages 43-44 of his tome with the inclusion of quarter-tones. In all likelihood, what Villoteau saw there was a 'millenial adulteration' of what had remained of the scribblings of al-Farabi and Urmavi. Similarities between Villoteau's observations and those of the earlier Toderini are worthy of note, for which one may refer to Aksoy [1994].

flats, and the latter four espoused the aforesaid Pythagorean tone-system regularization on staff with full-blown expansion into diatonic function descriptions such as finalis/tonic (*karar/durak*), dominant/cofinal (*güçlü*), and leading tone (*yeden*) when explaining makams as reliant upon scales made up of tetrachordal+pentachordal or pentachordal+tetrachordal genera [cf. Özkan].

On the one hand, one can glimpse the verbatim usage of *karar*, alongside even *asma karar* (tonicization) and *tetimme-i perde* (complementary/leading tone), in earlier treatises such as by Dimitrie Kantemir [1698, pp. 8-9 & 128-9] when he says: "… Know that *tetimme-i perde* is that which, upon reaching the *karar* of a *perde*, the semitone below it is touched and then it concludes at the whole *perde*[2] …" and "… after an *asma karar* is made on *perde* hüseyni, it returns once more to *perde* hüseyni after performing *maqam* Hisar with *perde* hisar[3] …", as well as by Abdülbaki Nasır Dede [Aksu, p. 171] when he says: "… though all *maqams*, from their *agâzhane*s (opening tones) to their *karargâhs* (final tones), are realized by a *seyir* (thematic flow), *maqam* Rast – on account of its *agâzhane* and *karargâh* being the same – relies on ascent and descent.[4] …". On the other hand, the remaining diatonic function names and descriptions such as *güçlü* (dominant), *yarım* or *muvakkat karar* (semi-cadence), and *kalış* (cadential rest) are without question direct borrowings from the ubiquitous literature of the idiom of European tonality; to say nothing of the proliferation, throughout the 20th Century, of '*şedd/göçürüm*' (transposition), '*geçki*' (modulation) and '*çeşni*' (modal/generic substitution).

To summarize, one can translate the Turkish diatonic function terms to their Western equivalents in the following way: i) *karar/durak* = finalis/tonic, ii) *yarım karar* = semi-cadence, iii) *asma karar* = tonicization, iv) *güçlü* = dominant/cofinal, v) *yeden* = leading/complementary tone, and vi) *kalış* = cadential rest.

In general, Western approaches to tonality pertain to 'straightened-out intervals' and to the musical role of those intervals in a polyphonic context; i.e., there is ordinarily neither much notion of the direction of melodic motion nor of the melodic contour of the executed pitch sequence. In contrast, the seyir (melodic progression/procedure) is an indispensible element in establishing a makam. Yet, one may very well have conspicuously 'different seyirs' in different pieces, but, all the same, still delineating a single given makam; such as with the *Hicaz* (*Hijaz*) *şarkıs* (songs) of respectively Dede Efendi (e.g., *Ey büt-i nev eda, olmuşum*

2 Ottoman-Turkish original transliteration: "*Âgâh ol ki tetimme-i perde oldur ki, bir perdenin qarârına varılduğı zemanda, altında olan nîm perdeyi doqınub gene temâm perdede qarâr qılar …*"

3 Ottoman-Turkish original transliteration: "*Ve Hüseynî perdesinde bir asma qarâr itdikten sonra, Hisâr perdesi ile, Hisâr maqâmını edâ idüb, gene Hüseynî perdesine 'avdet ider.*"

4 Ottoman-Turkish original transliteration: "*… cemî'an maqâmât âgâz-hânelerinden qarargâhlarına dek bir seyr ile hâsıl olub, ammâ maqâm-ı Rast âgâz-hânesi ve qarargâhı bir olduğundan, su'ûd ve hübûta muhtâçdır.*"

müptela) and Şevki Bey (e.g., *Sen bu yerden gideli ey saçı zer, seni söyler bana dağlar dereler*). Under these circumstances, the 'problem of seyir' becomes even more complicated. This is all the more so if a piece, although said to be, for instance, in Zirgüle'li Hicaz (or Zengûle), later turns out to be in Zirgüle'li Suzinak instead. What really makes a piece belong to a certain makam, other than the way a set of perdes ('bus stops' along the melodic route, so to speak) occur throughout the melody? The present study attempts to determine empirically ways in which, on one hand, such diatonic functions as finalis, dominant, and leading tone and, on the other hand, pitch contours are common to pieces in a particular makam, so as to distinguish such pieces from those in other makamlar.

Additional background on the particulars of makam theory and its historical development may be read in Touma [1934], Zannos [1990], Powers [1988], Signell [1977], and Yarman [2016].

To recapitulate, it will be useful to present below a synopsis of the historical landscape that molded quotidian classic music-making in Turkey up until the most recent and significant alternative theoretical developments:

1) More than a millenium ago, during the time of the 'Islamic Golden Age' (spearheaded by no doubt the rationalist discourse of Mu'tazilah primarily circa 9th Century AD), scientific curiosity and factual investigation received prodigious patronage that fuelled the 'knowledge transfer' of Hellenistic musical thinking & mathematics to the seat of the Caliphate as well as other Muslim centers of learning. The '*Bayt al-Hikmah*' (House of Wisdom) founded by the Mu'tazili Caliph al-Ma'mun in Baghdad, for example, was the hallmark of the piously inquisitive and moderately inclusive scholastic ethos of the era following in the footsteps of the long-gone *Library of Alexandria* and the later Sassanid *Farhangestân-e Jundišâpur* [Modanlou], where huge translation projects were carried out, and whereupon the Oriental music of the time began to be explained in the manner of Pythagoras, Archytas, Aristoxenos and Claudius Ptolemy. A notable curiosity of this 'Golden Age' – which would seldom (and just arbitrarily) be repeated in later centuries under Mamluk, Ottoman, Timurid and Safavid rule – was, for instance, how Caliph Al-Ma'mun himself organized a discovery expedition to the Giza Necropolis in Egypt; leading, among other things, to the excavation of a new tunnel inside the Great Pyramid. (It is rumored that he took as trophy the marble lid of the sarcophagus in the so-called 'King's Burial Chamber' (cf. [al-Idrīsī]). Such was the spirit of objective inquiry about the world back in those days that incentivized curious minds to seek direct and academically credible answers to enigmatic existential questions instead of relying on uncharted and unsubstantiated narratives.

2) After the fall and sack of Baghdad at the hands of the Mongol Horde under Hülagü in the 13th Century, the 'Islamic Golden Age' collapsed along with the Abbasid Empire, and later periods under the archetypically equesterian Mamluk, Ottoman, Timurid and Safavid

rule (given their remarkable disregard for state-sponsored science organizations of free chroniclers, explorers, translators, researchers and inventors) showed no true fascination by natives in the ancient historical heritage whence their contemporaneous culture clearly drew roots. Only much later, in the 19th and 20th Centuries, would European Orientalists take active interest in the sociological and archeological scenery of the Middle East in a 'naturalistic manner' owing to the political weakening and gradual dismantling of Muslim 'Gunpowder Empires'. (The 'Reconquista of al-Andalus' and the 'British Raj' in India can be considered seperate issues to be investigated in this regard.)

3) Said lack of interest in minutely accounting for one's own culture was so much so that little to no effort was made by later Muslims or Islamicized non-Muslims to methodically, systematically and empirically recount their aesthetical commonwealth. Such apathy idiosyncratically included the arena of music-making and all possible records pertaining to it; e.g., 'explicit calculation of intervals', 'precise location descriptions of pitches', 'indication of the exact number of strings or fingerholes per instrument', 'their mathematical tuning/stringing/drilling methods – construction schematics – scientifically accurate drawings' and 'details of materials to be used thusly' – alongside 'weight', 'length' and 'periodical data' in every kind of instrument-making – not to mention 'the manner in which such instruments were to be played, taught, and preserved'… Said technicalities and nuances (and particularly any established notational standard next to a follow-up score engraving industry) were given absolutely no precedence (throughout a protracted period which the first co-author had dubbed 'The Dark Ages of Maqam Theory' in his Doctorate Dissertation [Yarman, p. 44]); and it seemed like everything was taken for granted until the advent of Western imperialism and colonialism starting, for our purposes, with the incursion of Napoleon Bonaparte into Egypt and Syria by the 19th Century. (This is when Guillaume André Villoteau enters the picture and would set in motion a series of events that irrevocably changed the intonational foundations of Middle Eastern maqam theory.)

4) Note that the prevalent obscruantism governing the artistry of all those centuries was, according to commonplace lore, based on such pretexts as 'trade secrecy', 'jealousy' towards the preservation of personally refined know-how, and the general wont to singularly gain 'monetary benefits' from rulers as well as other wealthy benefactors. It may also be that certain merchant professions were exclusively in the monopoly of autochthonous non-Muslims that prevented accurate technical/artistic illustrations by their Muslim compatriots; seeing as the sociological primacy of the Muslim caste necessitated their active participation in the feeding of mouths, running of empires, and manning of armies.

5) Yet, even before Villoteau, there were European ambassadors and travellers to the Middle East, such as Giambatista Toderini and Charles Fonton (cf. [Aksoy, pp. 97-110 & 146-55]), who gave detailed descriptions of the musical scenery that we can compare with the common practice period in the West. Whereas the impact of such pioneering intelligence

gathering activities would not be truly appreciated until the 20th and even 21st Century, without this 'Rosetta's Stone', there is, in fact, no serious way in which one can understand the lost Maqam music centuries. (Here, Wojciech Bobowski aka 'Ali Ufki' and Dimitrie Kantemir aka 'Kantemiroğlu' might be the sole two native-bred Westernized exceptions to confidently refer to for the task of internally deciphering the authentic makam tone-system.)

6) It is thence easy to imagine how Villoteau's portrayal of 1/3rd tones alongside 1/4th tones on the neck of some Egyptian instruments (pointing to an irregular 17-tones to the octave fretting) confused the likes of Jean-Benjamin de La Borde, François-Joseph Fétis and Hugo Riemann (cf. Ghrab [2005]). This is known to have resulted in the faulty description by such continental dilettantes (who had never seen the Levant with their own eyes) of Oriental (i.e., 'Arab') music mostly in terms of 24-tone Equal Temperament. It goes without saying that the idea of temperament was a mathematical necessity in Europe and overseas for unbounded polyphonic transposition; especially given how the 'concert pitch' varied across the Western world and how composers pushed for wider modulational expression throughout the cycle of fifths that challenged normative keyboard playing and even construction.

7) The 12/24-tone Equal Temperament (tET) idiom then summarily boomeranged back to Lebanon (as would be expected after prolonged interaction with more advanced foreigners and the resulting culture transfer) into the hands of Mikha'il Mishaqah who had been mentioned previously, and who promptly appropriated the 'doubly equal temperament' idea for Oriental (i.e. 'Arab') music. Notice that, by this time, the notion of Arab music as a distinct entity compared to Turkish or Persian music began to be recognized, especially given how the Orientalists' categorization of nearly all of the Middle East as 'Arabic' was gradually felt as denigrating to non-Arabs. Needless to say, this move exacerbated adverse nationalistic sentiments that led to the divarication of Turkish/Arabic/Persian music as distinct and disconnected entities – although they were, as a matter of fact, not entirely so.

8) By the time of the 'Music Congress of Cairo' in 1932, it was too late to remedy the situation. Arabs almost altogether unequivocally adopted 24-tET, while Rauf Yekta insisted on his appropriation of the first wholesome incidence of a three-tiered 'nim[5]'-selfsame-'dik[6]' accidented perde prefıx nomenclature from Mishaqah (which would later stick with Arel-Ezgi-Uzdilek) for an extended variant of the quintessential Pythagorean tuning as the actual tone-system of Middle Eastern (or at least Turkish) music [Erguner, pp. 87-171]. Yet, Yekta – and later Arel, Ezgi and Uzdilek – were not without historical basis either. Confusingly enough, Safiyuddin Urmavi (from 7 Centuries ago, at around the time of the Mongol devastation of Baghdad) had just the needed 17-tone Pythagorean infrastructure that became the foundational premise of the 'Yekta-Arel-Ezgi school' (the way it had been coined by O.

5 literally and intentionally, "half(-tone)" in Arabic, as it originated from Persian;

6 literally and intentionally, "raised (by a small diesis)" in Arabic, as it originated from Turkish;

Yarman in his Doctorate Dissertation) which held that "there were no quarter-tones in Turkish music". But even this should not come as a surprise, seeing as much of the 'Islamic Golden Age' was substantially about the adaptation of Hellenistic lore to the Fertile Crescent – including the local infusion of a bona fide multi-millenial tuning method of stacking hemiola, which was attributed to the most legendary and foremost of all music mathematicians in Ancient Greece (i.e., Pythagoras).

9) Yet, even more confoundingly, institutionalized Turkish Folk music later began to diverge from Turkish Classical/Art music during the 1940s and 50s as the nationalism movement progressed; which lead, in time, to their own music philosophy – and later, their seperate music theory enterprise [e.g., Emnalar]. Backed by the 'Muzaffer Sarısözen notation' (which probably is a 'bastardization' of Kemal İlerici's original 53-comma discreteness approach), quarter-tones were underhandedly re-introduced into the transcription of traditional music of Turkey through 'comma number indices' attached over ordinary sharps and flats. (As a sidenote, Yalçın Tura [1988] seems to be the first academician who explicitly mentioned the occurrence of quarter-tones on the neck of the Bağlama.)

10) In the meanwhile, the description of modes through the conjunction of tetrachords to pentachords (or vice versa) had, on any account, remained a dependable intervallic systematization that was utilized for more than a millenium (barring the protracted period which the first co-author refers to as 'The Dark Ages of Maqam Theory' in just the way emphasized above). This methodology was revitalized by Orientalists, and later, by modern Arabs, Turks and Persians. Actually, it was none other than Yekta who was instrumental in the reinstating of the tetrachordal/pentachordal parlance to explain modern Turkish music theory after the aforementioned mathematical hiatus, which was immediately picked up and re-purposed by Arel, Ezgi and Uzdilek following his death. Incidentally, institutionalized Folk music in Turkey is also thought to have independently begun to be affected by this archaic parlance of 'exploiting genera to build scales' since about the last 40 years.

