INTERNATIONAL AUDIO LABORATORIES ERLANGEN

Tutorial
Automatisierte Methoden der Musikverarbeitung
47. Jahrestagung der Gesellschaft für Informatik

Music Structure Analysis

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FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

Fraunhofer IIS

Book: Fundamentals of Music Processing

Meinard Müller
Fundamentals of Music Processing
Audio, Analysis, Algorithms, Applications
483 p., 249 illus., hardcover
ISBN: 978-3-319-21944-8
Springer, 2015

Accompanying website:
www.music-processing.de

Book: Fundamentals of Music Processing

Chapter	Music Processing Scenario
1	Music Representations
2	Fourier Analysis of Signals
3	Music Synchronization
4	Music Structure Analysis
5	Chord Recognition
6	Tempo and Beat Tracking
7	Content-Based Audio Retrieval
8	Musically Informed Audio Decomposition

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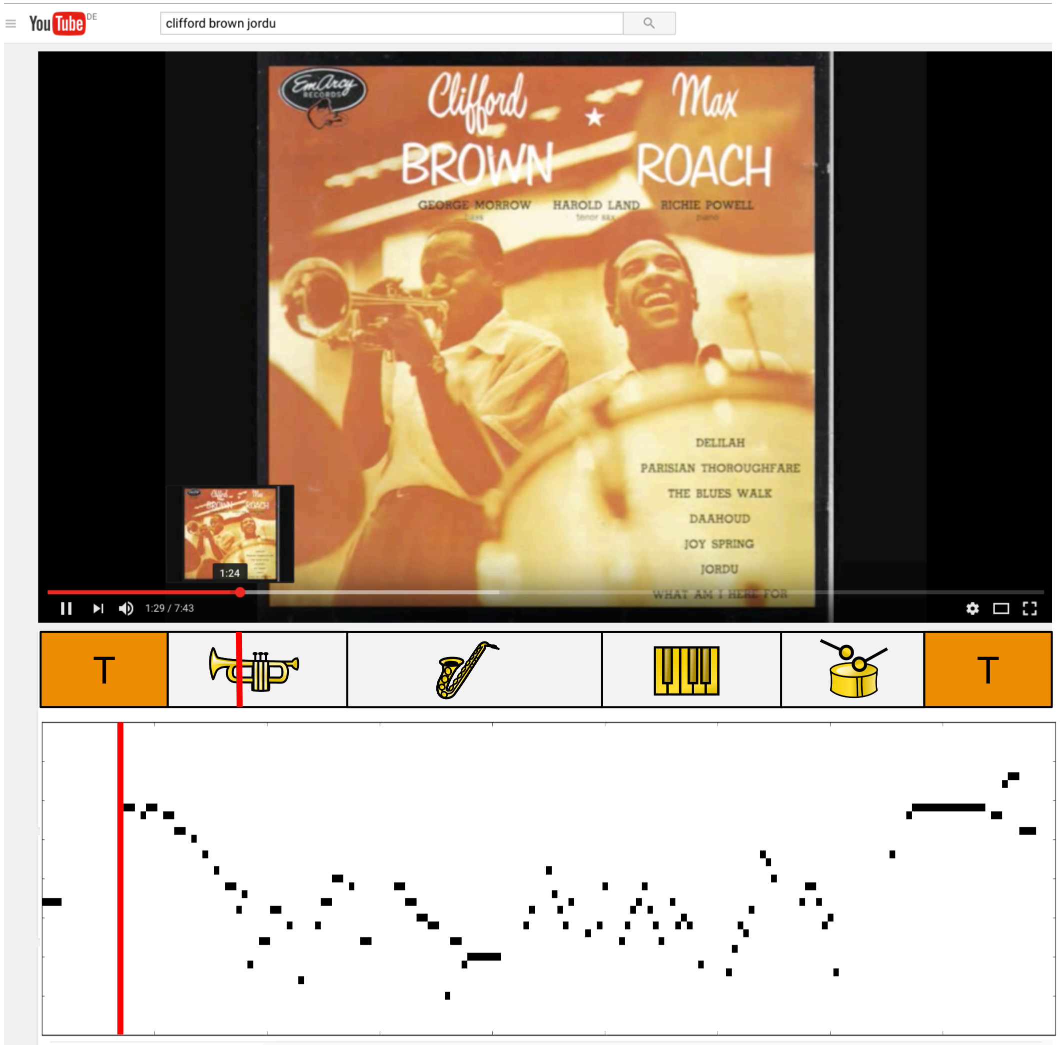
Motivation



clifford brown jordu
Clifford BROWN ★ Max ROACH
GEORGE MORROW
HAROLD LAND
RICHIE POWELL
DELILAH
PARISIAN THOROUGHFARE
THE BLUES WALK
DAAHOUD
JOY SPRING
JORDU
WHAT AM I HERE FOR
1:24
1:29 / 7:43
T
T

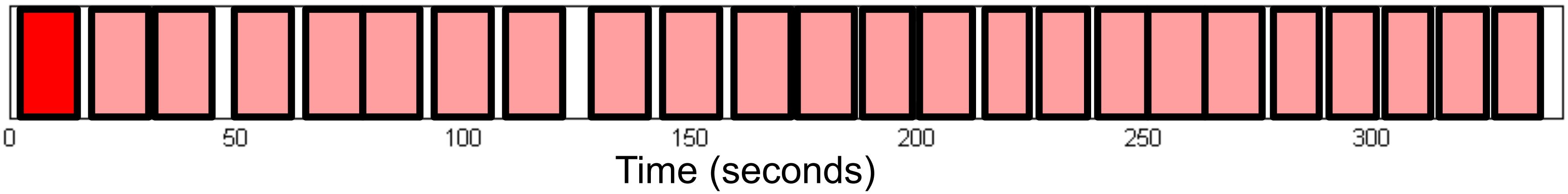
Music Structure Analysis

- **General Goal:**
  Divide an audio recording into temporal segments corresponding to musical parts and group these segments into musically meaningful categories.

- **Examples:**
  - Stanzas of a folk song
  - Intro, verse, chorus, bridge, outro sections of a pop song
  - Exposition, development, recapitulation, coda of a sonata
  - Musical form ABACADA … of a rondo
  - Solo parts in a jazz recording

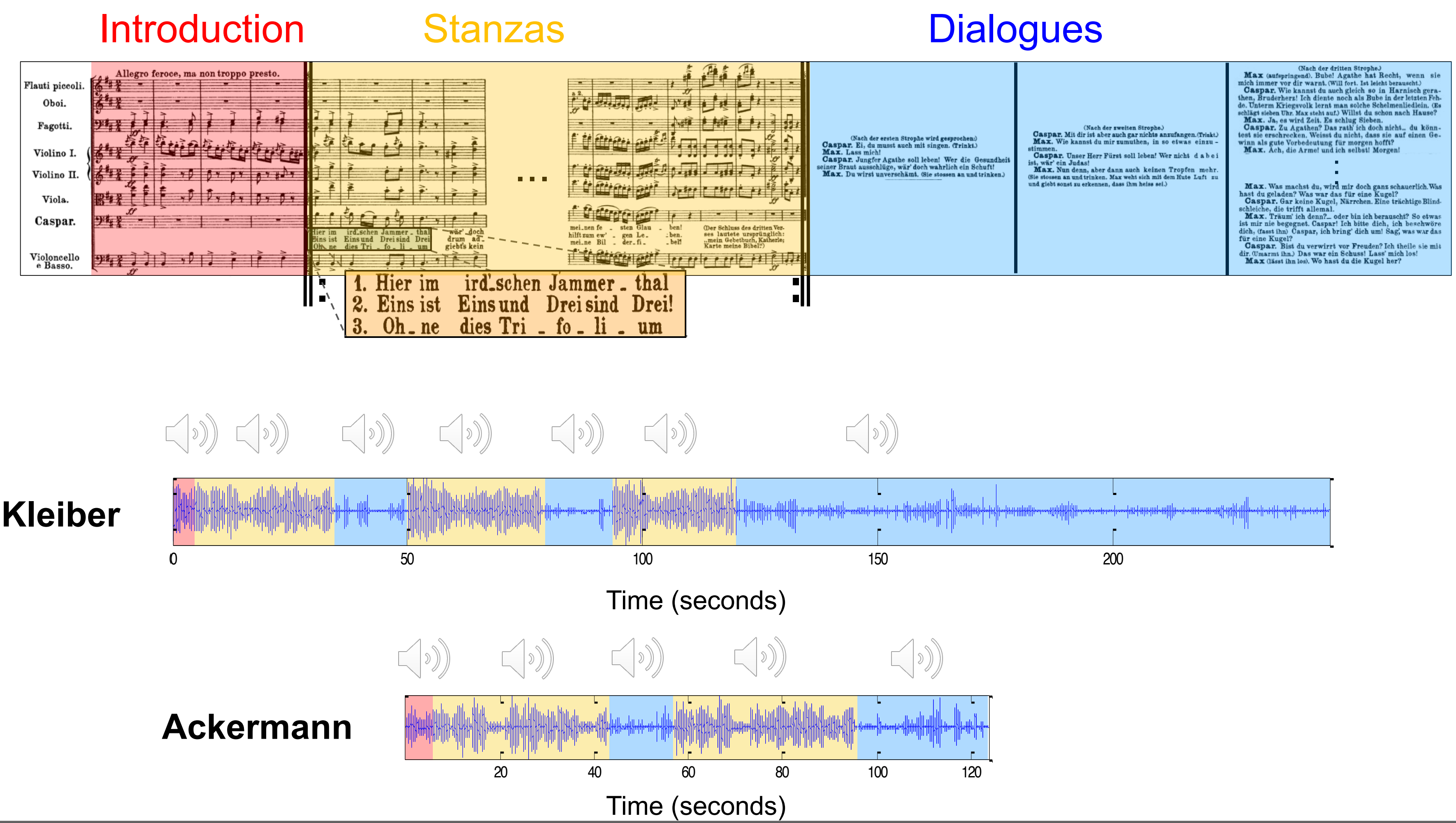
Example: Folk Song

Nederlandse Liederenbank

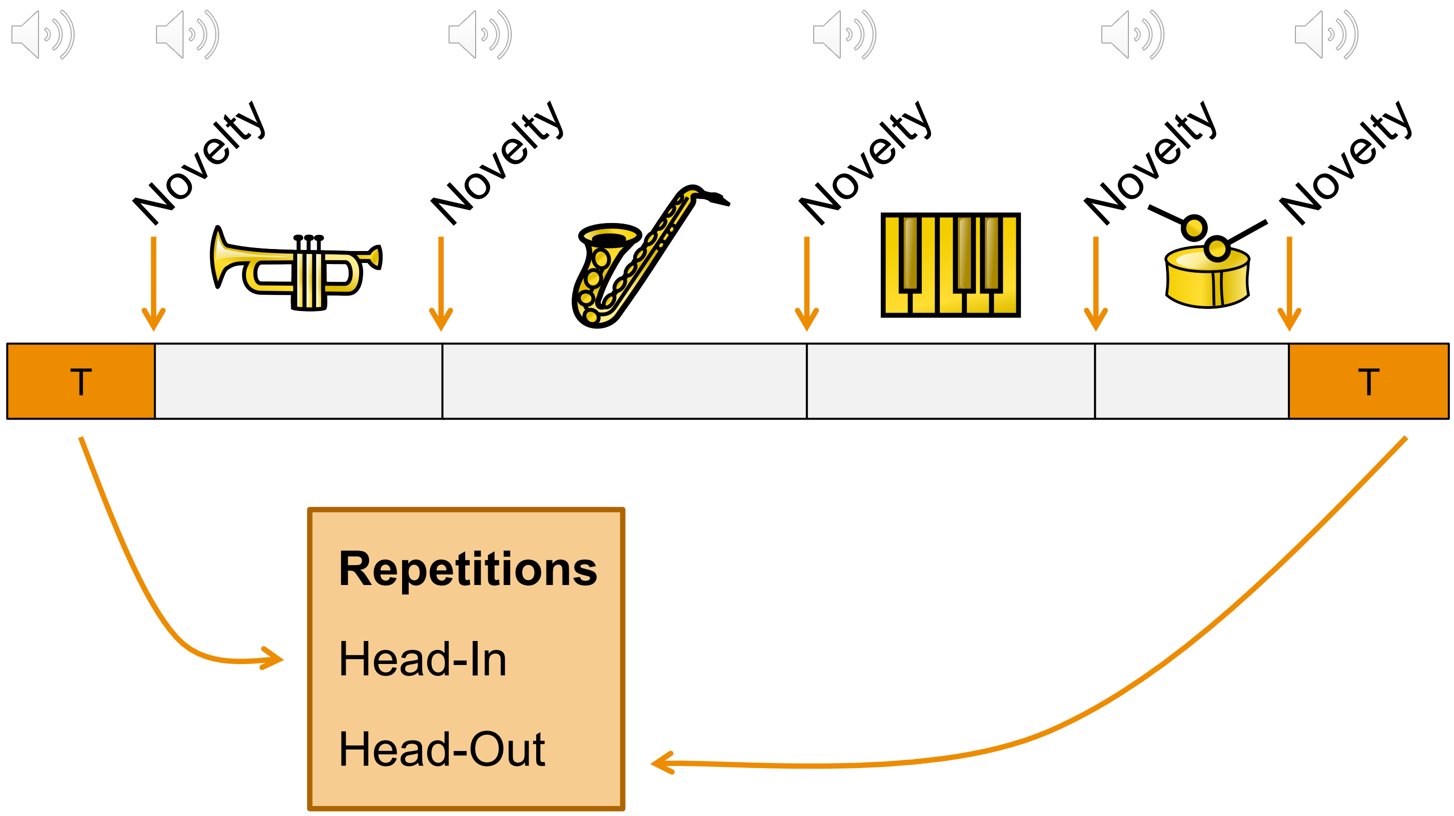


Example: Opera

Weber, Song (No. 4) from “Der Freischütz”



