

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

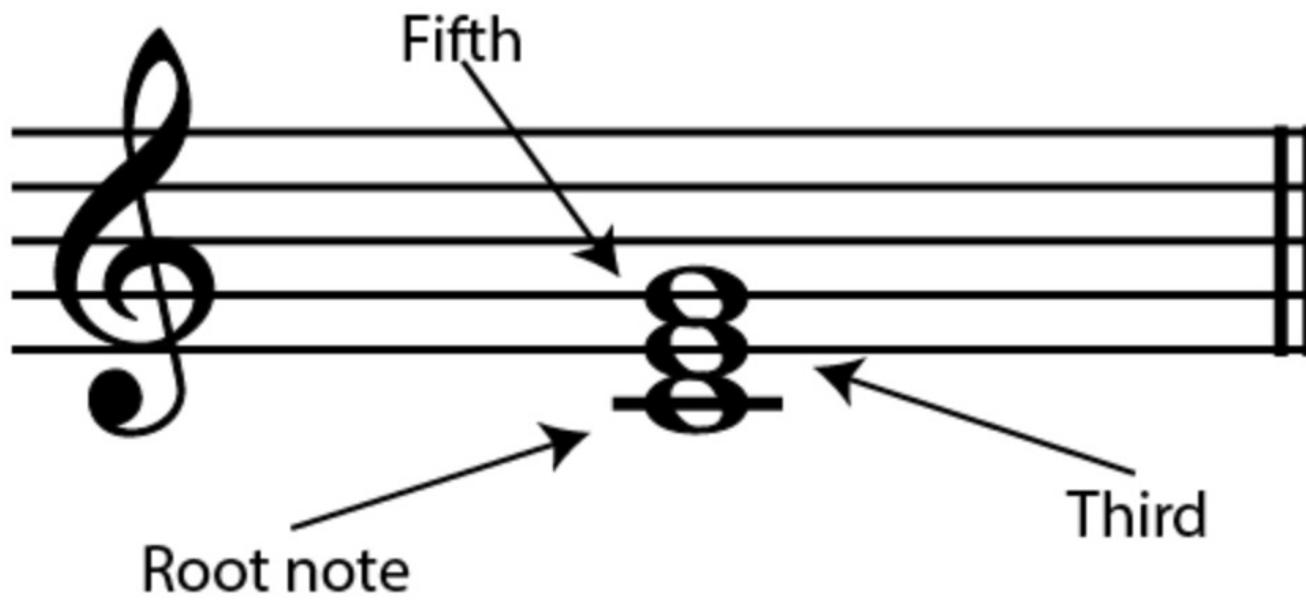
- ▶ **(Chord) Root – Lowest note in the chord's most compact position**
- ▶ **Scale degree – Position of a note relative to a musical scale**
- ▶ **Chord tones – Notes that are part of the current chord**
- ▶ **Non-chord tones – Notes that are not part of the current chord**
- ▶ **(Chord) Quality – Describes 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

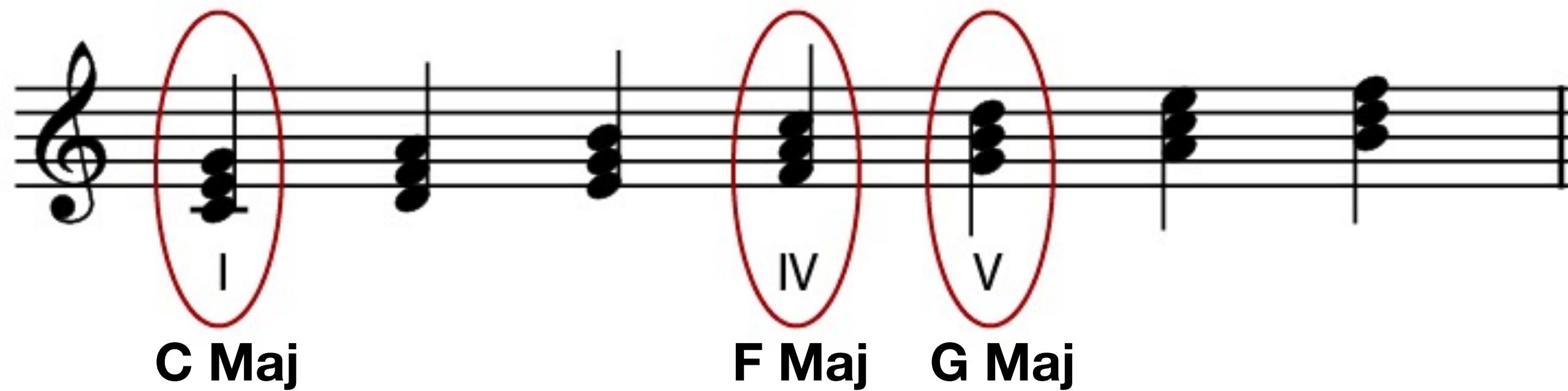
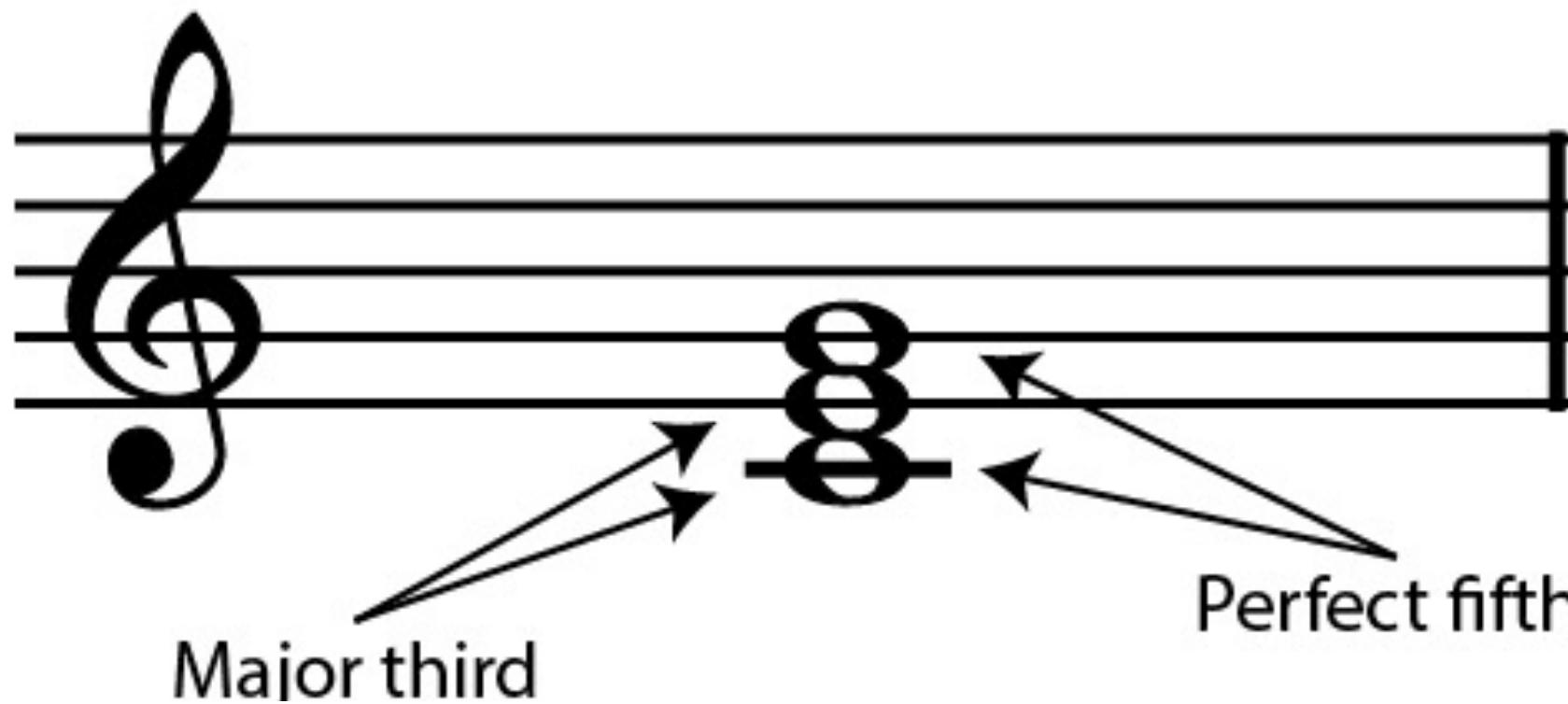
Chords



