

Exploiting expert domain knowledge for automatic symbolic music analysis

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Introduction

Motivations.

1

Phrase model

Hierarchical analysis.

2

Preliminary work

Modeling Roman numerals and function labels.

3

Current work

Extending analysis to symbolic musical surface.

4

Conclusions

Summary and future directions.

5

About me

Background and research interests

- ▶ **Master's degrees in music composition and music theory and a PhD music technology**
- ▶ **Research in the areas of music information retrieval, music cognition, and music theory**
- ▶ **Music performance analysis**
 - Automatically extracting perceptually-meaningful performance data from audio recordings
 - Developing models of how musicians perform
 - ***Generalizing across different pieces***
 - Understanding listener reception

And would it be useful to teach this to a computer?

Köch. Verz. N^o 265.

TEMA.



What do music theorists teach?

And would it be useful to teach this to a computer?

The image displays two staves of musical notation, likely piano music, illustrating musical structure. The top staff is marked with a yellow 'A' above the first measure and a yellow 'B' above the first measure of the second system. The first measure of the top staff is labeled 'TEMA.' and 'mf'. The bottom staff is marked with a yellow 'A' above the first measure of the first system and a yellow 'A' above the first measure of the second system. The notation includes treble and bass clefs, a 2/4 time signature, and various musical notes and rests. Dashed orange boxes highlight specific musical phrases in both staves, and solid yellow vertical lines mark the boundaries of the sections labeled A and B.

What do music theorists teach?

And would it be useful to teach this to a computer?

TEMA.



mf

C+ F+ C+ d- b⁰ C+ a- d- G+ C+

What do music theorists teach?

And would it be useful to teach this to a computer?

VAR. I
legato

The image displays a musical score for a piece labeled "VAR. I" in 2/4 time. The score consists of two systems, each with a piano (treble) staff and a bass (bass) staff. Yellow circles are drawn around specific notes in both staves of each system. Below the piano staff of the first system, the following chords are labeled: C+, F+, C+, d-, and b⁰. Below the piano staff of the second system, the following chords are labeled: C+, a-, d-, G+, and C+.

C+ F+ C+ d- b⁰

C+ a- d- G+ C+

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Hierarchical music analysis

Phrase model of harmonic function.

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4

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5

Hierarchical music analysis

Phrase Model

► **Phrases are complete musical statements**

- Tonic function (T)
 - at the beginning of a phrase it serves to establish the tonal center
 - at the end of a phrase it provides closure
- Pre-dominant function (PD)
 - prepares for the arrival of the dominant function
 - may not be present in short phrases
- Dominant function (D)
 - creates a sense of tension that is resolved by the return of the tonic function

Phrase model

Simple example

Haydn, String Quartet in D major, "The Frog," op. 50, no. 6, Hob 111.49, Menuetto

The image displays a musical score for a string quartet in D major, 3/4 time. The score consists of four staves. The first staff (treble clef) features a melodic line with a forte (*f*) dynamic marking. The second staff (treble clef) has a forte (*f*) dynamic marking. The third staff (bass clef) has a forte (*f*) dynamic marking. The fourth staff (bass clef) has a forte (*f*) dynamic marking. Below the staves, a harmonic analysis is provided, showing the progression of chords: D: I, IV, V⁷, I. The chords are labeled as I, IV, V⁷, and I. The V⁷ chord is further labeled as D. A bracket under the V⁷ and I chords is labeled PAC, indicating a phrase ending.

Stephen Laitz. *The Complete Musician*, p 201

Phrase model

Complex example

Mozart, Piano Sonata in D major, K. 576, Allegro

The image displays two systems of musical notation for the first movement of Mozart's Piano Sonata in D major, K. 576. The first system consists of two staves (treble and bass clef) with a key signature of two sharps (F# and C#) and a 3/4 time signature. The music begins with a forte (f) dynamic and includes trills (tr) and a mezzo-forte (mf) section. The second system starts at measure 4 and continues with various dynamics and articulations. Below each system is a harmonic analysis line with Roman numerals and other musical symbols.

