Christian Sacred Music in the Americas

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ROWMAN & LITTLEFIELD
Lanham • Boulder • New York • London

Published by Rowman & Littlefield
An imprint of The Rowman & Littlefield Publishing Group, Inc.
4501 Forbes Boulevard, Suite 200, Lanham, Maryland 20706
www.rowman.com

6 Tinworth Street, London SE11 5AL, United Kingdom

British Library Cataloguing in Publication Information Available

Library of Congress Control Number: 2020948894
ISBN 9781538148730 (cloth)
ISBN 9781538148747 (electronic)

The paper used in this publication meets the minimum requirements of American National Standard for Information Sciences—Permanence of Paper for Printed Library Materials, ANSI Z39.48-1992

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Chapter Two

The Guatemalan Choirbooks

Facilitating Preservation, Performance, and Study of the Colonial Repertoire

Martha E. Thomae

Six large choirbooks were in use in the cathedral of Guatemala's main city between c. 1600 and c. 1800.[1] They were mostly copied in the seventeenth century (see table 2.1).[2] Currently, they are held in the music vault of the Archdiocesan Historical Archive of Guatemala (AHAG).[3] The choirbooks contain essentially sixteenth-century polyphonic music by Spanish composers (for example, Victoria, Morales, and Guerrero), as well as a few pieces by Lassus and Palestrina. They also contain music by composers who worked as choirmasters at the cathedral. Although the first four choirbooks have been inventoried and a general overview of the repertoire and history of the whole collection has been provided, access to the musical contents of these sources (with the notable exception of the transcribed fourth choirbook) is difficult.[4] There are poor digital images of some of the books made from microfilm, but they are almost unusable because many pages are cropped. Access to the books on site requires special permission. Furthermore, the use of mensural notation restricts performance of the music to experts. Local musicologists Dieter Lehnhoff and Omar Morales Abril have made efforts to preserve and disseminate these colonial sources by transcribing them into modern notation and performing their music, but these efforts cover only a small fraction of the music found in the choirbooks.[5]

It is my goal to increase access to the music of this collection in order to understand the role of music in the liturgy of colonial Guatemala. To achieve this, I use digitization and music-encoding technologies, including optical music recognition and automatic transcription. In this essay, I will focus on the book of masses GuatC 1, describing the digitization and encoding processes carried out. I will also illustrate the advantages of encoded music for accessibility purposes, through modern transcriptions and audio playback, and musicological analysis. I will compare the Kyrie of Palestrina's *Missa*

sine nomine as it appears in GuatC 1 with a concordant European source already encoded in a symbolic format (**kern), showing how future scholars will use these tools to evaluate the transmission of music from Europe to Latin America and identify local traditions of counterpoint and performance.[6]

BACKGROUND

The Guatemalan Cathedral Choirbooks

The collection of choirbooks from Guatemala's cathedral (GuatC) consists of five large bound books and a sixth small unbound one. In choirbook format, each voice is presented as a self-contained block occupying its own space on the page or opening. These blocks are synchronized either by fitting an entire section on an opening or by coordinating the page breaks in all voices. For four-part texture, as is the case for most pieces in GuatC 1, each voice occupies one of the four quadrants of the opening (figure 2.1). The actual distribution of the voices in these quadrants depends on the source.[7]

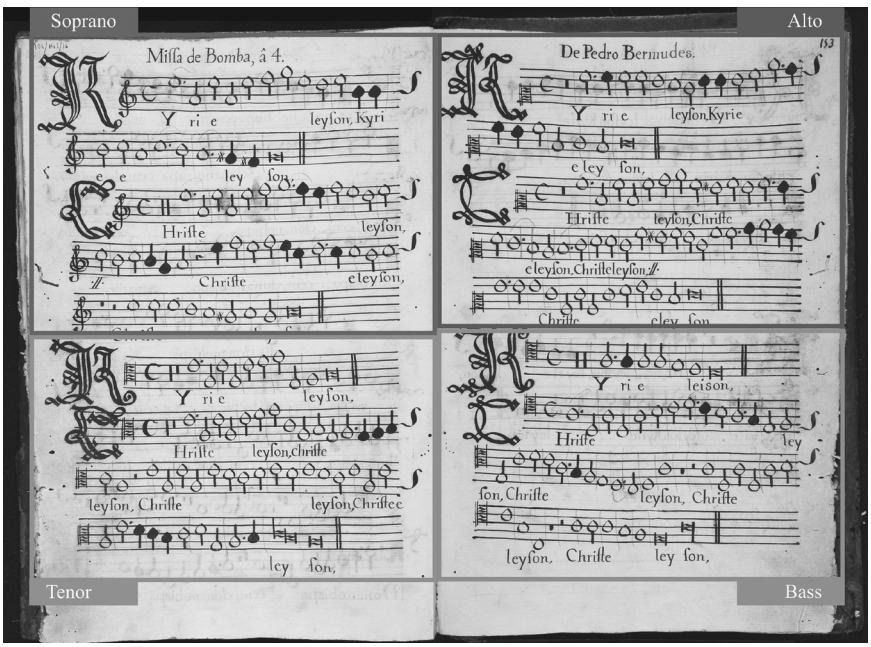

Figure 2.1. Example of choirbook format for a four-voice section in GuatC 1.

Three of the six GuatC choirbooks have been known for a few decades. GuatC 1–3 were inventoried by Pujol, Stevenson, and Snow.[8] GuatC 4, discovered after the 1976 earthquake, was studied and transcribed in its entirety by Snow.[9] The last two choirbooks were discovered in 2010 in the AHAG. The fifth book was found by Omar Morales Abril and Javier Marín López in July 2010.[10] In October of the same year, Morales Abril found, among unclassified music sheets, what he considered to be a small unbound choirbook.[11] This sixth book consists of a few pages attached together with three pieces of thread. Despite its small dimensions (21.5 cm × 30 cm) and number of folios (nineteen folios), the parts are written in choirbook format.

GuatC 1 is a book of masses, GuatC 2 is a book of hymns and Magnificats, GuatC 3 and 5 are books with miscellaneous contents, GuatC 4 is a book for Holy Week and Salve services, and GuatC 6 presents an Office for the Dead. Table 2.1 provides general information about each of the six books in the collection.

The choirbooks contain pieces from composers active in different regions (see figure 2.2), maintaining a balance between the number of Hispanic composers active and not active in the Americas. Of the twenty-seven composers present in the GuatC corpus, ten of them visited and worked in the territory of the Viceroyalty of New Spain (nine in Guatemala and one in Mexico). There are also ten Iberian-Peninsular composers who never set foot in the Americas, together with four other non-Hispanic composers and three composers whose origin remains to be uncovered. Non-Hispanic composers include names such as Palestrina and Lassus, while Peninsular composers include the great triumvirate of Spanish polyphonists Tomás Luis de Victoria, Cristóbal de Morales, and Francisco Guerrero, among others. The most prolific local composers include Hernando Franco, Pedro Bermúdez, and Gaspar Fernández, who were choirmasters at the Metropolitan Cathedral of Guatemala from 1569 to 1574, 1601 to 1603, and 1603 to 1606 respectively.[12] These three are among the most frequently found composers in various archives from the Mesoamerican region.[13] Gaspar Fernández was also the scribe of choirbooks 2 and 4 and of a *Libro de Kyries* on which choirbook 1 was based. Out of the ten composers active in the Viceroyalty of New Spain, five of them were born or trained in the Americas: Gaspar Fernández, Juan José Guerrero, Manuel José de Quirós, and Fray Francisco de Quirós in Guatemala, and Juan Matías de Rivera in Mexico.[14]

Table 2.1. General information for each of the choirbooks GuatC 1–6

Choirbook Number		*Type*	*General Information and Copyists*
1		Book of Masses	Copied from Gaspar Fernández's book (*Libro de Kyries* 1602) by Manuel José de Quiroz c. 1760–1765
2	A	Hymns	Copied by Gaspar Fernández and obtained by the cathedral in 1606
	B	Magnificats (and Benedicamus settings)	
3		Many motets and varied content (hymns, sequences, litanies, and masses)	Intervention in the eighteenth century: new folios were pasted over old ones either to hide a piece or to substitute it with another one. The binding was not restored and, eventually, it became infested by silverfish. This caused both the old and new folios to be detached, resulting in the disorganized/incomplete aspect of the book. Nicolás Márquez Tamariz (1627–93), choirmaster from November 1669 to October 1693, copied most of the music of the original folios. Juan Fernández de Leon (1671–1731), originally from Oaxaca (México), was active in Guatemala beginning in 1696 and served as choirmaster between 1717–31. He added two pieces to the last folio. Manuel José de Quirós (fl. 1694–1765), choirmaster and Guatemalan composer, copied the music of the new folios during the mid-eighteenth century.
4		Holy Week and Salve services	Gaspar Fernández (in 1605)

5	Diverse content	Copied by different scribes during the mid-seventeenth to mid-eighteenth centuries: Juan José Guerrero, who was active as a composer in the Metropolitan Cathedral of Guatemala since 1644 and served as choirmaster from July 1658 to October 1669. He copied and composed a set of polychoral psalms for Vespers. Nicolás Márquez Tamariz, who was Guerrero's successor. He copied two motets, an invitatory, and a psalm for Vespers. The Oaxacan musician Juan Fernández de León copied two responsories. An unknown scribe copied another invitatory. Manuel José de Quirós copied the last ten pieces, which consist of a Benedicamus Domino, a Christmas invitatory, and various sections of the Mass Ordinary.
6	Office of the Dead	Probably copied during the first half of the seventeenth century. Maybe by Diego de Galvez Prado (fl. 1597–1648), choirmaster between 1636 and 1648.

Omar Morales Abril, "Música local y música foránea en los libros de polifonía de las Catedrales de Guatemala y México," *Jahrbuch für Renaissancemusik* 14 (2015): 96–103.

