A DIPLOMATIC EDITION OF IL LAURO SECCO: GROUND TRUTH FOR OMR OF WHITE MENSURAL NOTATION

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ABSTRACT

Early musical sources in white mensural notation—the most common notation in European printed music during the Renaissance—are nowadays preserved by libraries worldwide trough digitalisation. Still, the application of music information retrieval to this repertoire is restricted by the use of digitalisation techniques which produce an uncodified output. Optical Music Recognition (OMR) automatically generates a symbolic representation of image-based musical content, thus making this repertoire reachable from the computational point of view; yet, further improvements are often constricted by the limited ground truth available. We address this lacuna by presenting a symbolic representation in original notation of *Il Lauro Secco*, an anthology of Italian madrigals in white mensural notation. For musicological analytic purposes, we encoded the repertoire in **mens and MEI formats; for OMR ground truth, we automatically codified the repertoire in agnostic and semantic formats, via conversion from the **mens files.

1. INTRODUCTION

White and black mensural notations are both defined by the use of strictly measurable unambiguous characters, a codification system introduced for the first time around 1280 in the *Ars cantus mensurabilis* [15]. Yet, white notation, unlike its predecessor black notation, passed through minimal changes during its period of existence (aprox. 1450–1600), thus becoming a consolidated European notation system typical of Renaissance vocal polyphonic music [1]. Furthermore, the development of relatively standardised musical sources in white mensural notation was also encouraged by the advancement of new printing technologies [12], which led at that time to a prolific production of early music prints, many of them still available nowadays.

The high cultural and historical value of these musical sources led to libraries worldwide utilising digitalisation mechanisms to preserve them. [1] Considering the often low quality of such scanned sources, this created a new challenge for Optical Music Recognition (OMR) systems. Much effort has already been made on symbolically representing this repertoire by developing suitable storage and encoding formats [28, 31] as well as improving OMR performance [5, 19, 24, 34]. Still, OMR technology is not yet reliable enough to accurately extract the musical content of some sources [28], making manual encoding—which provides the ground truth needed to improve the systems—often necessary. Despite this, digital editions of early music in original notation, as that presented in the *Measuring Polyphony Project*, [2] are still an exception [9, 20, 29].

We present a diplomatic edition and OMR ground truth of the anthology *Il Lauro Secco*—originally printed in 1582 in white mensural notation, previously encoded in original notation in Lilypond format by [20], and also transcribed in modern notation in **kern and MEI formats by [21]. To encode the anthology in the original (white mensural) notation, we considered **mens [28] and MEI [31] formats, chosen as the most adequate for manual encoding and storage, respectively. We also encoded the repertoire in the so-called 'agnostic' and 'semantic' formats, chosen as adequate to provide OMR ground truth [6, 27]. These were automatically generated from the **mens files through the `mens2agnostic` and `mens2semantic` converters, which we present as a way to reduce human efforts. A total of 660 codified scores, 150 engraved images, 150 original prints, and the converters are freely available. [3]

The paper is laid out as follows: in Section 2, an overview of related work is given; Section 3 describes our methodology; Sections 4 and 5 discuss the encoding criteria; finally, in Sections 6 and 7, we deal with limitations of our work, conclusions, and future directions.

2. PREVIOUS WORK

Manuscripts and prints, since the only remaining source of Renaissance music, have great value for the conservation and understanding of this music and its historical context,

[1] *Gallica* (Bibliothèque Nationale de France) and *Early Music Online* (British Library) have digitised around 600 musical sources from the 16^{th} century which are freely accessible and downloadable online.

