

Melodic Stability and Memory Analysis in Semi-Oral Chant Traditions: A Computational Study of Qur'an Recitation and Torah Trope

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We have been devising transcription methods of oral traditions via computational means based on research conducted over an eight-year period. In particular, we have developed new computational models for analyzing chant with twenty-first century technology, thereby continuing the project of folk music transcription initiated by Béla Bartók (1881-1945). In analyzing relationships between parameters of pitch, melodic gesture and melodic scale in examples of Hungarian laments, Jewish Torah cantillation and Qur'an recitation with computational tools we have also created a new paradigm for chant transcription by enriching traditional transcription techniques with results from computational analysis based on pitch histograms. In the present study, we have recorded examples of Torah trope and Qur'an recitation from specific reciters, analyzing parameters of pitch, melodic gesture, scales and *maqamat* both within and also across traditions. Over a four-year period we have returned to these reciters, asking them to recite the same text passage several times. We thereby aim to better understand the functionality of melodic stability within semi-oral chant traditions and how this relates to the short- and long term-memory of given reciters and religious communities.

For this study, we are collecting and comparing data from field recordings. Instead of analyzing pitch contours in terms of pre-defined melodic scales, we derive a scale from the audio-recording. First we construct a pitch histogram, showing for each pitch the relative frequency of occurrence of that pitch during the recording. Each Qur'an and Torah recording has been converted to a sequence of frequency values using the SWIPEP fundamental frequency estimator (Camacho 2007) by estimating the fundamental frequency in non-overlapping time-windows of 10ms.

Figure 1 shows two sections of the beginning of the Hebrew Bible as read by Amir Naamani in November 2011. This graph on the left side shows the pitches employed for the reading of Chapters 1–4 and the graph on the right side shows the pitches employed for the reading of Chapters 5. In comparing the data of the two graphs it is clear that there was a high degree of pitch stability in his reading of these chapters.

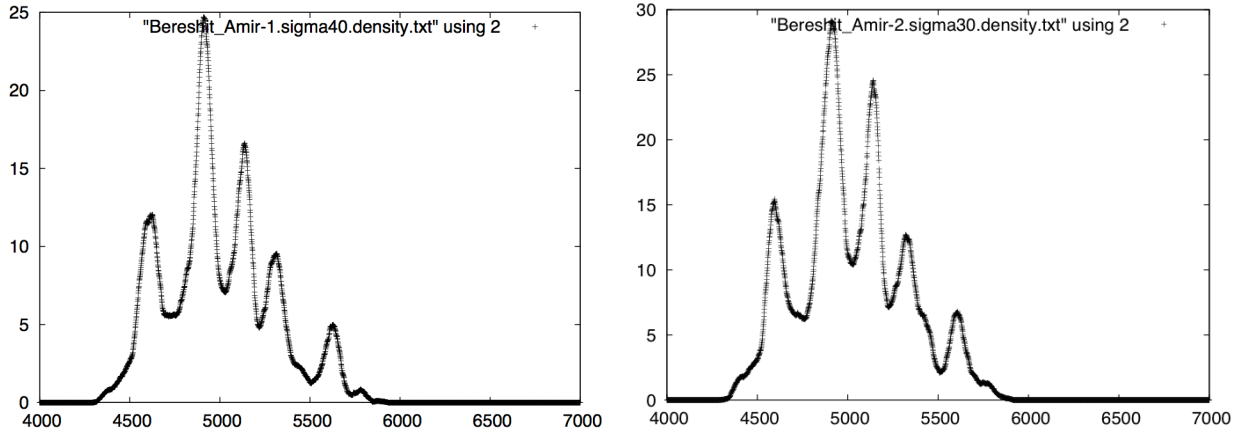


Figure 1. Pitch-Histograms of Genesis 1-4 (left) and Genesis 5 (right) as read in The Hague by a Torah Reader (Ashkenazi) from the Hague, Netherlands in November 2011. **Media Example 1:** Audio of recitation and corresponding computational transcription using scales based on pitch histogram.

