



## Tutorial

# Automatisierte Methoden der Musikverarbeitung 47. Jahrestagung der Gesellschaft für Informatik

## Introduction to MIR

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International Audio Laboratories Erlangen

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**Music**

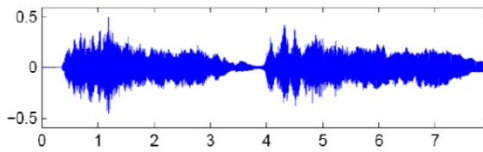


# Music Information Retrieval (MIR)

Sheet Music (Image)



CD / MP3 (Audio)



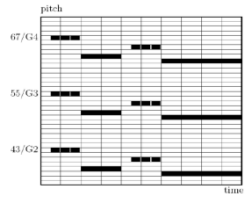
MusicXML (Text)

```
<note>  
  <pitch>  
    <step>E</step>  
    <alter>-1</alter>  
    <octave>4</octave>  
  </pitch>  
  <duration>2</duration>  
  <type>half</type>  
</note>
```

Dance / Motion (Mocap)



MIDI



Singing / Voice (Audio)



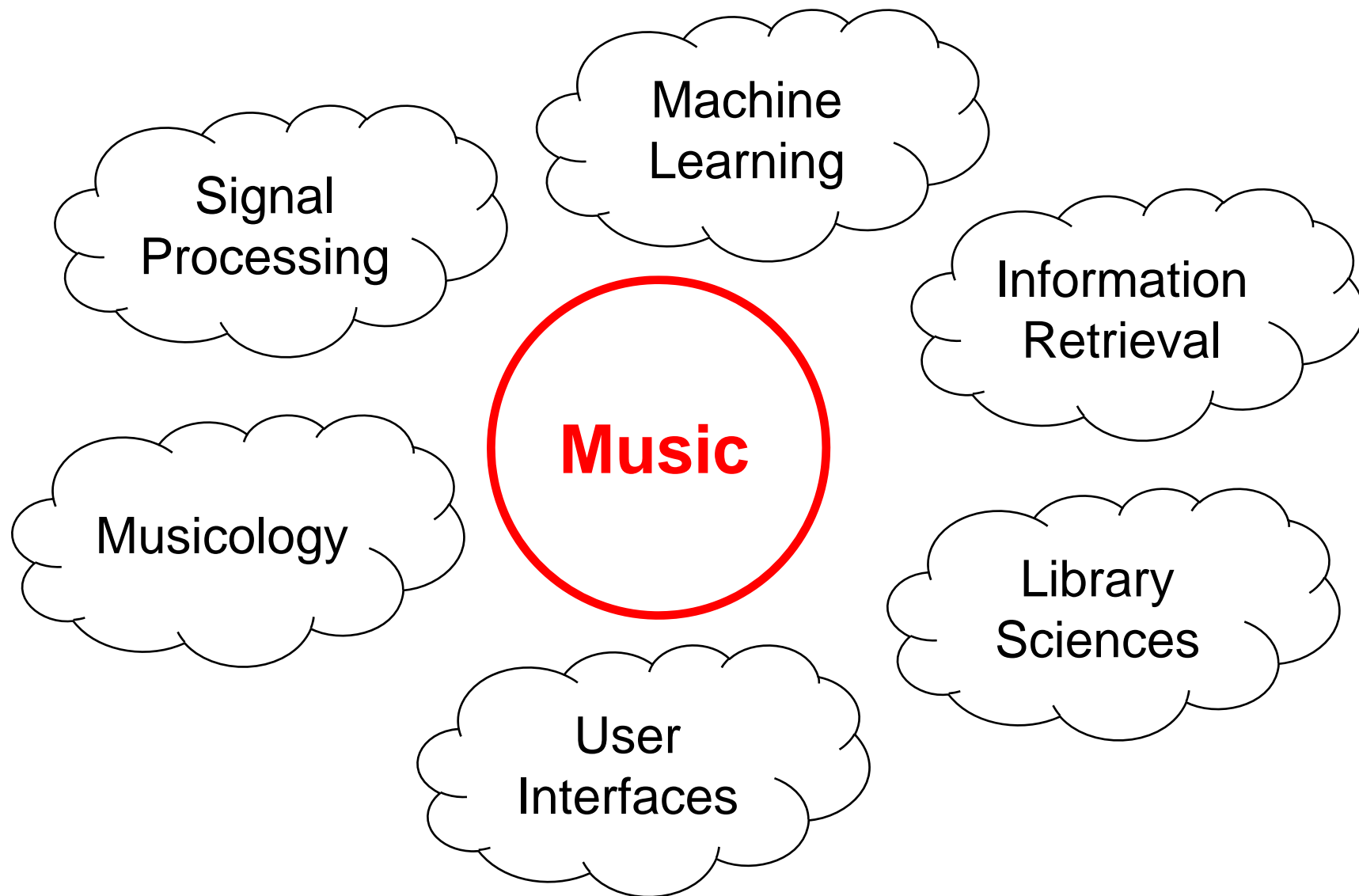
Music Film (Video)



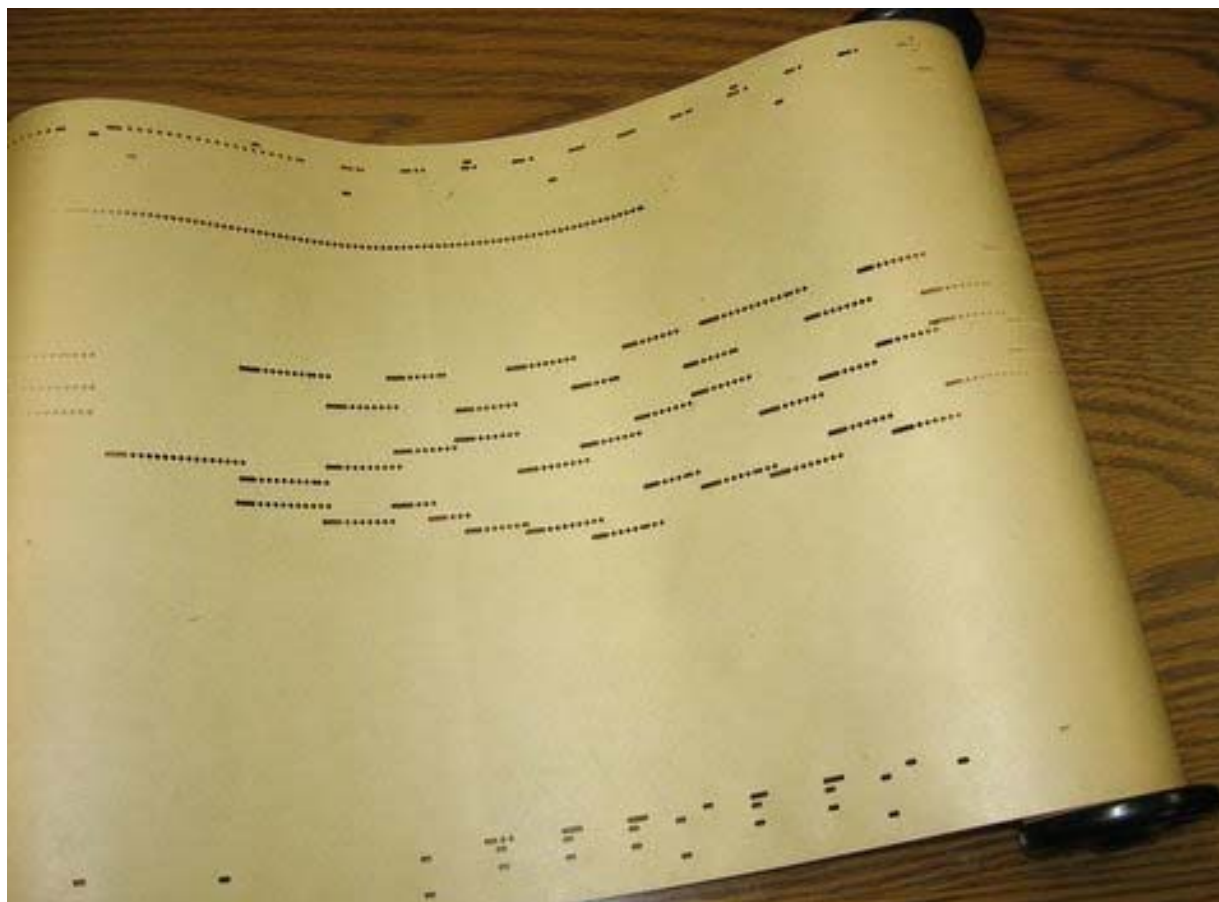
Music Literature (Text)