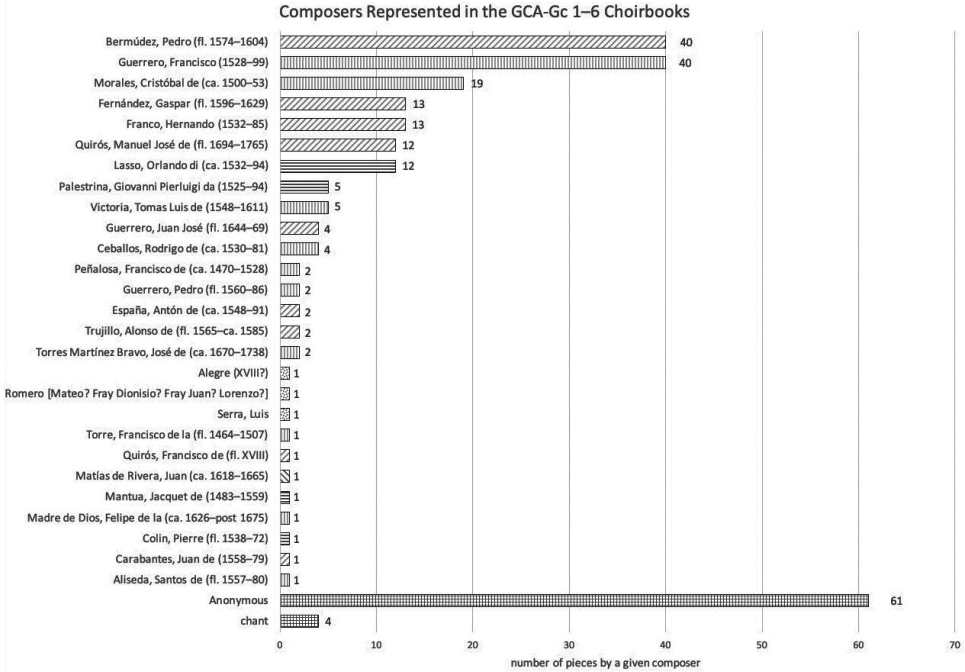

Figure 2.2. Composers present in the GuatC choirbooks and number of pieces written by each of them.
Key: upward diagonal stripes for local composers (i.e., composers active in Guatemala), downward diagonal stripes for composers active in other parts of the Viceroyalty of New Spain (here only Juan Matías de Rivera, in Oaxaca), vertical stripes for Iberian Peninsular composers, dots for Iberoamerican composers whose actual region of activity is undetermined, horizontal stripes for composers from other parts of Europe, and grid for Anonymous and chant.

Morales Abril, "Musica local," 119–21

The GuatC 1 Choirbook

In this project, I created high-quality digital images (digitized) and encoded the music of the GuatC 1 choirbook. According to the conservation report requested to the Centro de Rescate, Estudios y Análisis Científico para el Arte (CREA), the GuatC 1 choirbook is one of the best preserved of the whole collection.[15] From the set of choirbooks suitable for digitization (based again on the conservation report), GuatC 1 was the only one with triple-meter sections, which are of special interest given the context-dependent nature of the duration of mensural notes in triple meter. This is why I chose this volume to be the first for digitization and encoding. The inventory of the GuatC 1 contents is provided in table 2.2.[16]

All of the masses from the original *Libro de Kyries* except one, Pedro Bermúdez's *Missa de Bomba*, were brought from Europe. Snow mentions concordant sources for Morales, Palestrina, Colin, and one of Ceballos's masses (his popular *Missa tertii toni*).[17] The *Missa de 8º Tono* by Ceballos is his *Missa Simile est regnum caelorum*, a parody mass based on a motet by Morales. The *Missa de Bomba* by Pedro Bermúdez, Guatemalan choirmaster between 1601 and 1603, is a parody mass based on the ensalada *La Bomba* by Mateo Flecha (el Viejo). According to Snow, from the group of six masses added in the eighteenth century, only the ones by Torres, Serra, Alegre, and Rivera appear to be unique to this manuscript.[18]

METHODOLOGY

The goal of this project is to increase access to the music of the GuatC 1–6 choirbook collection, which will be achieved through digitization and music-encoding technologies. There are three barriers to accessibility in this corpus: (1) the lack of high-quality digital images, (2) the notation style, and (3) its layout. While digital images obtained from microfilms from 1984 can be found online, the set of microfilms is incomplete. It only includes the books 1–3, it is missing a few pages at the beginning of the GuatC 1, and some of the folios seem cropped.[19] Therefore, access to the complete collection has been limited to people visiting the AHAG. Second, the use of mensural notation restricts performance of the music to experts because in triple sections the duration of the notes depends on the context and there are no barlines. Last, the choirbook layout separates the parts on different areas of the opening instead of aligning them vertically as in a modern score format. Together the context-dependent nature of the notation and the separate-parts layout hinder the appreciation of the polyphonic texture of the music. It is only when musicians acquainted with the notation sing the various parts together or

Table 2.2. Inventory of the GuatC 1 choirbook

No.	*Folios*	*Piece*	*Composer*	*Genre*	*Voices*	*Information*
1	1v–4r	*Asperges me*	[¿Pedro Bermúdez?]	antiphon	4	
2	4v–7r	*Asperges me*	Anonymous	antiphon	5	
3	7v–11r	*Vidi aquam*	Pedro Bermúdez	antiphon	4	
4	11v–14r	*Vidi aquam*	[Hernando Franco]	antiphon	4	
5	14v–17r	*Asperges me*	[Alonso de Trujillo]	antiphon	4	
6	17v–31r	*Missa sobre las vozes*	Cristóbal de Morales	mass	4	From the 1602 book. This is Morales's hexachord mass.
7	31v–43r	*Missa sine nomine*	Giovanni Pierluigi da Palestrina	mass	4	From the 1602 book.
8	43v–54r	*Missa Pere de nous*	Pierre Colin	mass	4	From the 1602 book.
9	54v–71r	*Missa de 3º tono*	Rodrigo de Ceballos	mass	4	From the 1602 book.
10	71v–85r	*Missa sine nomine*	José de Torres y Martínez Bravo	mass	4	Added in the eighteenth century.
11	85v–95r	*Missa O quam gloriosum*	Tomás Luis de Victoria	mass	4	Added in the eighteenth century.
12	95v–109r	*Missa Ave maris stella*	Tomás Luis de Victoria	mass	4	Added in the eighteenth century.
13	109v–119r	*Missa de 5º tono*	Luis Serra	mass	4	Added in the eighteenth century.
14	119v–133r	*Missa de 4º tono*	Alegre	mass	4	Added in the eighteenth century.
15	133v–152r	*Missa de 8º tono*	Rodrigo de Ceballos	mass	4, Agnus a 5	From the 1602 book. Ceballos's *Missa Simile est regnum cælorum*, parody mass based on a motet by Morales.

16	152v–169r	*Missa de Bomba*	Pedro Bermúdez	mass	4	From the 1602 book. Parody mass based on Mateo Flecha's (el Viejo) ensalada *la Bomba*.
17	169v–180r	*Missa sine nomine*	Juan Matías de Rivera	mass	4	Added in the eighteenth century.
18	180v–181r	*Christus natus est*	Pedro Bermúdez	invitatory	4	
19	181v–183r	*Christus natus est*	Pedro Bermúdez	invitatory	8	
20	183v–184r	*Christus natus est*	Anonymous	invitatory	5	
21	184v–186r	*Surrexit Dominus vere*	Anonymous	invitatory	5	
22	186v–187r	*Lumen ad revelationem*	Hernando Franco	antiphon	5	
23	187v–188r	*Lumen ad revelationem*	Pedro Bermúdez	antiphon	5	
24	188v–189r	*Lumen ad revelationem*	Pedro Bermúdez	antiphon	4	
25	189v–190r	*Surrexit Dominus vere*	Anonymous	invitatory	4	
26	190v–192r	*Victimæ Paschali laudes*	Francisco Guerrero	sequence	4, 2a Pars a 5	
27	192v–193r	*Tantum ergo*	[Pedro Bermúdez]	hymn	4	

when an expert transcribes the music into a modern score that these textures can be really perceived and enjoyed. The layout of the original music deters its study even for experts because it is hard to visualize the vertical relationships between notes sung simultaneously in two different voices, something that only becomes clear when the music is presented in score format.

To unravel these barriers, I followed a three-stage methodology:

1. *Digitization* to obtain full-color high-resolution digital images of each of the pages of the choirbook, allowing high-quality access to the original sources of the music.
2. *Optical music recognition* (OMR) to obtain symbolic files encoding the music content as it appears in the source.
3. *Automatic scoring up* to transform the encoded music of the piece from a separate-parts layout into a score by interpreting the duration of the notes according to the context and combining them in score.

This three-stage methodology transforms the physical object into symbolic scores (that is, machine-readable scores that encode the music content of each piece) and performable modern scores. While the first stage will handle the digitization barrier, the third stage will handle the context-dependent nature of the notation and the layout barriers. The OMR process is the link between the two technologies, transforming a digital (pixel) domain into a symbolic (machine-readable) domain. The process will result in the digitization and encoding of the repertoire as musical scores in Music Encoding Initiative (MEI) format, one of the few formats that provide support for mensural notation.[20] More details about each of these steps follow.

Digitization Process

The digitization process was authorized by the chancellor of the Ecclesiastical Curia of Santiago de Guatemala and director of the AHAG, father Eddy René Calvillo, on October 31, 2018. The process was conducted at the AHAG to avoid the transportation of the books outside of their current location. There are some characteristics of the GuatC collection that influenced the choice of imaging systems to use, namely that the volumes are old manuscripts, bound, and oversize items. According to the Federal Agencies Digital Guidelines Initiative specifications, for bound volumes of rare or special collections, the recommended imaging technology is a manually operated planetary book scanner (or similar setups that digitize the pages from the top using digital cameras and book cradles) without glass or plastic platens.[21] Because no book scanner of the appropriate dimensions was available in Guatemala, I made my

own and created high-quality color images of the manuscript. All the parts of the book scanner were either built or borrowed.[22]

The digitization process of GuatC 1 took place in the AHAG between January 7 and 15, 2019. Because the AHAG does not have conservation and digitization departments, these tasks had to be outsourced. The conservators from CREA were in charge of the assessment of the material for digitization, and its preparation for it. Unfortunately, I was not able to find a digitization technician with training on special collections.

By the end of November 2018, I received the conservation report (written by CREA) evaluating the conservation conditions of the choirbooks and whether they were suitable for digitization. On January 7, GuatC 1 received basic conservation treatment to prepare it for digitization. The equipment was set up and tested the next day (Daniel Hernandez Salazar, a Guatemalan professional photographer, set up the camera parameters). Imaging started on January 9 and continued for the next four business days. I handled the manuscript during digitization.

