Encoding and publishing critical editions of medieval music with MedMel (with a special focus on Romance-language lyrics)

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In recent years, medieval musicology has experienced significant growth in the digital realm, leading to the creation of large databases such as the Cantus Database,[1] the Corpus Monodicum,[2] the Troubadour Melodies Database[3] and Cantigas de Santa Maria for Singers.[4] Additionally, software applications for the optical recognition of medieval music notation have emerged.[5] These projects employ different encoding formats and practices, each tailored to specific needs related to the level of detail required, visualization tools used and data input efficiency.

The most widely used standard for encoding medieval music is Volpiano—a font that displays melodies in modern stemless notation.[6] Yet, today, scholarly efforts are increasingly projected towards MEI (Music Encoding Initiative)—a highly expressive XML standard.[7] MEI's 'neume module' is specifically designed to encode medieval music.[8] Software like Gregorio, available online through the Illuminare tool, is optimal for Gregorian chant, while Neon.js—a web application that allows users to trace the notation onto a manuscript image and visualize an MEI file—can also be used to transcribe medieval notation.[9] The options available for traditional paper editions, however, are limited: desktop editor software for modern Western notation is typically used to display neutral stemless notation. The main challenge for all these tools is the balance between the steepness of the user's learning curve, the time required for encoding, the expressivity and accuracy of the encoded information, and the quality and flexibility of the visualization. Each tool has its strengths and weaknesses according to the specific purpose for which it was developed.

To tackle these challenges, MedMel: The Music of Medieval Vernacular Lyric provides an online platform of digital editions of medieval monodic music.[10] MedMel is primarily a database through which high-quality music digital editions can be accessed and visualized. Furthermore, the online repository and the viewer are combined with analytical tools to query the database as well as an advanced editor tailored for medieval notation, through which MedMel digital editions are created. From encoding to publication and in-depth study, MedMel offers a seamless, end-to-end solution for exploring vernacular musical repertories. It has been developed specifically for non-mensural monodic medieval music, with the dual aims of enabling detailed representation and efficient data entry. Designed for academics who work with melodic corpora of any scale, MedMel supports the creation of both digital and printed editions. It also provides a user-friendly way for scholars to generate high-quality images and excerpts for their publications. While tailored to the medieval Romance-language lyric repertoire, MedMel is highly adaptable, extending its possible use to other domains of medieval music. Its potential reaches across disciplines, serving not only

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musicologists, but also philologists, palaeographers and performers.

Towards a critical edition of the Romance-language monodic repertoire

Printed editions of troubadour and trouvère melodies have been fundamental tools for medieval scholars. Editions such as those published by Hendrik van der Werf are examples of great accuracy and the complete edition of trouvère melodies by Tischler accomplished a monumental undertaking.[11] Nevertheless, as with other available editions, these works remain the expression of specific methodological approaches: Friedrich Gennrich and Hans Tischler offer mensural interpretations, though it is widely acknowledged that the notation of these melodies in most manuscripts does not specify rhythm and speculative rhythmic interpretations in modern Western notation are considered inconsistent with current academic standards.[12] While it has the merit of providing information on the shape of the neumes upon the melodic transcription, the edition curated by Ismael Fernández de la Cuesta presents several inaccuracies, failing to display the music according to the prosody of the lyrics and accompanying the melodies with a text that was established on an arbitrary basis.[13]

Providing a new, comprehensive digital edition of the Romance-language lyric corpora would mark a significant advancement in the field, while the dynamic visualization enabled by digital formats can accommodate diverse research goals, surpassing the limitations of print. As Daniel E. O'Sullivan observes, musical editions of vernacular repertoires have traditionally struggled to balance readability and accuracy, especially in representing melodic variance.[14] Moreover, the choice between transcribing in modern or medieval notation has long been a subject of debate—a challenge that dynamic visualization can help to address.[15] Most importantly, digital encoding represents a transformative opportunity for large-scale analysis across the corpus.

Principal features of MedMel digital editions

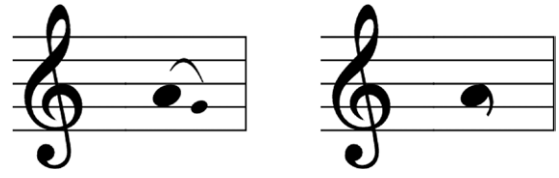
MedMel is primarily a database that is aimed at hosting the entire repertoire of the melodies of French, Occitan and Galician-Portuguese medieval lyric in both modern and medieval notation. MedMel digital editions are freely accessible and indexed by title, author and identifier in the repertories, language and manuscript in which they are preserved.

The visual rendering of MedMel exceeds print-quality standards, allowing scholars to enjoy the benefits of a digital format without compromising the quality afforded by print editions. Among the advantages of digital encoding is the possibility of going beyond methodological stances and preferences that shape how an edition is visually represented and organized from the form of liquescent neumes to the visualization of the text.

In Modern Notation mode, the music is displayed on a five-line stave as stemless noteheads without any indication of duration; groups of notes that are sung on the same syllable are connected with a slur. According to the generally agreed editing standards of metrical texts, each line of music corresponds to a metrical line and each syllable is aligned vertically with those which, in the other lines, occupy the same prosodic position.

In order to accommodate different editorial approaches, users can choose to display or hide the line number, to show the standard G-clef or the octave G-clef and to display liquescents as two different notes—the second smaller in size—connected by a slur (shown on the left in illus.1) or as a single note with a comma-like tail, as is customary in troubadour and trouvère editions by van de Werf (shown on the right in illus.1).

An algorithm analyzes the encoded melody to automatically generate its melodic structure, which can be displayed at the top left of the musical line in Latin or Greek characters, hidden or replaced with custom values, as needed. Automating the analysis of melodic structure can make the process both faster and more consistent. While scholars may interpret melodic structures differently, this application



1 Options for rendering liquescents in modern notation

ensures that all melodies are analysed with uniform criteria, providing a standardized basis for comparison. Classifying songs by melodic structure has proven effective, as shown by Elizabeth Aubrey in her study of the troubadour corpus.[16] Although both Raynaud–Spanke's catalogue and Tischler's edition include melodic structures, no comprehensive study has yet undertaken a broad comparative analysis of musical structure in the trouvère repertoire, which could be facilitated by a digital approach.[17]

To generate the melodic scheme, every melodic phrase—understood as the notes that are sung on each metrical line—is compared with all the following ones. Lines are compared syllable by syllable with the following outcomes:

- if the total of matched syllables is higher than 80 per cent, then the letter assigned to the first of the two compared lines is also assigned to the second;
- if the score is between 80 per cent and 45 per cent, then the same letter is assigned, but a prime symbol is added to the second;[18] multiple prime symbols can be assigned to differentiate between multiple variations of a melodic phrase;
- with less than 45 per cent of matching syllables, a new letter is assigned.

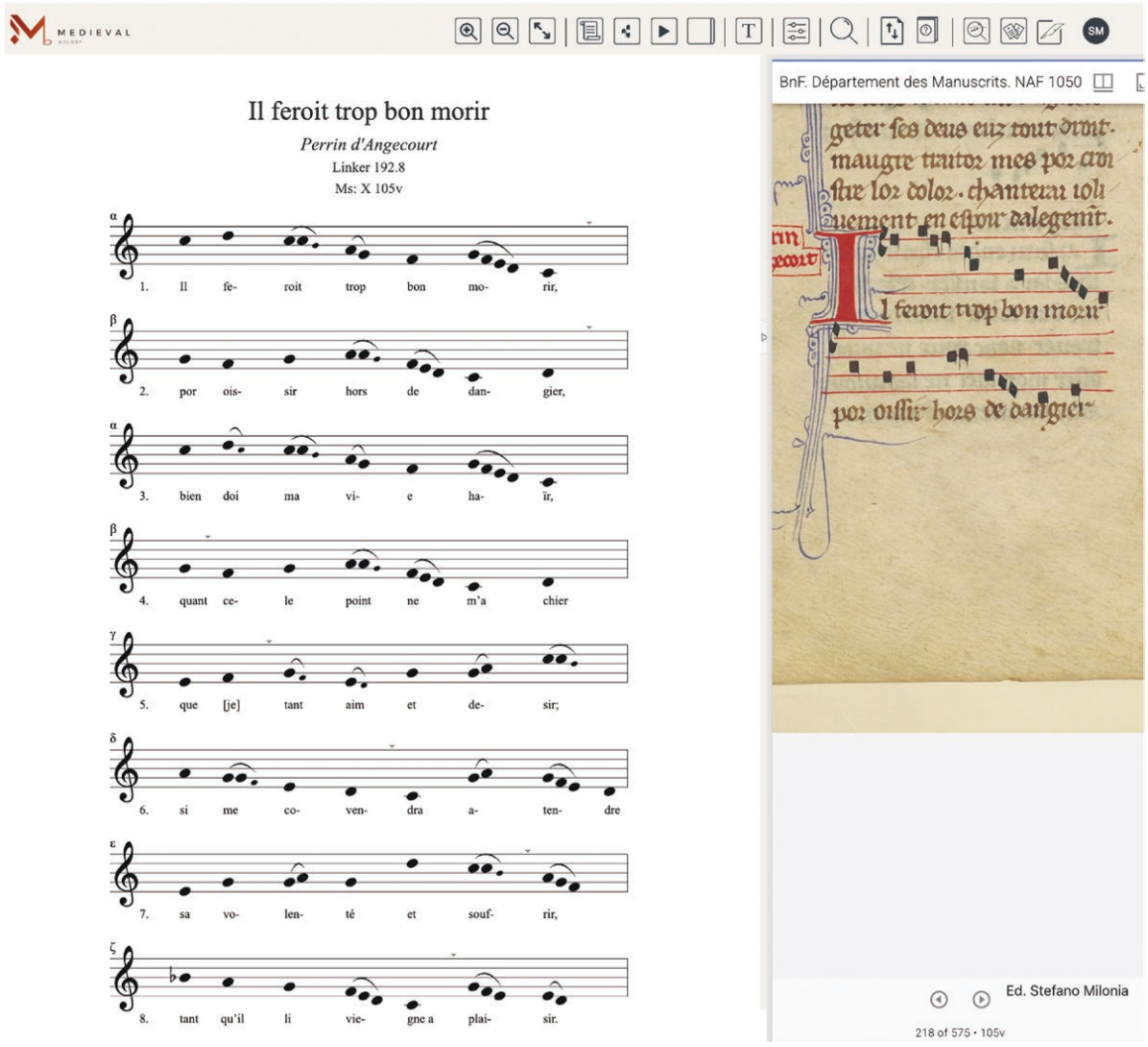
A few adjustments are added to this logic to take into account the ending note of the musical phrase: a 10 per cent bonus is given to the lines that end with the same note; if the last note does not match, then a prime symbol is added to the letter of the second line even if the score is higher than 80 per cent.

