A SEMI-AUTOMATIC METHOD TO PRODUCE SINGABLE MELODIES FOR THE LOST CHANT OF THE MOZARABIC RITE

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ABSTRACT

The Mozarabic rite provided the dominant context for Christian worship on the Iberian Peninsula and Southern France from the sixth till eleventh centuries. Over 5,000 chants of the Mozarabic rite are preserved in neumatic contour notation. Since pitch-readable notation only became in use in the eleventh century and hardly any Mozarabic chant was found in such notation, scholars believe that most Mozarabic melodies are irretrievably lost. Based on similarities between the chant of Mozarabic and other rites, this paper presents a method for the computational composition of melodies agreeing in all detail with our knowledge of the early Mozarabic neumatic notation. We first describe how we came to look for such a method. Then we give a detailed description of the eight steps of the method. Finally, we propose objective criteria that supposedly are indicative for the authenticity of our compositions, we restate our goals, and refer to several sound examples on the internet.

1. INTRODUCTION

The study of medieval chant-repertoires is of great importance for our understanding of the transition from primarily oral musical cultures to the written and notated history of Western music. At least five medieval chant-repertoires (partially) survive in pitch readable notation from the eleventh and twelfth centuries: Gregorian, Milanese, Old-Roman, Beneventan and Mozarabic chant. Their histories are closely related and go back to times long before the eleventh and twelfth centuries (Hiley, 1993; Fernández de la Cuesta, 2013). Two of these repertoires are also preserved in tenth-century neumatic notation: Gregorian and Mozarabic chant (see Table 1). The Mozarabic rite and its chant were officially abolished in 1085 and replaced by the Roman rite with its Gregorian chant. In Toledo, however, Mozarabic chant survived orally until it was partly notated in sixteenth century mensural notation. In these pitch-specific notations hardly any correspondence can be found with the early neumatic notation.

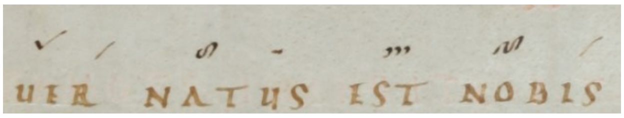

Figure 1. Beginning of the introit *Puer natus,* CH-SGs 339, St. Gall, Switzerland, 980-1000 (initial *P* omitted)

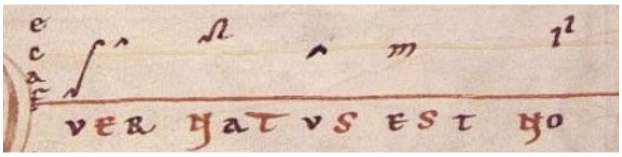

Figure 2. Beginning of the introit *Puer natus,* A-Gu 807, St. Florian, Austria, XII c. (initial *P* omitted). The two horizontal lines respectively represent the f (lower line) and the c' (upper line).

Neumatic notation was meant as a memory aid. It consists of a sequence of symbols written above the text, indicating the contour of the melody. For example, the first neume in Figure 1 refers to an ascending interval of two notes. The second neume represents a single note. The

	neumatic notation		correspondence	pitch notation		database
	century	*chants*		*century*	*chants*	*C*
GRE: Gregorian chant	X-XI	4,000	> 99 %	XI-XII	10,000	281
MIL: Milanese chant	-		-	XI-XII	3,000	167
ROM: Old Roman chant	-		-	XI-XII	3,000	141
BEN: Beneventan chant	-		-	XI-XII	200	51
MOZ: Mozarabic chant	X-XI	5,000	< 1 %	XI-XVI	500	149

Table 1. Estimation of the number of chants in five traditions, the correspondence between the two types of notation, and the number of chants in our database *C*.