The successful digitization of GuatC 1 would not have been possible without the advice of staff at the Digital Image Archive of Medieval Music (DIAMM), the Bibliothèque et Archives Nationales du Québec (BAnQ), and the Digitization Lab at McGill University Library.[23] These institutions have experience in the digitization of special collections. DIAMM has experience with digitizing medieval music manuscripts and has some guidelines about this topic.[24] DIAMM's project manager Julia Craig-McFeely and main photographer Lynda Sayce provided specific advice for this project through email. BAnQ has its own conservation and digitization departments. These departments offered a great number of useful recommendations for the project, including handling of the material, general conservation treatments for paper, evaluation of parts of the equipment (for example, light choices), and possible configurations of the equipment (cradle, lights, and camera).[25] The McGill Library, in addition to pointing to an online resource for DIY book scanners, provided advice on where to get archival materials (for example, book serpents) and possibilities for improving the design of the book scanner in the future.[26]

Optical Music Recognition

Optical music recognition (OMR) is the process of converting the digital image of a music document into a machine-readable file encoding the music content of that image. This process is similar to optical character recognition (OCR), which is used to make digital text documents readable by the computer. Well-established OMR applications already exist for common Western music notation (CWMN).[27] There are, however, not many early

music notation OMR systems. The only OMR system developed explicitly for mensural notation is Aruspix, a music scanning software for early music prints.[28] Some machine learning-based OMR models can be trained on a particular notation system by presenting them with examples of the different "characters" (that is, music symbols) of that notation until they learn enough to recognize them. A few examples of these systems include:

- The Gamera recognition framework, which has already been used for building recognition systems for lute and neumatic notation.[29]
- A holistic staff-level recognition method. This is a method that recognizes the sequence of symbols in a staff as a whole, provided that there is only one voice per staff. It has been used for CMN and mensural notation.[30] The latter, the holistic mensural model, is the one used in this essay.[31]
- A page-level recognition method that was used for mensural notation.[32]

All of these machine learning (ML) models need to first learn the different classes of symbols present in the corpus; this process is known as training. Once the ML model has been trained, it can be used to classify (identify) the music symbols of the complete manuscript; this process is referred to as classification. To train an ML model, one needs to present it with labeled examples from which it can learn. These examples normally consist of pages where each symbol of the page has been manually labeled as belonging to a particular class of music symbol (for example, minim note, breve rest, custos, and G clef). This set of labeled examples used to train the model to learn the different classes of symbols present in a corpus is known as training data or a training set. The preparation of the training data can be a very time-consuming task. To minimize the training data preparation time, I used the holistic staff-level OMR model developed by Calvo-Zaragoza, Toselli, and Vidal (2019) because it has already been trained in Spanish mensural notation, very similar in appearance to the mensural notation in the GuatC collection.[33]

OMR also requires the preprocessing of the data to make it a suitable input for the model and the correction of the results of the model (figure 2.3). Because the model used works at the staff level, the data (that is, the image of a digitized manuscript page) has to be annotated to show the staff regions (figure 2.4). This staff annotation step constitutes the preprocessing stage for the symbol recognition task.

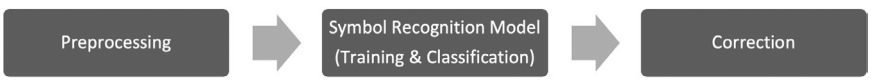

Figure 2.3. Stages of symbol recognition within OMR.

I used the Music Recognition Encoding and Transcription (MuRET) framework to facilitate the preprocessing, symbol recognition, and correction of the results during the OMR. MuRET is an online framework for OMR.[34] With MuRET, I selected the staff regions of the page for preprocessing using its so-called "Document Analysis" interface (figure 2.4). The pretrained symbol recognition model was uploaded into MuRET, which facilitated visualizing the results of the OMR (the symbols recognized by the model), as well as correcting them.

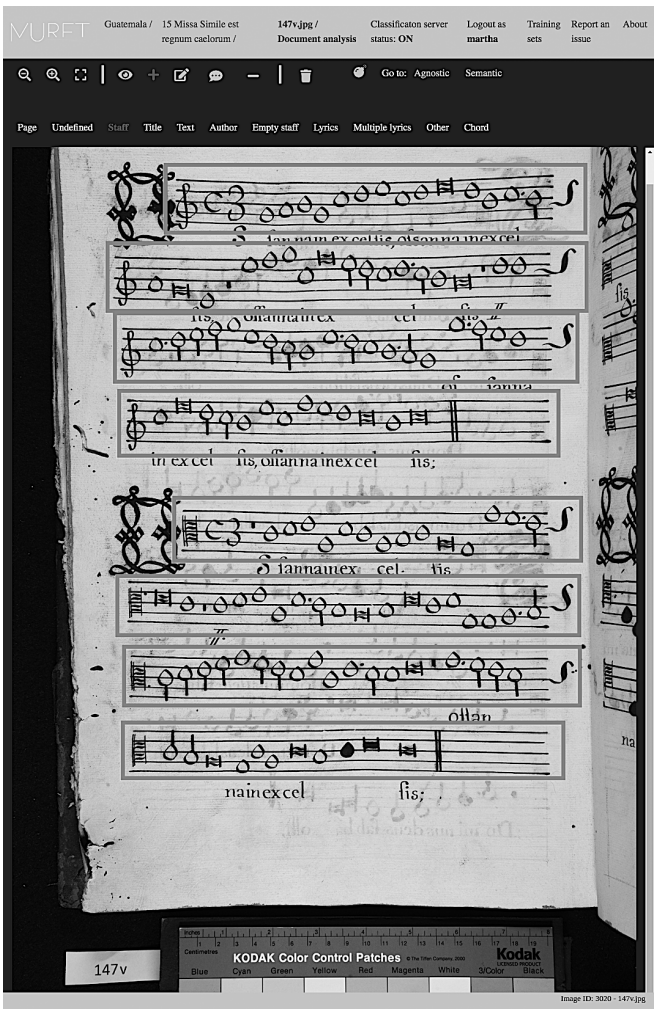

Figure 2.4. Document Analysis interface in MuRET. This is a preprocessing interface that allows the user to draw bounding boxes to select the different regions in the image (for example, staff, lyrics, and text). Here, only the staff regions are shown.

The visualization and correction of the results are done within the "Agnostic" interface of MuRET (figure 2.5). In the Agnostic interface, the user can select any of the staff regions created in the Document Analysis interface, as well as the classification model to be used to classify the symbols in that staff. The selected staff is shown as a region of the image, and the recognized symbols are shown in the transcription below. If any of the recognized symbols is wrong, the user can correct them by clicking on the symbol and changing either the category of the symbol (by using the lower panel) or its pitch (by using the arrows to the left).

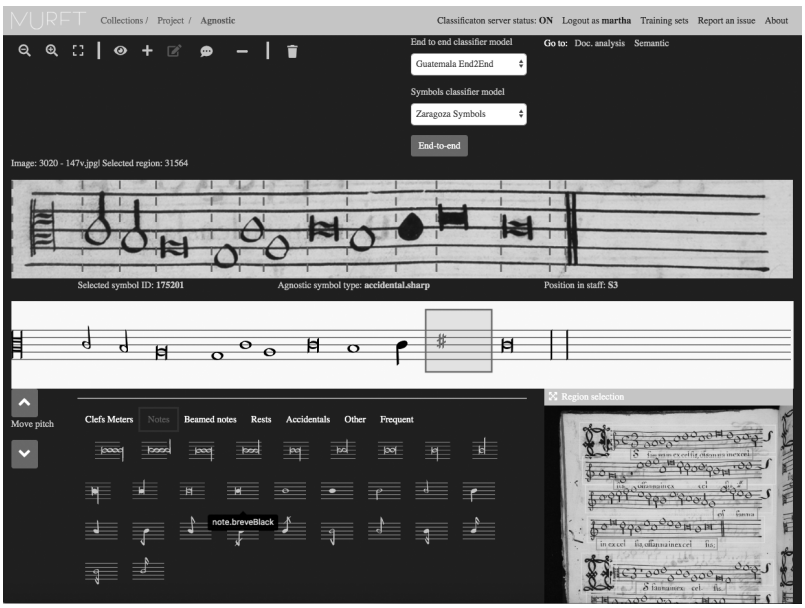

Figure 2.5. MuRET's Agnostic interface. This is a classification and correction interface. The user selects a region and the OMR model to be used to classify the symbols in the region. Correction options, the lower panel and arrows, are activated when clicking over a symbol (see highlighted accidental).

Scoring Up, Transcription into Modern Values, and Playback

The scoring up (combining the voices in mensural notation into a score) was done with MuRET. In the case of sections in duple meter, the score can be generated immediately after the correction of the symbol recognition results. In the case of triple meter sections, one can use the "Semantic" interface of MuRET (figure 2.6) to include details regarding the *perfect*, *imperfect*, and *altered* quality of the notes, as well as the *addition* or *division* function of the dots.[35] These details are needed to convey the correct

duration of the notes in order to score up the voices correctly. MuRET will soon incorporate the Mensural Scoring-Up Tool as a plug-in to automatically interpret the note duration in triple meter movements.[36] MuRET's Semantic interface provides a table indexing the symbols recognized in a particular staff (figure 2.6). The user can edit this table to provide semantic information about the symbols (this is, the perfect / imperfect / altered quality of the notes and the addition / division functionality of the dots) provided that the user is familiar with the **smens encoding shown in the table, a variation of the **mens encoding.[37]

The mensural scores obtained from MuRET are encoded into Mensural MEI files. MEI was chosen as the encoding format because it provides support for mensural notation. The translation of these mensural scores into

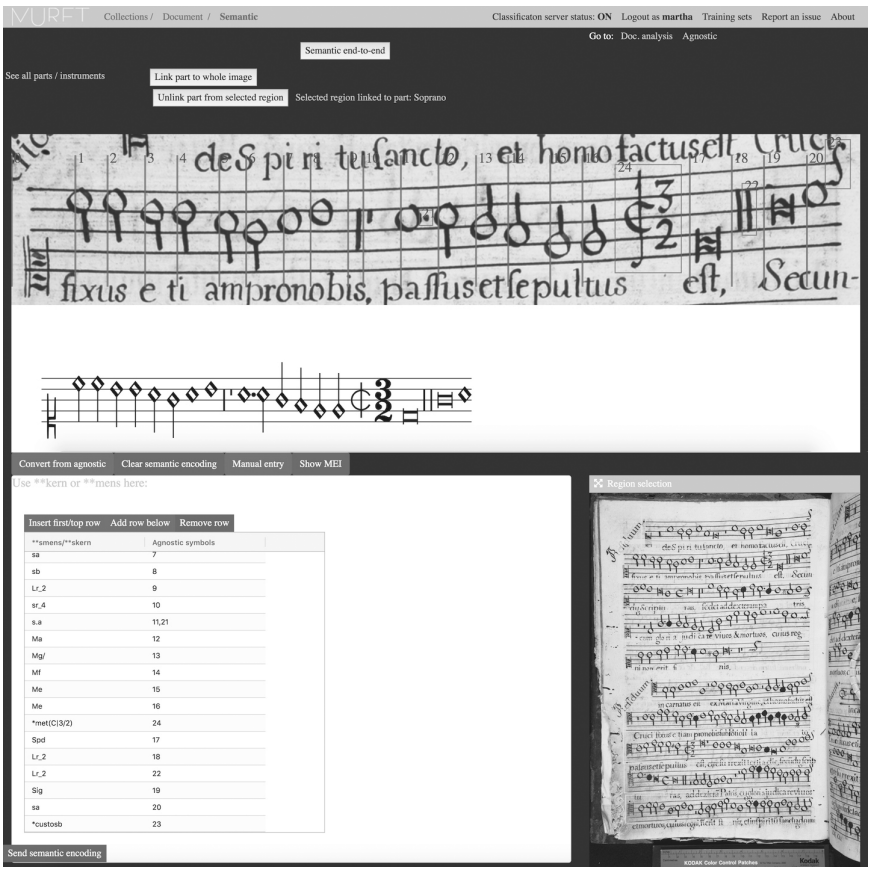

Figure 2.6. MuRET's Semantic interface. Here the user can provide information regarding the semantics of the symbols rather than just the graphical information provided by the symbol recognition model.

