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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FRIEDRICH-ALEXANDER
UNIVERSITÄT
ERLANGEN-NÜRNBERG

Fraunhofer
IIS

Meinard Müller

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

universitätbonn

AUDIO LABS

- Since 2012: Professor for Semantic Audio Processing

FAU FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

- 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)

University of Music
Hochschule
für Musik
Karlsruhe

AUDIO
LABS

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

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

Group Members

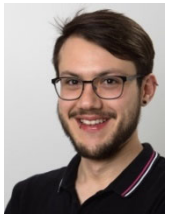
- Frank Zalkow
- Christof Weiß
- Michael Krause
- Sebastian Rosenzweig
- Hendrik Schreiber

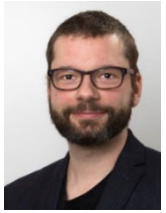





Former PhD Students

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

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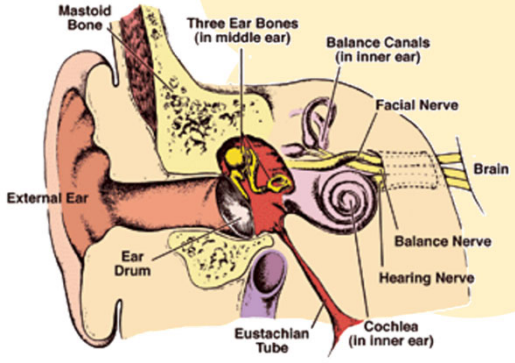
Audio Coding

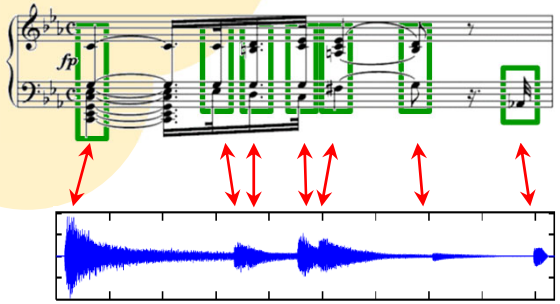
3D Audio

Virtual Reality

Audio



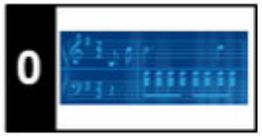
Psychoacoustics



Music Processing

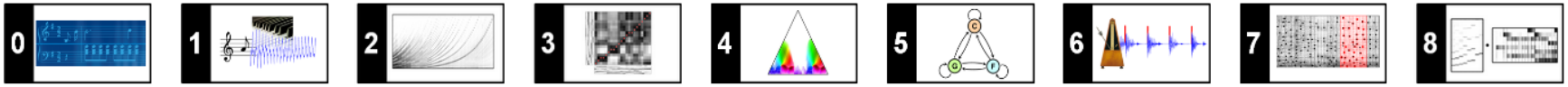
FMP Notebooks

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

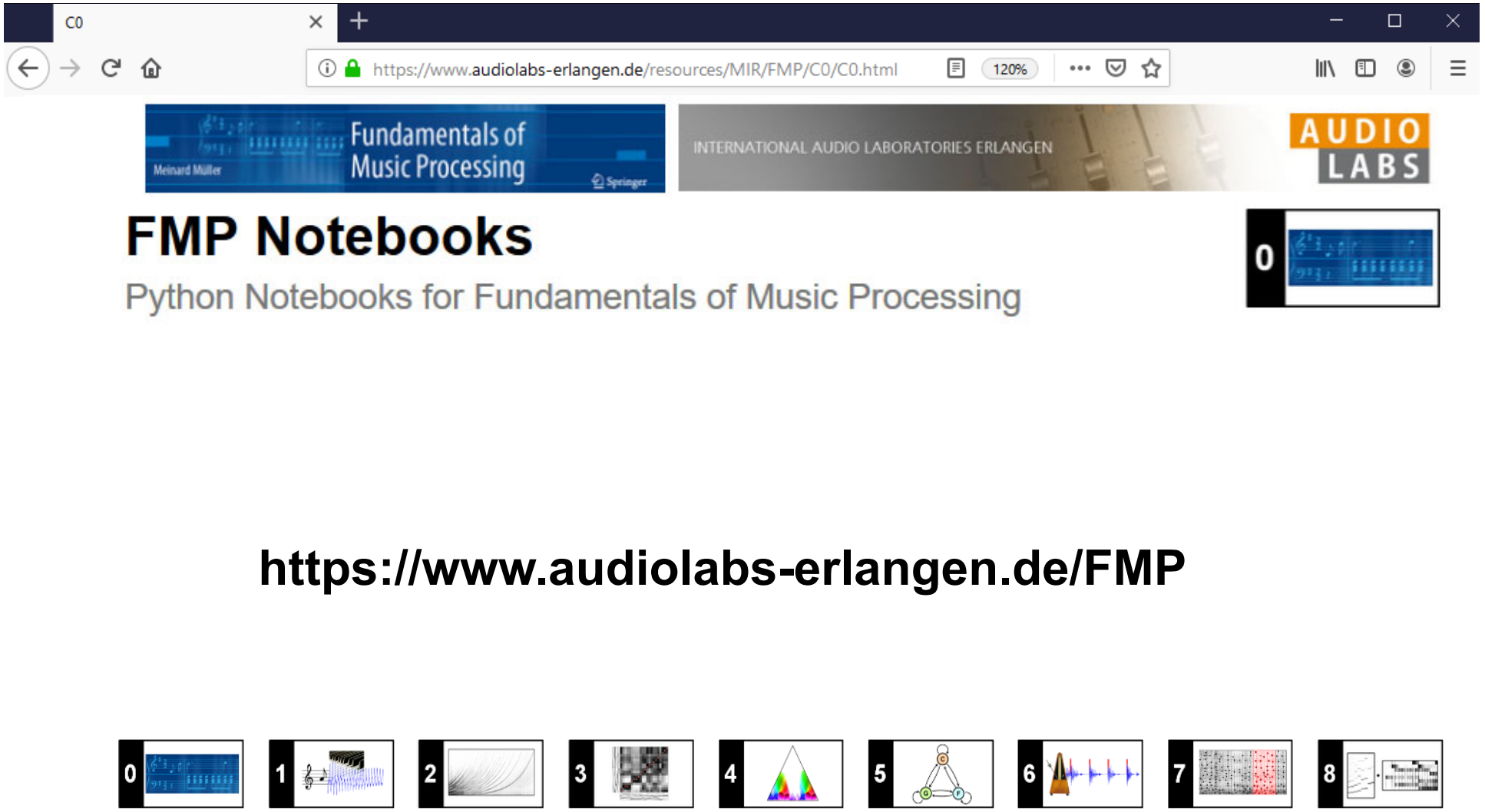
9:00 – 9:20	Overview
9:20 – 9:55	Music Representations and Retrieval
9:55 – 10:30	Audio Structure Analysis

