AUDIO LABS

Music Processing Analysis

Music Representations

Exercise

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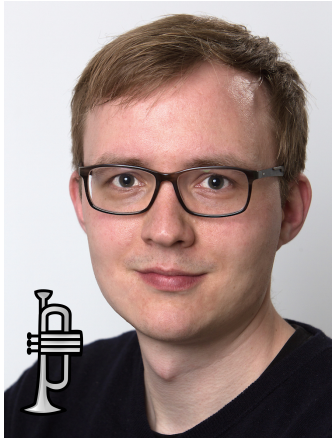
Introduction
Stefan Balke



- 2008-2013: Electrical Engineering
  Leibniz Universität Hannover
- Since 2014: Working towards my PhD

- Research Interests:
  - Content-based retrieval
  - Fundamental frequency estimation
  - Jazz music
  - Web technologies

- Hobbies: Trumpet playing!
- Further infos: https://www.audiolabs-erlangen.de/fau/assistant/balke

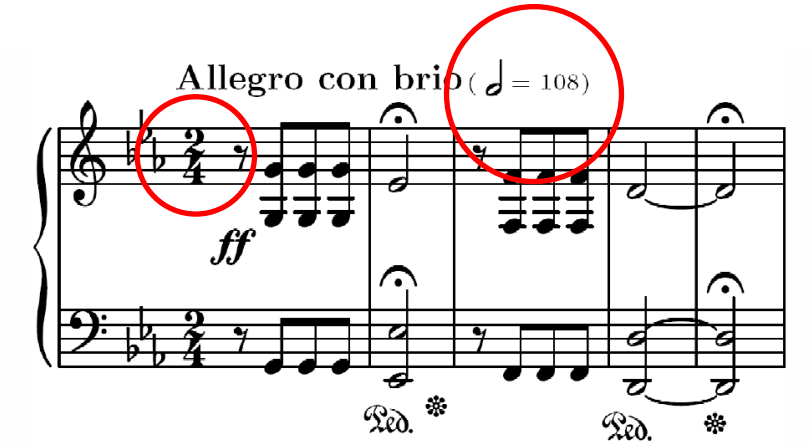
Session Outline

Music Representations

- Homework discussion + demos
- Introduction of practical exercises (STFT + HPSS)

Homework

Exercise 1.1



- A measure consists of 2 quarter notes (equals 1 half note).
- The tempo of a half note is notated as 108 BPM.
- Thus, a minute is divided into 108 bars: 60 s / 108 = 555.56 ms.
- A quarter note has half o the duration: 277.78 ms.

Homework
Recap MIDI

- **M**usical **I**nstrument **D**igital **I**nterface
- Standard format for controlling synthesizers.
- “Abused” as format for symbolic music.
- Format consists of events on a musical time line.
- Timeline is usually 120 ticks per quarter note (TPQN).

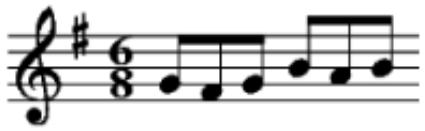
- Relevant events for symbolic music:
  - Note On/Off
  - Parameters: Note number (pitch), Velocity, Channel

Homework

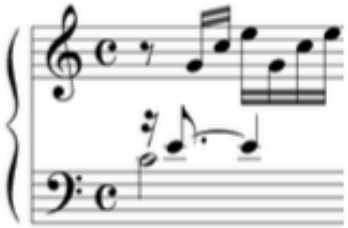
Exercise 1.2(a)

Exercise 1.2. Specify the MIDI representation (in tabular form) and sketch the piano-roll representation (similar to Figure 1.13) of the following sheet music representations. Assume that a quarter note corresponds to 120 ticks. Set the velocity to a value of 100 for all active note events. Furthermore, assign the notes of the G-clef to channel 1 and the notes of the F-clef to channel 2.

