INTERNATIONAL AUDIO LABORATORIES ERLANGEN

AUDIO LABS

ISMIR 2017, SUZHOU, CHINA

Tutorial T3
A Basic Introduction to Audio-Related Music Information Retrieval

Audio Structure Analysis

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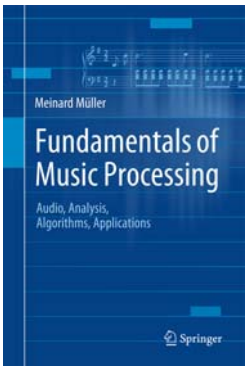
Book: Fundamentals of Music Processing



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

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Chapter	Music Processing Scenario
1	Music Represenations
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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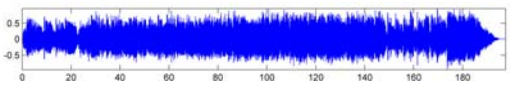
Chapter 4: Music Structure Analysis

In Chapter 4, we address a central and well-researched area within MIR known as music structure analysis. Given a music recording, the objective is to identify important structural elements and to temporally segment the recording according to these elements. Within this scenario, we discuss fundamental segmentation principles based on repetitions, homogeneity, and novelty—principles that also apply to other types of multimedia beyond music. As an important technical tool, we study in detail the concept of self-similarity matrices and discuss their structural properties. Finally, we briefly touch the topic of evaluation, introducing the notions of precision, recall, and F-measure.

Music Structure Analysis

Example: Zager & Evans “In The Year 2525”



Music Structure Analysis

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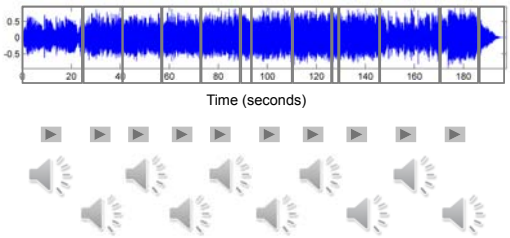

Music Structure Analysis

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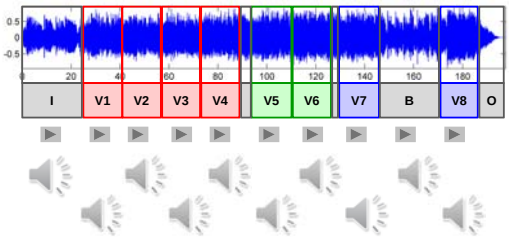
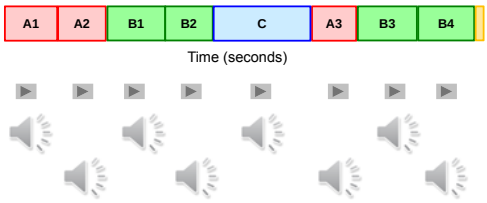


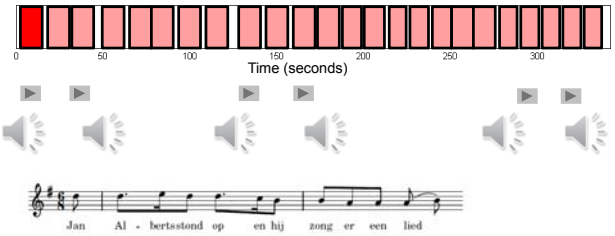
Music Structure Analysis

Example: Brahms Hungarian Dance No. 5 (Ormandy)



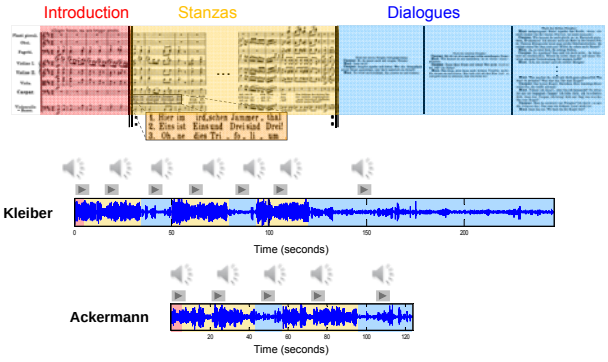
Music Structure Analysis

Example: Folk Song Field Recording
(Nederlandse Liederenbank)