First System Harmonic Analysis:

D: I
T
T

V₂⁴ I⁶ V⁶ I ii⁶ PD

Second System Harmonic Analysis:

4

V₄⁶ — 5 — 3 ii (mf)

(vii^{o6} of ii) ii⁶ V I

(BRD) PD D—T PAC

HC

Phrase model

Back to Mozart

TEMA.

C+ F+ C+ d- b^o C+ a- d- G+ C+

I IV I ii vii^o I vi ii V I

T (PD D T) PD D T

T PD D T

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Rule-based Model

Roman Numeral- and Phrase-level Rules

- ▶ **18 Roman numeral-level rules were derived from the Laitz chapters on diatonic harmony (Ch. 7–14)**
 - Example
 - “I6 is an ideal choice for a passing chord between ii and ii6. The I6 chord is subordinate to the prevailing pre-dominant”
 - IF currentChord == I6 AND previousChord == ii AND nextChord == ii6
THEN currentFunction = predominant
- ▶ **3 phrase-level rules to ensure that the phrase model was adhered to**

Rule-based Model

Roman numeral-level rules

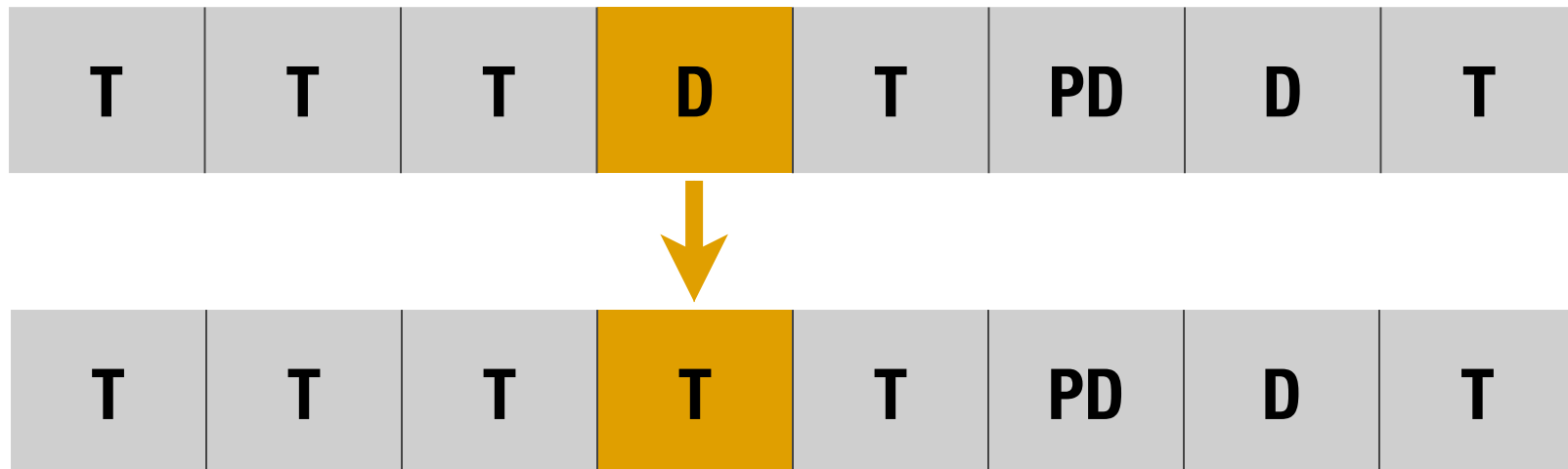
I Chords		
1	Opening and closing I chords	T
2	I ⁶⁴ followed by a V chord	D
3	I ⁶ chords between a ii and a ii ⁶	PD
4	I ⁶⁴ chords between a IV and a IV ⁶	PD
ii Chords		
5	ii chords	PD
6	ii ⁶⁵ chords before or after a I chord	T
iii Chords		
7	iii chords	T
IV Chords		
8	IV chords	PD
9	IV chords before or after a I chord	T
10	IV ⁶ chords between I and I ⁶ chords	T
11	IV ⁶ chords between V and V ⁶ chords	D
V Chords		
12	V and V ⁷ chords	D
13	V ⁶ between two I chords	T
vi chords		
14	vi chords	T
15	vi chords between two V chords	D
vii ^o Chords		
16	vii ^o chords	D
17	vii ^{o 6} between two I chords	T
Second Inversion Chords		
18	Any remaining second inversion chords are assigned the function of the previous sonority	

