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></th>
<th>BM7</th>
<th>D7</th>
<th>GM7</th>
<th>B♭7</th>
<th>E♭M7</th>
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<td>⊥</td>
<td>8</td>
<td>⊥</td>
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</table>
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:

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

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

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

- Information content profiles calculated with 10-fold cross validation.
- Viewpoint selected with forward stepwise selection algorithm.
- Viewpoints: $\text{ROOTINT} \otimes i_c i, \text{CHORDTYPE} \otimes \text{ROOTINTTHRBAR},$
  $\text{CHORDTYPE} \otimes \text{ROOTINTFIP}, \text{POSINBAR} \otimes \text{ROOTINTFIP},$
  $\text{CHORDTYPE} \otimes \text{POSINBAR}, \text{CHORDTYPE} \otimes \text{ROOTINT}, \text{ROOT} \otimes \text{CHORDTYPE}$
Information theoretic segmentation

- Information content profiles calculated with 10-fold cross validation.
- Viewpoint selected with forward stepwise selection algorithm.
- Viewpoints: $\text{ROOTINT} \otimes \text{ICI}$, $\text{CHORDTYPE} \otimes \text{ROOTINTTHRBAR}$, $\text{CHORDTYPE} \otimes \text{ROOTINTFIP}$, $\text{POSINBAR} \otimes \text{ROOTINTFIP}$, $\text{CHORDTYPE} \otimes \text{POSINBAR}$, $\text{CHORDTYPE} \otimes \text{ROOTINT}$, $\text{ROOT} \otimes \text{CHORDTYPE}$
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 
\[ d = 2.6 \]

\[ \begin{array}{cccccc}
    B & D7 & G & Bb7 & Eb & Am7 & D7 \\
    G & Bb7 & Eb & F#7 & B & Fm7 & Bb7 \\
    Eb & Am7 & D7 & G & C#m7 & F#7 \\
    B & Fm7 & Bb7 & Eb & C#m7 & F#7 \\
    B & & & & & & \\
\end{array} \]
Giant Steps - John Coltrane

Threshold
\( d = 2.6 \)

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Giant Steps - John Coltrane

Threshold

\[ d = 2.6 \]
# Giant Steps - John Coltrane

Threshold

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[Image of a graph showing information content over time with key musical progressions marked.]
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)
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
cclab bonus: ’Round Midnight