Musik trifft Informatik in Dagstuhl

Meinard Müller

International Audio Laboratories Erlangen
meinard.mueller@audiolabs-erlangen.de

Festkolloquium
32 Jahre Informatik in Schloss Dagstuhl
24. Juni 2022

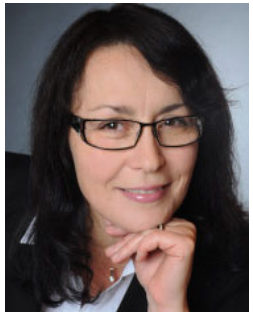
Friedrich-Alexander-Universität
Erlangen-Nürnberg

Fraunhofer
IIS

Meinard Müller: Research Group

- Christof Weiß

- Vlora Arifi-Müller



- Sebastian Rosenzweig

- Michael Krause

- Yigitcan Özer

- Simon Schwär

- Peter Meier (external)

Meinard Müller

- Mathematics (Diplom/Master, 1997)
  Computer Science (PhD, 2001)
  Information Retrieval (Habilitation, 2007)
  Bonn University

- Senior Researcher (2007-2012)
  Max-Planck Institute, Saarland

- Professor Semantic Audio Processing (since 2012)
  Erlangen-Nürnberg University

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universitätbonn

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Cluster of Excellence on
Multimodal Computing and Interaction

- Professor Semantic Audio Processing (since 2012)
  Erlangen-Nürnberg University

FAU

AUDIO LABS

Multimodal Music Processing

SCHLOSS DAGSTUHL
Leibniz-Zentrum für Informatik

2011, January 23 – 28, Dagstuhl Seminar 11041

Organizers:

Simon Dixon (Queen Mary University of London, GB)

Masataka Goto (AIST – Ibaraki, JP)

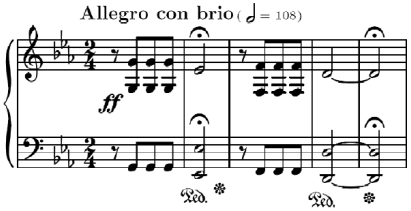
Meinard Müller (MPI Informatik, DE)

AUDIO LABS

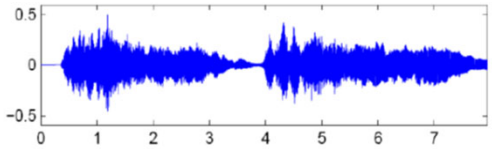
Multimodal Music Processing

Multimodal Music Processing

Sheet Music (Image)



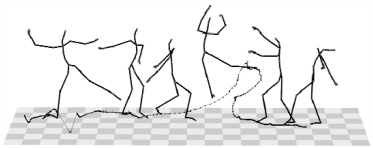
CD / MP3 (Audio)



MusicXML (Text)

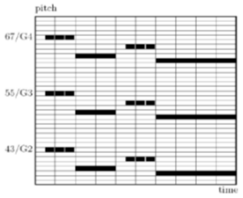
```
<note>
  <pitch>
    <step>E</step>
    <alter>-1</alter>
    <octave>4</octave>
  </pitch>
  <duration>2</duration>
  <type>half</type>
</note>
```

Dance / Motion (Mocap)



Music

MIDI



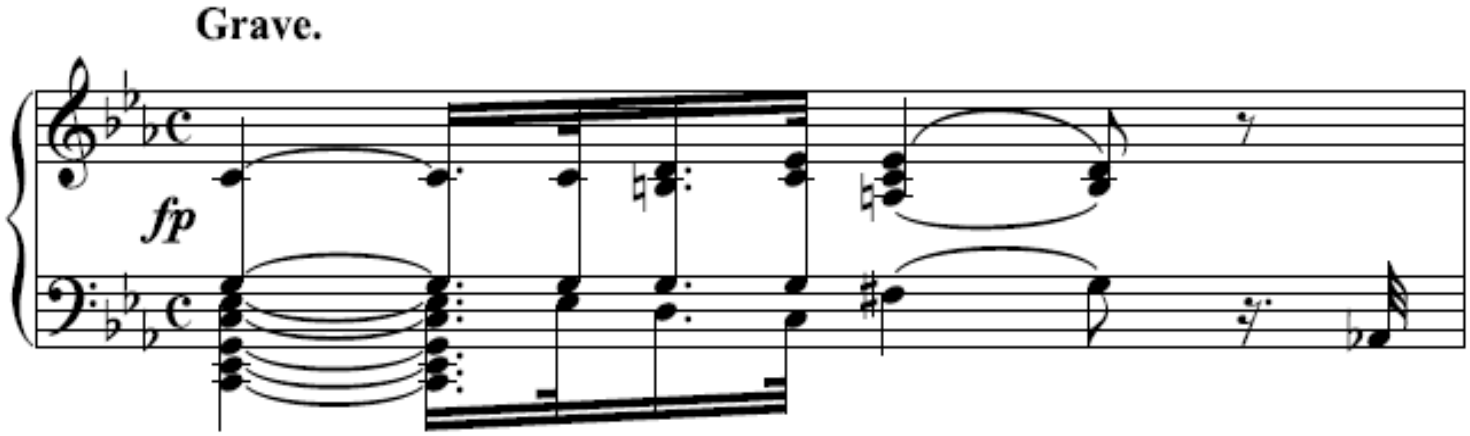
Singing / Voice (Audio)

Music Film (Video)

Music Literature (Text)

Multimodal Music Processing

Image



Audio

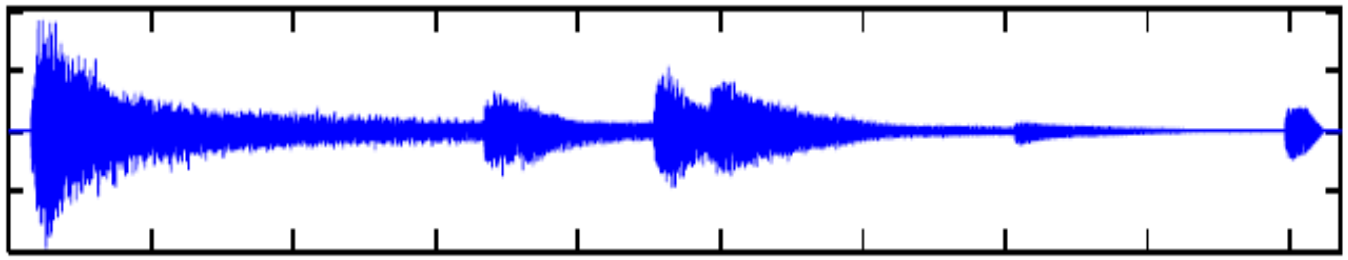
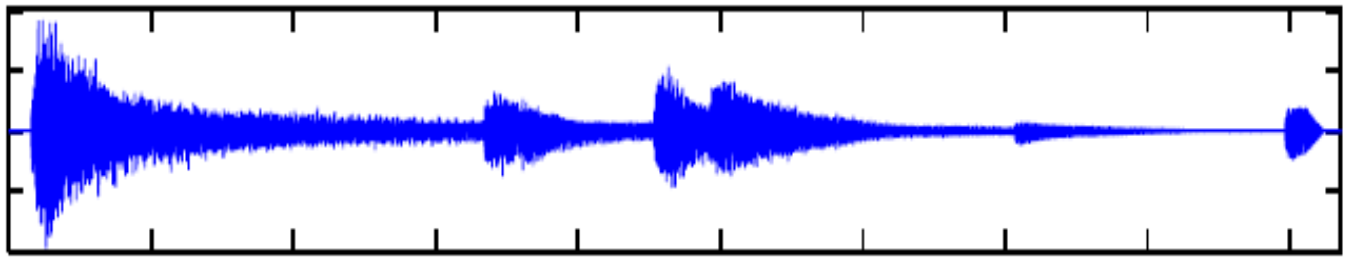


