Exploiting expert domain knowledge for automatic symbolic music analysis

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Introduction 1
Motivations.

Phrase model 2
Hierarchical analysis.

Preliminary work 3
Modeling Roman numerals and function labels.

Current work 4
Extending analysis to symbolic musical surface.

Conclusions 5
Summary and future directions.

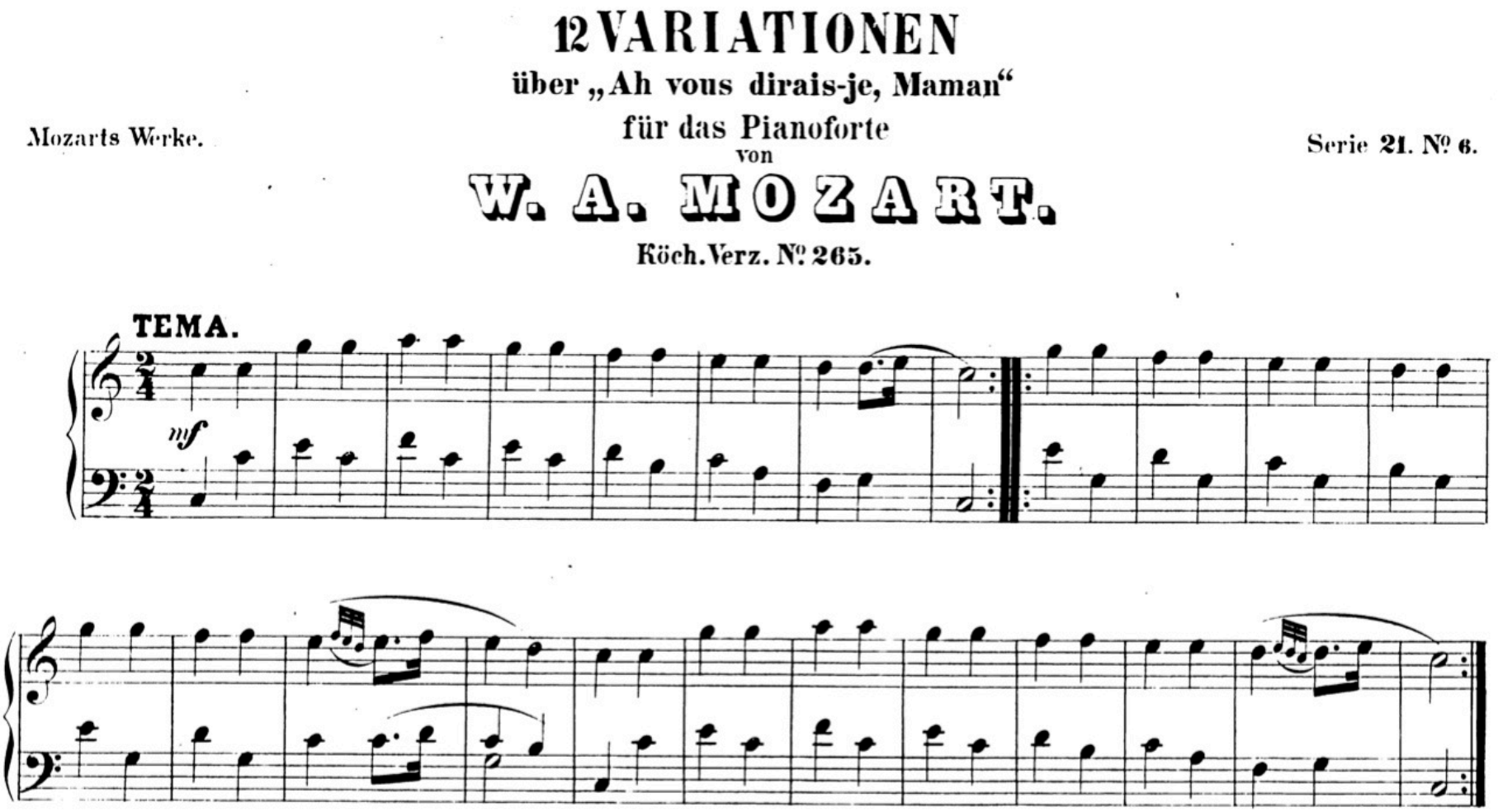
About me

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

What do music theorists teach?

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



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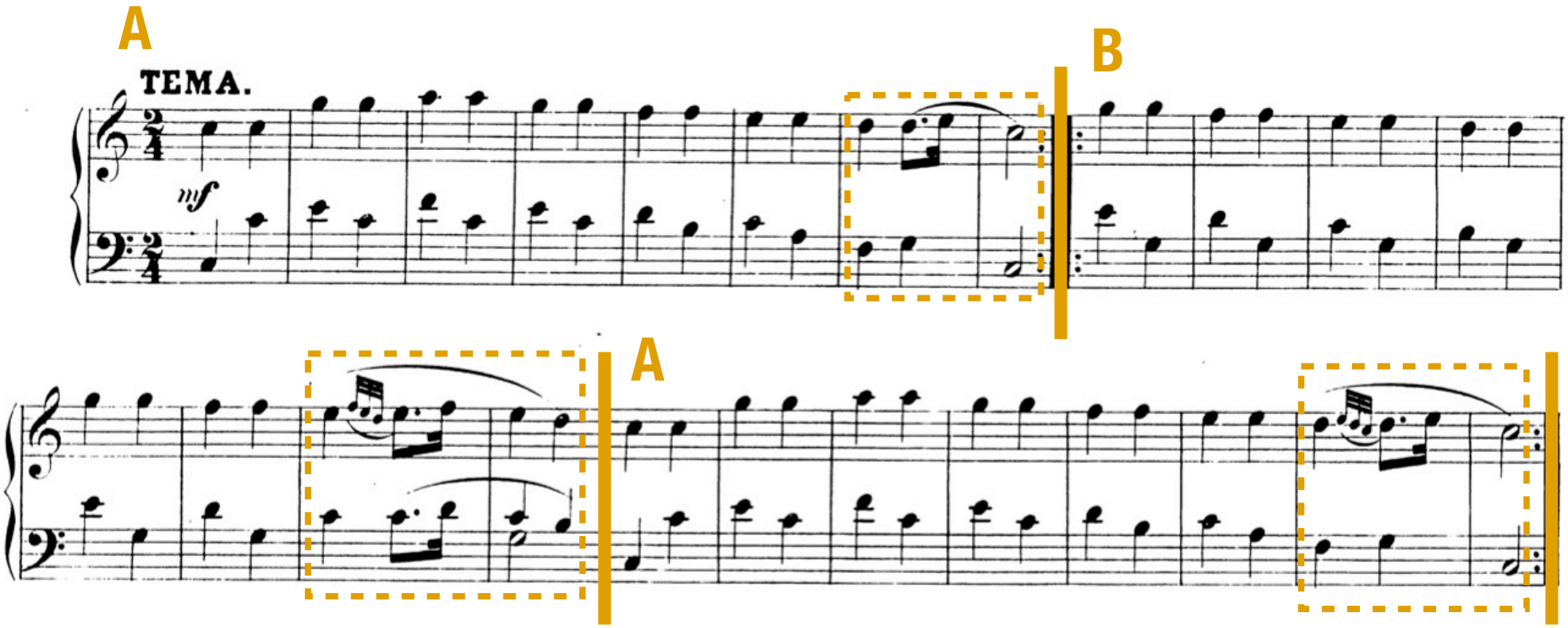