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third neume represents an ascending interval followed by a descending interval. In the early sources, the exact sizes of the intervals are not indicated. The historic performer knew the melody by heart.[1] For us, the only way to obtain knowledge of the historical melodies is by consulting sources from later date that contain pitch-specific notation for corresponding chants. We can find these corresponding chants by comparing liturgical assignment (feast and function) and texts of the chants. For example, in Gregorian chant, the mass of Christmas Day starts with the introit *Puer natus.* Comparing unpitched tenth-century neumes of this chant (see Figure 1) with corresponding twelfth-century pitches (see Figure 2), we can see a perfect correspondence in musical detail. Both introits (most likely) refer to the same melody (`gd'-d' d'e'd'-c' c'c'c' d'c'e'd'`, on *Pu-er na-tus est no-*).

However, virtually all Mozarabic chants preserved in early, unpitched neumatic notation do not correspond to their pitch-readable counterparts, if these exist at all. Figure 3 shows the Mozarabic *Parvulus natus,* the sacrificium (offertory) for the mass of Christmas Day. Just to mention one striking difference, we can observe different numbers of notes in the two versions. The neume above the first syllable of *Parbulus* in León indicates a single note. Above the second syllable we see three notes: a single note is followed by a *clivis,* an ascending note followed by a descending note. Conform Rojo and Prado (1929) and González-Barrionuevo (2015) León thus shows 1-3-6, 1-2, 4 and 13-2 notes on the first four words, while Toledo shows 1-1-1, 3-3, 2 and 4-9.

Because of this lack of correspondence, the vast majority of Mozarabic melodies are unknown. Therefore, until recently, Mozarabic chant did not receive much scholarly attention. The contrast with Gregorian chant is reflected in the correspondence figures in Table 1. The availability of melodies would greatly improve our access to the lost tradition. As the exact reconstruction of the musical past obviously seems not achievable, in this paper we aim to construct historically informed, *singable* melodies that correspond with the neumatic contour notation of the early manuscripts. This, at least, will render the repertoire performable for contemporary ensembles.

Our first attempt was to compose chants manually ourselves. We put the results of this to the test by providing them to the ensemble Gregoriana Amsterdam during a regular rehearsal, without telling the source of the chants. The singers, however, did not accept the chants. They even guessed themselves that these were new compositions before they were informed about it. The melodies apparently disagreed too much from the styles familiar to them.

Next, we asked several professional composers to make melodies that agree with the early contour notations, in order to rehearse and perform these. One of them made several different compositions in different modes for several chants. We rehearsed and performed a selection of these (Swaan, 2012). A second composer explored her artistry in microtonal directions (Driessen, 2013). In all cases, however, the chants the composers produced, stylistically seemed not to correspond to our knowledge of the five traditional styles of Table 1. We became convinced that inviting modern composers was not the best option to recreate something of the lost Mozarabic music.

We set out to design a more objective method to find pitches that match the neumatic contour notation. We know that the five pitch-readable chant repertoires are interrelated (Hiley, 1993; Levy, 1998). Therefore, it is plausible to employ the melodic material from these traditions for our purpose. Our current approach is to automatically search a database of digitized chants from pitch-readable sources in order to retrieve a melody that matches the neumatic contour notation of a lost melody as much as possible. This procedure renders the lost melodies singable again using stylistically related historic melodic material.

This paper presents our method. We first discuss the representations we use. Then, the central steps of the method are presented. We propose a scoring mechanism to evalutate the authenticity of the retrieved melody and conclude with some examples performed by Gregoriana Amsterdam on YouTube.

Figure 3. Beginning of *Parvulus natus,* top, E-L 8, León, early X c; bottom, E-Tc Cantoral I, Toledo, early XVI c.

[1] In fact, the historic performer did not perform from notation at all. In the best case notation was only used as a reference (see Hiley, 1993).

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2. METHOD

The method we propose consists of the following eight steps:

1. Represent the neumes as sequence of contour letters *t*;
2. Construct a database *C* with pitched melodies;
3. Divide *t* into phrases;
4. Find a matching source melody *s* for *t* in *C*;
5. Make a raw composition r_0 based on *s*;
6. Adjust for recurring formulas;
7. Adjust for singability;
8. Transcribe and perform.

These steps will be explained in detail in the following subsections.