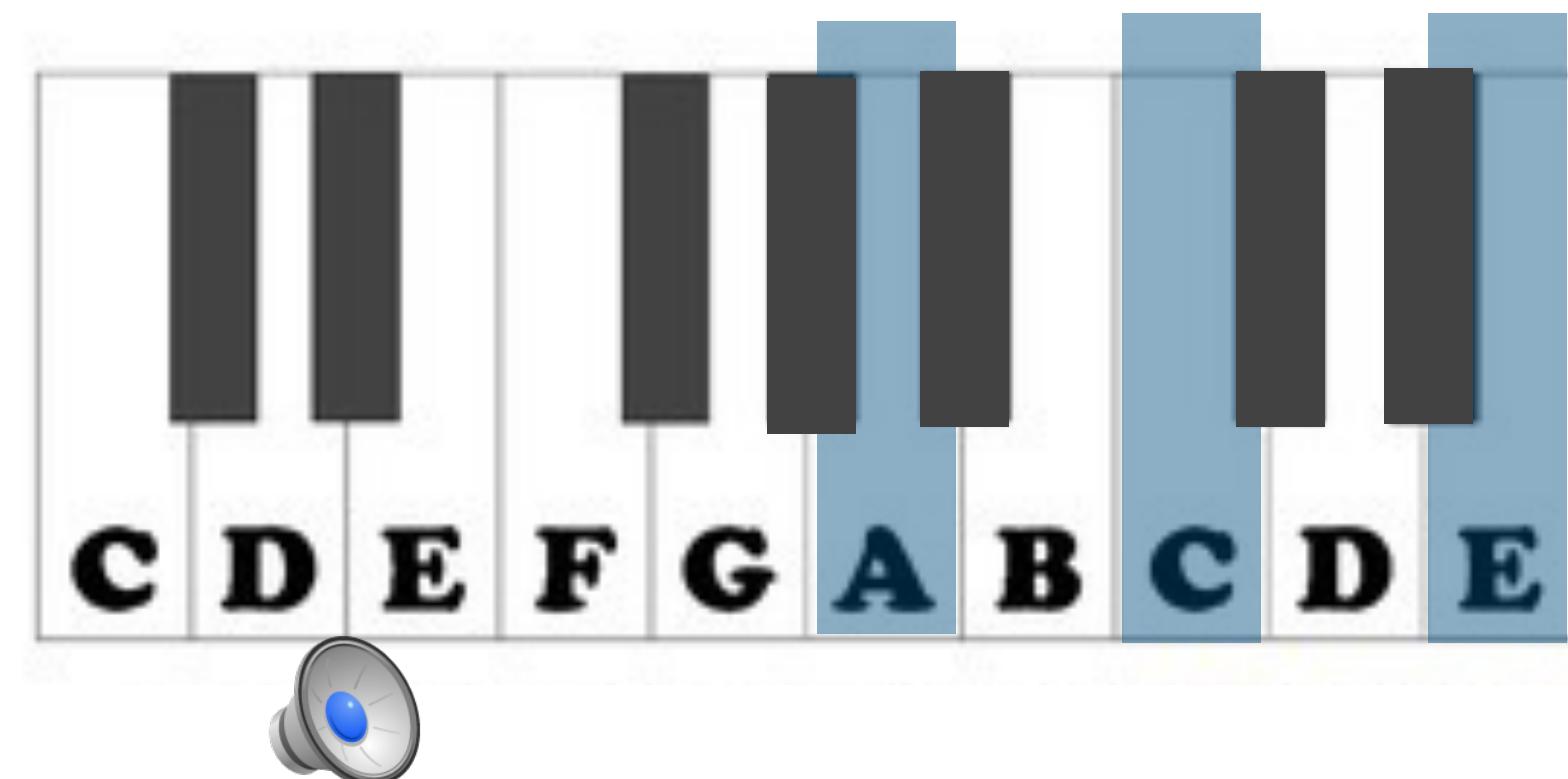
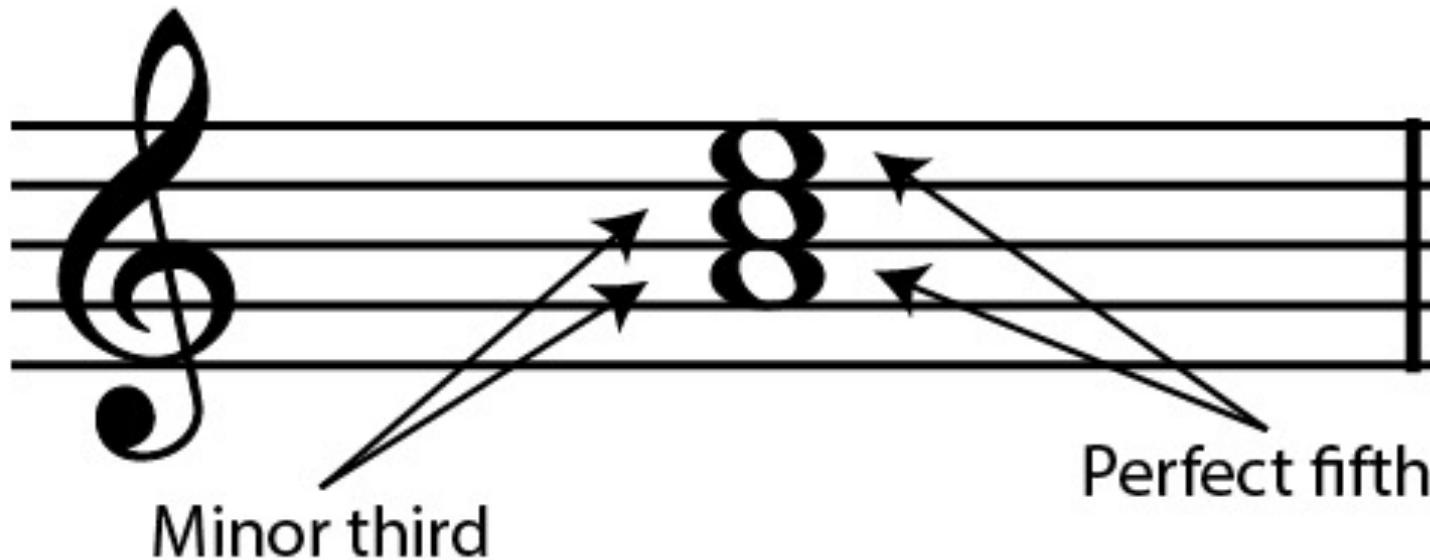
I	ii	iii	IV	V	vi	vii ^o
Cmaj	Dmin	Emin	Fmaj	Gmaj	Amin	Bdim



Quality: Major Triads

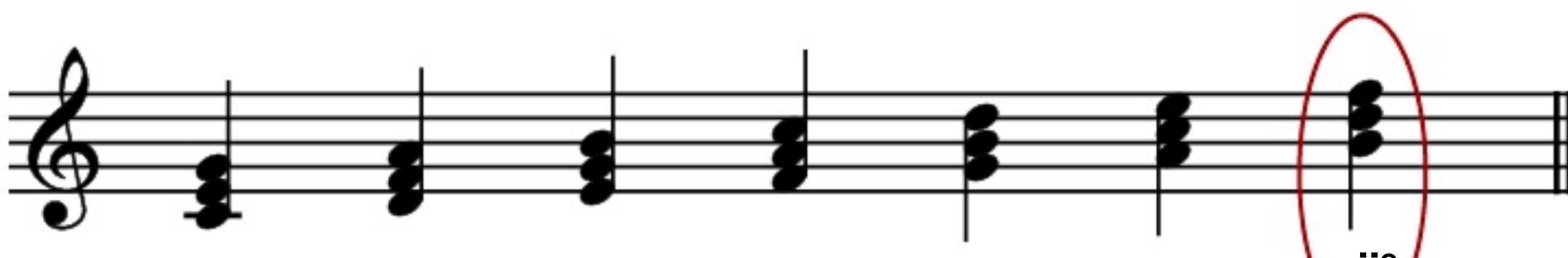
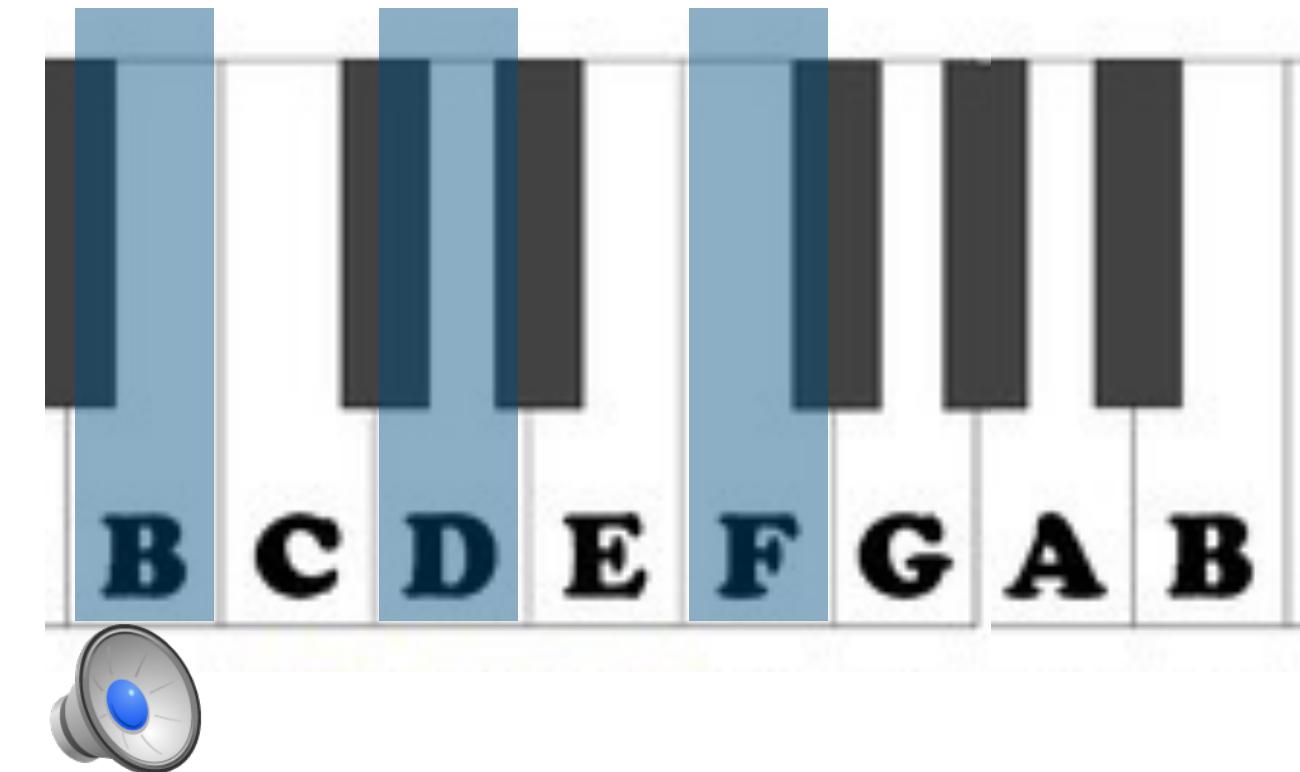
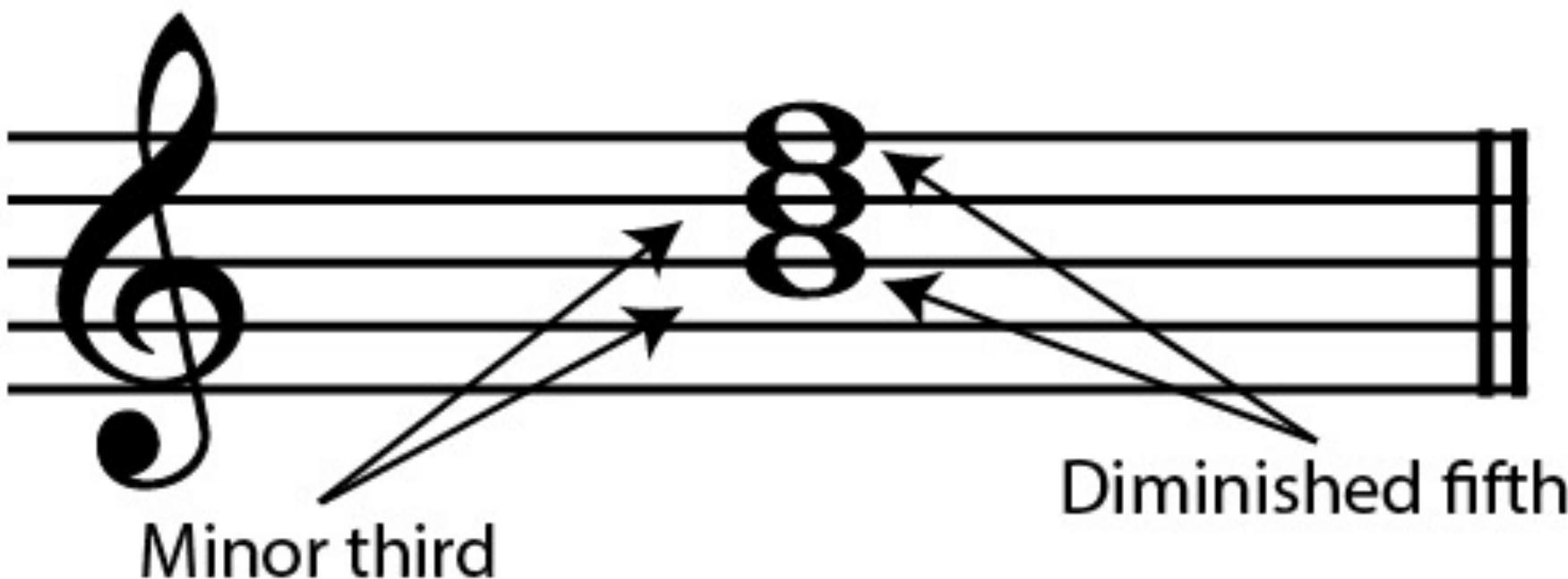