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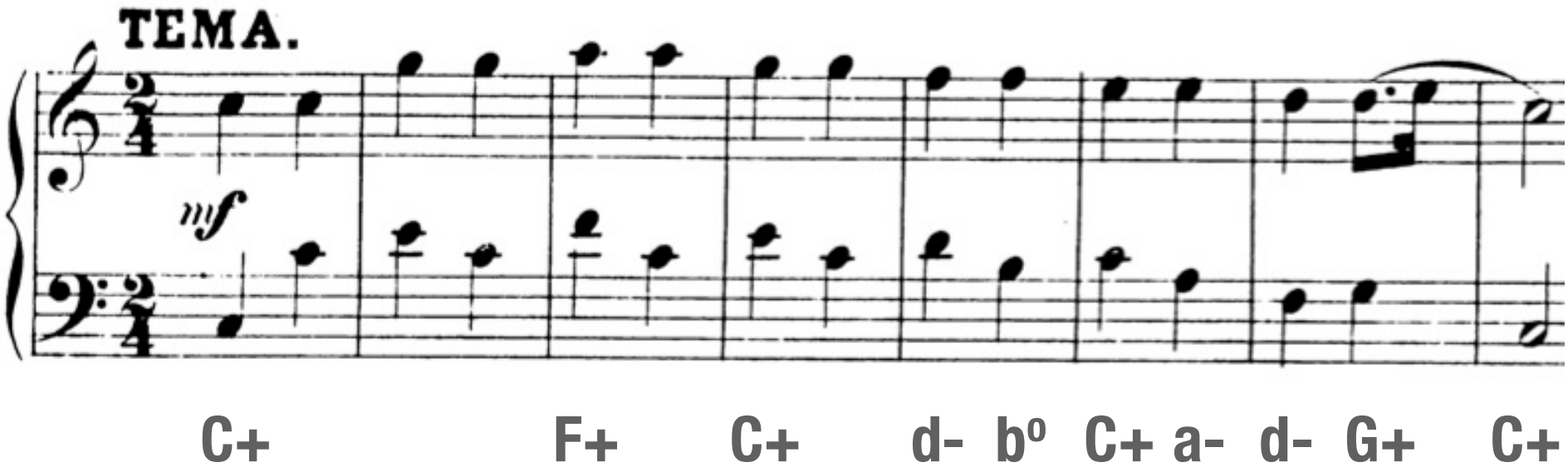

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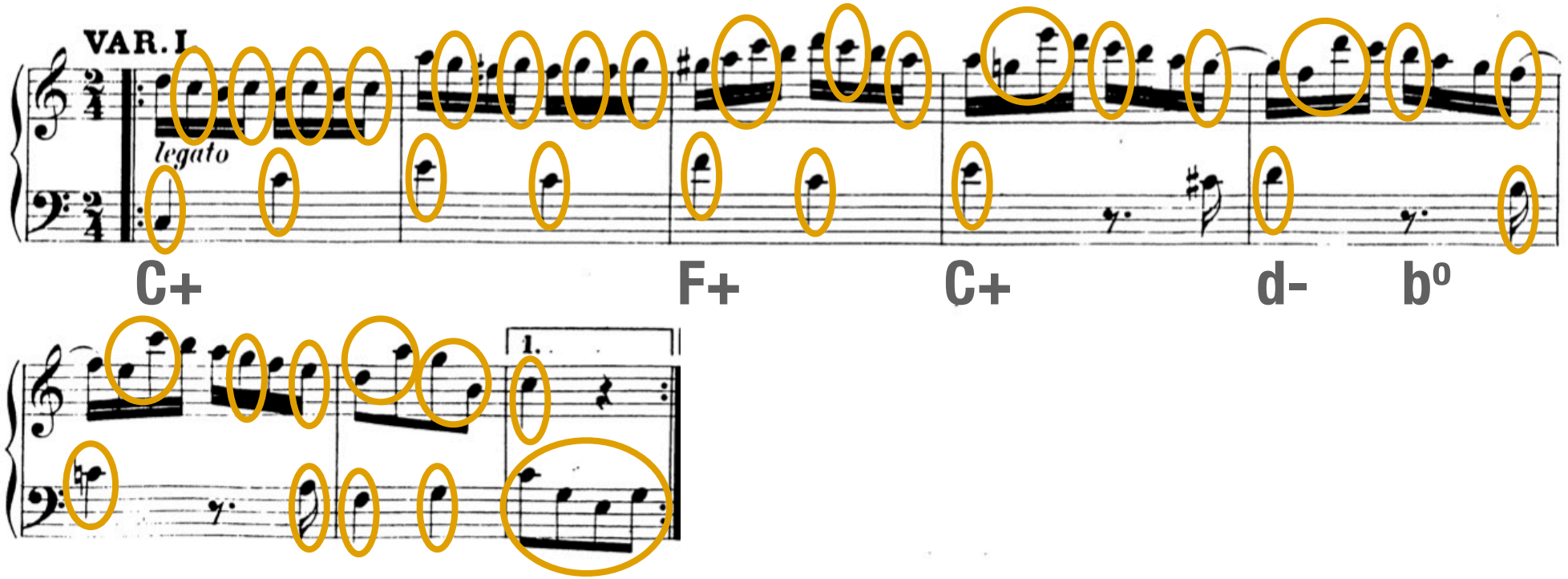

