# A COMPUTATIONAL RE–EXAMINATION OF BÉLA BARTÓK'S TRANSCRIPTION METHODS AS EXEMPLIFIED BY HIS *SIRATÓ* TRANSCRIPTIONS OF 1937/1938 AND THEIR RELEVANCE FOR CONTEMPORARY METHODS OF COMPUTATIONAL TRANSCRIPTION OF QUR'AN RECITATION

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## ABSTRACT

This is a study about furthering transcription methods via computational means. In particular we re-examine Bartók's methods of transcription to see how his project of transcription might be continued incorporating 21st century technology. We then go on to apply our established analytical and computational tools to examples of Qur'an recitation, in order to test hypotheses about connections between the rules of Qur'an recitation (*tajwīd*) and the establishment of salient tones within Qur'an recitation performance.

## 1. INTRODUCTION

The current study is an outgrowth of a talk given during the panel session on methods of folk music transcription at the third International Workshop on Folk Music Analysis, Amsterdam, Netherlands, June 7, 2013. The panel was moderated by John Ashley Burgoyne (University of Amsterdam) and included Kofi Agawu (Princeton University), Dániel P. Biró (University of Victoria, Canada), Olmo Cornelis (University College Ghent, Belgium), Emilia Gómez (Universitat Pompeu Fabra, Barcelona), and Barbara Titus (Utrecht University).

In transcribing indigenous and world music, ethnomusicologists have to deal not only with subjective hearing, imagination and technologies but also with the history or histories of transcription. The present study re-examines Bartók's methods of transcription by testing it with technology recently developed as part of a research project undertaken by researchers at the University of Victoria, Utrecht University and the Meertens Institute.[1]

In comparing Bartók's transcriptions of *siratók* (Hungarian improvised ritual laments) with those done with the help of computer technology, we are able to reassess Bartók's production process and methodology, as well as to see if and how Bartók's projects of transcription can be applied, reevaluated and continued. Taking this analysis further, we apply the resulting computational analysis procedures to examples of Qur'an recitation.

The *siratό* is a lament ritual from Hungary that goes back at least to the Middle Ages. This improvised song type is integral for our study, as it exemplifies inherent relationships between speech and singing while demonstrating stable melodic formulae within an oral/aural ritual context. While the performance practice of *siratók* (plural of *siratό*) had been determined by traditions of textual and melodic improvisation, the performance framework for Qur'an recitation are determined by rules of recitation that are primarily handed down orally.

## 2. METHODOLOGIES OF PITCH ALALYSIS

In this study we have taken Bartók's recordings of *siratók,* applying computational audio analysis of these recordings to find the most prevalent pitches. We have set out to find these pitches in order to reinterpret Bartók's transcription using a scale derived by automatically detecting the peaks in a density estimation of the distribution of pitches. These density-estimation based scales can be analyzed in terms of their functionality in forming melodic contour and pitch identity. Such analysis helps to demonstrate salient structural features of oral transmission.

In early 2014 we applied the same analysis to examples of Tunisian Qur'an recitation. In so doing, we have been able to investigate the practice of *maqamat* (a set of pitches for melodic performance found in Qur'an recitation) in terms of quasi–Schenkerian analysis showing the most prevalent pitches within a given performance in terms of foreground, middle-ground and background frequency analysis. These pitches relate roughly to *maqamat* traditions of instrumental music, although the melodic

[1] This research project, which involved scholars of musicology and computer science, similarity measures for melodies from oral tradition have been developed, especially designed for the monophonic chant repertoires in coordination with the Department of Computer Science, University of Victoria, School of Music, University of Victoria, Department for Information and Computer Science, University of Utrecht and the Meertens Institute, Amsterdam Netherlands. This research has resulted in a series joint journal papers including Steven R. Ness, Dániel P. Biró, and George Tzanetakis: "Computer-Assisted Cantillation and Chant Research Using Content-Aware Web Visualization Tools," in *Multimedia Tools and Applications* (2009), Van Kranenburg, P, D.P. Biró, S.R. Ness, and G. Tzanetakis (2011), "A Computational Investigation of Melodic Contour Stability in Jewish Torah Trope Performance Traditions". In: *Proceedings of the International Society on Music Information Retrieval (ISMIR2011) Conference*, pp. 163-168., and D.P. Biró, P. van Kranenburg, S.R. Ness, G. Tzanetakis, and A. Volk (2012) "Stability and Variation in Cadence Formulas in Oral and Semi-Oral Chant Traditions – a Computational Approach." *Proceedings of the 12th International Conference on Music Perception and Cognition and the 8th Triennial Conference of the European Society for the Cognitive Sciences of Music*. Thessaloniki. 2012. pp. 98-105.

entities within Qur'an recitation do not adhere directly to *maqam* traditions within instrumental music.[2]

We set to compare such analysis to the cultural perception within traditional *maqamat* practice. Our method sets out to delineate the main pitches of a given scale or *maqam* from secondary "ornamental" pitches. By doing so, we present a hierarchy of scale degrees, thereby showing how surrounding "ornamental" pitches structurally interact with the main "skeletal" notes of the scale. In addition, we investigate how such scale structures function in the context of the rules of Qur'an recitation (*tajwīd* and *tartīl*). In this manner, we are able to show how the parameters of textual recitation, pronunciation and interpretation interact with melodic contour and scale structures within these two traditions.

