Comparative Melodic Analysis of A Cappella Flamenco *Cantes*

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Background in ethnomusicology and music analysis. A cappella singing styles (called *cantes* in the flamenco jargon) are among the most fundamental song styles within the flamenco repertoire. Until very recently, flamenco singers have been only using oral transmission to learn them. Because of this form of diffusion, melody has become one of the main musical facets to be listened to, remembered, elaborated and spread in flamenco singing styles. Moreover, melody has helped flamenco enthusiasts to remember and identify variants of a particular style or genre. A frequent discussion and unanswered question among flamenco scholars is how to quantify the similarity between two melodies, and how to use this similarity measure to differentiate different styles and variants among performers, and to study the roots and evolution of flamenco styles.

Background in computing, mathematics and statistics. State of the art techniques in melodic analysis of audio allow us to obtain different representation levels of a music recording (Gómez et alt. 2003). There are different representation levels for melody. Energy (intensity) and fundamental frequency (pitch) curves are the main low-level melodic features. In a higher structural level, note duration and pitch provide a symbolic representation, which can be the input to higher-level analyses. Finally, deviations of the analyzed recording with respect to the obtained score are related to expressivity. There have been some attempts to apply these techniques to the analysis of flamenco music (Donnier 1997, Gómez and Bonada 2008). There also a corpus of research on how to measure similarity between melodies using computational models, which are usually inspired in methods for string comparison (Crawford et alt. 1998, Mongeau and Sankoff 1990).

Aims. After some previous studies on rhythmic similarity of flamenco styles (Díaz-Bañez et alt. 2004), the aim of this work is to compare different approaches of melodic and tonal analysis of flamenco a capella singing styles. The ultimate goal is to perform a multidisciplinary analysis that will provide us with tools to compare different versions of the same style, and, as a consequence, to clarify the roots of styles and their evolution. We contrast historical knowledge, we carry out manual melodic and tonal analysis assisted with automatic melodic description tools. In order to achieve this goal, it is also necessary to gather a representative musical corpus, a significantly difficult task due to the variety of media (mostly vinyl and magnetic tapes) and poor quality of existing flamenco recordings.

Main contribution. One of the main contributions of this work is to gather a representative music collection for this study. The corpus was found on very diverse media (mostly vinyl and magnetic tapes), and comprises recording from the 40's up to day. We have considered a music collection of songs without instrumentation or in some cases with some percussion, known in flamenco music as *cantes a palo seco*. This corpus is composed of two main styles, namely: *martinetes* and *tonás*. In total, there are 135 monophonic voice pieces covering the most representative flamenco singers. Musicological and historical criteria were followed when selecting the pieces.

As a second step, we have performed different analysis of this music collection. From a musical and computational perspective, we first define a melodic representation capable of coping with the relevant subtleties of this kind of style, characterized by ornamentations. This melodic representation is automatically computed from the selected phrases (Gómez and Bonada 2008). Critical issues have risen regarding the location of the main notes of the melody, the idiosyncratic use of vibrato and the presence of non-equal-tempered intervals. After that, some similarity measures between each pair of pieces have been computed, such as the edit distance (Gascuel 1997), in order to obtain a similarity matrix for the studied corpus. We compared the obtained similarity matrix with a set of manual annotations produced by flamenco experts; those manual annotations included perceptual melodic contour, tonal analysis as well as historical data based on previous well-established facts and tenets about the analyzed corpus. The different analyses are presented in the paper, and we will listen to some examples of the analyzed pieces in the conference presentation.

Conclusions. Melody is one of the most important aspects to consider when analyzing a cappella flamenco singing styles. Automatic melodic description tools have proven useful to the analysis of flamenco voices, notwithstanding the traditional techniques of music analysis. These automatic tools allow us obtaining quantitative measures that can complement historical data on the roots and the evolution of oral transmission styles.