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Phrase model of harmonic function.

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Hierarchical music analysis

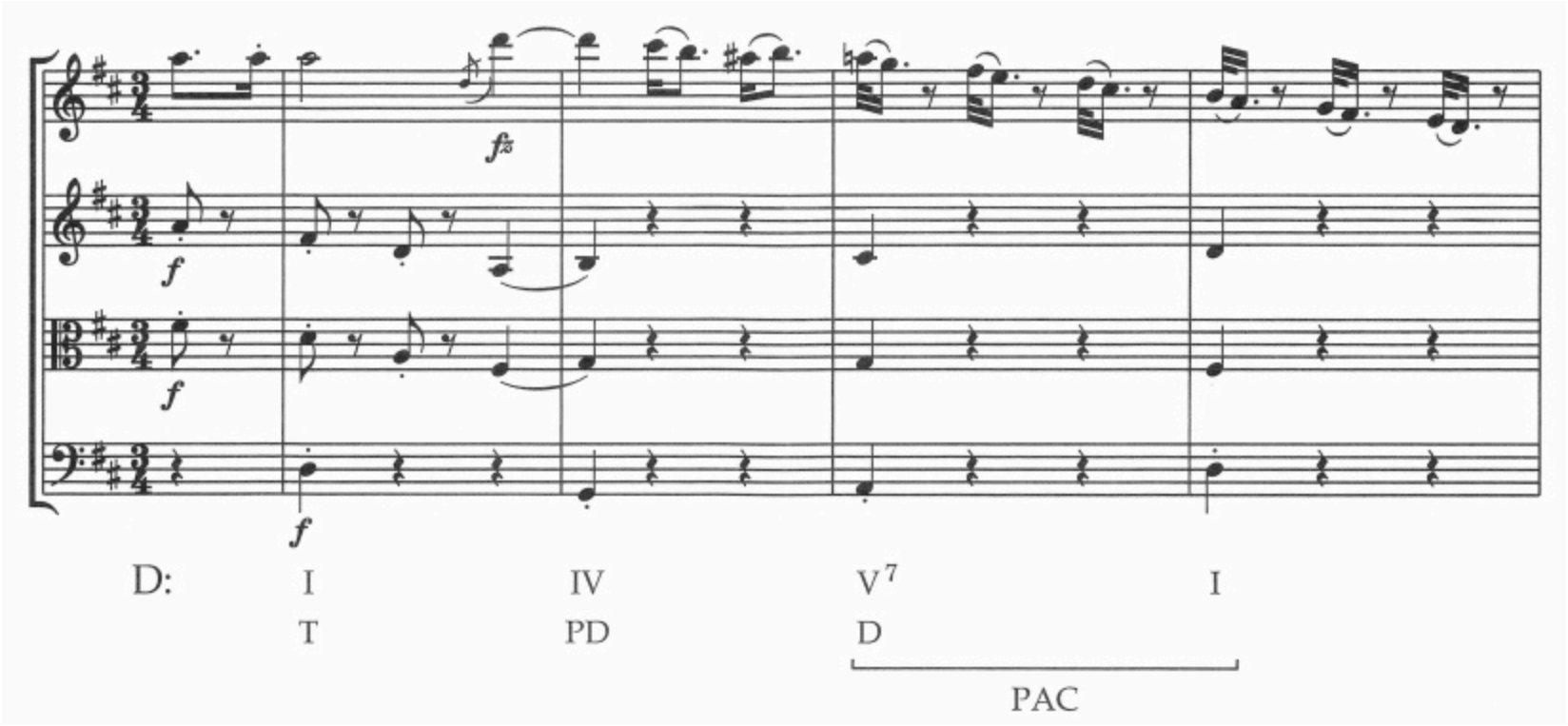
Phrase Model

