

# Digital Images and Symbolic Encoding of Guatemalan Polyphonic Choirbooks

Enhancing Preservation and Access  
for Early Music Sources through  
Digitization and Music Information Retrieval

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PhD Music Technology (McGill University)

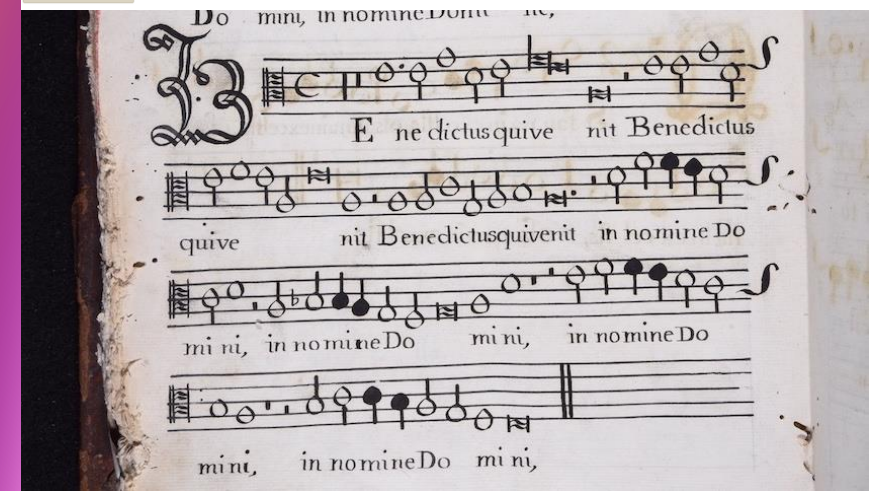
**1st Latin American Music Information Retrieval (LAMIR) Workshop**  
Universidade Federal de Rio de Janeiro, Brazil  
December 11th, 2024



superius  
altus  
tenor  
bassus

141v.jpg\_p1\_1 141v.jpg\_p1\_2 z g  
142r.jpg\_p1\_1 142r.jpg\_p1\_2 p s  
141v.jpg\_p1\_5 141v.jpg\_p1\_6 s g s  
142r.jpg\_p1\_6 142r.jpg\_p1\_7 p g a z g P g

Bar by: [semibreve] Switch to Modern Clefs Add Dissonance Labels  
Continue in Editorial Mode



# Some Background

I am from Guatemala

I was fortunate to do my Master's and PhD studies in *Music Technology* in Canada (at McGill University)

And what I wanted with this project was to **take all that music technology background** I got during my studies and **apply it to the musical heritage of my home country (Guatemala)** to help in its preservation

# **Introduction**

Motivation and Corpus

# Introduction: Motivation

- Digitization and encoding of music books from Guatemala
- Part of Guatemala's colonial past and an important part of its cultural heritage
- **Goal:** Preserve and enhance access to this music
- Through the digitization and music information retrieval (MIR) technologies

# Introduction: Corpus

- Six choirbooks held at the Archivo Histórico Arquidiocesano de Guatemala (AHAG), an archive located next to the Metropolitan Cathedral in Guatemala City
- Manuscripts (handwritten music)
- Average page dimensions: 30 cm x 45 cm
- Material: Paper
- Copied in the 17<sup>th</sup> and 18<sup>th</sup> centuries
- Contain mostly Renaissance European polyphonic music (16<sup>th</sup> c.), which continued to be used in Guatemala until the 19<sup>th</sup> c.

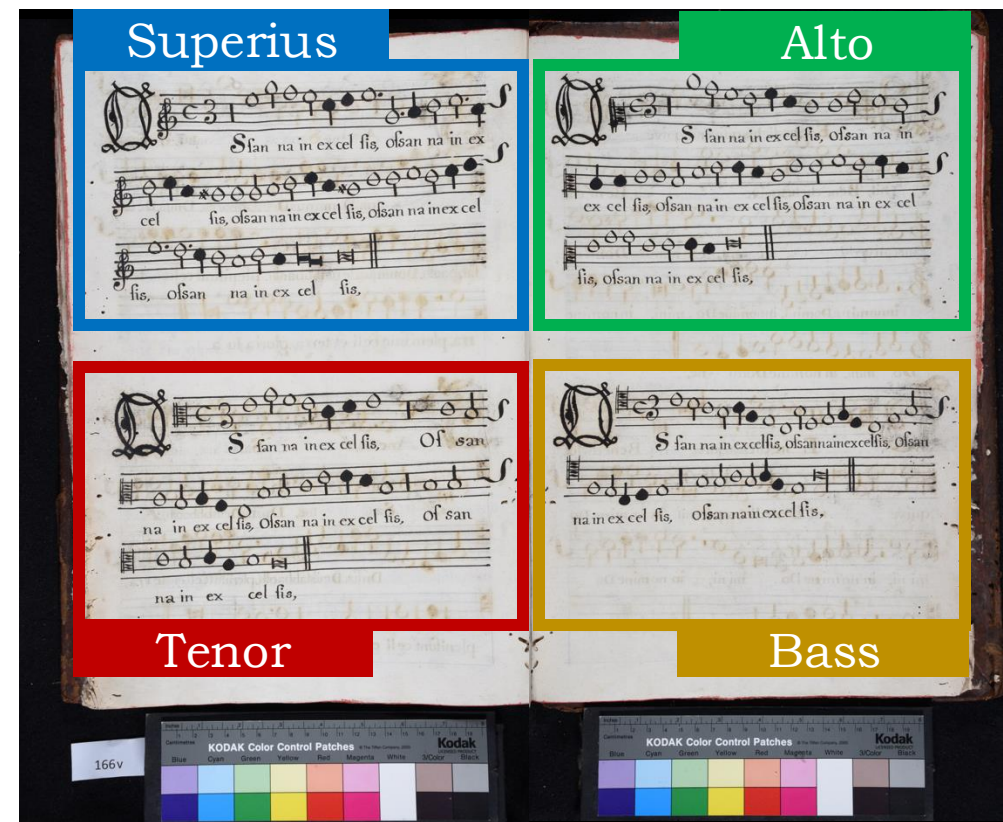
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# Introduction: Corpus

Contain mostly Renaissance European **polyphonic music** (16<sup>th</sup> c.)

- Each of the different voices (soprano, alto, tenor, bass) sing their own melody
- Rather than the whole choir singing the same melody (**monophonic** music)
- Written in **mensural notation**
- Written in a **separate-parts layout** (**voices separated** rather than lined up in a **score layout**)

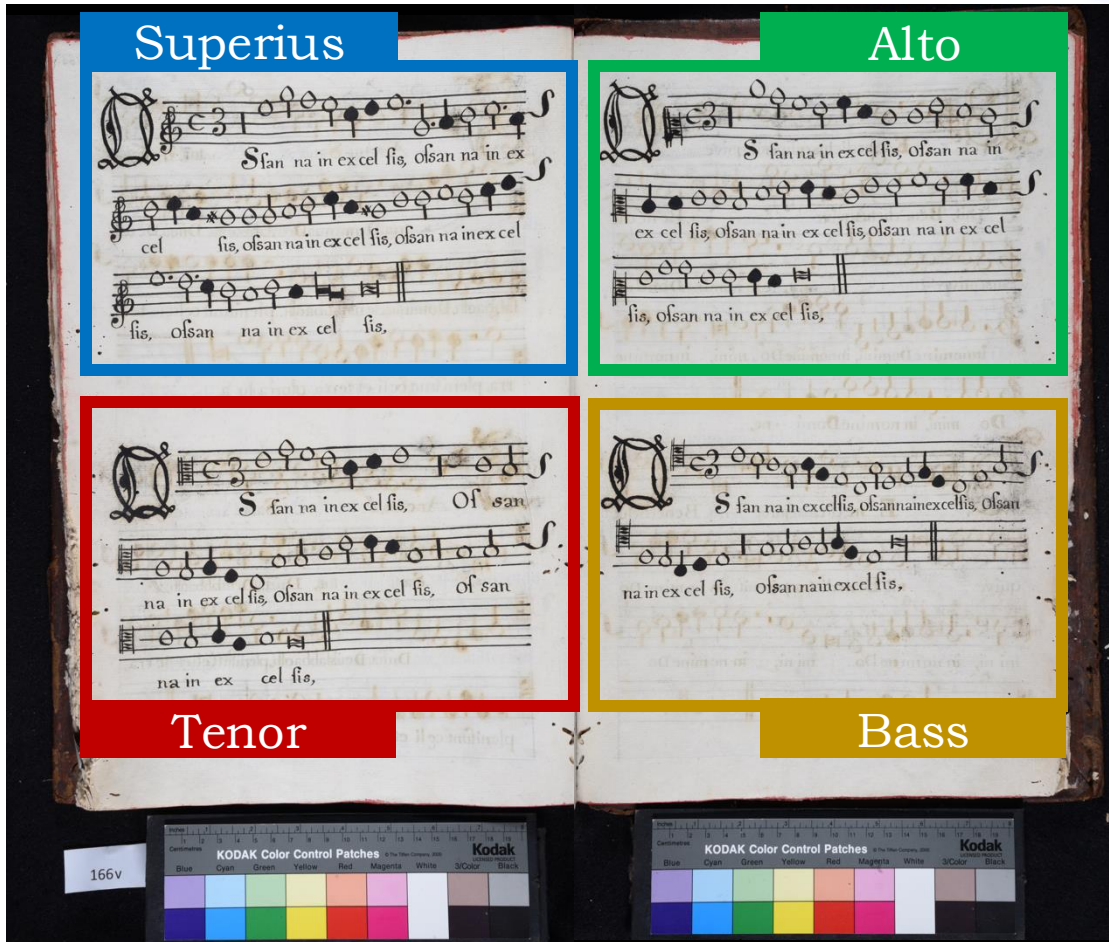


# Introduction: Corpus (*Mensural Music Books*)

- Usually in some **separate-parts** layout



**Score**



Superius  
Os - san-na - in - ex - cel - sis

Altus  
Os - san-na - in - ex - cel - sis

Tenor  
Os - san-na - in - ex - cel - sis

Bassus  
Os - san-na - in - ex - cel - sis - Os - san-na - in - ex - cel - sis

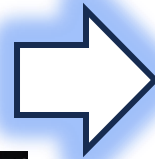
which implies dealing with the issue of this early music notation (the interpretation of the notes' duration)

You need an expert to interpret the duration of the notes in this notation



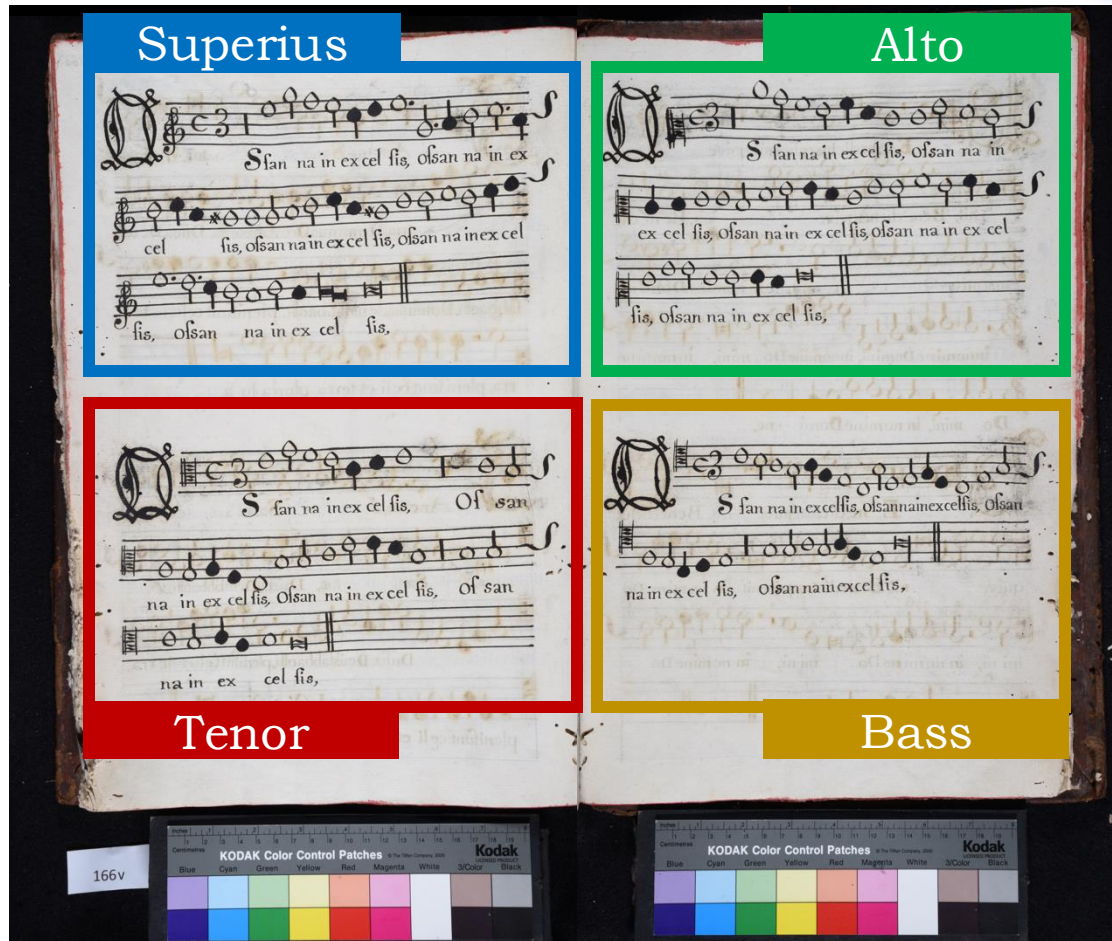
# Introduction: Corpus (*Mensural Music Books*)

- Usually in some **separate-parts** layout



## Symbolic Score

- A score encoded in a *symbolic* or *machine-readable* format



Superius  
Os - san-na - in - ex - cel - sis

Altus  
Os - san-na - in - ex - cel - sis

Tenor  
Os - san-na - in - ex - cel - sis

Bassus  
Os - san-na - in - ex - cel - sis - Os - san-na - in - ex - cel - sis

which implies dealing with the issue of this early music notation (the interpretation of the notes' duration)

You need an expert to interpret the duration of the notes in this notation

# Introduction: Motivation

- **Goal:** Preserve and enhance access to this music
- Through the digitization and music information retrieval (MIR) technologies
- **Pilot project:** First book



Manuscript



Digital images  
of the mensural pieces

Superius  
Altus  
Tenor  
Bassus

Os - san - na - in - ex - cel - sis  
Os - san - na - in - ex - cel - sis  
Os - san - na - in - ex - cel - sis  
Os - san - na - in - ex - cel - sis

**Symbolic Score**  
interpreted durations,  
an issue in mensural notation

playback

automatic  
transcription into  
modern values

comparison to  
concordant sources

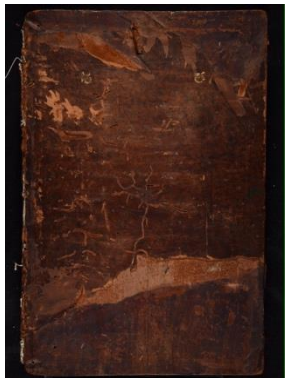
# Introduction: Motivation

- **Goal:** Preserve and enhance access to this music
- Through the **digitization** and **music information retrieval (MIR)** technologies:
  - A **do-it-yourself (DIY) book scanner** for high-resolution images
  - **Optical music recognition (OMR)** software trained for handwritten mensural notation
  - An **interpreter for mensural notation**
  - A **music-analysis tool** served as an **error checker**
- Present these tools and their integration into a **digitization and MIR pipeline** to create the digital images and symbolic scores

# Work

The Digitization and Music  
Information Retrieval (MIR) Pipeline

# Digitization & MIR Pipeline



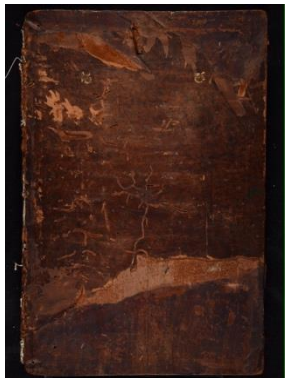
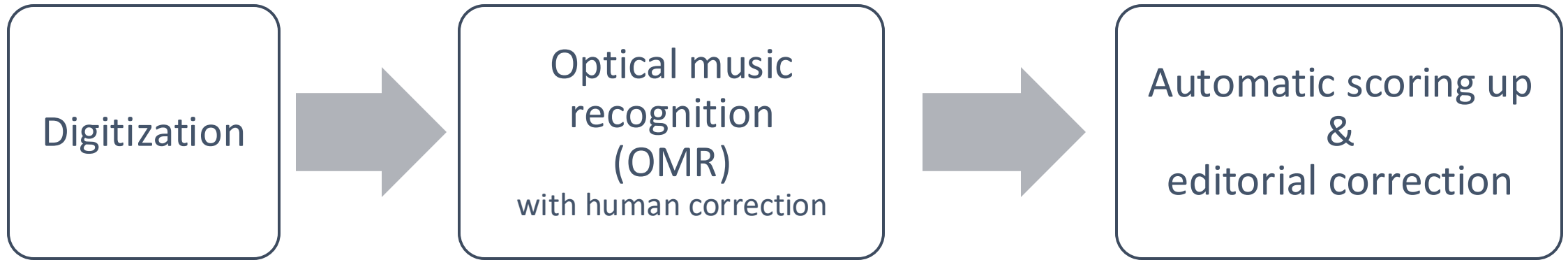
**Manuscript**

