

On Local Keys, Modulations, and Tonicizations:

A Dataset and Methodology for Evaluating Changes of Key

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Key estimation



A musical score in 4/4 time, consisting of two staves: a treble clef staff and a bass clef staff. The key signature has one flat (B-flat). The melody in the treble clef starts on G4, moves to F4, then G4, and continues with various intervals. The bass clef staff provides a harmonic accompaniment with chords and single notes. The piece concludes with a double bar line.

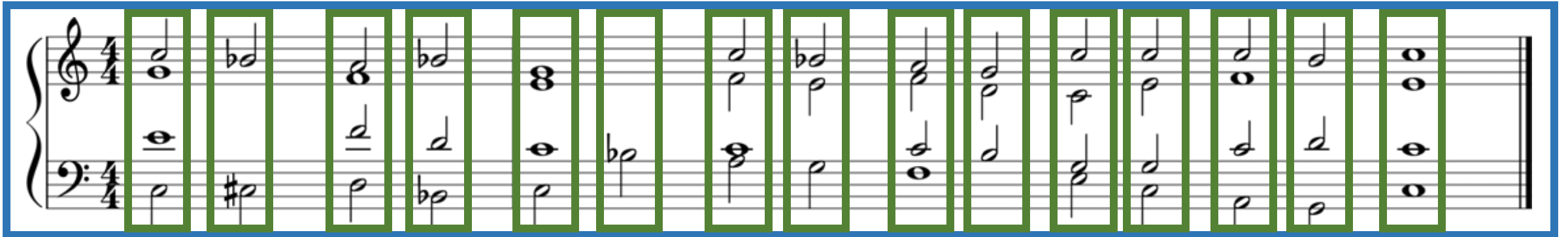
Key estimation



A musical score in 4/4 time, consisting of two staves: a treble clef staff and a bass clef staff. The key signature has one flat (B-flat). The melody in the treble clef starts on G4, moves to F4, then E4, and continues with various intervals. The bass clef accompaniment starts on G3, moves to F3, then E3, and continues with various intervals. The score ends with a double bar line.

- Global key estimation

Key estimation



A musical score in 4/4 time, consisting of two staves (treble and bass clef). The score is divided into 15 measures by vertical green lines. The notes in each measure are as follows:

Measure	Treble Clef	Bass Clef
1	C4, G4	F3, C4
2	Bb4, G4	C#4, F3
3	A4, G4	D4, F3
4	Bb4, G4	D4, Bb3
5	A4, G4	F3, C4
6	Rest	Bb3, F3
7	A4, G4	F3, C4
8	Bb4, G4	F3, C4
9	A4, G4	F3, C4
10	A4, G4	F3, C4
11	A4, G4	F3, C4
12	A4, G4	F3, C4
13	A4, G4	F3, C4
14	A4, G4	F3, C4
15	A4, G4	F3, C4

- Global key estimation
- Local key estimation

Water Revival [Have You Ever Seen The Rain](#)

Black/Lady Gaga & [A Star Is Born - Shallow](#)

er

Key	
B	4,991
Bb	4,455
Eb	4,136
Cm	3,970
F#m	2,923
Ab	2,799
C#m	2,748
F#	2,470
C#	1,600
G#m	1,232

ck [A Star Is Born - Always Remember Us This Way](#)

[Hey Jude \(ver 7\)](#)

[When We Were Young](#)

Global key and their applications

Search parameters in a digital library :

- Ultimate guitar



- Beat port



TaiJI Records	Techno (Peak Time / ...	A min
Liquid V	Drum & Bass	D# min
Progrezo Records	Melodic House & Tec...	A maj
Progrezo Records	Melodic House & Tec...	A min
Anjunadeep	Melodic House & Tec...	F# maj
Record Union	Indie Dance	C min

Local keys and their applications

Used mostly as mid-level MIR features for other tasks:

- Roman numeral analysis (Temperley, 2004; Micchi et al., 2020)
- MIDI pitch spelling (Teodoru et Raphael, 2007)
- Music generation (Hadjeres et al., 2017)

Potentially usable in digital music libraries too:

- Search for pieces with similar modulations or tonicizations patterns

Local keys, modulations, and tonicizations

Outline the necessity for studying local keys more in depth

Particularly, the relationship to concepts like modulation and tonicization

Change of key

- Modulation
- Tonicization
- Local keys

Local keys, modulations, and tonicizations

Outline the necessity for studying local keys more in depth

Particularly, the relationship to concepts like modulation and tonicization

Change of key – tonal music theory

- Modulation
- Tonicization
- Local keys????

Local keys, modulations, and tonicizations

Outline the necessity for studying local keys more in depth

Particularly, the relationship to concepts like modulation and tonicization

Change of key – music information retrieval

- Modulation????
- Tonicization????
- Local keys

Local keys, modulations, and tonicizations

Outline the necessity for studying local keys more in depth

Particularly, the relationship to concepts like modulation and tonicization

Change of key

- Modulation
- Tonicization
- Local keys

Investigate!