Introduction

A cappella singing styles (called *cantes* or *palos* in the flamenco jargon) are among the main styles within the flamenco repertoire. Until very recently, flamenco singers have been only using oral transmission to learn them. In oral transmission, melody has become one of the main musical facets to be listened to, remembered, elaborated and spread in flamenco singing styles. Moreover, melody has helped flamenco enthusiasts to remember and identify variants of a particular style or genre. A frequent discussion and also unanswered question among flamenco scholars is how to quantify the similarity between two melodies, and how to use this similarity measure to differentiate different styles and variants among performers, and to study the roots and the evolution of flamenco styles.

After some previous studies on rhythmic similarity of flamenco styles (Díaz-Bañez et alt. 2004), we intended to compare complementary approaches for the melodic and tonal analysis of flamenco a capella singing styles. The aim of this work is then to analyze flamenco singing melodies from different perspectives, and use such analyses to compare different versions of the same style. This would eventually lead to a clarification of the roots of styles and their evolution. We provided some historical information, manual melodic and tonal analysis and automatic melodic description tools for the analysis of a corpus of *cantes*. We carried out a clustering analysis based on similarity measures both for manual and automatic descriptions.

In order to achieve this goal, it is also necessary to gather a representative musical corpus, a significantly difficult task due to the variety of media (mostly vinyl and magnetic tapes) and poor quality of existing flamenco recordings.

A cappella flamenco *Cantes*

We consider a music collection made of songs without instrumentation or in some cases with some percussion, known in flamenco music as *cantes a palo seco*. This corpus is composed of *tonás*. *Tonás* are songs without any musical accompaniment that in a generic form encompass *martinetes*, *deblas, saetas, tonás* and *carceleras*. In this paper, we concentrate ourselves on two main styles, namely *deblas* and *martinetes*.

A *toná* is a song with a 'copla' of verses of either three or four or eight syllables, where the second and the forth verses may have assonant rhythm, which is usually finished with an imperfect tercet (off-rhyme tercet). Although its origin is uncertain, many people in the flamenco world believe that the *toná* is the mother of all flamenco styles (*cante madre*), and that from it all other styles are derived. Some researchers, honestly trying to build a corpus of research but not counting on a fully rigorous methodology, have dated its origin in the XVIII century in Jerez and Triana

(Molina and Mairena 1963), but more recent studies propose a later appearance (Jaramillo 2002, among others). Many *tonás* have been given a particular name along history, especially due to the work of Molina and Mairena. Many of those names are merely names familiar to the singers, but they don't reflect any musical feature. In spite of this fact, they speak about *the toná del Cristo*, *toná de los pajaritos*, *toná liviana de Tia Sarvaora*, *toná de la Junquera*, *toná de Jaunelo*, etc.

The *debla* is a song that stems from the basis of the *toná.* Its melody requires a melismatic ornamentation, more abrupt than the rest of the songs of the *tonás group*.

The m*artinete* is also considered a variety of the *toná*. It differs from the latter in lyrics and its melodic model, which always finishes in the major mode. It is usually a sad style and it is played without guitar accompaniment, as the *tonás group*. Nevertheless, *martinetes* are usually accompanied by the percussion of a mallet struck against an anvil.

Music collection

One of the main contributions of this work is to gather a representative music collection for this study. The corpus was found on very diverse media (mostly vinyl and magnetic tapes) and comprises recording from the 40's up to day. In total, there are 135 monophonic voice pieces covering the most representative flamenco singers. Musicological, geographical and historical criteria were followed when selecting the pieces. For instance, the singer *Tomás Pabón* is known as the one who established the *debla* style, and some relevant contributors were *Antonio Mairena* and *Naranjito de Triana*. These last two artists are considered as the big masters from the 80's, and they influenced all the rest of singers. Table 1 provides some details on this music collection.

Singer	Year	Location	School
Antonio Mairena	1960	Mairena del Alcor	Pabón
Chano Lobato	2002	Cádiz	Pabón Mairena
Chocolate	1999	Jerez de la Frontera	Pabón Mairena
J. Almadén	1985	Ciudad Real	Pabón Mairena
Jesús Heredia	2002	Écija	Pabón Mairena
M. Simón	1985	Jerez de la Frontera	Pabón
M. Vargas	1972	Cazalla de la Sierra	Mairena
Naranjito	2002	Triana (Sevilla)	Pabón Mairena
Pepe de Lucía	1963	Algeciras	Pabón
Talegón	2002	Córdoba	Pabón Mairena
Tomás Pabón	1950	Triana (Sevilla)	El Baboso
Turronero	1989	Utrera	Pabón Mairena

Table 1. Set of analyzed pieces.

