# INTERVALS BASED APPROACH TO MELODIC PATTERN IDENTIFICATION ON ARAB-ANDALUSIAN NAWBAS

**Gabriel Bibbó**
Universitat Pompeu Fabra
gabriel.bibbo01@estudiant.upf.edu

**Nicolás Schmidt**
Universitat Pompeu Fabra
nicolas.schmidt01@estudiant.upf.edu

## ABSTRACT

In Arab-Andalusian, compositions are created using a melodic composition technique called centonization [4]. The melodies are based on pre-existing melodic figures and formulas [1]. Some authors argue that tabs, as melodic modes, can be characterized by characteristic patterns specific to each tab. These structures are called centos. [4]. The goal of this work is to find melodic patterns in a dataset of machine readable music scores utilizing computational analysis. The proposed approach relies on intervalic based motif representations computed from music scores by analyzing and comparing all the scores of each one of 11 tabs selected. The music scores database was obtained from the Dunya platform [9], comprising a total of 11 tabs and 149 music scores. We propose an original method for patter recognition based on interval constructed motifs and provide the identified patterns represented by counting the number of instances of re-occurring sub-sections of intervals in a musical sequence.

## 1. INTRODUCTION

This study targets the recognition of underlying motifs that characterizes each tab of Arab-Andalusian music recordings, a task that has only recently begun to be investigated by Nuttall et. al. [7]. Unlike the approach they use, based on tf-idf analysis over sequences of notes, our approach relies on the tf-idf analysis of patterns based on the musical intervals. The study makes use of a database of the Arab-Andalusian corpus obtained from the Dunya [9], which has a total of 149 music scores for 11 different tabs. The results are then compared with the ones highlighted by [7] where similar work in the field of melodic characterization of the tabs is performed.

Arab-Andalusian music cannot be analysed with algorithms designed for Western music without taking into account the particularities of this style. In this paper we will also analyse the difficulties that arise from using systems designed for Western music, like EMViz [2], that are state of the art.

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### 1.1 Arab-Andalusian music

Arab-Andalusian music was formed in the medieval Islamic territories of the Iberian Peninsula, drawing on local traditions and assuming Arabic influences. A period of cultural syncretism that lasted about 8 centuries until the beginning of the 17th century, was marked by coexistence of the Islamic, Jewish and Christian religions. This allowed a remarkable cultural exchange that had a decisive influence on the culture of the inhabitants of the southern part of the current sector of Spain. This new culture is called Al-Andalus is characterized by gathering elements of Christianity, Judaism and Islam, with notable consequences in architecture, clothing, culinary and musical traditions. Arab-Andalusian music heavily draws on local Iberian practices, and especially on plainchant in terms of composition principles [3].

Among the musical traditions that were forged in Al-Andalus, the Nawba stands out. This musical genre was originated from the musical tradition of North Africa, with elements from the Iberian Peninsula. The word Nawba is from the work ’sawt’, which means voice.

Originally there were 24 Nawbas, one for each hour of the day of about 1 hour duration each. The Nawba is constituted from many voices at the same time or a solo voice. In Andalucía they are also accompanied by instruments. The lyrics are taken from the Muwashah, which is a form of poem [14]. In terms of its structure, each Nawba is written in a specific Tab or melodic mode and divided in 5 parts or Myazen (plural word for Mizan) [8].

The study of the Nawba from the point of view of musicology is especially important to understand the syncretism that occurred in the Andalusian region. This musical tradition contains motifs that escape from the western classical music logic. Our aim is to quantify the importance of particular melodic patterns with respect to the available Nawbas and provide an empirical ranking of melodic content for each.

This paper is structured as follows. First, the motivation for focusing the analysis on the recognition of melodic patterns in this musical tradition is presented. Next, the methodology of the study is described. Later, the main results of the research are presented. Finally, the conclusions, scope and limitations of the study are presented.

### 1.2 Motivation

A primary learning objective in music theory and musicology courses is the ability to analyze musical form, often using a bracketed diagram. This humanistic process often involves listening with a score, stopping the recording for a close reading of the score, flipping back and forth through the document to make comparisons, and so on. While manual analysis is important, the conventional method of summarizing one's analysis as a bracket diagram is reductive without being illustrative.