[2] `http://measuringpolyphony.org/`

[3] `https://github.com/SEILSdataset/SEILSdataset`

a process in which digital technology plays a fundamental role [13]. Despite symbolic codification of the musical content is essential for a systematic study of the considered repertoire, the lack of a common methodology across the available digital collections makes their comparison difficult and might even bias research outcomes [8]. Furthermore, although initiatives such as *Tasso in Music Project* [26], [4] *Gesualdo Online Project*, [5] *Marenzio Online Digital Edition* (MODE), [6] *Josquin Research Project*, [7] or *The Lost Voices Project* [8] have as a main goal the codification of early musical sources in machine-readable formats, those preserving the original notation during the symbolic representation process are still rare [9, 20, 29]. In addition, despite the limitations of editing music in book format [35], even recently published—carefully curated—diplomatic editions of early music present transcriptions in modern notation of the musical content [10], without providing any symbolically codified support.

Music XML, considered the best music notation interchange format [11], is commonly used to transfer codified music across different platforms; still, Music XML might present limitations when working with early music, e. g., in the codification of different notations. In this regard, the Music Encoding Initiative (MEI) has been established [30], not only covering the encoding of a wide range of notations but also providing a set of features especially suited to the digital edition of music such as the inclusion of critical comments [22]. However, conversion routines between user-friendly encoding formats which support early notation, as, e. g., Lilypond [18] [9] and MEI, are still missing. Indeed, only recently suitable formats for manual encoding and conversion into MEI, such as the Humdrum representation scheme **kern [17], have been adapted for mensural notation, i. e., the representation scheme **mens [28], which as well as MEI can be rendered with the dedicated music engraving library Verovio [23] and through the online platform Verovio Humdrum Viewer (VHV [33]).

OMR has been progressively improved, e. g., by processing inconsistently notated handwritten scores [16, 25] and low quality early printed sources [24, 34]. Still, for all the machine learning systems, an adequate ground truth is essential to properly set-up an OMR framework. The so-called 'annotated dataset' or ground truth is a version of the evaluated data in which every instance (musical character) is identified with the label expected to be predicted. From a musicological prospective, a digital diplomatic edition [14], i. e., a symbolically codified source that faithfully mirrors the original print, would be the most appropriate approach to encode OMR ground truth of early music.

3. METHODOLOGY

We present a digital diplomatic edition of the anthology encoded in two open community driven formats with the capability to codify white mensural notation: **mens (a Humdrum representation scheme which presents a user-friendly encoding syntax [28]), and MEI (which has a specific module to encode mensural notation [31] and is considered to be the most appropriate storing format [28]). For OMR applications, we encoded the anthology's 'ground truth' in agnostic and semantic formats, i. e., two symbolic representations originally presented for western modern notation [6] but considered also as being appropriate to codify early notated sources [27].

3.1 Data description

The *Il Lauro Secco* anthology is a collection of 30 madrigals—secular polyphonic a cappella compositions—for five voices, [10] which has been published in a set of separate 'partbooks', i. e., according to a printing format in which each vocal part is presented in a different book [12]. This means that for each of the 30 madrigals in the anthology, five 'parts', i. e., individual scores presented in the corresponding partbooks (we will use the Italian term *particella(s)* to refer to these) are presented; no 'choral score', i. e., a score in which all the voices are displayed over-imposed in the same sheet, is available. Since the anthology encompasses 150 *particellas* (30 madrigals x 5 voices), and we considered four encoding formats—**mens, MEI, agnostic, and semantic—a total of 600 symbolically codified *particellas* are presented.

For the diplomatic edition, the 150 *particellas* were encoded in **mens and MEI (i. e., a total of 300 files), which present a faithful representation of the original source. The MEI files were also engraved with Verovio [23] and saved as images in pdf format (i. e., 150 files). Additionally, one choral score with the five voices over-imposed, from the lower to the higher in the same sheet, was also encoded in **mens and MEI for each madrigal (i. e., a total of 60 files). Still, the choral scores are only presented to encourage / facilitate analysis and performance; thus, they should not be considered as part of the diplomatic edition: They do not respect the original's editorial choice (i. e., partbook printing), and, contradicting the original print, lyrics normalisation and musical corrections to preserve vertical alignment were applied to them.