Image Processing: Optical Music Recognition

Image

Audio



Multimodal Music Processing

Image Processing: Optical Music Recognition

Image

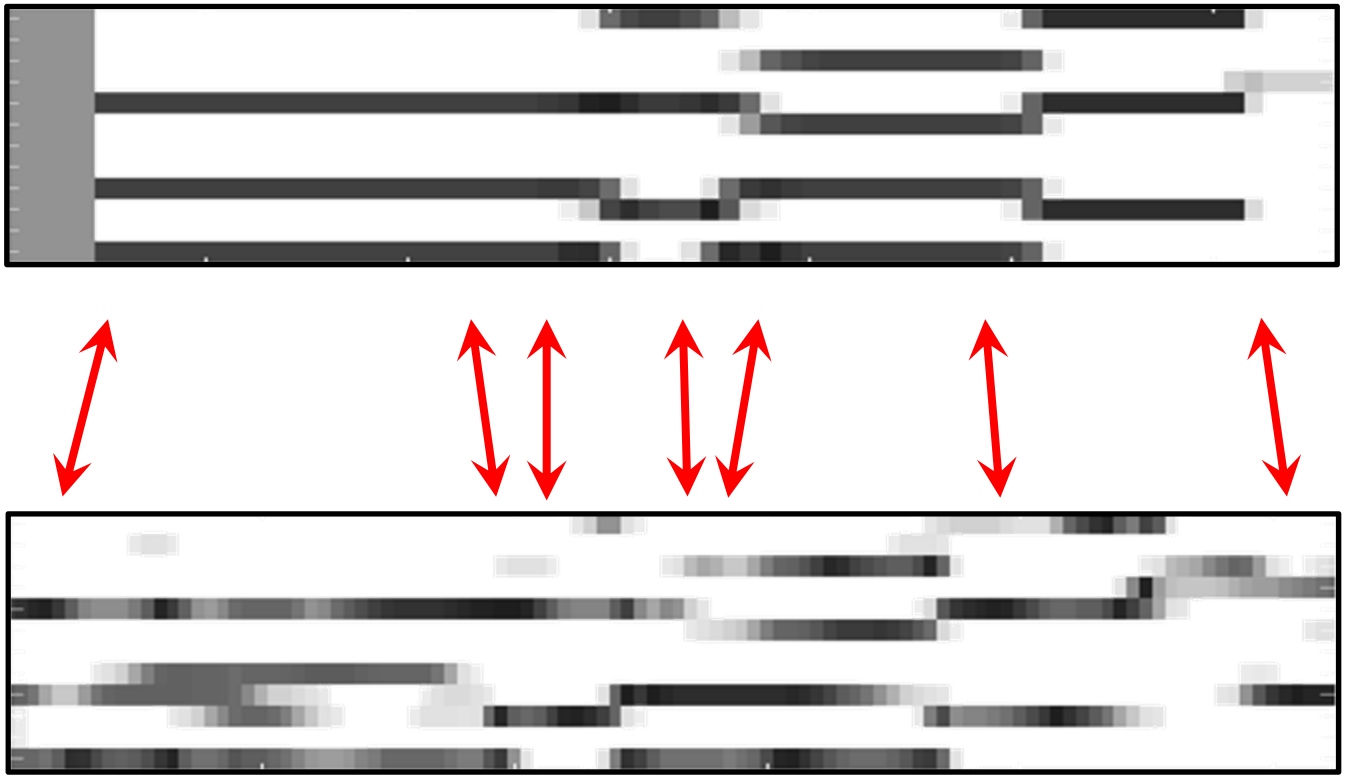
Audio

Audio Processing: Fourier Analysis

Multimodal Music Processing

Image Processing: Optical Music Recognition

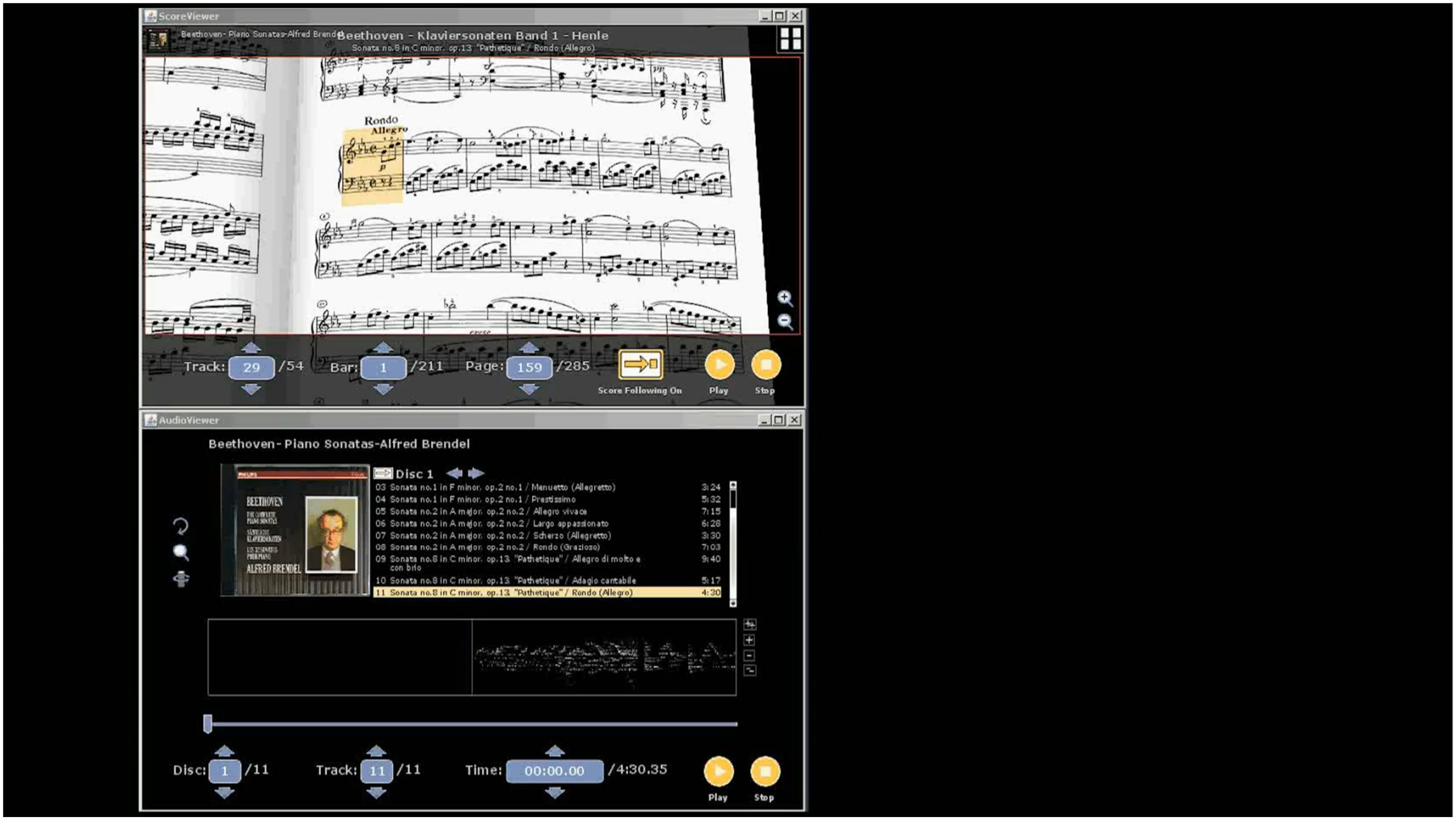
Image



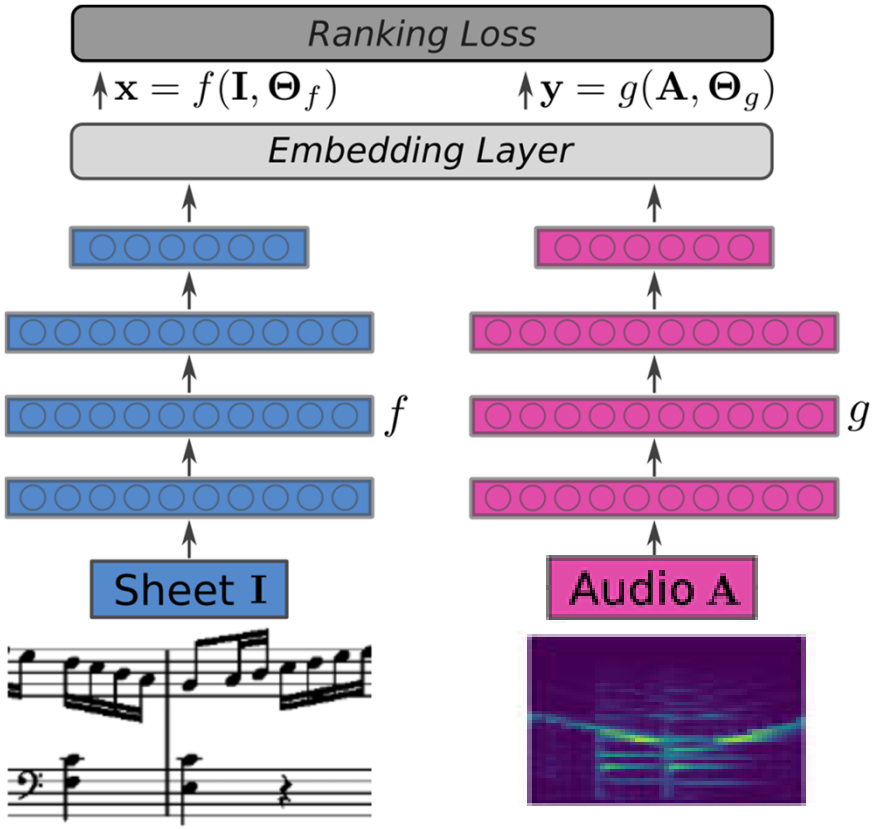
Audio

Audio Processing: Fourier Analysis

Multimodal Music Processing



Multimodal Music Processing



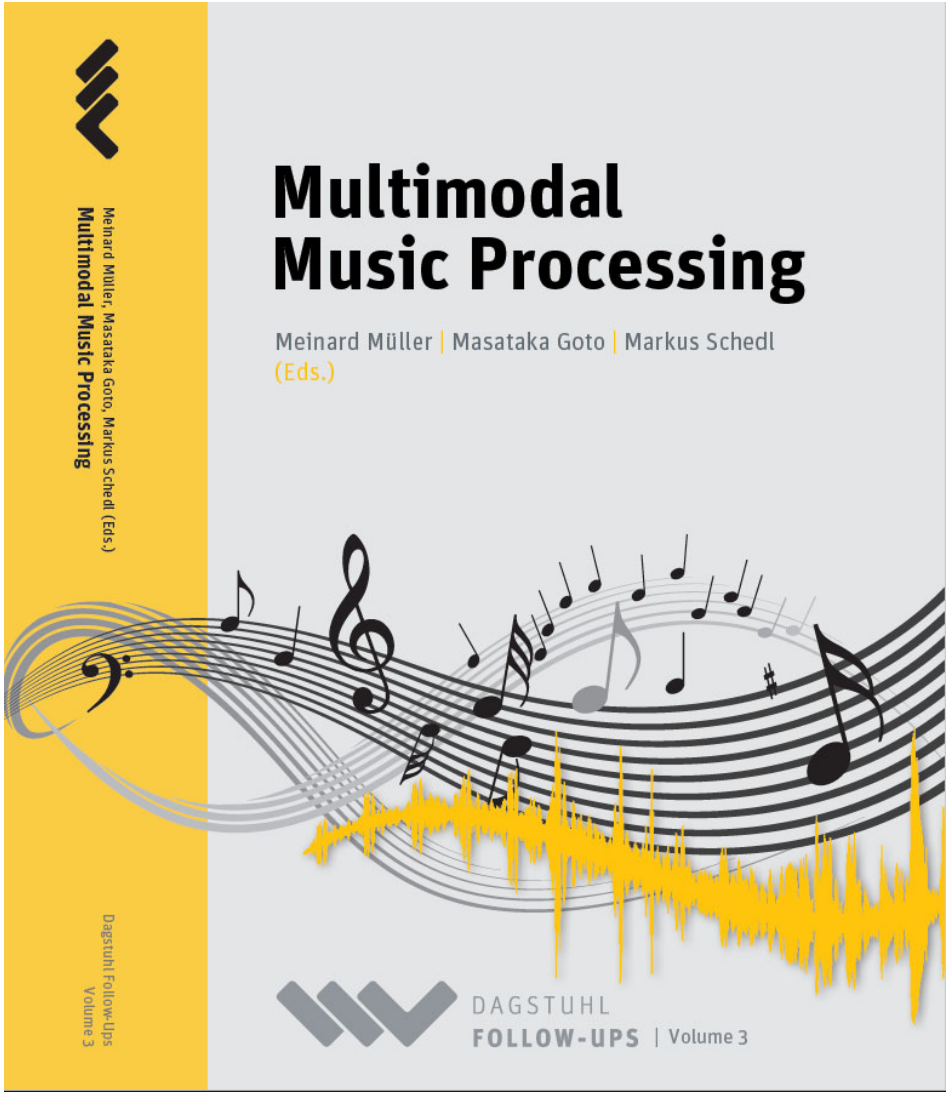
- Deep learning
- Embedding techniques
- Music transcription
- Lyrics alignment
- …

Multimodal Music Processing

Marc Herbstritt

Thank you!

Cluster of Excellence on
Multimodal Computing and Interaction



AUDIO LABS

Computational Audio Analysis

SCHLOSS DAGSTUHL
Leibniz-Zentrum für Informatik

2013, November 3 – 8, Dagstuhl Seminar 13451

Organizers:

Shrikanth S. Narayanan (USC, US)

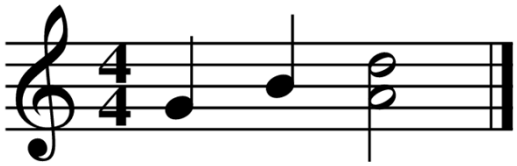
Björn Schuller (TU München, DE)

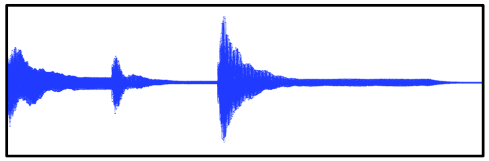
Meinard Müller (FAU, DE)

