



An Automatic Chord Estimation Method based on Chord-Scale Theory

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Objectives

- To develop a system for automatic audio analysis of individual chords containing diatonic and non-diatonic extensions (common to jazz harmony)
- To expand this system to the analysis of short progressions consisting of root position chords.

ACE Current State-of-the-art

- Phase 1: Signal Processing – extracting note level information
- Phase 2: Context – what does the note level information mean?
- Expert systems vs. Machine learning/Neural networks
 - Expert systems: lack of relationship between chords
 - Machine learning: “Black Box”

MIREX Evaluation Exchange

Billboard 2013

Algorithm	Root	MajMin	MajMinInv	Sevenths	SeventhsInv	MeanSeg	UnderSeg	OverSeg
CM3	57.84	44.87	39.37	17.04	14.42	77.87	81.21	77.39
DK4	61.07	57.98	55.85	45.88	44.17	80.51	77.61	87.41
DK5	66.75	63.17	60.39	49.69	47.37	79.86	75.75	88.74
DK6	70.32	65.37	55.99	51.73	44.51	80.75	78.10	87.25
DK7	70.76	65.80	61.04	49.40	45.72	80.82	78.15	87.31
DK8	70.76	65.80	57.06	50.24	43.53	80.71	78.10	87.22
DK9	70.02	66.08	64.66	50.01	48.80	80.24	76.25	88.60
KO1	75.36	71.39	69.43	53.57	51.78	81.63	79.61	87.75

Figure 6: Results of Automatic Chord Estimation task at MIR Evaluation Exchange 2015 [1]

Billboard 2013

Algorithm	MirexRoot	MirexMajMin	MirexMajMinBass	MirexSevenths	MirexSeventhsBass	MeanSeg	UnderSeg	OverSeg
CM1	71.16	67.28	65.20	48.99	47.17	81.54	83.11	82.63
DK1	72.06	68.69	67.26	54.54	53.29	80.82	77.58	88.06
DK2	70.18	66.54	64.66	52.97	51.41	80.85	77.68	88.02
DK3	72.39	68.53	66.55	48.99	47.28	80.76	77.26	88.30
DK4	69.56	65.83	64.78	51.81	50.93	74.55	86.31	69.18
FK2	80.07	77.89	75.42	55.41	53.22	82.94	82.43	86.80
FK4	74.66	71.85	69.44	51.93	49.80	80.61	77.19	88.70
KO1	75.36	71.39	69.43	53.57	51.78	81.63	79.61	87.75

Figure 2: Results of Automatic Chord Estimation task at MIREX 2016 [1]

Overview

- Leonard B. Meyer – Emotion and Meaning in Music
- Carol Krumhansl, Lola Cuddy – Tonal Hierarchy

(a) Octave (root) level:	X											
(b) Fifths level:	X	X										
(c) Triad level:	X	X	X									
(d) Diatonic level:	X	X	X	X	X	X	X					
(e) Chromatic level:	X	X	X	X	X	X	X	X	X	X	X	
	C	C#	D	D#	E	F	F#	G	G#	A	Bb	B

Figure 3: Krumhansal, Cuddy's Tonal Hierarchy [4]

- Berklee Chord-Scale Theory

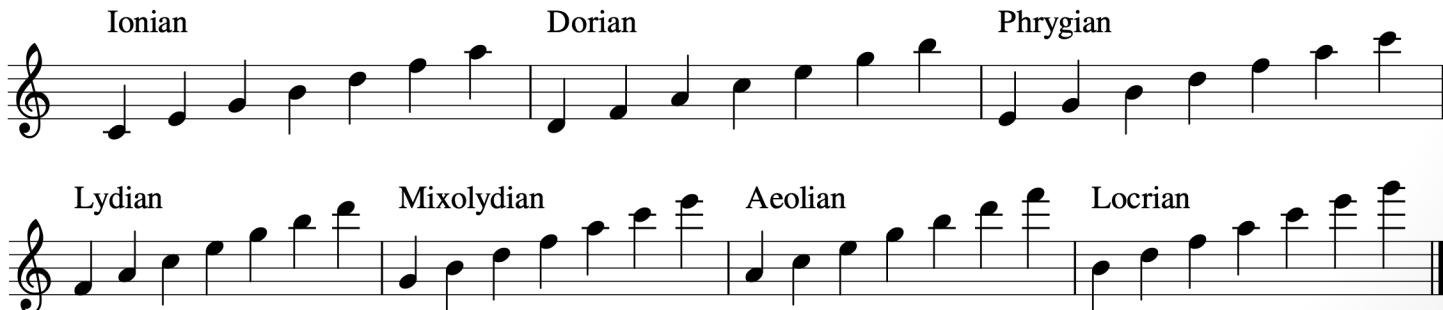


Figure 4: Chord – Scale Theory – The Major Modes

Algorithm

- FFT
 - Large FFT size, since chords move slowly relative to melody. E.g. at 120bpm 4/4, 4 chords per bar = 22050 samples per chord, at 44100 sample rate
 - Normalisation
 - Thresholding
 - Windowing
 - Zero padding

Algorithm

- Chord Analysis
 - Chord root – first peak above threshold
 - Look for expected chord tones in order of tonal hierarchy: third, seventh, ninth
 - Reduce thresholds for higher frequencies
 - 5th is redundant
 - No partials of the root within an octave range, so voicings must be closed

Results

	<p>['F4- Dominant 7 #9']</p> <p>In [820]:</p>
	<p>['G3+ Dominant 7 b9', 'G3- Dominant 7 b9']</p> <p>In [776]:</p>
	<p>['F4- Dominant 7 sus', 'C#4 Major 6/9']</p> <p>In [780]:</p>
	<p>['A#4 Minor 6']</p> <p>In [778]:</p>
	<p>['A3- Minor 7', 'A3- Minor 7']</p> <p>In [777]:</p>
	<p>['A4- Minor 7', 'C5- Major 9']</p> <p>In [821]:</p>
	<p>['G3+ Dominant 7 b9', 'G3- Dominant 7 b9', 'G3+ Dominant 9', 'G3- Dominant 9', 'C3- Major 7', 'C3- Major 7', 'C3- Major 6/9']</p> <p>In [823]:</p>

Limitations/Future Work

- Chord Inversions
- Open Voicings
- Multiple instruments (harmonic information without needing to separate signals)
- Refine thresholds (relate to instrument timbre: partial amplitudes)
- Refine FFT - interpolation

References

- [1] "2016:Audio Chord Estimation Results - MIREX Wiki". *Music-ir.org*. N.p., 2017. Web. 6 December 2017
- [2] "2015 :Audio Chord Estimation Results - MIREX Wiki". *Music-ir.org*. N.p., 2017. Web. 6 December 2017
- [3] L. B. Meyer, *Emotion and meaning in music*. University of Chicago Press, 1956.
- [4] Krumhansl, C. L., & Cuddy, L. L. (2010). A theory of tonal hierarchies in music. In M. R. Jones, R. R. Fay, & A. N. Popper (Eds.), *Springer handbook of auditory research: Vol. 36. Music perception* (pp. 51-87). New York, NY, US: Springer Science + Business Media.