

Bayesian Model Selection for Harmonic Labelling

Christophe Rhodes

Goldsmiths, University of London

Friday 18th May

- 1 Introduction
Overview
Motivation
Model Selection
- 2 Harmonic Model
Individual chords
Extended regions
- 3 Examples and evaluation
- 4 Future and Conclusions

The task: identifying chords and assigning harmonic labels in popular music.

- currently to MIDI transcriptions of performances;
- could be applied to audio directly (given suitable processing).

Applications:

- generating fake books, guitar chords
- feeding into models of music cognition, melodic memory

The task: identifying chords and assigning harmonic labels in popular music.

- currently to MIDI transcriptions of performances;
- could be applied to audio directly (given suitable processing).

Applications:

- generating fake books, guitar chords
- feeding into models of music cognition, melodic memory

The task: identifying chords and assigning harmonic labels in popular music.

- currently to MIDI transcriptions of performances;
- could be applied to audio directly (given suitable processing).

Applications:

- generating fake books, guitar chords
- feeding into models of music cognition, melodic memory

The task: identifying chords and assigning harmonic labels in popular music.

- currently to MIDI transcriptions of performances;
- could be applied to audio directly (given suitable processing).

Applications:

- generating fake books, guitar chords
- feeding into models of music cognition, melodic memory

Previous work:

- preference rules / knowledge representation
- implicit models of harmony and key (e.g. profiles)
- embedding in suitable space (spiral, torus)

Common feature: label small section and then smooth.

We attempt to build a model with some desirable attributes:

- credible, at least at the descriptive level;
- quantitative enough to be usable in further inference;
- able to be extended incorporate new information quantitatively.

Previous work:

- preference rules / knowledge representation
- implicit models of harmony and key (e.g. profiles)
- embedding in suitable space (spiral, torus)

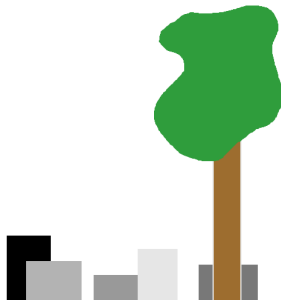
Common feature: label small section and then smooth.

We attempt to build a model with some desirable attributes:

- credible, at least at the descriptive level;
- quantitative enough to be usable in further inference;
- able to be extended incorporate new information quantitatively.

What is the next number in the series -1, 3, 7, 11, ...?

How many boxes in this scene?



For pitch-class vector \mathbf{x} , we express probability density given chord c as

$$p(\mathbf{x}|c; \Omega) = p_{\mathcal{D}}(t\bar{t}|c; \Omega)p_{\mathcal{D}}(rmd|c; \Omega)$$

where

$$p_{\mathcal{D}}(\mathbf{x}|\alpha_c) = \frac{1}{B(\alpha)} \prod_i x_i^{\alpha_i - 1} \quad \left(\sum_i x_i = 1 \right)$$

Then by Bayes' theorem, for a given pitch-class vector \mathbf{x}

$$p(c|\mathbf{x}\Omega) = \frac{p(\mathbf{x}|c\Omega)p(c\Omega)}{\sum_c p(\mathbf{x}|c\Omega)p(c\Omega)}$$

For pitch-class vector \mathbf{x} , we express probability density given chord c as

$$p(\mathbf{x}|c; \Omega) = p_{\mathcal{D}}(t\bar{t}|c; \Omega)p_{\mathcal{D}}(rmd|c; \Omega)$$

where

$$p_{\mathcal{D}}(\mathbf{x}|\alpha_c) = \frac{1}{B(\alpha)} \prod_i x_i^{\alpha_i - 1} \quad \left(\sum_i x_i = 1 \right)$$

Then by Bayes' theorem, for a given pitch-class vector \mathbf{x}

$$p(c|\mathbf{x}\Omega) = \frac{p(\mathbf{x}|c\Omega)p(c\Omega)}{\sum_c p(\mathbf{x}|c\Omega)p(c\Omega)}$$