This paper

Method for encoding modulation/tonicization ground truth

Dataset with 201 excerpts (five tonal music theory textbooks)

Comparing local-key predictions with modulation and tonicization ground truth annotations

Using the data and methodology, evaluate three local-key estimation models from the literature

Example

The musical score is in 4/4 time and consists of 8 measures. It is divided into three sections: C major (measures 1-3), F major (measures 4-6), and C major (measures 7-8). The Roman numeral analysis is as follows:

C:I	vii ^{o7} /ii	ii	IV/IV	V/IV	V ⁷ /IV	F:I ⁶	V ₃ ⁴	I	V ² /V	V ⁶	V	I ⁶	V ⁷ /V	C:I
f	F	F	F	F	F	F	F	F	C	C	C	C	C	C

1. Modulations are **always** taken from the textbooks
2. Tonicizations are inferred from roman numerals
3. Roman numeral analysis is **not always** provided in the textbooks

Example

departure key destination key

C major F major C major

C:I vii^{o7}/ii ii IV/IV V/IV V⁷/IV F:I⁶ V₃⁴ I V²/V V⁶ V I⁶ V⁷/V C:I

f F F F F F F F F C C C C C C

1. Modulations are **always** taken from the textbooks
2. Tonicizations are inferred from roman numerals
3. Roman numeral analysis is **not always** provided in the textbooks

Example

The musical score is in 4/4 time and consists of 8 measures. The key signature is one flat (F major). The first measure is in C major (labeled 'C major' above). The second measure is in F major (labeled 'F major' above). The final measure is in C major (labeled 'C major' above). The Roman numeral analysis is as follows:

C:I	vii ^{o7} /ii	ii	IV/IV	V/IV	V ⁷ /IV	F:I ⁶	V ³ ₄	I	V ² /V	V ⁶	V	I ⁶	V ⁷ /V	C:I
f	F	F	F	F	F	F	F	F	C	C	C	C	C	C

A blue arrow points from the text 'tonicized second degree' to the highlighted Roman numeral vii^{o7}/ii .

1. Modulations are **always** taken from the textbooks
2. Tonicizations are inferred from roman numerals
3. Roman numeral analysis is **not always** provided in the textbooks

Example

C major F major C major

C:I vii^{°7}/ii ii IV/IV V/IV V⁷/IV F:I⁶ V_{3/4} I V²/V V⁶ V I⁶ V⁷/V C:I

f	F	F	F	F	F	F	F	F	C	C	C	C	C	C
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

local key predictions at every onset

1. Modulations are **always** taken from the textbooks
2. Tonicizations are inferred from roman numerals
3. Roman numeral analysis is **not always** provided in the textbooks

Example

The musical score is in 4/4 time and consists of 14 measures. The key signature changes from C major (no sharps or flats) to F major (one flat) in measure 7, and returns to C major in measure 14. The Roman numeral analysis and figured bass notation are as follows:

C:I	vii ^{o7} /ii	ii	IV/IV	V/IV	V ⁷ /IV	F:I ⁶	V ₃ ⁴	I	V ² /V	V ⁶	V	I ⁶	V ⁷ /V	C:I
f	F	F	F	F	F	F	F	F	C	C	C	C	C	C

1. Modulations are **always** taken from the textbooks
2. Tonicizations are inferred from roman numerals
3. Roman numeral analysis is **not always** provided in the textbooks

Example

The musical score is in 4/4 time and consists of 14 measures. It is divided into three sections: C major (measures 1-3), F major (measures 4-11), and C major (measures 12-14). The Roman numeral analysis and chord symbols are as follows:

Measure	Chord	Roman Numeral
1	f	C:I
2	F	vii ^{o7} /ii
3	F	ii
4	F	IV/IV
5	F	V/IV
6	F	V ⁷ /IV
7	F	F:I ⁶
8	F	V ₃ ⁴
9	F	I
10	C	V ² /V
11	C	V ⁶
12	C	V
13	C	I ⁶
14	C	V ⁷ /V
15	C	C:I

1. Modulations are **always** taken from the textbooks
2. Tonicizations are inferred from roman numerals
3. Roman numeral analysis is **not always** provided in the textbooks

Example

Modulation 1
(departure key) ↓ (destination key)

C Major ----- ambiguity ----- F Major

C:I $\text{vii}^{\circ 7}/\text{ii}$ ii IV/IV V/IV V^7/IV F:I⁶ V₃⁴

5

----- ambiguity -----

(departure key) ↓ (destination key)

C Major

I V^2/V V⁶ V I⁶ V^7/V C:I

Example 3-17b in Rimsky-Korsakov's *Practical Manual of Harmony*

Example

Modulation 1
(departure key) → (destination key)

C Major → F Major

ambiguity

Modulation 2
(departure key) → (destination key)

F Major → C Major

ambiguity

Chord symbols for Modulation 1: C:I, vii^{o7}/ii, ii, IV/IV, V/IV, V⁷/IV, F:I⁶, V₃

Chord symbols for Modulation 2: I, V²/V, V⁶, V, I⁶, V⁷/V, C:I

Example 3-17b in Rimsky-Korsakov's *Practical Manual of Harmony*

Original edition by Rimsky-Korsakov

Образец (До—Фа—До).

The image shows a musical score for piano, consisting of two staves (treble and bass clefs) joined by a brace on the left. The music is written in G major, Dorian mode, with a key signature of one flat (F major). The tempo and dynamics are not specified. The score is divided into seven measures. Above the treble staff, the notes 'До' (Do), 'Фа' (Fa), and 'До' (Do) are written above the first, third, and seventh measures respectively. The first measure contains a half note G4 in the treble and a half note G3 in the bass. The second measure contains a half note A4 in the treble and a half note F3 in the bass. The third measure contains a half note B4 in the treble and a half note G3 in the bass. The fourth measure contains a half note C5 in the treble and a half note A3 in the bass. The fifth measure contains a half note D5 in the treble and a half note B3 in the bass. The sixth measure contains a half note E5 in the treble and a half note C4 in the bass. The seventh measure contains a half note F5 in the treble and a half note D4 in the bass. The piece concludes with a double bar line.