**Direct
Labels**

**Multiple-
progressions**

Rule-based Model

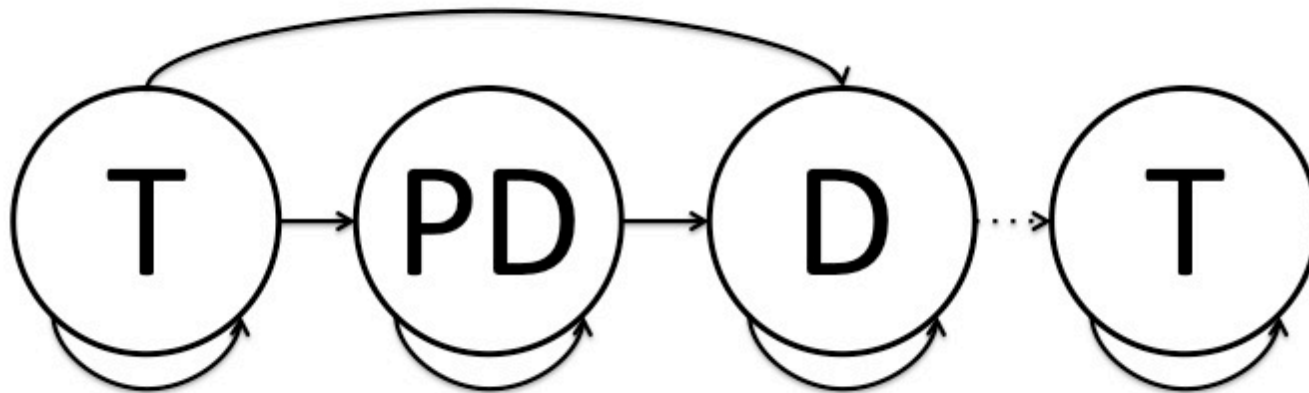
Phrase-level Rules	
1	No P or D between two Ts
2	No T or D between two PDs
3	No T or P between two Ds



