Automatische Erschließung von Musikdaten

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- Mathematics (Diplom/Master, 1997)
- Computer Science (PhD, 2001)
- Information Retrieval (Habilitation, 2007)
- Senior Researcher (2007-2012)
- Professor Semantic Audio Processing (since 2012)
- Former President of the International Society for Music Information Retrieval (ISMIR)
- IEEE Fellow for contributions to Music Signal Processing

Meinard Müller: Research Group
Semantic Audio Processing

- Yigitcan Özer
- Simon Schwal
- Johannes Zeller
- Peter Reise
- Sebastian Strahl
- LB Berendes
- Chiu Ching/Sunny
- Vlora Arti- Müller
- Michael Krause
- Christoph West
- Sebastian Rosenmann
- Frank Zablocki
- Hendrik Schmieder
- Christian Dähme
- Stefan Bethke
- Jonathan Diediker
- Thomas Philipp

International Audio Laboratories Erlangen

- Fraunhofer Institute for Integrated Circuits IIS
- Largest Fraunhofer institute with ≈ 1000 members
- Applied research for sensor, audio, and media technology
- Friedrich-Alexander Universität Erlangen-Nürnberg (FAU)
- One of Germany’s largest universities with ≈ 40,000 students
- Strong Technical Faculty

International Audio Laboratories Erlangen

Audio Coding
3D Audio
Psychoacoustics
Music Processing
Internet of Things
Music Information Retrieval (MIR)

Sheet Music (Image)  
CD / MP3 (Audio)  
MusicXML (Text)  
Dance / Motion (Mocap)  
Singing / Voice (Audio)  
Music Film (Video)  
Music Literature (Text)  

Music Film (Video)  
Music Literature (Text)  

Piano Roll Representation (1900)

J.S. Bach, C-Major Fuge  
(Well Tempered Piano, BWV 846)

Piano Roll Representation

Query:  
Goal: Find all occurrences of the query

Matches:
Bernstein (1962)
Beethoven, Symphony No. 5

Beethoven, Symphony No. 5:
- Bernstein (1962)
- Karajan (1982)
- Gould (1992)

- Beethoven, Symphony No. 9
- Beethoven, Symphony No. 3
- Haydn Symphony No. 94

Music Synchronization: Image-Audio

Audio Processing: Fourier Analysis

Image Processing: Optical Music Recognition
Music Synchronization: Image-Audio

- Deep learning
- Embedding techniques
- Weak annotations
- Loss functions
- ...

Score-Informed Audio Decomposition
Score-Informed Audio Decomposition

Audio mosaicing (style transfer)

Target signal: Beatles–“Let it be”
Source signal: Bees

Mosaic signal: “Let it Bee”

Why is Music Processing Challenging?

Example: Chopin, Mazurka Op. 63 No. 3

- Waveform
  - Amplitude
  - Time (seconds)

- Waveform / Spectrogram
  - Frequency (Hz)
  - Time (seconds)

Why is Music Processing Challenging?

Example: Chopin, Mazurka Op. 63 No. 3

- Performance
  - Tempo
  - Dynamics
  - Note deviations
  - Sustain pedal
- Polyphony
  - Main Melody
  - Additional melody line
  - Accompaniment

Source Separation

- Decomposition of audio stream into different sound sources
- Central task in digital signal processing
- “Cocktail party effect”
Source Separation

- Decomposition of audio stream into different sound sources
- Central task in digital signal processing
- “Cocktail party effect”
- Several input signals
- Sources are assumed to be statistically independent

Source Separation (Music)

- Main melody, accompaniment, drum track
- Instrumental voices
- Individual note events
- Only mono or stereo
- Sources are often highly dependent

Source Separation (Music)

- Only Piano!
  - Where is the orchestra?

AI-Based Source Separation

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

AI-Based Source Separation

- Yigitcan Özer
  - PhD student in engineering
  - Pianist
**AI-Based Source Separation**

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

**Computational Musicology**

- **Cooperation:**
  - Rainer Kleinertz (Saarbrücken)
  - Stephanie Klauk (Saarbrücken)
  - Christof Weiß (Würzburg)

- **Objectives**
  - Harmony-based structural analysis
  - Beethoven Sonatas & Wagner’s Ring
  - Interdisciplinary dialogue
  - Since 2014: DFG-funded project

- **Different concepts**
  - Different temporal levels

- **Computational Musicology: Harmony Analysis**

  - Movement level: Global Key
  - Segment level: Local Key
  - Chord level: CM, Gm, Am
  - Note level: melody, middle voice, bass line

  - Global key estimation
  - Local key estimation
  - Chord recognition
  - Music transcription
Computational Musicology: Harmony Analysis

- Different concepts
- Different temporal levels

Local Key Estimation

Example: J.S. Bach, Choral "Durch Dein Gefängnis" (Johannespassion)

Stollen Abgesang

Local Key Estimation

Spectrogram

Chromagram

Chromagram after smoothing
Local Key Estimation

Arrange pitch classes according to perfect fifth series

Summarize pitch class content according to diatonic scales

Multiply chroma values (in each column)
Local Key Estimation
Summarize pitch class content according to diatonic scales
Multiply chroma values

Local Key Estimation
Normalize representation relative to global key

J.S. Bach: Choral "Durch Dein Gefängnis" (Johannespassion)
Recording: Scholars Baroque Ensemble, Naxos 1994

Recording: Barenboim, EMI 1998
Local Key Estimation

R. Wagner: WWV 86 B (Die Walküre)

Act 1

Act 2

Act 3

Local Key Estimation

R. Wagner: WWV 86 B (Die Walküre)

Act 1

Act 2

Act 3

Local Key Estimation

R. Wagner: WWV 86 B (Die Walküre)

Act 3, measure 724–789 (Wotan’s punishment)

Local Key Estimation

R. Wagner: WWV 86 B (Die Walküre)

Act 3, measure 724–789 (Wotan’s punishment)

Computational Ethnomusicology: Traditional Georgian Vocal Music

- Interdisciplinary research project
  - Prof. Dr. Frank Scherbaum (Potsdam)
  - Dr. Nana Mzhavanadze (Tbilisi)
  - Sebastian Rosenzweig (FAU)

- Objective: Tonal analysis

- 2018 – 2022: DFG-funded project

Traditional Georgian Vocal Music

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)
Traditional Georgian Vocal Music

Example: Erkomaishvili corpus

- Frequency [Hz]
- Time [sec]

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

- Recordings from field expedition in 2016
- 216 performances
- Multitrack audio + video
  - Room, HSM, LRX
- Total duration: 6 h
Music Information Retrieval (MIR)

- Signal Processing
- Machine Learning
- Information Retrieval
- Musicology
- User Interfaces
- Digital Humanities

Music

Fundamentals of Music Processing (FMP)

- Meinard Müller
  - Fundamentals of Music Processing
  - Audio, Analysis, Algorithms, Applications
  - Springer, 2015
  - Accompanying website: www.music-processing.de

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

References (FMP Notebooks)


  https://joss.theoj.org/papers/10.21105/joss.03326

  https://www.mdpi.com/2624-6120/2/2/18

  https://zenodo.org/record/3527872#.YOhEQOgzaUk


FMP Notebooks: Education & Research

- https://www.audiolabs-erlangen.de/FMP
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/PCPhtml
  https://github.com/meinardmueller/PCP