Superius  
Altus  
Tenor  
Bassus

Os - san - na - in - ex - cel - sis

**Score file**  
interpreted durations

# Digitization & MIR Pipeline



Manuscript



Digital images

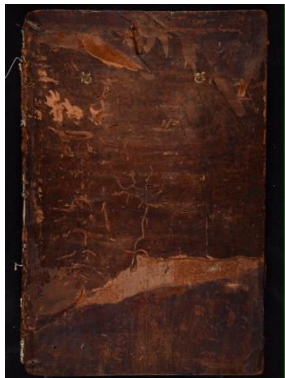
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<music>
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<note dur="semibrevis" pname="d" oct="5"/>
<dot/>
<note dur="minima" pname="c" oct="5"/>
<ligature form="recta">
<note dur="semibrevis" pname="d" oct="5"/>
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</ligature>
<note dur="brevis" pname="b" oct="4"/>
</staff>
</music>
</mei>
```

Parts file

encodes the **symbols** in each **part/voice** of the images

**Score file**  
interpreted durations

# Digitization & MIR Pipeline



Manuscript

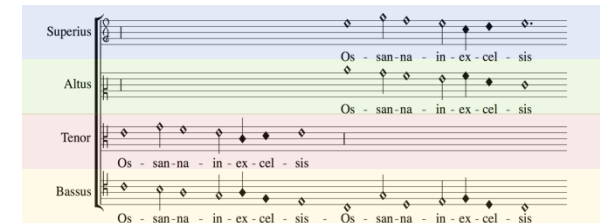


Digital images

```
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<music>
<staff n="1">
<clef line="2" shape="G"/>
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<ligature form="recta">
<note dur="semibrevis" pname="d" oct="5"/>
<note dur="semibrevis" pname="g" oct="4"/>
</ligature>
<note dur="brevis" pname="b" oct="4"/>
</staff>
</music>
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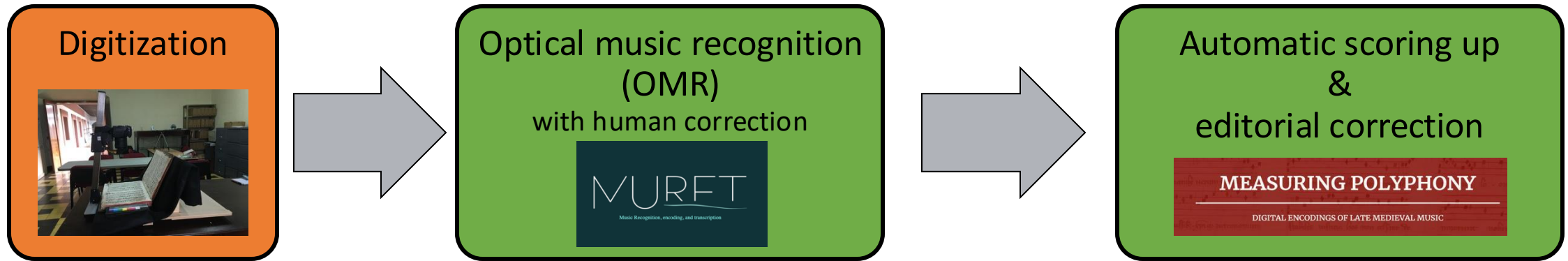
Parts file

encodes the **symbols** in each **part/voice** of the images



**Score file**  
interpreted durations

# Digitization & MIR Pipeline



Manuscript

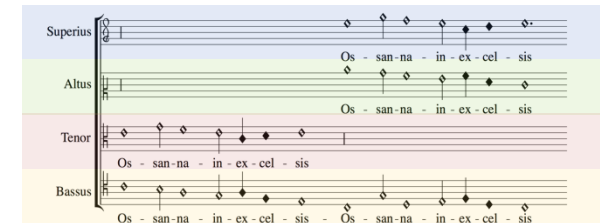


Digital images

```
<mei>
<music>
<staff n="1">
<clef line="2" shape="G"/>
<note dur="semibrevis" pname="g" oct="5"/>
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<note dur="semibrevis" pname="g" oct="4"/>
</ligature>
<note dur="brevis" pname="b" oct="4"/>
</staff>
</music>
</mei>
```

Parts file

encodes the **symbols** in each **part/voice** of the images



**Score file**  
interpreted durations



# 1. Digitization

Obtaining digital images

Do-it-yourself book scanner

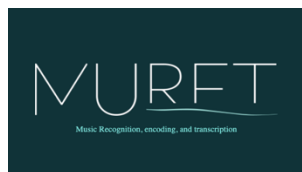
# Digitization

Do-it-yourself (DIY) book scanner

Digitization



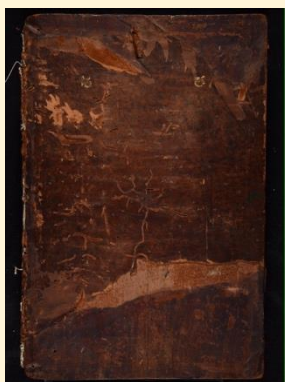
Optical music recognition  
(OMR)



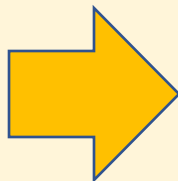
Automatic scoring up  
&  
editorial correction

**MEASURING POLYPHONY**

DIGITAL ENCODINGS OF LATE MEDIEVAL MUSIC



Manuscript

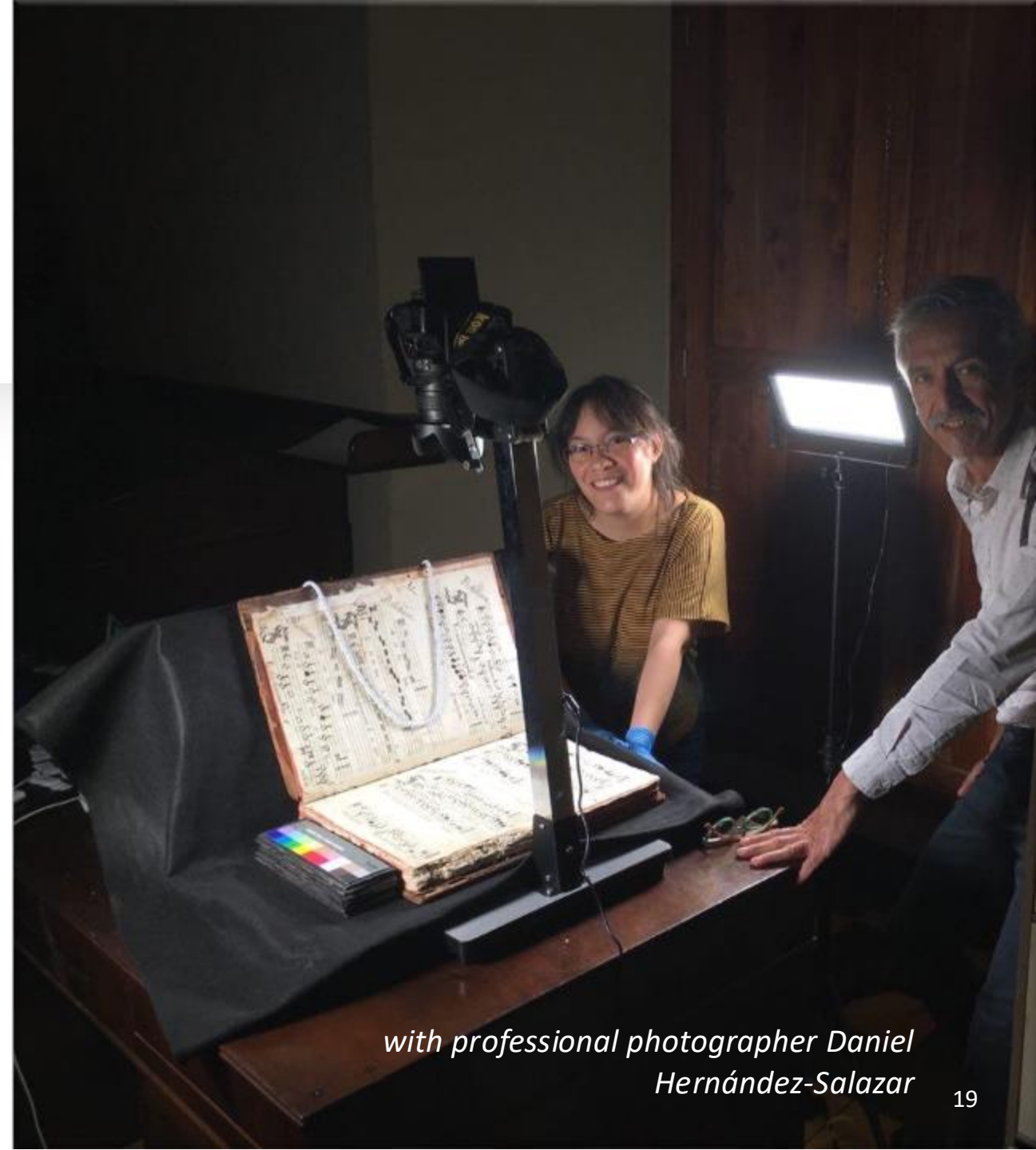


Digital image

# Technology Used

## DIY Book Scanner

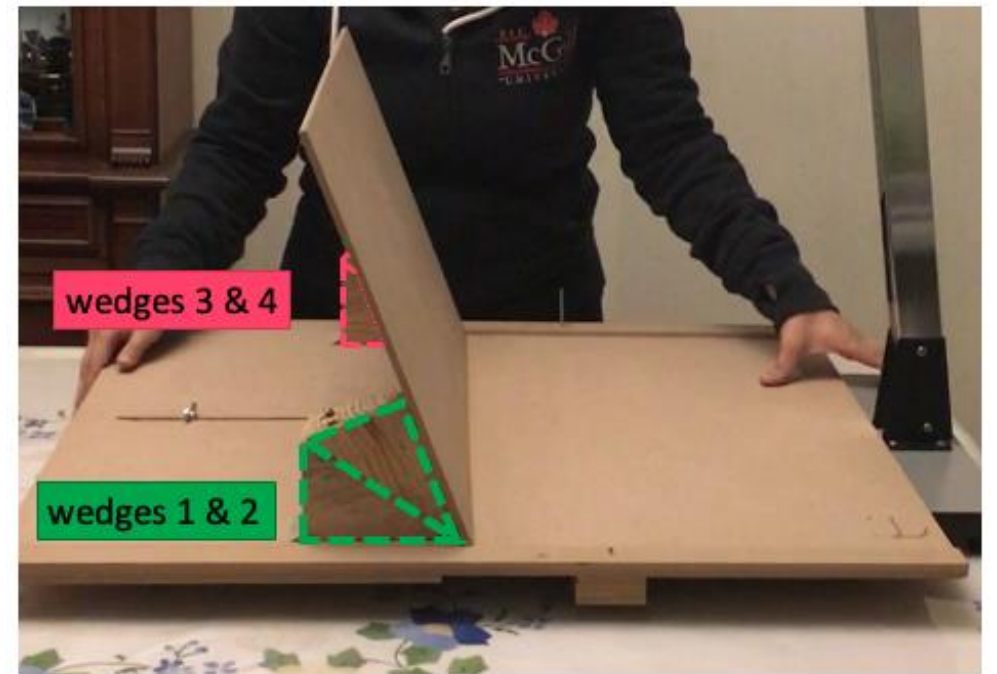
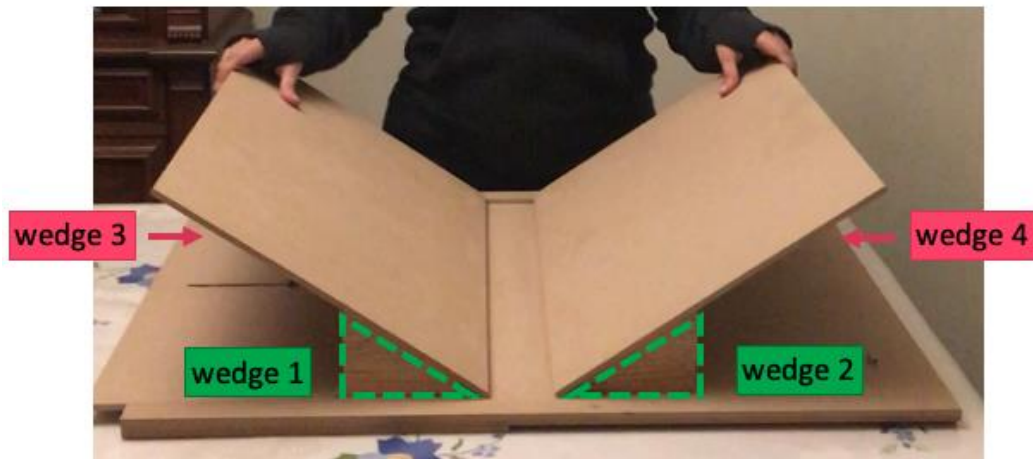
- With **borrowed** (camera & lights) and **built** parts (cradle)
- Advice from various institutions including the *Digital Image Archive of Medieval Music (DIAMM)*



with professional photographer Daniel  
Hernández-Salazar

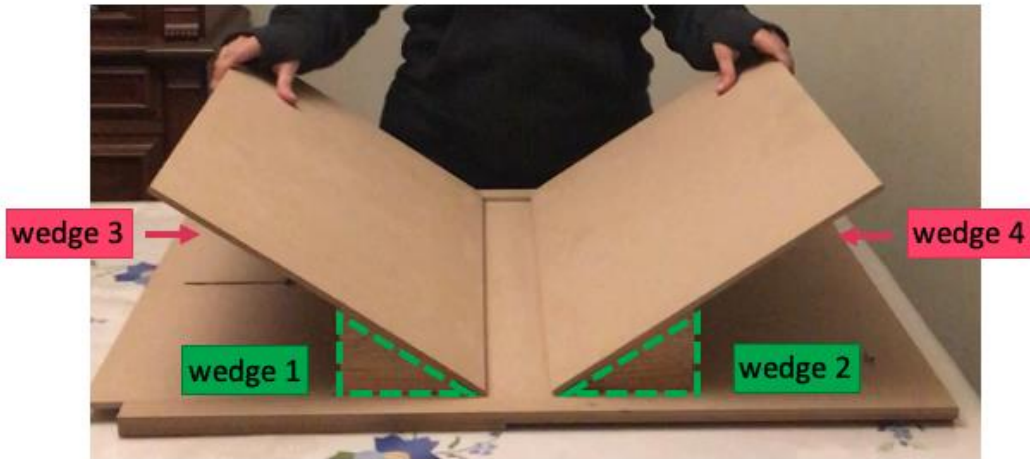
# Book Cradle: Configurations

Hold the book opened at  $110^\circ$  angle  
by using four wedges of  $35^\circ$



# Book Cradle: Configurations

Hold the book opened at  $110^\circ$  angle  
by using four wedges of  $35^\circ$



