

Lecture

Music Processing

Introduction

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Music

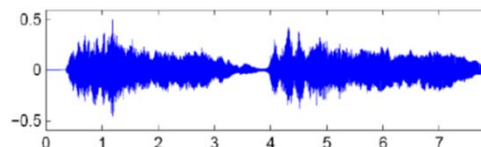


Music Information Retrieval (MIR)

Sheet Music (Image)



CD / MP3 (Audio)



MusicXML (Text)

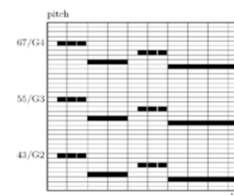
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Dance / Motion (Mocap)



Music

MIDI



Singing / Voice (Audio)



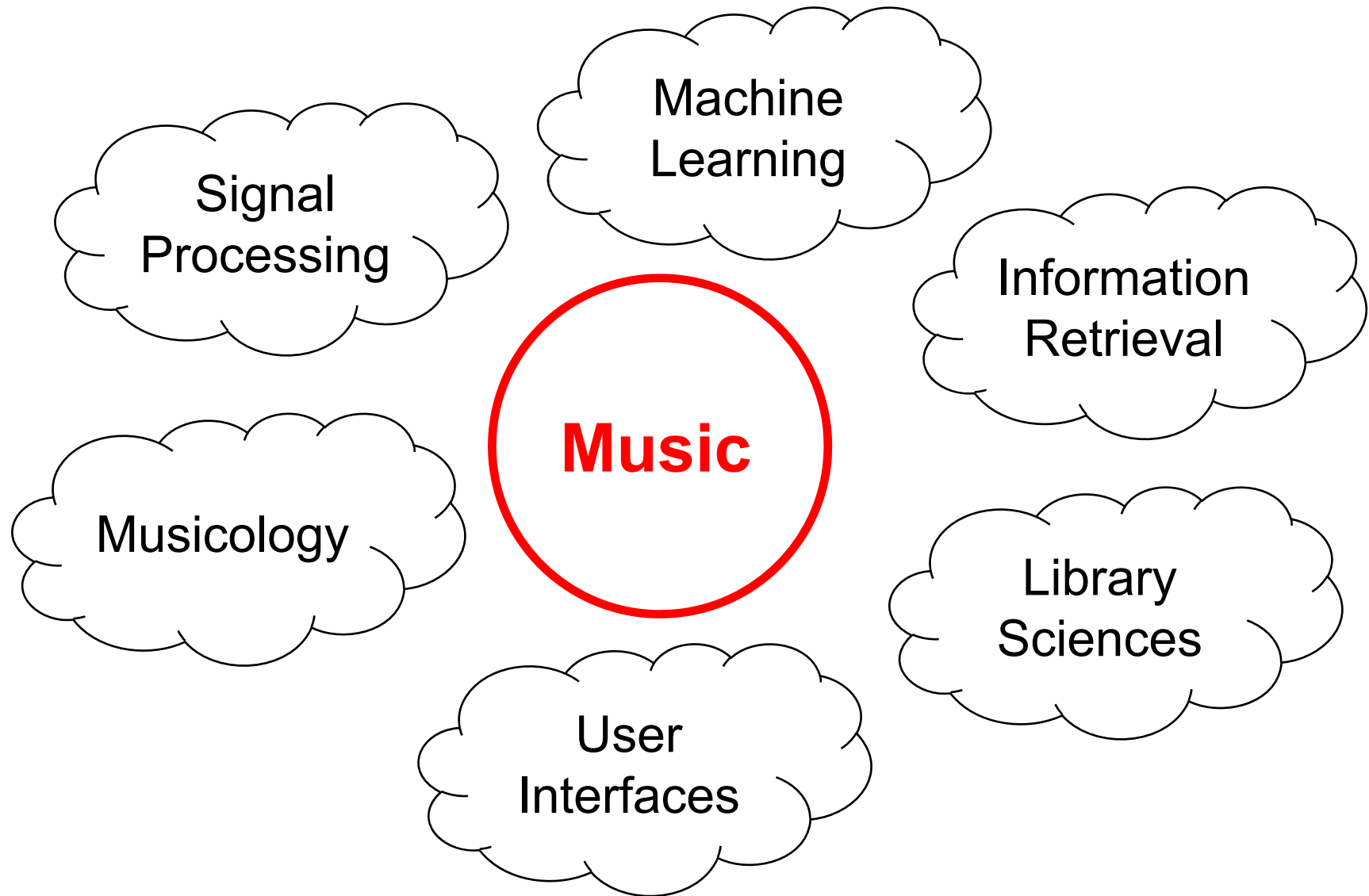
Music Film (Video)



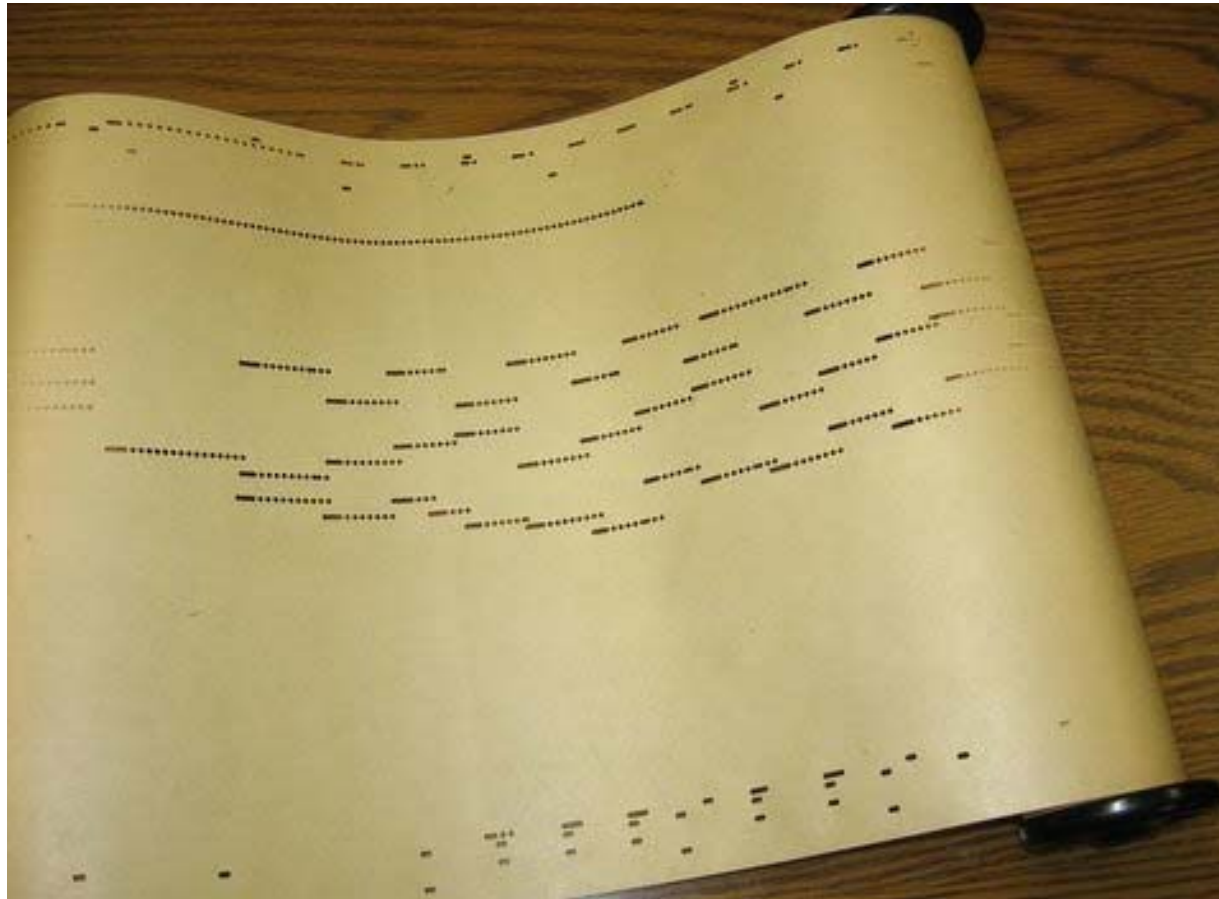
Music Literature (Text)



