1 Student presentations (PA1)

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2 Announcement: Schlepping reminder

- Please remember if you are signed up for pre- or post-class schlepping for either recording session on Mon, 11/28, Wed, 11/30.
- Pre-class schlepping: Meet at room [•] 10 minutes before class

3 Digital sound quality

3.1 Sample rate

- Higher sample rate: higher frequencies can be accurately reproduced
- Remember sampling theorem: \( f_S \geq 2 \cdot f_{\text{max}} \)
- But since upper range of hearing is 20 kHz, what justifies \( f_S = 192 \) kHz?
- Practical engineering reason: Reconstruction filter design (filter slope)!
- Montgomery [2012] argues that even so, “192 kHz digital music files offer no benefits” since transducers and power amplifiers are not designed to be distortion-free in the ultrasonic range.
- Katz [2014b] also discusses subject in depth
- Also: Sound fidelity as a social & cultural product (Sterne [2003])

3.2 Bit depth

- No hard limit comparable to sampling theorem
- Higher bit depth \( N \): larger dynamic range \( \Delta L \approx 6 \cdot N \) (cf., table 1)
- Compare to dynamic range of human ear (≈ 130 dB)

<table>
<thead>
<tr>
<th>( N )</th>
<th>( \Delta L / \text{dB} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>48</td>
</tr>
<tr>
<td>16</td>
<td>96</td>
</tr>
<tr>
<td>24</td>
<td>144</td>
</tr>
</tbody>
</table>

Table 1. Dynamic range \( \Delta L \) for different bit depths \( N \)
• For bit depths > 24, other rationales apply (DSP round-off errors etc.)
• But what if music itself exhibits a much smaller dynamic range?
• Sound examples: Can you hear the difference between 8 bit & 16 bit?

4 Ear training

• Represents limiting factor more often than gear (Senior 2011 p. 2)
• Ladies and gentlemen, meet the human ear!
  – Detects pressure changes of a billionth of atmospheric pressure
  – Handles sound pressures 10 000 000 000 times larger than that
  – Covers a range of 9–10 octaves
  – Is an excellent learner!
• Integrate ear training into everyday music listening (Katz 2014a pp. 25 f.)
• Ear training exercises specifically for sound engineers:
  – Katz (2014a pp. 27 ff.)
  – Corey (2010)

4.1 Rhythm, melody, harmony

• Ear training as part of a traditional music education (e.g., 21M.051)
• Examples of typical exercises:
  – Meter identification (e.g., 3/4 vs. 6/8)
  – Rhythm transcription
  – Interval recognition (song mnemonics)
  – Triad identification (M, m, A, or d? Root position or inversion?)
  – Scale recognition (M or m? Natural, harmonic, or melodic minor?)
  – Melody transcription (monophonic or polyphonic)
  – Cadence identification (Authentic, plagal, deceptive, or half?)
• Open source software package (Mac, Win, Linux): GNU Solfege

Figure 1. “Transcribe both parts” (key and first note for both staves given). Example from an entry exam for the Tonmeister program at the Vienna University of Music.
• Excellent hardware tool: your voice!
  – Freely available, cross-platform, open source 📒
  – Rule of 📒: If you can sing it, you can hear it.

4.2 Learning to distinguish different frequency ranges

• Popular exercise:
  – 10 bandpass-filtered noise bands at different center frequencies
  – Bandpass center frequencies given
  – Put center frequencies in order in which examples were played

• Available as online listening test series by Pigeon (2007–2014)
• Also: Golden Ears series of training CDs (Moulton 1995)

4.3 Recognizing bandwidth limiting

Sound examples in SoX:

$ play test.wav rate 44.1k 📒
$ play test.wav rate 22.05k 📒
$ play test.wav rate 16k 📒
$ play test.wav rate 8k 📒

4.4 Identifying musical instruments

• Upright vs. electric bass
• Soprano vs. alto vs. tenor vs. baritone saxophone
• Curved vs. straight soprano sax
• Trumpet vs. flugelhorn
• Oboe vs. bassoon vs. English horn
• String quartet: first vs. second violin
• Piano: beating strings on same key

4.5 Distinguishing sampled from ‘real’ pianos

• Sound example: Same tune played by 2 different pianos
• Which is sampled, which is ‘real’?

