

Lecture

Music Processing

Introduction

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Music

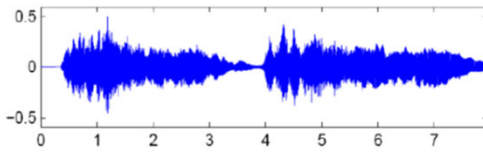


Music Information Retrieval (MIR)

Sheet Music (Image)



CD / MP3 (Audio)



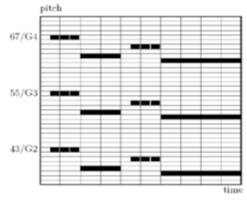
MusicXML (Text)

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  <pitch>  
    <step>E</step>  
    <alter>-1</alter>  
    <octave>4</octave>  
  </pitch>  
  <duration>2</duration>  
  <type>half</type>  
</note>
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Dance / Motion (Mocap)



MIDI



Singing / Voice (Audio)



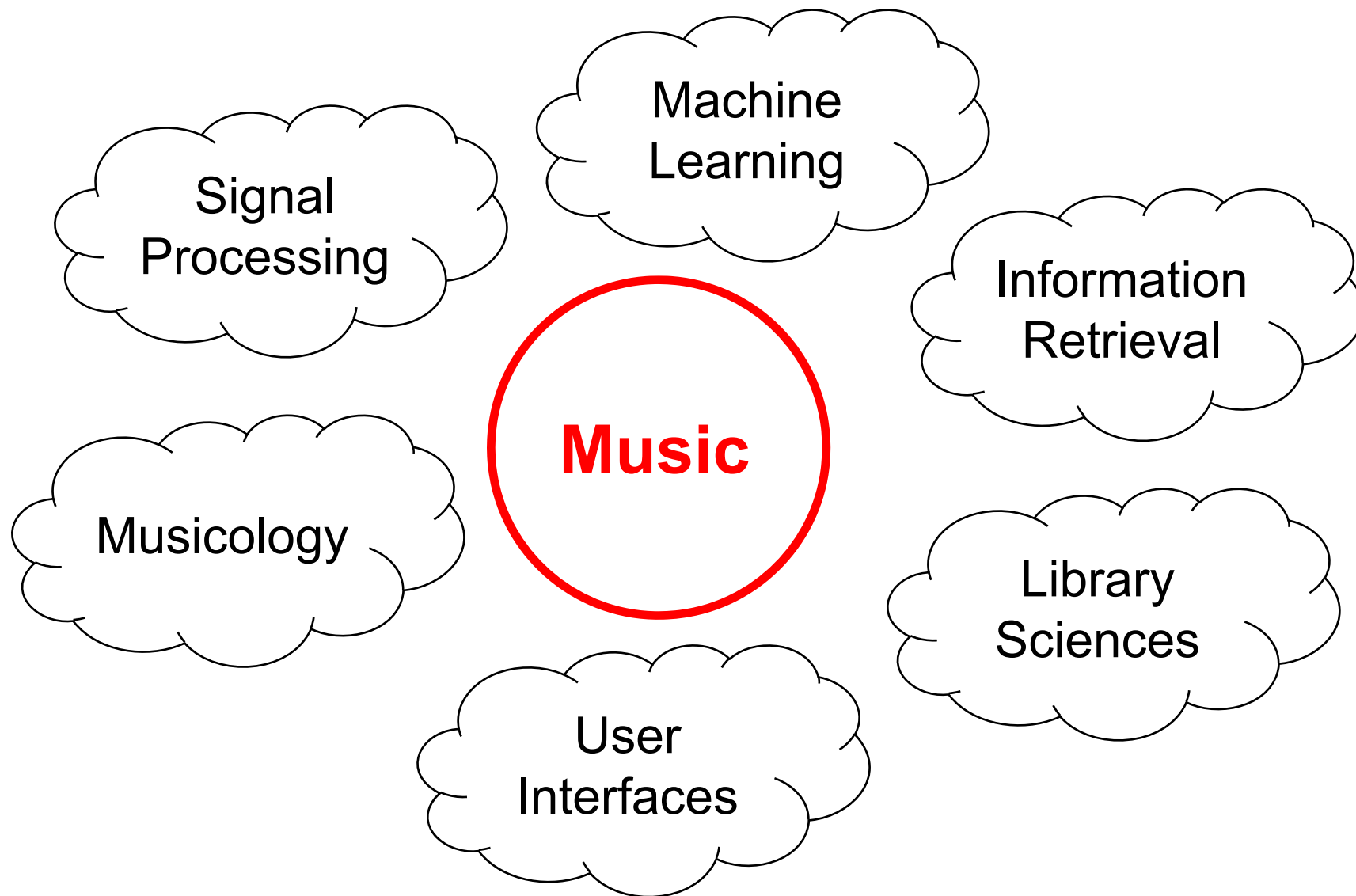
Music Film (Video)



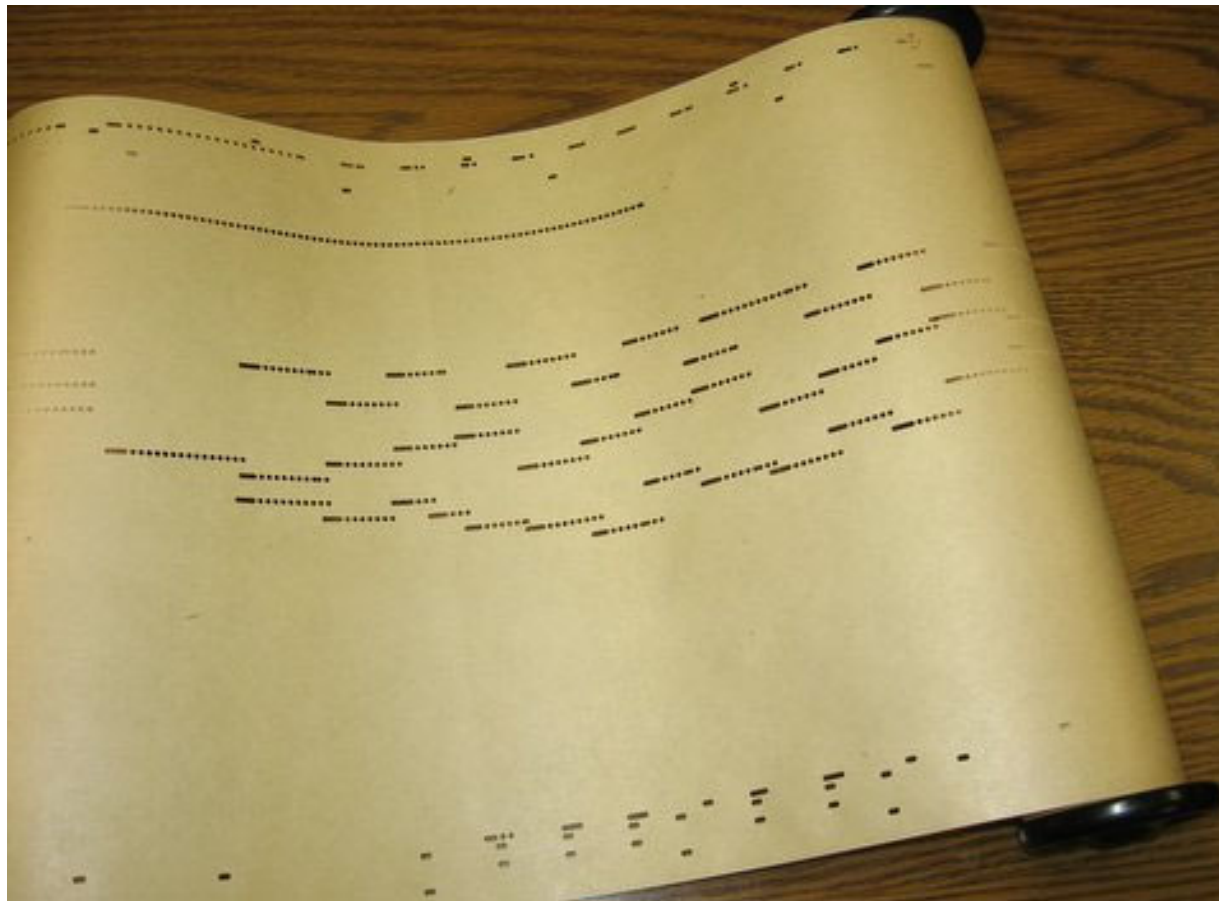
Music Literature (Text)