German Thomae



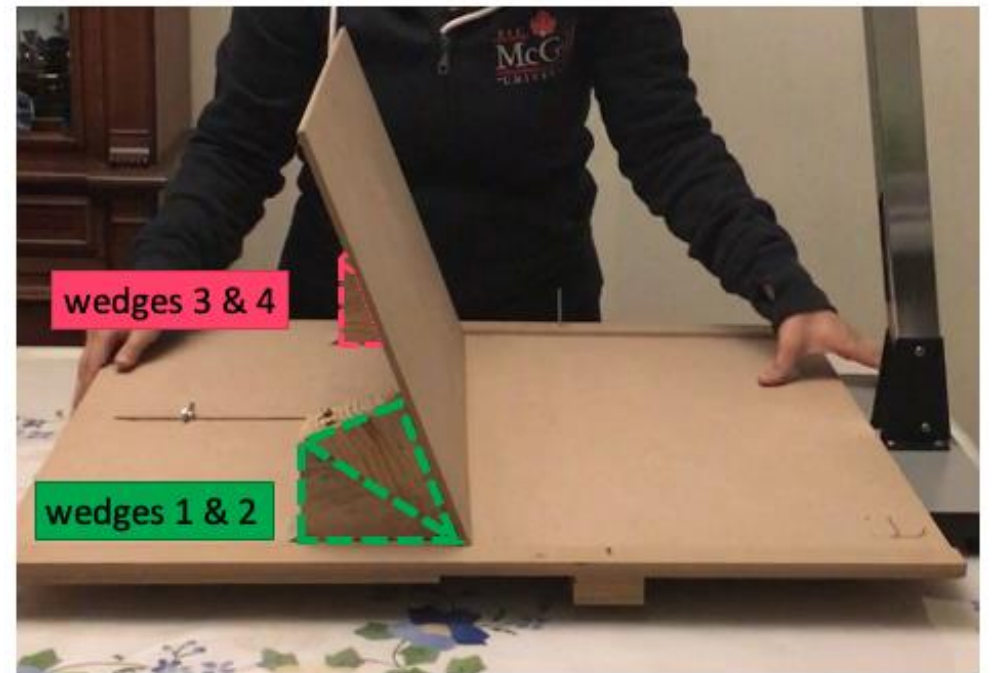
<https://caso.com/services/document-scanning/book-scanning/>

# Book Cradle: Configurations

Hold the book opened at  $110^\circ$  angle  
by using four wedges of  $35^\circ$



<https://www.telescopiomania.eu/9161-reproduction-table-bresser-br-cst-copy-stand-40x48-cm-4007922033389.html>



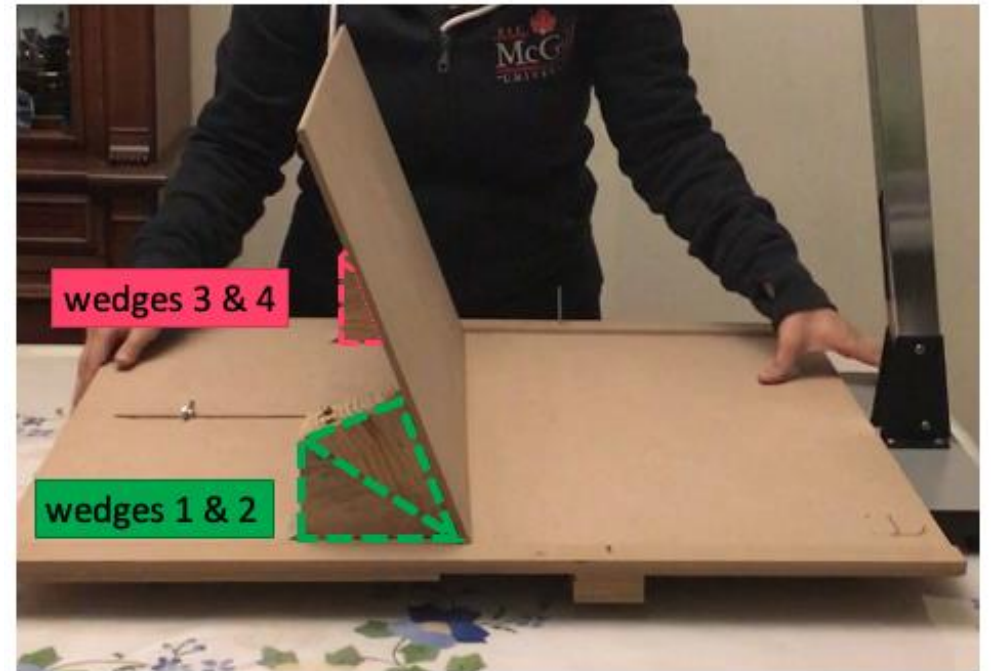
German Thomae

# Book Cradle: Configurations

Hold the book opened at  $110^\circ$  angle  
by using four wedges of  $35^\circ$



<https://www.bsb-muenchen.de/einblicke/vom-buch-zum-byte-digitalisierung-an-der-bayerischen-staatsbibliothek>



German Thomae

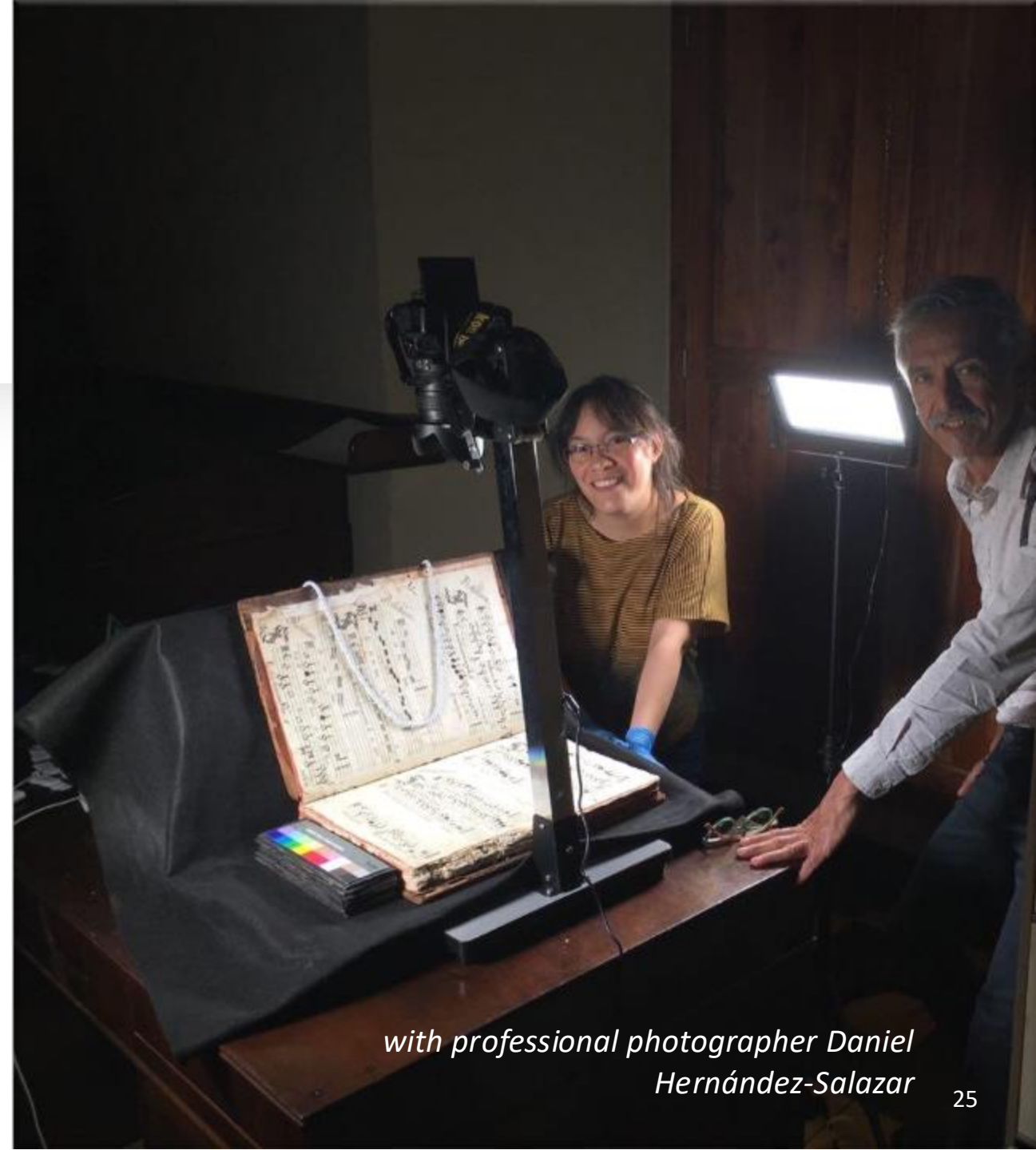




# Digitization Stage

## AFFORDABLE

- **Equipment:** Do-it-yourself (DIY) book scanner
- **Conservation task:** Outsourced to non-profit institution
- **Digitization task:** Conducted by me with a professional photographer hired for a few of sessions to set up the camera parameters



*with professional photographer Daniel Hernández-Salazar*

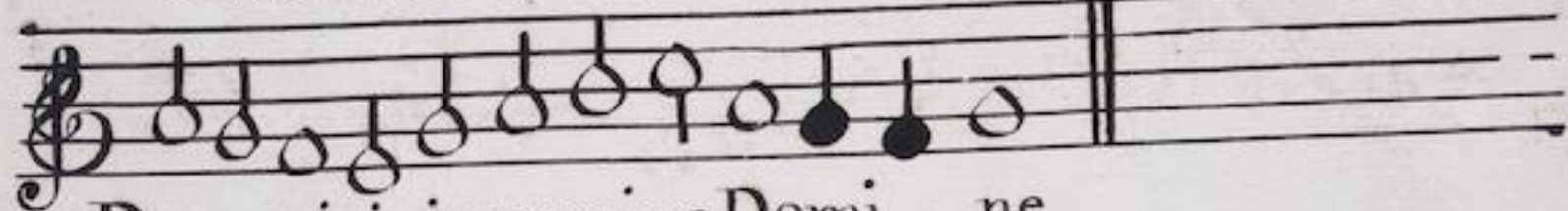
# Results

167v

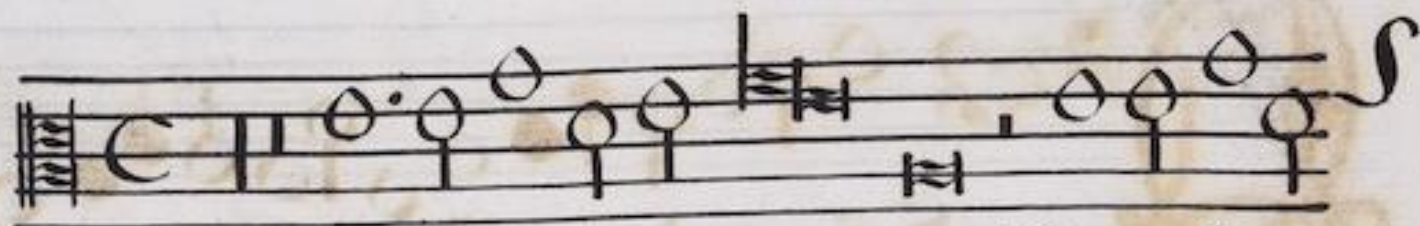
E nedictus quivenit quive  
nit, Benedictus quive nit, Be ne dic  
tus quive nit, in nomine Domini  
in nomine Domini, in nomine Do mini, in nomine  
Do mini, in nomine Domi ne,  
E ne dictus quive nit Benedictus  
quive nit Benedictus quivenit in nomine Do  
mi ni, in nomine Do mi ni, in nomine Do  
mi ni, in nomine Do mi ni,

KODAK Color Control Patches  
Blue Cyan Green Yellow Red Magenta White 3/Color Black  
Kodak

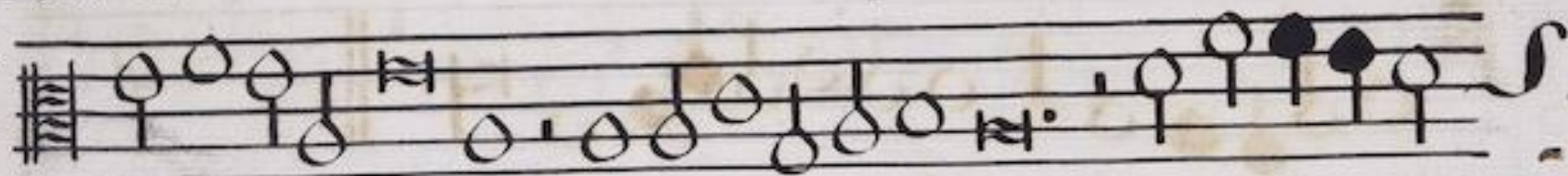
innomine Domini, innomine Do mini, innomine



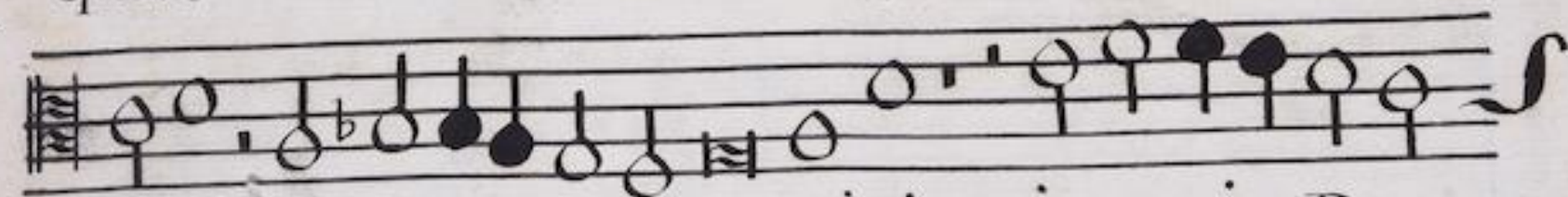
Do mini, in nomine Domi ne,



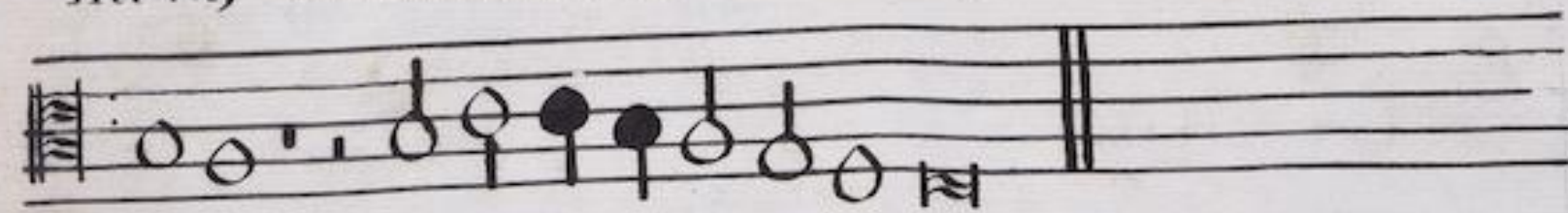
E ne dictus quive nit Benedictus



quive nit Benedictus quivenit in nomine Do



mi ni, in nomine Do mi ni, in nomine Do



## **2. MIR Technologies**

Obtaining symbolic files

Optical Music Recognition

# What is Optical Music Recognition (OMR)?

- Similar to Optical Character Recognition (OCR)
- OCR recognizes the characters in a digital text document and makes it searchable
- OMR recognizes the music characters in a digital music document and makes the images searchable by their music content

- **OMR is the process of converting images of music documents into symbolic computer representation, such as MIDI, MusicXML, or MEI (Music Encoding Initiative)**



Pixel Domain

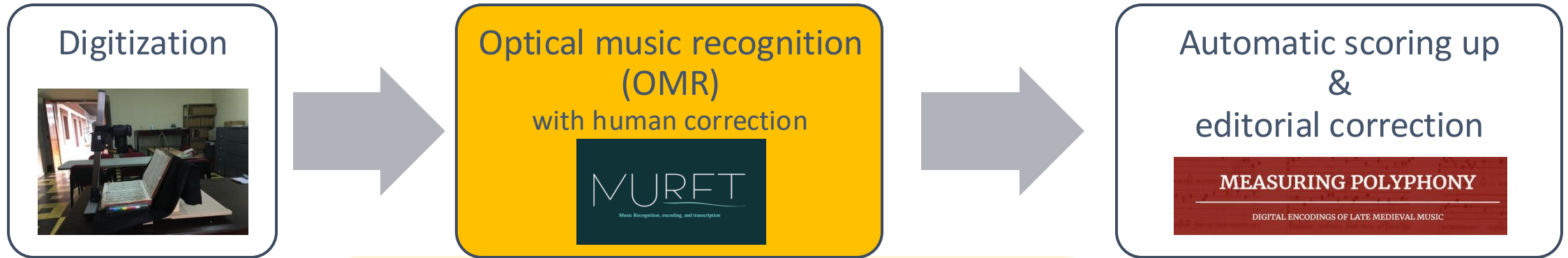


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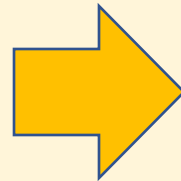
Symbolic Domain

# Optical Music Recognition (OMR)

MuRET (Music Recognition Encoding and Transcription)