AUDIO LABS

Computational Audio Analysis

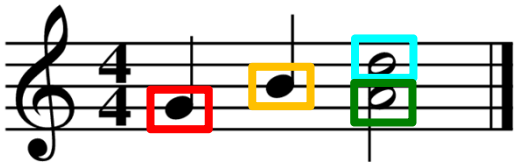
Score-informed audio decomposition

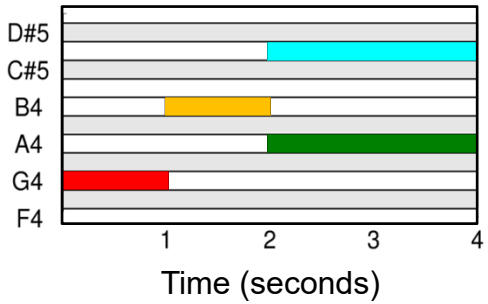


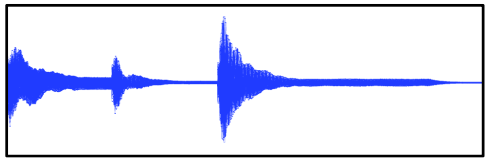


Computational Audio Analysis

Score-informed audio decomposition

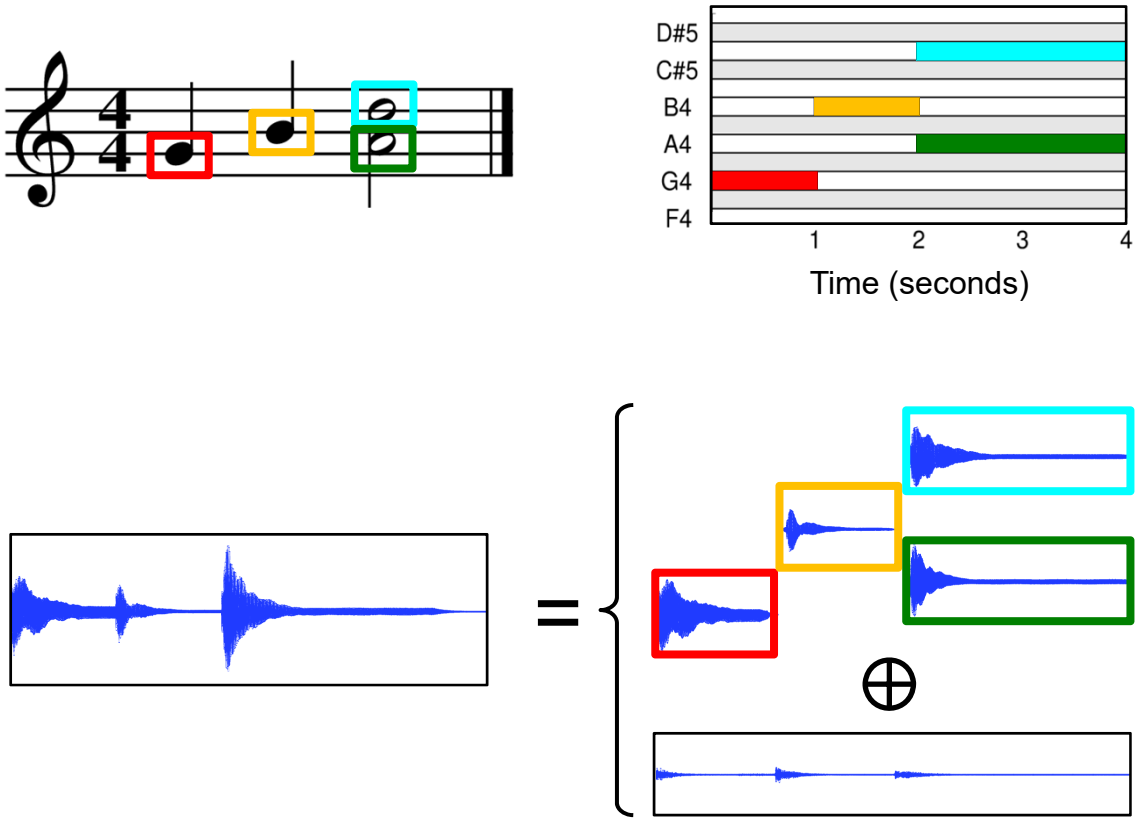






Computational Audio Analysis

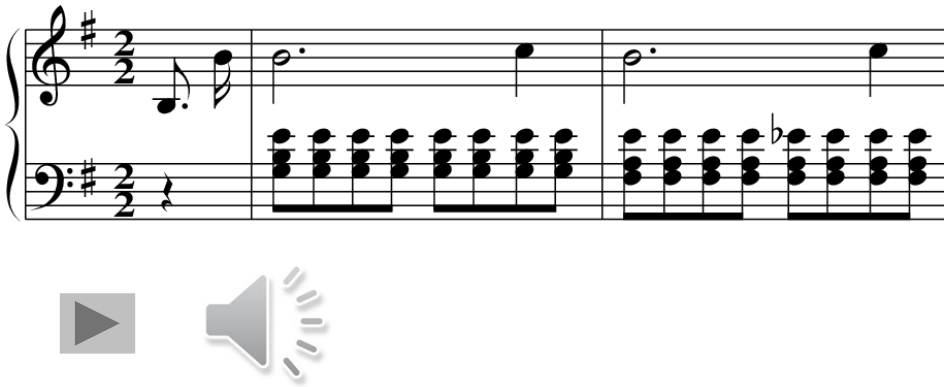
Score-informed audio decomposition



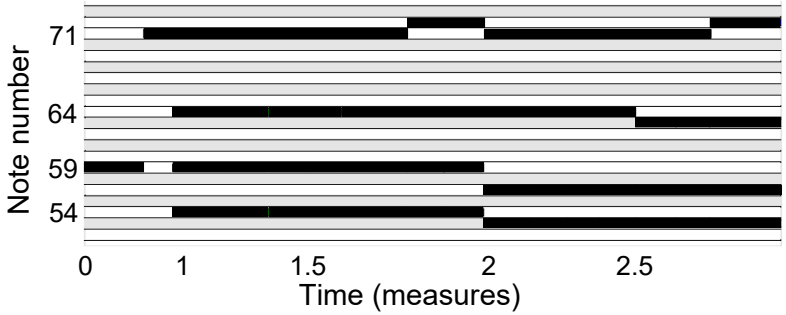
Computational Audio Analysis

Score-informed audio decomposition

Sheet music



Piano roll



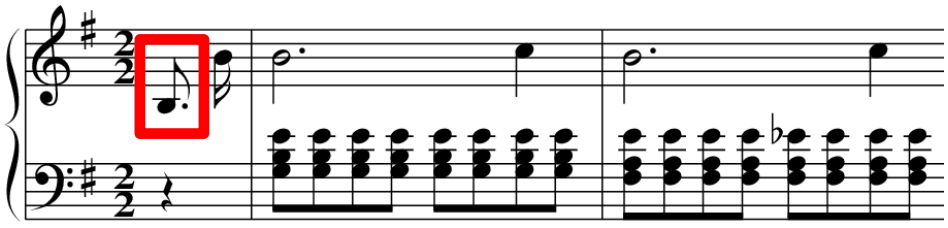
Computational Audio Analysis

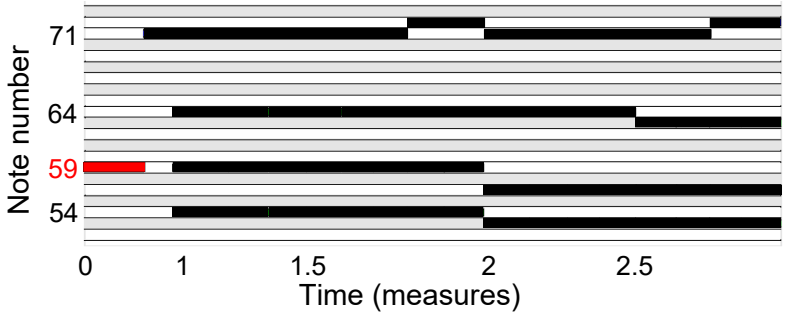
Score-informed audio decomposition

Sheet music

$p = 59$

Piano roll

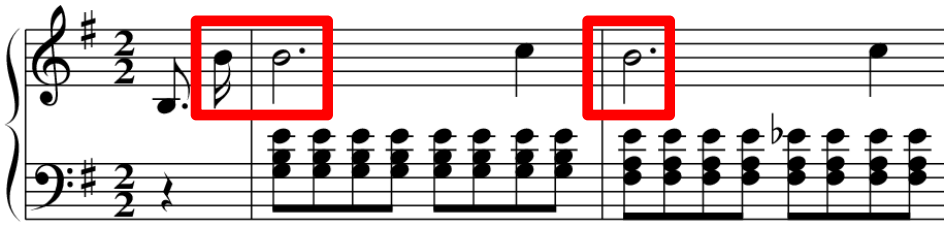




Computational Audio Analysis

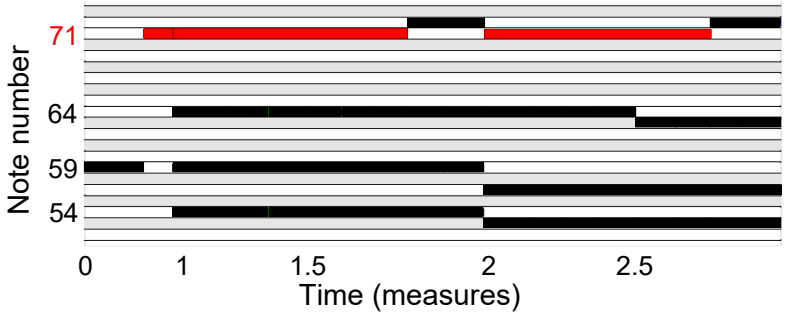
Score-informed audio decomposition

Sheet music



p = 71

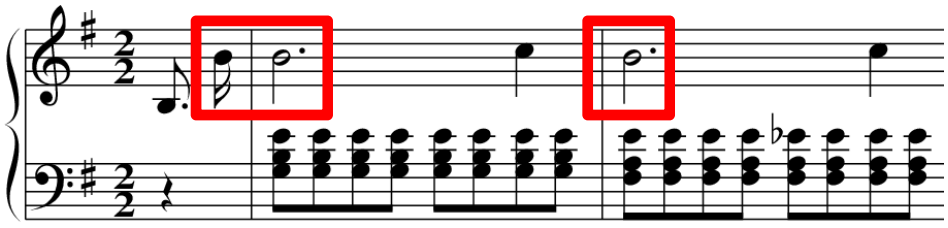
Piano roll



Computational Audio Analysis

Score-informed audio decomposition

Sheet music



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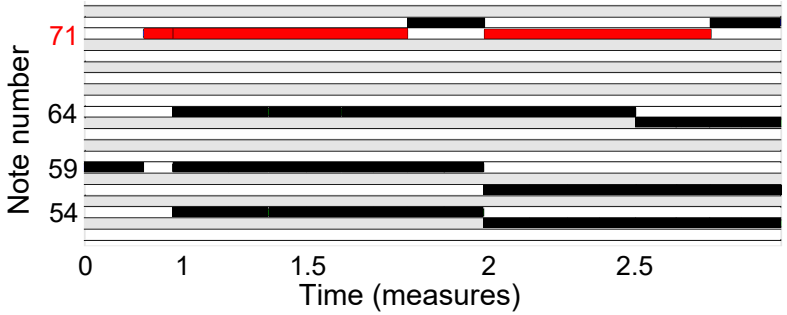
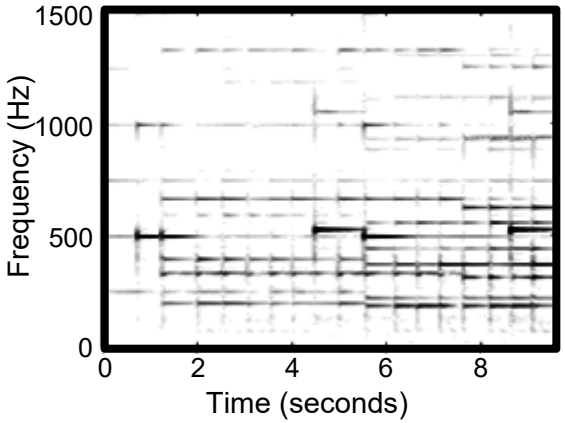
Piano roll



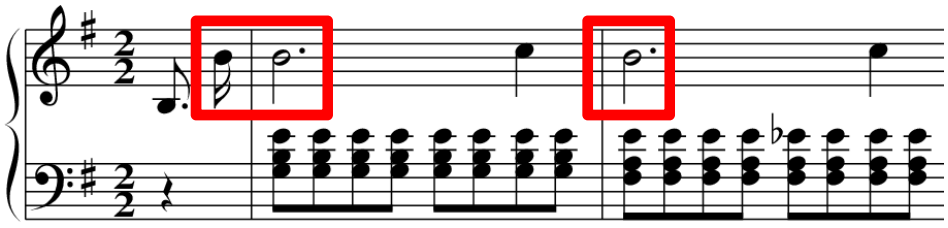
Spectrogram



Computational Audio Analysis

Score-informed audio decomposition

Sheet music



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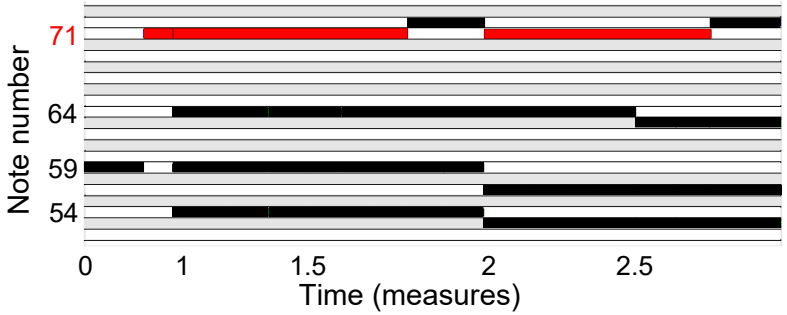
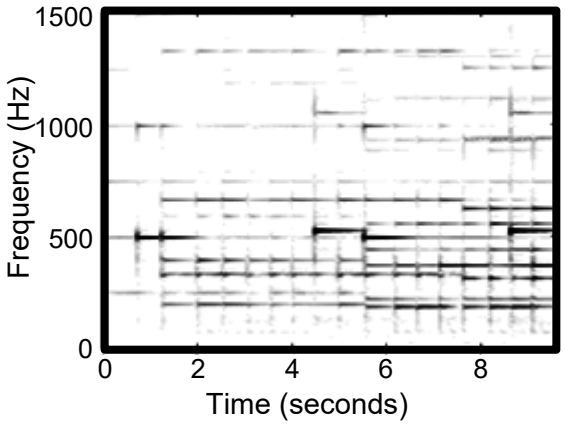
Piano roll



Spectrogram



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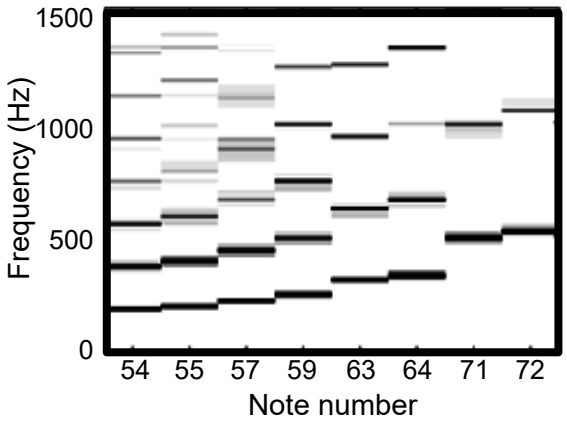
Spectral patterns



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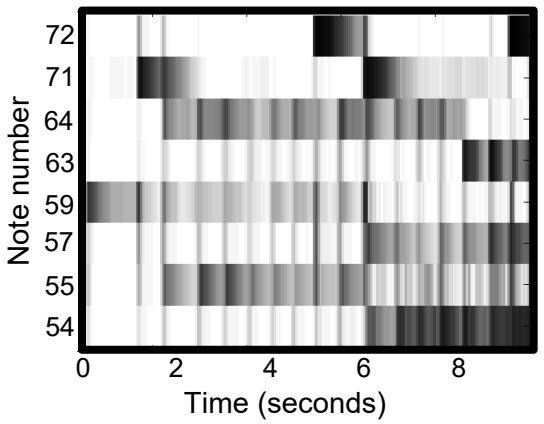
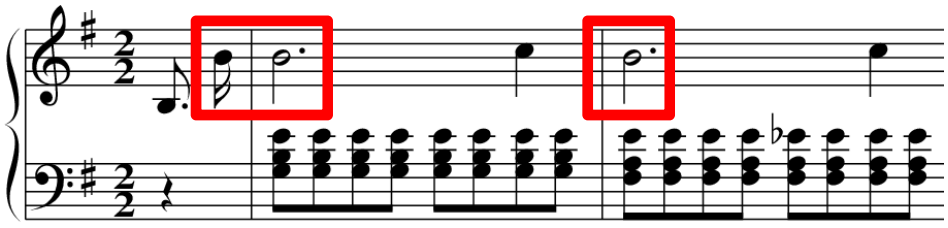
Activity patterns



Computational Audio Analysis

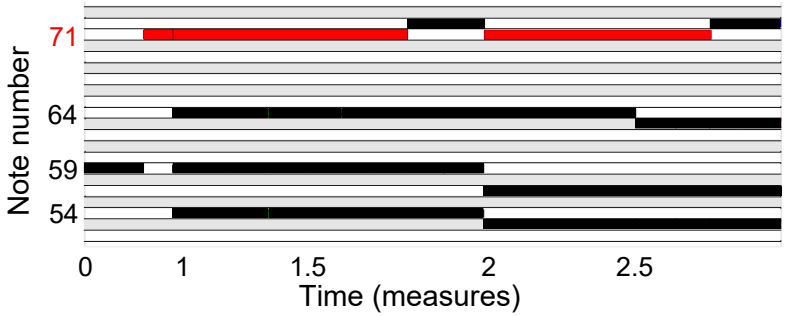
Score-informed audio decomposition

Sheet music

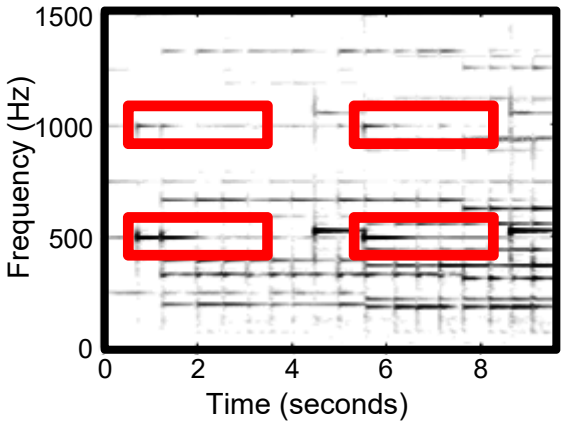


$p = 71$

Piano roll



Spectrogram



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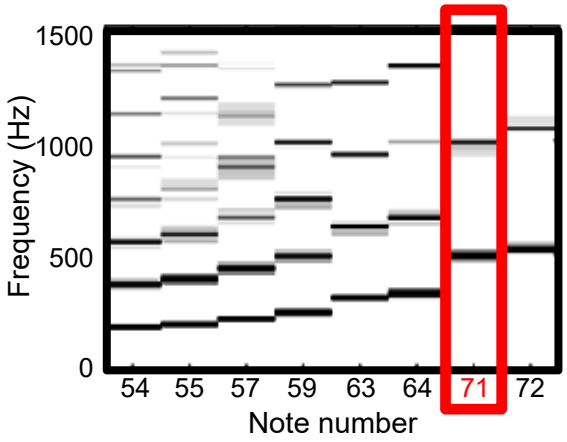
Spectral patterns