Musical themes and motives are often transposed or otherwise modified in the course of a piece. A concept learned by music majors is the subject and answer of a fugue, an imitative polyphonic composition. The subject is the initial statement of a fugue's theme, stated in a monophonic texture, and the answer is the first interpolation stated in a polyphonic texture against counterpoint. Sometimes the answer is an exact transposition, also called real answer, and sometimes the answer is transposed and modified, known as tonal answer.

Those and other melodic figures are frequently repeated and the entire piece can be seen as a sort of puzzle that consists of such melodic fragments [12]. In counterpoint, which is a theory of creating polyphonic music, motifs are seen as identical under certain types of transformations, i.e., inversion, retrograde, argumentation, diminution, transpositions.

Centonization, the melodic composition technique, usually used in Gregorian chant, is also used as the basic technique for the creation of the Arab-Andalusian music [4]. The expression comes from the latin *cento* meaning patchwork, that is a melodic composition by synthesis of pre-existing musical units known as centos. Since [7] proposed that a set of *centos* characterises a particular tab, we could say this technique strengthens the connection between this tradition and Iberian local practices [4].

## 2. RELATED WORK

There exists many studies into melodic pattern recognition. For their significant contribution to improving the state of the art, it is worth highlighting two simultaneous studies on the subject, with different approaches, Tanaka Tsubasa's post-doc [12] and Carter-Enyi's EMViz implementation [2], both from 2016. Despite the value of these contributions, there is a lack of agreement on the current state-of-the-art that stems from the difficulty in evaluating approaches, with expertly annotated ground truth often required for performance measurement, more often than not on a study-by-study basis [7].

Tsubasa first investigated the style of baroque polyphonic music, in which melodic motifs are important as the basic vocabulary. Using the typical transformation group in counterpoint, he defines equivalence classes of motif derived by the relation given by this group. He proposed a formulation to generate sequences of musical patterns controlling some global structures of the sequences especially focusing on hierarchy and degree of redundancy in each level. To realize this, he takes an integer programming-based approach and formalizes this problem as a set partitioning problem, a well-known optimization problem. He showed that such structures can be expressed only by linear constraints, which are necessary to apply integer programming [12].

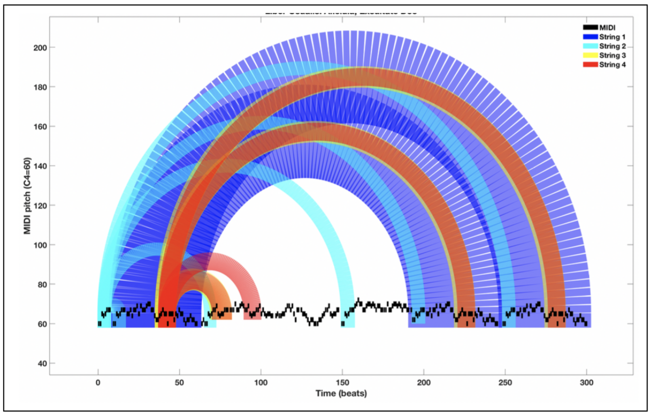


**Figure 1**. Arcs diagram of EMViz, from Carter-Enyi.

In parallel, Carter-Enyi [2] created a contour recursion algorithm for pattern recognition in symbolic music (MIDI), provided in a built-in implementation that allows visualization, called EMViz (Early Music Visualization). Enyi based his work on the arc diagrams proposed by Wattenberg in 2002 [15], who created a digital method for visualization of musical form using arcs that connects two matching passages, where a 'match' means that they contain similar sequence of pitches. While Wattenberg offers the possibility of matching melodic intervals (instead of pitch-strings), this too would not match a subject to its tonal answer. Envy states that algorithms informed by humanistic understanding of music work much better than those that are not. For that reason his implementation brings together the contour theory of Morris [6] and Quinn [10] with studies on melodic accent of Thomassen [13] and Huron [5]. EMViz implements a pattern-matching algorithm based on heuristics from music theory, a theme identification by user input, and a color-coding of arcs between matched patterns (see Figure 1) .

While both of the above-mentioned approaches perform very well in analysing Western music, their use in Arab-Andalusian music may not yield the same results. For this and other reasons it is not trivial to extend the use of melody pattern identification systems developed for Western music to non-Western music.