Music Structure Analysis

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



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

Music Structure Analysis

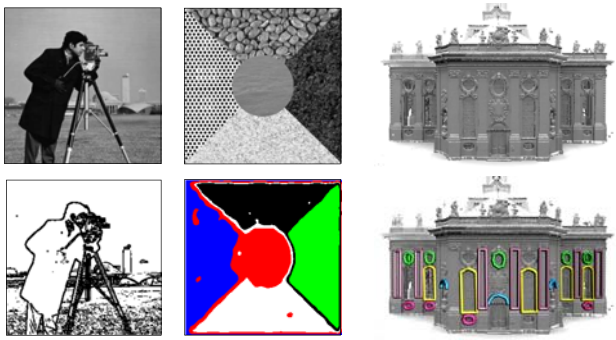
General goal: Divide an audio recording into temporal segments corresponding to musical parts and group these segments into musically meaningful categories.

Challenge: There are many different principles for creating relationships that form the basis for the musical structure.

- Homogeneity: Consistency in tempo, instrumentation, key, …
- Novelty: Sudden changes, surprising elements …
- Repetition: Repeating themes, motives, rhythmic patterns,…

Music Structure Analysis

Novelty | Homogeneity | Repetition



Overview

- Introduction
- Feature Representations
- Self-Similarity Matrices
- Novelty-Based Segmentation

Thanks:

- Clausen, Ewert, Kurth, Grohganz, …
- Dannenberg, Goto
- Grosche, Jiang
- Paulus, Klapuri
- Peeters, Kaiser, …
- Serra, Gómez, …
- Smith, Fujinaga, …
- Wiering, …
- Wand, Sunkel, Jansen
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Feature Representation

General goal: Convert an audio recording into a mid-level representation that captures certain musical properties while supressing other properties.

- Timbre / Instrumentation
- Tempo / Rhythm
- Pitch / Harmony

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Feature Representation

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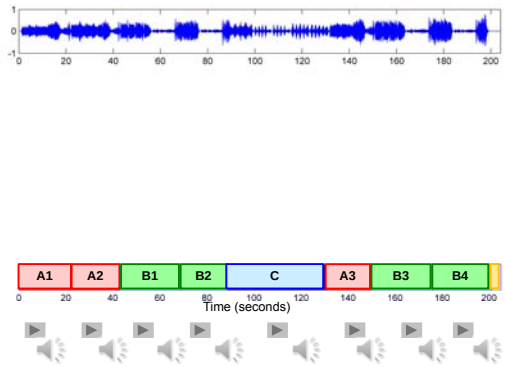
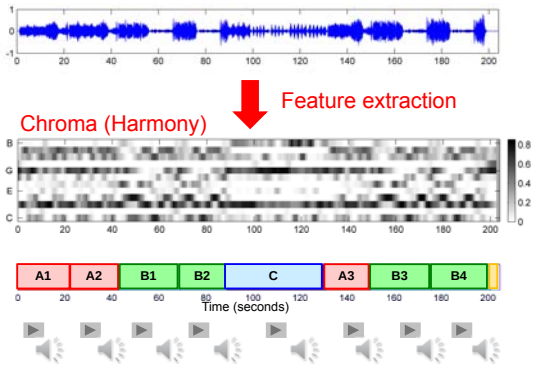


Feature Representation

Example: Brahms Hungarian Dance No. 5 (Ormandy)



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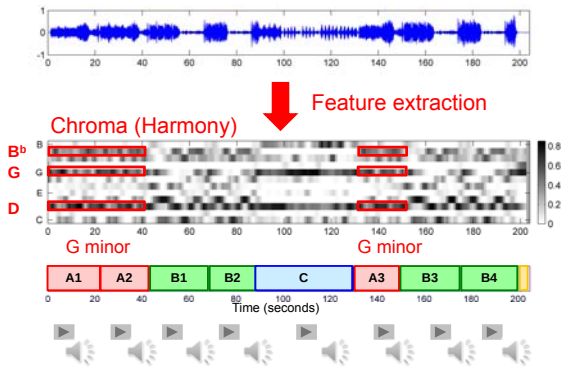

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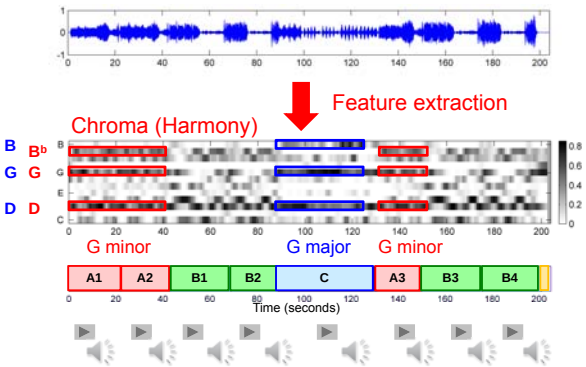

Overview

- Introduction
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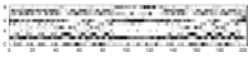
Self-Similarity Matrix (SSM)

General idea: Compare each element of the feature sequence with each other element of the feature sequence based on a suitable similarity measure.

