

A decorative graphic on the left side of the slide, consisting of a grid of squares in various shades of blue and purple, arranged in a pattern that suggests a staircase or a grid.

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Topics

- Introduction to “features” (from a machine learning perspective)
 - And how they can be useful for musicologists and music theorists
- jSymbolic2
 - What it is
 - How it's useful to music theorists and musicologists

What are “features”?

- Pieces of information that can **characterize something** (e.g. a piece of music) in a (usually) **simple** way
- (Usually) **numerical values**
 - Can be **single values** or can be **vectors of related values**
 - **Histograms** are a common type of vector
- (Usually) represent a piece **as a whole**
 - Or at least regularly spaced windows / musical segments within the piece

Chopin's *Nocturne in B, Op. 32, No. 1*

Piano



- Average Note To Note Dynamics Change: 6.03
- Chromatic Motion: 0.0769
- Dominant Spread: 3
- Harmonicity of Two Strongest Rhythmic Pulses: 1
- Importance of Bass Register: 0.2
- Interval Between Strongest Pitch Classes: 3
- Most Common Pitch Class Prevalence: 0.433
- Note Density: 3.75
- Number of Common Melodic Intervals: 3
- Number of Strong Pulses: 5
- Orchestral Strings Fraction: 0
- Overall Dynamic Range: 62
- Pitch Class Variety: 7
- Range: 48
- Relative Strength of Most Common Intervals: 0.5
- Size of Melodic Arcs: 11
- Stepwise Motion: 0.231
- Strength of Strongest Rhythmic Pulse: 0.321
- Variability of Note Duration: 0.293
- Variation of Dynamics: 16.4

Mendelssohn's *Piano Trio No. 2*

The image displays a musical score for Mendelssohn's Piano Trio No. 2. It features three staves: Violin (top), Violoncello (middle), and Piano (bottom). The Violin and Violoncello parts consist of melodic lines with various intervals and rhythms. The Piano part features a complex harmonic structure with many chords and some melodic fragments. A yellow speaker icon is located to the right of the score, indicating that there is an audio recording of this music available.

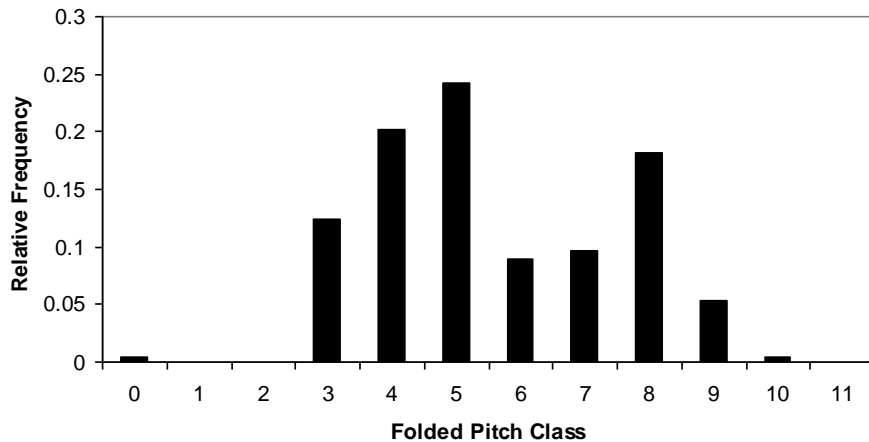
- Average Note To Note Dynamics Change: 1.46
- Chromatic Motion: 0.244
- Dominant Spread: 2
- Harmonicity of Two Strongest Rhythmic Pulses: 1
- Importance of Bass Register: 0.373
- Interval Between Strongest Pitch Classes: 7
- Most Common Pitch Class Prevalence: 0.39
- Note Density: 29.5
- Number of Common Melodic Intervals: 6
- Number of Strong Pulses: 6
- Orchestral Strings Fraction: 0.56
- Overall Dynamic Range: 22
- Pitch Class Variety: 7
- Range: 39
- Relative Strength of Most Common Intervals: 0.8
- Size of Melodic Arcs: 7.27
- Stepwise Motion: 0.439
- Strength of Strongest Rhythmic Pulse: 0.173
- Variability of Note Duration: 0.104
- Variation of Dynamics: 5.98