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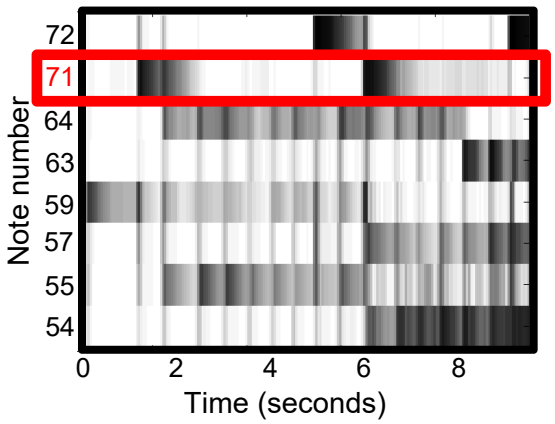
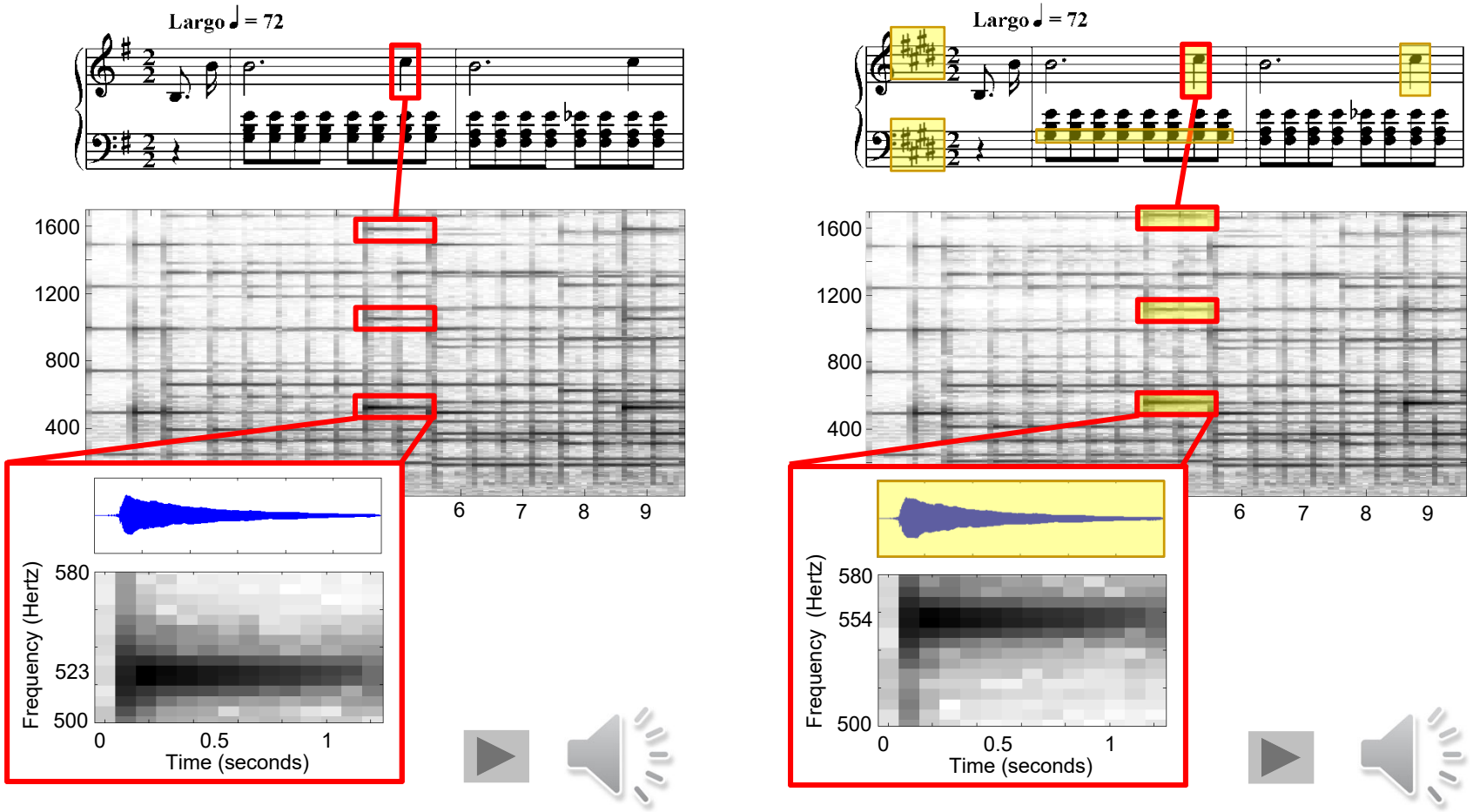
Activity patterns



Computational Audio Analysis

Score-informed audio decomposition

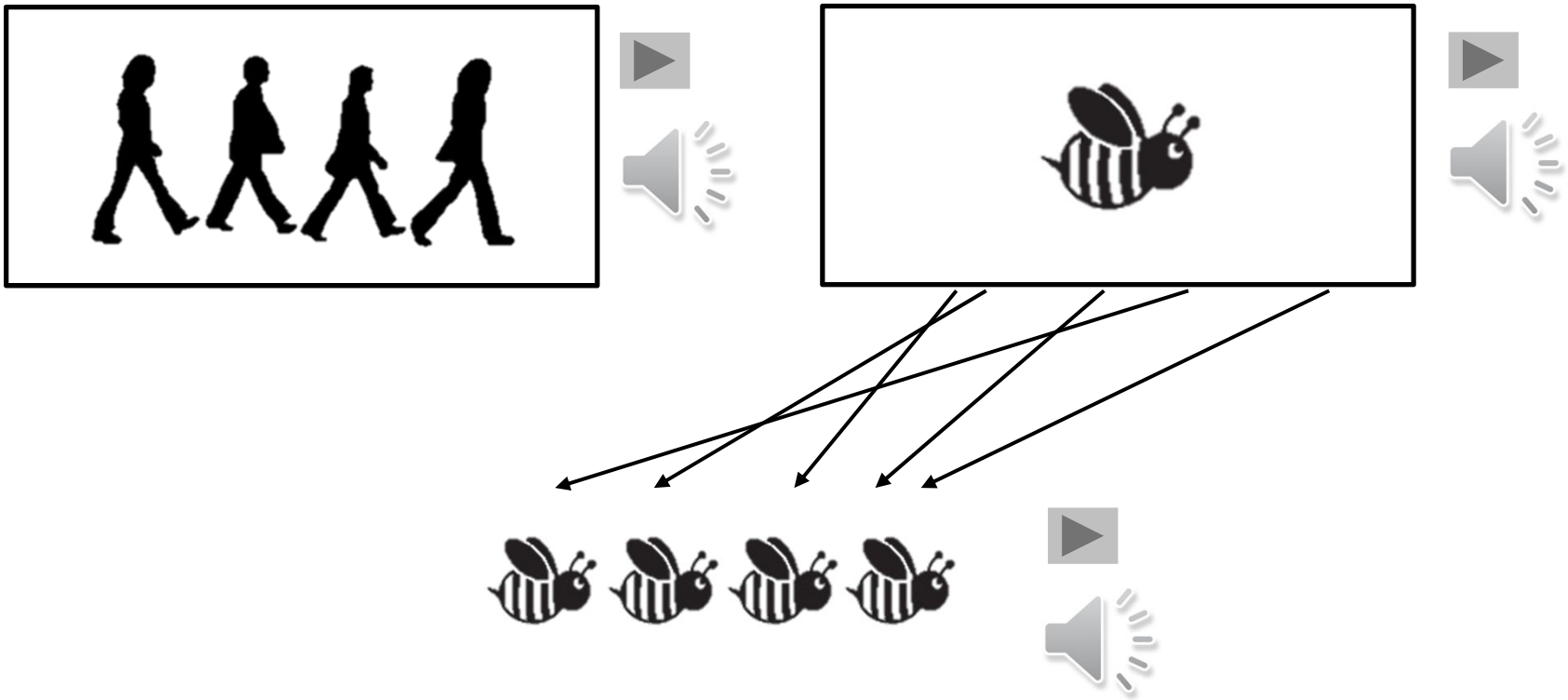


Computational Audio Analysis

Audio mosaicing (style transfer)

Target signal: Beatles–Let it be

Source signal: Bees



Mosaic signal: Let it Bee

Computational Audio Analysis

- Decomposing complex audio scenes
- Source separation
- Understanding acoustic, linguistic, or musical properties
- Extracting emotion-related parameters
  (e.g., stress, confidence, frustration)
- …

Computational Audio Analysis

Roswitha Bardohl

SCHLOSS DAGSTUHL
Leibniz-Zentrum für Informatik

Saarbrücken, 23. Oktober 2013

Schloss Dagstuhl: Können Computersysteme Emotionen erkennen?

Thank you!

Deutschlandfunk

Zwischentöne für Computer

06.11.2013

AUDIO LABS

Computational Music Structure Analysis

SCHLOSS DAGSTUHL
Leibniz-Zentrum für Informatik

2016, February 28 – March 4, Dagstuhl Seminar 16092

Organizers:

Juan Pablo Bello (New York University, US)

Elaine Chew (Queen Mary University of London, GB)

Meinard Müller (FAU, DE)

AUDIO LABS

Computational Music Structure Analysis

Example: Carl Maria von Weber: “Der Freischütz”

FREISCHÜTZ DIGITAL

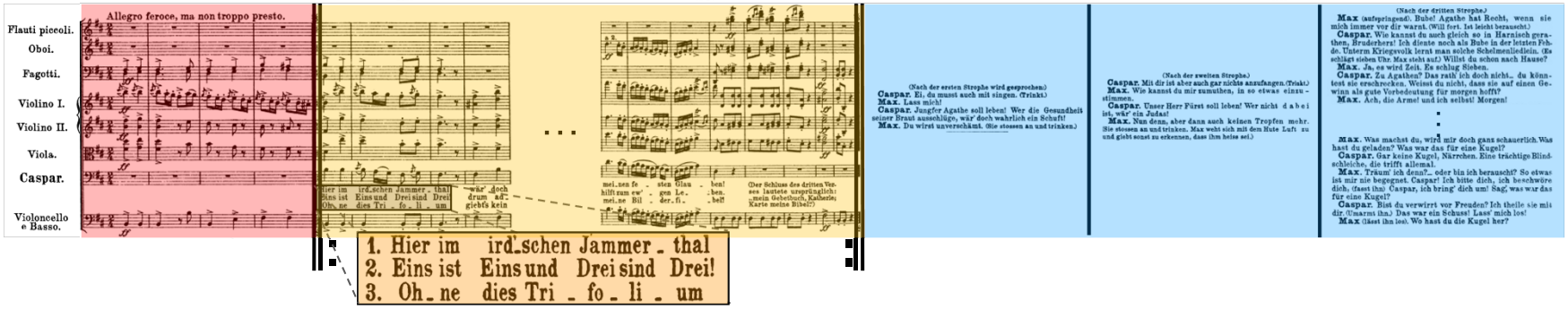
Variations	Performance
	Kleiber C. , 1973
Tempo	Elmendorff, 1944
Language	Penin (fr.),1998
Key	Orlov (russ.), 1946
Sound quality	Gui (it.), 1957

AUDIO LABS

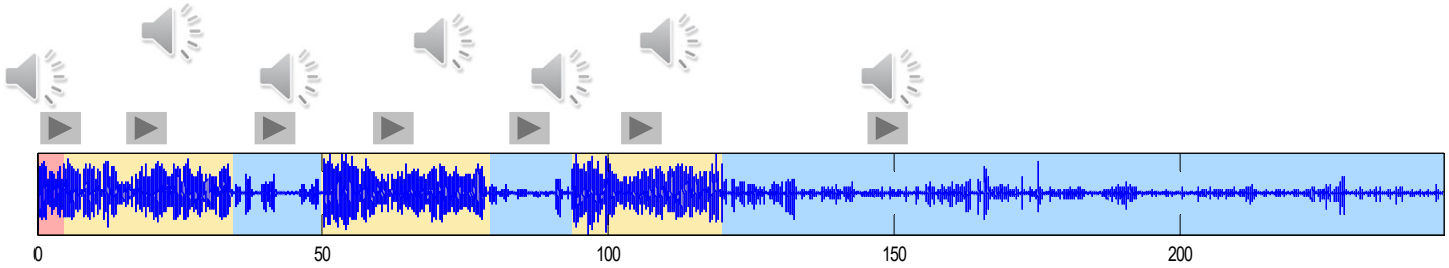
Computational Music Structure Analysis

Example: Carl Maria von Weber: “Der Freischütz” (No. 4)

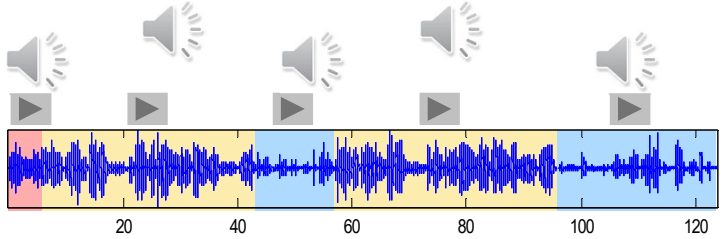
Introduction Stanzas Dialogues



Kleiber

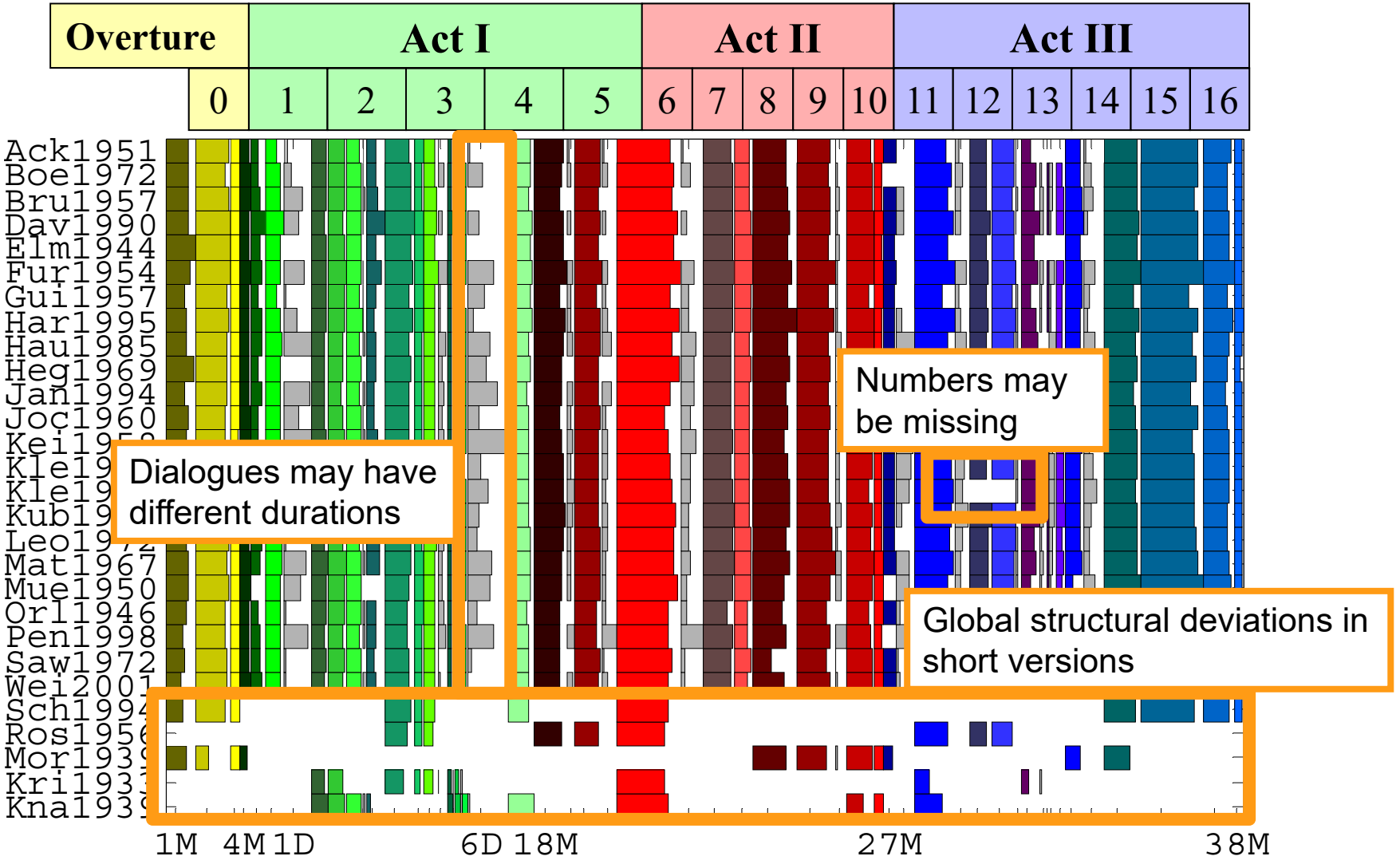


Ackermann



Computational Music Structure Analysis

FREISCHÜTZ DIGITAL



AUDIO LABS

Computational Music Structure Analysis

- Extraction of musical form
- Finding (nearly) repeating patterns
- Instrument detection and classification
- Language detection
- Detection of musical keys, chords, …
- Detection of time signature, tempo, measures, beats, …
- …

Computational Music Structure Analysis

Susanne Bach-Bernhard

Heike Clemens

Simone Schilke

Jutka Gasiorowski

dblp

Michael Wagner

Thank you!