Quality: Minor Triads



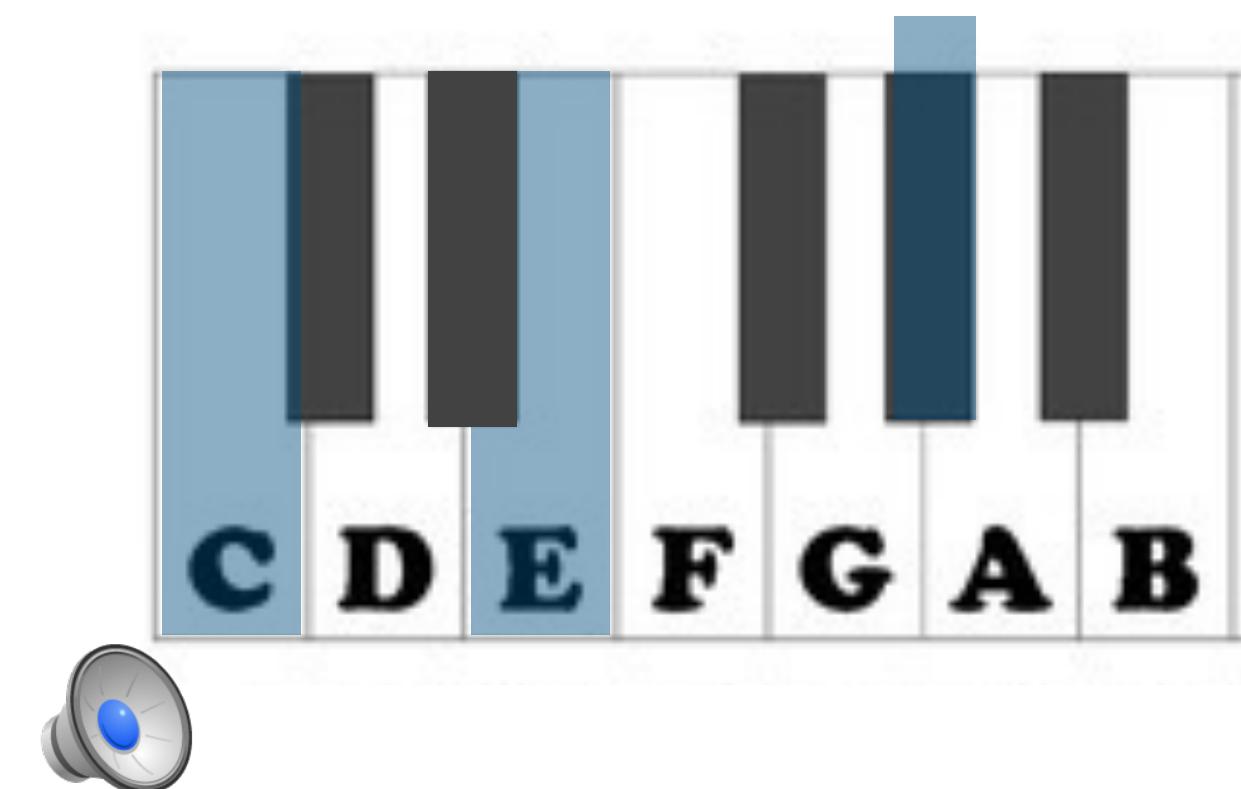
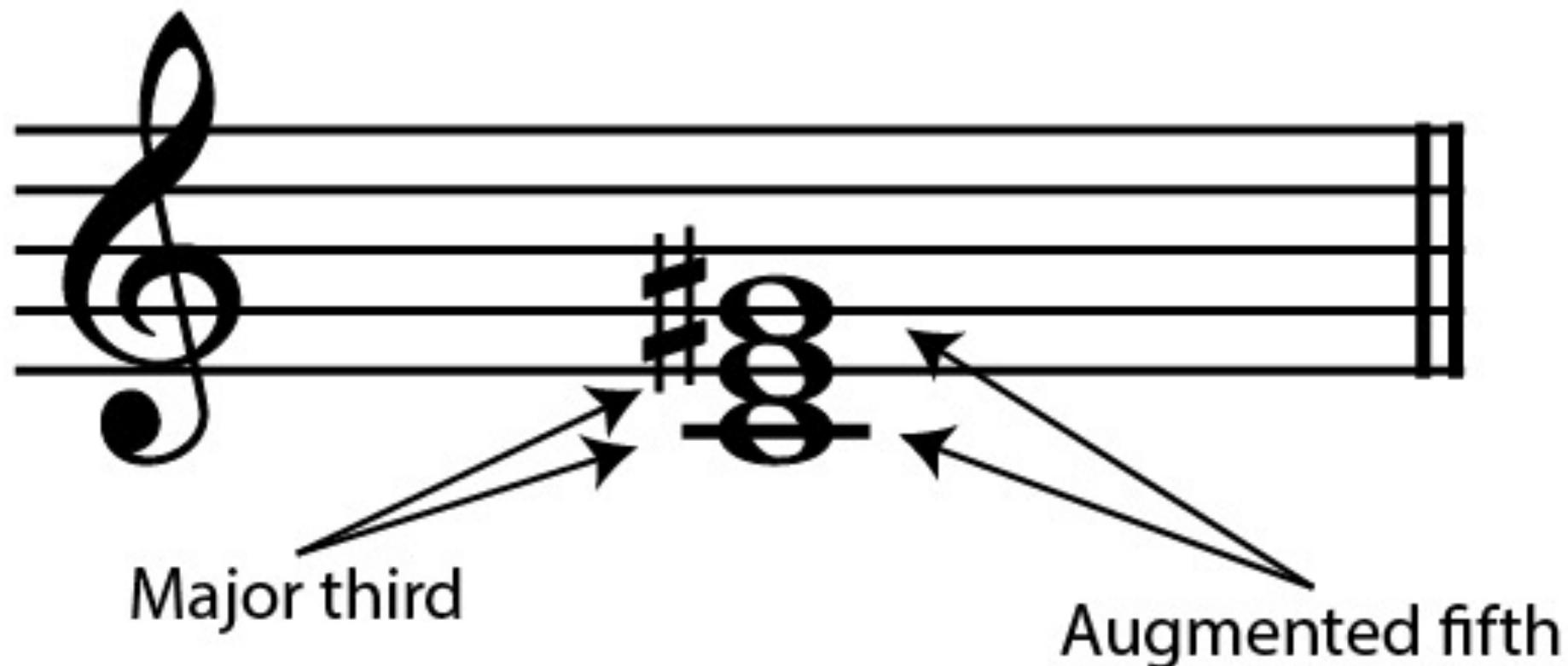
A musical staff with a treble clef. It shows three chords: d min (two black notes), e min (three black notes), and a min (three black notes). Red ovals highlight the second and third chords. Below the staff, Roman numerals indicate the chords: II, III, and VI. Below these, lowercase Roman numerals identify the specific chords: ii, iii, and vi.

Quality: Diminished Triads



b dim

Quality: Augmented Triads



A musical score on a treble clef staff. It consists of several measures. The fourth measure features a red oval around the third chord, which is a double-sharp seventh chord. Below this chord is the Roman numeral "III⁺". The label "Caug" is centered below the staff.