- **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

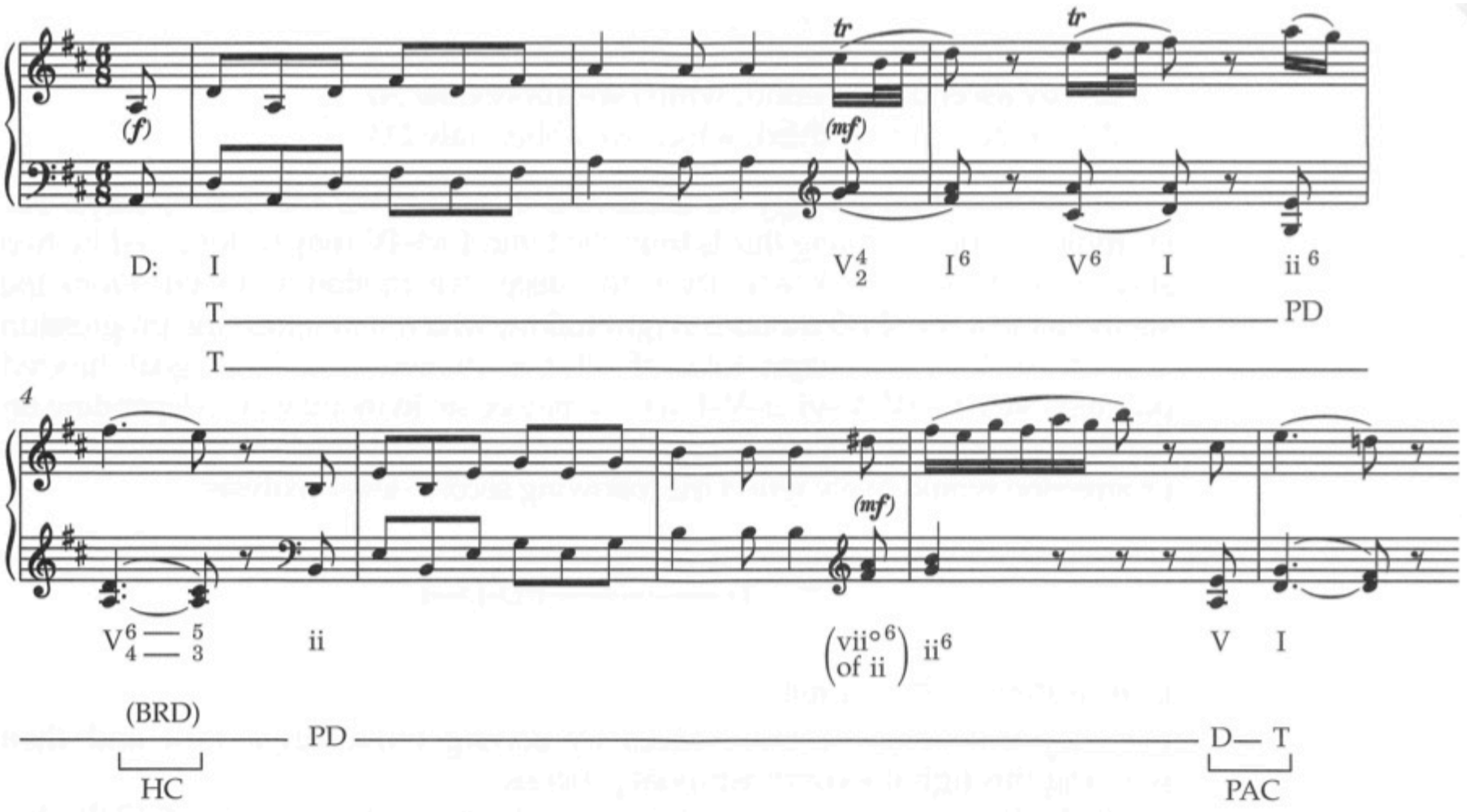


Stephen Laitz. *The Complete Musician*, p 201

Phrase model

Complex example

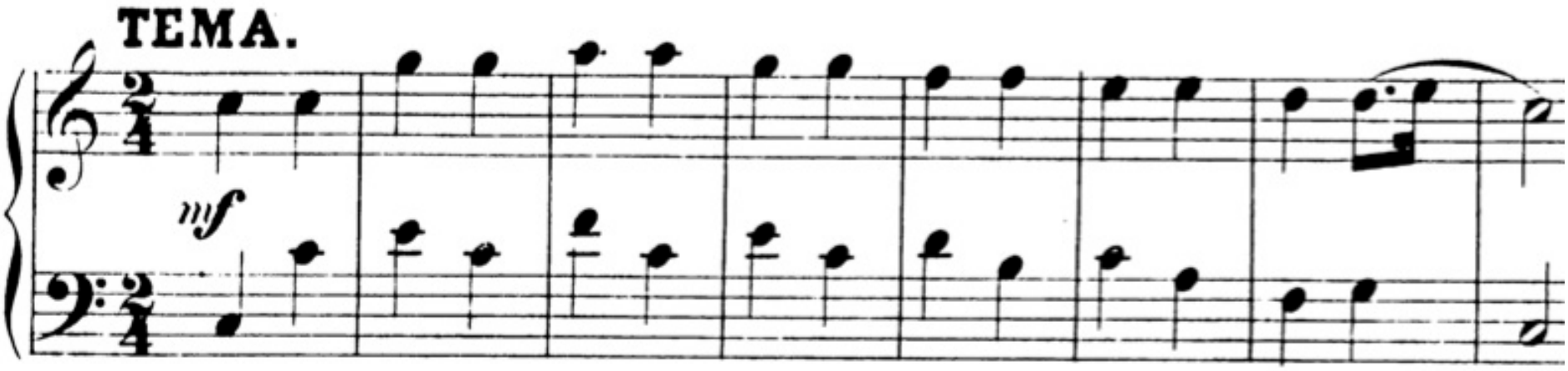
Mozart, Piano Sonata in D major, K. 576, Allegro