Original edition by Rimsky-Korsakov

C Major

F Major

C Major

Образец (До—Фа—До).

До Фа До

The musical score consists of two staves: a treble clef staff and a bass clef staff. The key signature has one flat (Bb). The melody is written in the treble clef, and the accompaniment is in the bass clef. The score is annotated with 'C Major', 'F Major', and 'C Major' above the first, third, and fifth measures respectively, with orange arrows pointing to the notes. The Russian text 'Образец (До—Фа—До)' is centered above the score, with 'До', 'Фа', and 'До' above the first, third, and fifth measures of the melody.

The one we used

Model (C major to F major to C major)

The image shows a musical score for a progression from C major to F major and back to C major. The score is written in treble and bass clefs. The bass line is highlighted with a red box, showing the following fingering: b7, 2, 6, 4, b3, 2, 6, 6, 7.

C F C

b7 2 6 4 b3 2 6 6 7

The one we used

Model (C major to F major to C major)

The musical score is written for two staves, Treble and Bass clef, in 2/4 time. The key signature is one flat (Bb). The progression is divided into three measures by vertical bar lines. Above the staff, the chords C, F, and C are indicated. Below the staff, the chord symbols I, vii/ii, ii, IV/IV, V/IV, I, V, I, V/V, V, I, V/V, I are written. The bass line consists of quarter notes and half notes, while the treble line consists of quarter notes and half notes. The bass line starts with a whole note chord (C) in the first measure, followed by a half note chord (Bb) and a quarter note chord (A). In the second measure, it has a half note chord (F) and a quarter note chord (Eb). In the third measure, it has a half note chord (C) and a quarter note chord (Bb). The treble line starts with a whole note chord (C) in the first measure, followed by a half note chord (Bb) and a quarter note chord (A). In the second measure, it has a half note chord (F) and a quarter note chord (Eb). In the third measure, it has a half note chord (C) and a quarter note chord (Bb).

C F C

b7 2 6 4 2 6 6 7

I vii/ii ii IV/IV V/IV I V I V/V V I V/V I

Processing annotations

Modulation 1
(departure key) (destination key)

C Major F Major

ambiguity

C:I vii^{o7}/ii ii IV/IV V/IV V⁷/IV F:I⁶ V₃

Modulation 2
(departure key) (destination key)

F Major C Major

ambiguity

I V²/V V⁶ V I⁶ V⁷/V C:I

Position	Annotation	Modulation	Tonicization
0	C=>:I	C major	C major
2	vii ^{o7} /ii	C major	D minor
4	ii	C major	C major
6	IV/IV	C major	F major
8	V/IV	C major	F major
10	V ⁷ /IV	C major	F major
12	F=>:I6	F major	F major
14	V43	F major	F major
16	I	F major	F major
18	V ² /V	F major	C major
20	V ⁶	F major	F major
22	V	F major	F major
24	I ⁶	F major	F major
26	V ⁷ /V	F major	C major
28	C=>:I	C major	C major

Dataset


- (ASC) Aldwell, Cadwallader and Schachter
Harmony and Voice Leading
- (KP) Kostka and Payne
Tonal Harmony
- (Reg) Reger
On the Theory of Modulation
- (Rim) Rimsky-Korsakov
Practical Manual of Harmony
- (Tch) Tchaikovsky
Guide to the practical study of Harmony

Sample	Files	Modulations	Tonicizations	Labels
ASC	7	8	7	185
KP	15	21	11	554
Reg	117	220	40	768
Rim	37	44	107	257
Tch	25	60	38	238
Total	201	555	203	2002

Some of the textbooks

e) From d^{\flat} -minor to:

89) E-major (e-minor).

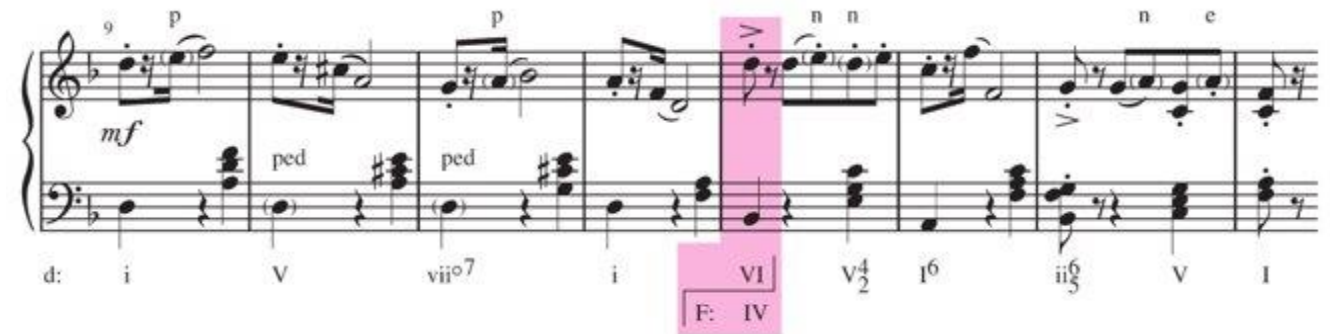


Tonic d^{\flat} -minor; dominant (A^{\flat} -major) of d^{\flat} -minor; use the 1st inversion of this A^{\flat} -major (chord of the sixth $c^{\flat} e^{\flat} a^{\flat}$), which is at the same time the chord of the Neapolitan sixth in G-major; dominant (D-major) of G-major; use this D-major, which is relative to the minor dominant (b-minor) of E-major (e-minor); minor sub-dominant (a-minor) of E-major (e-minor). (Cadence!)

