

Scales, Chords, and Cadences: Practical Music Theory for MIR Researchers

Chords

Main Topics

- ▶ **Chord Basics**
- ▶ **Chord Labels**
- ▶ **Evaluation for Automatic Chord Recognition**
- ▶ **Higher-Level Organization of Harmonic Material**

Terminology

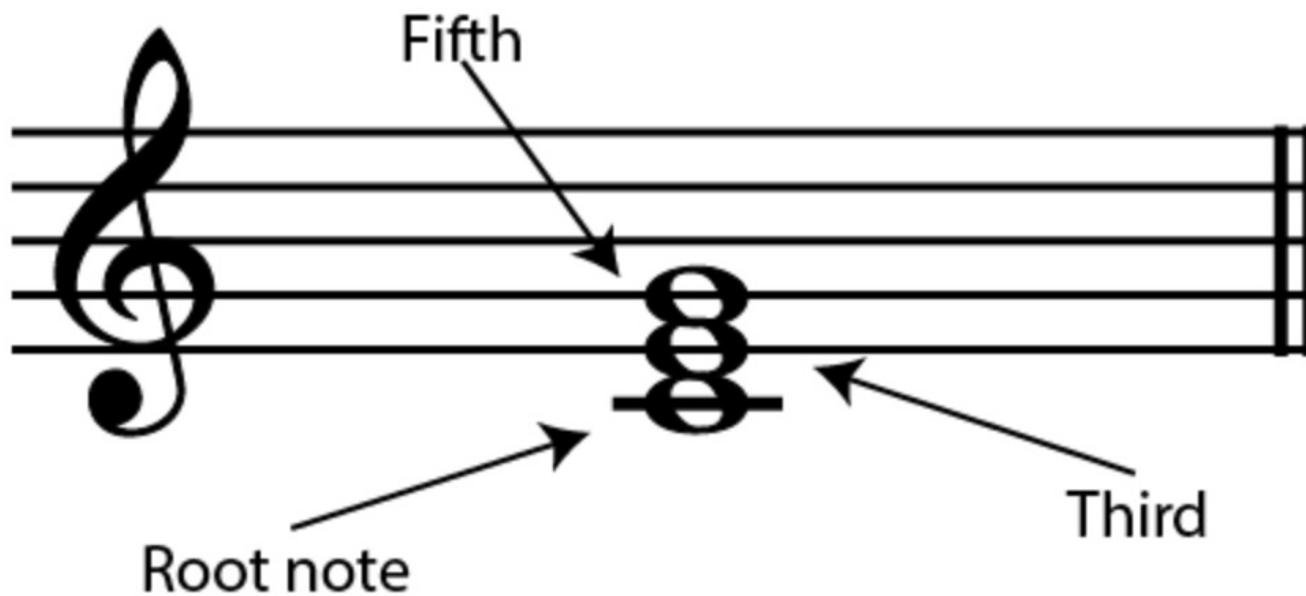
- ▶ **(Chord) Root – Lowest note in the chord's most compact position**
- ▶ **Scale degree – Position of a note relative to a musical scale**
- ▶ **Chord tones – Notes that are part of the current chord**
- ▶ **Non-chord tones – Notes that are not part of the current chord**
- ▶ **(Chord) Quality – Describes the intervals within a chord**
 - **Triad qualities: Major, Minor, Augmented, Diminished**
- ▶ **Triads – Chords with three notes**
- ▶ **Seventh chords – Chords with seven notes**
- ▶ **Added Notes/Extensions – Additional chord notes beyond a 7th from the root**

Chord Basics

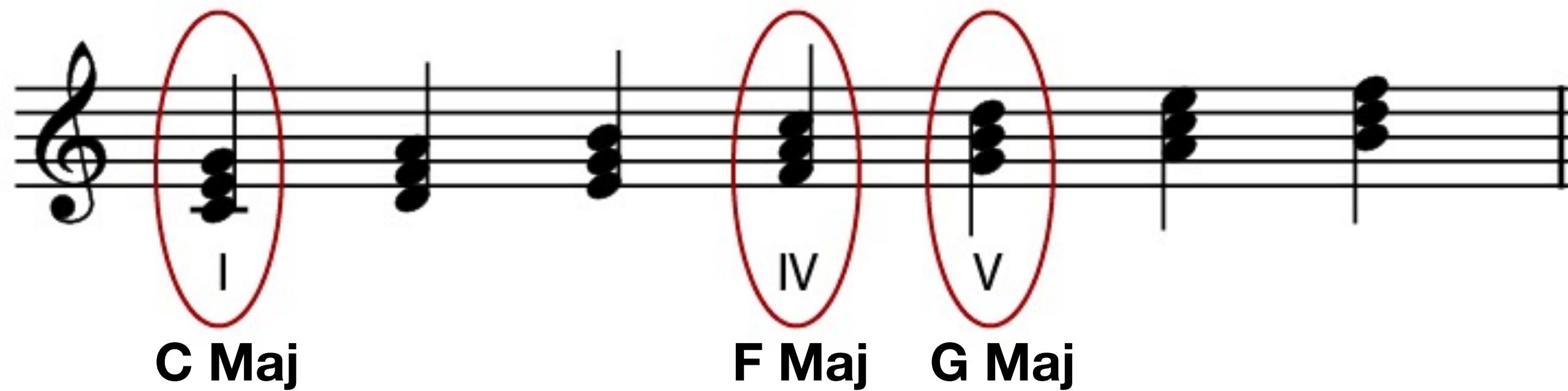
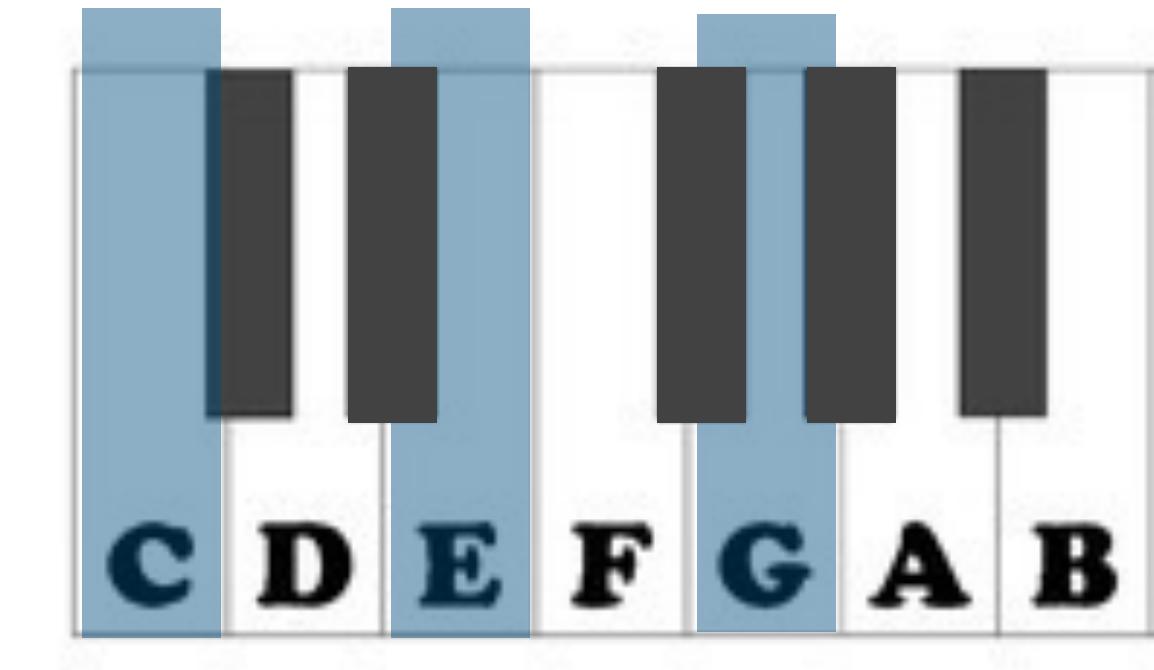
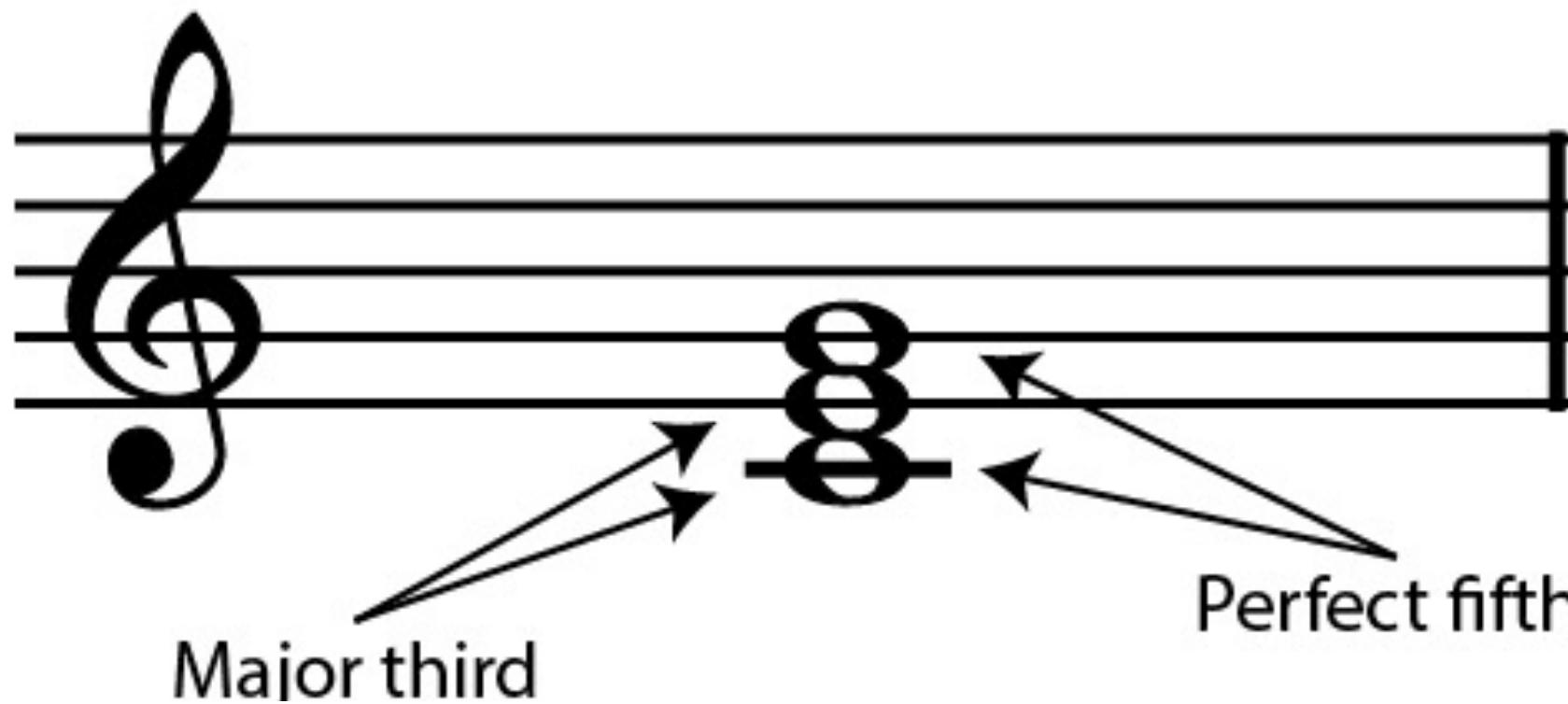
Chords