modern values was performed with the Mensural MEI Score to CMN MEI Score Translation Tool.[38] The modern transcriptions are encoded on another flavor of MEI for encoding common Western music notation, the CMN MEI. The music encoded in both MEI files (the one encoding the mensural score and the one encoding the modern transcription) can be displayed and played back through the Verovio MEI Viewer.[39] The next section shows examples of the mensural and modern scores generated in this project as rendered by Verovio, together with a discussion of the advantages of music encoding.

BENEFITS OF DIGITIZATION AND OMR

Digitization of the choirbook resulted in full-color high-resolution images that provide high-quality access to the music of this manuscript. In appendix A, one can find four images corresponding to the 31v–33r folios of GuatC 1, which contain the Kyrie movement of the *Missa sine nomine* by Palestrina (concordant with that of the 1567 *Missarum liber secundus*, RISM A/I P 660); these are examples of the images produced during digitization. Examples of the symbolic scores obtained at the end of the OMR and Scoring-up processes are shown in figure 2.7 (in mensural values) and figure 2.8 (in modern values) as rendered by Verovio. These scores show only the second Kyrie, corresponding to the folios 32v–33r. For the complete Kyrie movement, see appendix B.

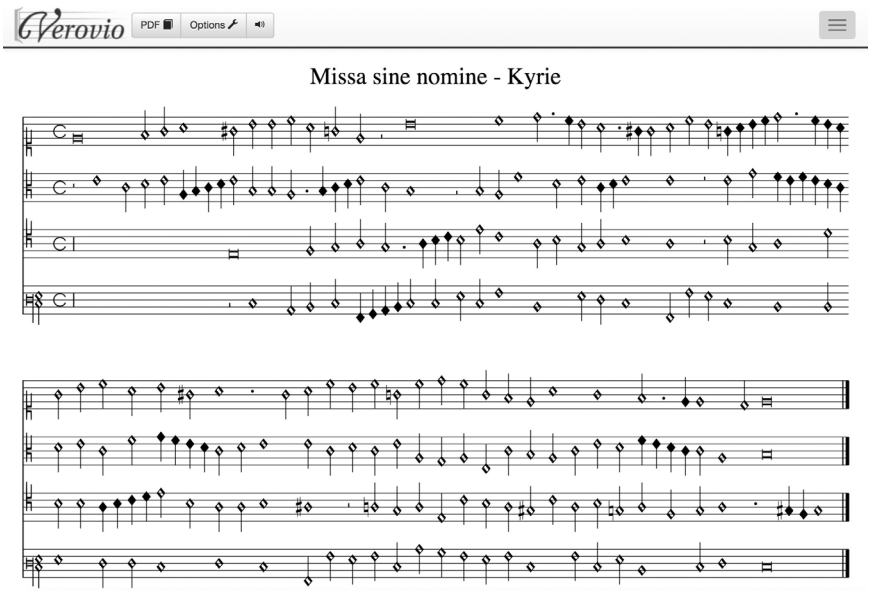

Figure 2.7. Verovio rendering of the Mensural MEI file encoding the second Kyrie of Palestrina's *Missa sine nomine* Kyrie movement as appears in GuatC 1 folios 32v–33r (images can be found in appendix A).

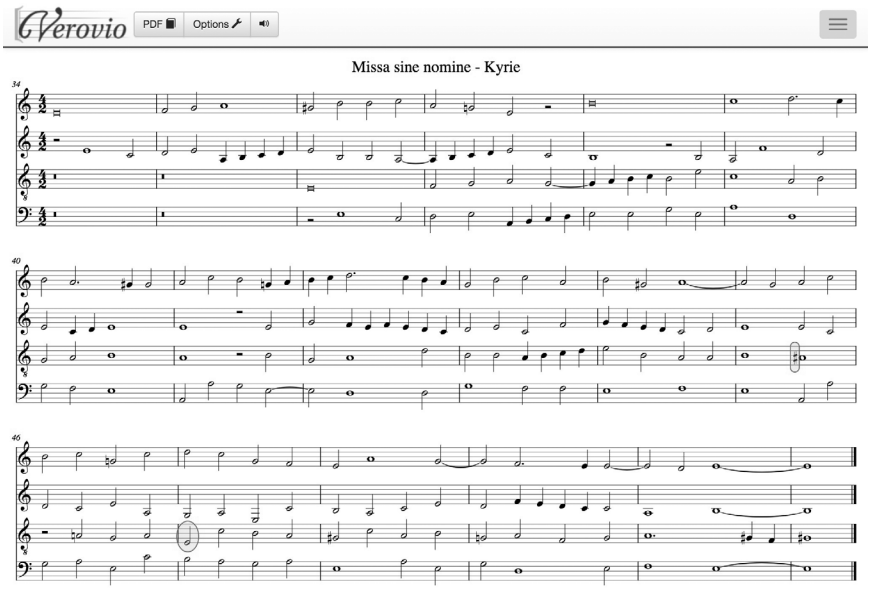

Figure 2.8. Verovio rendering of the CMN MEI file encoding the modern transcription of the second Kyrie of Palestrina's *Missa sine nomine* Kyrie movement as it appears in GuatC 1 folios 32v–33r (images can be found in appendix A). This file was obtained from the Mensural MEI score (figure 2.7) encoding the same passage, with the Mensural MEI Score to CMN MEI Score Translator.

The clear advantage of both the mensural and the modern score is the visualization of vertical sonorities, which are not available in the choirbook layout of the original source, and the possibility of playback, which makes the music accessible to a broader audience. The Verovio MEI Viewer includes a speaker button to play the encoded music in both Mensural and CMN MEI files (see figure 2.7 and figure 2.8, top left corner), together with a button for exporting the score into a PDF.

The main benefit of a modern transcription, though, is that it allows modern musicians to perform the music (figure 2.8). On the other hand, mensural scores have their own benefits as well (figure 2.7). While a mensural score shows the vertical alignment of the voices, it does so without any loss of information due to translation of the music into modern values, providing a better source for musicological studies than a modern transcription.[40]

Symbolic files encoding the scores offer other advantages over mere digital images. Because these files are machine readable, the computer can extract a wide variety of information from them useful for music analysis. There are many tools developed for empirical symbolic music research (for example, music21, Humdrum, jSymbolic, and the VIS Framework).[41]

Feature-extraction software, such as jSymbolic, can extract quantitative information associated with a wide range of musical characteristics (including pitch statistics, melodic intervals, vertical intervals, rhythm, instrumentation, texture, and dynamics). The extracted features can be used to train the computer to classify music into different categories (for example, classify music by composer, genre, style, or region).[42] Symbolic files have been used for counterpoint studies as well, with the help of the Vertical Interval Successions (VIS) Music Analysis Framework. In these studies, the VIS Framework is used to extract successions of vertical intervals (called n-grams) and use them to analyze different contrapuntal aspects.[43] In the present study, the VIS Framework was used to facilitate the detection of counterpoint errors in the recognized pieces (see rounded boxes in figure 2.8).[44] An additional error was found in the Christe section of the Kyrie, as will be seen shortly.

Another benefit of symbolic music is that it facilitates the comparison of variant readings in versions of a piece found in different sources. The Palestrina *Missa sine nomine* in GuatC 1 is concordant with the third mass of the 1567 *Missarum liber secundus* (RISM A/I P 660).[45] The movements of the *Missa sine nomine* in RISM A/I P 660 have been encoded into **kern files, which can be found in the ELVIS Database.[46] These **kern files are easily convertible into CMN MEI files. Current technologies for comparing two sources in MEI require lots of cleaning up to remove "noisy" information in the coding. Still, they do show where the differences between the two files are, which significantly reduces the amount of work because one can go right to those sections rather than going through each note of the movement. Future work will make these comparison techniques more efficient and automate the cleanup of the MEI files before comparison.

Examples of this comparison process for the Kyrie movement of the *Missa sine nomine*, between GuatC 1 and the RISM A/I P 660 sources, are shown in figure 2.9. The first Kyrie is nearly identical in both sources, except for two accidentals shown in figure 2.9a. The actual difference between the movements starts at the end of the Christe section, where GuatC 1 has extra notes (see figure 2.9b and figure 2.10). Using the VIS Framework, we can detect that there is a mistake in measure 32 of GuatC 1 Christe because the F in the bass is dissonant against the E and G in the soprano and alto respectively. It is possible that the penultimate measure in the bass should have been C F (rather than F C). This way, the chord formed at the beginning of measure 32 in GuatC 1 would be the same as the one shown in measure 32 of RISM A/I P 660 (see figure 2.10). In addition to these variant readings in the first two sections, Kyrie 2 is entirely different in both sources. The second Kyrie in RISM A/I P 660 is a repetition of the first one, while the second Kyrie in GuatC 1 is completely new. Both Kyrie sections can be seen in figure 2.16

Figure 2.9a.