$[d^{\flat}I, d^{\flat}V_{\frac{3}{2}} (= GIV_{\frac{6}{3}}^{\flat})], GV \left\{ \begin{array}{l} (= E_{\frac{2}{4}}^{\sharp}VII), EIV_{\frac{2}{4}} \\ (= e_{\frac{2}{4}}^{\sharp}VII), eIV \end{array} \right.$
 $EV, | EI]$
 $eV_{\frac{2}{4}}^{\sharp}, | eI]$



Example 18-6 Tchaikovsky, Mazurka, op. 39, no. 10



d: i V vii^o7 i VI V₂⁴ I⁶ ii⁶₅ V I

F: IV

Extract from Kostka and Payne

Extract from Reger

Models

Baseline

- (B1) Random guess
- (B2) Global key

MIR models

- (M1) Nápoles López et al. (2019)
- (M2a-b) Feisthauer et al. (2020)
- (M3) Micchi et al. (2020)

Position	Annotation	Modulation	Tonicization
0	C:=>I	C	C
2	vii ^o 7/ii	C	d
4	ii	C	C
6	IV/IV	C	F
8	V/IV	C	F
10	V7/IV	C	F
12	F:=>I6	F	F
14	V43	F	F
16	I	F	F
18	V2/V	F	C
20	V6	F	F
22	V	F	F
24	I6	F	F
26	V7/V	F	C
28	C:=>I	C	C

Models

Baseline

- (B1) Random guess
- (B2) Global key

MIR models

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- (M2a-b) Feisthauer et al. (2020)
- (M3) Micchi et al. (2020)

Position	Annotation	Modulation	Tonicization	B1
0	C:=>I	C	C	Bb
2	vii ^o 7/ii	C	d	a
4	ii	C	C	Bb
6	IV/IV	C	F	eb
8	V/IV	C	F	C#
10	V7/IV	C	F	f
12	F:=>I6	F	F	C#
14	V43	F	F	g
16	I	F	F	c
18	V2/V	F	C	C#
20	V6	F	F	C#
22	V	F	F	g
24	I6	F	F	b
26	V7/V	F	C	e
28	C:=>I	C	C	d

Models

Baseline

- (B1) Random guess
- (B2) Global key

MIR models

- (M1) Nápoles López et al. (2019)
- (M2a-b) Feisthauer et al. (2020)
- (M3) Micchi et al. (2020)

Position	Annotation	Modulation	Tonicization	B1	B2
0	C:=>I	C	C	Bb	F
2	vii ^o 7/ii	C	d	a	F
4	ii	C	C	Bb	F
6	IV/IV	C	F	eb	F
8	V/IV	C	F	C#	F
10	V7/IV	C	F	f	F
12	F:=>I6	F	F	C#	F
14	V43	F	F	g	F
16	I	F	F	c	F
18	V2/V	F	C	C#	F
20	V6	F	F	C#	F
22	V	F	F	g	F
24	I6	F	F	b	F
26	V7/V	F	C	e	F
28	C:=>I	C	C	d	F

Models

Baseline

- (B1) Random guess
- (B2) Global key

MIR models

- (M1) Nápoles López et al. (2019)
- (M2a-b) Feisthauer et al. (2020)
- (M3) Micchi et al. (2020)

Position	Annot.	Mod.	Ton.	B1	B2	M1	M2 a	M2 b	M3
0	C:=>I	C	C	Bb	F	f	C	C	F
2	vii ^o 7/ii	C	d	a	F	F	C	C	F
4	ii	C	C	Bb	F	F	d	C	F
6	IV/IV	C	F	eb	F	F	d	C	F
8	V/IV	C	F	C#	F	F	d	C	F
10	V7/IV	C	F	f	F	F	d	C	F
12	F:=>I6	F	F	C#	F	F	d	C	F
14	V43	F	F	g	F	F	d	C	F
16	I	F	F	c	F	F	F	C	F
18	V2/V	F	C	C#	F	C	F	C	F
20	V6	F	F	C#	F	C	F	C	C
22	V	F	F	g	F	C	F	C	C
24	I6	F	F	b	F	C	F	F	F
26	V7/V	F	C	e	F	C	F	F	C
28	C:=>I	C	C	d	F	C	F	F	C

Accuracy and MIREX

Key Relationship (Reference, Predicted)	Accuracy	MIREX
Same key	1.0	1.0
Dominant / SubDominant	0.0	0.5
Relative Major / Relative Minor	0.0	0.3
Parallel Major / Parallel Minor	0.0	0.2
Other	0.0	0.0

Example :

Ground truth key	Prediction	Accuracy	MIREX
C	F	0.0	0.5

Accuracy and MIREX

Key Relationship (Reference, Predicted)	Accuracy	MIREX
Same key	1.0	1.0
Dominant / SubDominant	0.0	0.5
Relative Major / Relative Minor	0.0	0.3
Parallel Major / Parallel Minor	0.0	0.2
Other	0.0	0.0

Example :

Ground truth key	Prediction	Accuracy	MIREX
C	F	0.0	0.5

Accuracy and MIREX

Key Relationship (Reference, Predicted)	Accuracy	MIREX
Same key	1.0	1.0
Dominant / SubDominant	0.0	0.5
Relative Major / Relative Minor	0.0	0.3
Parallel Major / Parallel Minor	0.0	0.2
Other	0.0	0.0

Example :

Ground truth key	Prediction	Accuracy	MIREX
C	F	0.0	0.5

Comparison of the models and the ground truth

Local keys vs. Modulation

- Accuracy weights
- MIREX weights

Local keys vs. Tonicization

- Accuracy weights
- MIREX weights

What do local keys coincide with?