For the OMR ground truth, the 150 *particellas* were encoded in agnostic and semantic format, yielding a total of 300 files. The agnostic encoding gives the sequential representation of the musical symbols by indicating their exact position within the staff but without providing any musical meaning [6]. Differently, the semantic representation gives a simplified version of the scores while still keeping the musical meaning, e. g., the indication FM (F major) for modern notation implies that a flat is considered in the key-signature [6]. To the best of our knowledge, lyrics have not been considered in any of these formats, neither for mensural [27] nor for modern [6] notation; thus, the *particellas* in agnostic and semantic formats do not contain lyrics. In the future, these might be required to perform Optical

[4] http://www.tassomusic.org/
[5] https://ricercar.gesualdo-online.cesr.univ-tours.fr/
[6] http://www.marenzio.org/
[7] http://josquin.stanford.edu/
[8] http://digitalduchemin.org/
[9] http://lilypond.org/

[10] Note that the polychoral madrigal composed by Luca Marenzio is not taken into account [20].

Character Recognition (OCR) and OMR together. Then, the codified lyrics and their musical alignment can be retrieved from the *particellas* in **mens and MEI.

3.2 Data conversion and manual encoding

Even though the *Il Lauro Secco* anthology has already been codified in original notation [20], since this work employed the encoding format Lilypond—mostly used as a 'final' encoding choice rather than an interchange format [27]—direct conversion to **mens or MEI was not possible. Considering this, as starting codified version of the anthology, we chose the modern notated transcription encoded in **kern format [21], which contains a choral score for each madrigal (i. e., 30 **kern files in total). We converted the 30 choral scores from **kern to **mens by compiling the filter `kern2mens` [11] implemented in the Verovio Humdrum Viewer [12] (VHV [33]). Conversion errors were corrected (cf. Section 3.3), and aspects exclusive for mensural notation—thus missing in the **kern files, as e. g., colorature or ligatures—were manually integrated in the **mens choral scores (cf. Section 4.1).

When the musical content of the 30 choral scores in **mens was edited according to the original sources—note, as already mentioned, that a few musical corrections were required in order to preserve vertical alignment across voices—these were split into the individual parts. The extraction of the voices in separated files was performed with the Humdrum Toolkit, [13] through the command `extractx` of the Humdrum extras, [14] by that generating five **mens files per madrigal with two spines (one for music and another for lyrics) each. After that, the lyrics of the 150 *particellas* in **mens were manually 'unnormalised', i. e., corrected according to the original source (cf. Section 4.2), and the few musical corrections in the choral scores to preserve vertical alignment were also made according to the original. Finally, the **mens *particellas* were automatically converted into MEI syntax through the Verovio command-line interface. [15]

For the encoding of the agnostic and the semantic files, two Python scripts to convert from **mens to both formats, `mens2agnostic` and `mens2semantic`, were created. Even though agnostic and semantic representations have already been considered to encode Spanish white mensural notation [27], the repertoire in this notation, unlike the music prints considered by us, is handwritten, thus presenting many differences with respect to the white mensural notation of printed sources [29]. Due to this, for the agnostic and semantic encoding, we followed specific criteria (cf. Sections 5.1 and 5.2), which were developed from those originally presented for modern western notation [6]. Since lyrics were not considered for these representations, before automatically converting the 150 **mens *particellas*, they were removed by extracting the spines with musical content as individual files.

[11] `http://doc.verovio.humdrum.org/filters/`
[12] `https://verovio.humdrum.org/`
[13] `http://www.humdrum.org/`
[14] `http://extras.humdrum.org/man/`
[15] `https://www.verovio.org/humdrum.xhtml`

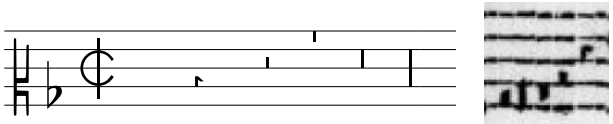

Figure 1. At left, a codified representation of mensural notation engraved in VHV presents (from left to right) the following symbols: C2 clef, B flat, 𝔠 time signature, and rests of *semiminima* in line 2 (L2), *minima* (L3), *semibrevis* (L5), *brevis* (L3), and *longa* (L3). At right, an extract of a original print taken from the *Basso* part of Belli's madrigal presents (from left to right) rests of: *minima* in line 1 (L1), *brevis* (L1), *semibrevis* (L2), *minima* (L2), and *semiminima* (L3). Rests position (standard in **mens) is given considering their proximity to the center of the staff (L3).