We have also analyzed scale-tones in repertoire of Qur'an recitation via computational means. Within a given recording we investigated the relative durations of scale-pitches within phrases 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.

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 phrases, as displayed in **Figure 2**.

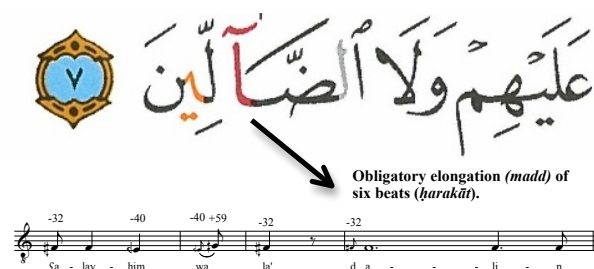


Figure 2. Last words of *Sura al-Fatiha* with indications of elongation (*madd*) in color; orange: variable elongation of 2-6 beats (*ḥarakāt*); red: obligatory elongation of 6 beats (*ḥarakāt*). **Media example 2:** Final *ayah* of *Sura al-Fatiha* juxtaposing recitation and corresponding computational transcription using scales based on pitch histogram.

Figure 3 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 phrases. In four of the five examples, the variable elongation of the fourth verse (*ayah*) displays variability to the predominant tone used in the phrase. In all five examples, the obligatory elongation helps to define the predominant tones of the phrase as well as the tonic of the *maqām* or set of tones employed for recitation.

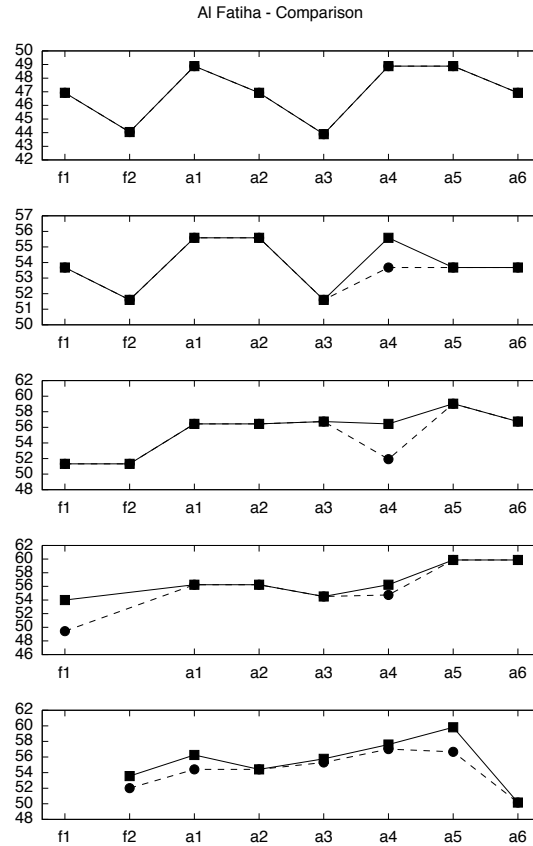


Figure 3. Each graph show the sequence of MIDI-values of the most frequently occurring pitches in the entire phrases (squared), and in the last words of the phrases (dotted) in various readings of *Sura Al Fatiha*. While the first two were performed by Saudi and Egyptian recitors, the last three examples were all performed by the same *qari* of Turkish background in Rotterdam, Netherlands. **Media example 3:** Turkish recitation example of *ayah* and corresponding scale based on pitch histogram.

In our analysis of Torah trope and Qur'an recitation we have set out to discover how salient pitch structures are determined over time in given religious communities and how these relate to performance parameters within these traditions. We are currently examining recordings of recitations of the same texts performed over a period of years by the same recitors. We thereby examine relationships of salient frequencies and contour and test their stability as performed by the same recitor and within a given religious community. In comparing these versions we hope to better understand the governing rules for melodic stability and variation within practices of Torah trope and to find further correlations between the rules of *tajwīd* and use of *maqamat* within Qur'an recitation.

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