Exemplar Model

Hidden-Markov model

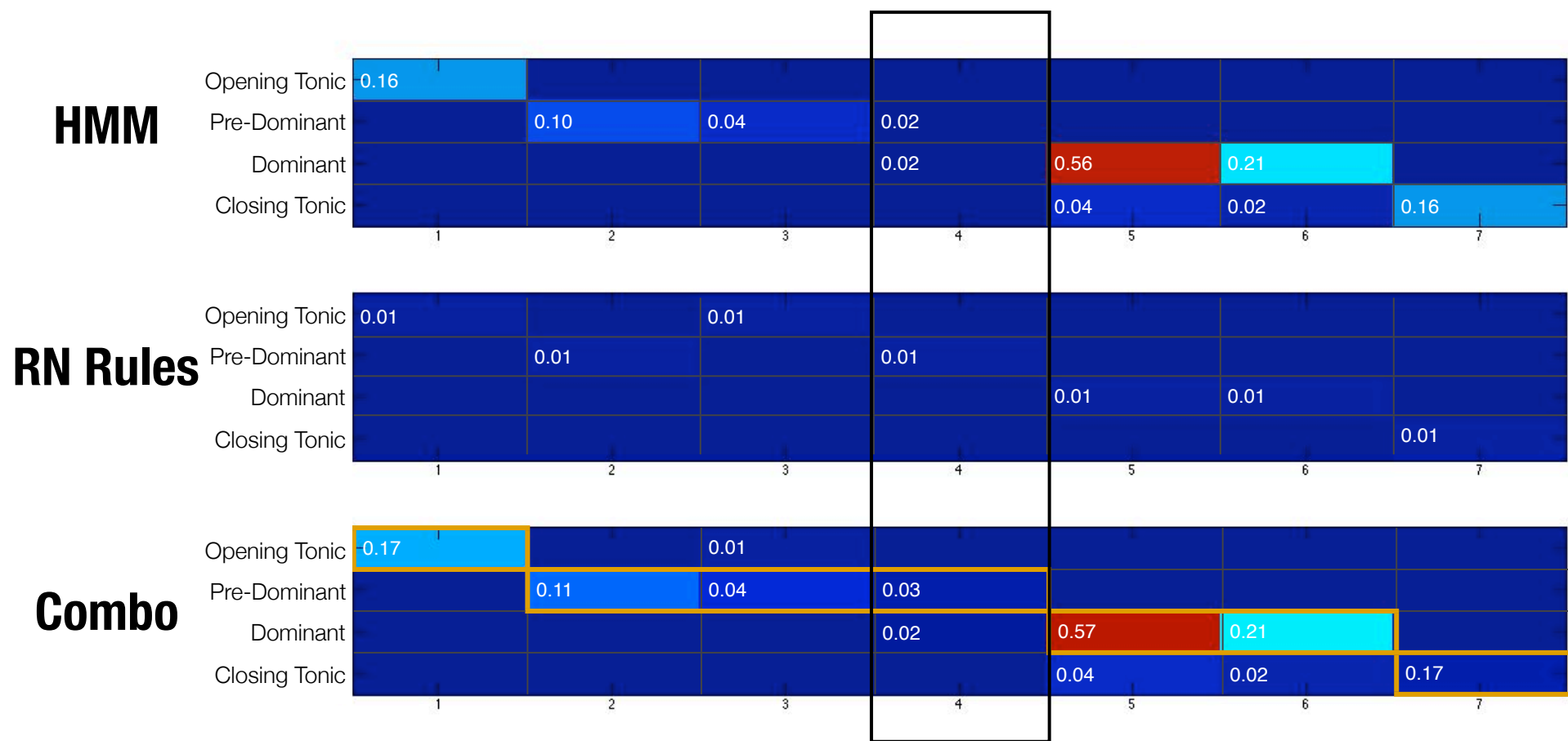
- ▶ **Observations:** chord labels
 - With and without duration information
- ▶ **Predictions:** function labels
- ▶ **State space:**