11) Eventually, by early 2000 in general, several electroacoustic measurements and computational musicology studies [Signell pp. 37-47 & 151-61, Akkoç, Karaosmanoğlu 2003, Kaçar 2002 & 2005, Beyhom, Bozkurt 2008 & 2011, Bozkurt & Yarman et al., Bozkurt et al. 2008-2010-2014, Gedik & Bozkurt 2009-2010, Özek 2011 & 2012] incontrovertibly revealed that the official tone-system widely known as Arel-Ezgi-Uzdilek and ubiquitously adopted by Turkish Classical/Art music circles to transcribe the repertory indeed falls short (as had long been suspected) of correctly representing certain abstruse makams such as Saba, Uşşak, Hüseyni, Hüzzam, Karcığar, etc… on paper; which turns out to be a factuality also corroborated through the software playback of quotidian microtonal score editors (to be specified a little below). Said failure is likewise echoed in the defiant usage by Folk musicians of an altogether different set of accidentals called the 'Muzaffer Sarısözen system' as previously mentioned – which was, by all accounts, developed in tandem with, or borrowed from, the

pioneering work of Kemal İlerici during either the 1930s or 40s – that had otherwise been perfunctorily associated with 53-tone Equal Temperament (53-tET), but seems rather to be an atypical shorthand for a subset of the similitude of 24-tET as it appears on the necks of conventional Bağlamas today.

12) At any rate, this 53-tET resolution had been employed in native score editors known as NOTIST by M. Uğur Keçecioğlu, MUS2 (both the 'alpha' version and the revamped Data-Soft release) by M. Kemal Karaosmanoğlu and Utku Uzmen, as well as NOTA 2.2 by Ömer Tulgan for realistic playback. Come what may, Arel-Ezgi-Uzdilek happens to be an almost perfect subset of 53-tET, thus allowing microtonal alterations to be faithfully rendered digitally via the usage of 'comma number indices' on top of customary sharps and flats that demarcate the intended 'commatic deviation' or 'pitch inflexion'.

13) That there is a serious discrepancy between theory and praxis was moreover unveiled especially with regards to how the semitone mandals on a Qanun were being endemically affixed in accordance with '0 cent offsets' of the needle of 12-tET tuners imported from Western countries, and then with respect to how the distance between each 'mandal' and the 'nut' visually apportioned into equal parts to yield – for all intents and purposes – multiples of 12-tET. (As a sidenote, here is an excerpt from the first co-author's pertinent wikipedia entry on 'Qanun': "On the regular diatonically tuned Qanun, mandal technology was first implemented, according to Turkish musicologist Rauf Yekta, some 30 years prior to his submission of his invited monograph on Turkish Music to the 1922 edition of Albert Lavignac's Encyclopédie de la Musique et Dictionnaire du Conservatoire. Levantine Qanuns, prior to that time, remained rather inflexible and cumbersome to perform on [especially as demanding modulations/transpositions came into vogue that were increasingly emulating Western tonality and key changes], requiring the player to use the fingernail of the thumb to depress on the leftmost ends of the courses to achieve on-the-fly intervallic alterations. With the advent of electronic tuners some decades later, standardization of the placement of 'reference mandals' on the Qanun began. While Armenian Kanuns now employ only equidistant half-tones and Arabic Qanuns exact quarter-tones as a result, Turkish Kanun-makers went so far as dividing the electroacoustically referenced equal-tempered semitone of 100 cents into 6 equal parts, yielding – for all intents and purposes – 72 equal divisions (or 'commas') of the octave pitch resolution. Not all pitches of 72-tone equal temperament are available on the Turkish Kanun, however, since Kanun-makers affix mandals that only accommodate modulations/transpositions popularly demanded by performers. This has subsequently lead to the familiar interrupted and irregular pattern of mandals on the Turkish Kanun becoming a visual guide for players in facilitating modal and intonational navigation on an instrument which is ordinarily bereft of pitch markers. Some Kanun-makers may also choose to divide the semitone distance from the nut of the lower registers into 7 parts instead for microtonal subtlety [and the highest registers, conversely, into 5 parts due to spacing constraints]; but do so at the expense

of octave equivalences. Despite the mentioned discrepancies, hundreds of mandal configurations are at the player's disposal when performing on an ordinary Turkish Kanun.")

14) As trivial and tedious as this revelation turns out, it was evidently O. Yarman who first theoretically and wholesomely identified the conundrum in the case of mandal affixtures on Qanuns right at the onset in the Summary pages of his Doctorate Dissertation about 14 years ago. After being mired so with approximately 100 cent semitones, the inescapable 'bike-chain multiples' of approximately 12-tET that arise subsequent to finer and finer uniform partitioning by instrument-makers can only result in irregular subsets out of 60, 72, 84 equal divisions when not all mandal spaces are filled, just as because the lower section of the register sometimes get crowded more than the treble section due to more available physical space under the bass string courses. On the whole, one finds it rather remarkable that, since about 14 years, the first co-author vociferated the presence of 72-tET on Turkish Qanuns before anyone else was verbal about it. Despite this fact, no mention was made of Yarman's preliminary theoretical explanation of the situation regarding Turkish Qanuns in a later study (no matter how much deeper – and possibly redundant – in scope) published in 2013, where Yarman's Dissertation was anyhow cited [Günalçin].

15) In what followed, a flurry of theoretical pursuits took to the stage during the past decade and a half that profoundly involved the first, second, and third co-authors (as well as others rushing to the frontlines [cf. Yarman 2010]), where much turmoil ensued over the already prevalent chaos, and nothing really productive had been achieved towards the solution of the crisis between theory and praxis in Turkish Art music. Even worse, the general tendency by executants and instrument-makers was an ever-growing antagonism towards, and a louder rejection of, mathematical labor in music – to say nothing of impulsive (not to mention fatuous) proclamations to the effect that there was no fixed pitch to take into account in tradition; wherefore, given the purported 'arbitrariness' and 'fickleness' of each and every perde when fiddling with makams, opinions were pushed forward that went as far as to suggest the removal of frets from instruments that for centuries had them installed to begin with, or to demand the 'fluidization of fixed-pitch instruments' like the Keyboard, Garmon (Turkish Accordeon), Qanun, Lavta, Tulum (Pontic Bagpipes), Çifte Kaval, Sipsi, Zurna, Mey (aka Balaban or Duduk) etc… in order for them to be deemed Turkish music compliant!

16) Still, the first co-author had been influential in carrying a set of prominent theoretical solutions to the digital platform at the forefront so as to succeed in getting tangible outcomes. Aside from his 79-tone Qanun tuning and theory proposal [cf. Yarman 2016] that was soon fortified with a template file housing the 'custom-built Sagittal music font and notation palette' under the efficacious MUS2 editor, he also propounded a mid-sized alternative dubbed 'Yarman-36' in a joint article with the third co-author [Yarman & Karaosmanoğlu] that had the unique feature of being entirely tunable by ear based on a special reference frequency and simple integer beat counts; and then finally a complete barebones replacement

for Arel-Ezgi-Uzdilek in mainly a single Ahenk (Concert Pitch) christened Yarman-24/31 that relied on the exact same arsenal of microtonal accidentals as the current 24-tone Pythagorean tone-system in effect – which Yarman detailed in a dedicated chapter in his book [Yarman 2010]. (This was the first variant dubbed 'a' – soon followed by 'Yarman-24b', 'Yarman-24c', etc…; whereby the 'c' version was applied not only to Yarman's bowed tanbur, but also to Tolgahan Çoğulu's acoustic guitar, and Andrew McPherson's patented 'Touch-Keys' – aside from the '24-tone Maqam Piano' web application [cf. http://www.ozanyarman.com/24tonemakampiano.html] that Yarman developed with the programming help of Mesut Güngör.)

17) Pertinent information regarding the Yarman-24 initiative can be found especially in related YouTube channel videos accessible from the first co-author's internet homepage (http://www.ozanyarman.com). In brief, at the core of Yarman-24c is a 12-tone cyclic 'Modified Meantone Temperament' compatible with Western common practice, alongside an embedded 17-tone cycle suitable for makam-flavored xenharmony pursuits. Recall, yet, that this approach necessitates no other accidental symbols than those already accustomed to in Arel-Ezgi-Uzdilek, and it moreover came out to be almost as successful as 53-tET in our joint publication [Bozkurt & Yarman et al.] in matching histogram peaks from measurements of the recordings of master executants. With these advantages, the Yarman-24c tone-system has now become a serious contender to the current theoretical model, whose shortcomings have already been pointed out earlier through and through.

18) Notwithstanding, the ongoing crisis between theory and praxis in terms of determining the actual tuning model used in traditional and classical music genres of Turkey (which had been made worse by the cornucopia of alternative tone-systems flooding the market today) – let alone the task of propounding a common or generally acceptable 'master tuning template' for all of the Levant and the Middle East – remains a daunting handicap in the face of the need to accurately explain the finer (viz., subtly microtonal) particulars of Oriental modality in the 21st Century. Other tone-system suggestions include, but are not restricted to, 34-tET and 41-tET by the fırst co-author [Yarman 2008]; 51-tET (to better acquire the 'Pythagorean comma') by Karaosmanoğlu and Akkoç [2003]; and the triple (or double – with respect to Yarman) simplified original idea of 17-tET based on a 'rather strangling interpretation' of Urmavi by Yalçın Tura [1988 – cf. the book itself].

The damage done by the 'Yekta-Arel-Ezgi school' has been compounded by the adverse 'twelvulation' of the Turkish music soundscape (for which O. Yarman had coined the term "*temperialism* / *temperyalizm*" about two years ago to denote 'conscious or inadvertent equal temperament inurement') by a succession of people who can be said to have understood little of actual temperament & tuning mathematics as a requirement for both authentically representing makamlar and leaving the door open for possible future xenharmony.

2. Framework of This Study

Under the prevalent influence of Westernization, 20th Century models of Turkish music theory have attempted to explain makams as analogous to European musical keys and tonalities. Chief among these models is the standard Arel-Ezgi-Uzdilek theory, which conceives of each makam as a static set of pitches (perdes), and borrows diatonic function ideas from the common practice era such as the finalis/tonic (*karar/durak*), dominant/cofinal (*güçlü*), and leading tone (*yeden*) to highlight the makam's mobility. In contrast, indigenous historical descriptions of Turkish music are often conceived of as a balance between the *perde* – i.e, any of the set of more or less flexible pitches used in the piece, and the *seyir* – that relates to temporal motion within the piece (for instance, repetitive or common motifs or melodic contour).

Computational approaches to Turkish music have encompassed both melodic and rhythmic aspects. For example, Gedik & Bozkurt [2009] address the question of makam structure and its relationship to AEU theory using a music information retrieval framework, while Ünal et al. [2014] explore a classification paradigm. A number of open issues in the field are surveyed by Bozkurt et. al [2014], including methods that can be applied to tuning analysis, automatic transcription, automatic melody analysis, and automated makam identification.

Pitch histograms have become a recurrent tool in the computational analysis of both Western and non-Western music. For example, Tzanetakis et. al. [2003] examine the use of both symbolic (MIDI or score-based) and acoustic (audio-based) pitch histograms in the automatic classification of musical genres (Electronica, Classical, Jazz, Irish Folk and Rock specifically). More recently, Bozkurt et. al [2009] and Gedik & Bozkurt [2010] attempt to identify the tonic of a performance along with its makam using pitch histogram templates that are derived from a statistical analysis of the frequency content of the makams under the assumption that each perde is represented by a central frequency value and a distribution about that central value. A similar study by Şentürk, Gulati & Serra [2013] for identifying the tonic of a piece with reference to its written score can be cited along this line. Akkoç [2002] initially argued that makam scales are contingent upon not fixed but 'stochastically fluid' intervals depending on the pull of the seyir, and he demonstrated through pitch histograms that 'indeterminate scales' delineate clusters of tones more or less centered around the theoretical AEU values. This idea of intervallic fluidity and dynamism is echoed in later computational studies by Karaosmanoğlu [2003]. Most recently, in Akkoç et. al. [2015], pitch histograms are combined with higher order statistical measures to investigate – in juxtaposition with input from select master participants – whether it is perde or seyir that plays a predominant role in the auditory identification of Turkish makams.

The contour of a melody has long been considered significant in the study of music before the advent of computational musicology. Adams [1976] writes: "The concept of melodic

contour (shape, configuration, outline) is frequently encountered, but its precise meaning and significance in musical analysis is elusive". Adams surveys a number of graphical techniques that attempt to encode the intuitive notion of contour, including those based on global motion, those based on linguistic forms, those based on symbolic forms and their computational simplifications; with most aimed at an evolving picture of melodic motion where the contours are divorced from particular notes of the underlying scale. Attempts have also been made [cf. Schmuckler] to define musical contour, assess its perceptual significance, and to identify physical correlates (e.g., Schmuckler considers measures of oscillation and Fourier analysis). Monahan et. al. [1987] have further studied the effect of melodic contour on pitch perception. Results show that listeners are 'sensitive to the presence of global shape information in melodic contour'. Perhaps because of the lack of a clear definition of melodic contour, not as much attention has been paid to contour as has been paid to pitch, harmony, and rhythm; though certain investigators, such as Phiwma & Sanguansat [2010] and Salamon & Gomez [2012], have found it useful in the extraction of a melody from a recording of polyphony. Friedmann [1985], Morris [1987], and Marvin & Laprade [1987] represent melodic contour as a collection of classes (or contour space segments) which are sets that describe the order of the pitch heights of the tones in each segment (for instance, each measure or phrase). This approach divorces the up/down-ness of the contour representation from the individual notes of the scale, and hence is not a good match for Makam music where scale steps are often considered to be related to particular directions of motion. Quinn [1999] partitions contour into three relations (up, down, and no-change), and focuses on the perceptual import of non-adjacent tones.

By focusing on trigrams, we incorporate a notion of contour that partitions into four relationships (viz., 'ascending', 'descending', 'peak' and 'valley'), but we restrict attention to adjacent tones.

This paper hence proposes a type of note-based trigram chain definition of contour, where each occurence of every note is assigned to one of four classes: 'ascending' (e.g., Do-Re-Mi), 'descending' (e.g., Sol-Fa-Mi), 'peak' (e.g., Re-Fa-Re), or 'valley' (e.g., La-Do-Mi). The collection of such attributions is used to form histograms of melodic contour analogous to the way pitch histograms record the proportion of time spent at each pitch. These *contour histograms* thus represent a simple computational analog of the pattern of ups and downs, as well as peaks and valleys, of the melody. In the context of Turkish makams, contour histograms roughly represent the seyir of the makam by highlighting principal diatonic functions of its musical scale, while pitch histograms correspond to the durational distribution of perdes. (It is necessary to emphasize at this point that, under our approach, highest and lowest tones are regarded as privileged.)

