Introduction to **Audio Content Analysis**

module 7.4: tuning frequency estimation

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corresponding textbook section

section 7.4

- **lecture content**
  - definition of the tuning frequency
  - approaches to tuning frequency estimation

- **learning objectives**
  - explain the term tuning frequency
  - discuss the necessity of automatic tuning frequency estimation
  - compare different approaches to tuning frequency estimation

introduction
overview

corresponding textbook section

section 7.4

- **lecture content**
  - definition of the tuning frequency
  - approaches to tuning frequency estimation
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tuning frequency

frequency of the concert pitch A4

- used to tune groups of instruments
- standardized as 440 Hz[1]

[1] I. 16:1975, "Acoustics â€" Standard tuning frequency (Standard musical pitch)," ISO, Standard, 1975.

tuning frequency
distribution

- historic tuning frequencies

Year	Lower Deviation	Upper Deviation
1750	$-50\,\mathrm{Hz}$	$+30\,\mathrm{Hz}$
1850	$-20\,\mathrm{Hz}$	$+20\,\mathrm{Hz}$
1950	$-5\,\mathrm{Hz}$	$+10\,\mathrm{Hz}$

- tuning frequencies today
  - electronic music: often exactly 440 Hz
  - 'classical' music:
    - CSO, NYP: 442 Hz
    - BPO, VPO: 443 Hz

[2] A. Lerch, "On the Requirement of Automatic Tuning Frequency Estimation," in *Proceedings of the 7th International Conference on Music Information Retrieval (ISMIR)*, Victoria, 2006.

tuning frequency
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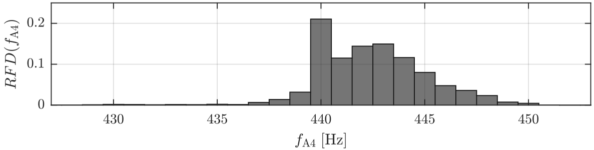

matlab source: plotTuningFreqs.m

[2] A. Lerch, "On the Requirement of Automatic Tuning Frequency Estimation," in *Proceedings of the 7th International Conference on Music Information Retrieval (ISMIR)*, Victoria, 2006.

tuning frequency estimation

quick example — noticeable difference?

which one is higher?

tuning frequency estimation
quick example — noticeable difference?

which one is higher?

- example 1: 443 Hz
- example 2: 440 Hz

tuning frequency estimation

requirement

- any pitch-based analysis system relies on tuning frequency (pre-defined or adaptive), recall

$$\mathfrak{p}(f) = 69 + 12 \cdot \log_2\left(\frac{f}{f_{A4}}\right)$$

- tuning frequency can be far from 440 Hz

⇒ wrong tuning frequency assumption can significantly impact pitch detection reliability

tuning frequency estimation
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$\Rightarrow$ wrong tuning frequency assumption can significantly impact pitch detection reliability

tuning frequency estimation

assumptions and limits

1. **key is unknown**, i.e., deviation $> 50\,\mathrm{Cent}$ will be mapped back to semitone range
2. **temperament/intonation is unknown**, i.e., equally tempered tuning has to be assumed
3. piece may be **polyphonic**
4. piece may **not contain pitch A4**
5. **tuning frequency does not change** or changes slowly over time

tuning frequency estimation

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tuning frequency estimation

typical processing steps

1. **estimate fundamental frequencies** or frequencies of tonal components
2. **calculate deviation** ΔC from the nearest equally tempered pitch frequency
3. **average all deviations**: $\mu_{\Delta C}$ (or look at histogram)
4. **estimate the tuning frequency** from the average deviation:

$$\hat{f}_{\mathrm{A4}} = 440\,\mathrm{Hz} \cdot 2^{\frac{\mu_{\Delta C}}{1200}}$$

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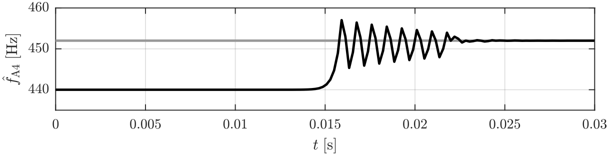
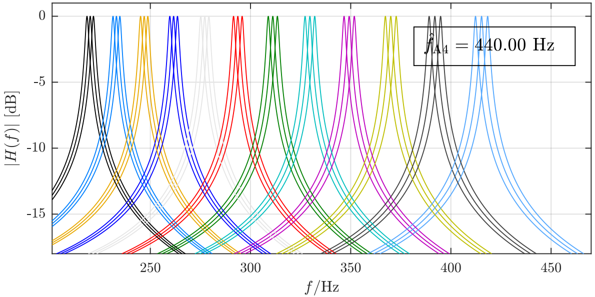
tuning frequency estimation
adaption example



matlab source: plotFA4Rprop.m

tuning frequency estimation

adaption example



matlab source: matlab/animateFA4FilterBank.m

summary
lecture content

- **tuning frequency**
  - important reference for all pitch-based algorithms
  - usually around 440 Hz
- **tuning frequency estimation**
  - assume equally tempered recording without intonation changes
  - map deviations to new estimate
- **potential issues**
  - frequencies of harmonics distort estimate
  - temperament and tuning break assumptions
  - insufficient reliable real-world ground truth data