As Susan Boynton has observed, the conventional method of editing medieval song—in which the melody is paired solely with the text of the first stanza—poses challenges, particularly from a performative perspective.[19] MedMel addresses this issue by allowing the visualization of multiple stanzas. Corresponding textual lines from all stanzas can be displayed beneath a single melodic line ('concise visualization')—a format that facilitates analysis of the relationship between prosody and music. Alternatively, each stanza can be presented with its respective text and melody ('extended visualization')—an arrangement that may prove especially beneficial for performers. Additionally, it is possible to create editions with multiple versions of a text—for example, a diplomatic transcription that strictly adheres to the source, an interpretative version with modern punctuation or editorial corrections or a version with normalized spelling accessible to a broader audience.

Transcriptions are accompanied by a facsimile of the relevant manuscript folio displayed on the right side of the screen when available in a public repository. Based on a list of International Image Interoperability Framework (IIIF) manifests of musical manuscripts of the Romance-language tradition, the siglum and language of the source and the folio number, the application retrieves the correct page and displays it via a Mirador viewer (illus.2 and illus.3).[20]

The full synoptic edition of a work is available through the MedMel synoptic viewer, which automatically retrieves and aligns concordances. This tool can also be used for comparative analysis between any melodies in the database (illus.4). The comparison is enhanced by two key features: all melodies are compared against the first one, and similarities and differences are automatically detected. The comparison rigorously aligns each syllable with its corresponding note, ensuring a precise syllable-by-syllable and note-by-note analysis. The user can then choose to hide identical variants in the compared melodies (illus.5), highlight the differences (illus.6) or both. The synoptic viewer additionally allows readers to customize the order of stacked witnesses so that the base melody—against which all others are compared—is not fixed, as in a paper edition, but can be adjusted according to the needs of the analysis.

As the vast majority of the music of Romance-language lyric does not preserve any indication of duration, auditory rendering is, to some extent, arbitrary. Nonetheless, a music player can provide a wider audience with a practical guideline for approaching these melodies. The generated melody retains a degree of abstraction, beginning with the anachronistic piano timbre, which was chosen to provide the listener with a standardized sound so that pitch remains the only relevant element. The duration assigned to the notes is dependent on its context and, while arbitrary, is consistent. This practical system is inspired by the main feature of Robert Lug's theory on the 'micro-rhythm' of the

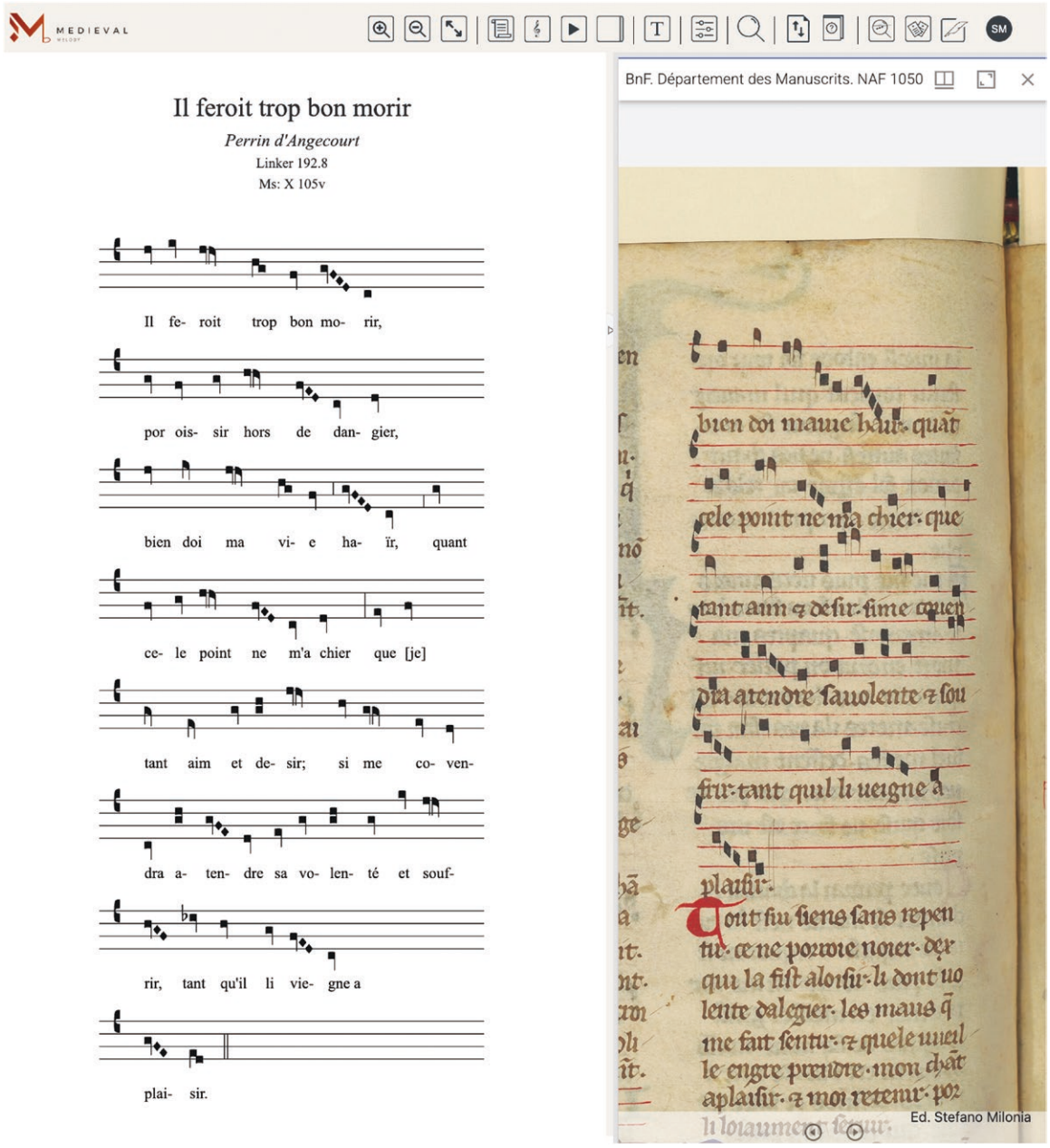


2 Transcription of Perrin d'Angicourt's *Il feroit trop bon morir* in modern stemless notation on the left compared with the Mirador visualization of the source's facsimile (detail of fol.105*v*) on the right. Source gallica.bnf.fr / Bibliothèque nationale de France

chansonnier of Saint-Germain-des-Prés, according to which 'the end note of a ligature is "naturally long"'.[21] The MedMel player assigns the same duration to single notes and the final notes of ligatures, while notes within a ligature are half as long. An exception is made for the final note of a two-note ligature, which is half the length of a single note.[22] The last note of each line is twice the duration of a single note. In this way, the melodic phrase, though far from aesthetically pleasing, retains a logical musical progression and is intelligible to the listener (see illus.7).

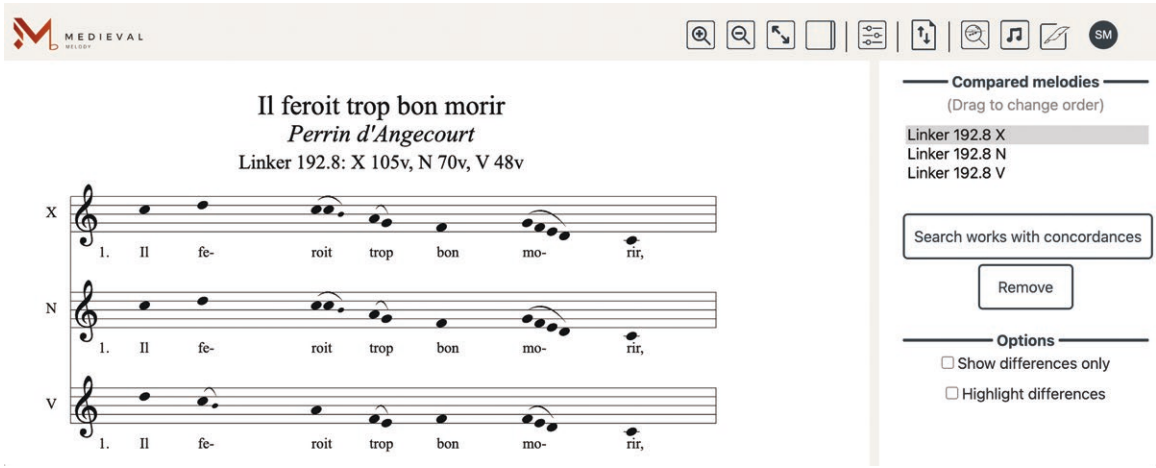
Search tools

One of the most relevant features for researchers in the field of Romance-language monody is the musical search interface, which allows users to input notes in order to search for a specific melodic sequence (see Illus.8). The search can be refined by entering crucial details such as liquescent notes and

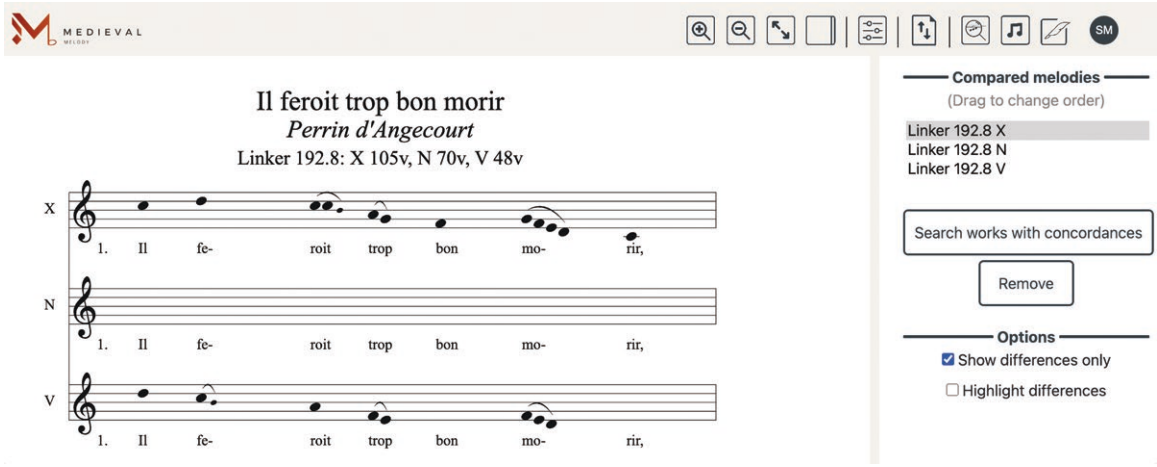


3 Transcription of Perrin d'Angicourt's *Il feroit trop bon morir* in square notation on the left compared with the Mirador visualization of the source's facsimile (detail of fol.105*v*) on the right. Source gallica.bnf.fr / Bibliothèque nationale de France

accidentals. In order to identify matches between medieval melodies, whereas oral and written transmission ordinarily determines the phenomena of variation and generates multiple versions of a song, the search tool is designed to recognize non-identical patterns. The most relevant feature, in this respect, is the possibility of selecting the degree of similarity between the input sequence and the melodies