Music Information Retrieval (MIR)



Piano Roll Representation



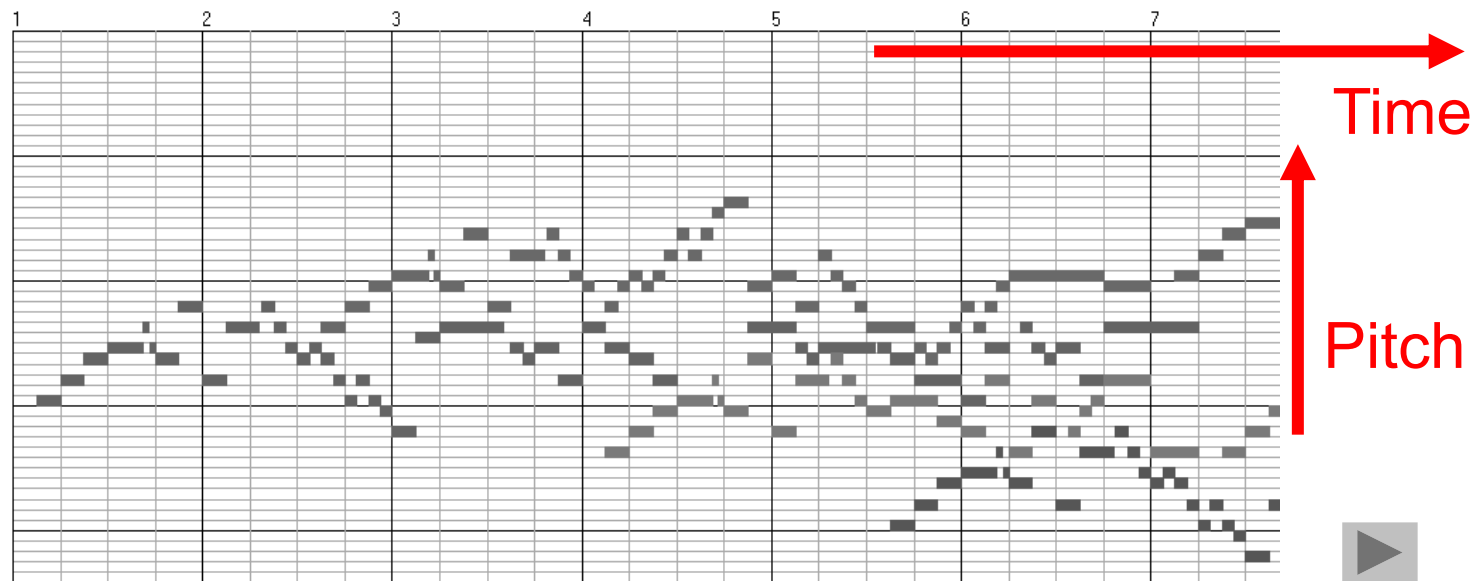
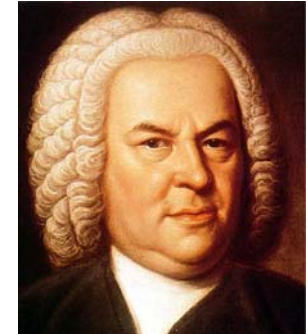
Player Piano (1900)



Piano Roll Representation (MIDI)

J.S. Bach, C-Major Fuge

(Well Tempered Piano, BWV 846)

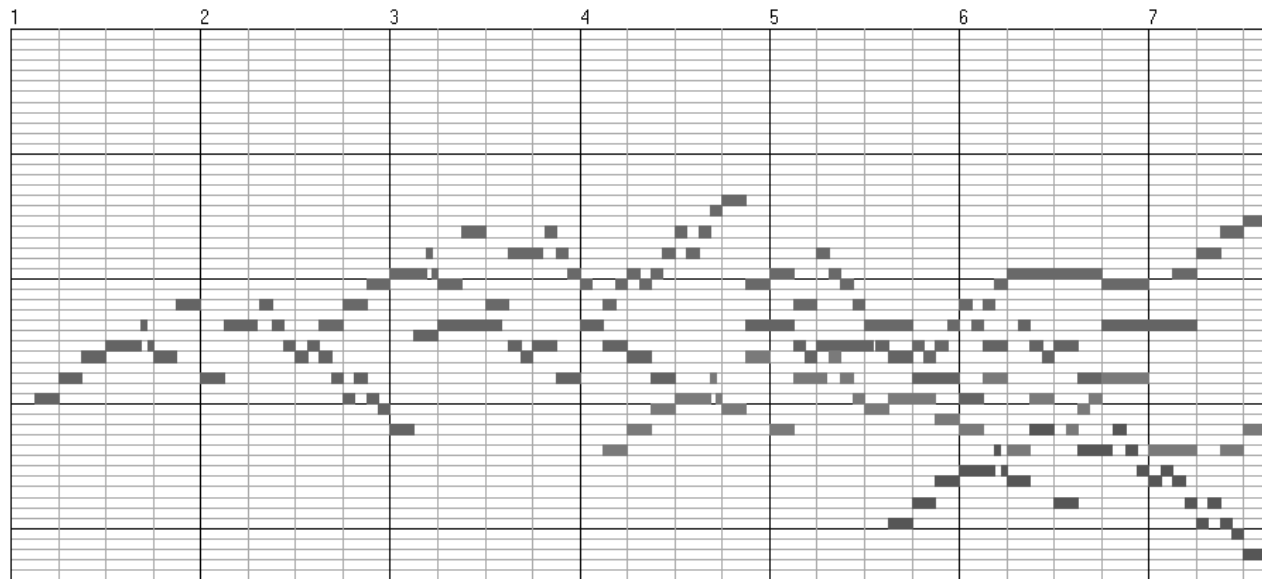
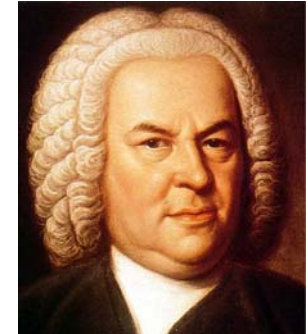


Piano Roll Representation (MIDI)

Query:



Goal: Find all occurrences of the query



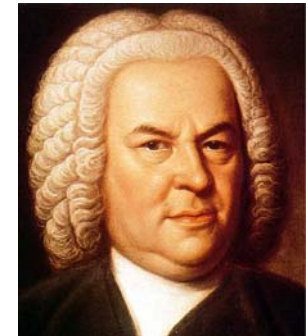
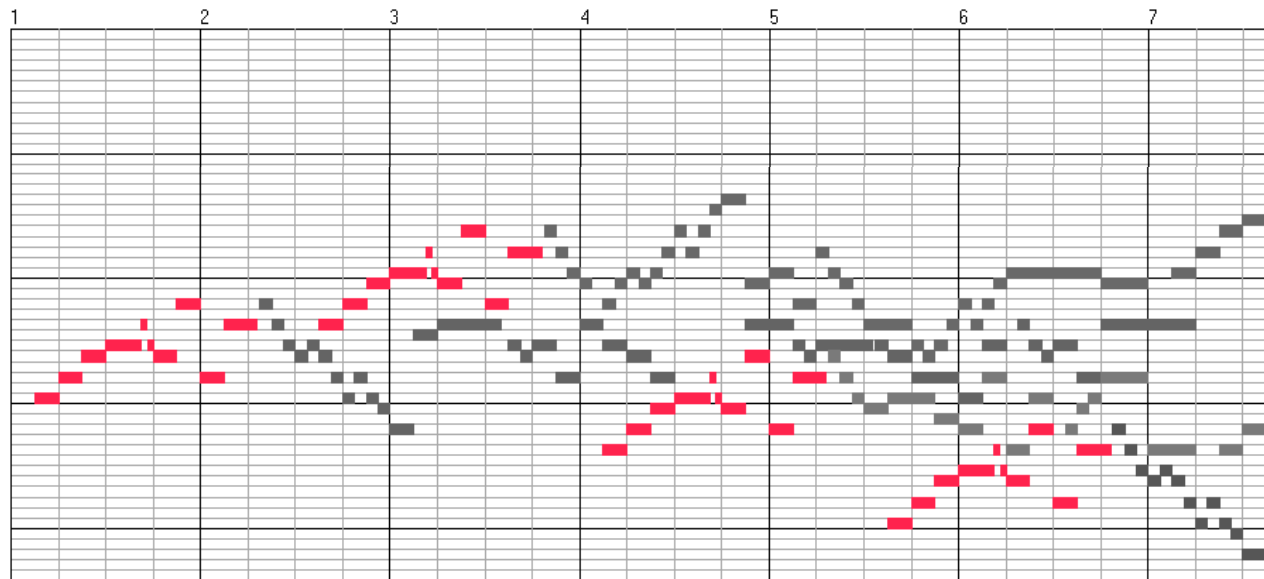
Piano Roll Representation (MIDI)

Query:

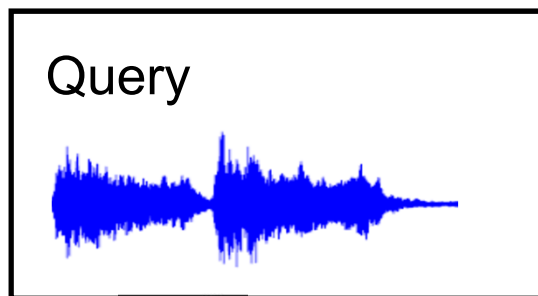


Goal: Find all occurrences of the query

Matches:



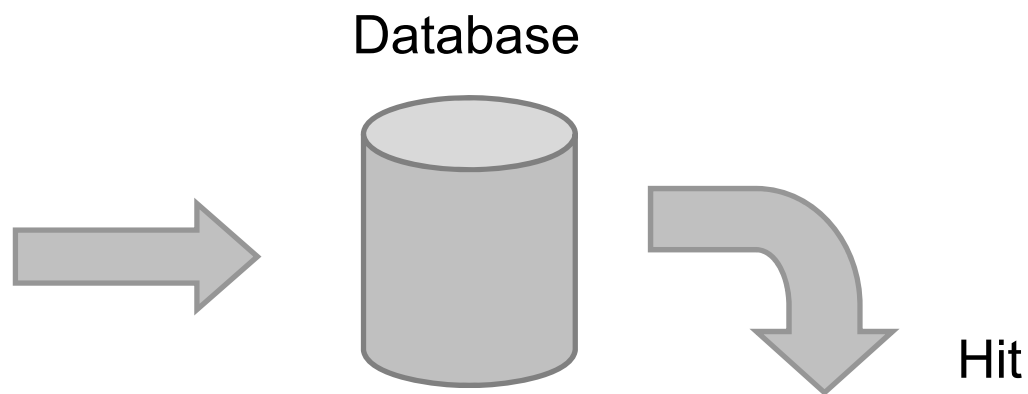
Music Retrieval



Audio-ID

Version-ID

Category-ID



Bernstein (1962)
Beethoven, Symphony No. 5

Beethoven, Symphony No. 5:

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

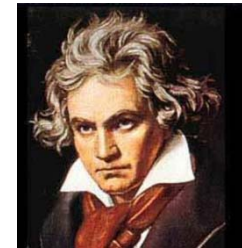


- Beethoven, Symphony No. 9
- Beethoven, Symphony No. 3
- Haydn Symphony No. 94



Music Synchronization: Audio-Audio

Beethoven's Fifth

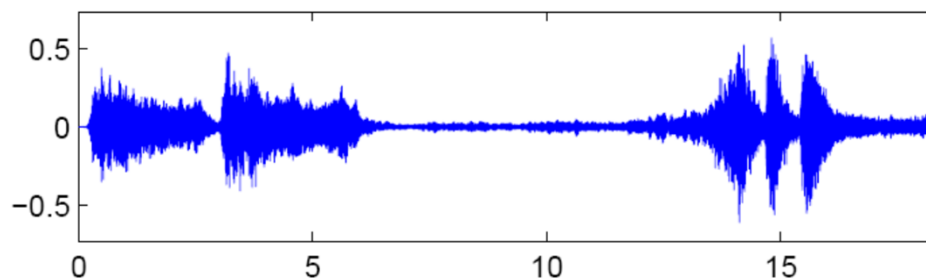


Music Synchronization: Audio-Audio

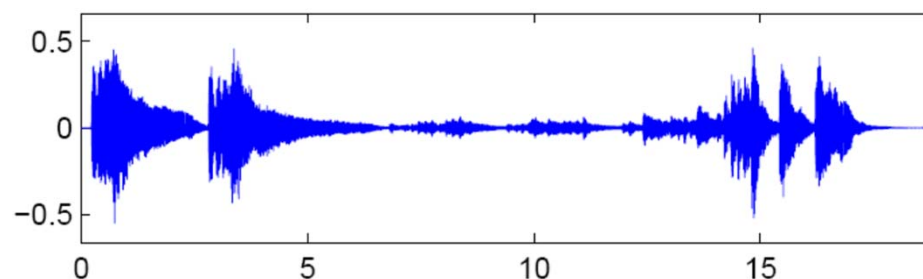
Beethoven's Fifth



Orchester
(Karajan)



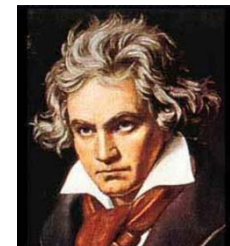
Piano
(Scherbakov)



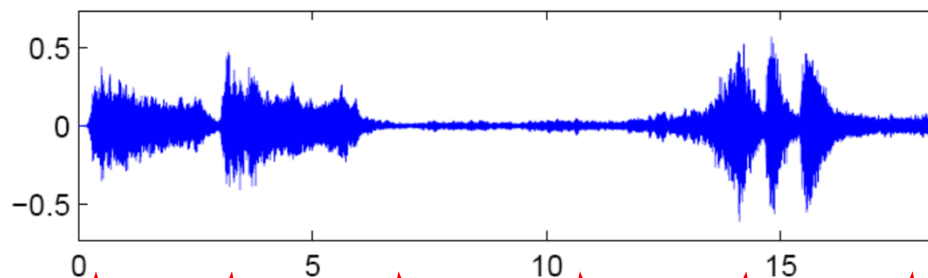
Time (seconds)