# Music Information Retrieval (MIR)



# Piano Roll Representation

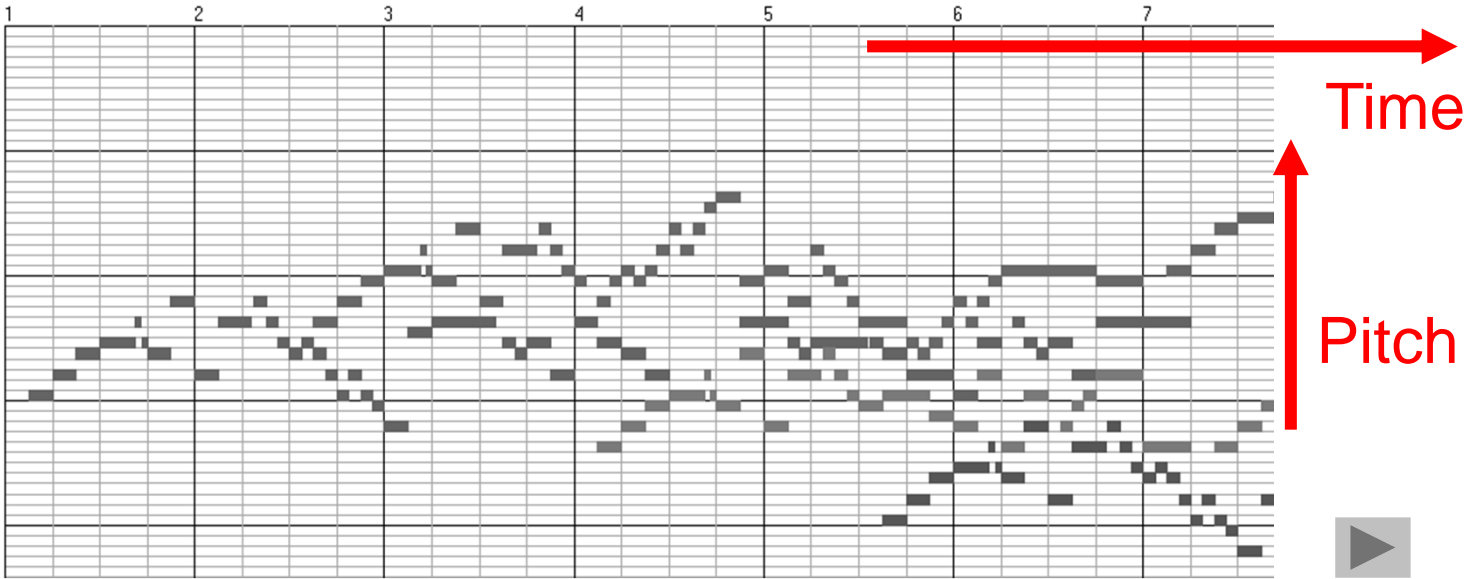
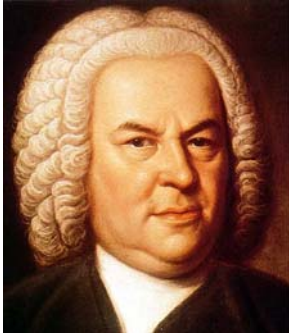


# Player Piano (1900)

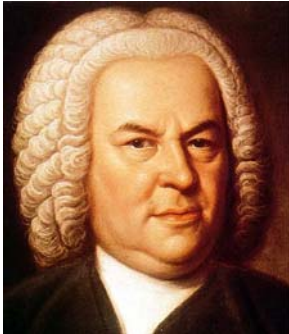


# Piano Roll Representation (MIDI)

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



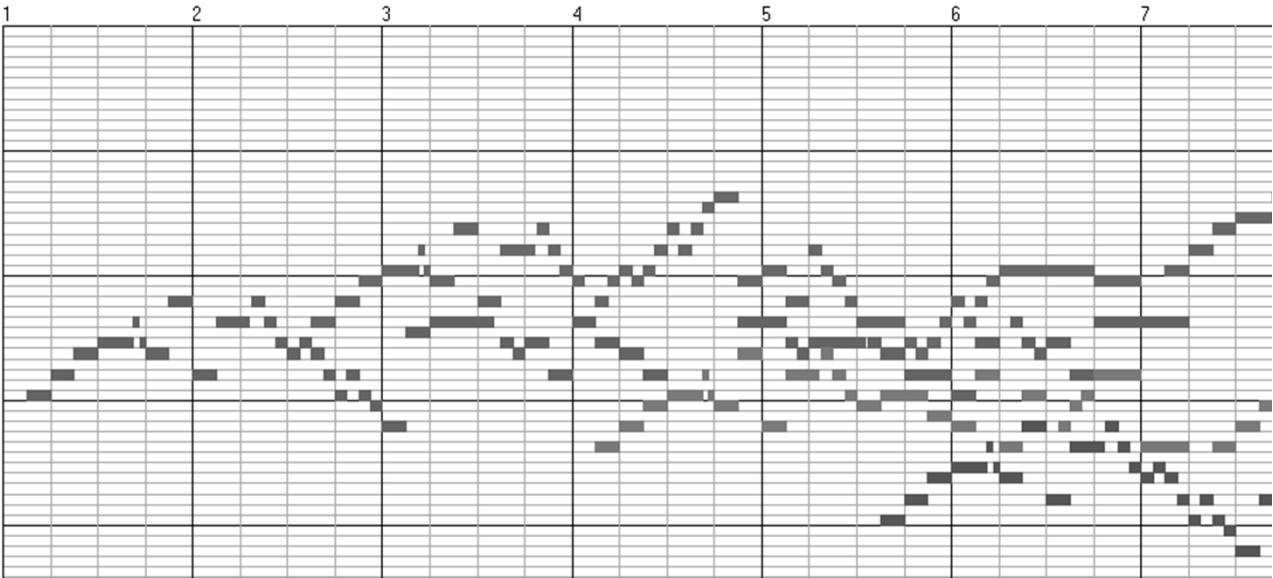
# Piano Roll Representation (MIDI)



Query:

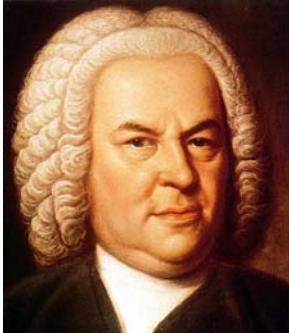


Goal: Find all occurrences of the query

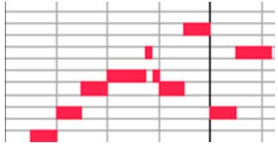




# Piano Roll Representation (MIDI)

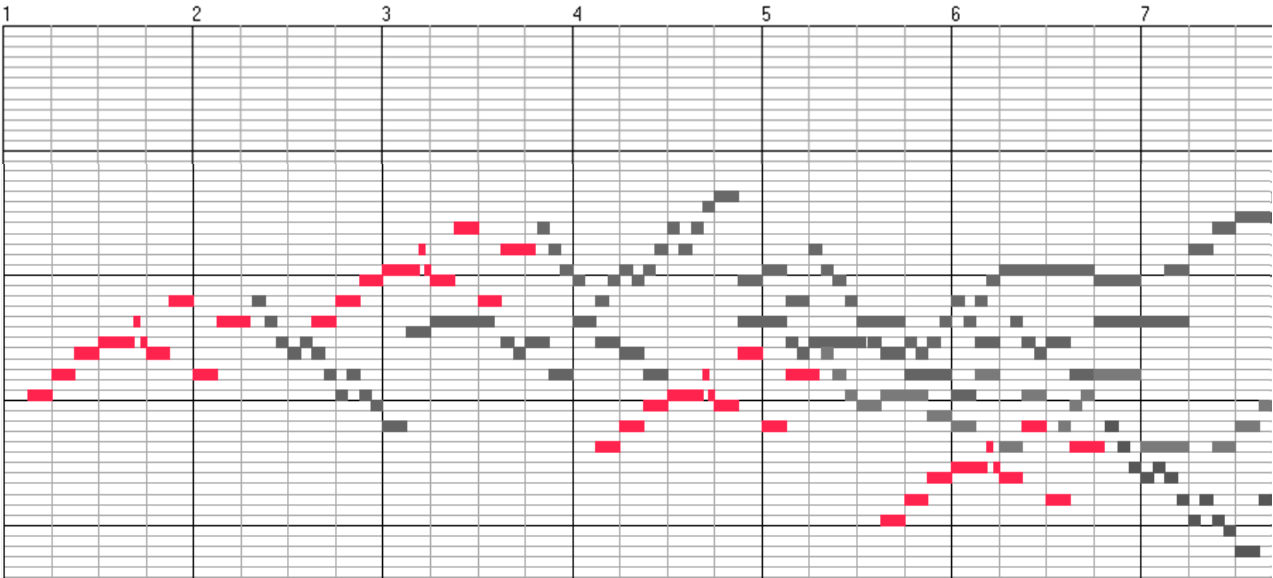


Query:

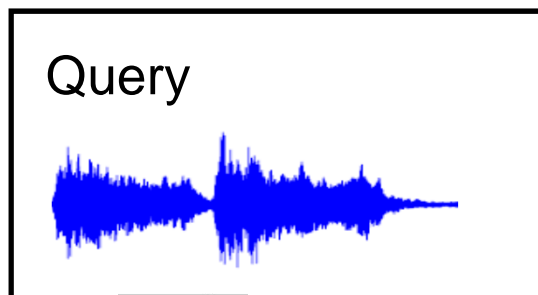


Goal: Find all occurrences of the query

Matches:



# Music Retrieval

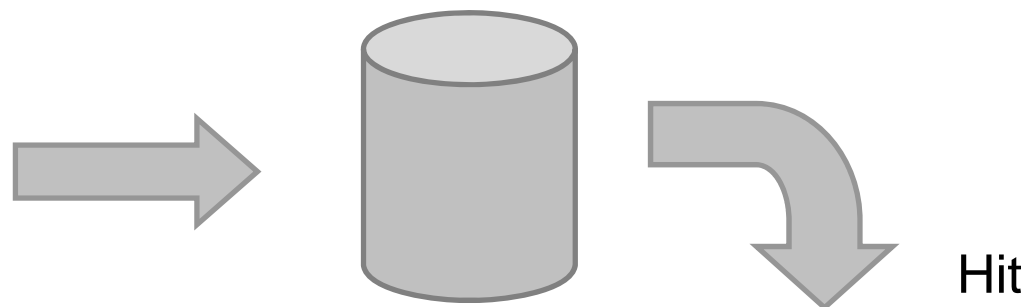


Audio-ID

Version-ID

Category-ID

Database



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: Audio-Audio

Beethoven's Fifth

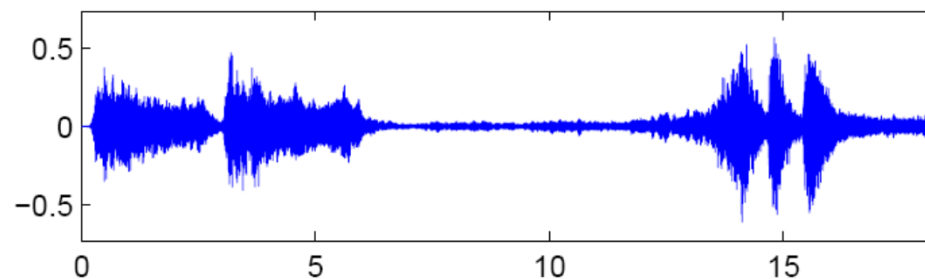


# Music Synchronization: Audio-Audio

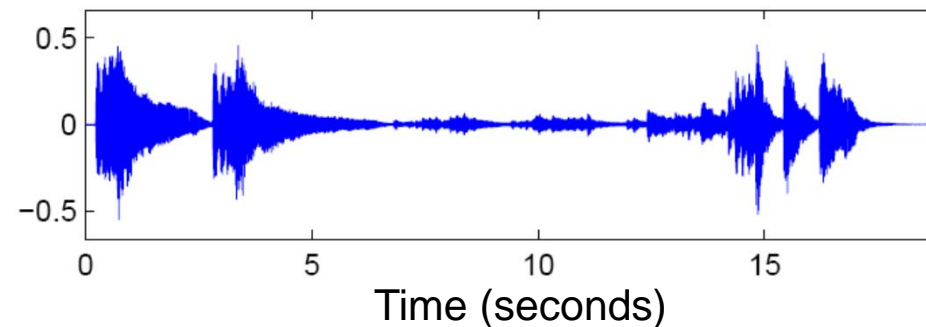
Beethoven's Fifth



Orchester  
(Karajan)

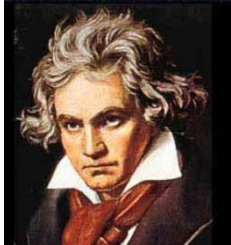


Piano  
(Scherbakov)

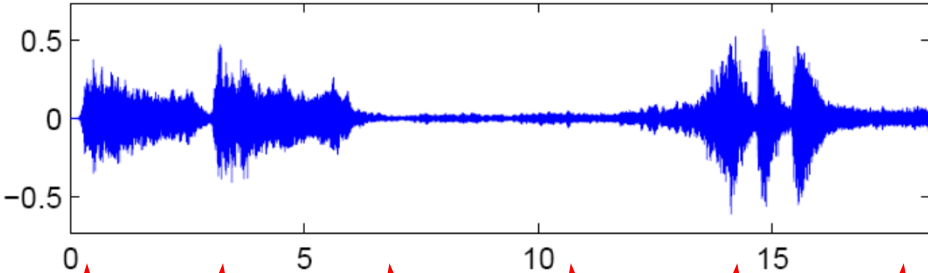


# Music Synchronization: Audio-Audio

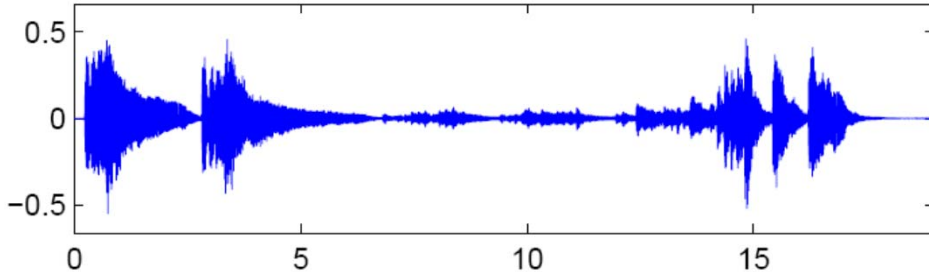
Beethoven's Fifth



Orchester  
(Karajan)



Piano  
(Scherbakov)



Time (seconds)



# Application: Interpretation Switcher

The screenshot shows a software window titled "Interpretation Switcher" for the piece "Beethoven, Op067-1\_Symphony5". The interface features four horizontal progress bars, each representing a different interpretation: "midi", "Bernstein", "Sawallisch", and "Scherbakov". Each bar is divided into three segments: blue, red, and green. A white playhead marker is positioned on the red segment of each bar, indicating the current playback position. The total duration for each interpretation is displayed at the end of the bar: "midi" (00:44.18), "Bernstein" (01:00.64), "Sawallisch" (00:58.35), and "Scherbakov" (00:52.45). On the right side, a list of checkboxes allows users to select or deselect interpretations: "midi", "Bernstein", "Sawallisch", and "Scherbakov", all of which are currently checked. Below this list is a "Deselect all" button. At the bottom of the window, there is a control bar with a radio button menu for "Absolute" (selected), "Relative", and "Reference"; a "Movement selection" button; an "Interval Repeat" checkbox; and an "Info" button. A "Deselect all" button is also present in the bottom right corner of the main content area.