Music Information Retrieval (MIR)



Piano Roll Representation



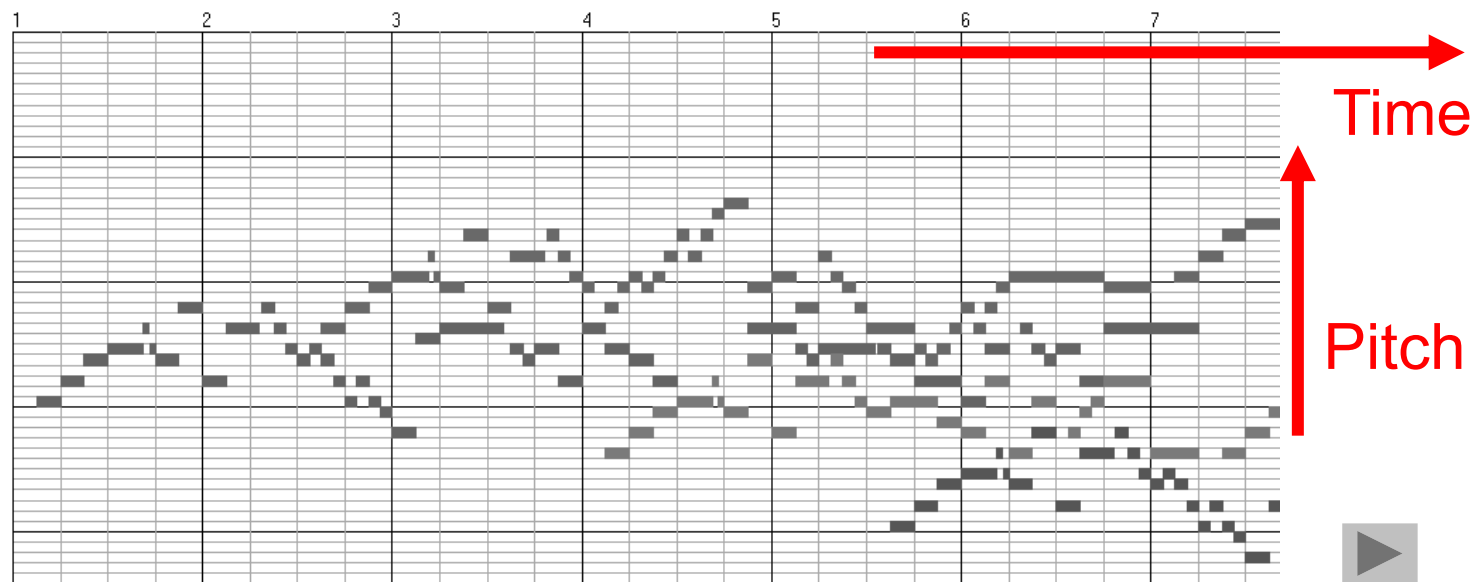
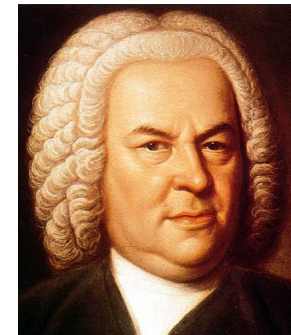
Player Piano (1900)



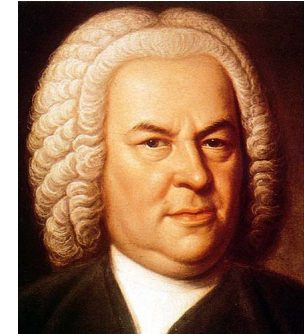
Piano Roll Representation (MIDI)

J.S. Bach, C-Major Fuge

(Well Tempered Piano, BWV 846)



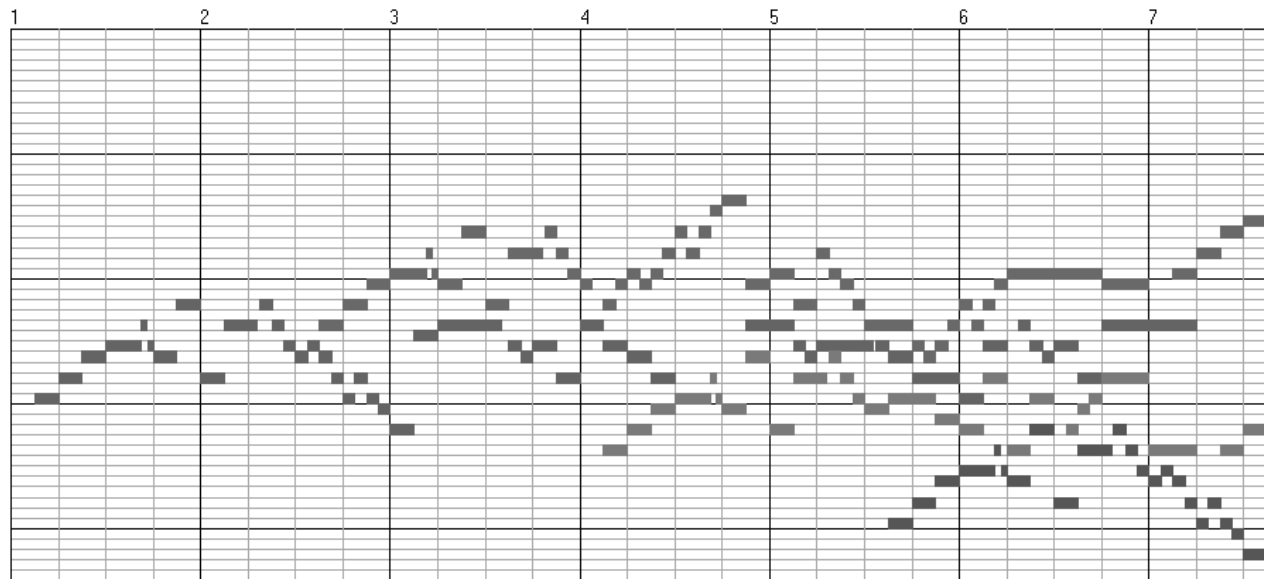
Piano Roll Representation (MIDI)



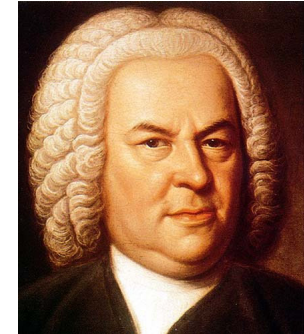
Query:



Goal: Find all occurrences of the query



Piano Roll Representation (MIDI)