Music Synchronization: Audio-Audio

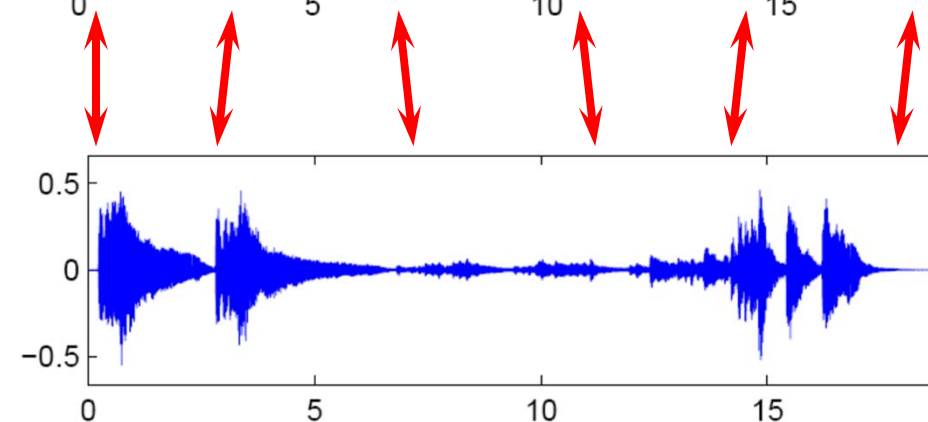
Beethoven's Fifth



Orchester
(Karajan)



Piano
(Scherbakov)



Time (seconds)

Application: Interpretation Switcher

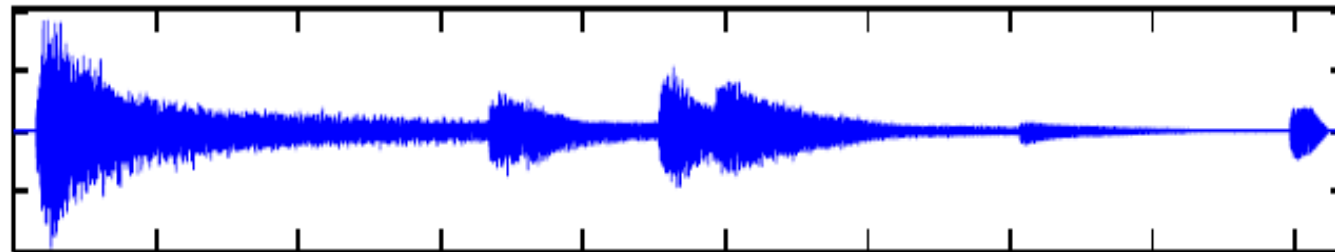


Music Synchronization: Image-Audio

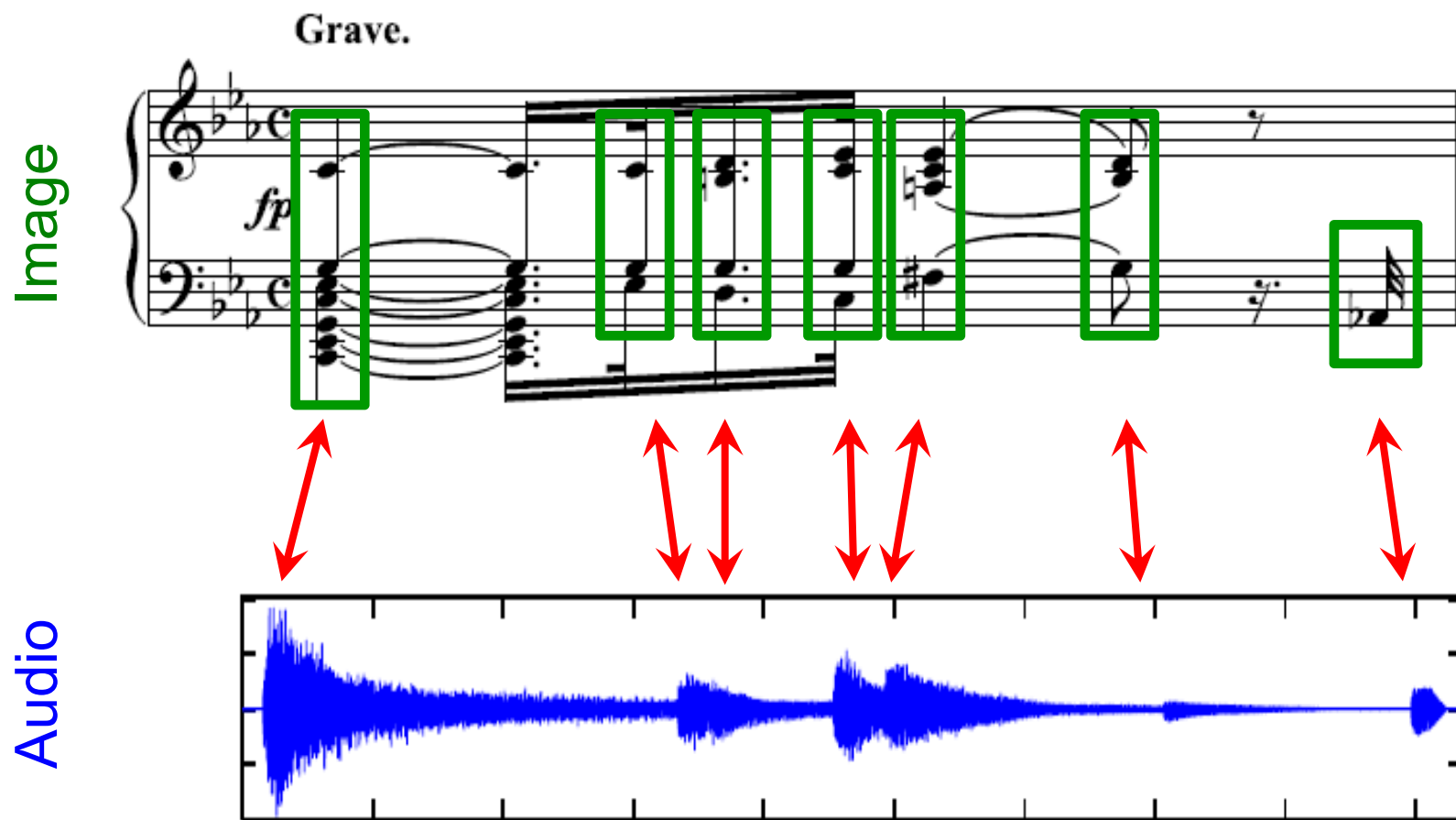
Image



Audio



Music Synchronization: Image-Audio

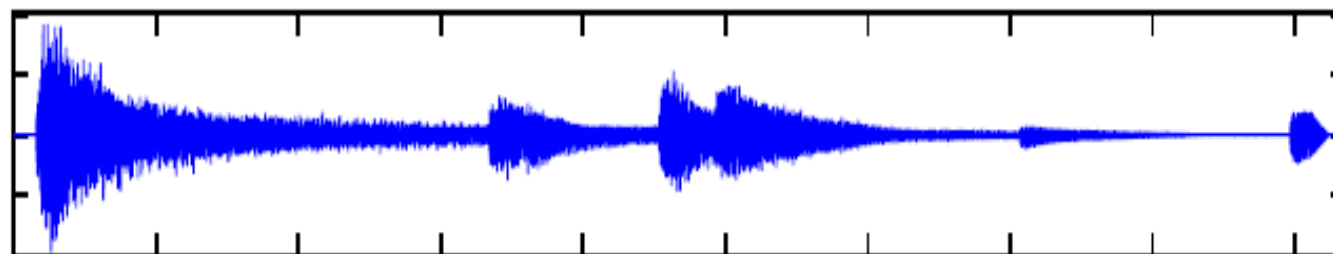


How to make the data comparable?