Stephen Laitz. *The Complete Musician*,, p 293

Phrase model

Back to Mozart



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

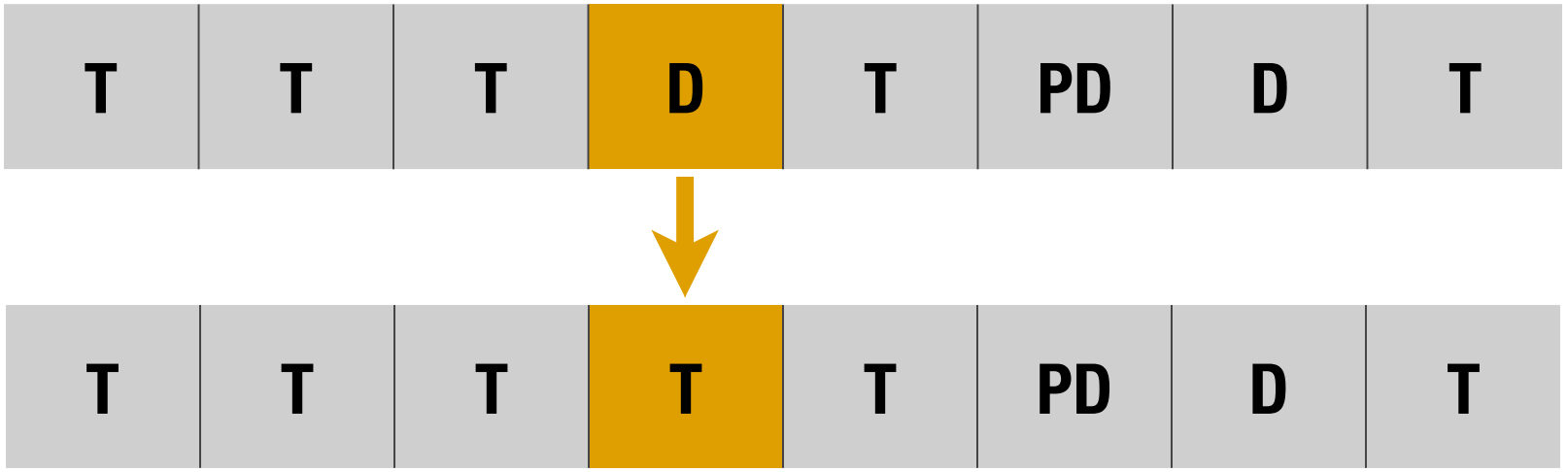
Direct Labels

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° Chords		
16	vii° chords	D
17	vii° ^{6} between two I chords	T
Second Inversion Chords		
18	Any remaining second inversion chords are assigned the function of the previous sonority	

Multiple-progressions

Rule-based Model

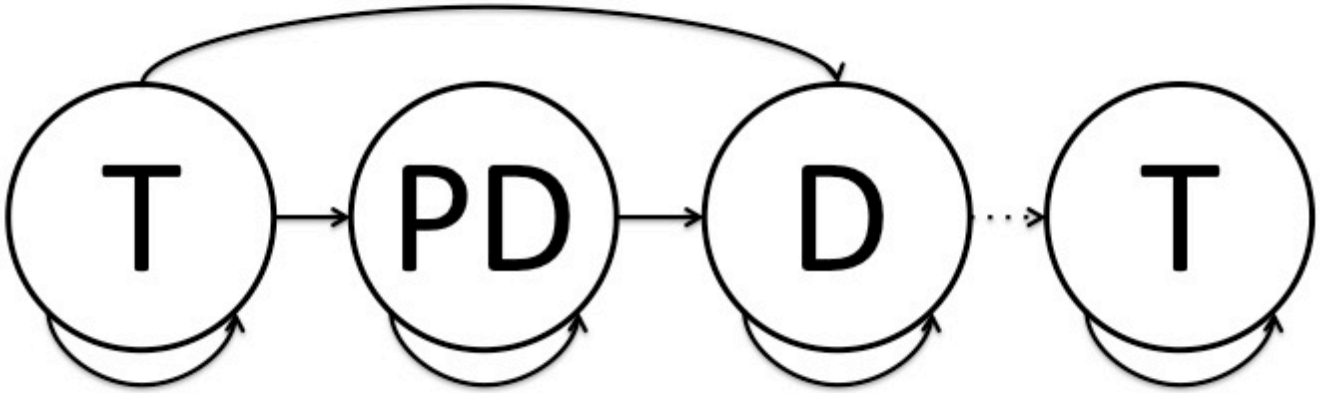
Phrase-level Rules	
1	No P or D between two Ts
2	No T or D between two PDs
3	No T or P between two Ds



Exemplar Model

Hidden-Markov model

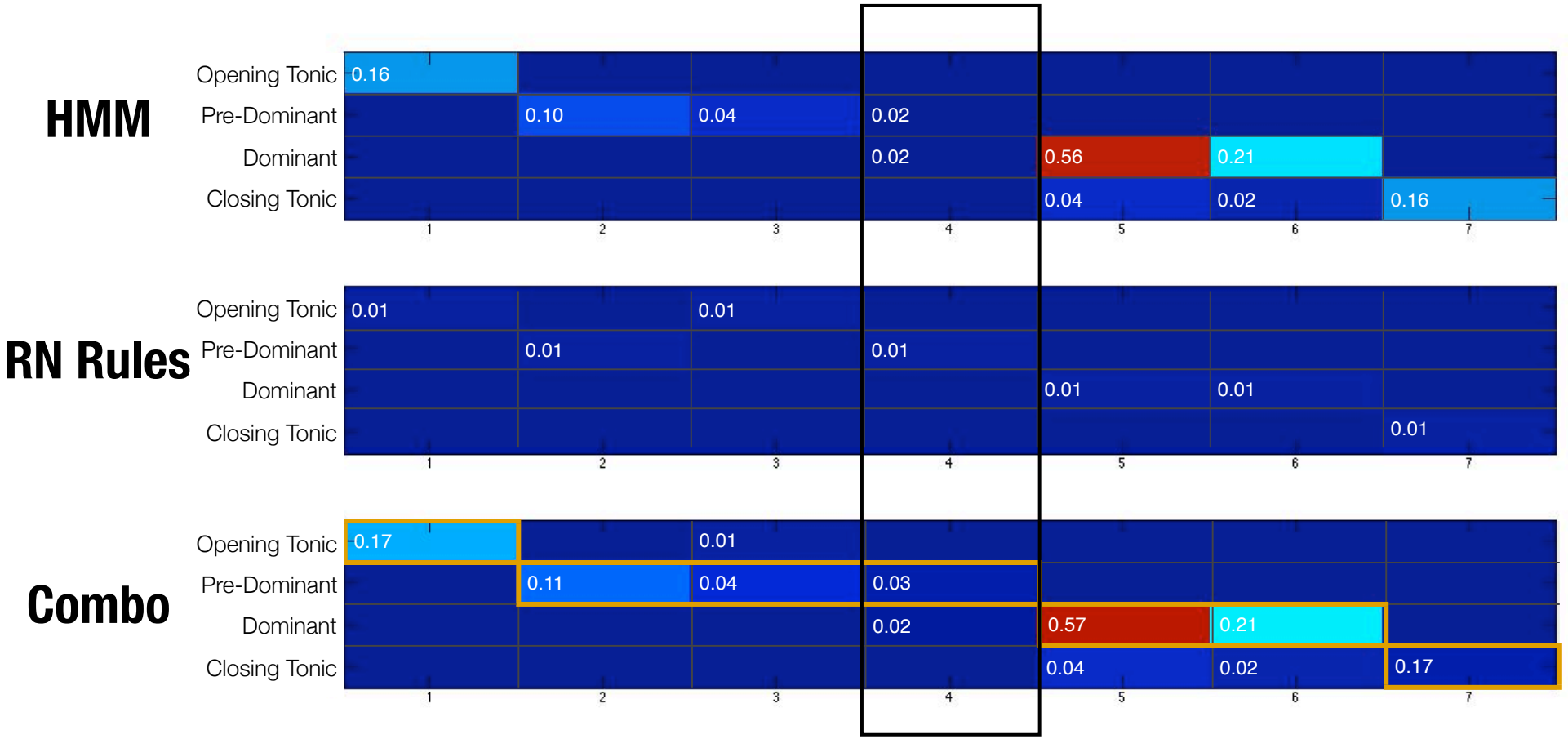
- **Observations:** chord labels
  - With and without duration information
- **Predictions:** function labels
- **State space:**