3.3 Data post-processing

Musical aspects specific of mensural notation, e. g., 'proportions' (transcribed in modern notation with triplets), were not interpreted in the conversion from **kern to **mens. Thus, manual post-processing of the **mens files was required to address the following conversion issues: (i) 16^{th} notes in **kern were converted in **mens as *semibrevis* instead of *semifusas*; (ii) triplets, used in **kern to transcribe *proportio tripla* of *tempus imperfectum* [1], i. e., the *diminution* of the *prolatio* (reduction of the subdivision values) by changing from a time signature with binary meter and binary subdivision (e. g., 𝐂 and 𝔠) to another with binary meter and ternary subdivision (e. g., `3` and $\mathbf{C}_2^3$), were not recognised in the conversion, yielding compilation failure of the **mens files.

Although 'coloration' and 'custos' can be encoded in MEI, these are not yet implemented in VHV for **mens (cf. Section 4.1). Due to this, in the conversion from **mens to MEI, these were not recognised, but manually encoded in MEI. Similarly, since lyrics linked to rests are not supported in VHV (cf. Section 4.2), these were not recognised in the conversion from **mens to MEI, but also manually encoded. In **mens representation, unlike in the original source, rests are indicated in a standard position within the staff (cf. Figure 1); yet, in the agnostic representation the original position of the rests should be indicated. The same applies for accidentals, which in **mens, unlike in the original source (cf. Figure 3), are displayed in the same staff position of the note they refer to. Since in the conversion from **mens to agnostic, the specific position of rests and accidentals was missing, this was manually encoded in the agnostic files (cf. Section 5.1).

4. CRITERIA FOR DIGITAL DIPLOMATIC EDITIONS OF WHITE MENSURAL NOTATION

While MEI is a suitable encoding format for storage, **mens is more appropriate for manual encoding [28]. The following criteria will refer mainly to the codification in **mens; manual interventions in MEI will only be described when required. For white mensural notation encoding guidelines in **mens, cf. [28]; [16] for MEI, cf. [32]. [17]

[16] `http://doc.verovio.humdrum.org/humdrum/mens/`
[17] `http://www.verovio.org/features.xhtml?id=mensural`

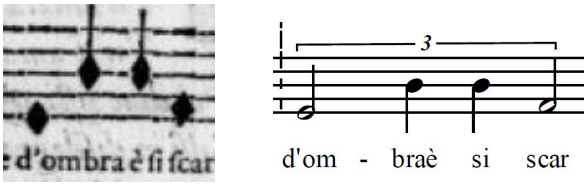

Figure 2. At left, the rhythmic sequence *semibrevis*, *minima*, *minima*, *semibrevis* (all blackened), which should be interpreted as *minor color*; at right, the transcription of this fragment of Belli's madrigal in modern notation [20].

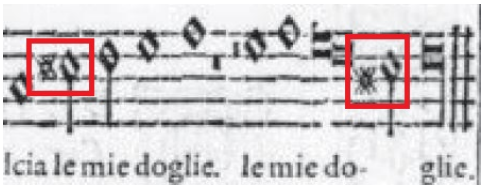

Figure 3. Two different representations of the accidental sharp displayed in Marenzio's madrigal. The first in the standard position, i. e., aligned to the note; the second not.

