Multimedia Systems

1. Introduction to SMC

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Agenda

1. Introduction to SMC

1.0. What is SMC?

1.1. Audio Signal Fundamentals

1.2. Music Representations

1.3. Sound and Music Descriptors

— break (20 mins) —

Practical

Software Tools
Sonic Visualiser, Audacity and *FMP Notebooks*

What is Sound and Music Computing (SMC)?

Sound and Music Computing (SMC) research approaches the whole sound and music communication chain from a multidisciplinary point of view. By combining scientific, technological and artistic methodologies it aims at understanding, modelling and generating sound and music through computational approaches.

This definition is generally considered to include all types of sounds and human communication processes except speech. Speech research has its own aims and methodologies and is outside the SMC field.

from:Sound and Music Computing Network (2007)

What is Sound and Music Computing (SMC)?

Disciplines

- Music Composition
- Musicology
- Music Performance
- Physics/Acoustics
- Mathematics
- Psychology
- **Engineering**

from:Sound and Music Computing Network (2007)

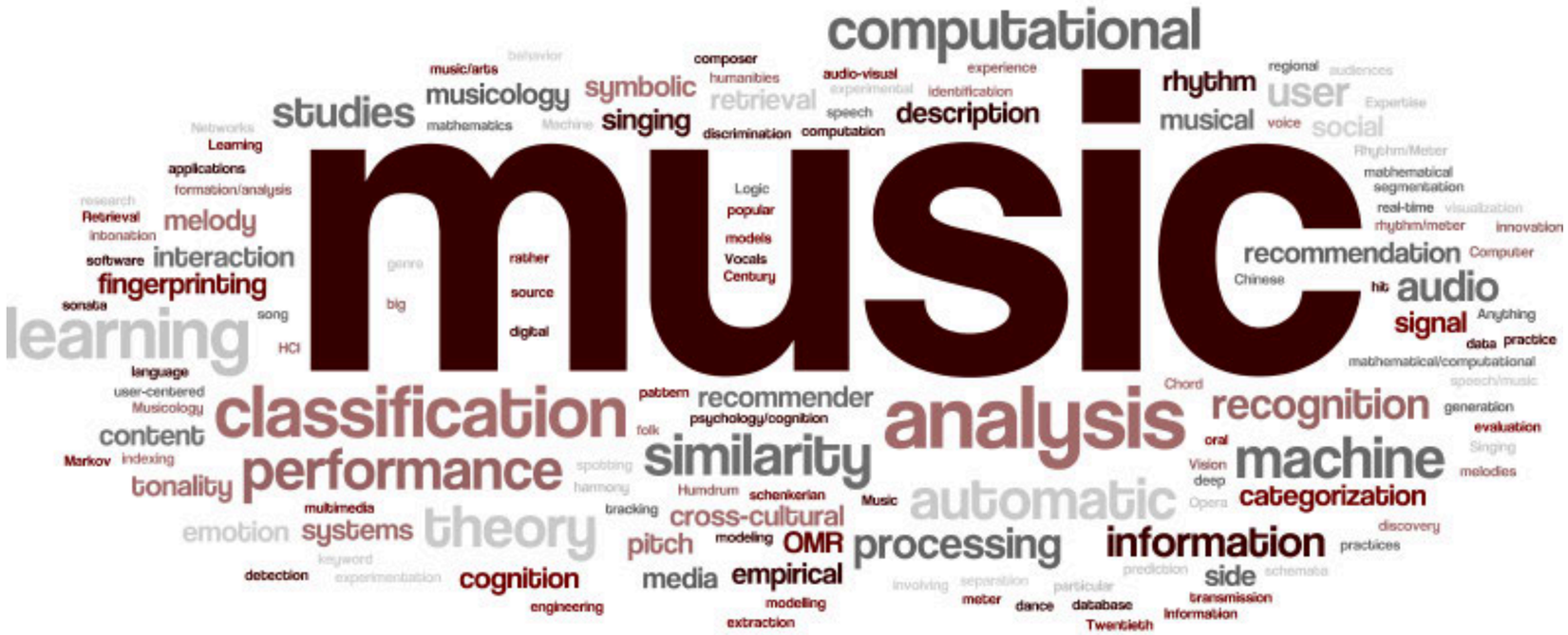
What is Sound and Music Computing (SMC)?

Areas of Application

- Digital Music Instruments
- Music Production
- **Music Information Retrieval**
- Digital Music Libraries
- Interactive Multimedia Systems
- Auditory Interfaces
- Augmented Action and Perception

from:Sound and Music Computing Network (2007)

What is Music Information Retrieval (MIR)?



from:Women in Music Information Retrieval

What is MIR?

Music Information Retrieval aims at extending the understanding and usefulness of music data, through the research, development and application of computational approaches and tools.

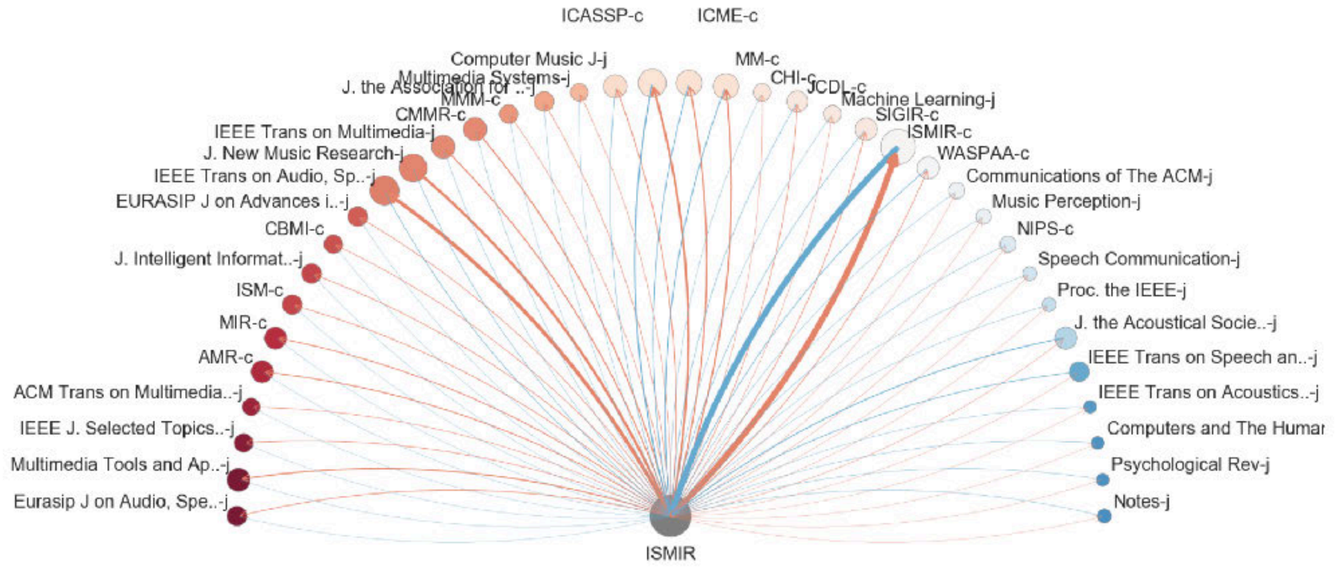
from: (Bello) MIR Lecture Notes - *New York University*

*MIR is the **interdisciplinary** science of retrieving information from music. Those involved in MIR may have a background in musicology, psychoacoustics, psychology, academic music study, signal processing, informatics, machine learning, optical music recognition, computational intelligence or some combination of these. MIR is a small but growing field of research with many real-world **applications**.*

from: Wikipedia

What is MIR?