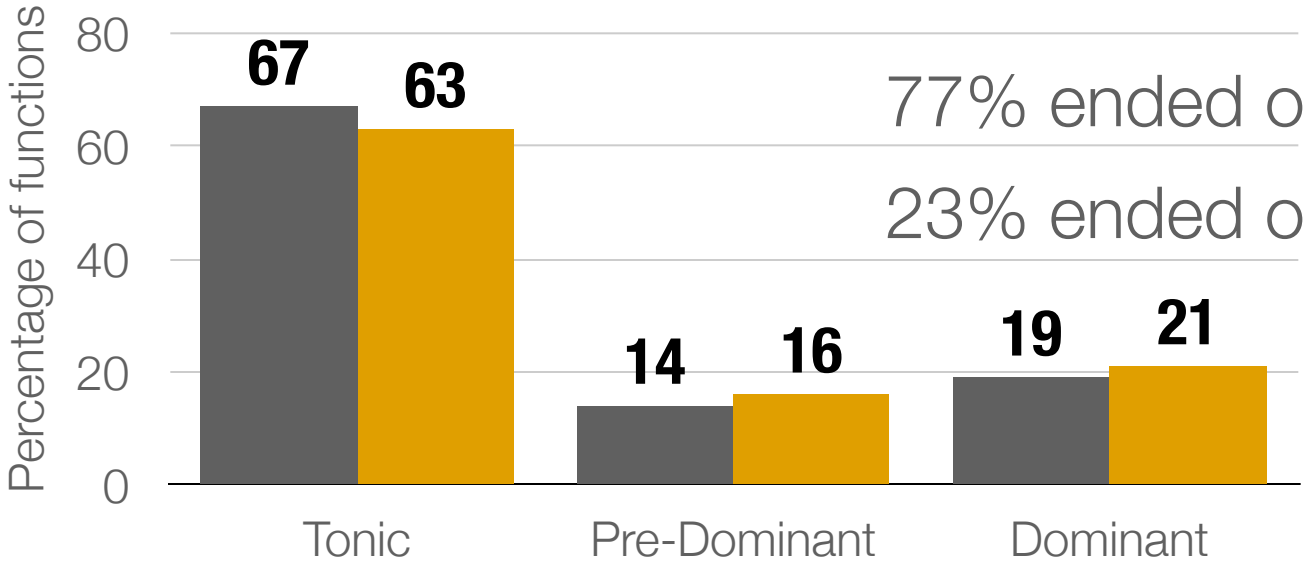
Combined Model

Rule-based + Exemplar-based

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



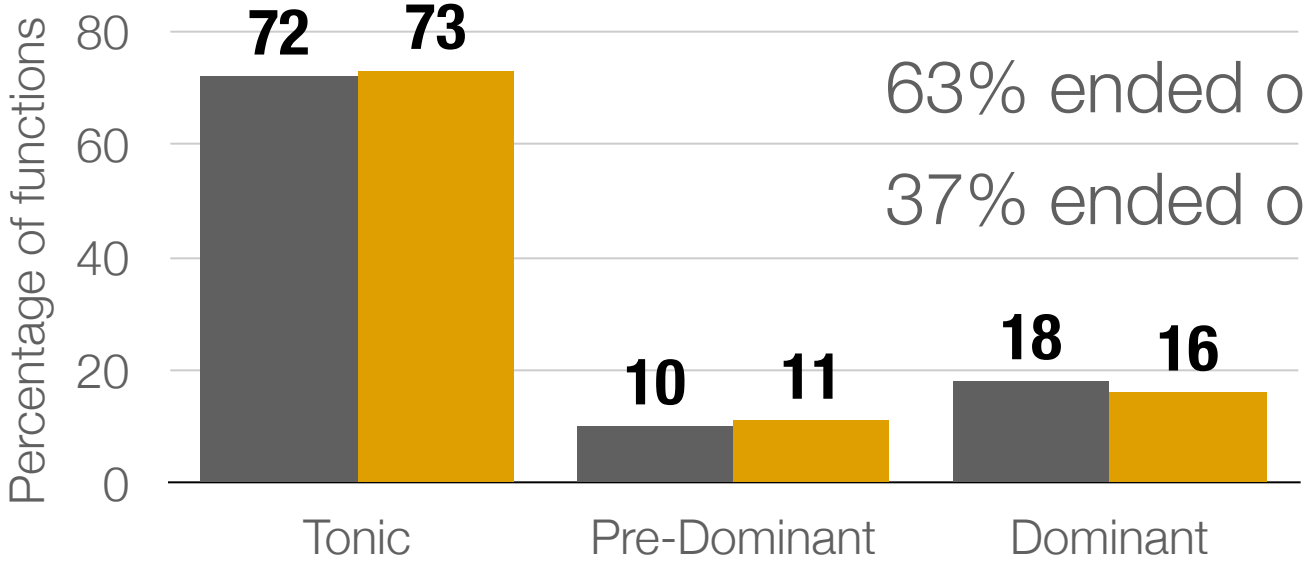
Textbook (85 phrases)