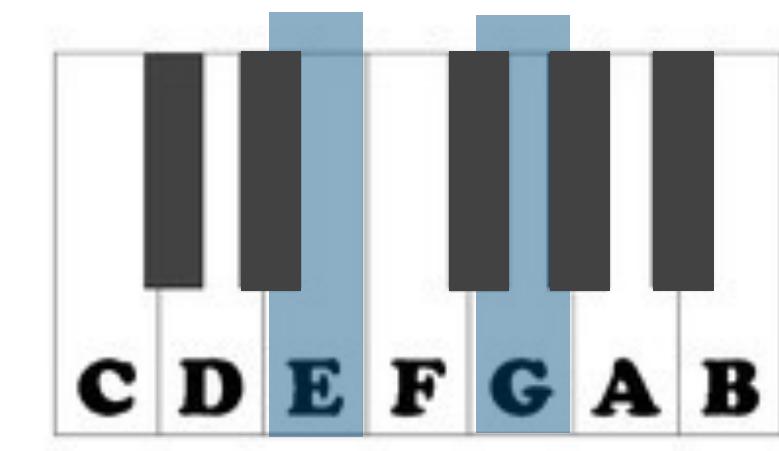
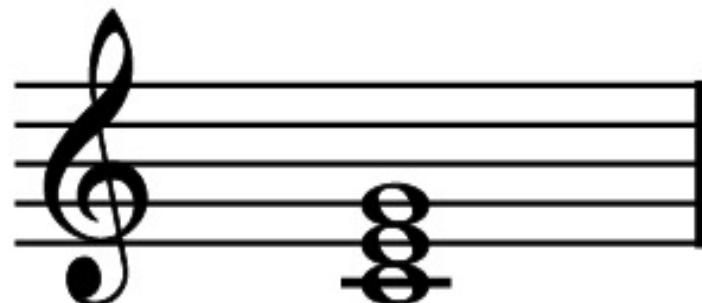
III⁺

Caug

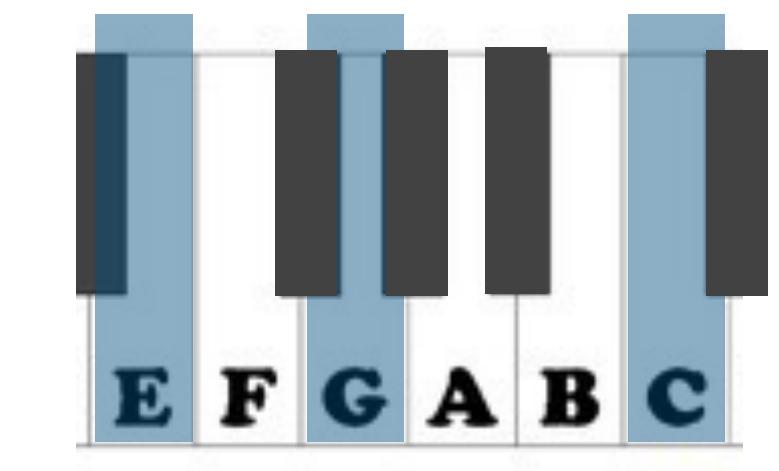
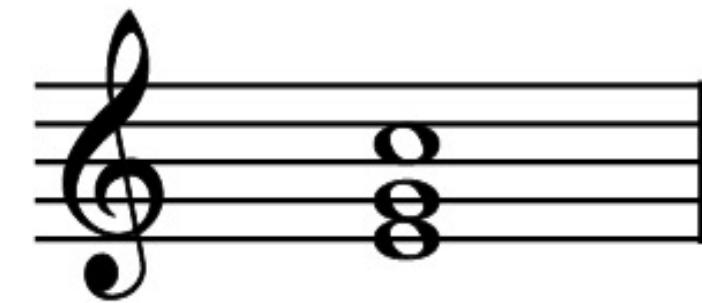
Triadic Inversions



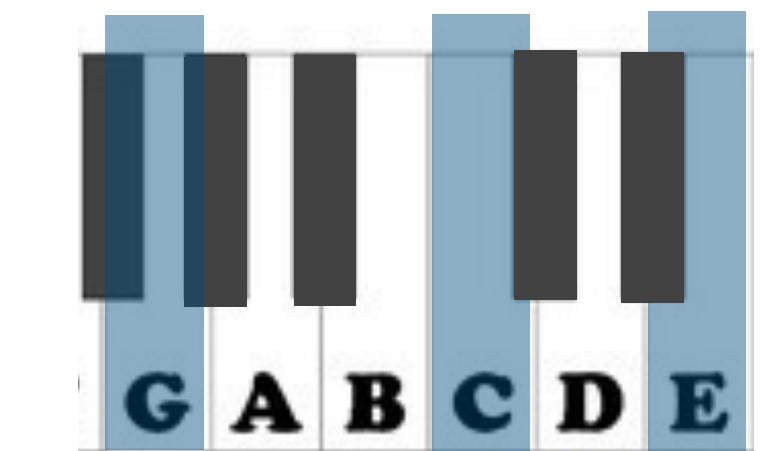
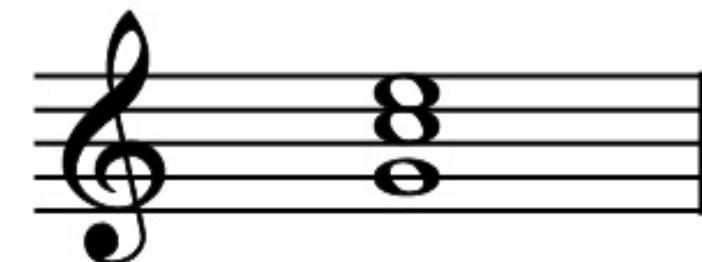
Root position



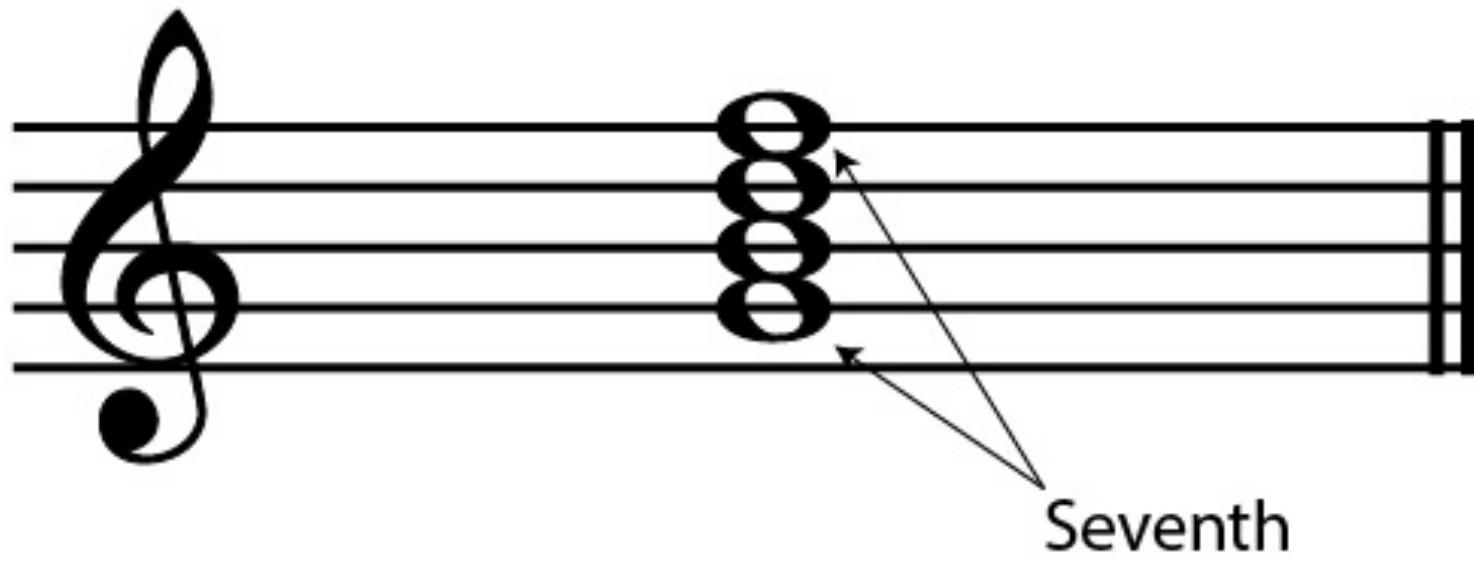
First Inversions



Second Inversions



Seventh Chords



Dominant Seventh Chords

A musical staff with a treble clef. It shows a G7 chord followed by a V7 chord. The G7 chord is composed of a major triad (labeled "Major triad") and a minor seventh (labeled "Minor seventh"). The V7 chord is labeled "V7". The notes are represented by black dots on the staff.

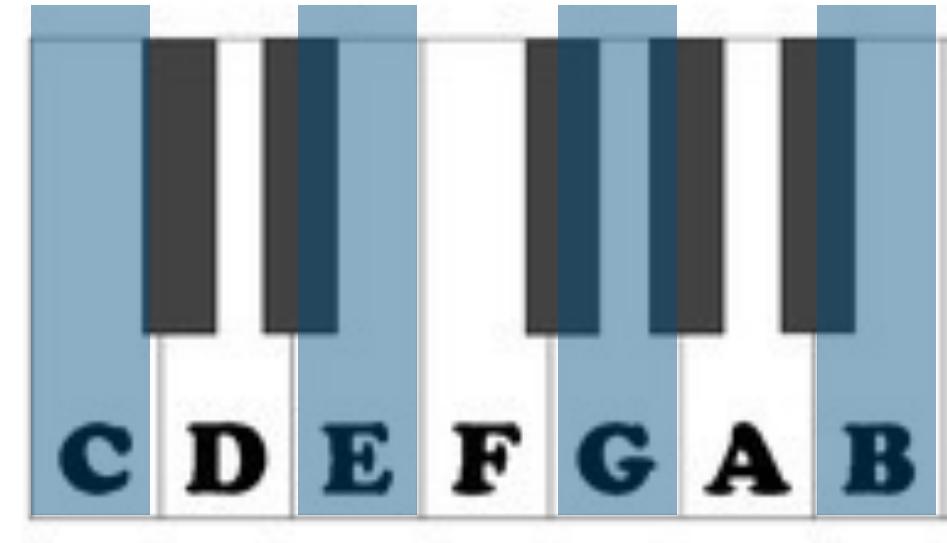
Seventh Chords

Major Seventh Chord

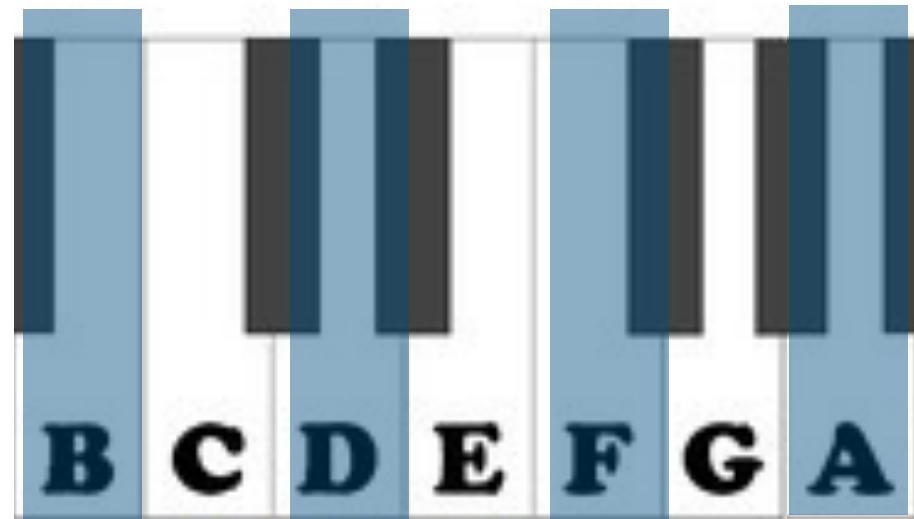
A musical staff in G clef shows three chords: CMaj⁷, CMaj⁷, and FMaj⁷. The first CMaj⁷ chord is analyzed with arrows pointing from the root (C) and the seventh (A) to the label "Major triad" and "Major seventh" respectively. The second CMaj⁷ chord is labeled I⁷. The FMaj⁷ chord is labeled IV⁷.