Feature value comparison

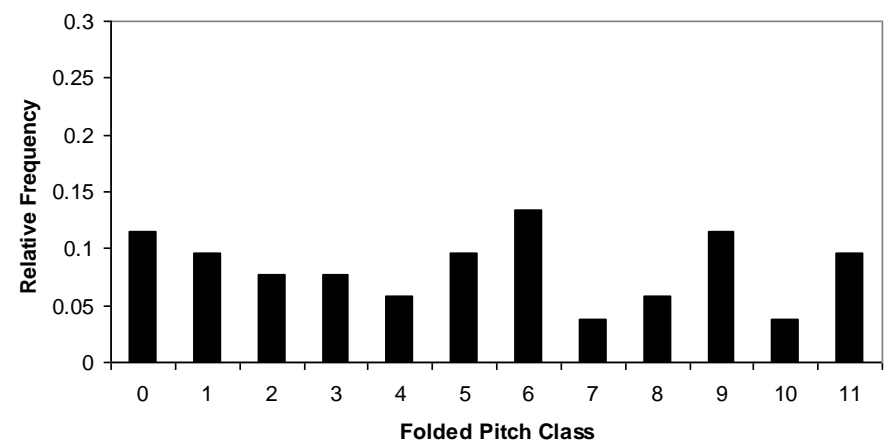
<i>Feature</i>	<i>Nocturne</i>	<i>Trio</i>
Average Note To Note Dynamic Change	6.03	1.46
Overall Dynamic Range	62	22
Variation of Dynamics	16.4	5.98
Note Density	3.75	29.5
Orchestral Strings Fraction	0	0.56
Variability of Note Duration	0.293	0.104
Chromatic Motion	0.077	0.244
Range	48	39

Fifths pitch class histogram

Fifths Pitch Histogram:
Four Seasons (Spring) by Vivaldi

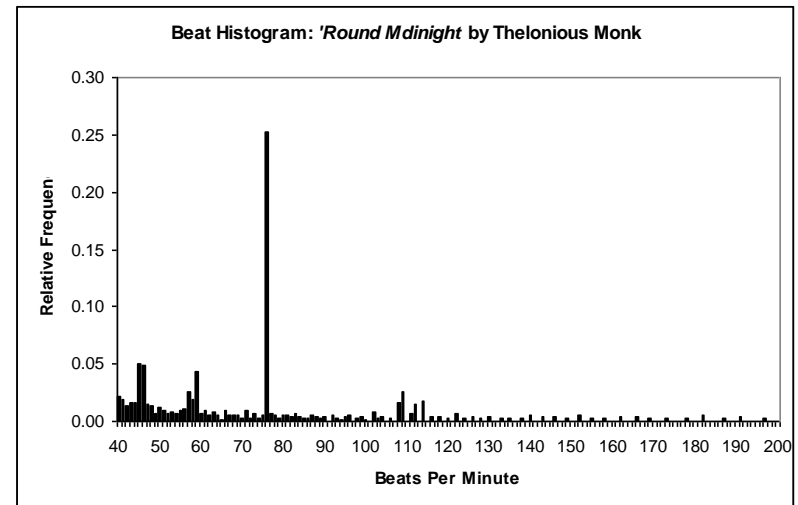
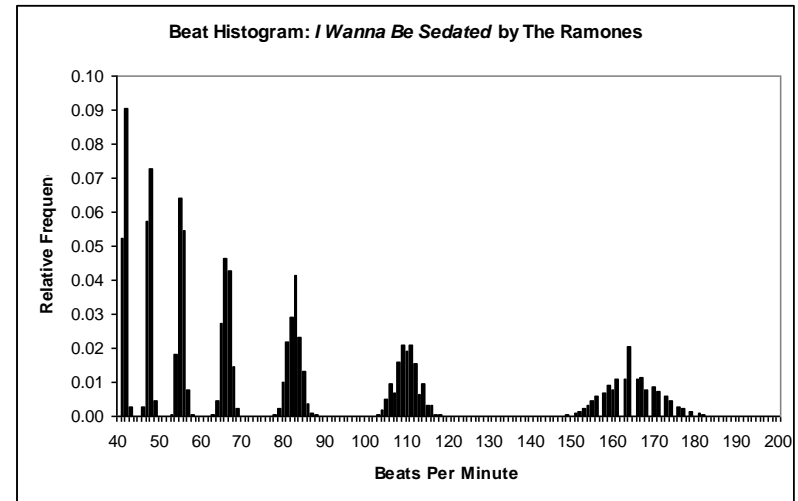