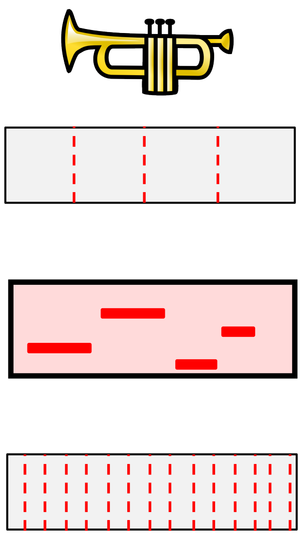
Example: Jazz Recording
Clifford Brown - Jordu



Instrument Comics by H. Grohganz: https://mir.sechsachtel.de/orchpics/

Weimar Jazz Database (WJD)

http://jazzomat.hfm-weimar.de



Transcription

Beats

| E^7 A^7 | D^7 G^7 | …

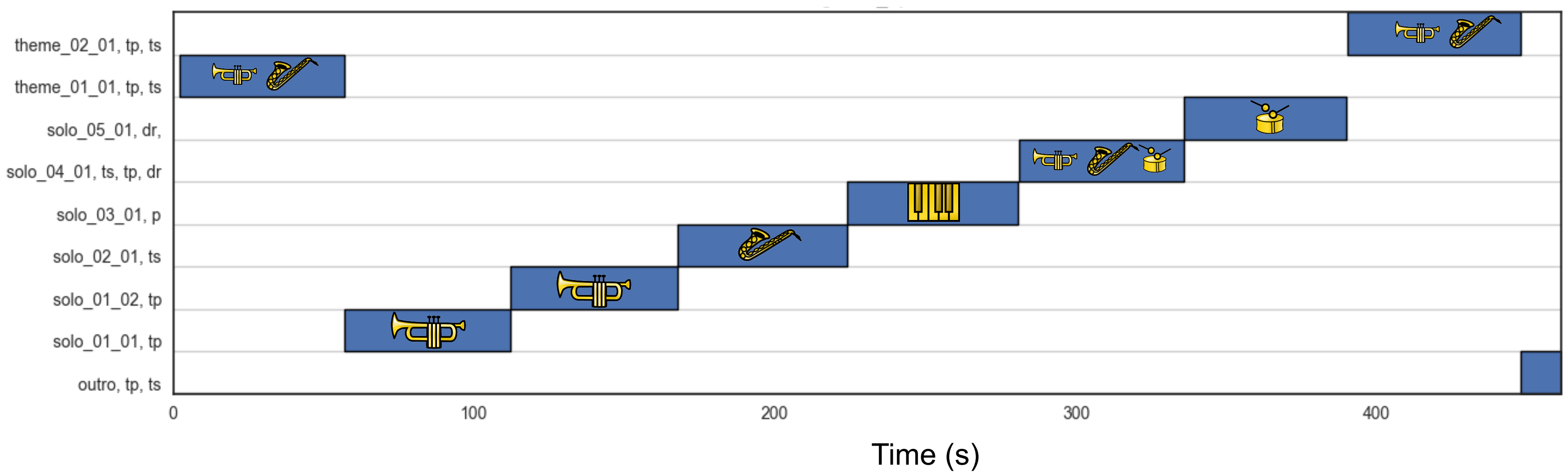
Chords

…

- 456 transcribed jazz solos of monophonic instruments.
- Transcriptions specify a musical pitch for physical time instances.
- 810 min. of audio recordings.
- **Soon available:** Track structure

Thanks to the Jazzomat research team: M. Pfleiderer, K. Frieler, J. Abeßer, W.-G. Zaddach

Annotation Example from the WJD
Clifford Brown - Jordu



Song-Centric Annotations:

- Chorus boundaries
- Solo choruses
- Theme repetitions

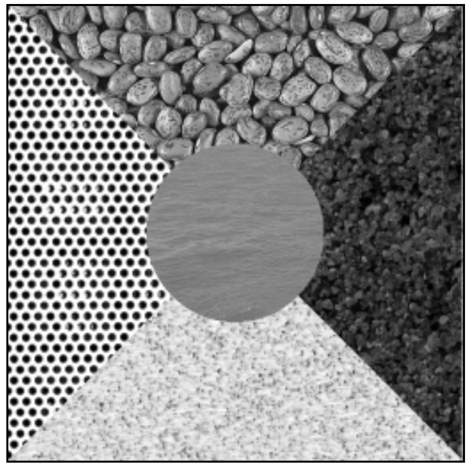
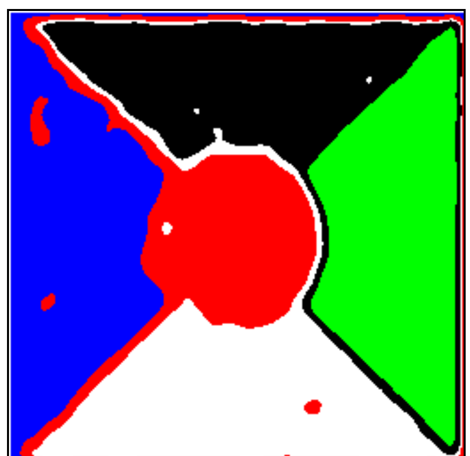
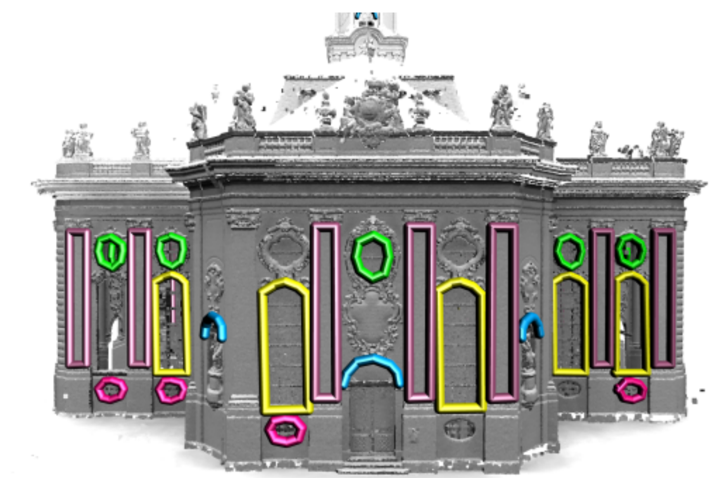
Many Thanks to
Moritz Berendes and
Julian Reck!

Music Structure Analysis

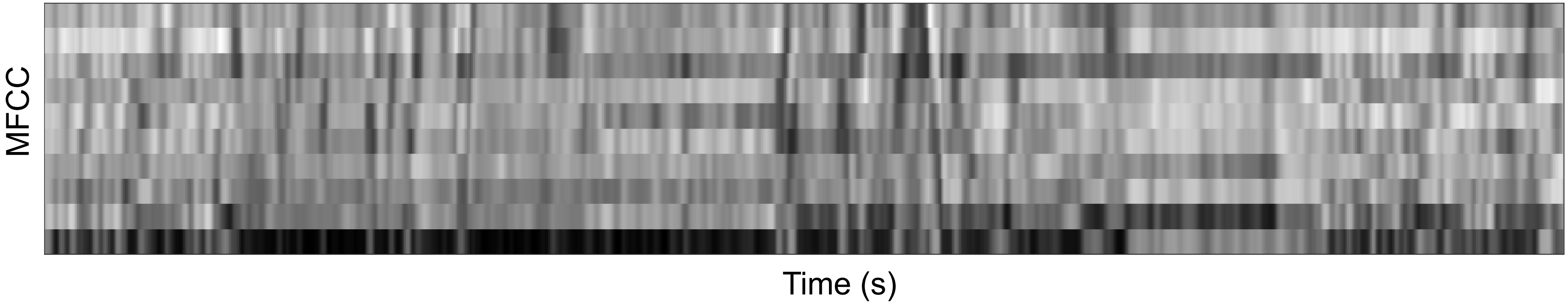
- Main principles:
  - **Repetition**-based Structure Analysis
  - **Homogeneity**-based Structure Analysis
  - **Novelty**-based Structure Analysis

Music Structure Analysis

Image Analogy

Novelty	Homogeneity	Repetition
		
		

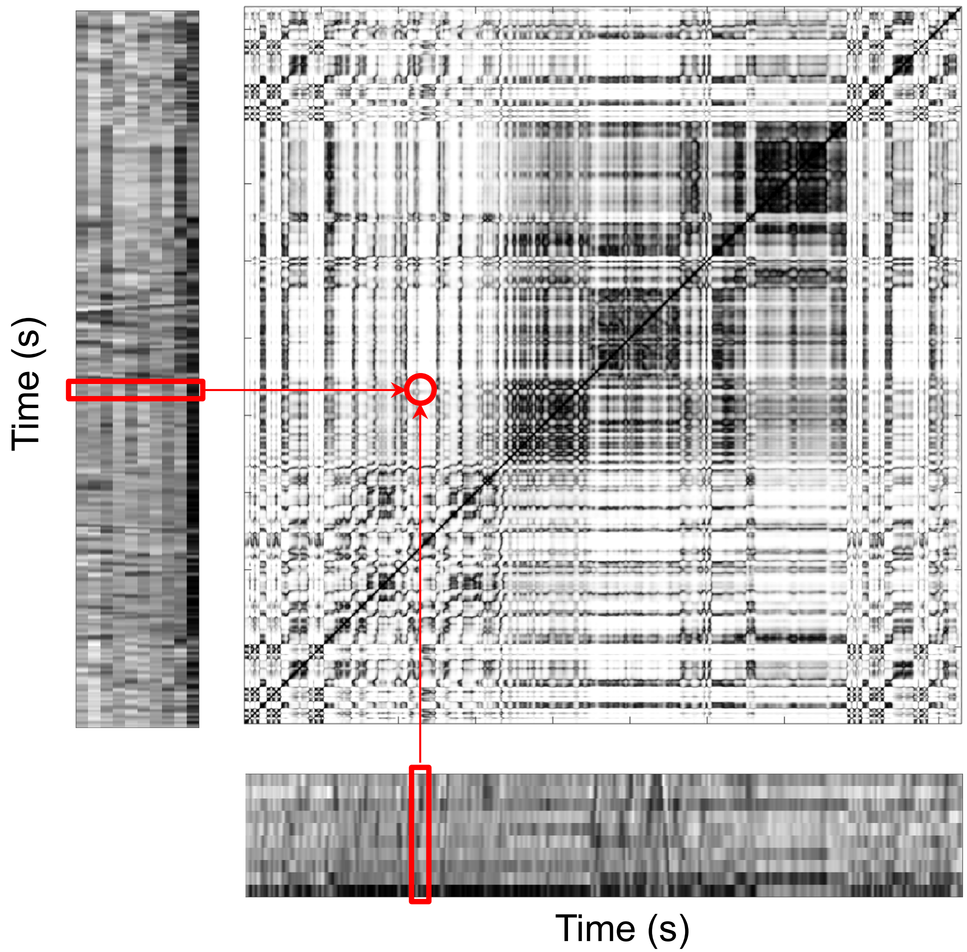
Self-Similarity Matrix
1. Step: Extract Audio Features



- Mel Frequency Cepstral Coefficients (MFCC) correlate to the timbre.