Combined Model

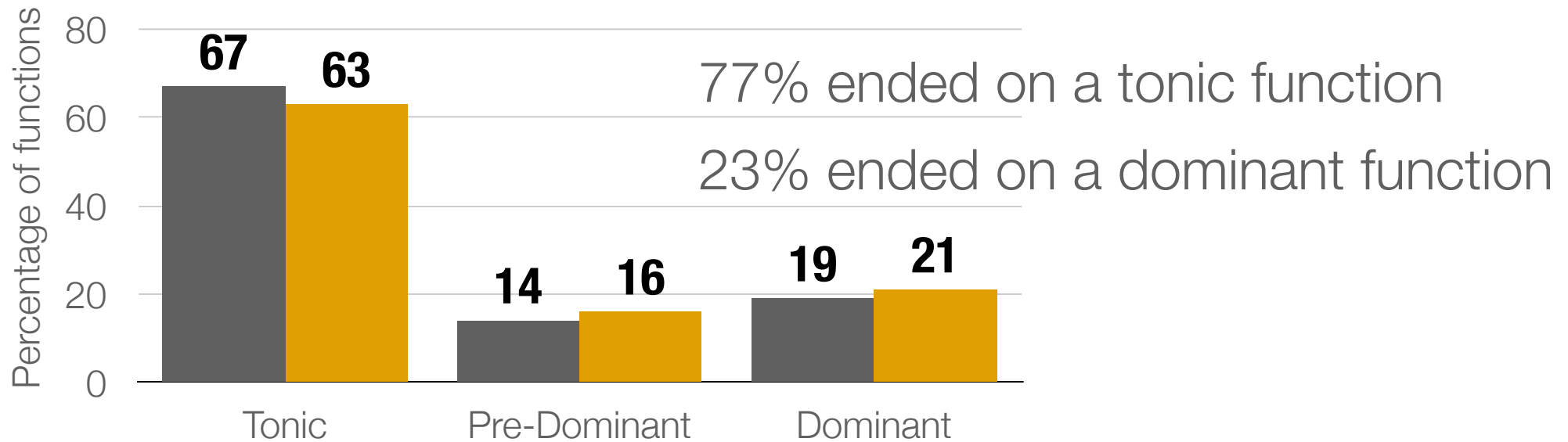
Rule-based + Exemplar-based

- Output of rules-based model used as prior the exemplar-based model's HMM

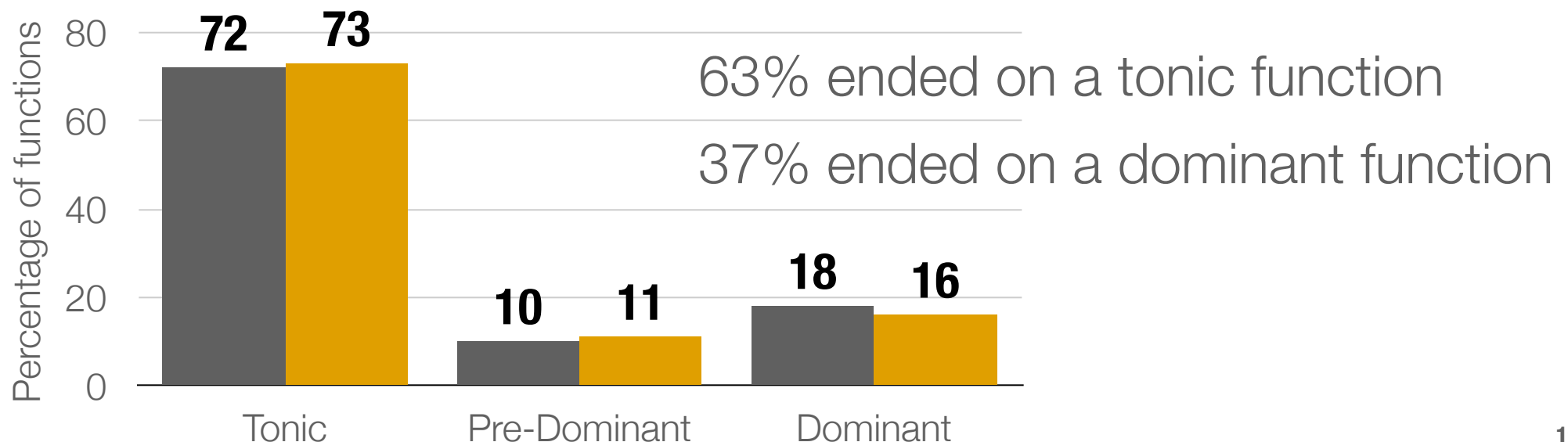


Textbook (85 phrases)

■ Duration
■ Non-Duration



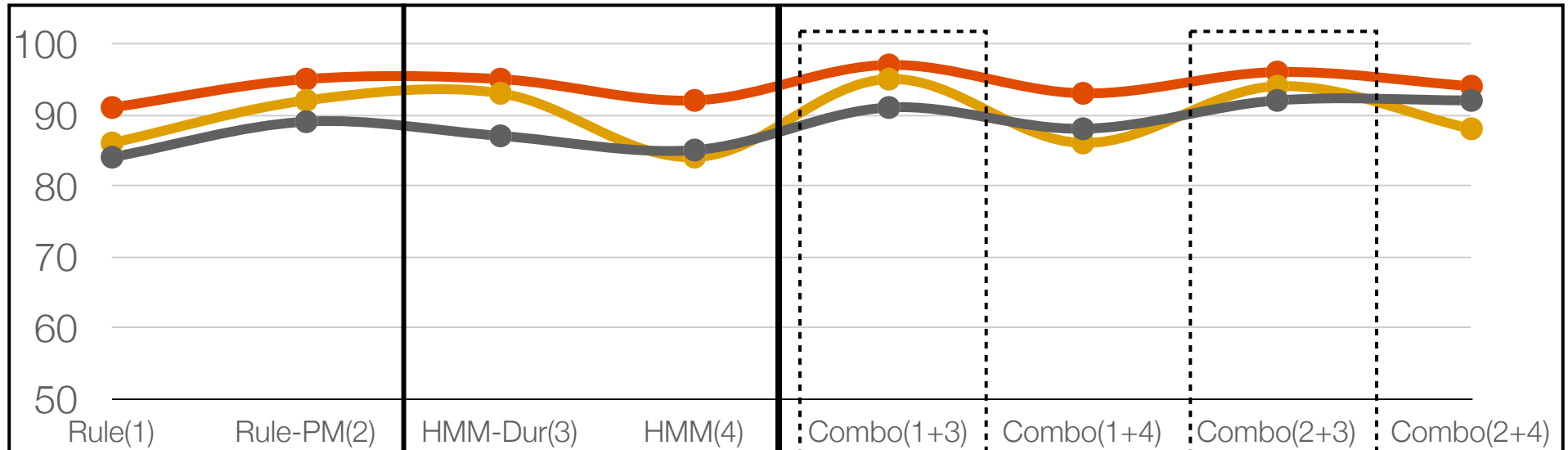
Workbook (51 phrases)