Image



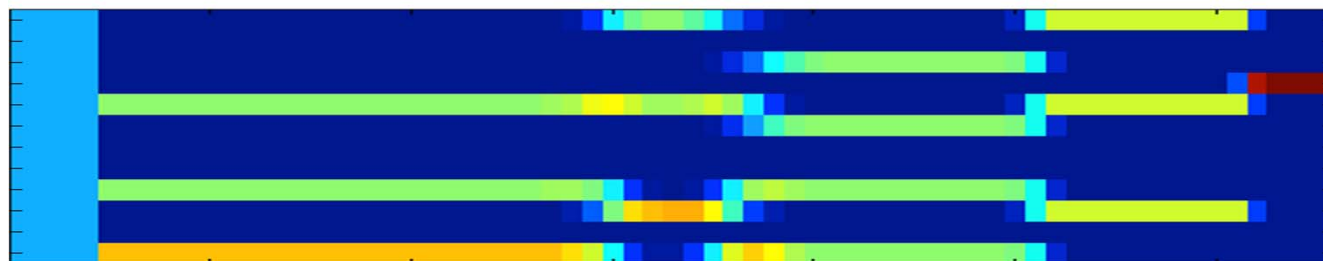
Audio



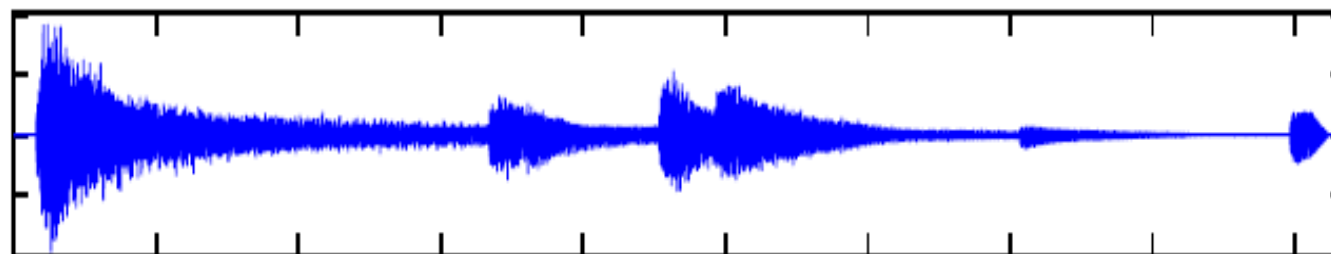
How to make the data comparable?

Image Processing: Optical Music Recognition

Image



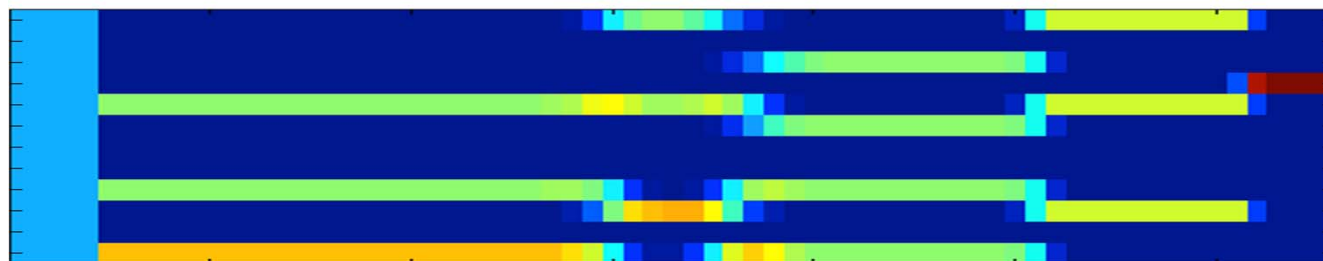
Audio



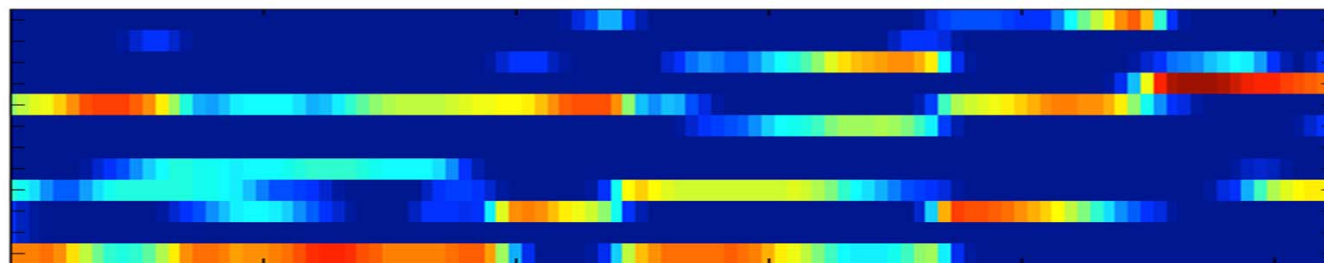
How to make the data comparable?