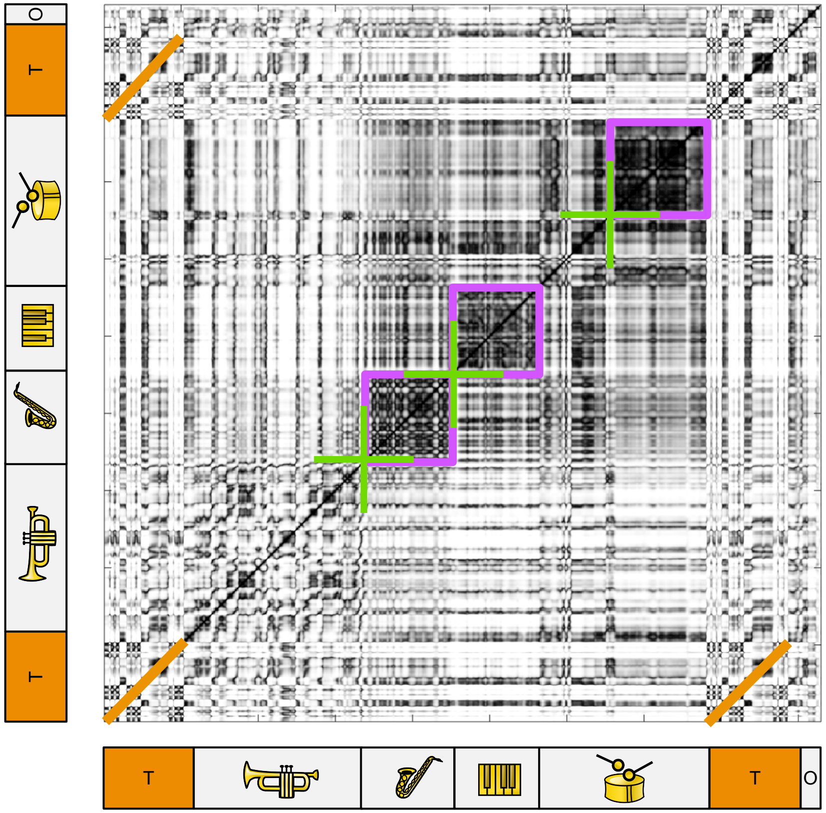
Self-Similarity Matrix

2. Step: Calculate Pairwise Similarity

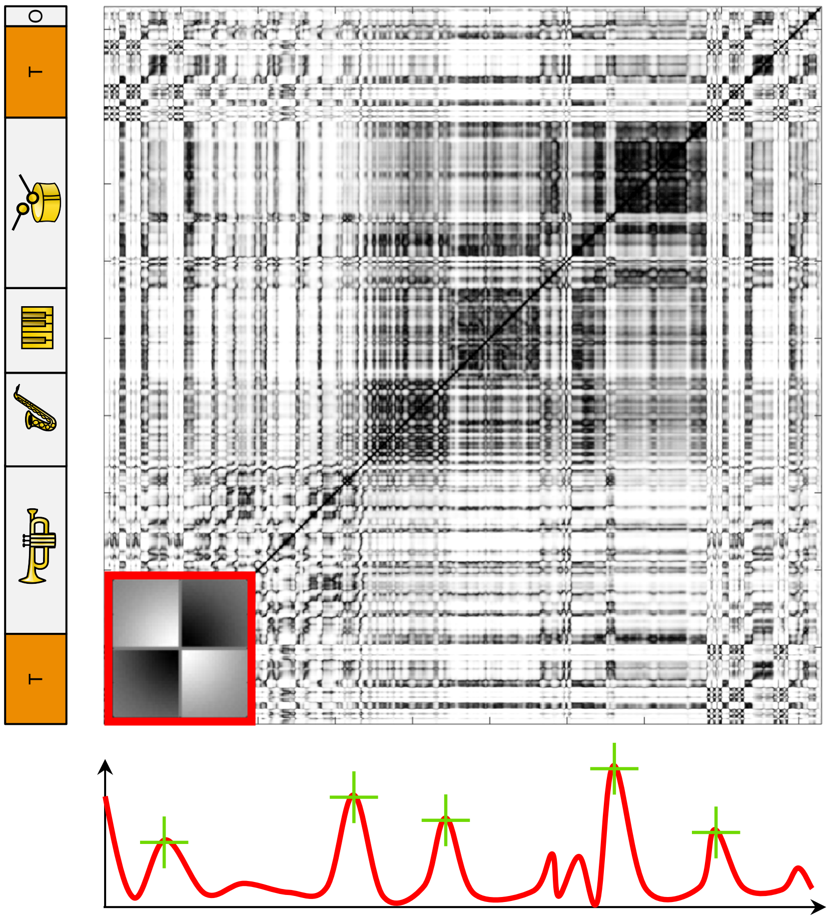


Self-Similarity Matrix
Analysis

- Repetitions:
  Path-like structures
- Homogeneity:
  Block-like structures
- Novelty:
  Corners



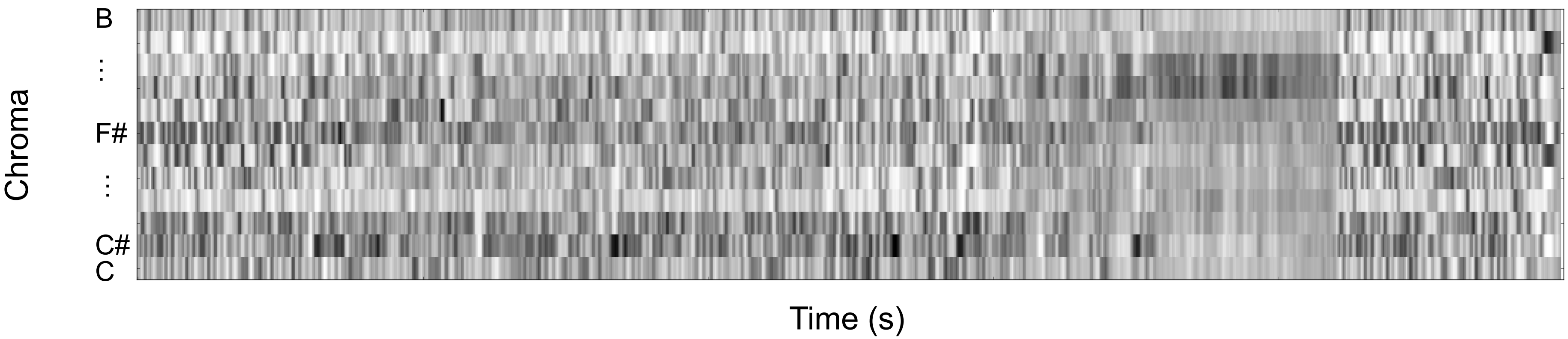
Self-Similarity Matrix
Novelty Detection



Idea (Foote):

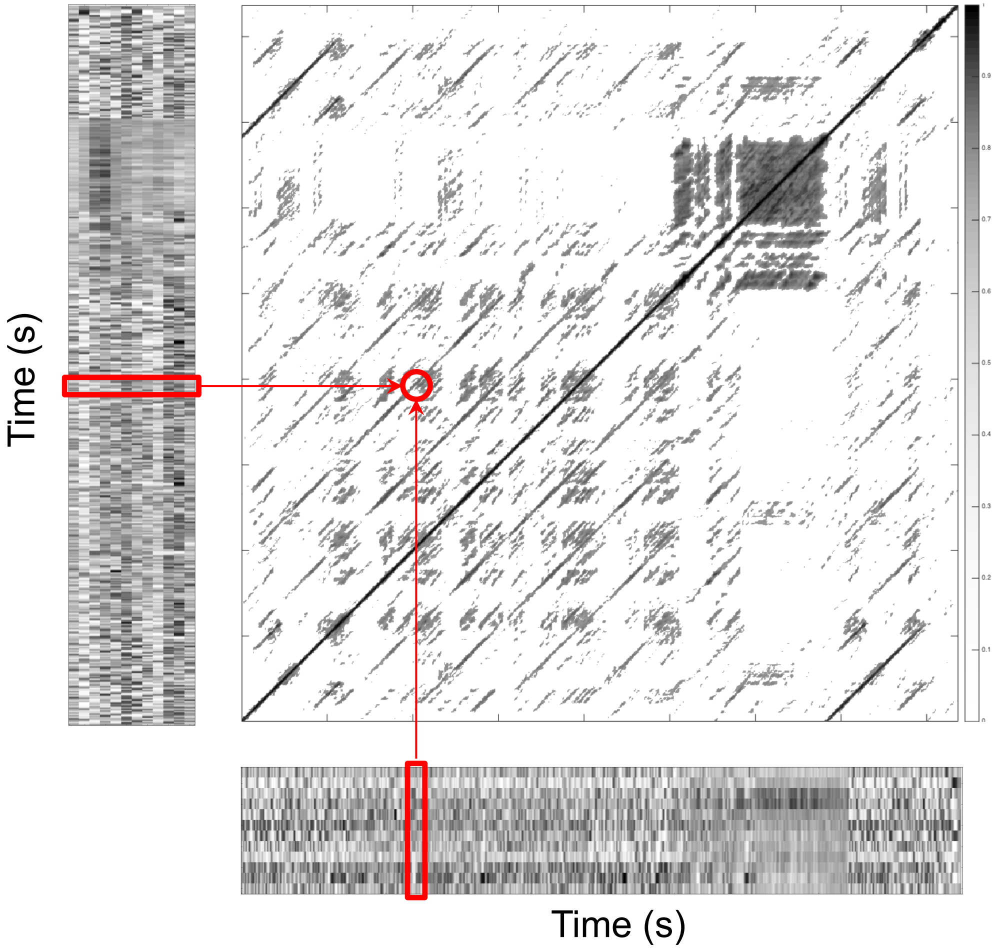
Use checkerboard-like kernel function to detect corner points on main diagonal of SSM.