Digital image



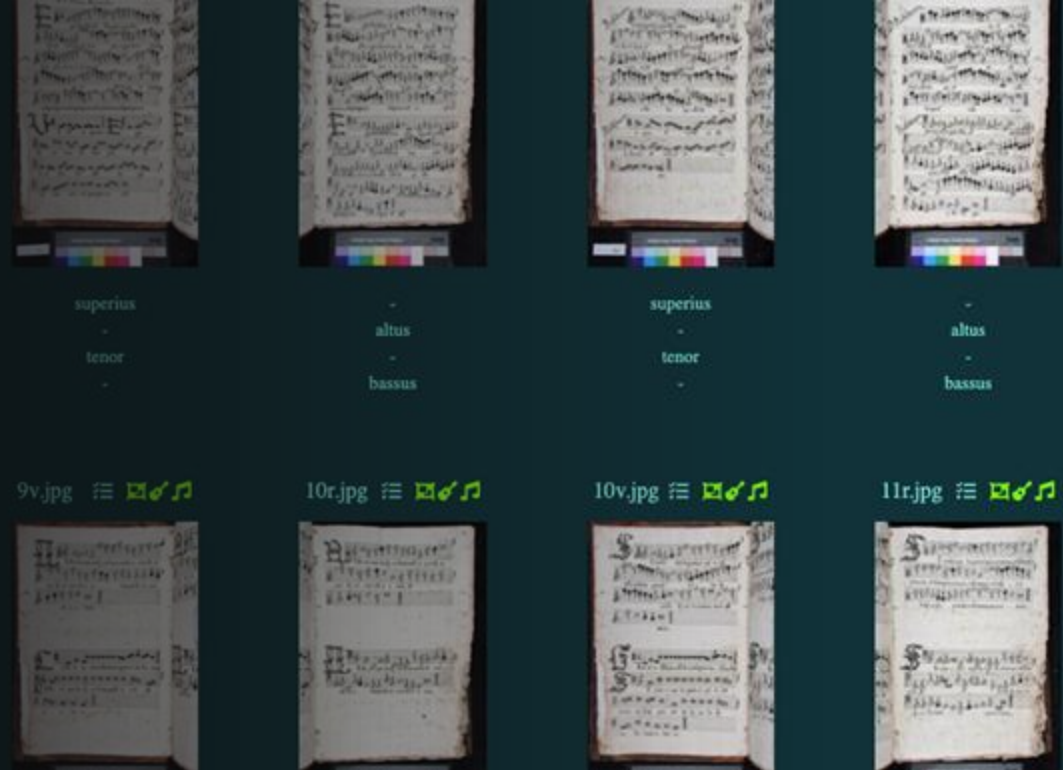
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<ligature form="recta">
<note dur="semibrevis" pname="d" oct="5"/>
<note dur="semibrevis" pname="g" oct="4"/>
</ligature>
<note dur="brevis" pname="b" oct="4"/>
</staff>
</music>
</mei>
```

MEI Parts file  
encodes the **symbols** in each  
**part/voice** of the images

# MuRET

Optical music recognition framework that supports mensural notation

Developed by David Rizo, University of Alicante



# MUREFT

Music Recognition, encoding, and transcription



Document overview

Right click on selected images for further exporting and part linking

Unassigned to section

New section...

Move all to default section...

7v.jpg



superius  
-  
tenor

8r.jpg



-  
altus  
-  
bassus

8v.jpg



superius  
-  
tenor

9r.jpg



-  
altus  
-  
bassus

9v.jpg



superius  
-  
tenor

10r.jpg



-  
altus  
-  
bassus

10v.jpg

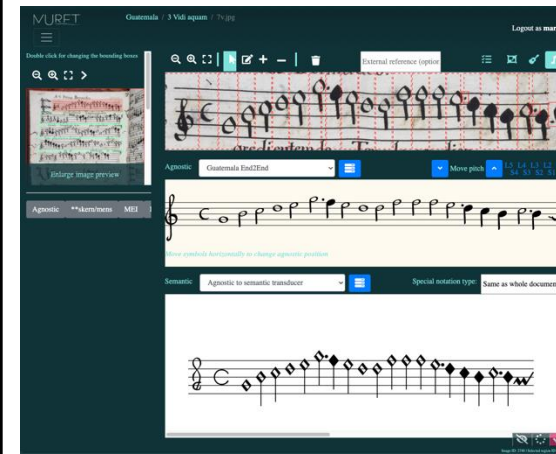
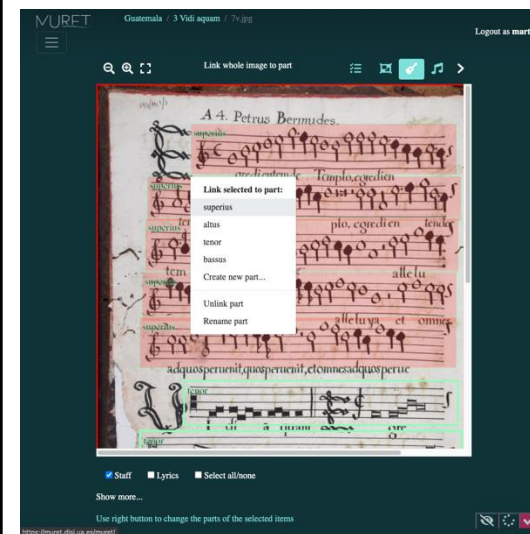
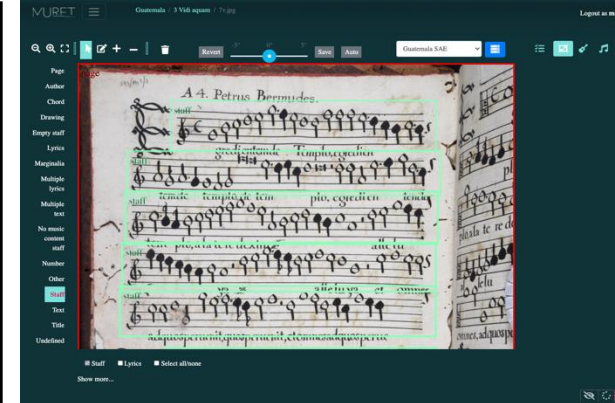


superius  
-  
tenor

11r.jpg



-  
altus  
-  
bassus







Revert



Save

Auto

Guatemala SAE



- Page
- Author
- Chord
- Drawing
- Empty staff
- Lyrics
- Marginalia
- Multiple lyrics
- Multiple text
- No music content staff
- Number
- Other
- Staff**
- Text
- Title
- Undefined

893/1451/3

A 4. Petrus Bermudes.

staff

gredientem de Templo, egredien

staff

tem de templo, de tem pio, egredien tencia

staff

tem plo, ala te re dexi

staff

afflu ya et omnes

ad quos peruenit, quos peruenit, et omnes ad quos perue

MuRET – Interface # 1

**OMR STAGE 1: Document Analysis**

*automatic process*



Link whole image to part



895/MS 1/3

A 4. Petrus Bermudes.

superius  
 credientem de Templo, egredien  
 superius  
 superius  
 plo, egredien tendes  
 superius  
 allelu  
 superius  
 allelu ya et omnes  
 ad quos peruenit, quos peruenit, et omnes ad quos perue

tenor  
 I di a quam ore  
 tenor

**Link selected to part:**  
 superius  
 altus  
 tenor  
 bassus  
 Create new part...  
 Unlink part  
 Rename part

MuRET – Interface # 2  
 Voice assignation  
*manual process*

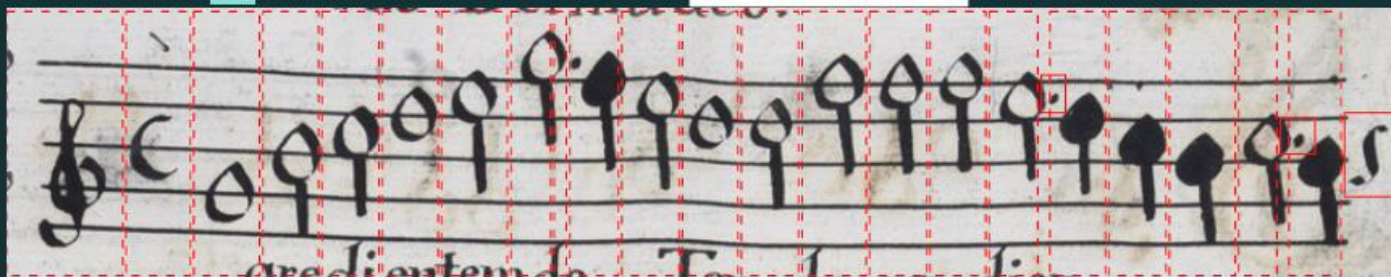
Double click for changing the bounding boxes



Enlarge image preview



External reference (option)



Agnostic

Guatemala End2End

Move pitch

L5 L4 L3 L2 L1  
S4 S3 S2 S1

Agnostic

\*\*skern/mens

MEI

PAEC

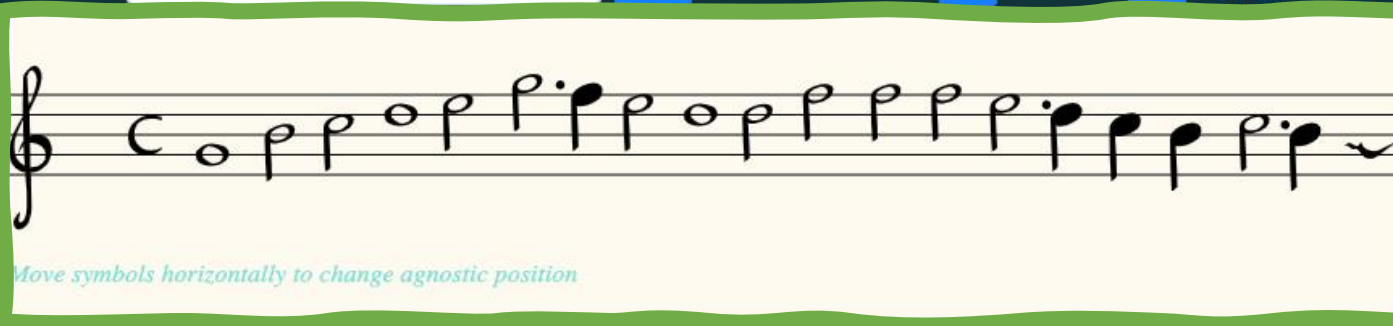
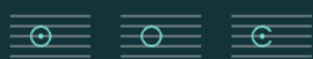
Clefs | Meters

Notes

Beamed notes

Rests | Accidentals

Other



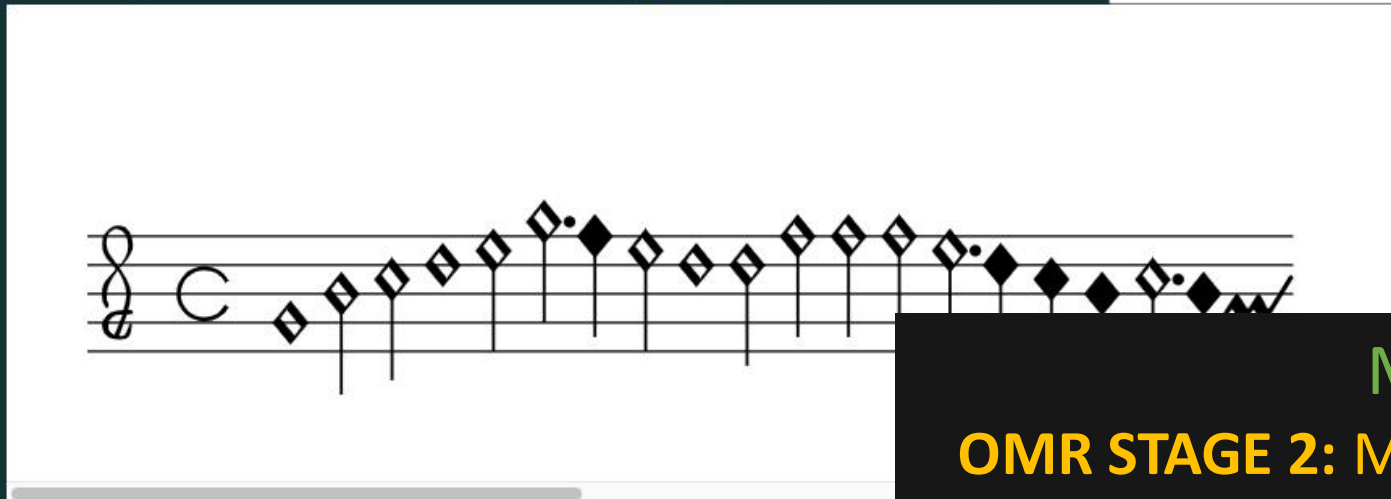
Move symbols horizontally to change agnostic position

Semantic

Agnostic to semantic transducer

Special notation type:

Same as whole document



agnostic  
encoding

MuRET – Interface # 3

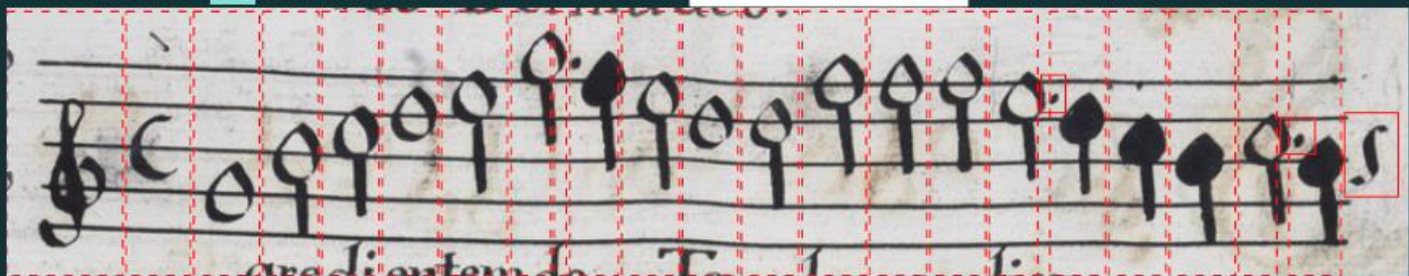
OMR STAGE 2: Music Symbol Recognition

automatic process

Double click for changing the bounding boxes



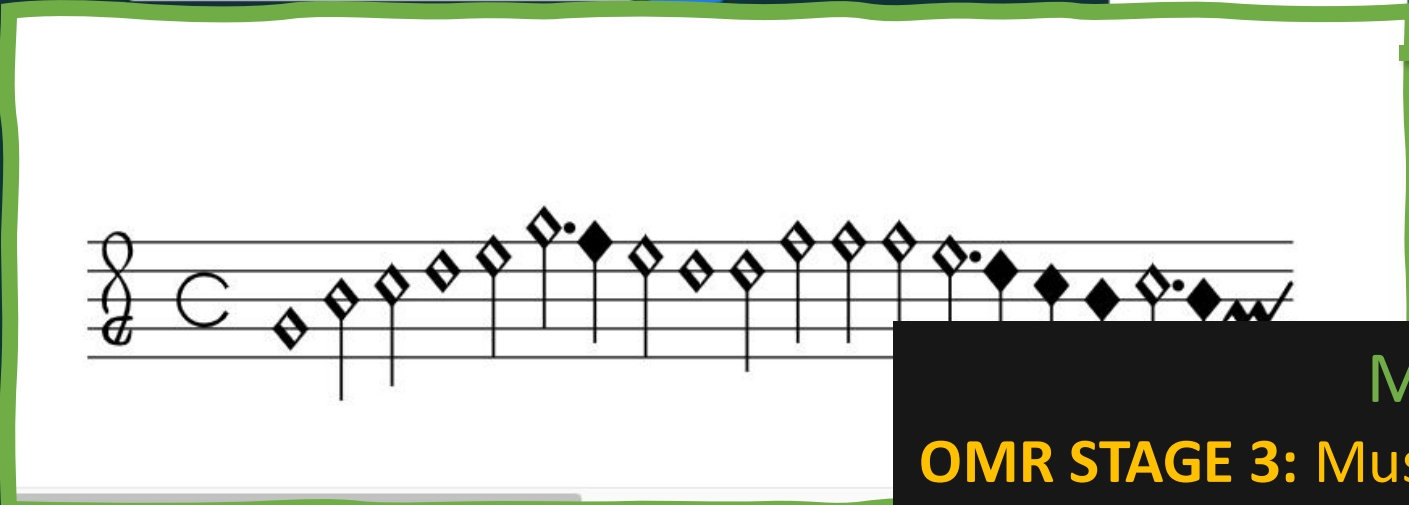
Enlarge image preview



Agnostic Guatemala End2End Move pitch L5 L4 L3 L2 L1 S4 S3 S2 S1



Semantic Agnostic to semantic transducer Special notation type: Same as whole document



Agnostic **\*\*skern/mens** MEI PAEC

**skm	Aç	+
*clefG2	2E	+
*met(C)	2E	-
Sr_3	2E	+
sr_3	2E	-
sg	2E	+
Ma	2E	-
Mb\	2E	+
Mcc	2E	-
Mdd	2E	+
see	2E	-
Mdd	2E	+
scc	2E	-
Mh\	2E	+

semantic encoding

MuRET – Interface # 3  
OMR STAGE 3: Music Notation Recognition  
automatic process



Document overview

Right click on selected images for further exporting and part linking

Unassigned to section

New section...

Move all to default section...

7v.jpg



superius  
-  
tenor

8r.jpg



-  
altus  
-  
bassus

8v.jpg



superius  
-  
tenor

9r.jpg



-  
altus  
-  
bassus

9v.jpg



superius  
-  
tenor

10r.jpg



-  
altus  
-  
bassus

10v.jpg

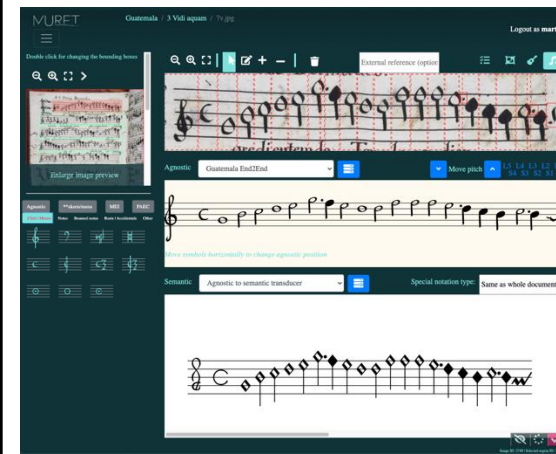
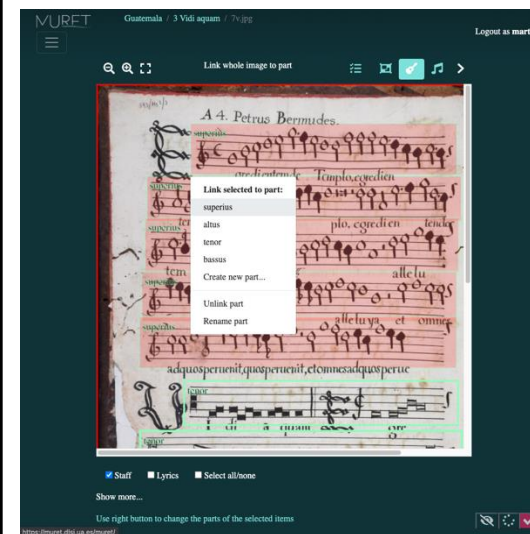
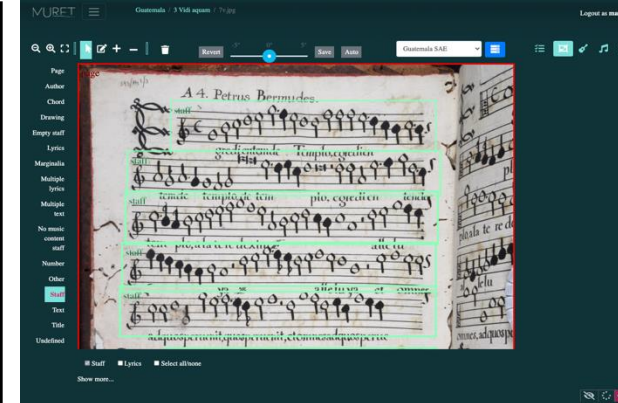


superius  
-  
tenor

11r.jpg



-  
altus  
-  
bassus





Document overview

Right click on selected images for further exporting and part linking

Unassigned to section

New section...

Move all to default section...

7v.jpg



superius  
-  
tenor  
-

8r.jpg



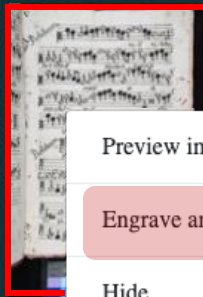
-  
altus  
-  
bassus

8v.jpg



superius  
-  
tenor  
-

9r.jpg



-  
altus  
-  
bassus

9v.jpg



superius  
-  
tenor  
-

10r.jpg



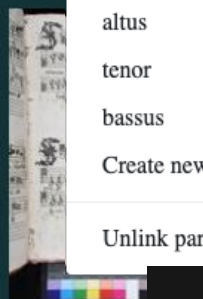
-  
altus  
-  
bassus

10v.jpg



superius  
-  
tenor  
-

11r.jpg



-  
altus  
-  
bassus

- Preview image...
- Engrave and export (MEI)...
- Hide
- Move to section:**
  - Unassign section
- Link whole image to part:**
  - superius
  - altus
  - tenor
  - bassus
  - Create new part...
- Unlink part

MuRET – Overview Interface  
OMR STAGE 4: Music Encoding  
*automatic process*

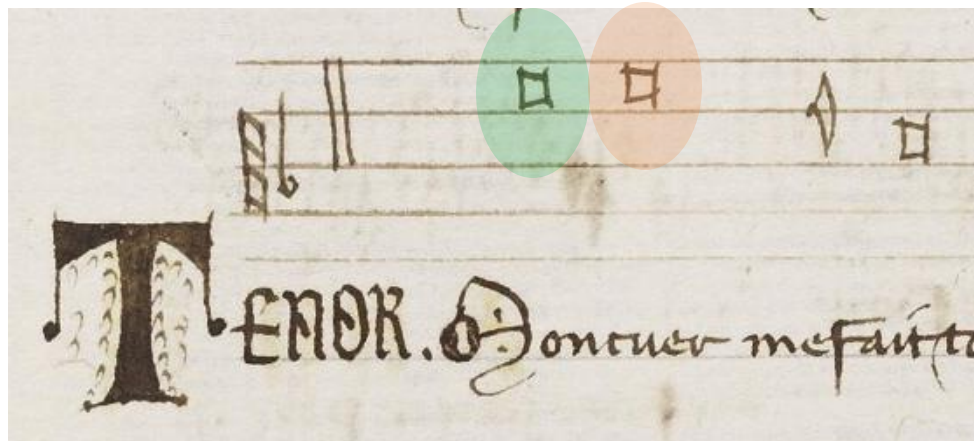
# 3. MIR Technologies

Obtaining symbolic files

Interpreter of mensural notation  
(automatic “scoring up” / “voice alignment”)

# What is the Issue with Mensural Notation?

The note shape (the type of note) is not enough to convey the duration of a note.



3 quarter notes

Mon

cuer

me

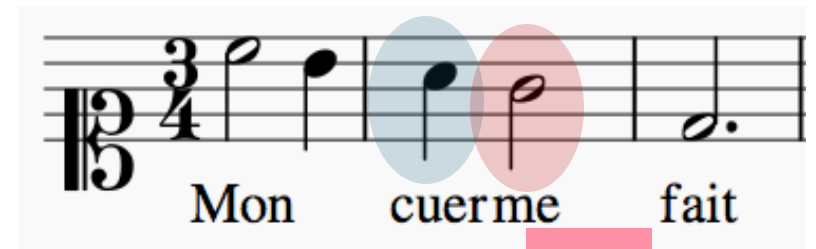
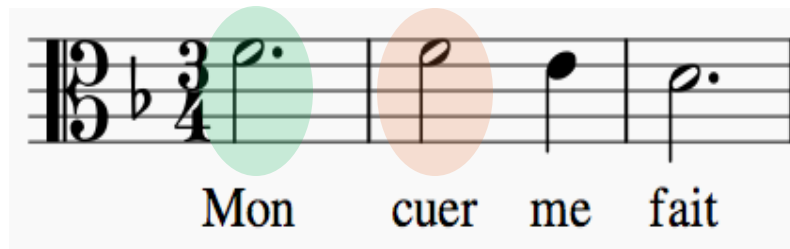
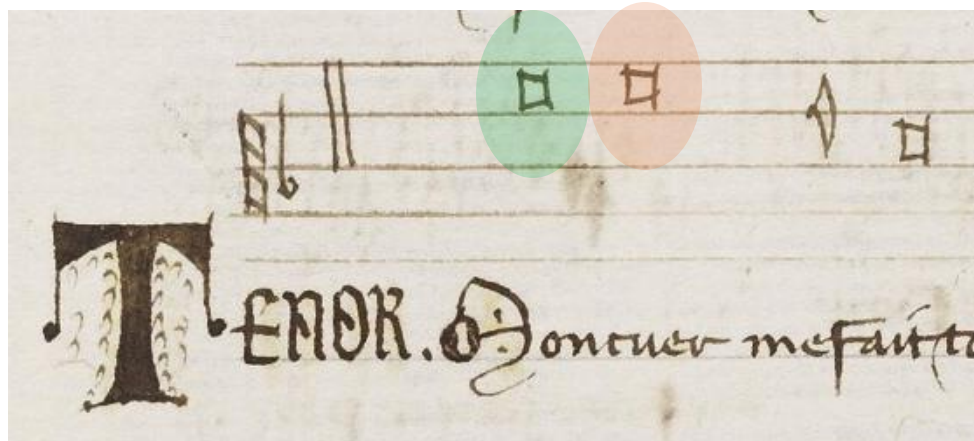
fait

2 quarter notes



# What is the Issue with Mensural Notation?

The note shape (the type of note) is not enough to convey the duration of a note.



x 2

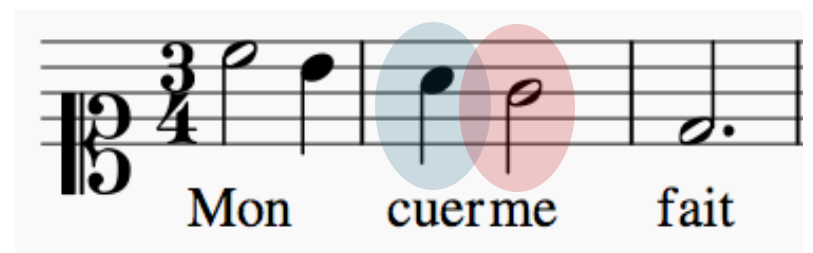
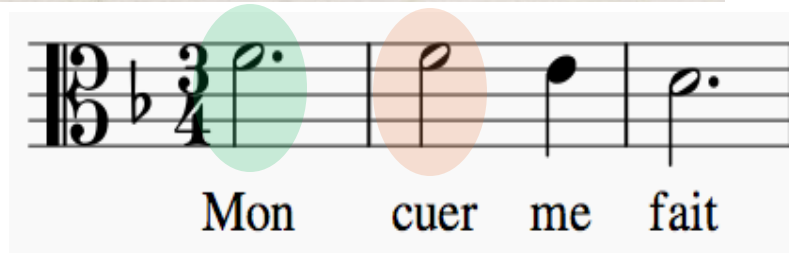
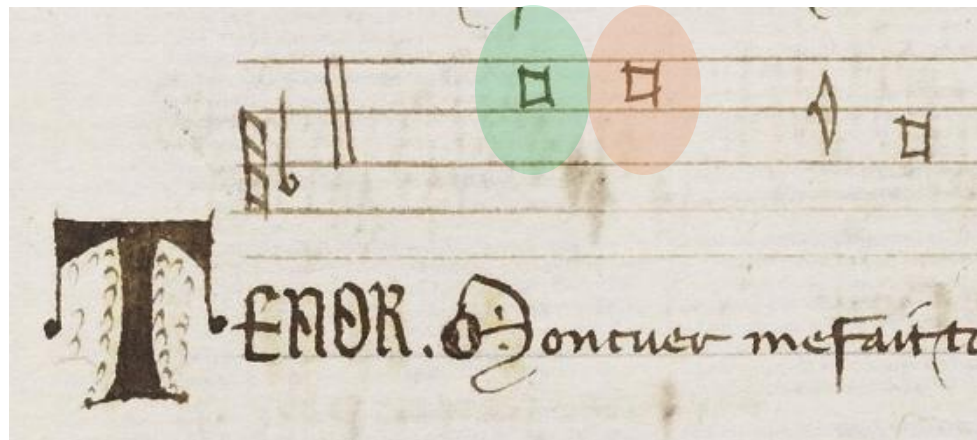
The duration of the individual note symbols in mensural notation depends on

(1) the “**mensuration**”  
or *meter* of the piece,  
which can be *duple or triple meter*  
(*gives the value of the note by default*)

(2) In triple meter,  
the duration of the individual  
note symbols is not absolute, but  
rather **depends on “context”**

# What is the Issue with Mensural Notation?

In **triple meter**, the note shape is not enough to convey the duration of a note. **The note's default duration can be modified by the context** (i.e., notes preceding or following)



# What is the Issue with Mensural Notation?

In **triple meter**, the note shape is not enough to convey the duration of a note. **The note's default duration can be modified by the context** (i.e., notes preceding or following)


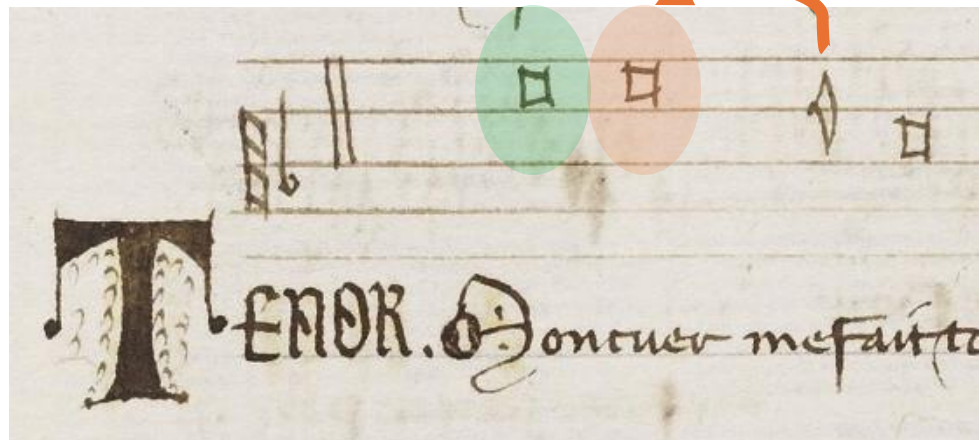
**IMPERFECTION**

perfecta (ternary) Mon cuer imperfecta (binary)

# What is the Issue with Mensural Notation?


In **triple meter**, the note shape is not enough to convey the duration of a note. **The note's default duration can be modified by the context** (i.e., notes preceding or following)

IMPERFECTION



perfecta (ternary) Mon cuer imperfecta (binary)

ALTERATION



regular altera (altered, twice as long)

# What is the Issue with Mensural Notation?

## Principles of Imperfection and Alteration

**IMPERFECTION**

perfecta (ternary) Mon cuer imperfecta (binary)

**ALTERATION**

regular altera (altered, twice as long)

# 3. MIR Technologies

Obtaining symbolic files

Interpreter of mensural notation  
(automatic “scoring up” / “voice alignment”)

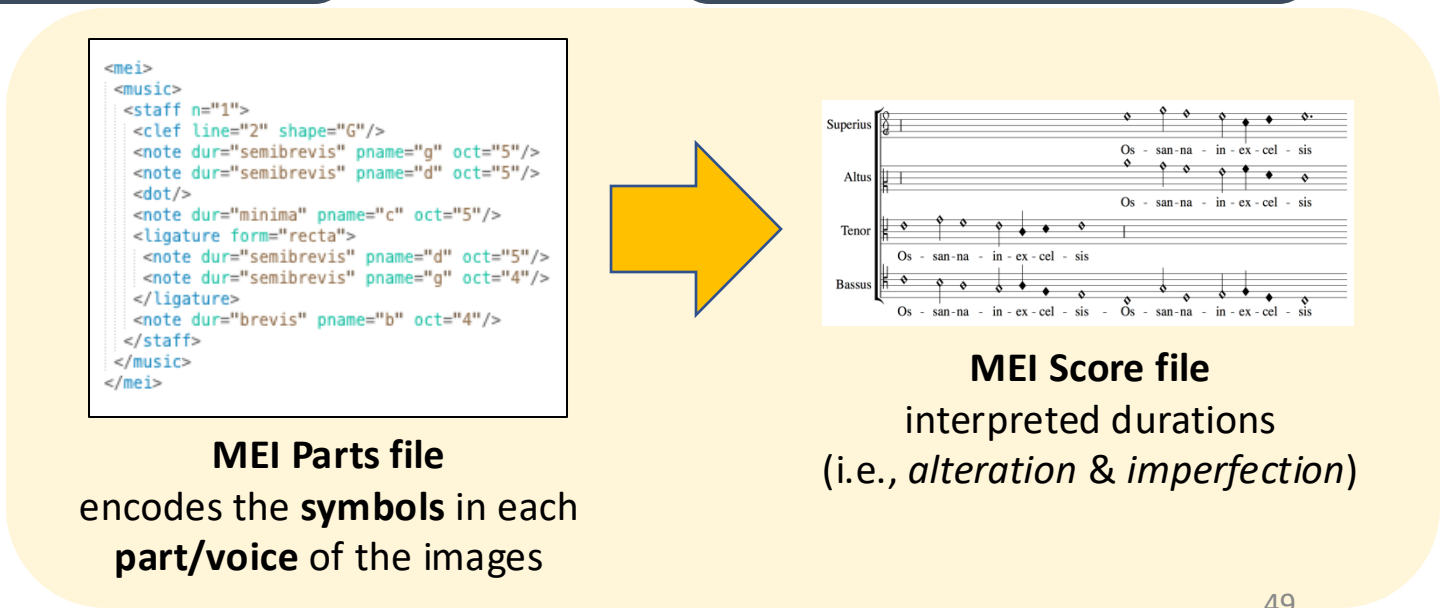
---

- Developed an expert system based on the “principles of imperfection and alteration”
- Implemented it into Python (Master’s degree)
- Re-implement it as a part of an online mensural notation editor, which is **the next tool used**



# Automatic Voice Alignment & Editorial Correction

Measuring Polyphony Editor (MP-Editor)



# Measuring Polyphony Editor

Online editor for mensural notation

Karen Desmond (PI), Maynooth University

Mostly developed at McGill University:

- **Juliette Regimbal** (lead developer)
- **Martha E. Thomae** (automatic voice alignment function)

And with **Laurent Pugin** (Verovio), **Craig Sapp** (Humdrum), and **Andrew Hankinson** (IIF)

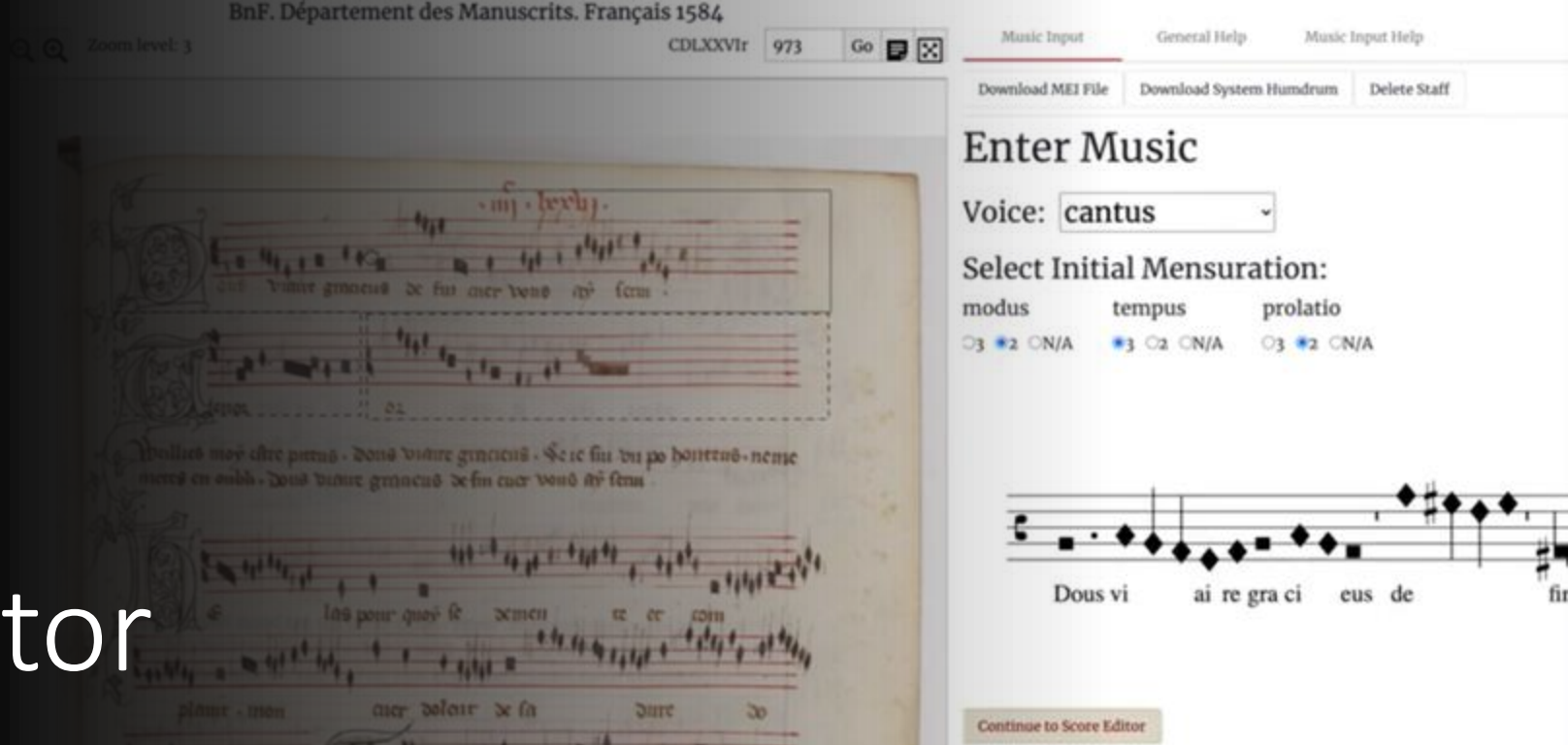


# MEASURING POLYPHONY

# Measuring Polyphony Editor

Online editor for mensural notation with **two parts**:

1. **Input Editor**: The user types in the notes using the computer keyboard
2. **Score Editor**: It processes the notes entered, computes their duration based on a system of rules, and lines up the piece in score layout



## MEASURING POLYPHONY



### Load a manuscript

Manuscript Repository:  URL:

For example, to transcribe a piece from the famous *Roman de Fauvel* manuscript, choose *Gallica* in the dropdown and paste this URL:

<https://gallica.bnf.fr/ark:/12148/btv1b8454675g>

### Load an .mei file

Compatible Parts-MEI File:  No file chosen

The Measuring Polyphony Music Editor (the MP Editor), funded by the [National Endowment for the Humanities](#), is a prototype web application that allows users with no expertise in music encoding to transcribe and digitally encode transcriptions of polyphony in mensural notation, and create links between these music transcriptions to zones of the digital images of the original medieval manuscripts. To download a White Paper on the MP Editor, click [here](#). For more information about the Measuring Polyphony project, click [here](#).

### Project Team

- Karen Desmond, Brandeis University, Massachusetts, USA: Principal Investigator & Project Director
- Juliette Regimbal, McGill University, Canada: Prototype developer
- Martha Thomae, McGill University, Canada: Prototype developer
- Andrew Hankinson, RISM, Switzerland: Consultant on diva.js, MEI
- Laurent Pugin, University of Bern & RISM, Switzerland: Consultant on Verovio, MEI
- Craig Sapp, Stanford University, California, USA: Consultant on Humdrum, MEI

### Student Research Assistants

- Caelan Gadweh-Meaden, Brandeis University, USA
- Zen Kuriyama, Brandeis University, USA
- Daniel Shapiro, Brandeis University, USA

With thanks also to Julie Cumming and her music palaeography students at McGill University - Christina Colanduoni, Mayu Egan, Geneviève Gates-Panneton, Namgon Lee, and Celia Morin - for testing the MP Editor in December 2020.

### Advisory Board

- Julie Cumming, McGill University, Canada
- Julia Craze McEvelly, University of Oxford, UK

### Load a manuscript

Manuscript Repository: Gallica URL:

For example, to transcribe a piece from the famous *Roman de Fauvel* manuscript, choose *Gallica* in the dropdown and paste this URL:  
<https://gallica.bnf.fr/ark:/12148/btv1b8454675g>

Load an .mei file  
Compatible Parts-MEI File:  No file chosen

The Measuring Polyphony Music Editor (the MP Editor), funded by the [National Endowment for the Humanities](#), is a prototype web application that allows users with no expertise in music encoding to transcribe and digitally encode transcriptions of polyphony in mensural notation, and create links between these music transcriptions to zones of the digital images of the original medieval manuscripts. To download a White Paper on the MP Editor, click [here](#). For more information about the Measuring Polyphony project, click [here](#).

### Project Team

Karen Desmond, Brandeis University, Massachusetts, USA: Principal Investigator & Project Director

# INPUT EDITOR

The notes were not typed in as the loaded file already had the symbols recognized in the previous step

editor.measuringpolyphony.org/#/input/iiif/https%25253A%25252F%25252Fmuret.dlsi.ua.es%25252Fiiif%25252F6%25252F223%25252Fmanifest.json

MEASURING POLYPHONY  
DIGITAL ENCODINGS OF LATE MEDIEVAL MUSIC

Pedro Bermudez

Zoom level: 3

166r.jpg - 167r.jpg 166v Go

Music Input General Help Music Input

Download MEI File Download System Humdrum Del


### Enter Music

Voice:

Select Initial Mensuration:


modus	tempus	prolatio
<input type="radio"/> 3	<input checked="" type="radio"/> 2	<input type="radio"/> N/A
<input type="radio"/> 3	<input checked="" type="radio"/> 2	<input type="radio"/> N/A
<input type="radio"/> 3	<input type="radio"/> 2	<input type="radio"/> N/A

Mensuration Sign:



166v.jpg\_p1\_s1

Continue to Score Editor



modus

3  2  N/A

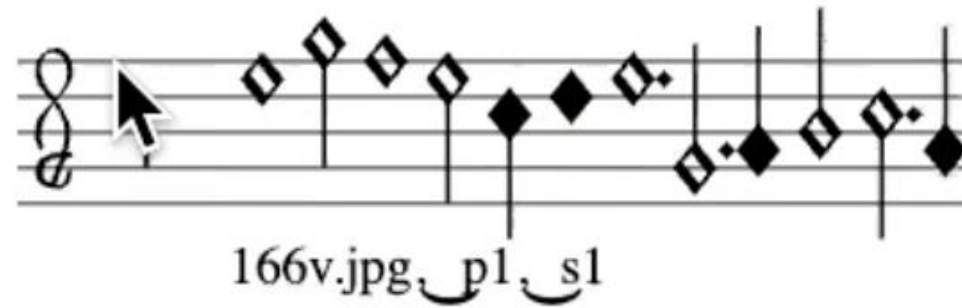
tempus

3  2  N/A

prolatio

3  2  N/A

Mensuration Sign:



Continue to Score Editor

# SCORE EDITOR

Automatic lining up of the voices into a score

Can provide editorial corrections  
And export into an MEI Score file

MuRET Editor

editor.measuringpolyphony.org/#/score/iiif/https%25253A%25252F%25252Fmuret.dlsi.ua.es%25252Fiiif%25252F6%25252F...

MEASURING POLYPHONY  
DIGITAL ENCODINGS OF LATE MEDIEVAL MUSIC

Pedro Bermudez

Zoom level: 3 152v.jpg - 153r.jpg Go

Score Editor Score Editor Help

Return to Music Input Download MEI File(s) Copy MEI Score to Clipboard

152v

KODAK Color Control Patches Kodak

### 16 Missa de Bomba

superius

166v.jpg\_p1\_s1 166v.jpg\_p1\_s2 1

altus

167r.jpg\_p1\_s1 167r.jpg\_p1\_s2 1

tenor

166v.jpg\_p1\_s4 166v.jpg\_p1\_s5

bassus

167r.jpg\_p1\_s4 167r.jpg\_p1\_s5

Bar by: **semibreve** Switch to Modern Clefs  Add Dissonance Labels

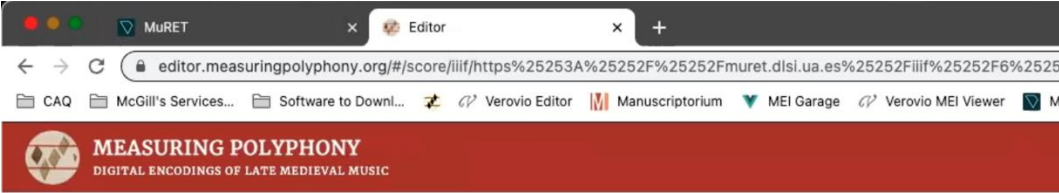
Continue in Editorial Mode



# SCORE EDITOR

Automatic lining up of the voices into a score

Can provide editorial corrections  
And export into an MEI Score file



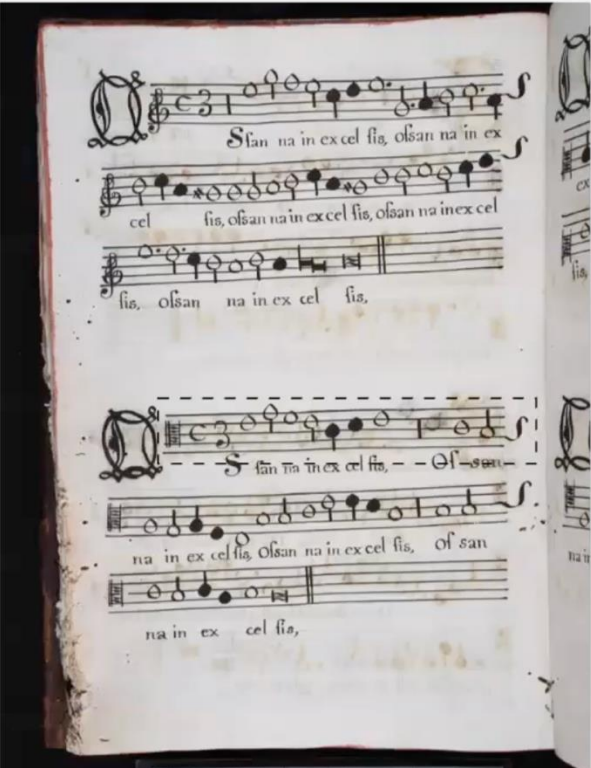
**MEASURING POLYPHONY**  
DIGITAL ENCODINGS OF LATE MEDIEVAL MUSIC

Pedro Bermudez

Zoom level: 3      166r.jpg - 167r.jpg      Go      [icon]

Score Editor      Score Editor Help

[Return to Music Input](#)   [Download MEI File\(s\)](#)   [Copy MEI Score to Clipboard](#)



16 Missa de Bomba

superius

altus

tenor

bassus

Bar by: **semibreve**    Switch to Modern Clefs     Add Dissonance Labels

[Continue in Editorial Mode](#)

# SCORE EDITOR

Automatic lining up of the voices into a score

Can provide editorial corrections  
And export into an MEI Score file

MEASURING POLYPHONY  
DIGITAL ENCODINGS OF LATE MEDIEVAL MUSIC

Pedro Bermudez

Zoom level: 3 166r.jpg - 167r.jpg

Score Editor Score Editor Help

Return to Music Input Download MEI File(s) Copy MEI Score to Clipboard

### 16 Missa de Bomba

superius  
166v.jpg\_p1\_s1 166v.jpg\_p1\_s2

altus  
167r.jpg\_p1\_s1 167r.jpg\_p1\_s2

tenor  
166v.jpg\_p1\_s4 166v.jpg\_p1\_s5

bassus  
167r.jpg\_p1\_s4 167r.jpg\_p1\_s5

Bar by: **semibreve** Switch to Modern Clefs  Add Dissonance Labels

[Continue in Editorial Mode](#)

# SCORE EDITOR

Automatic lining up of the voices into a score

Can provide editorial corrections  
And export into an MEI Score file

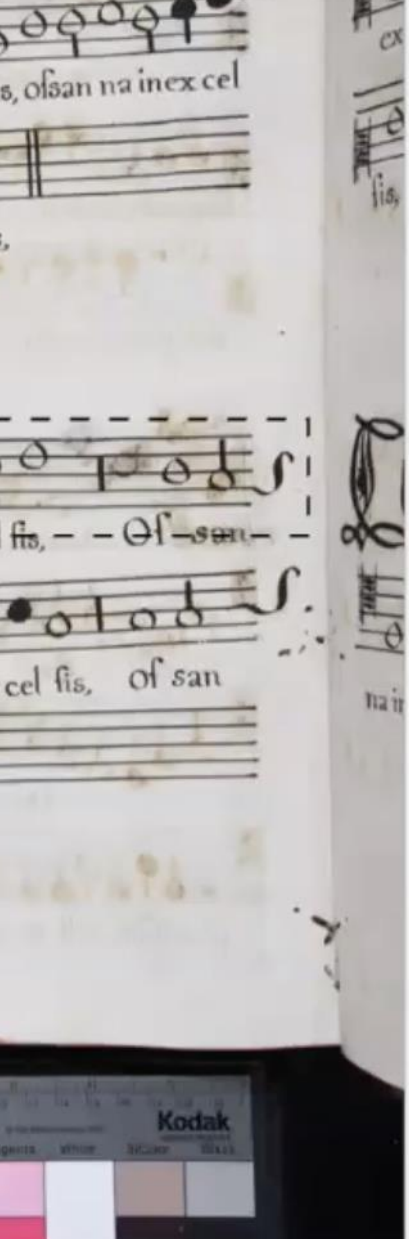
The screenshot shows the MEI Score Editor interface. On the left, a manuscript image of a page from the '166v.jpg - 167r.jpg' manuscript is displayed. The manuscript contains Latin text: "San na in ex cel fis, olsan na in ex cel fis, olsan na in ex cel fis, of san na in ex cel fis, of san na in ex cel fis, of san na in ex cel fis." The manuscript is annotated with red and blue lines. On the right, the digital score is displayed, showing the same text and musical notation. The score is divided into four staves: superius, altus, tenor, and bassus. The score is in 3/4 time and features a semibreve note. The interface includes a search bar, zoom level, and navigation buttons.

# SCORE EDITOR

Automatic lining up of the voices into a score

Can provide editorial corrections

And export into an MEI Score file



superius

altus

tenor

bassus

166v.jpg\_p1\_s4

167r.jpg\_p1\_s4

167r.jpg\_p1\_s5

166v.

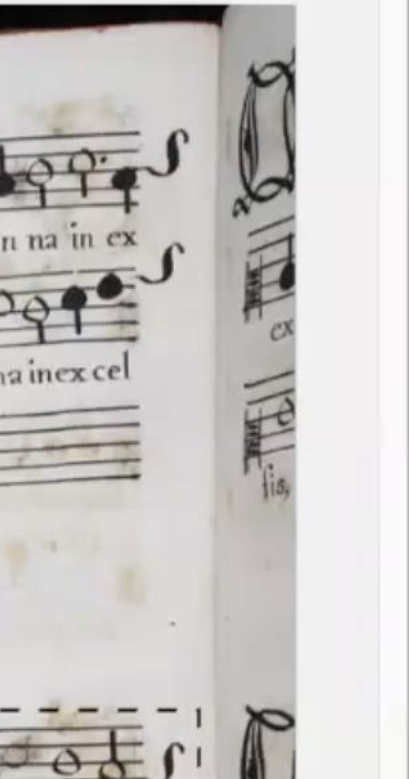
**SCORE EDITOR**  
Automatic lining up of the voices into a score  
**Can provide editorial corrections**  
And export into an MEI Score file

Bar by: **semibreve**  Switch to Modern Clefs  Add Dissonance Labels

Continue in Editorial Mode

**SCORE EDITOR**  
Automatic lining up of the voices into a score  
Can provide editorial corrections  
**And export into an MEI Score file**

BROWSE TRAN



### 16 Missa de Bomba

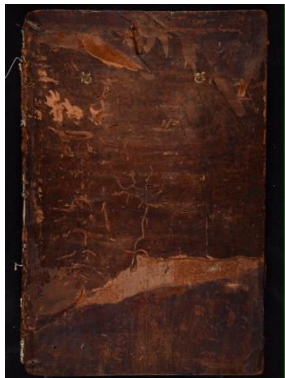
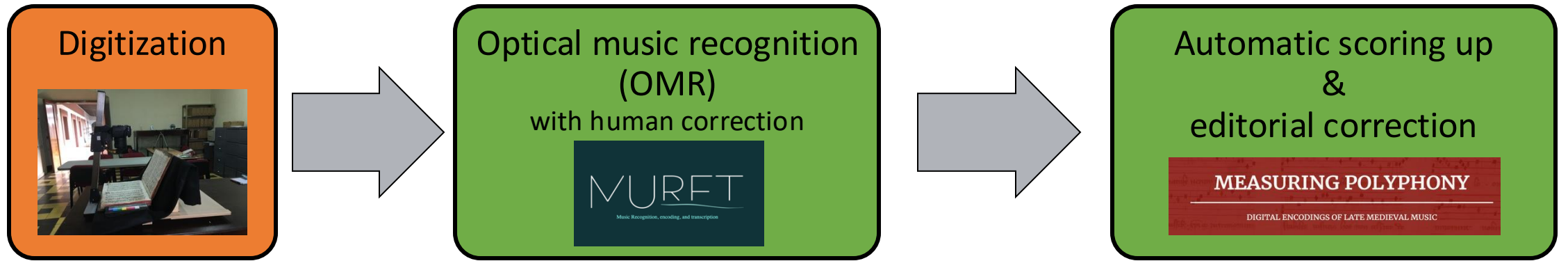
superius

altus

166v.jpg\_p1\_s1 166v.jpg\_p1\_s2

167r.jpg\_p1\_s1 167r.jpg\_p1

# Digitization & MIR Pipeline



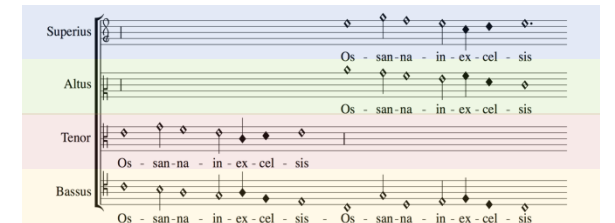
Manuscript



Digital images