Considering these facts, a study by Nuttall et. al. (2019) [7] targets testing the distribution template matching for nawba detection in Arab-Andalusian music context. Their approach can be compared with a bag-of-words representation of a document, because they represent each score as a bag-of-patterns. That is, they extract from each every possible n-gram up to a specified length, N. A high-order n-gram model is applied to a corpus of 149 prescriptive transcriptions of heterophonic recordings, representing each as an unordered multiset of patterns. Computing the tf-idf statistic of each pattern in this corpus they get a means by which the motif content across Nawba can be ranked and compared. Their analysis does not take into account any note/rest duration, and they omit all octave information from the data, observing that melodic lines in the corpus very rarely jump between octaves. Although the patterns discovered by their analysis were found to be as predictive as those manually annotated for classifying Nawba (44% of the found patterns matched the centos on their database), it is worth noting that it is the first reference to pattern recognition in Arab-Andalusian music in the literature.

## 3. METHODOLOGY

In this work we analyse different options within the state of the art to identify melodic patterns. First, we use the EMViz tool implemented in Matlab, which allows the visualisation of melodic patterns. Subsequently, we propose a pattern detection technique based on the intervals of the notes in the score. This implementation is done in Python and is based on Nuttall's et. al. [7]. Finally we evaluate the performance and compare the results obtained from both implementations.

### 3.1 Early Music Visualization

This tool was originally designed for classical music. The scores were generally equivalent in length to Josquin des Prez's "Ave Maria Virgo Serena", which was no more than 5 minutes of music. In figure 1 can be seen the arcs resulting from the identification of patterns in a short melody. To address the goal of this paper, we decided to concatenate several scores from the tabs obtained from Dunya. In this way we could identify the patterns that were repeated in different scores of the same tab. The MIDI score resulting from the concatenation was so long that in some cases the score was up to 5.2 hours long (the case of the concatenation of 10 scores from the al-rasd tab). These files were uploaded to EMViz for further analysis.

Due to a combination of factors such as the weight of the file, poor performance of the personal computers at our disposal and a poor implementation of the tool in Matlab, our analyses took a whole night to run each. The time required for this research did not allow us to continue with this approach, which was slowly beginning to yield results. Due to the lack of complete analysis data, we chose not to present these intermediate results.

### 3.2 Intervals based approach

This section is framed under the methodology of comparative research, since it seeks, on the one hand, to replicate the results obtained by [7]. On the other hand, this study proposes a new method for the identification of musical motifs in the Nawbas. This new method, in contrast with the centos-based proposed by [7] and [8], is based on the identification of patterns based on intervals. The aim of this analysis is to generate a new musical feature that could be used in the future for Nawbas classification tasks, and thus evaluate its accuracy in comparison with traditional methods.

The methodology used is based on the work of [7], where, in a first instance, a pre-processing of the scores belonging to the different tabs of Arab-Andalus music is performed. The scores were obtained from the Dunya corpora, part of the CompMusic project. The pre-processing consists in downloading all the available pieces of the 11 main tabs available in the Dunya platform, and then processing them in a dictionary type data structure. For each set of scores belonging to a tab, a dictionary entry is instantiated, using the tab name as a key. The scores per tab number can be seen in table 1.

| Tab | Number of scores |
|---|---|
| al-istihlal | 23 |
| raml al-maya | 19 |
| iraq al-ayam | 7 |
| al-maya | 12 |
| garibat al-husayn | 12 |
| al-hiyaz al-masriqi | 5 |
| al-rasd | 23 |
| al-hiyaz al-kabir | 10 |
| al-isbahan | 14 |
| rasd al-dayl | 17 |
| al-ussaq | 7 |

**Table 1**. Number of scores analyzed per tab

Then, the system iterated over all scores of each tab, and for each tab it generated a bag of words of the existing intervals in the score. It is decided to use the bag of words approach, a technique mainly used in the field of natural language processing, to identify the weighted frequency of each interval, for each of the tabs in the dataset.

Unlike [7] and [8] it is decided to use the intervals as word abstraction for this bag of words, and not the musical phrases with their absolute pitch, precisely to explore a potential new descriptor for Andalusian music. In order to follow this method, in a first instance, the intervals between all the notes of the scores were calculated. Grace notes were removed from the analysis, but Rest notes were included in this arrangement, which helped later to identify word exclusion factors.