With these case studies we show how to establish a direct interaction between automatically derived scales and traditional practices of transcription, therewith enriching the arsenal of methods ethnomusicologists have at their disposal.

## 3. DATA

We have employed recordings of *siratók* found in the sound recording *Hungarian Folk Music: Gramophone Records with Bartók's Transcriptions,* edited by László Somfai. *Magyar népzenei hanglemezek Bartók Béla lejegyzéseivel,* szerkesztette, Somfai László, (Budapest: Hungaroton, 1981).

In our study we employed recordings of Qur'an recitation from *Sura Al-Fatiha, Sura Ash Shams, Sura Al-Qaria* and *Sura Ghafir*. These have been extracted from Michael Sells' *Approaching the Qur'an: The Early Revelations* (Ashland: White Cloud Press, 2007) and field recordings conducted by the authors in Rotterdam (Netherlands).

Each recording has been segmented in terms of syntactical units (phrases) and, in the recordings of Qur'an recitation, analysis has also been based on audio segments corresponding to the individual words of the given *sura.*

Each recording has been converted to a sequence of frequency values using the YIN pitch extraction algorithm (De Cheveigne & Kawahara, 2002) by estimating the fundamental frequency in a series of overlapping time-windows of 40ms, with a hopsize of 10ms. The frequency sequences have been converted to sequences of real-valued MIDI pitches with a precision of approximately 1 cent (which is 1/100 of an equally tempered semitone, corresponding to a frequency difference of about 0.06%). A MIDI-value of 60.0 corresponds with the c', 61 with equal tempered c#', 62, with d', and so on. A value of e.g., 60.23 would correspond to a pitch that is 23 cents higher than c'.

We employ two post-processing filters to correct for possible errors of the pitch extractor. First, all samples with a signal energy of more than 40 dB below the maximum value are considered silence. Second, all pitches that are further than an octave away from the average pitch of the entire curve are considered silence as well.

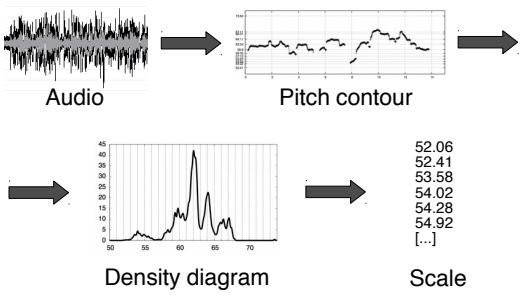


**Figure 1.** Schematic overview of the computational analysis method.

In the resulting pitch contour, we perform a non-parametric density estimation using a Gaussian kernel with $\sigma$=5 cents. The Gaussian kernel has a smoothing effect on the resulting density curve. By performing peak detection in the density curve, we obtain the pitches that recur most often during the recording. The height of a peak indicates the frequency of occurrence of the corresponding pitch. The set of pitches that correspond to the peaks in the density estimation can be considered the scale the singer, or reader, is adhering to. In the peak detection, we set the constraint that the peaks should be at least 10 cents apart to be considered separate scale tones. This leads to a fine-grained scale that reduces the pitch content of a recording to a relatively small set of pitches, while retaining enough detail to perform precise analyses. By sorting the scale tones according to their density values (the heights of the peaks), we get an ordering of pitches according to their prevalence in the recording.

By replacing each detected pitch with the pitch of its nearest scale tone, we obtain a reduced contour. It is in these contours that we perform an analysis of occurrences of pitches. For the Qur'an readings, we determine for each verse the durations of all pitches that occur in the verse as percentage of the duration of the entire verse. Thus, we get an indication of the importance of each pitch within the verse. We do the same for the pitches in each word.

[2] Lois Ibsen al Faruqi: "The Cantillation of the Qur'an" *Asian Music*, Vol. 19, No. 1 (Autumn - Winter, 1987), p. 9, "Although Qur'anic recitation does not adhere strictly to the modal (*maqām*) practice of the secular music, and although members of the culture maintain a notion of rigid boundaries separating Qur'ānic chant from all the other sound arts, Qur'ānic recitation does conform to many of the theoretical aspects of Arabian music. It employs many of the interval combinations (trichordal, tetrachordal or, pentachordal) that identify *ajnās* (s. jins) on which the secular music is based - e.g., bayyātī, ḥijāz, kurd, rāst, nahāwand, ṣabā, sīkāh, etc. It similarly evidences a predominance of serial treatment of individual ajnās rather than utilization of the whole modal scale in a single phrase. Cantillation of the scripture is punctuated, like secular improvisations, by returns to the tone (qarār) of resolution in the jins. It is marked by transpositions and modulations internal or external to the phrase, which are also characteristic of the secular genres. Some reciters are knowledgeable about maqām practice and the theory of music. Others have no formal exposure to music theory and only conform to its rules in such measure as their ears and listening experience have trained them."