Image Processing: Optical Music Recognition

Image



Audio

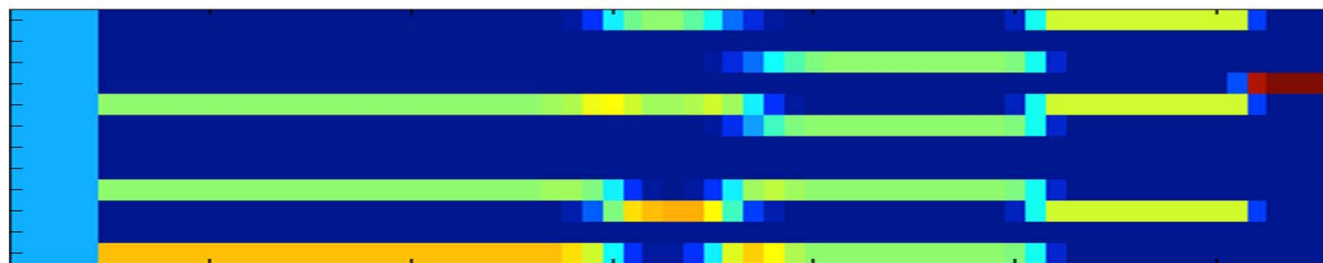


Audio Processing: Fourier Analysis

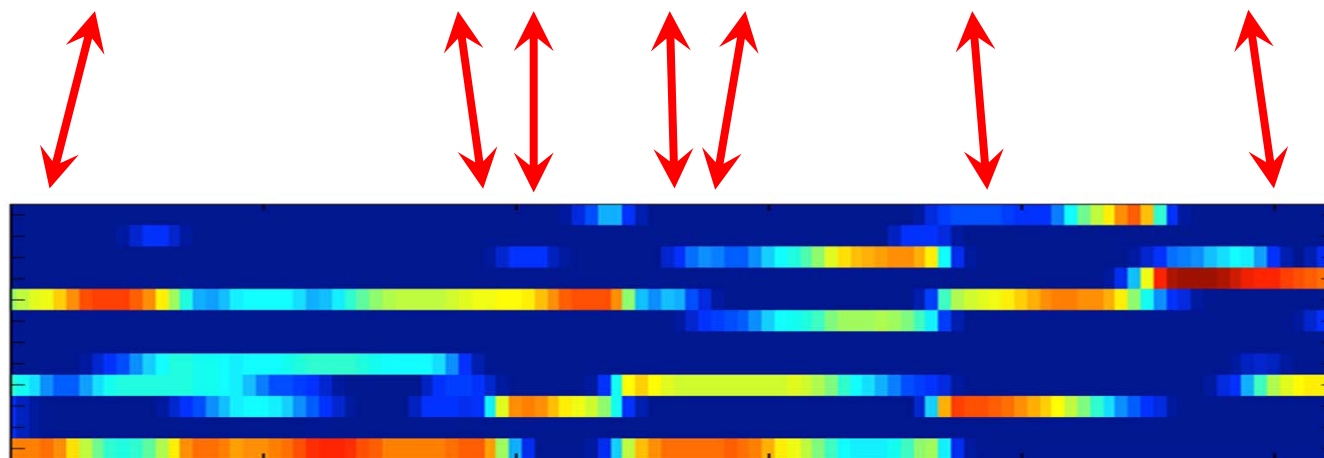
How to make the data comparable?

Image Processing: Optical Music Recognition

Image



Audio



Audio Processing: Fourier Analysis



Application: Score Viewer

The screenshot displays two windows from a music application. The top window, titled "ScoreViewer", shows a musical score for "Beethoven - Klaviersonaten Band 1 - Henle". The score is for "Sonata no.8 in C minor, op.13 'Pathétique' / Rondo (Allegro)". The score is displayed in a multi-staff format. The bottom window, titled "AudioViewer", shows a list of tracks for "Beethoven - Piano Sonatas - Alfred Brendel". The list includes tracks 03 through 11, with track 11, "Sonata no.8 in C minor, op.13 'Pathétique' / Rondo (Allegro)", selected. The audio player interface includes a progress bar and playback controls.

ScoreViewer

Beethoven - Klaviersonaten Band 1 - Henle
Sonata no.8 in C minor, op.13 "Pathétique" / Rondo (Allegro)

Rondo
Allegro

Track: 29 / 54 Bar: 1 / 211 Page: 159 / 285

Score Following On Play Stop

AudioViewer

Beethoven - Piano Sonatas - Alfred Brendel

Disc 1

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.8 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

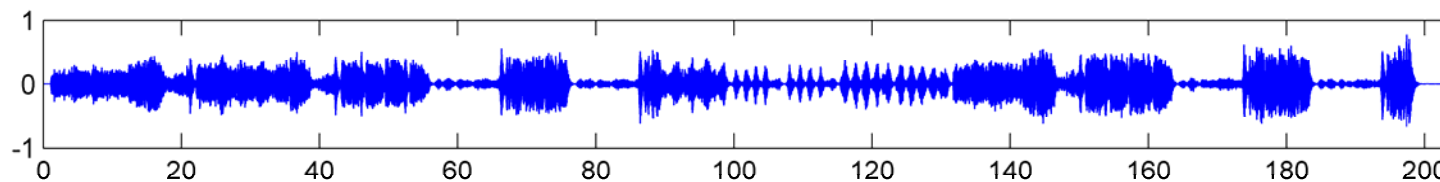
Disc: 1 / 11 Track: 11 / 11 Time: 00:00.00 / 4:30.35

Play Stop



Music Structure Analysis

Example: Brahms Hungarian Dance No. 5 (Ormandy)

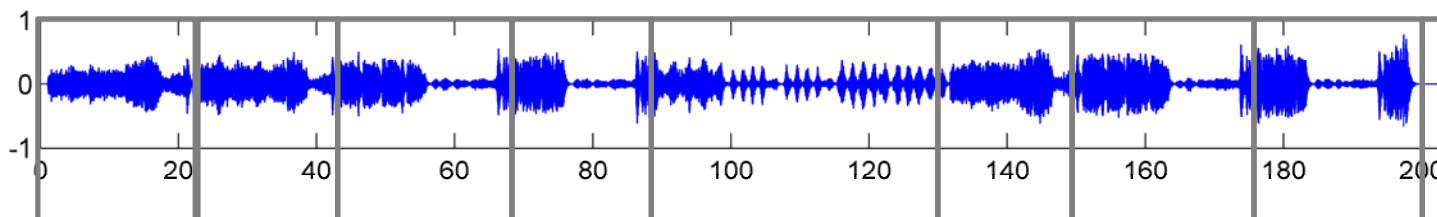


Time (seconds)

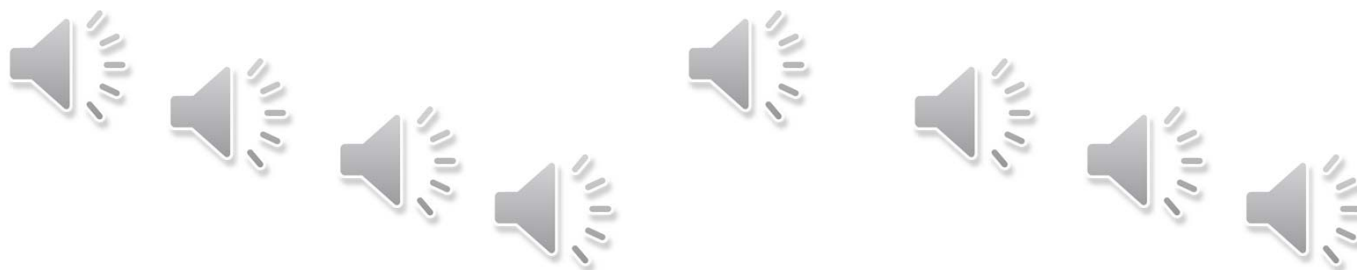


Music Structure Analysis

Example: Brahms Hungarian Dance No. 5 (Ormandy)

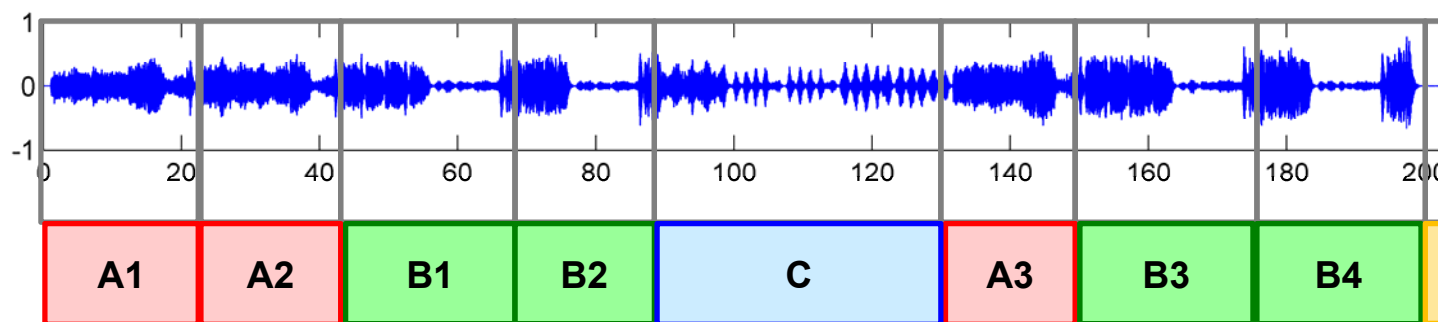


Time (seconds)



