

Musical Style Modification as an Optimization Problem

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1. Introduction and Overview
2. Data corpus
3. Local search within neighborhood
4. Objective functions
5. Results

Introduction and Overview

Motivation

- Origin of project

Introduction and Overview

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- Origin of project



Introduction and Overview

Motivation

- Origin of project
- Musical style modification



Introduction and Overview

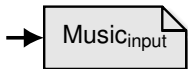
Motivation

- Origin of project
- Musical style modification
- Applications



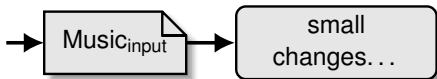
Introduction and Overview

Overview of modification procedure



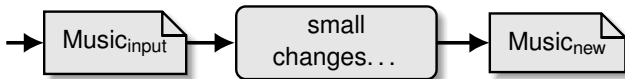
Introduction and Overview

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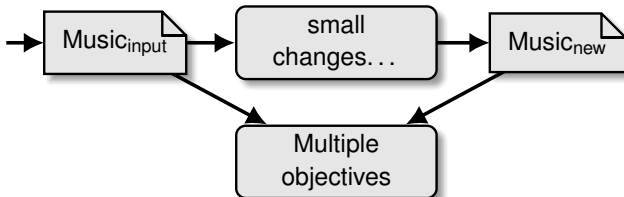
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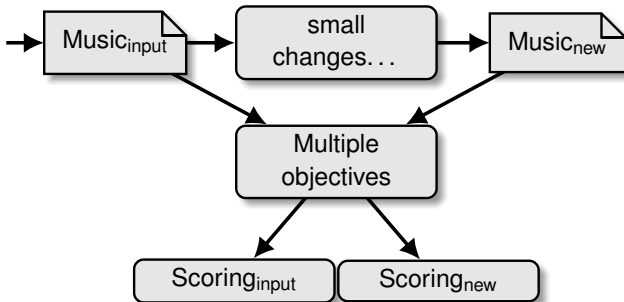
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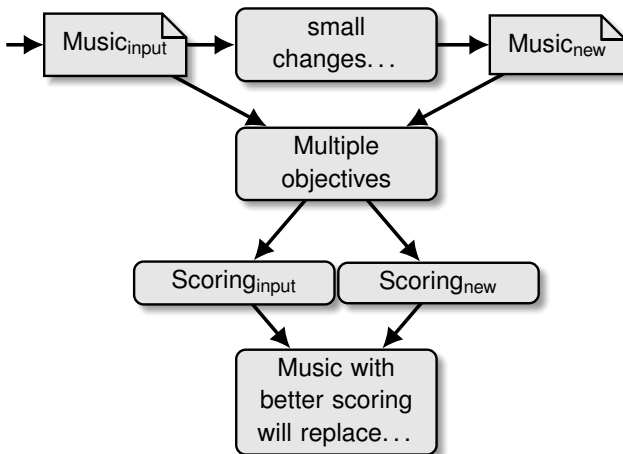
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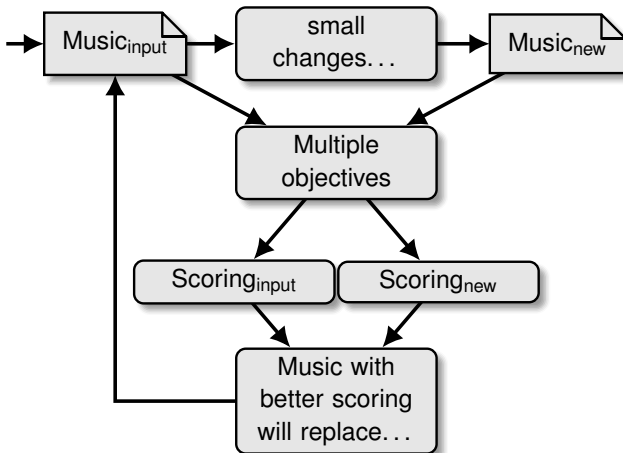
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Introduction and Overview

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Data corpus

Pieces

Jaco Pastorius [Malone, 2002]

Victor Wooten [Wooten, 2003]