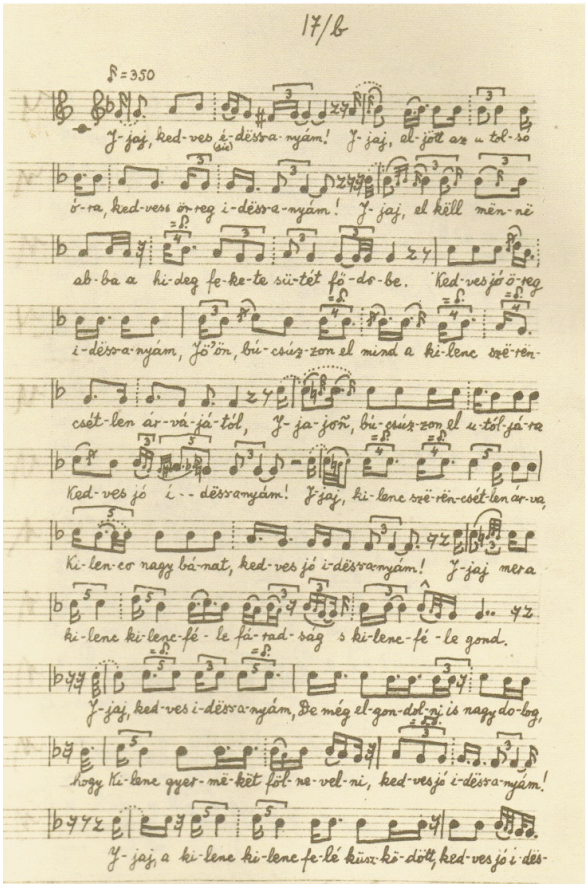


**Figure 2.** Béla Bartók's sirató Transcription. Recording of Mrs. János Péntek completed in Köröszfő on December 14, 1937 and transcribed by Bartók in 1937–1938.

## 4. SIRATÓK

### 4.1 Cultural context of the sirató

The *sirató's* performance connects the life of the singer not only with her ancestral past but also with the larger community. It is an integral part of the performer's life: the enactment of the sirató most often has no clear beginning or ending. Although the *sirató* is improvised, each time exhibiting a personal melodic expression, the song-type is clearly discernible and exhibits a remarkable consistency of textual and musical form. Elements of both formal semblance and improvisational variability can be observed among the various examples of *sirató*, proving its mythical nature. The song is not determined individually but collectively, as the boundaries of its enactment are explicit enough to be reconstructed by the individual and recognized by the village collective.[3]

The *sirató* is most often improvised in a recitative manner. In its unfolding, melody and text function symbiotically, as gestures of improvised speaking are applied to the melodic and rhythmic domain.[4] Kodály described such a dichotomy between singing and speaking: "This is the only type of musical prose of this kind and can only be done spontaneously […]. Musical prose, on the border of music and speaking […]. The rhythm therein is no different from the rhythm of spoken speech […] the sections between the rests are not the same."[5] The *musical vocabulary* of the *sirató* is comprised of the same cadential formulas and modality found in other types of Hungarian folksong and chant.

The recording of Mrs. János Péntek was completed in Köröszfő on December 14, 1937 and transcribed by Bartók in 1937–1938.[6] The *sirató* is a lament sung by women after a loved-one passes away. Sometimes a lament is sung by a so-called "professional" and it seems that here Ms. János Péntek is indeed a "professional" who would do this type of lament for a relative or someone else in her village if necessary. Here the lament is done for a deceased mother using the language common in *siratók,* which can be found in renditions done by a variety of performers across large territories.[7]

[3] Aleida and Jan Assmann, "Schrift, Tradition und Kultur," Zwischen Festtag und Alltag, Zehn Beiträge zum Thema 'Mündlichkeit und Schriftlichkeit, (Tübingen: Günter Narr Verlag, 1988), "In schriftloser Kommunikation vermag das, was beim Publikum nicht auf unmittelbare Akzeptanz stößt, schon den Augenblick der Darbietung nicht zu überdauern. Weltbildkonformität ist hier schon in dem Merkmal 'haltbarer' Geformtheit eingebaut. Sie reguliert durch "Präventivzensur," die gar nicht erst Form gewinnen läßt, was seines Ortes im kulturellen Gedächtnis sicher sein kann und daher riskiert, als a-topos ('albern,' eigentlich: ortlos) eingestuft zu werden." "In non-textual communication, what is not met with immediate acceptance by the general public, can not survive in the moment of its rendition. Conformity of world view is built in to the atribute of the preserved formal unit. This is regulated through 'preventive censorship.' Such censorship does not even start to allow for forms to take hold, which, risking to be labled a-topos (absurd; actually without place), do not have a secure function within the context of cultural memory." (English translation by Biró)

[4] Although the *sirató* is most often sung by a female relative of the deceased, a "professional," or a designated singer from the local vicinity, will often sing the sirató; this type of sirató is termed *parodia* or "parody." Even in this form the song type remains intact as the "professional" takes the place of the mourner and "improvises" the typical expressions of mourning like "My dearest mother, why have you left me?" "What will I do without you?" "You were so good to us" etc..