For pitch-class vector \mathbf{x} , we express probability density given chord c as

$$p(\mathbf{x}|c; \Omega) = p_D(t\bar{t}|c; \Omega)p_D(rmd|c; \Omega)$$

where

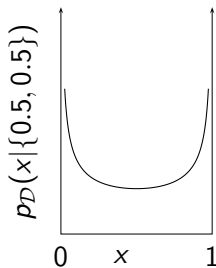
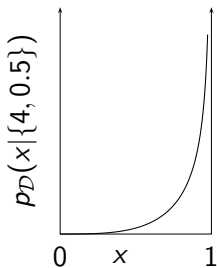
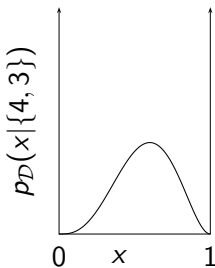
$$p_D(\mathbf{x}|\alpha_c) = \frac{1}{B(\alpha)} \prod_i x_i^{\alpha_i - 1} \quad \left(\sum_i x_i = 1 \right)$$

Then by Bayes' theorem, for a given pitch-class vector \mathbf{x}

$$p(c|\mathbf{x}\Omega) = \frac{p(\mathbf{x}|c\Omega)p(c\Omega)}{\sum_c p(\mathbf{x}|c\Omega)p(c\Omega)}$$

$$p_D(\mathbf{x}|\alpha_c) = \frac{1}{B(\alpha)} \prod_i x_i^{\alpha_i - 1} \quad \left(\sum_i x_i = 1\right)$$

For two variables, choose one x (and the other is $1 - x$)



A Dirichlet distribution over k variables has k parameters. Our model has (in principle) two Dirichlet distributions per distinct chord.

Based on initial inspection of our corpus, we tie parameters such that there are only three distinct cases (instead of the $4 \times 12 \times 6$ that there are in principle for our chord repertoire):

- major or minor chord over a whole bar;
- major or minor chord over a sub-bar window;
- anything else (aug, dim, sus4, sus9).

Estimate parameters for these distributions

- Maximize likelihood of training set;
- Maximize posterior of training set given a suitable prior;
- Tune to maximize performance of labelling task on training set.

A Dirichlet distribution over k variables has k parameters. Our model has (in principle) two Dirichlet distributions per distinct chord.

Based on initial inspection of our corpus, we tie parameters such that there are only three distinct cases (instead of the $4 \times 12 \times 6$ that there are in principle for our chord repertoire):

- major or minor chord over a whole bar;
- major or minor chord over a sub-bar window;
- anything else (aug, dim, sus4, sus9).

Estimate parameters for these distributions

- Maximize likelihood of training set;
- Maximize posterior of training set given a suitable prior;
- Tune to maximize performance of labelling task on training set.

A Dirichlet distribution over k variables has k parameters. Our model has (in principle) two Dirichlet distributions per distinct chord.

Based on initial inspection of our corpus, we tie parameters such that there are only three distinct cases (instead of the $4 \times 12 \times 6$ that there are in principle for our chord repertoire):

- major or minor chord over a whole bar;
- major or minor chord over a sub-bar window;
- anything else (aug, dim, sus4, sus9).

Estimate parameters for these distributions

- Maximize likelihood of training set;
- Maximize posterior of training set given a suitable prior;
- Tune to maximize performance of labelling task on training set.

Limitations of this chord model

Bayesian
Model

Selection for
Harmonic
Labelling

Christophe
Rhodes

Introduction

Overview
Motivation
Model Selection

Harmonic
Model

Individual chords
Extended regions

Examples and
evaluation

Future and
Conclusions

- no special treatment of bass note;
- more generally, no handling of register of individual notes;
- no modelling of transitions between chords.

When does one chord end and another begin?

Assumptions:

- *barline* as fundamental division;
- new chords only on beats.

The first assumption is probably reasonable for our task; the second leads to problems in strongly-syncopated passages.

When does one chord end and another begin?

Assumptions:

- *barline* as fundamental division;
- new chords only on beats.

The first assumption is probably reasonable for our task; the second leads to problems in strongly-syncopated passages.