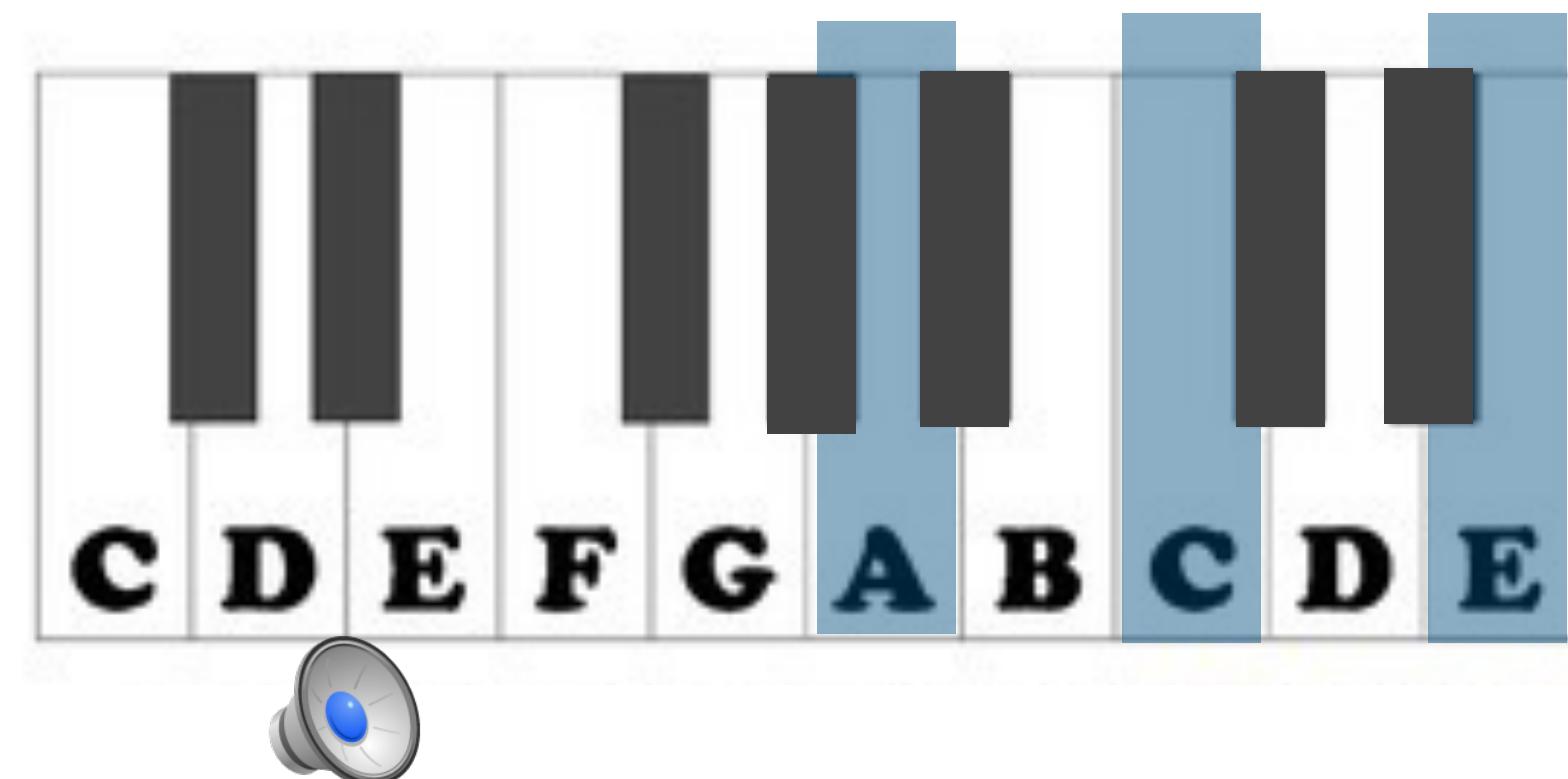
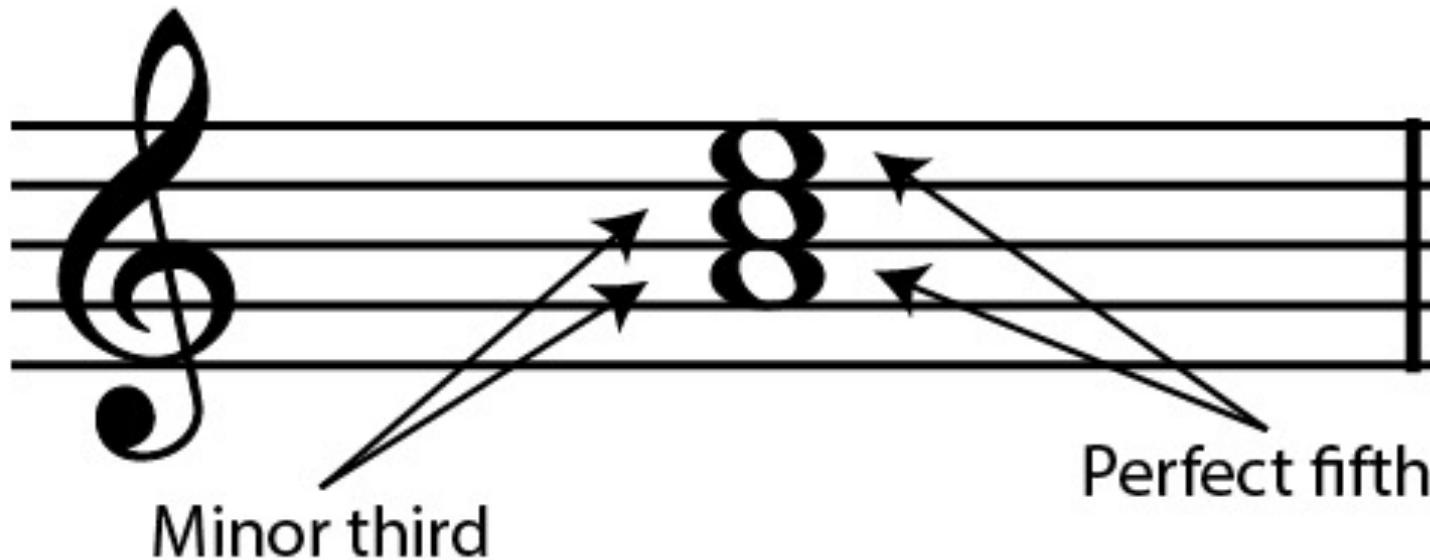
I	ii	iii	IV	V	vi	vii ^o
Cmaj	Dmin	Emin	Fmaj	Gmaj	Amin	Bdim



Quality: Major Triads

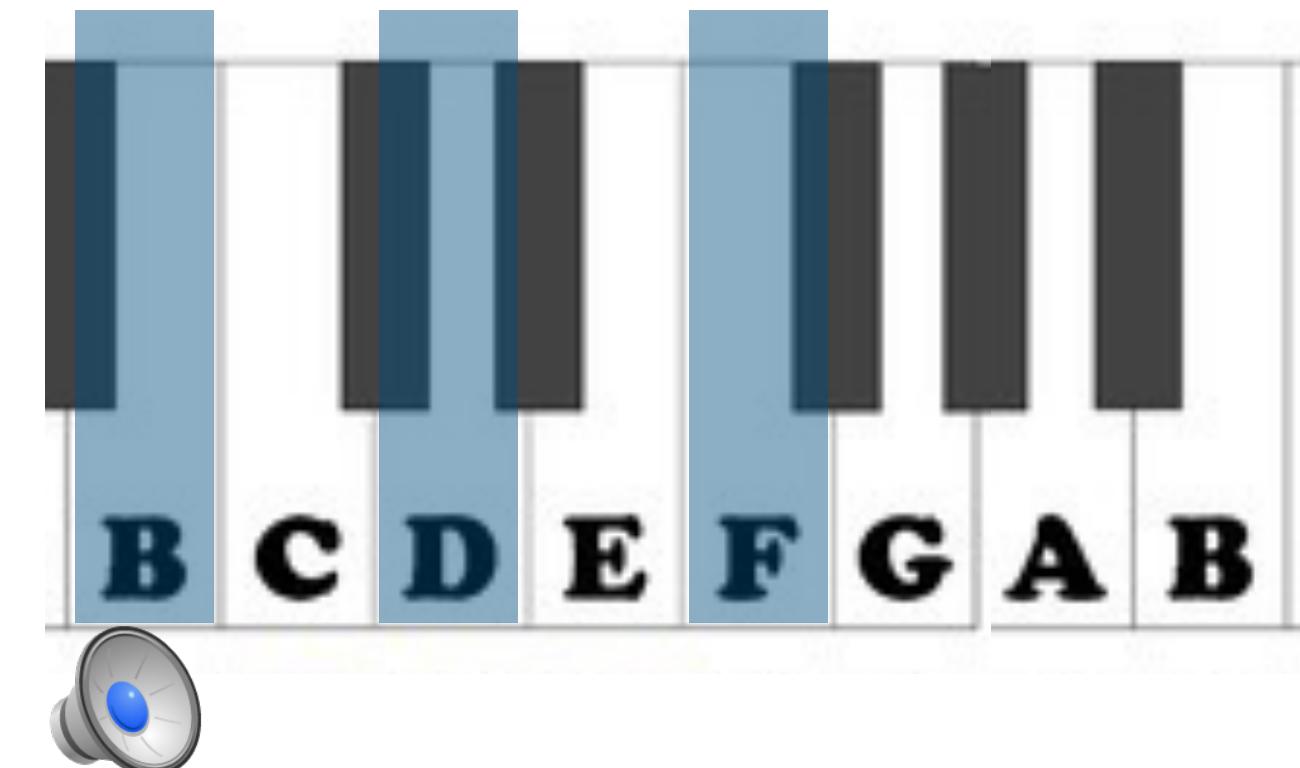
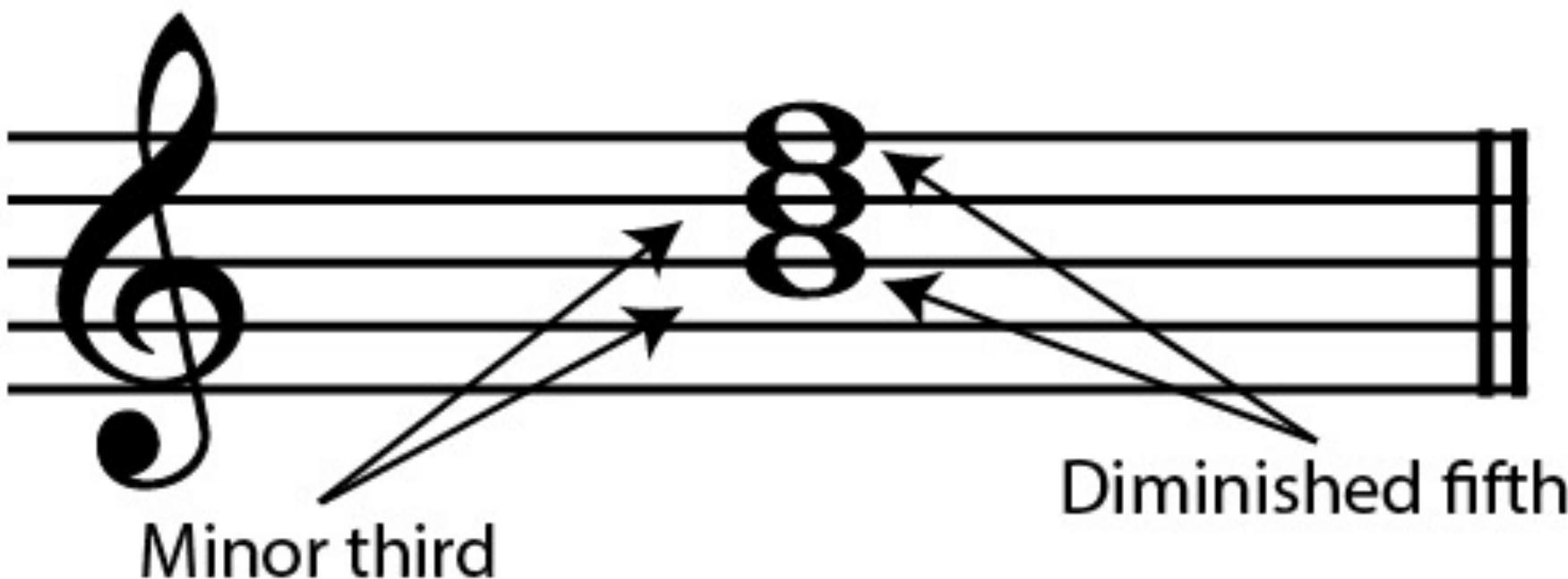