(a)



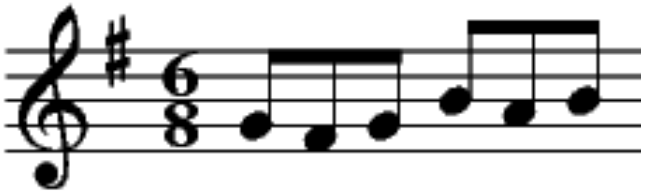
(b)

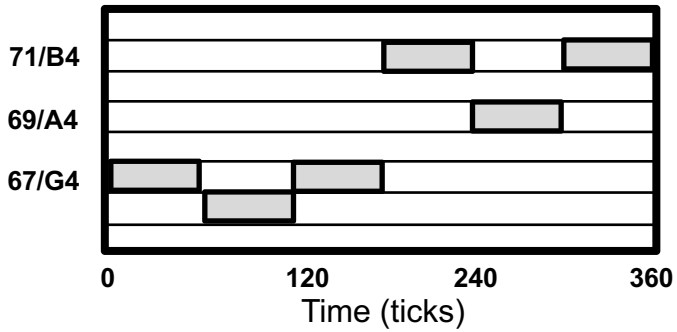


[**Hint:** In this exercise, we assume that the reader has some basic knowledge of Western music notation.]

Homework

Solution 1.2(a)

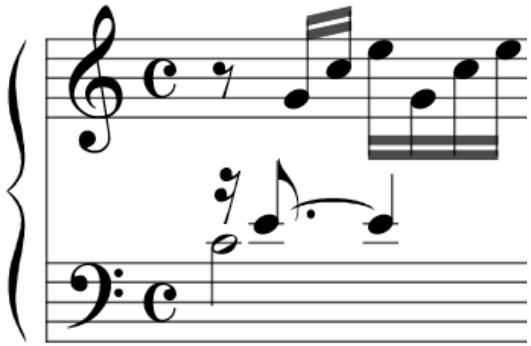


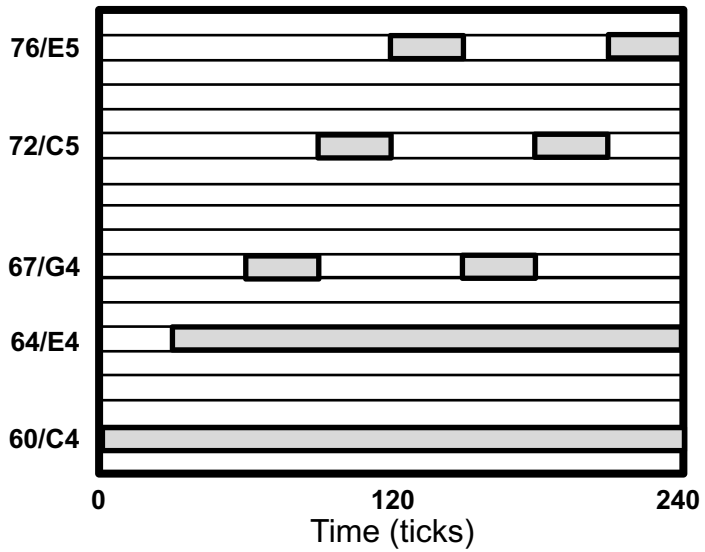


Time (Ticks)	Message	Channel	Note Number	Velocity
0	NOTE ON	1	67	100
60	NOTE OFF	1	67	0
0	NOTE ON	1	66	100
60	NOTE OFF	1	66	0
0	NOTE ON	1	67	100
60	NOTE OFF	1	67	0
0	NOTE ON	1	71	100
60	NOTE OFF	1	71	0
0	NOTE ON	1	69	100
60	NOTE OFF	1	69	0
0	NOTE ON	1	71	100
60	NOTE OFF	1	71	0

Homework

Solution 1.2(b)