→ Quadratic self-similarity matrix

Self-Similarity Matrix (SSM)

Example: Brahms Hungarian Dance No. 5 (Ormandy)



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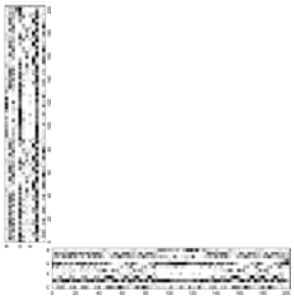

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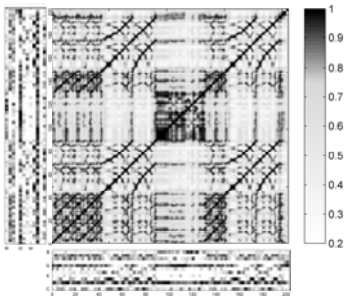

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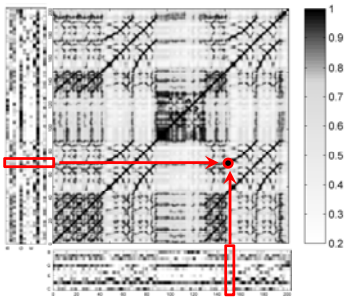

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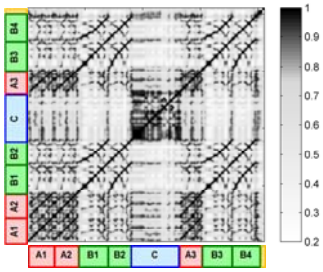

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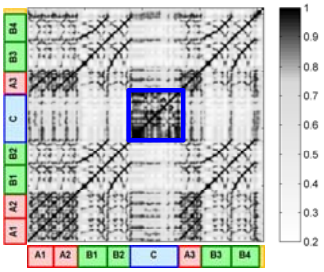

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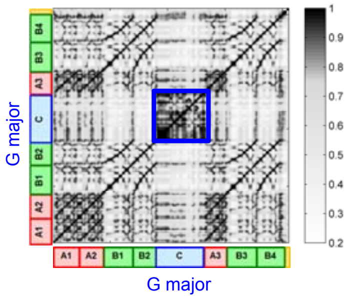

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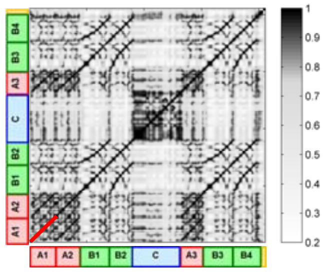

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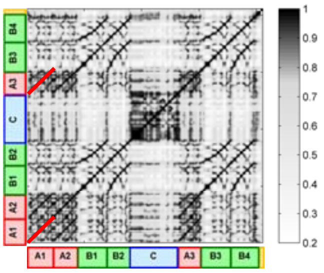

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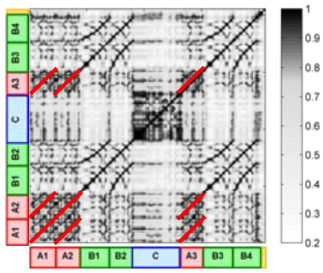

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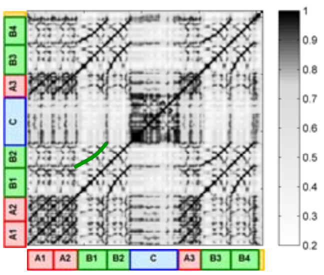

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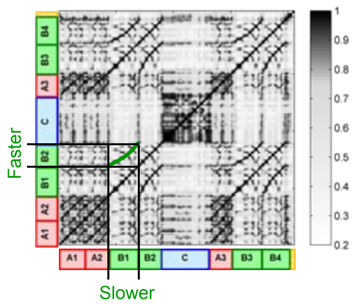