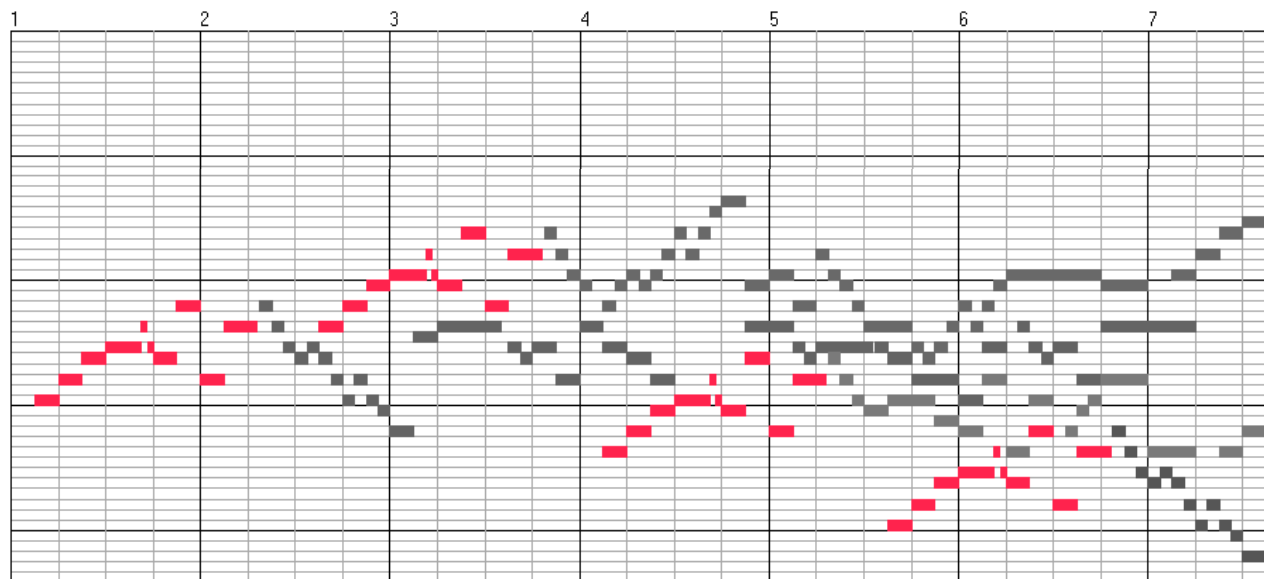


Query:

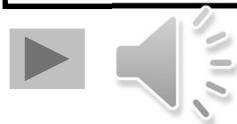
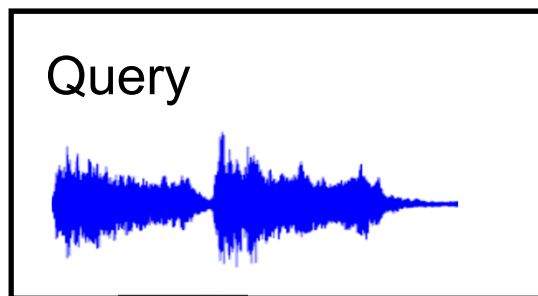


Goal: Find all occurrences of the query

Matches:



Music Retrieval

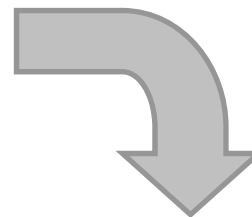
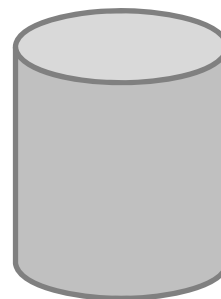


Audio-ID

Version-ID

Category-ID

Database



Hit

Bernstein (1962)
Beethoven, Symphony No. 5

Beethoven, Symphony No. 5:

- Bernstein (1962)
- Karajan (1982)
- Gould (1992)

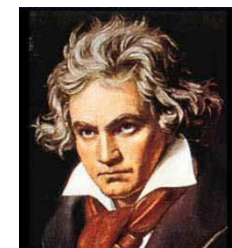


- Beethoven, Symphony No. 9
- Beethoven, Symphony No. 3
- Haydn Symphony No. 94



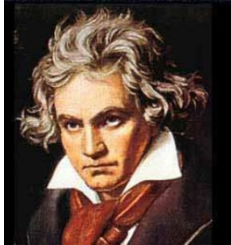
Music Synchronization: Audio-Audio

Beethoven's Fifth

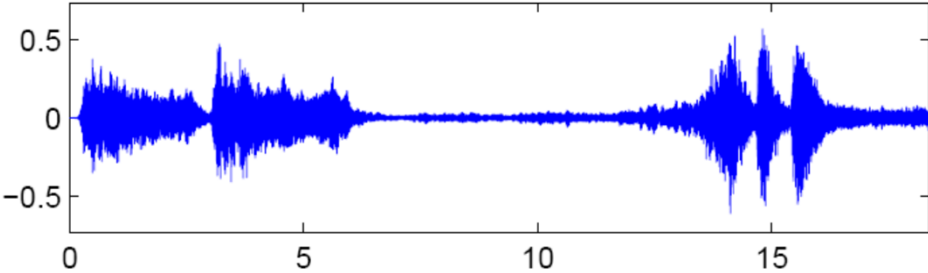


Music Synchronization: Audio-Audio

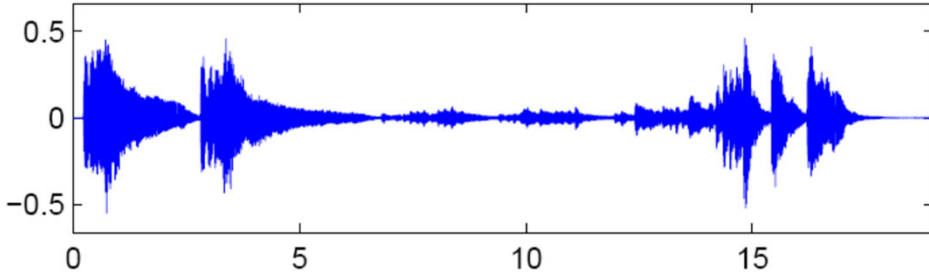
Beethoven's Fifth



Orchester
(Karajan)



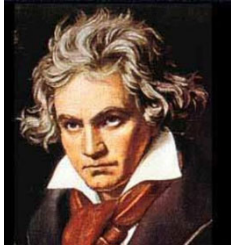
Piano
(Scherbakov)



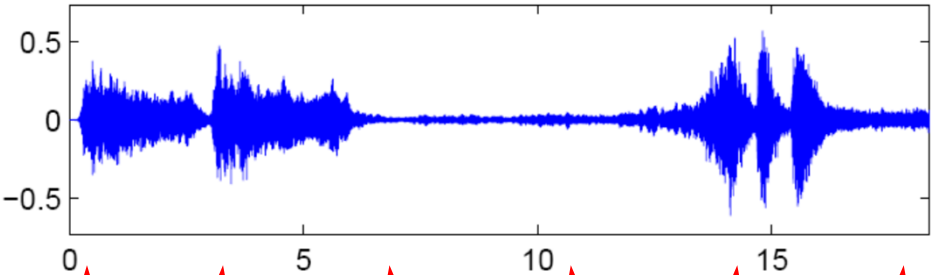
Time (seconds)