Self-Similarity Matrix
Chroma Features



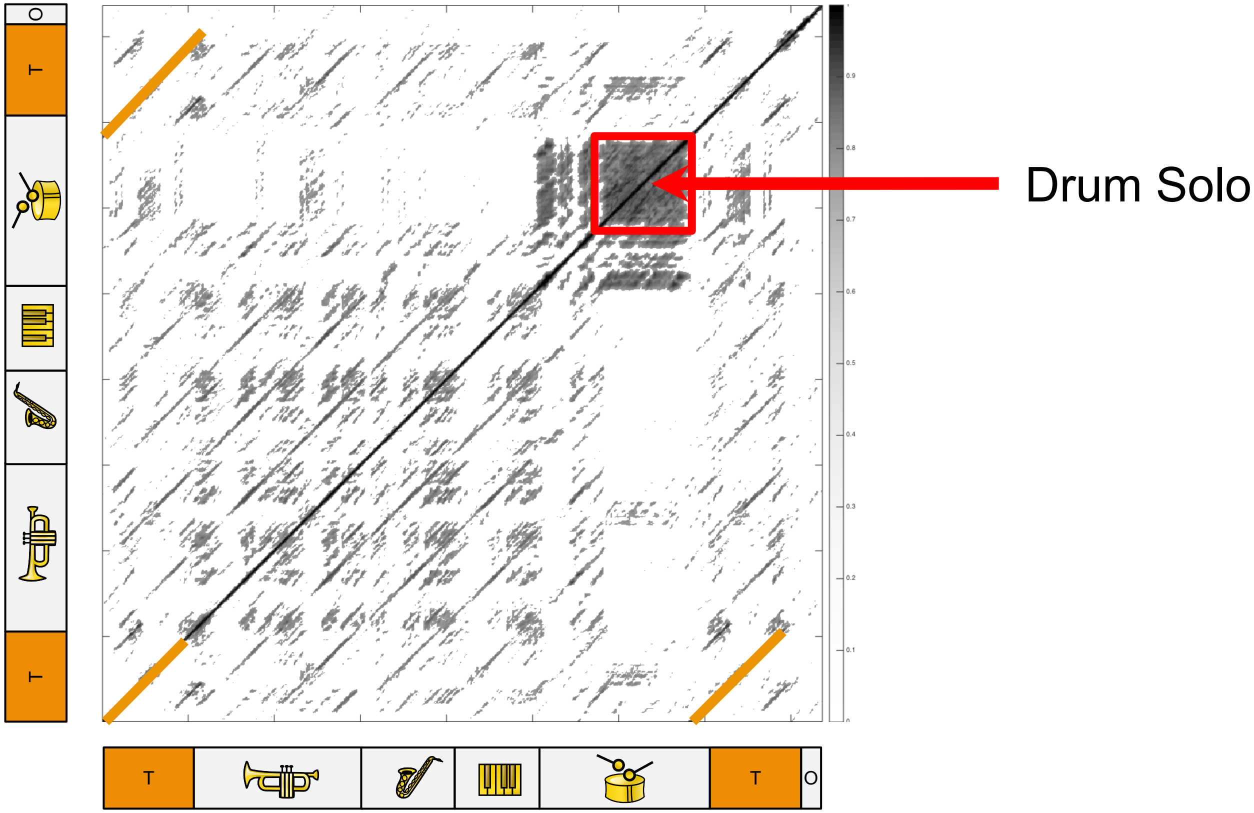
- Chroma Feature correlate to harmonic and melodic progressions.

Self-Similarity Matrix
Chroma Features



Self-Similarity Matrix
Chroma Features

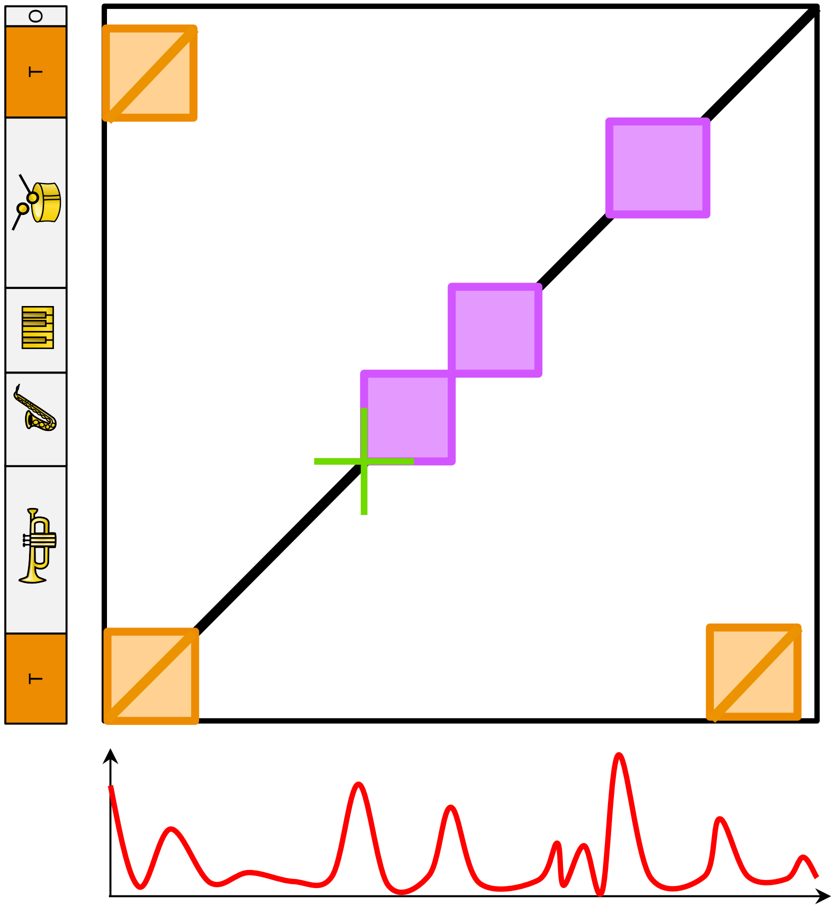
- Chroma instead of MFCC
- Repetitions result in path-like structures
- Head-In and Head-Out



Self-Similarity Matrix
Recap

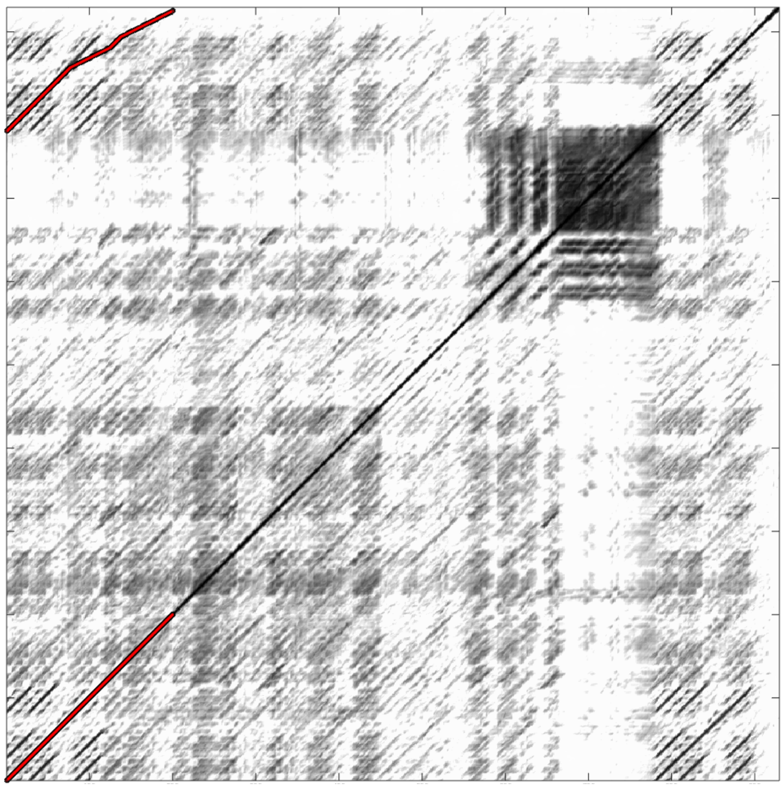
- Repetitions:
  Path-like structures
- Homogeneity:
  Block-like structures
- Novelty:
  Corners

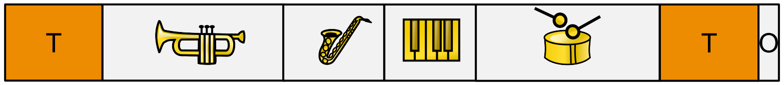
- Features are important!