Quality: Minor Triads



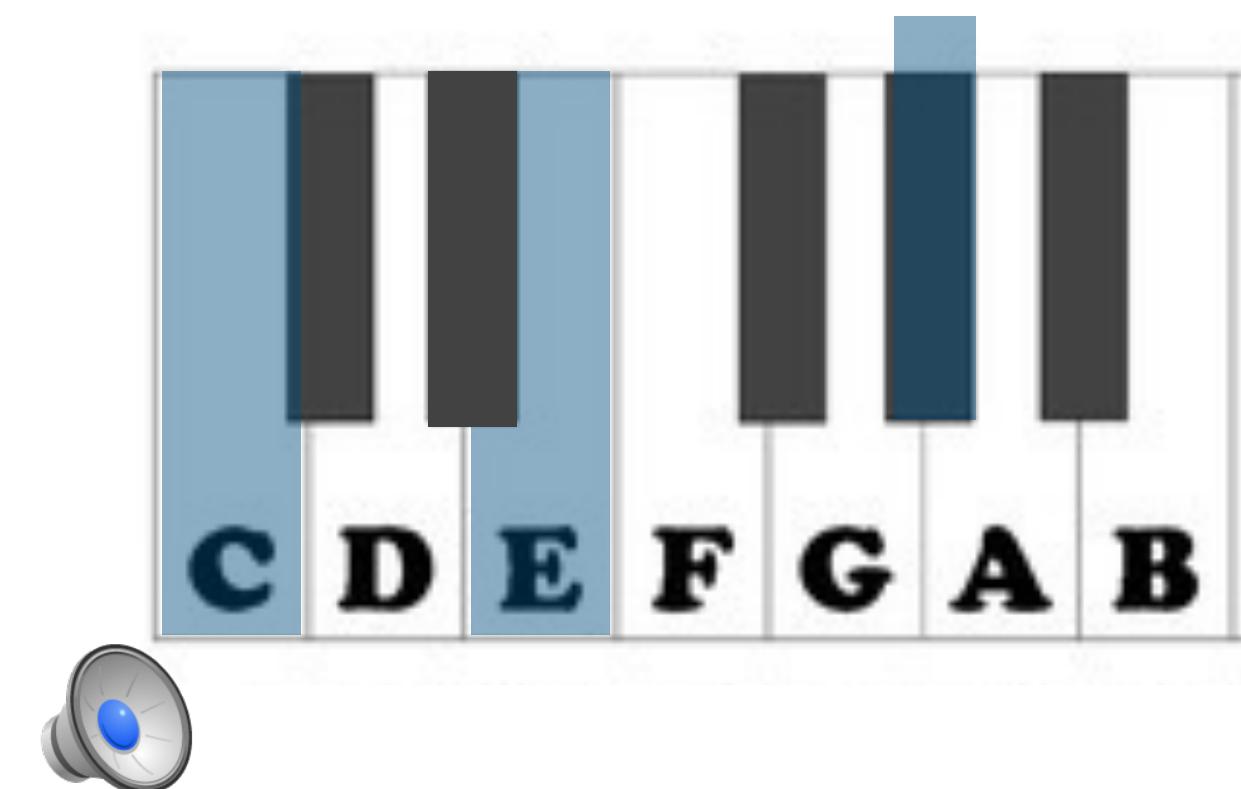
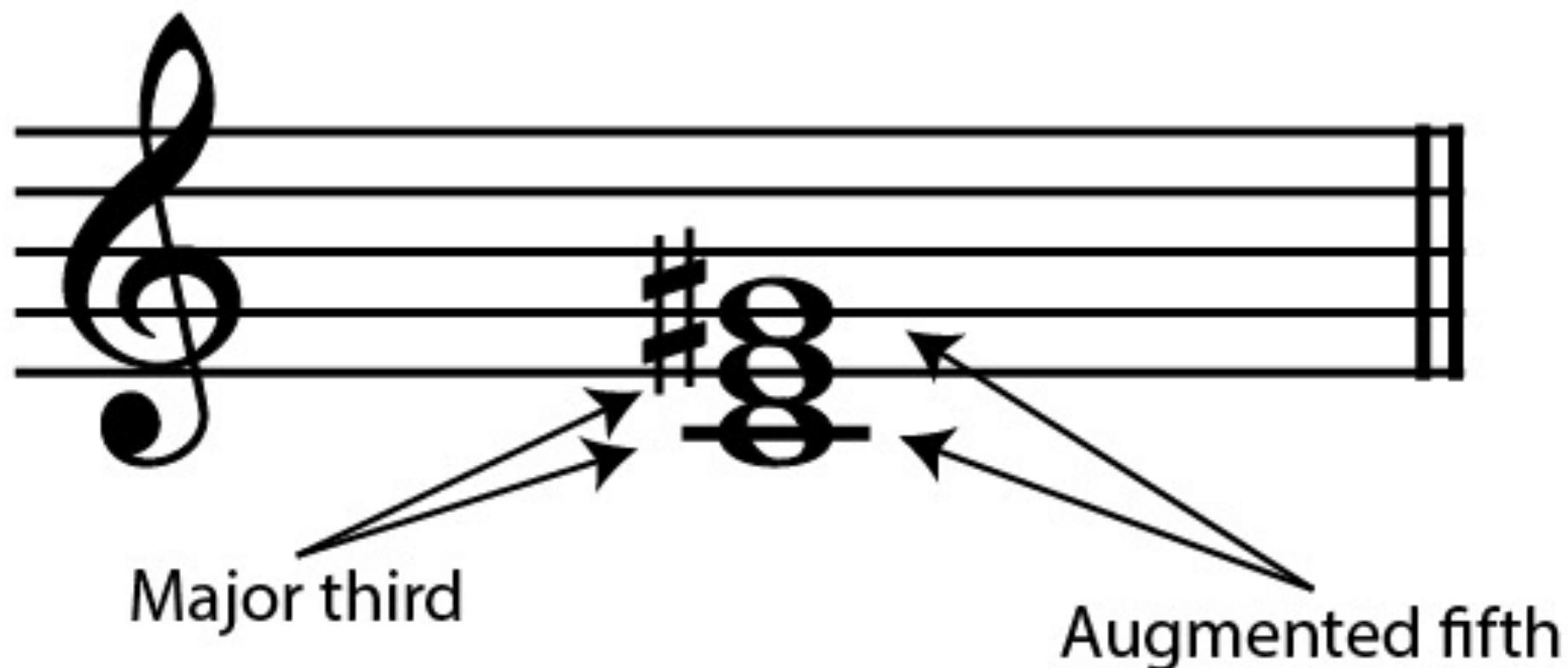
A musical staff with a treble clef. It shows three chords: d min (two black notes), e min (three black notes), and a min (three black notes). Red ovals highlight the second and third chords. Below the staff, Roman numerals indicate the chord qualities: II, III, and VI. The labels ii, iii, and vi are placed below the corresponding chords.

Quality: Diminished Triads



b dim

Quality: Augmented Triads



A musical score with a treble clef staff. The notes are: B (open), A (open), G# (circled in red), B (closed), A (closed), G# (closed), A (closed), B (closed), A (closed). A red oval encircles the G# note, and below it is the label "III⁺".

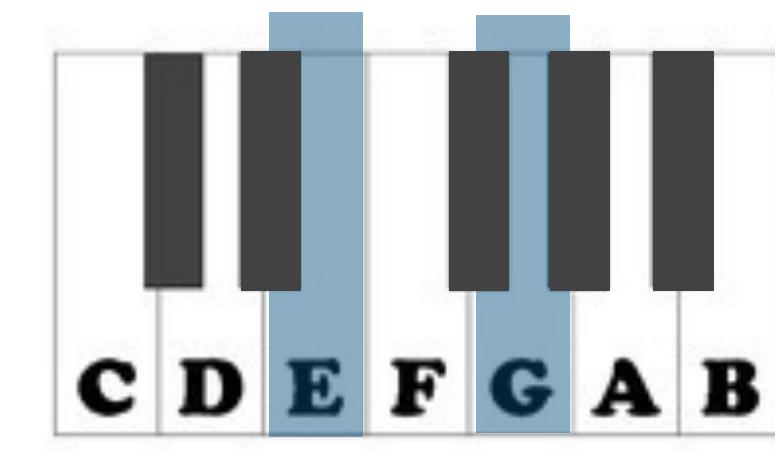
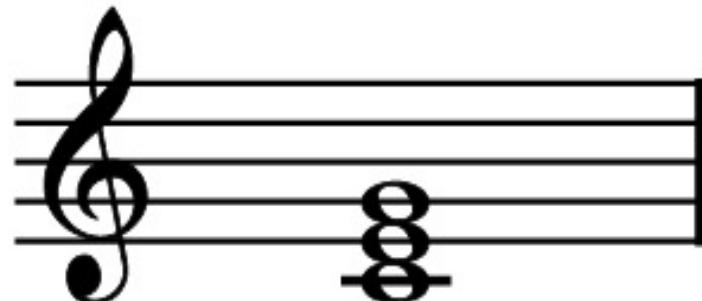
III⁺

Caug

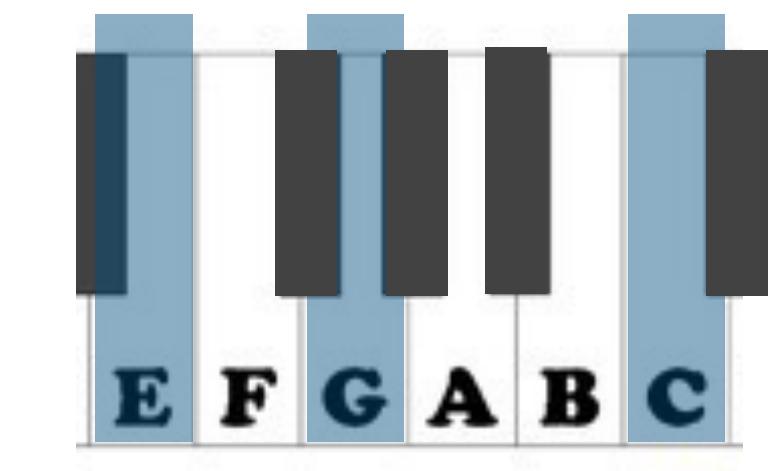
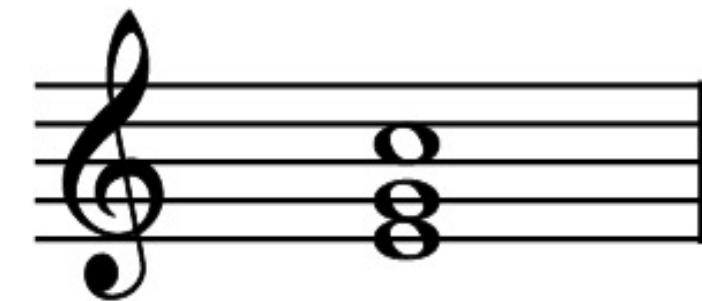
Triadic Inversions



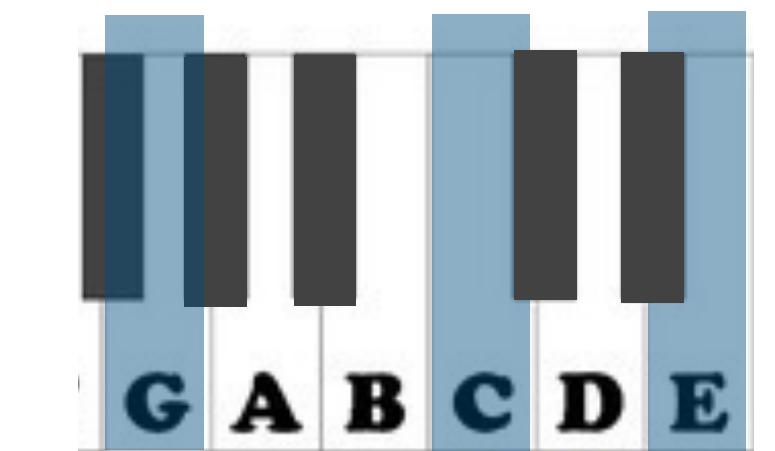
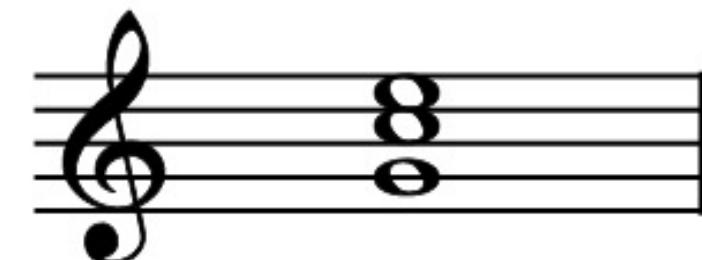
Root position