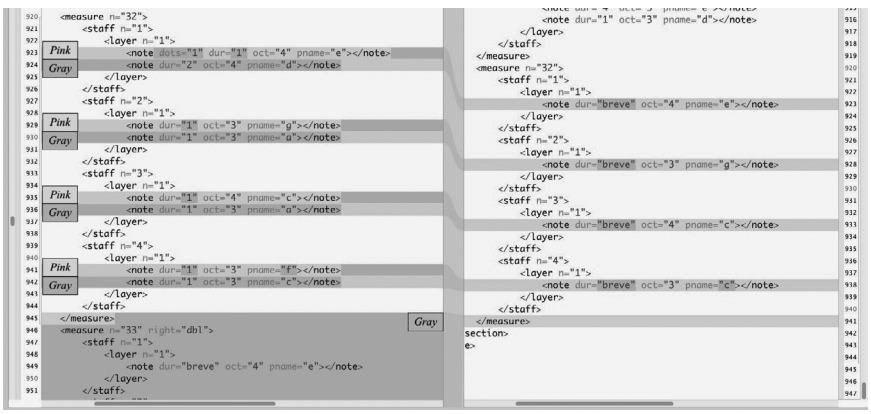

Figure 2.9b.

Comparison of the CMN MEI files obtained from the OMR of GuatC 1 (left) and the ELVIS Database **kern file encoding the *Missa sine nomine* from the *Missarum liber* 2 (*right*). The comparison was made using the "Diff files" application from Oxygen. Diff uses blue to indicate an addition on the right side, gray to indicate an addition on the left side, and pink to identify modifications on either side. (a) Extra accidental in the *Missarum liber* 2 at measure 11 and 16 (see highlighted accid="s"). (b) Ending of the Christe section. Measure 32 has similar notes but with different durations, and measure 33 only exists for GuatC 1. These differences can be visualized in figure 2.10, where the music at the end of the Christe section is displayed.

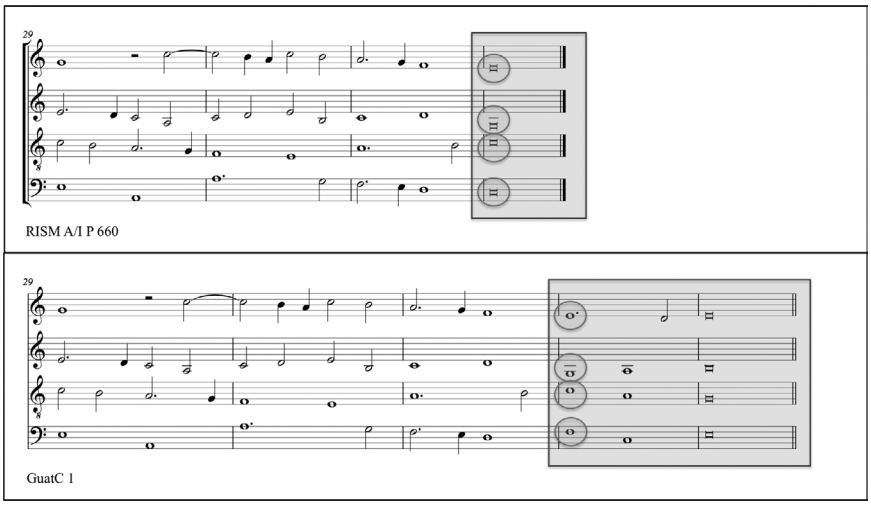

Figure 2.10. Ending of the Christe section of the Kyrie movement in Palestrina's *Missa sine nomine*.

(appendix B). Kyrie 1, the same in both sources, is shown in measures 1–17, and the new Kyrie 2 is in measures 34–51.

CONCLUDING REMARKS

Online digitization platforms are opening the music collections of archives and libraries to a global audience. Digital images are, however, only the start of true accessibility because the music content of these images cannot be searched by a computer. Optical music recognition makes the most out of these images by encoding their music content into a machine-readable representation. This makes it possible to search and analyze images of music documents online, dramatically increasing the accessibility and usefulness of digital collections. Moreover, software for automatic transcription of early music into modern values facilitates the publishing of modern editions, increasing access to early music. The advantages of these music-encoding technologies have been shown in this essay using one of the Guatemalan choirbooks.

The set of six choirbooks from the Guatemala cathedral documents a continuous performance tradition of sacred polyphonic music from the Renaissance until the end of the eighteenth century. I digitized and encoded the contents of the first choirbook (GuatC 1) to guarantee the preservation of the

manuscript and increase access to its contents. The images obtained in this project offer high-quality access to the manuscript source, and the symbolic files (obtained through optical music recognition and automatic scoring up of the individual parts) increase access to the music itself by allowing for playback, modern transcriptions of the pieces, and performance. The symbolic files also allow for computational analysis of the repertoire, facilitating the comparison of variant readings and the study of counterpoint. Therefore, in addition to preservation and increasing access to the music, the encoding of the Guatemalan choirbooks can contribute to study the transmission of music from Europe to Latin America.

I plan to use the lessons learned in this pilot project to improve my procedures and technologies and to apply them to the complete choirbook collection. All the tools I used are open access (see the "Further Reading" section) for use by other scholars and musicians who want to rescue and preserve other forgotten repertories.[47]

MANUSCRIPT AND PRINTED SOURCES

GuatC 1

- [Census Catalogue of Music] Guatemala. Guatemala City. Catedral, Archivo Capitular. *MS 1*.
- [Signature, current location] Guatemala. Guatemala City. Archivo Histórico Arquidiocesano de Guatemala (AHAG). *Archivo de la catedral de Santiago de Guatemala. Sección litúrgica, libro de misas 1602–1760.*
- Other sigla: GCA-Gc 1

RISM A/I P 660

Palestrina, Giovanni Pierluigi da. Missarum liber secundus. Rome: Dorico, Valerio, eredi and Luigi Dorico, eredi. 1567. Print.

APPENDIX A: EXAMPLES OF THE IMAGES OBTAINED FROM GUATC 1

Kyrie movement of Palestrina's *Missa sine nomine a 4* as appearing in GuatC 1, folios 31v–33r.

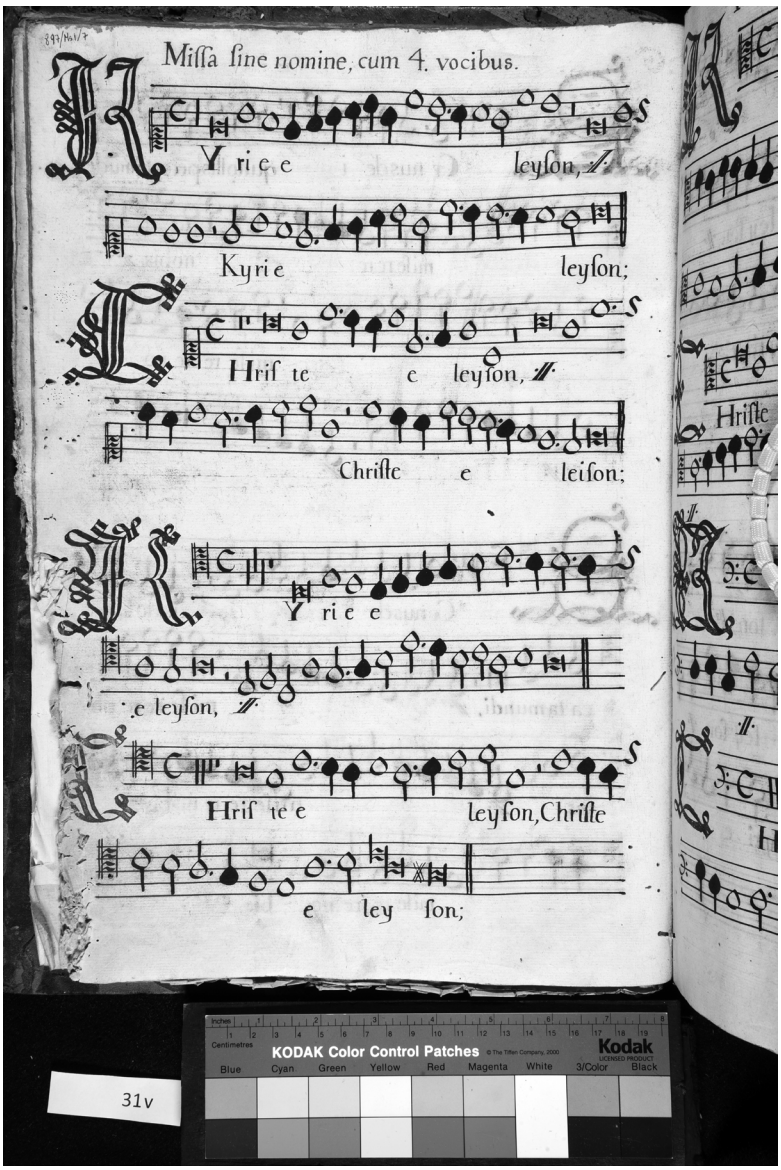

Figure 2.11.

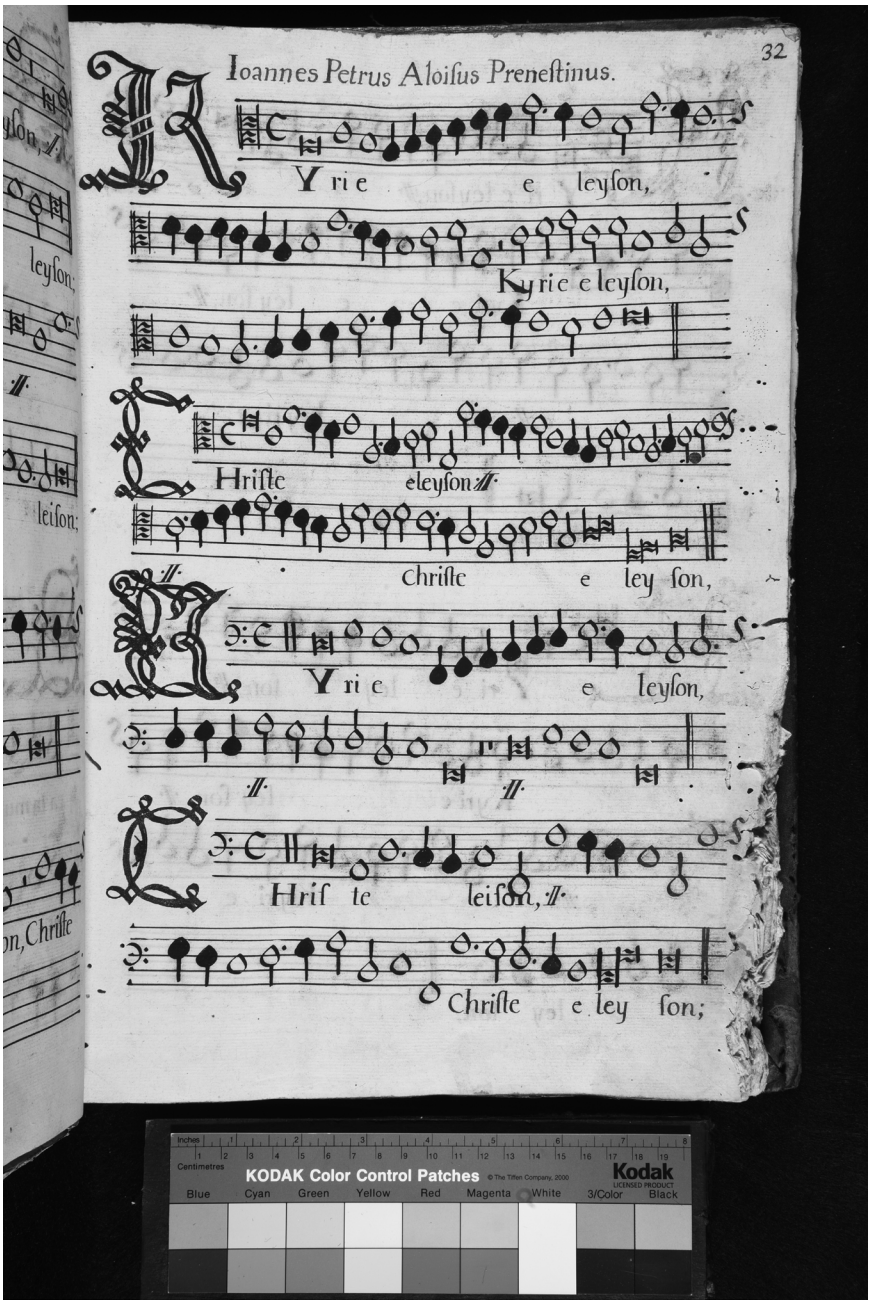
32
Ioannes Petrus Aloisus Prenestinus.
Yrie e leyson,
Kyrie eleyson,
Hriſte eleyſon
Chriſte e ley ſon,
Yrie e leyson,
Hriſ te leiſon,
Chriſte e ley ſon;
KODAK Color Control Patches
Kodak
Blue Cyan Green Yellow Red Magenta White 3/Color Black