Models: all possible beatwise divisions of a bar. For example, for $\frac{4}{4}$,

- {4}
- {3,1}, {1,3}
- {2,2}
- {2,1,1}, {1,2,1}, {1,1,2}
- {1,1,1,1}

Choose between bar divisions ω using Bayesian model selection:

$$p(\omega|\mathbf{x}\Omega') \propto \sum_c p(\mathbf{x}|c\omega\Omega')p(c\omega\Omega')$$

Models: all possible beatwise divisions of a bar. For example, for $\frac{4}{4}$,

- {4}
- {3,1}, {1,3}
- {2,2}
- {2,1,1}, {1,2,1}, {1,1,2}
- {1,1,1,1}

Choose between bar divisions ω using Bayesian model selection:

$$p(\omega | \mathbf{x} \Omega') \propto \sum_c p(\mathbf{x} | c\omega \Omega') p(c\omega \Omega')$$

Saving all my love for you (Michael Masser)

The image shows a musical score for the song "Saving all my love for you" by Michael Masser. The score is in 12/8 time and consists of two staves: a treble clef staff and a bass clef staff. The key signature is two sharps (F# and C#). The treble clef staff contains the melody, and the bass clef staff contains the bass line. Above the treble clef staff, several chords are labeled: A^{maj7}, F#^{min 7}, B^{sus9}^{add4}, A^{sus4}_E, and A^{maj7}_{F#}^{add6}. The bass line consists of a series of notes, including a whole note G#2, a half note A2, and a quarter note B2, followed by a series of eighth notes: G#2, A2, B2, C#3, D3, E3, F#3, G#3, A3, B3, C#4, D4, E4, F#4, G#4, A4, B4, C#5, D5, E5, F#5, G#5, A5, B5, C#6, D6, E6, F#6, G#6, A6, B6, C#7, D7, E7, F#7, G#7, A7, B7, C#8, D8, E8, F#8, G#8, A8, B8, C#9, D9, E9, F#9, G#9, A9, B9, C#10, D10, E10, F#10, G#10, A10, B10, C#11, D11, E11, F#11, G#11, A11, B11, C#12, D12, E12, F#12, G#12, A12, B12, C#13, D13, E13, F#13, G#13, A13, B13, C#14, D14, E14, F#14, G#14, A14, B14, C#15, D15, E15, F#15, G#15, A15, B15, C#16, D16, E16, F#16, G#16, A16, B16, C#17, D17, E17, F#17, G#17, A17, B17, C#18, D18, E18, F#18, G#18, A18, B18, C#19, D19, E19, F#19, G#19, A19, B19, C#20, D20, E20, F#20, G#20, A20, B20, C#21, D21, E21, F#21, G#21, A21, B21, C#22, D22, E22, F#22, G#22, A22, B22, C#23, D23, E23, F#23, G#23, A23, B23, C#24, D24, E24, F#24, G#24, A24, B24, C#25, D25, E25, F#25, G#25, A25, B25, C#26, D26, E26, F#26, G#26, A26, B26, C#27, D27, E27, F#27, G#27, A27, B27, C#28, D28, E28, F#28, G#28, A28, B28, C#29, D29, E29, F#29, G#29, A29, B29, C#30, D30, E30, F#30, G#30, A30, B30, C#31, D31, E31, F#31, G#31, A31, B31, C#32, D32, E32, F#32, G#32, A32, B32, C#33, D33, E33, F#33, G#33, A33, B33, C#34, D34, E34, F#34, G#34, A34, B34, C#35, D35, E35, F#35, G#35, A35, B35, C#36, D36, E36, F#36, G#36, A36, B36, C#37, D37, E37, F#37, G#37, A37, B37, C#38, D38, E38, F#38, G#38, A38, B38, C#39, D39, E39, F#39, G#39, A39, B39, C#40, D40, E40, F#40, G#40, A40, B40, C#41, D41, E41, F#41, G#41, A41, B41, C#42, D42, E42, F#42, G#42, A42, B42, C#43, D43, E43, F#43, G#43, A43, B43, C#44, D44, E44, F#44, G#44, A44, B44, C#45, D45, E45, F#45, G#45, A45, B45, C#46, D46, E46, F#46, G#46, A46, B46, C#47, D47, E47, F#47, G#47, A47, B47, C#48, D48, E48, F#48, G#48, A48, B48, C#49, D49, E49, F#49, G#49, A49, B49, C#50, D50, E50, F#50, G#50, A50, B50, C#51, D51, E51, F#51, G#51, A51, B51, C#52, D52, E52, F#52, G#52, A52, B52, C#53, D53, E53, F#53, G#53, A53, B53, C#54, D54, E54, F#54, G#54, A54, B54, C#55, D55, E55, F#55, G#55, A55, B55, C#56, D56, E56, F#56, G#56, A56, B56, C#57, D57, E57, F#57, G#57, A57, B57, C#58, D58, E58, F#58, G#58, A58, B58, C#59, D59, E59, F#59, G#59, A59, B59, C#60, D60, E60, F#60, G#60, A60, B60, C#61, D61, E61, F#61, G#61, A61, B61, C#62, D62, E62, F#62, G#62, A62, B62, C#63, D63, E63, F#63, G#63, A63, B63, C#64, D64, E64, F#64, G#64, A64, B64, C#65, D65, E65, F#65, G#65, A65, B65, C#66, D66, E66, F#66, G#66, A66, B66, C#67, D67, E67, F#67, G#67, A67, B67, C#68, D68, E68, F#68, G#68, A68, B68, C#69, D69, E69, F#69, G#69, A69, B69, C#70, D70, E70, F#70, G#70, A70, B70, C#71, D71, E71, F#71, G#71, A71, B71, C#72, D72, E72, F#72, G#72, A72, B72, C#73, D73, E73, F#73, G#73, A73, B73, C#74, D74, E74, F#74, G#74, A74, B74, C#75, D75, E75, F#75, G#75, A75, B75, C#76, D76, E76, F#76, G#76, A76, B76, C#77, D77, E77, F#77, G#77, A77, B77, C#78, D78, E78, F#78, G#78, A78, B78, C#79, D79, E79, F#79, G#79, A79, B79, C#80, D80, E80, F#80, G#80, A80, B80, C#81, D81, E81, F#81, G#81, A81, B81, C#82, D82, E82, F#82, G#82, A82, B82, C#83, D83, E83, F#83, G#83, A83, B83, C#84, D84, E84, F#84, G#84, A84, B84, C#85, D85, E85, F#85, G#85, A85, B85, C#86, D86, E86, F#86, G#86, A86, B86, C#87, D87, E87, F#87, G#87, A87, B87, C#88, D88, E88, F#88, G#88, A88, B88, C#89, D89, E89, F#89, G#89, A89, B89, C#90, D90, E90, F#90, G#90, A90, B90, C#91, D91, E91, F#91, G#91, A91, B91, C#92, D92, E92, F#92, G#92, A92, B92, C#93, D93, E93, F#93, G#93, A93, B93, C#94, D94, E94, F#94, G#94, A94, B94, C#95, D95, E95, F#95, G#95, A95, B95, C#96, D96, E96, F#96, G#96, A96, B96, C#97, D97, E97, F#97, G#97, A97, B97, C#98, D98, E98, F#98, G#98, A98, B98, C#99, D99, E99, F#99, G#99, A99, B99, C#100, D100, E100, F#100, G#100, A100, B100, C#101, D101, E101, F#101, G#101, A101, B101, C#102, D102, E102, F#102, G#102, A102, B102, C#103, D103, E103, F#103, G#103, A103, B103, C#104, D104, E104, F#104, G#104, A104, B104, C#105, D105, E105, F#105, G#105, A105, B105, C#106, D106, E106, F#106, G#106, A106, B106, C#107, D107, E107, F#107, G#107, A107, B107, C#108, D108, E108, F#108, G#108, A108, B108, C#109, D109, E109, F#109, G#109, A109, B109, C#110, D110, E110, F#110, G#110, A110, B110, C#111, D111, E111, F#111, G#111, A111, B111, C#112, D112, E112, F#112, G#112, A112, B112, C#113, D113, E113, F#113, G#113, A113, B113, C#114, D114, E114, F#114, G#114, A114, B114, C#115, D115, E115, F#115, G#115, A115, B115, C#116, D116, E116, F#116, G#116, A116, B116, C#117, D117, E117, F#117, G#117, A117, B117, C#118, D118, E118, F#118, G#118, A118, B118, C#119, D119, E119, F#119, G#119, A119, B119, C#120, D120, E120, F#120, G#120, A120, B120, C#121, D121, E121, F#121, G#121, A121, B121, C#122, D122, E122, F#122, G#122, A122, B122, C#123, D123, E123, F#123, G#123, A123, B123, C#124, D124, E124, F#124, G#124, A124, B124, C#125, D125, E125, F#125, G#125, A125, B125, C#126, D126, E126, F#126, G#126, A126, B126, C#127, D127, E127, F#127, G#127, A127, B127, C#128, D128, E128, F#128, G#128, A128, B128, C#129, D129, E129, F#129, G#129, A129, B129, C#130, D130, E130, F#130, G#130, A130, B130, C#131, D131, E131, F#131, G#131, A131, B131, C#132, D132, E132, F#132, G#132, A132, B132, C#133, D133, E133, F#133, G#133, A133, B133, C#134, D134, E134, F#134, G#134, A134, B134, C#135, D135, E135, F#135, G#135, A135, B135, C#136, D136, E136, F#136, G#136, A136, B136, C#137, D137, E137, F#137, G#137, A137, B137, C#138, D138, E138, F#138, G#138, A138, B138, C#139, D139, E139, F#139, G#139, A139, B139, C#140, D140, E140, F#140, G#140, A140, B140, C#141, D141, E141, F#141, G#141, A141, B141, C#142, D142, E142, F#142, G#142, A142, B142, C#143, D143, E143, F#143, G#143, A143, B143, C#144, D144, E144, F#144, G#144, A144, B144, C#145, D145, E145, F#145, G#145, A145, B145, C#146, D146, E146, F#146, G#146, A146, B146, C#147, D147, E147, F#147, G#147, A147, B147, C#148, D148, E148, F#148, G#148, A148, B148, C#149, D149, E149, F#149, G#149, A149, B149, C#150, D150, E150, F#150, G#150, A150, B150, C#151, D151, E151, F#151, G#151, A151, B151, C#152, D152, E152, F#152, G#152, A152, B152, C#153, D153, E153, F#153, G#153, A153, B153, C#154, D154, E154, F#154, G#154, A154, B154, C#155, D155, E155, F#155, G#155, A155, B155, C#156, D156, E156, F#156, G#156, A156, B156, C#157, D157, E157, F#157, G#157, A157, B157, C#158, D158, E158, F#158, G#158, A158, B158, C#159, D159, E159, F#159, G#159, A159, B159, C#160, D160, E160, F#160, G#160, A160, B160, C#161, D161, E161, F#161, G#161, A161, B161, C#162, D162, E162, F#162, G#162, A162, B162, C#163, D163, E163, F#163, G#163, A163, B163, C#164, D164, E164, F#164, G#164, A164, B164, C#165, D165, E165, F#165, G#165, A165, B165, C#166, D166, E166, F#166, G#166, A166, B166, C#167, D167, E167, F#167, G#167, A167, B167, C#168, D168, E168, F#168, G#168, A168, B168, C#169, D169, E169, F#169, G#169, A169, B169, C#170, D170, E170, F#170, G#170, A170, B170, C#171, D171, E171, F#171, G#171, A171, B171, C#172, D172, E172, F#172, G#172, A172, B172, C#173, D173, E173, F#173, G#173, A173, B173, C#174, D174, E174, F#174, G#174, A174, B174, C#175, D175, E175, F#175, G#175, A175, B175, C#176, D176, E176, F#176, G#176, A176, B176, C#177, D177, E177, F#177, G#177, A177, B177, C#178, D178, E178, F#178, G#178, A178, B178, C#179, D179, E179, F#179, G#179, A179, B179, C#180, D180, E180, F#180, G#180, A180, B180, C#181, D181, E181, F#181, G#181, A181, B181, C#182, D182, E182, F#182, G#182, A182, B182, C#183, D183, E183, F#183, G#183, A183, B183, C#184, D184, E184, F#184, G#184, A184, B184, C#185, D185, E185, F#185, G#185, A185, B185, C#186, D186, E186, F#186, G#186, A186, B186, C#187, D187, E187, F#187, G#187, A187, B187, C#188, D188, E188, F#188, G#188, A188, B188, C#189, D189, E189, F#189, G#189, A189, B189, C#190, D190, E190, F#190, G#190, A190, B190, C#191, D191, E191, F#191, G#191, A191, B191, C#192, D192, E192, F#192, G#192, A192, B192, C#193, D193, E193, F#193, G#193, A193, B193, C#194, D194, E194, F#194, G#194, A194, B194, C#195, D195, E195, F#195, G#195, A195, B195, C#196, D196, E196, F#196, G#196, A196, B196, C#197, D197, E197, F#197, G#197, A197, B197, C#198, D198, E198, F#198, G#198, A198, B198, C#199, D199, E199, F#199, G#199, A199, B199, C#200, D200, E200, F#200, G#200, A200, B200, C#201, D201, E201, F#201, G#201, A201, B201, C#202, D202, E202, F#202, G#202, A202, B202, C#203, D203, E203, F#203, G#203, A203, B203, C#204, D204, E204, F#204, G#204, A204, B204, C#205, D205, E205, F#205, G#205, A205, B205, C#206, D206, E206, F#206, G#206, A206, B206, C#207, D207, E207, F#207, G#207, A207, B207, C#208, D208, E208, F#208, G#208, A208, B208, C#209, D209, E209, F#209, G#209, A209, B209, C#210, D210, E210, F#210, G#210, A210, B210, C#211, D211, E211, F#211, G#211, A211, B211, C#212, D212, E212, F#212, G#212, A212, B212, C#213, D213, E213, F#213, G#213, A213, B213, C#214, D214, E214, F#214, G#214, A214, B214, C#215, D215, E215, F#215, G#215, A215, B215, C#216, D216, E216, F#216, G#216, A216, B216, C#217, D217, E217, F#217, G#217, A217, B217, C#218, D218, E218, F#218, G#218, A218, B218, C#219, D219, E219, F#219, G#219, A219, B219, C#220, D220, E220, F#220, G#220, A220, B220, C#221, D221, E221, F#221, G#221, A221, B221, C#222, D222, E222, F#222, G#222, A222, B222, C#223, D223, E223, F#223, G#223, A223, B223, C#224, D224, E224, F#224, G#224, A224, B224, C#225, D225, E225, F#225, G#225, A225, B225, C#226, D226, E226, F#226, G#226, A226, B226, C#227, D227, E227, F#227, G#227, A227, B227, C#228, D228, E228, F#228, G#228, A228, B228, C#229, D229, E229, F#229, G#229, A229, B229, C#230, D230, E230, F#230, G#230, A230, B230, C#231, D231, E231, F#231, G#231, A231, B231, C#232, D232, E232, F#232, G#232, A232, B232, C#233, D233, E233, F#233, G#233, A233, B233, C#234, D234, E234, F#234, G#234, A234, B234, C#235, D235, E235, F#235, G#235, A235, B235, C#236, D236, E236, F#236, G#236, A236, B236, C#237, D237, E237, F#237, G#237, A237, B237, C#238, D238, E238, F#238, G#238, A238, B238, C#239, D239, E239, F#239, G#239, A239, B239, C#240, D240, E240, F#240, G#240, A240, B240, C#241, D241, E241, F#241, G#241, A241, B241, C#242, D242, E242, F#242, G#242, A242, B242, C#243, D243, E243, F#243, G#243, A243, B243, C#244, D244, E244, F#244, G#244, A244, B244, C#245, D245, E245, F#245, G#245, A245, B245, C#246, D246, E246, F#246, G#246, A246, B246, C#247, D247, E247, F#247, G#247, A247, B247, C#248, D248, E248, F#248, G#248, A248, B248, C#249, D249, E249, F#249, G#249, A249, B249, C#250, D250, E250, F#250, G#250, A250, B250, C#251, D251, E251, F#251, G#251, A251, B251, C#252, D252, E252, F#252, G#252, A252, B252, C#253, D253, E253, F#253, G#253, A253, B253, C#254, D254, E254, F#254, G#254, A254, B254, C#255, D255, E255, F#255, G#255, A255, B255, C#256, D256, E256, F#256, G#256, A256, B256, C#257, D257, E257, F#257, G#257, A257, B257, C#258, D258, E258, F#258, G#258, A258, B258, C#259, D259, E259, F#259, G#259, A259, B259, C#260, D260, E260, F#260, G#260, A260, B260, C#261, D261, E261, F#261, G#261, A261, B261, C#262, D262, E262, F#262, G#262, A262, B262, C#263, D263, E263, F#263, G#263, A263, B263, C#264, D264, E264, F#264, G#264, A264, B264, C#265, D265, E265, F#265, G#265, A265, B265, C#266, D266, E266, F#266, G#266, A266, B266, C#267, D267, E267, F#267, G#267, A267, B267, C#268, D268, E268, F#268, G#268, A268, B268, C#269, D269, E269, F#269, G#269, A269, B269, C#270, D270, E270, F#270, G#270, A270, B270, C#271, D271, E271, F#271, G#271, A271, B271, C#272, D272, E272, F#272, G#272, A272, B272, C#273, D273, E273, F#273, G#273, A273, B273, C#274, D274, E274, F#274, G#274, A274, B274, C#275, D275, E275, F#275, G#275, A275, B275, C#276, D276, E276, F#276, G#276, A276, B276, C#277, D277, E277, F#277, G#277, A277, B277, C#278, D278, E278, F#278, G#278, A278, B278, C#279, D279, E279, F#279, G#279, A279, B279, C#280, D280, E280, F#280, G#280, A280, B280, C#281, D281, E281, F#281, G#281, A281, B281, C#282, D282, E282, F#282, G#282, A282, B282, C#283, D283, E283, F#283, G#283, A283, B283, C#284, D284, E284, F#284, G#284, A284, B284, C#285, D285, E285, F#285, G#285, A285, B285, C#286, D286, E286, F#286, G#286, A286, B286, C#287, D287, E287, F#287, G#287, A287, B287, C#288, D288, E288, F#288, G#288, A288, B288, C#289, D289, E289, F#289, G#289, A289, B289, C#290, D290, E290, F#290, G#290, A290, B290, C#291, D291, E291, F#291, G#291, A291, B291, C#292, D292, E292, F#292, G#292, A292, B292, C#293, D293, E293, F#293, G#293, A293, B293, C#294, D294, E294, F#294, G#294, A294, B294, C#295, D295, E295, F#295, G#295, A295, B295, C#296, D296, E296, F#296, G#296, A296, B296, C#297, D297, E297, F#297, G#297, A297, B297, C#298, D298, E298, F#298, G#298, A298, B298, C#299, D299, E299, F#299, G#299, A299, B299, C#300, D300, E300, F#300, G#300, A300, B300, C#301, D301, E301, F#301, G#301, A301, B301, C#302, D302, E302, F#302, G#302, A302, B302, C#303, D303, E303, F#303, G#303, A303, B303, C#304, D304, E304, F#304, G#304, A304, B304, C#305, D305, E305, F#305, G#305, A305, B305, C#306, D306, E306, F#306, G#306, A306, B306, C#307, D307, E307, F#307, G#307, A307, B307, C#308, D308, E308, F#308, G#308, A308, B308, C#309, D309, E309, F#309, G#309, A309, B309, C#310, D310, E310, F#310, G#310, A310, B310, C#311, D311, E311, F#311, G#311, A311, B311, C#312, D312, E312, F#312, G#312, A312, B312, C#313, D313, E313, F#313, G#313, A313, B313, C#314, D314, E314, F#314, G#314, A314, B314, C#315, D315, E315, F#315, G#315, A315, B315, C#316, D316, E316, F#316, G#316, A316, B316, C#317, D317, E317, F#317, G#317, A317, B317, C#318, D318, E318, F#318, G#318, A318, B318, C#319, D319, E319, F#319, G#319, A319, B319, C#320, D320, E320, F#320, G#320, A320, B320, C#321, D321, E321, F#321, G#321, A321, B321, C#322, D322, E322, F#322, G#322, A322, B322, C#323, D323, E323, F#323, G#323, A323, B323, C#324, D324, E324, F#324, G#324, A324, B324, C#325, D325, E325, F#325, G#325, A325, B325, C#326, D326, E326, F#326, G#326, A326, B326, C#327, D327, E327, F#327, G#327, A327, B327, C#328, D328, E328, F#328, G#328, A328, B328, C#329, D329, E329, F#329, G#329, A329, B329, C#330, D330, E330, F#330, G#330, A330, B330, C#331, D331, E331, F#331, G#