[5] Zoltán Kodály, *A Magyar népzene* (Budapest: EMB, 1952) 38-39 "Egyetlen példája a prózai recitáló énekeknek és szinte egyedüli tere a rögtönzésnek [. . .] zenei próza, a zene és beszéd határán [. . .] Ritmus nincs benne más mint a beszéd ritmusa [. . .] a nyugvópontok közti részek nem egyenlõk."

[6] Hungaroton

[7] The text reads as follows: Jaj, kedves idëssanyám!
Jaj, eljött az utolsó óra, kedves öreg idëssanyám!
Jaj, el këll mënë abba a hideg fekete sütét födbe.
Kedves jó öreg idëssanyám,
Jö'ön, búcsúzzon el mind a kilenc szërëncsétlen árvájától,
Jajon, búcsúzzon el utóljára
Kedves jó idëssanyám!
Jaj, kilenc szërëncsétlen árva,
Kilenc nagy bánat, kedves jó idëssanyám!
Jaj mer a kilenc kilencféle fáradság s kilencféle gond.
Jaj, kedves idëssanyám, De még elgondolni is nagy dolog, hogy
Kilenc gyermëkët fölnevelni, kedves jó idëssanyám!
Jaj, a kilenc kilenc felé küszködött, kedves jó idëssanyám!
Alas, my dear sweet mother!
Alas, the last hour has come, my dear, old sweet mother!
Alas, one has to descend into that cold, black, dark earth.
My dear, old sweet mother,
Come and say goodbye to all your nine orphans,
Alas, say goodbye for the last time,
My dear, good sweet mother!
Alas, nine wretched orphans,
Nine great sorrows, my dear, good sweet mother!
Alas, because nine is nine kinds of weariness and nine kinds of worry.

### 4.2 Computational transcription of the sirató: a re-evaluation of Bartók's transcriptions

One can imagine how Bartók the composer might have been intrigued by this text and by the performance, and the resulting, for him both archaic and modernist musical structure. Bartók often carried the very heavy cylinder recorder to record his subjects, as this was the most sophisticated way to transcribe folk music in his day. In transcribing the recordings to paper he would often slow down the recordings, allowing him to achieve detailed transcription of ornaments.

Bartók always transcribed the recordings to have g' be the *tonus finalis*. This was done in order to better compare the tonal language of large quantities of transcriptions. So in this way a tonal "reduction" or transposition served to allow for easier analysis within and across folk music traditions. This is also the case in his transcription of Mrs. János Péntek shown in **Figure 2.**

A product of his education and European musical culture, Bartók employs the five-line stave in his transcriptions. He was very aware of tuning and the differences in tuning within folk music. **Figure 3** shows the sequence of pitches as estimated by the YIN-algorithm. **Figure 4** shows the estimated pitch density. The peaks demonstrate the most prevalent pitches in the scale.

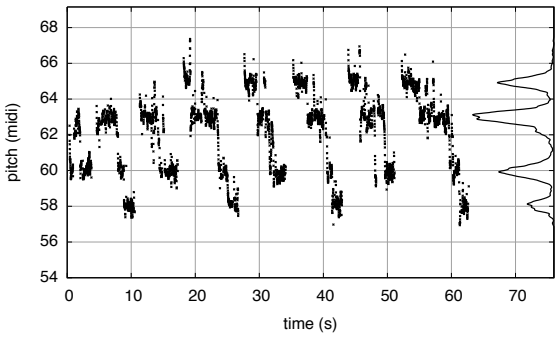


**Figure 3.** Pitch contours over time in the recording of the *sirató*, with the density curve shown at the right.

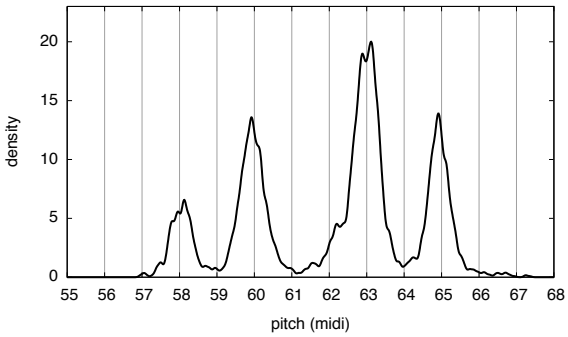


**Figure 4.** Density plot of frequencies occurring in recording of *sirató.*

We set out to find these pitches in order to reinterpret Bartók's transcription using a scale derived by a density estimation of the pitch-content of the recording. These density-estimation based scales can be compared in terms of their melodic contour and pitch identity and such comparison helps to demonstrate salient structural features of oral transmission.

**Figure 5** shows the pitches corresponding to the peaks in the density curve as they are ordered in terms of their density-value.