77% ended on a tonic function

23% ended on a dominant function

Workbook (51 phrases)

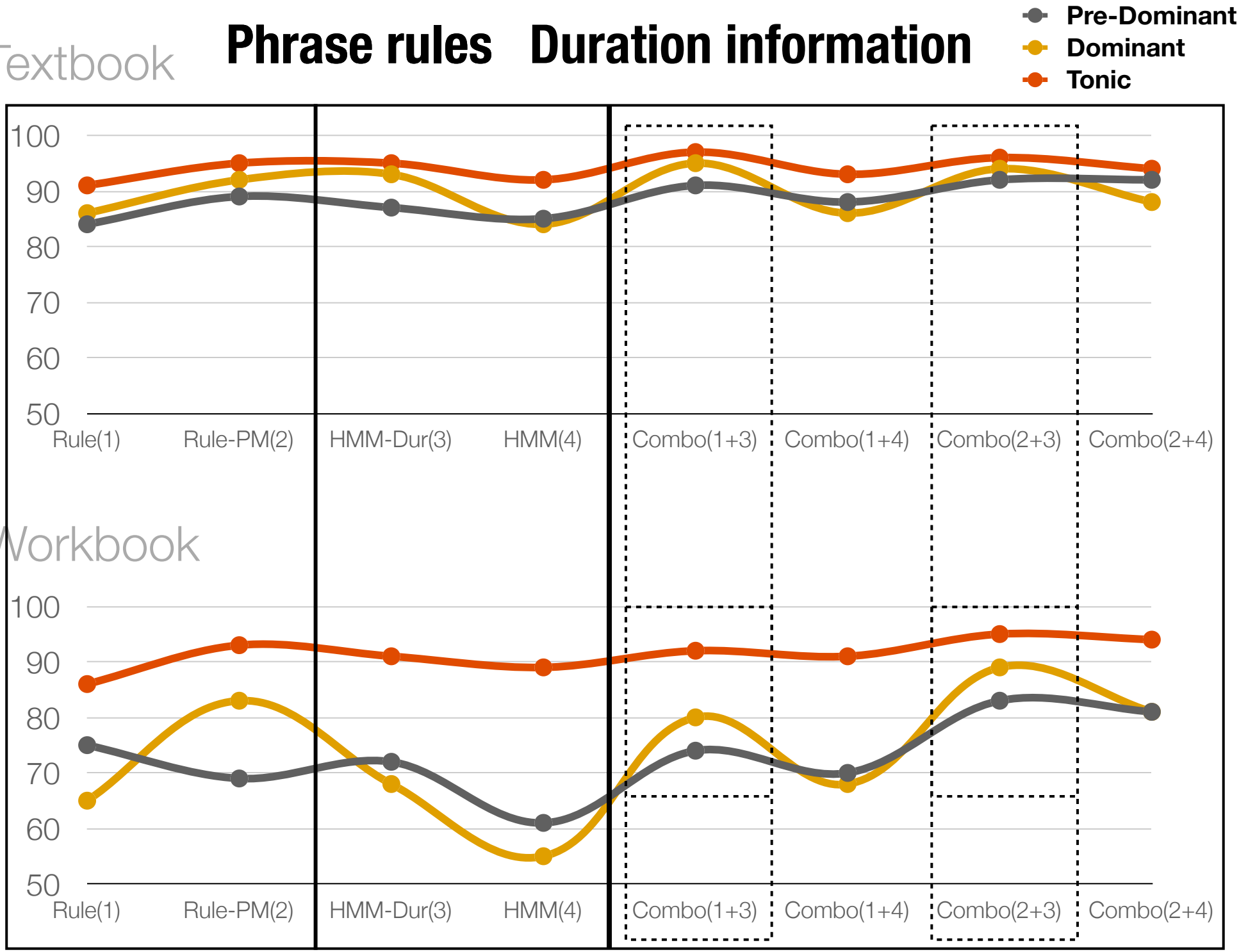


63% ended on a tonic function

37% ended on a dominant function

Textbook

Phrase rules Duration information



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

x - sequence of observations

- bass note
- intervals above the bass
- note length
- metrical position

y_{i-1} - previous output label

y_i - current output label

- joint estimates of Roman numeral and function label

Transition feature functions used to incorporate rules

Potentials defined in order to restrict function order