2.1 Step 1: Represent the Neumes as Contour Letters

To represent the melodic contour information of the tenth-century neumatic notation, we designed a representation with an alphabet of six symbols, {h, l, e, o, b, p}, each representing a note of the (lost) melody. This representation can be considered an extension of the Parsons code (Parsons, 1975; Randel, 2001; Maessen, 2015). We use the letter h for a note higher than the preceding note, the l for a note lower than the preceding note and the e for notes of equal pitch. The letter o represents the first note of each chant, and also all notes for which the relative height with respect to the previous note is not determinable. In principle, this is the case for the first note of each neume. This would imply many o's in the transcriptions. This is undesirable since in order to represent as much contour information as possible in the transcription, the number of o's should be as low as possible. In many cases, however, the vertical position of a neume provides some indication of the pitch height with respect to the previous neume, enabling us to avoid the use of an o for the first note of the neume. To cover some remaining uncertainty, we also defined the letters b and p, respectively representing notes higher or equal, and lower or equal.

Apart from these letters, dashes and numerals are used for interpunction: 1 indicates the beginning of the chant, 5 the end, 4 the end of a main part of the melody and 3 a division within main parts. Three consecutive dashes, ---, indicate the beginning of a new word; two dashes, --, a new syllable and one dash, -, a new neumatic group.

We designate the lost melody represented by the tenth-century neumes with *x*. The transcription into contour representation we call *t*.

2.2 Step 2: Construct a Database with Pitched Melodies

Since eleventh and twelfth-century manuscripts do not provide information about rhythm and meter, but only about pitch, embellishments and interpunction, we are able to use the encoding developed for the music font Volpiano[2] to represent the melodies of pitch-readable chants in the database. In Volpiano font the characters 8, 9, a, b, c till o, p, q, r, s, represent the pitches F, G, A, B, c' till g'', a'', b'', c''', d''' on a five-line staff, the i being the flat sign on the third line. Numerals and dashes represent the interpunction as described in Section 2.1. For example, if we typeset the string "1---h-j-k-" in Volpiano font, we obtain .

We designate the database with *C*, and the *i*-th chant in the database with c_i.

Currently *C* is a subset of all chants referred to in Table 1 (see Table 1). For each of the five traditions all chants of four specific genres (tracts, cantus, benedictiones and offertories) are included. These belong to the longest chants of these traditions. From each tradition, several other chants are included as well, making *C* a collection of nearly 800 chants, good for almost 250,000 notes.

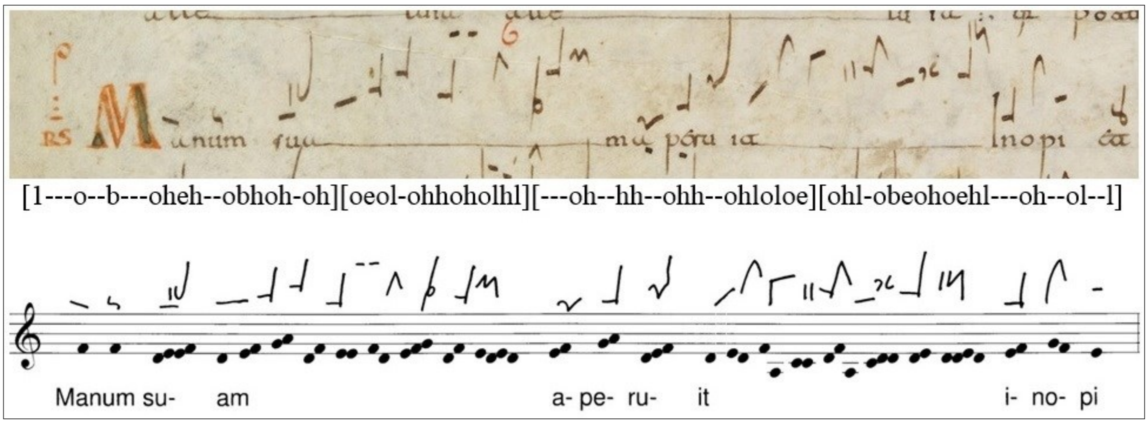

Figure 4. Beginning of the responsory *Manum suam aperuit* for St. Martin; top: the neumes of León, early X c.; between square brackets the transcription to contour letters; bottom: the final composition with León transcription.