Fifths Pitch Histogram:
Sechs Kleine Klavierstücke by Schoenberg



Beat histogram

- Beat histograms use a technique called “autocorrelation” to calculate the **relative strengths of different beat periodicities**
- “I Wanna Be Sedated” by The Ramones (top)
 - Several harmonic peaks with large spreads around them
- “Round Midnight” by Thelonious Monk (bottom)
 - Only one strong peak, with a large low-level spread
- Histograms like this can be **used directly**, or **other features may be derived from them**
 - e.g. peak statistics



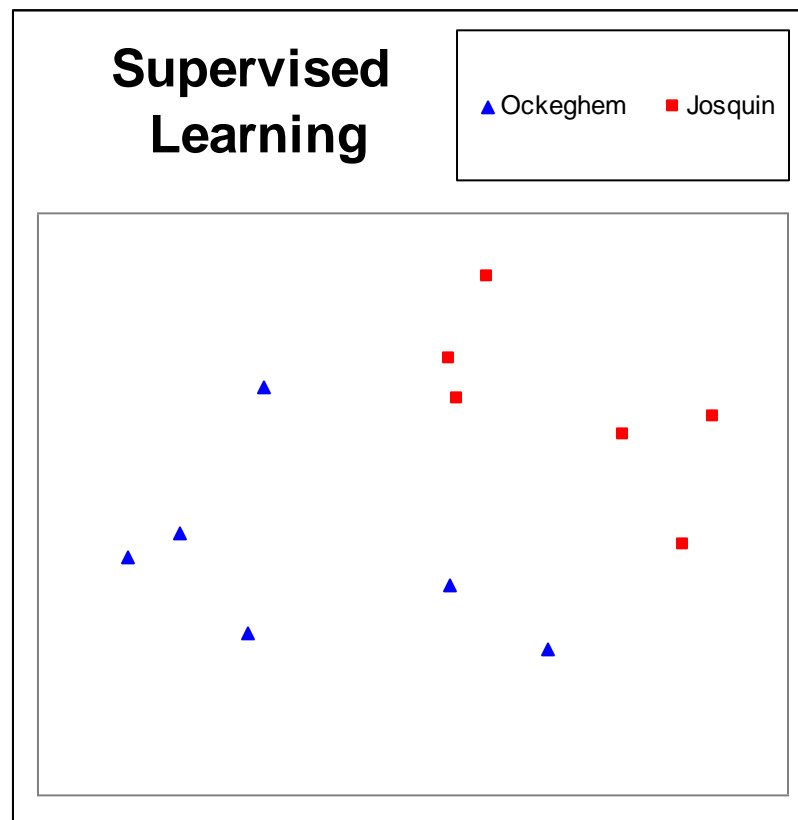
How can features be useful?

- Sophisticated **searches** of large musical databases
 - e.g. find all pieces with no more than X amount of chromaticism, and less than Y amount of parallel motion
 - **ELVIS database + Musiclibs**
- Using **statistical analysis** and **visualization tools** to study the empirical musical importance of various features when extracted from large datasets
 - e.g. features based on instrumentation were most effective for distinguishing genres (McKay & Fujinaga 2005)
- Using **machine learning** to **classify** or **cluster** music
 - Supervised or unsupervised learning
 - e.g. identify the composers of unattributed musical pieces

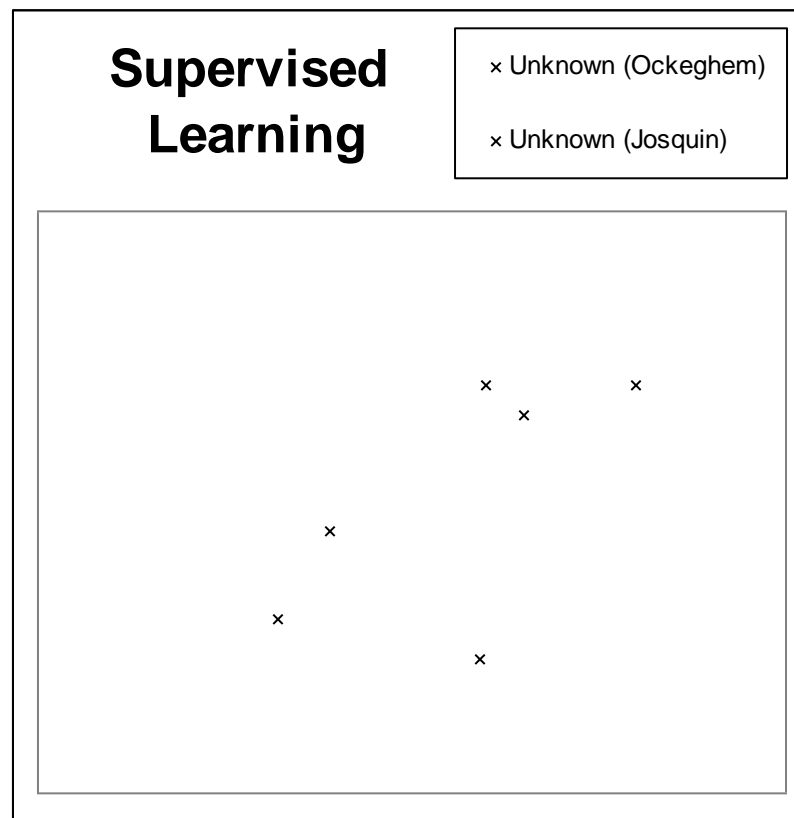
Sample expert system

```
if ( parallel_fifths == 0 &&  
    landini_cadences == 0 )  
    then composer → Palestrina  
else composer → Machaut
```

