Handout

Pre-Viva Talk:

Parsing Jazz: Harmonic Analysis of Music Using Combinatory Categorial Grammar

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Supervisors:

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School of Informatics
University of Edinburgh

15th March 2013

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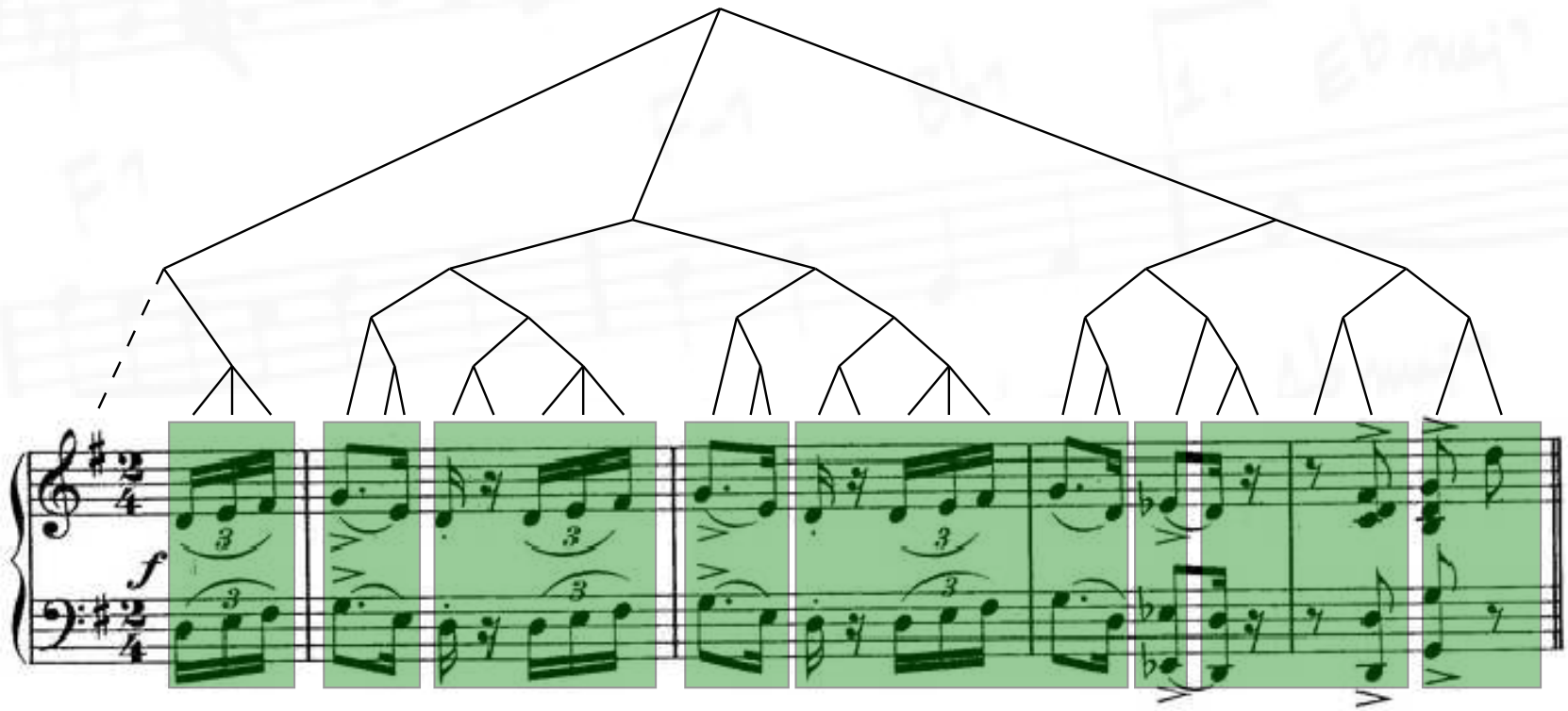
Introduction

- Structures underly music
- Hierarchical structures
- Metrical structure
- Harmonic structure



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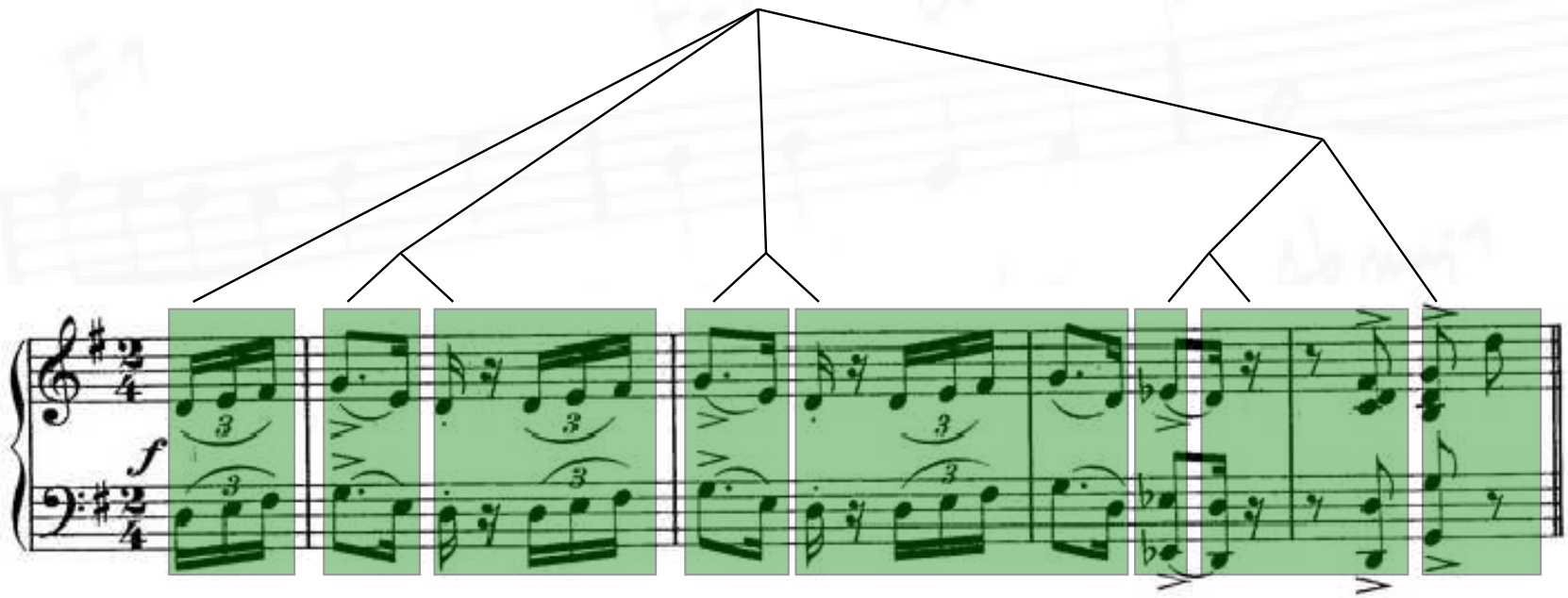


Approaches to Musical Analysis

- Varying goals:
  1. model/aid compositional process
  2. model listener's cognition
  3. suggest interpretations
- Often not clearly defined

Thesis

- Tonal harmony has a syntax like that of language
- Statistical parsing can be used to infer harmonic structure

Contributions:

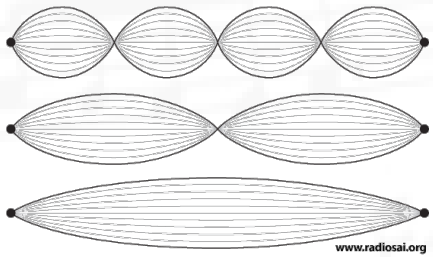
- Formal grammar for syntax of harmony
- Harmonic analysis by parsing
- Practical statistical parsing of chord sequences
- Extension to analysis of performance data

A Few Applications
(speculative)

- Automatic generation:
  - melodic variations
  - accompaniments
- Song identification
- Language modelling for transcription

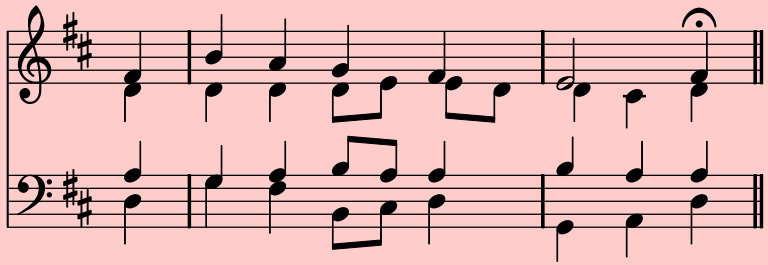
Consonance and Harmony

- Simultaneous notes create
  dissonance / *consonance*



- Used by composers:
  tension / relaxation

- *Harmony*:
  formation of chord phrases

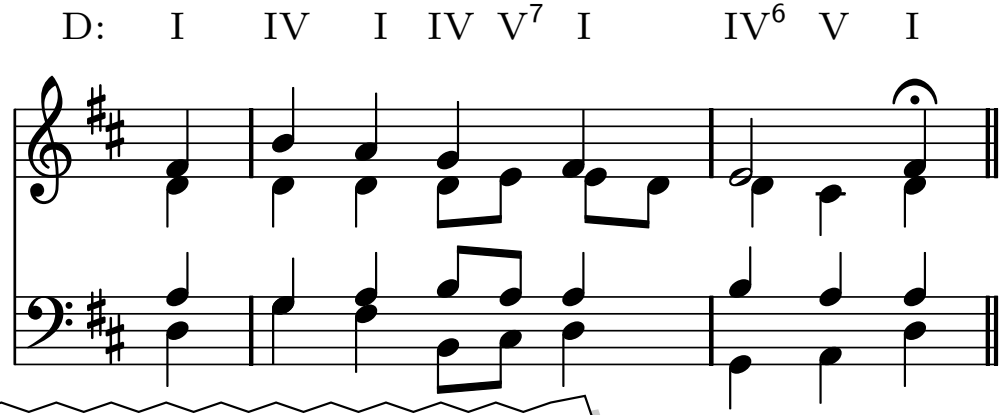


- Relationships between chords
- Expectation / fulfilment

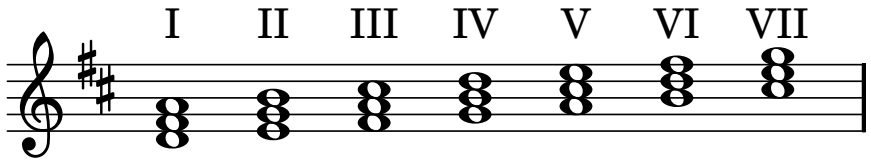
Approaches to Harmonic Analysis

Rameau (1722): *Traité de l'harmonie*

Roman numeral analysis



Key of D



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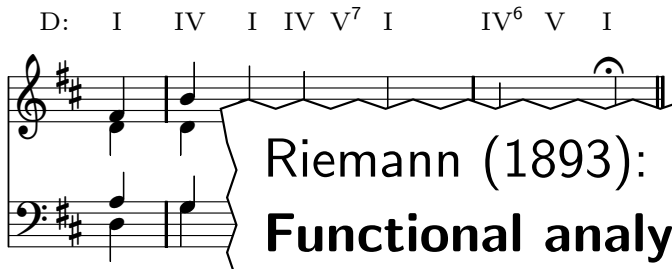
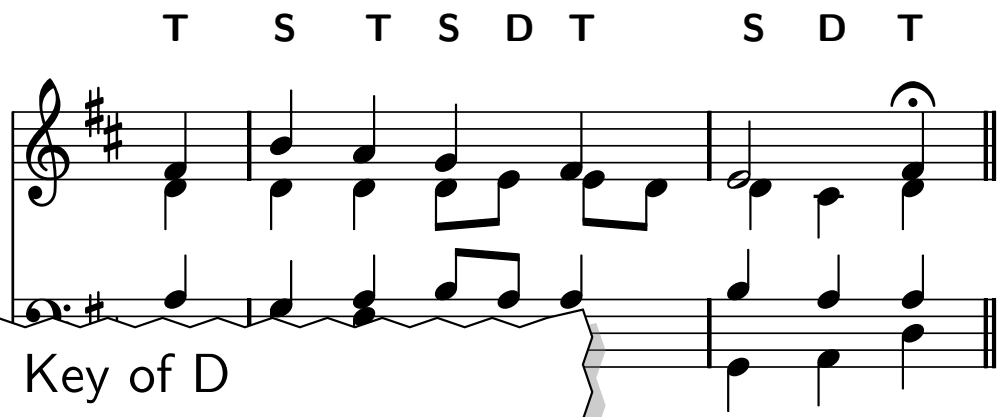