AUDIO LABS

Computational Methods for Melody and Voice Processing in Music Recordings

SCHLOSS DAGSTUHL
Leibniz-Zentrum für Informatik

2019, January 27 – February 1, Dagstuhl Seminar 19052

Organizers:

Emilia Gómez (UPF – Barcelona, ES)

Yi-Hsuan Yang (Academica Sinica – Taipei, TW)

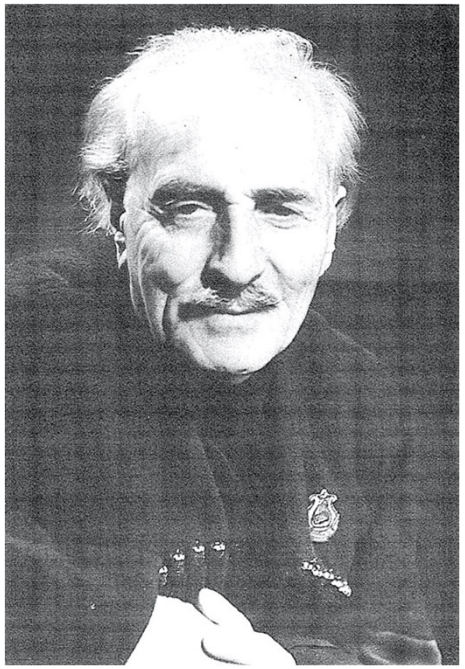
Meinard Müller (FAU, DE)

AUDIO LABS

Computational Methods for Melody and Voice Processing in Music Recordings

Example: Erkomaishvili corpus

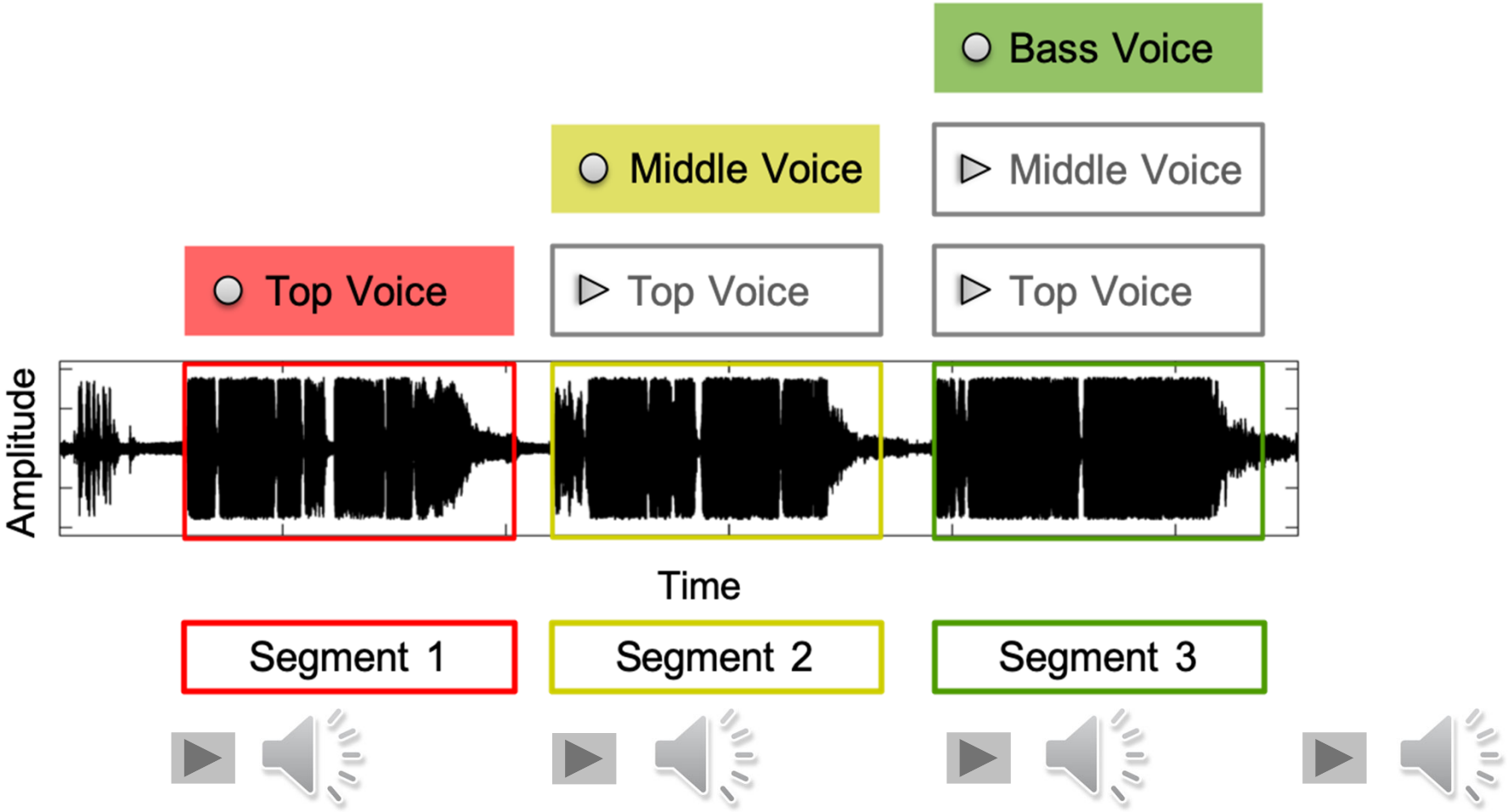
- Collection of traditional three-voice Georgian songs
- Performed by the former Georgian master chanter Artem Erkomaishvili (1887-1967)
- Recordings of 100 songs using tape recorders (1966)



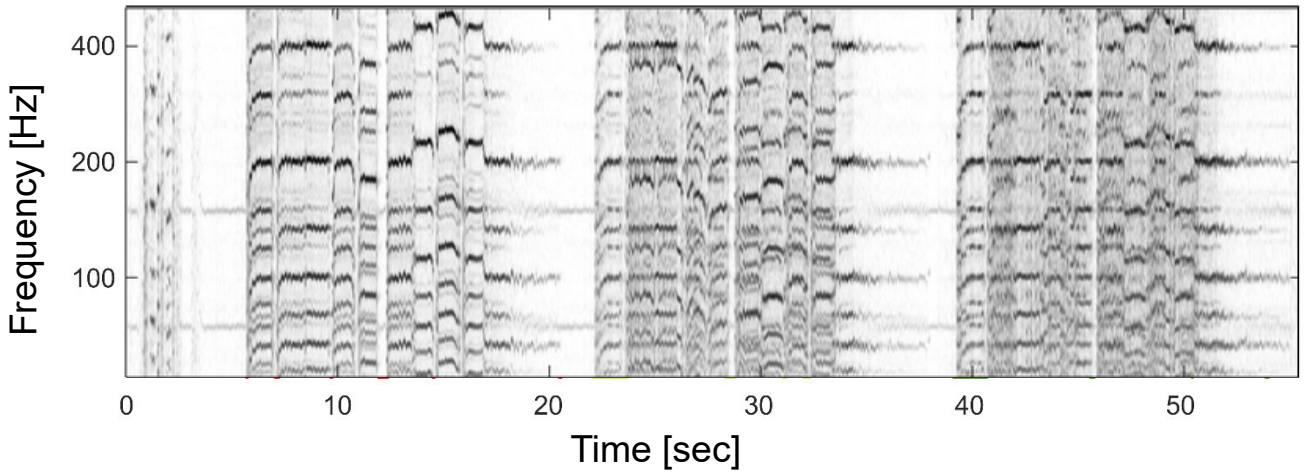
> "*Original masterpieces of Georgian musical thinking.*" (Shugliashvili, 2014)

Computational Methods for Melody and Voice Processing in Music Recordings

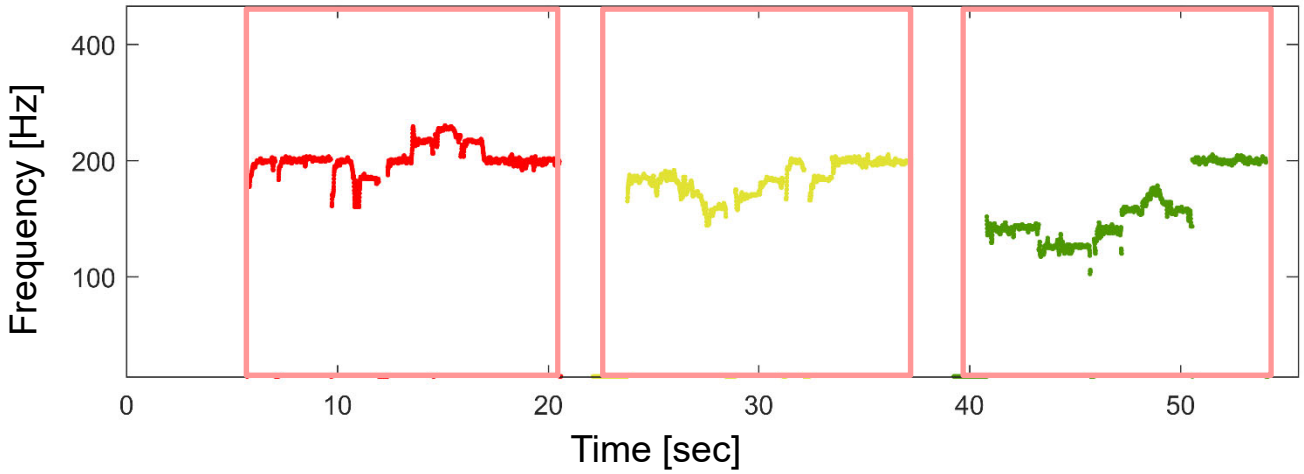
Example: Erkomaishvili corpus



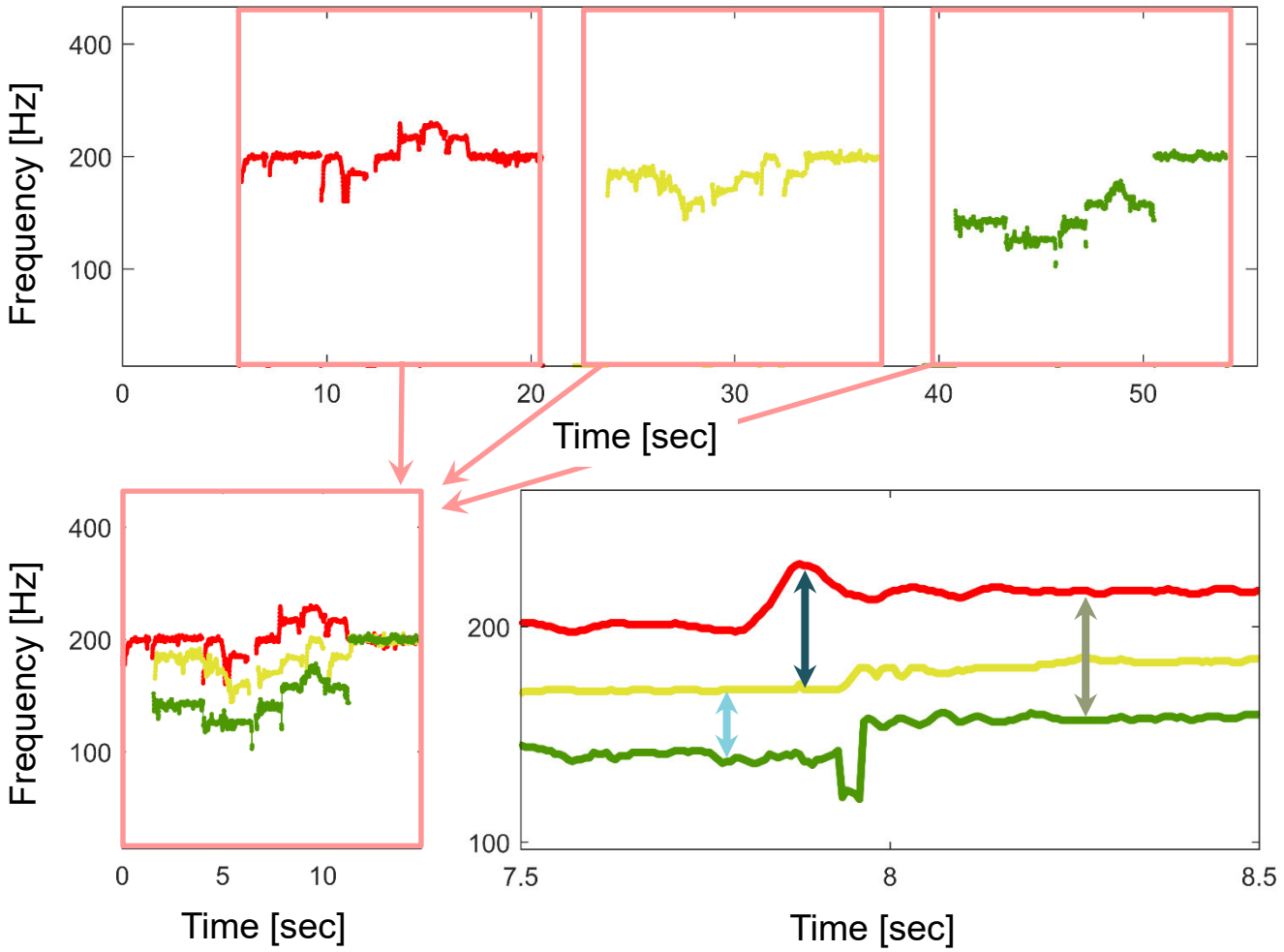
Computational Methods for Melody and Voice Processing in Music Recordings