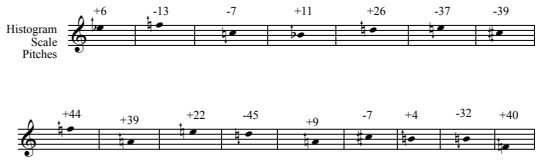


**Figure 5.** Pitches occurring in recording of *sirató* in order of density.

**Figure 6** shows their ordering in terms of scale tone.

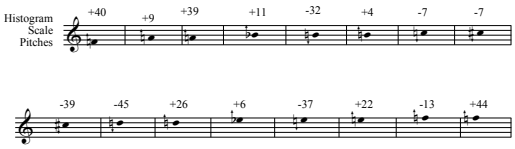


**Figure 6.** Pitches occurring in recording of *sirató* in order of scale-tone.

The density-estimation based scale presents a series of pitches determined by the frequency of use in a particular recording. **Figure 7** presents Bartók's transcription on top and the more-or-less same transcription on the bottom now with cent deviations according to the density-estimation based scale analysis. Here we can see how Bartók *perceived* certain microtonal deviations and *integrated* them into the conventional tonal framework he had knowledge of.

In employing density-estimation based scales it is possible to examine the levels of pitch hierarchy in the scales. **Figure 8** shows the most prevalent pitches and where they occur in the transcription. In this way we are able to see a kind of foreground, middle–ground and background of pitch hierarchies. We are also better able to appreciate the diversity of scale species present in these recordings.

Alas, my dear sweet mother, It is a great deed - to think that you raised your nine children, my dear, good sweet mother!
Alas, the nine, you suffered nine times, my dear good sweet mother!

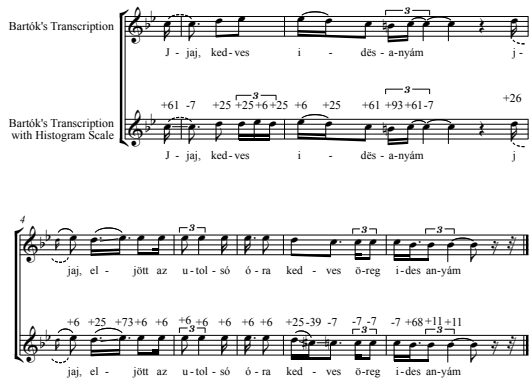


**Figure 7.** Comparison of Bartók's transcription with a transcription according to the density-estimation based scale: cent differences are indicated

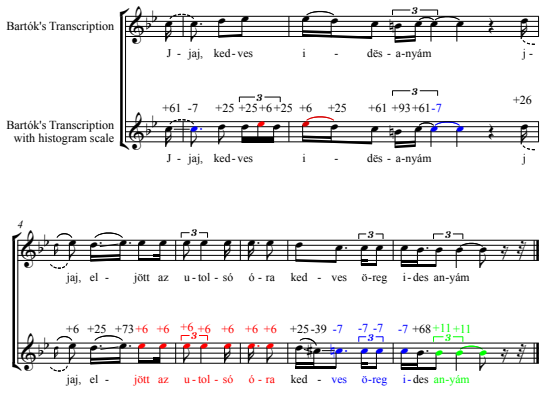


**Figure 8.** Bartók's transcription juxtaposed by transcription done with density-estimation based scale. Colors indicate primary, secondary and tertiary degrees of occurrence in recording: Primary pitches in red, secondary pitches in blue, and tertiary pitches in green.

## 5. QUR'AN RECITATION

### 5.1 Computational analysis of Qur'an recitation

We have applied this method of analysis of scale-tones to a repertoire of Qur'an recitation. We show how the durations of tones, determined by the rules of *tajwīd,* affects the density of structurally salient pitches within a given recording of recitation.


**Figure 9.** Qur'an text of *Sura al-Fatiha* with color indications for rules of *tajwīd.*

### 5.2 Cultural context of Qur'an recitation

The performance framework for Qur'an recitation is not determined by text or by notation but by rules of recitation that are primarily handed down orally (Zimmermann 2000, p. 128).[8] Here the hierarchy of spoken syntax, expression and pronunciation play a major role in determining the rules of *Tajwīd.*[9] The resulting melodic phrases, performed not as "song" but "recitation" are determined by both the religious and larger musical cultural contexts. In the context of "correct" recitation contexts, improvisation and repetition exist in conjunction (as is the case with the Hungarian *siratό).* In this way the traditions of *siratók* and Qur'an recitation are examples of "oral literature,"[10] as their given modes of production are collective-

[8] "Like the Hebrew *miqra'* the primary name 'Qur'an' derives from the root q-r, i.e., 'reading': the visual implication of text is not implied with this root. Rather the concepts 'pronounce, calling, reciting' are expressed with the word, so that an adequate translation of Qur'an (Qur'ān) could be 'the recited'" (Translation from the German by Dániel Péter Biró). Heidi Zimmermann, *Tora und Shira: Untersuchungen zur Musikauffassung des rabbinischen Judentums* (Bern: Peter Lang, 2000), 27.

[9] "*Tajwīd* [is] the system of rules regulating the correct oral rendition of the Qur'an. The importance of *Tajwīd* to any study of the Qur'an cannot be overestimated: *Tajwīd,* preserves the nature of a revelation whose meaning is expressed as much as by its sound as by it content and expression, and guards it from distortion by a comprehensive set of regulations which govern many of the parameters of the sound production, such as duration of syllable, vocal timbre and pronunciation." Kristina Nelson, *The Art of Reciting the Qur'an* (Austin: University of Texas Press, 1985), 21.