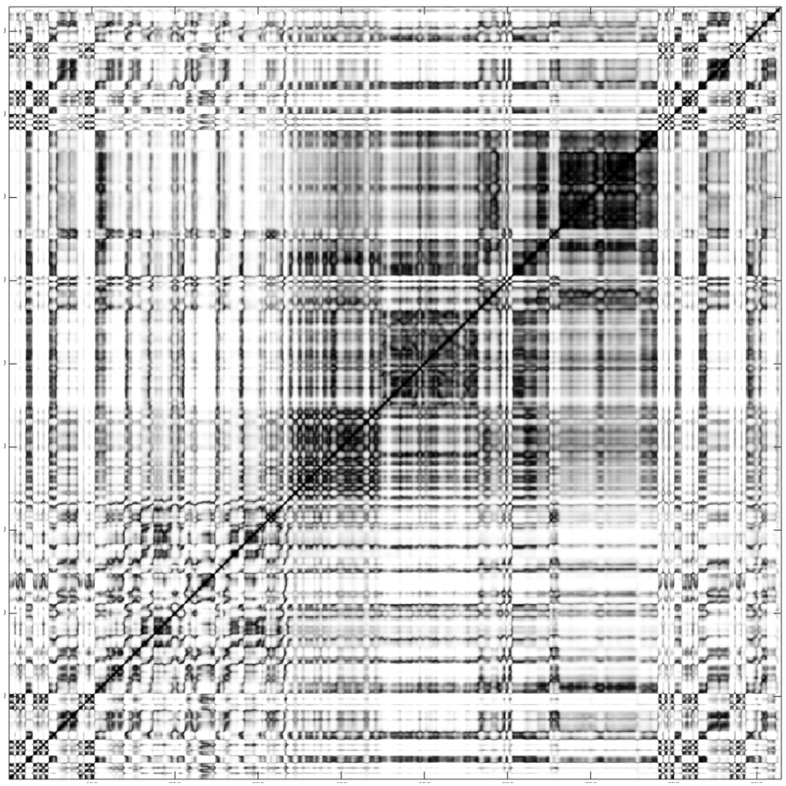
Audio Examples
Clifford Brown – Jordu

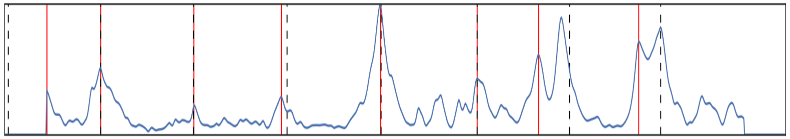
Chroma





MFCC

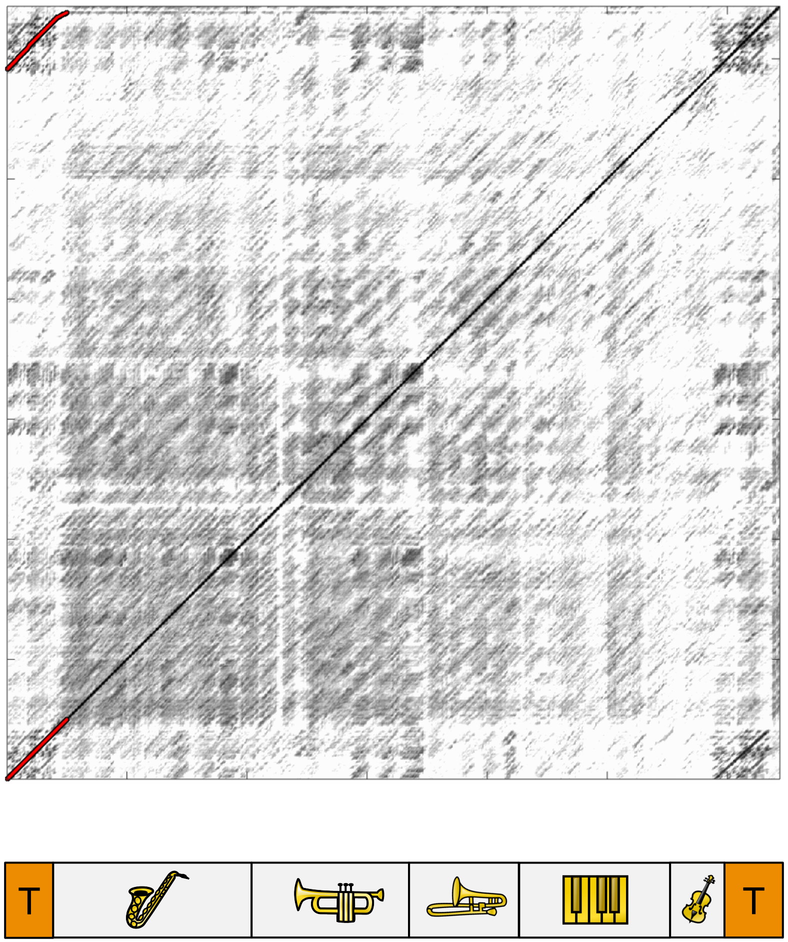




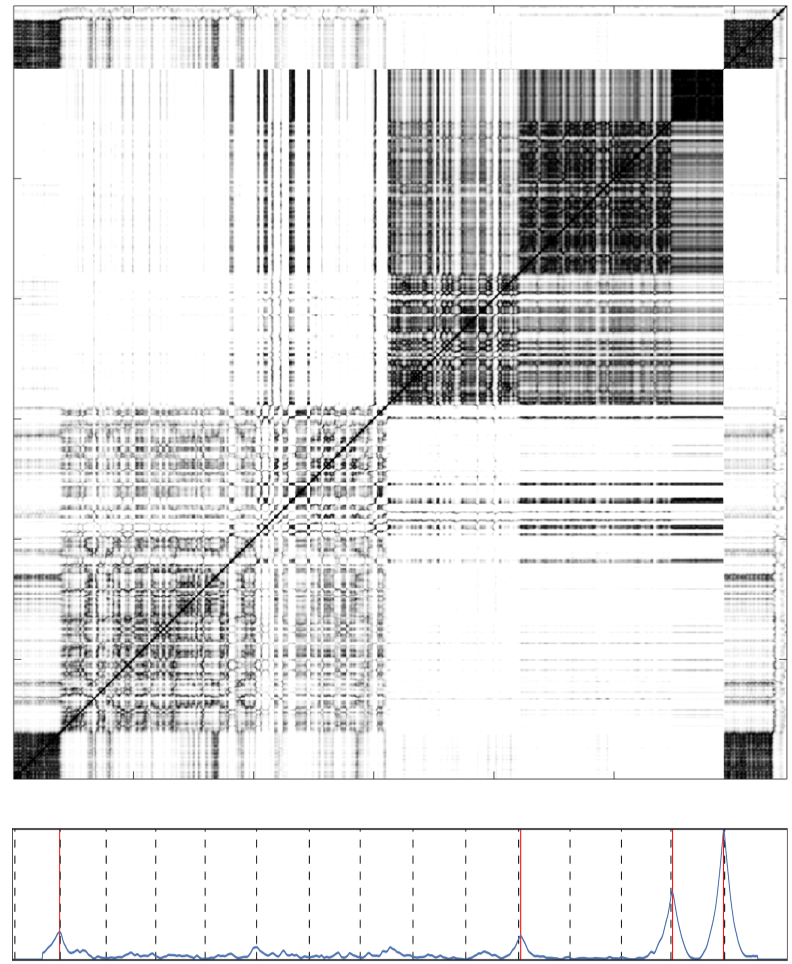
Audio Examples

John Coltrane – Blue Trane

Chroma



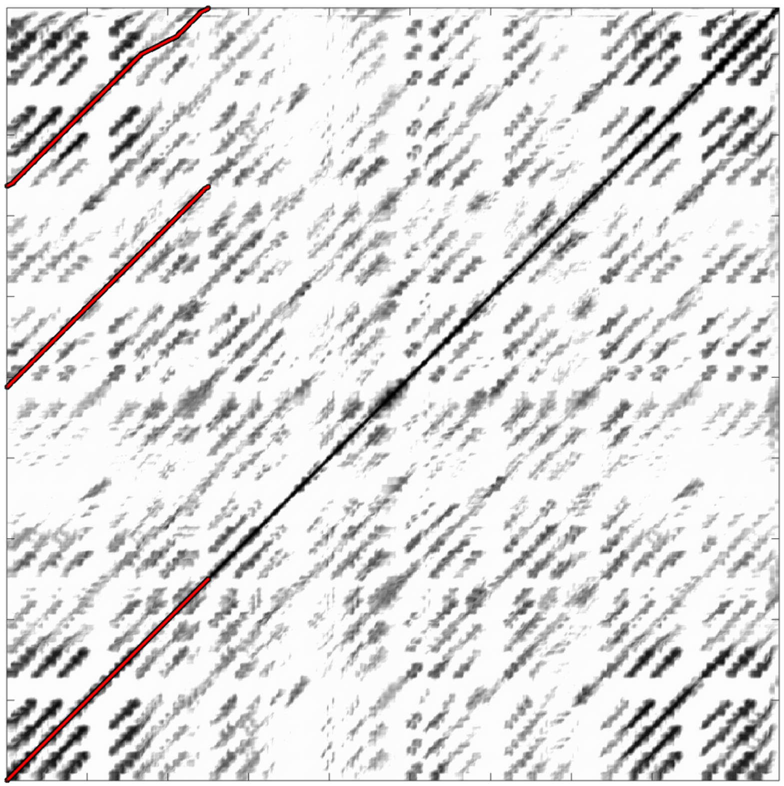
MFCC



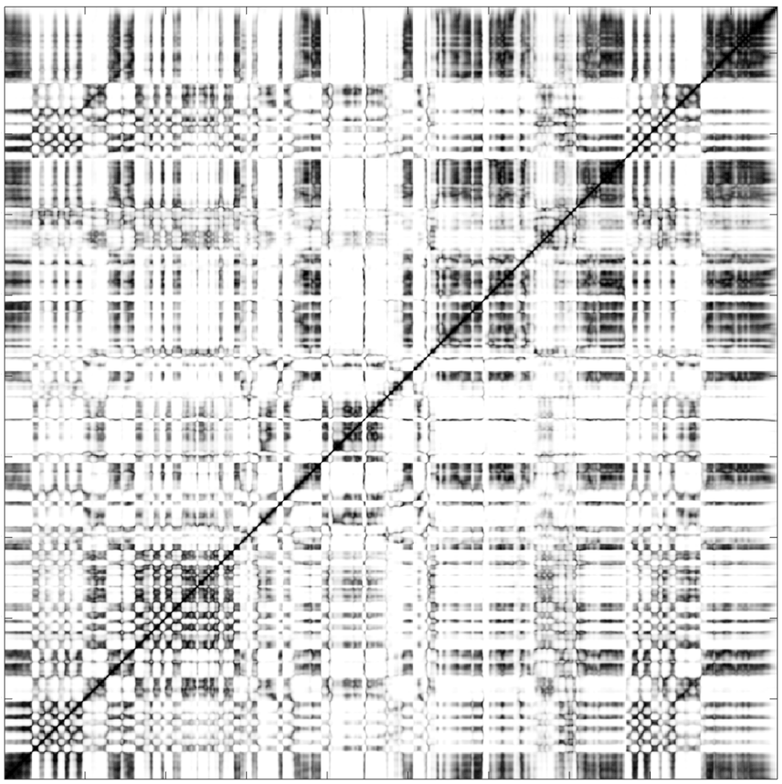
Audio Examples

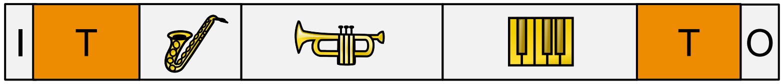
Herbie Hancock – Maiden Voyage

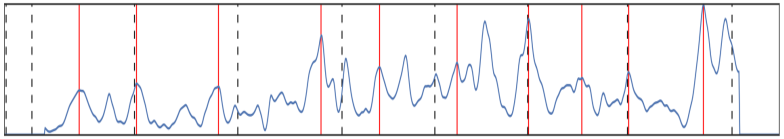
Chroma



MFCC

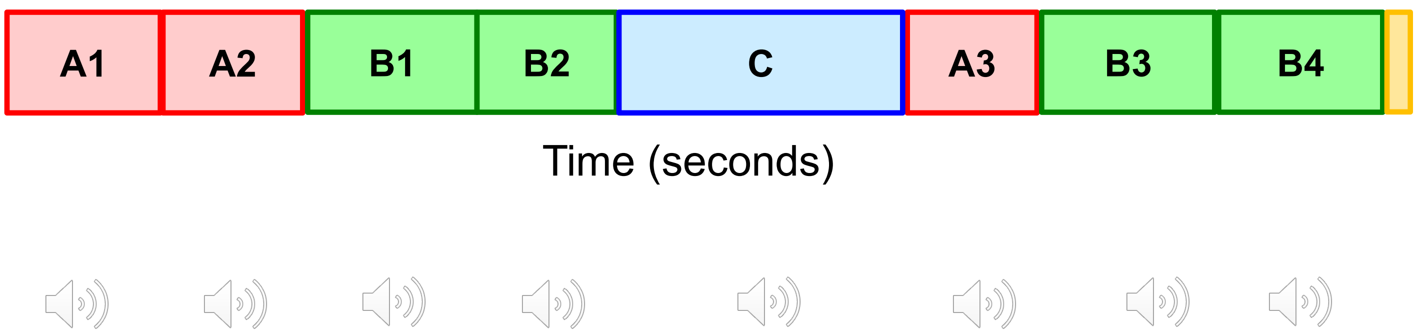






Self-Similarity Matrix

- **Example:** Brahms Hungarian Dance No. 5 (Ormandy)



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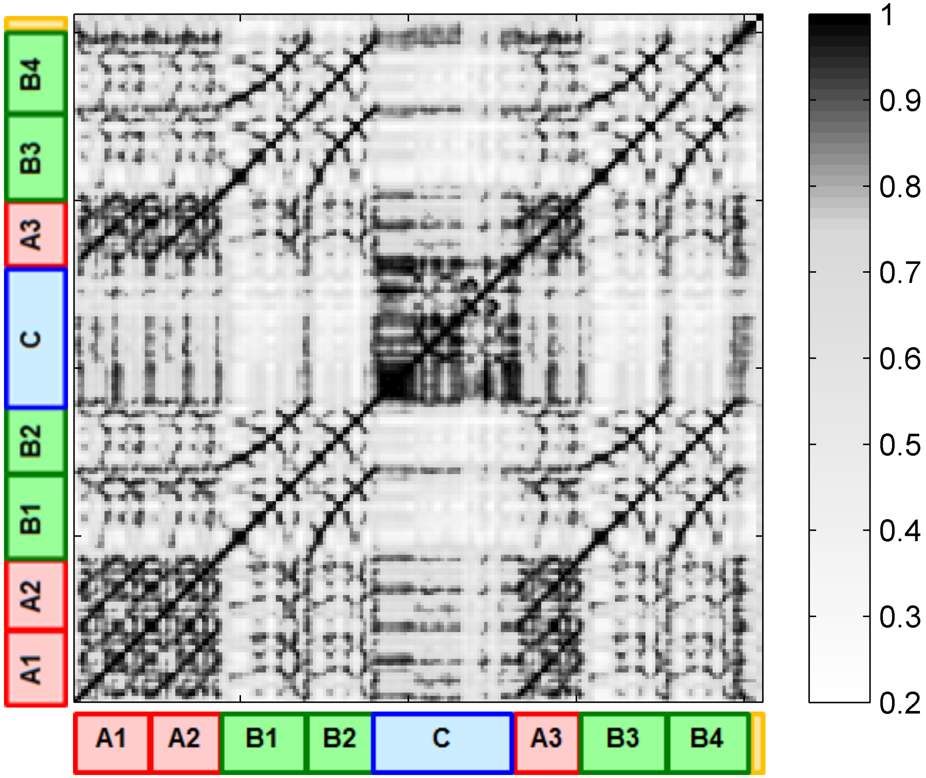

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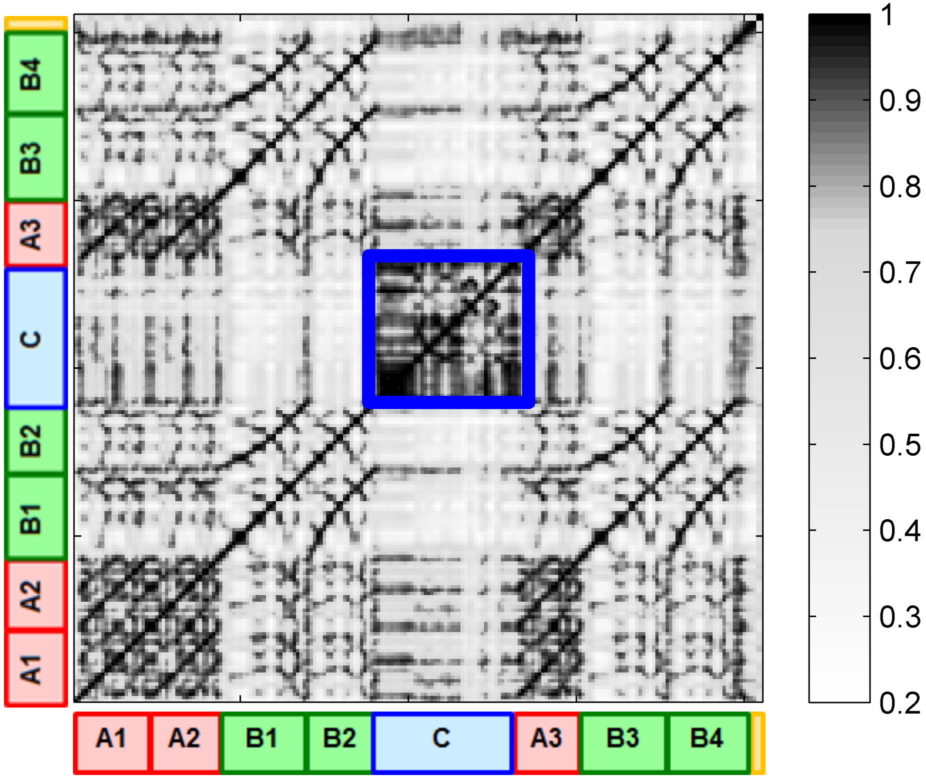