Singer	Key
Antonio Mairena	C Major
Chano Lobato	Bb Major
Chocolate	G Major
J. Almadén	B Major
J. Heredia	Bb Major
M. Simón	C Major
M. Vargas	A Major
Naranjito	C Major
Pepe de Lucía	C# Major
Talegón	C# Major
Tomás Pabón	Bb Major
Turronero	B Major

Table 2. Keys of the analyzed Deblas.

The chosen pieces have been manually segmented into phrases, and we have selected the first phrase, as it provides the main melodic theme. This choice has been motivated by the rigidity of musical form that *martinete* and *debla* exhibit. From these 135 excerpts, we have started by selecting 12 singers with the most representative *deblas* and *martinet*es.

Tonal analysis

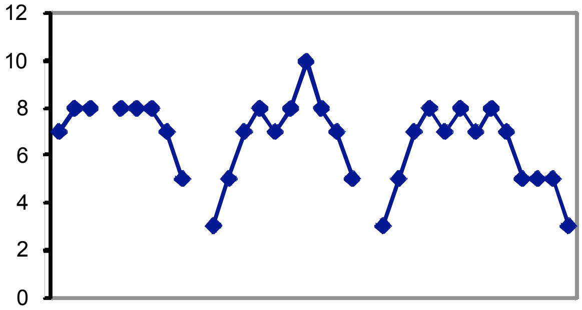

Figure 1-a. Manual transcription of a debla performed by Antonio Mairena.

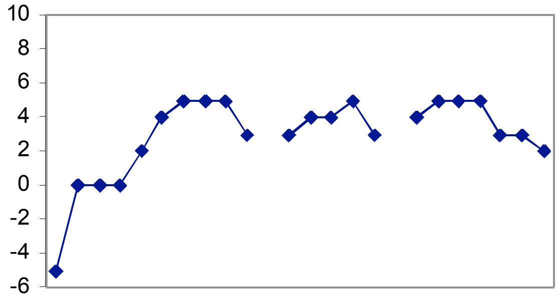

Figure 2-a. Manual transcription of a martinete performed by Antonio Mairena.

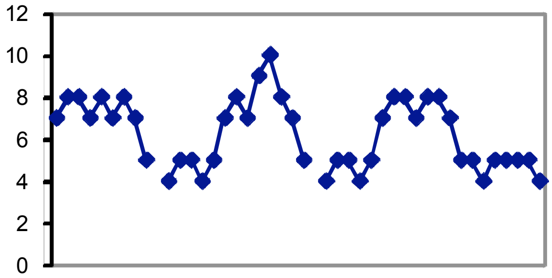

Figure 1-b. Manual transcription of a debla performed by Tomás Pabón.

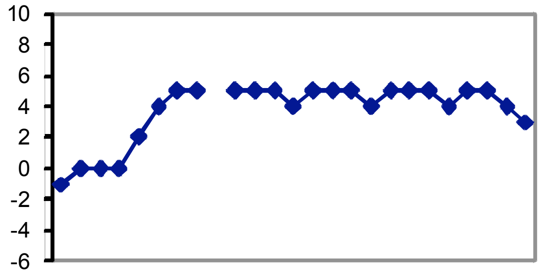

Figure 2-b. Manual transcription of a martinete performed by Tomás Pabón.

A tonal analysis of the selected 12 *deblas* in terms of global key and modulations is provided in this section. The analyzed *deblas* provides a modal context, according to the following tonal structure: Tonic (I) - Subdominant (IV) - Tonic (I). We observe a wide range of keys at the analyzed pieces, as shown in Table 2.

According to its key, we identify 6 different groups: pieces in G Major (Chocolate), A Major (Vargas), Bb Major (Pabón, Lobato and Heredia), B Major (Almadén and Turronero), C Major (Mairena, Simón and Naranjito) and C# Major (Pepe de Lucía and Talegón).