Riemann (1893): *Vereinfachte Harmonielehre*

Functional analysis



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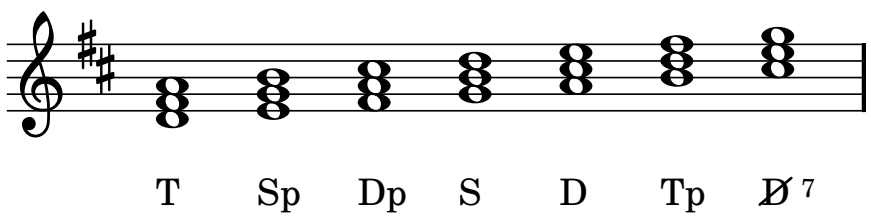

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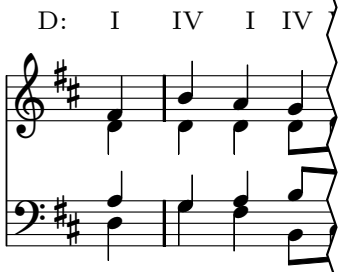

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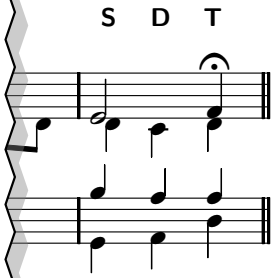

Lerdahl & Jackendoff (1983):

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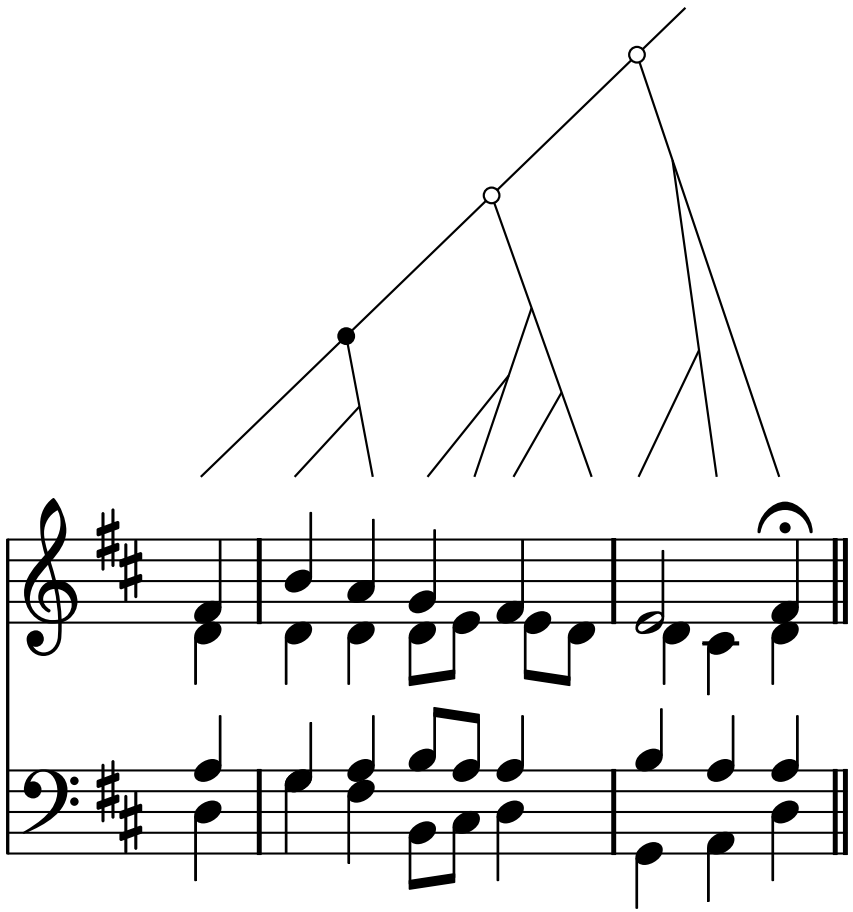

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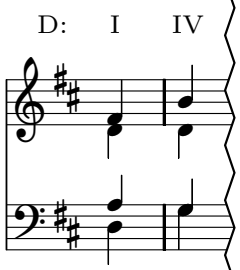

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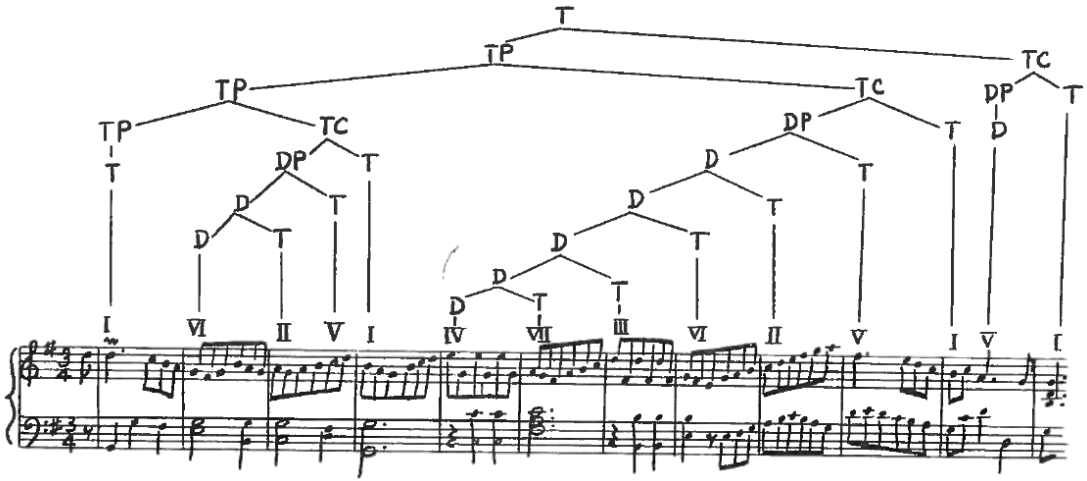
Steedman (1984), Rohrmeier (2011)
Structured functional analysis



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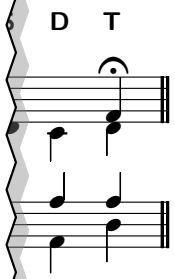

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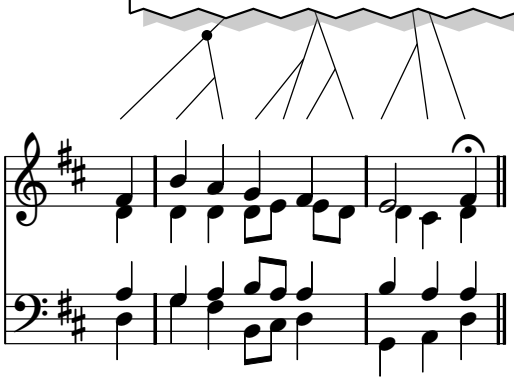

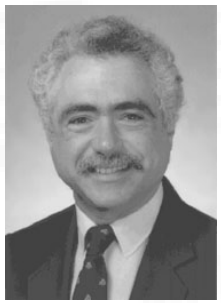

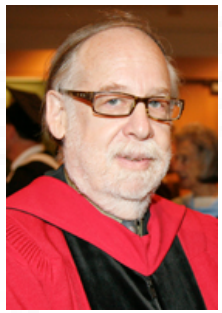

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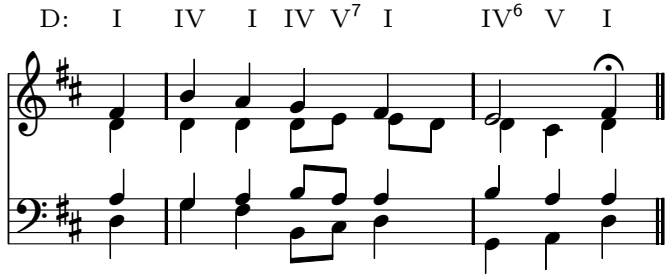

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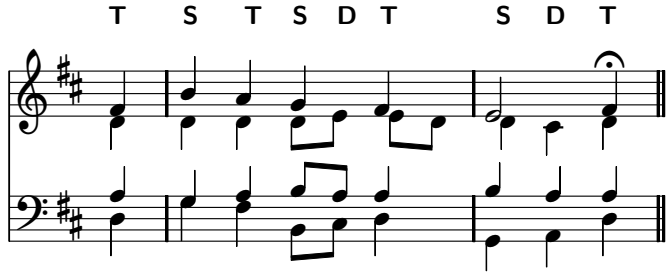

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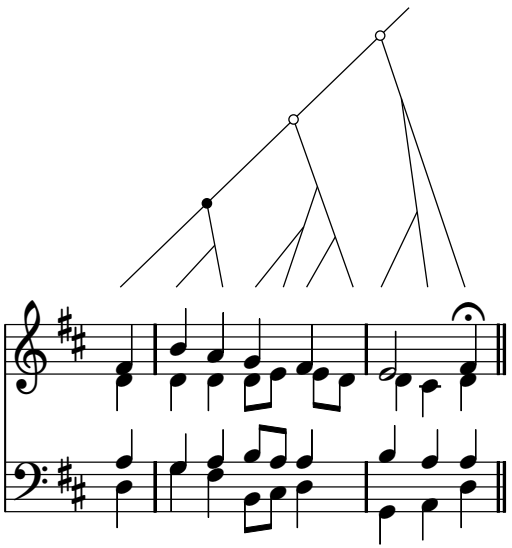

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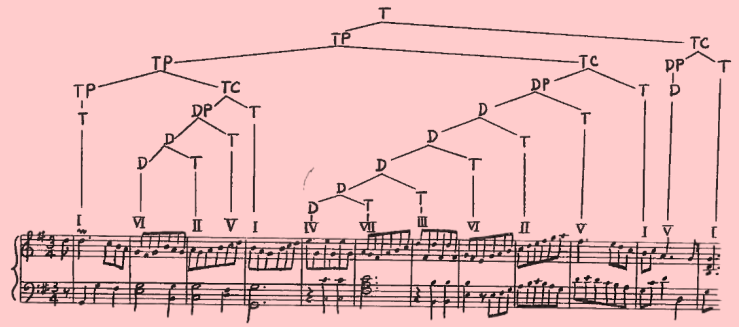
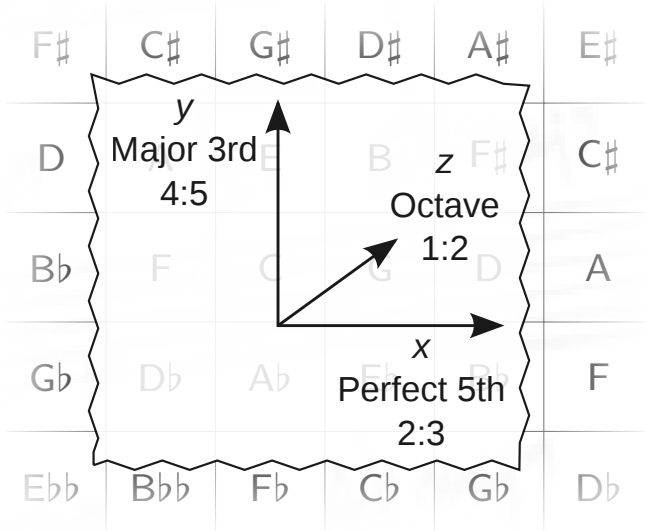