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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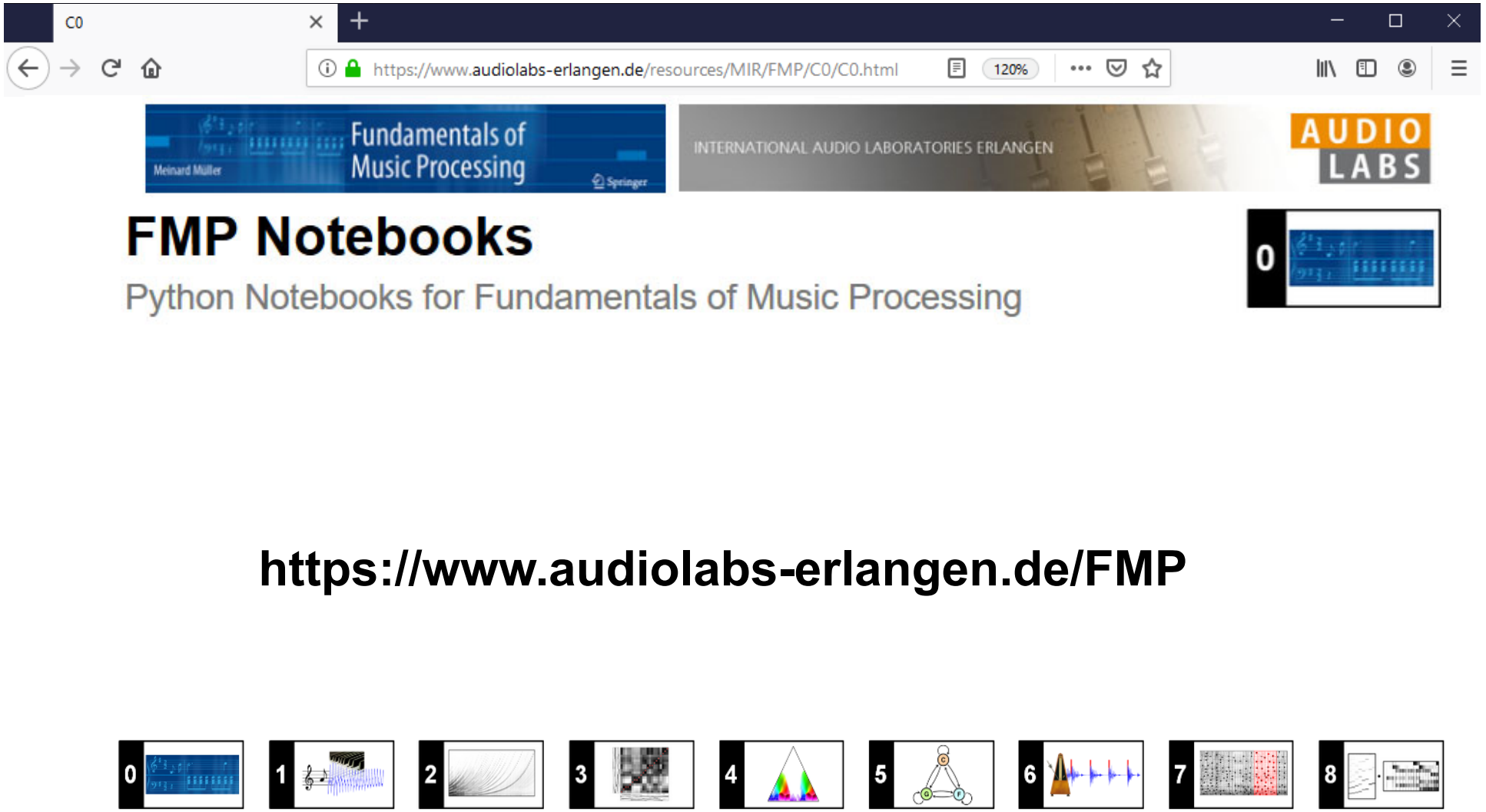
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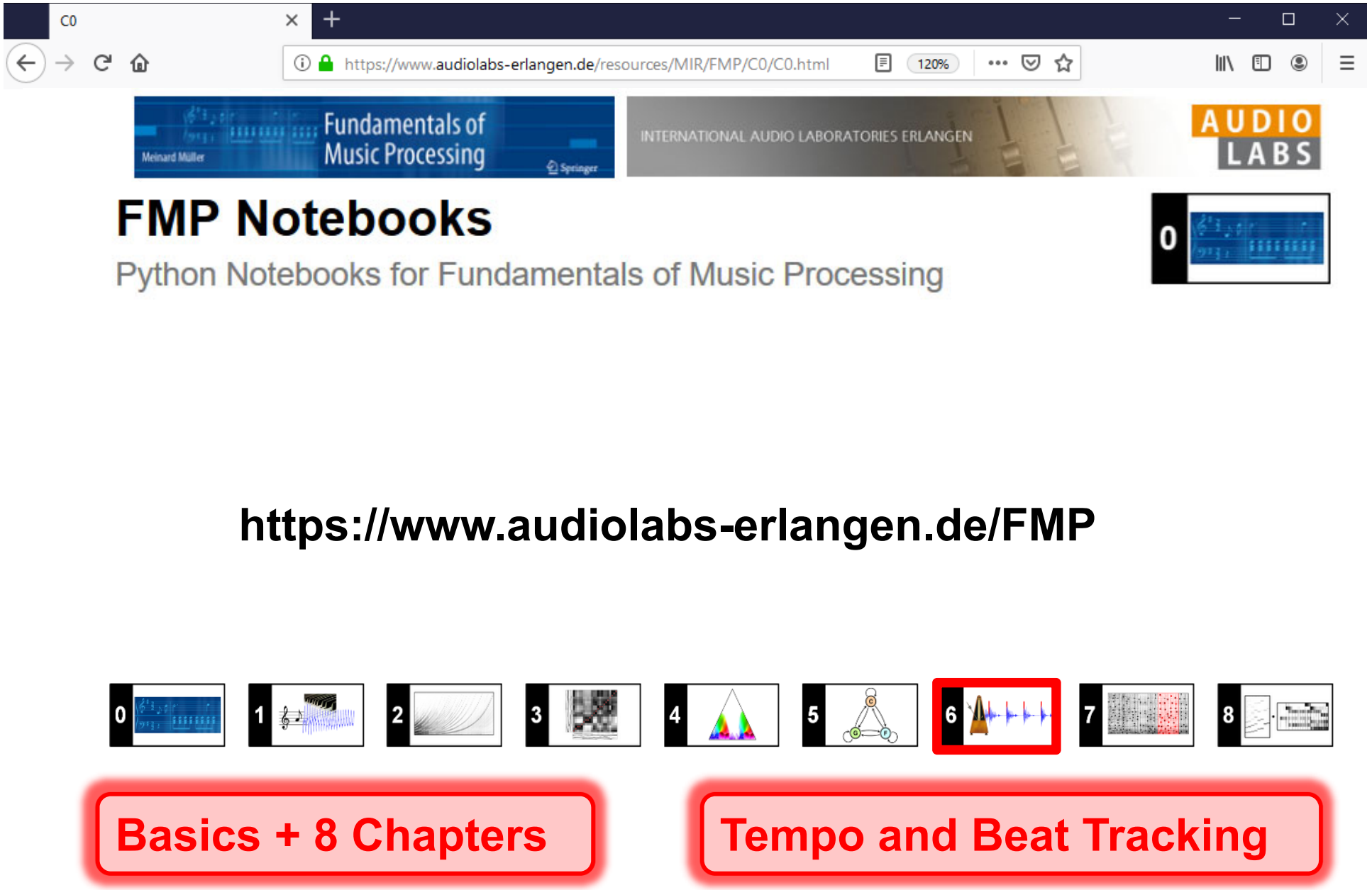
Basics + 8 Chapters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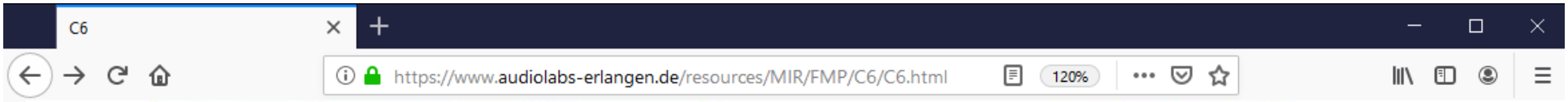
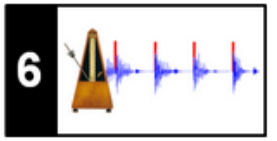
Basics + 8 Chapters
Tempo and Beat Tracking