Figure 2.12.

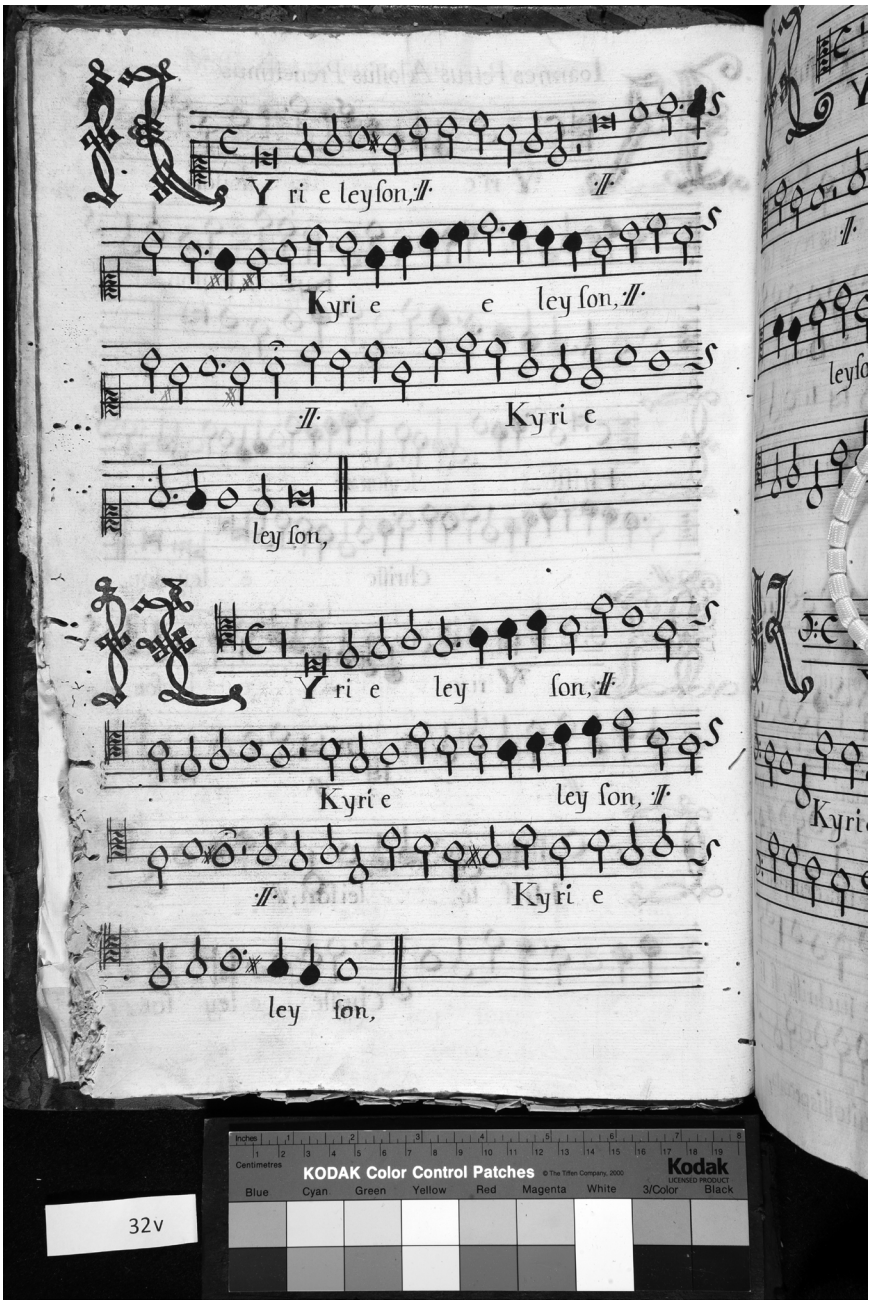
Yri e leyſon,
Kyri e e leyſon,
Kyri e
leyſon,
Yri e ley ſon,
Kyri e leyſon,
Kyri e
ley ſon,
32v
KODAK Color Control Patches
Kodak

Figure 2.13.

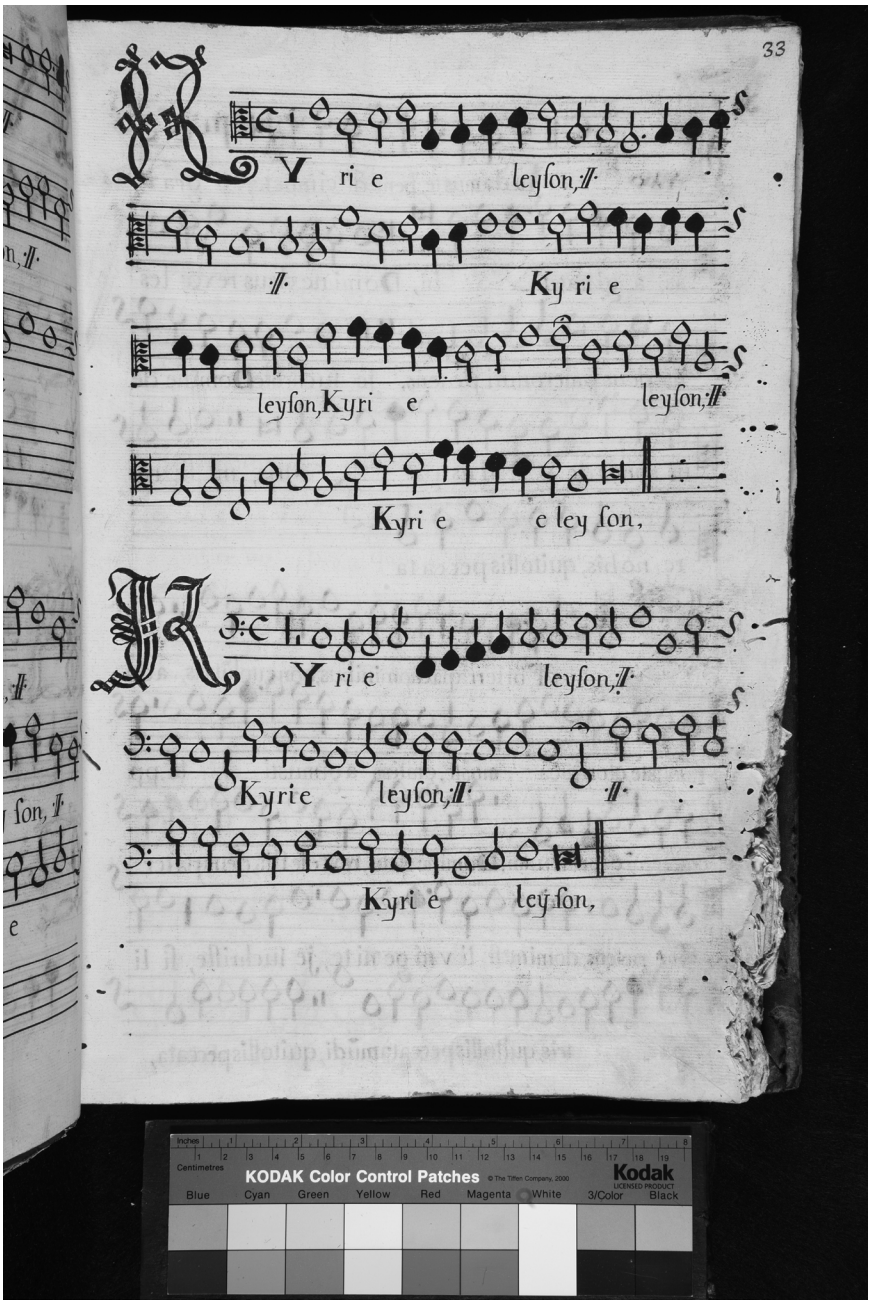
33
Y ri e leyſon,
Ky ri e
leyſon, Kyri e leyſon,
Kyri e e ley ſon,
Y ri e leyſon,
Kyrie leyſon,
Kyri e ley ſon,
KODAK Color Control Patches
Kodak
Blue Cyan Green Yellow Red Magenta White 3/Color Black

Figure 2.14.

