INTERNATIONAL AUDIO LABORATORIES ERLANGEN

Tutorial T1
Fundamentals of Music Processing:
An Introduction using Python and Jupyter Notebooks

Overview

Meinard Müller, Frank Zalkow

International Audio Laboratories Erlangen
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Meinard Müller

- Mathematics (Diplom/Master)
- Computer Science (PhD)
- Information Retrieval (Habilitation)

- Since 2012: Professor for Semantic Audio Processing

- ISMIR Board Member since 2010 (currently President-Elect)
- IEEE Audio and Acoustic Signal Processing TC (2010 - 2016)
- Member of Senior Editorial Board, IEEE Signal Processing Magazine

Frank Zalkow

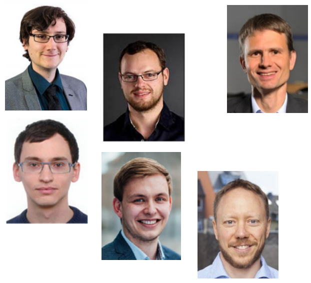
- Musicology/Music Informatics (Bachelor)
- Music Informatics (Master)

- Since 08/2016: PhD student in MIR (supervisor: Meinard Müller)

- Improving Music Retrieval with Machine Learning
- Cross-Connections between Musicology and Computer Science
- Choir Singing

Group Members

- Frank Zalkow
- Christof Weiß
- Michael Krause
- Sebastian Rosenzweig
- Hendrik Schreiber



Former PhD Students

- Patricio López-Serrano
- Christian Dittmar
- Stefan Balke
- Thomas Prätzlich
- Jonathan Driedger
- Harald Grohganz
- Nanzhu Jiang
- ...

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Fraunhofer IIS

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FAU Friedrich-Alexander Universität Erlangen-Nürnberg

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Audio

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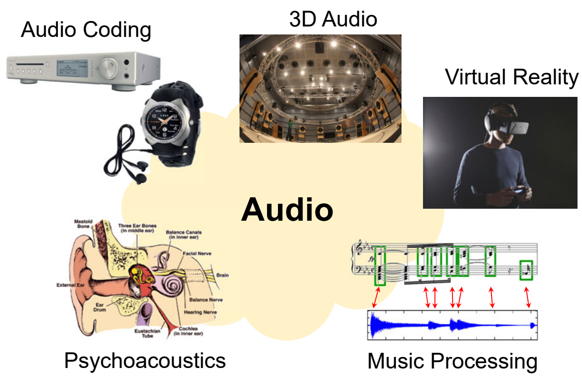
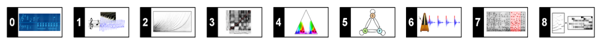


FMP Notebooks

Python Notebooks for Fundamentals of Music Processing

- Introductions of MIR scenarios
- Textbook-like explanations and algorithms
- Python code examples
- Numerous illustrations and sound examples

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



Schedule

9:00 – 9:20 Overview
9:20 – 9:55 Music Representations and Retrieval
9:55 – 10:30 Audio Structure Analysis

10:30 – 11:00 Coffee Break

11:00 – 11:30 Tempo and Beat Tracking
11:30 – 12:00 Audio Decomposition
12:00 – 12:30 Further Topics & Conclusions

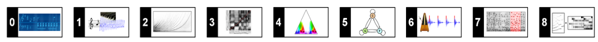
Slides:
https://www.audiolabs-erlangen.de/resources/MIR/2019_TutorialFMP_ISMIR/

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

FMP Notebooks

Python Notebooks for Fundamentals of Music Processing

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



FMP Notebooks

Python Notebooks for Fundamentals of Music Processing

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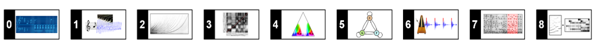
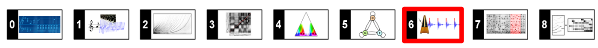