Tempo and Beat Tracking



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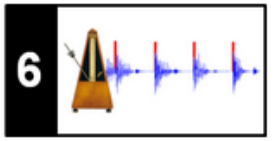
Tempo and Beat Tracking



Definition

We assume that we are given a discrete-time novelty function $\Delta : \mathbb{Z} \to \mathbb{I}$ 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 cc 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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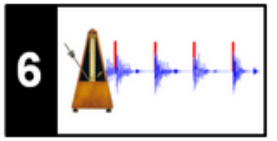
Tempo and Beat Tracking



Definition

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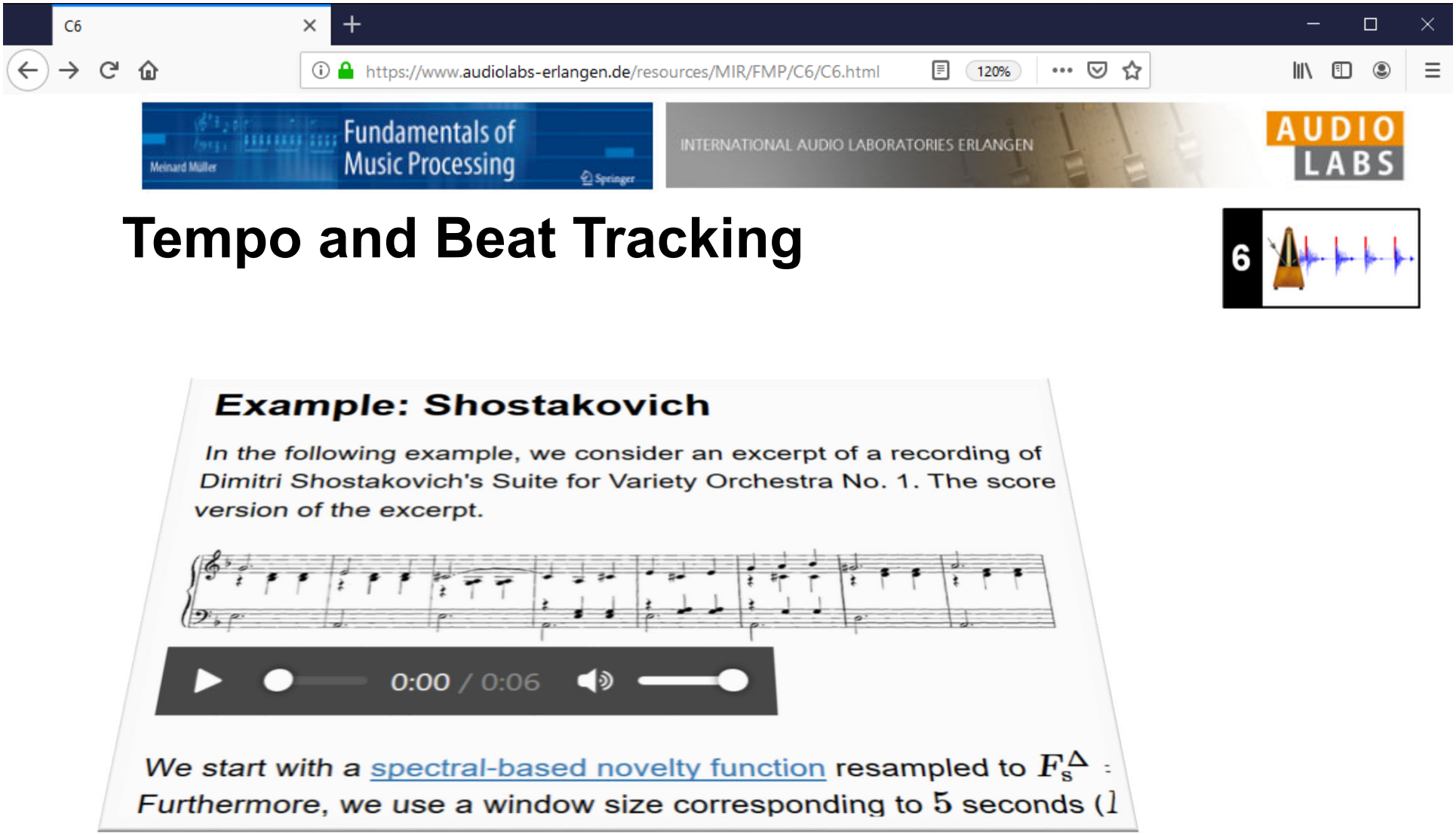
Explanations