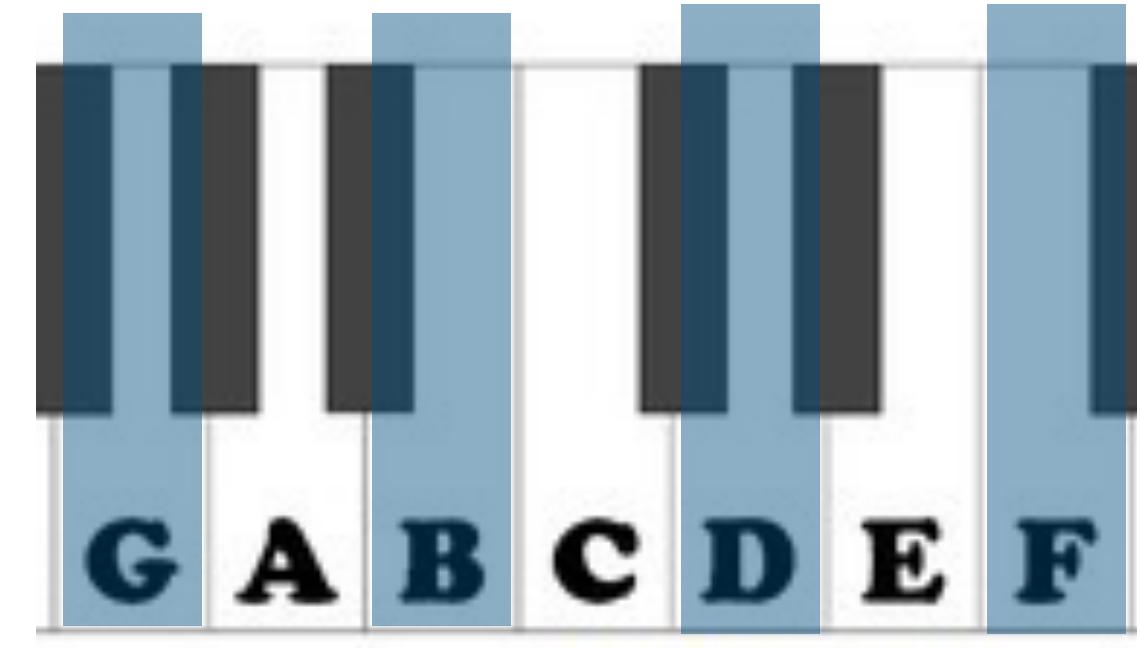
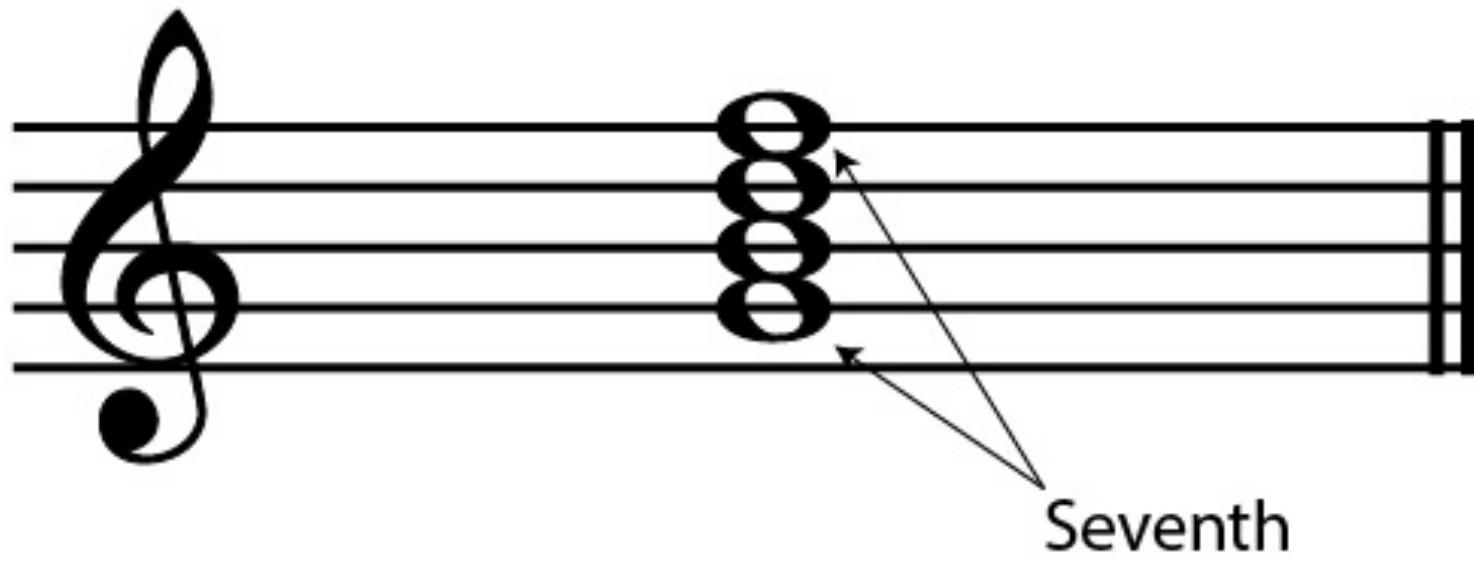
First Inversions



Second Inversions



Seventh Chords



Dominant Seventh Chords

A musical staff with a treble clef. It shows a sequence of notes: a major triad (G, B, D) followed by a minor seventh (G, B, D, F). The label "Major triad" is placed under the first three notes, and "Minor seventh" is placed under the last four notes. Above the staff, the label "G⁷" is shown above the minor seventh notes. To the right, another staff begins with a major triad (G, B, D) followed by a minor seventh (G, B, D, F). The label "V⁷" is placed under the minor seventh notes. Above this second staff, the label "G⁷" is shown.

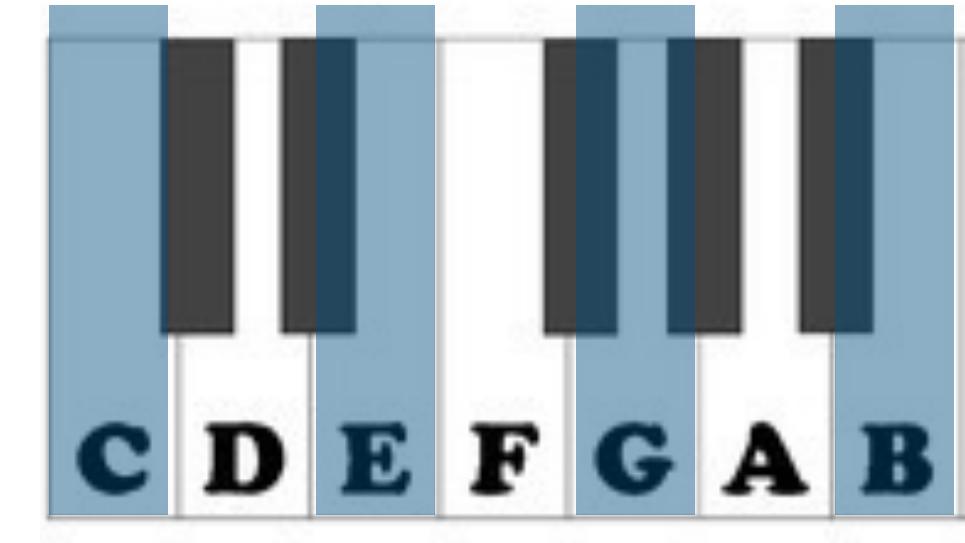
Seventh Chords

Major Seventh Chord

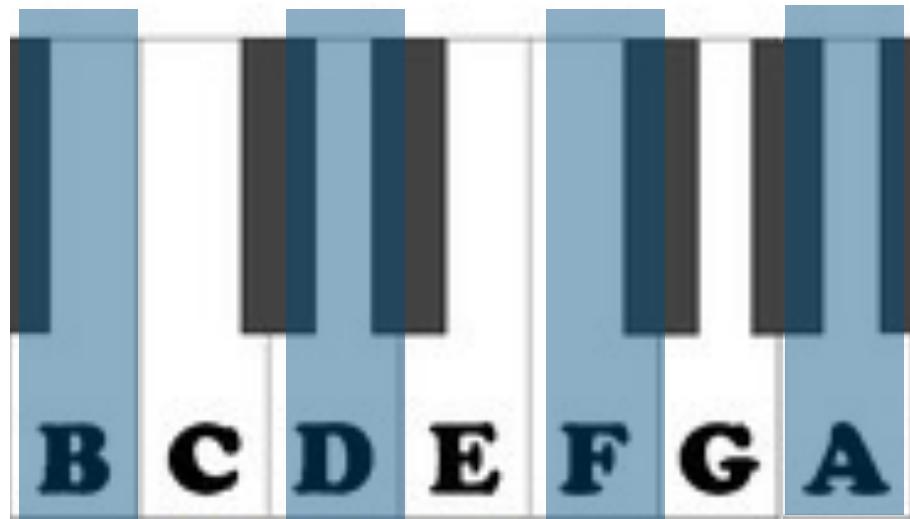
A musical staff in G clef shows three chords: CMaj⁷, CMaj⁷, and FMaj⁷. The first CMaj⁷ chord is analyzed with arrows pointing from the root (C) and the seventh (B) to the label "Major triad" and "Major seventh" respectively. The second CMaj⁷ chord is labeled I⁷. The FMaj⁷ chord is labeled IV⁷.

Minor Seventh Chord

A musical staff in G clef shows three chords: Dm⁷, Em⁷, and Am⁷. The first Dm⁷ chord is analyzed with arrows pointing from the root (D) and the seventh (B) to the label "Minor triad" and "Minor seventh" respectively. The second Dm⁷ chord is labeled ii⁷. The Em⁷ chord is labeled iii⁷. The Am⁷ chord is labeled vi⁷.