4 Simple synoptic view

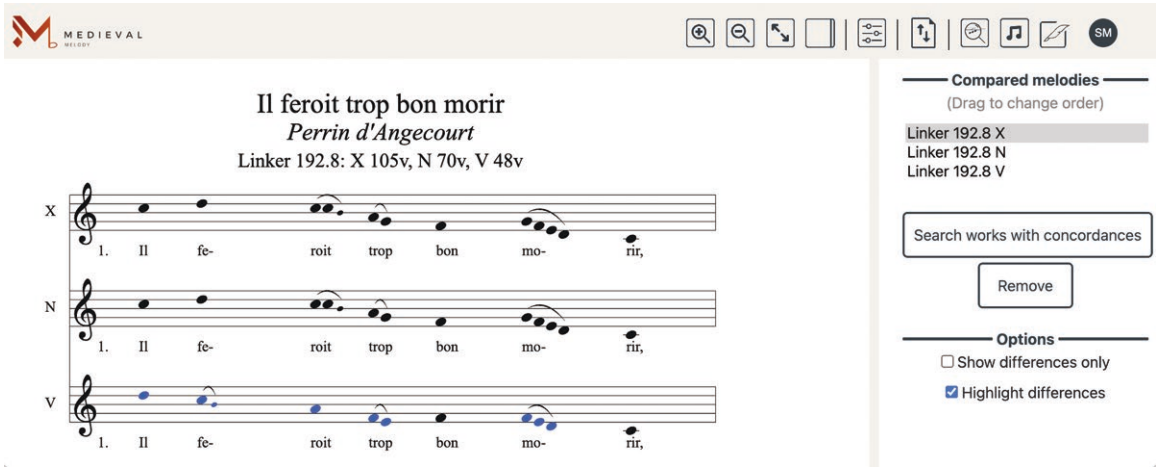


5 Synoptic view with only diverging variants visible

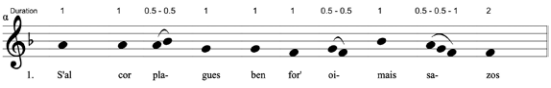
matched. This feature is based on an implementation of the Needleman–Wunsch algorithm.[23] Other important features are the possibility to search by interval, thus including the same melodic sequences set to different pitches; to consider or ignore the distribution of pitches across syllables; and, finally, to consider the liquescent nature of plicated neumes or process them as ordinary notes. Users can also define whether the sequence should be matched only when it appears at the beginning or the ending of the metrical line or match the whole line.

A second search tool has been developed to search melodic similarities between a whole song and the rest of the repertory, without requiring the user to input a melodic sequence.[24] This tool also allows the user to compare the selected songs with the liturgical repertory encoded in the Cantus Database.

The selected song is broken down into metrical units and compared line by line with every line of every song in the repertory. Here, a coefficient of similarity can be selected. Two fundamental parameters can be set: 'Consider syllable division'



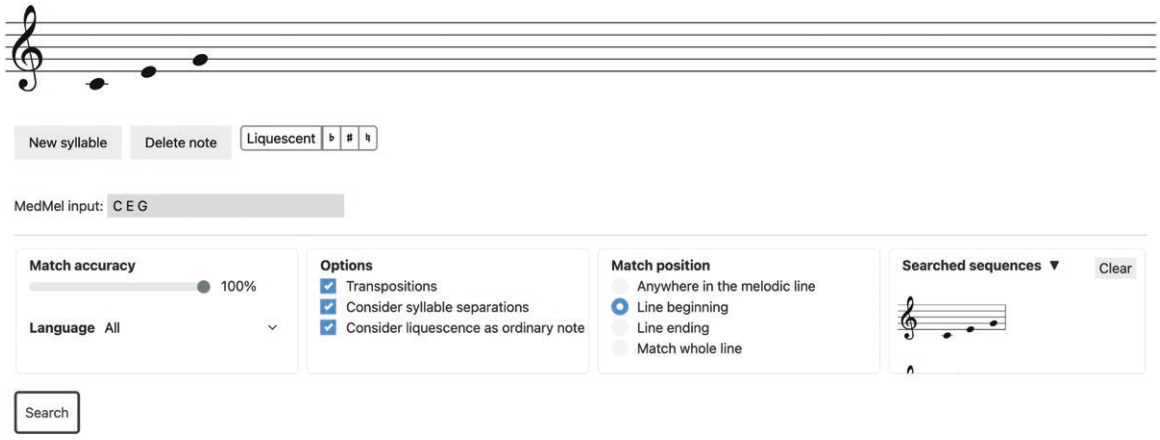
6 Synoptic view with diverging variants highlighted



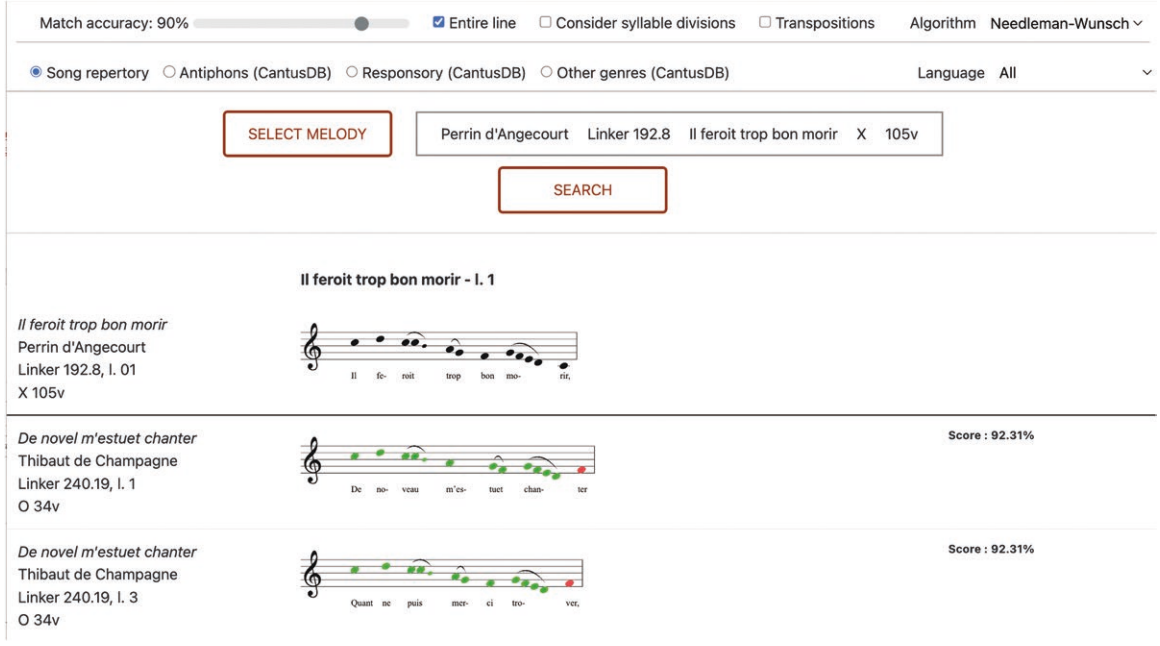
7 Example of a melodic line with duration automatically assigned in the audio reproduction, expressed in proportional values

and 'Entire line'. Unchecking 'Consider syllable division' compresses the melody into a continuous sequence of notes, thereby allowing for more flexible correspondences and shorter processing time. Unchecking 'Entire line' allows the tool to search for correspondences of the selected song's line within the lines of the searched songs. The match score will be calculated only within the limits of this match. If the 'Entire line' checkbox is selected, then it will calculate the match score against the entire line. This means that only lines of similar length are likely to match: it is important, then, to consider this aspect when comparing a song with relatively short lines with chants, which can have much longer uninterrupted melodies. Two algorithms can be used: the Needleman–Wunsch and a 'Syllable based' algorithm. This last mode breaks the melodic lines into syllables and compares them syllable by syllable. The comparison between syllables is calculated by using the Levenshtein distance.[25] This is a much stricter method for the comparison of melodies and is efficient when searching for contrafacta or reuse that involves a metrical component. To indicate clearly which notes constitute a match within a line, corresponding notes are highlighted in green whereas non-matching notes are coloured red (see illus.9).

Comparing the song by Perrin d'Angicourt with the available repertory, one connection emerges as being remarkably close. The first line of *Il feroit trop bon morir* (a melody repeated for line 3) is strikingly similar to the first (and third) lines of *De novel m'estuet chanter* (Linker 240.19, RS 1428) by Thibaut de Champagne, particularly as transmitted in Paris, BnF, fr.856 (trouvère O), although closing on a different cadence pitch. Here, both line 1 and line 3 of *De novel m'estuet chanter* received the same similarity score, even though line 3 is a slightly better match when considering the distribution of notes at syllables 4 and 5. This is because the search was conducted without accounting for syllable division. As a result, the method allowed the identification of two different renditions of a melodic segment, which are equivalent and interchangeable in performance. As the two songs also share a similar stanza structure—both composed of eight heptasyllables with comparable rhyme schemes (*Il feroit*: abab ac'aa; *De novel*: abab ac'c'a in stanzas 1, 2 and 5, and abab bc'c'b in stanzas 3 and 4)—the hypothesis of a stylistic influence cannot be ruled out, especially considering Perrin's artistic debt to the works of Thibaut.[26] Whether or not this particular case can be counted among these influences, examples of melodic similarities such as this are particularly relevant to the



8 Sequence search tool



9 Song search tool showing search of Perrin d'Angicourt's *Il feroit trop bon morir* executed with 'Consider syllable division' and 'Transpositions' checkbox unchecked, 'Entire line' checked and tolerance at 90 per cent

study of compositional techniques. Even when they do not reveal direct connections, they do help to define musical practices involving melodic formulas and their adaptability to different musical contexts. Here, for example, the opening must have been particularly suited to a heptasyllable and flexible enough for alternative melodic resolutions.