Data corpus

Pieces

Jaco Pastorius [Malone, 2002]

P. Metheny: *Bright Size Life*

C. Parker: *Donna Lee*

J. Pastorius: *Havona*

W. Shorter: *Port Of Entry*

J. Pastorius: *Punk Jazz*

J. Pastorius: *Slang*

H. Mancini: *The Days of Wine and Roses*

J. Pastorius: *(Used To Be A) Cha Cha*

Victor Wooten [Wooten, 2003]

V. Wooten: *A Show of Hands*

B. Fleck, V. Wooten and H. Levy: *Blu-Bop*

R. Noble: *Cherokee (Indian Love Song)*

V. Wooten: *Classical Thumb*

J. Lennon and P. McCartney: *Norwegian Wood (This Bird Has Flown)*

V. Wooten: *Sex in a Pan*

B. Fleck: *Sinister Minister*

V. Wooten and B. Fleck: *Stomping Grounds*

Data corpus

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2227.5 quarter length total

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3642.75 quarter length total

Data corpus

Pieces – Examples

Jaco Pastorius [Malone, 2002]

Victor Wooten [Wooten, 2003]

Donna Lee

♩ = 218
A \flat

3 B \flat 7 B \flat m7

6 E \flat 7 A \flat E \flat m7 D7

9 D \flat D \flat m7 A \flat

12 F7 B \flat 7

The image shows a musical score for the piece 'Donna Lee' in bass clef, 4/4 time, with a tempo of 218 beats per minute. The key signature is one flat (A-flat). The score consists of six staves of music. Above the first staff, the tempo is indicated as '♩ = 218' and the key signature as 'A \flat '. Above the second staff, the chords 'B \flat 7' and 'B \flat m7' are written. Above the third staff, the chords 'E \flat 7', 'A \flat ', 'E \flat m7', and 'D7' are written. Above the fourth staff, the chords 'D \flat ', 'D \flat m7', and 'A \flat ' are written. Above the fifth staff, the chords 'F7' and 'B \flat 7' are written. The music features various rhythmic patterns, including triplets and sixteenth notes.

Audio from J. Pastorius: *Jaco Pastorius*, Epic 1976.

Data corpus

Pieces – Examples

Jaco Pastorius [Malone, 2002]

Victor Wooten [Wooten, 2003]

Donna Lee

Musical score for *Donna Lee* by Jaco Pastorius. The score is in bass clef, 4/4 time, and B-flat major. It features a tempo of quarter note = 218 and includes various chords such as A^b, B^b7, B^b m⁷, E^b7, A^b, E^b m⁷, D⁷, D^b, D^b m⁷, A^b, F⁷, and B^b7. The score is divided into measures 3, 6, 9, and 12.

Audio from J. Pastorius: *Jaco Pastorius*, Epic 1976.

Classical Thumb

Musical score for *Classical Thumb* by Victor Wooten. The score is in bass clef, 4/4 time, and B-flat major. It features a tempo of quarter note = 132 and includes the notation "N.C.". The score is divided into measures 3, 5, and 7.

Audio from V. Wooten: *A Show of Hands*, Compass 1996.

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Local search within neighborhood

Note events: $N = (n_1, n_2, \dots, n_I)$ where $n_i = (p_i, d_i)$

Local search within neighborhood

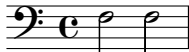
Note events: $N = (n_1, n_2, \dots, n_I)$ where $n_i = (p_i, d_i)$

Chord events: $C = (c_1, c_2, \dots, c_J)$ where $c_j = (s_j, d_j)$

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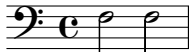
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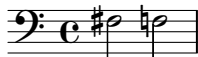
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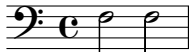
- Changing the pitch p_i



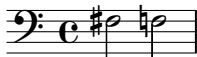
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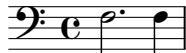
Chord events: $C = (c_1, c_2, \dots, c_J)$ where $c_j = (s_j, d_j)$



- Changing the pitch p_i



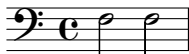
- Changing the duration of two notes d_{i_1} and d_{i_2}