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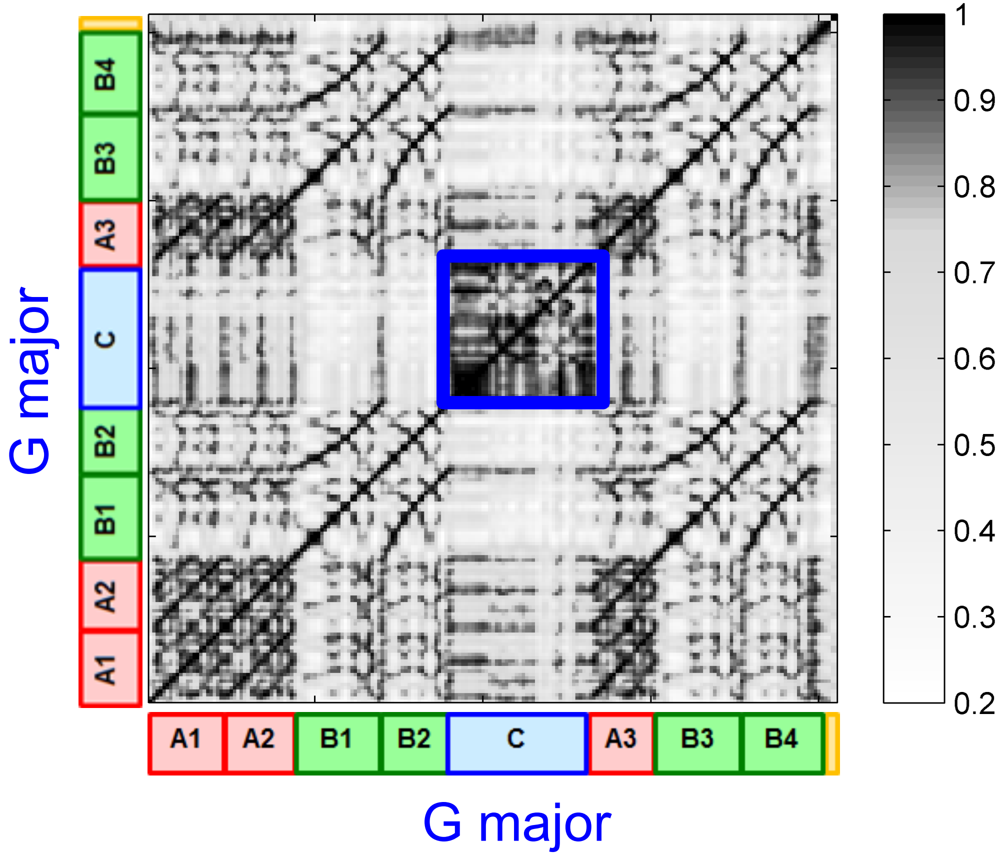

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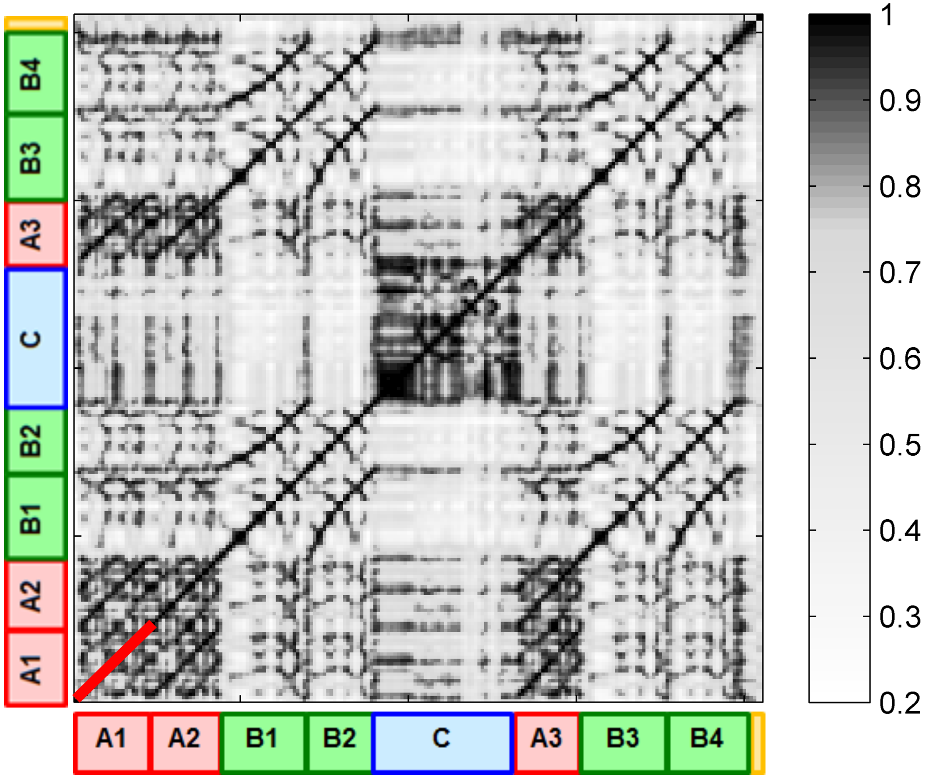

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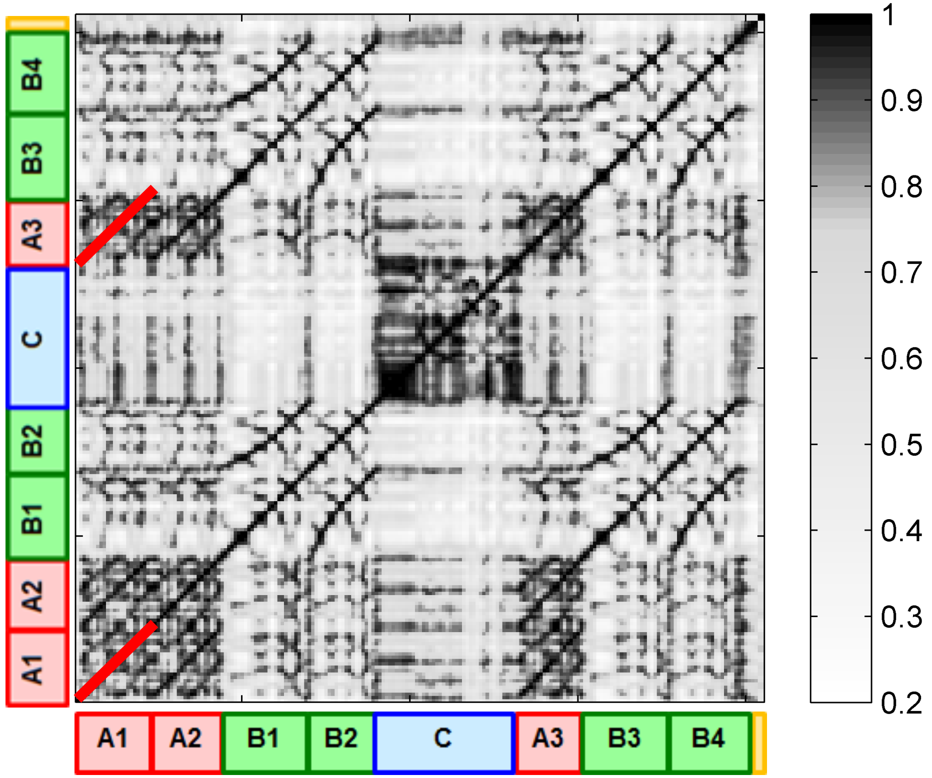

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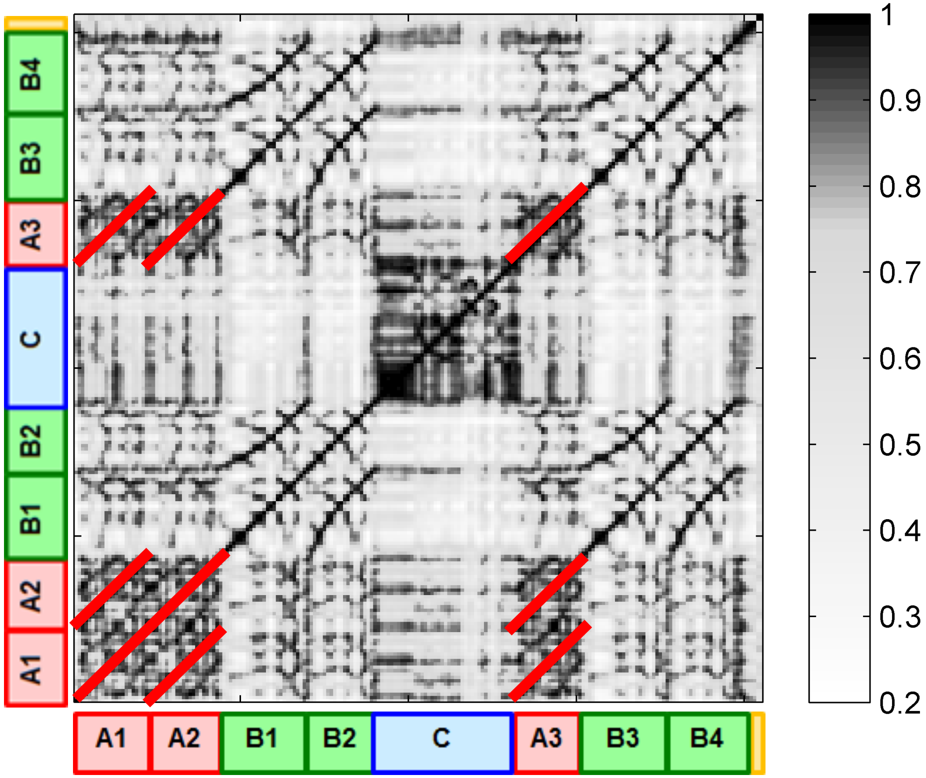

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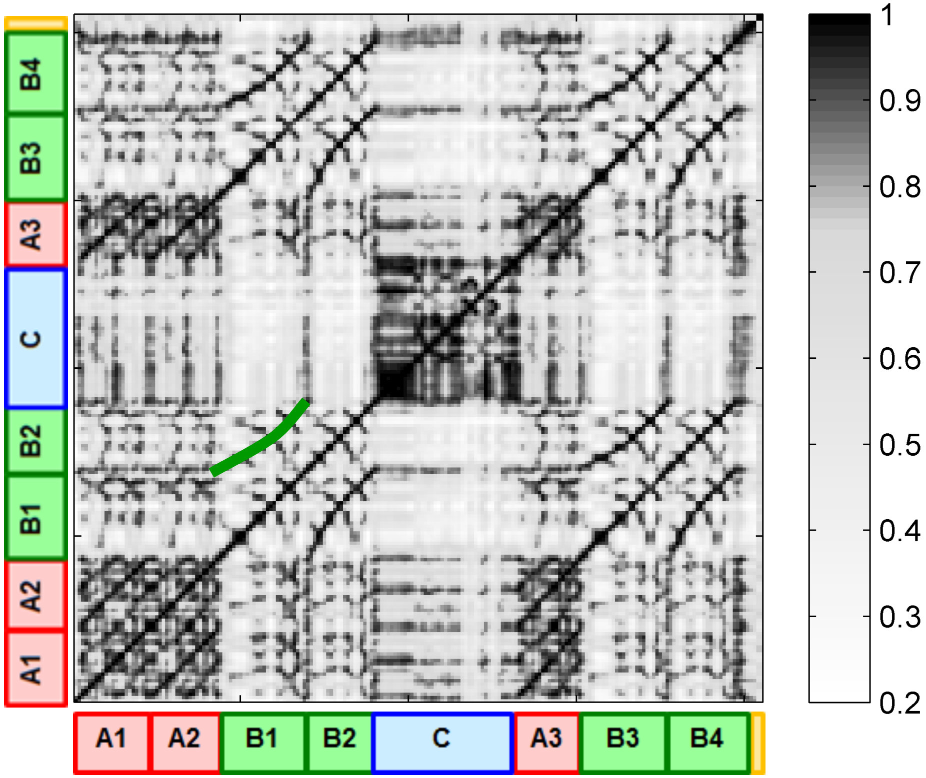