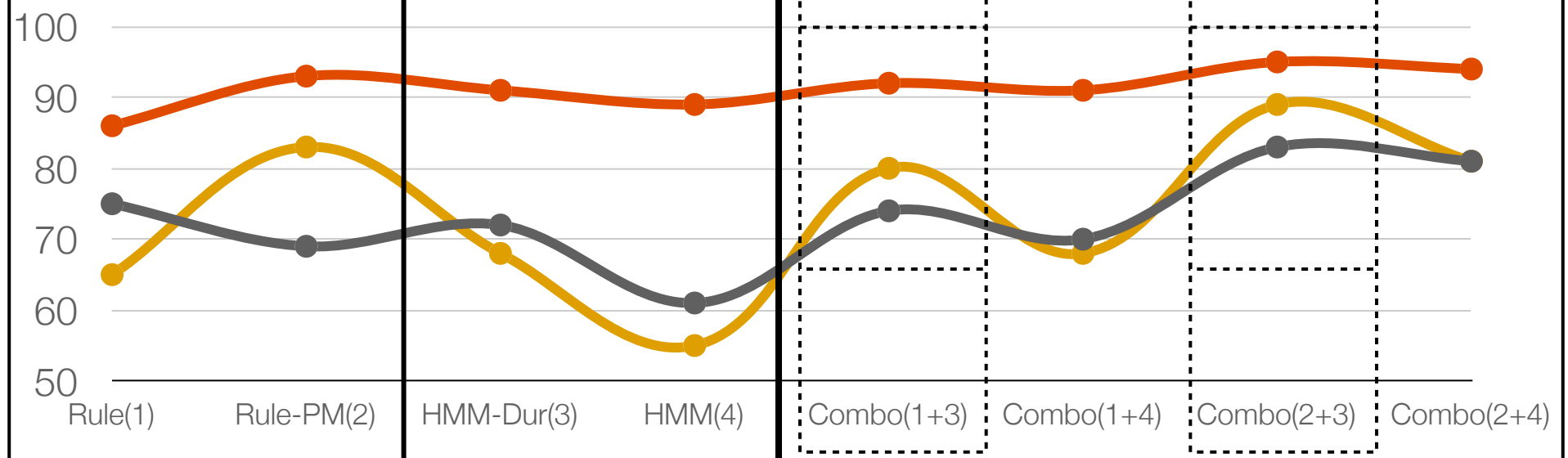
Textbook

Phrase rules Duration information

- Pre-Dominant
- Dominant
- Tonic



Workbook



Summary

Rules versus exemplar-based systems

- ▶ **There is unique information captured by both the Rule- and Exemplar-based models**
 - phrase-level rules may be overzealous in re-assigning pre-dominant function labels
 - duration modeling is useful for the exemplar-based model