Seventh Chords



Half-diminished Seventh Chord

Bm^{7(b5)}

Diminished triad Minor seventh

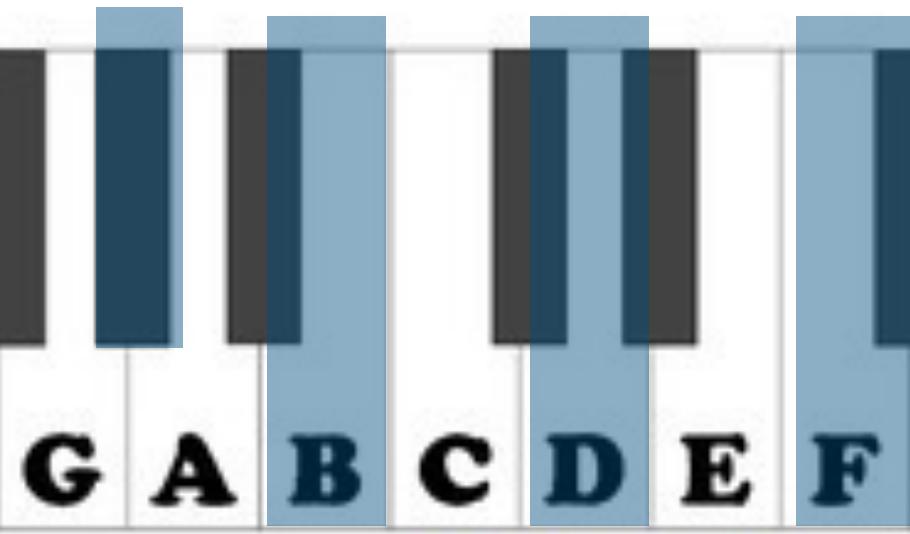
vii

Diminished Seventh Chord

G^{#dim7}

Diminished triad Diminished seventh

vii°



Seventh Chords - Summary

Chord	Triad type	Seventh interval	Chord symbol		
Dominant seventh	Major	Minor seventh	C ⁷		
Major seventh	Major	Major seventh	CMaj ⁷	CMa ⁷	C ^Δ
Minor seventh	Minor	Minor seventh	Cm ⁷	C ⁻⁷	Cmin ⁷
Half-diminished seventh	Diminished	Minor seventh	Cm7 ^(b5)	C ^ø	
Diminished seventh	Diminished	Diminished seventh	Cdim7	C ^{ø7}	



G⁷

Major triad Minor seventh



CMaj⁷

Major triad Major seventh



Dm⁷

Minor triad Minor seventh

Bm7(b5)

Diminished triad Minor seventh

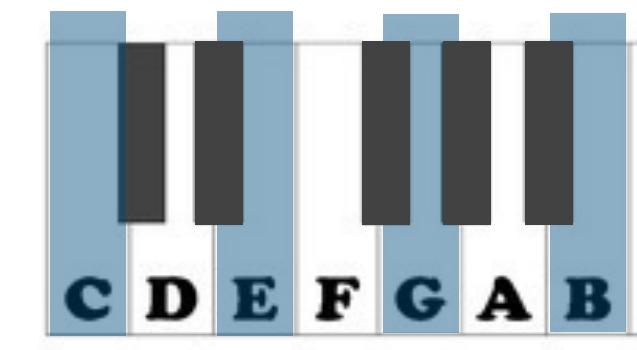
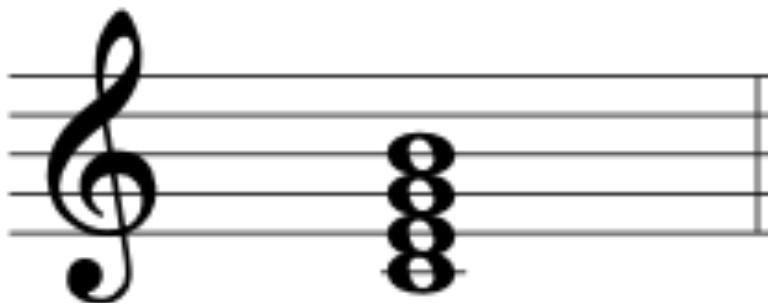


G#dim⁷

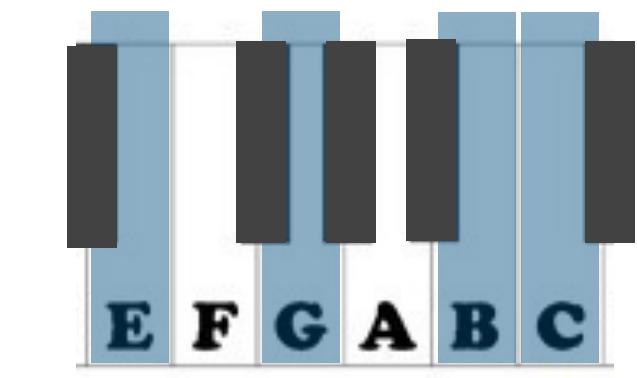
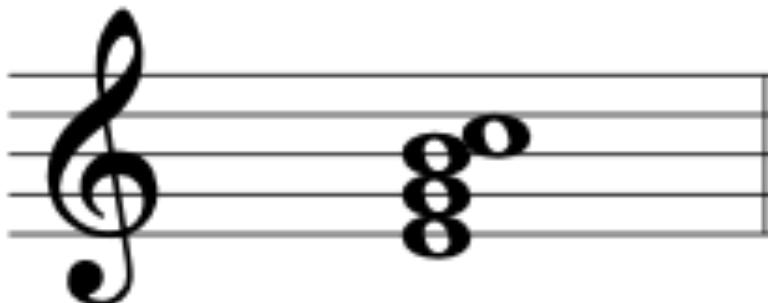
Diminished triad Diminished seventh

Seventh Inversions

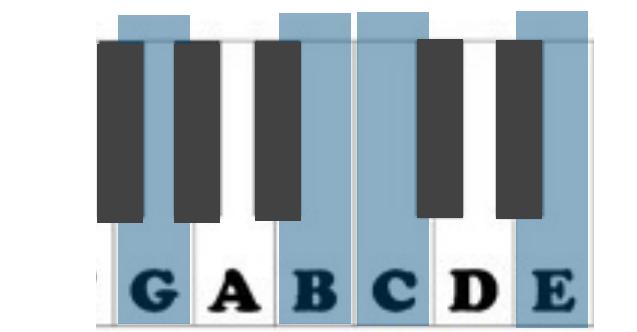
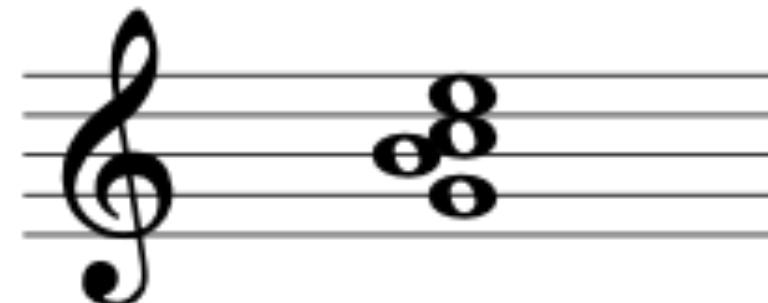
Root position



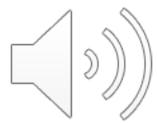
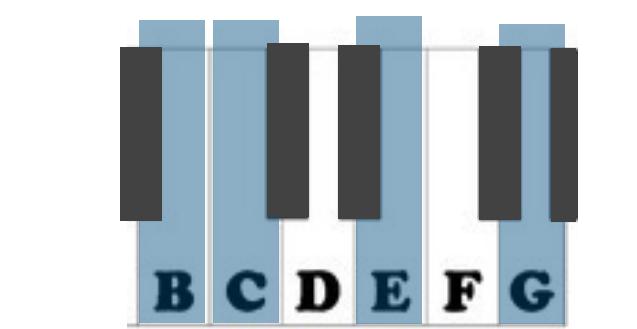
First Inversion



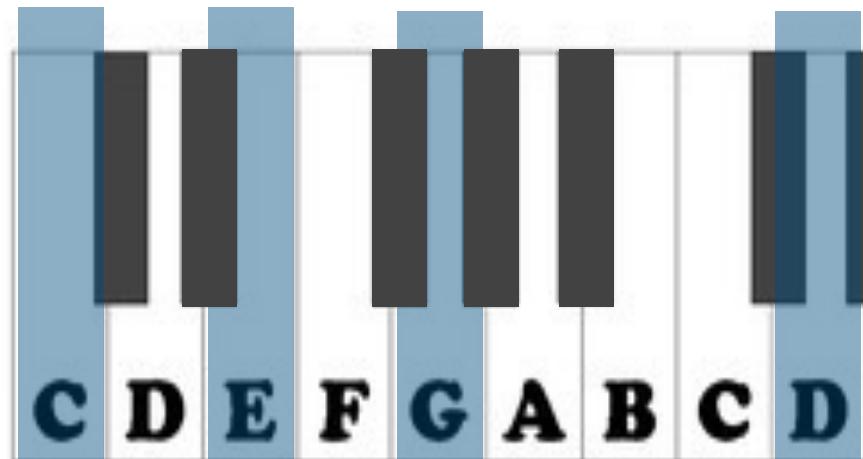
Second Inversion



Third Inversion

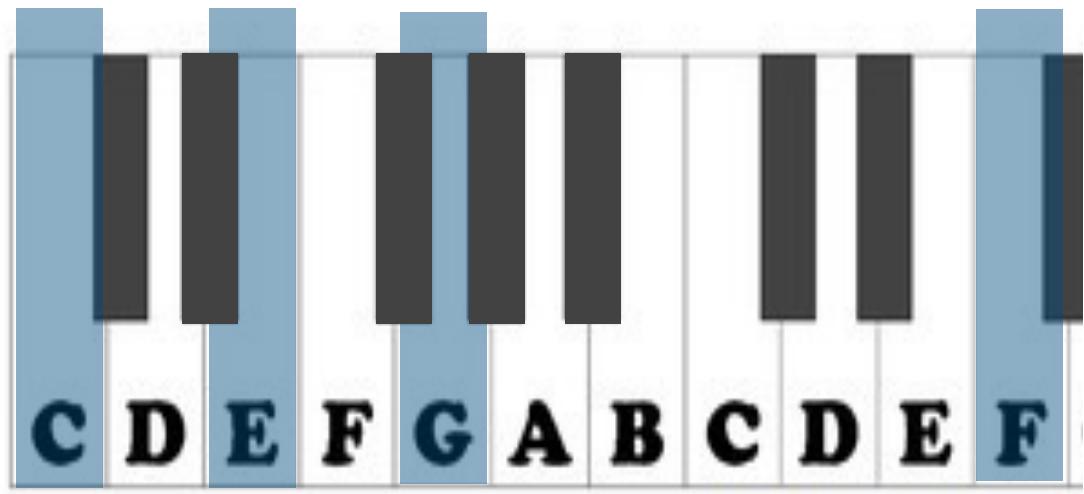
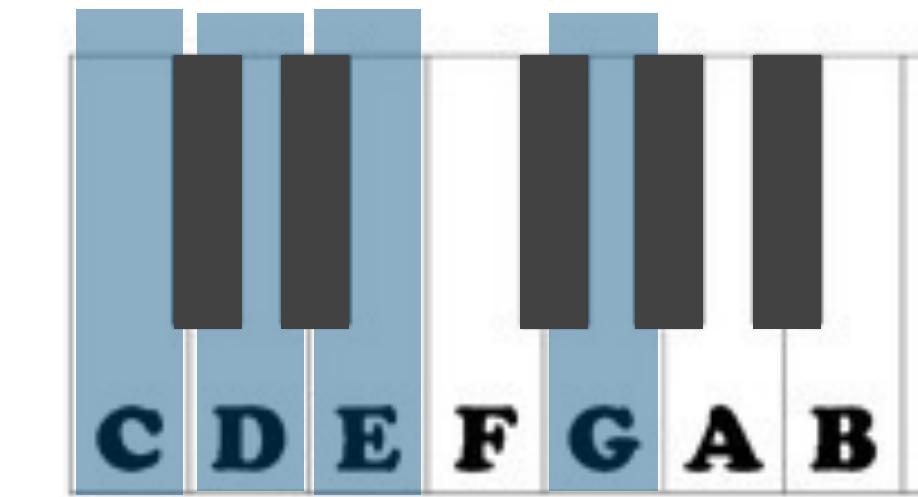