- Main event: International Society for Music Information Retrieval conference (ISMIR)
- ISMIR has been running since 1999
- **Highly** multidisciplinary: Electronic Engineering, Library and Information Science, Computer Science, Music/Musicology, Psychology, Law
- Papers and sessions at other conferences: ICASSP, ICMC, SMC, DAFx, NIME, WASPAA, CMMR, AES, etc.



What is MIR?

Ever-changing: *Music Informatics Research?*

Feature Engineering —> Machine Learning

System-Centred —> User-Centred

Evaluation

What is MIR?

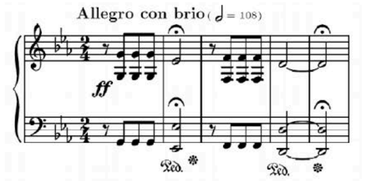
Music Information Retrieval Evaluation eXchange (MIREX) since 2008

- 2018:Audio Classification (Train/Test) Tasks
  - Audio US Pop Genre Classification
  - Audio Latin Genre Classification
  - Audio Music Mood Classification
  - Audio Classical Composer Identification
- 2018:Audio K-POP Mood Classification
- 2018:Audio K-POP Genre Classification
- 2018:Audio Fingerprinting
- 2018:Multiple Fundamental Frequency Estimation & Tracking
- 2018:Set List Identification
- 2018:Audio Melody Extraction
- 2018:Audio Onset Detection
- 2018:Audio Beat Tracking
- 2018:Audio Key Detection
- 2018:Audio Downbeat Estimation
- 2018:Real-time Audio to Score Alignment (a.k.a Score Following)
- 2018:Audio Cover Song Identification
- 2018:Audio Chord Estimation
- 2018:Automatic Lyrics-to-Audio Alignment
- 2018:Drum Transcription
- 2018:Patterns for Prediction
- 2018:Audio Tempo Estimation

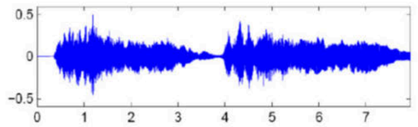
What is MIR?

Music Information

Sheet Music (Image)



CD / MP3 (Audio)



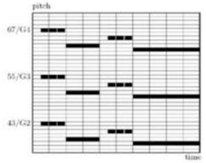
MusicXML (Text)

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

Dance / Motion (Mocap)

Music

MIDI



Singing / Voice (Audio)

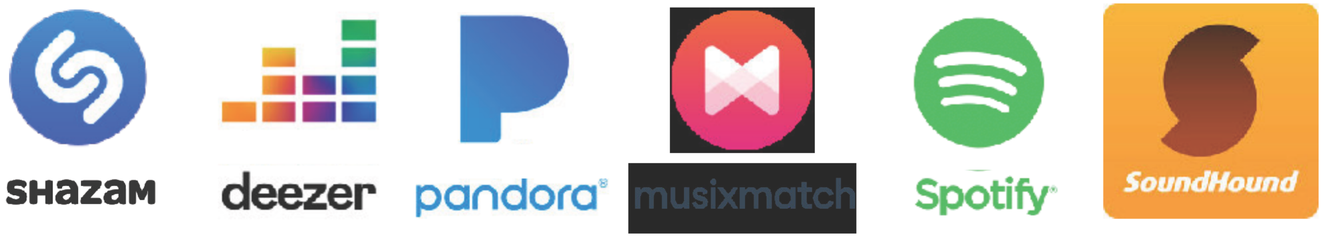
Music Film (Video)

Music Literature (Text)

from: (Müller) Fundamentals of Music Processing, *Springer 2015*

What is MIR?

Applications



Music fingerprinting/melody identification: *Shazam, Gracenote, SoundHound*

Music Recommendation and Playlist generation: *YouTube, Google, Last.fm, Pandora, Spotify*

Score Following: *SmartMusic, RockBand*

Music Interaction: *Chordify*

Pro Tools: *Melodyne, Autotune*

Others: *Smule, Native Instruments, ROLI, Steinberg*

What is MIR?

Uses

listen

allow browsing, discovery, recommendation

produce

enhance music production intelligently

educate

support music students interactively

create

generate new content

Multimedia Systems

MIR Components

Basics

- Sound and Music Fundamentals
- Music Representations
- Sound and Music Descriptors

Musical Elements

- Rhythm, Structure
- Melody, Harmony, Timbre

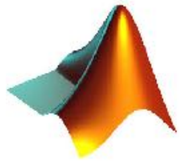
Applications

- Content-based audio retrieval
- Source Separation
- Music Identification
- Automatic Mashup

Multimedia Systems

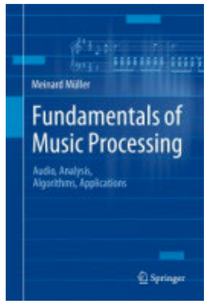
MIR Software Tools

Sonic Visualiser



Matlab

Audacity



Meinard Müller

Fundamentals of Music Processing

Audio, Analysis, Algorithms, Applications

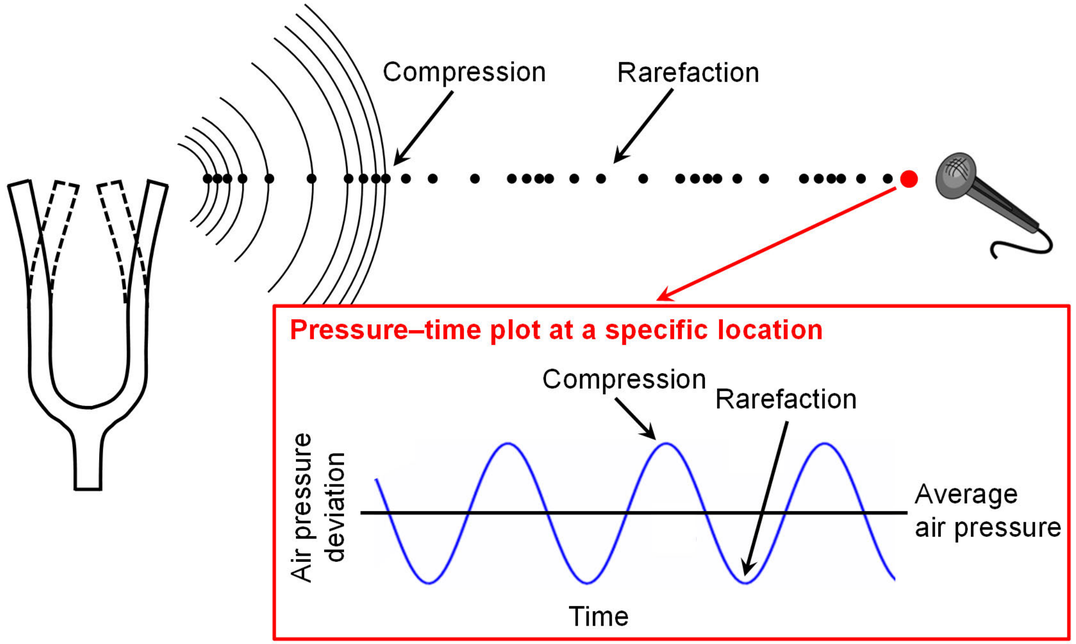
ISBN: 978-3-319-21944-8

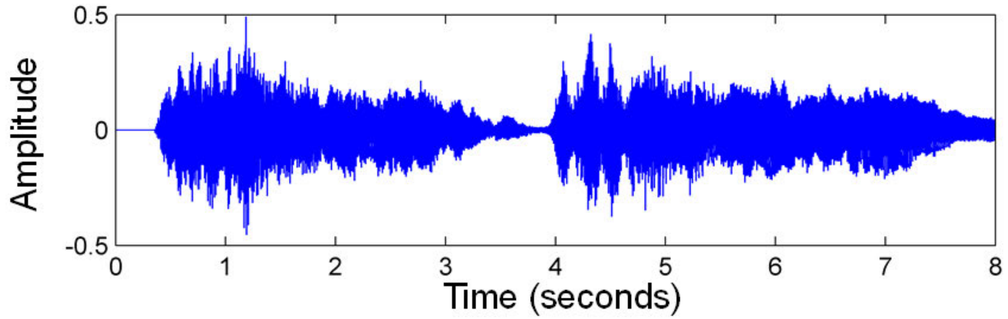
Springer, 2015

Chapter	Title
B	Basics
0	Overview
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