APPENDIX B: EXAMPLES OF THE SYMBOLIC FILES OBTAINED

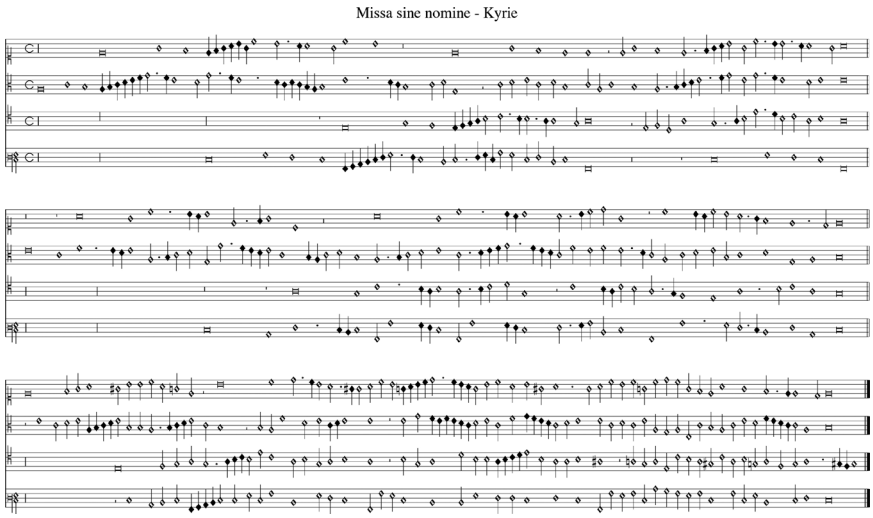

Figure 2.15. Mensural score of the complete Kyrie movement (folios 31v–33r) of Palestrina's *Missa sine nomine* as appearing in GuatC 1, as encoded in the Mensural MEI file obtained from the OMR and Scoring-up processes. Each system shows each of the three sections of the Kyrie: the first Kyrie, the Christe, and the second Kyrie.

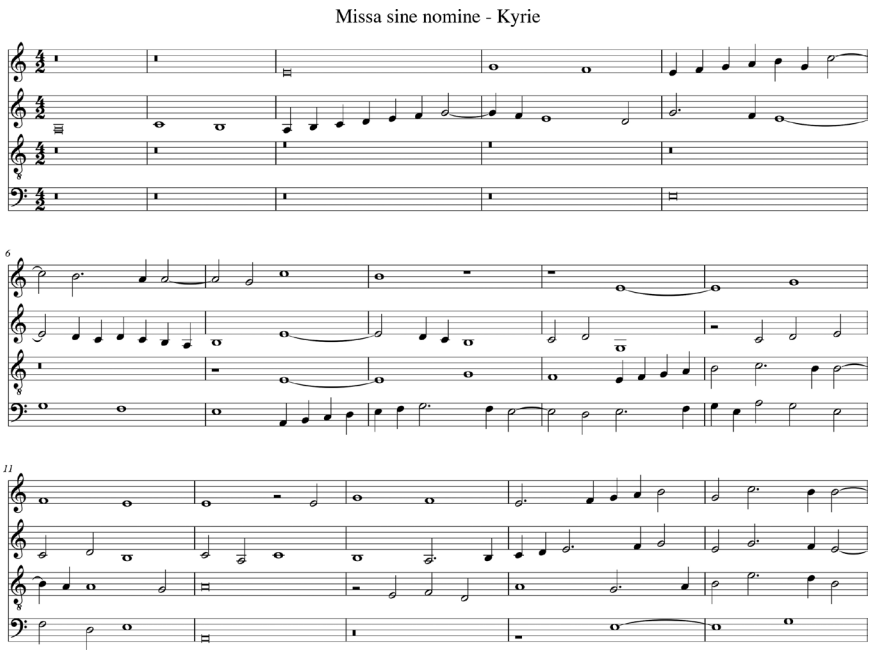

Figure 2.16. Modern transcription of the complete Kyrie movement of Palestrina's *Missa sine nomine* in GuatC 1, as encoded in the CMN MEI file obtained from the Mensural MEI score (figure 2.15). The first Kyrie is mm. 1–17, the Christe is mm. 18–33, and the second Kyrie is mm. 34–51.

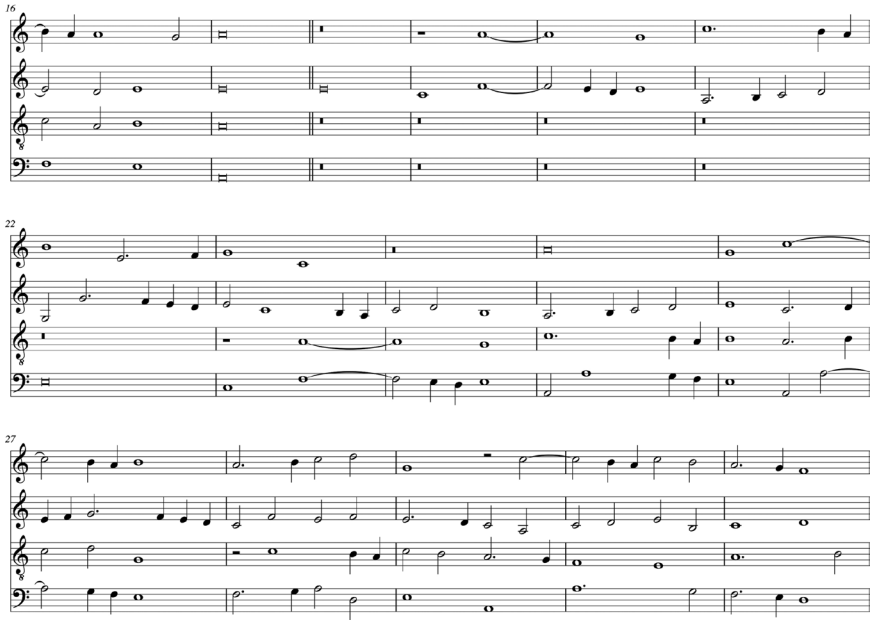

Figure 2.16. ***(Continued)***

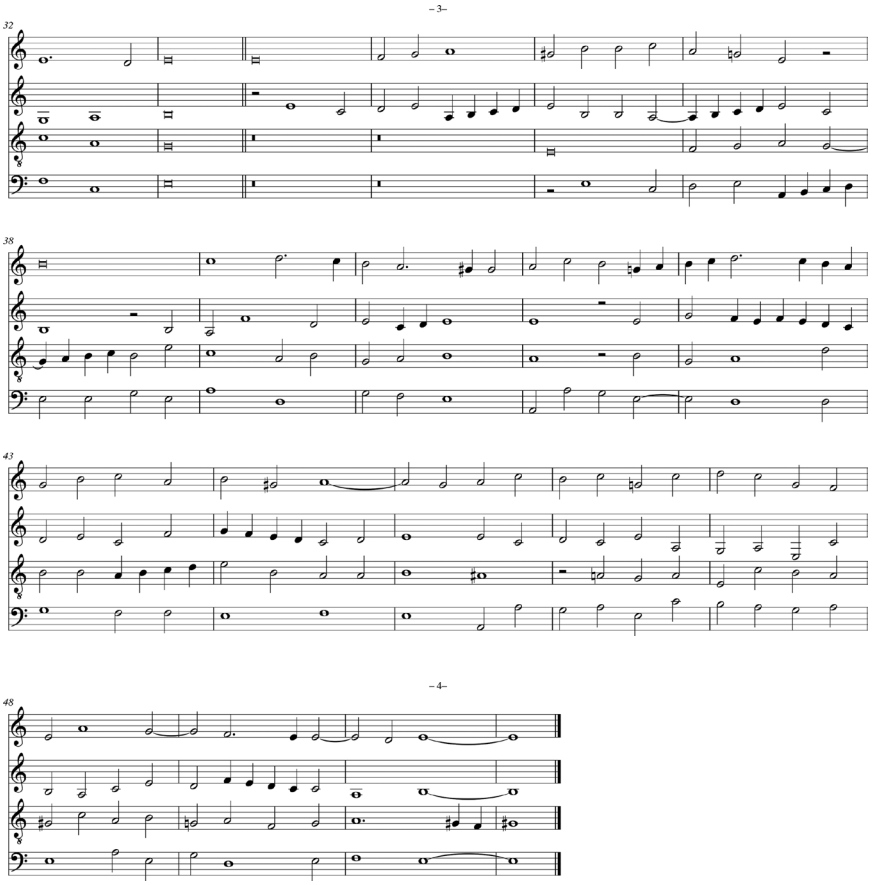

Figure 2.16. ***(Continued)***

NOTES

1. The main city changed place in 1776. The city moved from Santiago de los Caballeros de Guatemala (now Antigua Guatemala) to the Nueva Guatemala de la Asunción (now Guatemala city, its current location).

2. Only choirbooks 1, 3, and 5 have pieces added in the eighteenth century. Half of the masses of GuatC 1 (copied in 1760–1765) come from a *Libro de Kyries* from 1602. GuatC 2 was copied in 1606. GuatC 3 and 5 were copied by different scribes during the mid-seventeenth to the mid-eighteenth centuries. GuatC 4 was copied in 1605. And GuatC 6 was probably copied during the first half of the seventeenth century.

3. Archivo Histórico Arquidiocesano de Guatemala, "Francisco de Paula García Peláez," located within the Palacio Arzobispal (7ª avenida 6-21 zona 1) next to the Metropolitan Cathedral.

4. Inventories: David Pujol, "Polifonía española desconocida conservada en el Archivo Capitular de la Catedral de Guatemala y de la Iglesia parroquial de Santa Eulalia de Jacaltenango," *Anuario Musical* 20 (1965): 3–10; Robert Stevenson, *Renaissance and Baroque Musical Sources in the Americas* (Washington, DC: General Secretariat, Organization of American States, 1970), 65–71; Robert Snow, "A New-World Collection of Polyphony for Holy Week and the Salve Service: Guatemala City, Cathedral Archive, Music MS 4," in *Monuments of Renaissance Music 9* (Chicago: University of Chicago Press, 1996), 25–26. Overview: Omar Morales Abril, "Música local y música foránea en los libros de polifonía de las Catedrales de Guatemala y México," *Jahrbuch für Renaissancemusik* 14 (2015): 95–124.

5. Transcriptions include Dieter Lehnhoff, *Música de la época colonial en Guatemala: primera antología* (Antigua Guatemala: Centro de Investigaciones Regionales Mesoamericanas, 1984); Dieter Lehnhoff, *Las misas de Pedro Bermúdez* (Guatemala City: Universidad Rafael Landívar, 2001); Dieter Lehnhoff, *Choral Music from Guatemala: For SATB Choir* (Niedernhausen: Edition Kemel, 2008); Omar Morales, Jorge Pellecer, Igor de Gandarias, and Arturo Duarte, *Missa de bomba a 4: Guatemala, siglo XVI* (2001); Omar Morales Abril, "'Jesu nostra redemptio,' himno de vísperas para la Ascensión, de Pedro Bermúdez," *Heterofonía: revista de investigación musical*, no. 129 (2003): 109–27. Recordings include Dieter Lehnhoff, conductor, Ensemble Millennium, and Schola Cantorum, compact disc "Coros de Catedral," in *Música Histórica de Guatemala*, Vol. 2 (Guatemala: Fundación para la Cultura y el Desarrollo, 1995), HGG20394CD.