Basics + 8 Chapters

FMP Notebooks

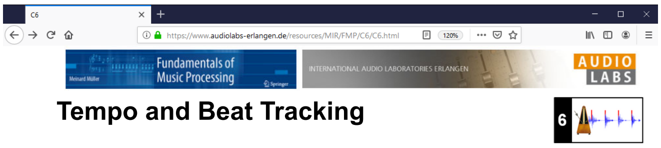
Python Notebooks for Fundamentals of Music Processing

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



Basics + 8 Chapters

Tempo and Beat Tracking



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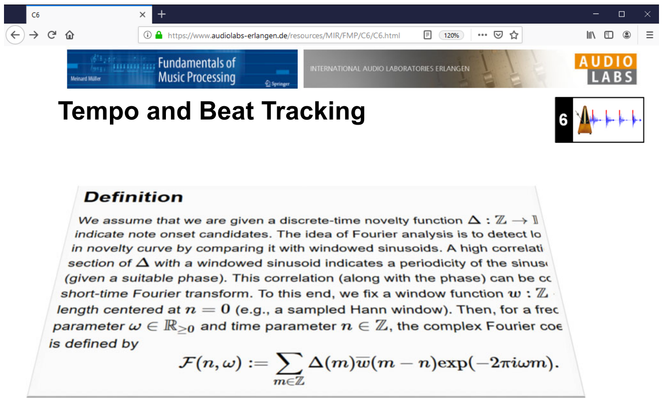
Tempo and Beat Tracking
6



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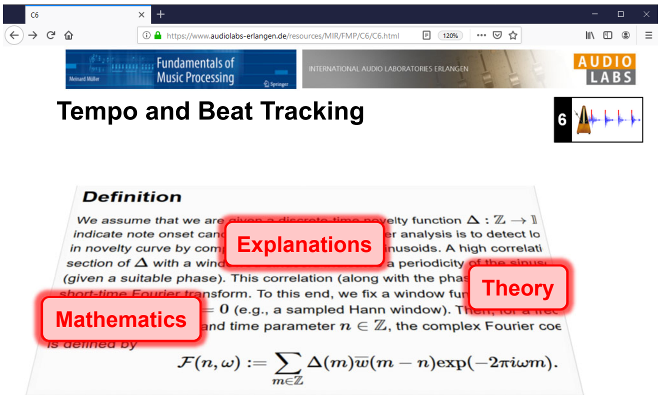
Definition
We assume that we are given a discrete-time novelty function $\Delta : \mathbb{Z} \to$
indicate note onset candidates. The idea of Fourier analysis is to detect lo
in novelty curve by comparing it with windowed sinusoids. A high correlati
section of Δ with a windowed sinusoid indicates a periodicity of the sinus
(given a suitable phase). This correlation (along with the phase) can be co
short-time Fourier transform. To this end, we fix a window function $w : \mathbb{Z}$
length centered at $n = 0$ (e.g., a sampled Hann window). Then, for a frec
parameter $\omega \in \mathbb{R}_{\geq 0}$ and time parameter $n \in \mathbb{Z}$, the complex Fourier coe
is defined by
$\mathcal{F}(n,\omega) := \sum_{m\in\mathbb{Z}} \Delta(m)\overline{w}(m-n)\exp(-2\pi i\omega m).$



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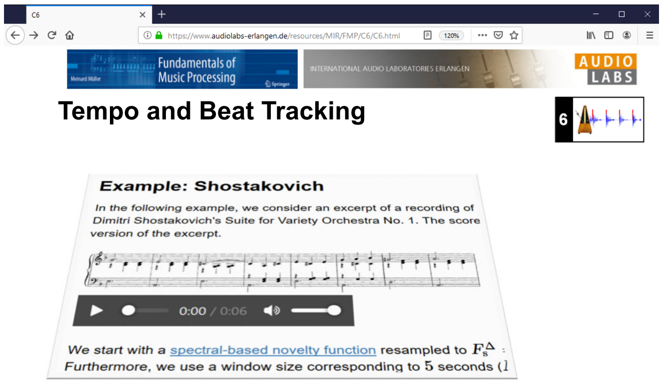
Definition
Explanations
Theory
Mathematics
$\mathcal{F}(n,\omega) := \sum_{m\in\mathbb{Z}} \Delta(m)\overline{w}(m-n)\exp(-2\pi i\omega m).$