We also observe the presence of microtonality in the modulations; most of the times this is due to tuning problems. In fact, the flamenco singer is not trained to perform accurate modulations whatsoever, at least in traditional flamenco singing.

The key is mostly related to the particular tessitura of the singer, but we might wonder if the chosen key could be also related to a similarity between singing styles. For instance, did Lobato and Heredia follow Pabón's version (in Bb Major)? Or did Simón and Naranjito follow Mairena's version (in C Major)?

Manual melodic transcription and clustering

A manual melodic analysis of our initial corpus was made by a flamenco expert (with formal musical training also).

For this manual analysis we have first normalized the melodic contour with respect to the tonic, and notes have been approximated to the closest note in the equal-tempered scale. Then, ornamentations or melisma have been removed according to some previous knowledge of the particular style under analysis.

There is no straight rhythmic representation, as manual annotation has been made following perception of rhythmic pulses, and not according to note durations.

Figures 1-a and 1-b show graphical representations of the main melodic contour of a *debla* performed by Antonio Mairena and Tomás Pabón respectively. The reader may observe that there are short-time differences, although the overall melodic contour is similar.

Figures 2-a and b show graphical representations of the main melodic contour of a *martinete* sung by Antonio Mairena and Tomás Pabón, respectively. We also found some short-time differences, although the overall melodic contour is kept.

With these manual patterns we have performed a similarity study based on multi-dimensional scaling, by using the Euclidean distance between the vector representations of the sequential values of melodies. A two-dimensional projection of the d-dimensional data is presented in Figure 3. We observe that *martinetes* (M) and *deblas* (D) are located in different regions of the 2-D plot. Note that m*artinetes* from Mairena and Pabón (Tomás) are close to each other, whereas their *deblas* are very far away from each other.

Computational analysis

A computational analysis is made in order to automate the melodic transcription and use alternative similarity distances proposed in the literature.

State of the art techniques in automatic melodic analysis of audio allow us to obtain different representation levels of a music recording (Gómez et alt. 2003). There are different representation levels for melody. Energy (intensity) and fundamental frequency (pitch) curves are the main low-level melodic features. In a higher structural level, note duration and pitch provide a symbolic representation, which can be the input to higher-level analyses. Finally, deviations of the analyzed recording with respect to the obtained score are related to expressivity. There have been some attempts to apply these techniques to the analysis of flamenco music (Donnier 1997, Gómez and Bonada 2008).

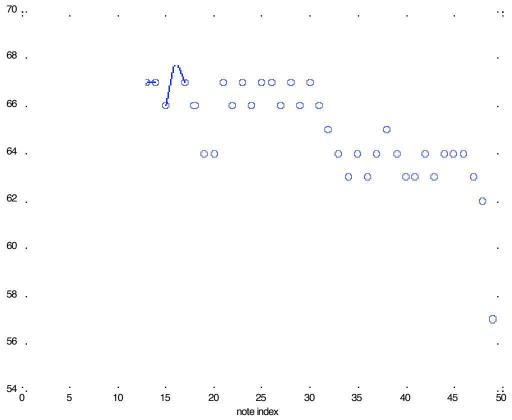

Figure 4-a. Automatic transcription of a debla performed by Antonio Mairena.

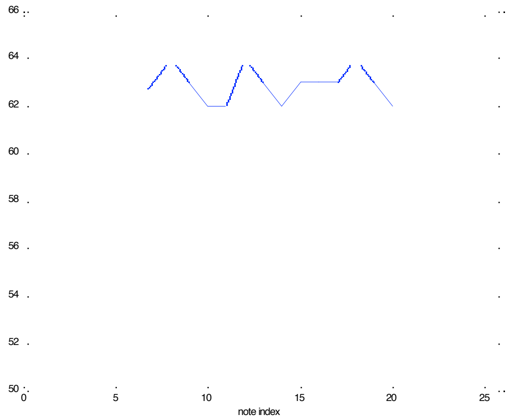

Figure 5-a. Automatic transcription of a martinete performed by Antonio Mairena.