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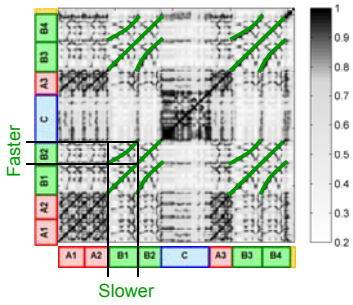
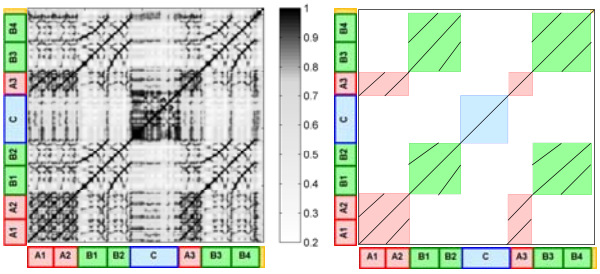


Self-Similarity Matrix (SSM)

Example: Brahms Hungarian Dance No. 5 (Ormandy)

Idealized SSM



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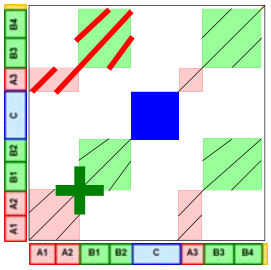


Blocks: Homogeneity

Paths: Repetition

Corners: Novelty

SSM Enhancement

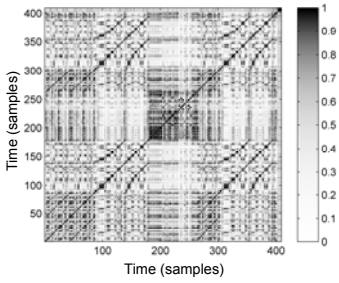
Challenge: Presence of musical variations

- Fragmented paths and gaps
- Paths of poor quality
- Regions of constant (low) cost
- Curved paths

Idea: Enhancement of path structure

SSM Enhancement

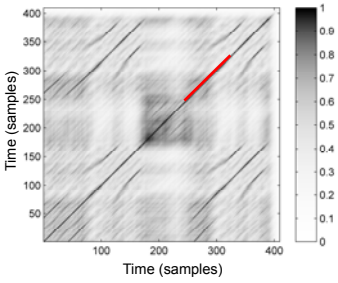
Path Enhancement



SSM Enhancement

Path Enhancement

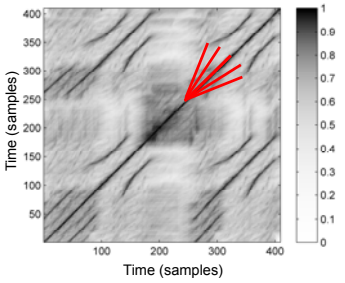
- Diagonal smoothing



SSM Enhancement

Path Enhancement

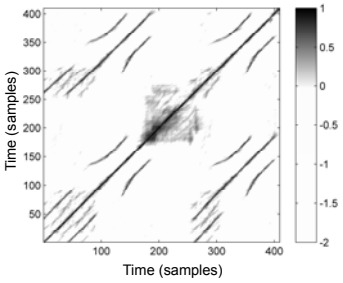
- Diagonal smoothing
- Multiple filtering



SSM Enhancement

Path Enhancement

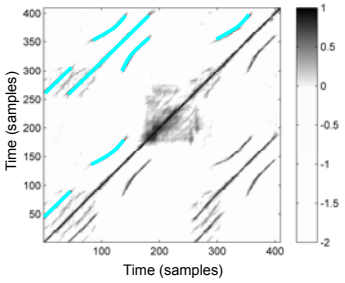
- Diagonal smoothing
- Multiple filtering
- Thresholding (relative)
- Scaling & penalty