The next section presents details on how the pitch and contour features are extracted, and how the method is first applied to the simple children's song known popularly as *Twinkle*

Twinkle Little Star. Several aspects of the *Twinkle* melody are clearly visible in the histograms. Section 4 then applies the method to a collection of monophonic pieces in Hicaz family makams in order to highlight the relationships between standard AEU-based theory and information extracted from our pitch and contour histograms. A selection of musical scores transcribed at a resolution of 53-commas to the octave (encapsulating AEU pitches too) are drawn from the SymbTr dataset [Karaosmanoğlu 2012] belonging to the Hicaz, Hümayûn, Uzzal and Zengûle makams, and encompass both Art and Folk music genres. Each note in the given scores may be a local maximum or minimum (a 'peak' or a 'valley'), or else it has a direction; i.e., it is part of an 'ascending' or 'descending' sequence. The approach is readily applicable to all related groups of makams, and may also be applied to any melodic corpus of Western music. Section 5 presents a statistical analysis that uses the Kullback-Liebler measure of relative entropy to compare the melodic contour histograms of the chosen Art and Folk pieces to cumulative contour histograms of four variants of Hicaz, and to cumulative contour histograms of four unrelated makams. Said statistical analysis reinforces the musicological analyses of earlier sections, and shows how the histograms readily distinguish the Hicaz variants from the unrelated makams. Finally, the topic is concluded under Section 6.

Before proceeding onward, we should remind that the main source of SymbTr is the TRT ("Radio and Television of Turkey") Institution, aside from other trustworthy archives such as "Recollection of Turkish Music Culture", in which the makam of a piece in Classical Turkish music has either been declared by its composer (as handed down in the oral tradition) or written on its score by the notist. The categorization of Folk music pieces are done during their admission into TRT by musicians who make the anthologies, or else, using automated classification using dedicated software. The 'source of transcription' is a kind of information that signifies the source person from whom a Folk music piece is compiled (rather than signifiying any persons in the Classical Turkish music genre). Even so, Art music scores seldom identify the engraver or score-checker.

3. Pitch and Contour Histograms: A Scale-Degree Vector Analysis

A melody may be represented by a list of notes with pitches $\{p_1, p_2, \ldots p_n\}$ and corresponding durations $\{d_1, d_2, \ldots d_n\}$. The durations may be measured in seconds, milliseconds, or some other convenient time base such as eighth-note (quaver) or quarter-note (crotchet) values. The pitches (but not grace notes) are drawn from some finite set **S** which is the musical scale upon which the piece is based. For Western music, **S** is all octaves of notes drawn from the 12-tone equal tempered chromatic scale. For Turkish music, **S** is all octaves of perdes drawn, as a general understanding, from the 53-note scale. Let $\mathbf{S}_o$ be the octave-reduced version of **S** and let $\mathbf{s} = \{s_1, s_2, \ldots s_m\}$ be the elements of $\mathbf{S}_o$. Thus, each s_j is an equivalence class consisting of all the pitch elements that differ by an octave. For Western music, with m=12,

two notes in the same pitch class such as p_i=A2 and p_j=A3 are represented by the same element s_k of **s**. Though octave equivalency may not be altogether applicable for Turkish music, from a general and widespread perspective, *m* might be as large as 53.

To represent the pitch histogram concisely, define the indicator function $\mathbf{1}_{\{pi\ e\ sk\}}$, which is 1 if the pitch p_i is a member of the *k*th equivalence class s_k of **s**, and is 0 otherwise. Then the sum over all the elements weighted by the durations gives the histogram values

$$\text{hist}(k) = \mathrm{S}_i\, d_i\, \mathbf{1}_{\{pi\ e\ sk\}} \text{ for } k=1, 2,\ldots, m. \qquad (1)$$

The first and last notes of the melody are handled separately, as they occur at perceptually salient locations. The first note is labeled a 'valley' if the second note is higher, and a 'peak' if the second note is lower; the final note is labeled a 'valley' if the penultimate note is higher, and a 'peak' if the penultimate note is lower. These are the only instances where two successive notes (i.e., bigrams) are taken instead of the three consecutive notes in our trigram analysis.

As an example, the *Twinkle* song of Table 1 shows the pitches in solfège form and in musical notation compared to the score of Fig. 1. Since all the notes are in the same octave, octave indicators are suppressed. Corresponding note durations are listed on the right-hand-side of the table in units of quarter-note beats. The pitch histogram is shown further below in Fig. 2. (An instance of 'peak' will be [Sool-Laa-Sol] and 'valley' [Ree-Do-Sol], compared to 'ascent' as exemplified by [Doo-Sool-La] and 'descent' as seen in [Faa-Mii-Re]).

Table 1: 'Twinkle' melody's pitches and durations

Do Do Sol Sol La La Sol \\ Fa Fa Mi Mi Re Re Do \\	1, 1, 1, 1, 1, 1, 2 \\ 1, 1, 1, 1, 1, 1, 2 \\
Sol Sol Fa Fa Mi Mi Re \\ Sol Sol Fa Fa Mi Mi Re \\	1, 1, 1, 1, 1, 1, 2 \\ 1, 1, 1, 1, 1, 1, 2 \\
Do Do Sol Sol La La Sol \\ Fa Fa Mi Mi Re Re Do	1, 1, 1, 1, 1, 1, 2 \\ 1, 1, 1, 1, 1, 1, 2

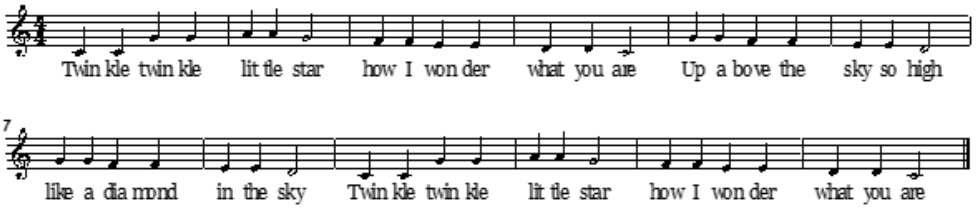


Figure 1: The *Twinkle* melody in the given score is used to demonstrate the construction of pitch and contour histograms.

The calculation (1) of the pitch histogram counts how many times each note occurs, and weighs that count by the durations. For example, 'Do' occurs six times; four of these are

quarter notes (indicated by 1) and two are half notes (indicated by 2), for a total of 8 beats duration. Fig. 2 shows that the pitches throughout the *Twinkle* melody are remarkably consistent, with four of the six pitches having exactly the same total duration. Of course, by design, this gives no indication of the motion or contour of the melody; pitch histograms show only how long the melody dwells on each pitch.

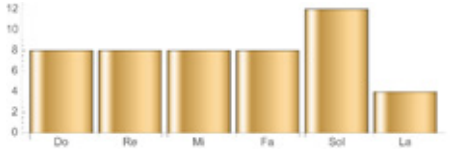


Figure 2: Pitch histogram of the *Twinkle* melody

Observe that repetitions of sections in a musical piece will affect the absolute number/count of the histograms, but they will not, in general, have an effect on the shape of the histograms. Since shape and contour are the primary features of this analysis, repetitions have little impact. With that said, we do not double-count repeated segments when parsing the songs.

The definition of the melodic contour will take place in two steps. The first step ensures that the contour is insensitive to note repetitions; the *reduced melodic representation* consolidates adjacent notes of the same pitch. This reduced representation treats a sequence of identically-pitched notes as if it were a single note with duration equal to that of all the repeated tones. To be precise, the pitches and durations of the melody can be placed in pairs $\{\{p_{1,}\ d_1\}, \{p_{2,}\ d_2\}, \ldots, \{p_{n,}\ d_n\}\}$. A new sequence $\{q_{j,}\ e_j\}$ is formed by setting $\{q_j = p_i\ ,\ e_j = d_i\}$ whenever $p_i \neq p_{i+1}$, and $\{q_j = p_i,\ e_j = d_i + d_{i+1}\}$ whenever $p_i = p_{i+1}$. This is repeated for all i=1, 2,…, *m-1*. Because of the removal of repeated notes, the sequence $\{q_j\ ,\ e_j\}$ is indexed by j=1, 2,…, n-1 with $n \leq m$. Observe that, by construction, the total duration of the $\{p_{i,}\ d_i\}$ representation is identical to the total duration of the $\{q_{j,}\ e_j\}$ representation; that is,

$$S_i\ d_i = S_j\ e_j. \qquad (2)$$

For example, suppose a piece were to contain the sequence {Do, La, La, La, Do} with durations {1, 1, 2, 1, 2}. This would be reduced to {Do, La, Do} with durations {1, 4, 2}.

Table 2 shows the reduced melodic representation of the *Twinkle* melody. In this case, all tones have equal duration, since all notes in Table 1 are either of duration 2 or occur in pairs (each with duration 1). Most melodies are not so regular. As expected, the total duration of both representations is an identical 48 beats.

Table 2: Reduced representation of the *Twinkle* melody: pitches and durations

Do Sol La Sol \\ Fa Mi Re Do \\	2, 2, 2, 2 \\ 2, 2, 2, 2 \\
Sol Fa Mi Re \\ Sol Fa Mi Re \\	2, 2, 2, 2 \\ 2, 2, 2, 2 \\
Do Sol La Sol \\ Fa Mi Re Do	2, 2, 2, 2 \\ 2, 2, 2, 2

The second step in the construction of a contour histogram is to represent it concisely in terms of four indicator functions that operate on the reduced melodic representation. The ascending indicator $\mathbf{1}_{\{qj-1< qj< qj+\square\square\}}$ is 1 if the previous pitch q_{j-1} is lower than the current pitch q_j and the succeeding pitch q_{j+1} is higher than the current pitch (and is 0 otherwise). Similarly, the descending indicator $\mathbf{1}_{\{qj-1> qj> qj\square+\square\}}$ is 1 if the previous pitch q_{j-1} is higher than the current pitch q_j and the succeeding pitch q_{j+1} is lower than the current pitch (and is 0 otherwise). The peak indicator $\mathbf{1}_{\{qj-1< qj> qj+\square\square\}}$ is 1 if the pitch q_j is higher than both its neighbors (and is 0 otherwise). Finally, the valley indicator $\mathbf{1}_{\{qj-1> qj< qj\square+\square\}}$ is 1 if the pitch q_j is lower than both its neighbors (and is 0 otherwise). These can be used to define the 'ascending' (asc), 'descending' (des), 'peak' (peak), and 'valley' (val) functions correspondingly, which are defined over all k in either $\mathbf{S}$ or $\mathbf{S}_o$ (as appropriate to the context).

$$\begin{aligned}
\mathrm{asc}(k) &= \mathrm{S}_j e_j \mathbf{1}_{\{qj-1< qj< qj+\square\square\}} \mathbf{1}_{\{qj\ e\ sk\}} \\
\mathrm{des}(k) &= \mathrm{S}_j e_j \mathbf{1}_{\{qj-1> qj> qj+\square\}} \mathbf{1}_{\{qj\ e\ sk\}} \\
\mathrm{peak}(k) &= \mathrm{S}_j e_j \mathbf{1}_{\{qj-1< qj> qj+\square\square\}} \mathbf{1}_{\{qj\ e\ sk\}} \\
\mathrm{val}(k) &= \mathrm{S}_j e_j \mathbf{1}_{\{qj-1> qj< qj\square+\square\}} \mathbf{1}_{\{qj\ e\ sk\}}.
\end{aligned} \tag{3}$$

The simplest application appears to plot the summary histogram of the functions in (2). These functions sum over all the possible pitches $A=S_k$ asc(k), $D=S_k$ des(k), $P=S_k$ peak(k), and $V=S_k$ val(k). The aggregates show how the melody tends to move; i.e., whether it is predominantly upwards, downwards, or evenly balanced.

For instance, the summary histogram – generated with a Mathematica code by the second co-author – for the *Twinkle* melody as shown in Fig. 3 reveals that the predominant motion is descending. Observe how the imbalance in the ascending and descending notes naturally implies that the melody must tend to make larger leaps when ascending.

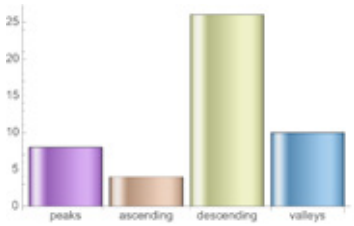


Figure 3: Summary contour histogram for the *Twinkle* melody

Alternatively, the summary histogram may be viewed as a function of pitch. Likewise Mathematica-generated Fig. 4 demonstrates that, for the *Twinkle* song, all the Do-s are valleys (toward which all else gravitates). All the Mi-s and Fa-s – and most of the Re-s – are descending (i.e., transitory stops along the melodic route). Only Sol impresses a balance of each (signifying a 'focal point' of the melodic path). All La-s are peaks (a 'roll-off zone', so to speak). Such features form a basic characterization of the analyzed melody.

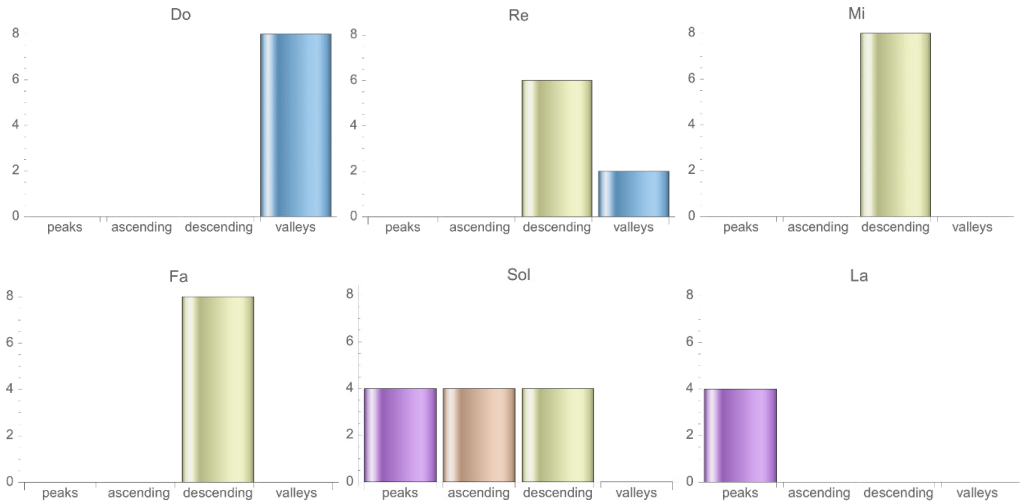


Figure 4(a), (b), (c), (d), (e), (f): Histograms show how often each note functions as part of an ascent or descent, and/or the portion of time that each note represents a turning point (peak or valley).

In general, contour histograms may make use of the full complement of pitches in the scale set **S,** or they may be consolidated to the octave-reduced pitch set $\mathbf{S}_o$. An insightful way to view these functions is to place the pitch set on the horizontal axis, and the four counts in different colors or shadings on the vertical axis. For example, once again Mathematica-generated Fig. 5 consolidates all the contour histograms for the *Twinkle* song. In this case, because all the notes lie within one octave, there is no distinction between **S** and $\mathbf{S}_o$.