Interpretation Switcher  
Beethoven, Op067-1\_Symphony5

midi 00:44.18  
Bernstein 01:00.64  
Sawallisch 00:58.35  
Scherbakov 00:52.45

midi  
 Bernstein  
 Sawallisch  
 Scherbakov

Deselect all

Absolute ✓  
Relative  
Reference

⏸ ⏹ ⏮ Movement selection  Interval Repeat ? Info



# Music Synchronization: Image-Audio

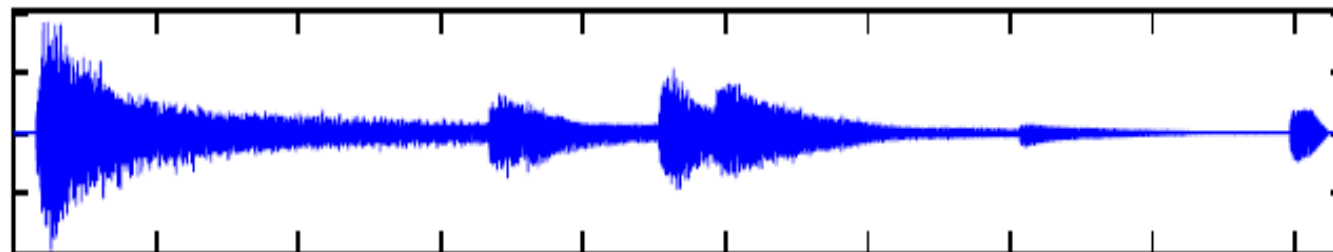
Image

Grave.

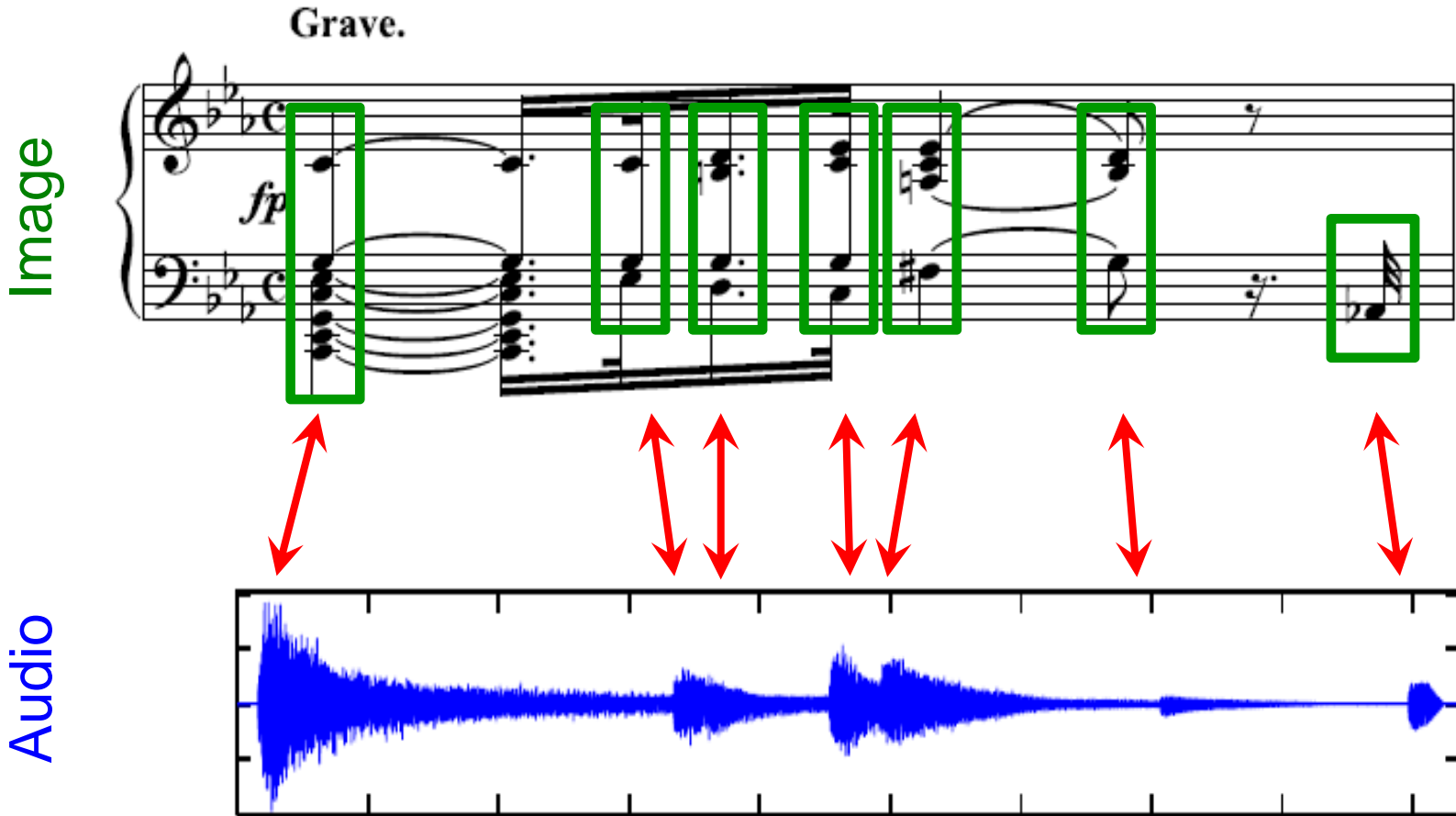


The image shows a musical score for piano in a slow tempo, marked "Grave." and "fp" (fortissimo). The score is written in a key signature of three flats (B-flat, E-flat, A-flat) and common time (C). It consists of two staves: a treble clef staff and a bass clef staff. The music features a series of chords and melodic lines, with a prominent bass line in the lower register. The tempo is indicated by the "Grave." marking, and the dynamic is indicated by "fp".

Audio



# Music Synchronization: Image-Audio



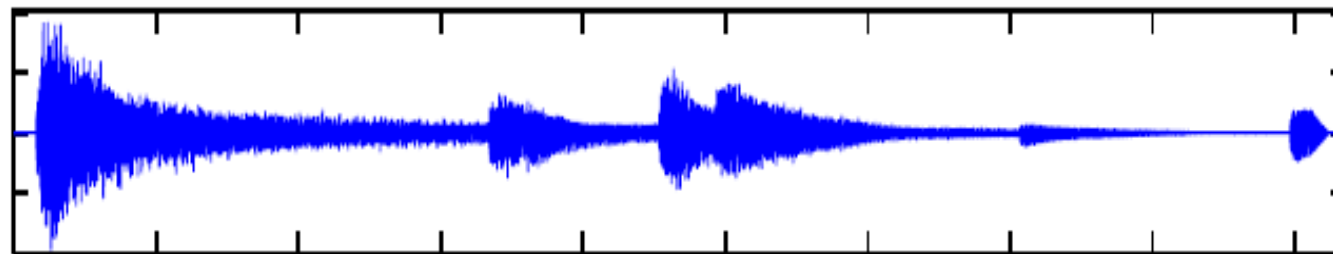


# How to make the data comparable?

Image



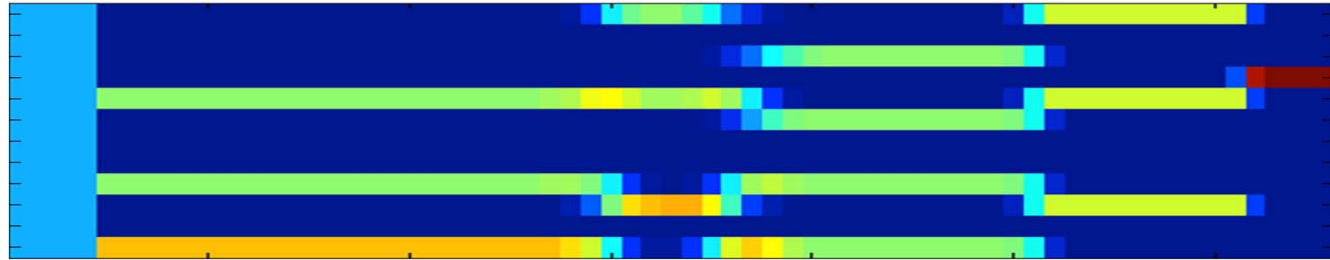
Audio



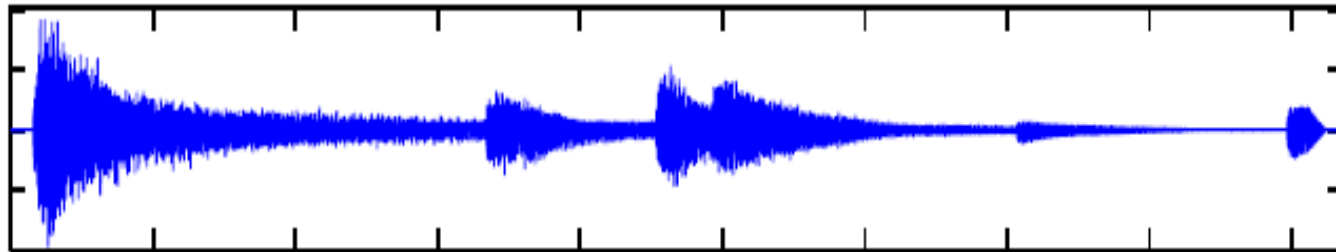
# How to make the data comparable?