Audio Signal Fundamentals

Physics of sound





from: (Müller) Fundamentals of Music Processing, *Springer 2015*

Audio Signal Fundamentals

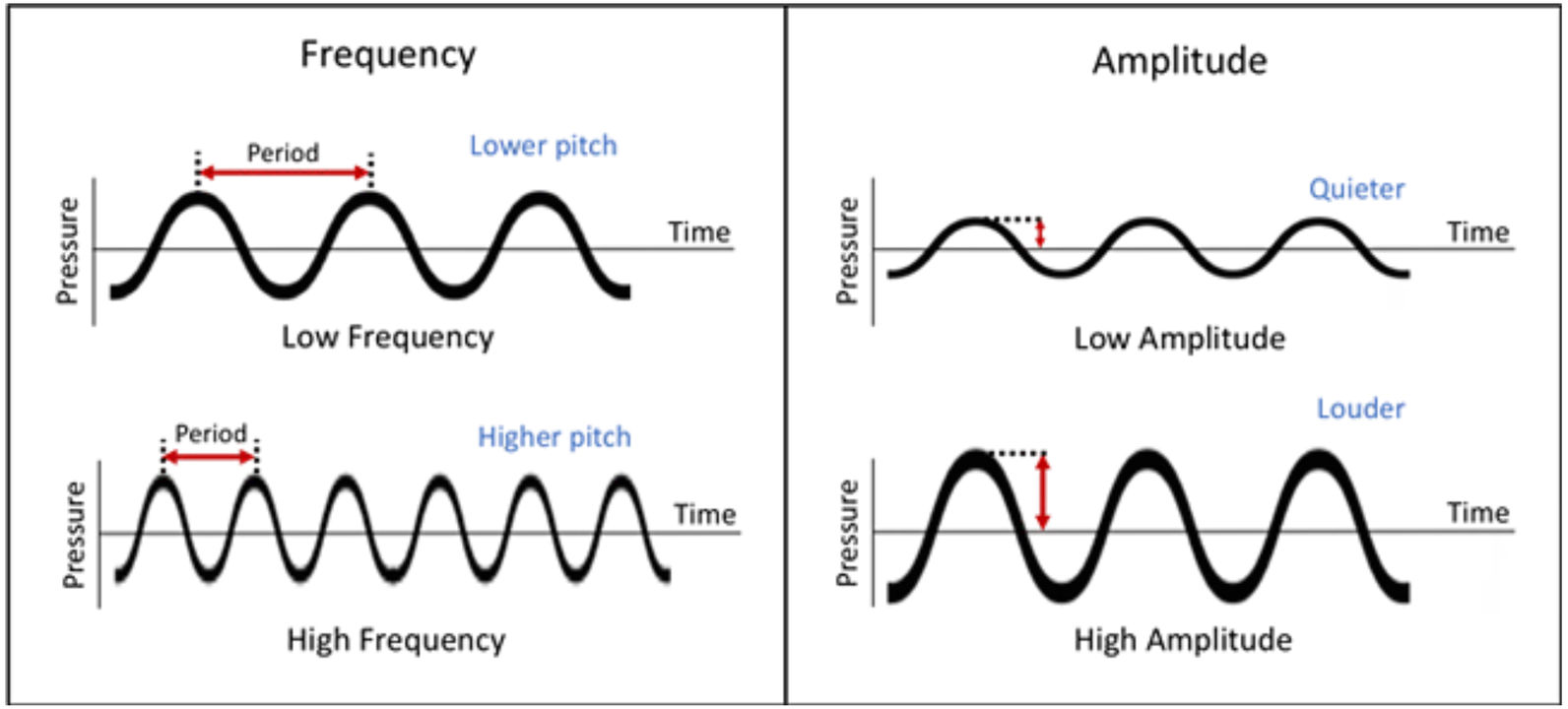
Physics of sound

$$v = f\lambda$$

v : speed $(m.s^{-1})$
λ : wavelength (m)
f : frequency $(Hz$ or $s^{-1})$

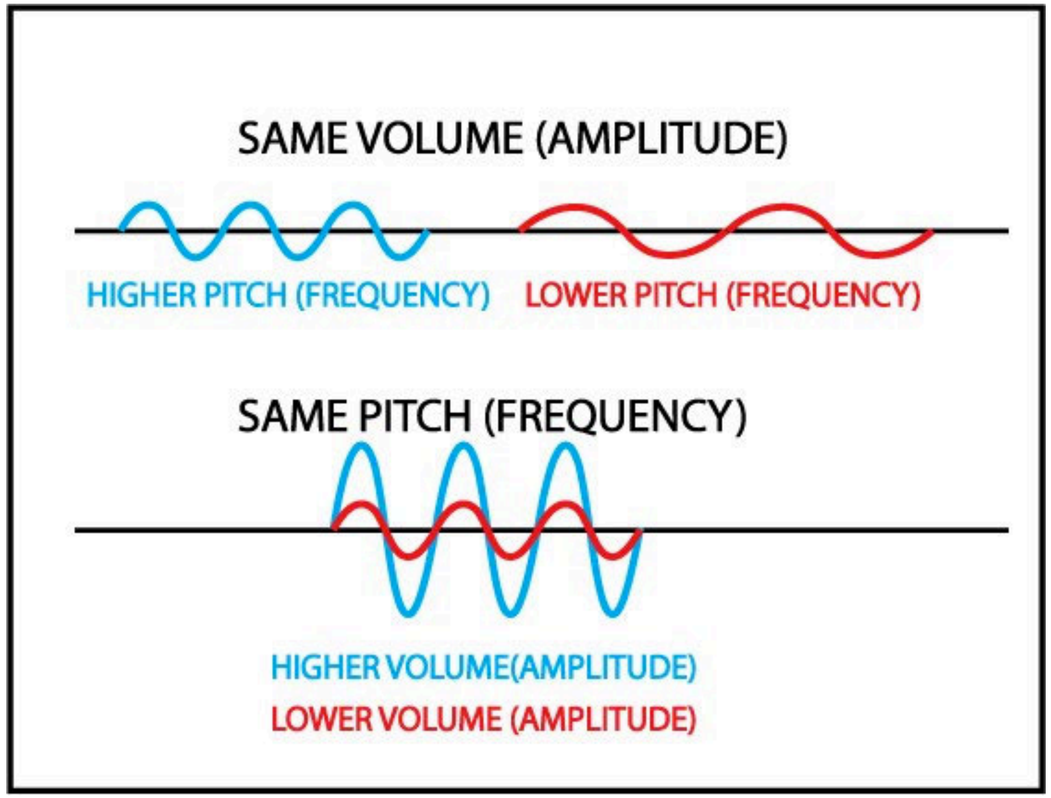
$$v = \frac{\lambda}{T}$$

v : speed $(m.s^{-1})$
λ : wavelength (m)
T : period (s)