A comparative approach to the music of medieval lyrics has the potential to enhance our understanding of the musical grammar of secular monody.

Analysing patterns in the social, geographical and chronological contexts in which musical segments occur can reveal how local traditions and tastes evolved, as well as deepen our understanding of the nuances of musical aesthetics—elements that largely escape us today but were evidently crucial for audiences and performers at the time.

The MedMel editor

Editions in MedMel are created through the integrated editor, which was designed to be as user-friendly as possible while still maintaining accuracy and expressiveness. Encoding a melody requires no coding experience and the intuitive interface enables project contributors and external users to get started with just a few minutes of guidance—or even on their own.[27] The easy note input method makes it an exceptionally fast tool for manually transcribing medieval monody and the instant visualization of the melody contributes to minimizing transcription mistakes. Its interface has two encoding sections—Modern Notation and Medieval Notation: these are interconnected, ensuring that transcription and corrections are reflected in both visualizations.

Creating a critical edition of the entire Romance-language repertoire is a task that can only be accomplished through a long-term collaborative project. For this reason, the MedMel database has been designed to meet the needs of a research team. While any user can access the editor and store their personal projects and draft editions, project collaborators can contribute to a structured workflow for digital editions. They have the option to store drafts in a common repository, in which other project members can peer review, modify and finally publish them. Each transcription is associated with its curator, ensuring proper credit for their work. Metadata including title, identifier, author, language, manuscript and folio can all be specified, both to display the information on the edition and, for editions included in the public database, to ensure that they can be easily retrieved.

One feature that greatly simplifies transcription is the ability to input text separately. The text syllables are then automatically displayed beneath the corresponding note group. Text is entered in a modern layout, in which each line corresponds to a metrical unit. In Modern Notation mode, each line of text is aligned with its accompanying melody on a separate stave. In Medieval Notation mode, in which the musical system follows that of the manuscript source rather than metrical units, the text is aligned continuously, disregarding metrical line breaks.

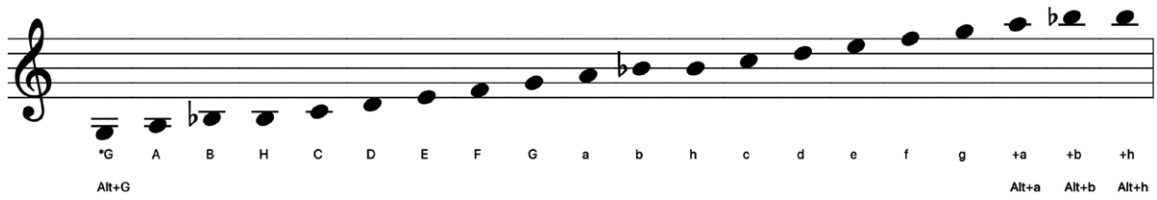
Syllables are separated by a hyphen, while an underscore joins two syllables in cases of elision. MedMel also provides an automatic syllable separator that exploits general linguistic principles. Although its efficiency varies depending on the specific language, it is applicable to all Romance languages.

A text area is dedicated to editorial notes or specifications, which are shown at the bottom of the page.

Modern Notation mode

In the Modern Notation interface, notes can be entered with keyboard commands or by typing the note names in the dedicated text area. The alphabetic notation reproduces the medieval system for the description of musical pitches: the case of the letter indicates the octave, the letter 'b' indicates B-flat (*mollis*) while the letter 'h' indicates B-natural (*durum*); the letter *Γ* and the notes of the highest octave are described by the signs *G and +a, +b, +h, +c, +d, as shown in illus.10.

Although rare, accidentals other than B-flat can be added to any note by using the signs: '_' for flat, '#' for sharp and '%' for natural.[28] The user can also indicate an implied B-flat by combining '_' with 'h': a small flat sign will be displayed on top of the B-natural, as it is customary to signal where an accidental is provided by the editor. Moreover, a key signature, limited to B-flat and B-natural, can be specified with the characters 'b}' and 'h}', respectively, placed at the beginning of the line (after the clef if there is one, see below) or mid-line. Manuscripts do not always follow an explicit rationale for how long an accidental affects the melody. Sometimes a B-flat at the beginning of the melody applies to the entire piece; sometimes it only affects a short part of the melody. Unlike a printed edition, which can adhere to a purely graphical principle by reproducing the visual appearance of the notation, encoding a melody requires specification of the actual pitch of the



10 Pitch encoding and visualization

note. This is not just a graphic mark on a page, but is also provided with unambiguous information in the MedMel editor (with the character 'b' or 'h'): this distinction is fundamental, such as when the transcription is exported to MEI or executed by the audio player. The different setting of the melody in the modern edition and in the manuscript may constitute an issue, as accidentals typically affect the melody until the ending of the manuscript's stave, which may contain only part of a metrical unit or extend across multiple units. To manage these fundamental issues and to adapt to different scribal habits, MedMel settings enable users to specify whether accidentals (limited to B-flat) are active for the entire piece, until the end of the metrical line or until the end of the manuscript system (possibly enclosing the key signature within square brackets when its effect extends onto a new modern staff line).

Encoding the divisions of metrical units and manuscript staff breaks thus plays a crucial role both for the visual rendering and in defining the effect of accidentals. For the music of metrical texts, the line breaks in the score of the edition must follow those of the metrical lines. On the other hand, metrical lines and staff lines do not coincide in the manuscripts. When the user is editing the melody in Modern Notation mode, line breaks in the notes' text area represent the separation of metrical units (lines of poetry) and correspond to the system breaks in the visualization; the system breaks of the manuscript are signposted in the notes' text area as single quote marker and represented in the score by a small downwards arrow. When the user switches to Medieval Notation mode, the note names remain the same, but the signposts are switched: separations of metrical units are signalled by a single quote and manuscript system breaks become line breaks. This allows the user always to keep track of the distribution of the music both as a metrical text and in its manuscript context.

Medieval Notation mode

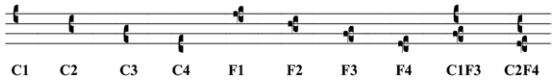
The Medieval Notation editor section inherits all the functionalities of the Modern Notation mode and allows the description of more detailed features of the manuscript. Almost every manuscript with musical notation of the Romance-language lyric tradition uses square notation, which is the standard employed by MedMel.

In MedMel clefs are encoded by their type (C or F) and the line number upon which they are positioned (counting from the top), as shown in illus.11. To be able to adapt to the different habits and inconsistencies of medieval scribes, it is possible to specify the number of lines in each system (including no line).

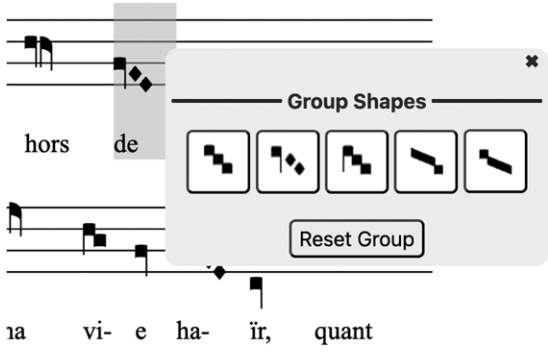
When the user inputs a note, a standard shape is assigned to it according to its position with respect to other notes of the syllable. The shape of the notes can be customized, however, by selecting from a visual menu (illus.12).

For note groups of fewer than four notes, it is possible to change the configuration of the entire note group (illus.13). Liquescent neumes are also considered as note groups. To represent more complex shapes, it is possible to select the shape of each single note (including liquescents), the presence and position of its stem and the line that connects it with the preceding note (Illuss.14 and 15).

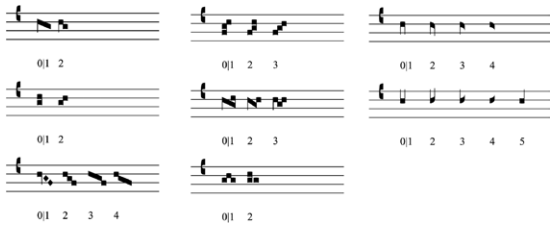
To optimize the process of transcription, it is possible to customize the default shapes for common note configurations. In this way, if a scribe consistently notates a single note as a *virga* instead of a *punctum* or a *clivis* as an oblique, then it will be possible to set them as default shapes and avoid specifying them at each occurrence.



11 Clef encoding and visualization



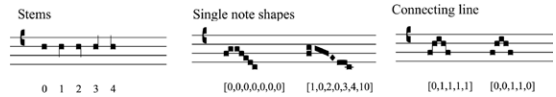
12 Group shape menu for *climacus*



13 Note groups modifiable at the group level from the visual menu, with corresponding encoding values assigned by the software. The first shape in each group configuration corresponds to 0 (or remains empty) when assigned as the default shape by the software (which updates if the default shape is changed). However, it corresponds to 1 when explicitly defined by the user, in which case it remains unchanged even if the default shape is modified

It is also possible to encode *divisiones*—the vertical strokes usually used by scribes to separate units of the melody. The description can be very specific, as it is possible to define the precise starting and ending points of the vertical line with respect to staff lines.

Finally, many medieval sources provide the singer with a guide note or *custos* at the end of each line that anticipates the first note on the line that follows.[29] It is possible to generate these guide notes automatically and adjust them in case of irregularities in the source or else to encode them manually.