## Image Processing: Optical Music Recognition

Image



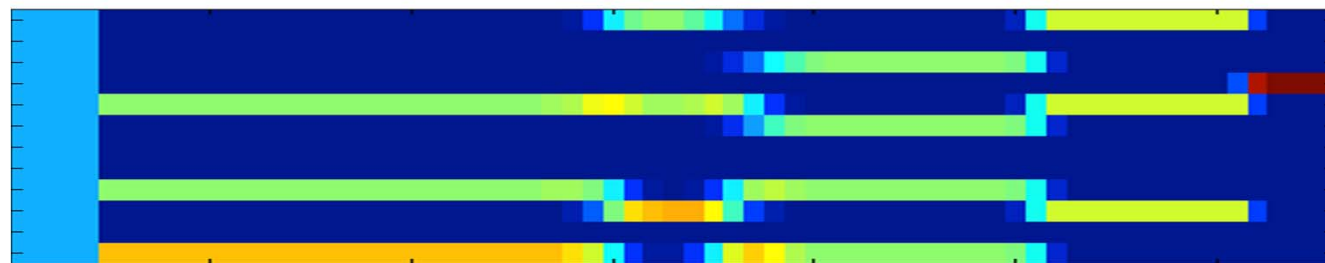
Audio



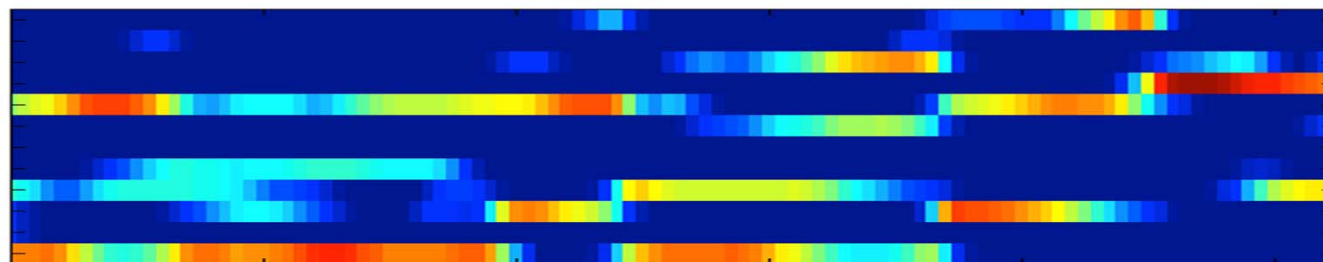
# How to make the data comparable?

## Image Processing: Optical Music Recognition

Image



Audio

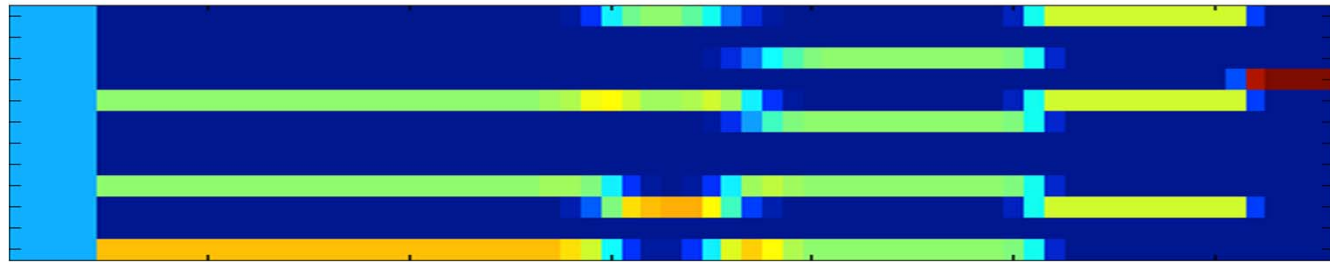


## Audio Processing: Fourier Analyse

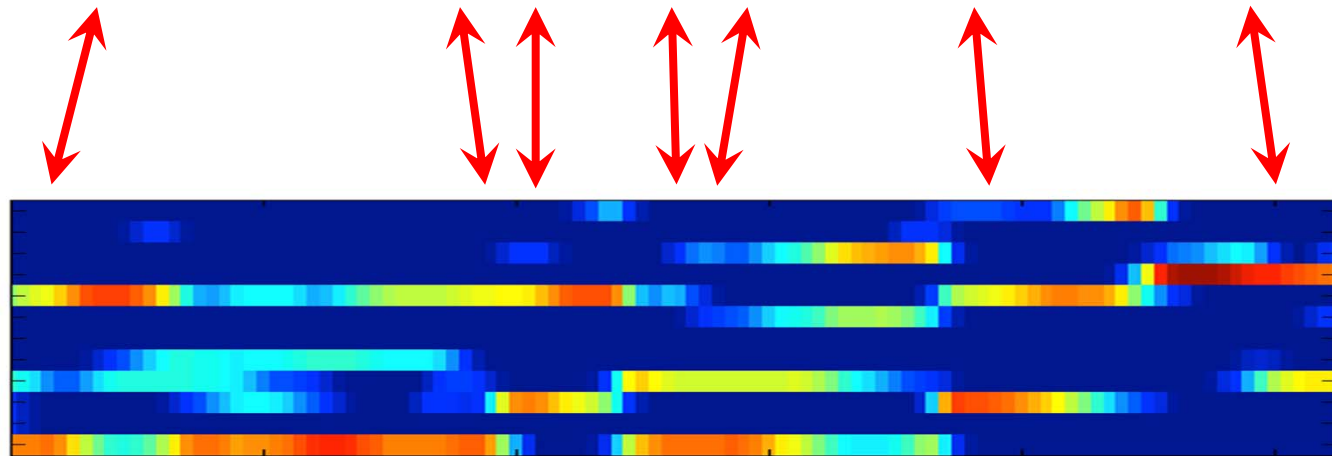
# How to make the data comparable?

## Image Processing: Optical Music Recognition

Image



Audio



## Audio Processing: Fourier Analyse



# Application: Score Viewer

The AudioViewer window displays the album cover for "Beethoven - Complete Piano Sonatas - Daniel Barenboim". Below the cover is a tracklist for "Disc 3".

Track	Duration
01 Sonata no.7 in D major, op.10 no.3: Presto	7:08
02 Sonata no.7 in D major, op.10 no.3: Largo e mesto	10:02
03 Sonata no.7 in D major, op.10 no.3: Menuetto (Allegro)	2:53
04 Sonata no.7 in D major, op.10 no.3: Rondo (Allegro)	4:05
05 Sonata no.8 in C minor, op.13, "Pathetique" / Allegro di molto e con brio	9:32
06 Sonata no.8 in C minor, op.13, "Pathetique" / Adagio cantabile	5:19
07 Sonata no.8 in C minor, op.13, "Pathetique" / Rondo (Allegro)	4:53
08 Sonata no.9 in E major, op.14 no.1: Allegro	6:48
09 Sonata no.9 in E major, op.14 no.1: Allegretto	4:16
10	

Navigation controls include a volume icon, a play/pause button, and a progress bar. Below the progress bar, the current selection is shown as "Disc: 3 / 10" and "Track: 7".

The ScoreViewer window displays a digital score for "Beethoven - Klaviersonaten Band 1 - Henle". The score is shown as an open book with two pages of musical notation. A yellow highlight is visible on the right page, and a yellow arrow points to it.