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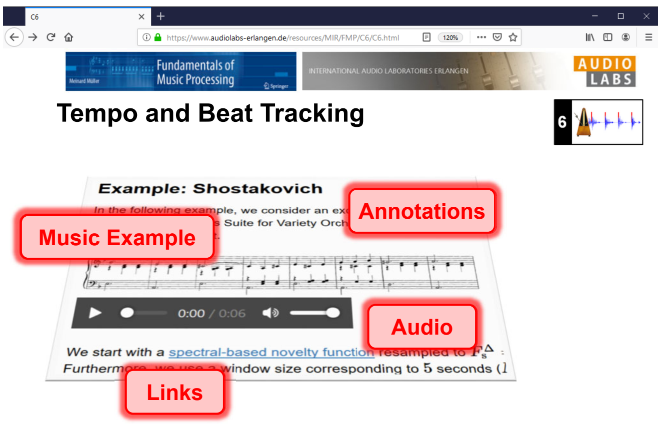
Example: Shostakovich
In the following example, we consider an excerpt of a recording of
Dimitri Shostakovich's Suite for Variety Orchestra No. 1. The score
version of the excerpt.
0:00 / 0:06
We start with a spectral-based novelty function resampled to F_s^Δ
Furthermore, we use a window size corresponding to 5 seconds (



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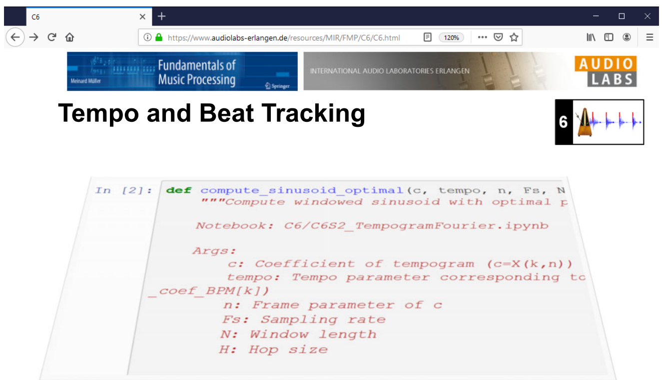
Example: Shostakovich
Annotations
Music Example
Audio
Links
0:00 / 0:06
We start with a spectral-based novelty function resampled to F_s^Δ
window size corresponding to 5 seconds (