Music Structure Analysis

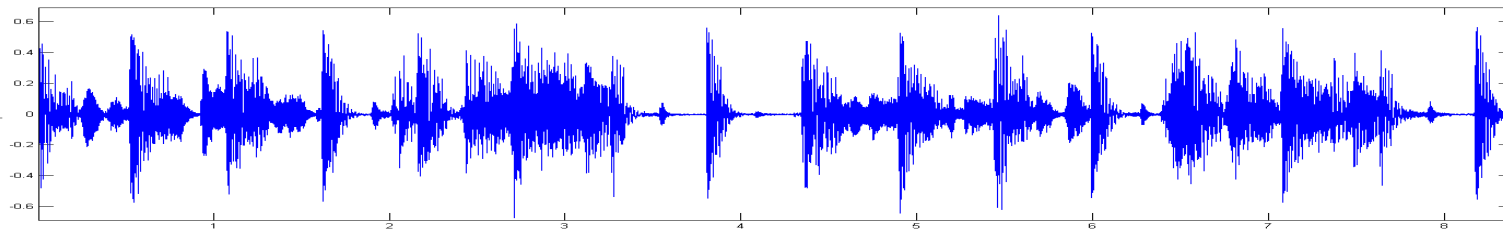
Example: Brahms Hungarian Dance No. 5 (Ormandy)



Tempo Estimation and Beat Tracking

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

Example: Queen – Another One Bites The Dust



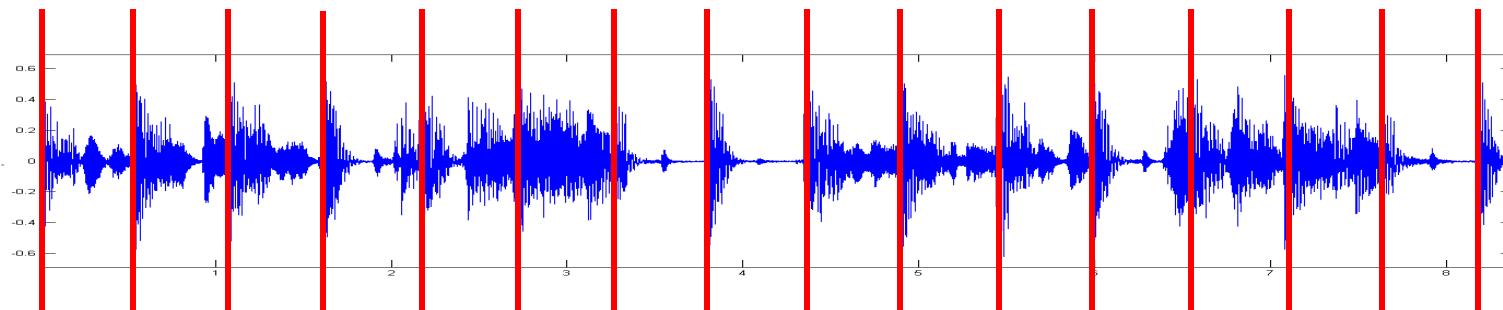
Time (seconds)



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.

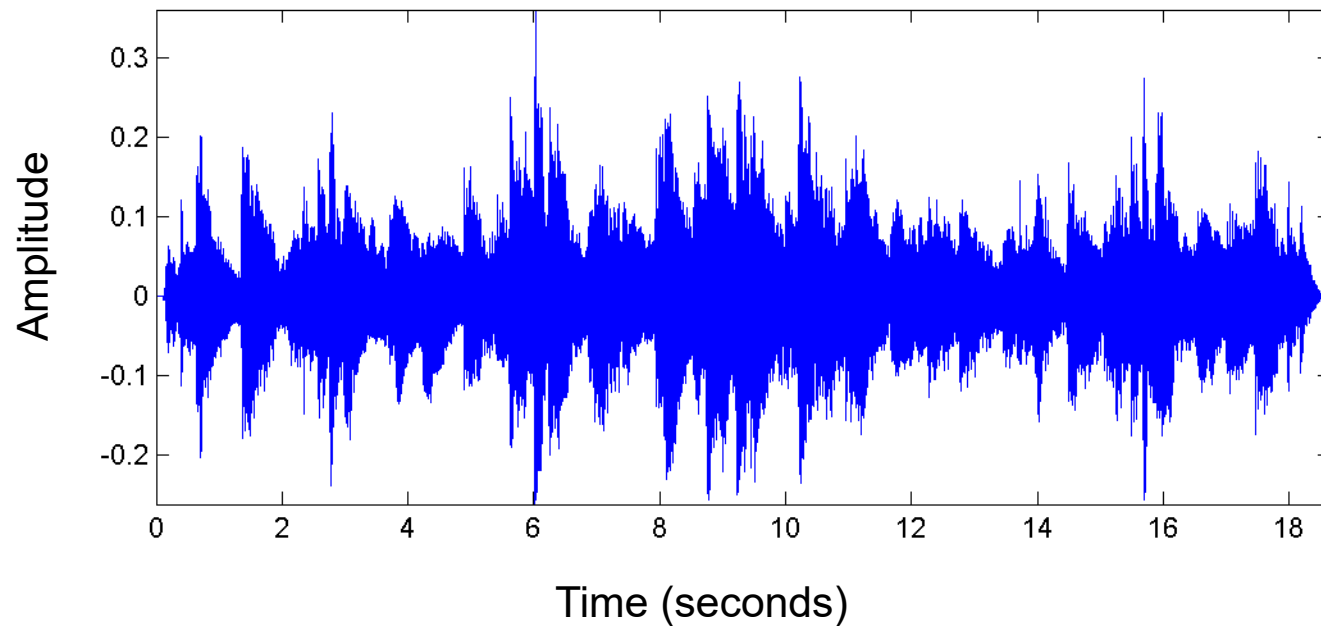
p

The image shows a musical score for Chopin's Mazurka Op. 63 No. 3, measures 41-50. The score is in 3/4 time, key of D major (two sharps), and marked 'Allegretto.' and 'p' (piano). The notation is for piano, with a grand staff (treble and bass clefs). The melody is in the right hand, and the accompaniment is in the left hand. The score includes fingerings (1, 2, 3, 4) and articulation marks (accents, slurs). The left hand features a rhythmic pattern of eighth notes and chords, with some measures marked with 'Ped.' and asterisks. The right hand features a melody with eighth and sixteenth notes, including triplets and slurs.

Why is Music Processing Challenging?