Navigation and playback controls are located at the bottom of the window:

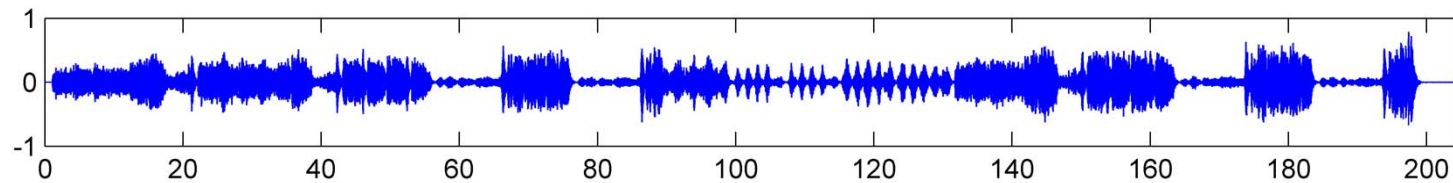
- Track: 29 / 54
- Bar: 9 / 211
- Page: 159 / 285
- Score Following Off (indicated by a red X over a book icon)
- Play (yellow play button)
- Stop (yellow stop button)

Zoom in (+) and zoom out (-) icons are also present on the right side of the score area.



# Music Structure Analysis

**Example:** Brahms Hungarian Dance No. 5 (Ormandy)

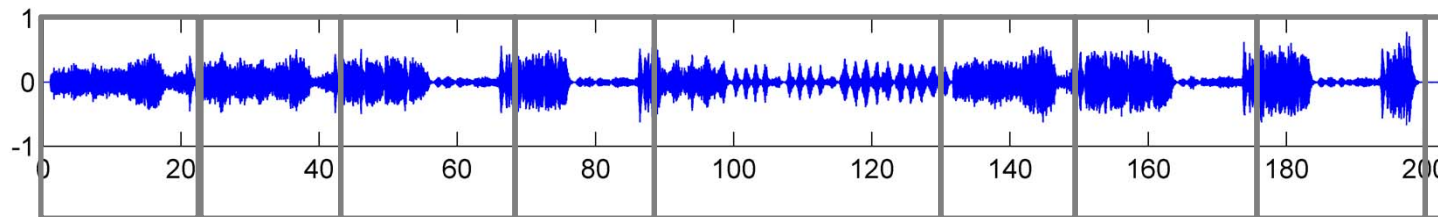


Time (seconds)



# Music Structure Analysis

**Example:** Brahms Hungarian Dance No. 5 (Ormandy)

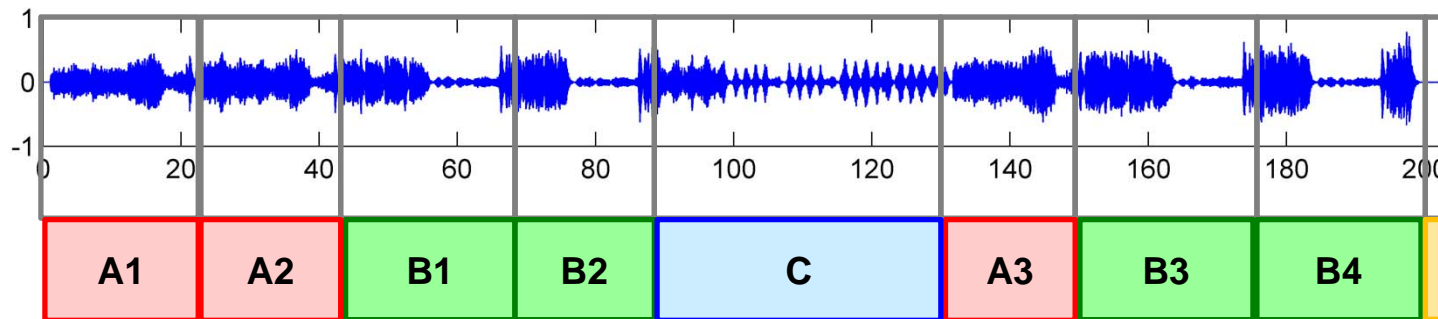


Time (seconds)



# Music Structure Analysis

**Example:** Brahms Hungarian Dance No. 5 (Ormandy)

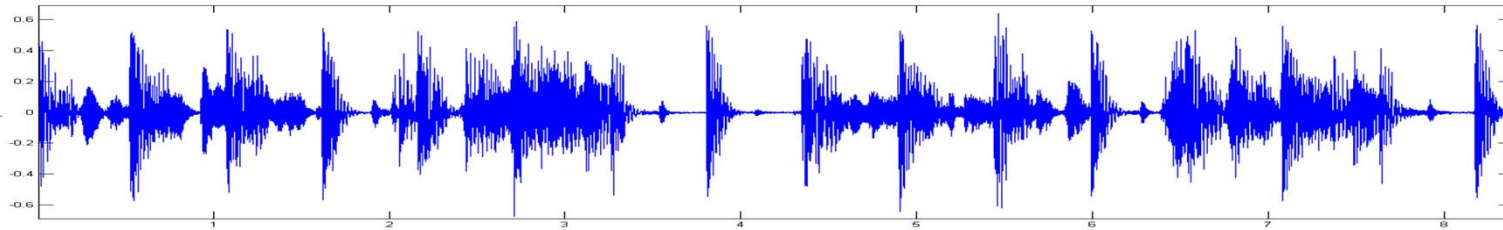




# Tempo Estimation and Beat Tracking

Basic task: “Tapping the foot when listening to music”

Example: Queen – Another One Bites The Dust

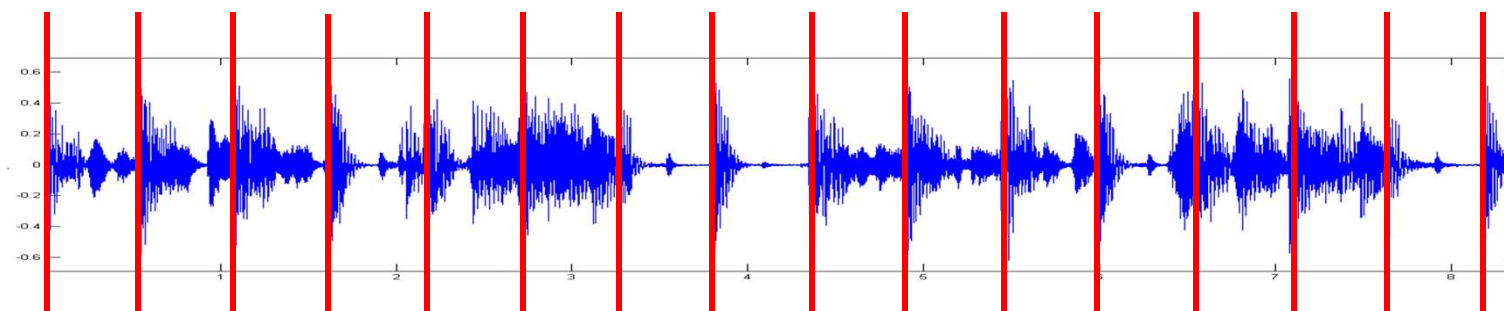


Time (seconds)

# Tempo Estimation and Beat Tracking

Basic task: “Tapping the foot when listening to music”

Example: Queen – Another One Bites The Dust



Time (seconds)