Audio Signal Fundamentals

Physics of sound



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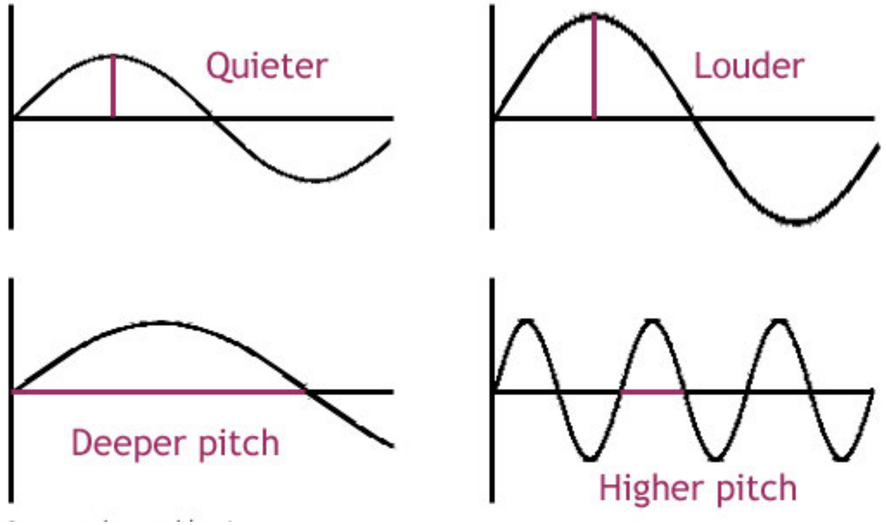
Audio Signal Fundamentals

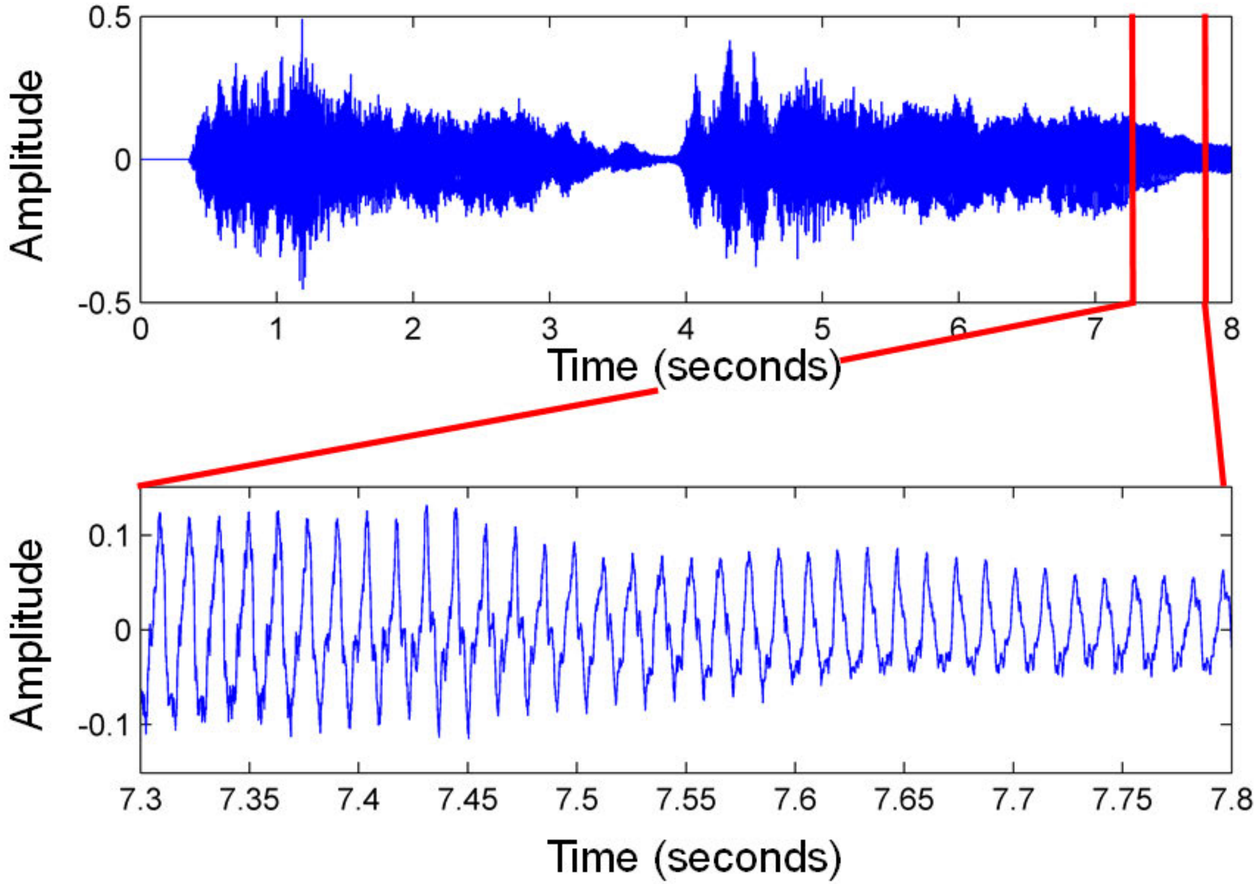
Physics of sound



What are the units/axis of interest?