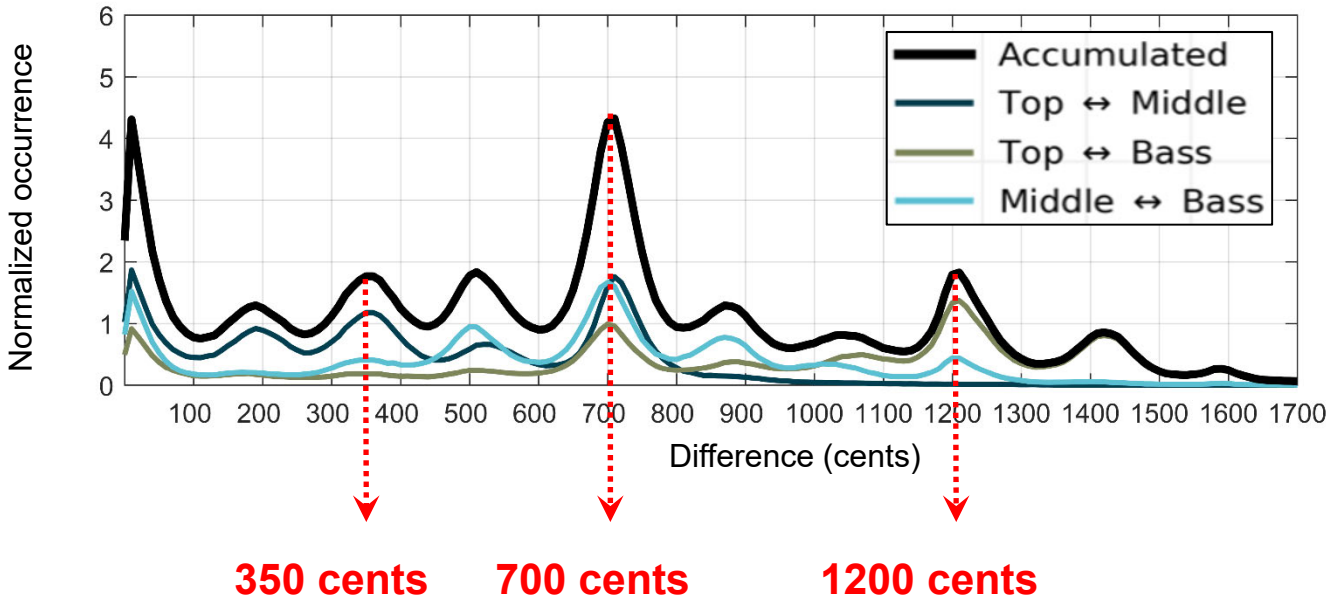
Computational Methods for Melody and Voice Processing in Music Recordings



Computational Methods for Melody and Voice Processing in Music Recordings



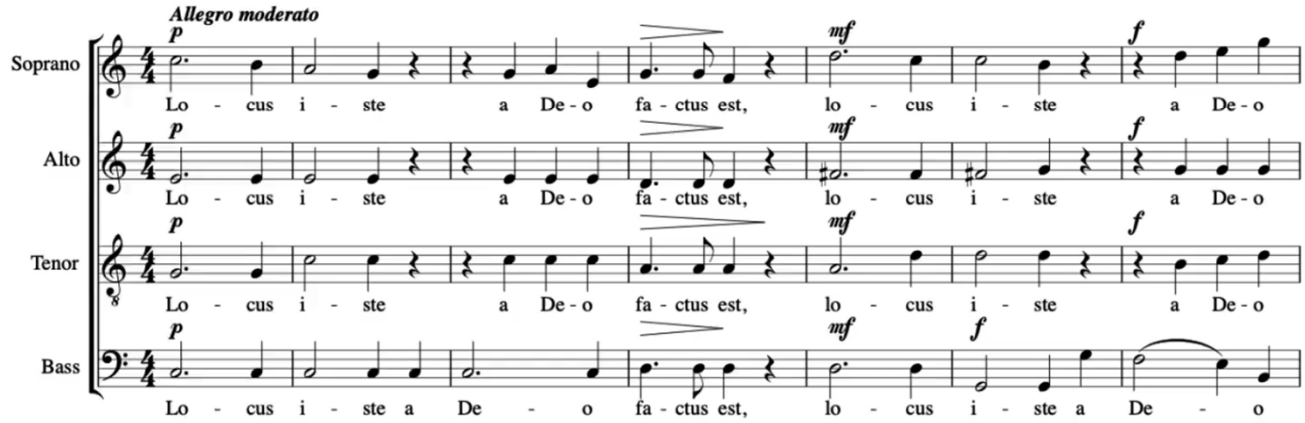
Computational Methods for Melody and Voice Processing in Music Recordings



- Peak at 350 cents (between minor and major third)
- **Non-western temperament**

Computational Methods for Melody and Voice Processing in Music Recordings

Computational Methods for Melody and Voice Processing in Music Recordings



Room Microphone

Computational Methods for Melody and Voice Processing in Music Recordings

Michael Gerke

Thank you!

Forschung und Lehre, 28.08.2020

Chor aus Wissenschaftlern will Beitrag zur KI-Forschung leisten

Internationale Forschende aus Musikwissenschaft und Informatik zeichneten zu Forschungszwecken Gesänge auf. Davon sollen KI-Studien profitieren.

Deep Learning and Knowledge Integration for Music Audio Analysis

SCHLOSS DAGSTUHL
Leibniz-Zentrum für Informatik

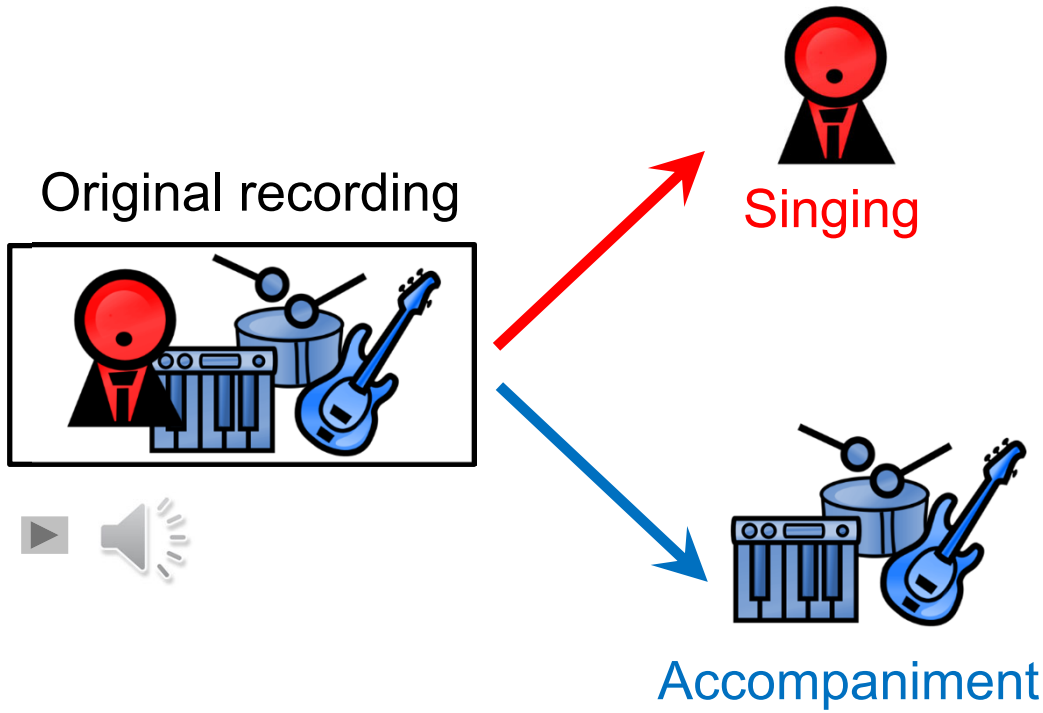
2022, February 20 – 25, Dagstuhl Seminar 22082

Organizers:

Rachel Bittner (Spotify – Paris, FR)
Juhan Nam (KAIST – Daejeon, KR)
Meinard Müller (FAU, DE)

AUDIO LABS

Deep Learning and Knowledge Integration for Music Audio Analysis



- Reference: Best possible result
- SP: Using traditional signal processing
- AI: Using data-driven approach

Deep Learning and Knowledge Integration for Music Audio Analysis

- Yigitcan Özer
- PhD student in engineering
- Pianist

Deep Learning and Knowledge Integration for Music Audio Analysis

- Yigitcan Özer
- PhD student in engineering
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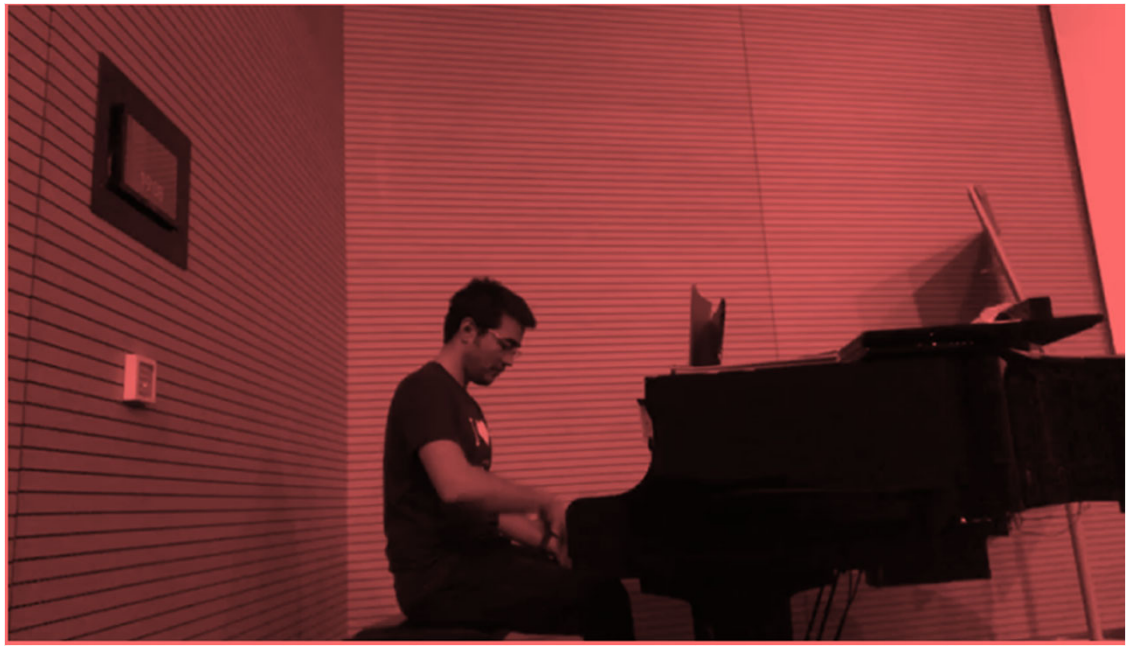
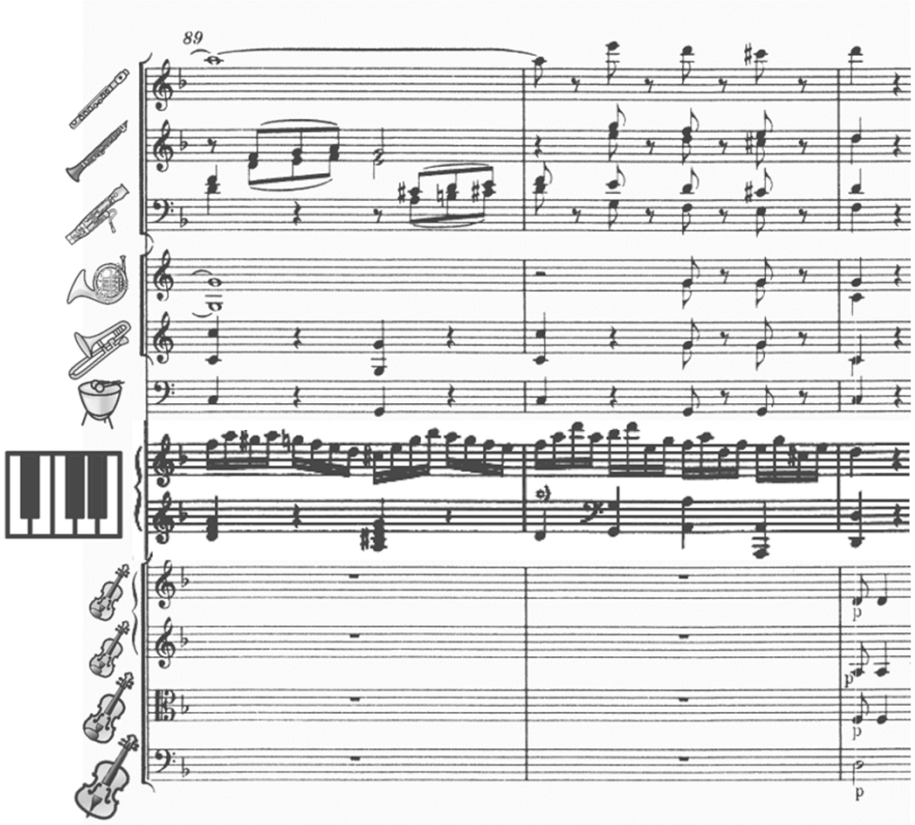
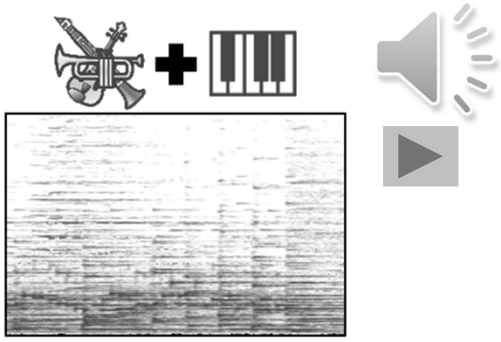


Only Piano!

