

# Advanced Functional Programming for Fun and Profit

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<http://dreixel.net>

January 10, 2014  
Amsterdam, The Netherlands

Three years ago...

The slide background features a grayscale architectural rendering of a modern building with a curved roof. On the left side, there are two overlapping colored shapes: a yellow rectangle at the top and a red shape below it. A circular sunburst logo is positioned at the intersection of these shapes.

Universiteit Utrecht

[Faculty of Science  
Information and Computing Sciences]

## Functional Modeling of Musical Harmony

José Pedro Magalhães  
joint work with Bas de Haas

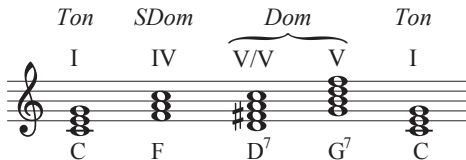
Dept. of Information and Computing Sciences, Utrecht University  
P.O. Box 80.089, 3508 TB Utrecht, The Netherlands  
Web pages: <http://www.cs.uu.nl/wiki/Center>

January 7, 2011

@ Dutch Functional Programming day 2011, University of Twente

- ▶ Modelling musical harmony using Haskell
- ▶ Applications of a model of harmony:
  - ▶ Musical analysis
  - ▶ Finding cover songs
  - ▶ Generating chords for melodies
  - ▶ Correcting errors in chord extraction from audio sources
- ▶ Chordify—a web-based music player with chord recognition

# What is harmony?



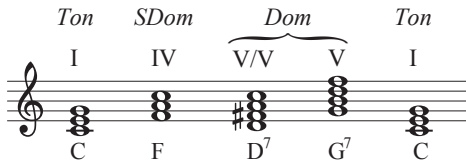
*Ton*     *SDom*     *Dom*     *Ton*

I     IV     V/V     V     I

C     F     D<sup>7</sup>     G<sup>7</sup>     C

- ▶ Harmony arises when at least two notes sound at the same time
- ▶ Harmony induces tension and release patterns, that can be described by music theory and music cognition
- ▶ The internal structure of the chord has a large influence on the consonance or dissonance of a chord
- ▶ The surrounding context also has a large influence

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Demo: how harmony affects melody

# Why are harmony models useful?



Having a model for musical harmony allows us to automatically determine the functional meaning of chords in the tonal context. The model determines which chords “fit” on a particular moment in a song.

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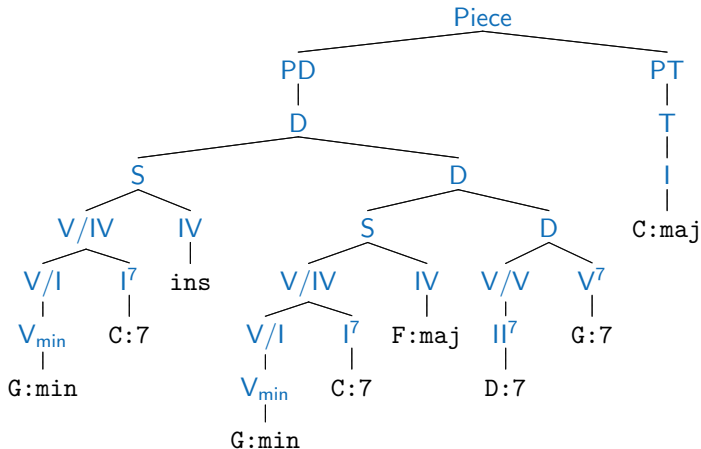


Having a model for musical harmony allows us to automatically determine the functional meaning of chords in the tonal context. The model determines which chords “fit” on a particular moment in a song. This is useful for:

- ▶ Musical information retrieval (find songs similar to a given song)
- ▶ Audio and score recognition (improving recognition by knowing which chords are more likely to appear)
- ▶ Music generation (create sequences of chords that conform to the model)

# Application: harmony analysis

Parsing the sequence  $G_{\min}$   $C^7$   $G_{\min}$   $C^7$   $F_{\text{Maj}}$   $D^7$   $G^7$   $C_{\text{Maj}}$ :





- ▶ A practical application of a harmony model is to estimate harmonic similarity between songs
- ▶ The more similar the trees, the more similar the harmony
- ▶ We don't want to write a diff algorithm for our complicated model; we get it automatically by using a *generic diff*
- ▶ The generic diff is a type-safe tree-diff algorithm, part of a student's MSc work at Utrecht University
- ▶ Generic, thus working for any model, and independent of changes to the model

# Application: automatic harmonisation of melodies



Another practical application of a harmony model is to help selecting good harmonisations (chord sequences) for a given melody:

The image displays a musical score for a single system. The top staff is in the treble clef, showing a melody in C major. The bottom staff is in the bass clef, showing a sequence of chords. The chords are labeled with Roman numerals: V, III, I, III, II, IV, III, IV, V. The melody consists of the following notes: C4, D4, E4, F4, G4, A4, B4, C5, B4, A4, G4, F4, E4, D4, C4. The chord sequence is: V (C4-E4-G4), III (C4-E4-G4), I (C4-E4-G4), III (C4-E4-G4), II (D4-F4-A4), IV (F4-A4-C5), III (C4-E4-G4), IV (F4-A4-C5), V (C4-E4-G4).

We generate candidate chord sequences, parse them with the harmony model, and select the one with the least errors.

# Application: chord recognition



Yet another practical application of a harmony model is to improve chord recognition from audio sources.

Chord candidates	0.92 C	0.96 Em	
	0.94 Gm	0.97 C	
	1.00 C	1.00 G	1.00 Em
Beat number	1	2	3

How to pick the right chord from the chord candidate list? Ask the harmony model which one fits best.

# Demo: Chordify



Demo:

chordify<sup>®</sup>

<http://chordify.net>

- ▶ Frontend

- ▶ Reads user input, such as YouTube/Soundcloud links, or files
- ▶ Extracts audio
- ▶ Calls the backend to obtain the chords for the audio
- ▶ Displays the result to the user
- ▶ Implements a queueing system, and library functionality
- ▶ Uses PHP, JavaScript, MongoDB

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## ▶ Backend

- ▶ Takes an audio file as input, analyses it, extracts the chords
- ▶ The chord extraction code uses GADTs, type families, generic programming (see the harmtrace package on Hackage)
- ▶ Performs PDF and MIDI export (using LilyPond)
- ▶ Uses Haskell, SoX, sonic annotator, and is mostly open source

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- ▶ Will replace the frontend queueing system (using Happstack)

## Musical modelling with Haskell:

- ▶ A model for musical harmony as a Haskell datatype
- ▶ Makes use of several advanced functional programming techniques, such as generic programming, GADTs, and type families
- ▶ When chords do not fit the model: error correction
- ▶ Harmonising melodies
- ▶ Recognising harmony from audio sources



# Play with it!



`http://hackage.haskell.org/package/HarmTrace`

**chordify**<sup>®</sup>

`http://chordify.net`