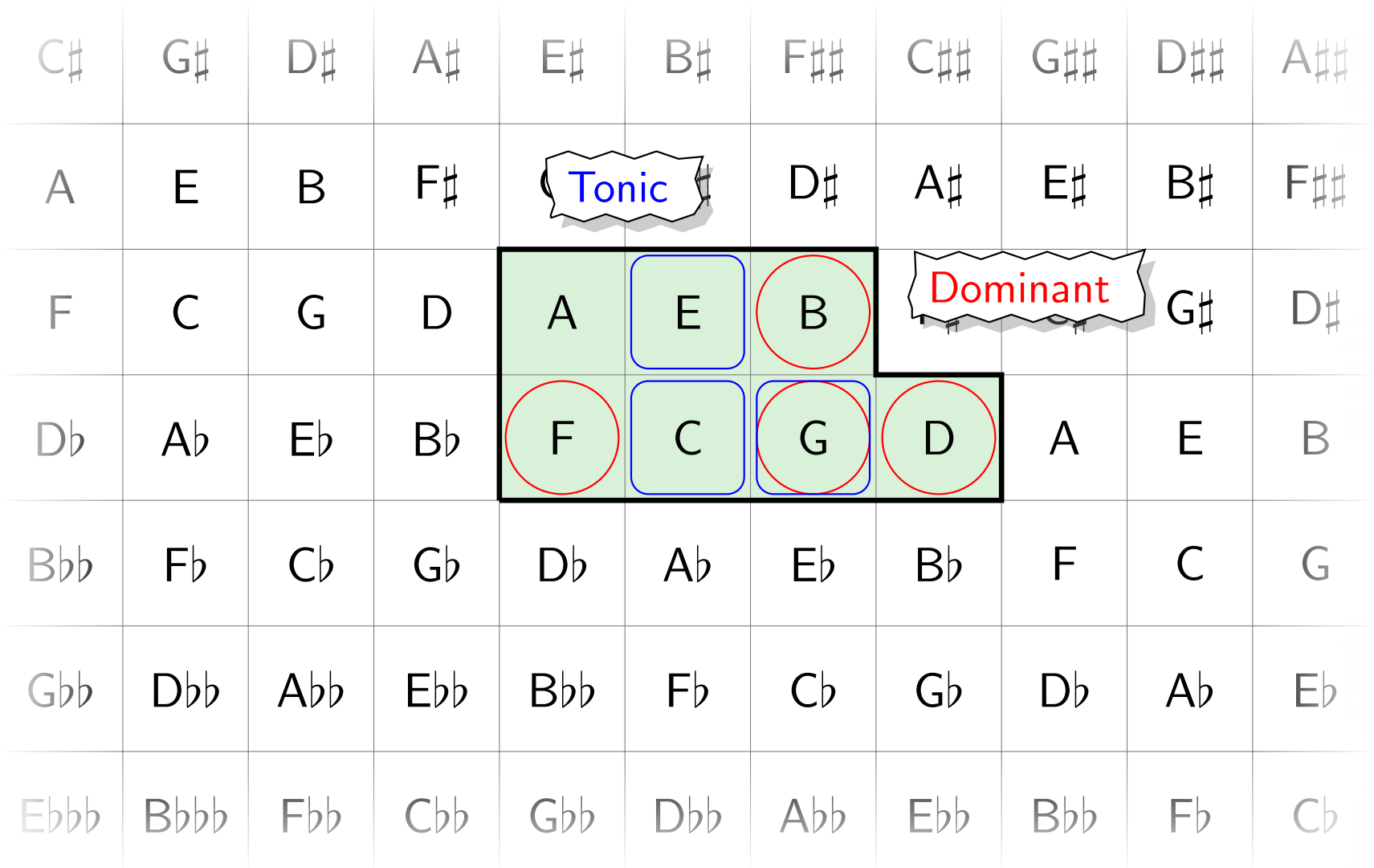
Tonal Space

- Longuet-Higgins' formalization of harmonic tonal theory
- Tonal relations between notes
  - Ambiguous in performance

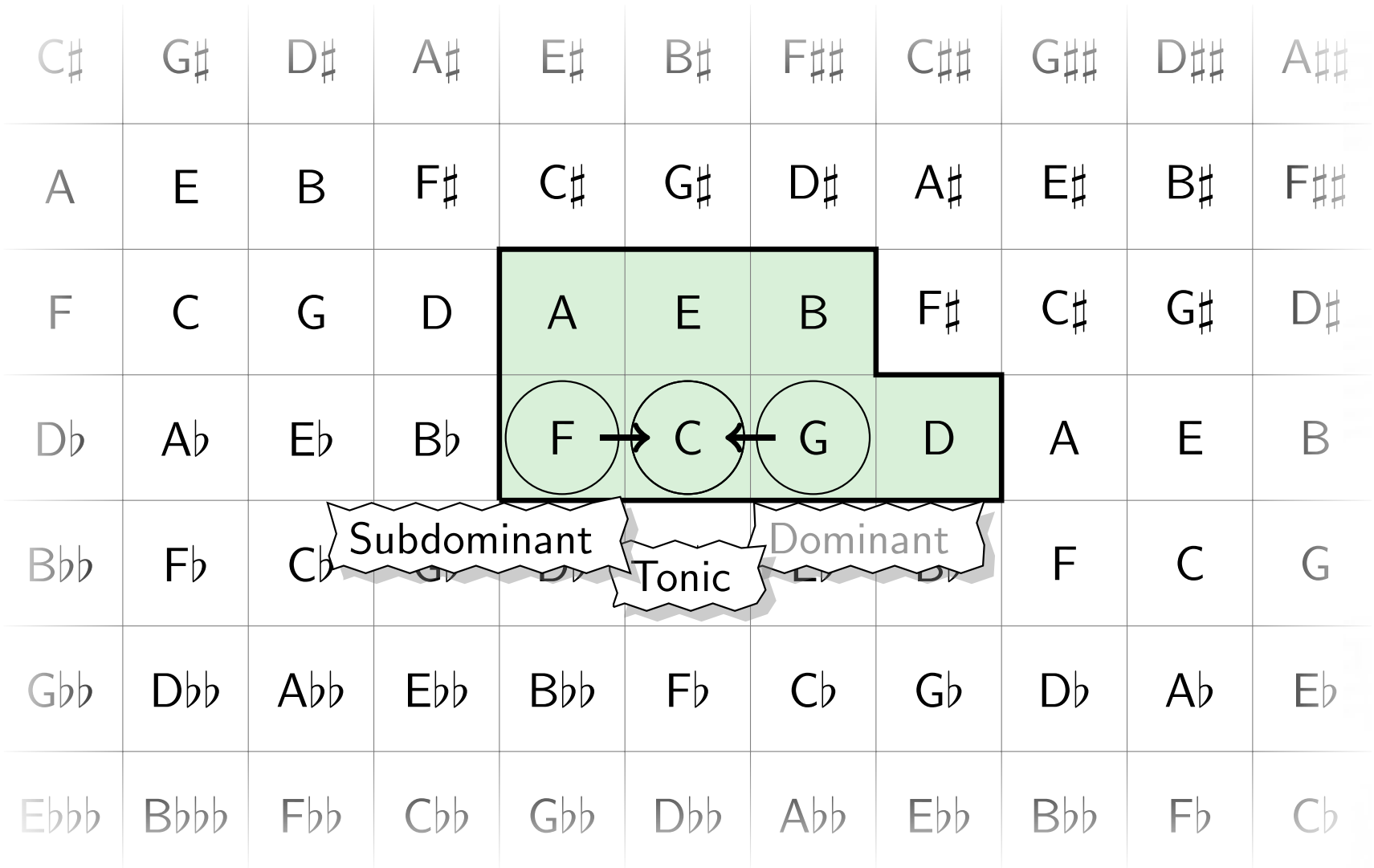


- Harmonic analysis disambiguates tonal relations

Harmony in the Tonal Space

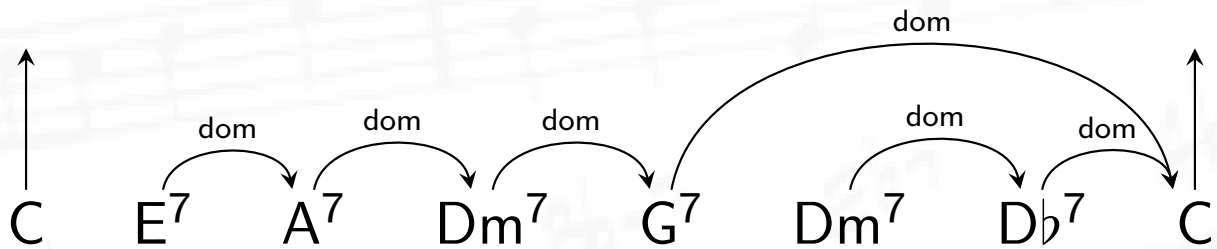


Functional Harmony



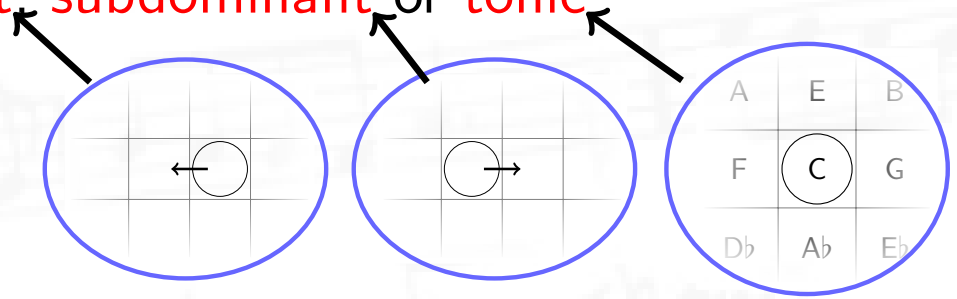
Harmonic Analysis

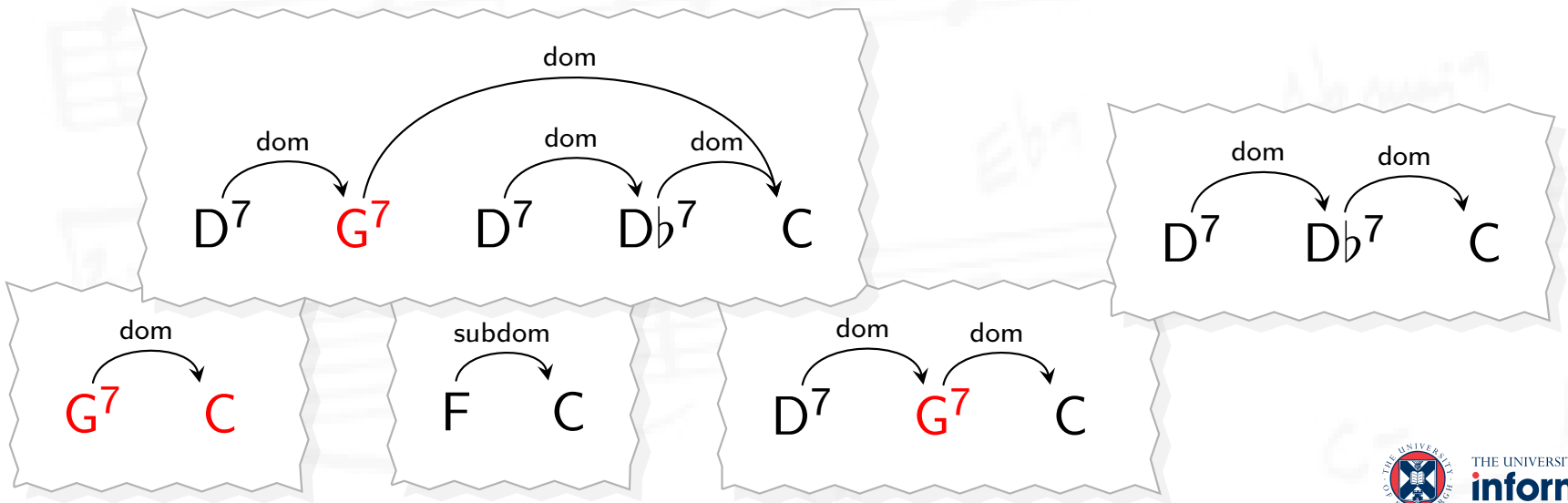
- Functional harmonic structure
- Segmentation into chords
- Identification of keys
- Functional relationships between chords