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Analyzing the music surface

Using Conditional Random Fields

partition function

potential function

$$p(y|x; \theta) = \frac{1}{Z(x, \theta)} \prod_{i=1}^n \left(\exp \left(\sum_{j=1}^{D_1} \theta_j f_j(y_{i-1}, y_i, x, i) \right) \prod_{j=1}^{D_2} \phi_j(y_{i-1}, y_i, x, i) \right)$$

feature functions

potentials

i - each position in sequence output

y_{i-1} - previous output label

x - sequence of observations

y_i - current output label

bass note
intervals above the bass
note length
metrical position

joint estimates of Roman
numeral and function label

Transition feature functions used to incorporate rules

Potentials defined in order to restrict function order

Theme and Variation Data set

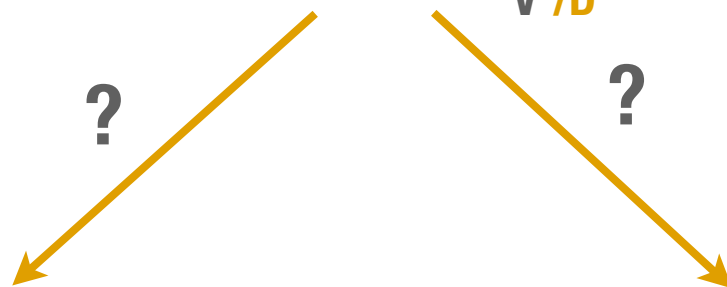
Expert annotated

- ▶ **Who:** Mozart and Beethoven
- ▶ **What:** 27 Theme and Variation for piano sets
 - 10 by Mozart and 17 by Beethoven
- ▶ **When:** ~1765–1810
- ▶ **How:** Each piece annotated with Roman numeral and function labels by two music theory PhD students

Classification

Matching variations to their themes

I/T V⁷/D I/D V⁷/D I/T



I/T V⁶⁵/T V⁷/T I/T V⁷/D

I/T V⁷/D I/D V⁷/D I/T

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4

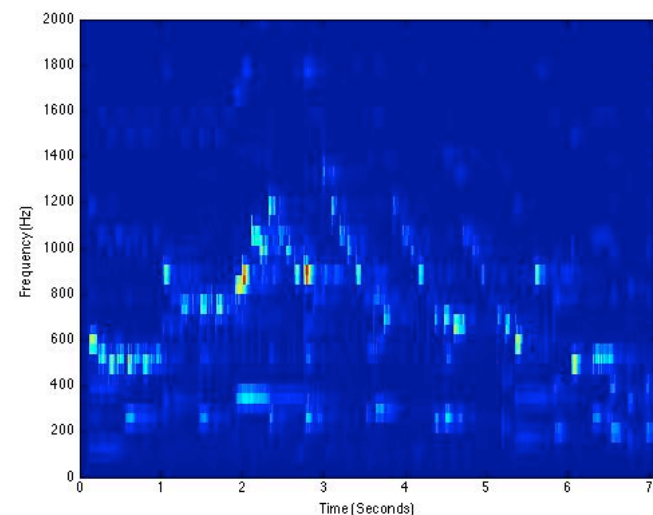
Conclusions

Future directions and summary.

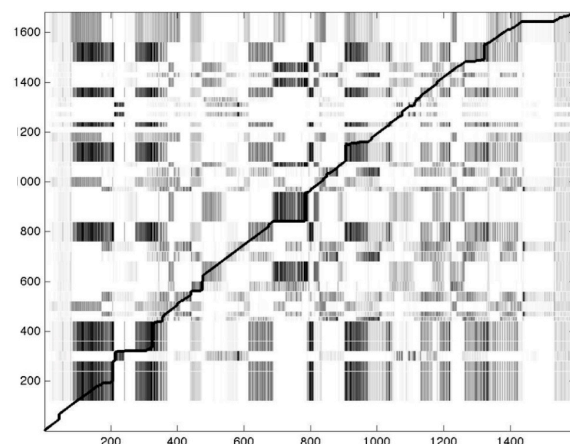
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Learning audio features

Using MIDI-audio alignment



MIDI



Audio

**Mid-level
audio features**

Summary

Take away messages

- ▶ **There is a learnable relationship between Roman numeral labels and function labels but certain heuristics are useful for refining the learned model**
- ▶ **The relationship between Roman numeral and functions is potentially useful for parsing the musical surface**
- ▶ **The ability to determine what is structurally significant in the symbolic musical surface is potentially useful for learning audio features**

Thank you!