Segmentation and grouping structures in jazz chord sequences: An information-theoretic approach
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Introduction

• How to model higher order / hierarchical structure with bottom-up, statistically driven models?

• Forth & Wiggins (2015) present IDyOT (Information Dynamics of Thinking), a cognitive architecture which expatiates IDyOM (Pearce 2005) to account for many aspects of human behaviour across multiple domains (language and music).

• The current research focusses on tonal harmony, in particular jazz.

• Segmentation is the first stage in these bottom-up models.
Jazz Leadsheets

- The entry point of the model is at the chord symbol level.
- 348 leadsheets (15,197 events) compiled by Pachet et al. (2013), taken from the Real Book vol. 1.
- Typical sequence learnt:
  Am7, D7, DM, CM, F#halfdim7, B7, Em
IDyOM: Statistical learning and modelling of the musical surface

- Information Dynamics Of Music (Pearce 2005)
- An unsupervised probabilistic model using variable order Markov models (PPM* - Cleary & Teahan 1997), interpolated smoothing (Cleary & Witten 1984, Moffat 1990) and multiple viewpoints weighted by entropy (Conklin & Witten 1995) to model expectation.

<table>
<thead>
<tr>
<th>Root</th>
<th>BM(^7)</th>
<th>D(^7)</th>
<th>GM(^7)</th>
<th>B</th>
<th>E</th>
<th>M(^7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ChordType</td>
<td>11</td>
<td>2</td>
<td>7</td>
<td>10</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>PosInBar</td>
<td>M</td>
<td>7</td>
<td>M</td>
<td>7</td>
<td>M</td>
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<tr>
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<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

| ici | RootIntFiP | 0 | 3 | 8 | 11 | 4 |
| Fip | RootInt⊕FiB | ⊥ | 3 | 5 | 1 | 8 |

BM\(^7\), D\(^7\), GM\(^7\), B\(^2\)\(^7\), E\(^2\)M\(^7\)
Information theoretic segmentation

• Perceived segment boundaries before difficult to predict events (Pearce et al. 2010, Wiggins 2012, Griffiths et al. submitted).

• Difficulty to predict modelled by unexpectedness, defined by information content:

\[ h(e_i|e_{i-1}^1) = -\log_2 p(e_i|e_{i-1}^1) \]

• Place segment when before large rise in information content, when ratio between \( h \) of two adjacent events exceeds a threshold, \( d \).

\[ \frac{h(e_i|e_{i-1}^1)}{h(e_{i-1}|e_{i-2}^1)} > d \]
Information theoretic segmentation

- Information content profiles calculated with 10-fold cross validation.
- Viewpoint selected with forward stepwise selection algorithm.
- Viewpoints: $\text{ROOTINT} \odot \text{ICI}$, $\text{CHORDTYPE} \odot \text{ROOTINTTHRBAR}$, $\text{CHORDTYPE} \odot \text{ROOTINTFIP}$, $\text{POSINBAR} \odot \text{ROOTINTFIP}$, $\text{CHORDTYPE} \odot \text{POSINBAR}$, $\text{CHORDTYPE} \odot \text{ROOTINT}$, $\text{ROOT} \odot \text{CHORDTYPE}$
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• Information content profiles calculated with 10-fold cross validation.
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  $\text{CHORDTYPE} \otimes \text{POSINBAR}$, $\text{CHORDTYPE} \otimes \text{ROOTINT}$, $\text{ROOT} \otimes \text{CHORDTYPE}$
Phrase Structure

• No ground truth.
• Harmonic segmentation approximately reflect phrase structure.
• 4-bar phrases can be found segmenting with $d = 2.6$
  • $\kappa: .24$, accuracy: .76
• Random segmenter segments with $p = .2$
  • $\kappa: .09$, accuracy: .70
Giant Steps - John Coltrane

Threshold
\[ d = 2.6 \]

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<thead>
<tr>
<th></th>
<th>B</th>
<th>D7</th>
<th>G</th>
<th>Bb7</th>
<th>Eb</th>
<th>Am7</th>
<th>D7</th>
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<tbody>
<tr>
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<td>Eb</td>
<td>F#7</td>
<td>B</td>
<td>Fm7</td>
<td>Bb7</td>
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<tr>
<td></td>
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<td>D7</td>
<td>G</td>
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Giant Steps - John Coltrane

Threshold \( d = 2.6 \)

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<td>F#7</td>
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</table>
Giant Steps - John Coltrane

Threshold $d = 2.6$
Giant Steps - John Coltrane

Threshold $d = 2.6$
Giant Steps - John Coltrane

Threshold

\[ d = 2.6 \]
Segment Types

- Segmenting the whole corpus (15,197 chords) at \( d = 2.6 \)
- 3,007 segment tokens
- 1,531 segment types (unique)

<table>
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<th>Rank</th>
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<td>30</td>
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<tr>
<td>10</td>
<td>22</td>
</tr>
</tbody>
</table>
Conclusion and Future Work

• Difficult to evaluate without a ground truth.
• Useful segmentations of jazz chord sequences.
• Rough phrase structure found.
• Key tonal-harmonic units identified (e.g. ii\(^7\)-V\(^7\)-I).
• No in-built knowledge of music theory or tonal harmony.
• Future work will compare with human segmentations of harmony.
References


cclab bonus: Imperfect Cadence Problem

![Graph showing information content vs. x, ii, V7, vi, or l for Imperfect Cadence and Perfect Cadence.](graph.png)
cclab bonus: ’Round Midnight