Harmonic Analysis

- Chords function as: dominant, subdominant or tonic
- Dominant-tonic resolution
- Subdominant-tonic resolution
- Recursion
- Substitution
- Delayed resolution: coordination





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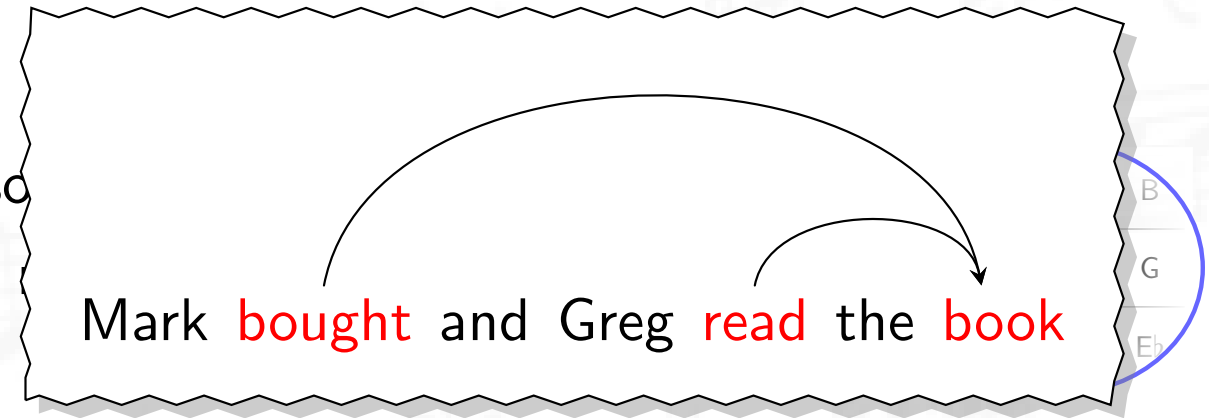

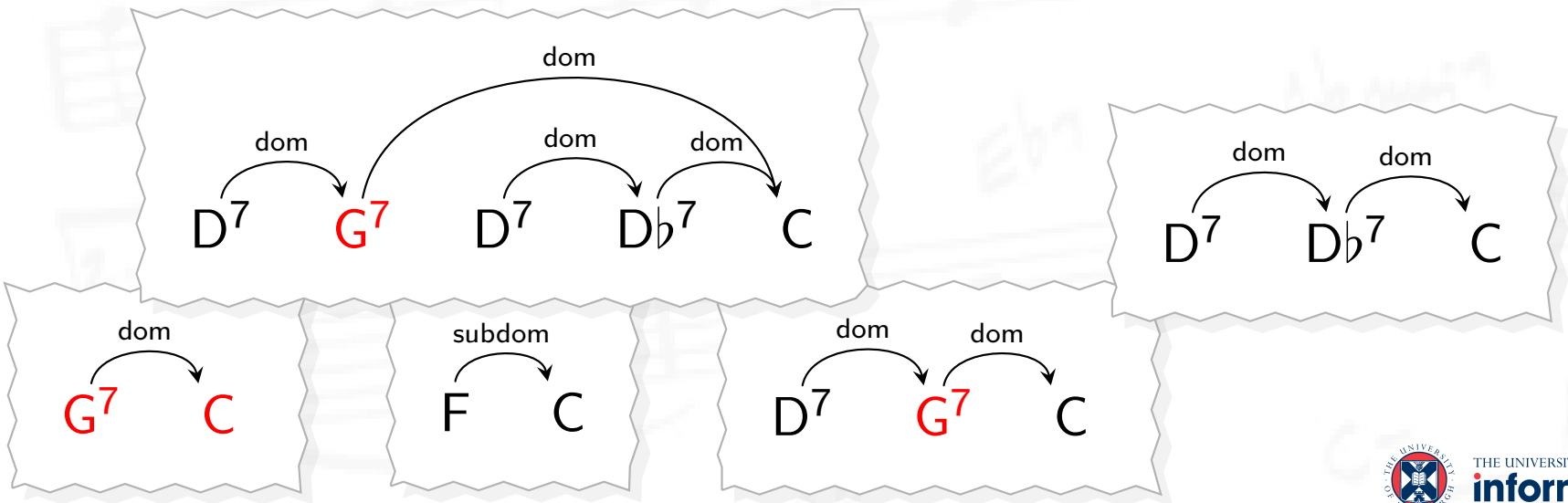

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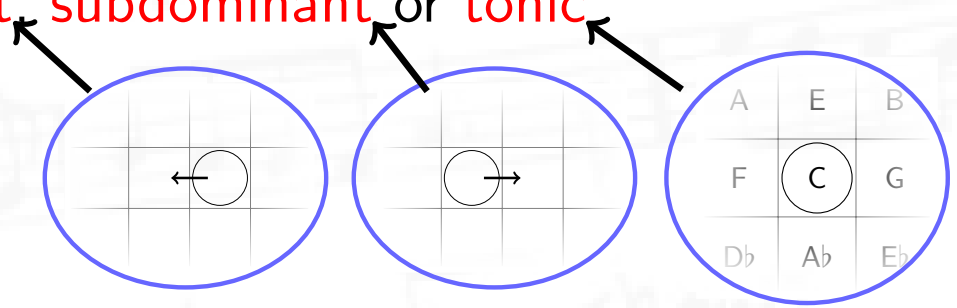
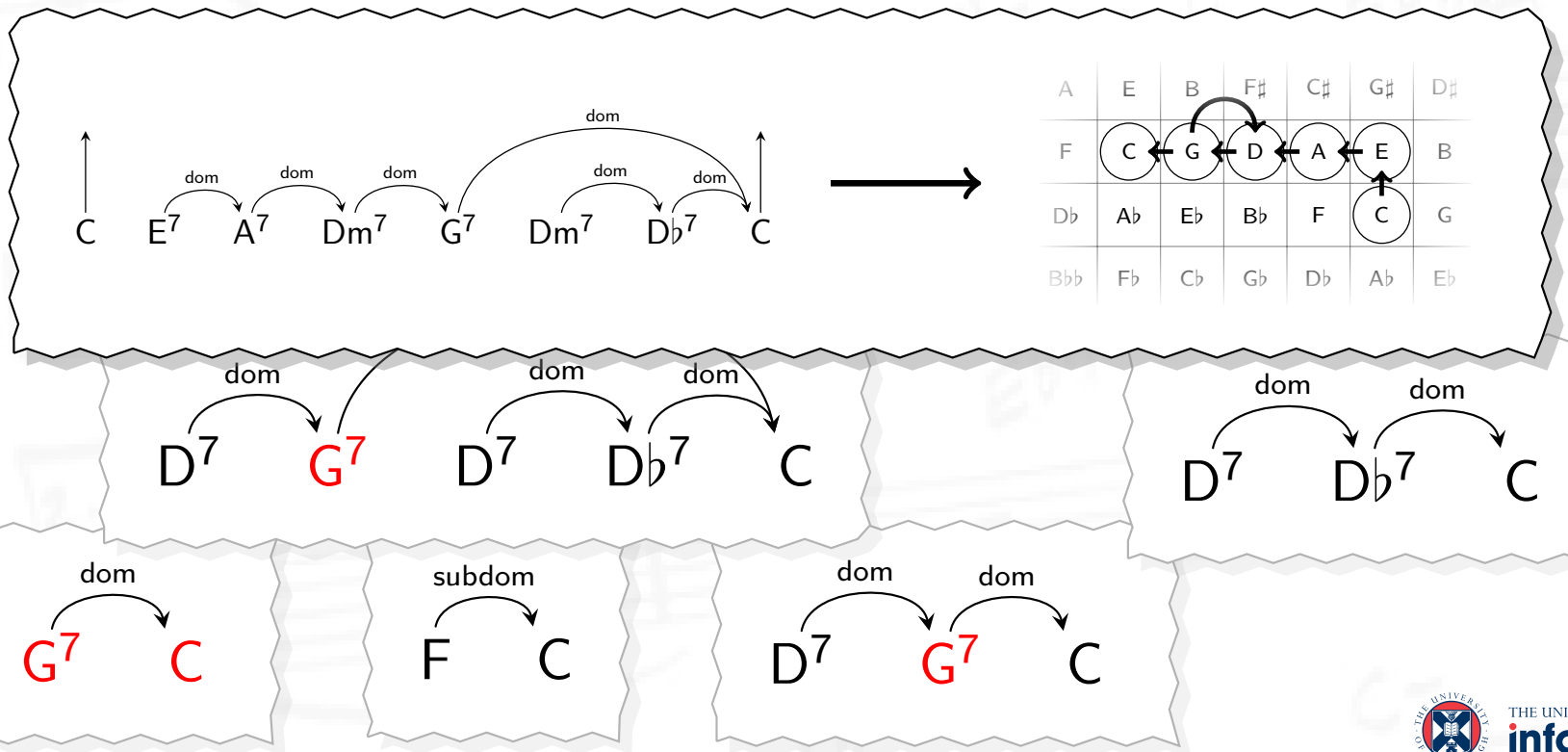
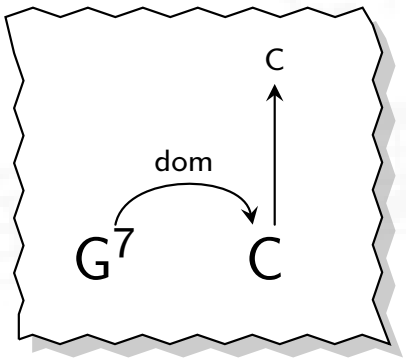


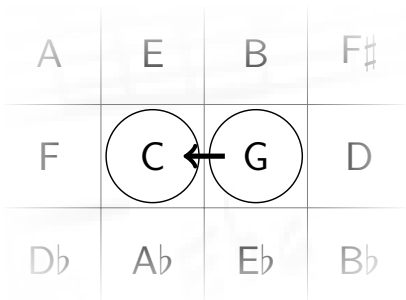


Harmonic Combinatory Categorial Grammar



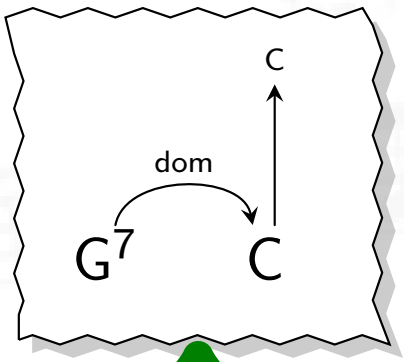
$$G^7 \Rightarrow G/C$$

$$C \Rightarrow C$$



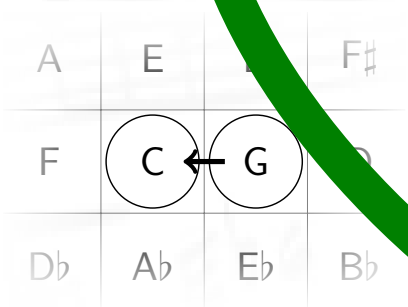
$$\dfrac{\dfrac{G^7}{G/C} \quad \dfrac{C}{C}}{G-C}>$$

Harmonic Combinatory Categorial Grammar



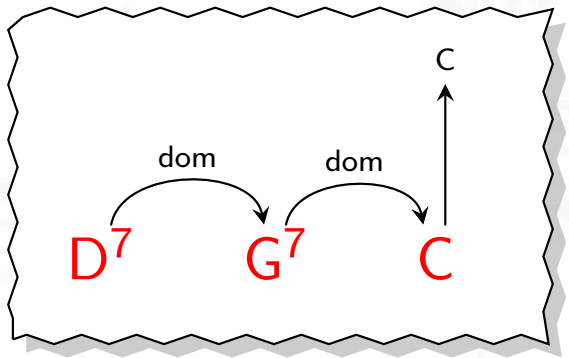
$$G^7 \Rightarrow G/C \ : \ \lambda x.\, dom(x)$$

$$C \Rightarrow C \ : C$$



$$\dfrac{\dfrac{G^7}{G/C \ : \ \lambda x.\, dom(x)} \quad \dfrac{C}{C \ : \ C}}{G{-}C \ : \ dom(C)}{>}$$