Audio Signal Fundamentals

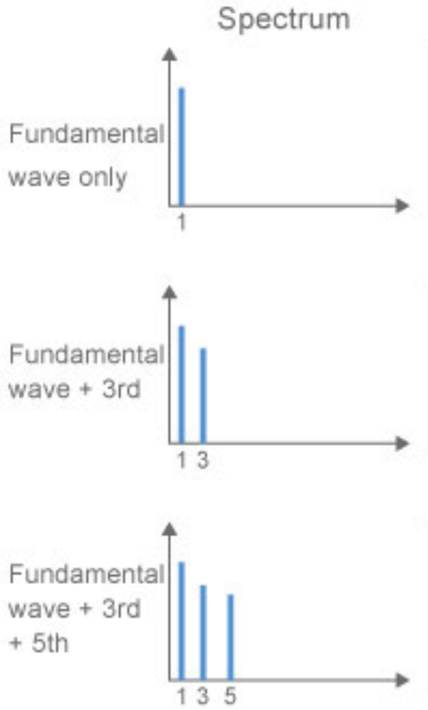
Waveform

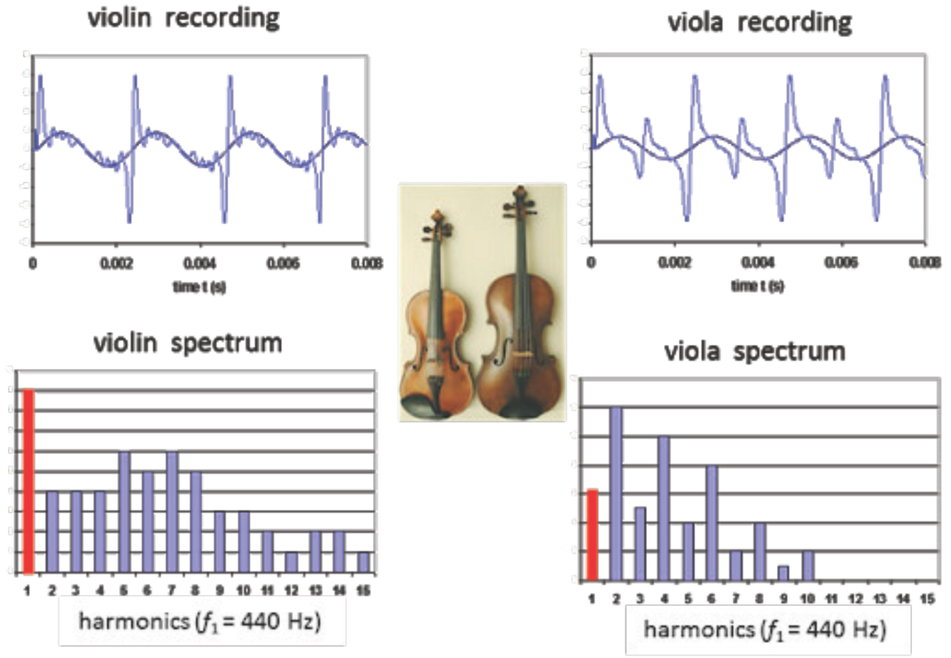


from: (Müller) Fundamentals of Music Processing, *Springer 2015*

Audio Signal Fundamentals

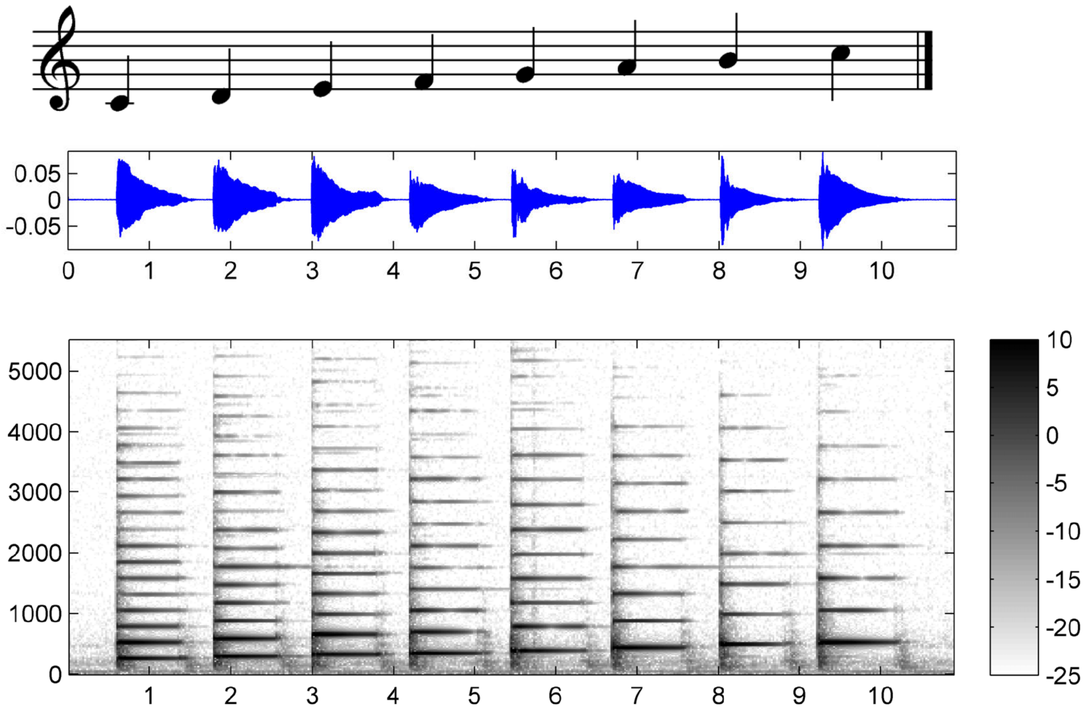
Spectrum





Audio Signal Fundamentals

Spectrogram

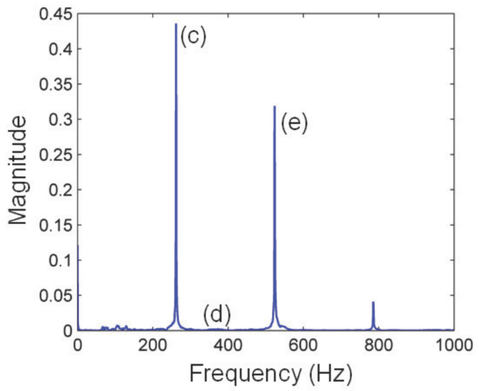


from: (Müller) Fundamentals of Music Processing, *Springer 2015*

Audio Signal Fundamentals

The Fourier Transform

FFT (Analysis) $$X_k = \sum_{n=0}^{N-1} x_n \cdot e^{-i 2\pi k n / N}$$ from **time** to **frequency**



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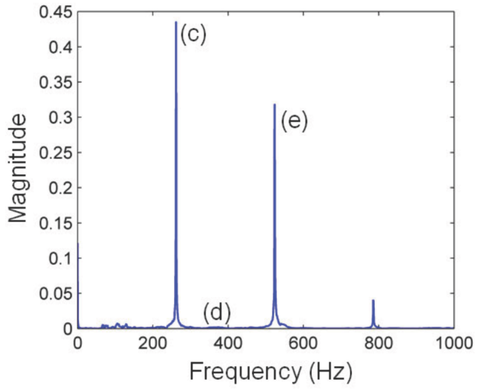
Audio Signal Fundamentals

The Fourier Transform

IFFT (Synthesis) $$x_n = \frac{1}{N} \sum_{k=0}^{N-1} X_k \cdot e^{i2\pi kn/N}$$ from **frequency** to **time**



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Audio Signal Fundamentals

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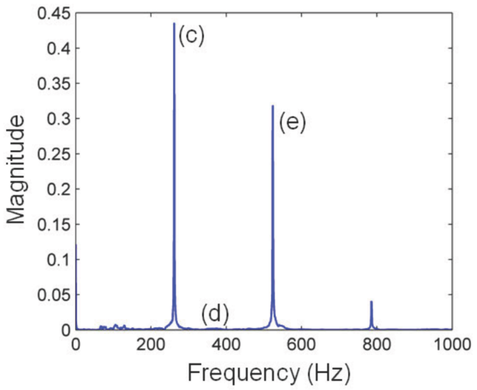
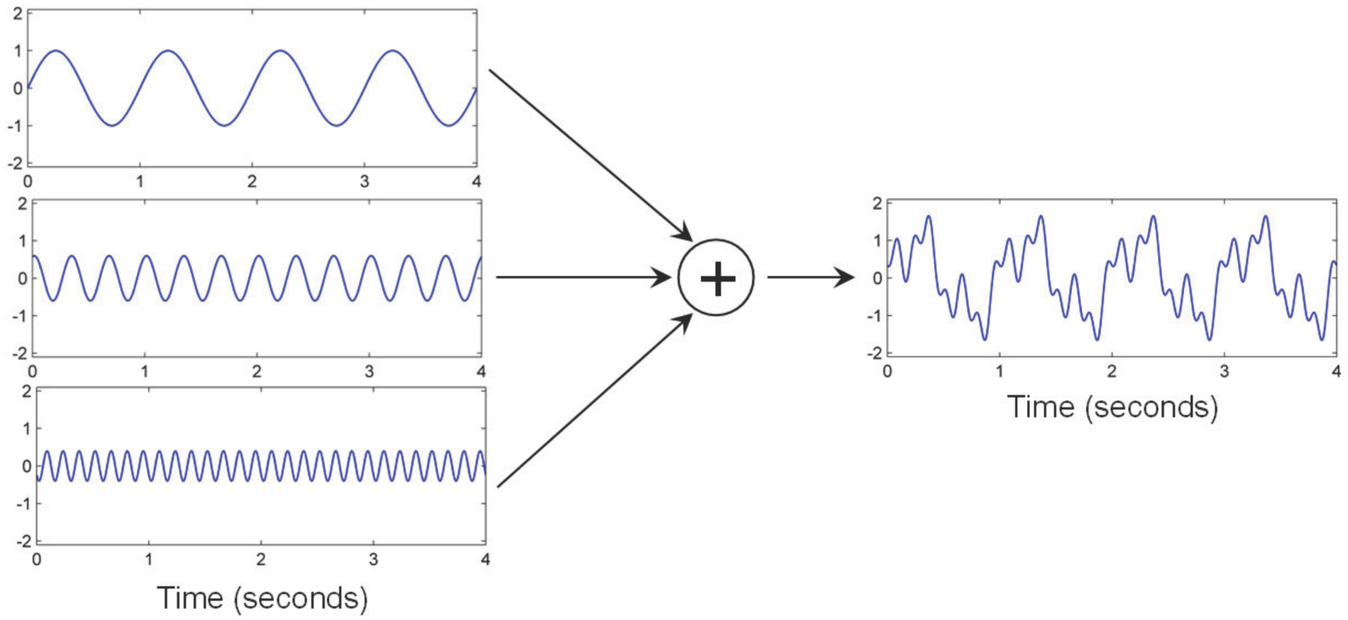