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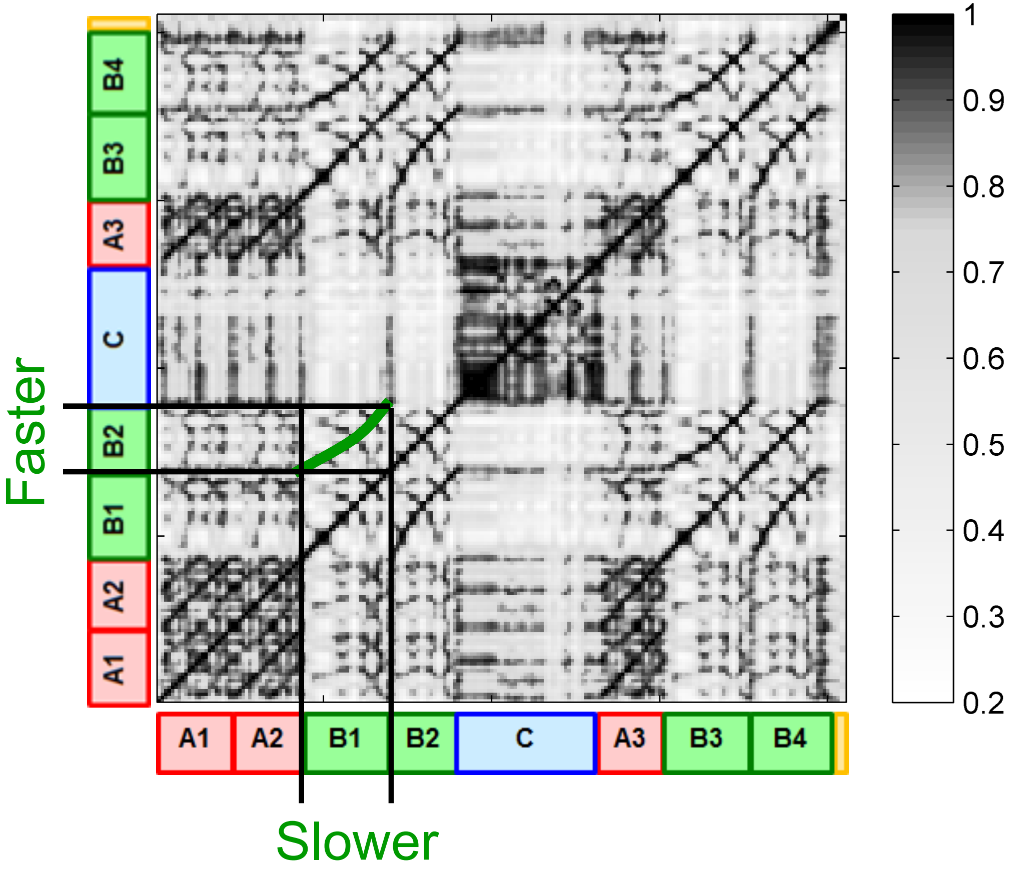

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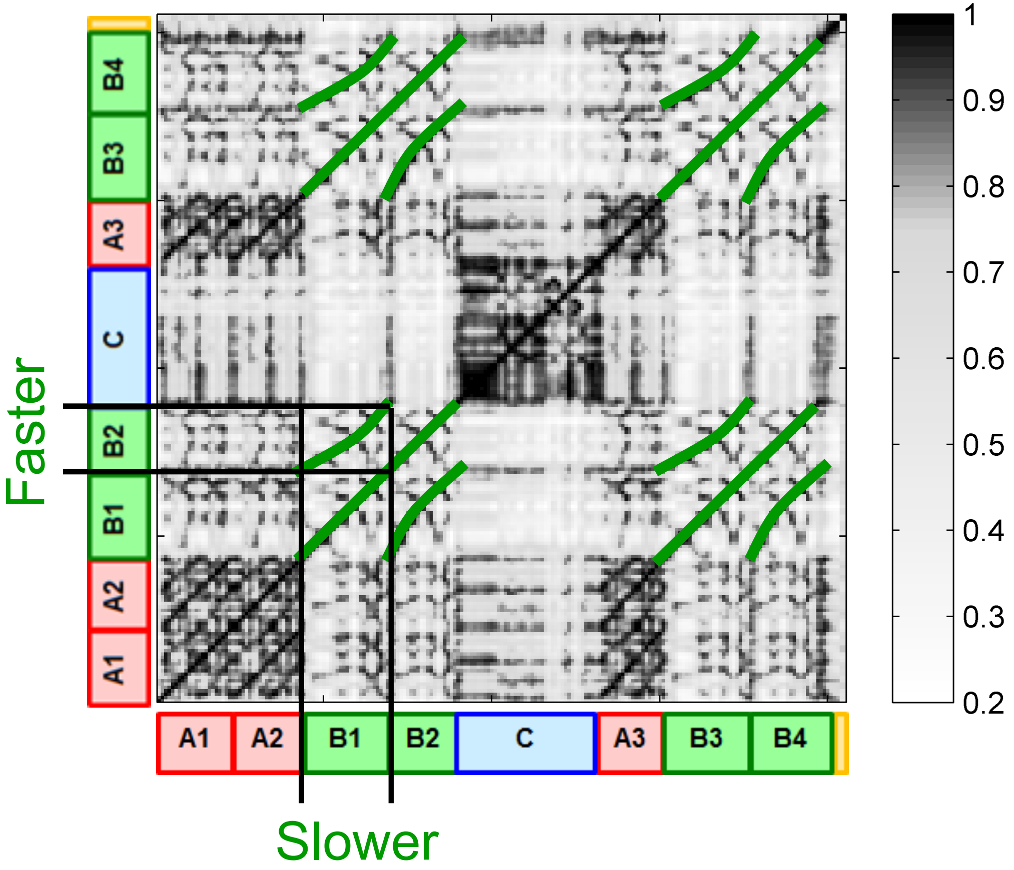

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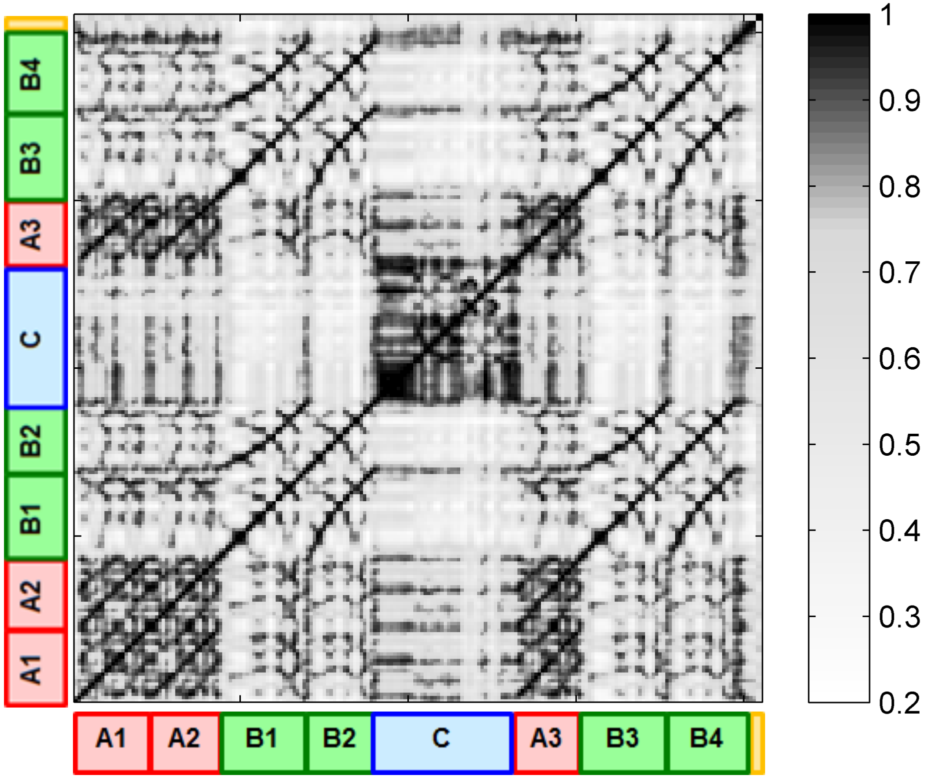
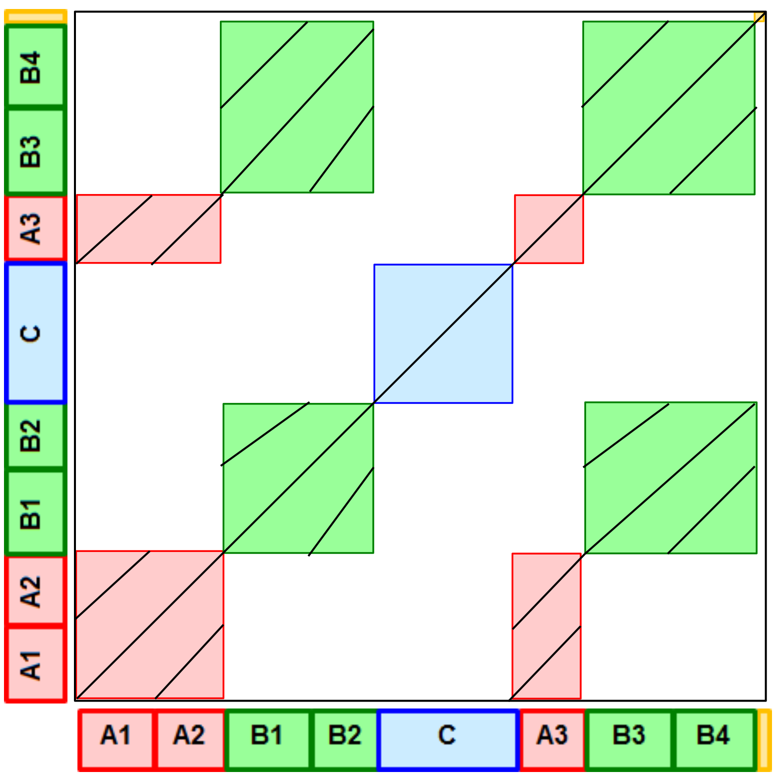
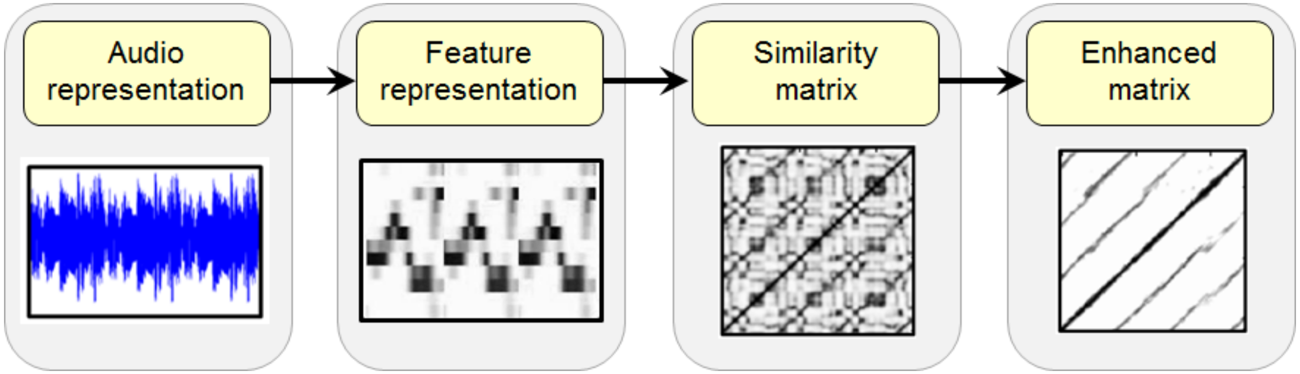