- Accuracy
- Mirex

Position	Annotation	Modulation (B3)	Tonicization (B4)	B1	B2	M1	M2a	M2b	M3
0	C:=>I	C	C	Bb	F	f	C	C	F
2	vii°7/ii	C	d	a	F	F	C	C	F
4	ii	C	C	Bb	F	F	d	C	F
6	IV/IV	C	F	eb	F	F	d	C	F
8	V/IV	C	F	C#	F	F	d	C	F
10	V7/IV	C	F	f	F	F	d	C	F
12	F:=>I6	F	F	C#	F	F	d	C	F
14	V43	F	F	g	F	F	d	C	F
16	I	F	F	c	F	F	F	C	F
18	V2/V	F	C	C#	F	C	F	C	F
20	V6	F	F	C#	F	C	F	C	C
22	V	F	F	g	F	C	F	C	C
24	I6	F	F	b	F	C	F	F	F
26	V7/V	F	C	e	F	C	F	F	C
28	C:=>I	C	C	d	F	C	F	F	C

What do local keys coincide with?

- Accuracy
- Mirex

Position	Annotation	Modulation (B3)	Tonicization (B4)	B1	B2	M1	M2a	M2b	M3
0	C:=>I	C	C	Bb	F	f	C	C	F
2	vii°7/ii	C	d	a	F	F	C	C	F
4	ii	C	C	Bb	F	F	d	C	F
6	IV/IV	C	F	eb	F	F	d	C	F
8	V/IV	C	F	C#	F	F	d	C	F
10	V7/IV	C	F	f	F	F	d	C	F
12	F:=>I6	F	F	C#	F	F	d	C	F
14	V43	F	F	g	F	F	d	C	F
16	I	F	F	c	F	F	F	C	F
18	V2/V	F	C	C#	F	C	F	C	F
20	V6	F	F	C#	F	C	F	C	C
22	V	F	F	g	F	C	F	C	C
24	I6	F	F	b	F	C	F	F	F
26	V7/V	F	C	e	F	C	F	F	C
28	C:=>I	C	C	d	F	C	F	F	C

Local keys vs. modulation

- Accuracy
- Mirex

C Major (departure key) → Modulation 1 → F Major (destination key)

ambiguity

Chord annotations: C:I, vii°7/ii, ii, IV/IV, V/IV, V7/IV, F:I⁶, V₄3

Position	Annotation	Modulation (B3)	Tonicization (B4)	B1	B2	M1	M2a	M2b	M3
0	C:=>I	C	C	Bb	F	f	C	C	F
2	vii°7/ii	C	d	a	F	F	C	C	F
4	ii	C	C	Bb	F	F	d	C	F
6	IV/IV	C	F	eb	F	F	d	C	F
8	V/IV	C	F	C#	F	F	d	C	F
10	V7/IV	C	F	f	F	F	d	C	F
12	F:=>I6	F	F	C#	F	F	d	C	F
14	V43	F	F	g	F	F	d	C	F
16	I	F	F	c	F	F	F	C	F
18	V2/V	F	C	C#	F	C	F	C	F
20	V6	F	F	C#	F	C	F	C	C
22	V	F	F	g	F	C	F	C	C
24	I6	F	F	b	F	C	F	F	F
26	V7/V	F	C	e	F	C	F	F	C
28	C:=>I	C	C	d	F	C	F	F	C

Local keys vs. modulation

- Accuracy
- Mirex

Position	Annotation	Modulation (B3)	Tonicization (B4)	B1	B2	M1	M2a	M2b	M3
0	C=>I	C	C	Bb	F	f	C	C	F
2	vii°7/ii	C	d	a	F	F	C	C	F
4	ii	C	C	Bb	F	F	d	C	F
6	IV/IV	C	F	eb	F	F	d	C	F
8	V/IV	C	F	C#	F	F	d	C	F
10	V7/IV	C	F	f	F	F	d	C	F
12	F:=>I6	F	F	C#	F	F	d	C	F
14	V43	F	F	g	F	F	d	C	F
16	I	F	F	c	F	F	F	C	F
18	V2/V	F	C	C#	F	C	F	C	F
20	V6	F	F	C#	F	C	F	C	C
22	V	F	F	g	F	C	F	C	C
24	I6	F	F	b	F	C	F	F	F
26	V7/V	F	C	e	F	C	F	F	C
28	C=>I	C	C	d	F	C	F	F	C

Local keys vs. tonicization

- Accuracy
- Mirex

Modulation 1
 (departure key) C Major ----- ambiguity ----- (destination key) F Major