Music Synchronization: Audio-Audio

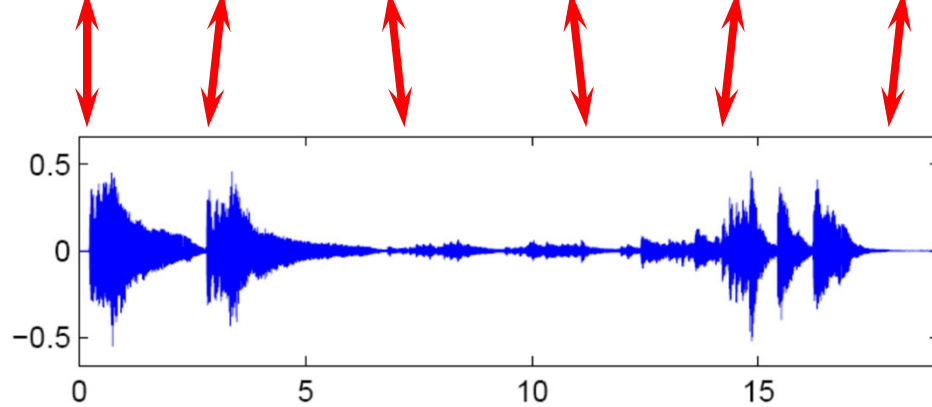
Beethoven's Fifth



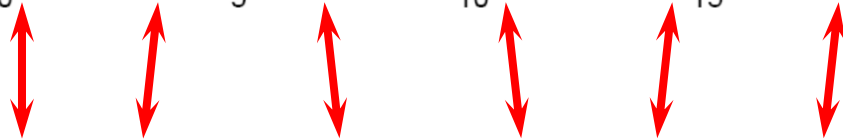
Orchester
(Karajan)



Piano
(Scherbakov)



Time (seconds)



Application: Interpretation Switcher

The screenshot shows the 'Interpretation Switcher' application window. The title bar reads 'Interpretation Switcher' and the subtitle is 'Beethoven, Op067-1_Symphony5'. The main area displays four horizontal bars representing different interpretations: 'midi', 'Bernstein', 'Sawallisch', and 'Scherbakov'. Each bar is divided into three segments: blue, red, and green. The 'midi' bar has the shortest segments, while 'Bernstein' has the longest. The 'Sawallisch' bar has a slight curve over the blue segment. Each bar has a play button icon on the left and a timestamp '00:00.00' on the right. On the right side, there is a list of checked checkboxes: 'midi', 'Bernstein', 'Sawallisch', and 'Scherbakov'. Below this list is a 'Deselect all' button. At the bottom, there is a control bar with the following elements: 'Absolute' (checked), 'Relative', 'Reference', a play button icon, a square icon, a double arrow icon, 'Movement selection', an 'Interval Repeat' checkbox, and an 'Info' button with a question mark icon.



Music Synchronization: Image-Audio

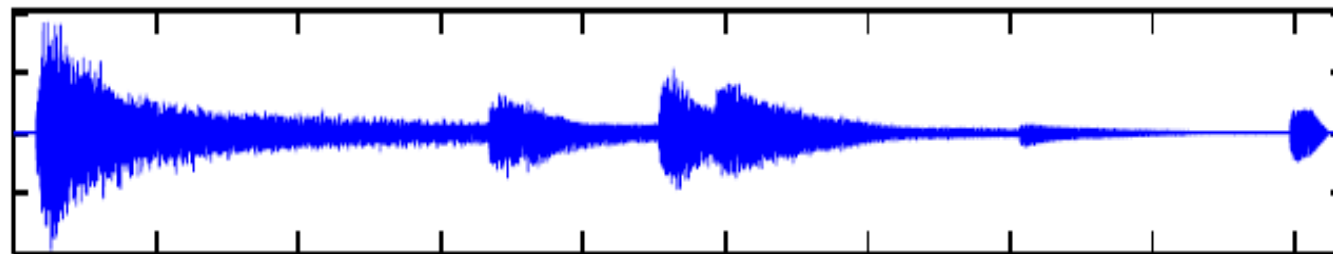
Image

Grave.

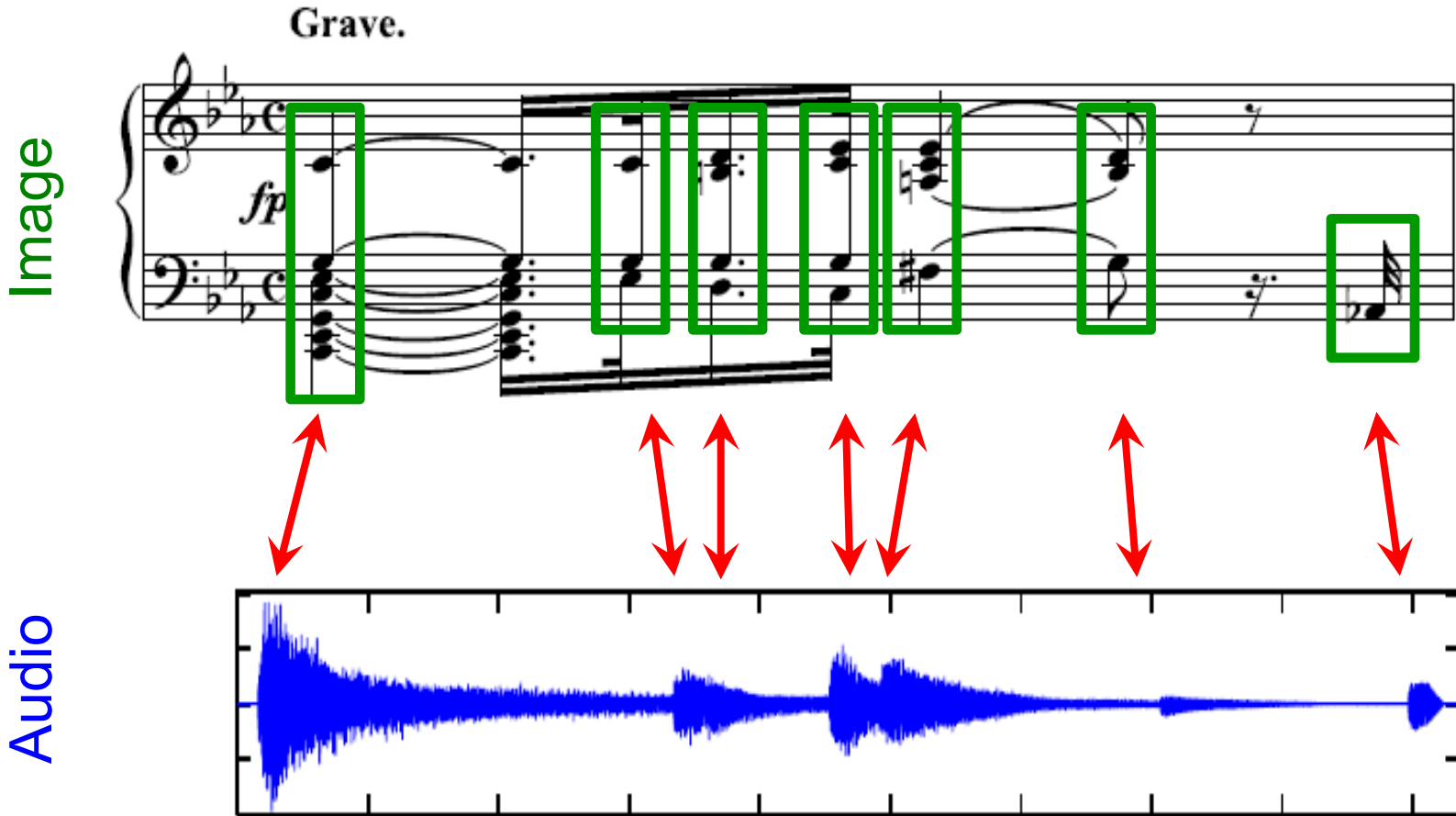


The image shows a musical score for piano, marked "Grave." and "fp". The score is written in G major (one sharp) and common time (C). It consists of two staves: a treble clef staff and a bass clef staff. The music features a slow, somber tempo with a focus on sustained chords and melodic lines. The first staff begins with a treble clef, a key signature of one sharp (F#), and a common time signature (C). The second staff begins with a bass clef, the same key signature, and a common time signature. The music is characterized by a slow, steady pace, with a focus on sustained chords and melodic lines. The first staff begins with a treble clef, a key signature of one sharp (F#), and a common time signature (C). The second staff begins with a bass clef, the same key signature, and a common time signature. The music is characterized by a slow, steady pace, with a focus on sustained chords and melodic lines.