Theory

Mathematics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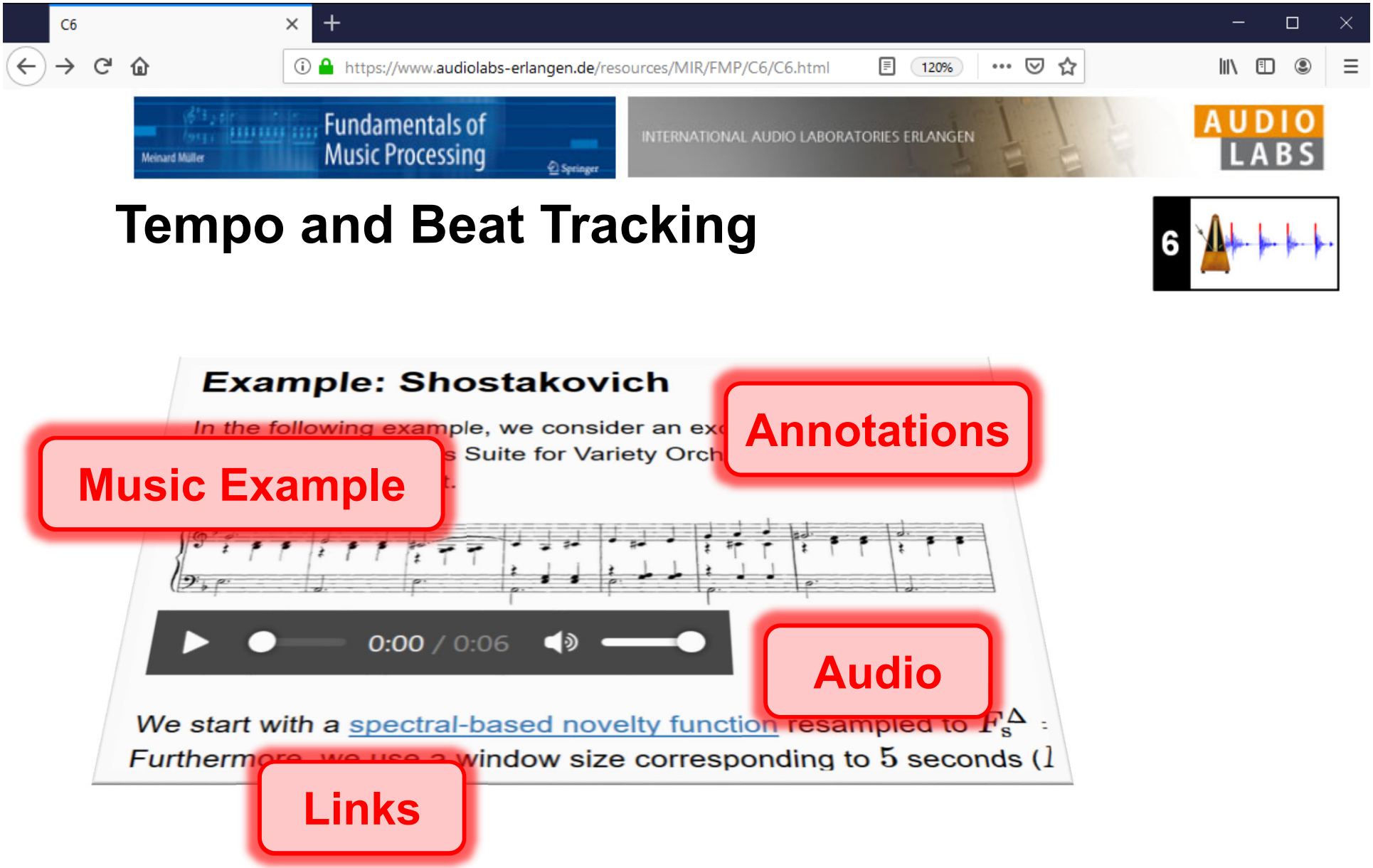
6
Example: Shostakovich
In the following example, we consider an excerpt of a recording of Dimitri Shostakovich's Suite for Variety Orchestra No. 1. The score version of the excerpt.
0:00 / 0:06
We start with a spectral-based novelty function resampled to F_s^Δ =
Furthermore, we use a window size corresponding to 5 seconds (1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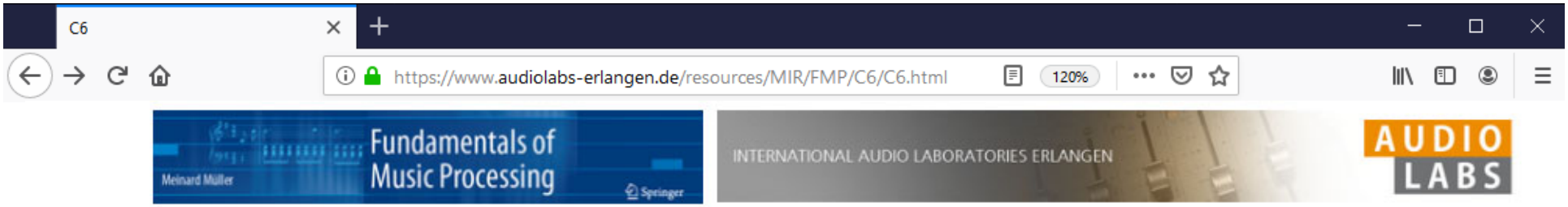
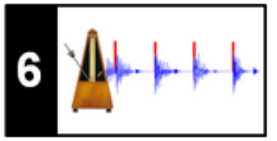
Music Example
Annotations
Audio
Links