C:I vii°7/ii ii IV/IV V/IV V7/IV F:I⁶ V₄³

Position	Annotation	Modulation (B3)	Tonicization (B4)	B1	B2	M1	M2a	M2b	M3
0	C=>I	C	C	Bb	F	f	C	C	F
2	vii°7/ii	C	d	a	F	F	C	C	F
4	ii	C	C	Bb	F	F	d	C	F
6	IV/IV	C	F	eb	F	F	d	C	F
8	V/IV	C	F	C#	F	F	d	C	F
10	V7/IV	C	F	f	F	F	d	C	F
12	F:=>I6	F	F	C#	F	F	d	C	F
14	V43	F	F	g	F	F	d	C	F
16	I	F	F	c	F	F	F	C	F
18	V2/V	F	C	C#	F	C	F	C	F
20	V6	F	F	C#	F	C	F	C	C
22	V	F	F	g	F	C	F	C	C
24	I6	F	F	b	F	C	F	F	F
26	V7/V	F	C	e	F	C	F	F	C
28	C=>I	C	C	d	F	C	F	F	C

Local keys vs. tonicization

- Accuracy
- Mirex

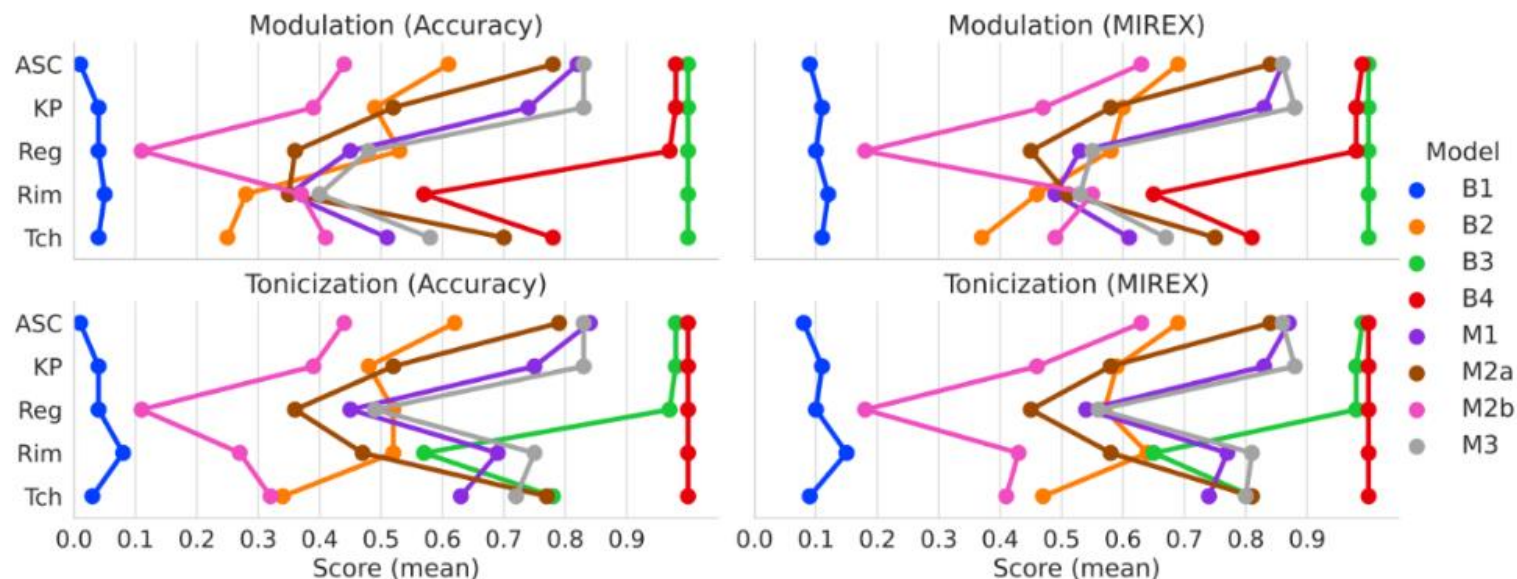
Modulation 1
 (departure key) C Major ----- ambiguity ----- (destination key) F Major

Chord symbols: C:I, vii^o7/ii, ii, IV/IV, V/IV, V⁷/IV, F:I⁶, V₄3

Position	Annotation	Modulation (B3)	Tonicization (B4)	B1	B2	M1	M2a	M2b	M3
0	C=>I	C	C	Bb	F	f	C	C	F
2	vii ^o 7/ii	C	d	a	F	F	C	C	F
4	ii	C	C	Bb	F	F	d	C	F
6	IV/IV	C	F	eb	F	F	d	C	F
8	V/IV	C	F	C#	F	F	d	C	F
10	V ⁷ /IV	C	F	f	F	F	d	C	F
12	F:=>I ⁶	F	F	C#	F	F	d	C	F
14	V ₄ 3	F	F	g	F	F	d	C	F
16	I	F	F	c	F	F	F	C	F
18	V ₂ /V	F	C	C#	F	C	F	C	F
20	V ₆	F	F	C#	F	C	F	C	C
22	V	F	F	g	F	C	F	C	C
24	I ₆	F	F	b	F	C	F	F	F
26	V ₇ /V	F	C	e	F	C	F	F	C
28	C=>I	C	C	d	F	C	F	F	C

Results

- Random guess (B1) is the worst-performing model
- Global key guess (B2) is OK, but except in one textbook, it is behind the specialized local-key-estimation models
- Use of tonicization varies by composer
- When there are many tonicizations (Rim and Tch), models seem to coincide better with tonicizations than modulations (unexpected!)