```
<mei>
<music>
<staff n="1">
<clef line="2" shape="G"/>
<note dur="semibrevis" pname="g" oct="5"/>
<note dur="semibrevis" pname="d" oct="5"/>
<dot/>
<note dur="minima" pname="c" oct="5"/>
<ligature form="recta">
<note dur="semibrevis" pname="d" oct="5"/>
<note dur="semibrevis" pname="g" oct="4"/>
</ligature>
<note dur="brevis" pname="b" oct="4"/>
</staff>
</music>
</mei>
```


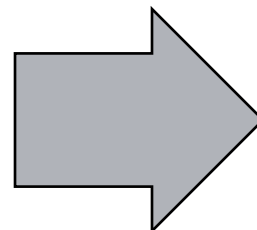
**MEI Parts file**  
encodes the **symbols** in each **part/voice** of the images



**MEI Score file**  
interpreted durations  
(i.e., *alteration & imperfection*)

# Get the Best of Both Tools!

Optical music recognition  
(OMR)  
with human correction

Automatic scoring up  
&  
editorial correction

**MEASURING POLYPHONY**

DIGITAL ENCODINGS OF LATE MEDIEVAL MUSIC

## Interoperability between MuRET & MP Editor

David Rizo, Juliette Regimbal, and Martha Thomae