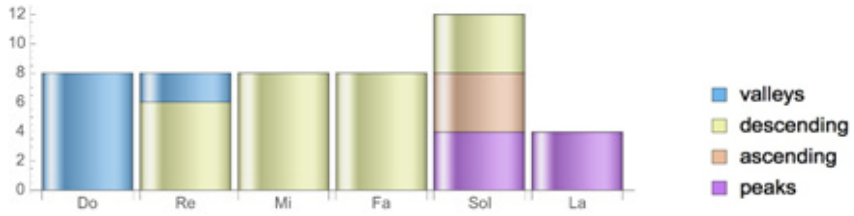


Figure 5: Contour histogram for the *Twinkle* melody. Observe that this is a specialization of the pitch histogram of Fig. 2, and a consolidation of the multiple histograms of Fig. 4.

The contour histogram featuring the analysis of scale-degree vectors shows several characteristics. Like the summary histogram of Fig. 3, it shows that the melody primarily consists of long descending passages and implies that the few ascending tones (all of them Sol) must contain relatively large leaps. Like the pitch histogram of Fig. 2, it shows that the pitches are quite evenly distributed. Observe that Fig. 4 is a partitioned (tiered), multi-color version of Fig. 2. This is no coincidence. Substituting the relationship between the d_i and the e_i given in (2) into the four functions of the contour histograms (3) shows that, for each k,

$$\begin{aligned}
&\text{asc}(k) + \text{dec}(k) + \text{peak}(k) + \text{val}(k) \\
&= S_j e_j \mathbf{1}_{\{qj-1< qj< qj+\square\square\}} \mathbf{1}_{\{qj\ e\ sk\}} + S_j e_j \mathbf{1}_{\{qj-1> qj> qj+\square\square\}} \mathbf{1}_{\{qj\ e\ sk\}} + S_j e_j \mathbf{1}_{\{qj-1< qj> qj+\square\square\}} \mathbf{1}_{\{qj\ e\ sk\}} + S_j e_j \mathbf{1}_{\{qj-1> qj< qj\square+\square\}} \mathbf{1}_{\{qj\ e\ sk\}} \\
&= S_j e_j (\mathbf{1}_{\{qj-1< qj< qj\square+\square\}} + \mathbf{1}_{\{qj-1> qj> qj+\square\square\}} + \mathbf{1}_{\{qj-1< qj> qj\square+\square\}} + \mathbf{1}_{\{qj-1> qj< qj+\square\square\}}) \mathbf{1}_{\{qj\ e\ sk\}} \\
&= S_j e_j \mathbf{1}_{\{qj\ e\ sk\}} = S_i d_i \mathbf{1}_{\{pi\ e\ sk\}} = \text{hist(k)}, \qquad (4)
\end{aligned}$$

where hist(k) is the pitch histogram of (1). Thus, the heights of the pitches in the contour histogram will always sum to equal heights in the pitch histogram.

But the contour histogram can reveal even more. For the *Twinkle* example, Fig. 3 shows that there are only a small number of valleys. Significantly, Fig. 5 reveals that these valleys are located predominantly (4 times out of 5) at Do – viz., the 'tonic' of the piece. Similarly, Fig. 5 shows that half of the peaks occur at Sol – viz., the 'dominant'. Furthermore, all ascents involve only Sol. Thus, the contour histogram is a generalization of the pitch histogram that can also reveal information about the motion of the melody – even without any underlying harmonic or polyphonic context. It moreover contains information about the most important tones and their diatonic functions within the melody, i.e., those that occur at perceptually salient positions such as peaks and valleys.

Two types of contour histograms are thence plotted: i) those without octave reduction (in which ascent and descent are unambiguous since the raw pitches are used), and ii) those that are octave-reduced. In the latter case, the assignment of ascending/descending/ peak/

valley is made before octave reduction, so that the contour (up/down-ness) is maintained. Thus, the octave reduction does not affect the analysis of the contour, only the presentation of the histograms.

4. Comparing AEU Theory Designations with Contour Histograms

Hicaz family makams in Turkish Art/Folk music ordinarily comprise Hicaz (proper), Hümayûn, Uzzal and Zengûle (cf. Özkan [2003] and Kutluğ [2000]). Other naming conventions exist where they may also be referred to as Hijaz, Hicaz-Humayun, Hicaz-Uzzal and Zirgüle'li Hicaz (or Hicaz-Zirgûle) respectively. Such differences in makam naming are common as can be seen by comparing D'Erlanger [1949], Touma [1934], Özkan [2003] and Kutluğ [2000].

Sometimes, difficulties in the identification of a piece's makam can arise when it has been registered, for instance, to be in Hicaz but actually turns out to be in Uzzal instead. (Our study reveals one such example). The proposed scale-degree vector analysis can particularly highlight whether the registered makam matches the performed makam, and so may help identify such incongruities through a comparison of the diatonic functions given in theory with the measured behaviors of the contour histograms.

4.1 Makams Belonging to the Hicaz Family

Figure 6 shows an overview of the Hicaz family, and juxtaposes the theoretical diatonic functions against information uncovered through upcoming contour histogram figures with respect to chosen Art music pieces. The seyir of all makams in the Hicaz family are said to be ascending-descending and differences between members of the family can allegedly be ascertained by 'their dominants and the *çeşnis* (genera flavors) over their dominants' (cf. Özkan [2003]). Ascent and descent tend to be global terms in AEU theory in contrast to the local aspects of contour delineated by our trigram analysis.

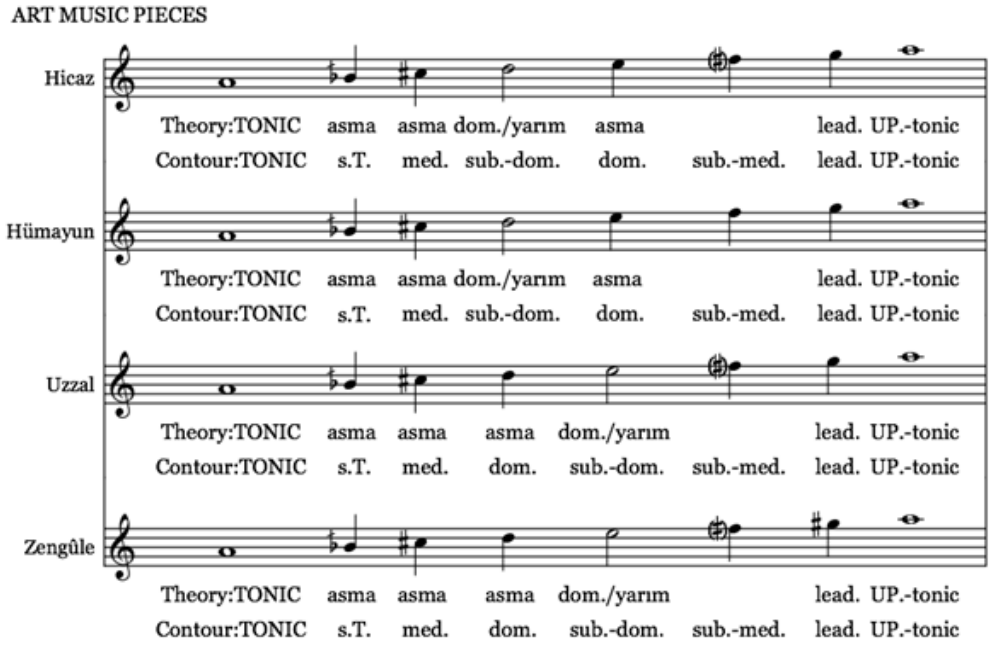


Figure 6: Overview of diatonic functions in AEU theory vs upcoming contour histograms derived from our selection of Art music pieces. *Asma* stands for *asma karar* (tonicization), *yarım* stands for *yarım karar* (semi-cadential tone), *dom.* stands for dominant (*güçlü*), *sub.-dom.* stands for sub-dominant, *med.* stands for mediant, *sub.-med.* stands for sub-mediant, *lead.* stands for leading tone (*yeden*), and *s.T.* stands for supertonic. Accidentals in parantheses indicate alternating microtonal variations. No distinction is made hence between the tonic and the upper (UP.-) tonic, given that scales of the Hicaz family of makams can be repeated at the octave.

Chief among the four members of the Hicaz family, and giving the family its name, is Hicaz. Hicaz is based on a heptatonic scale constructed from the adjoining of a hicaz tetrachord [a bb4(limma ♭) c#4(limma ♯) d] at the bottom with a rast pentachord [d e f#3 g' a'] at the top, where the dominant is the adjunct tone 'd' (perde neva) upon which a 'Rast semi-cadence' may take place, and whose leading tone 'g' (perde rast) is a wholetone below the tonic 'a' (perde dügah). Its specific seyir is said to be descending-ascending (i.e., commencing from the mid-register) and sometimes ascending (starting from the tonic's vicinity). Microtonal implications of f#4 in ascent and f#3 in descent do not really signify a particular role in the global assessment, but they remain salient features of the subtleties of seyir. The same is true of the fact that bb4 can often become bb3 while c#4 drops to c#3 to yield a 'Garip' (off-key) kind of Hicaz (with a wholetone-wide 'augmented second' interval at the center of the Hicaz tetrachord) during actual performance.

Hümayûn is constructed by joining a hicaz tetrachord [a bb4 c#4 d] with a buselik pentachord [d e f g' a'], where the dominant is the same as that of Hicaz (the adjunct tone 'd' or perde neva) upon which a 'Buselik semi-cadence' may take place, and whose leading tone 'g' (perde rast) is a wholetone below the tonic 'a' (perde dügah) – unless a semitonal one at g#4 (perde nim zengûle/zirgüle) is used instead. Its specific seyir is said to be ascending-descending (commencing from the mid-register) though this is not systematically covered by AEU theory.

Uzzal is constructed by joining a hicaz pentachord [a bb4 c#4 d e] with an uşşak tetrachord [e f#3 g' a'], where the dominant is the adjunct tone 'e' (perde hüseyni) upon which an 'Uşşak semi-cadence' may take place, and whose leading tone 'g' (perde rast) is a whole tone below the tonic 'a' (perde dügah) – unless a semitonal one at g#4 (perde nim zengûle/zirgüle) is used instead. Its specific seyir is said to be descending-ascending (i.e., commencing from the mid-register) and sometimes ascending (starting from the tonic's vicinity).

Finally, Zengûle is constructed by joining a hicaz pentachord [a bb4 c#4 d e] with a hicaz tetrachord [e f#1 g#4' a'], where the dominant is the adjunct tone 'e' (perde hüseyni) upon which a 'Hicaz semi-cadence' may take place, and whose leading tone g#4 (perde nim zengûle/zirgüle) is a semitone below the tonic 'a' (perde dügah). Its specific seyir is said to be descending-ascending (i.e., commencing from the mid-register). Note that the microtonal implications of g#4 as a leading tone to g, and f#1 replacing f as a necessity for the theoretical exactness of the Hicaz tetrachord, once again do not really signify a particular role in our global assessment, but remain salient features of accurate intonation and the subtleties of seyir.

4.2 Art Music

We select four pieces of Art music from the SymbTr database for detailed study: The anonymous '*Ada sahillerinde bekliyorum*' İstanbul Türküsü (İstanbulite Türkü) in purportedly Hicaz Düyek, '*Kurbanın olam ey afet-i can*' Hicaz-Hümayûn Aksak Şarkı (Song) by Hacı Arif Bey, '*Ülfet etsem yar ile, ağyare ne?*' Hicaz Yürük Semai Şarkı by Şevki Bey – because the first song shall momentarily be revealed to be in Uzzal instead while this one is apparently wrongly classified under SymbTr as Uzzal, and '*Ne boş yere yanmışım, meğer ben aldanmışım*' Zengûle Düyek Şarkı by Saadettin Kaynak. Downloadable addresses for these compositions are provided in Table 3 under Conclusions.

Mathematica-generated contour histogram and summary contour histogram results from *Ada sahillerinde bekliyorum* (which is also known as 'Arap Kantosu' or 'Arabian Canto') are given in Fig. 7 and Fig. 8.

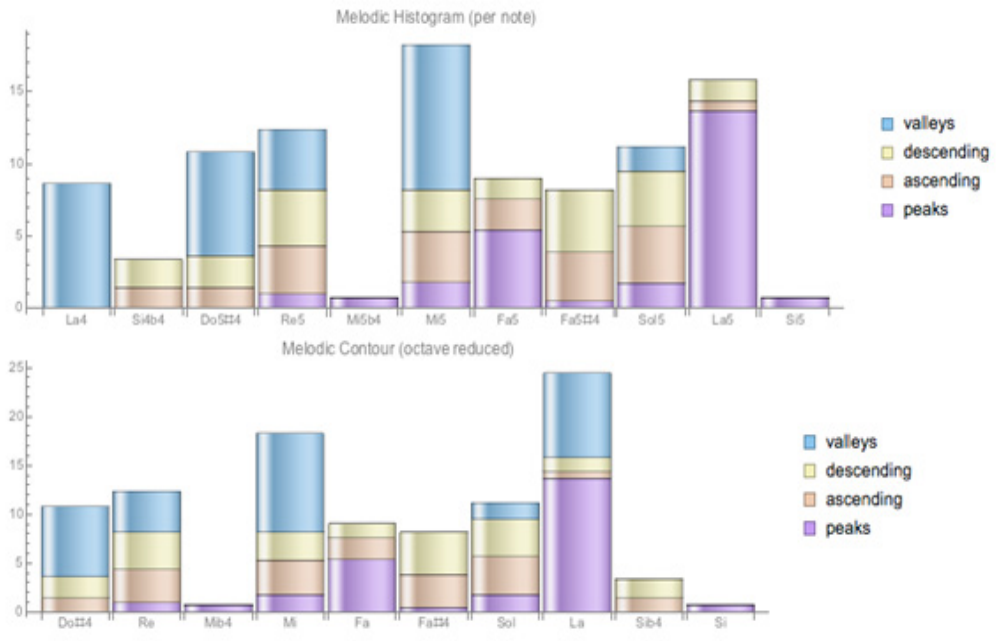


Figure 7(a), (b): Contour histograms for *Ada sahillerinde bekliyorum*, which is registered as a Hicaz makam piece, with both full-scale and octave-reduced displays. Tonic is said to be La, dominant is said to be Re, leading tone is said to be Sol, and tonicizations are said to occur at Sib4, Do#4, Re, and Mi. There is a near-correlation with what AEU theory says and what these histograms reveal, except for the discrepancy of the dominant, which occurs at Mi instead of Re. This implies that the piece is actually in Uzzal makam.