6. **kern is an encoding format that provides support for common Western music notation.

7. Thomas Christian Schmidt, Christian Thomas Leitmeir, and J. P. Gumbert, *The Production and Reading of Music Sources: Mise-En-Page in Manuscripts and Printed Books Containing Polyphonic Music, 1480–1530* (Turnhout: Brepols, 2018), 32–34.

8. Pujol, "Polifonía," 3–10; Stevenson, *Renaissance*, 65–71; and Snow, "A New-World," 25–26.

9. Snow, "A New-World," ix.

10. Morales Abril, "Música local," 97.
11. Ibid.
12. See the "Further Reading" section.
13. Alfred Lemmon, "Toward an International Inventory of Colonial Spanish American Cathedral Music Archives," *Revista de Musicología* 16, no. 1 (1993): 92–98.
14. Morales Abril, "Música local," 115. While it was previously believed that Fernández was born in Évora (Portugal), in "Gaspar Fernández: su vida y obras como testimonio de la cultura musical novohispana a principios del siglo XVII" (see the "Further Reading" section), Morales Abril has provided evidence that Guatemala's chapelmaster and Évora's Gaspar Fernandes are two different people. The de Quirós brothers, identified as such in the header of the GuatC 3 *Sancta Maria Succurre* piece, were both born in Guatemala as well (see the "Further Reading" entries for Lemmon and Stevenson). Finally, Juan José Guerrero and Juan Matías de Rivera are identified as "criollo" and "indigeneous" respectively in their corresponding entries on the Books of Hispanic Polyphony website (see the "Further Reading" section).
15. Centro de Rescate, Estudios y Análisis Científico del Arte (CREA, Center for Restoration, Study, and Scientific Analysis of the Art Work), https://fundacionrozasbotran.org/cultura-y-arte/crea/, a nonprofit organization focused on the conservation and restoration of Guatemalan religious heritage.
16. The information in table 2.2 comes from the index page of GuatC 1 (which separates the twelve masses into two groups, the ones copied from the *Libro de Kyries* and the newly added ones) and the inventories by Pujol, "Polifonía," 4; Stevenson, *Renaissance*, 65–71; Snow, "A New-World," 25–26; and Morales Abril (unpublished). Most information regarding genre was obtained from Pujol, although he divides piece 21 into two invitatories (*Surrexit Dominus vere* and *Alleluia, alleluia, alleluia*) and identifies piece 26 as the motet *Agnus redemit*. The latter has been corrected by Snow to *Dic nobis Maria* from *Victimae paschali laudes*, which is a sequence. The composer attribution comes from Morales Abril. Information regarding the folios and number of voices has been doubled checked against the manuscript.
17. Snow, "A New-World," 19.
18. Ibid.
19. The microfilms are held at the archive of the Centro de Investigaciones Regionales de Mesoamérica (CIRMA) in Antigua Guatemala, Guatemala. CIRMA made them in 1984 with the authorization of the chancellor of the Ecclesiastical Curia, Monsignor Efraín Hernández (Thelma Porres, director of CIRMA's historical archive, email communication, March 2020). Guatemalan musicologist Dieter Lehnhoff conducted the microfilming process, starting in June 1984, with staff and equipment provided by William Swezey, current director of CIRMA. This is according to Dieter Lehnhoff, *Rafael Antonio Castellanos: vida y obra de un músico guatemalteco* (Guatemala: Universidad Rafael Landívar, 1994), 3–4. According to the Música Colonial Archive (http://www3.cpdl.org/wiki/index.php/Música_Colonial_Archive), the microfilms were borrowed from CIRMA and brought momentarily to the Miami University Libraries in 2002. Here the microfilms were digitized into TIFF files in 2003, and they were then converted into DjVu files in 2004 to be shared online. These DjVu files can be consulted at http://conan.lib.miamioh.edu/musica/data/. The files belong-

ing to the ninth reel (starting with the number "9") are the ones corresponding to the GuatC choirbooks. Selected items from the microfilms have been transcribed into modern scores and are available in the Choral Public Domain Library "Música colonial scores" site (http://www0.cpdl.org/wiki/index.php/Category:Música_colonial_scores). Unsurprisingly, because the GuatC 1 choirbook is well preserved, many of its pieces have been transcribed. Ten out of its twelve masses can be found in the CPDL Música colonial scores website (missing only 7 and 12 from table 2.2), together with four out of its fifteen short pieces (corresponding to numbers 18, 20, 22, and 25 from table 2.2).

20. Perry Roland, Andrew Hankinson, and Laurent Pugin, "Early Music and the Music Encoding Initiative," *Early Music* 42, no. 4 (2014): 605–11.

21. Federal Agencies Digital Guidelines Initiative, "Technical Guidelines for Digitizing Cultural Heritage Materials: Creation of Raster Image Files," 2016, http://www.digitizationguidelines.gov/guidelines/FADGI%20Federal%20%20Agencies%20Digital%20Guidelines%20Initiative-2016%20Final_rev1.pdf.

22. The book cradle was built by German Thomae (my father) in Guatemala, the camera was borrowed from the Marvin Duchow Music Library at McGill University, and the lights were borrowed from the Distributed Digital Music Archives and Libraries (DDMAL) Lab, also at McGill University. The camera allowed for an image resolution of 300ppi, an adequate archival resolution value (consistent with a three-star FADGI project). For more details on DIY book scanners, see the "Further Reading" section.

23. DIAMM, https://www.diamm.ac.uk; BANQ, http://www.banq.qc.ca/accueil/; McGill Library's Digitization Lab, https://www.mcgill.ca/library/services/research/digitization.

24. "Technical Overview," DIAMM, accessed February 25, 2019, https://www.diamm.ac.uk/about/technical-overview/.

25. Special thanks to Jessica Régimbald (conservator at the direction du dépôt légal et de la conservation des collections patrimoniales), Marie-Chantal Anctil (coordinator of the section de la reproduction et des ateliers audiovisuels and direction de la numérisation), and Michel Legendre (photographer of the direction de la numérisation and section de la reproduction).

26. Special thanks to Gregory Houston (New Media and Digitization Administrator of the Digital Initiatives Department, McGill Library).

27. Finale and Sibelius include their own OMR software.

28. The tool, developed by Laurent Pugin, can be accessed at http://www.aruspix.net. See the "Further Reading" section.

29. See the "Further Reading" section.

30. For the CMN model, see the "Further Reading" section.

31. Jorge Calvo-Zaragoza, Alejandro H. Toselli, and Enrique Vidal, "Handwritten Music Recognition for Mensural Notation with Convolutional Recurrent Neural Networks," *Pattern Recognition Letters* 128 (2019): 115–21.

32. See the "Further Reading" section.

33. The page-level model has also been used with Spanish mensural notation. Still, I decided on using the staff-level model instead because, although a model that works

at the page level makes the classification process more efficient, it is more susceptible to errors, prolonging the time invested in correcting the results.

34. MuRET was introduced in David Rizo, Jorge Calvo-Zaragoza, and José M. Iñesta, "MuRET: A Music Recognition, Encoding, and Transcription Tool," in *Proceedings of the 5th International Conference on Digital Libraries for Musicology* (Paris: ACM, 2018), 52–56. The tool can be accessed at https://muret.dlsi.ua.es/muret/#/. Currently, it requires log-in credentials that can be provided by its developer, David Rizo.

35. The *punctus additionis* (dot of addition) and *punctus divisionis* (dot of division) have different functions in mensural notation. A dot of addition behaves like a common dotted note; it adds half the value to the original length of a note. A dot of division is used in triple meter to divide the notes into perfect groupings; this division changes the interpretation of some notes.

36. This tool is introduced in Martha E. Thomae, Julie E. Cumming, and Ichiro Fujinaga, "The Mensural Scoring-Up Tool," in *Proceedings of the 6th International Workshop on Digital Libraries for Musicology* (The Hague: ACM, 2019), 9–19. The source code is available at https://github.com/ELVIS-Project/scoring-up.

37. The **mens encoding was introduced in David Rizo, Nieves Pascual León, and Craig Stuart Sapp, "White Mensural Manual Encoding: From Humdrum to MEI," *Cuadernos de Investigación Musical*, no. 6 (2018): 373–93. The specifications of this format can be found at http://doc.verovio.humdrum.org/humdrum/mens/.

38. Source code available at https://github.com/DDMAL/Mensural_MEI_Score_to_CMN_MEI_Score.

39. The Verovio MEI Viewer can be found at https://www.verovio.org/mei-viewer.xhtml. Verovio is a music notation engraving library developed by Laurent Pugin.

40. Examples of information that can be lost in a modern transcription are the use of dots of division and the difference between an imperfect note and an altered note of the next smaller degree.

41. Music21, https://web.mit.edu/music21/; Humdrum, https://www.humdrum.org; jSymbolic, http://jmir.sourceforge.net/jSymbolic.html; VIS Framework, https://vis-framework.readthedocs.io/en/v3.0.5/.

42. jSymbolic, along with machine learning, has been used for studying composer attribution, exploring the stylistic origins of genres, and distinguishing between regional styles (such as Iberian and Franco-Flemish). For more information, see the "Further Reading" section.

43. Including stylistic change between the Ockeghem, Josquin, and Palestrina generations in the Renaissance, contrapuntal repetition on Lassus duos, and consistency between theory and practice. For more information, see the "Further Reading" section.

44. The VIS Framework can index the piece according to different events. Indexing the piece by the melodic and vertical intervals (or by 2-grams) can aid with the identification of counterpoint errors.

45. Original source at https://imslp.org/wiki/Missarum%2C_Liber_2_(Palestrina%2C_Giovanni_Pierluigi_da).

46. https://database.elvisproject.ca/piece/2309/.

47. This research has been supported by Fonds de Recherche du Québec—Société et Culture (FRQSC), Bourse au doctorat en recherche (13D - Musique) 2019-B2Z-261749. Special thanks to Professor Julie Cumming for the help in editing this essay, and to Professor Ichiro Fujinaga for his revision of the "Optical Music Recognition" section.

FURTHER READING

Computational Music Analysis

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Optical Music Recognition

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VIS (Vertical Interval Successions) Music Analysis Framework, https://vis-framework.readthedocs.io/en/v3.0.5/#.

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