14. Examples of elements modified at the single-note level: stems, individual note shapes and connecting line attributes, with corresponding encoded values assigned by the software. The value 0 represents the default and may also be empty. For single-note shapes, two ascending notes can form a *pes* shape (in which case the first note has a value of 1, while the second has 0 or no value). Two descending notes can form an oblique shape (where the first note has a value of 2 and the second has 0 or no value). Other values include *punctum inclinatum* (3), *longa* (4) and *punctum* with a ledger line (10)

As an example, illus.16 shows lines 3–5 of Perrin d'Angicourt's song, shown already in illuss.2, 3 and 9, as they appear in the editor. The right sidebar accommodates metadata attributes and widgets; the music and text are entered in the bottom bar. In this example, the first line visualized (line 3) corresponds to the encoding:

C1 c d(c) cc(h) aG F GFED C

The first element, C1, identifies the C-clef positioned on the first line of the stave: this is ignored in the modern transcription, but is relevant in the medieval visualization (illus.17). In line with the encoding standards outlined above (illus.10), the seven note groups corresponding to the seven syllables of the metrical line are divided by a space, the characters encoding pitches correspond to their common English names and the octave is specified by the caps of the characters. Pitches in round brackets indicate liquescent notes. The corresponding text line also has seven syllables, separated by either a space or a dash:

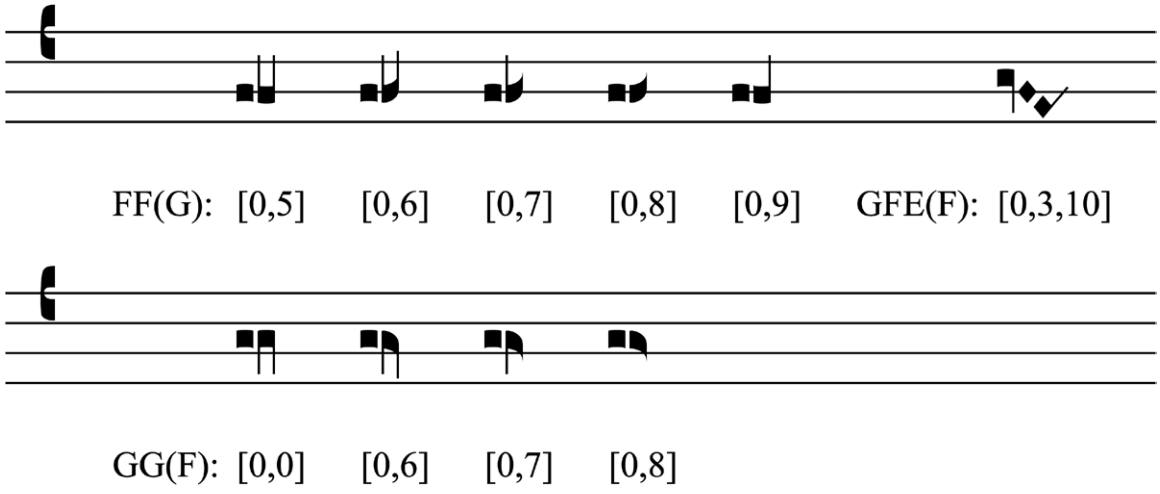
bien doi ma vi-e ha-ïr,

The correspondence in the number of note groups and syllables allows the automatic text–music alignment in the edition.

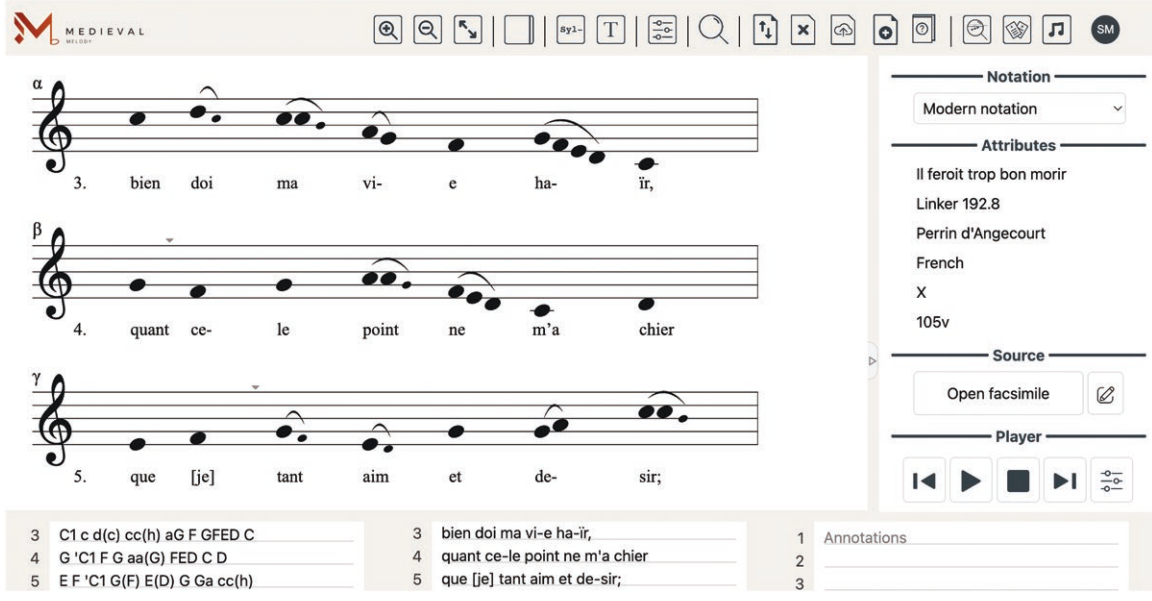
The following melodic line (line 4) shows an additional feature:

G 'C1 F G aa(G) FED C D

Here, a single quote marker follows the first note (*G*), indicating a system break in the manuscript. This is



15 Ligatures with final liquescent note. MedMel character encoding (input by the user) indicates the notes, including the liquescent inflection, in round brackets, indicating the ascending or descending movements. In square brackets, the values are associated with the single notes: in these cases, the first value is always 0 (or empty), the second value represents the noteheads shape of the main note of the liquescent neume, while the note representing the liquescent inflection always has an empty value and it is thus not specified



16 Editor view (Modern Notation mode) of Perrin d'Angicourt's *Il feroit trop bon morir*, lines 3–5, in Paris, BnF, nouv. acq. fr.1050, fol.105*v*

followed by a C-clef (C1), which is the first visual element of the source's stave. In Medieval Notation mode (illus.17), the encoding of the corresponding melodic segment, is:

C1 c d(c) cc(h) aG F GFED C 'G

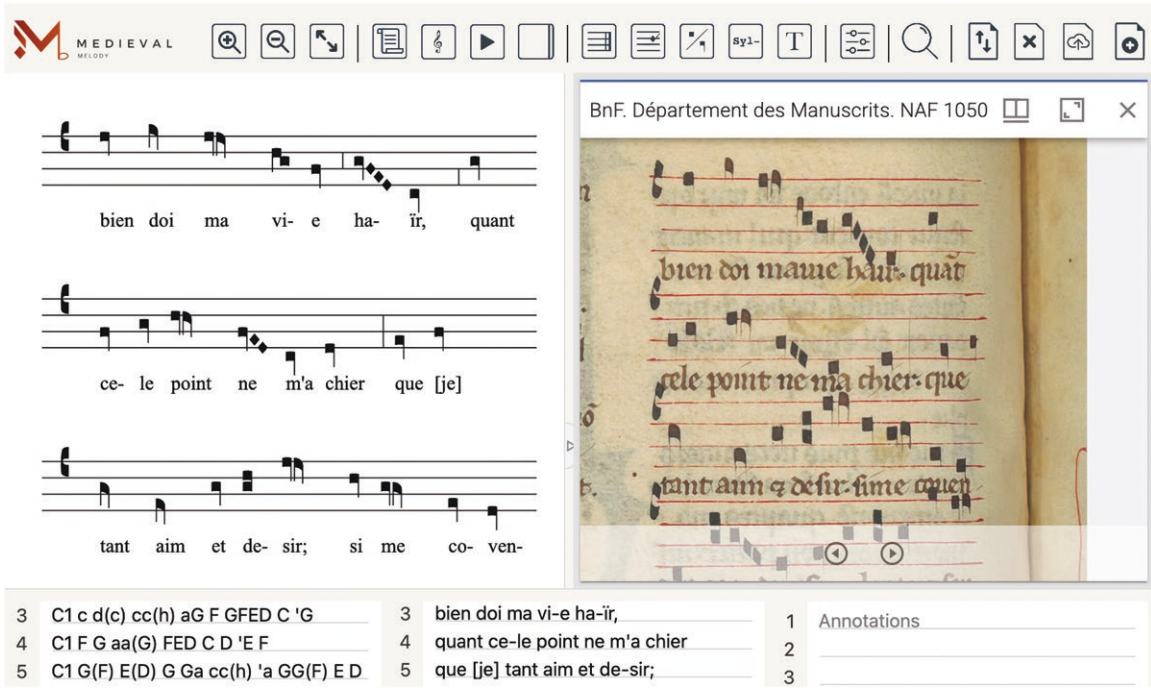
C1 F G aa(G) FED C D 'E F

Following the manuscript layout, the lines start here with the clefs and the single quote marker indicates the division between metrical lines rather than the system break in the manuscript. This switch in the input layout makes it easier for the user to follow the connection between visualization and encoding. In the second line of the column (l. 4 of Perrin's song), a text syllable is missing and can be reintegrated by the editor, re-establishing the correct correspondence between music and text.

While music, text and metadata are encoded directly and are stored in the database exactly as provided by the user, information about the shape of the note groups—that of the single notes, their stems and the line connecting them, and the *divisiones*, *custodes* and the number of lines of each stave—is encoded as arrays that are entirely managed by the software. This ensures that their complex structure and the correspondence to the relevant music element are preserved, while the user can define all the transcription's details through the interface. This not only provides a more intuitive transcription experience, but also prevents any encoding errors: the user may make reading mistakes but never generate an invalid input.

Illus.18 shows the information assigned behind the scenes for the first line of the transcription when using Medieval Notation mode, which corresponds to line 3 and the first syllable of line 4 in Perrin's melody.

At the level of the stave, information on features that affect the whole line can be modified from the visual menus and are encoded by the system as a single array. In the example provided, all staves in the song score, including the one visualized, are consistent in having four lines. As there are no *custodes* in the source, in this example, all values in the relevant array are null. Where present, a *custos* would be



17 Editor view (Medieval Notation mode, with facsimile) of Perrin d'Angicourt's *Il feroit trop bon morir*, lines 3–5, in Paris, BnF, nouv. acq. fr.1050, fol.105*v*

Stave level (values for whole song, underlined values corresponding to l. 3)

Lines in stave: [4, 4, 4, 4, 4, 4, 4, 4]

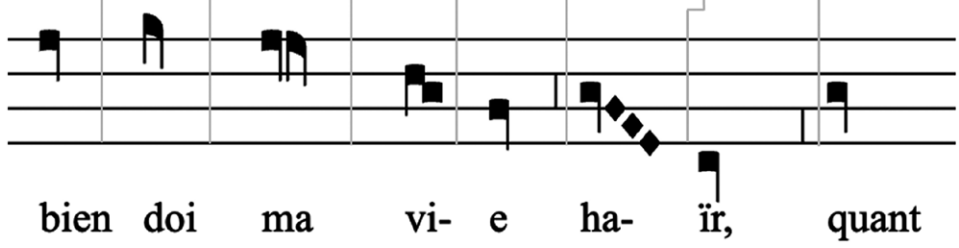
Custodes: [null, null, null, null, null, null, null, null]

Syllable level (values for l. 3)

Group note shape:	[null,	2,	null,	null,	null,	null,	null,	null]
Divisiones:	[null,	null,	null,	null,	[1,2,0],	null,	[2,3,0],	null]

Note level (values for l. 3)

Single note shape:	[[],	[],	[null,6],	[],	[],	[null,3,3,3],	[],	[]]
Stems:	[[2],	[],	[2],	[],	[2],	[2],	[2]	[2]]



18 Main arrays representing note shapes, with values aligned with the transcription of the first line of fol.105*v* in Paris, BnF, nouv. acq. 1050 (source gallica.bnf.fr / Bibliothèque nationale de France), corresponding to line 3 and the first syllable of line 4 of Perrin d'Angicourt's *Il feroit trop bon morir*

encoded as a numeric value, counting from the top line of the stave, including spaces. For example, a *custos* on the first line from the top is encoded as '1', and the one on the first space is encoded as '2'.