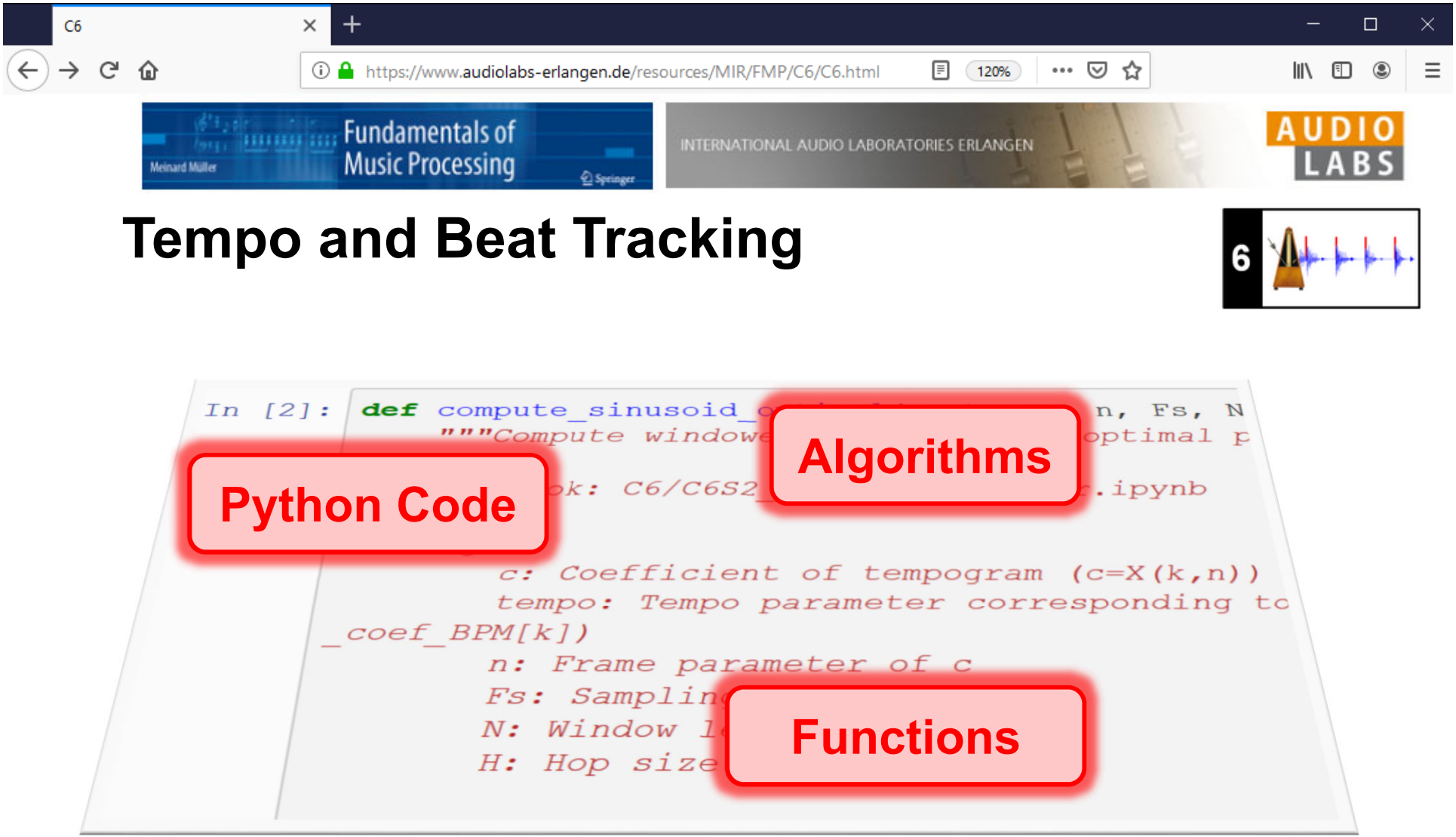
Tempo and Beat Tracking




```
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
```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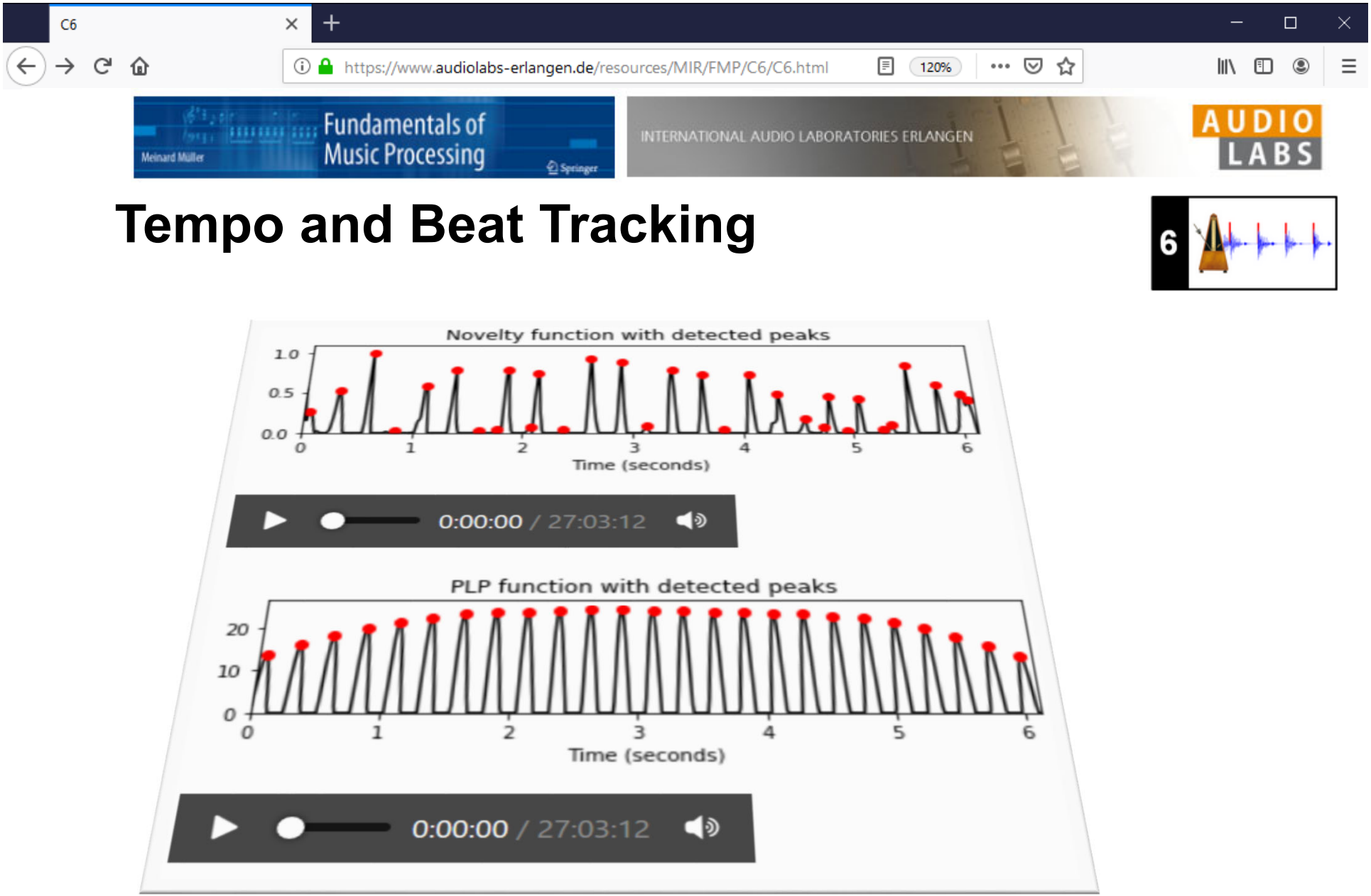
Python Code
Algorithms
Functions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Tempo and Beat Tracking
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Novelty function with detected peaks
1.0
0.5
0.0
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6