Harmonic CCG: Recursion

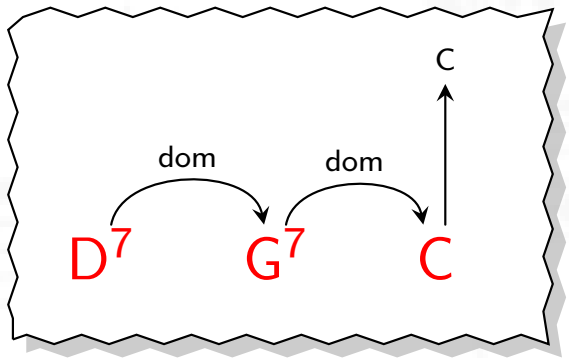


$$\frac{D^7 \qquad G^7 \qquad C}{\dfrac{D/G \;:\; \lambda x.\, dom(x) \qquad \dfrac{G/C \;:\; \lambda x.\, dom(x) \qquad C \;:\; C}{G{-}C \;:\; dom(C)}}{D{-}C \;:\; dom(dom(C))}}$$

Dom: $G^7 \;\Rightarrow\; G/C \;:\; \lambda x.\, dom(x)$

Ton: $C \;\Rightarrow\; C \;:\; C$

Harmonic CCG: Recursion

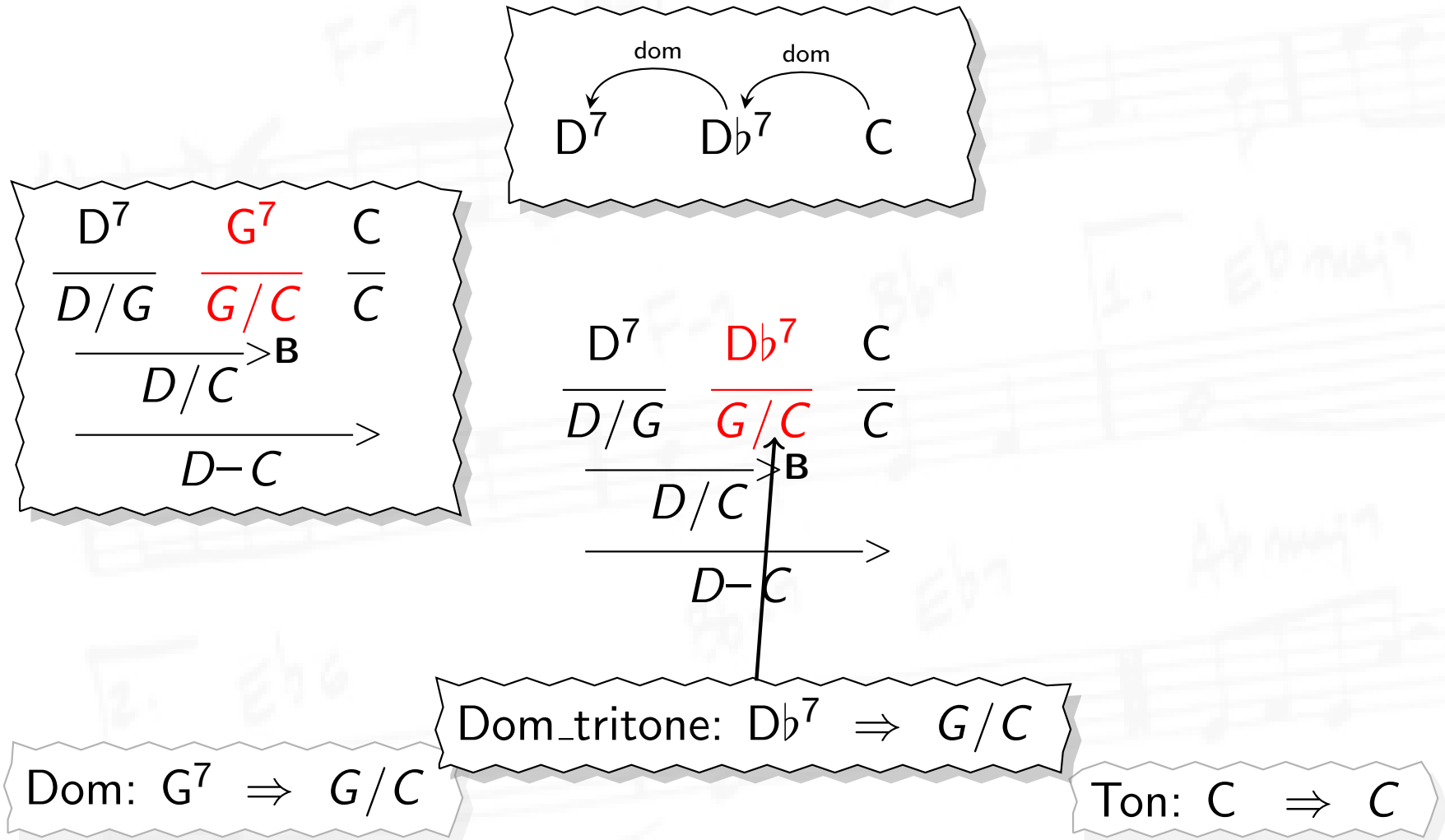


$$\dfrac{\dfrac{\mathrm{D}^7}{D/G \;:\; \lambda x.\, dom(x)} \quad \dfrac{\mathrm{G}^7}{G/C \;:\; \lambda x.\, dom(x)}}{\dfrac{D/C \;:\; \lambda x.\, dom(dom(x))}{D{-}C \;:\; dom(dom(\mathrm{C}))}\,{>}\mathbf{B}} \quad \dfrac{\mathrm{C}}{C \;:\; \mathrm{C}}\,{>}$$

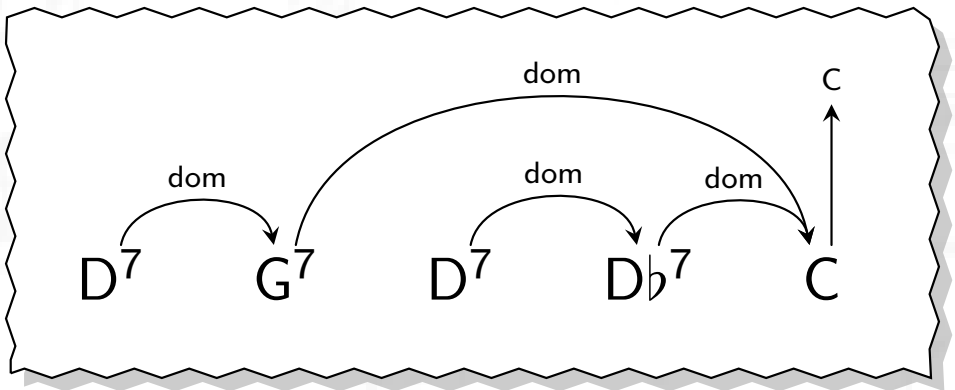
Dom: $\mathrm{G}^7 \;\Rightarrow\; G/C \;:\; \lambda x.\, dom(x)$

Ton: $\mathrm{C} \;\Rightarrow\; C \;:\; \mathrm{C}$

Harmonic CCG: Substitution



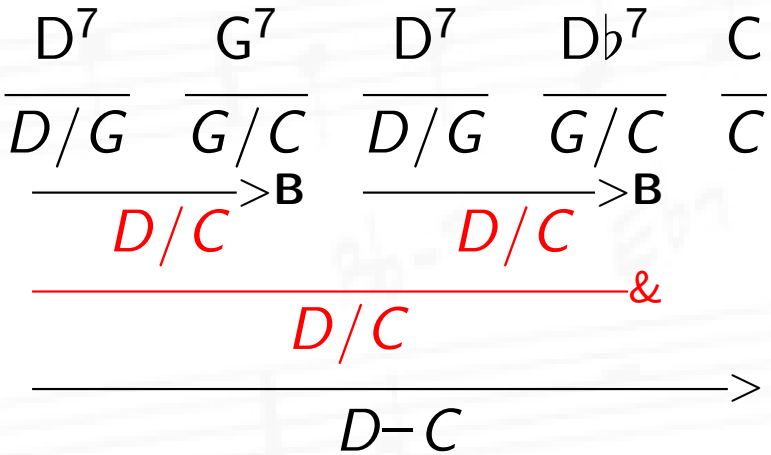
Harmonic CCG: Coordination



$$\dfrac{\dfrac{\dfrac{\mathrm{D}^7}{D/G}\quad\dfrac{\mathrm{G}^7}{G/C}}{D/C}>\mathbf{B}\qquad\dfrac{\dfrac{\mathrm{D}^7}{D/G}\quad\dfrac{\mathrm{D}\flat^7}{G/C}}{D/C}>\mathbf{B}}{D/C}\,\&\qquad\dfrac{\dfrac{\mathrm{C}}{C}}{D\text{–}C}>$$

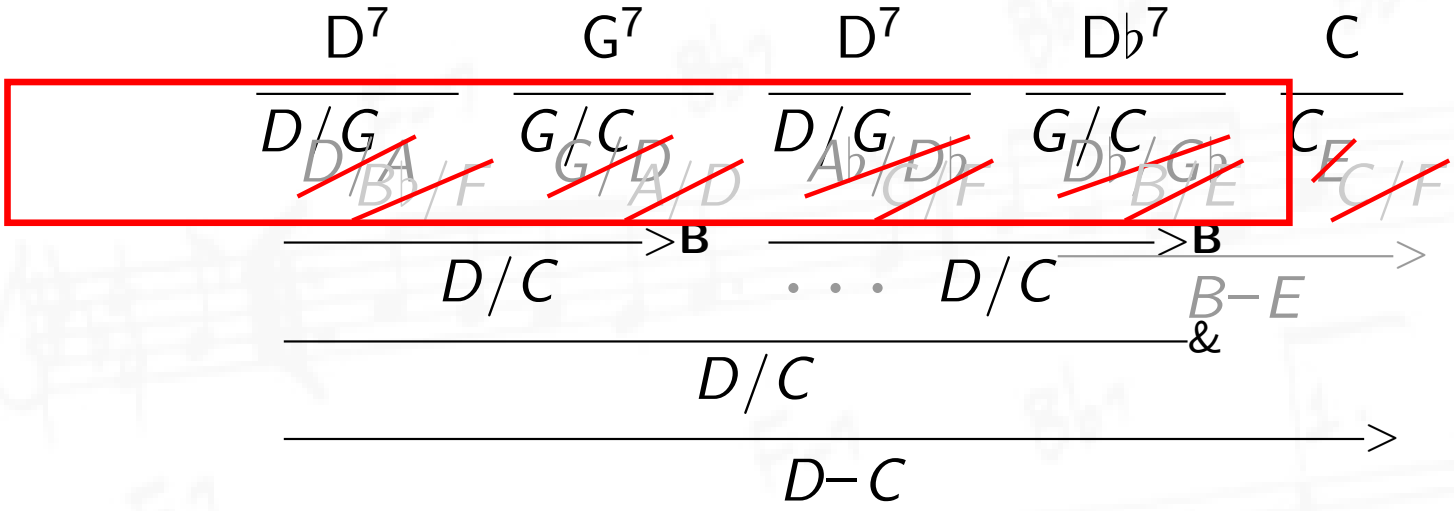
Derivation Model

- Supervised statistical parsing model
- Parsing model: Hockenmaier & Steedman (2002)[1]
- Model of CCG derivations: PCCG
- Supervised training, smoothing
- CKY parser with beam



[1] Generative models for statistical parsing with Combinatory Categorial Grammar. ACL