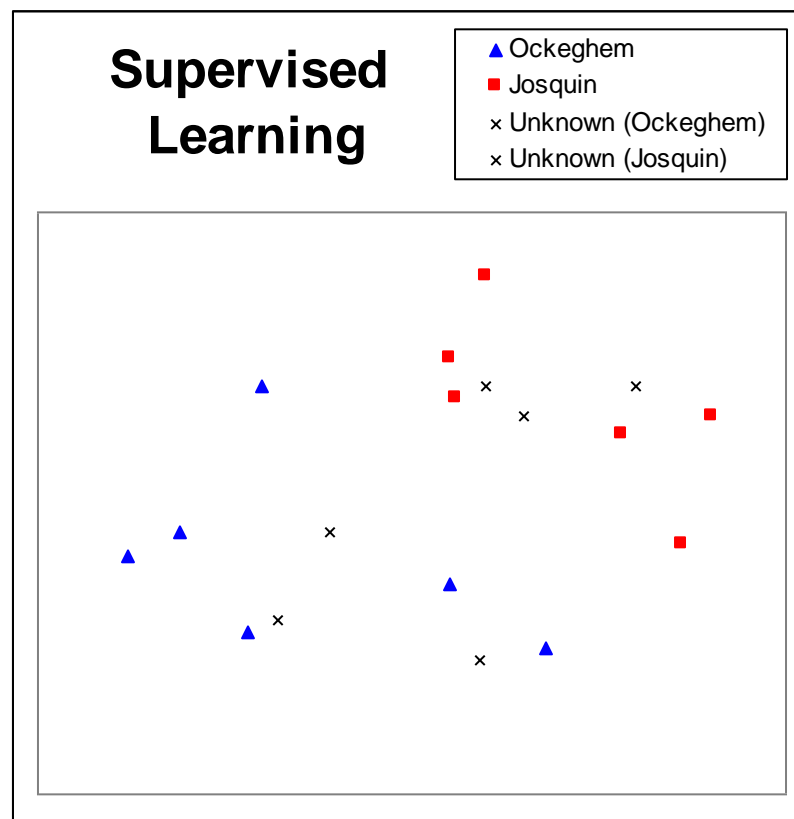
Sample supervised learning



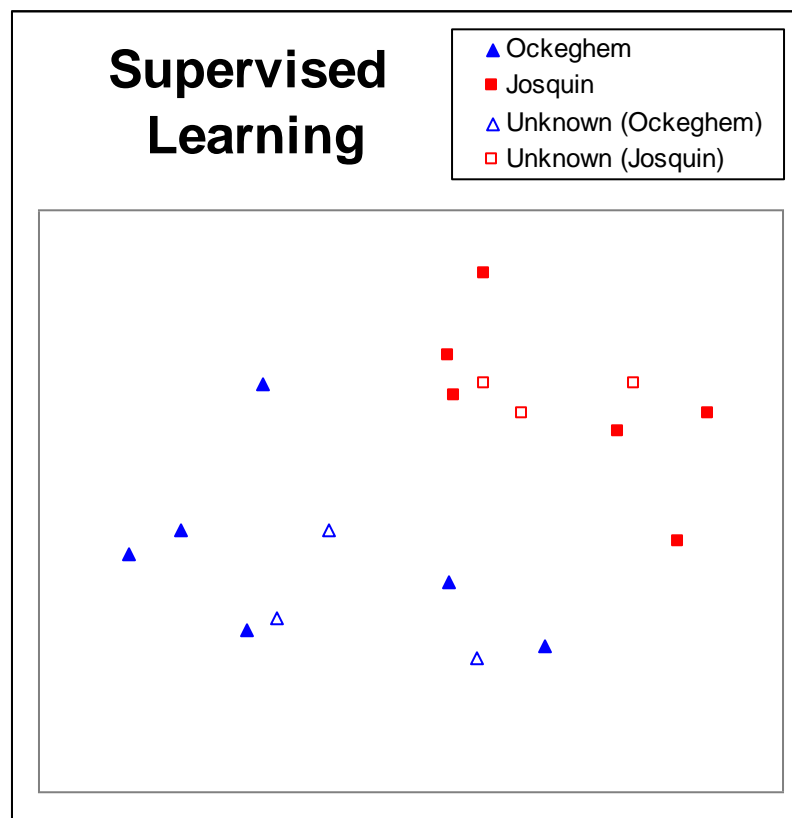
Sample supervised learning



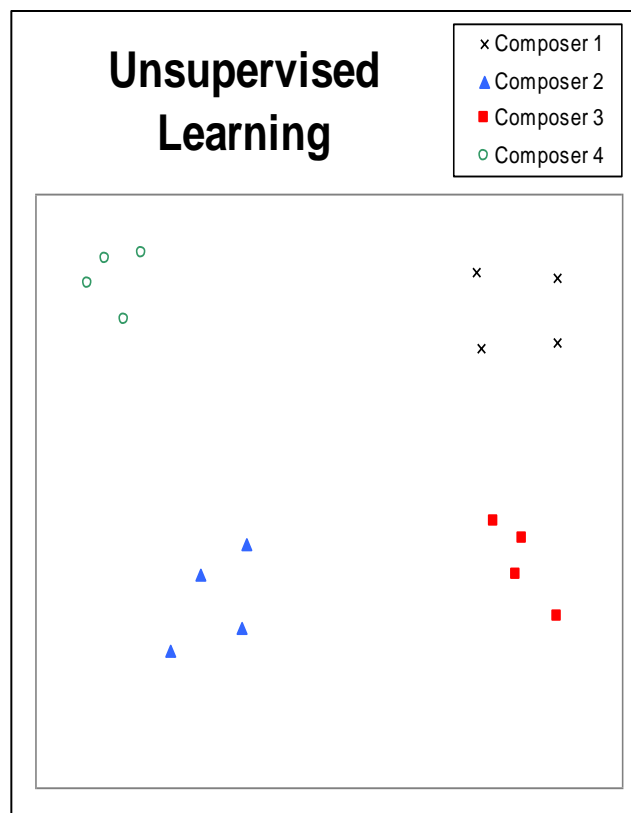
Sample supervised learning



Sample supervised learning



Sample unsupervised learning

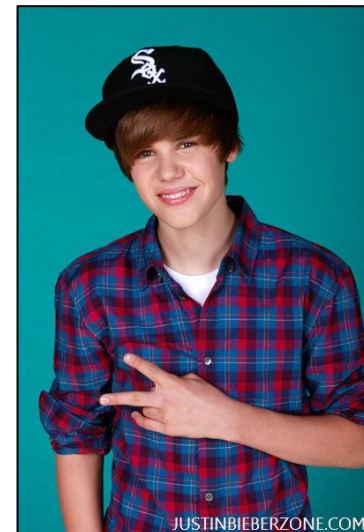


Benefits of features and machine learning

- Can quickly perform consistent **empirical studies** involving **thousands of pieces**
- Can be applied to **diverse types of music**
- Can simultaneously consider **thousands of features** and their interrelationships
 - And can **statistical condense** many features into low-dimensional spaces when needed
- **No need to formally specify** any heuristics or queries before beginning analyses
 - Unless you want to, of course
- Can avoid (or validate) potentially **incorrect ingrained biases** and assumptions

jSymbolic's lineage

- Bodhidharma (2004)
 - Specialized feature extraction and machine learning for genre classification research
- jSymbolic (2006)
 - General-purpose feature extraction
 - Part of **jMIR**
- jSymbolic2 (2016)
 - Bigger and better!



What does jSymbolic2 do?