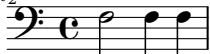
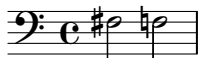
Local search within neighborhood

Note events: $N = (n_1, n_2, \dots, n_I)$ where $n_i = (p_i, d_i)$

Chord events: $C = (c_1, c_2, \dots, c_J)$ where $c_j = (s_j, d_j)$



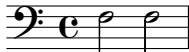
- Changing the pitch p_i
- Changing the duration of two notes d_{i_1} and d_{i_2}
- Dividing n_i into multiple notes



Local search within neighborhood

Note events: $N = (n_1, n_2, \dots, n_I)$ where $n_i = (p_i, d_i)$

Chord events: $C = (c_1, c_2, \dots, c_J)$ where $c_j = (s_j, d_j)$



- Changing the pitch p_i
- Changing the duration of two notes d_{i_1} and d_{i_2}
- Dividing n_i into multiple notes
- Joining n_i and n_{i+1} into single note



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Objective functions

Feature classification

- Windowing (overlapping segments of 2–12 quarter lengths)

Objective functions

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- 324 of music21's feature extractors [Cuthbert et al., 2011] as well as 86 customly designed ones

Objective functions

Feature classification

- Windowing (overlapping segments of 2–12 quarter lengths)
- 324 of music21's feature extractors [Cuthbert et al., 2011] as well as 86 customly designed ones
- Gradient Tree Boosting [Hastie et al., 2009], outputting probability

Objective functions

Feature classification

Example of customly designed features:

(46)

The image shows a musical staff in bass clef with a 4/4 time signature and a key signature of two flats (B-flat and E-flat). The staff contains a sequence of notes: a quarter rest, followed by a quarter note G2, a quarter note A2, and a quarter note B2. This is followed by a series of eighth notes grouped into six triplets. The notes in the triplets are: G2, A2, B2; G2, A2, B2; G2, A2, B2; G2, A2, B2; G2, A2, B2; and G2, A2, B2. Above the staff, a dashed line is labeled '8va'. Brackets above the staff group the notes into six segments, each corresponding to a triplet. The number '3' is written below each triplet. A '3' is also written below the first triplet.

Objective functions

Feature classification

Example of customly designed features:

(46)

8va

$$f_{\text{Jaco}} = \frac{f_{\text{Len}}}{b} \bmod 1 \text{ where } \frac{a}{b} = f_{\text{Dur}},$$

$$\text{gcd}(a, b) = 1$$

Objective functions

Feature classification

Example of customly designed features:

(46)

8va

$$f_{\text{Jaco}} = \frac{f_{\text{Len}}}{b} \bmod 1 \text{ where } \frac{a}{b} = f_{\text{Dur}},$$
$$\text{gcd}(a, b) = 1$$

$f_{\text{Len}} = 4$ and $f_{\text{Dur}} = 1/3$, so $f_{\text{Jaco}} = 4/3 \bmod 1 = 1/3$

Objective functions

Markov probability

- Separate Markov chains for durations and pitches

Objective functions

Markov probability

- Separate Markov chains for durations and pitches
- Separate Markov chains per chord symbol type

Objective functions

Markov probability

- Separate Markov chains for durations and pitches
- Separate Markov chains per chord symbol type
- Linear interpolation smoothing

Objective functions

Markov probability

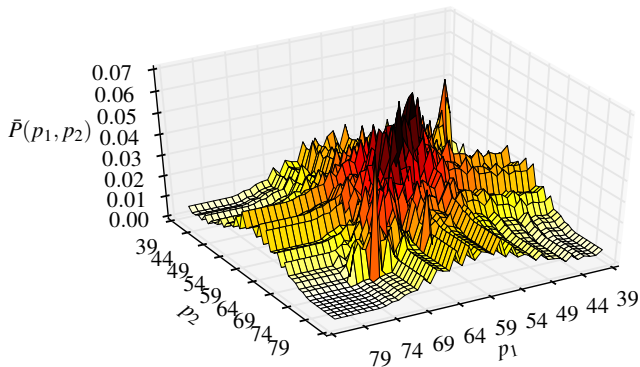
- Separate Markov chains for durations and pitches
- Separate Markov chains per chord symbol type
- Linear interpolation smoothing
- Additive smoothing