SSM Enhancement

Further Processing

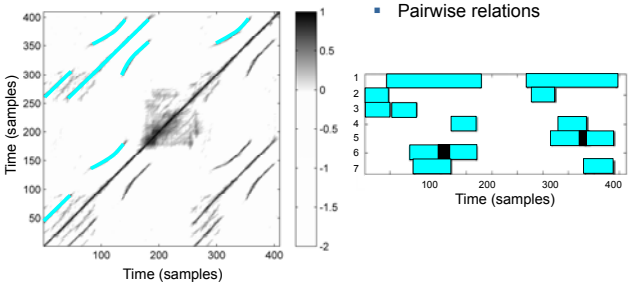
- Path extraction



SSM Enhancement

Further Processing

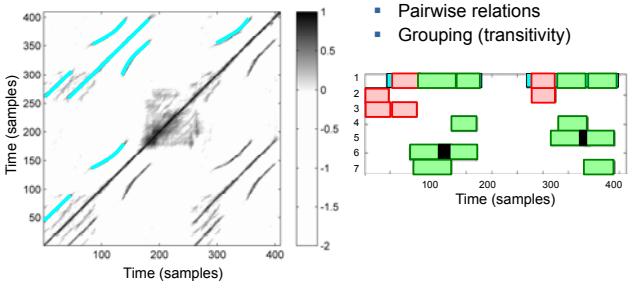
- Path extraction
- Pairwise relations



SSM Enhancement

Further Processing

- Path extraction
- Pairwise relations
- Grouping (transitivity)



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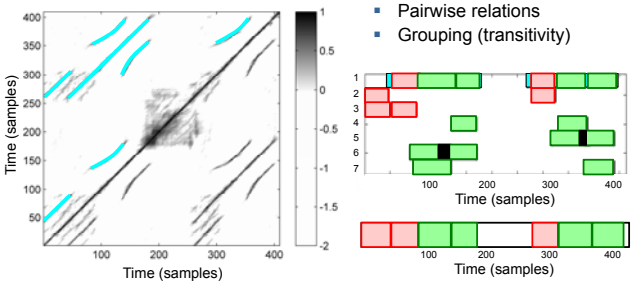
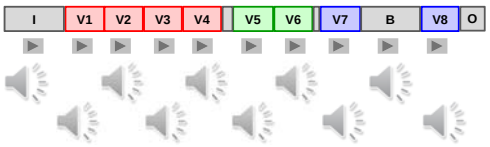


SSM Enhancement

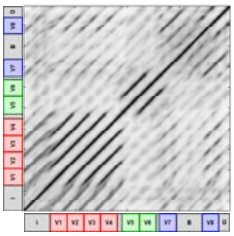
Example: Zager & Evans “In The Year 2525”



SSM Enhancement

Example: Zager & Evans “In The Year 2525”

Missing relations because of transposed sections

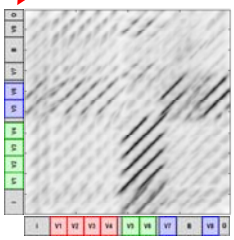


SSM Enhancement

Example: Zager & Evans “In The Year 2525”

Idea: Cyclic shift of one of the chroma sequences

One semitone up



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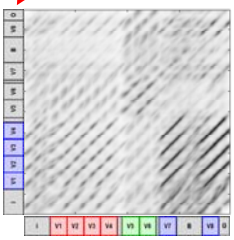
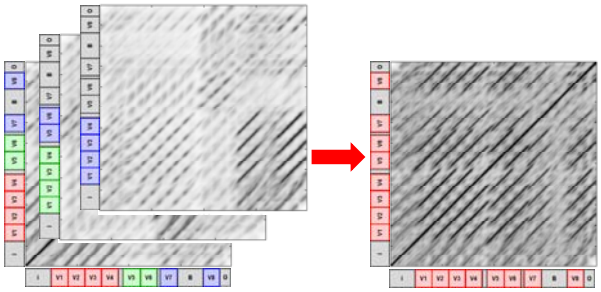


SSM Enhancement

Example: Zager & Evans “In The Year 2525”

Idea: Overlay & Maximize ⟶ Transposition-invariant SSM



Overview

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- Self-Similarity Matrices
- Novelty-Based Segmentation

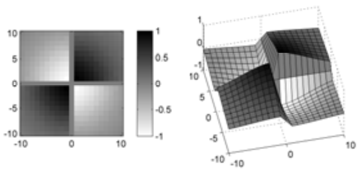
Novelty-Based Segmentation

General goals:

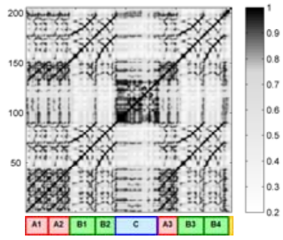
- Find instances where musical changes occur.
- Find transition between subsequent musical parts.