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

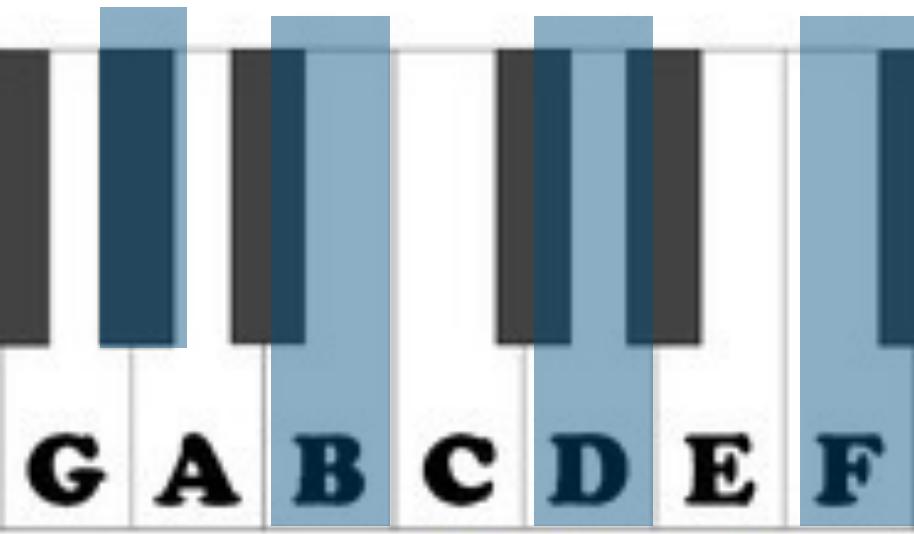
vii[°]

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

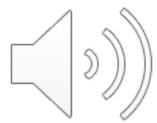
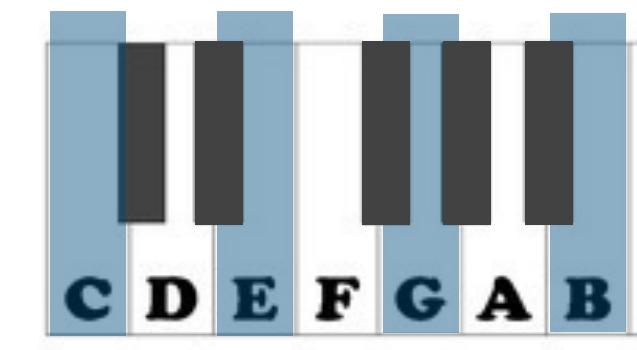
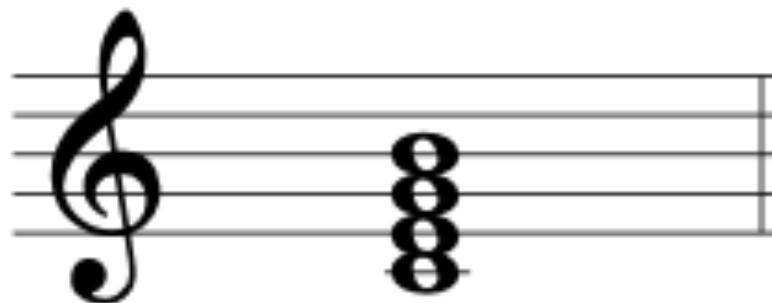


G#dim⁷

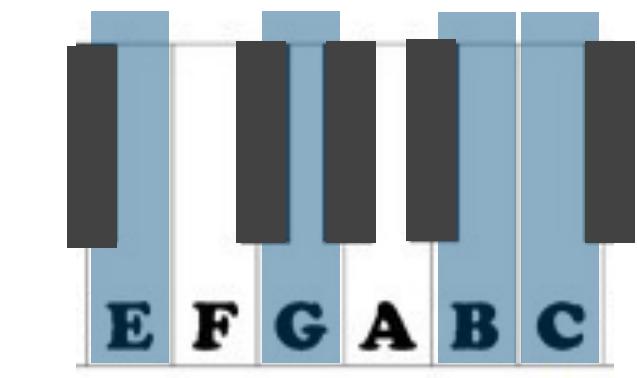
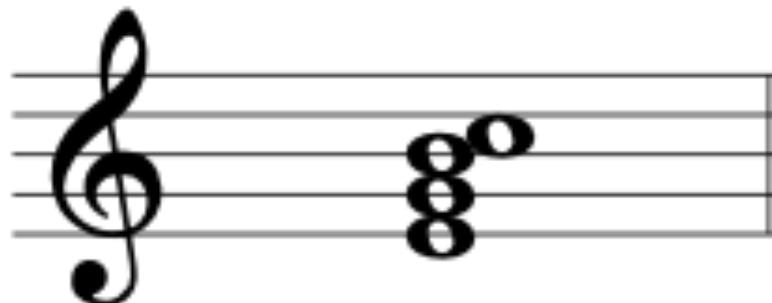
Diminished triad Diminished seventh

Seventh Inversions

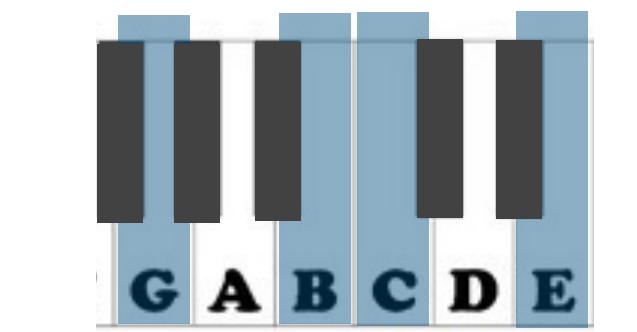
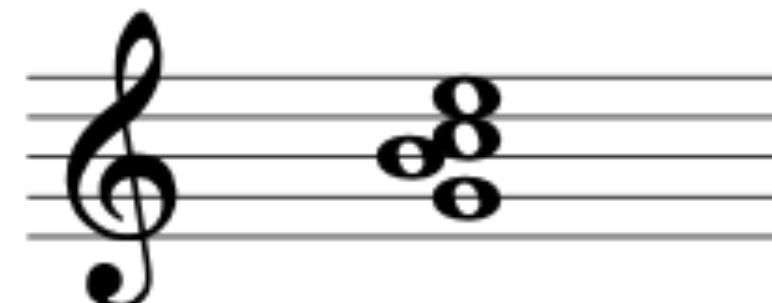
Root position



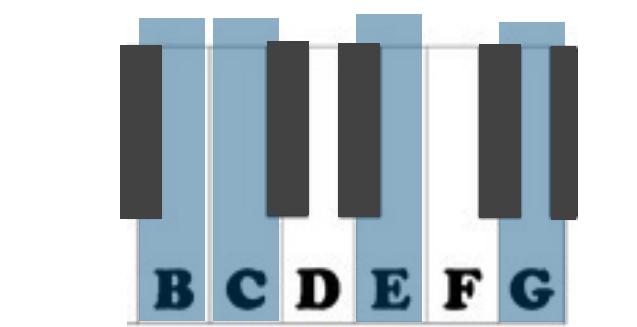
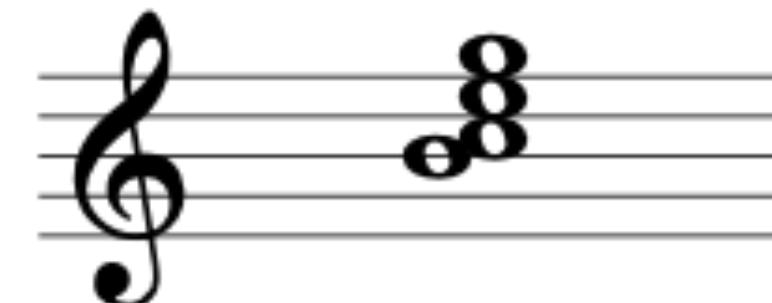
First Inversion