Idealized SSM



Similarity Matrix Toolbox



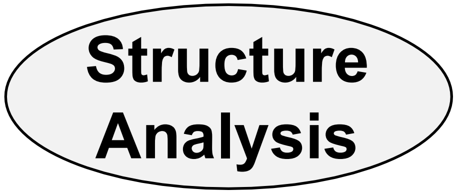
Meinard Müller, Nanzhu Jiang, Harald Grohganz
SM Toolbox: MATLAB Implementations for Computing and Enhancing Similarity Matrices

http://www.audiolabs-erlangen.de/resources/MIR/SMtoolbox/

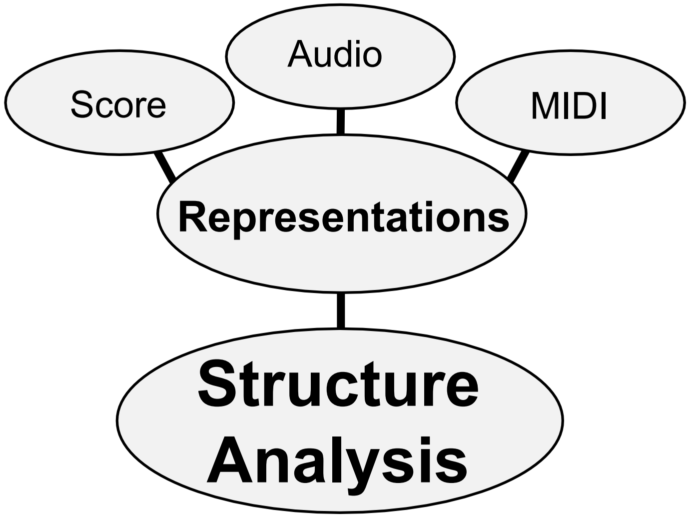
Demo

Code: https://github.com/stefan-balke/mpa-exc

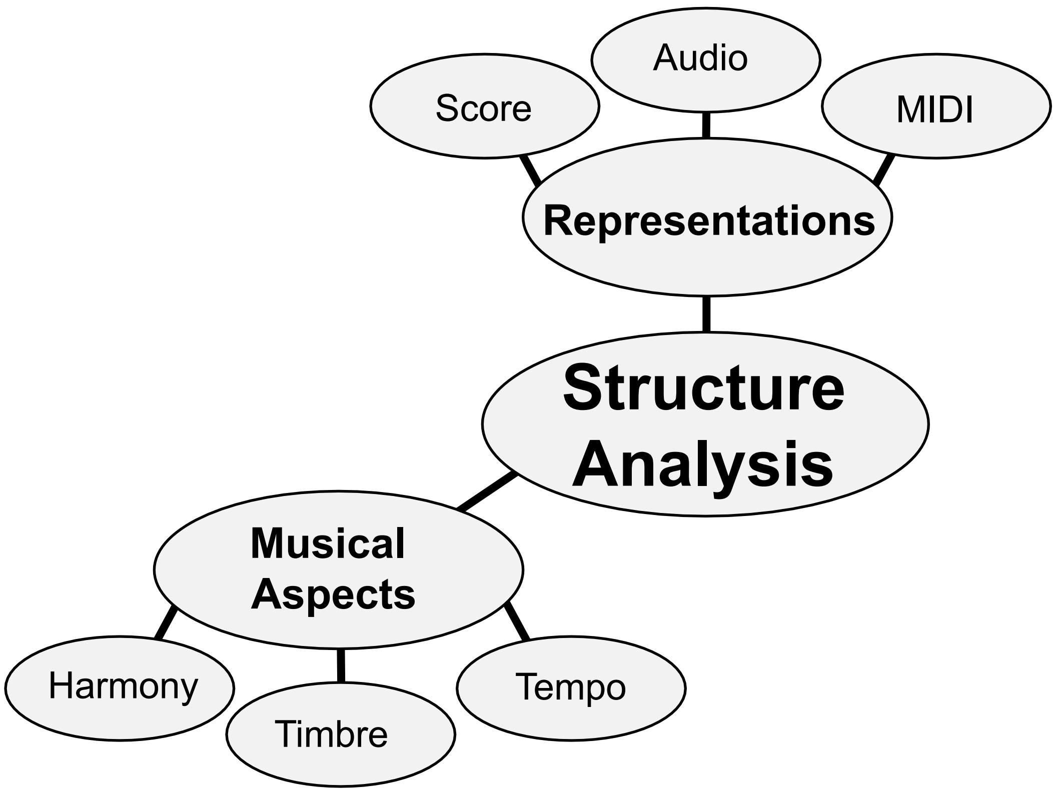
Conclusions



Conclusions



Conclusions



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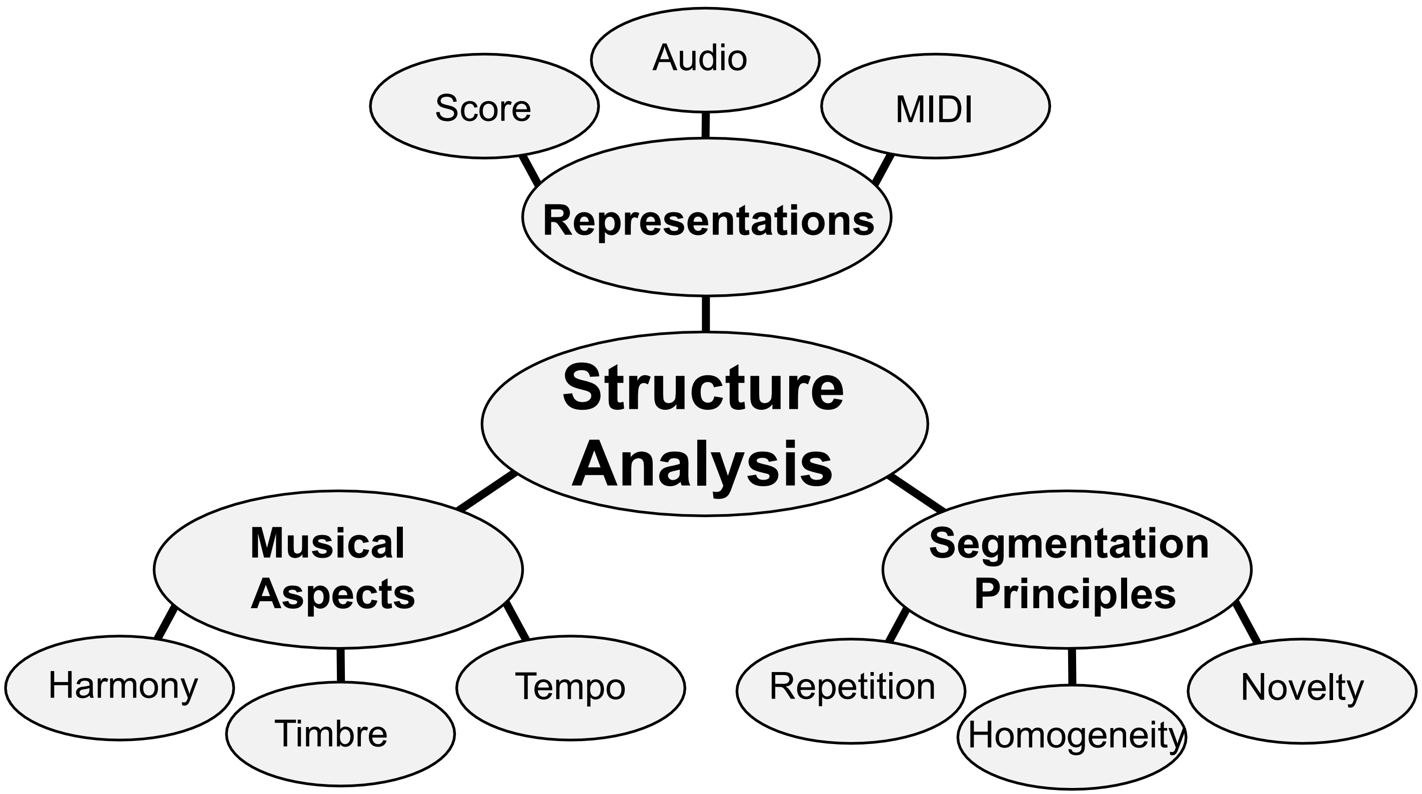

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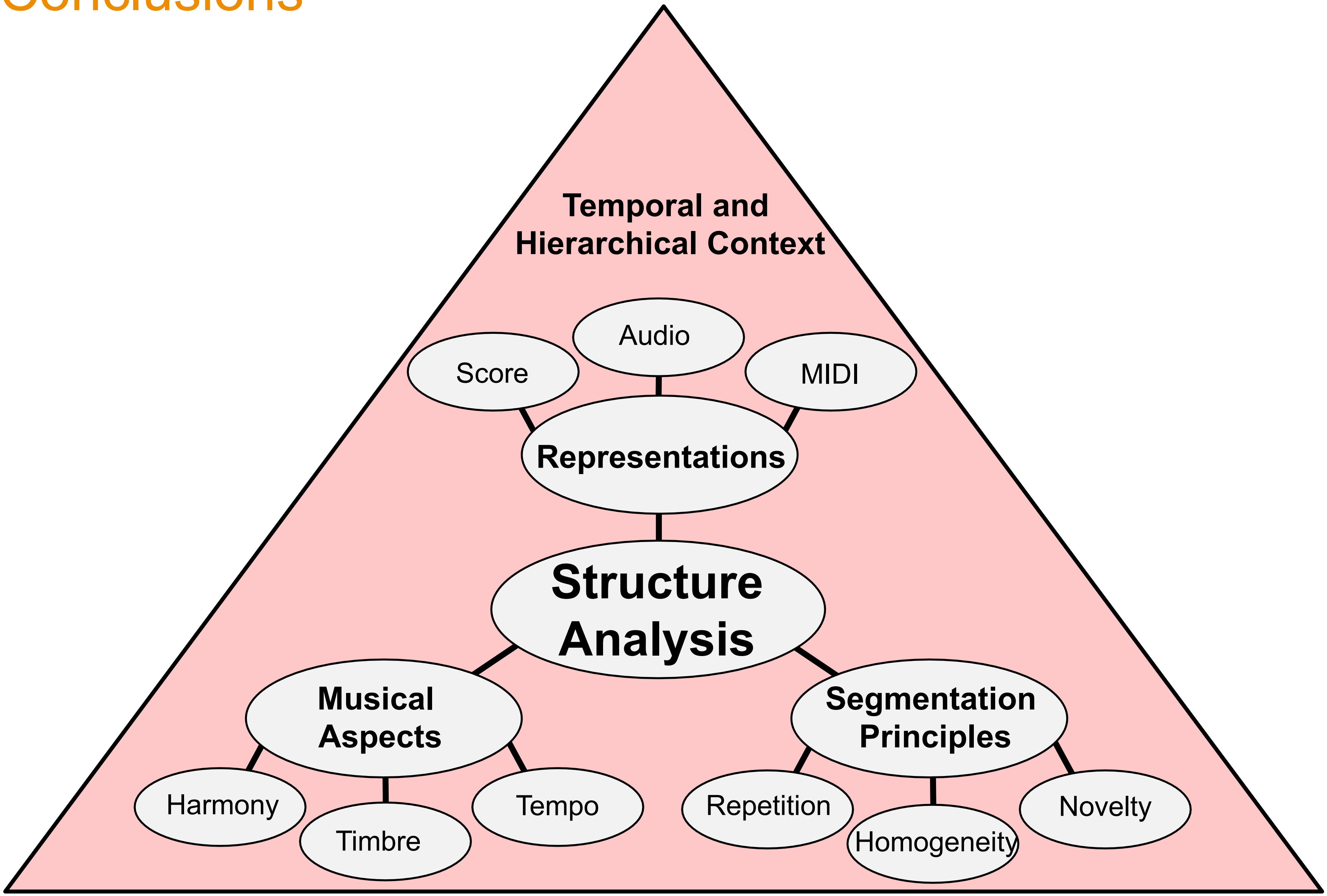

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