Audio



Music Synchronization: Image-Audio

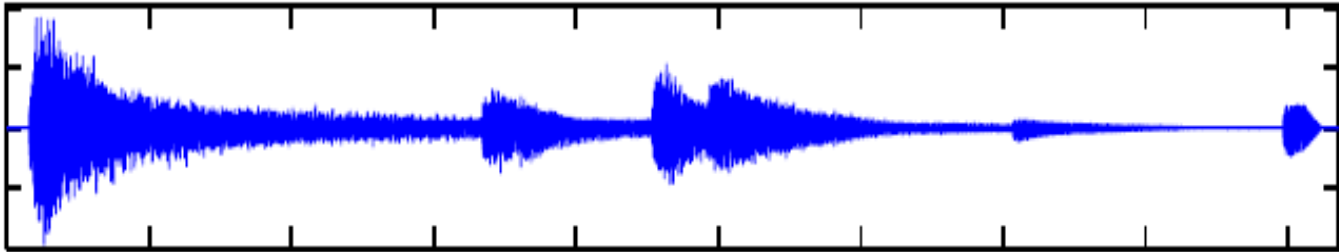


How to make the data comparable?

Image



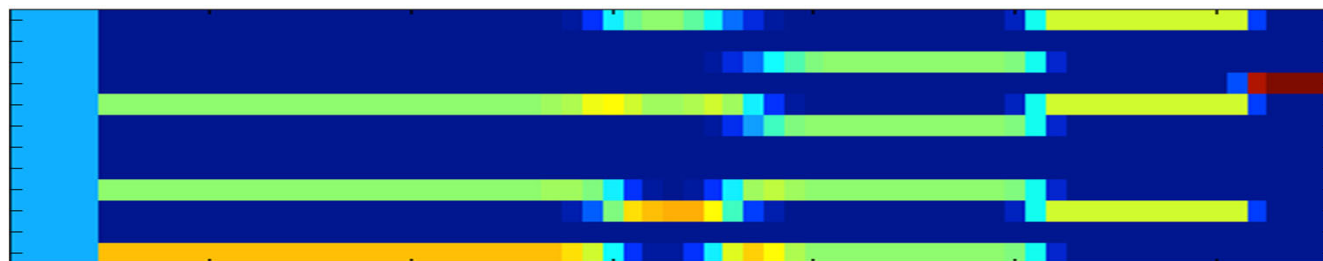
Audio



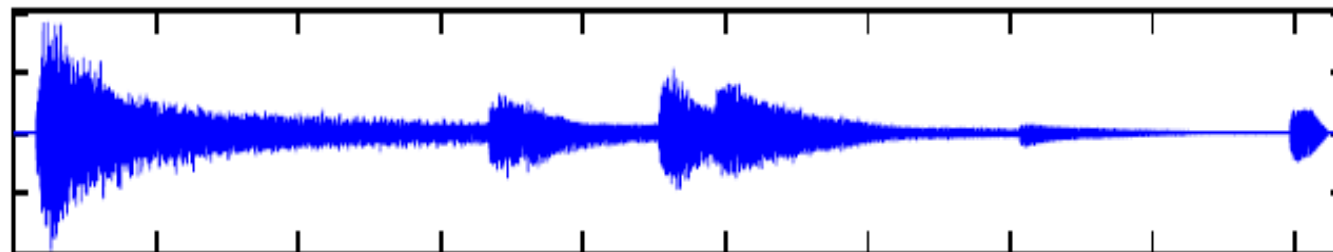
How to make the data comparable?

Image Processing: Optical Music Recognition

Image



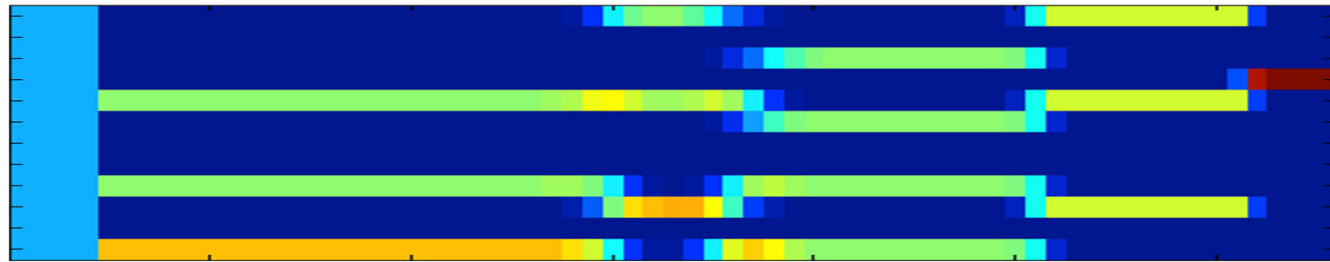
Audio



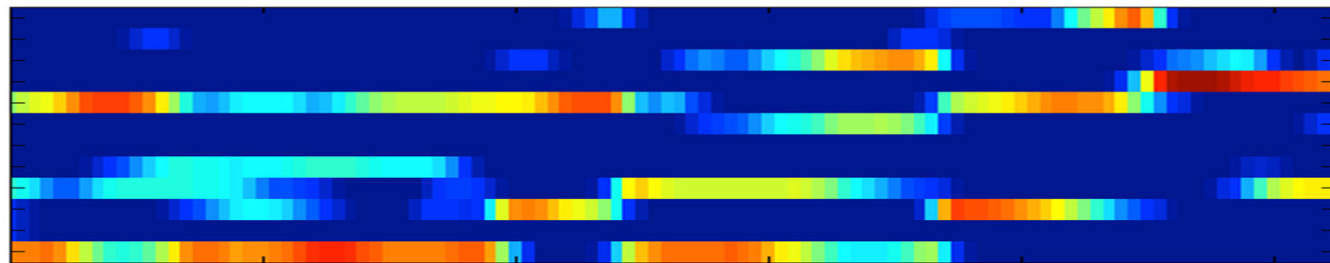
How to make the data comparable?

Image Processing: Optical Music Recognition

Image



Audio

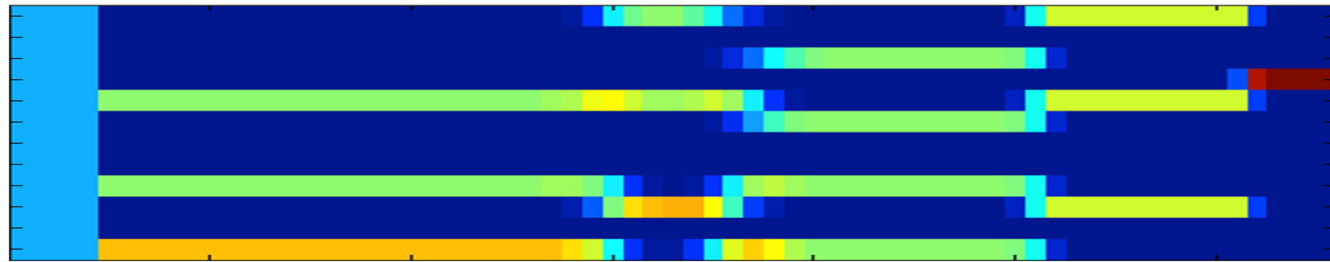


Audio Processing: Fourier Analysis

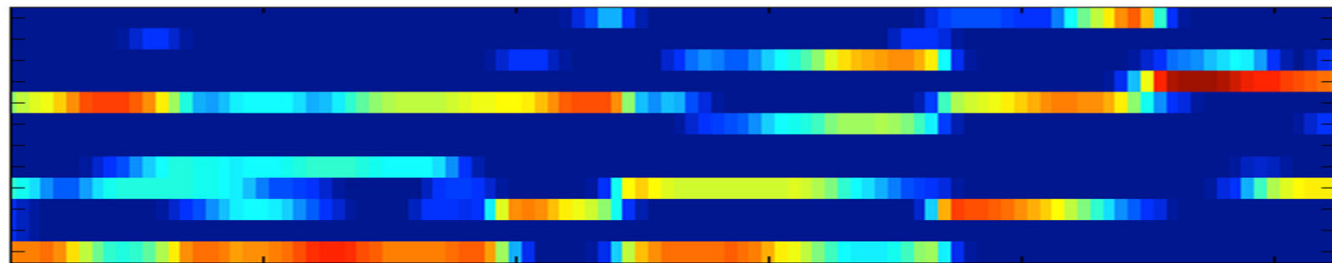
How to make the data comparable?