[10] Al Faruqi p. 21, "The term "literature" is derived from *littera*, a Latin word meaning "letter" or, in plural form, "writing." However, to limit literature to only that imaginative and artistic organization of words which is written would be to succumb to a type of cultural chauvinism dictated by a Western European emphasis on the written word. The

ly determined by set of rules which are transmitted orally from generation to generation.

### 5.3 Analysis Criteria for Qur'an recitation

Within a given recording we investigated the relative durations of scale-pitches within verses and within words. In particular, we looked at the sections of elongation within a given *sura* and tried to see how these sections of elongation affected the central tones within the *sura* in terms of a) scale degree and b) degree of density. We looked at the results in several recordings of a given *sura* and compared pattern relationships between scale degree and scale of density in these examples.

In our study we found relationships between scale degree and density of occurrence in final words of verses and especially in sections where syllables are elongated.[11] Locating these tones we are able to determine "stable" and "variable" structural tones within the recording. While certain scale tones show a clear stability in some examples, other tones display an amount of identity variability, and entail an "ornamental" functionality, as in the higher pitches in **Figure 10**. This may relate to the culture of *maqāmat* from instrumental music, which affects the tonal structure of Qur'an recitation.

### 5.4 Qur'an recitation: outcomes of analysis

In our examinations of recorded renditions of *sura al-Fatiha* we observe relationships between structural scale tones within verses (*ayat*) and scales tones used in sections of syllable elongation (*madd*). The rules of *tajwīd* specify that specific sections of words require either variable extensions of vowels from two to six beats (*ḥarakāt*) or an obligatory six beats (*ḥarakāt*).[12] While such elongations have been studied in terms of correct pronunciation based on the rules of *tajwīd,* there has not been considerable study of how such elongations might contribute to the establishment of structurally salient tones, as employed in a given recitation, and how these relate to *maqāmat.* We base our analysis on the frequency of occurrence of scale pitches in each verse (*ayah*) of the *sura* and in the final words of each verse, as displayed in **Figure 12.**

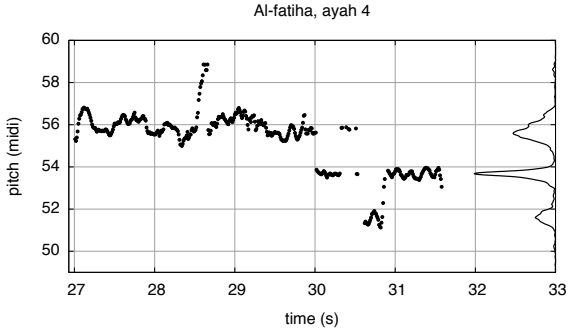


**Figure 10.** Pitch contour for fourth verse (*ayah*) of *sura al-Fatiha* in recording of al-Minshawi.

In our computational analysis we have looked for salient pitches within a recording, within each verse and within words with syllable elongations (*madd*). Comparing the pitches employed in sections of textual elongation with those employed throughout a given recitation, we have found that the rules of *tajwīd* display a profound influence on creating and stabilizing salient pitches. In addition, through comparative analysis of the same *sura* recited by the same person,[13] we are able to show scale relationships and recurring patterns of final selections of tones within these sections of elongation.

In our study, we have set out to test the performance of syllable elongation in Qur'an recitation via computational means. *Sura al-Fatiha* contains syllables to be specifically performed with types of elongations (*madd*)*;* either with a variable duration of two to six beats or with a obligatory six beats (*ḥarakāt*). These are displayed in **Figure 11.**

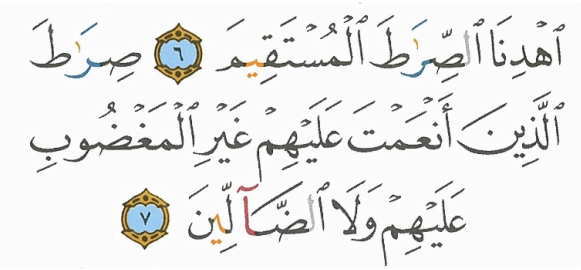


**Figure 11.** Last two *ayaat* (verses) of *Sura al-Fatiha* with indications of elongation (*madd*) in color; orange: variable elongation of 2-6 beats (*ḥarakāt*); red: obligatory elongation of 6 beats (*ḥarakāt*).

"literature" of many peoples in the world - and even of certain genres in Western culture - is not preserved in written form. Such genres are usually designated as "oral literature."