Having obtained the array with all the intervals of the score, including the Rest notes, it was analyzed using a queue data structure of length 4 to serve as a moving window with stride size equal to 1. This moving window has the function of identifying patterns of a maximum length of 4 intervals, therefore 4 notes as the longest centos identified by [8]. As the moving window moves through the interval array, all sub-words or sub-motifs found within the moving window are added to a dictionary to count the frequency of appearance

This dictionary of words is our bag of words, and one of the conditions to be able to include a new word, is that it must not contain Rest notes in it. This is an important point raised by [7], which is justified by the fact that a musical motif in a Nawba should not be interrupted by a rests or silences. Finally, all words with a frequency of less than 50 occurrences are excluded from the bag of words.

Once we have gone through all the scores of all the tabs, we obtained N dictionaries or bag of words, one for each score. Over this data we proceeded to calculate the same statistic presented in [7], the TF-IDF, which is calculated as the multiplication of $tf_{i,j}$ and $idf(w)$

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| raml al-maya | 1,2,-2,-1 | 0,0,0,0 | 0,-2,-1 | 0,0,-2 | 2,-2,-2,-1 |
| al-istihlal | -2,-1,-2,-2 | 4,-2,-2,-1 | -2,-2,-1,-2 | -2,-1,-2,2 | -1,-2,-2,-1 |
| iraq al-ayam | -2,-1,-2,2 | 0,0,-2 | -2,-2,2,2 | -2,2,2,1 | -1,-2,2,1 |
| al-maya | 0000 | 1,2,-3,1 | 2,-3,1,-1 | 1,2,-2,-1 | -3,1,-1,-2 |
| garibat al-husayn | 0,0,0,0 | 2,-2,-2,-1 | 1,-1,-2,-2 | 2,2,-2,-2 | -2,-3,1,-1 |
| al-hiyaz al-masriqi | -1,1,-1,1 | 1,2,-2,-1 | -2,-1,1,2 | 1,-1,1,-1 | -2,-2,2,-2 |
| al-rasd | -2,-2,-1,-2 | -2,-1,-2,-2 | 0,0,0,0 | 2,-2,-2,-3 | 2,2,-2,-2 |
| al-hiyaz al-kabir | -1,-3,-3,2 | -3,-3,2,1 | -1,-3,-1,-2 | 1,-1,-2,-2 | 2,-2,-1,-3 |
| al-isbahan | 0,0,0,0 | 4,1,2,2 | 2,2,1,-3 | 2,1,-3,2 | 1,-3,2,-4 |
| rasd al-dayl | 0,0,0,0 | -2,-1,-2,2 | 2,2,-2,-2 | 1,-1,-2,-2 | 2,-2,-2,-1 |
| al-ussaq | 0,0,0,0 | 0,0,0,-2 | -2,-2,-1,-2 | -2,-2,2,2 | 0,0,-2,-2 |

**Table 2**. Top 5 most characteristic patterns per nawba, obtained with our algotithm counting intervals

$$tf_{i,j} = \frac{n_{i,j}}{\sum_{k=0}^{K} n_{i,j}}$$

With $n_{i,j}$ being the number of times a word appears in a document and $\sum_{k=0}^{K} n_{i,j}$ being the total number of motif in the score [11].

$$idf(w) = \log \frac{N}{df_t}$$

Being N the number of scores in the tab collection and $df_t$ the number of scores that contains the motif $w$ [11].

Having calculated the TF-IDF for each of the word in each of the scores of every tab, we proceeded to calculate the average of this statistic for all the scores of the same tab. Finally, the words of the bag of words for the same tab are sorted according to this average TF-IDF. Using this methodology, a ranking was obtained with the 9 most characteristic musical motifs for each tab, in terms of musical intervals. These will be described in the following section

## 4. RESULTS

The results of the experimental process described in the previous section are presented here. The results are expressed in comparative terms using the research conducted by [7] and [8] as a baseline. Since the recognition of musical motives in this work was performed in terms of intervals, the notation presented is also different from that of the predecessor literature. The intervals are expressed in terms of semi-tones. Thus, a musical motive expressed as: -1,1,0,2

Represents a musical motive in terms of its intervals. For the above example, 4 values, both positive and negative, can be seen. This represents a sequence of 5 notes, where the distance between the first and second note is a negative or descending interval of 1 semitone. Between the second and third note there is an ascending interval of 1 semitone. A value equal to zero represents a unison interval.