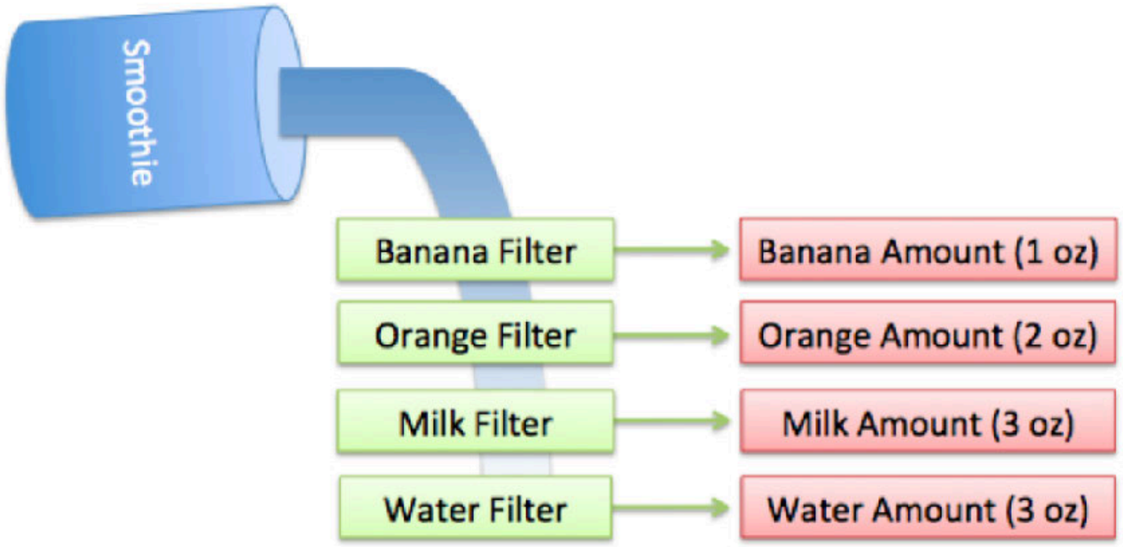
from: (Müller) Fundamentals of Music Processing, *Springer 2015*

Audio Signal Fundamentals

The Fourier Transform

FFT (**Analysis**)

from **smoothie** to **recipe**

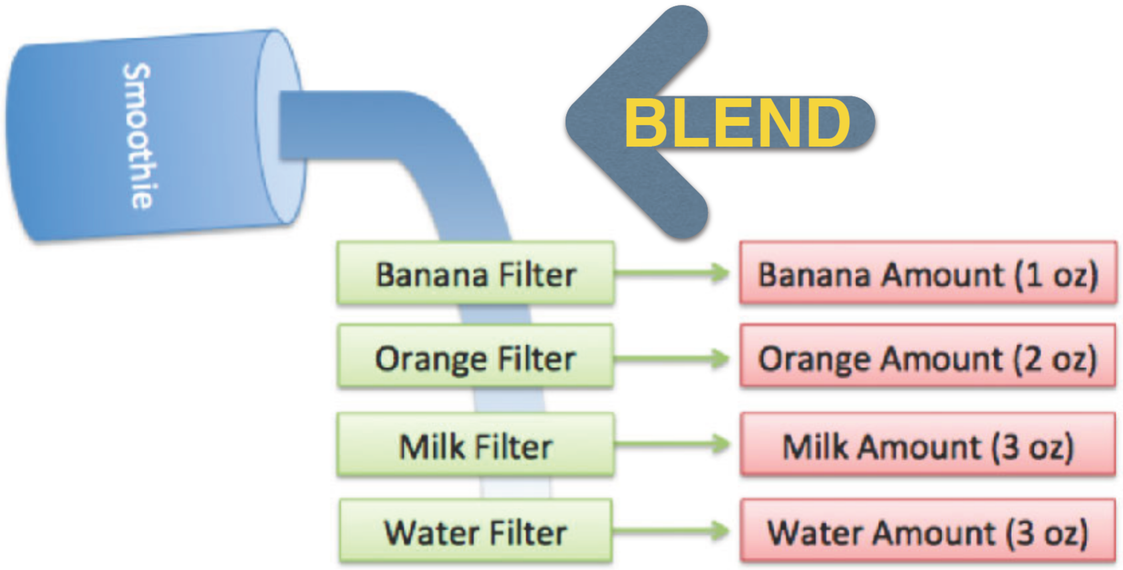


Audio Signal Fundamentals

The Fourier Transform

FFT (**Synthesis**)

from **recipe** to **smoothie**



Audio Signal Fundamentals

The Fourier Transform

FFT (Analysis) $$X_k = \sum_{n=0}^{N-1} x_n \cdot e^{-i 2\pi k n / N}$$ from **time** to **frequency**

IFFT (Synthesis) $$x_n = \frac{1}{N} \sum_{k=0}^{N-1} X_k \cdot e^{i 2\pi k n / N}$$ from **frequency** to **time**

Recommended Resources

BetterExplained: An interactive guide to the Fourier transform (web)

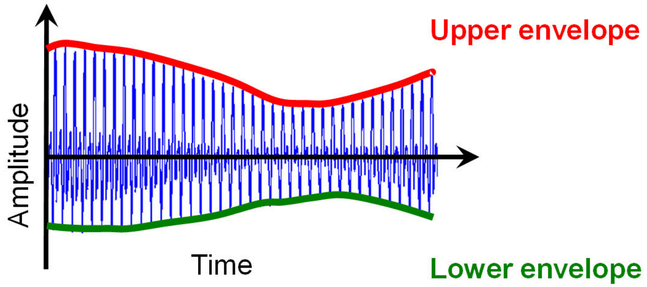
An Interactive Introduction to Fourier Transforms (web)

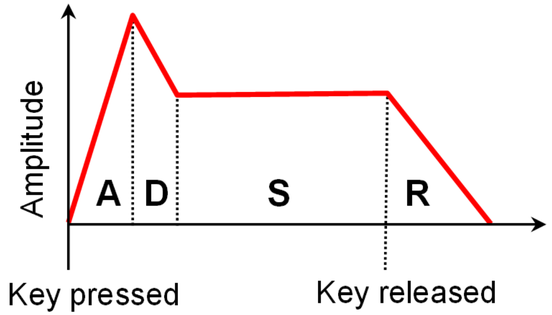
A Visual Introduction to the Fourier Transform (youtube)

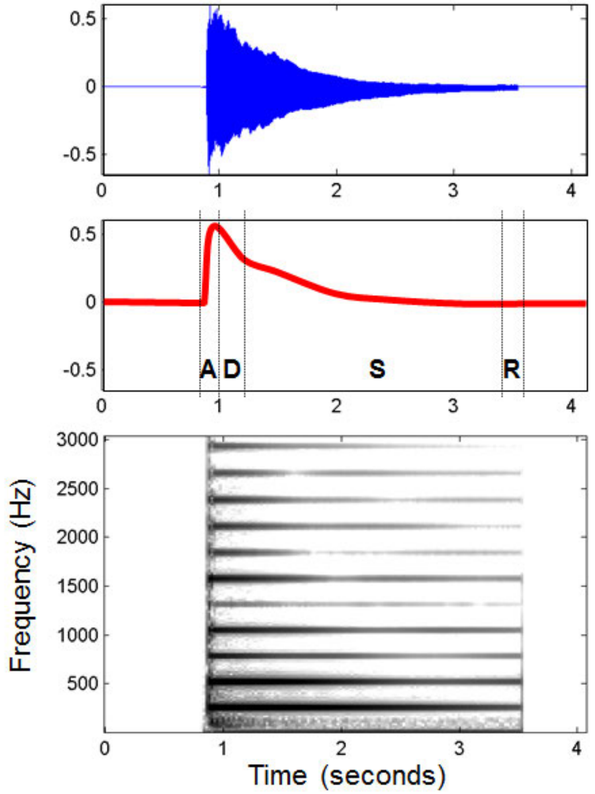
The Harmonic Analyzer (Mechanical Machine)