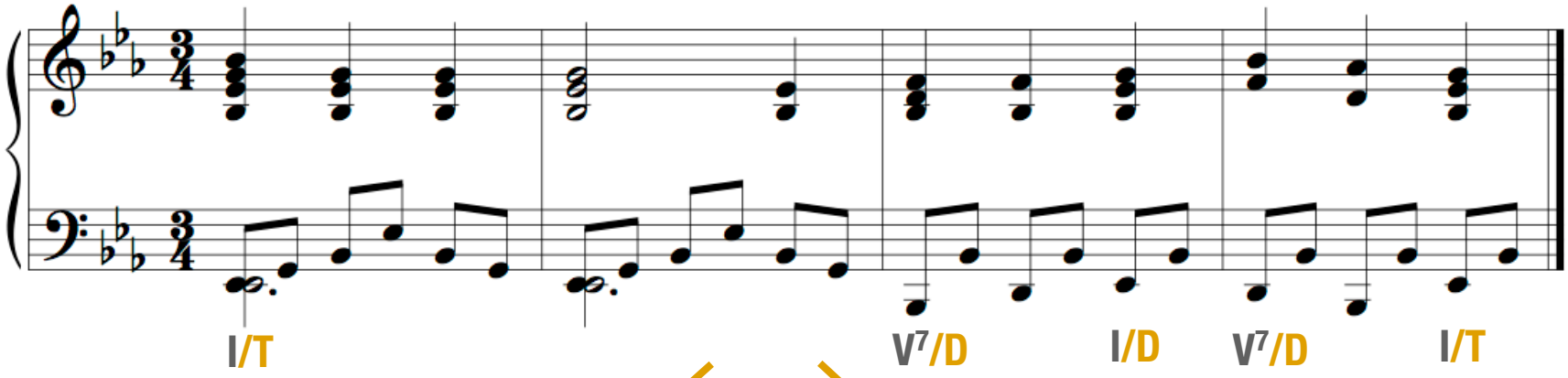
Theme and Variation Data set

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



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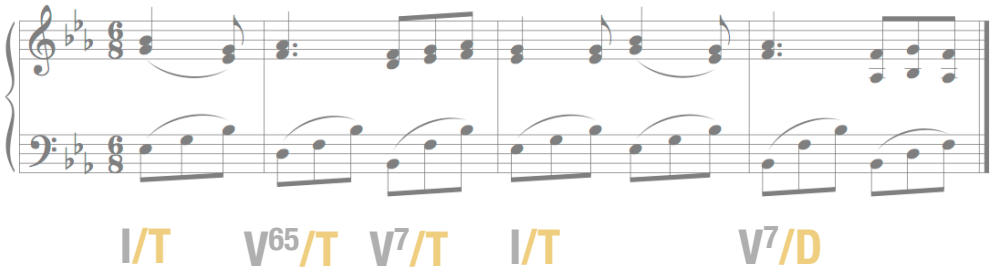

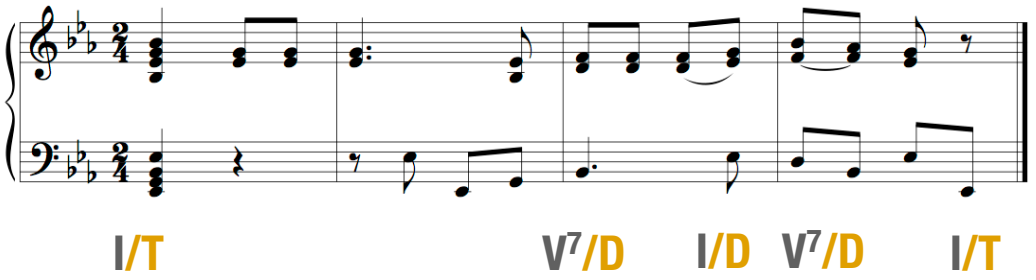

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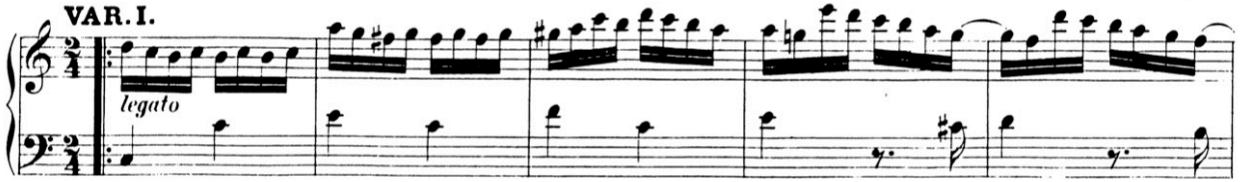
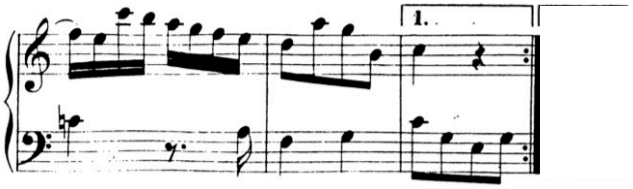
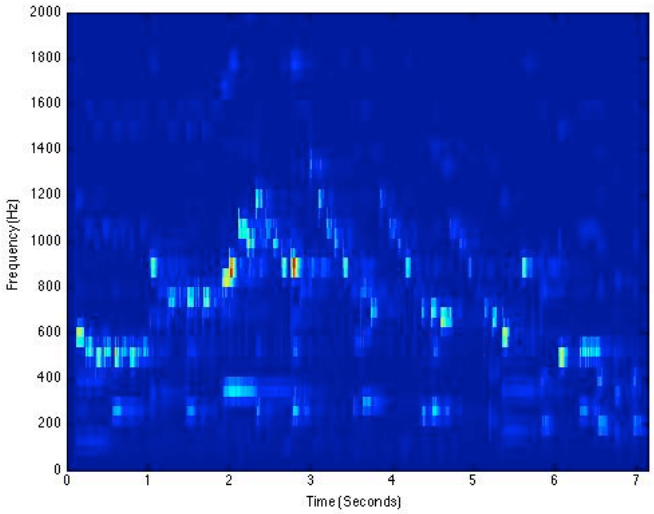
Learning audio features

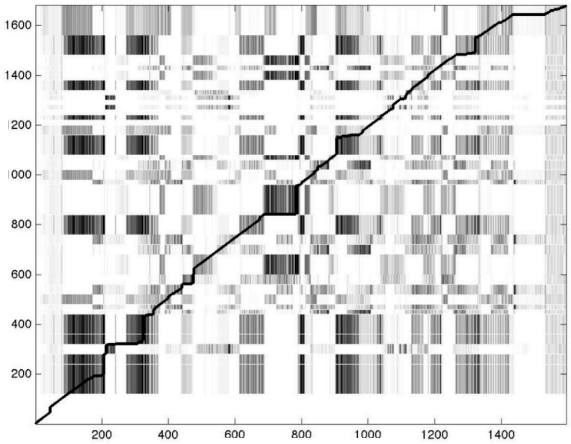
Using MIDI-audio alignment







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!