4.1 Musical encoding criteria

Unlike the anthology codified in Lilypond [20], where different musical aspects are modified w.r.t. the original source to encourage the analysis and performance of the repertoire, the present encoding in **mens and MEI tries to represent the original source as much as possible. For this, the following criteria were considered:

(i) In previous symbolic versions of the anthology [20, 21], rests have often been encoded in shorter length than in the original source. This was due to the use of barlines, which made it impossible to display rests longer than a measure. In **mens and MEI encoding, the exact duration of the rests indicated in the original source was considered; yet, as in these formats the position of rests within the staff cannot be defined, the default position displayed in the images engraved with VHV might not always coincide with that given in the original print (cf. Figure 1).

(ii) Stems up to the third staff line (included) are generally displayed upwards, while above the third space (included), they are displayed downwards. This applies always when engraving codified scores in VHV; yet, for melodic reasons, notes in the third line of the original source might also present downwards stems. Thus, the direction of the stems which did not follow the standard disposition in the original source was manually specified in the **mens encoding. Furthermore, since *Longa*'s stems in VHV are always engraved downwards, these were also specified, when needed, according to the original.

(iii) Coloration or 'blackening' [1]—used to indicate rhythms with ternary subdivision (i. e., *perfect prolatio*)—is an attribute unique of white mensural notation; thus, it was not indicated in the modern notated transcription in **kern [21]. Due to this, coloration was manually encoded in **mens according to [28] by indicating '∼'. Since coloration is not yet implemented in VHV, this is not displayed when engraving **mens files, and it was also not correctly converted from **mens to MEI; thus, coloration was manually encoded in MEI by specifying the note attribute 'colored="true"' [32]. As blackened *minimas* appear graphically as *semiminimas*, it depends on the musicological interpretation whether such a character should be encoded as the former or the latter. To prevent interpretation bias, coloration was only indicated for *brevis* and *semibrevis*, i. e., the notes which do not have an already existing equivalent when blackened. Still, from a musicological prospective, the so-called *minor color*—a *semibrevis* followed by a *minima* both blackened that must be performed as a triplet of whole and half notes [1]—should be considered; thus, in some cases, *semiminimas* might be interpreted as blackened *minimas* (cf. Figure 2).

(iv) *Ligatures*—symbols that in mensural notation represent a combination of two or more notes [1]—were indicated according to the VHV documentation, [18] i. e., notes within the ligature are delimited with brackets: square brackets were used for *recta ligatures*, angle brackets for *obliquous ligatures*. However, since the rhythmic stems of *ligatures* are not yet implemented in VHV, they are not displayed when engraving **mens and MEI encoding.

(v) *Custodes* (singular: custos)—a symbol at the end of a staff indicating the pitch of the first note in the next staff [1]—are not yet implemented for **mens encoding. Considering this, we introduced the indication `*custos` in the *particellas* in **mens, which although is not engraved, indicates the exact position where the custos is displayed, i. e., the end of each staff as shown in the original source. This might be similar to the indication `!!linebreak:original`, typically used in **kern encoding. Unlike in **mens, *custodes* are already implemented in MEI encoding [32]; thus, these were manually indicated by adding the event `<custos/>`, in which the exact position of the symbol is also indicated by the attributes pitch name (`pname`) and octave (`oct`).

(vi) Accidentals in mensural notation present differences w.r.t. modern notation; e. g., single sharps in mensural are indicated with 'x', while this symbol indicates double sharp in modern notation. Furthermore, unlike in modern notation, accidentals in mensural are not always aligned—displayed in the same vertical staff position—to the note they precede (cf. Figure 3). Still, since in **mens encoding accidentals' position cannot be specified, these are displayed, when engraved in VHV, according to the default alignment; [19] thus, their position in the engraved images may not coincide with that of the original source.

(vii) Measures were considered in the *particellas* to indicate staff breaks, i. e., after each `*custos`, a new measure was indicated to break the musical content according to the distribution displayed in the original source. [20]

(viii) Clefs, key, and time signatures were indicated at the beginning of the score (first staff) and within staves, [21] but not at the beginning of consecutive staves, since automatically engraved in VHV. In mensural notation, unlike

[18] `http://doc.verovio.humdrum.org/humdrum/mens/`

[19] Despite in MEI the specific position of the accidentals can be specified, this was not yet performed due to time-constraints.