Example: Chopin, Mazurka Op. 63 No. 3

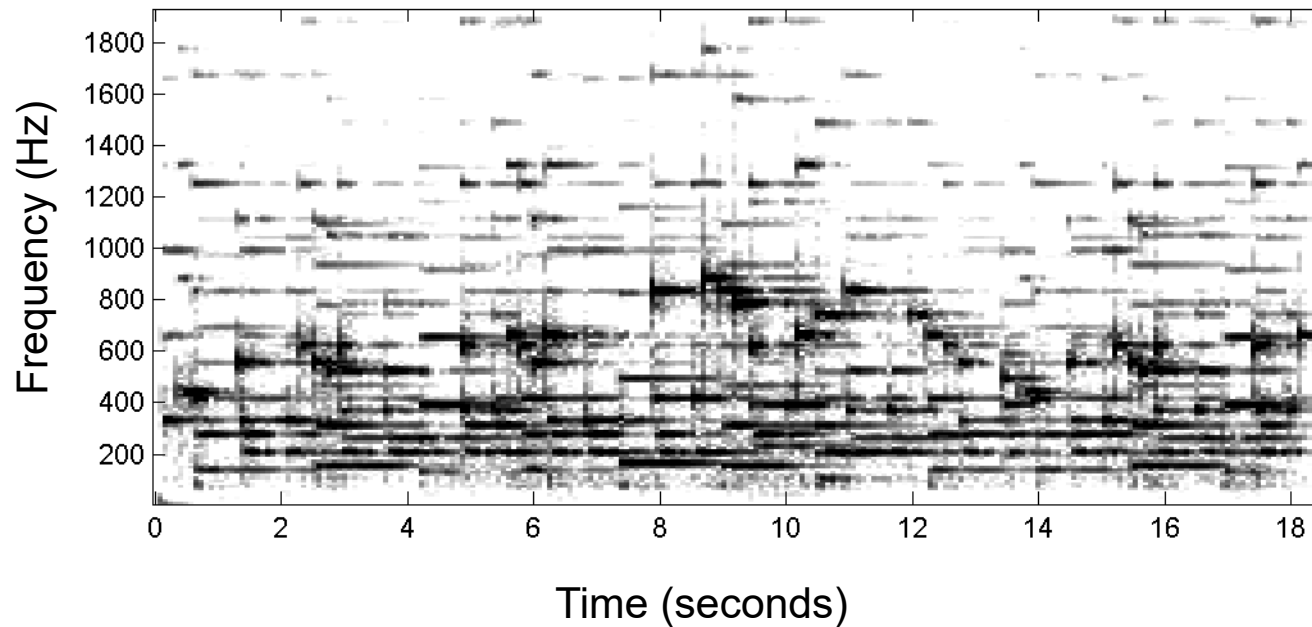
- Waveform



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

- Polyphony



Main Melody



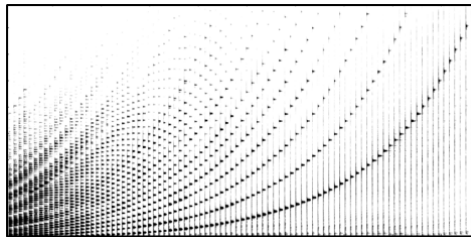
Additional melody line



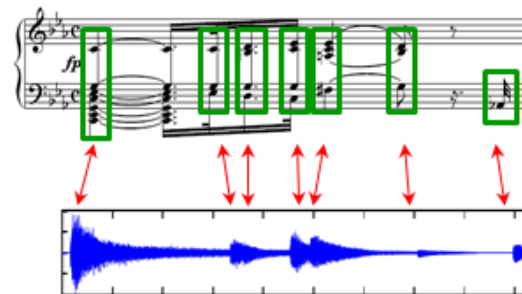
Accompaniment

Music Processing

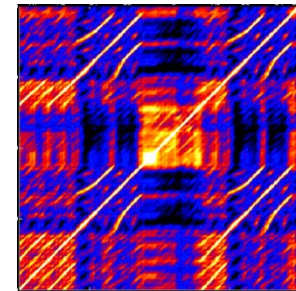
Fourier Transform Audio Features



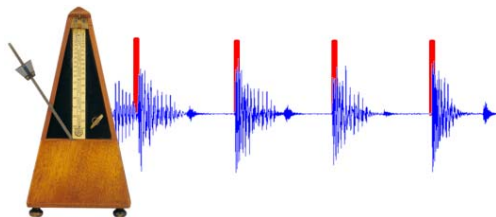
Music Synchronization



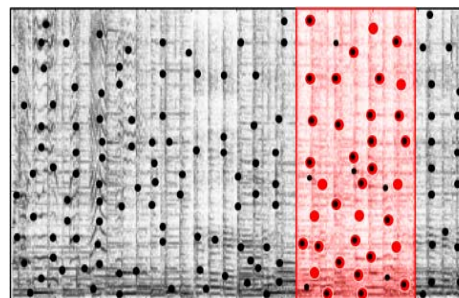
Structure Analysis



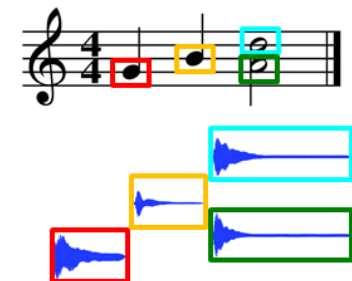
Tempo and Beat Tracking



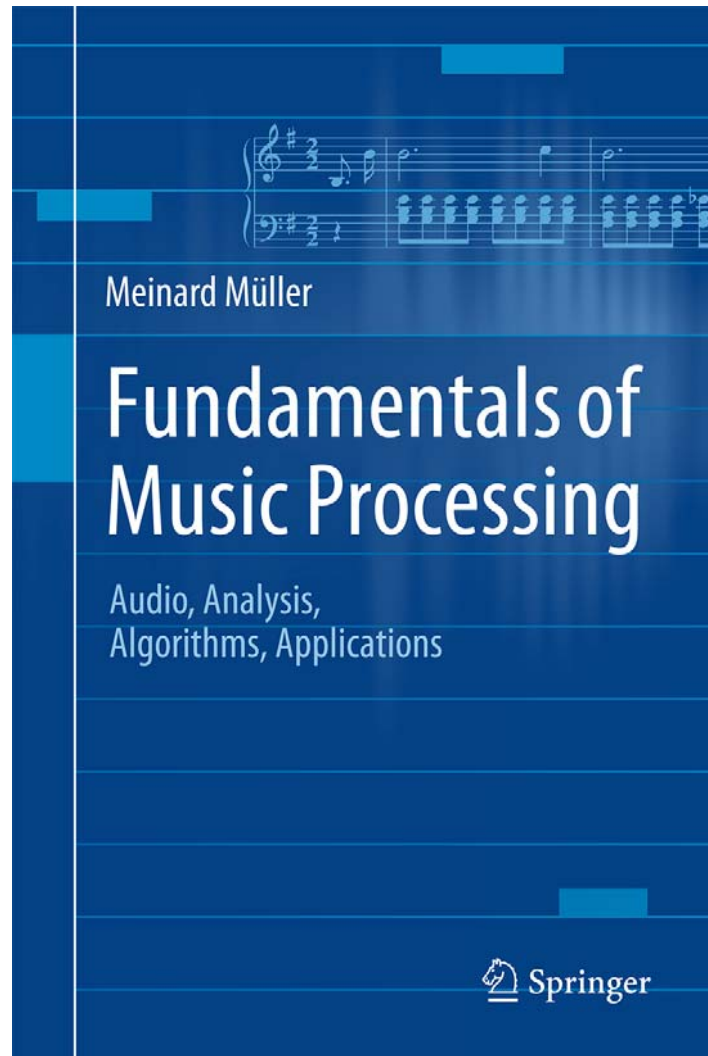
Audio Identification



Audio Decomposition



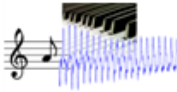
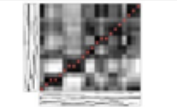
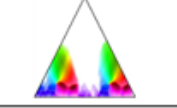
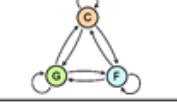
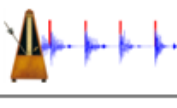
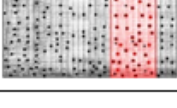
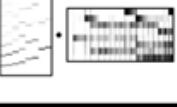
Book: Fundamentals of Music Processing



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

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