- Extracts **158 features**
- Some of these are **multi-dimensional** histograms, including:
 - Pitch and pitch class histograms
 - Melodic interval histogram
 - Vertical interval histograms
 - Chord types histogram
 - Beat histogram
 - Instrument histograms

jSymbolic2's feature types (1/2)

- Instrumentation:
 - What types of instruments are present and which are given particular importance relative to others?
- Texture:
 - How many independent voices are there and how do they interact (e.g., polyphonic, homophonic, etc.)?
- Rhythm:
 - Time intervals between the attacks of different notes
 - Duration of notes
 - What kinds of meters and rhythmic patterns are present?
 - Rubato?
- Dynamics:
 - How loud are notes and what kinds of dynamic variations occur?

jSymbolic feature types (2/2)

■ Pitch Statistics:

- What are the occurrence rates of different pitches and pitch classes?
- How tonal is the piece?
- How much variety in pitch is there?

■ Melody:

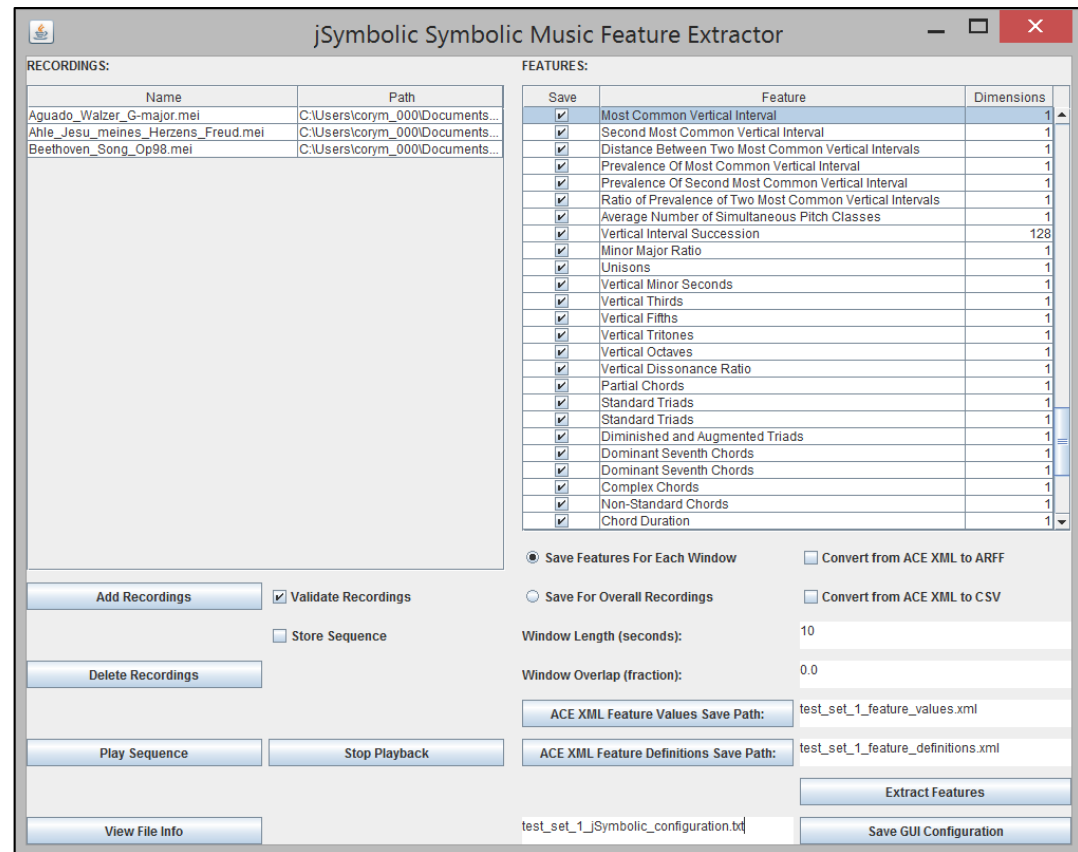
- What kinds of melodic intervals are present?
- How much melodic variation is there?
- What kinds of melodic contours are used?
- What types of phrases are used?

■ Chords:

- What vertical intervals are present?
- What types of chords do they represent?
- How much harmonic movement is there?

