Research questions

• What musical characteristics distinguish the styles of Josquin and La Rue?
• How can computational methods help us approach such problems?
Difficult task!

Josquin Des Prez
- c. 1450-55 to 1521
- Varied career in France and Italy

Pierre de la Rue
- c. 1452 to 1518
- Hapsburg-Burgundian chapel, Low Countries and Spain

Meconi, *Grove*: “Despite differences in style, La Rue’s music was probably most strongly influenced by that of Josquin. … There are curious parallels between the works of the two.”

11 conflicting attributions to the two composer in the NJE

Even experts in the period cannot identify the composer for pieces they don’t know
Our corpus: comparing apples to apples

Same texture, same genre
Duos from securely attributed Masses by the two composers:
• 44 duos by La Rue
• 33 duos by Josquin
Duos are:
• The purest form of Renaissance counterpoint, and basic training for composers
• Relatively easy to study
Most were excerpted from the files in the Josquin Research Project; some of the La Rue duos were transcribed from the La Rue *Opera Omnia*, with original note values restored
Formats: MIDI and MusicXML
Three approaches to computer-aided style analysis, plus comparison

• Part 1: Vertical intervals and contrapuntal 3-grams (Néstor Nápoles López and Julie Cumming)
• Part 2: Measuring imitation (Sylvain Margot and Peter Schubert)
• Part 3: Feature extraction and machine learning (Cory McKay)
• Part 4: Comparison of each method in an attribution task
Part 1: Vertical intervals

Distribution of vertical intervals in diatonic steps (as a percentage of the total number of vertical intervals for each composer)

Josquín has
• More 3rds
• More voice crossing
Part 1: Vertical intervals

Distribution of vertical intervals in diatonic steps (as a percentage of the total number of vertical intervals for each composer)

La Rue has
- More 7ths and 9ths
- More 6ths
Part 1: Contrapuntal 3-grams

Cadential 3-gram (La Rue, Missa Inviolata, ‘Pleni’, bb. 20-21)

\[ [7] (1 -2) [6] (-2 2) [8] \]
### Top 5 3-gram types in the corpus.

<table>
<thead>
<tr>
<th>Row number</th>
<th>Occurrences</th>
<th>3-gram type</th>
<th>Description</th>
<th>Occurrences in La Rue</th>
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<tr>
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<td>11</td>
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<td>Cadential 7-6-8 to the 8ve with suspension</td>
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<td>15</td>
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<td>32</td>
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<tr>
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<td>[6] (-3 -2) [7] (1 -2) [6]</td>
<td>Incomplete cadence: 6-7-6 with suspension: La Rue fingerprint</td>
<td>30</td>
<td>0</td>
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</table>
3-gram types in the corpus

No. of 3-gram types in the whole corpus: 1661
3-grams types that occur only once (60%): 1010
3-gram types that occur more than once (40%): 651
Top 5 3-gram types in the corpus.

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Cadential figure found only in duos by La Rue (‘La Rue fingerprint’)

Extra dissonance
Part 2: Measuring imitation

Core: a musical unit that is diatonically and rhythmically exactly the same when it recurs in the other voice

Smallest musical unit that can count as the core: at least three semiminims, and at least three notes (attacks)
La Rue vs. Josquin: Pitch intervals of imitation

![Bar chart showing the proportion of imitations for pitch intervals between La Rue and Josquin. The chart indicates that the fifth pitch interval is most commonly used by both composers, followed by the sixth and seventh intervals.](image-url)
Length of core melodies in imitation

Length of imitated cores in semiminims

Proportion of imitations

- La Rue
- Josquin
Number of imitations per piece in canonic duos

<table>
<thead>
<tr>
<th></th>
<th>All duos Josquin 33 - La Rue 44</th>
<th>Canonic duos Josquin 7 - La Rue 7</th>
<th>Non-canonic duos Josquin 26 - La Rue 37</th>
</tr>
</thead>
<tbody>
<tr>
<td>Josquin</td>
<td>68</td>
<td>116</td>
<td>55</td>
</tr>
<tr>
<td>La Rue</td>
<td>78</td>
<td>68</td>
<td>80</td>
</tr>
</tbody>
</table>
Time interval of imitation less than 32 semiminims long in non-canonic duos
Time interval of imitation more than 32 semiminims long in non-canonic duos
Part 3: Feature extraction and machine learning
What are “features”?

- Pieces of information that can characterize a piece of music in a simple and consistent way
- Numerical values
  - A feature can be a single value
  - Can be a set of related values (e.g. a histogram)
- Provide a summary description
  - Describes the characteristic for the music overall, not locally
Sample one-dimensional feature

**Range:** Difference in semitones between the highest and lowest pitches in a piece

![Musical notation](image)

Value of this feature: 7

G - C = 7 semitones
Sample multi-dimensional feature

- **Pitch Class Histogram**: Consists of 12 values, each representing the fraction of all notes belonging to a pitch class.

- **Graph shows feature values:**
  - Note counts: C: 3, D: 10, E: 11, G: 2
  - Most common note is E (11/26 notes), which thus has a feature value of 0.423
When things get interesting . . .