1 Cf., Katz[2014a] p. 27.
3 Cf., Katz[2014a] p. 35.
4.6 Identifying tiny differences\(^5\)

Make a test master with 0.5 dB difference in equalization of one band. Can you hear the difference in a blind test? (Katz 2014a, p. 30)

- Implemented as SoX example:

  $\textit{play test.wav equalizer 4k 0.50 +18}$

  $\textit{play test.wav equalizer 4k 0.50 +18.5}$

- Get to know (and improve) your JND for various sound parameters

- Online exercises by Pigeon (2007–2014)

4.7 Is it actually stereo?\(^6\)

- Try to judge this solely by ear!

- Confirm your judgement with the help of:
  1. Level meter
  2. Visual waveform inspection (at high zoom levels)
  3. Phase correlation meter
  4. Mix l with phase-inverted r. If result is silence, it was mono!

4.8 Identifying lossy encoder artifacts\(^7\)

- Sound example: mp3 file re-encoded 0, 5, 20 & 50 times

- Many more examples can be found on YouTube ©

4.9 Identifying other artifacts\(^8\)

- Comb filtering (interference between reflections and direct sound)

- Phasing & flanging (comb filtering that varies over time)

- Proximity effect (bass boost for directional microphones close to source)

- Different flavors of overload (e.g., tube saturation vs. digital clipping)

- Clicks due to rapid amplitude changes (e.g., bad splices)

- Pops due to dc offset

- Dropouts (digital vs. analog; best checked on headphones)

- Bad edits (inconsistent reverberation; obvious cuts, splices, or cross-fades; etc.)

- Polarity problems (e.g., out-of-phase stereo speaker pair)

- ‘Pumping’ or ‘breathing’ compressors


\(^6\) Cf., Katz (2014a) pp. 31 f.

\(^7\) Cf., Katz (2014a) pp. 27 ff., 35 f.

\(^8\) Cf., Katz (2014a) pp. 27 ff., 35 f.
• Stereo center shift
• Unstable phantom source localization
• Hum frequencies (60 Hz in us, 50 Hz in eu)
• Wow and flutter (tape speed irregularities)

5 Listening beyond the ears

• Video: Demonstration of the McGurk effect (BBC\textsuperscript{2017})

• Factors beyond the auditory system which affect auditory perception:
  – Visual perception (Katz\textsuperscript{2014a} p. 34)
  – Habituation (Katz\textsuperscript{2014a} p. 31)
  – Focus (Katz\textsuperscript{2014a} p. 32)
  – Peer pressure (Katz\textsuperscript{2014a} p. 34)
  – Psychology (expectations) (Katz\textsuperscript{2014a} pp. 30 f.)

• Anecdote: The Vienna high-end audio store

• Importance of systematic, unbiased listening test methodologies

6 Subjective listening tests

• Listening test terminology
  – Objective tests (models) vs. subjective tests (human subjects)
  – Blind tests & double-blind tests (subject and tester blinded)
  – Preference vs. discrimination (or equality) tests

• Software tool squishyball
  – Open-source command-line tool by 'Monty' Montgomery (xiph.org)
  – Implements basic subjective listening test methodologies
  – On Debian-based Linux systems (e.g., Ubuntu):
    \texttt{sudo apt-get install squishyball}

6.1 Casual comparison

• Mixing requires frequent and rapid decision making

• Good idea to establish a method to efficiently \textit{compare} different versions

• Squishyball demo:

  \$ squishyball --casual A.wav B.wav C.wav D.wav [...] \\
  \textbullet \texttt{Use \texttt{[1], [2], [3] or \\
  \textbullet \texttt{or \texttt{\dagger}, \texttt{\dagger} keys to switch between samples}}}

  \textbullet \texttt{Samples are presented in specified order (no randomization)}
  \textbullet \texttt{Single trial without selection}
6.2  (AB) or XY: Paired comparison

- More informative than casual comparison: Ask a specific question
- (AB) or XY test: Which of 2 samples is preferred in terms of _?
  - Samples are known to be different (not an equality test)
  - Need to know in advance the attribute likely to change ⓞ