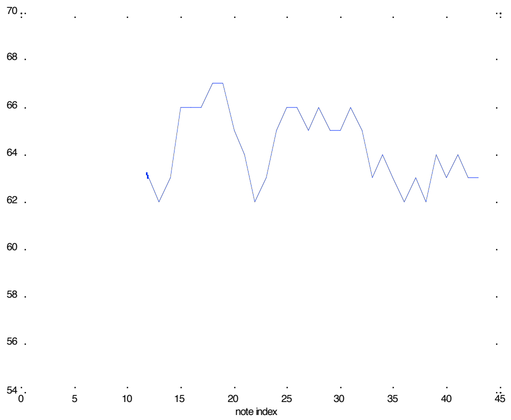

Figure 4-b. Automatic transcription of a debla performed by Tomás Pabón.

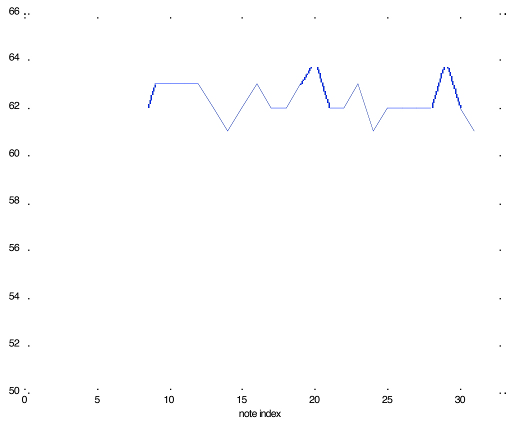

Figure 5-b. Automatic transcription of a martinete performed by Tomás Pabón.

Automatic melodic transcription

We have tested two methods for automatic melodic analysis (Gómez and Bonada 2008, Leman et alt. 2003), which allow us to obtain a MIDI-like representation of singing melodies (onsets, offsets and frequency of every pitch event). It's important to note that each singer has its own reference tone in mind and he/she sings each note relatively to the scale constructed on that tone (Haus and Pollastri, 2001). It is then necessary to estimate this tuning frequency by dividing the semitone into ten overlapping bins, each one being 0.2 semitones wide with an overlapping region of 0.1 semitones. The mean of the deviations that belong to the maximum bin is the constant average distance in semitones from the user's reference tone. Thus, the scale can be shifted by this estimated amount.

Figures 4-a and 4-b provide a graphical representations of the extracted melodic contour of a *debla* performed by Antonio Mairena and Tomás Pabón respectively. We observed some differences with respect to manual annotations. Although there are some errors in the automatic transcription due to the lack of tuning, most of the differences are due to simplifications and assumptions made when manually labeling the melodies (i.e. melisma are not considered, note durations are neglected and only the main melodic anchor points are notated).

Once we had every piece converted into MIDI notes, we needed to normalize it with respect to the key, so that the melodic representation is invariant to transposition. In order to obtain this, we compute the intervals between consecutive pitches, instead of working with the absolute pitch values.