Image Processing: Optical Music Recognition

Image



Audio



Audio Processing: Fourier Analysis



Application: Score Viewer

The image displays a music application interface with two main windows: ScoreViewer and AudioViewer.

ScoreViewer: This window shows a digital score for Beethoven's Piano Sonata no. 8 in C minor, op. 13, "Pathétique", Rondo (Allegro). The score is displayed in a standard musical notation format. Below the score, there are navigation controls: Track: 29 / 54, Bar: 1 / 211, and Page: 159 / 285. There are also buttons for "Score Following On", "Play", and "Stop".

AudioViewer: This window shows a track list for "Beethoven - Piano Sonatas - Alfred Brendel". The track list includes:

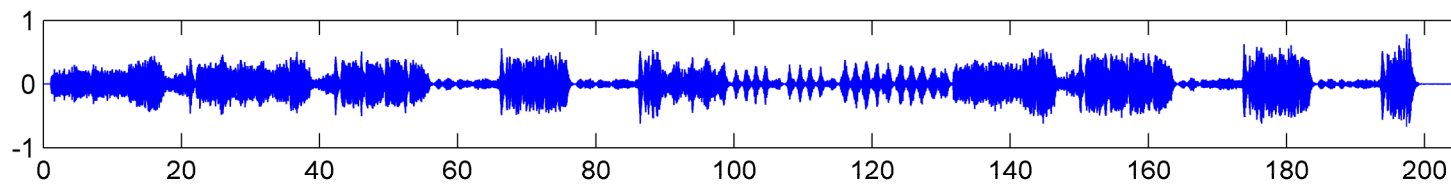
Track	Track Name	Duration
03	Sonata no.1 in F minor, op.2 no.1 / Menuetto (Allegretto)	3:24
04	Sonata no.1 in F minor, op.2 no.1 / Prestissimo	5:32
05	Sonata no.2 in A major, op.2 no.2 / Allegro vivace	7:15
06	Sonata no.2 in A major, op.2 no.2 / Largo appassionato	6:28
07	Sonata no.2 in A major, op.2 no.2 / Scherzo (Allegretto)	3:30
08	Sonata no.2 in A major, op.2 no.2 / Rondo (Grazioso)	7:03
09	Sonata no.6 in C minor, op.13 "Pathétique" / Allegro di molto e con brio	9:40
10	Sonata no.8 in C minor, op.13 "Pathétique" / Adagio sostenuto	5:17
11	Sonata no.8 in C minor, op.13 "Pathétique" / Rondo (Allegro)	4:30

Below the track list, there are navigation controls: Disc: 1 / 11, Track: 11 / 11, and Time: 00:00.00 / 4:30.35. There are also buttons for "Play" and "Stop".



Music Structure Analysis

Example: Brahms Hungarian Dance No. 5 (Ormandy)

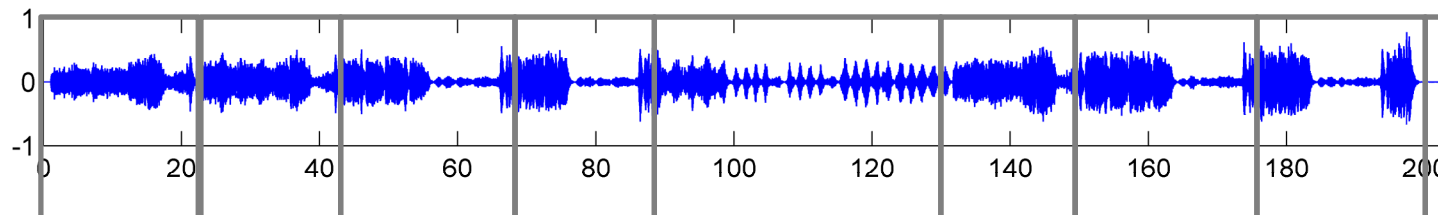


Time (seconds)

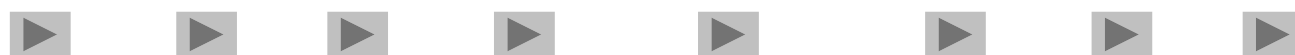


Music Structure Analysis

Example: Brahms Hungarian Dance No. 5 (Ormandy)

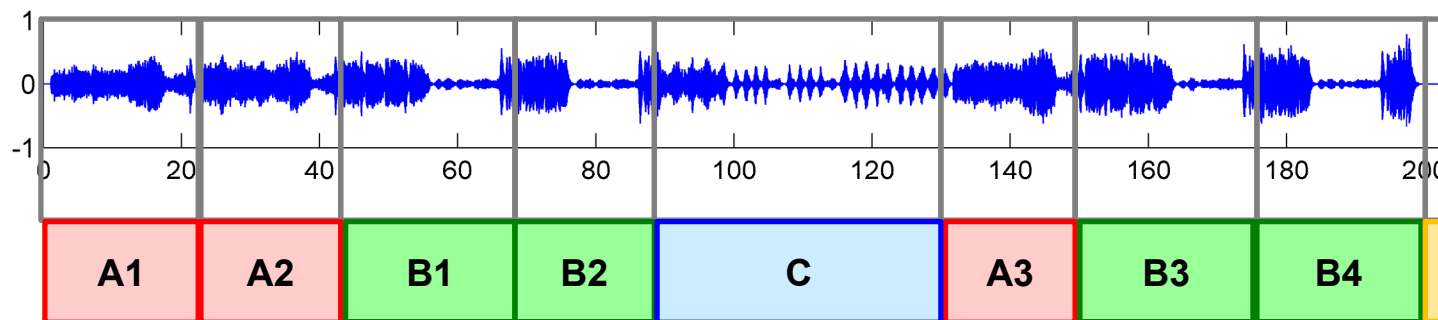


Time (seconds)



Music Structure Analysis

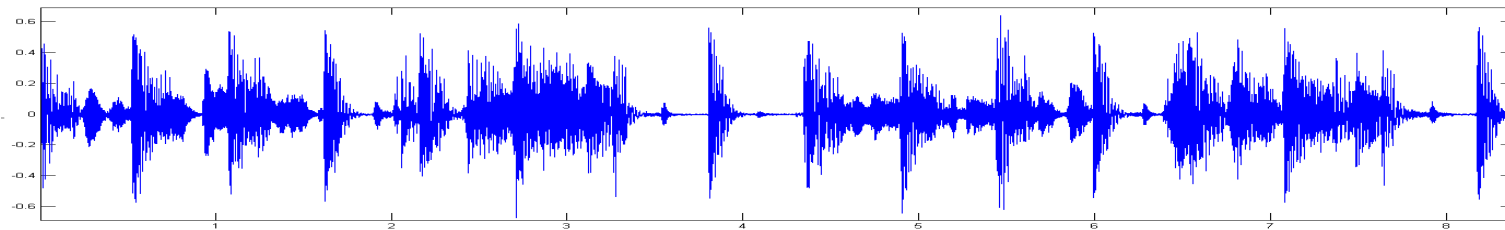
Example: Brahms Hungarian Dance No. 5 (Ormandy)