Objective functions

Ratio of example/counter-example Markov probability

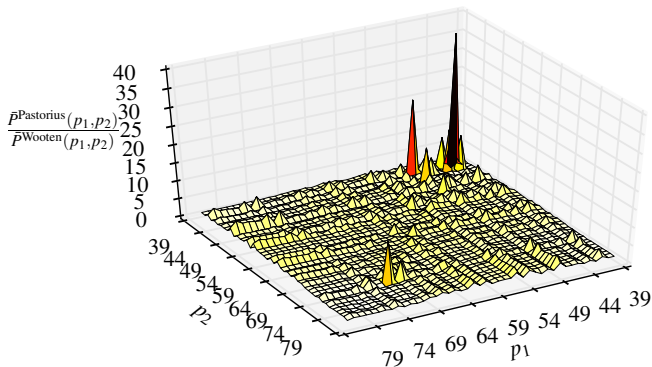
Objective functions

Ratio of example/counter-example Markov probability



Objective functions

Ratio of example/counter-example Markov probability



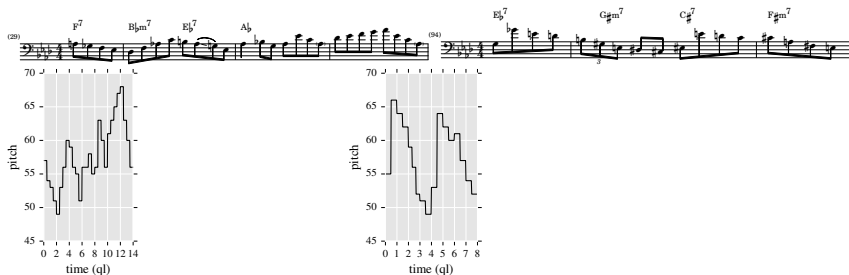
Objective functions

Time correlations for chord-repetitions

The image displays two segments of a bass line in 4/4 time, written in a key with two flats (B-flat major or D-flat minor). The first segment, starting at measure 289, contains four measures with the following chord labels: F⁷, B \flat m⁷, E \flat ⁷, and A \flat . The second segment, starting at measure 94, contains four measures with the following chord labels: E \flat ⁷, G \sharp m⁷, C \sharp ⁷, and F \sharp m⁷. The notation includes stems, beams, and accidentals (flats and sharps) for the notes.

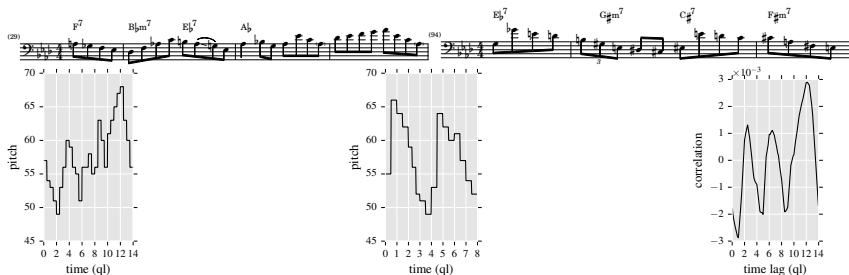
Objective functions

Time correlations for chord-repetitions



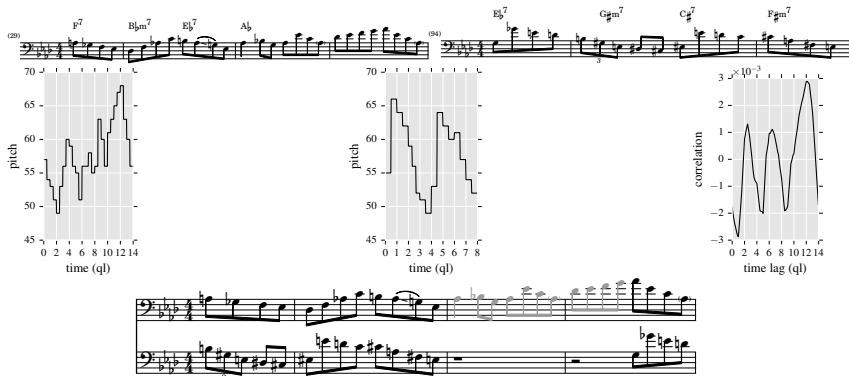
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Objective functions