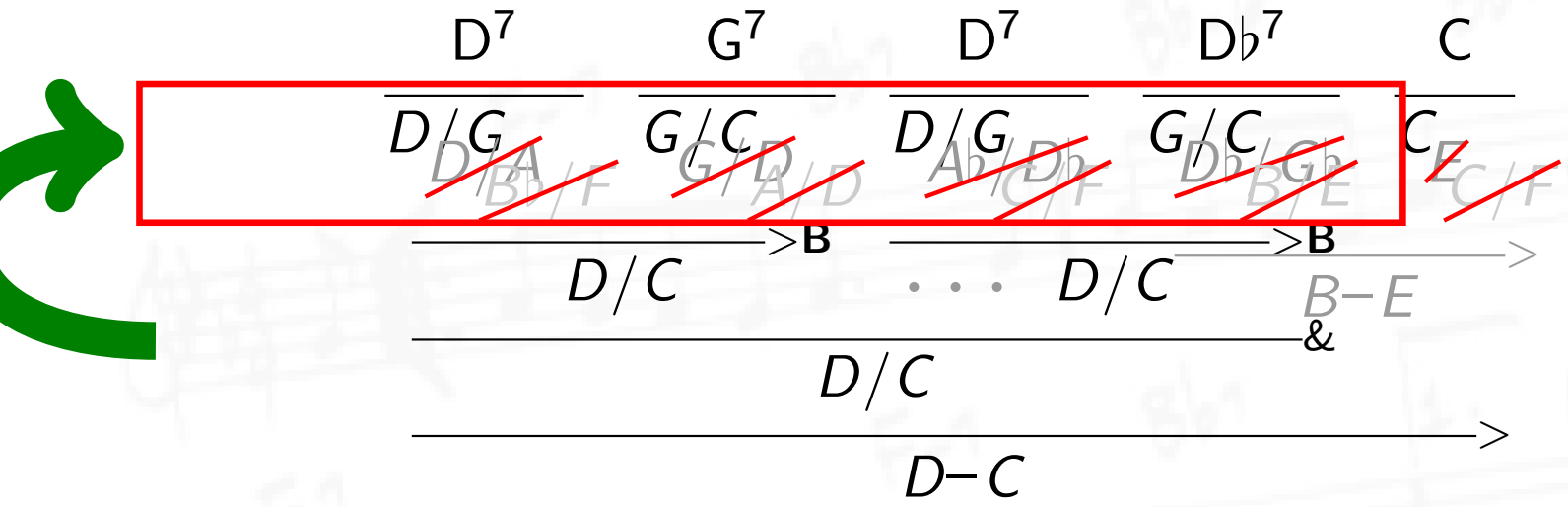
Supertagging



- Experimented with n-gram models
- Small corpus: trigrams don't help
- For parsing experiments:
  - bigram (HMM)
  - Katz backoff
  - Witten-Bell discounting
  - adaptive supertagging (Clark & Curran, 2007)[2]

[2] Wide-Coverage Efficient Statistical Parsing with CCG and Log-Linear Models

Supertagging



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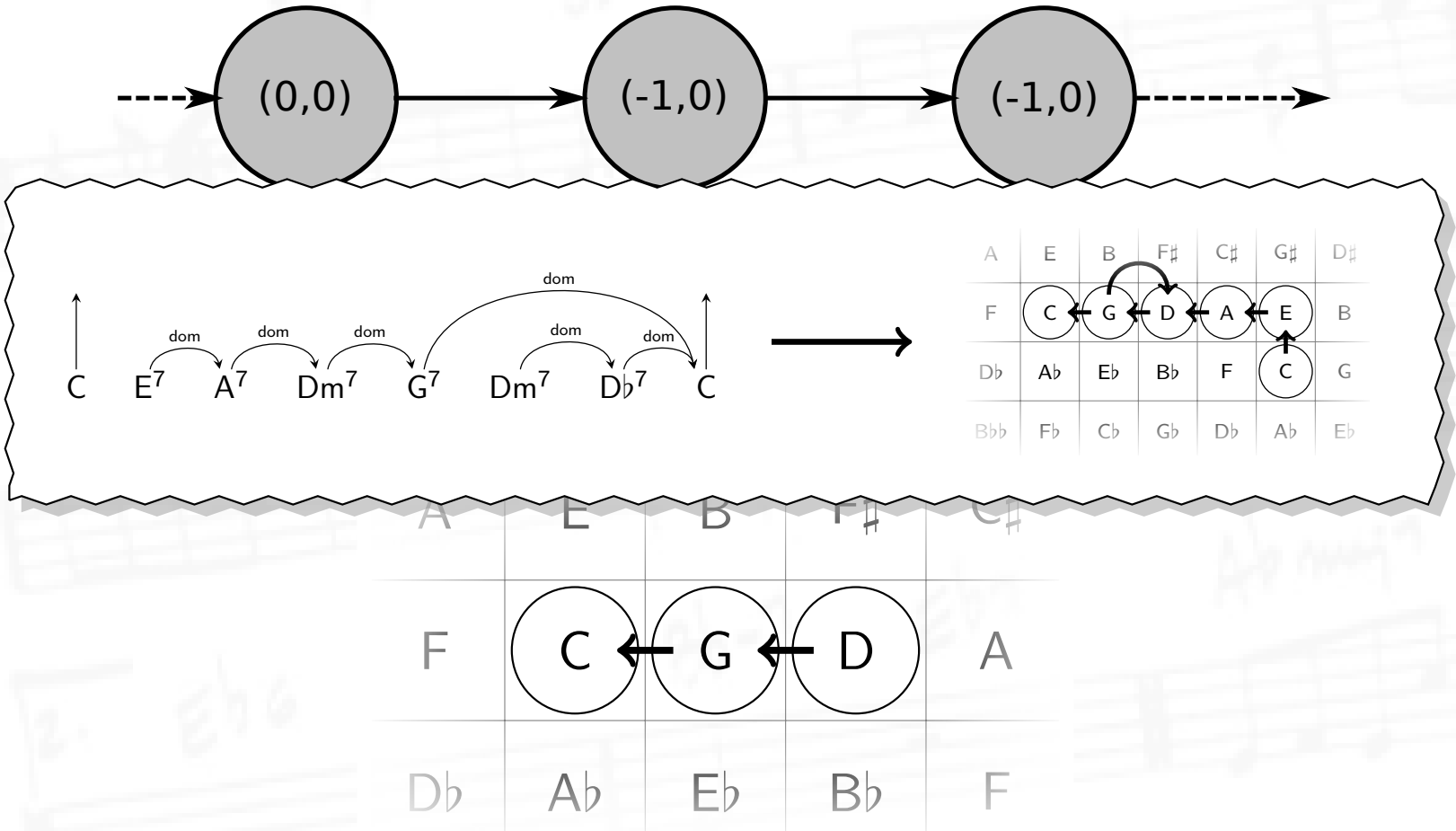
- Construct path with HMM:



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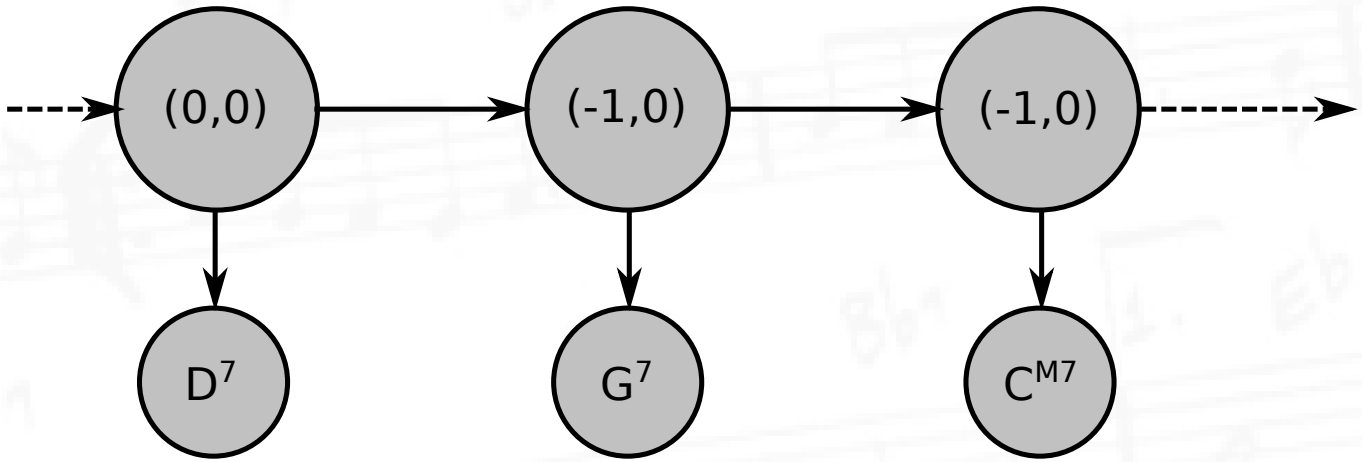
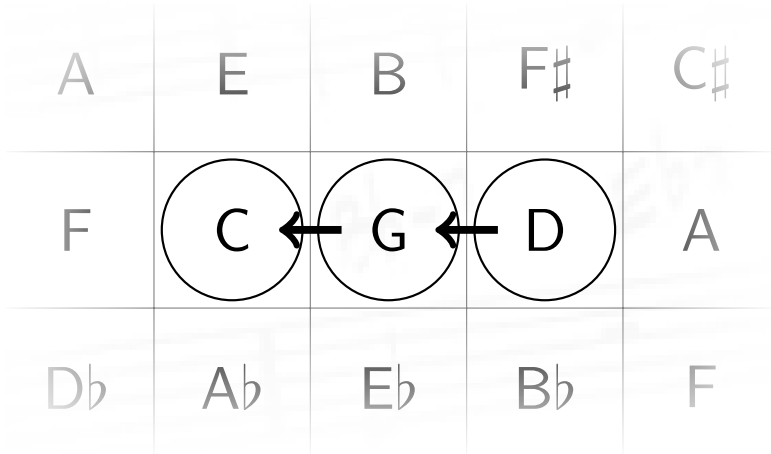
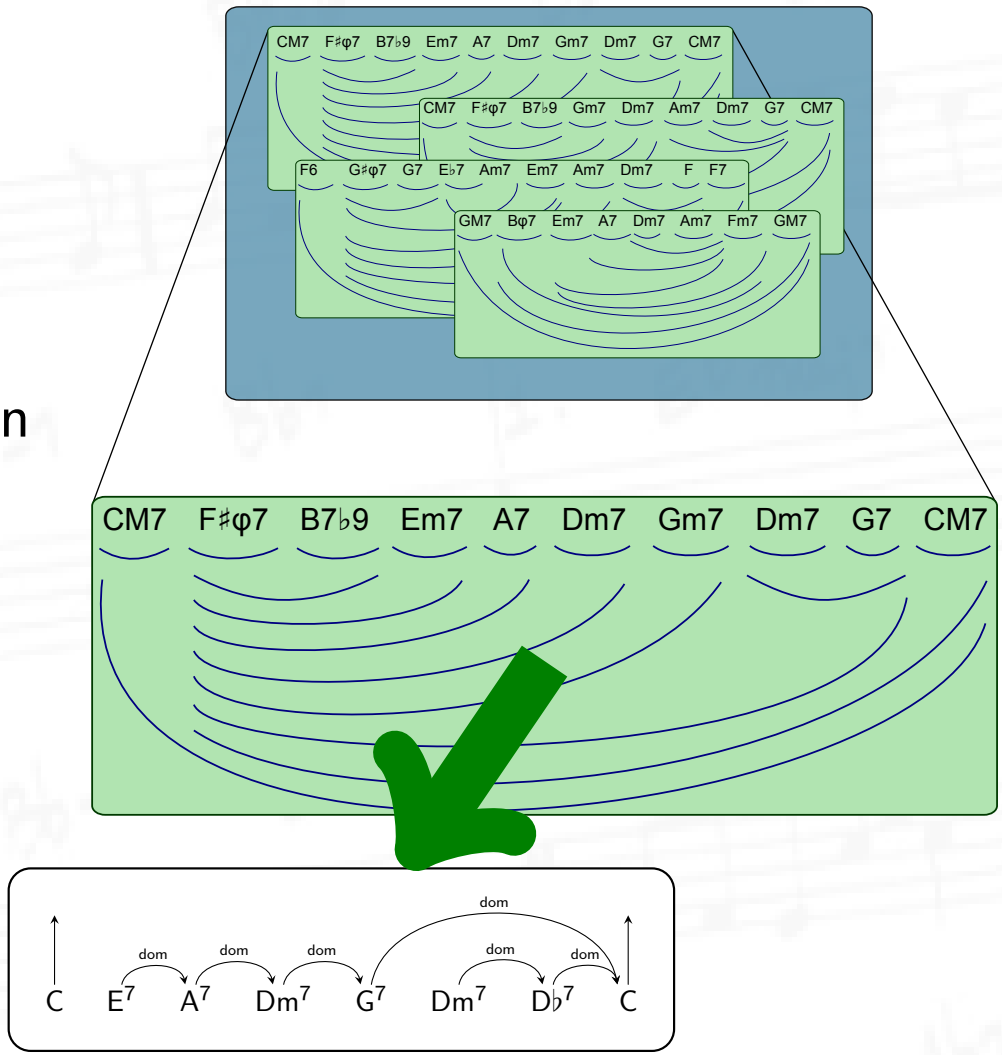