- Squishyball demo:
  $ squishyball -n 5 --ab A.wav B.wav ⓞ

- -n ... number of trials (defaults to 20)
- [a] [b]: switch between samples
- [A] [B]: select preferred sample and move on to next trial
- Presentation order re-randomized for each trial

6.3  ABX test

- Rule of 👍 in mixing: If you can’t hear an edit, don’t do it.
- So question becomes: Perceptible difference between 2 samples?
- Problem: How to reliably determine whether there is?
  - Answer: Through an equality test
  - Different methodologies exist: ABX, AXY, (AB)X, (XY)

- Simplest is ABX test (Munson and Gardner 1950)
  - Widely used in testing audio data compression algorithms
  - Flaw: Sample order bias (test always starts with AB) ⓞ
  - Method: Is X identical to A or identical to B?

- Squishyball demo:
  $ squishyball -n 5 --abx A.wav B.wav ⓞ

- -n ... number of trials (defaults to 20)
- [a] [b] [x]: switch between ABX
- [A] [B]: select sample that X matches and move on to next trial
- Presentation order re-randomized for each trial

6.4  (AB)X: Duo-trio test with constant reference

- Objective: Perceptible difference between 2 samples?
- Method: Is X identical to 1 or identical to 2?
- Partly eliminates sample order bias (can be ABX or BAX) ⓞ
- But not entirely (since X is always last) ⓞ
- Not implemented in squishyball

Table 2. Listening test notation

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A, B</td>
<td>knowns</td>
<td>X, Y</td>
</tr>
<tr>
<td>(AB)</td>
<td>order unknown</td>
<td></td>
</tr>
</tbody>
</table>

Hence, (AB) = XY
6.5 (XXY): Triangle test

- Objective: Perceptible difference between 2 samples?
- Method: Which of 3 samples is the odd one out?
- Eliminates sample order bias ☺
- Squishyball demo:
  $\$ squishyball -n 5 --xxy A.wav B.wav ☑

  - -n ... number of trials (defaults to 20)
  - 1, 2, 3: switch between (XXY)
  - Mark odd one out and move on to next trial:
    \[ 
    \hat{\mathbf{1}} + 1 = \hat{!} \text{ for } Y = 1 \\
    \hat{2} + 2 = \hat{0} \text{ for } Y = 2 \\
    \hat{\mathbf{3}} + 3 = \hat{#} \text{ for } Y = 3 
    \]
  - Identities (A = Y vs. B = Y) and order re-randomized per trial

7 Caring for your ears

- Arguably the sound engineer’s most important tool
- A ‘piece of equipment’ that no money in the world can replace!
- Ear training also means learning when and how to protect your ears.

7.1 Hearing disorders

- Stapedius reflex: ear’s (very limited!) built-in protection mechanism
- Hearing loss due to age (review: \( \approx 1 \text{kHz per life decade} \))
- Noise-induced hearing loss: irreversible damage to inner ear hair cells
- Tinnitus: Hearing sound when no external sound is present
  - Often described as ringing, whistling, buzzing, roaring, etc.
  - Various causes: Noise-induced hearing loss, ear infections, brain tumors, emotional stress, certain drugs, etc.
  - Objective vs. subjective tinnitus
  - Intermittent tinnitus (for a few seconds) is a common occurrence
  - Continuous tinnitus requires early treatment before it becomes chronic!
7.2 Hearing protection

- Consider getting custom-moulded earplugs (ca. $100)
  - Option No1: Non-neutral frequency response, but high attenuation
  - Option No2: Neutral frequency response, but lower net attenuation

- Avoid long-term exposure to high sound pressure levels.

- Avoid loud impulses close to your ears (e.g., firecrackers).

- Don’t mix at too high sound pressure levels.
  - Studio monitor calibration procedure recommended by Katz (2014c, pp. 263 f.)
  - Pink noise at 0 dB monitor control should yield 83 dB_{SPL} (C-weighted, slow meter response) at sweet spot

- Be particularly careful when programming audio (e.g., Pd).

- Be particularly careful with headphones.

- Take breaks.

References & further reading