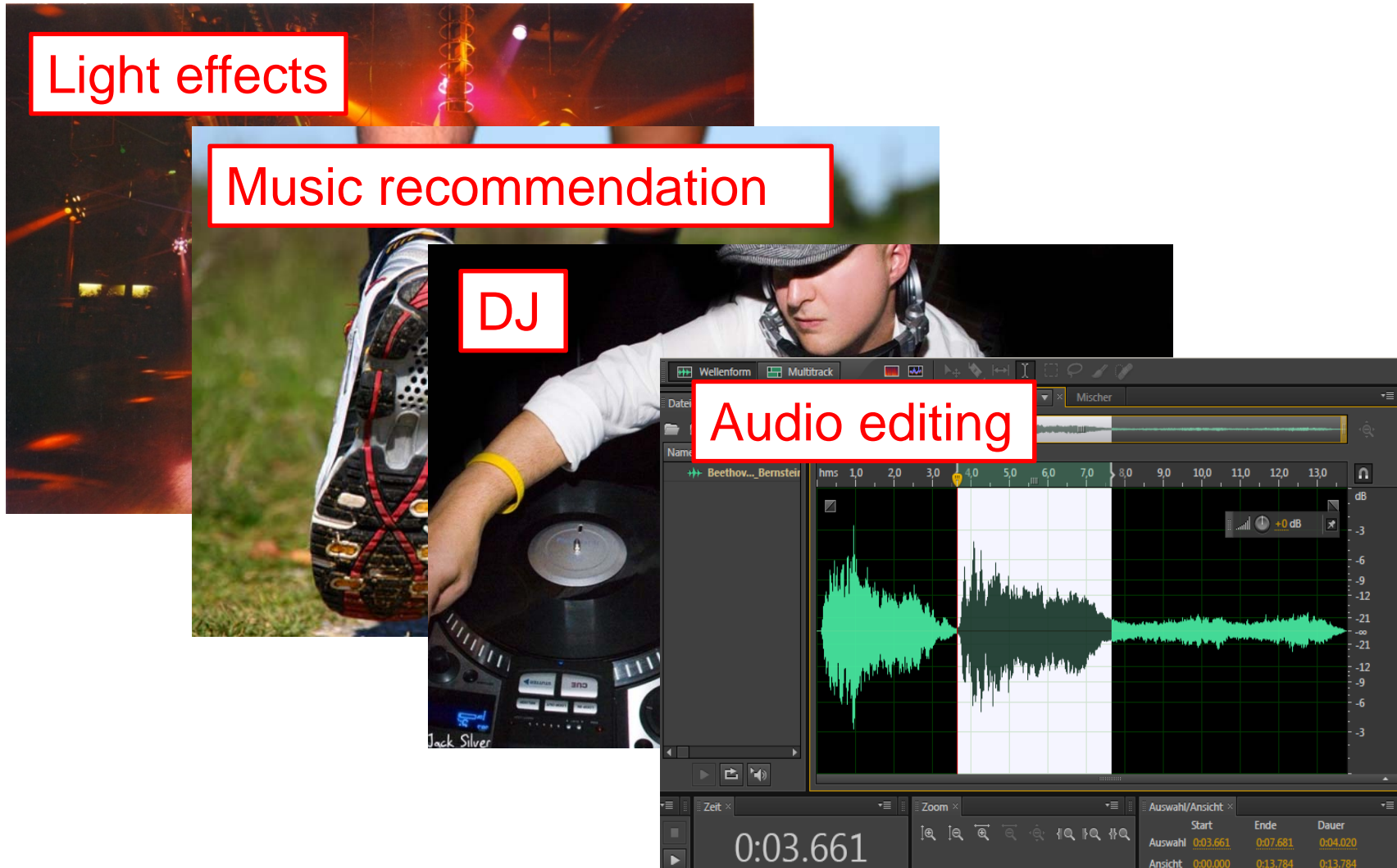
# Tempo Estimation and Beat Tracking

Light effects

Music recommendation

DJ

Audio editing



# Why is Music Processing Challenging?

**Example:** Chopin, Mazurka Op. 63 No. 3



## Mazurka.

F. CHOPIN. Op. 63, № 3.

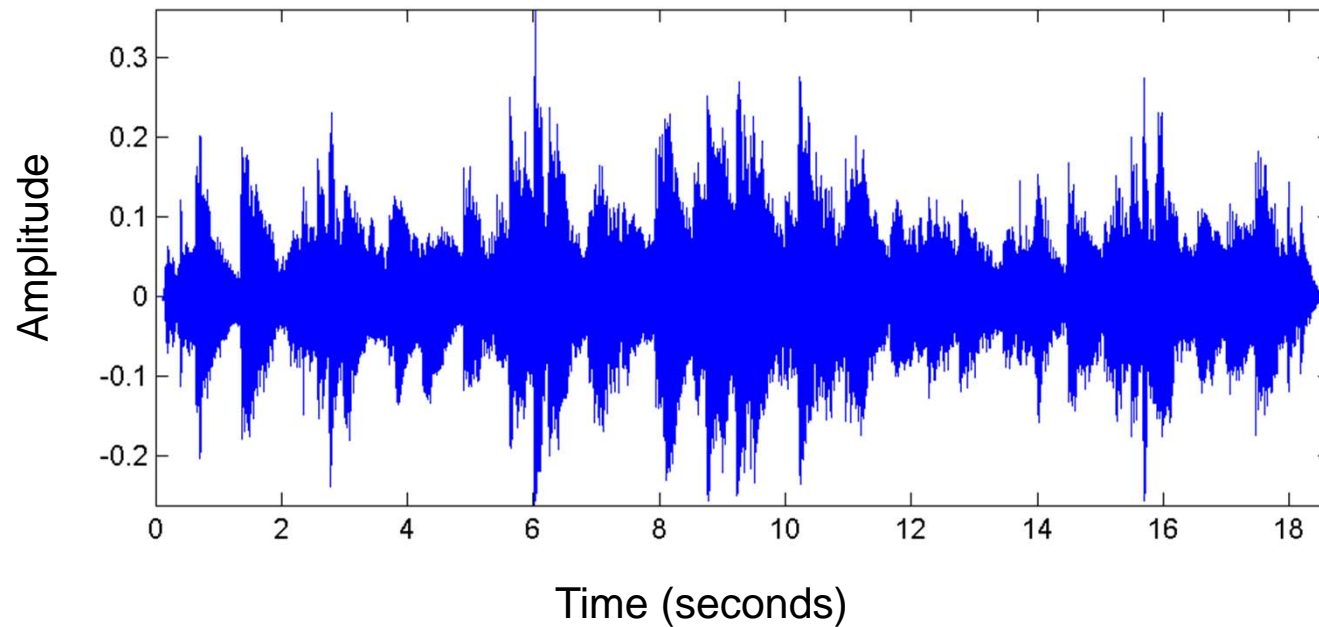
41. Allegretto. *p*

The image shows two systems of musical notation for Chopin's Mazurka Op. 63 No. 3, measures 41-50. The first system (measures 41-46) features a treble clef with a key signature of three sharps (F#, C#, G#) and a 3/4 time signature. The melody includes triplets and a fourth-note figure. The bass clef accompaniment consists of chords, with some marked 'Ped.' and asterisks. The second system (measures 47-50) continues the melody and accompaniment, also featuring triplets and 'Ped.' markings.