[11] Al Faruqi, p. 10, "Durations of tones and rhythmic motifs are strongly affected by the rules of pronunciation set down in the manuals on *tajwīd.* Those rules prescribe determined durational relationships between the short vowels or *ḥarakāt* (the *fatḥah*, *ḍammah*, and *kasrah*) and the long vowels (i.e., the letters *alif*, *waw* and *yā*). *Tajwīd* also determines the extension or *madd* of the long vowels according to their place in the word, their combination with certain other letters of the Arabic alphabet, and their use with unvowelled consonants (i.e., with *sukūn*) or doubled consonants (*tashdīd*). These rules insure that the difference between the short and long syllables does not exceed the ratio of 1 to 6 (e.g., the difference between a 16th note and a dotted quarter). Often the actual differences are much less. Many of the prohibited practices regarding Qur'ānic chant, which have been repeated and reemphasized in each successive century of Islamic history, have been restrictions against vocal practices that exaggerated durational contrast. Among these condemned practices are the exaggerated lengthening of short vowels (*tshbā' al ḥarakāt*), the lengthening of the long vowels (*ziyādah al, madd*), omission of short vowels (*taqtī' al ḥurūf*), and the improper addition of short vowels (*taḥrīk al ḥarf al sākin*) (al Sa'īd 1967:347)."

[12] Nelson, 24. "Arabic prosody classifies the syllable into long and short durations, one long being approximately equivalent to two short. The durations of syllables in Qur'anic range from one to six beats (*ḥarakāt*) or longer."

[13] Mesrur Coşkun performed multiple recitations of specific *surat* in Rotterdam in May 2014.

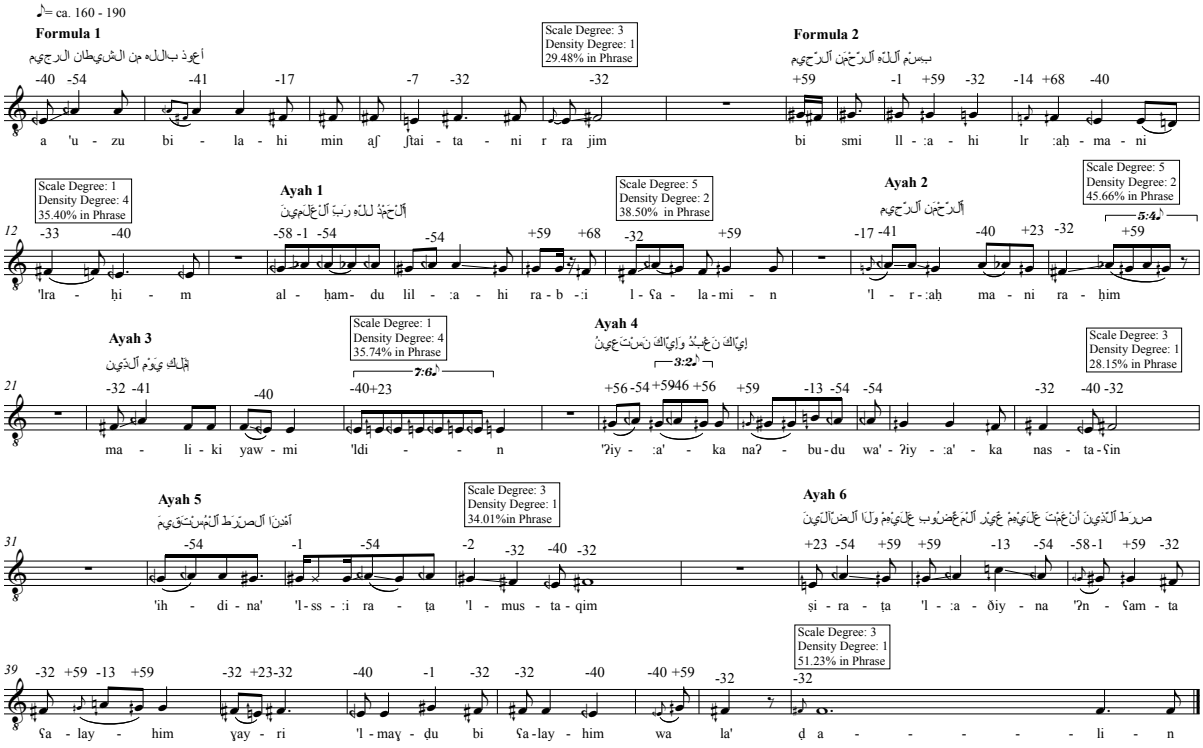


**Figure 12.** Transcription of *Sura Al-Fatiha* as performed by Siddiq al-Minshawi. Computational analysis shows scale degrees and density degrees of each word with elongation (*madd*) as well as overall percentage of pitch within a given verse.

The salient tones used for elongation of syllables within given words (*madd*) correspond to salient frequencies used within the given recitation. Comparing recorded examples of the *sura al-Fatiha,* we found paradigmatic connections between salient tones within given words and verses as displayed in **Figure 12**. While some tones used in association with variable elongation of durations (two to six beats) show more variability in terms of their relationship to the salient pitches within corresponding verses, the pitch associated with obligatory elongation of durations of six beats (*ḥarakāt*) show an exact correlation with the salient pitches of corresponding verses, as displayed in **Figures 13 and 14.**

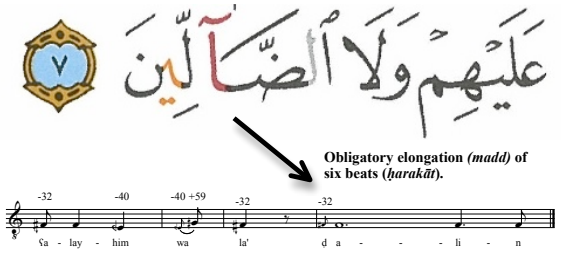


**Figure 13.** Last words of *Sura al-Fatiha* with indications of elongation (*madd*) in color; orange: variable elongation of 2-6 beats (*ḥarakāt*); red: obligatory elongation of 6 beats (*ḥarakāt*); comparison to transcription of performance by Muhammad Siddiq al-Minshawi.