[2] Volpiano font has been developed by David Hiley and Fabian Weber at the Institut für Musikwissenschaft of Regensburg University, it is downloadable from: http://www.uni-regensburg.de/Fakultaeten/phil_Fak_I/Musikwissenschaft/cantus/

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2.3 Step 3: Divide *t* into Phrases

It is of course possible for the database to contain a melody c_i that fully corresponds with the contour *t*, and thus might be the lost melody *x*, but we consider this very unlikely. Nevertheless, our method is designed in such a way that *if* the lost melody is included in the database, we will find it. In any case, we do expect to be able to find a c_i that provides melodic material that sufficiently corresponds with *t*. In most cases, this will not be a correspondence between the complete contour *t* and c_i, but parts of c_i may correspond to parts of *t*. Therefore, our strategy is to manually divide *t* into melodic phrases. In our contour representation, these phrases are represented by square brackets (see Figure 4 for an example). We designate the *j*-th phrase in *t* with t_j.

To perform the division into phrases, we need an indication of the optimal phrase length. Phrases of one note would match to every melody of equal or greater length. Phrases of the full length of *t* would, in most cases, match no melody in *C* at all. Experimentally we found the best results for phrases between 9 and 18 notes, with the optimum around 12. We perform the segmentation into phrases by hand, as much as possible in accordance with the grammatical and musical syntax of *x*, as witnessed by the early neumatic notation. For different purposes the length of the phrases may be different (see Section 2.5).

2.4 Step 4: Choose a Source Melody

In our method, the final composition *r* (result) is based on a melody c_i that is closest to *x*: the source melody *s*.

Given the specific features of the transcribed chant *t*, and knowing the repertoire, we could choose a source melody c_i by hand from similar chants in related pitch-readable traditions GRE, MIL, ROM, BEN and MOZ (see Table 1). The similarity would be based on liturgical assignment, text, genre, and structure. Sometimes we may also have information about mode or historic relations of the lost chant, in which case we could prefer a source chant in a specific mode from a specific tradition.

Instead of choosing a single source melody by hand, however, it is preferable to create a database *C'* based on all these features – where *C'* is a subset of *C* – and automatically retrieve a suitable source melody *s* from *C'*. To this end, we computationally search matches for all phrases t_j of *t* in the melodies of *C'*. We implemented a brute force string matching algorithm to perform this search. The algorithm finds exact matches for a given t_j by comparing the sequence of contour letters in t_j with the notes of the melody string c_i at all possible positions in c_i. To compare a contour letter in t_j with a note in c_i, the interval that the note in c_i makes with a previous note is used. In case of a skip (explained below), not the direct preceeding note, but a more previous note is used. As a consequence, we cannot use a representation of the melody in which each note is represented as the interval with the direct preceeding note. This also prevents us from using a standard alignment algorithm on sequences of intervals.

The algorithm allows to skip a maximum of n_{skip} notes of c_i between each consecutive pair of matching notes in c_i. n_{skip} is a user-provided parameter of the algorithm. The higher n_{skip}, the more likely we find a match for a phrase t_j. However, for higher n_{skip}, the execution time increases, as well as the possibility to obtain perceptually unexpected successions of notes (see Section 2.7). For larger databases, n_{skip}=0 or n_{skip}=1 should be preferred. By using an exhaustive search rather than, for example, a string alignment approach, we are able to exactly control the maximum number of skipped notes.

The aim is to find the melody c_i that has matches for as many phrases t_j as possible, while each of these matches is as good as possible. To assess the quality of a phrase match, we introduce a numerical score based on two properties of the match: the total number of skipped notes and the position of the match within the full melody.

Figure 5 shows an example of a match m_j for contour `[olhollhohoh]` in a database melody c_i. Two notes of c_i needed to be skipped for the contour t_j to match the sequence of pitches.