To avoid specifying the shape of each single note for a common configuration, it is useful to define the shapes of an entire note group. Behind the scenes, the shape of each note group in a manuscript line is stored as an array. The example above represents a line with eight note groups. Among them, seven retain their default shape (null), while only the second group (a *D* with a descending liquescence) has been modified via the interface. To determine the exact shape of a note group, the software combines the pitch configuration of the group with the numeric value assigned in the array.

The example importantly illustrates the matter of the default values for note groups raised above. As the notator of BnF, nouv. acq. 1050 consistently represents the *clivis* as it appears in the fourth syllable of the example, the default representation of a two-note descending group has been modified for the entire score (now assigned the value '2'; see illus.13). This ensures the desired shape without requiring further specification by the user (both the stem and group note shape values remain null or empty).

The example in illus.18 also illustrates the encoding of *divisiones*. A *divisio* can be assigned to a syllable and is encoded as an array of three elements, indicating the start position, end position and type of *divisio*, respectively. The position of the *divisio* is counted from the top line of the stave (corresponding to 0) and supports decimal numbers. In the example above, there are two *divisiones*, after the fifth and seventh syllables. The first *divisio* starts at height 1 (second line from the top) and ends at height 2 (third line from the top) and is type 0, indicating a simple vertical stroke (double strokes and a point after the *divisio*—found in Paris, BnF, fr.844—are also available).

The information on a single note is stored in a hierarchical array structure: each manuscript line is represented as an array, which contains sub-arrays for note groups. Within each note-group array, numeric values define the features of individual notes. In illus.18, the third and sixth syllables contain information modifying the shape of single noteheads. In the third syllable, the sub-array [null,6]

indicates that the first note of the group retains its default shape (that of a *punctum*) and the second note assumes that of a tilted liquescence with a right and a left stem (shape corresponding to the value 6, see illus.15).[30] In the sixth syllable, the value [null,3,3,3] indicates that, within the group, the first note has a default shape and the three following notes are *puncta inclinata* (corresponding to the value 3, see illus.14).

Similarly to the noteheads, sub-arrays for stems may include numeric values: in all syllables except for the second and the fourth, the first note has a downward right stem (corresponding to the value 2, see illus.14).[31]

While Perrin's song appears in the Saint Germain-des-Prés Chansonnier (Paris, Bibliothèque nationale de France, français 20050), the oldest songbook of both the Occitan and the French lyric repertoire, dating back to the mid-13th century, it is in a section that has space for staves and notation that were never entered.[32] Had they been notated there, however, it would still have been possible to encode in the Medieval Notation mode, even though this earliest source is the only manuscript to employ Lorraine notation (often referred to as Messine notation).[33] As in the case of square notation, a default shape configuration is assigned to individual neumes based on the intervals within the note group. This can then be modified by clicking on a note and selecting the desired shape. The number of possible configurations is greater than in the more regular square notation but, given the smaller corpus of melodies that employ this notation, it was possible to reproduce the complete set of shapes used by the chansonnier, as described by Robert Lug and extended when necessary (see illus.19 and illus.20).[34]

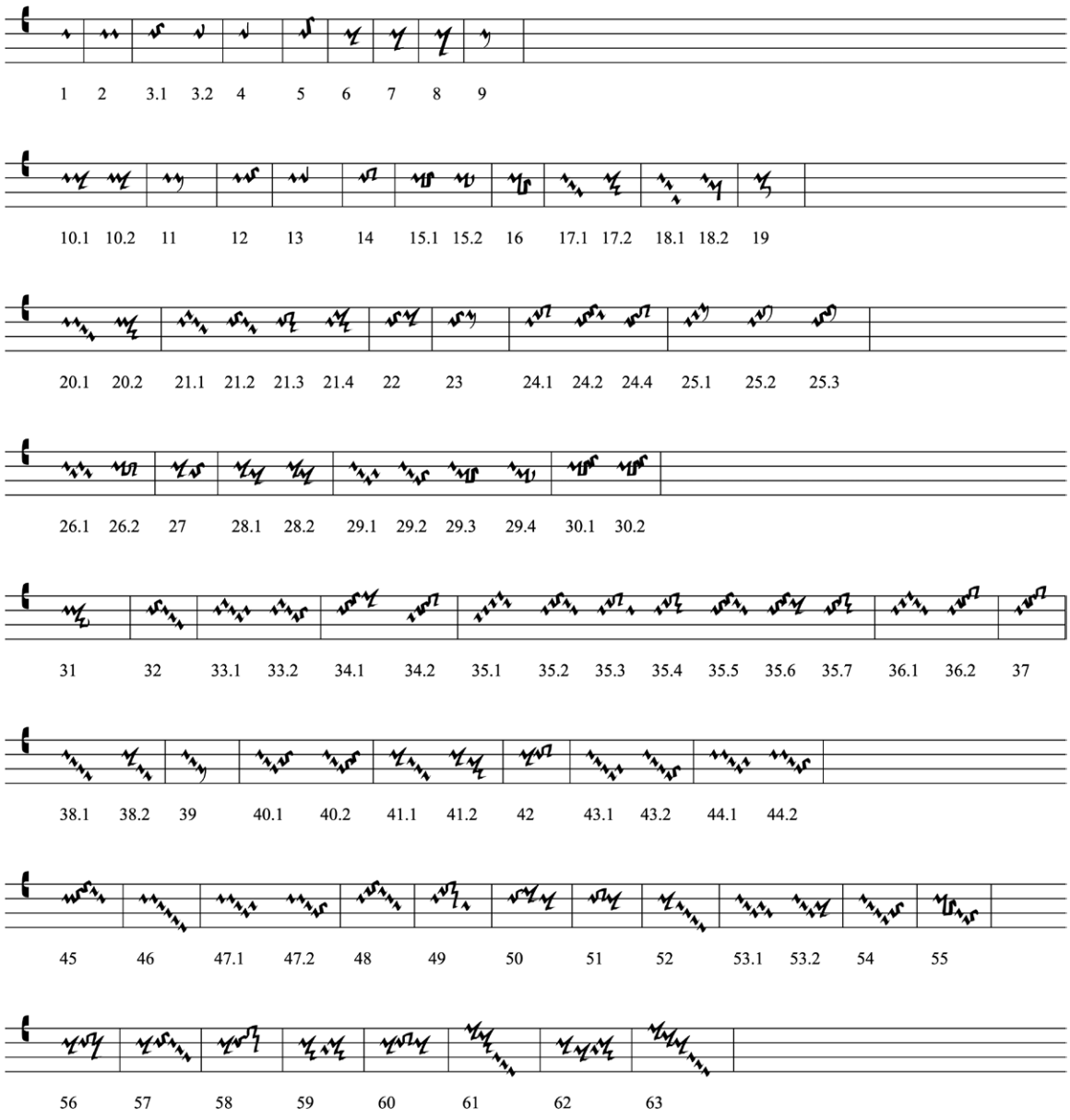
Data structure summary

MEI's way of storing all information in one document and concentrating different types of information at the level of the relevant syllable offers many advantages and may result in a very robust data storage practice, as it prevents any possibility of mismatching of the layers, such as text and notes pertaining to a same syllable. As illustrated above, MedMel stores all information separately as strings, arrays and objects. They are stored in a MySQL database and combined by the relevant MedMel interpreter when displayed or exported. The possibility of handling different layers of information separately shifts the complexities of the encoding from the user to the application. This presents a significant advantage, as it allows the transcription of text and pitch, and the definition of shapes, bar lines, *custodes*, etc. in a more fluent, manageable way, which prevents encoding errors. The data pertaining to each edition are structured as follows:

- A unique ID is generated for each transcription.
- Simple information is stored as strings: title, repertory identifier, author, language, manuscript and folio, as well as the automatically generated melodic structures.
- Melody, text and annotations are stored as arrays of strings. This allows a user to encode different versions of a melody or a text, such as a transcription of a text with or without editorial interventions. The melody array contains two versions of the melody—one for the Modern Notation and one for the Medieval Notation visualization.
- Parameters (font size and family, liquescence rendition in modern style, display of line numbers and melodic structure, etc.) and facsimile URIs (Uniform Resource Identifiers) are stored by using JSON (JavaScript Object Notation).
- Values of shapes in Medieval Notation are stored in a series of multidimensional arrays containing numeric values that are associated with a shape by the algorithm. These arrays are integrated by the visualizer through a strict correspondence of indices (as discussed above).
- Default shapes are encoded as integers. These are overridden whenever more specific information is provided.
- Other settings, such as the public or private status of the transcription, the user ID and the availability of Modern Notation and/or Medieval Notation transcription, are also encoded as integers.
- A set of tables allows the matching of users with user IDs and manuscript sigla with complete information about repositories and shelf marks.