Idea (Foote):

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



Novelty-Based Segmentation



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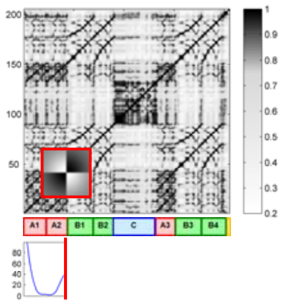

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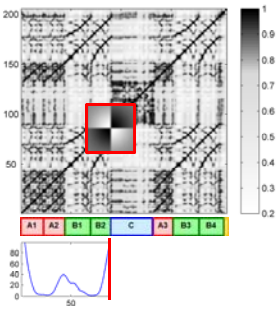

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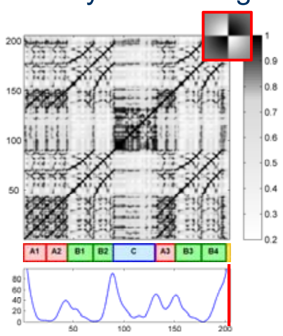
Use checkerboard-like kernel function to detect corner points on main diagonal of SSM.

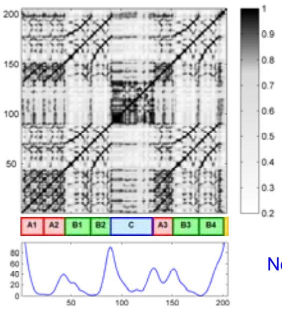
Novelty-Based Segmentation



Idea (Foote):

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

Novelty-Based Segmentation

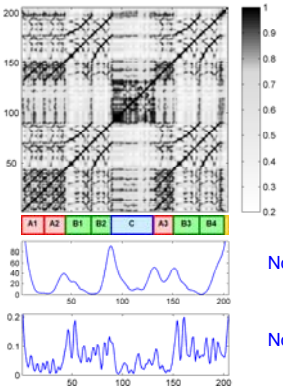


Idea (Foote):

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

Novelty function using 

Novelty-Based Segmentation



Idea (Foote):

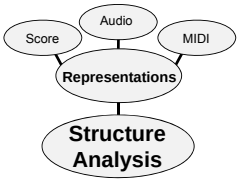
Use checkerboard-like kernel function to detect corner points on main diagonal of SSM.

Novelty function using 

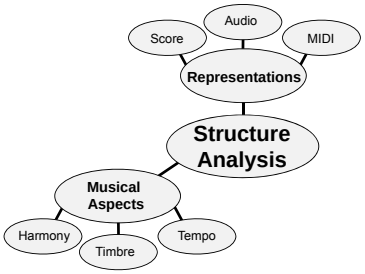
Novelty function using 

Conclusions

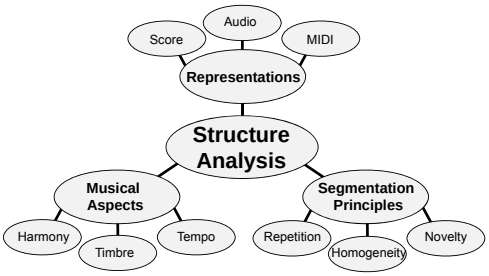
Conclusions



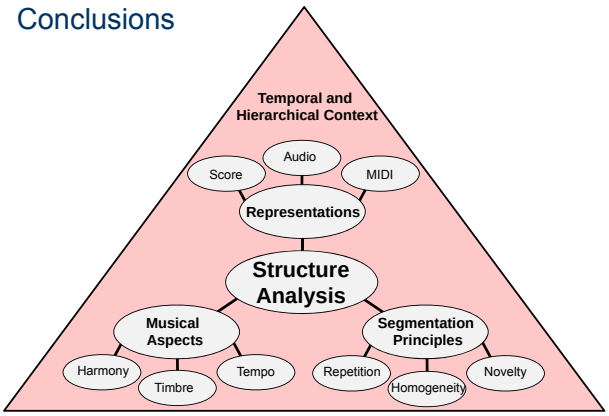
Conclusions



Conclusions



Conclusions



Links

- SM Toolbox (MATLAB)
  http://www.audiolabs-erlangen.de/resources/MIR/SMtoolbox/
- MSAF: Music Structure Analysis Framework (Python)
  https://github.com/urinieto/msaf
- SALAMI Annotation Data
  http://ddmal.music.mcgill.ca/research/salami/annotations
- LibROSA (Python)
  https://librosa.github.io/librosa/
- Evaluation: mir_eval (Python)
  https://craffel.github.io/mir_eval/
- Deep Learning: Boundary Detection
  Jan Schlüter (PhD thesis)