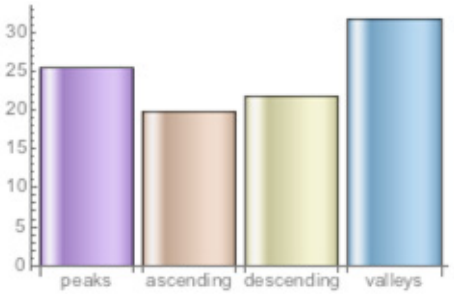


Figure 8: Summary contour histogram for *Ada sahillerinde bekliyorum*. The profusion of peaks and valleys suggests that there are many short turnarounds in a melodic path that is biased towards descent.

Although the dominant of Hicaz is designated as Re in AEU theory (on account of the conjuction of the lower Hicaz tetrachord with the higher Rast pentachord over this note),

Fig. 7 reveals that most of the valleys, as well as a sizeable number of peaks, occur at Mi instead of Re. This implies that the piece is actually in Uzzal rather than the registered Hicaz. Otherwise, the 'secondary dominant' Sol being the leading tone in the same character as the 'sub-dominant' being Re is conspicuous from the way peaks and valleys occur in proportion to ascending and descending tones for these pitches. In other words, Sol and Re are nearly the same tiered shape and size, indicating that they are used with a similar diatonic function in the melody. Therefore, the leading tone to the tonic La is indeed Sol, just as the 'shifted leading tone' to the tonicized (asma/yarım karar) Mi is indeed Re. AEU theory suggests that Mi is where an Uşşak semi-cadence ought to occur in the case of Uzzal, which is exactly what happens at the start of the melody. The tonic of the piece is indisputably La for having the greatest 'almost solo' concentration of peaks at its octave next to a similar number of valleys at the root.

More can be said about the 'mediants'. These are the alterating shifted mediant duo Fa / Fa#4 with respect to Re (the 'anticipated sub-dominant') and the mediant Do#4 with respect to La (the tonic). The former (regularly alterating) duo is evidently the 'sub-mediant' of a tonicized Re, and the latter a proper mediant for the tonic La. The reversal of the role of peak vs valley in these mediants (Fa / Fa#4 duo vs Do#4) indicates how the shifted mediant (i.e., sub-mediant) demarcates the upper part of the register and the proper mediant the lower part of it. In other words, the shifted mediant Fa / Fa#4 duo acts as a twin apex to the principally descending melody, while the proper mediant Do#4 acts like a basin as the melody wanders upwards before settling on La. Of particular interest besides are the 'passing tones' Mib4 and Si, which only occur in the form of peaks, and Sib4 which only occurs without any peaks or valleys.

Concerning Fig. 8, the seyir has significant pitstops in the form of peaks and valleys while the melody meanders down from the uppermost register at each thematic reprise. The greater proportion of valleys in comparison to peaks can be interpreted as an effective downward pull on the melody when it is coupled with the fact that descent is somewhat more accentuated. That is to say, the piece is by necessity required to commence each time from the treble compass of the makam scale when the thematic material is repeated, and this can be ascertained from the combination of a large number of descents and a profusion of peaks. In comparison to the textbook definition of Uzzal's seyir (that is said to be descending-ascending and sometimes ascending), there is not an exact match. Instead, this shows a descending seyir that starts flowing down from the region of the upper tonic.

Next, the contour histogram and summary contour histogram results – once more generated by the Mathematica code of the second co-author – from *Kurbanın olam ey afet-i can* are given in Figs. 9 and 10.

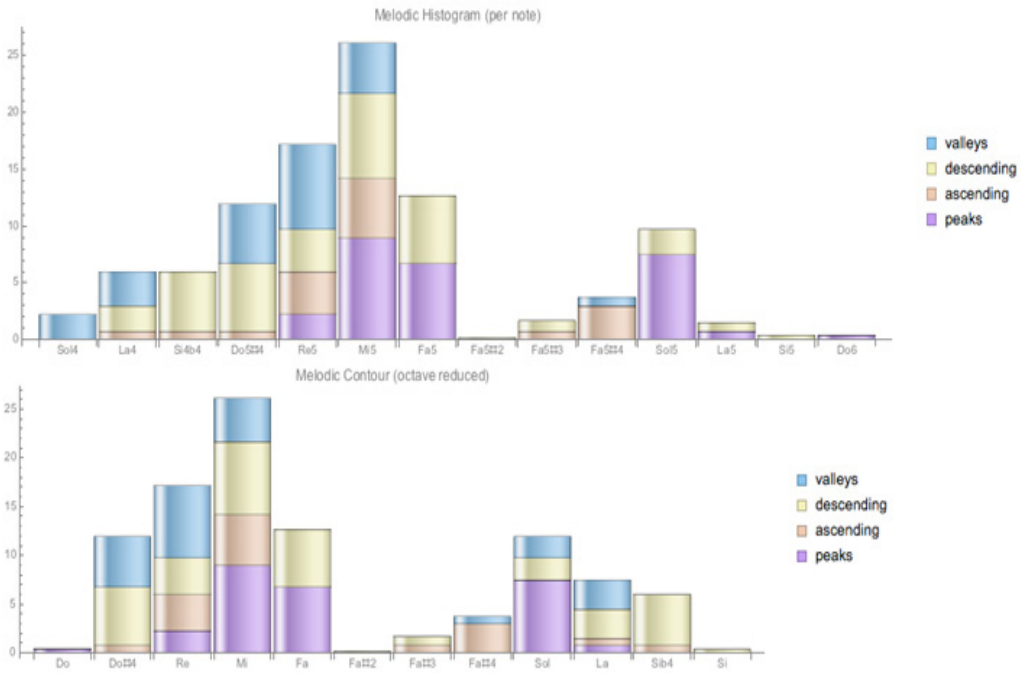


Figure 9(a), (b): Contour histograms for *Kurbanın olam ey afet-i can* in Hümayûn makam (sometimes inadvertently classified as Hicaz), with both full-scale and octave-reduced displays. Tonic is said to be La, dominant is said to be Re, leading tone is said to be Sol or Sol#, and tonicizations are said to occur at Sib4, Do#4, Re, and Mi. There is a visible discrepancy with the dominant being at Mi instead of Re; signifying that the piece does not conform to textbook descriptions of Hümayûn.

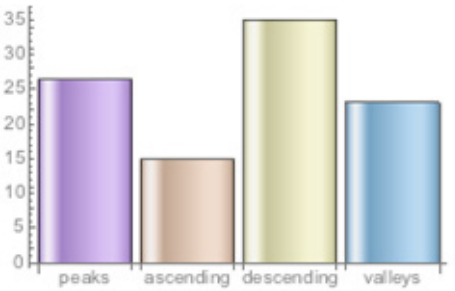


Figure 10: Summary contour histogram for *Kurbanın olam ey afet-i can*. This picture reveals that the piece is overwhelmingly a descending one, but one with a great number of peaks; also noticeable the way

relatively large intervallic leaps back up to treble registers are recurrent as shown by fewer valleys and more peaks. This may be interpreted as a kind of 'ascending-cadencing seyir' not covered by AEU theory.

Fig. 9 immediately reveals that, although the dominant of Hümayûn is designated as Re in AEU theory on account of the conjuction of the lower Hicaz tetrachord with the higher Buselik pentachord over this note, the piece at hand – while chiefly remaining faithful to the principal scale of the makam – makes salient use of Mi as evidenced by the prevalence of its peaks. Thus, we may attribute to this composition the unfamiliar makam name 'Uzzal-Hümayûn'. Confusion in pinpointing the makam of the piece is also seen in its different score versions. However, the tonic is not quite possible to make out to be La, nor the leading tone straightforwardly identifiable as Sol despite the secondary importance of peaks here. On the other hand, the 'sub-dominant character' of Re is punctuated by the prevalence of valley notes. Meanwhile, Fa shows a sub-mediant function with respect to Re owing to the tertiary importance of peaks. It is significant that Sib4 never exhibits a valley or peak character, and is therefore primarily a transitionary tone. It is akin to Fa#2 / Fa#3 / Fa#4, although this is even less pronounced for the latter trio of alternant notes. Finally, Do#4 can be explained partly as a 'shifted leading-tone' to a tonicized Re, and partly as a 'mediant' to La on account of the secondary importance of its valleys.

Figure 10 hints at the possible existence of an 'ascending-cadencing seyir' not covered by AEU theory (but mentioned by such theorists as Eric Ederer [2015, p. 26]), given that the overall ascent-descent distribution is skewed toward the latter, combined with the fact that fewer valley notes and more peak notes seem to account for the recurrence of relatively large intervallic leaps to the treble register. Also, the predominance of peaks vs valleys raises the importance of the actual dominant Mi with respect to the accustomed tonic La. This provides a good match with the unsystematized textbook definition of Hümayûn makam's seyir which is given as an ascending-descending seyir.

The Mathematica-generated contour histogram and summary contour histogram results from *Ülfet etsem yar ile, ağyare ne?* are provided in Figs. 11 and 12.

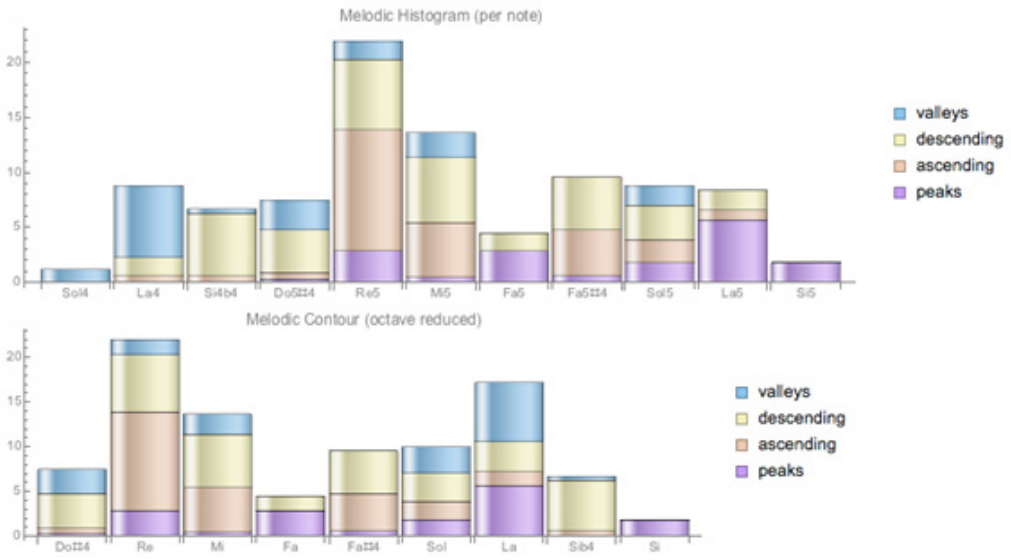


Figure 11(a), (b): Contour histograms for *Ülfet etsem yar ile, ağyare ne?* in Hicaz makam, with both full-scale and octave-reduced displays. Tonic is said to be La, dominant is said to be Re, leading tone is said to be Sol or Sol#, and tonicizations are said to occur at Sib4, Do#4, Re, and Mi. There is a close correlation between AEU theory and what these histograms reveal.

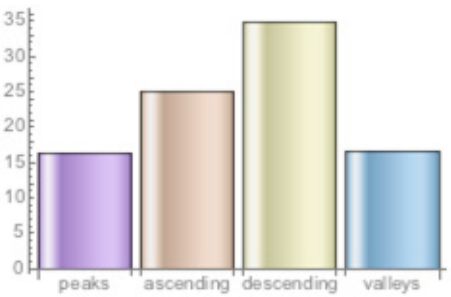


Figure 12: Summary contour histogram for *Ülfet etsem yar ile, ağyare ne?*. This picture reveals that the piece is overwhelmingly a descending one, but one coupled with much ascent and the balance of comparatively fewer peaks and valleys, which describes a 'descending-ascending seyir'.

Figure 11 shows that the tonic of the piece is La for having the greatest nearly-equal-height concentration of peaks and valleys in the octave-reduced display. Furthermore, it makes the most use of Re (i.e., the dominant) while remaining faithful to the principal scale of

the makam. This is shown by the prevalence, after the tonic, of its peak notes with respect to the usage of valleys. The histograms signify Hicaz – instead of SymbTr's categorization of the piece as Uzzal. Indeed, the composition does not seem to conform to textbook descriptions of Uzzal, and it is often stated as Hicaz in the repertory. Otherwise, the 'secondary dominant' Sol being the leading tone in the same character as the 'sub-dominant' being, this time, Mi is deducible from the way peaks and valleys occur in proportion to ascending and descending tones for these pitches. In other words, Sol and Mi (as well as Do#4) are roughly the same tiered shape and size, indicating that they are used with a similar diatonic function in the melody. Therefore, the leading tone to the tonic La is indeed Sol, just as the shifted leading tone to the tonicized Fa is indeed Mi, and the shifted leading tone to the tonicized (asma/yarım karar) Re is Do#4. Recall that AEU theory suggests that an Uşşak semi-cadence ought to take place at Mi in Uzzal, but this does not occur in this piece. Instead, there are many Rast semi-cadences on Re, as would be normal for a Hicaz makam. The mediant duo Fa / Fa#4 with respect to Re (the 'true dominant' for this composition) and the mediant Do#4 with respect to La (the tonic) parallel the previous analysis of *Ada sahillerinde bekliyorum*. Finally, Sib4 signals a shifted sub-mediant function to Re.

Figure 12 shows that the piece is overwhelmingly descending, though coupled with much ascent and the balance of comparatively fewer peaks and valleys; thereby implying a 'descending-ascending seyir'. The equal balance of both peaks and valleys seem to indicate that the dominant is Re instead of Mi. When compared to the textbook definition of Hicaz makam's seyir that is said to be descending-ascending and sometimes ascending, there is good agreement.

Completing the four Art music pieces, the contour histogram and summary contour histogram results from *Ne boş yere yanmışım, meğer ben aldanmışım* (the way they were generated by the code of the second co-author under Wolfram Mathematica) are presented in Figs. 13 and 14.