For each phrase t_j in *t*, we compute the scores S_{skip} and S_{pos}. The score concerning skips is computed as

$$S_{skip} = max\left(0, 1 - \frac{skips}{\frac{1}{2}\left|t_j\right|}\right),$$

where *skips* is the total number of skipped notes, and $\left|t_j\right|$ is the length of phrase t_j from *t*. We include a factor ½ because we consider it undesirable to have more skips than half of the length of the phrase. In the example in Figure

```
ci   …  k  h  l  h  k  j  h  h  g  k  j  h  k  l  m  m  l  …

mj            l  h  k  j  h     g  k  j     k  l  m

tj         [  o  l  h  o  l     l  h  o     h  o  h  ]
```

Figure 5. Example of a match m_j for phrase t_j in database melody c_i. Two skips were needed to fit contour t_j to the notes of c_i.

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5, the total number of skips is 2 and the length of t_j is 11, so the score S_{skip} is 0.64.

The score for position, S_{pos}, is computed as:

$$S_{pos} = 1 - \left|pos(t_j) - pos(m_j)\right| ,$$

where $pos(t_j)$ is the position of the first note of t_j relative to the full length of t, and $pos(m_j)$ is the position of the first note of m_j relative to the full length of c_i. $pos(t_j)$ and $pos(m_j)$ both are real numbers in [0,1], where 0 is the position of the first note and 1 the position of the last note.

We compute one score for the entire melody c_i according to

$$S = \lambda\overline{S_{pos}} + (1 - \lambda)\overline{S_{skip}} ,$$

where $\overline{S_{pos}}$ and $\overline{S_{skip}}$ are averages over the phrases, and λ is a regularization parameter that determines the relative weight of the scores. Experimentally, we found $\lambda = 0.7$ to be a good value.

A phrase t_j might have more than one match in a database melody c_i. In that case, we obtain multiple scores for c_i, one for each possible configuration of matching phrases.

The scoring scheme is designed such that if the lost melody x is present in the database, we will find it, since in that case we will not need any skips, and the positions of the phrases will exactly correspond.

The melody s, which will serve as the source melody, is the melody in the database that obtained the highest score S.

2.5 Step 5: Make a Raw Composition

Given the source melody s found in step 4, we make a raw composition r_0 for t. This is the sequence of closest matches in s for the sequence of phrases in t. The procedure to construct r_0 is completely analogue to the procedure to find s in step 4. The crucial difference is that we replace the database C with the single source melody s, such that we find matches for all phrases of t in s. In the case that we do not find a match for a phrase t_j, we increase n_{skip}, accepting longer skips. If necessary, we also can adapt the segmentation of t to obtain shorter or longer phrases. By following this procedure, we get a composition for the lost melody that is entirely based on the melodic material from one other historic melody.

2.6 Step 6: Adjust Formulas

Many of the chants in neumatic notations will exhibit recurring patterns, *formulas* (intra-opus repeated segments) of between approximately 7 to 18 notes. As is the case in the five pitched traditions, it may be preferable to give specific formulas in all (or at least most) instances the same melodic content in our composition. To do so, we proceed as follows: we detect the formulas manually, we either manually pick a preferred pitch sequence (from r_0), or we calculate the closest matching sequence (as in step 4) of t_j in s, where t_j is a transcription of the formula to contour letters, and substitute this for the preferred formulas. The resulting melody we designate with r_1.

2.7 Step 7: Correct for Singability

Although steps 5 and 6 may seem to include some arbitrary decisions, the most subjective step is 7. It consists in singing r_1 and deciding (if necessary) to adjust the melody in minor details, or, in some cases, even greater parts. For many melodies this is necessary, since some pitches of r_1 may be judged to be very uncharacteristic for the style, especially at beginning and end of phrases. It may be good to "normalize" these manually, in agreement with our knowledge of medieval style. For the same reason, it may also be good to transpose some phrases a second, a fourth or a fifth. The criterion for these adjustments, however, should be that a small change should generate a great improvement in the melody, thus producing the final composition r. The number of adjustments can be considered an indication for the quality of our composition. We judge adjustments above 5 % of the total number of notes to become problematic. For those cases, we better start new calculations with different phrase divisions, other source chants and/or other pitch sequences for formulas. The 36 chants in Maessen (2016) have an average correction percentage of 3.95 for only first calculations. For the complete melody of Figure 4 we needed only 1 correction in 195 notes (we lowered the final pitch from e to d).