Time (Ticks)	Message	Channel	Note Number	Velocity
0	NOTE ON	2	60	100
30	NOTE ON	2	64	100
30	NOTE ON	1	67	100
30	NOTE OFF	1	67	0
0	NOTE ON	1	72	100
30	NOTE OFF	1	72	0
0	NOTE ON	1	76	100
30	NOTE OFF	1	76	0
0	NOTE ON	1	67	100
30	NOTE OFF	1	67	0
0	NOTE ON	1	72	100
30	NOTE OFF	1	72	0
0	NOTE ON	1	76	100
30	NOTE OFF	1	76	0
0	NOTE OFF	2	64	0
0	NOTE OFF	2	60	0

Homework

Exercise 1.5

Exercise 1.5. Using (1.1), compute the center frequencies for all notes of the C-major scale C4, D4, E4, F4, G4, A4, B4, C5 and for all notes of the C-minor scale C4, D4, E♭4, F4, G4, A♭4, B♭4, C5 (see also Figure 1.5).

Homework

Solution 1.5

$$F_{Pitch}(p) = 2^{p-69/12}\ 440\ \text{Hz}$$

C-major scale		
Note	p	$F_{\text{pitch}}(p)$
C4	60	261.63
D4	62	293.66
E4	64	329.63
F4	65	349.23
G4	67	392.00
A4	69	440.00
B4	71	493.88
C5	72	523.25

C-minor scale		
Note	p	$F_{\text{pitch}}(p)$
C4	60	261.63
D4	62	293.66
E♭4	63	311.13
F4	65	349.23
G4	67	392.00
A♭4	68	415.30
B♭4	70	466.16
C5	72	523.25

Homework

Exercise 1.6

Exercise 1.6. Using (1.1), compute the frequency ratio $F_{\text{pitch}}(p+1)/F_{\text{pitch}}(p)$ of two subsequent pitches $p+1$ and p (see (1.2)). How does the frequency $F_{\text{pitch}}(p+k)$ for some $k \in \mathbb{Z}$ relate to $F_{\text{pitch}}(p)$? Furthermore, derive a formula for the distance (in semitones) for two arbitrary frequencies ω_1 and ω_2.

Homework

Solution 1.6

$$
\begin{aligned}
F_{\text{pitch}}(p+1)/F_{\text{pitch}}(p) &= 2^{(p+1-69)/12} \cdot 440 \cdot 2^{-(p-69))/12} \cdot (1/440) \\
&= 2^{1/12} \cdot 2^{(p-69)/12} \cdot 2^{-(p-69))/12} \\
&= 2^{1/12} \approx 1.059463.
\end{aligned}
$$

$$
F_{\text{pitch}}(p+k) = 2^{k/12} \cdot F_{\text{pitch}}(p).
$$

$$
\log_2 \left(\frac{\omega_1}{\omega_2} \right) \cdot 12.
$$

Homework

Exercise 1.8

Exercise 1.8. Assume an equal-tempered scale that consists of 17 tones per octave and a reference pitch $p = 100$ having a center frequency of 1000 Hz. Specify a formula similar to (1.1), which yields the center frequencies for the pitches $p \in [0 : 255]$. In particular, determine the center frequency for the pitches $p = 83$, $p = 66$, and $p = 49$ in this scale. What is the difference (in cents) between two subsequent pitches in this scale?

Homework

Solution 1.8

$$F^{17}_{\text{pitch}}(p) = 2^{(p-100)/17} \cdot 1000.$$

In particular, one has $F^{17}_{\text{pitch}}(83) = 500$, $F^{17}_{\text{pitch}}(66) = 250$, and $F^{17}_{\text{pitch}}(59) = 125$. By (1.4), the difference (in cents) between two subsequent pitches is given by

$$\log_2 \left(\frac{F^{17}_{\text{pitch}}(p+1)}{F^{17}_{\text{pitch}}(p)} \right) \cdot 1200 = \log_2(2^{1/17}) \cdot 1200 = 1200/17 \approx 70.6.$$