```
<mei>
<music>
<staff n="1">
<clef line="2" shape="G"/>
<note dur="semibrevis" pname="g" oct="5"/>
<note dur="semibrevis" pname="d" oct="5"/>
<dot/>
<note dur="minima" pname="c" oct="5"/>
<ligature form="recta">
<note dur="semibrevis" pname="d" oct="5"/>
<note dur="semibrevis" pname="g" oct="4"/>
</ligature>
<note dur="brevis" pname="b" oct="4"/>
</staff>
</music>
</mei>
```

**MEI Parts file**  
encodes the **symbols**  
in each **part/voice**

	MuRET	MP Editor
Note shapes (and other symbols)	<b>Automatic</b> recognition	<b>Manual entry</b> (in input editor by computer keyboard)
Note duration	<b>Manual entry</b> ( <a href="#">in semantic encoding, stage 3</a> )	<b>Automatic</b> computation

**MEI Score file**  
interpreted durations  
(i.e., *alteration & imperfection*)



# Human Correction After Each Automatic Processes

“Symbol recognition” in *MuRET*  
& “Scoring up” in *MP Editor*

How to facilitate this?

Double click for changing the bounding boxes

External reference (option)

Agnostic Guatemala End2End Move pitch L5 L4 L3 L2 L1 S4 S3 S2 S1

Enlarge image preview

Agnostic \*\*skern/mens MEI PAEC

Clefs | Meters Notes Beamed notes Rests | Accidentals Other

Move symbols horizontally to change agnostic position

**MuRET – Interface # 3**  
**OMR STAGE 2: Music Symbol Recognition**  
*automatic process*

**MuRET already has an interface that facilitates spotting and correcting errors in the “symbol recognition” process**

The recognized symbols are lined up with the image  
 & The user can add/delete/modify the symbols

# What about the MP Editor?

How can we facilitate human correction here?

The corrections done here are **editorial** in nature, we correct **errors made by the scribe**

**How can we make it easier to spot these errors?**

# SCORE EDITOR

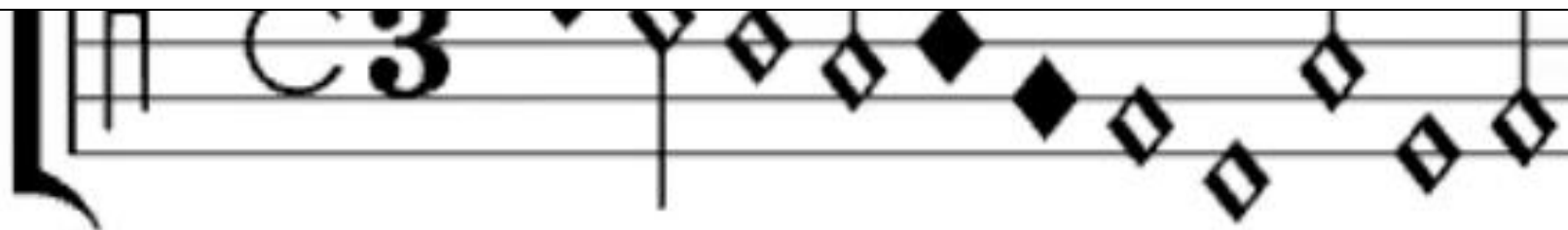
Automatic lining up of the voices into a score

Can provide editorial corrections

And export into an MEI Score file

The screenshot displays the 'MEASURING POLYPHONY' web application. The left pane shows a scanned manuscript page titled 'Missa de Bomba, à 4.' with four staves of music and Latin lyrics: 'Y ri e ley fon, kyri', 'Hriite ley fon, ley fon.', 'Chriite eley fon.', and 'Y ri e ley fon, Hriite ley fon, chriite'. The right pane, titled '16 Missa de Bomba', shows a digital score with four staves labeled 'superius', 'altus', 'tenor', and 'bassus'. Each staff contains diamond-shaped markers and file references such as '166v.jpg\_p1\_s1' through '167r.jpg\_p1\_s5'. The interface includes a 'Zoom level: 3' control, a 'Go' button, and navigation links like 'Return to Music Input', 'Download MEI File(s)', and 'Copy MEI Score to Clipboard'. At the bottom, there are options for 'Bar by: none', 'Switch to Modern Clef', and 'Add Dissonance Labels', along with a 'Continue in Editorial Mode' button.

bassus



167r.jpg, p1, s4

Bar by:  ▾

Switch to Modern Clef

Add Dissonance Labels

Continue in Editorial Mode

# “Add Dissonance Labels” Filter

Labels the different types of dissonances according to their functions

Dissonances that function as passing tones (P/p), neighbour tones (N/n), suspensions (s), etc.

& dissonances whose functionality is not known

→ possible scribal errors?

superius

altus

tenor

bassus

Bar by:  ▾

Switch to Modern Clefs

Add Dissonance Labels

Continue in Editorial Mode

# Interoperability between MP Editor & Dissonance Filter (Humlib)

Craig Sapp, Juliette Regimbal, and Martha Thomae

The image shows a musical score for four voices: superius, altus, tenor, and bassus. The score is written in C major and common time. Each voice part contains various dissonances, which are labeled with letters in colored boxes. The labels are: P/p (blue), N/n (blue), s (green), g (red), Z/z (orange), and l (purple). The labels are placed below the notes they describe. For example, in the superius part, there is a Z label above a note. In the altus part, there is a g label above a note. In the tenor part, there are P, P, s, and p l p labels. In the bassus part, there are s, g, s, n, p l v, and a Z label above a note.

- P/p:** rising/downward passing tone
- N/n:** upper/lower neighbor tone
- s:** suspension
- g:** agent
- Z/z:** unclassified dissonance (2<sup>nd</sup> or 7<sup>th</sup> / 4<sup>th</sup>)
- l:** unclassified dissonance in parallel accompaniment

**MP Editor with “known” and “unknown” dissonances**  
(labels come from *humlib*'s dissonant filter,  
developed by Alex Morgan and Craig Sapp for the Josquin Research Project)



# Interoperability between MP Editor & Dissonance Filter (Humlib)

Craig Sapp, Juliette Regimbal, and Martha Thomae

Does the use of “counterpoint” rules  
(an older concept than “harmony”)  
help in detecting scribal errors?

Does marking “unknown dissonances” make the correction  
of the scoring-up results more efficient?

Yes!

A musical score for the bassus part, showing a series of notes with diamond-shaped markers indicating dissonances. Labels 'p', 's', 'P', and 'g' are placed below the notes. The score is part of a larger interface with other staves visible in the background.

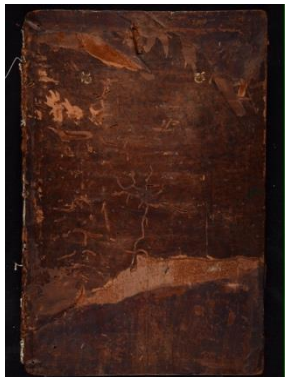
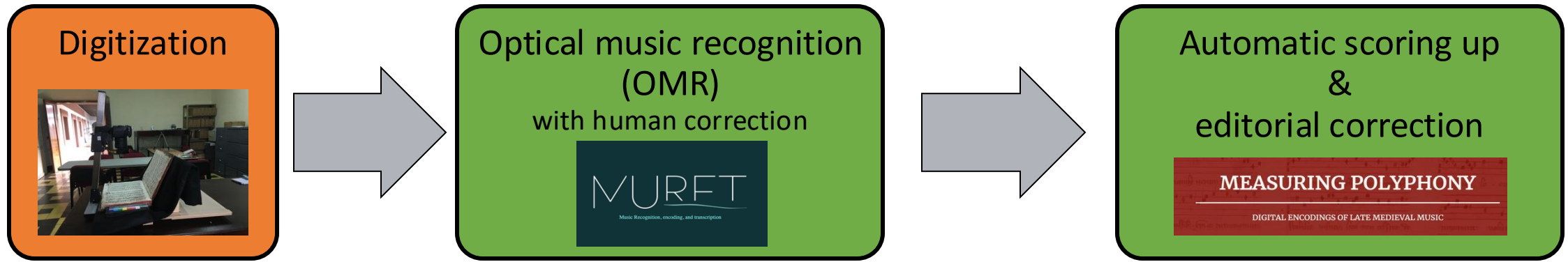
Bar by: none

Switch to Modern Cl

Add Dissonance Labels

Continue in Editorial Mode

# Digitization & MIR Pipeline



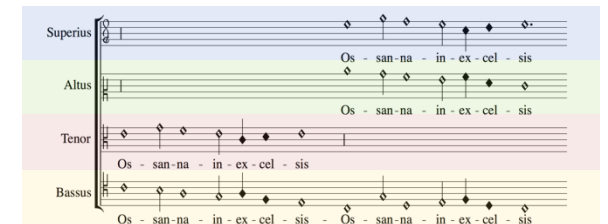
Manuscript



Digital images

```
<mei>
<music>
<staff n="1">
<clef line="2" shape="G"/>
<note dur="semibrevis" pname="g" oct="5"/>
<note dur="semibrevis" pname="d" oct="5"/>
<dot/>
<note dur="minima" pname="c" oct="5"/>
<ligature form="recta">
<note dur="semibrevis" pname="d" oct="5"/>
<note dur="semibrevis" pname="g" oct="4"/>
</ligature>
<note dur="brevis" pname="b" oct="4"/>
</staff>
</music>
</mei>
```

MEI Parts file  
encodes the **symbols** in each  
**part/voice** of the images



MEI Score file  
interpreted durations  
(i.e., *alteration & imperfection*)  
& Humlib's Dissonant  
Filter (DF)

# Outcomes

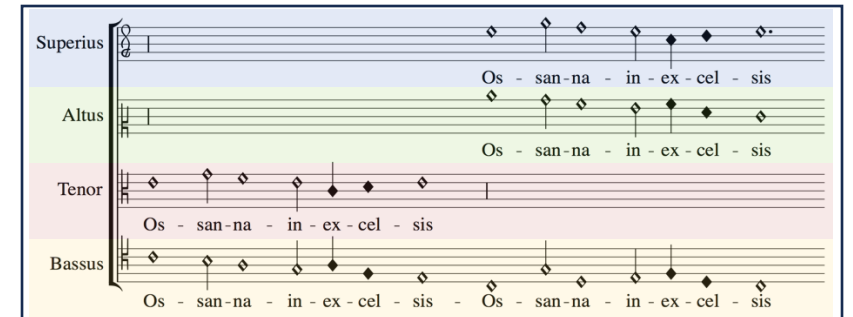
# Preservation and enhanced access of Guatemala's historical music heritage through:

- Digital images
- Mensural MEI files encoding the separate parts and the scores