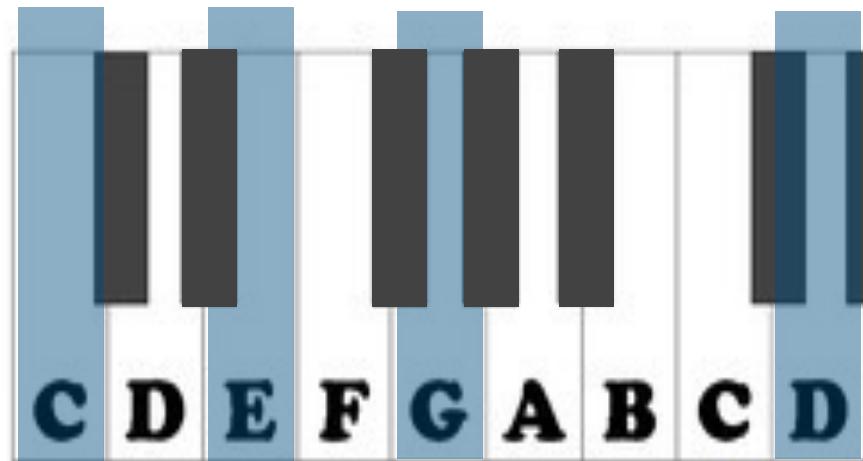
Second Inversion



Third Inversion

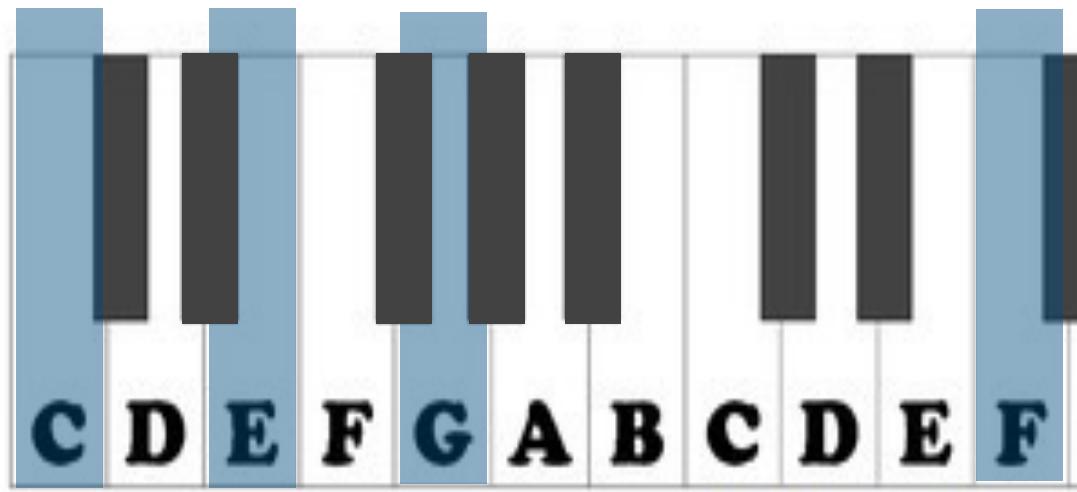
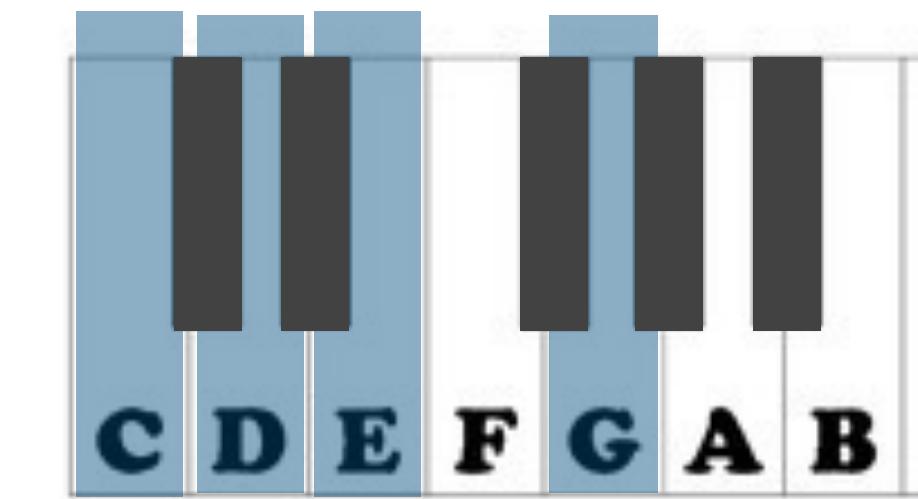


Other Added Notes/Extensions



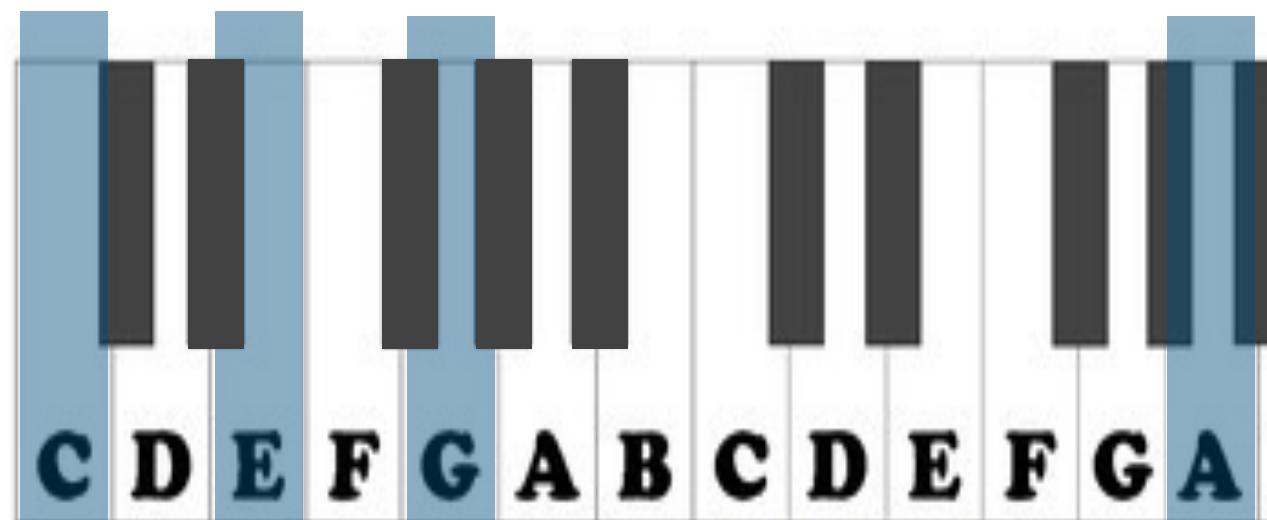
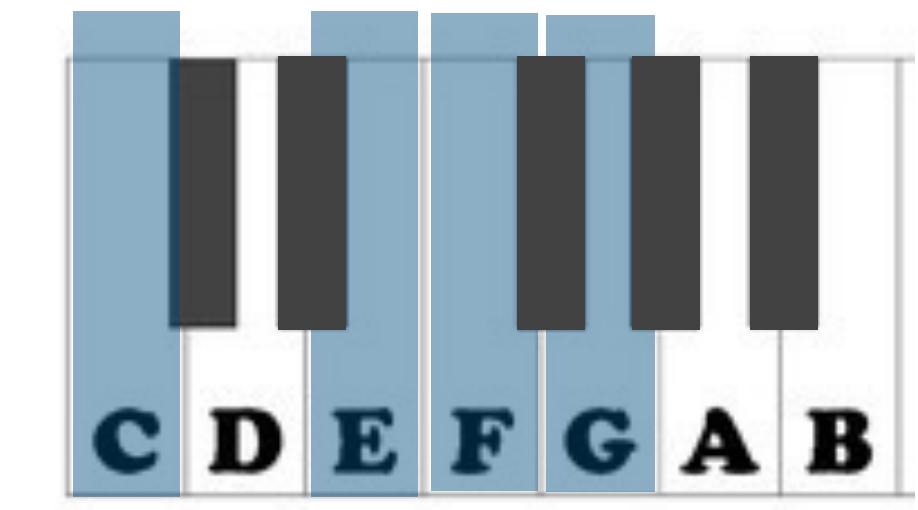
add9

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



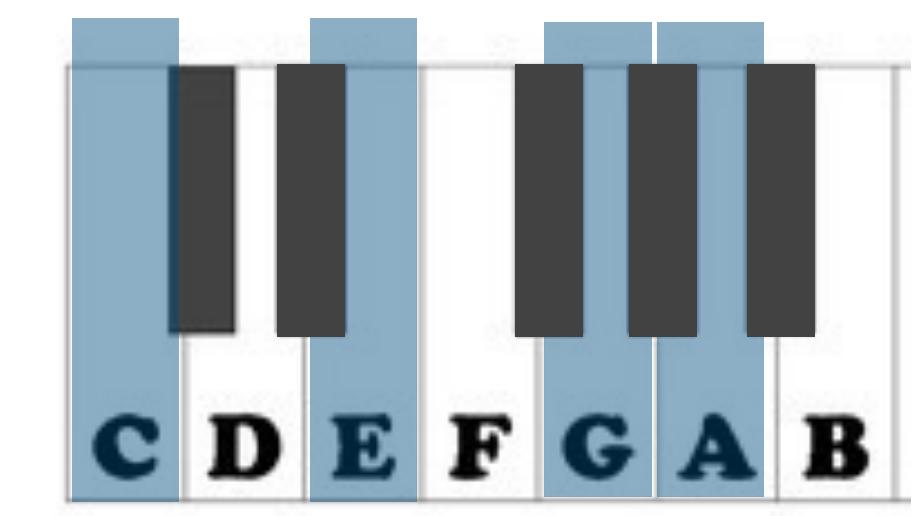
add11

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



add13

Musical notation for an add13 chord. It consists of a treble clef followed by two eighth notes on the second and fifth strings of a guitar. Two small speaker icons are positioned below the staff, one on each side of the note heads.