How can you use jSymbolic2

- Graphical user interface
- Command line interface
- Rodan workflow
- Java API



jSymbolic2's file formats

■ Input:

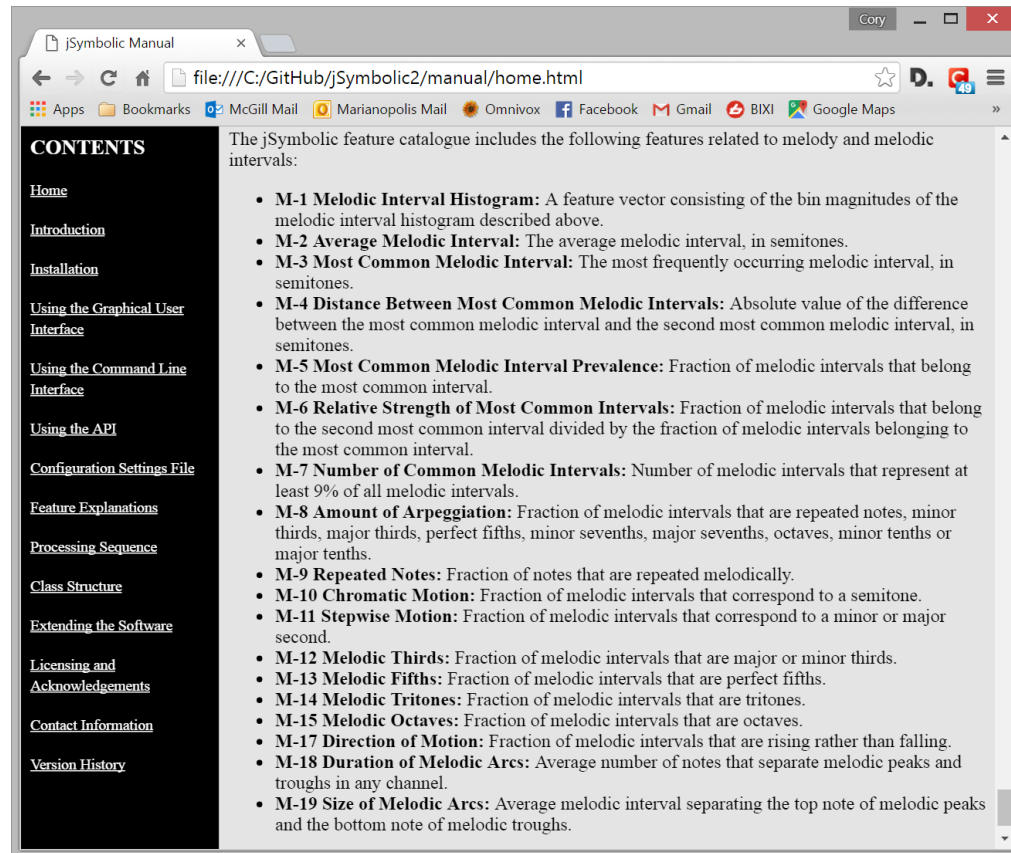
- MIDI
- MEI
- MusicXML (via Rodan workflow only)

■ Output:

- ACE XML
- Weka ARFF
- CSV

jSymbolic2's documentation

- Super-mega-ultra detailed **manual**
 - At least compared to most academic software manuals
 - In HTML
- Super-mega-ultra detailed **Javadocs**
 - For programmers



The screenshot shows a web browser window displaying the jSymbolic2 manual. The browser address bar shows the file path: file:///C:/GitHub/jSymbolic2/manual/home.html. The page title is "jSymbolic Manual". The browser's address bar also shows various icons for apps, bookmarks, and email accounts.

The main content area is titled "CONTENTS" and lists various sections: Home, Introduction, Installation, Using the Graphical User Interface, Using the Command Line Interface, Using the API, Configuration Settings File, Feature Explanations, Processing Sequence, Class Structure, Extending the Software, Licensing and Acknowledgements, Contact Information, and Version History.

The main content area also displays a list of melodic interval features related to melody and melodic intervals:

- **M-1 Melodic Interval Histogram:** A feature vector consisting of the bin magnitudes of the melodic interval histogram described above.
- **M-2 Average Melodic Interval:** The average melodic interval, in semitones.
- **M-3 Most Common Melodic Interval:** The most frequently occurring melodic interval, in semitones.
- **M-4 Distance Between Most Common Melodic Intervals:** Absolute value of the difference between the most common melodic interval and the second most common melodic interval, in semitones.
- **M-5 Most Common Melodic Interval Prevalence:** Fraction of melodic intervals that belong to the most common interval.
- **M-6 Relative Strength of Most Common Intervals:** Fraction of melodic intervals that belong to the second most common interval divided by the fraction of melodic intervals belonging to the most common interval.
- **M-7 Number of Common Melodic Intervals:** Number of melodic intervals that represent at least 9% of all melodic intervals.
- **M-8 Amount of Arpeggiation:** Fraction of melodic intervals that are repeated notes, minor thirds, major thirds, perfect fifths, minor sevenths, major sevenths, octaves, minor tenths or major tenths.
- **M-9 Repeated Notes:** Fraction of notes that are repeated melodically.
- **M-10 Chromatic Motion:** Fraction of melodic intervals that correspond to a semitone.
- **M-11 Stepwise Motion:** Fraction of melodic intervals that correspond to a minor or major second.
- **M-12 Melodic Thirds:** Fraction of melodic intervals that are major or minor thirds.
- **M-13 Melodic Fifths:** Fraction of melodic intervals that are perfect fifths.
- **M-14 Melodic Tritones:** Fraction of melodic intervals that are tritones.
- **M-15 Melodic Octaves:** Fraction of melodic intervals that are octaves.
- **M-17 Direction of Motion:** Fraction of melodic intervals that are rising rather than falling.
- **M-18 Duration of Melodic Arcs:** Average number of notes that separate melodic peaks and troughs in any channel.
- **M-19 Size of Melodic Arcs:** Average melodic interval separating the top note of melodic peaks and the bottom note of melodic troughs.

