INTERNATIONAL AUDIO LABORATORIES ERLANGEN
A joint institution of Fraunhofer IIS and Universität Erlangen-Nürnberg

AUDIO LABS

FMP Notebooks: Educational Material for Teaching and Learning Fundamentals of Music Processing

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Overview

In this contribution, we introduce a novel collection of educational material for teaching and learning fundamentals of music processing (FMP) with a particular focus on the audio domain. This collection, referred to as FMP notebooks, covers well-established topics in Music Information Retrieval (MIR) as motivating application scenarios. The FMP notebooks provide the following:

- Introductions of MIR scenarios.
- Textbook-like explanations of central techniques and algorithms.
- Python code examples that illustrate how to implement the theory.
- Numerous illustrations and sound examples.

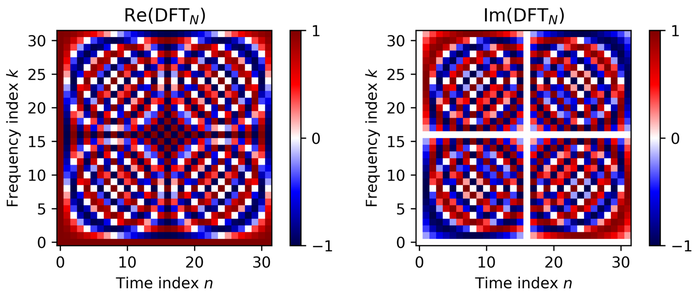
All components are integrated into a consistent and comprehensive framework based on Jupyter notebooks. The FMP notebooks are suited for studying the theory and practice, for generating educational material for lectures, as well as for providing baseline implementations for many MIR tasks, thus addressing students, teachers, and researchers.

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

Part	Title	Notions, Techniques & Algorithms	HTML	IPYNB
B	Basics	Basic information on Python, Jupyter notebooks, Anaconda package management system, Python environments, visualizations, and other topics	[html]	[ipynb]
0	Overview	Overview of the notebooks (https://www.audiolabs-erlangen.de/FMP)	[html]	[ipynb]
1	Music Representations	Music notation, MIDI, audio signal, waveform, pitch, loudness, timbre	[html]	[ipynb]
2	Fourier Analysis of Signals	Discrete/analog signal, sinusoid, exponential, Fourier transform, Fourier representation, DFT, FFT, STFT	[html]	[ipynb]
3	Music Synchronization	Chroma feature, dynamic programming, dynamic time warping (DTW), alignment, user interface	[html]	[ipynb]
4	Music Structure Analysis	Similarity matrix, repetition, thumbnail, homogeneity, novelty, evaluation, precision, recall, F-measure, visualization, scape plot	[html]	[ipynb]
5	Chord Recognition	Harmony, music theory, chords, scales, templates, hidden Markov model (HMM), evaluation	[html]	[ipynb]
6	Tempo and Beat Tracking	Onset, novelty, tempo, tempogram, beat, periodicity, Fourier analysis, autocorrelation	[html]	[ipynb]
7	Content-Based Audio Retrieval	Identification, fingerprint, indexing, inverted list, matching, version, cover song	[html]	[ipynb]
8	Musically Informed Audio Decomposition	Harmonic/percussive separation, signal reconstruction, instantaneous frequency, fundamental frequency (F0), trajectory, nonnegative matrix factorization (NMF)	[html]	[ipynb]