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

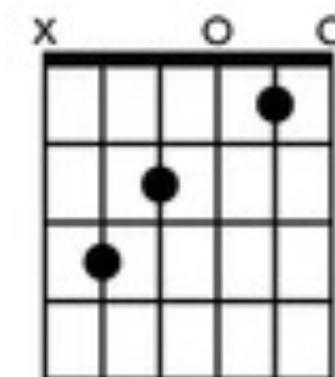
- ▶ **Chord Symbols**

- 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

Mozart

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

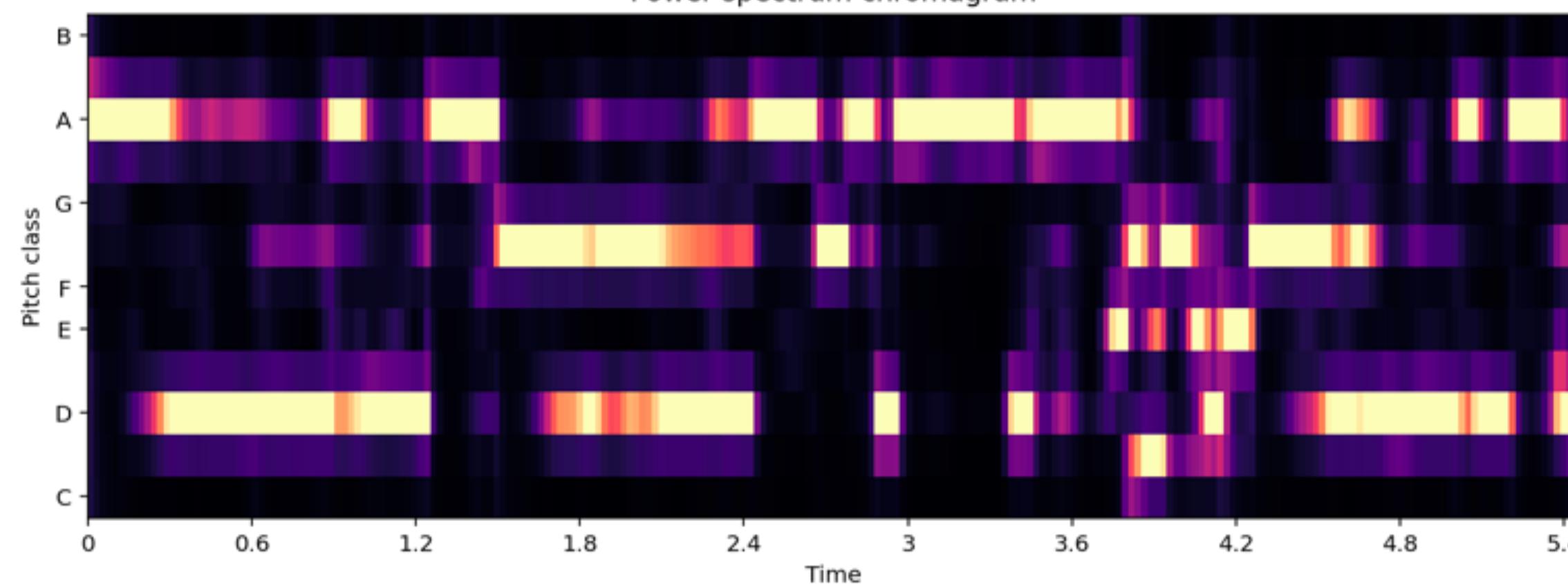
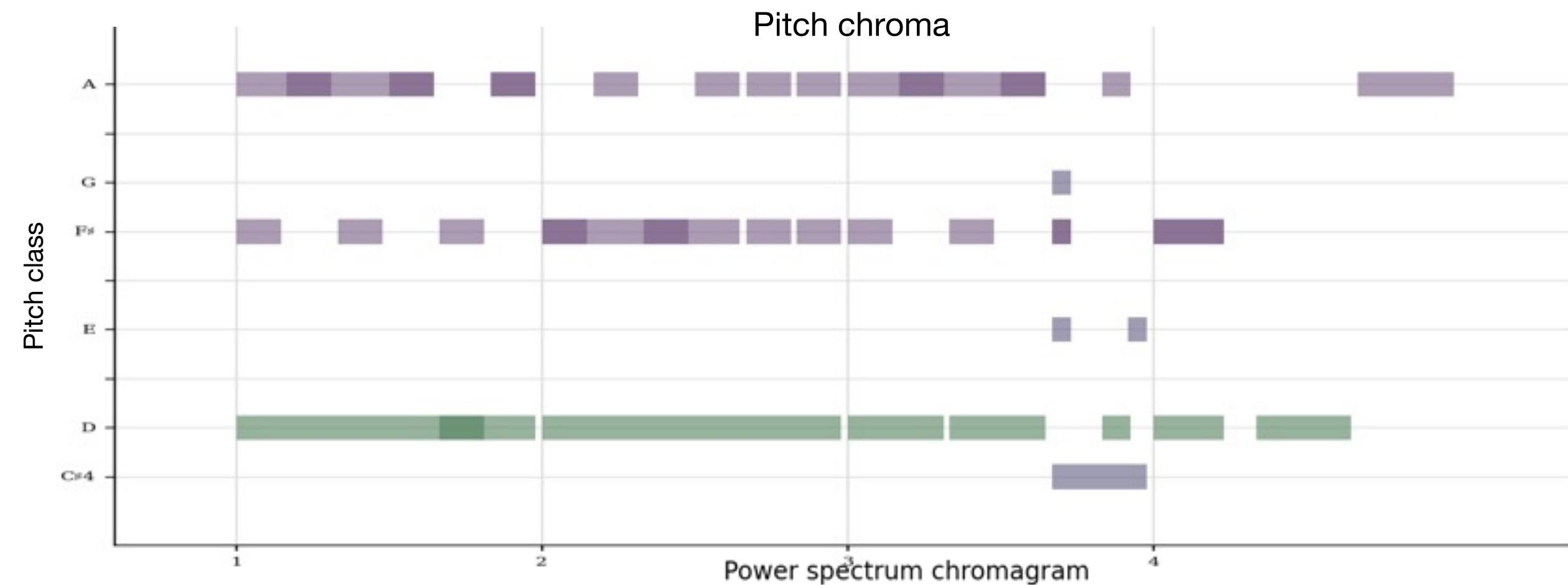
Information Different Labels Contain

9 Variationen über ein Minuett von Duport

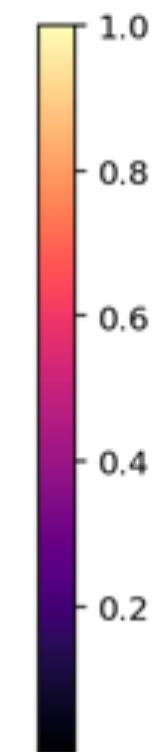
Mozart

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

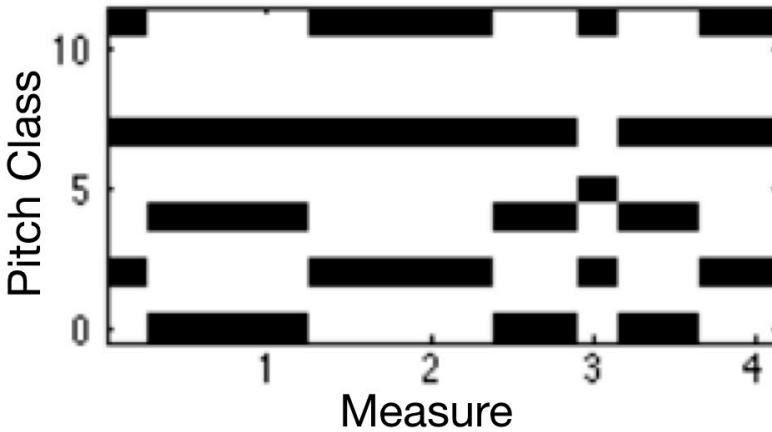
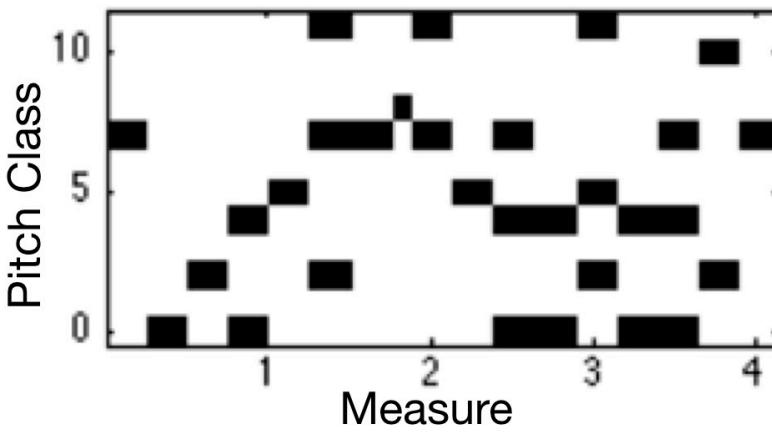
Theme

T

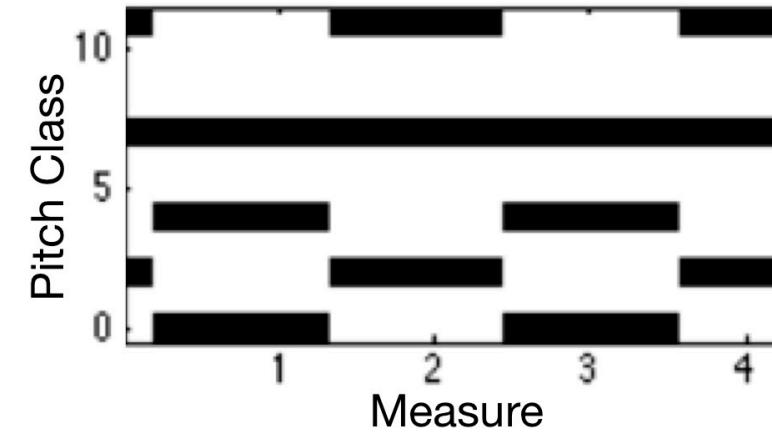
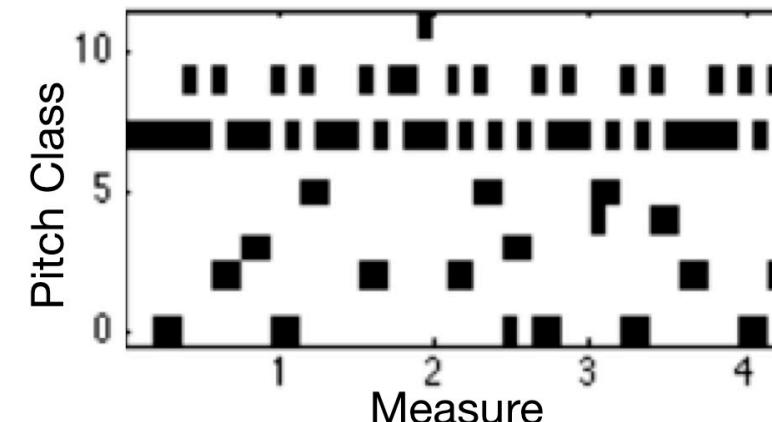
V I V6 I I6 viio6 I V64 V

D

Theme (Symbolic)



Variation (Symbolic)