Interoperability

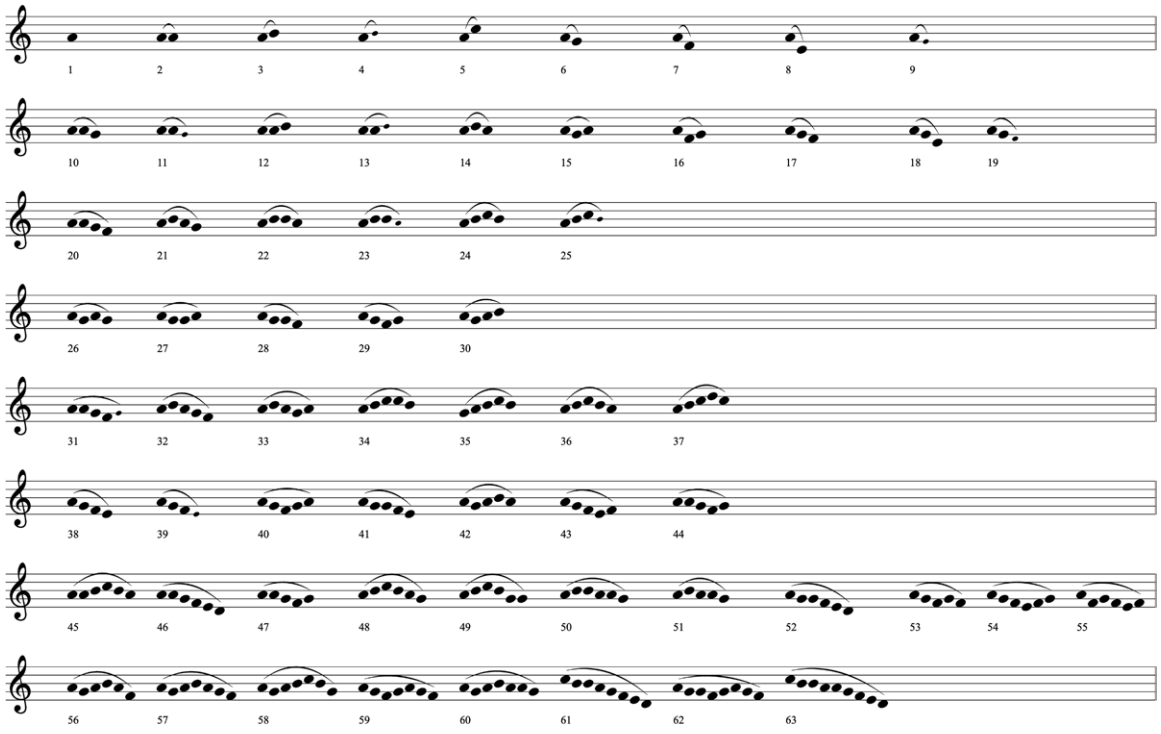
MedMel supports importing and exporting of Volpiano strings, MEI Neume files and MedMel files



19 Medieval Notation rendering of note-group configuration in MS. Paris, BnF, fr.20050

in JSON format. It can also export high-resolution PDF and PNG images, generate HTML pages and create code snippets to embed transcriptions in a webpage. This makes it as useful for traditional critical editions as it is for digital projects. Indeed, the static HTML/SVG code can easily be reused in any webpage without causing any resolution loss, thereby providing a stable solution for any project. The possibility of exporting MEI files allows melodies that are encoded with MedMel to be compatible with other ongoing and future projects.

Ensuring compatibility with XML standards is a priority in the development of MedMel, which was designed both as a viewer for MEI Neumes and as



20 Pitch rendering of note-group configurations illustrated in illus.19

a potential recipient for MEI transcriptions that are generated through optical recognition techniques.

'MEI Neumes' is the MEI module for medieval notation: this provides a schema—that is, a set of rules to ensure that the encoding is consistent with the agreed standard. MedMel exploits available descriptive features of the MEI schema at the level of single notes, such as `@ligated` (for obliques), `@con` (to define connected or unconnected neumes) and `@tilt` (strictly describing the direction of the pen stroke and not stems).[35] However, the latest release of the guidelines (MEI 5.0) does not account for every possible shape in square notation: for example, there are no attributes to describe either the difference between a *pes* formed by two *puncta* that are vertically aligned and one in which they are not or for the different ways in which notators can draw the *porrectus*, the *scandicus* and the *plica*. To describe these shapes, a few additions to the MEI Neumes schema are needed.[36]

To balance the need for detailed encoding and the necessity to generate MEI-compliant documents, MedMel provides multiple export options. The user can opt to extend the schema with non-MEI features that allow the description of every possible shape in square notation, thus entirely preserving the information of the MedMel transcription; alternatively, exported files can fully comply with the MEI Neumes rules, although the information that cannot be encoded in standard MEI will in that case be lost.

The additions to the MEI.Neumes schema, which were introduced to avoid information loss in the process of importing and exporting, include four attributes: `nc@stem.pos`, `nc@stem.dir`, `divLine@start` and `divLine@end`.[37] The attributes `@stem.pos` and `@stem.dir` are necessary to describe the exact positions of stems.[38] The attributes `@start` and `@end` within `<divLine>` are necessary to define precisely the length and position of a *divisio*, which in MedMel can be specified with great accuracy (up to a tenth of a space between two staff lines). The MEI.Neumes schema only allows `@form="[caesura | finalis | maior | maxima | minima | virgula]"`,

which does not guarantee the same level of granularity, nor does it use terminology that is applicable to the notation of vernacular medieval songbooks in non-mensural notation.[39] The attributes have been added to a customized version of the MEI.Neumes 5.0 schema hosted by MedMel to allow XML validation of the generated document. Alternatively, if one wishes to validate the file against the official MEI Neumes scheme, then these additional attributes can be excluded. In this case, while information concerning stems is completely lost, the *divisiones* are approximated to the nearest valid value of `@form`.

The most significant information concerning the neume shape is recorded through MedMel-specific values assigned to the `neume@class` attribute. While this attribute is valid within the MEI framework, the semantic correspondence of its values is conventional: the taxonomy of `@class` attributes is defined within the `<meiHeader>`, under `<classDecls>`. Users can opt to include full descriptions of these classes, thereby providing within the encoded document a detailed key for interpreting these values and, in any case, a complete table of correspondences between neume shapes and MedMel-generated MEI is provided on the MedMel website.[40] While the `@class` attribute does not affect compatibility with the MEI schema, users may decide to disable it. This causes a significant loss of information regarding neume shapes.

Furthermore, it is possible to include the attribute `@type` to `<nc>` elements, which describes the name of the neume (*scandicus*, *climacus*, etc.). This has no role in the preservation of information, but it can increase readability.

Finally, users can choose to export minimalistic encoding that excludes all specifics regarding the shape of the neumes and only preserves the pitches and octaves of the notes. This is ideal for transcriptions that are created in modern stemless notation.

For the transcription of Romance-language lyric, encoding prosodical units (e.g. metrical line divisions) is fundamental. However, MEI Neumes does not provide a way to encode this information. As metrical lines are visually marked by line breaks in modern transcriptions, MedMel exports them in MEI as `<sb>` (system breaks). To differentiate metrical units from manuscript system breaks—which are also encoded as `<sb>` in MEI—these are assigned different `@type` values (`metricalLineBreak` or `msSystemBreak`).

Hosting and sustainability

While the project has been funded by several institutions—mainly via Marie Skłodowska-Curie Actions, first through Warwick University (2019–22) and then through the University of Tübingen (2023–5), and additionally via the Scuola Superiore Meridionale in Naples (2022–3)—it is hosted by the Dipartimento di Studi Europei, Americani e Interculturali at the Sapienza University of Rome. Offering perpetual and free-of-charge hosting, with weekly backup, it provides the ideal environment for a long-lasting project. To further ensure durability, significant software and data updates are preserved in external repositories (Github and Zenodo). By employing widely supported programming languages (JavaScript, PHP, SQL) and relying on external libraries only for limited functionalities, MedMel requires minimal maintenance. More importantly, as a researcher-developed application, updates and improvements do not depend on external developers or the availability of future funding—an essential factor in ensuring its long-term sustainability.

Conclusions

The creation of MedMel arose from the need to provide a platform for comparing melodies across European repertories, allowing scholars to uncover relationships between lyrics throughout the Middle Ages and move beyond language-based disciplinary divisions between corpora. Moreover, encoded datasets enable computational analysis to extend beyond melodic influence, encompassing compositional techniques and semiography, while facilitating comparative investigations across different sources, periods and cultural settings.

While digital tools are bound to play an increasingly important role in musicological and textual research, as well as in medieval studies more broadly, they can also offer innovative perspectives in editorial practices. Enabling a significant advancement in the resources available to all domains related to medieval music primarily requires removing the need for technical expertise in music encoding.

MedMel thus aims to make digital editions not only more accessible, dynamically visualizable, searchable and interoperable for readers, but also a more efficient and advantageous option for editors—saving time and effort in producing scholarly editions. With current data preservation practices, digital editions are becoming increasingly durable. Indeed, as encoded transcriptions can be indefinitely reused as the foundation for new editions—which would otherwise need to be entirely recreated—their ability to adapt to different research approaches and audiences, as well as to evolving academic practices, surpasses that of any printed edition. While digital tools may seem to distance us from the materiality of our object of study, they actually enable renewed and stronger connections with its sources, which always accompany the transcription, ultimately fostering a more transparent interpretative process. From photographic reproduction to diplomatic transcription to modern rendering, digital editions make these melodies accessible without erasing the complexities of medieval notation. In this sense, MedMel has not only proven to be a crucial asset for research, but also emerged as a formidable teaching tool for the study of monophony in higher education.

Currently, the database hosts the entire corpus of troubadour songs with all their musical sources and over 350 trouvère melodies. The seven Galician-Portuguese pieces from the *Pergaminho Vindel* (New York, Pierpont Morgan Library, MS M.979) are encoded, as well as the *Cantigas de Santa Maria* (though these latter are not publicly available).[41] The advantages of the digital platform increase with the number of encoded items, and the primary aim of the MedMel project is to encode the entire repertoire of French monodic sources, comprising over 4,000 attestations. Furthermore, it could support collaborative projects that are focused on non-Romance-language lyric, from *Minnesang* to the Latin *conducti*.[42] It thereby has the potential to shed light on cultural connections that transcend linguistic boundaries, the interplay between religious and secular environments and, more broadly, the role of music in shaping European cultures and shared identities during the Middle Ages.

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[1] Cantus Database, directed by D. Lacoste (2011–present), T. Bailey (1997–2010) and R. Steiner (1987–96); developed for the web by J. Koláček (2011–23), McGill University Distributed Digital Music Archives & Libraries Lab (DDMAL) (2023–present); and funded through the Digital Analysis of Chant Transmission project at Dalhousie University, Halifax, Nova Scotia, Canada (SSHRC 895-2023-1002), https://cantusdatabase.org. Date accessed 14 March 2025.

[2] A. Haug and F. Puppe. Corpus Monodicum: Die einstimmige Musik des lateinischen Mittelalters. Digitale Ausgabe. Beta-Version 1.0. https://corpus-monodicum.de/.

[3] K. Chapman and J. Koláček. Troubadour Melodies Database (last update 2023). https://www.troubadourmelodies.org/.

[4] A. Casson. Cantigas de Santa Maria for Singers (2011). http://cantigasdesantamaria.com/.