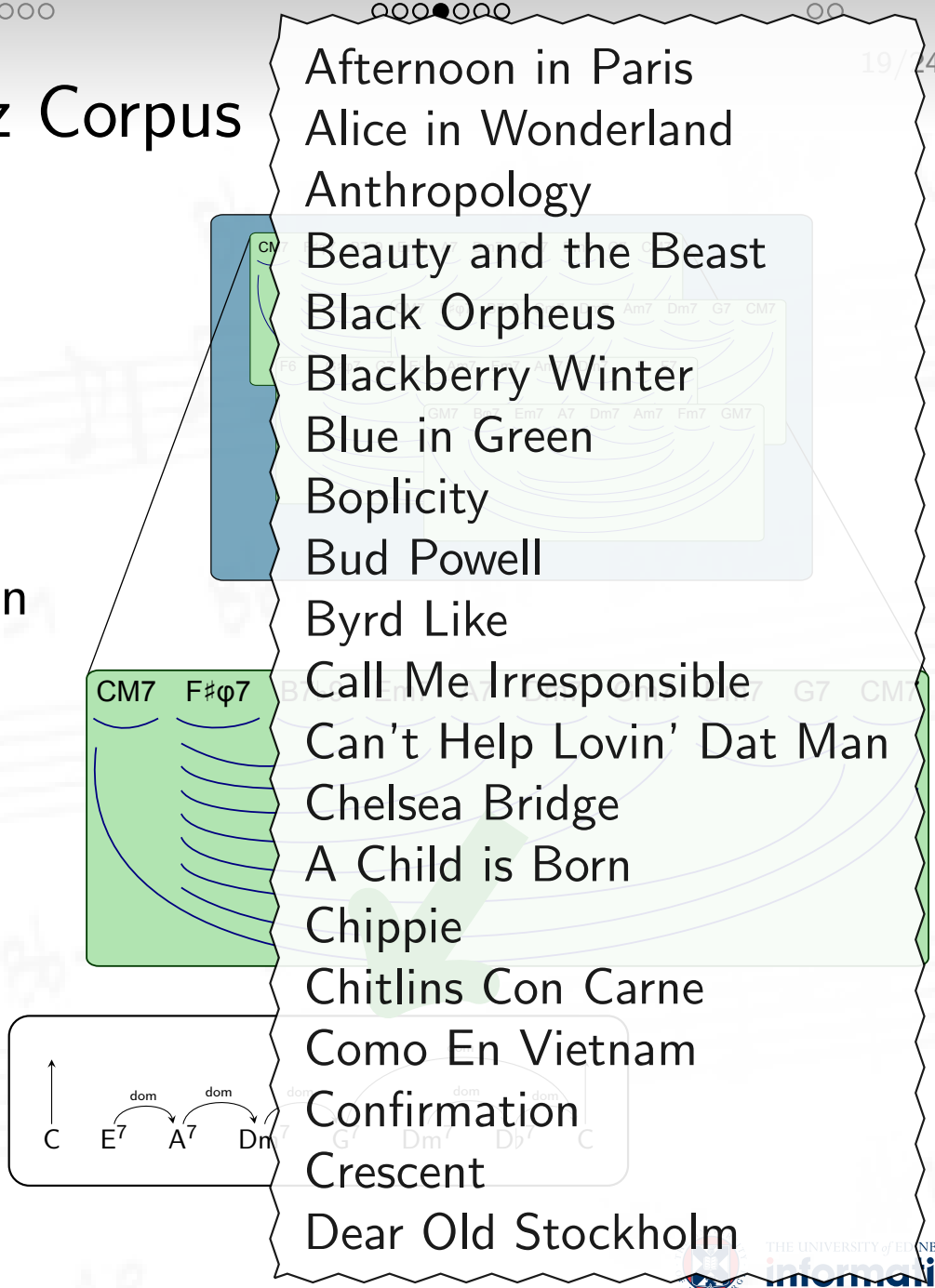
Jazz Corpus

- Annotated training corpus
- Jazz chord sequences
- Full grammatical derivation annotated
- $\rightarrow$ full harmonic analysis
- 74 sequences: $\sim$3k chords
- Cross-validation



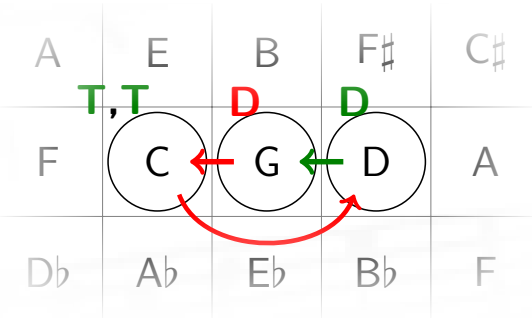
Jazz Corpus

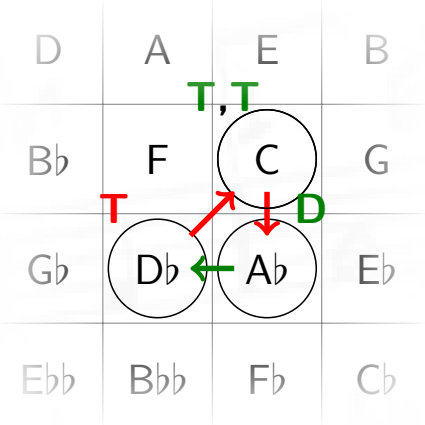
- Annotated training corpus
- Jazz chord sequences
- Full grammatical derivation annotated
- $\rightarrow$ full harmonic analysis
- 74 sequences: $\sim$3k chords
- Cross-validation



Evaluation Metric

Tonal space edit distance

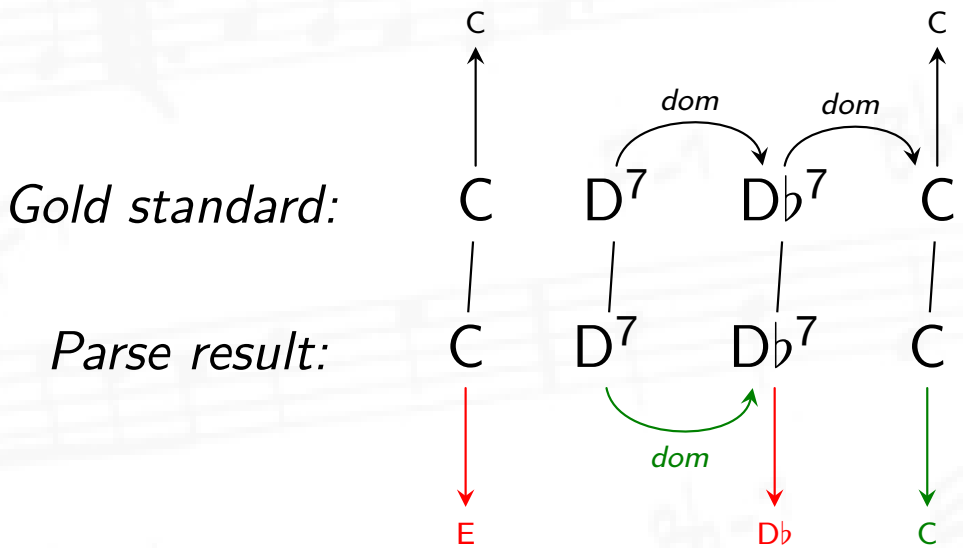




Precision, recall, f-score

Evaluation: Dependency Recovery

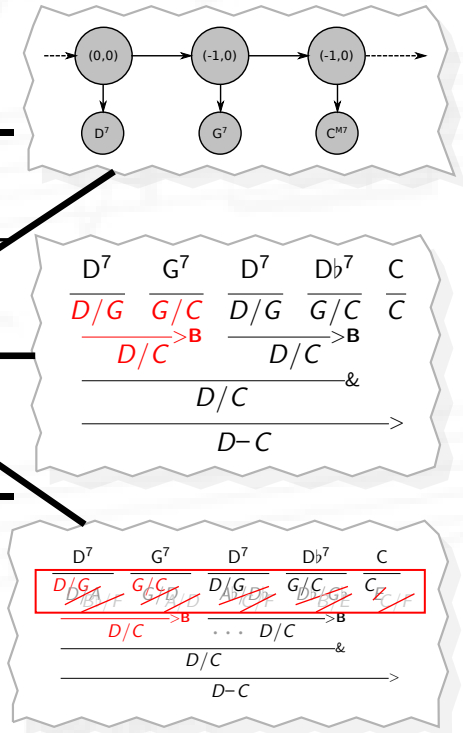
- Dependency recovery of harmonic analysis



Results

- Tonal space metric:

	P (%)	R (%)	F (%)	Cov. (%)
HmmPath	77.44	84.87	80.98	100
PCCG	**92.29**	88.78	**90.50**	97.37
St+PCCG	**90.18**	**92.79**	**91.46**	100

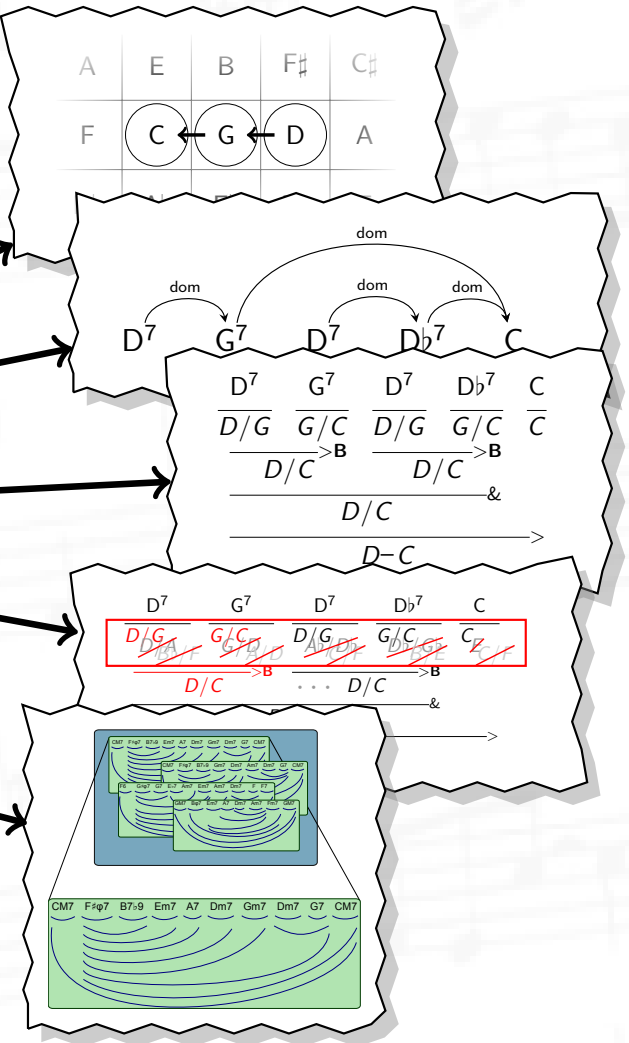


- Dependency recovery:

	P (%)	R (%)	F (%)
PCCG	90.25	86.83	88.51
St+PCCG	88.22	90.78	89.48

Conclusion

- Harmonic analysis in the tonal space
- Hierarchical structure in harmony
- Harmonic adaptation of CCG
- Statistical parsing, adapted from NLP
- Chord sequence treebank



Conclusion

Thesis:

- Tonal harmony has a syntax like that of language
- Statistical parsing can be used to infer harmonic structure