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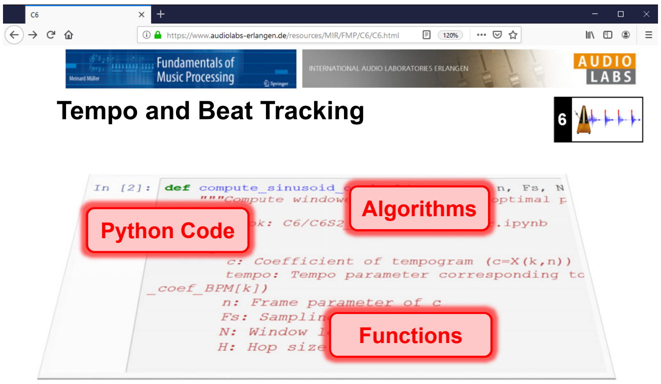
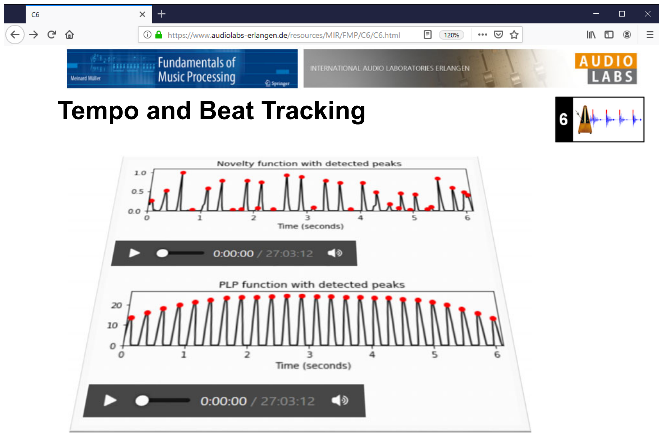
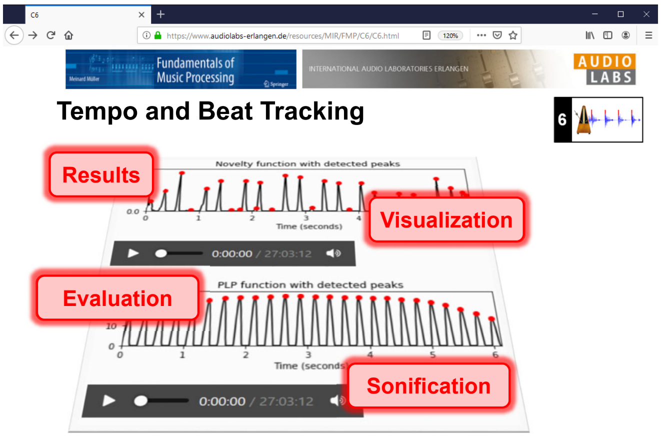
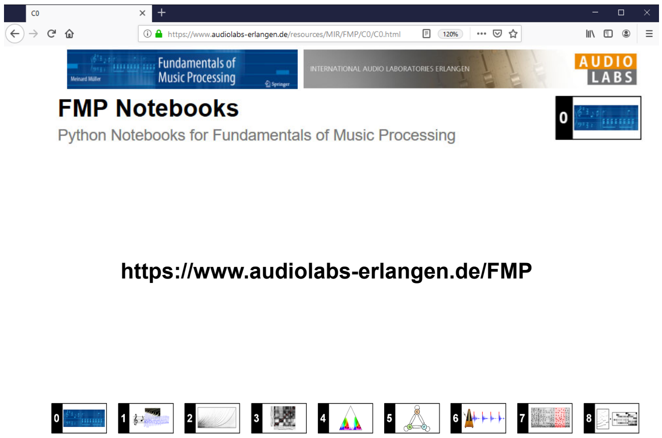
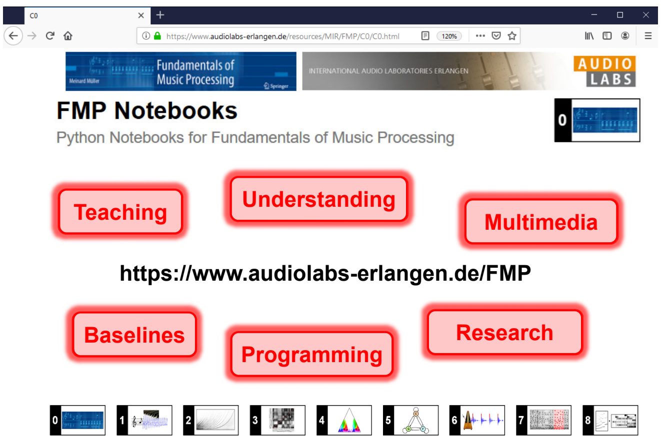
In [2]: def compute_sinusoid_optimal(c, tempo, n, Fs, N
"""Compute windowed sinusoid with optimal p
Notebook: C6/C6S2_TempogramFourier.ipynb
Args:
c: Coefficient of tempogram (c=X(k,n))
tempo: Tempo parameter corresponding to
_coef_BPM[k])
n: Frame parameter of c
Fs: Sampling rate
N: Window length
H: Hop size



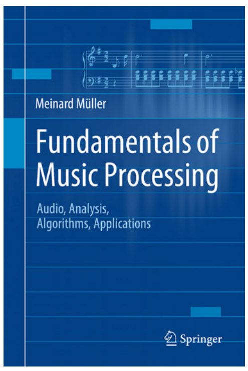








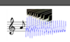
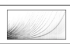
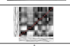
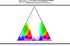
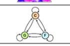
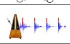
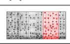
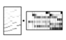
Book: Fundamentals of Music Processing



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 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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