[5] The two most advanced pieces of software to date are Rodan, developed by the Distributed Digital Music Archives & Libraries Lab at McGill University, under the direction of Ichiro Fujinaga (https://ddmal.music.mcgill.ca/e2e-omr-documentation/overview/rodan.html); and OMMR4all, developed at the Julius-Maximilians-Universität Würzburg (https://www.ommr4all.informatik.uni-wuerzburg.de/en/); see A. Hartelt, T. Eipert and F. Puppe, 'Optical medieval music recognition—a complete pipeline for historic chants', *Applied Sciences*, xiv/16 (2024), p.7355, https://doi.org/10.3390/app14167355. For an overview of neural networks applied to medieval music, see X. Fresquet, 'Artificial neural networks and medieval music', *Early Music* (2024), https://doi.org/10.1093/em/caae039.

[6] https://www.fawe.de/volpiano/.

[7] https://music-encoding.org/.

[8] https://music-encoding.org/guidelines/v5/content/neumes.html.

[9] Illuminare, https://editor.sourceandsummit.com/legacy/; Neon, https://ddmal.music.mcgill.ca/software/neon/.

[10] Available at https://medmel.seai.uniroma1.it/.

[11] H. van der Werf, *Trouvères-Melodien*, 2 vols. (Bärenreiter, 1977–9) and *The extant troubadour melodies: transcriptions and essays for performers and scholars* (Rochester, 1984); H. Tischler, *Trouvère lyrics with melodies: complete comparative edition*, 15 vols. (Neuhausen, 1997).

[12] F. Gennrich, *Der musikalische Nachlass der Troubadours. Vol. 1: Kritische Ausgabe der Melodien; Vol. 2: Kommentar* (Darmstadt, 1958). A notable exception to the lack of rhythmic notation in the sources is the trouvère songbook O (Paris, BnF, fr.846); see J. Beck, *Les chansonniers des troubadours et des trouvères, publiés en facsimilé et transcrits en notation moderne. Bibliotheque nationale de France. Manuscript. Fr. 846* (Paris, 1927) and, recently, R. Lug, *Semi-mensurale Informationen zur Liedrhythmik des 13. Jahrhunderts* (Stuttgart, 2020). Other examples of rhythmic notation are extant in the French and Occitan repertory, although they are liminal or isolated attestations, as is the case for Marcabru's *L'autrier just'una sebissa* (Occitan songbook R: Paris, BnF, fr.22543, fol.5*r*) or the later additions found in trouvère songbook M: Paris, BnF, fr.844; see A. M. Hatzikiriakos, *Musiche da una corte effimera: lo Chansonnier du Roi (BnF f. fr. 844) e la Napoli dei primi angioini* (Verona, 2020).Conceptually and practically distinct from the modal rhythmic interpretations that shaped many 20th-century editions, a theory of micro-rhythm applicable to trouvère songbooks—particularly Paris, BnF, fr.20050—is proposed by R. Lug, 'Vocal ornaments in troubadour song and recent northern traditions', in *Vokal folkemusikk verden rundt: studies in global vocal traditions*, ed. I. Bergheim (Trondheim, 2007), pp.57–99.

[13] I. F. de la Cuesta, *Las cançons dels trobadors* (Toulouse, 1979). The Troubadour Melodies Database in n.3, which uses Volpiano, may be added to these editions of the music, but does not provide texts.

[14] D. E. O'Sullivan, 'Editing melodic variance in Trouvère Song', *Textual Cultures*, iii/2 (2008), pp.54–70.

[15] In this respect, the premises as well as the conclusions of Margaret Bent's reflections on polyphony may be easily applied to monophonic song: 'We have tried to make our editions do double duty, accessible to performers but provided with scholarly apparatus; perhaps we need to be more aware of these different goals. […] At the same time as we try to present the edited original texts with as little graphic or conceptual distortion as possible, we may—I think legitimately—seek to enhance the graphic element of the presentation by making some compensating virtue out of the necessity of modern score', M. Bent, 'Editing early music: the dilemma of translation', *Early Music*, xxii/3 (1994), pp.373–92, at p.390.

[16] E. Aubrey, *The music of the troubadours* (Bloomington, 1996).

[17] G. Raynaud and H. Spanke, *G. Raynauds Bibliographie des altfranzösischen Liedes* (Leiden, 1955); Tischler, *Trouvère lyrics with melodies*.

[18] The range is restricted to 80 to 65 per cent for lines shorter than four syllables.

[19] 'Because the alignment of music and text is demonstrated graphically for the first strophe only, musical analysis of troubadour song sometimes focuses on the shape of the melody in the first strophe without taking into account the associations between music and text that are established over the course of the song', S. Boynton, 'Troubadour song as performance: a context for guiraut riquier's "Pus sabers no'm val ni sens"', *Current Musicology*, xciv (2012), pp.7–36, at p.8.

[20] https://projectmirador.org/.

[21] Lug, 'Vocal ornaments', p.72.

[22] This adjustment is based purely on empirical auditory experience: quite consistently, when both components of the *pes* and *clivis* neumes have the same duration, the melody flows more smoothly and achieves a more cohesive overall rendition.

[23] S. B. Needleman and C. D. Wunsch, 'A general method applicable to the search for similarities in the amino acid sequence of two proteins', *Journal of Molecular Biology*, xlviii/3 (1970), pp.443–53.

[24] https://medmel.seai.uniroma1.it/searchSong.html.

[25] The Levenshtein distance is a measure of the difference between two sequences, based on the number of edits (insertions, deletions or substitutions) needed to transform one into the other. It is one of the most common methods for comparing the similarity of text strings.

[26] L. Spetia, 'Un'attribuzione discordante e un caso di intertestualità: Perrin d'Angicourt e Thibaut de Champagne', *Rivista di studi testuali*, vi–vii (2004–5), pp.247–69.

[27] The online manual is available at https://medmel.seai.uniroma1.it/pages/manual.html.

[28] If the user inputs data directly into the text area, then these conventional signs must precede the note.

[29] In the vernacular repertory, *custodes* are regularly used, for example, by the notator of troubadour songbook G (Milan, Biblioteca Ambrosiana, R 71 sup) and the *Cantigas de Santa Maria* codex To: Madrid, Biblioteca Nacional de España, MS. 10069.

[30] The same tilted liquescent shape appears at syllable two, but no value is assigned to it at the single-note level: this is because the information on its shape was already provided at a group level—this is possible only if the liquescent note constitutes the whole note group. Liquescent notehead values are: 5 or absent: *punctum* with right and left stem; 6: tilted liquescent notehead with right and left stem; 7: tilted liquescent notehead with right stem; 8: tilted liquescent notehead without stems; 9 (only ascending): *punctum* with upwards right stem; 10 (only ascending): *punctum* with tilted upward right stem.

[31] Stem values are: 0 or absent: none (default); 1: downwards left; 2: downwards right; 3: upwards right; 4: upwards left.

[32] R. Lug proposes that the initial nucleus of the songbook (U1) was

assembled as early as 1231. As it includes works of poets who were active until the end of the third quarter of the 13th century, the manuscript was compiled across a long period of time; see R. Lug, 'Politique et literature à Metz autour de la guerre des amis (1231–1234): le témoignage du Chansonnier de Saint-Germain-des-Prés', in *Autour du Tournoi de Chauvency: lettres, musique et société en Lorraine médiévale*, Actes du colloque de Metz 2007 (Genève, 2012), pp. 451–86 and, more recently, R. Lug, 'Common exemplars of U and C', in *A medieval songbook: trouvère MS C*, ed. E. E. Leach, J. W. Mason, M. P. Thomson, Studies in Medieval and Renaissance Music (Woodbridge, 2022), pp.82–120. For a study of its dating and composition, see M. Tyssens, *Le chansonnier français U: publié d'après le manuscript Paris, BnF, fr.20050*, 2 vols. (Paris, 2015–20), i, pp.XVIII–X.

[33] Another Occitan source in which a similar notation is used is the fragment of Sant Joan de les Abadesses (Barcelona, Biblioteca de Catalunya, 3871), which consists of two loose leaves preserving four melodies of anonymous Occitan *unica*. For a study and edition of this fragment, see I. de Riquer and M. Gómez Muntané, *Las canciones de Sant Joan de les Abadesses, Estudio y edición filológica y musica* (Barcelona, 2003). Beldon notes that the term 'Messine notation', which properly refers to the distinct adiastematic notation produced in Metz, is somewhat inappropriate when applied to the notation of BnF, fr.20050. Instead, she proposes 'lorenese' as a more accurate descriptor, here translated as 'Lorraine'; see V. Beldon, 'Osservazioni sulla tradizione manoscritta della lirica d'oc e d'oïl in area lorenese', *Critica del Testo* vii/1 (2004), pp.425–46, at pp.437–9.

[34] R. Lug, 'Das "vormodale" Zeichensystem Beldon des Chansonnier de Saint-Germain-des-Prés', *Archiv für Musikwissenschaft* 52 (1995), pp.19–65, at pp.24–5.

[35] See MEI guidelines: https://music-encoding.org/guidelines/dev/attribute-classes/att.ncForm.html. I use the term 'stem' as interchangeable with 'tail', as neither of them can claim to be historically accurate.

[36] https://music-encoding.org/guidelines/v5/content/neumes.html.

[37] The notation `'nc@stem.pos'` refers to stem.pos as an attribute of the element nc, which stands for 'neume component'. In MEI Neumes-encoded documents, an `<nc>` element corresponds to a single note, as it carries information about pitch and octave.

[38] The use of `@tilt` for stems is, in my opinion, not entirely correct and does not allow the description of every possible case. In particular, left-top stems cannot be distinguished by right-bottom, as they would both use `@tilt="s"`. While MedMel does not currently implement it, the use of a `<stem>` element within `<nc>` (as it is allowed in the `<note>` of the `MEI.shared` module) would be the only way to describe every possible scenario, i.e. plicas or, regardless of its semantic meaning, any neume components with more than one stem.

[39] Values for `@start` and `@end` refer to the rules of MEI's Staff location (`data.STAFFLOC`), available at https://music-encoding.org/guidelines/dev/data-types/data.STAFFLOC.html.

[40] https://medmel.seai.uniroma1.it/pages/medmel-and-mei.html.

[41] The encoded melodies of the *Cantigas de Santa Maria* from El Escorial, Real Biblioteca del Monasterio de San Lorenzo, MS B.I.2 have been kindly shared by Andrew Casson for research purposes only.

[42] An edition of the earliest German lyric using MedMel is currently underway by Philip Wetzler (for the *Lyrik des deutschen Mittelalters* project). Ita Hijmans is also transcribing a corpus of melodies spanning 'from the North Sea to the Alps and Central Europe', which is primarily composed of 15th-century Dutch and German monodic songs.