- CCG grammar of harmonic structure
- Statistical parser for harmonic analysis
- Parser outperforms HMM baseline
- Extension to analysis of performances

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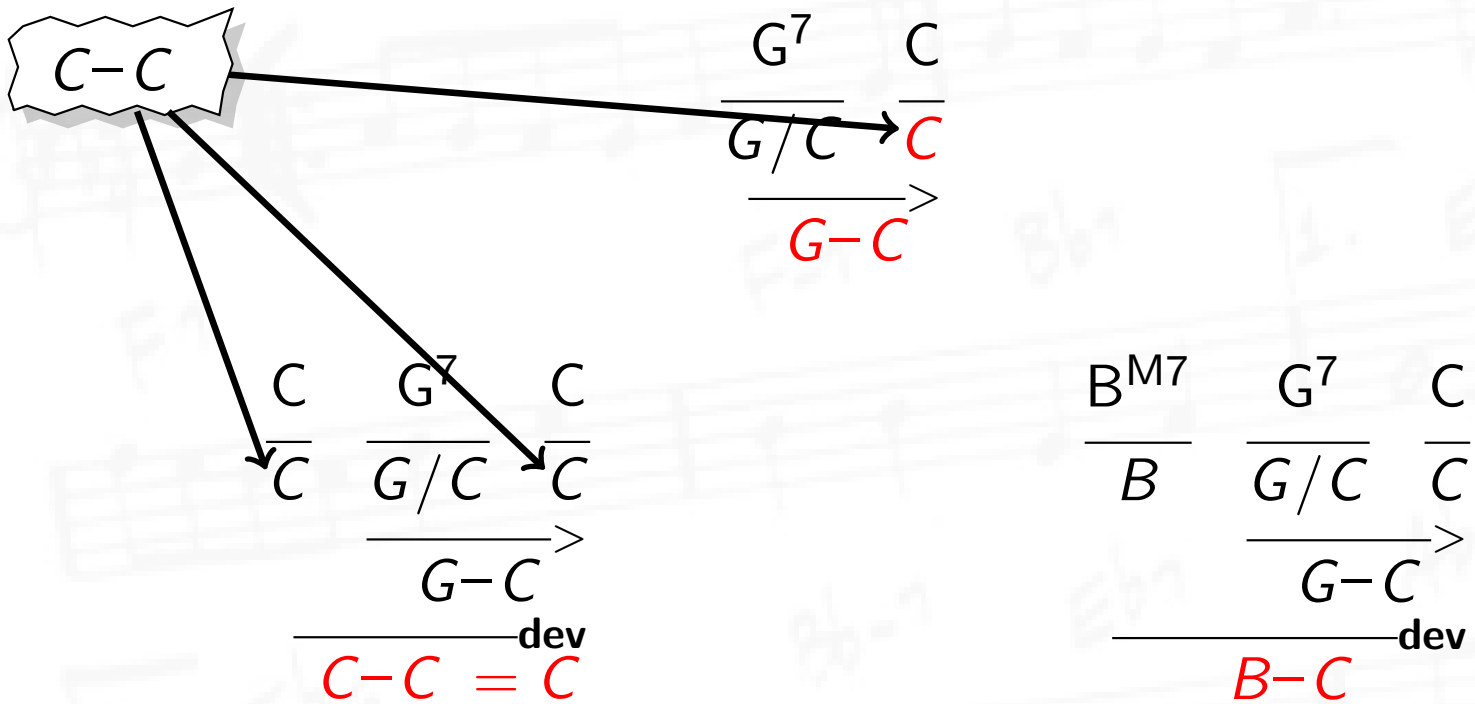
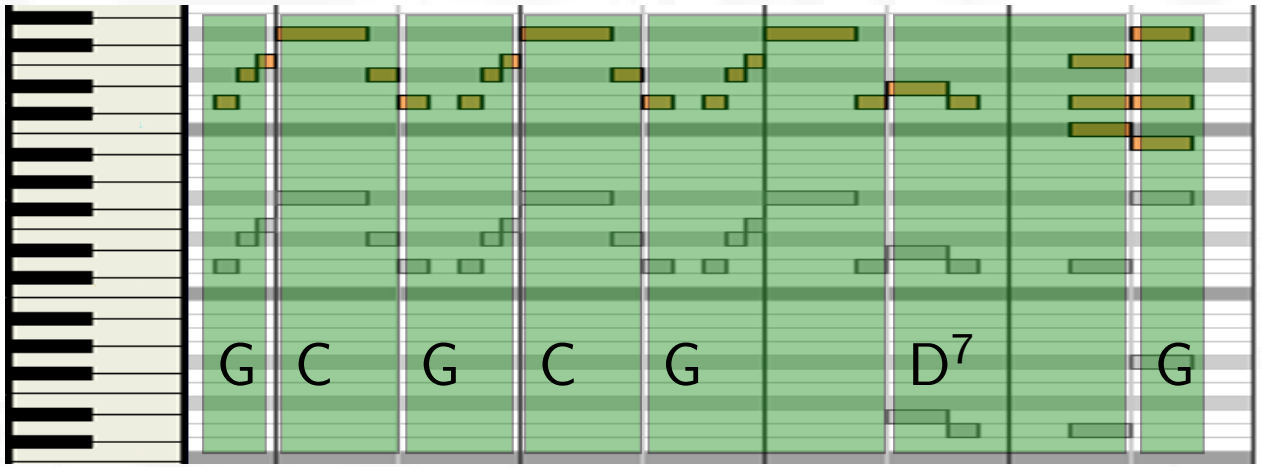
Extra slide

Atomic Categories



Parsing Performances

- Can we parse a musical performance?



- Proof-of-concept extension
- HMM chord recognizer
- Parse chord labels as before

Parsing Performances

- Parser beats baseline
- Much lower results than chord task
- Chord recognizer over-commits, parse a lattice
- Need rhythmic/metrical models
- Harder modelling task:
  voice-leading, polyphony, chord inversion, octave separation, ...
- Evaluation harder: model does segmentation
- Unlabelled data

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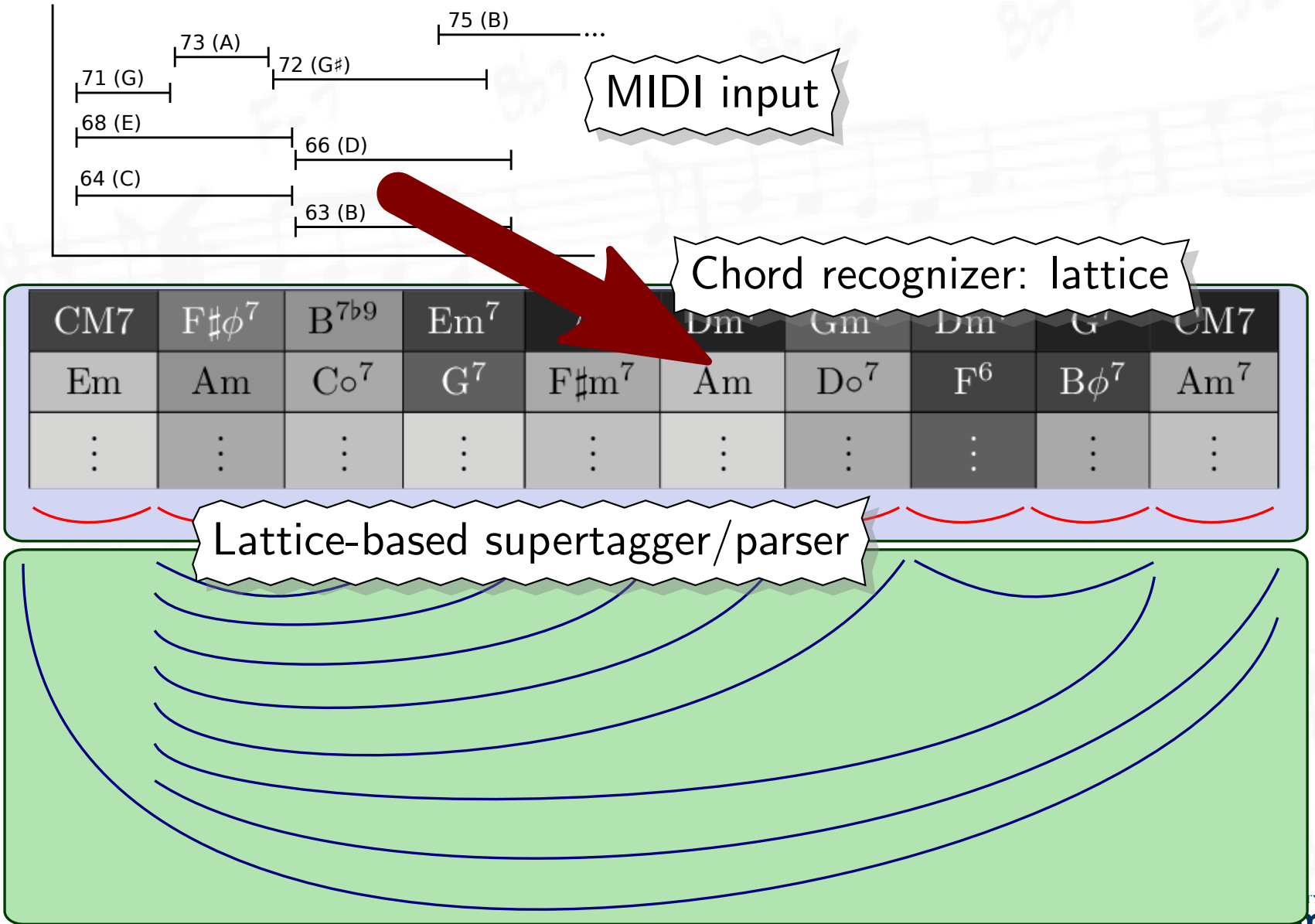
MIDI Parsing



Tonal Space

C♯	G♯	D♯	A♯	E♯	B♯	F♯♯	C♯♯	G♯♯	D♯♯	A♯♯
A	E	B	F♯	C♯	G♯	D♯	A♯	E♯	B♯	F♯♯
F	C	G	D	A	E	B	F♯	C♯	G♯	D♯
D♭	A♭	E♭	B♭	F	C	G	D	A	E	B
B♭♭	F♭	C♭	G♭	D♭	A♭	E♭	B♭	F	C	G
G♭♭	D♭♭	A♭♭	E♭♭	B♭♭	F♭	C♭	G♭	D♭	A♭	E♭
E♭♭♭	B♭♭♭	F♭♭	C♭♭	G♭♭	D♭♭	A♭♭	E♭♭	B♭♭	F♭	C♭

Roman Numeral Tonal Space

♯I^{-}	♯V^{-}	♯III^{-}	♯VI^{-}	♯III	♯VII	♯♯IV	♯♯I	♯♯V^{+}	♯♯III^{+}	♯♯VI^{+}
VI^{-}	III^{-}	VII^{-}	♯IV^{-}	♯I	♯V	♯II	♯VI	♯III^{+}	♯VII^{+}	♯♯IV^{+}
IV^{-}	I^{-}	V^{-}	II^{-}	VI	III	VII	♯IV	♯I^{+}	♯V^{+}	♯II^{+}
♭II^{-}	♭VI^{-}	♭III^{-}	♭VII^{-}	IV	I	V	II	VI^{+}	III^{+}	VII^{+}
♭♭VII^{-}	♭IV^{-}	♭I^{-}	♭V^{-}	♭II	♭VI	♭III	♭VII	IV^{+}	I^{+}	V^{+}
♭♭V^{-}	♭♭II^{-}	♭♭VI^{-}	♭♭III^{-}	♭♭VII	♭IV	♭I	♭V	♭II^{+}	♭VI^{+}	♭III^{+}
♭♭♭III^{-}	♭♭♭VII^{-}	♭♭IV^{-}	♭♭I^{-}	♭♭V	♭♭II	♭♭VI	♭♭III	♭♭VII^{+}	♭IV^{+}	♭I^{+}

Parsing Time

Average parse time per chord sequence:

Model	Mean	(std. dev.)
HmmPath	0:03	(0:01)
PCCG	34:17	(75:23)
St+PCCG	9:22	(33:32)

Extra Slides