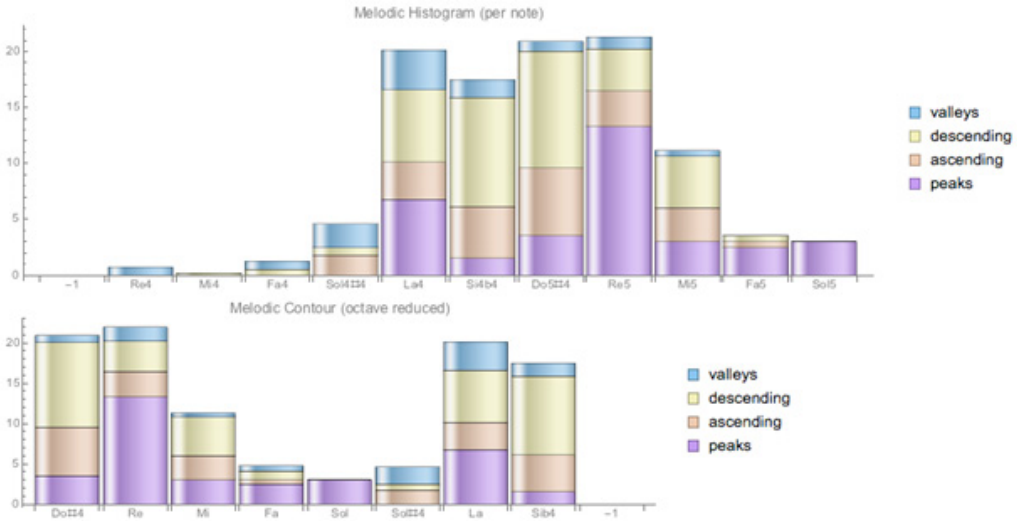


Figure 13(a), (b): Contour histograms for *Ne boş yere yanmışım, meğer ben aldanmışım* in Zengûle or Hicaz-Zirgûle makam, with both full-scale and octave-reduced displays. Tonic is said to be La, dominant is said to be Mi, leading tone is said to be Sol#, and tonicizations are said to occur at Sib4, Do#4, Re, and Mi. Given the discrepancy of the dominant at Re instead of Mi, there is little correlation between these histograms and AEU theory. The piece does not conform hence to a textbook description of Zengûle.

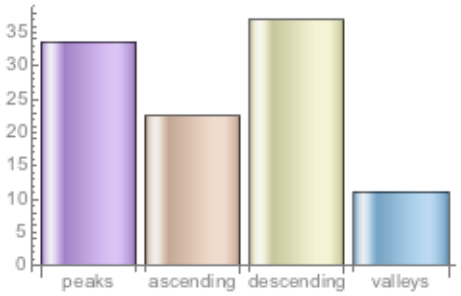


Figure 14: Summary contour histogram for *Ne boş yere yanmışım, meğer ben aldanmışım* reveals an overwhelmingly descending seyir. The recurrence of large intervallic leaps up to the treble register is shown by the disparity in the numbers of valleys and peaks. This signifies the possible existence of an 'ascending-cadencing seyir' not covered by AEU theory.

Figure 13 suggests that the tonic is La due to the large number of peaks and valleys occuring together on this pitch. Re is similar, though, and is evidently the actual dominant of the piece instead of the nominally posited Mi (according to AEU theory) on account of the number of peaks. The unusual picture with the near-equal distribution of ascending, descending,

peak, and valley notes for the pitches La, Sib4, Do#4, Re in order seem to suggest that this makam has a plagal character akin to Hypo-type Gregorian modes. For this reason, Do#4 may be interpreted as a shifted leading tone to a semi-cadential tonicized Re, just as we may infer the same for Sol#4 with respect to the tonic La. However, it must be admitted that the proper leading tone character of Sol#4 is not immediately apparent from these histograms. Yet, we can say even more about Do#4 as further being a mediant to the tonic La. This kind of a double feature in diatonic functions would seem to manifest recurrently for the Zirgüle'li Hicaz in question. Such an approach not only demotes Mi to the position of 'sub-dominant', but also reassigns it to a shifted leading tone status to a tonicized Fa – with this latter being the sub-mediant to the actual dominant Re. As for the puzzling nature of Sib4, we may suggest that it is sometimes an unusual shifted leading tone over an augmented second interval to a tonicized Do#4, aside from also encapsulating the function of a supertonic to La. Sol, on the other hand, can be viewed as the secondary dominant to Re.

Wrapping up this analysis, observe that Fig. 14 has almost the same markings as with *Kurbanın olam ey afet-i can* in Fig. 10. Hence, all that has been said before concerning that piece now applies to *Ne boş yere yanmışım, meğer ben aldanmışım*. In comparison to the textbook definition of Zirgüle'li Hicaz makam's seyir that is said to be descending-ascending, there is good agreement.

Comparing these results with Fig. 6 reveals that the anonymous *Ada sahillerinde bekliyorum* in purportedly Hicaz Düyek actually better fits Uzzal, *Kurbanın olam ey afet-i can* Hicaz-Hümayûn Aksak Şarkı by Hacı Arif Bey is more likely in what can be novelly dubbed as 'Uzzal-Hümayûn' or 'Acemli Uzzal', and that *Ülfet etsem yar ile, ağyare ne?* has been wrongly categorized in SymbTr as Uzzal (it should be Hicaz).

4.3 Folk Music

Consequent to our undertaking above for Art music pieces, we now commence the contour and summary contour histogram analyses of Folk music pieces in juxtaposition to their Art music siblings. The SymbTr database presents us with the choice of Hicaz Aksak Türkü '*Karanfil oylum oylum*'; the Karadeniz (Black Sea) Türkü in Hümayûn Türk Aksağı '*Ben seni sevduğumi da dünyalara bildirdum*'; the Uzzal Aksak Türkü '*Öte yakaya geçelim, atlara yonca biçelim*'; and lastly, the Zengûle Sofyan Azeri Mahnı *(Sulh Mahnısı)* '*Ana gelbim odlanır söz düşende davadan*' from the Turkish Folk music repertory. Downloadable addresses for these compositions are provided in Table 3 under Conclusions.

Contour histogram and summary contour histogram results from *Karanfil oylum oylum* are given in Fig. 15 and Fig. 16 below:

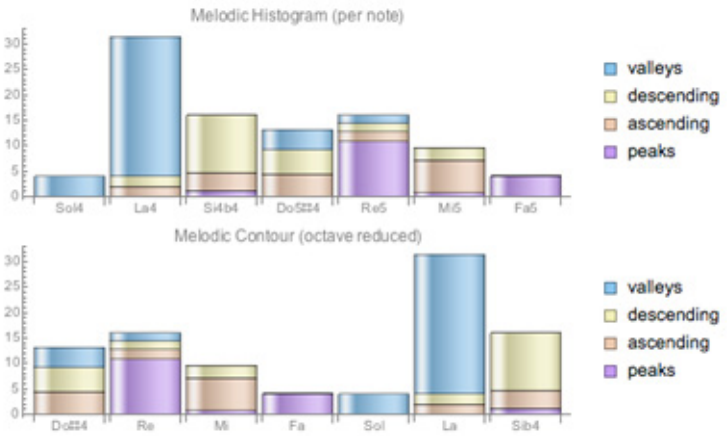


Figure 15(a), (b): Contour histograms for *Karanfil oylum oylum* in Hicaz makam, with both full-scale and octave-reduced displays. The usage of scale degrees clearly conforms to Hicaz.

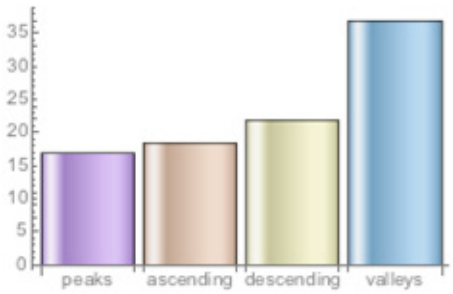


Figure 16: Summary contour histogram for *Karanfil oylum oylum*. This picture reveals that there are more valley tones than any other kind, that peaks are relatively infrequent, and that ascending-descending distribution is more or less even, but with a visible bias towards descent.

In comparison to Fig. 11 pertaining to *Ülfet etsem yar ile, ağyare ne?*, the established tonic La for the former piece conforms with La as tonic for the latter *Karanfil oylum oylum* given the prevalence of valleys in both. Likewise for Re, given the prominence of peaks coupled with the presence of valleys in both pieces, the dominant Re for the former conforms to Re as dominant for the latter. The mediant function of Do#4 is also on par in both examples; whereas, for Sib4, the presence of peaks instead of valleys for the latter piece seems to accentuate a shifted mediant function to a tonicized Sol instead of a shifted sub-mediant function to Re. This is akin to the shifted mediant function Mi assumes with respect to a tonicized Do#4 instead of a sub-dominant function as in *Ülfet etsem yar ile, ağyare ne?*. Yet, it is not clear how Sol can be identified as the proper leading tone of *Karanfil oylum oylum* unless we settle with a direct octave-unreduced comparison with *Ülfet etsem yar ile, ağyare ne?* (cf. Fig. 11a). Finally, it is possible to identify the sub-mediant character of Fa with respect to a semi-cadential Re owing to the meager number of peaks.

The seyir depicted in Fig. 16 has significant pitstops in the form of valleys as the motif develops in the vicinity of the tonic. The greater proportion of valleys in comparison to peaks can be interpreted as an effective downward pull on the melody when it is coupled with the fact that descent is accentuated. Yet, the meagerness of peaks is an indication that the piece does not tend to climb very high overall. This is in agreement with the textbook definition of Hicaz makam's seyir that is said to be descending-ascending and sometimes ascending, because the histogram essentially signifies an ascending melody.

Next, contour histogram and summary contour histogram results from *Ben seni sevduğumi da dünyalara bildirdum* are given in Figs. 17 and 18.

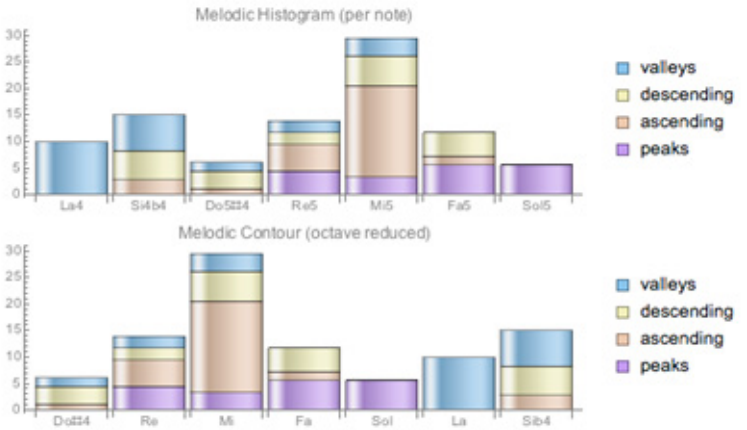


Figure 17(a), (b): Contour histograms for *Ben seni sevduğumi da dünyalara bildirdum* in purportedly Hümayûn makam, with both full-scale and octave-reduced displays. Owing principally to the status of Mi as the actual dominant (instead of Re), the usage of scale degrees does not give the impression of conformance with the textbook definition of Hümayûn.

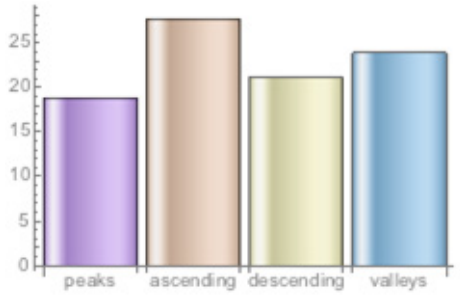


Figure 18: Summary contour histogram for *Ben seni sevduğumi da dünyalara bildirdum*. This picture reveals that, next to a profusion of valleys, there are more ascending tones than any other kind, and that ascending-descending distribution is skewed toward ascent – essentially signifying, therefore, an ascending-cadencing melody outside of the scope of AEU.

Fig. 15 immediately reveals the following: Although the dominant of Hümayûn is designated as Re in AEU theory on account of the conjuction of the lower Hicaz tetrachord with the higher Buselik pentachord over this note, the piece at hand – while remaining faithful to the principal scale of the makam – makes salient use of Mi as evidenced by the prevalence of its combined peaks and valleys. This is another instance where an unfamiliar makam name 'Uzzal-Hümayûn' or 'Acemli Uzzal' may be appropriate. The tonic is easily seen to be La due to the maximum presence of valleys, while the leading tone is Sol due to the primary importance of solely peaks. Alternatively, it might be better to view Sol as a shifted mediant to a tonicized Mi. On the other hand, the 'sub-dominant character' of Re is less punctuated than the shifted mediant function this note assumes with respect to a tonicized Sib4, and a shifted sub-mediant function it assumes with respect to a tonicized Fa. Meanwhile, Fa shows a sub-mediant character with respect to Re owing to the secondary importance of peaks. Finally, the shifted leading tone to the tonicized (asma/yarım karar) Re can be attributed to Do#4, just as the supertonic function to La can be assumed by Sib4.

Figure 18 hints at the possible existence of an 'ascending-cadencing seyir' not covered by AEU theory, since the overall ascent-descent distribution is biased toward the former – on top of the fact that more valley notes and fewer peak notes seem to account for a decisive downward pull. Also, the predominance of valleys vs peaks raises the importance of tonicizations in the piece with respect to the accustomed tonic La. Viewing this as an ascending-descending seyir is in agreement with the unsystematized textbook definition of Hümayûn makam's seyir.

Proceeding along the adopted line, contour histogram and summary contour histogram results from *Öte yakaya geçelim, atlara yonca biçelim* are given in Figs. 19 and 20.

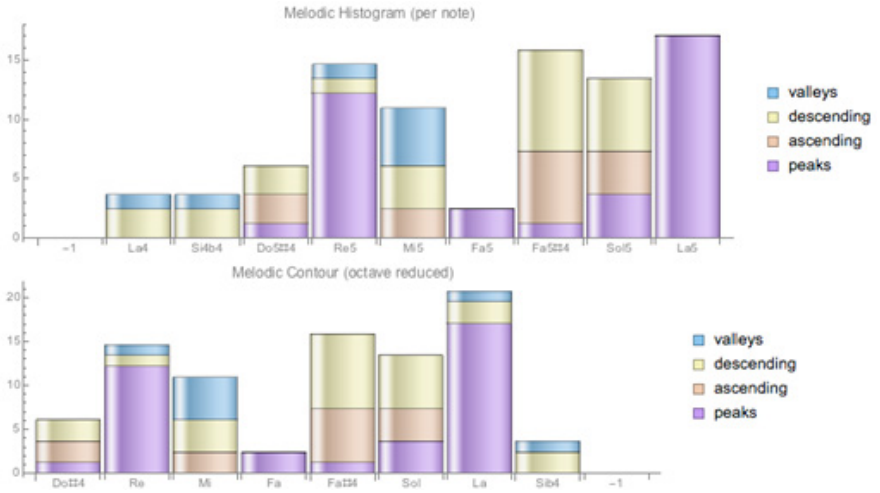


Figure 19(a), (b): Contour histograms for the Uzzal Aksak Türkü *Öte yakaya geçelim, atlara yonca biçelim*, with both full-scale and octave-reduced displays. The usage of scale degrees conforms to Uzzal.