Sound and Music Representations

Audio



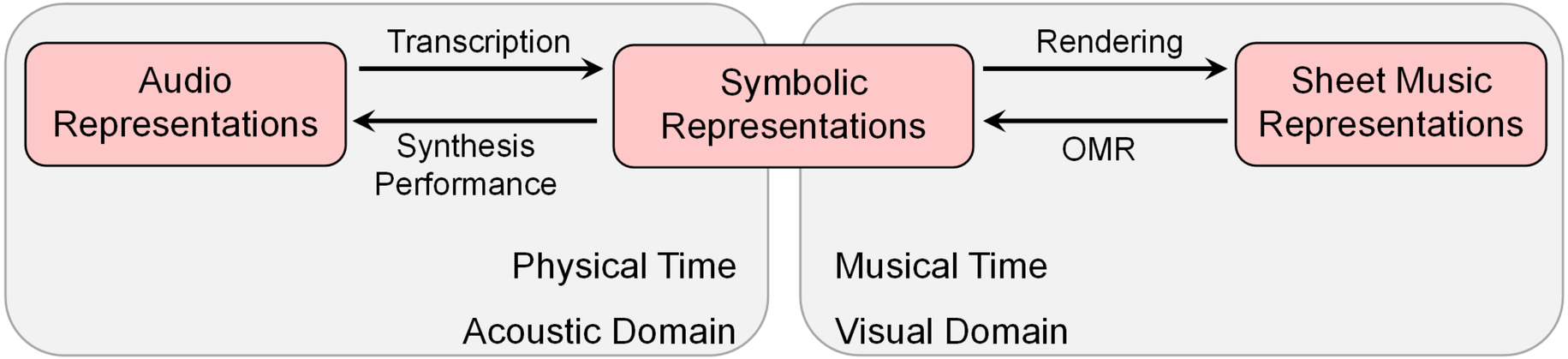




from: (Müller) Fundamentals of Music Processing, *Springer 2015*

Sound and Music Representations

Audio / Symbolic

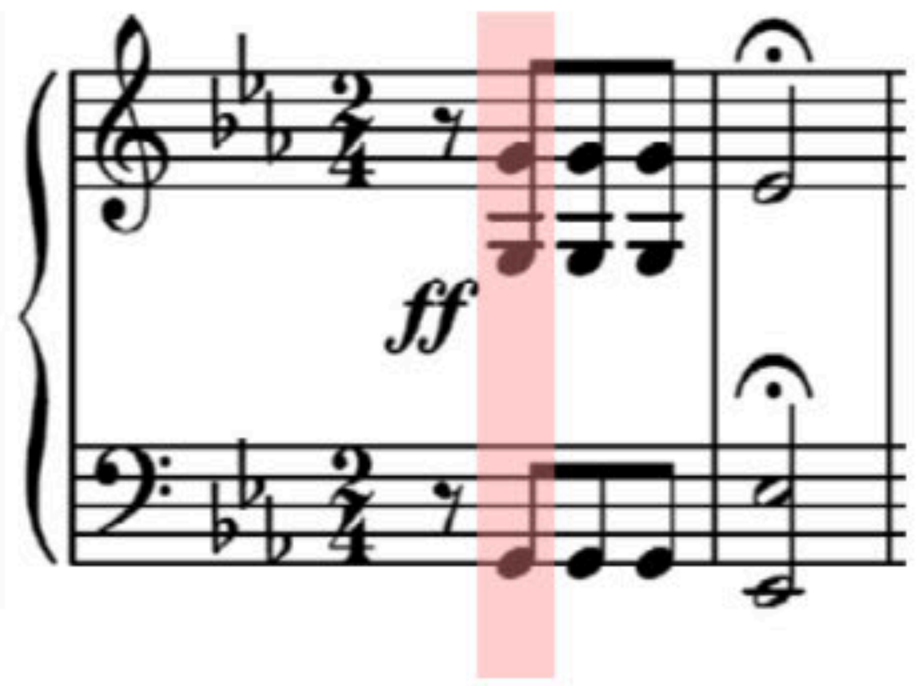


from: (Müller) Fundamentals of Music Processing, *Springer 2015*

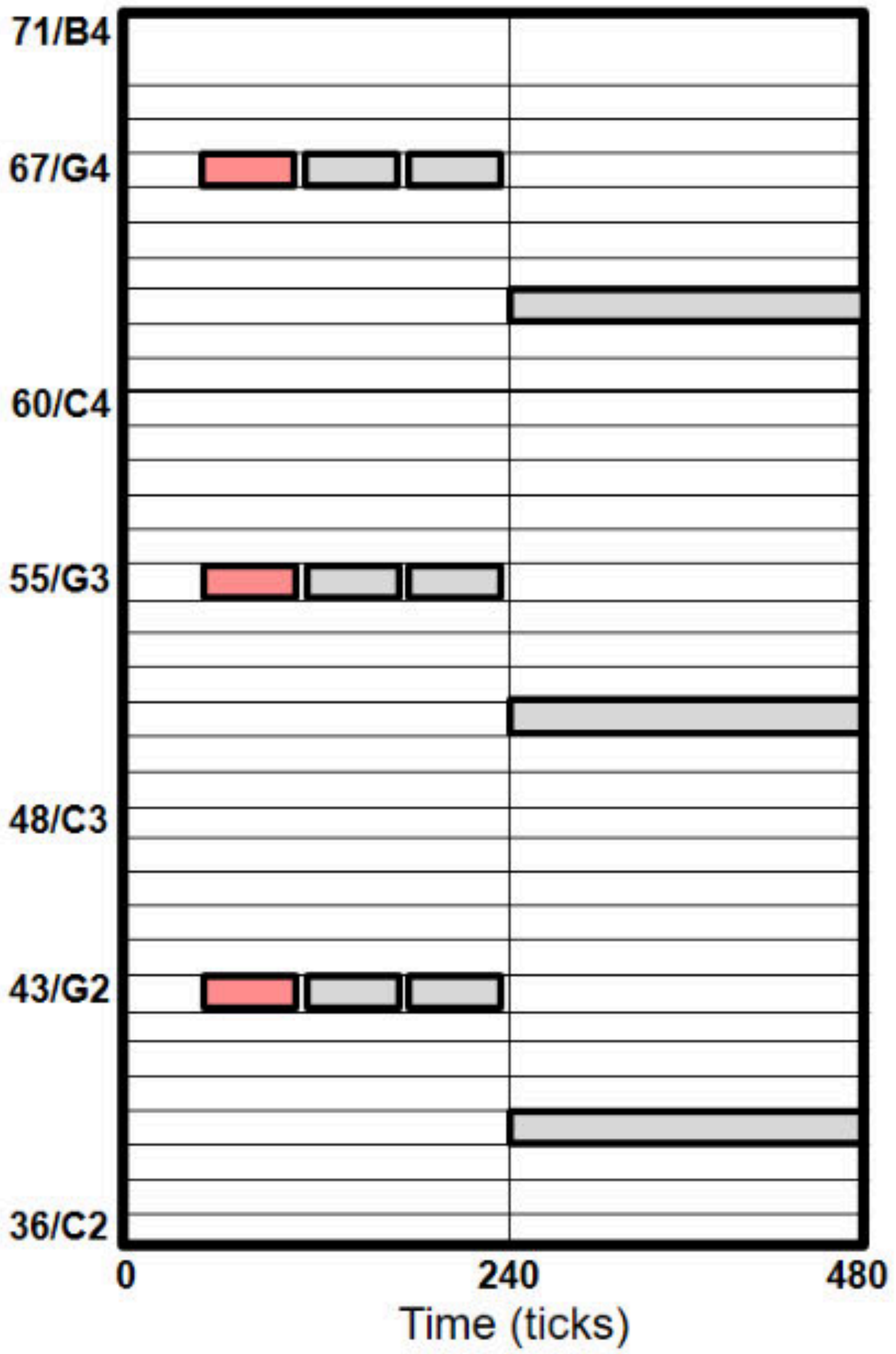
Sound and Music Representations

Symbolic

Figure 1.13 from
[Müller, FMP, Springer 2015]