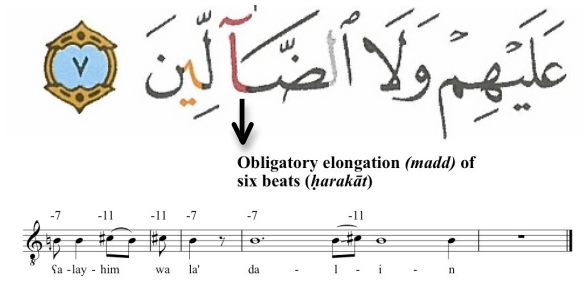


**Figure 14.** Last words of *Sura al-Fatiha* with indications of elongation (*madd*) in color; orange: variable elongation of 2-6 beats (*ḥarakāt*); red: obligatory elongation of 6 beats (*ḥarakāt*); comparison to transcription of performance by Muhammad Khalil al-Husari.

**Figure 15** displays how, in five recorded recitations of *sura al-Fatiha*, central tones relate in terms of a) their use in elongation of syllables (*madd*), and b) their use in verses. In four of the five examples, the variable elongation of the fourth verse (*ayah*) displays variability to the predominant tone used in the verse. In all five examples, the obligatory elongation helps to define the predominant tones of the verses as well as the tonic of the *maqām* or set of tones employed for recitation.

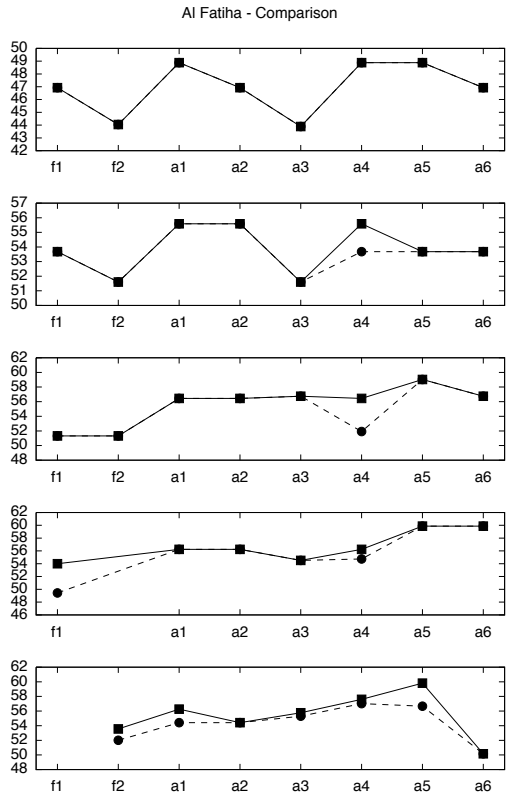


**Figure 15.** Each graph show the sequence of MIDI-values of the most frequently occurring pitches in the entire verses (squared), and in the last words of the verses (dotted) in various readings of *Sura Al Fatiha*. The readers are from top to bottom: Muhammad Khalil Al-Husari, Muhammad Sidduq Al-Minshawi, Mesrur Coşkun (first rendition), Mesrur Coşkun (second rendition), and Mesrur Coşkun (third rendition).

## 6. CONCLUSIONS

In our analysis of *siratók* and Qur'an recitation we have set out to discover how salient pitch structures are determined and how these relate to performance parameters of these traditions. The computational analysis of *siratók* transcribed by Béla Bartók in the 1930s, allows us to re-evaluate his work and to better comprehend how pitch hierarchies function within this type of chant ritual. Combining computational analysis of resultant pitch structures determined by specific rules of *tajwīd*, such as the use of elongation (*madd*) with analysis of tonal structures (*maqāmat)*, we better understand how the rules for correct enunciation help to form and interact with given tonal hierarchies found within performances of Qur'an recitation, as the pitches of the elongated syllables help to create the salient pitches within a given recitation.

## 7. FUTURE WORK

We are currently examining recordings of *sura al qadr, sura al-qaria, sura ghafir* and *sura ash-shams*. In addition we are examining relationships of salient frequencies and contour in examples of the same sura texts, as exemplified in *mujawwad* and *murattal* versions. In comparing these versions we hope to find further correlations between the rules of *tajwīd* and use of *maqamat* within Qur'an recitation.

**Acknowledgements**. We are grateful to Imam Mesrur Coşkun for allowing us to record his recitations of Qur'an. Peter van Kranenburg is supported by the Computational Humanities Programme of the Royal Netherlands Academy of Arts and Sciences, under the auspices of the Tunes & Tales project.

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