Other Added Notes/Extensions



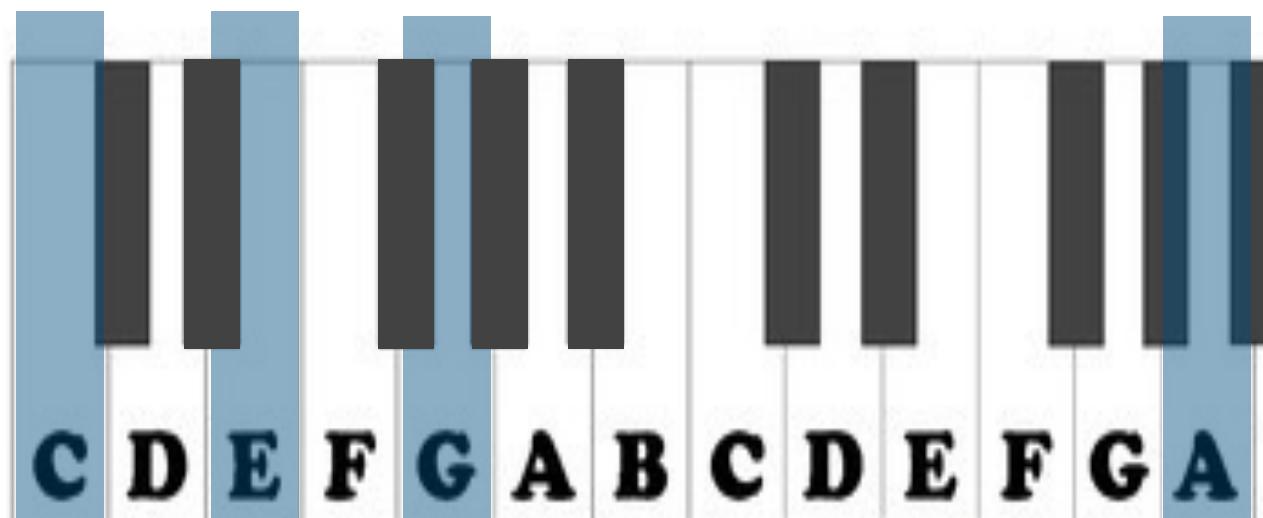
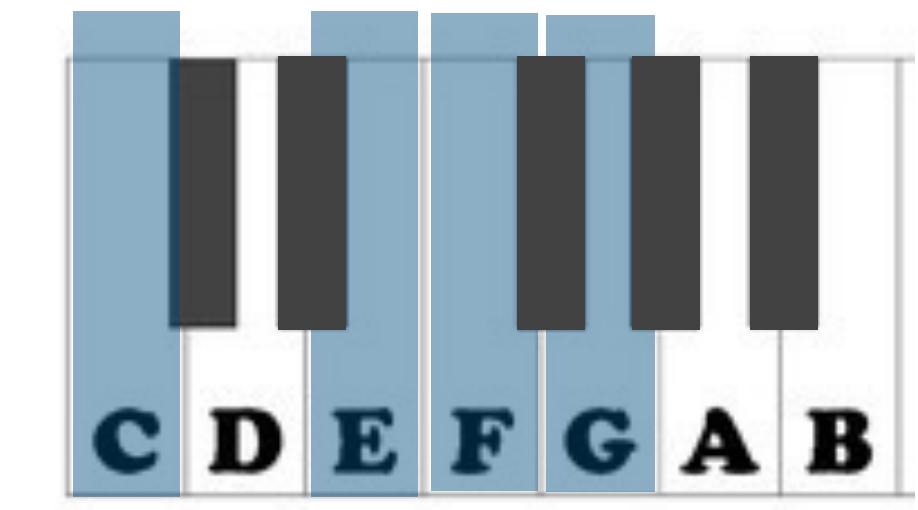
add9

Musical notation for an add9 chord. It consists of a treble clef followed by two eighth notes on the second and third lines of the staff. Two small speaker icons are positioned below the staff, one on each side of the notes.



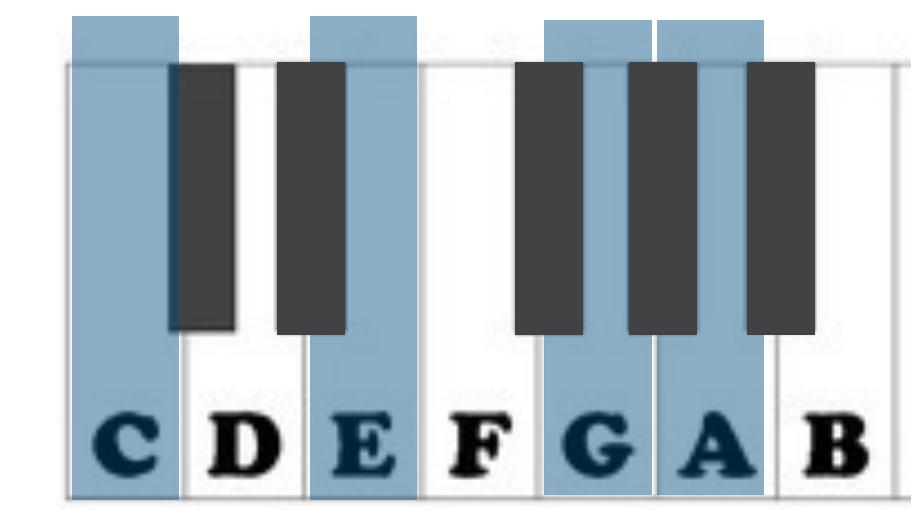
add11

Musical notation for an add11 chord. It consists of a treble clef followed by three eighth notes on the second, third, and fourth lines of the staff. Two small speaker icons are positioned below the staff, one on each side of the notes.



add13

Musical notation for an add13 chord. It consists of a treble clef followed by four eighth notes on the second, third, fourth, and fifth lines of the staff. Two small speaker icons are positioned below the staff, one on each side of the notes.



Chord Labels

What Information Different Labels Contain

- ▶ **Roman numerals**

- Scale degree + quality (major, minor, diminished, etc.)
- Indicate if any notes are added (7, 9, etc.)
- *Explicitly linked to key*

I
in C major

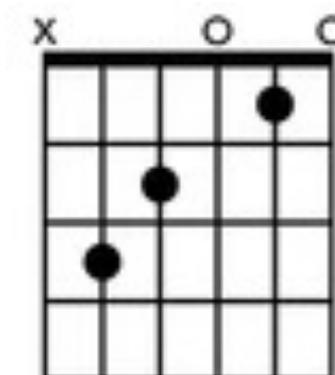
- ▶ **Chord Symbols**

- Root + quality (major, minor, diminished, etc.)
- Indicate if any notes are added (7, 9, etc.)
- *Independent of key*

C
or
Cmaj

- ▶ **Tabulature**

- Denotes fingering on guitar fretboard
- *Independent of root and key*



Information Different Labels Contain



9 Variationen über ein Minuett von Duport

Mozart

D: I Dmaj

I Dmaj

V⁷ A⁷

I Dmaj

Chords can be expressed vertically, horizontally,
or a combination of the both

Information Different Labels Contain

9 Variationen über ein Minuett von Duport

Mozart

Non-chord tones

D: I I V⁷ I

Dmaj Dmaj A⁷ Dmaj

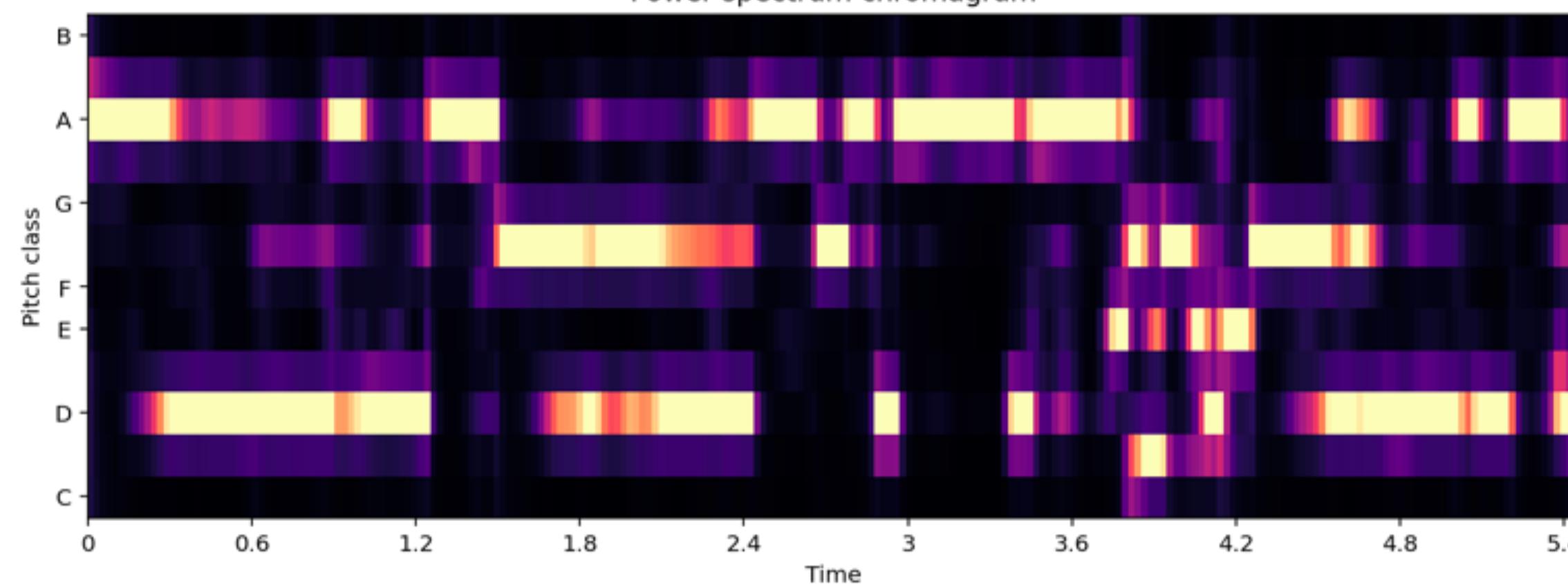
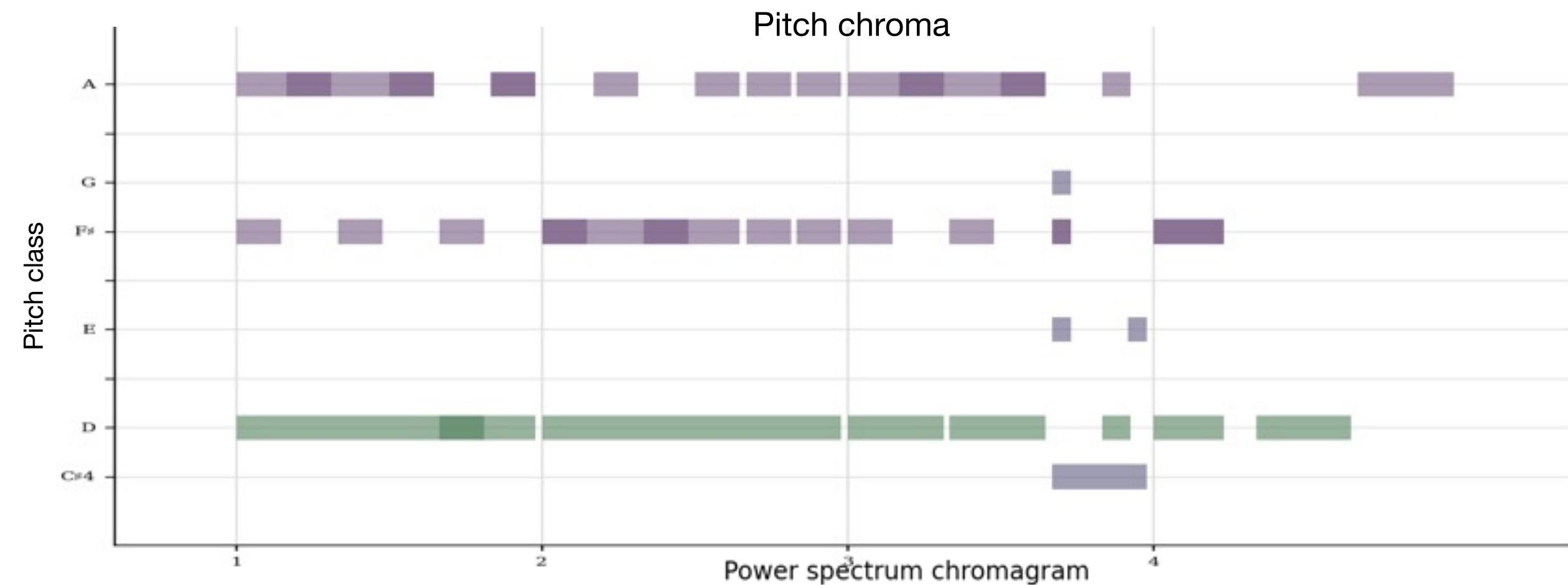
Information Different Labels Contain