Time (seconds)
0:00:00 / 27:03:12
PLP function with detected peaks
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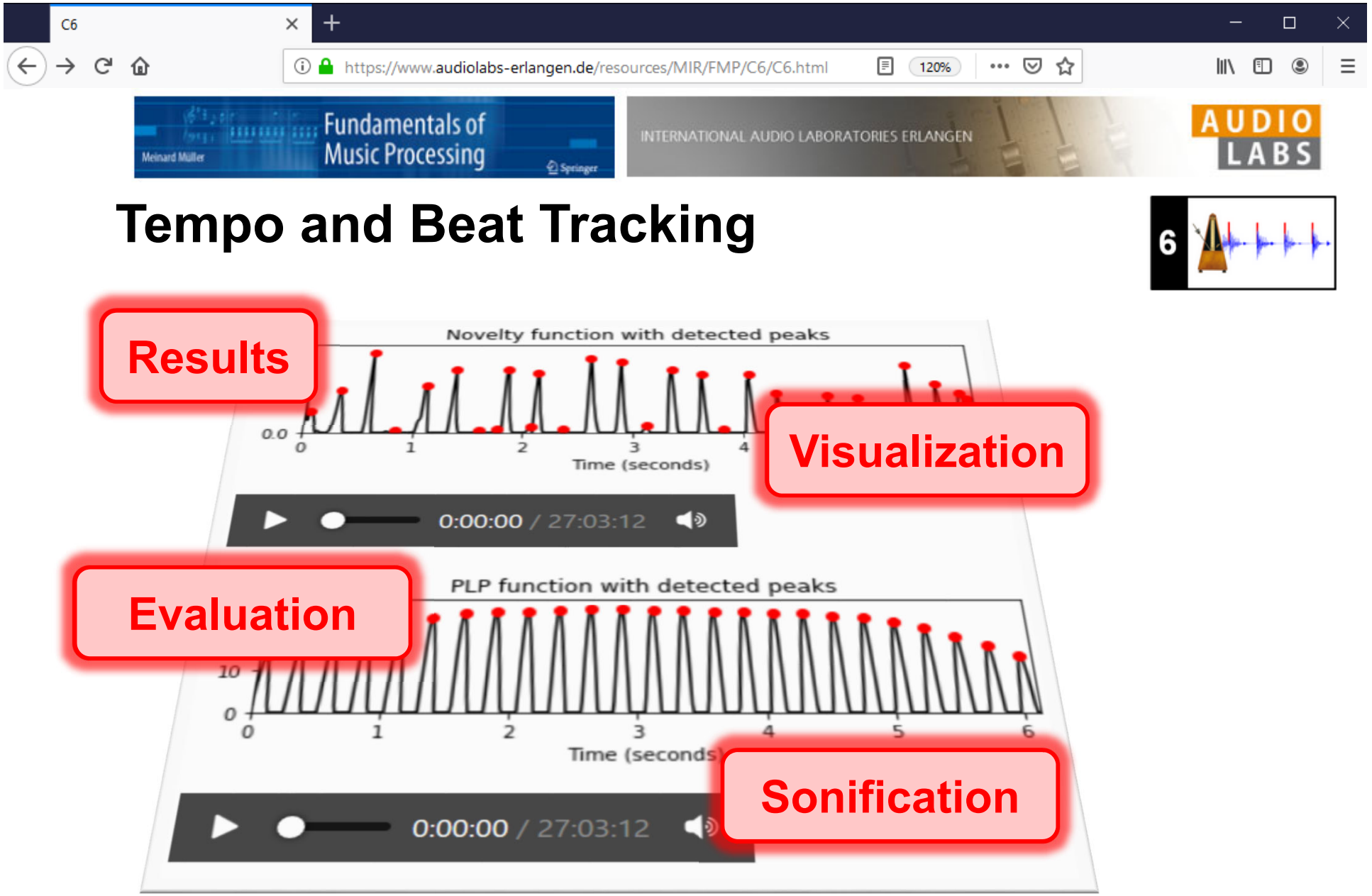
Time (seconds)
0:00:00 / 27:03:12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Results
Novelty function with detected peaks
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Time (seconds)
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Visualization
Evaluation
PLP function with detected peaks