[20] In the 'choral scores', in order to facilitate interpretation and analysis, the numbers of measures are given regularly to fragment the music.

[21] Since verovio and VHV are still in development, repetitions within a staff of the same clef and some time signatures might not be engraved.

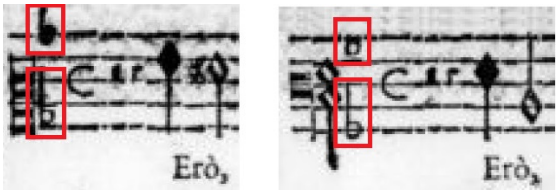

Figure 4. B–flat showed twice for C2 (left) and F3 (right) clefs, in the *Canto* and *Basso* parts of da L'Occa madrigal.

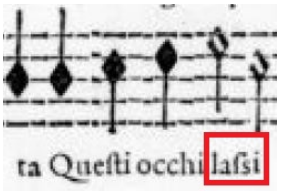

Figure 5. Two different representations of the letter 's' in the word *lassi*, displayed in Fiorino's madrigal.

in modern, when having a flat in key signature, this is displayed twice for C2 and F3 clefs (cf. Figure 4); yet, only one is engraved by VHV for **mens and MEI encoding.

4.2 Textual encoding criteria

The lyrics of the *particellas* encoded in **mens were 'unnormalised' w.r.t. the standardised transcription in **kern format [21], i. e., they were rewritten according to the original source. In this process, punctuation was introduced when missing, and modified or removed when needed. Contractions (e. g., *altrov'adopra*), abbreviations (e. g., *hãno*, *pche*, or *ij*), and the *tironian* symbol '&', previously transcribed as 'et', were indicated as in the original. The arbitrary use of diacritic marks (e. g., *più* and *piu*), letters (e. g., *verde* and *uerde*), links between words (e. g., *invano* and *in vano*), and letter capitalisation was kept inconsistent across voices as in the original partbooks.

Unlike in the transcription encoded in **kern [21], lyrics linked to long rests at the beginning of a voice were encoded in the *particellas* in **mens and MEI; still, since these are not supported in VHV, they are not displayed in the engraved images. Indeed, even though lyrics might be printed under rest in the original source, these should not be sung—they are given for performance reasons, to indicate verse sung by the other parts to voices which start with long rests. Finally, due to graphical limitations, the two different spellings of the letter 's' (cf. Figure 5) were indicated with the unique graphical symbol 's'.

5. ENCODING CRITERIA FOR OMR GROUND TRUTH OF WHITE MENSURAL NOTATION

The vocabularies for agnostic and semantic encoding of modern notation [6] were adapted to the characteristics of white mensural notation. Thus, aspects typical of modern notation, such as slurs or dynamics, were not considered, while elements characteristic of mensural notation, e. g., 'ligatures' and 'coloration', were taken into account. Division and addition dots were indicated as shown by [6] for modern notation. Note that in white mensural notation, the following notes are used [1]: *maxima*, *longa*, *brevis*, *semibrevis*, *minima*, *semiminima*, *fusa*, and *semifusa*.

5.1 Criteria for agnostic encoding

Since in the agnostic format, musical symbols are encoded as graphical objects without musical meaning, for each element, its position within the staff (line or space) is indicated. Lines and spaces are enumerated from the bottom to the top: the five lines from L1 to L5, the additional line below the staff L0, the one above L6; the four spaces from S1 to S4, the space below the staff S0, the one above S5.

(i) The position of rests within the staff is not standardised in mensural notation (cf. Figure 1); thus, all the possible positions were considered in the vocabulary. Still, since in the conversion from **mens to agnostic, such a position was not indicated (cf. Sections 3.3 and 4.1–i), this was manually encoded in the agnostic files.

