Interpreting Music Using Grammars
An Introduction

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♫ *Some musical examples* ♫

Overview

- We want to produce interpretations of underlying structure in music
- Similar to what musicians do
- By understanding this structure we can:
  - recognize variations
  - model expectations
  - transcribe music on scores
  - generate accompaniments
  - do lots more cool stuff

How Is Music Like Language?

- Language analogy for music is common
- Neurological evidence suggests common processing faculties
- Identity Thesis for Language and Music (Katz & Pesetsky):

> All formal differences between language and music are a consequence of differences in their fundamental building blocks... In all other respects, language and music are identical.

- Similar types of structure: e.g. in harmony

How Is Music Not Like Language?

- Some important differences affect approaches to processing
- Timing
- Huge lexical ambiguity
- Not much of a real-world semantics

Why Use Grammars?

- Structures like cadences are similar to NL syntactic structures
- Interpretation dependent on structure
- Long-range dependencies: e.g. key
- Markov models get lost
- Lexicalized grammar neatly expresses chord function
- We want a musical interpretation: semantics

Harmonic Function

- Harmony divided into chords
- Each chord analysed as having a *function*
- *Tonic*, *dominant*, *subdominant*
- Relates to expectation of what follows
- Some clues in realization, but ambiguous
- Dependent on position in harmonic structure

Function and Resolution

- Common pattern of tension and resolution
- Dominant chords create tension
- Expect a *resolution*
- Resolution provided by tonic
- ♫ Some examples
- Can even hear expected resolution (?)

Some Structure

- Chords with functions form structures
- Basic tension-resolution pattern: *cadence*
- Marks significant points in music
- Bigger structures: tension partially resolves to more tension
- ♫ *Don't Stop Me...*
- *Now* still unresolved
- Lots of extended cadences in jazz, with substitutions

Musical Semantics: Longuet-Higgins Tonal Space

- Spatial semantic domain of pitches
- Close points closely perceptually related
- Chords express a point or movement in space
- Chord's underlying position in space is ambiguous
- Resolve ambiguity by understanding harmonic structures

$\sharp V^-$	$\sharp II^-$	$\sharp VI^-$	$\sharp III$	$\sharp VII$	$\sharp\sharp IV$	$\sharp\sharp I$	$\sharp\sharp V^+$	$\sharp\sharp II^+$
III^-	VII^-	$\sharp IV^-$	$\sharp I$	$\sharp V$	$\sharp II$	$\sharp VI$	$\sharp III^+$	$\sharp VII^+$
I^-	V^-	II^-	VI	III	VII	$\sharp IV$	$\sharp I^+$	$\sharp V^+$
$\flat VI^-$	$\flat III^-$	$\flat VII^-$	IV	I	V	II	VI^+	III^+
$\flat IV^-$	$\flat I^-$	$\flat V^-$	$\flat II$	$\flat VI$	$\flat III$	$\flat VII$	IV^+	I^+
$\flat\flat II^-$	$\flat\flat VI^-$	$\flat\flat III^-$	$\flat\flat VII$	$\flat IV$	$\flat I$	$\flat V$	$\flat II^+$	$\flat VI^+$

A Semantics for Harmony

- Harmonic semantics of a piece is a path through the space
- Chords re-express the current point or move to a nearby point
- Corresponds to harmonic analysis done by:
  - musicologists
  - jazz performers (when improvising)
  - you (unconciously)

CCG Syntax

- Fairly standard combinatory categorial grammar (CCG)
- Category assigned to each chord
- Grammatical rules combine categories
- Mostly the same combinatorial rules as language
- Semantics on each lexical item
- Use λ-calculus to build up a path through the space

Atomic Categories

- Atomic categories of form:

$$X{-}Y$$

- Important syntactic information: start and end points of span
- Simple tonic chord at I interpreted as:

$$I{-}I$$

- Just one point in space

Complex Categories

- Complex categories built up with slashes
- ♫ Unsubstituted dominant chord on V expects resolution to I

$$V\text{–}X \;/\; I\text{–}X$$

- Next category must begin at I

$$V\text{–}X \;/\; I\text{–}X \quad I\text{–}I \Rightarrow_{>} V\text{–}I$$

- Interprets this chord as a movement from V to I

Adding the Semantics

- Add λ-calculus semantics to lexicon
- Build up a list of points in tonal space
- Use functional-style lists with :: cons operator
- Tonic chord (on *I*):

$$I\text{–}I \quad : \quad (I :: Nil)$$

Adding the Semantics

- Dominant chord (on V):

$$V\text{–}X \;/\; I\text{–}X \quad : \quad \lambda x.V :: x$$

Adding the Semantics

- Also include harmonic function (T, D or S)
- Tonic:

$$I\text{–}I \;:\; (I_T :: Nil)$$

- Dominant chord (on V):

$$V\text{–}X \;/\; I\text{–}X \;:\; \lambda x.V_D :: x$$

- E.g. extended cadence:

$$\dfrac{II\text{–}X \;/\; V\text{–}X \;:\; \lambda x.II :: x \qquad \dfrac{V\text{–}X \;/\; I\text{–}X \;:\; \lambda x.V :: x \qquad I\text{–}I \;:\; I :: Nil}{V\text{–}I \;:\; V :: I :: Nil}>}{II\text{–}I \;:\; II :: V :: I :: Nil}>$$