# Why is Music Processing Challenging?

**Example:** Chopin, Mazurka Op. 63 No. 3

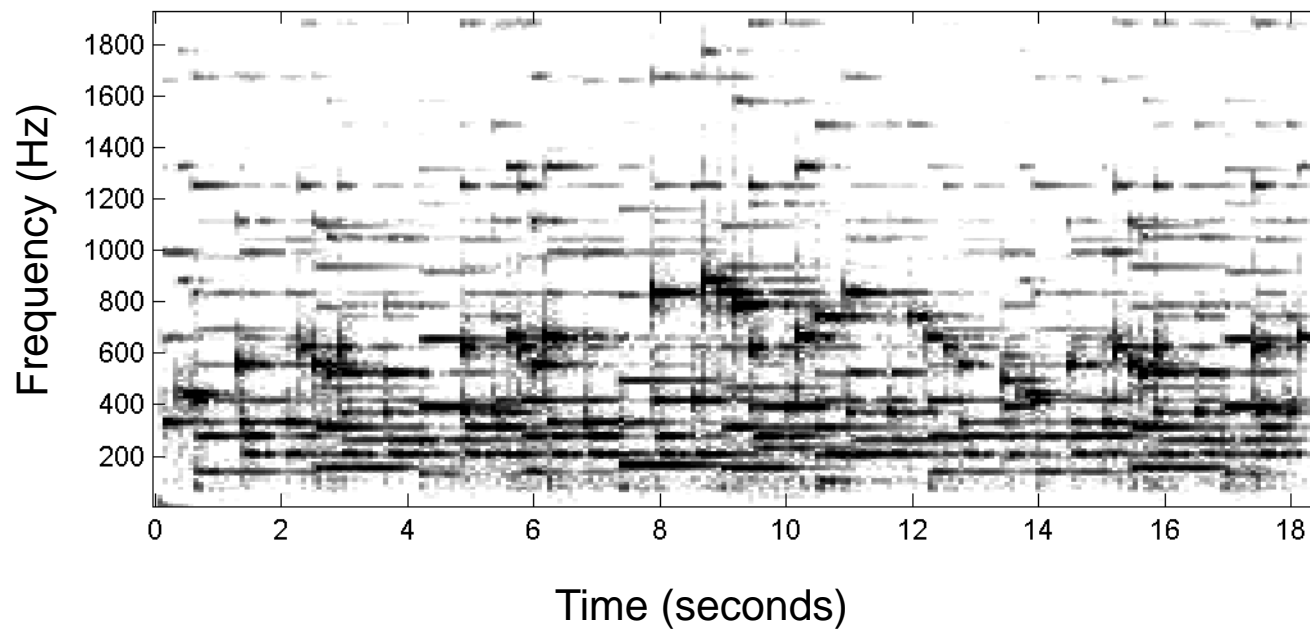
- Waveform



# Why is Music Processing Challenging?

**Example:** Chopin, Mazurka Op. 63 No. 3

- Waveform / Spectrogram



# Why is Music Processing Challenging?

**Example:** Chopin, Mazurka Op. 63 No. 3

- Waveform / Spectrogram
- Performance
  - Tempo
  - Dynamics
  - Note deviations
  - Sustain pedal

# Why is Music Processing Challenging?

**Example:** Chopin, Mazurka Op. 63 No. 3

- Waveform / Spectrogram



- Performance

- Tempo
- Dynamics
- Note deviations
- Sustain pedal

A musical score for Chopin's Mazurka Op. 63 No. 3, showing two systems of music. The score is annotated with performance markings: blue highlights for the main melody, red highlights for an additional melody line, and yellow highlights for the accompaniment. The score includes various musical notations such as notes, rests, and dynamic markings like 'p' and 'f'. There are also asterisks and 'Ped' markings indicating pedal use.

- Polyphony



Main Melody



Additional melody line

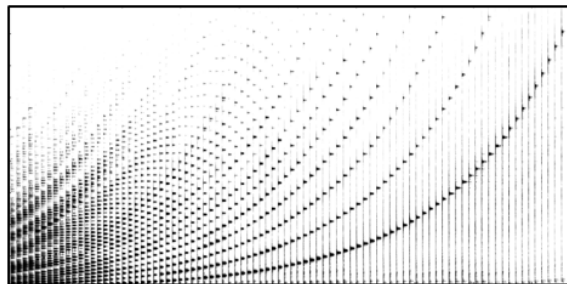


Accompaniment

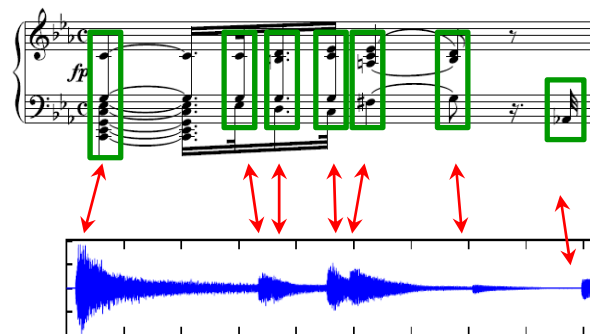


# Music Processing

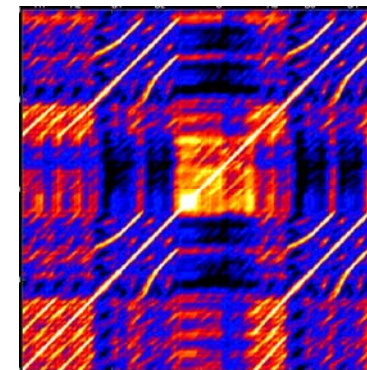
**Fourier Transform  
Audio Features**



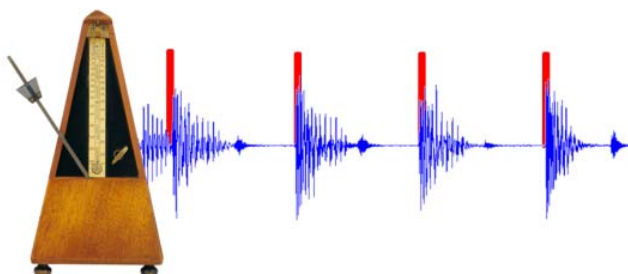
**Music Synchronization**



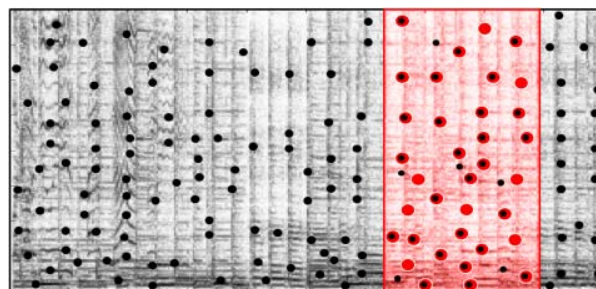
**Structure Analysis**



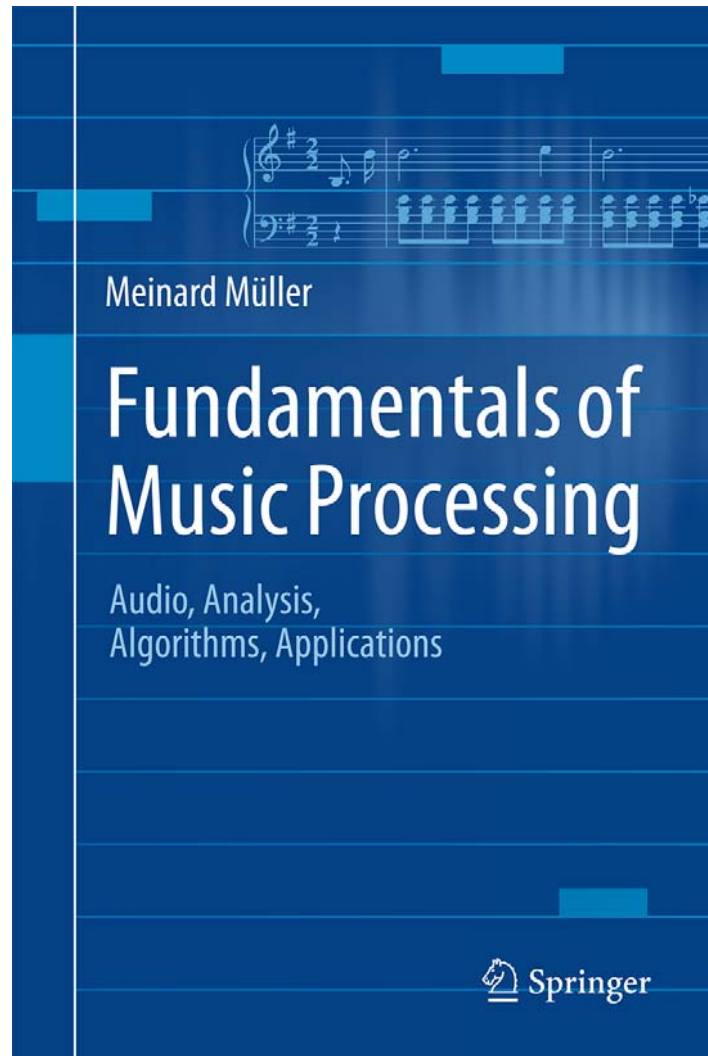
**Tempo and Beat Tracking**



**Audio Identification**



# Book: Fundamentals of Music Processing



Meinard Müller

Fundamentals of Music Processing

Audio, Analysis, Algorithms, Applications

483 p., 249 illus., hardcover

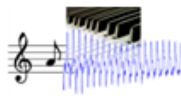

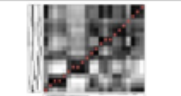


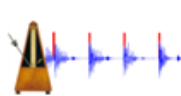
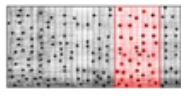
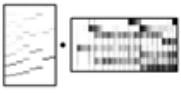
ISBN: 978-3-319-21944-8

Springer, 2015

Accompanying website:

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

# Book: Fundamentals of Music Processing

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

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