(ii) The stems whose direction in the original source did not follow the standard rule (cf. Section 4.1–ii), were marked with back-slash '\' or slash '/', to indicate downwards and upwards directions, respectively, e. g., 'note.semifusa\-L3'. Note that this does not apply to *brevis* and *semibrevis*, i. e., notes without stem.

(iii) Coloration (cf. Section 4.1–iii) was indicated for *brevis*, *semibrevis*, and ligatures by adding '∼' when applicable, e. g., 'note.breve∼-S3' or 'ligature∼.start-L5'.

(iv) Ligatures (cf. Section 4.1–iv) were indicated by the word 'ligature' instead of 'note'. Since the considered anthology presents only *recta* ligatures of two notes, in the vocabulary, only the starting and final notes of the ligature, without distinction between *recta* and *obliqua*, were indicated, e. g., 'ligature.start-L2'. Still, middle notes, ligature type, and other attributes could also be defined if needed.

(v) *Custodes* (cf. Section 4.1–v) were indicated by the word 'custos' followed by their position, e. g., 'custos-S3'.

(vi) The position of accidentals is not always standardised in mensural notation (cf. Figure 3); still, since in **mens encoding this cannot be specified (cf. Section 4.1–vi), in the conversion from **mens to agnostic, the accidentals' default position was indicated and manually modified in the agnostic files when required (cf. Sections 3.3).

(vii) Clefs, key, and time signatures were encoded as in the original source, i. e., also at the beginning of each staff—note that the agnostic encoding might be split in staves by introducing a break-line after each custos, if needed. B–flat in key signature, displayed twice for some clefs, was also codified, e. g., C2 clef with a B–flat in key signature (cf. Figure 4) would be encoded in agnostic as 'clef.C-L2 accidental.flat-L5 accidental.flat-S1'.

5.2 Criteria for semantic encoding

In the semantic encoding, each element is intended with its musical meaning; thus, no position markers such as staff line or stem direction are given, since implicitly indicated.

(i) Renaissance music can be grouped into two systems, *durus* and *mollis*, which together with the cleffing, i. e., the use of standard (up to C1) or high (up to G2) clefs, were the common criteria used by publishers in the 16^{th} cen-

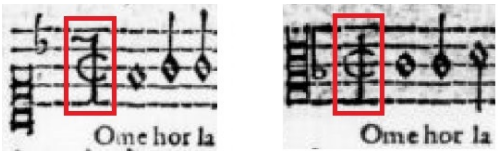

Figure 6. Representations of the time signature ¢ showed in the *Canto* (left) and *Alto* (right) of Fronti's madrigal.

tury to group madrigals in different collections [7]. *Durum*, in Latin, corresponds to B–natural in modern terminology while *molle* corresponds to B–flat [12]; thus, madrigals in *durus* system (i. e., with B–*durum* in key signature) would use the Lydian scale while those in *mollis* (i. e., with B–*molle* in key signature) would use the F major scale [1]. In the semantic encoding, the words 'mollis' and 'durus' were considered to indicate B–flat and no alteration in key signature, e. g., 'keySignature-durus'.

(ii) Accidentals in mensural notation must be interpreted according to the musical context, e. g., a sharp might indicate that a note is natural (instead of sharp) if it previously was flat, and altered notes might be notated without accidentals. Indeed, in early music—specially from the 14^{th} century—there was a tendency to use many altered notes for performance (the so-called *musica ficta*); still, often it was not allowed to indicate such altered notes in written music, since these did not follow the 'guidonian rule' of the hexachords (the so-called *musica retta*) written music was based upon at that time [15]. The theorisation on this topic creates great interest in the research community [2], and due to its complexity—which goes beyond the purpose of this paper—we only encode the accidentals printed in the original source without further interpretations; for a transcription in modern notation which contains 'editorial accidentals' of the *musica ficta*, cf. [20].