9 Variationen über ein Minuett von Duport

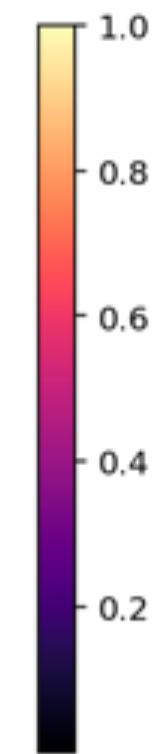
Mozart

Non-chord tone

D:	I	I	I ⁶⁴	V ⁷	I
	I	I	V ⁷	I	
Dmaj	Dmaj	A⁷		Dmaj	



D: I I V⁷ I
 Dmaj Dmaj A⁷ Dmaj



Pitch Class Content in Chords

Variations on 'Es war einmal ein alter Mann', WoO 66

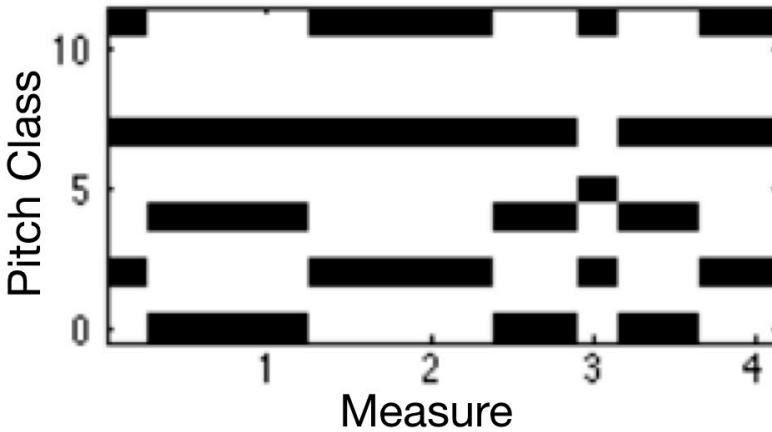
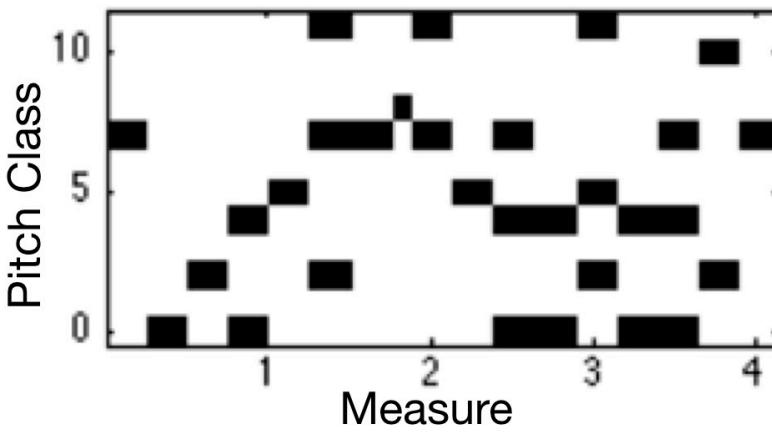
Theme

T

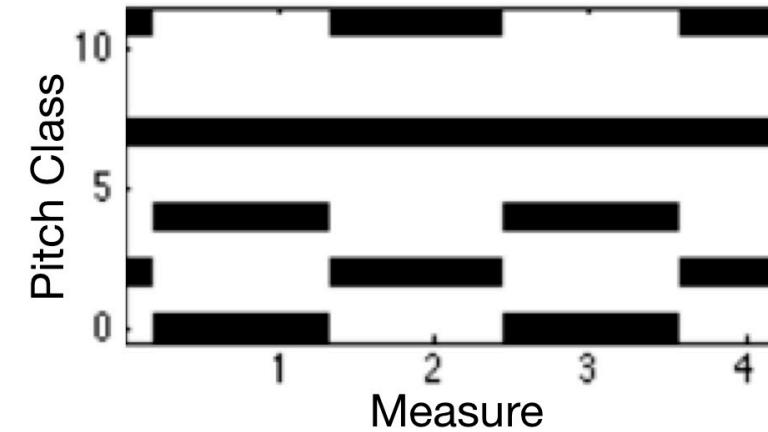
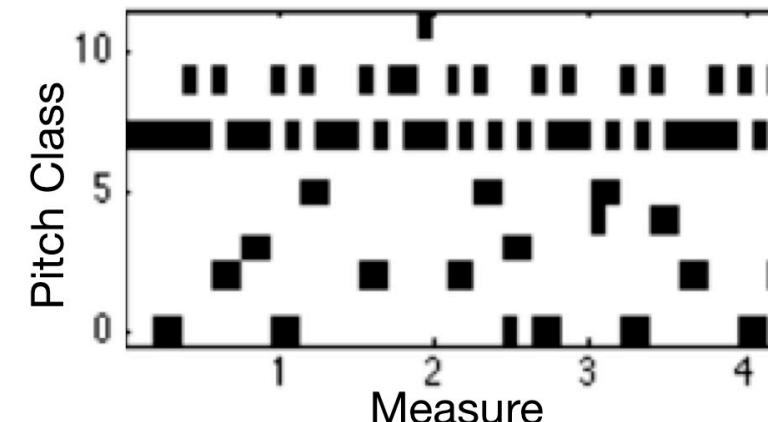
V I V6 I I6 viio6 I V64 V

D

Theme (Symbolic)



Variation (Symbolic)



Variation

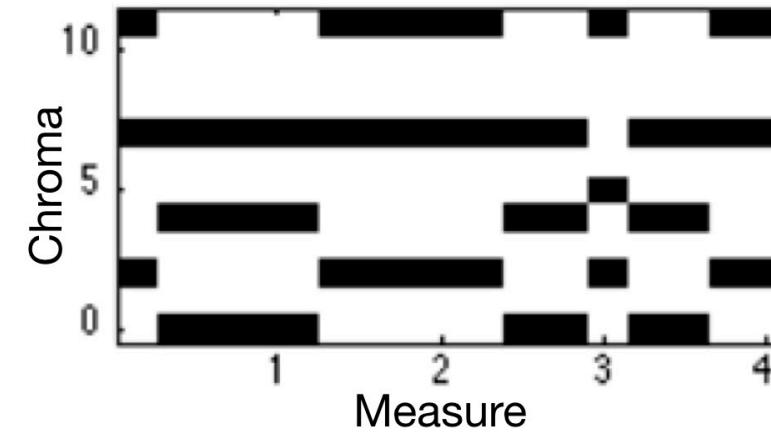
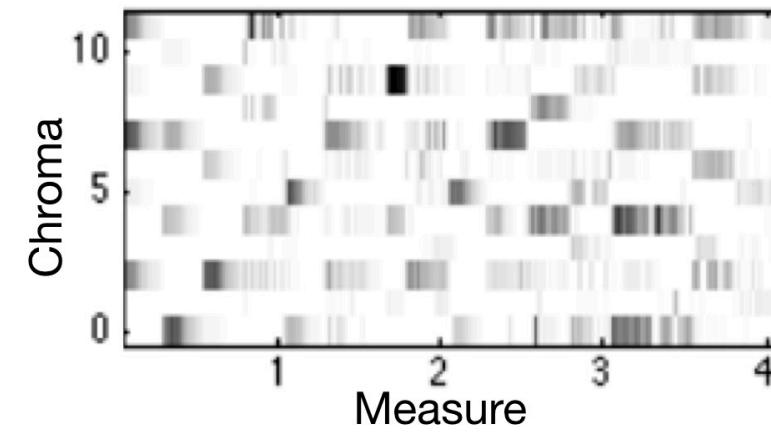
Beethoven

T

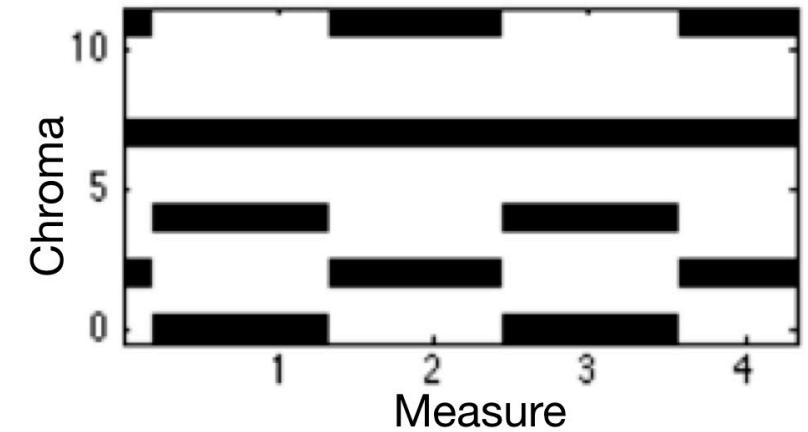
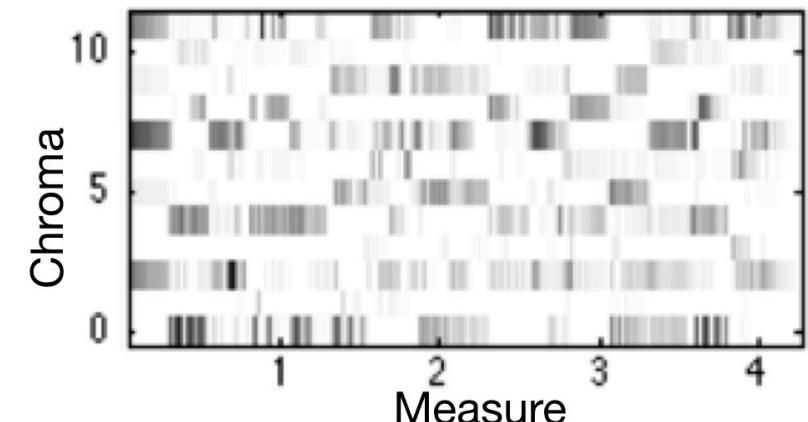
V I V I V I V

D

Theme (Audio)



Variation (Audio)



Corpora

Some Corpora

	Name	Label Type
(i)	Kostka-Payne	Chord tones
(ii)	iRealB	Chord symbols
(iii)	Beatles	Chord symbols
(iv)	Real World Computing (RWC)	Roman numerals
(v)	Billboard	Chord symbols

(i)

(ii)

(iii)

(iv)

(v)

```

Key 0 18333 3 1
Key 17499 26666 1 0
Key 24999 37499 0 0
Key 35833 46666 3 1
Chord 0 416 3
Chord 416 833 8
Chord 833 1666 3
Chord 1666 2499 4
Chord 2499 3333 3
Chord 3333 4166 8
Chord 4166 4999 3

```

```

!!!OTL: Embraceable You
!!!COM: Gershwin, George
!!!ODT: 1928
**jazz
*>[A,B,A2,C]
*>A
*M4/4
*G:
1G:maj7
=
1B-o7
=
1A:min7

```

```

0.000000 0.414094 N
0.414094 1.329503 D
1.329503 1.770682 D:maj6
1.770682 2.258301 D
2.258301 3.117439 E/b7
3.117439 3.593448 E:maj6/b7
3.593448 3.999798 E/b7
3.999798 4.893766 G/5
4.893766 5.323335 G:maj6/5
5.323335 5.764514 G/5
5.764514 6.623653 D

```

```

% RWC-MDB-C-2001 No.2
% Mozart: Symphony No.40 in g minor, 1st Movement
@K=g @M=2/2 % key=g-minor, meter=2/2
% bars 1- (theme I)
g:
||: i | i | i | i | ii-7''' | ii-7''' | V7' |
V7 | i | !V9''' | i' | !V9''' | i' | {v: ii-7 |
!V-9'' | I! 1/2!V9'''' 1/2!V9''''/I |
I 1/2!V9'''' 1/2!V9'''' | I 1/2!V9'''' 1/2!V9'''' |
I !V9''''/I I !V9''''/I | I} V3!7'' | i V' |
i | i | iv7' | iv7={III: ii7 | V7 | V7 |