The Modelling Problem

- Overview of the modelling problem
- Some of the things that make it different from language

The Modelling Problem

- As with language, complete parsing infeasible
- Huge lexical ambiguity
- $\rightarrow$ Even more need to cut search space
- Lots of improbable interpretations
- Probabilities of chord interpretations depend on harmonic structure
- Strong melodic expectations too

Timing is Important

- Music has a metrical structure
- Timing in relation to this structure is important
- Interpret harmony differently at different times
- Expectations vary depending position in this structure

More Modelling Difficulties

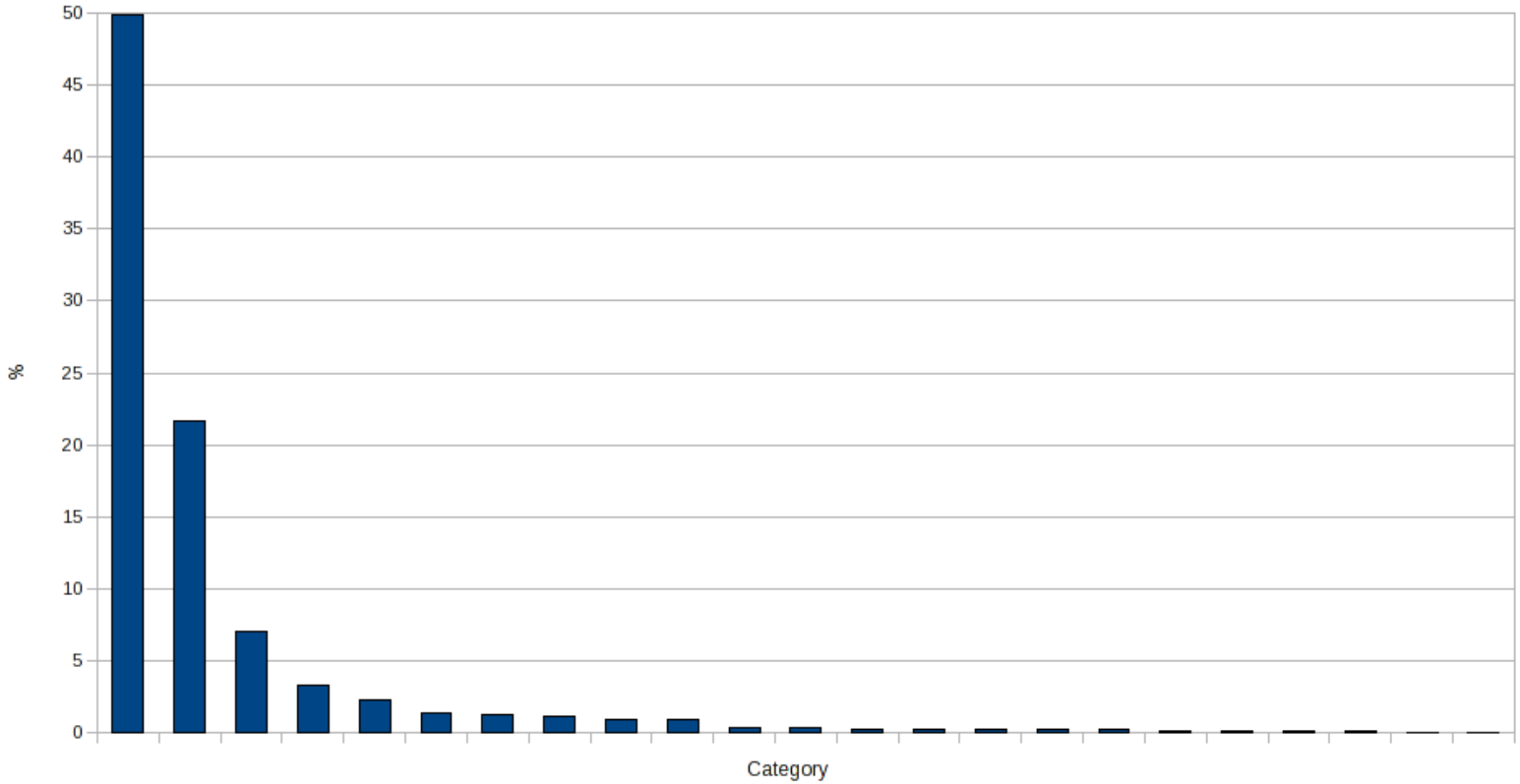
- Cadences don't always resolve
- Sometimes stop in the middle and repeat
- Structurally like coordination in language
- No "and"s or other conjunctions to help us out

More Modelling Difficulties

- Cadences usually resolve to main tonic of the current key
- Might resolve to a related tonic
- Might move to a new key (*modulation*)

More Modelling Difficulties

- Most common category (simple dominant): ∼50% of chords
- Next most common (simple tonic): ∼20%
- Some interpretations are very rare



Summary: Musical Modelling Challenges

- Huge lexical ambiguity
- Salience of timing structures
- Unsignalled coordination
- Sparse data

Conclusion

- Music and language have much in common
- Interesting structure in harmony
- Traditional music theory analyzes this structure
- Grammars are a good way to handle it

Conclusion

- Longuet-Higgins tonal space
- Semantic domain for concrete analysis
- CCG allows us to use structure in harmony to build an analysis
- We need a model
- Outlined some features important for a good model