Time correlations for chord-repetitions



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Results

Problem of evaluation

Results

Example

Original

Original musical score in bass clef, 3/4 time signature, one flat key signature (B-flat). The score consists of three staves of music. Above the first staff are the chords: N.C., F, F⁷, B \flat , F. Above the second staff are the chords: C, C⁷, F, F⁷. Above the third staff are the chords: B \flat , F, C⁷, F. The music features a consistent eighth-note bass line with a triplet of eighth notes in the right hand.

iteration 0

(0 accepted changes, target style Pastorius)

Iteration 0 musical score, which is identical to the original score. It is in bass clef, 3/4 time signature, one flat key signature (B-flat). The score consists of three staves of music. Above the first staff are the chords: N.C., F, F⁷, B \flat , F. Above the second staff are the chords: C, C⁷, F, F⁷. Above the third staff are the chords: B \flat , F, C⁷, F. The music features a consistent eighth-note bass line with a triplet of eighth notes in the right hand.

Results

Example

Original

Original musical score in bass clef, 3/4 time, key of Bb. The score consists of three staves of music. The first staff contains measures 1-5 with chords N.C., F, F⁷, Bb, and F. The second staff contains measures 6-11 with chords C, C⁷, F, and F⁷. The third staff contains measures 12-15 with chords Bb, F, C⁷, and F. The music features a mix of quarter notes, eighth notes, and triplets.

iteration 140

(5 accepted changes, target style Pastorius)

Iteration 140 musical score in bass clef, 3/4 time, key of Bb. The score is identical to the original score but includes 5 accepted changes, as indicated by the text above. The changes are: a sharp sign on the first note of the first staff, a flat sign on the last note of the second staff, and a flat sign on the last note of the third staff.

Results

Example

Original

Original musical score in bass clef, 3/4 time, key of Bb. The score consists of three staves of music. The first staff has a whole rest followed by a quarter note G2, a half note F2, and a quarter note G2. Above the staff are chords: N.C. F, F⁷, Bb, and F. The second staff starts at measure 6 with a quarter note G2, a half note F2, and a quarter note G2. Above the staff are chords: C, C⁷, F, and F⁷. The third staff starts at measure 12 with a quarter note G2, a half note F2, and a quarter note G2. Above the staff are chords: Bb, F, C⁷, and F. The piece ends with a double bar line.

iteration 644

(10 accepted changes, target style Pastorius)

Iteration 644 musical score in bass clef, 3/4 time, key of Bb. The score consists of three staves of music, identical to the original but with 10 accepted changes. The first staff has a whole rest followed by a quarter note G2, a half note F2, and a quarter note G2. Above the staff are chords: N.C. F, F⁷, Bb, and F. The second staff starts at measure 6 with a quarter note G2, a half note F2, and a quarter note G2. Above the staff are chords: C, C⁷, F, and F⁷. The third staff starts at measure 12 with a quarter note G2, a half note F2, and a quarter note G2. Above the staff are chords: Bb, F, C⁷, and F. The piece ends with a double bar line.

Results

Example

Original

N.C. F F⁷ B^b F

6 C C⁷ F F⁷

12 B^b F C⁷ F

iteration 2058

(14 accepted changes, target style Pastorius)

N.C. F F⁷ B^b F

6 C C⁷ F F⁷

12 B^b F C⁷ F

Results

Example

Original

N.C. F F⁷ B \flat F

6 C C⁷ F F⁷

12 B \flat F C⁷ F

iteration 1776

(24 accepted changes, target style Wooten)

N.C. F F⁷ B \flat F

6 C C⁷ F F⁷

12 B \flat F C⁷ F

Results

Recap

- Method for musical style modification

Results

Recap

- Method for musical style modification
- Local optimization is great for this task

Results

Recap

- Method for musical style modification
- Local optimization is great for this task
- Hard to evaluate

References

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