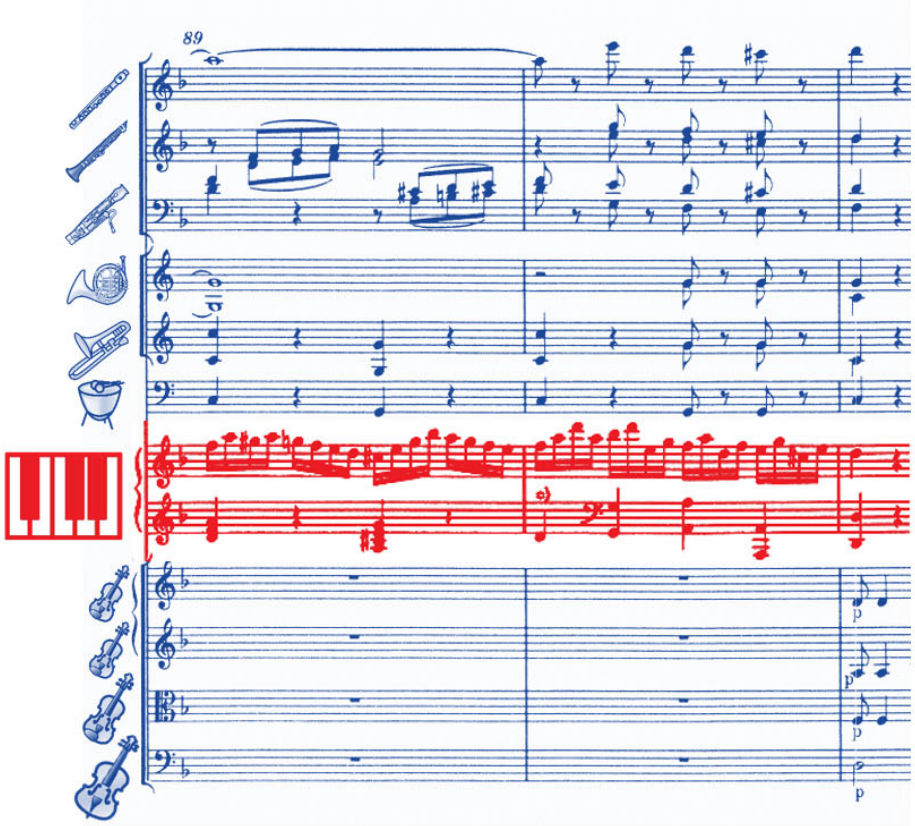
Where is the orchestra?

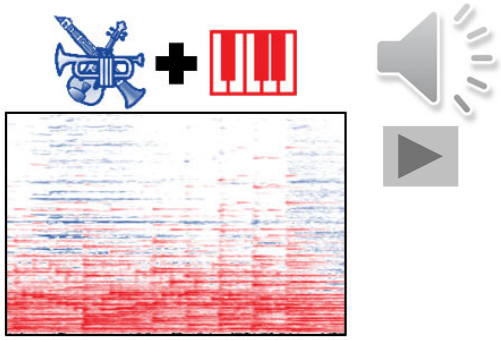
Deep Learning and Knowledge Integration for Music Audio Analysis



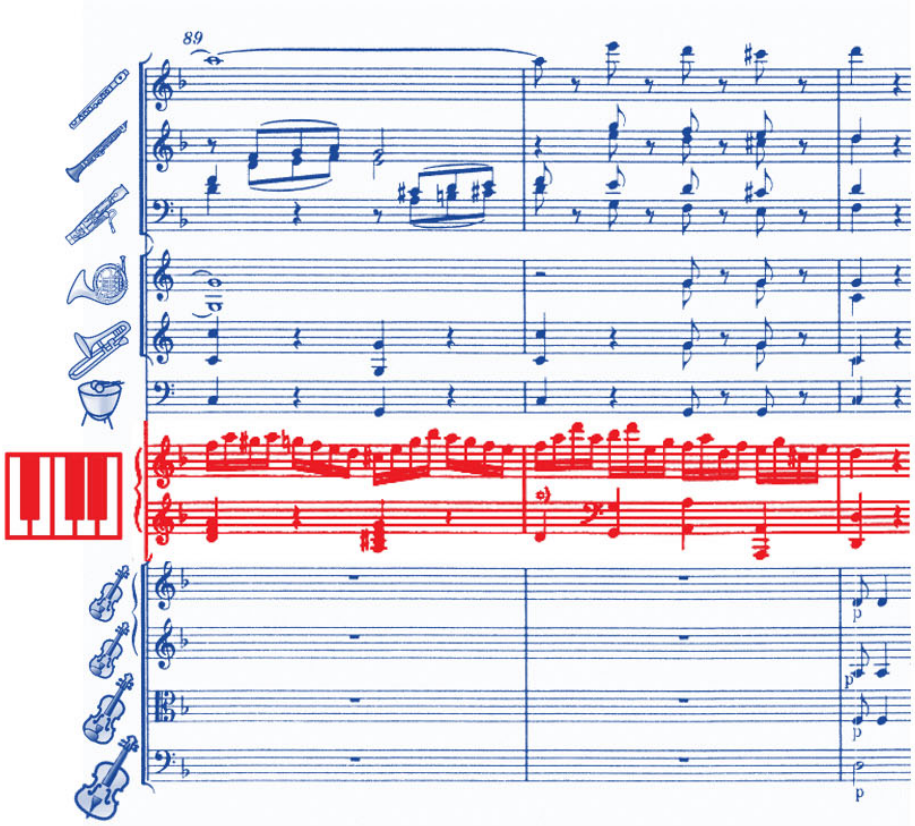


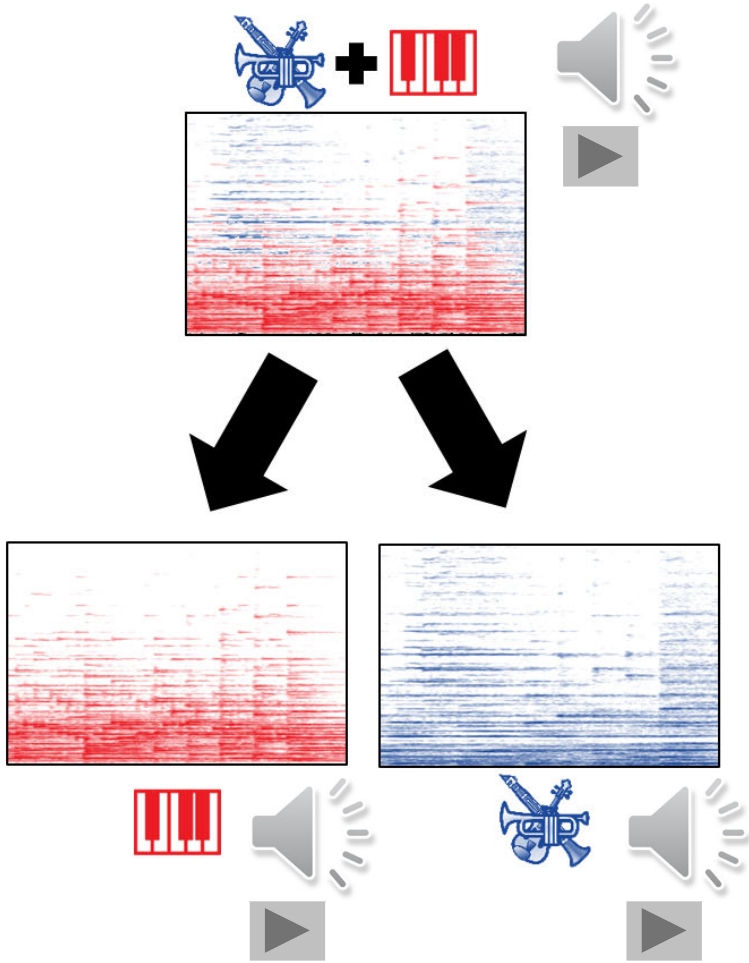
Deep Learning and Knowledge Integration for Music Audio Analysis



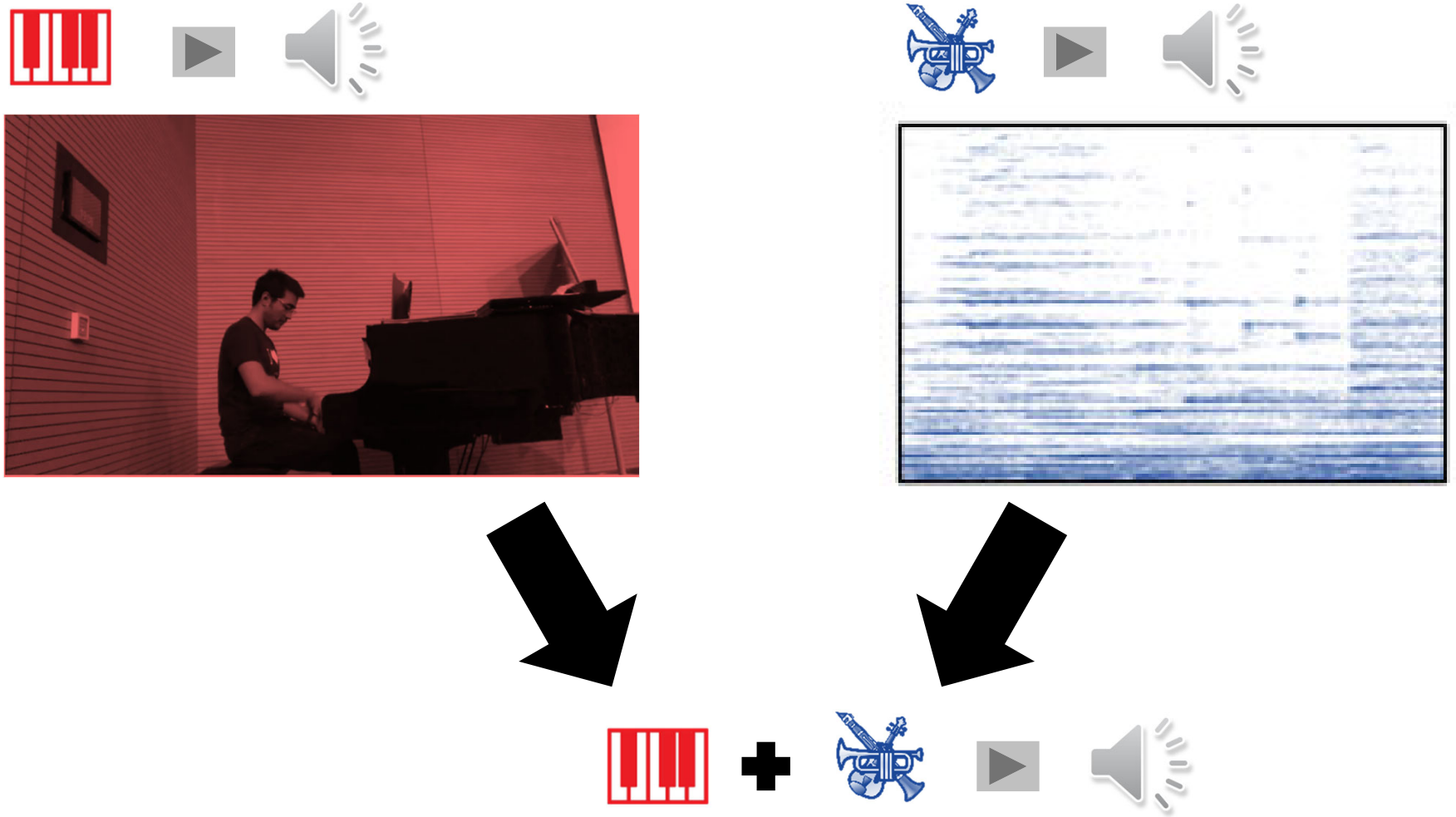


Deep Learning and Knowledge Integration for Music Audio Analysis





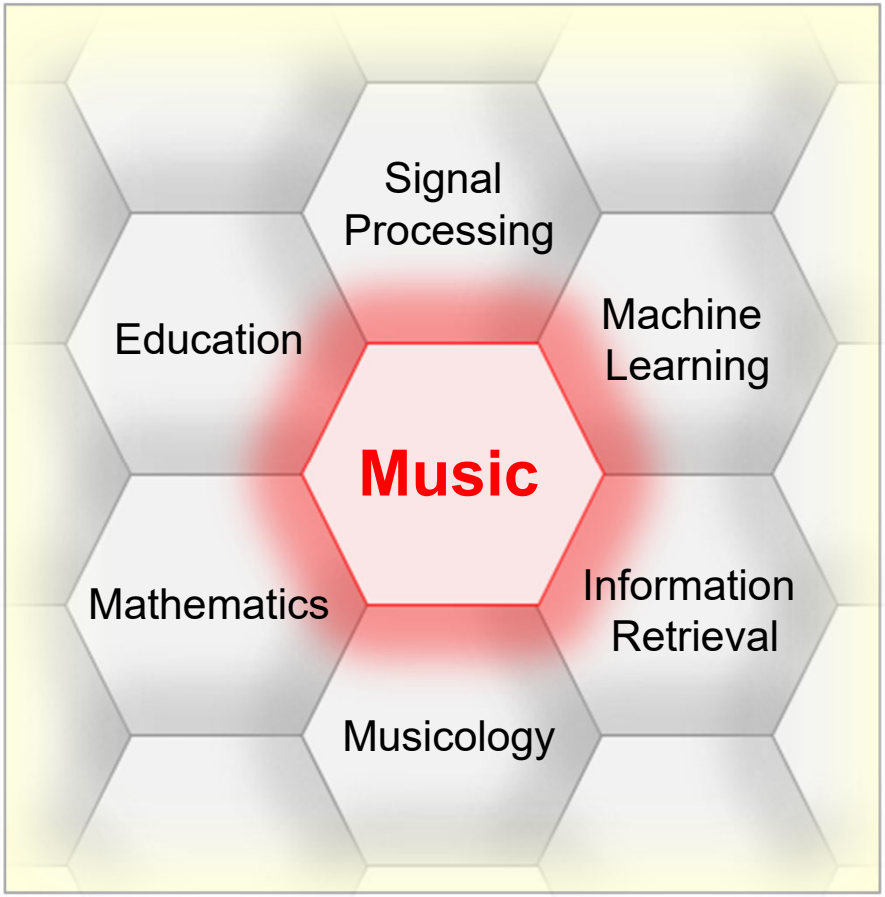
Deep Learning and Knowledge Integration for Music Audio Analysis