```

(v)

```

# title: I Don't mind
# artist: James Brown
# metre: 6/8
# tonic: C

0.0      silence
7.3469387e-2    A, intro, | A:min | A:min | C:maj | C:maj |
8.714013605    | A:min | A:min | C:maj | C:maj |
15.611995464   | A:min | A:min | C:maj | C:maj |
22.346394557   B, verse, | A:min | A:min | C:maj | C:maj |
29.219433106   | A:min | A:min | C:maj | C:maj |
36.279501133   | F:maj | F:maj | D:maj | D:maj |
43.053922902   | G:maj | G:maj | C:maj | C:maj |

```

Some Datasets

	Name	Label Type
(i)	Theme and Variations with Roman Numeral Encoding (TAVERN)	Roman numerals
(ii)	(ABC)	Chord symbols
(iii)	(BPH-FS)	Chord symbols

(i)	!!!COM: Mozart !!!OTL: 12 Variations on "Ah Vous dirais-je, Maman" !!!Variation: Theme a **function **harm **kern **kern * * *clefF4 *clefG2 * * *k[] *k[] *M4/4 *M4/4 *M2/4 *M2/4 *C: *C: *C: *C: =1 =1 =1 =1 4T 4I 4C 4cc 4T 4I 4c 4cc =2 =2 =2 =2 4T 4Ib 4e 4gg 4T 4Ib 4c 4gg =3 =3 =3 =3 4T 4IV 4f 4aa 4T 4IV 4c 4aa =4 =4 =4 =4 4T 4Ib 4e 4gg 4T 4Ib 4c 4gg =5 =5 =5 =5 4T 4ii 4d 4ff 4T 4viio 4B 4ff =6 =6 =6 =6 4T 4I 4c 4ee 4T 4vi 4A 4ee =7 =7 =7 =7 4P 4iib 4F 4dd 4D 4V 4G (8.ddL . . . 16eeJk =8 =8 =8 =8 2T 2I 2C 2cc) *- *- *- *-	(ii)	-1 8 f 1 m 0 i 8 16 f 5 D7 1 V65 16 20 f 1 m 0 i 20 24 f 5 D7 2 V43 24 26 f 1 m 1 i6 26 28 f 2 d 1 ii-6 28 31 f 5 D7 0 V 31 40 A- 3 m 0 iii
(iii)	chord measure beat totbeat timesig op no mov length global_key local_key numeral figbass changes phraseend .Eb.I 1 1 1 2/4 127 12 1 2.5 Eb FALSE V43 2 1.5 3.5 2/4 127 12 1 1.5 Eb V 43 FALSE I 3 1 5 2/4 127 12 1 2.5 Eb I FALSE V2 4 1.5 7.5 2/4 127 12 1 1.5 Eb V 2 FALSE I6 5 1 9 2/4 127 12 1 1 Eb I 6 FALSE vi 5 2 10 2/4 127 12 1 1 Eb vi FALSE IV\\ \\ 6 1 11 2/4 127 12 1 2 Eb IV TRUE IV 7 1 13 3/4 127 12 1 1 Eb IV FALSE ii6 7 2 14 3/4 127 12 1 1 Eb ii 6 FALSE V2 7 3 15 3/4 127 12 1 1 Eb V 2 FALSE I6 8 1 16 3/4 127 12 1 2 Eb I 6 FALSE vi64 8 3 18 3/4 127 12 1 1 Eb vi 64 FALSE ii7 9 1 19 3/4 127 12 1 2 Eb ii 7 FALSE V43 9 3 21 3/4 127 12 1 1 Eb V 43 FALSE I6(7) 10 1 22 3/4 127 12 1 1 Eb I 6 7 FALSE		

Higher-Level Organization of Harmonic Material

Some Standard Pop Music Chord Progressions

Blues

C - F - G
I - IV - V



Musical staff showing chords C, F, G, I, IV, V.

Axis

C - G - a - F
I - V - vi - IV



Musical staff showing chords C, G, a, F, I, V, vi, IV.

**50's
Doo wop**

C - a - F - G
I - vi - IV - V



Musical staff showing chords C, a, F, G, I, vi, IV, V.

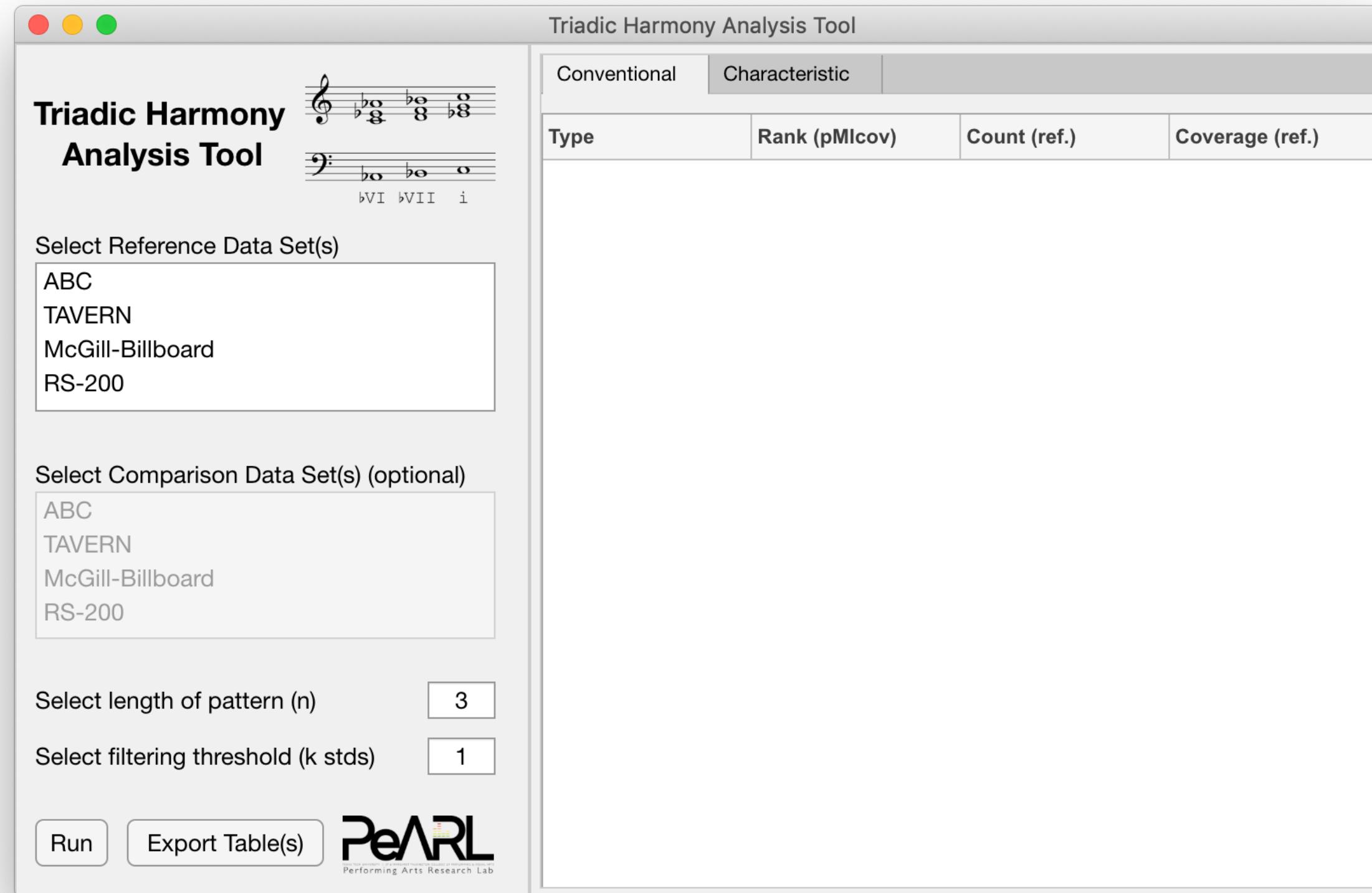


4 Chords
(2011)



Chord Progressions in Corpora

Sears and Forrest (2001)



Function

- ▶ **Casual: Certain chords tend to lead to other chords**
 - V-I can give a sense of closure in certain musical styles
 - will get into more details about this later
- ▶ **Formal: Hierarchical model to capture how chords work together to build phrases**
 - Tonic (I) – Pre-dominant (ii or IV) – Dominant (V)

TAVERN (gettavern.org)

12 VARIATIONEN über „Ah vous dirais-je, Maman“

Mozarts Werke.

für das Pianoforte
von

Serie 21. № 6.

W. A. M O Z A R T.

Köch. Verz. № 265.

TEMA.



TAVERN (gettavern.org)



TAVERN (gettavern.org)

Quiz: Matching a variation to a theme

A musical staff in G clef, 3/4 time, and A-flat key signature. The top line consists of eighth notes, and the bottom line consists of sixteenth notes. Several notes are circled in yellow. Below the staff, labels indicate note patterns: 'I/T' under the first measure, 'V7/D' under the second measure, and 'I/D' under the third measure. A large orange box encloses the last two measures.

I/T V⁷/D I/D

I/T



Three variations of musical staves below the main staff. The first variation (left) has a 6/8 time signature and labels 'I/T', 'V⁶⁵/T', 'V⁷/T', and 'I/T' at the bottom. The second variation (middle) has a 2/4 time signature and labels 'V⁷/D' at the bottom. The third variation (right) has a 2/4 time signature and labels 'I/D', 'V⁷/D', and 'I/T' at the bottom. The notes in these variations are circled in yellow, corresponding to the circled notes in the main staff.

I/T V⁶⁵/T V⁷/T I/T

V⁷/D

I/T

V⁷/D

I/D

V⁷/D I/T

Evaluation of Automatic Chord Estimation Algorithms

MIREX Evaluation Metrics

1. Chord root note only
2. Major and minor: N, maj, min
3. Seventh chords: N, maj, min, maj7, min7, 7
4. Major and minor with inversions: N, maj, min, maj/3, min/b3, maj/5, min/5
5. Seventh chords with inversions: N, maj, min, maj7, min7, 7, maj/3, min/b3, maj7/3, min7/b3, 7/3, maj/5, min/5, maj7/5, min7/5, 7/5, maj7/7, min7/b7, 7/b7

Labels not independent due to
overlapping content between labels

BEYOND CHORD VOCABULARIES: EXPLOITING PITCH-RELATIONSHIPS IN A CHORD ESTIMATION METRIC

Johanna Devaney

Brooklyn College and the Graduate Center, CUNY
johanna.devaney@brooklyn.cuny.edu

note name	C	C#	D	D#	E	F	F#	G	G#	A	A#	B
pitch class	0	1	2	3	4	5	6	7	8	9	10	11
C (I)	o	-	-	-	o	-	-	o	-	-	-	-
d (ii)	-	-	o	-	-	o	-	-	-	o	-	-
e (iii)	-	-	-	-	o	-	-	o	-	-	-	o
F (IV)	o	-	-	-	-	o	-	-	-	o	-	-
G(V)	-	-	o	-	-	-	-	o	-	-	-	o
a (vi)	o	-	-	-	o	-	-	-	-	o	-	-
b ^o (vii ^o)	-	-	o	-	-	o	-	-	-	-	-	o

Let C be the number of predicted notes \hat{y} in the ground truth correctly identified y

$$C = |y \cap \hat{y}| \quad (1)$$

Let I be the number of insertions (extra predicted notes) in the estimated chord that are not present in the ground truth.

$$I = |\hat{y} \setminus y| \quad (2)$$

Let A be the accuracy measurement for each chord estimate, calculated from C and I scaled between 0 and 1.

$$A = \frac{C - I + |y|}{2|y|} \quad (3)$$

Main Takeaways

- ▶ **Chord Labels**
 - **Different types of chord labels (roman numerals, pop chord labels, tablature) contain different types of information with respect to key and chord root**
 - **Chord labels represent which notes or chroma are chord tones versus non-chord tones**
- ▶ **Higher-Level Organization of Harmonic Material**
 - **Chords do not occur in isolation**
- ▶ **Evaluation for Automatic Chord Recognition**
 - **Chord labels are not independent of one another**