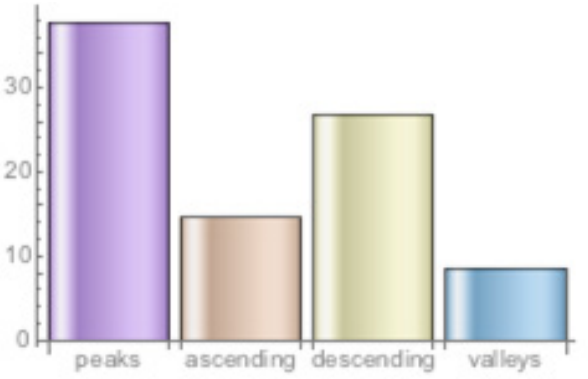


Figure 20: Summary contour histogram for Öte yakaya geçelim, atlara yonca biçelim. This picture reveals that the piece is primarily descending. The recurrence of relatively large intervallic leaps up to the treble register can be inferred from the small number of valleys and the dominance of peaks. This may signify the existence of an 'ascending-cadencing seyir' not covered by AEU theory.

Figure 19 confirms (as was the case with *Ada sahillerinde bekliyorum*) that the dominant is Mi due to the prevalence of valleys for this note, and that the upper tonic is La because of the overwhelming predominance of peaks. Given that the piece remains faithful to the principal scale of the Uzzal makam, coupled with the dominant being Mi, it becomes obvious that this is Uzzal. The sub-dominant role is then to be assumed by Re due to the secondary significance of both peaks and valleys at this note, and the leading tone role by Sol due to the tertiary occurence of peaks there.

All that has been previously said when analyzing *Ada sahillerinde bekliyorum* about the alterating shifted mediant duo Fa / Fa#4 with respect to Re (the sub-dominant) also applies to *Öte yakaya geçelim, atlara yonca biçelim*. However, concerning the mediant Do#4 with respect to La (the tonic), there is a reversal of peaks vs valleys. This may be interpreted to mean that the proper mediant Do#4 has an upward pull towards Mi instead of a downward pull towards La, which may have to do with the different character of its seyir as disclosed in Fig. 20. Finally, Sib4 can once more be referred to as a 'passing tone', but perhaps even better identified as a supertonic to La at the root.

Lastly, Fig. 20 has nearly the same markings as *Kurbanın olam ey afet-i can* in Fig. 10, and especially as *Ne boş yere yanmışım, meğer ben aldanmışım* in Fig. 14. Hence, all that has been said before concerning the former two now applies to *Öte yakaya geçelim, atlara yonca biçelim* – in that we have an 'ascending-cadencing seyir' not covered by AEU theory. So, in comparison to the textbook definition of Uzzal's seyir that is said to be descending-ascending and sometimes ascending, we appear to have found a satisfactory match.

Figures 21 and 22 show the contour histogram and summary contour histogram results for *Ana gelbim odlanır söz düşende davadan.*

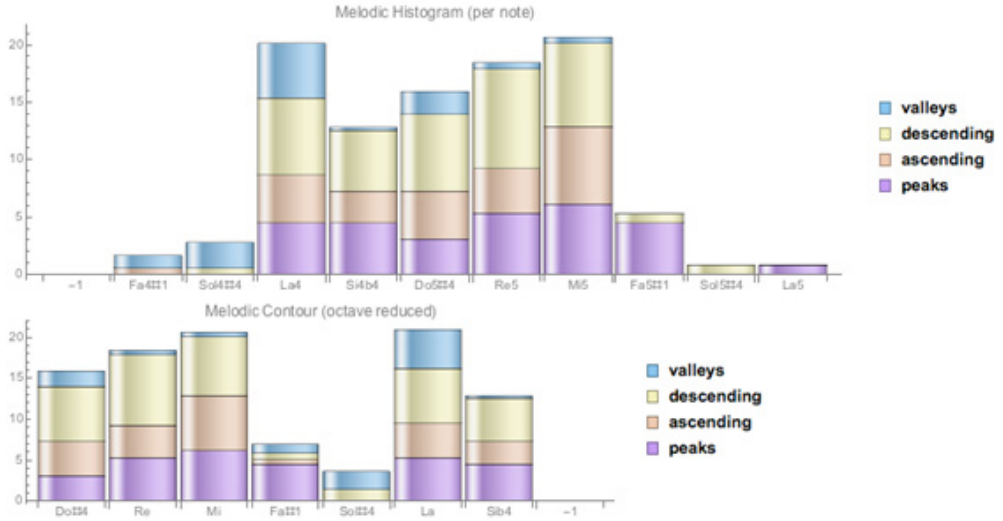


Figure 21(a), (b): Contour histograms for Ana gelbim odlanır söz düşende davadan (Azeri Sulh Mahnısı) in Zengûle or Hicaz-Zirgûle makam, with both full-scale and octave-reduced displays.

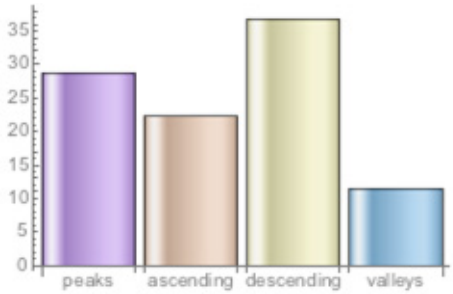


Figure 22: Summary contour histogram for *Ana gelbim odlanır söz düşende davadan*. This picture reveals that the piece, like its Art music sibling in the same makam, is overwhelmingly descending, but one through the recurrence of relatively large intervallic leaps back up to treble registers (as shown by the small number of valleys and larger number of peaks. Again, this may signify an 'ascending-cadencing seyir' not covered by AEU theory.

Since these are nearly identical, in both the contour and summary contour histograms, with respect to what was revealed for Zengûle Düyek Şarkı *Ne boş yere yanmışım, meğer ben aldanmışım* in Figs. 13 and 14, all that discussion applies directly to *Ana gelbim odlanır söz düşende davadan*.

5. Statistical Analysis

A total of eight Turkish music pieces chosen from the SymbTr database [Karaosmanoğlu 2012] for our computational investigation have the following filenames in their order of appearance in this text (Table 3):

Table 3: Select Turkish Art and Folk music pieces from the Hicaz Family as they appear in SymbTr

FILENAME	ACTUAL DISCLOSED MAKAM
hicaz—kanto—sofyan—ada_sahillerinde—.txt	Uzzal
hicaz_humayun—sarki—aksak—kurbanin_olam—haci_arif_bey.txt	Uzzal-Hümayun (Acemli Uzzal)?
hicaz_uzzal—sarki—yuruksemai—ulfet_etsem—sevki_bey.txt	Hicaz
hicaz_zirgule—sarki—duyek—ne_bos—sadettin_kaynak.txt	non-conform Zengûle?
hicaz—turku—aksak—karanfil_oylum_oylum—.txt	Hicaz
hicaz_humayun—turku—turkaksagi—beni_seni—trabzon.txt	Uzzal-Hümayun (Acemli Uzzal)?
hicaz-uzzal—turku—aksak—ote_yakaya—kutahya.txt	Uzzal
hicaz_zirgule—turku—sofyan—ana_gelbim—ali_ekber_tagiyev.txt	non-conform Zengûle?

Table 3 shows that several pieces are actually in makams that do not match the given makam name owing to the way the perdes are used – just as we have disclosed through our scale-degree vector analysis. Among these compositions, it is interesting to note the need to identify at least two cases as belonging to the unusual makam denomination which we referred to herein as Uzzal-Hümayûn or Acemli Uzzal (as also noted by Özkan [2003, p. 170]). This was on account of the discrepancy in the dominant tone of these pieces. Also, consider that neither of the Zirgüle'li Hicaz (i.e., Zengûle) examples adequately demonstrate the textbook definition of a Hicaz-Zirgûle, and this is again due to the same discrepancy. Moreover, we have revealed incongruities with respect to theoretical seyir descriptions for these pieces as given in Table 4.

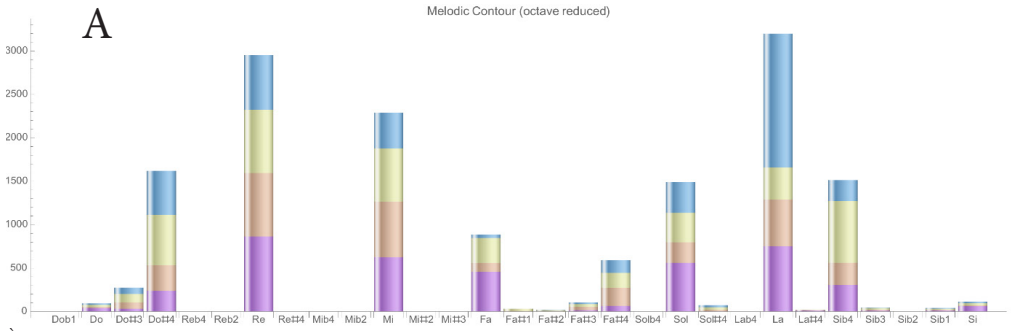
Table 4: Disclosed seyir vs the makam's theoretical seyir for the eight compositions

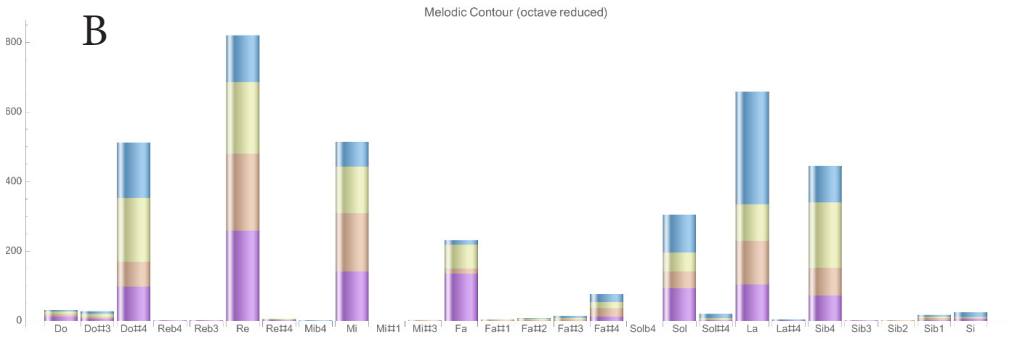
NAME OF COMPOSITION	DISCLOSED SEYIR	THEORETICAL SEYIR
Ada sahillerinde bekliyorum (Fig. 8)	descending (D)	D-A and sometimes ascending
Kurbanın olam ey afet-i can (Fig. 9-10)	ascending-cadencing (A-C)	*unsystematized* A-D
Ülfet etsem yar ile, ağyare ne? (Fig. 11-12)	descending-ascending (D-A)	D-A and sometimes ascending
Ne boş yere yanmışım … (Fig 13-14)	ascending-cadencing (A-C)	D-A
NAME OF COMPOSITION	DISCLOSED SEYIR	THEORETICAL SEYIR
Karanfil oylum oylum (Fig. 15-16)	ascending (A)	D-A and sometimes ascending
Ben seni sevduğumi da … (Fig. 17-18)	ascending-cadencing (A-C)	*unsystematized* A-D
Öte yakaya geçel im … (Fig. 19-20)	ascending-cadencing (A-C)	D-A and sometimes ascending
Ana gelbim odlanır … (Fig. 21-22)	ascending-cadencing (A-C)	descending-ascending (D-A)

Table 4 displays the mismatch in the disclosed seyir of *Ada sahillerinde bekliyorum* vs the theoretical seyir description of its actual revealed makam (i.e., Uzzal); while the remaining pieces conform to the theoretical seyir descriptions of their actual makams. Notice how the

unsystematized 'ascending-descending seyir' description is considered to be on par with our 'ascending-cadencing seyir' definition.

Comparisons between the various kinds of makams can also be conducted quantitatively. Figures 23 and 24 show cumulative melodic contour histograms for collections of pieces. Fig. 23(b)-(c)-(d) display histograms of all pieces in the SymbTr database that are labeled, in order of appearance, as Hümayûn, Uzzal and Zengûle, while Fig. 23(a) displays all the Hicaz (except for those listed in (b)-(c)-(d)). Figure 24 shows cumulative melodic contour histograms of four unrelated makams (also from the SymbTr database) – i.e., those for Buselik, Uşşak, Nihavent and Rast in their order of appearance.