```
<mei>
<music>
<staff n="1">
<clef line="2" shape="G"/>
<note dur="semibrevis" pname="g" oct="5"/>
<note dur="semibrevis" pname="d" oct="5"/>
<dot/>
<note dur="minima" pname="c" oct="5"/>
<ligature form="recta">
<note dur="semibrevis" pname="d" oct="5"/>
<note dur="semibrevis" pname="g" oct="4"/>
</ligature>
<note dur="brevis" pname="b" oct="4"/>
</staff>
</music>
</mei>
```

**MEI Parts file**  
encodes the **symbols** in each  
**part/voice** of the images



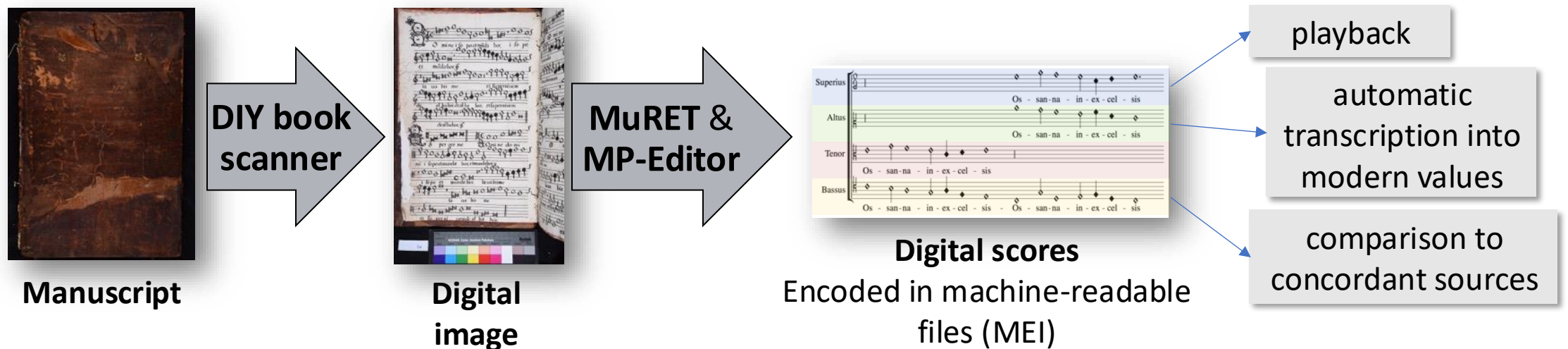
Superius  
Altus  
Tenor  
Bassus

Os - san - na - in - ex - cel - sis  
Os - san - na - in - ex - cel - sis  
Os - san - na - in - ex - cel - sis  
Os - san - na - in - ex - cel - sis - Os - san - na - in - ex - cel - sis

**MEI Score file**  
interpreted durations  
(i.e., *alteration & imperfection*)

# Methodology: the digitization and MIR pipeline

- Allows for the **semi-automatic transcription** of mensural music from digital images of manuscripts in mensural notation
- **Applicable** to other mensural music sources
- It considers the use of DIY tools and free, online, and open software to be as accessible as possible to **institutions with limited resources**



# Final Remarks

- Following the idea of “preservation and dissemination”
- Focused on using existing software rather than building another tool
- While the main goal of the project was related to preserving cultural heritage (i.e., preserving historical music works)
- Strived to preserve the previous work from people who put the effort and resources into building these MIR tools

# Final Remarks

- Idea of “collaboration”
- Collaborating to preserve a heritage that can be lost
- Or collaborating on preserving these MIR technologies by acknowledging their existence and the specialized tasks they were built for, improving them, and bringing them together for a larger task using their individual advantages
- A lot of work can be done by collaborating instead of working in silos

# Acknowledgements

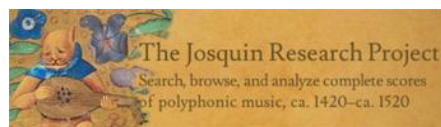
This collaborative project would not have been possible without the support from:

- **Archivo Histórico Arquidiocesano de Guatemala (AHAG)** for granting permission for the project
- **Omar Morales Abril**, Guatemalan musicologist that provided me with advice and information about the choirbooks
- **Alejandro Conde**, AHAG's archivist that supported and facilitated the project
- **José German Thomae Villela** for constructing the cradle
- **Darryl Cameron** for lending the copystand
- **Daniel Hernández-Salazar** for setting the camera parameters
- **Distributed Digital Music Archives and Libraries (DDMAL) Lab at McGill University** for lending the lights and other parts of the equipment
- **Marvin Duchow Music Library at McGill University** for lending the camera
- **Centro de Rescate, Estudio y Análisis Científico del Arte (CREA)** for the conservation assessment of the collection and the conservation treatment of the choirbook



# Acknowledgements

- **Julia Craig-McFeely** and **Lynda Sayce** (DIAMM), **Jessica Régimbald**, **Marie-Chantal Anctil**, and **Michel Legendre** (BAnQ), and **Gregory Houston** (McGill Library) for their advice regarding digitization and conservation of special collections
- **David Rizo**, **Karen Desmond**, and **Juliette Regimbal** who made possible for MuRET and the MP-Editor to communicate with one another
- **Craig Stuart Sapp** whose work allowed for the dissonance labels to be displayed in the MP-Editor
- **Jorge Calvo-Zaragoza**, **Francisco Castellanos**, **Antonio Ríos Vila**, and **José Manuel Iñesta** who developed the models used in MuRET
- **Laurent Pugin** for his work on Verovio
- **Alexander Morgan** for his Renaissance dissonance labeler script
- **Peter Schubert** for his expert advice in counterpoint matters
- **Geneviève Gates-Panneton** for her work in the experiment
- My **supervisors**: **Julie Cumming** and **Ichiro Fujinaga**



Social Sciences and Humanities Research Council of Canada

Conseil de recherches en sciences humaines du Canada



# Thank you!

[marthathomae@fcsh.unl.pt](mailto:marthathomae@fcsh.unl.pt)

<https://martha-thomae.github.io/projects/guatemala.html>

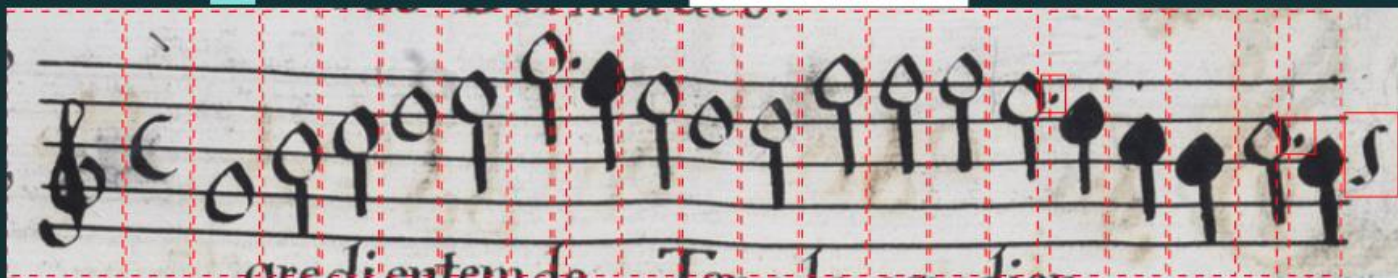
# Extra Slides



Double click for changing the bounding boxes



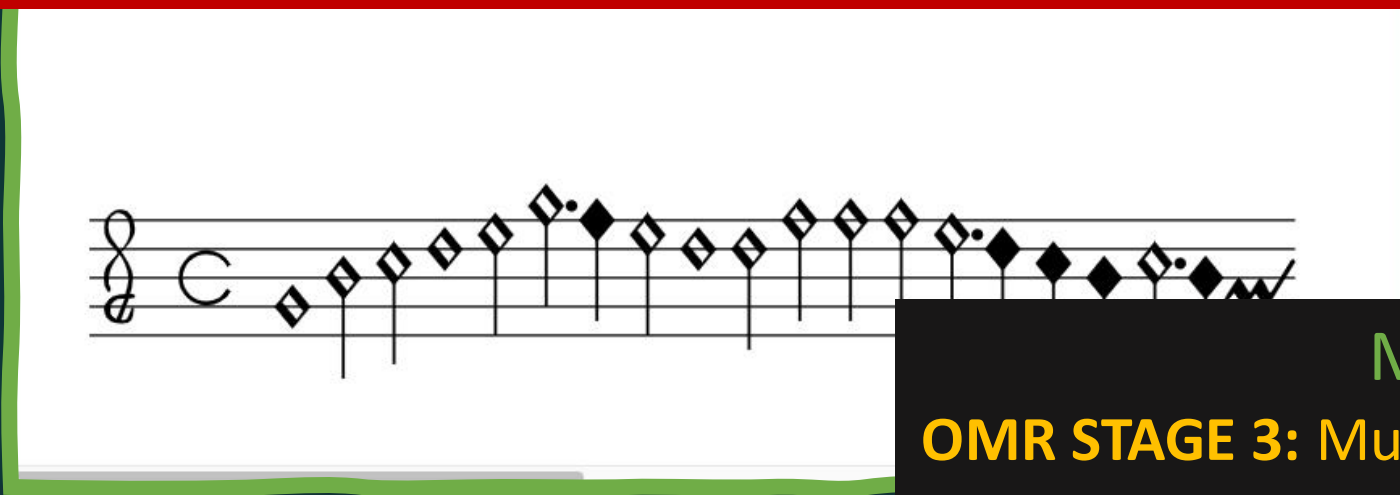
Enlarge image preview



Agnostic Guatemala End2End  L5 L4 L3 L2 L1 S4 S3 S2 S1



Semantic Agnostic to semantic transducer



Inserting the note durational quality (perfecta, imperfecta, or altera) requires manual encoding

Agnostic **\*\*skern/mens** MEI PAEC

**skm	Aç	+
*clefG2	2E	+
*met(C)	2E	-
Sr_3	2E	+
sr_3	2E	+
sg	2E	+
Ma	2E	+
Mb\	2E	+
Mcc	2E	+
Mdd	2E	+
see	2E	+
Mdd	2E	+
scc	2E	+
Mh\	2E	+

MuRET – Interface # 3  
**OMR STAGE 3: Music Notation Recognition**  
*automatic process*

1. **Marking unknown dissonances** reduces the correction time (at least to a half)  
→ allows for a focused search for errors

The image displays a musical score for four voices: superius, altus, tenor, and bassus. Each voice part is written on a staff with a common time signature (C). The score is annotated with diamond-shaped markers and labels indicating dissonances. The labels are color-coded: blue for 'g', 'p', 's', 'p l p', 'w', 'v', 'v w', 'z', 's', 'g', 's', 'n', 'p l v', 'v', 'p', 's'. The markers are placed on specific notes across the staves. Below the staves, there are labels for specific sections: '141v.jpg\_p1\_s1', '141v.jpg\_p1\_s2', '141v.jpg\_p1\_s5', '141v.jpg\_p1\_s6', '141v.jpg\_p1\_s7', '142r.jpg\_p1\_s1', '142r.jpg\_p1\_s2', and '142r.jpg\_p1\_s3'. The labels 'z', 'g', 'g', 'z' are placed above the superius staff, 'g', 'p', 'P', 's', 'p l p', 'w', 'v', 'v w', 'z' are placed above the altus staff, 's', 'g', 's', 'n', 'p l v', 'v', 'p', 's' are placed below the tenor staff, and 's', 'g', 's', 'n', 'p l v', 'v', 'p', 's' are placed below the bassus staff.

1. **Marking unknown dissonances** reduces the correction time (at least to a half)  
→ allows for a focused search for errors

The image displays a musical score with four staves. The notes are represented by diamond-shaped markers. Below the staves, there are labels for specific segments, including file names and segment identifiers, and a series of letters in blue and orange. The labels are: 142v.jpg\_p1\_s2, 142v.jpg\_p1\_s3, 142v.jpg\_p1\_s4, 143r.jpg\_p1\_s2, 143r.jpg\_p1\_s3, 143r.jpg\_p1\_s4, 142v.jpg\_p1\_s5, 142v.jpg\_p1\_s6, and 142v.jpg\_p1\_s7. The letters are: s, K s, Z K, z g, w z, Z Z p, w z, y g, w g, e Z, P s, t s, z K, v, g w, T f s, t V Z, P Z, Z V Z, P f s, w, g, T, t, a, g, k, p, p, s, g, z, E, s, K, k, s, p, s.



1. **Marking unknown dissonances** reduces the correction time (at least to a half)  
→ allows for a focused search for errors

superius  
altus  
tenor  
bassus

141v.jpg\_p1\_s1 141v.jpg\_p1\_s2 z g  
142r.jpg\_p1\_s1 142r.jpg\_p1\_s2 p l p w  
141v.jpg\_p1\_s5 141v.jpg\_p1\_s6 s g s n p l v  
142r.jpg\_p1\_s6 p 142r.jpg\_p1\_s7 P g a Z g P g 142r.jpg\_p1\_s8 v  
141v.jpg\_p1\_s7 141v.jpg\_p1  
p l v

Region to look at for an error

1<sup>st</sup> orange label

## 2. Marking unknown dissonances increases accuracy of corrections

The image shows a musical score for four voices: superius, altus, tenor, and bassus. The score is in common time (C) and features various annotations. A red arrow points to a specific measure in the altus part. Two purple dashed boxes highlight areas of dissonance in the altus and bassus parts. A purple dashed line with a downward-pointing arrow indicates a region to look at for an error. An orange arrow points to a label 'z' in the bassus part. The score includes various musical notations such as notes, rests, and dynamic markings (p, P, g, s, n, v, p, s, g, w, Z, V, W, Z).

Region to look at for an error

1<sup>st</sup> orange label

Cadence does not line up; alto is a minim too long



## 2. Marking unknown dissonances increases accuracy of corrections

The image displays a musical score for four voices: superius, altus, tenor, and bassus. The score is written in C major and common time (C). The notes are marked with diamond symbols, and various annotations are present below the staves. A red arrow points to a specific dissonance in the altus part.

Annotations include:

- 141v.jpg\_p1\_s1
- 141v.jpg\_p1\_s2
- 142r.jpg\_p1\_s1
- 142r.jpg\_p1\_s2
- 142r.jpg\_p1\_s3
- 141v.jpg\_p1\_s5
- 141v.jpg\_p1\_s6
- 141v.jpg\_p1\_s7
- 142r.jpg\_p1\_s6
- 142r.jpg\_p1\_s7
- 142r.jpg\_p1\_s8

Other annotations include letters: *g*, *g*, *z*, *z*, *p*, *P*, *g*, *p*, *p*, *s*, *c*, *f*, *s*, *s*, *n*, *p*, *p*, *s*, *p*, *s*, *p*, *g*, *a*, *P*, *g*, *p*, *g*.

## 2. Marking unknown dissonances increases accuracy of corrections

The image shows a musical score for four voices: superius, altus, tenor, and bassus. The score is written in C major and common time. The lyrics are: "a z g p l v v p v v g". The score is annotated with various elements:

- A red arrow points to a dissonance in the altus part, labeled "z g".
- A purple dashed box highlights a region in the altus part, labeled "142r.jpg\_p1\_s3".
- A purple dashed box highlights a region in the bassus part, labeled "141v.jpg\_p1\_s7".
- A purple dashed line with a downward-pointing arrow is labeled "Region to look at for an error".
- An orange arrow points to a label "a z g P g" in the bassus part, labeled "1st orange label".
- A purple arrow points to a label "v p v v g" in the bassus part, labeled "Cadence does not line up; alto is a minim too long".

Region to look at for an error

1<sup>st</sup> orange label

Cadence does not line up; alto is a minim too long



## 2. Marking unknown dissonances increases accuracy of corrections

superius

altus

tenor

bassus

141v.jpg\_p1\_s1 141v.jpg\_p1\_s2

142r.jpg\_p1\_s1 142r.jpg\_p1\_s2 142r.jpg\_p1\_s3

141v.jpg\_p1\_s5 141v.jpg\_p1\_s6 141v.jpg\_p1\_s7

142r.jpg\_p1\_s6 142r.jpg\_p1\_s7 142r.jpg\_p1\_s8

g g g p p s c s n p p s p g p g

**Cadence lining up**



3. **Marking unknown dissonances** even helped detecting OMR errors that went unnoticed on the previous stage of the pipeline