Table 2 presents a summary with the 5 most frequent musical motives for each of the 11 tabs analyzed:

Table 3 shows the centons identified by [7]. Comparing both tables, it can be quickly seen that the musical motifs identified on the basis of intervals appear as sub-patterns of the centons identified in the previous work.

Taking for example the tab al-istihlal, we can see that one of the most frequent motifs is the DCBA. This can be clearly seen as a submotif at the interval level in table 1 at position 1: -2, -1, -2, -2. For the same tab, the FAG pattern can also be seen 4, -2 , -2, -1 in position 2.

This same analysis can be extended in the comparison of both tables, and it can be concluded that the patterns were identified as submotifs. This is because when trying to identify motives based on intervals instead of absolute notes, the possible universe of motives is compressed. This could be explained with an example: a rising interval of one semitone has 11 possible combinations of notes that can cause it, if the scale is not taken into consideration. If the scale is taken into consideration, the possible combinations become as many as the number of notes in the corpus register.

In a way, the dimensional space of possible motives for the case of absolute pitch notes is much larger than in the case of interval-based motives. Thus, several musical motives found by their absolute pitch can be mapped to a single interval-based motive. For this reason, it is also explained that interval-based motives tend to be longer than those based on absolute notes.

## 5. CONCLUSION

In this paper, we have presented a system for automatic melodic pattern recognition of Nawba music tradition. This work also shares the code to replicate the experiments, including metadata and scores.

Our approach follows some previous strategies for that music culture [7], to which we provide a different focus based on the intervals in the music score. Our results show that the patterns identified by our system in some cases include the centons proposed in table 3. It is probably an intrinsic characteristic of our method due to the intervals identifications instead of notes, what reduces the dimensional space and ends up finding longer patterns.

Our identified patterns (see table 2), reflect one of the characteristics o Arab-Andalusian music: most of the patterns in a Nawba are ascending or descending. That may suggest that the centons model is more optimal that the intervals based approach for this type of music. From a

| Nawba | Most Charasteristics Patterns |
|---|---|
| raml al-maya | EFG, FGF, GFEDC, DCD, FEF, CDEF, AAG, DCB, AGFED, FGA |
| al-isbahan | CDEF, CBA, GAGFE, FEF, FEDCB, GFEDC, EFE, AGFED, DCBC, DEFG |
| al-maya | B-AG, AGFEDC, FGEF, DEFG, DCB, EEF, GAGFE, FGA, CEE, EFEDC |
| rasd al-dayl | CDEC, ECD, DEFG, CCD, EDCDE, CDEF, AGFEDC, FAG, CDC, GAGFE |
| al-istihlal | ABC, DCBA, FAG, AGFEDC, EDCB, GAGFE, DEFG, BCD, EDE, CBAG |
| al-rasd | EDC, AGED, ABAGE, GAB, EF#GA, F#GAG, GF#G, EDECD, AGG, GGA |
| garibat al-husayn | EDE, GAGFE, DEFG, CDE, FGA, AGFED, AAG, GFEDC, CCD, DCD |
| al-hiyaz al-kabir | E-DC, GAGF#E-, DCB, DEF#, BCB, EF#GAG, CBAG, AGF#E-D, BAGF# |
| al-hiyaz al-masriq | EFG, FEF, FGF, FGA, FFG, AGFED, GFEDC, GAG, DEF, EFE |
| iraq al-ayam | BAGF#E, GAB, ABC, CBAG, EF#GA, EDC, DCBA, GGA, GF#ED, F#GAG |
| al-ussaq | GAG, GFED, DED, GAB, FEDC, ABC, EDCB, GGA, EFE, CBAG |

**Table 3**. Top 10 most characteristic patterns per nawba, obtained by Nuttall et. al. [7]

musicological point of view, the intervals based approach is less adequate as it looses the information of the absolute pitch.

An attempt was also made to analyse other tools for pattern identification. The time constraints of this project did not allow for significant results for this research. As future works, we plan to re-run the EMViz tool [2] and compare its results with our intervals based approach.

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