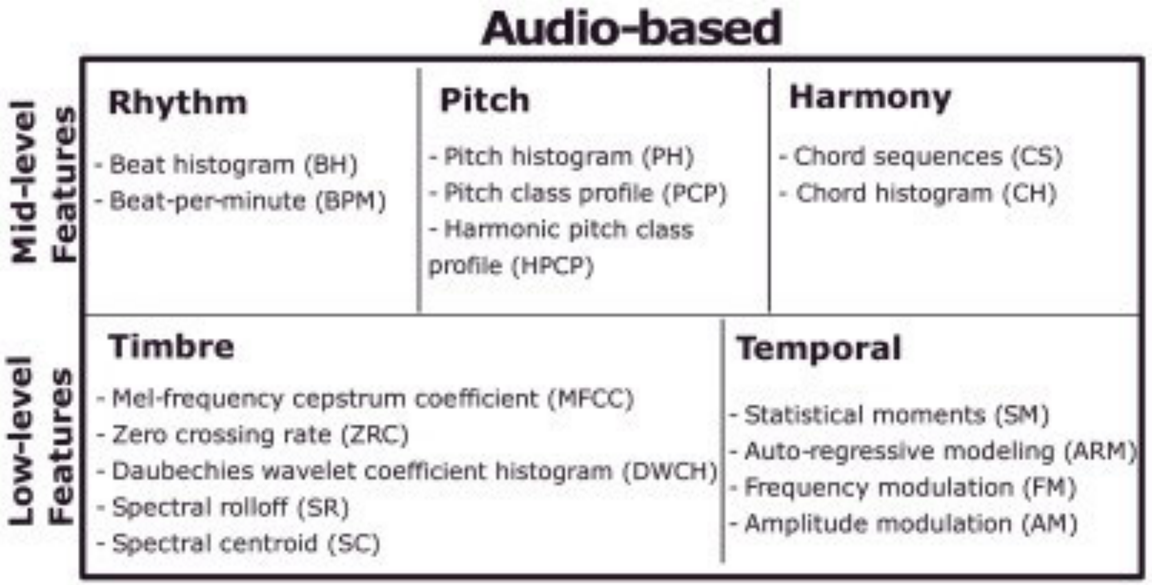


Time (Ticks)	Message	Channel	Note Number	Velocity
60	NOTE ON	1	67	100
0	NOTE ON	1	55	100
0	NOTE ON	2	43	100
55	NOTE OFF	1	67	0
0	NOTE OFF	1	55	0
0	NOTE OFF	2	43	0
5	NOTE ON	1	67	100
0	NOTE ON	1	55	100
0	NOTE ON	2	43	100
55	NOTE OFF	1	67	0
0	NOTE OFF	1	55	0
0	NOTE OFF	2	43	0
5	NOTE ON	1	67	100
0	NOTE ON	1	55	100
0	NOTE ON	2	43	100
55	NOTE OFF	1	67	0
0	NOTE OFF	1	55	0
0	NOTE OFF	2	43	0
5	NOTE ON	1	63	100
0	NOTE ON	2	51	100
0	NOTE ON	2	39	100
240	NOTE OFF	1	63	0
0	NOTE OFF	2	51	0
0	NOTE OFF	2	39	0



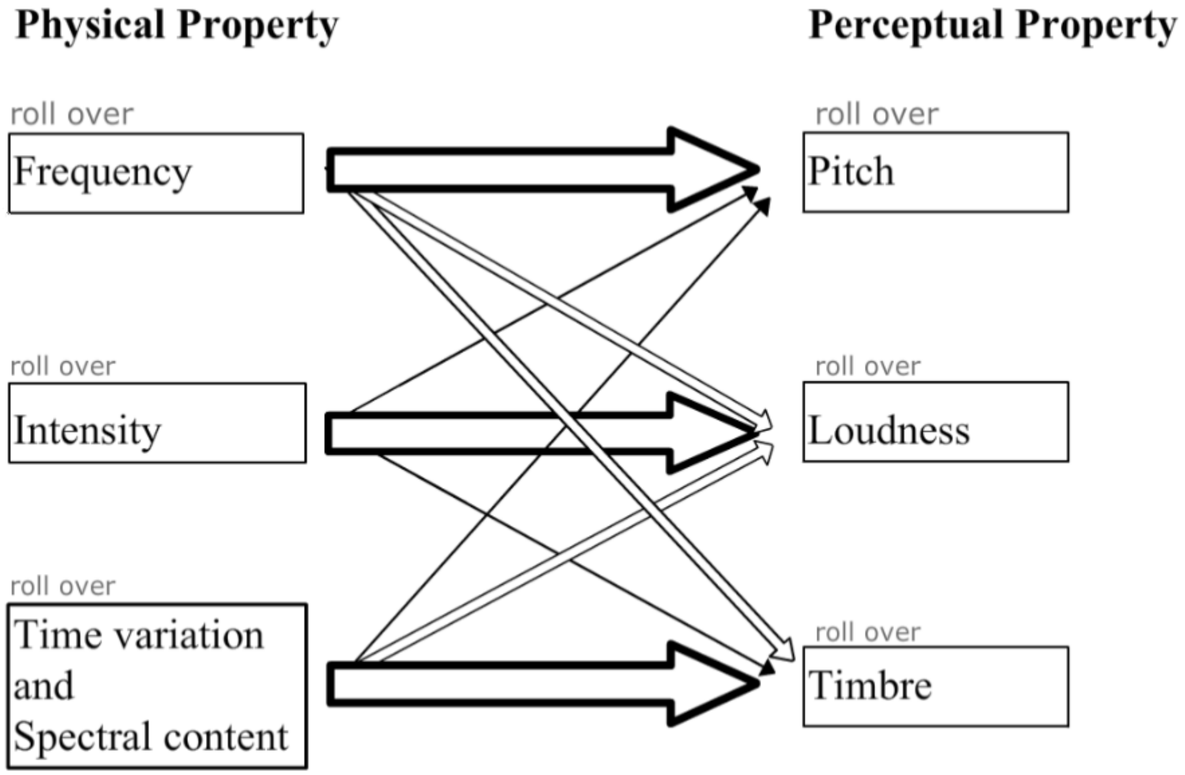
Sound and Music Descriptors

Audio/Symbolic-based



Sound and Music Descriptors

Physical/Perceptual



from: (UNES.EDU) Introduction to Sound

notes

Some of the ideas on these slides were inspired in the following recommended resources:

(Müller) Fundamentals of Music Processing - *Springer, 2015*

(Bello) MIR Lecture Notes - *New York University*

(Serra and Smith) Audio Signal Processing for Music Applications - *Coursera*

(Davies) AGPCM Lecture Notes - *FEUP*

(Tjoa) *Notes on Music Information Retrieval - musicinformationretrieval.com*

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End.