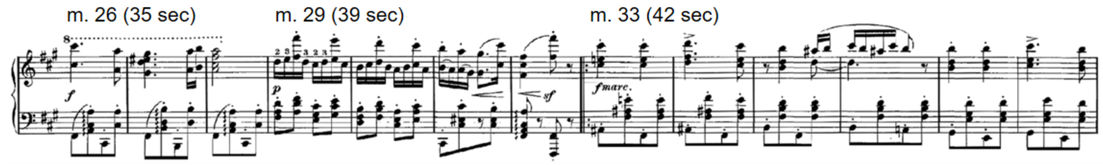
Scenario 1: Discrete Fourier Transform

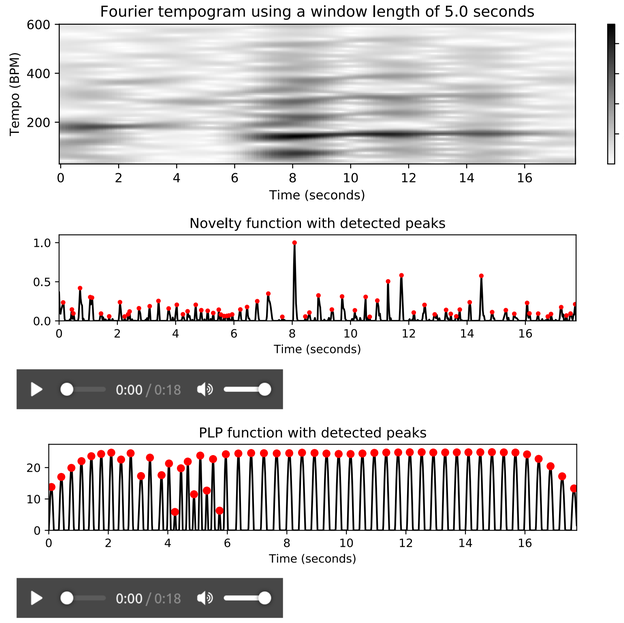
$$\mathrm{DFT}_N = \begin{pmatrix} 1 & 1 & 1 & \dots & 1 \\ 1 & \sigma_N & \sigma_N^2 & \dots & \sigma_N^{N-1} \\ 1 & \sigma_N^2 & \sigma_N^4 & \dots & \sigma_N^{2(N-1)} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1 & \sigma_N^{N-1} & \sigma_N^{2(N-1)} & \dots & \sigma_N^{(N-1)(N-1)} \end{pmatrix}$$



- Mathematical definitions
- Fast algorithm (FFT)
- Implementation
- Visualization
- Examples
- Experiments
- …

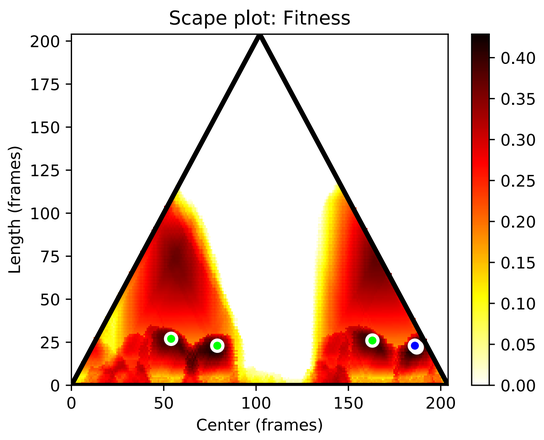
Scenario 2: Tempo Analysis and Pulse Tracking

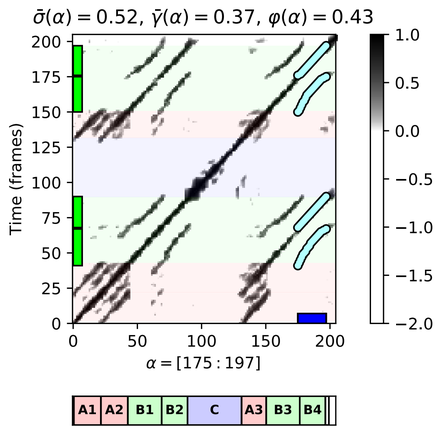




- Problem formalization
- Periodicity analysis
- Onset detection
- Axis-aligned visualizations
- Real-world examples
- Sonification
- Critical discussion of results
- …

Scenario 3: Audio Structure Analysis






```
Segment (alpha): [175, 197]
Length of segment: 23
Length of feature sequence: 205
Induced segment path family:
 [[ 41  67]
 [ 68  90]
 [150 175]
 [176 197]]
Fitness: 0.4286698275
Score: 68.0249471352
Normalized score: 0.5175281280
Coverage: 98, 98
Normalized coverage: 0.3658536585
Length of all paths of family: 87
```

- Data representations
- Annotations
- Evaluation
- Visualization
- …

References & Acknowledgments

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