Tempo Estimation and Beat Tracking

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

Example: Queen – Another One Bites The Dust



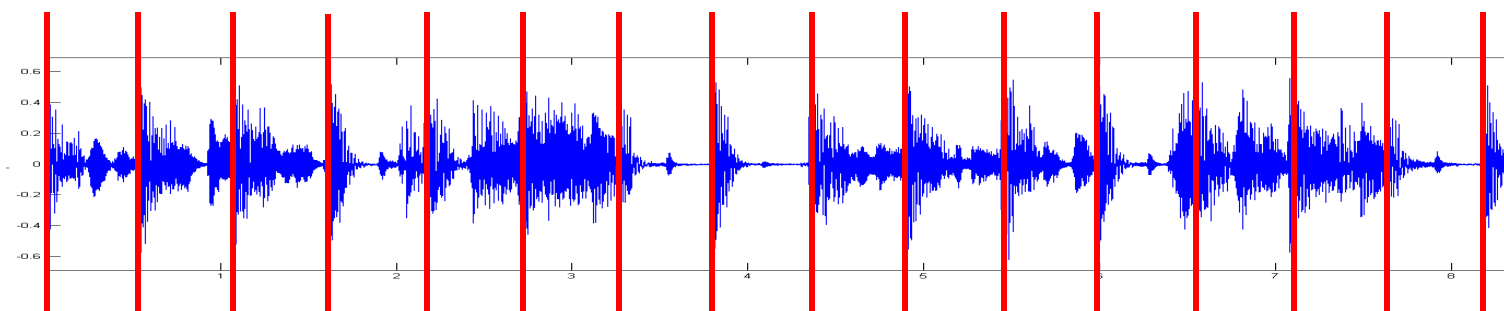
Time (seconds)



Tempo Estimation and Beat Tracking

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

Example: Queen – Another One Bites The Dust



Time (seconds)



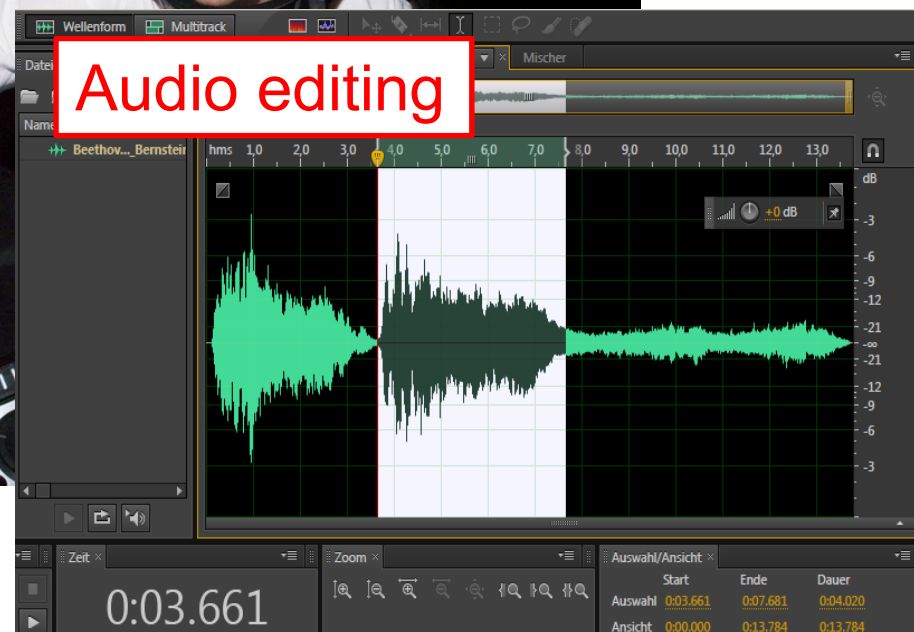
Tempo Estimation and Beat Tracking

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.

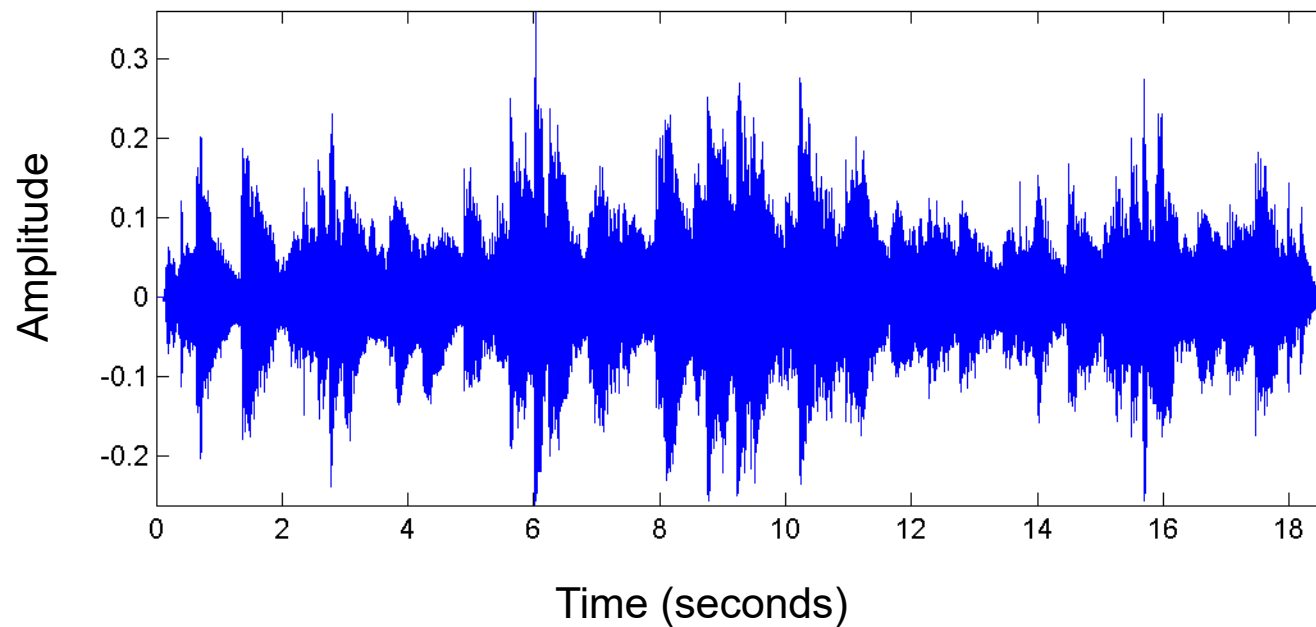
41. Allegretto. *p*

The image shows two systems of musical notation for measures 41-50 of Chopin's Mazurka Op. 63 No. 3. The first system (measures 41-46) features a treble clef with a melody marked 'Allegretto.' and 'p'. The melody includes triplets and a fourth-note figure. The bass clef accompaniment consists of chords marked 'Ped.' and asterisks. The second system (measures 47-50) continues the melody and accompaniment with similar markings.

Why is Music Processing Challenging?