Variation

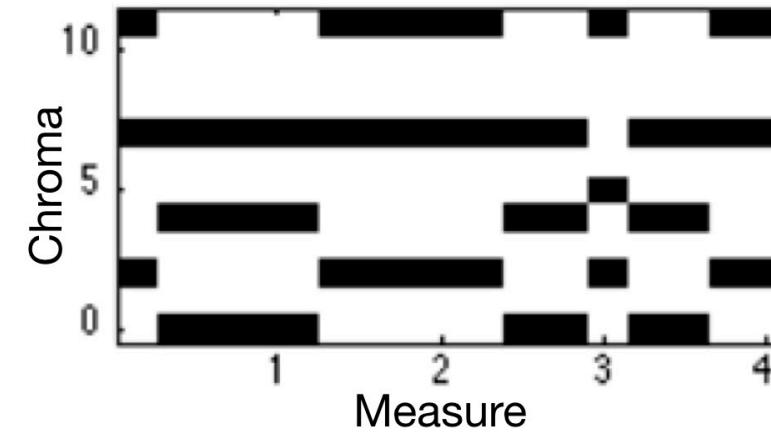
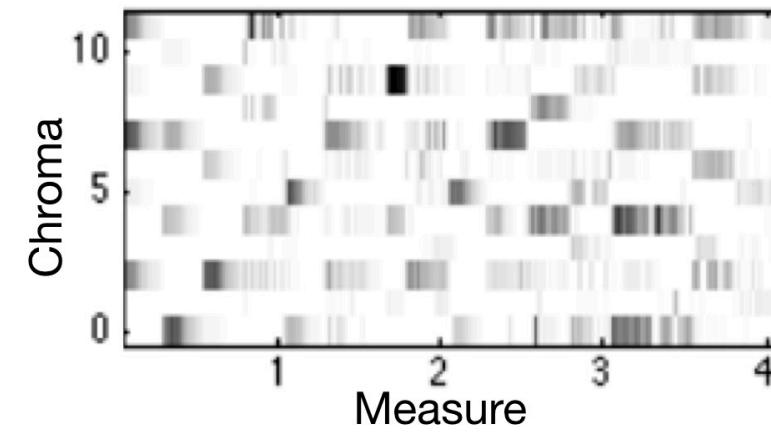
Beethoven

T

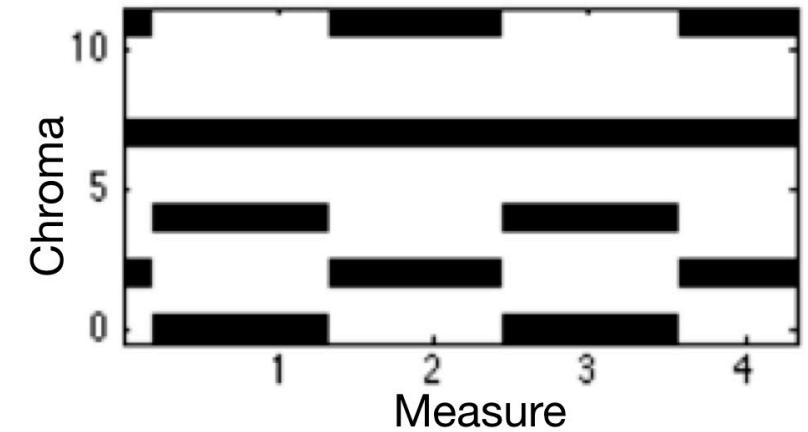
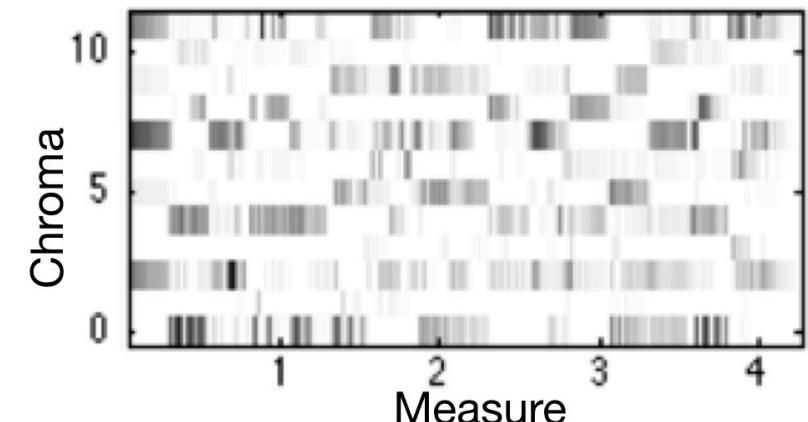
V I V I V I V

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 |

```

```

# 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) 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	I	I			FALSE
V43	2	1.5	3.5 2/4	127	12	1	1.5	Eb	I	V	43		FALSE
I	3	1	5 2/4	127	12	1	2.5	Eb	I	I			FALSE
V2	4	1.5	7.5 2/4	127	12	1	1.5	Eb	I	V	2		FALSE
I6	5	1	9 2/4	127	12	1	1	Eb	I	I	6		FALSE
vi	5	2	10 2/4	127	12	1	1	Eb	I	vi			FALSE
IV\\\\\\	6	1	11 2/4	127	12	1	2	Eb	I	IV		TRUE	
IV	7	1	13 3/4	127	12	1	1	Eb	I	IV			FALSE
ii6	7	2	14 3/4	127	12	1	1	Eb	I	ii	6		FALSE
V2	7	3	15 3/4	127	12	1	1	Eb	I	V	2		FALSE
I6	8	1	16 3/4	127	12	1	2	Eb	I	I	6		FALSE
vi64	8	3	18 3/4	127	12	1	1	Eb	I	vi	64		FALSE
ii7	9	1	19 3/4	127	12	1	2	Eb	I	ii	7		FALSE
V43	9	3	21 3/4	127	12	1	1	Eb	I	V	43		FALSE
I6(7)	10	1	22 3/4	127	12	1	1	Eb	I	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.

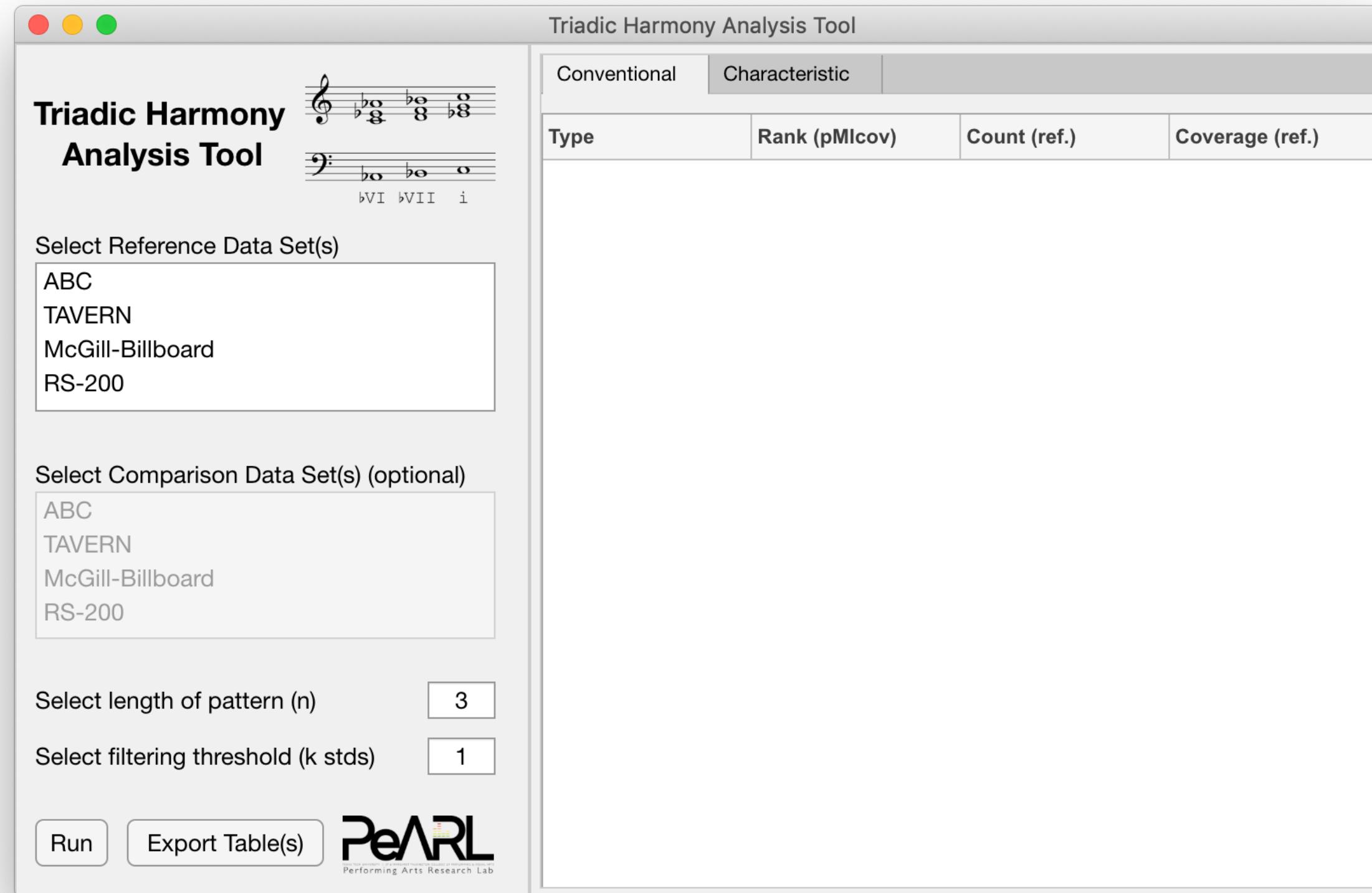


4 Chords
(2011)



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)

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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.



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Quiz: Matching a variation to a theme

A musical staff in G clef, 3/4 time, and A-flat key signature. The staff consists of two systems of music. The first system starts with a measure of three eighth-note chords (G, C, E) circled in orange. The second system starts with a measure of eighth-note pairs (A-flat, C) circled in orange. Below the staff, labels are provided: "I/T" under the first circled measure, "V⁷/D" under the second circled measure, and "I/D" under the third circled measure. A large orange box encloses the last measure of the staff.

I/T V⁷/D I/D

V⁷/D I/T

?

?

Three sets of musical variations, each consisting of two measures. The first set (bottom left) has a G clef, 6/8 time, and A-flat key signature. It includes labels: "I/T" under the first measure, "V⁶⁵/T" under the second measure, "V⁷/T" under the third measure, and "I/T" under the fourth measure. The second set (bottom middle) has a G clef, 2/4 time, and A-flat key signature. It includes labels: "I/T" under the first measure, "V⁷/D" under the second measure, and "I/T" under the third measure. The third set (bottom right) has a G clef, 2/4 time, and A-flat key signature. It includes labels: "V⁷/D" under the first measure, "I/D" under the second measure, "V⁷/D" under the third measure, and "I/T" under the fourth measure. Each measure contains circled notes for comparison.

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

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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**