Deep Learning and Knowledge Integration for Music Audio Analysis

- Understanding modern machine learning techniques
- Critical questioning of artificial intelligence (AI) concepts
- Developing explainable AI models
- Educating next generation of scientists
- …

Musik trifft Informatik in Dagstuhl

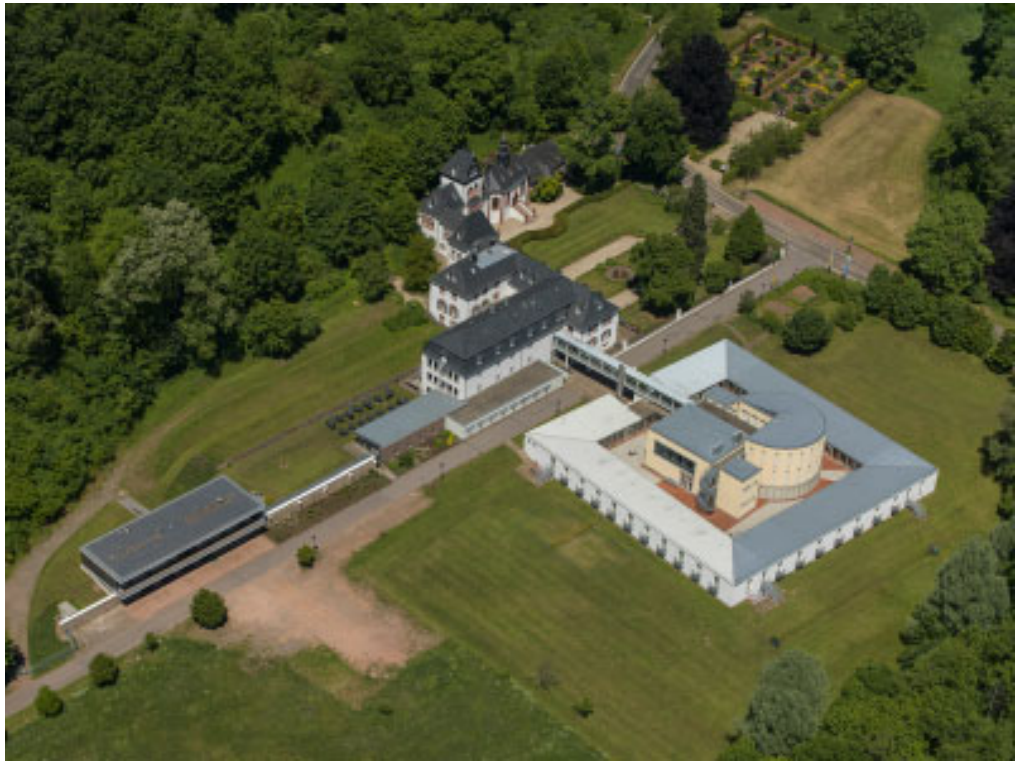


- Music is a ubiquitous and vital part of our lives
- Digital music services: Spotify, Pandora, iTunes, …
- Music yields intuitive entry point to support and motivate education in technical disciplines
- Music bridges the gap between engineering, computer science, mathematics, and the humanities

Musik trifft Informatik in Dagstuhl

Reinhard Wilhelm

Raimund Seidel



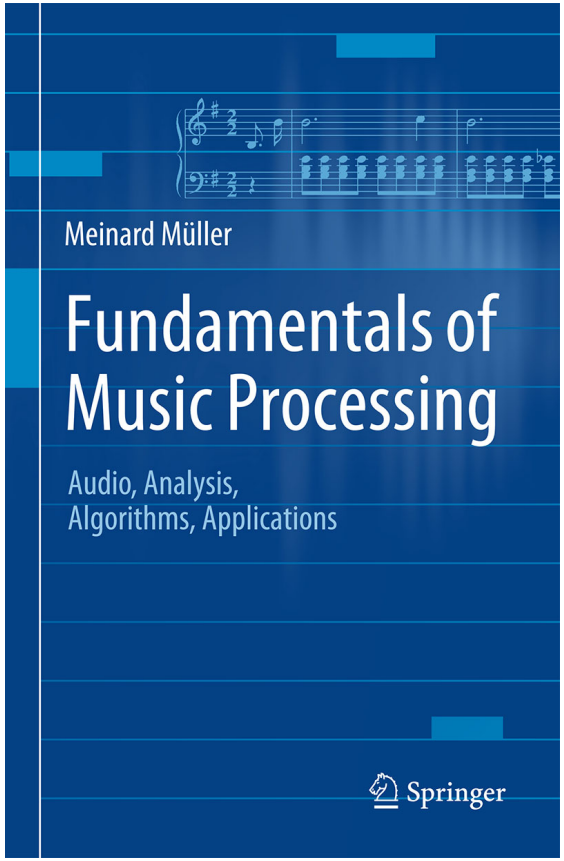
Leibniz Gemeinschaft

SCHLOSS DAGSTUHL
Leibniz-Zentrum für Informatik

Thank you!

AUDIO LABS

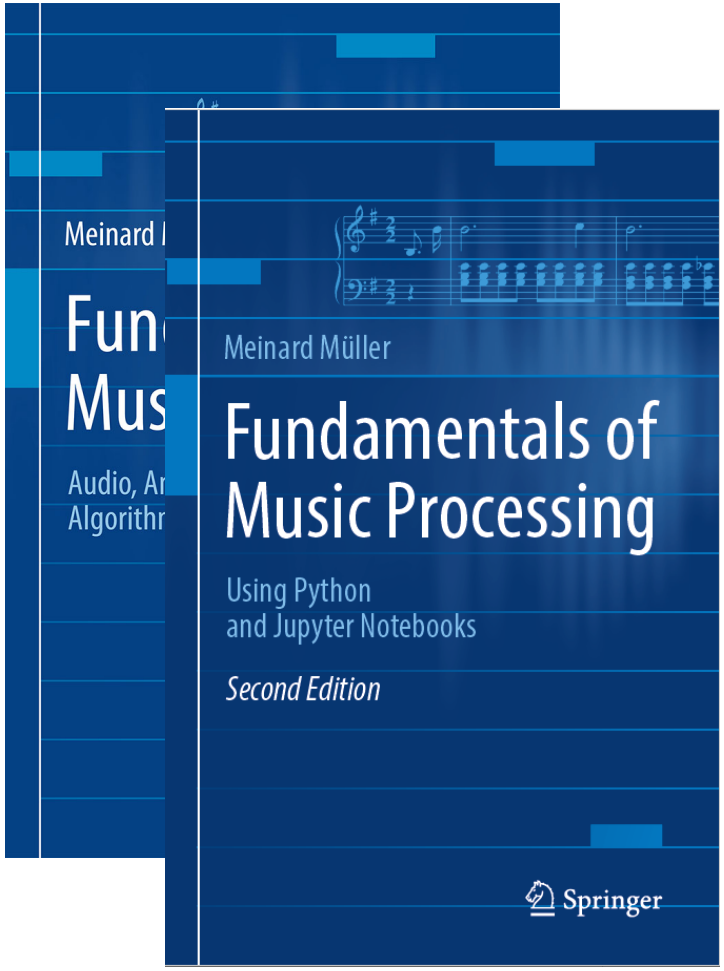
Fundamentals of Music Processing (FMP)



Meinard Müller
Fundamentals of Music Processing
Audio, Analysis, Algorithms, Applications
Springer, 2015

Accompanying website:
www.music-processing.de

Fundamentals of Music Processing (FMP)



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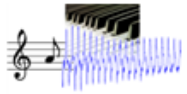
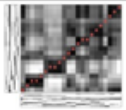
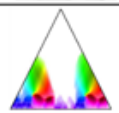
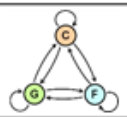
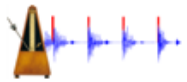
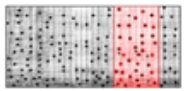
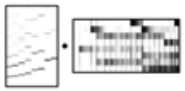
2nd edition
Meinard Müller
Fundamentals of Music Processing
Using Python and Jupyter Notebooks
Springer, 2021

Fundamentals of Music Processing (FMP)

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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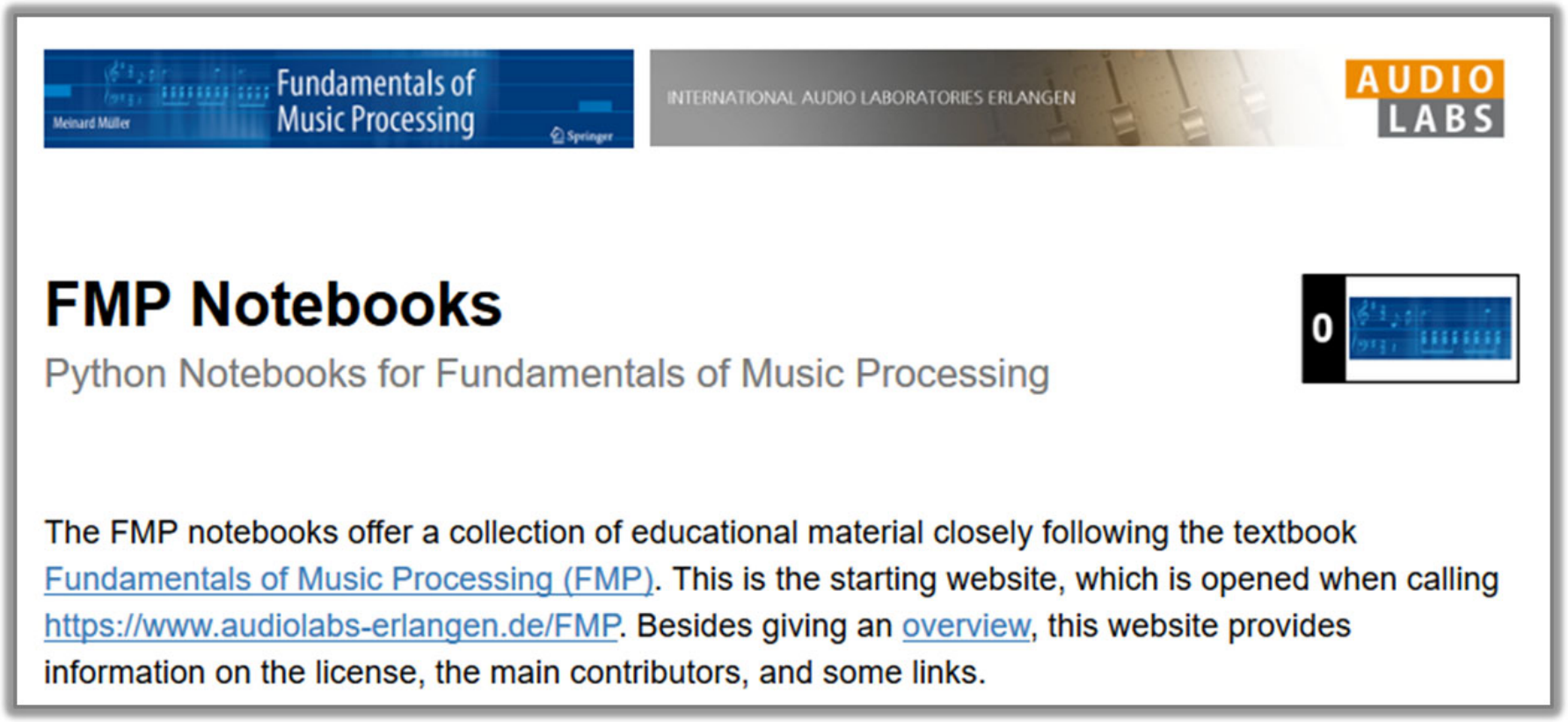
FMP Notebooks: Education & Research



https://www.audiolabs-erlangen.de/FMP

References

- Meinard Müller: Fundamentals of Music Processing – Using Python and Jupyter Notebooks. 2nd Edition, Springer, 2021.
  https://www.springer.com/gp/book/9783030698072

- Meinard Müller and Frank Zalkow: libfmp: A Python Package for Fundamentals of Music Processing. Journal of Open Source Software (JOSS), 6(63): 1–5, 2021.
  https://joss.theoj.org/papers/10.21105/joss.03326

- Meinard Müller: An Educational Guide Through the FMP Notebooks for Teaching and Learning Fundamentals of Music Processing. Signals, 2(2): 245–285, 2021.
  https://www.mdpi.com/2624-6120/2/2/18

- Meinard Müller and Frank Zalkow: FMP Notebooks: Educational Material for Teaching and Learning Fundamentals of Music Processing. Proc. International Society for Music Information Retrieval Conference (ISMIR): 573–580, 2019.
  https://zenodo.org/record/3527872#.YOhEQOgzaUk

- Meinard Müller, Brian McFee, and Katherine Kinnaird: Interactive Learning of Signal Processing Through Music: Making Fourier Analysis Concrete for Students. IEEE Signal Processing Magazine, 38(3): 73–84, 2021.
  https://ieeexplore.ieee.org/document/9418542

Resources (Group Meinard Müller)

- FMP Notebooks:

  https://www.audiolabs-erlangen.de/FMP

- libfmp:

  https://github.com/meinardmueller/libfmp

- synctoolbox:

  https://github.com/meinardmueller/synctoolbox

- libtsm:

  https://github.com/meinardmueller/libtsm

- Preparation Course Python (PCP) Notebooks:

  https://www.audiolabs-erlangen.de/resources/MIR/PCP/PCP.html

  https://github.com/meinardmueller/PCP