Model	Task	ASC	KP	Reg	Rim	Tch
B1	Mod	0.05	0.03	0.02	0.04	0.03
	Ton	0.05	0.03	0.02	0.07	0.05
B2	Mod	0.61	0.49	0.53	0.28	0.25
	Ton	0.62	0.48	0.52	0.52	0.34
M1	Mod	0.82	0.74	0.45	0.35	0.51
	Ton	0.84	0.75	0.45	0.69	0.63
M2a	Mod	0.78	0.52	0.36	0.35	0.70
	Ton	0.79	0.52	0.36	0.47	0.77
M2b	Mod	0.44	0.39	0.11	0.37	0.41
	Ton	0.44	0.39	0.11	0.27	0.32
M3	Mod	0.83	0.83	0.48	0.40	0.58
	Ton	0.83	0.83	0.49	0.75	0.72
B3	Mod	1.00	1.00	1.00	1.00	1.00
	Ton	0.98	0.98	0.97	0.57	0.78
B4	Mod	0.98	0.98	0.97	0.57	0.78
	Ton	1.00	1.00	1.00	1.00	1.00

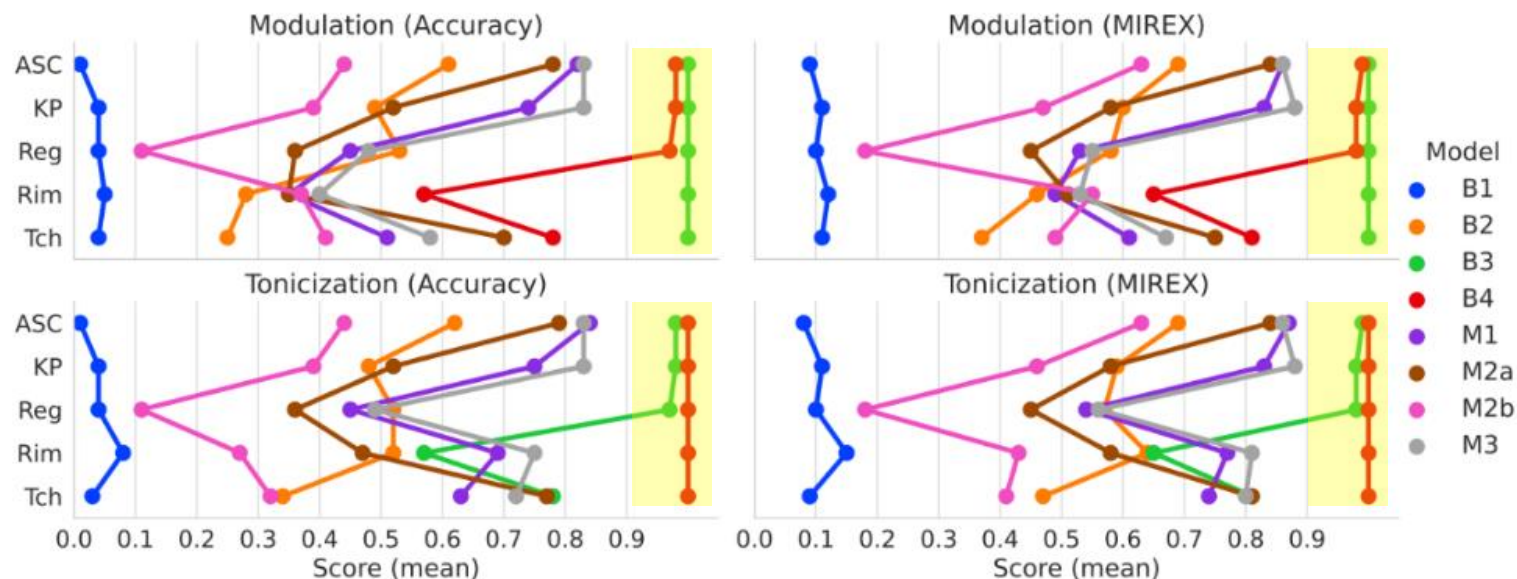
Accuracy weights

Model	Task	ASC	KP	Reg	Rim	Tch
B1	Mod	0.09	0.10	0.08	0.11	0.10
	Ton	0.10	0.10	0.08	0.13	0.13
B2	Mod	0.69	0.60	0.58	0.46	0.37
	Ton	0.69	0.59	0.57	0.64	0.47
M1	Mod	0.86	0.83	0.53	0.49	0.61
	Ton	0.87	0.83	0.54	0.77	0.74
M2a	Mod	0.84	0.58	0.45	0.51	0.75
	Ton	0.84	0.58	0.45	0.58	0.81
M2b	Mod	0.63	0.47	0.18	0.55	0.49
	Ton	0.63	0.46	0.18	0.43	0.41
M3	Mod	0.86	0.88	0.55	0.53	0.67
	Ton	0.86	0.88	0.56	0.81	0.80
B3	Mod	1.00	1.00	1.00	1.00	1.00
	Ton	0.99	0.98	0.98	0.65	0.81
B4	Mod	0.99	0.98	0.98	0.65	0.81
	Ton	1.00	1.00	1.00	1.00	1.00