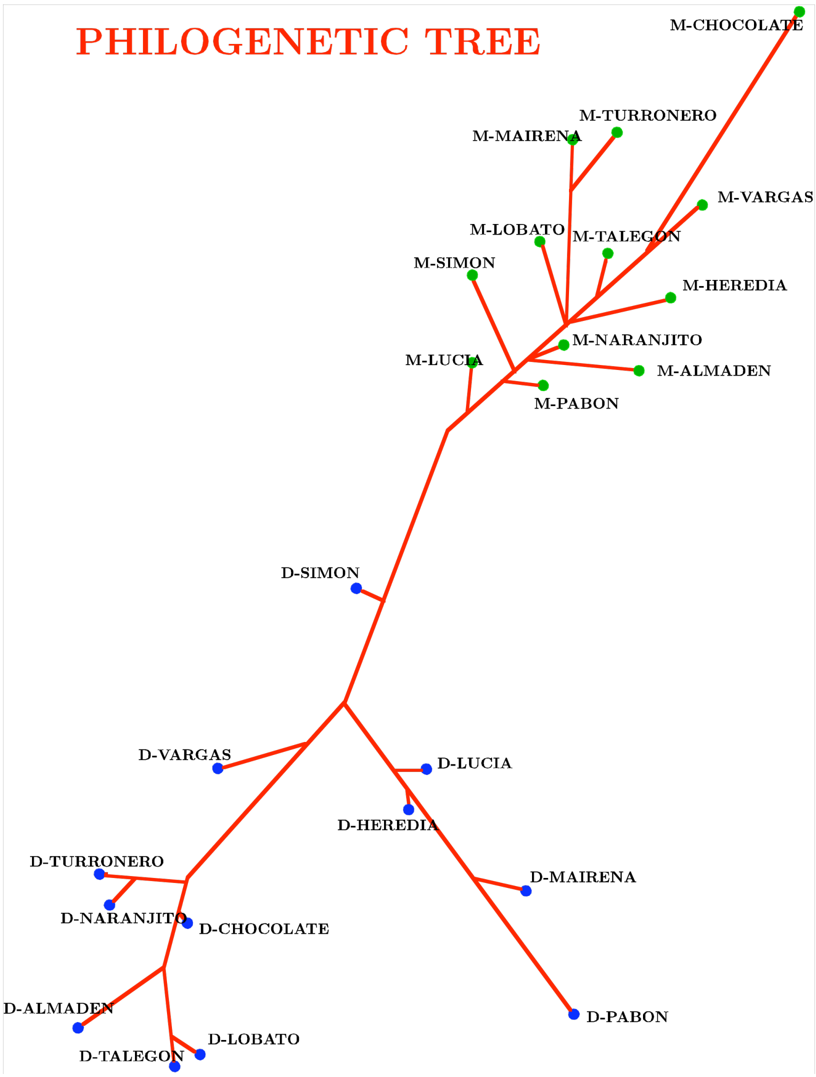

Figure 5. A SplitTree for 12 Deblas and 12 Martinetes.

Besides, we wanted the representation of the pieces not to be affected by tempo. We then normalized note durations with respect to the duration of the previous note.

Measures for similarity computation

There is a vast corpus of research on how to measure similarity between melodies using computational models, usually inspired in methods for string comparison (Crawford et alt. 1998, Mongeau and Sankoff 1990).

We implemented several melodic similarity measures. As a preliminary study, we have computed some of them so far to find out which measure would be the most appropriated for our study. For the time being, we have dealt with two different measures.

The first one is the *correlation coefficient between note histograms*. We measured how interval distributions correlate without considering its ordering. Correlation indicates the strength and direction of a linear relationship between two random variables. We obtained this coefficient for each pair of pieces, resulting in a similarity matrix.

The second measure considered was the distance between the note sequences: *the edit distance* (Mongeau and Sankoff 1990). It is a metric that counts the difference between two sequences under certain operations. The edit distance between two strings is given by the minimum number of operations needed to transform one string into the other, where an operation is an insertion, deletion, or substitution of a single note. Both pitch and note duration information were considered in the algorithm, as they increases the discrimination (López and Rocamora 2005).

Phylogenetic trees

In addition to similarity analysis, a phylogenetic analysis is made in order to study relationships among the transcribed performances.

Several techniques exist for generating phylogenetic trees from distance matrices. Once we computed the different similarity matrixes, we generated a phylogenetic tree using the tool SplitsTree (Huson 1998). SplitsTree computes a tree with the property that the distance in the drawing between any two nodes reflects as closely as possible the true distance between the corresponding two pieces in the distance matrix. In Figure 5 we can see a SplitsTree generated with the similarity matrix between note histograms. As expected, due to the different melodic contour of every style, two clusters appeared: a first cluster with the *deblas*, and a second clearly distinct cluster including the *martinetes*.

Conclusions and future work

Melody is one of the most important aspects to be considered in the analysis of a cappella flamenco singing styles. Automatic melodic description tools can be effectively used to the analysis of flamenco singing. These automatic tools allow obtaining quantitative and qualitative measures that can complement historical and musical data (and other types) on the roots and evolution of oral transmission of flamenco styles.

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