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Time (seconds)
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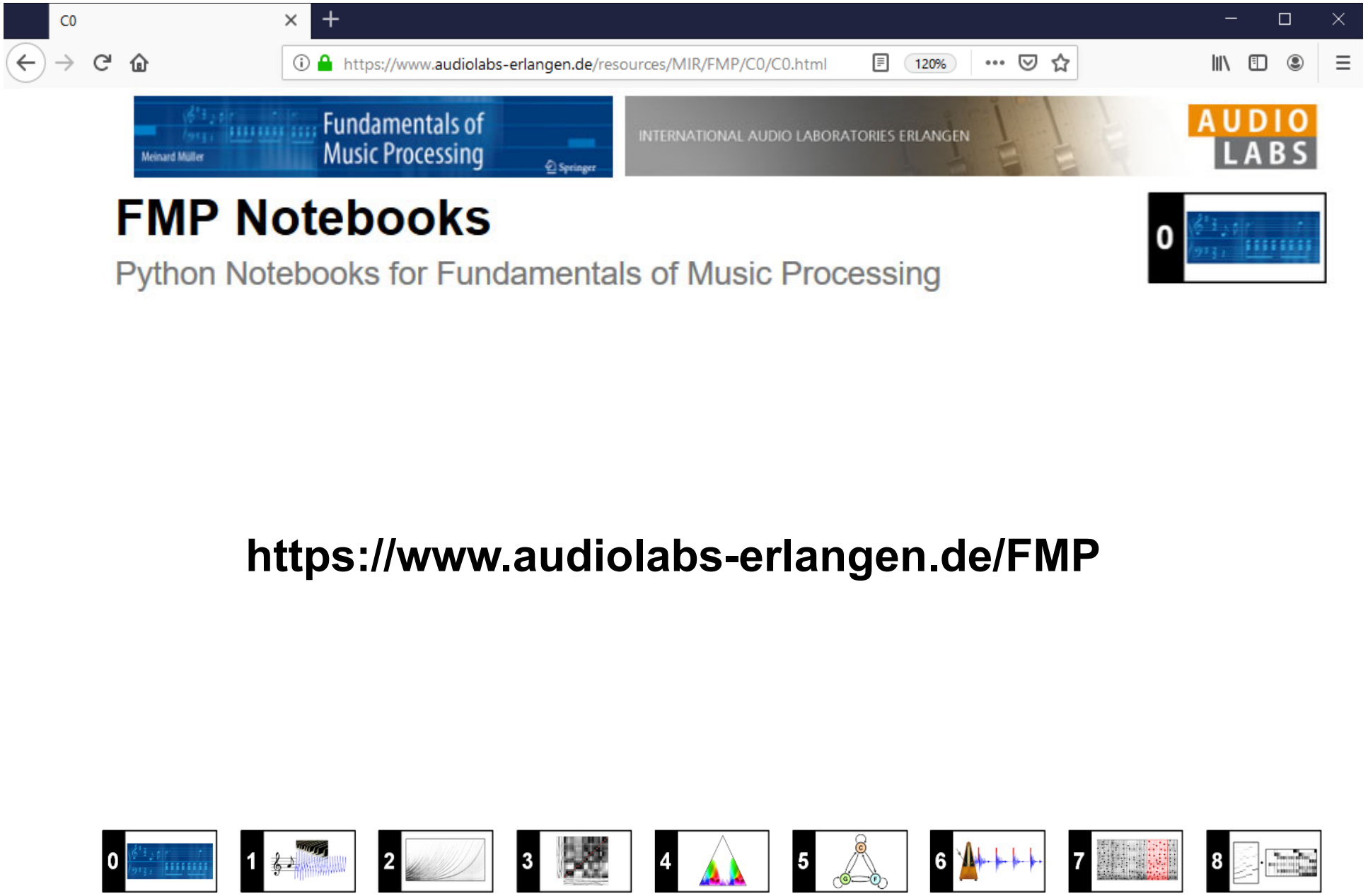
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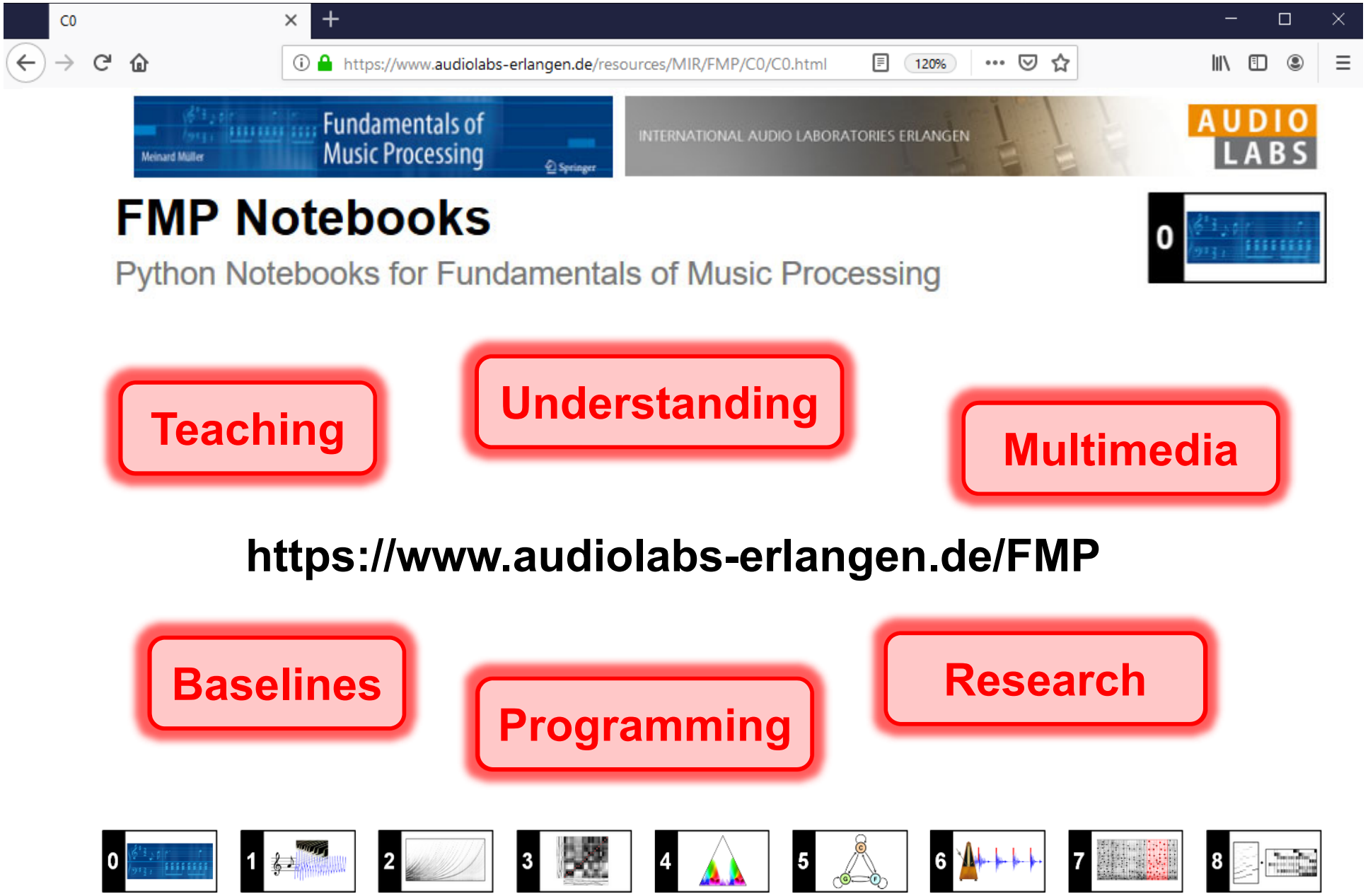
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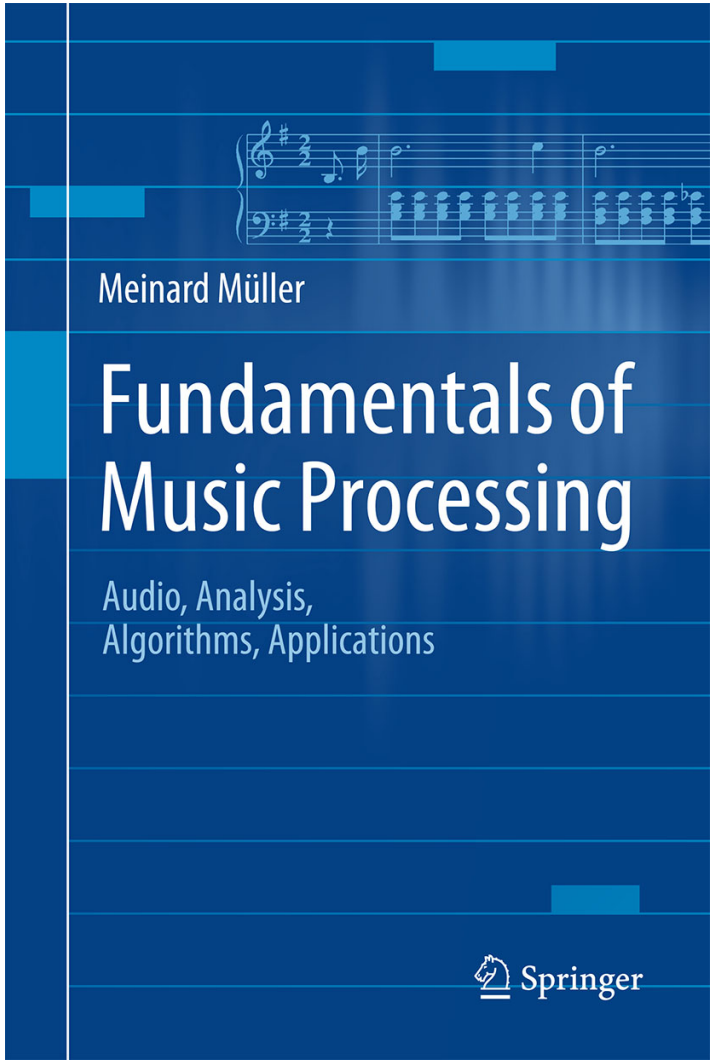
Book: Fundamentals of Music Processing



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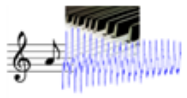
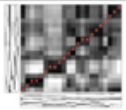
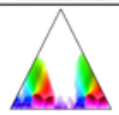
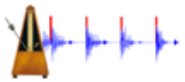
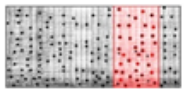
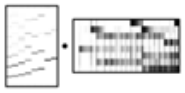
Fundamentals of Music Processing
Audio, Analysis, Algorithms, Applications
483 p., 249 illus., hardcover
ISBN: 978-3-319-21944-8
Springer, 2015

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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