(iii) Unlike modern notation, where—except for dotted notes—each note is always divided in two equal neighbour smaller notes (e. g., a quarter note is divided by two eighth notes), in mensural notation a non dotted note might be divided not only in two, but also in three neighbour smaller notes, depending on its 'mensuration' [1]. The mensuration of *brevis* and *semibrevis* (so-called *tempus* and *prolatio*) is indicated by the time signature, e. g., 𝐂 indicates *tempus imperfectum cum prolatione imperfecta* [1], i. e., a duple metre with binary subdivision. While imperfect *prolatio* would be the equivalent of a simple metre in modern notation (i. e., binary subdivision of each bit), perfect *prolatio* would be the equivalent of a compound metre (i. e., ternary subdivision of each bit). [22] In the semantic encoding, mensuration was indicated by adding '_imperfect' or '_perfected' to each note, rest, and ligature, e. g., 'note-D4_minima_imperfect'.

6. LIMITATIONS

Beyond the already discussed aspects that might differ between the engraved images, i. e., the visual representation of **mens and MEI files engraved by VHV, and the original source, such as different position of accidentals and rests, or missing elements (e. g., custos, ligature stems, or clefs, time, and key signatures in specific cases), other differences between the presented diplomatic edition and the original print should be mentioned. One is the time signature so-called, the *alla breve* [1], i. e., ¢, which indicates, as well as 𝐂, *tempus* and *prolatio* imperfect. Although in the original source, this time signature presents two graphical variants (cf. Figure 6), this is displayed by a unique symbol in the engraved images (cf. Figure 1). Another element which is not included in the engraved images is the use of descriptive or decorative initials, which gained great relevance in printing music collections since, unlike ordinary text editions, music prints required normally one or even two woodcut initials for every page [3]. Since the *Il Lauro Secco* anthology was the first music collection published by Baldini as ducal printer in the court of Alfonso II d'Este, ornamental elements as the initials (cf. Figure 7) received special attention in the luxurious collection [4]. [23]

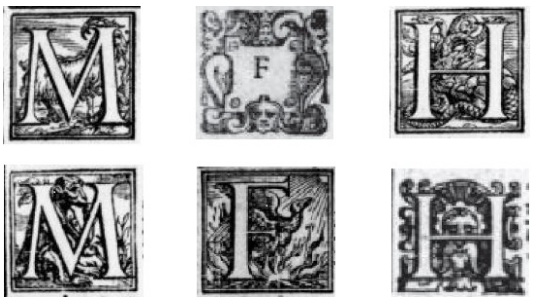

Figure 7. The anthology presents two different sets of decorative initials, which also contemplate variations of the same letter. In the musical parts two alternatives of the initials 'M' (left), 'F' (middle), and 'H' (right) are displayed.

7. CONCLUSIONS AND FUTURE WORK

We symbolically codified the *Il Lauro Secco* anthology in white mensural notation. For analytic and performance purposes, a diplomatic edition, encoded in **mens and MEI formats as well as its engraved images in pdf format, is provided. For OMR applications, ground truth in agnostic and semantic formats is presented, and the converters required to automatically generate such files from **mens encoding are also freely available. The recent development of a user-friendly encoding format for mensural notation (**mens) and a suitable encoding interface (VHV) made this work possible. Yet, given the novelty of these tools, specific aspects of mensural notation are still being developed, e. g., the lack of rests' and accidentals' position markers, or a custos indicator. By evaluating these aspects, we aim at encouraging a further development of the available tools. Due to the higher standardisation—w.r.t. handwritten and black mensural notation—of white mensural notated printed sources, and to the vast array of available scanned copies, we want to apply the methodology presented in this work to similar repertoires, thus stimulating further advance of OMR technology for early music.

[22] In modern notation, a dot must be added to the quarter note (bit note) in compound metre while in mensural notation this would not be required.

[23] Given the importance of decorative initials in Renaissance prints, the possibility to include them in VHV might be something to consider.

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