2.8 Step 8: Transcribe and Perform

After completion of the final composition r the musical score must be produced to enable others to sing the chant. Since our database consists of chants represented in Volpiano font (see Section 2.2), our compositions are also in Volpiano font. Therefore, we can easily transform our compositions to printable scores. Copying the original neumes above the score (see Figure 4) has proven to be a good way to give directors and singers inspiration for the manner of performance, especially concerning duration of notes and embellishments. The influential semiological interpretation of Gregorian neumatic notation (Cardine, 1968; González-Barrionuevo, 2015) can be considered important for their interpretation. See the original neumatic notation running along with the performance of Example 4 (and some other chants) by Gregoriana Amsterdam, uploaded to *YouTube*.[3]

3. EVALUATION

We do not claim lost melodies of the Mozarabic rite to survive in any number in pitch notation. We neither claim

[3] Accessible at: https://www.youtube.com/lelalilu

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they did not. All steps in our method are developed with the possibility in mind that *if* the lost melody *x* would be included in our database, our final composition *r* will represent it. Maessen (2015) gives some examples of the original melody *x* found this way. Melodies very close to *x* may also be represented by *r*. However, although our method always finds a melody, not all possibly related melodies to *x* will be found. Many closely related melodies simply disagree too much to be found with our method. For the melodies we do find, several indications can be a sign that we are on the wrong track for recovering the lost melody. The more we have to shorten our phrases, increase n_{skip}, or have to adjust notes to singability, the less likely our composition is related to the lost melody.

In order to make any claim on the relationship with the lost chant, we could have developed a rating system in which all these kinds of aspects for each composition were combined. We chose, however, not to proceed this way, because our main concern is not any authenticity claim. Our concern is the semi-automatic production of singable melodies agreeing in all detail with our knowledge of the early notation. We believe that we can only understand something of the deeper layers of the lost tradition through the singing of its chant. Even without any authenticity claim we can experience many aspects of the lost musical tradition through its singing. Notably, the way the texts interact with the alternation of syllabic and melismatic passages, and the way recurring formulas interact with non-formulaic passages.

Since our first compositions in 2014, we are working on the improvement of the method in order to come to better melodic results. This paper presents the state of affairs in February 2017. An apparent weakness in our method still is the fact we do not use the interpunction encoded in Section 2.1. This information could make it possible to align not only single notes, but also, syllables, words and even sentences. There are many other problems we are still working on. We are also experimenting with generative probabilistic models and pattern detection algorithms. We do think, however, that our method, even in this stage, might be relevant for the comparison of other oral musical genres where rhythm and meter are not clearly prescribed in notation. Apart from Western and Eastern medieval liturgical music, we can think e.g. about troubadour songs.

Although it is not our main focus, and there is still a lot of work to be done, we can get some idea of the authenticity of our compositions when we consider the score *S* we obtain in step 4 (see Section 2.4). A score of 1 would indicate a 100 % agreement of the phrases of contour transcription *t* with our source melody *s,* i.e., no skips would be needed and the positions of the matches in *s* would exactly agree to the positions of the phrases in *t.* In most cases (average and more complex chants) this would (most likely) mean that we would have found the lost melody *x*. Under specific conditions, scores greater than 0.7 could indicate a close resemblance to the lost melody.[4] Up till now we recomposed and performed over 100 Mozarabic chants of diverse nature for several occasions. Most scores we found are below 0.4, indicating that we did not find lost melodies. Our compositions, however, can be sung. Some people even think some of them are beautiful. In all cases, however, our compositions proof perfectly suitable for liturgical practice. Examples of complete compositions can be found on *YouTube* and in Maessen (2015 & 2016).

[4] Maessen (2016) illustrates these conditions.

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