Example: Chopin, Mazurka Op. 63 No. 3

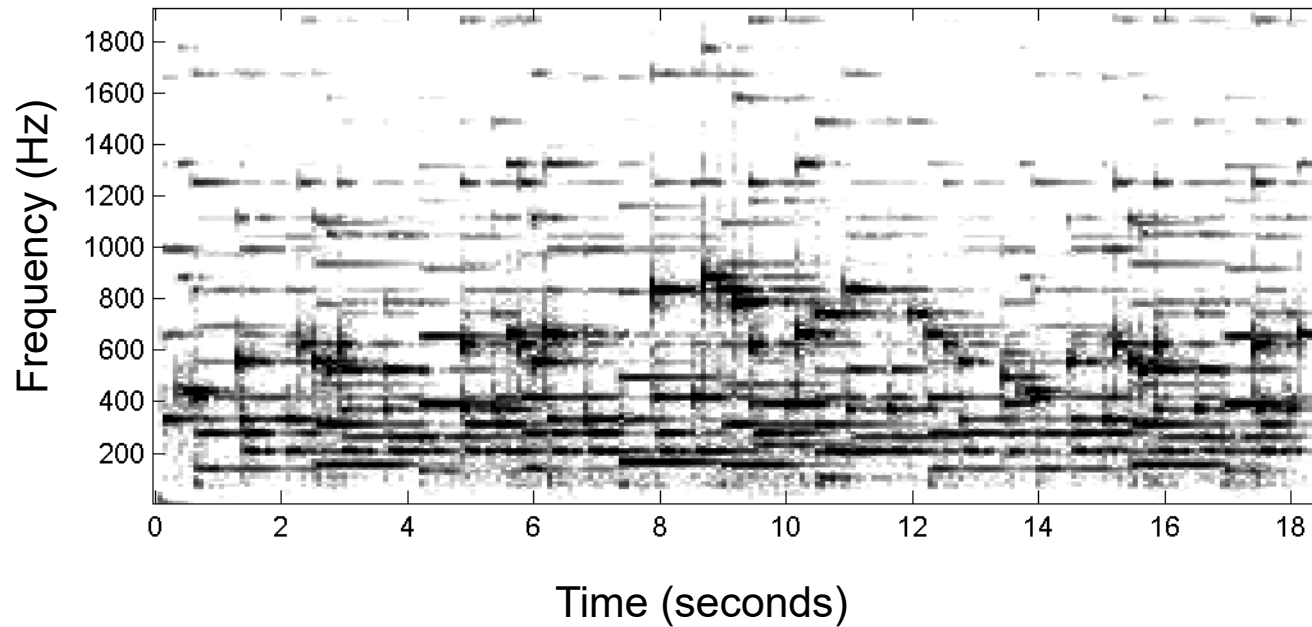
- Waveform



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 information: 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 under the bass line, likely indicating sustain pedal use.

- Polyphony



Main Melody



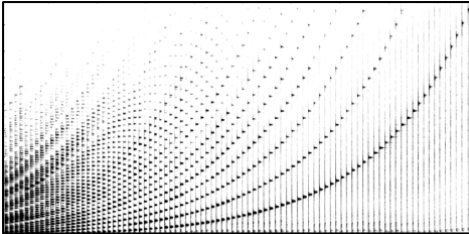
Additional melody line



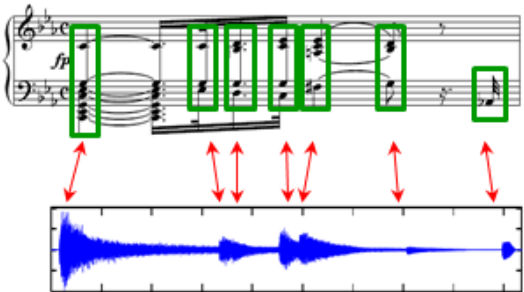
Accompaniment

Music Processing

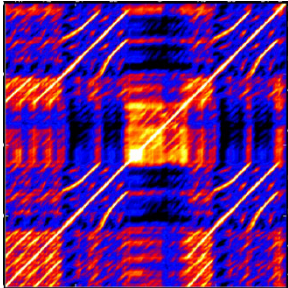
Fourier Transform Audio Features



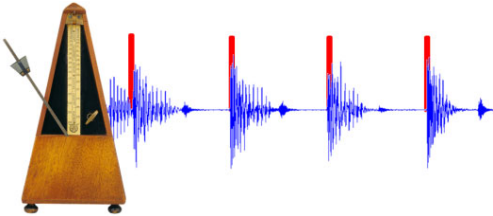
Music Synchronization



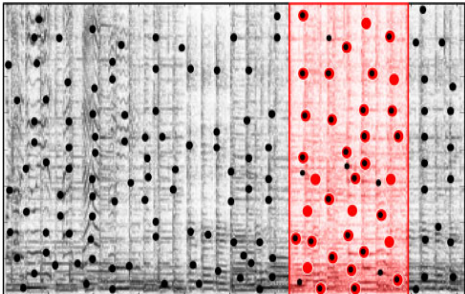
Structure Analysis



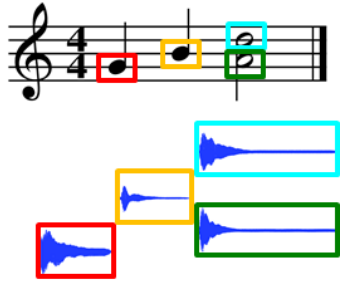
Tempo and Beat Tracking



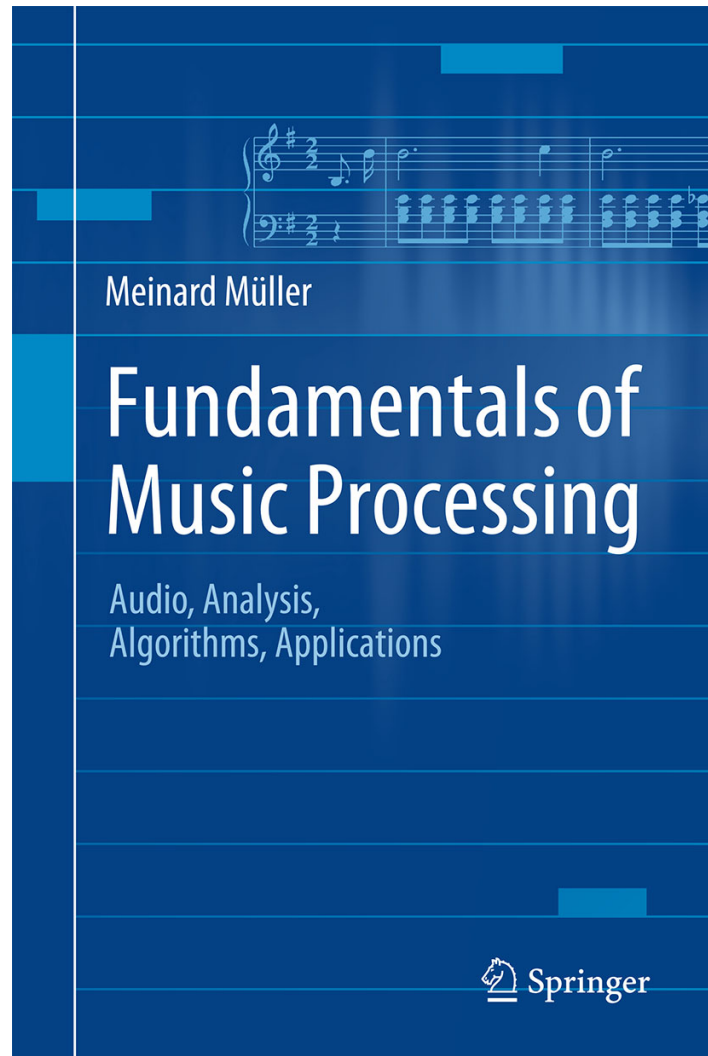
Audio Identification



Audio Decomposition



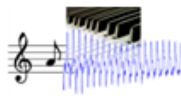

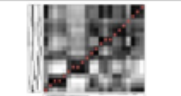
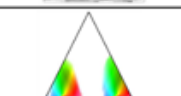

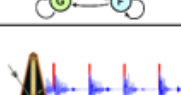


Book: Fundamentals of Music Processing



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 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

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