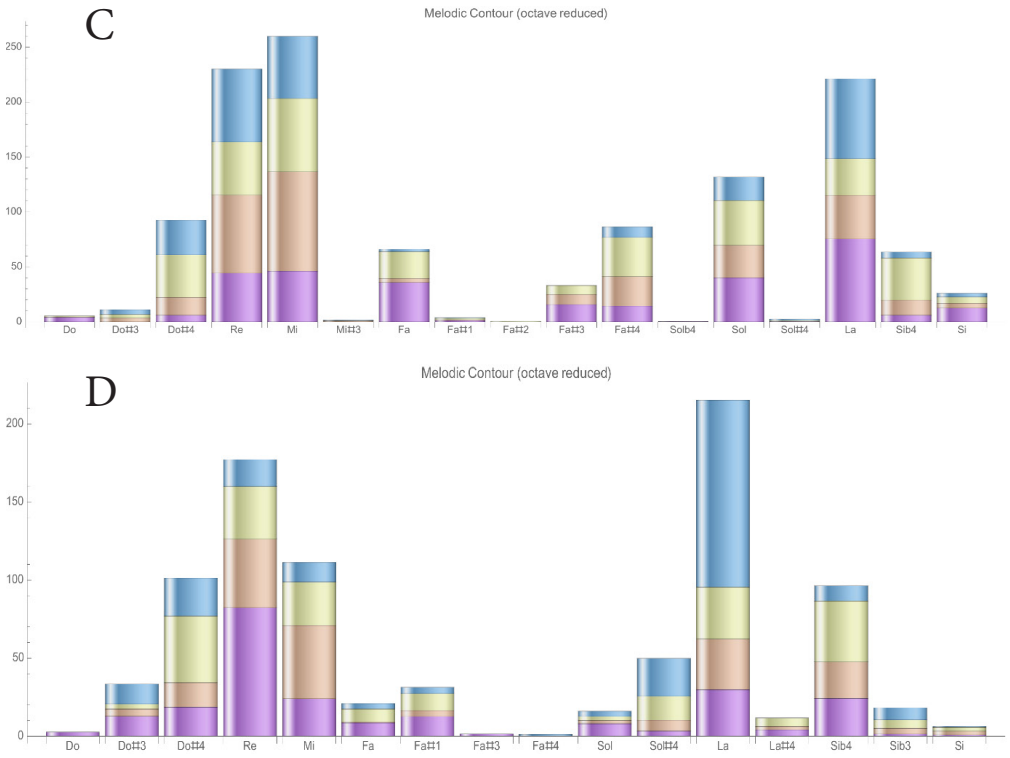
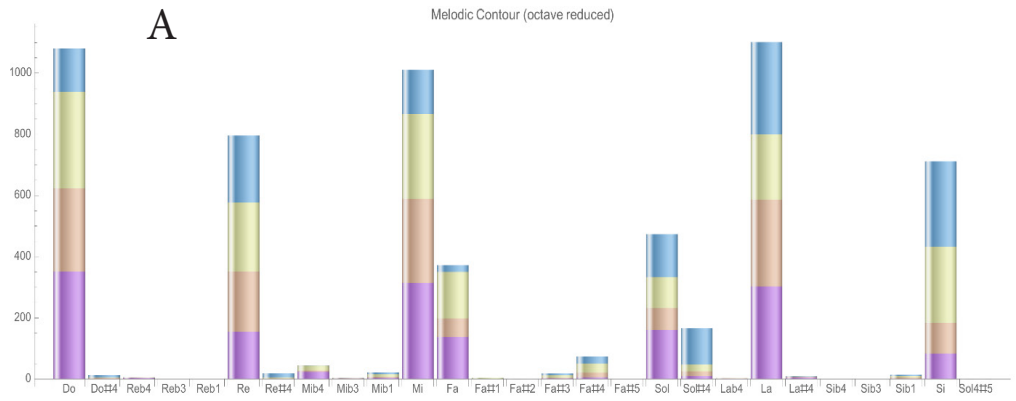
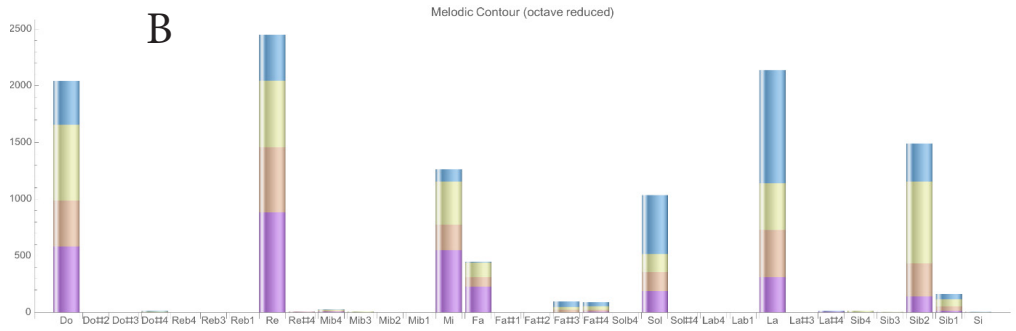
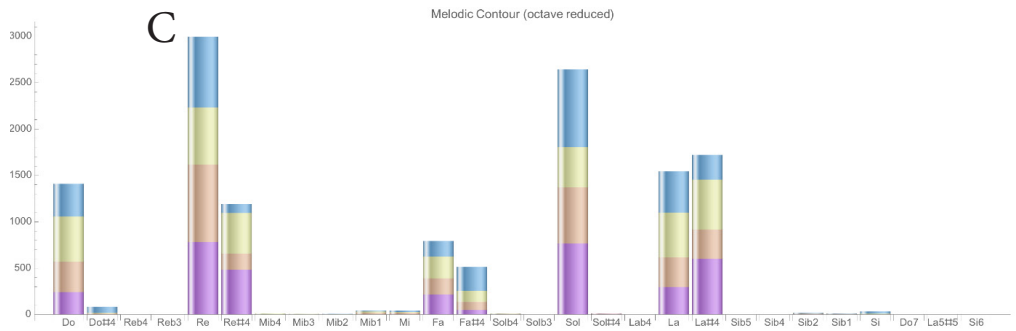


Figure 23(a-Hicaz), (b-Hümayûn), (c-Uzzal), (d-Zengûle): Cumulative contour histograms for all pieces in Hicaz (158 files), Hümayûn (38 files), Uzzal (13 files) and Zengûle (9 files) respectively from the SymbTr database. These reveal the generalized seyir behavior for each makam.


A
Melodic Contour (octave reduced)
1000
800
600
400
200
0
Do
Do♯4
Reb4
Reb3
Reb1
Re
Re♯4
Mib4
Mib3
Mib1
Mi
Fa
Fa♯1
Fa♯2
Fa♯3
Fa♯4
Fa♯5
Sol
Sol♯4
Lab4
La
La♯4
Sib4
Sib3
Sib1
Si
Sol4♯5


B
Melodic Contour (octave reduced)
2500
2000
1500
1000
500
0
Do
Do♯2
Do♯3
Do♯4
Reb4
Reb3
Reb1
Re
Re♯4
Mib4
Mib3
Mib2
Mib1
Mi
Fa
Fa♯1
Fa♯2
Fa♯3
Fa♯4
Solb4
Sol
Sol♯4
Lab4
Lab1
La
La♯3
La♯4
Sib4
Sib3
Sib2
Sib1
Si


C
Melodic Contour (octave reduced)
3000
2500
2000
1500
1000
500
0
Do
Do♯4
Reb4
Reb3
Re
Re♯4
Mib4
Mib3
Mib2
Mib1
Mi
Fa
Fa♯4
Solb4
Solb3
Sol
Sol♯4
Lab4
La
La♯4
Sib5
Sib4
Sib2
Sib1
Si
Do7
La5♯5
Si6

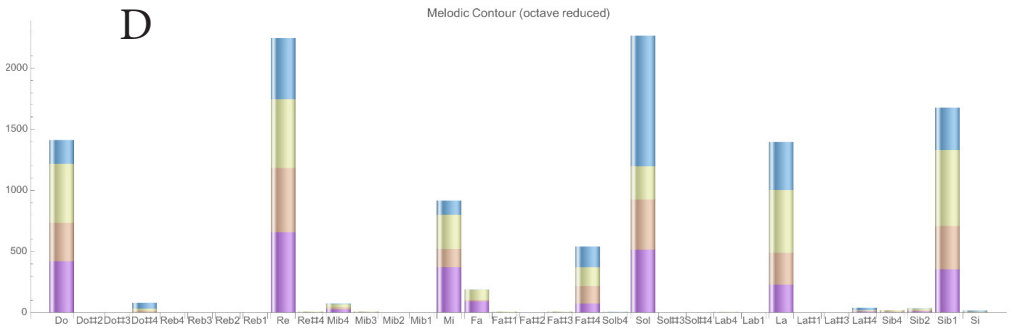


Figure 24(a-Buselik), (b-Uşşak), (c-Nihavent), (d-Rast): Cumulative contour histograms for all pieces in Buselik (59 files), Uşşak (118 files), Nihavent (130 files) and Rast (111 files) respectively from the SymbTr database, revealing the generalized seyir behavior for each makam.

The contour histograms of the eight pieces are now compared below with all of the cumulative histograms in Figures 23 and 24 by measuring the Kullback–Leibler divergence [Kullback & Liebler]. Given two probability distributions (i.e., normalized versions of the histograms) the Kullback–Leibler divergence measures the relative entropy of how one probability distribution differs from the other via calculating

$$KL(p,q) = \text{Si } p(i) \text{ Log}(p(i)/q(i)), \qquad (5)$$

where p(i) are the values of the first distribution and q(i) are the values of the second. A KL(p,q) value of zero would mean that the two distributions p and q are identical, while a large value would indicate that p and q are very different. The results of this analysis are presented in Table 5, which lists the KL measure for all eight pieces when measured against each of the makam types. For example, the pieces from Fig. 7 and Fig. 9 in the first two rows are closest to the Uzzal variation of Hicaz since the minimum value occurs in the third column (minimum values are represented in bold). Observe that all eight pieces are closest to the four Hicaz variants than to any of the unrelated makams.

Table 5: The Kullback-Leibler divergence of the eight pieces from Figures 7, 9, 11, 13, 15, 17, 19 and 21 shows how closely the pieces align with the given makam type. Lowest values are in bold.

Fig.	Hicaz (157)	Hümayun (38)	Uzzal (13)	Zengûle (9)	Buselik (59)	Nihavent (130)	Uşşak (118)	Rast (111)
7	0.68	0.9	**0.44**	1.45	1.76	1.95	2.2	1.8
9	0.55	0.61	**0.48**	1.29	1.89	2.9	2.03	1.74
11	0.44	0.57	**0.31**	0.99	1.8	3.41	1.88	1.5
13	0.64	0.51	0.95	**0.49**	3	5	3.08	3.04
15	0.84	**0.76**	1.26	0.8	3.49	4.28	2.79	2.9

17	0.81	**0.74**	0.94	1.13	2.01	3.11	2.68	2.97
19	1.09	1.45	**0.93**	1.72	2.19	2.71	2.57	2
21	0.9	0.87	1.09	**0.41**	2.52	3.5	2.43	3.07

From this panorama, one can, in the case of Art music pieces, immediately see that i) '*Ada sahillerinde bekliyorum*' İstanbulite Türkü in purportedly Hicaz is indeed a best-fit to Uzzal as previously disclosed; ii) '*Kurbanın olam ey afet-i can*' Hicaz-Hümayûn Şarkı, which we established to be in Uzzal-Hümayûn instead, is found to be closest to Uzzal, iii) '*Ülfet etsem yar ile, ağyare ne?*' Hicaz Şarkı is shown to be in Uzzal the way it was categorized in SymbTr, and iv) '*Ne boş yere yanmışım, meğer ben aldanmışım*' Zengûle Şarkı is a best-fit to Zengûle as expected.

Similarly, in the case of Folk music pieces, i) the Hicaz Türkü '*Karanfil oylum oylum*' is a slightly better-fit to Hümayûn, ii) the Hümayûn Black Sea Türkü '*Ben seni sevduğumi da dünyalara bildirdum*' is indeed Hümayûn (although we discussed the possibility of it being in Uzzal-Hümayûn), iii) the Uzzal Türkü '*Öte yakaya geçelim, atlara yonca biçelim*' neatly fits Uzzal, and iv) the Zengûle Azeri Mahnı '*Ana gelbim odlanır söz düşende davadan*' is non-problematically revealed to be in Zengûle.

For all Hicaz and all Hümayûn, the theoretical definition of the seyirs of these makams matches the discussion surrounding Figs. 9-10; i.e., an 'ascending-cadencing seyir' that begins around the mid-register and concludes at the tonic. Likewise, for all Uzzal, the contour histograms are in conformance with a 'descending-ascending seyir' as described in AEU theory. In contrast, for Zengûle, there is a mismatch because the revealed seyir is typically 'descending' as compared to the theoretical expectation of a 'descending-ascending seyir'. It is thereby important to accentuate the revealed 'plagal character' of Zengûle, as rather spanning perde yegâh [D] to its octave perde neva [d] by the joining of a nikriz pentachord [D E F#1 g#4 a] to a hicaz tetrachord [a bb4 c#4 d], instead of the theoretical octave species that spans perde dügâh [a] to its octave complement muhayyer [a'].

6. Conclusions

This paper presents a comparison between the *de facto* theoretical diatonic functions of standard Arel-Ezgi-Uzdilek theory and the actual disclosed function of scale degrees through the usage of new contour histograms. Such an endeavor is significant, because the quandary of melodic contour/seyir of makams in Turkish music is an active, ongoing, and inviting area of scholarly investigation. We moreover believe that our work is musicologically relevant, because it follows and augments previous computational research on Turkish music along similar lines.

In our study, whereas pitch histograms – which are commonly used as a surrogate for the 'perde' – represent the proportion of time that a melody rests on each pitch, the newly introduced contour histograms, which are herein used as a surrogate for the 'seyir', display the proportion of time the melody is 'ascending' (e.g., Do-Re-Mi), reaches a 'peak' (e.g., Re-Fa-Re), is 'descending' (e.g., Sol-Fa-Mi), or remains in a 'valley' (e.g., La-Do-Mi).

These sets of mathematical properties can be conceived in terms of a scale-degree vector analysis of a 3-gram chain of musical notes that demarcates both perde and seyir elements of Turkish makam scales. In this way, it becomes possible to uncover whether diatonic functions, as described by any theory, match our analytical interpretation of contour histograms. Thus, we are able to confirm or refute the registered makam of a piece. This is especially important for cases where there is ambiguity in or trouble with the registered makam of a composition – such as when a piece is said to be in Hicaz but actually turns out to be in Uzzal (which happens quite often especially with regards to Folk music).

Contour histograms also convey information about generalized flow. Theoretical melodic procedure guidelines such as 'ascending', 'descending', or 'descending-ascending' seyir can hence be corroborated or discredited in light of what our summary contour histograms reveal. Mismatches found here can shed further light on the actual structure of a makam in comparison to its textbook definition – such as when Zengule is found to be 'plagal' rather than relying on its octave species proper.

In summary, this paper advances a novel method of extracting contour information from any melodic material using four classes – i.e, ascending (e.g., Doo-Sool-La), descending (e.g., Faa-Mii-Re), peak (e.g., Sool-Laa-Sol) and valley (e.g., Ree-Do-Sol) – which relates quite well to the seyir phenomenon of Turkish makams. The suggested 'scale-degree vector analysis' approach is readily applicable to the melodic corpus of Western music also. Our study validates previous investigations which have found good correlations between pitch histograms and the perdes of makams [Akkoç, Bozkurt et al. 2009, Gedik & Bozkurt 2010, Akkoç et al.]. Together, these studies examine the continuing relevance of standard Arel-Ezgi-Uzdilek (AEU) tone-system to praxis, and simultaneously highlight the inherent limitations of AEU theory in the face of monophonic music that requires directional or motional information in order for one to make important distinctions about the diatonic function of the tones of a makam's scale.

After contour histograms had been illustrated in a simple setting, they were applied to a set of Turkish music pieces from under both Art and Folk denominations. Analyses show how the contour information reinforces typical classifications of makams and extends the simplistic 'ascending-descending' paradigm of seyir.

In some cases, contour histograms provide information that can be used as evidence that a makam may have been misregistered; though such arguments need to be evaluated

holistically. The results of the proposed method are then analyzed statistically by comparing the melodic contour histograms of the eight select pieces to cumulative melodic histograms of the four variants of Hicaz, and to cumulative melodic histograms of four unrelated makams. As expected, the distributions of the pieces are substantially closer to the Hicaz variations than to unrelated makams, and melodic contour histograms supply a plausible classification chance even within the Hicaz family.

As a result, this work demonstrates how the investigation of the role of diatonic functions (such as tonic, dominant and leading tone) relate to uncovering the underlying makam of a composition even when there is an uncertainty or a mismatch with the registered makam, and how the general seyir behavior described in theory can be corroborated or refuted with the novel contour histograms through statistical analysis. Further application of the method elucidated in this paper to other makam families or groups may reveal similar information, and may provide a fruitful venue for subsequent modal or tonal studies.

Finally, the suggested scale-degree vector analysis can be applied to any melodic material – and especially to the repertory of Western music without any harmony/polyphony connotations – with the aim of understanding the role of melody, contour, and motion in shaping mellifluous music.

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