jSymbolic2: More great things

- Windowed feature extraction
 - Including overlapping windows
- Configuration files
 - Pre-set feature choices
 - Pre-set input and output choices
 - More
- jMei2Midi
 - Most complete MEI to MIDI converter in the universe!
 - General-purpose (not just for jSymbolic2)
 - Specialized pipeline for transmitting relevant MEI data that cannot be represented in MIDI

Exploratory simple pilot study

- **Josquin vs. Ockeghem** composer identification / attribution
 - 124 jSymbolic2 features extracted from the JRP data
 - 105 Josquin pieces and 98 Ockeghem
- Achieved **89.7% classification accuracy**
 - 10-fold cross-validation
- Lots of room for improving results still further
 - Only used simple SVM classifier with default settings
 - No dimensionality reduction was used
 - Both expert insights and automatic analysis can be applied
 - Still more jSymbolic2 features to come
- Interesting future research applications:
 - Determine which features are most effective
 - Can analyze feature data both visually and statistically
 - Apply trained classifiers to unattributed or uncertain pieces
 - Expand scope to other composers

What you can do with jSymbolic

- Empirically study huge collections of music in new ways
 - Search music databases based on feature values
 - Analyze and visualize music based on feature values
 - Use machine learning
- Design your own **custom features**
 - jSymbolic2 is specifically designed to make it easy to add new custom features
 - Easy to iteratively build increasingly complex features based on existing features
- Perform **multimodal research**
 - Combine symbolic features with other features extracted from audio, lyrics and cultural data
 - This improves results substantially! (McKay et al. 2010)

Use jSymbolic2 with jMIR

- **ACE**: Meta-learning classification engine
- **Bodhidharma MIDI**, **SLAC** and **Codaich**: datasets
- **jAudio**: Audio feature extraction
- **jLyrics**: Extracts features from lyrical transcriptions
- **jWebMiner**: Cultural feature extraction
- **ACE XML**: File formats
 - Features, feature metadata, instance metadata and ontologies
- **lyricFetcher**: Lyric mining
- **jMusicMetaManager**: Metadata management
- **jSongMiner**: Metadata harvesting
- **jMIRUtilities**: Infrastructure for conducting experiments
- **jProductionCritic**: Automated production error-checking

Research collaborations

- We would love to collaborate with music theorists and musicologists on their work
- We can help you apply and adapt jSymbolic to specific research projects
- We can help you come up with novel ways to study music



jSymbolic2: Currently in progress

- Final testing and debugging
- Annotation of all valid files in the ELVIS database with extracted features
 - And Musiclibs, eventually
 - Auto-annotation scripts
- MEI pre-modern notation
- Designing new features
 - Requests welcome!

Seq.
1.

I-es irae, dí-es illa, Sólvēt saeclum in favílla :
Tēste Dávid cum Sibýlla. Quántus trémor est futúrus,
Quando jú-dex est ventúrus, Cúnc̄ta stricte discussúrus!

Acknowledgements

- **Tristano Tenaglia**
 - Implemented almost all of the new jSymbolic2 code
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- **Ryan Bannon, Dr. Andrew Hankinson and Dr. Reiner Krämer**
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 - Great financial generosity

Thanks for your attention

- **E-mail:** cory.mckay@mail.mcgill.ca
- **jSymbolic2:** github.com/DDMAL/jSymbolic2
- **jMIR:** jmir.sourceforge.net



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SIMSSA | Single Interface for Music
| Score Searching and Analysis

