

Tutorial T3, EUROGRAPHICS  
Saarbrücken, May 8, 2023



## Learning with Music Signals: Technology Meets Education

### Overview

**Meinard Müller**

International Audio Laboratories Erlangen  
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## Meinard Müller



- 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 (MIR)
- IEEE Fellow for contributions to Music Signal Processing

## Meinard Müller: Research Group Semantic Audio Processing

- Michael Krause
- Yigitcan Özer
- Simon Schwär
- Johannes Zeitler
- Peter Meier (external)
- Christof Weiß
- Sebastian Rosenzweig
- Frank Zalkow
- Christian Dittmar
- Stefan Balke
- Jonathan Driedger
- Thomas Prätzlich
- ...



## International Audio Laboratories Erlangen



- Fraunhofer Institute for Integrated Circuits IIS
- Largest Fraunhofer institute with ≈ 1000 members
- Applied research for sensor, audio, and media technology

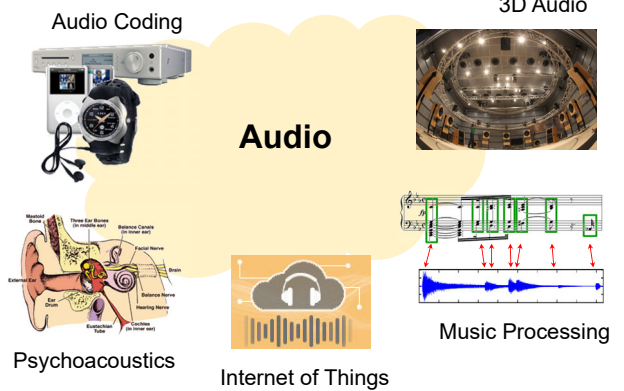


- Friedrich-Alexander Universität Erlangen-Nürnberg (FAU)
- One of Germany's largest universities with ≈ 40,000 students
- Strong Technical Faculty

## International Audio Laboratories Erlangen

Audio

## International Audio Laboratories Erlangen



## AudioLabs – FAU

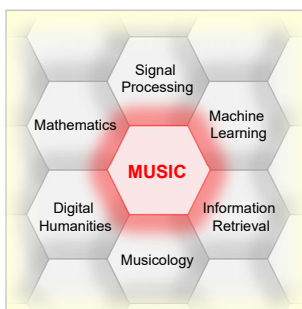
- Prof. Dr. Jürgen Herre  
Audio Coding
- Prof. Dr. Bernd Edler  
Audio Signal Analysis
- Prof. Dr. Meinard Müller  
Semantic Audio Processing
- Prof. Dr. Emanuël Habets  
Spatial Audio Signal Processing
- Prof. Dr. Nils Peters  
Audio Signal Processing
- Dr. Stefan Turowski  
Coordinator AudioLabs-FAU



## Music Processing



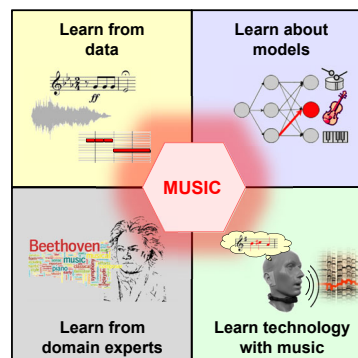
## Music Processing: A Multifaceted Research Area



### Music ...

- important part of our lives ...
- ... Spotify, Pandora, iTunes, ...
- interdisciplinary research
- intuitive entry point to education

## Learning with Music Signals Technology Meets Education



- Machine learning for music signal processing
- Interpretable models and knowledge integration
- Music understanding and applications
- Interactive learning in engineering through music

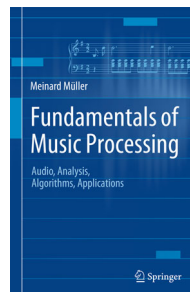
## Schedule

- Part 0: Overview
- Part I: Music Retrieval
- Coffee Break**
- Part II: Audio Decomposition
- Part III: FMP Notebooks

### Slides/Material:

<https://www.audiolabs-erlangen.de/meinard>  
<https://www.audiolabs-erlangen.de/FMP>

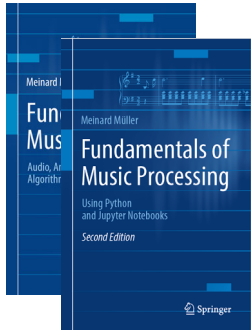
## Fundamentals of Music Processing (FMP)



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

Accompanying website:  
[www.music-processing.de](http://www.music-processing.de)

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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 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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Fundamentals of Music Processing  
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Springer, 2015

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## FMP Notebooks: Education & Research

**FMP Notebooks**  
Python Notebooks for Fundamentals of Music Processing

The FMP notebooks offer a collection of educational material closely following the textbook [Fundamentals of Music Processing \(FMP\)](https://www.audiolabs-erlangen.de/FMP). This is the starting website, which is opened when calling <https://www.audiolabs-erlangen.de/FMP>. Besides giving an [overview](#), this website provides information on the license, the main contributors, and some links.

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

## References (FMP Textbook & Notebooks)

- 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#.YQhEQzqaUk>
- 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>

## Resources

- librosa:  
<https://librosa.org/>
- madmom:  
<https://github.com/CPJKU/madmom>
- Essentia Python tutorial:  
[https://essentia.upf.edu/essentia\\_python\\_tutorial.html](https://essentia.upf.edu/essentia_python_tutorial.html)
- mirdata:  
<https://github.com/mir-dataset-loaders/mirdata>
- open-unmix:  
<https://github.com/sigsep/open-unmix-pytorch>
- Open Source Tools & Data for Music Source Separation:  
<https://source-separation.github.io/tutorial/landing.html>