MIREX weights

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B1	Mod	0.05	0.03	0.02	0.04	0.03
	Ton	0.05	0.03	0.02	0.07	0.05
B2	Mod	0.61	0.49	0.53	0.28	0.25
	Ton	0.62	0.48	0.52	0.52	0.34
M1	Mod	0.82	0.74	0.45	0.35	0.51
	Ton	0.84	0.75	0.45	0.69	0.63
M2a	Mod	0.78	0.52	0.36	0.35	0.70
	Ton	0.79	0.52	0.36	0.47	0.77
M2b	Mod	0.44	0.39	0.11	0.37	0.41
	Ton	0.44	0.39	0.11	0.27	0.32
M3	Mod	0.83	0.83	0.48	0.40	0.58
	Ton	0.83	0.83	0.49	0.75	0.72
B3	Mod	1.00	1.00	1.00	1.00	1.00
	Ton	0.98	0.98	0.97	0.57	0.78
B4	Mod	0.98	0.98	0.97	0.57	0.78
	Ton	1.00	1.00	1.00	1.00	1.00

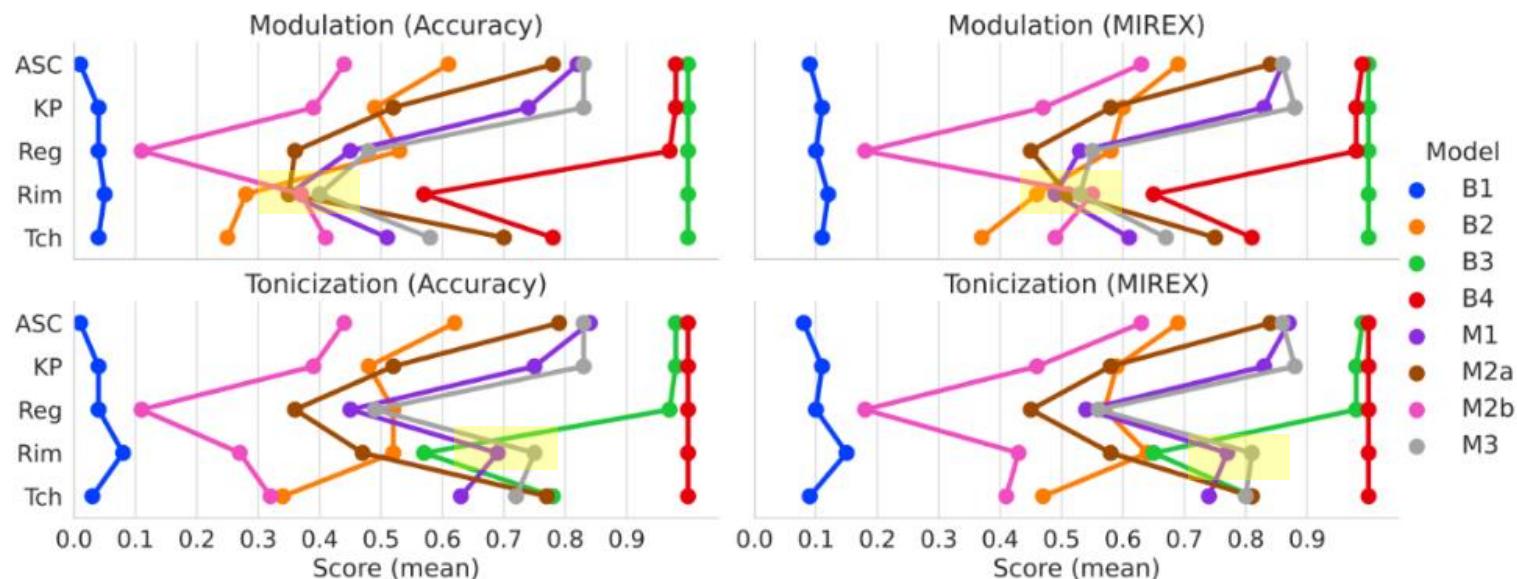
Accuracy weights

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	Ton	0.69	0.59	0.57	0.64	0.47
M1	Mod	0.86	0.83	0.53	0.49	0.61
	Ton	0.87	0.83	0.54	0.77	0.74
M2a	Mod	0.84	0.58	0.45	0.51	0.75
	Ton	0.84	0.58	0.45	0.58	0.81
M2b	Mod	0.63	0.47	0.18	0.55	0.49
	Ton	0.63	0.46	0.18	0.43	0.41
M3	Mod	0.86	0.88	0.55	0.53	0.67
	Ton	0.86	0.88	0.56	0.81	0.80
B3	Mod	1.00	1.00	1.00	1.00	1.00
	Ton	0.99	0.98	0.98	0.65	0.81
B4	Mod	0.99	0.98	0.98	0.65	0.81
	Ton	1.00	1.00	1.00	1.00	1.00

MIREX weights

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	Ton	1.00	1.00	1.00	1.00	1.00

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	Ton	0.87	0.83	0.54	0.77	0.74
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	Ton	0.84	0.58	0.45	0.58	0.81
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	Ton	0.99	0.98	0.98	0.65	0.81
B4	Mod	0.99	0.98	0.98	0.65	0.81
	Ton	1.00	1.00	1.00	1.00	1.00

MIREX weights

Conclusions

- Investigate relationship between local keys, modulations, and tonicizations
- Encoding modulation and tonicization ground truth in a dataset with 201 excerpts of music
- Method for comparing local keys to modulations and tonicizations
- Use of tonicizations among theorists varies considerably
- Generally, local-key-estimation models seem to coincide more with tonicizations

Thank you !



Dataset is available here :

https://github.com/DDMAL/key_modulation_dataset



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