Saving all my love for you (Michael Masser)

The image shows a musical score for the song "Saving all my love for you" by Michael Masser. The score is in 12/8 time and consists of two staves: a treble clef staff and a bass clef staff. The key signature is two sharps (F# and C#). The treble clef staff contains the melody and chords, while the bass clef staff contains the bass line. Above the treble clef staff, the following chords are labeled: A^{maj7}, F#^{min} 7, Bsus9^{add4}, Asus4_E, and A^{maj7} add6_{F#}. The bass line consists of a series of notes, including a whole note G#2, a half note A#2, and a quarter note B2.

Bass note assignments and extensions are heuristically derived *after* the harmonic labelling; future work would incorporate those judgments into the framework.

Evaluation: how good is our algorithm?

Bayesian
Model

Selection for
Harmonic
Labelling

Christophe
Rhodes

Introduction

Overview
Motivation
Model Selection

Harmonic
Model

Individual chords
Extended regions

Examples and
evaluation

Future and
Conclusions

Maximum likelihood parameters estimated from training set
(233 bars):

- 53% regions correctly bounded;
- 75% chords labelled correctly.

Parameters tuned to training set:

- 75% regions correctly bounded;
- 76% chords labelled correctly.

Lady Madonna (Lennon/McCartney)



Is there even a right answer?

Current investigation: how much do experts' opinions on this task differ?

- send machine-generated labels to acknowledged experts for evaluation and corrections;
- four experts, forty excerpts;
- for each expert, score and audio provided for thirty and audio only for ten;
- lead sheet format – also include lead sheets from song books.

Watch this space...

Current investigation: how much do experts' opinions on this task differ?

- send machine-generated labels to acknowledged experts for evaluation and corrections;
- four experts, forty excerpts;
- for each expert, score and audio provided for thirty and audio only for ten;
- lead sheet format – also include lead sheets from song books.

Watch this space...

If we have more domain knowledge, then we can use the same framework to incorporate that knowledge:

- bass note: $p(c|\mathbf{x}b\Omega') \propto p(\mathbf{x}|cb\Omega')p(c|b\Omega')$
- genre: $p(c|\mathbf{x}g\Omega'') \propto p(\mathbf{x}|cg\Omega'')p(c|g\Omega'')$

Bayesian inference doesn't give just one answer, but a probability distribution over labels and windows. We can quantify our uncertainty (e.g. distribution entropy).

- Can segment bars and generate harmonic labels with reasonable accuracy.
- Actual accuracy figures are indicative only: ongoing investigation into performance of human experts.
- Framework is extensible: can incorporate specific information (e.g. knowledge of bass note, alphabet of chord labels for a known genre) in a principled way.

- David Lewis, Daniel Müllensiefen
- Geerdes midimusic (<http://www.midimusic.de/>)
- EPSRC grants GR/S84750/01, EP/D038855/1