• Comparing hundreds or thousands of features per piece, not just one or two

• Looking for patterns among hundreds or thousands of pieces, not just a few
  • Especially if grouped in interesting ways (like composer)

• Our jSymbolic software lets us do these things quickly and easily . . .
jSymbolic: Feature types

- Pitch statistics
- Melody / horizontal intervals
- Chords / vertical intervals
- Texture
- Rhythm
- Instrumentation
- Dynamics
Number of features (jSymbolic 2.2)

• 246 features are calculated per piece
• 1497 feature values per piece when multi-dimensional features are expanded
  • 801 of these are “secure” (less sensitive to dataset encoding biases or inconsistencies)
Machine learning: Josquin vs. La Rue

• Used machine learning (SVMs) to train models that could distinguish between (classify) the secure duos of each composer

• Trained on all the (secure) jSymbolic 2.2 features from the secure La Rue and Josquin duos
  • Without prejudging which features are relevant
  • Permits the system to discover potentially important patterns that we might not have thought to look for
Success rate for distinguishing composers

- The system was able to distinguish between the secure Josquin duos and the secure La Rue duos:
  - 85.5% of the time
  - 26 of the 33 secure Josquin duos identified correctly
  - 39 of the 43 secure La Rue duos identified correctly
- Clearly there are indeed measurable stylistic differences in the music of the two composers
Which features best (individually) distinguished Josquin and La Rue?

<table>
<thead>
<tr>
<th>Feature</th>
<th>Overall Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Note Density of Highest Line</td>
<td>Much higher for Josquin</td>
</tr>
<tr>
<td>Prevalence of Very Long Rhythmic Values</td>
<td>Much higher for Josquin</td>
</tr>
<tr>
<td>Vertical Sevenths</td>
<td>Higher for La Rue</td>
</tr>
<tr>
<td>Distance Between Two Most Common Vertical Intervals</td>
<td>Higher for La Rue</td>
</tr>
<tr>
<td>Repeated Notes</td>
<td>Higher for La Rue</td>
</tr>
<tr>
<td>Note Density per Quarter Note</td>
<td>Somewhat higher for La Rue</td>
</tr>
<tr>
<td>Number of Pitches</td>
<td>Somewhat higher for La Rue</td>
</tr>
<tr>
<td>Prevalence of Most Common Pitch</td>
<td>Somewhat higher for Josquin</td>
</tr>
<tr>
<td>Range</td>
<td>Somewhat higher for La Rue</td>
</tr>
<tr>
<td>Partial Rests Fraction</td>
<td>Somewhat higher for La Rue</td>
</tr>
<tr>
<td>Parallel Motion</td>
<td>Somewhat higher for La Rue</td>
</tr>
<tr>
<td>Variability of Number of Simultaneous Pitch Classes</td>
<td>Slightly higher for La Rue</td>
</tr>
</tbody>
</table>
Part 4: Three approaches to attribution

Possibly by La Rue:

• The two-voice ‘Benedictus’ and ‘In nomine’ from Missa Tous les regretz. This Mass has two versions of the ‘Benedictus’ section of the Sanctus in different sources: a three-voice ‘Benedictus’ and these two shorter duos. There is some question as to whether these duos are by La Rue

• Le renvoye / Num stultem est mortem. This duo is found first with a French text in Vienna, Österreichische Nationalbibliothek, Mus. Hs. 18832/1-2 (VienNB Mus. 18832), a duo collection, without attribution; it is attributed to La Rue in the Montanus and Neuber duo collection of 1549, Diphona amoena et florida, selectore Erasmo Rotenbucher (RISM 154916), with a Latin text, Num stultem est mortem.
Possibly by Josquin

• ‘Crucifixus’ (not from any known Mass). This duo is found only in the duo collection containing Le renvoye / Num stultem (RISM 154916), where it is attributed to Josquin; both the New Josquin Edition and the Josquin Research Project reject it as a Josquin work
Comparison of the attribution results

<table>
<thead>
<tr>
<th>Duo Title</th>
<th>Source Attribution</th>
<th>Contrapuntal analysis</th>
<th>Analysis of imitation</th>
<th>Feature-based</th>
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<tbody>
<tr>
<td><em>Missa Tous les regretz</em> ('Benedictus')</td>
<td>La Rue</td>
<td>La Rue (medium confidence)</td>
<td>Inconclusive</td>
<td>Josquin</td>
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<td><em>Le renvoye / Num stultem</em></td>
<td>La Rue?</td>
<td>Josquin (medium confidence)</td>
<td>La Rue (high confidence)</td>
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</tr>
<tr>
<td>‘Crucifixus’</td>
<td>Josquin?</td>
<td>La Rue (low confidence)</td>
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Conclusions

• Part 1: Vertical intervals and contrapuntal 3-grams
  • La Rue fingerprint
  • La Rue uses more dissonance (especially 7ths)
  • Josquin has more voice crossing
  • Josquin has a more limited contrapuntal vocabulary

• Part 2: Measuring imitation
  • Josquin has more more “sub-imitations” in the canonic duos
  • La Rue has much more imitation at long odd-numbered time intervals (in semiminims (half notes))

• Part 3: Feature extraction and Machine Learning
  • Distinguishes the composer of 86% correctly
  • Confirms findings of the other studies
  • Josquin has more long notes, more notes in the top line
  • La Rue has more eighth notes and more repeated notes
Thank you!

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• To Honey Meconi and David Burn for inspiring the project

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