



# Introduction to **Audio Content Analysis**

Module 7.4: Tuning Frequency Estimation

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# introduction

overview

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



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# tuning frequency

## introduction

### tuning frequency

frequency of the concert pitch A4

- used to tune groups of instruments
- standardized as 440 Hz<sup>1</sup>

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<sup>1</sup>I. 16:1975, "Acoustics – Standard tuning frequency (Standard musical pitch)," ISO, Standard, 1975.

# tuning frequency distribution

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

Year	Lower Deviation	Upper Deviation
1750	-50 Hz	+30 Hz
1850	-20 Hz	+20 Hz
1950	-5 Hz	+10 Hz

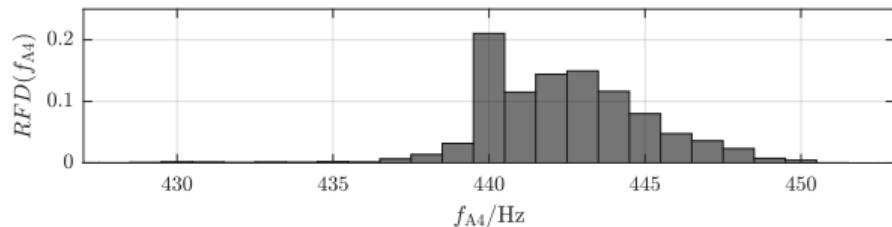
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<sup>2</sup>A. Lerch, "On the Requirement of Automatic Tuning Frequency Estimation," in *Proceedings of the 7th International Conference on Music Information Retrieval (ISMIR)*, Victoria, 2006.

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# tuning frequency estimation

## quick example



**which one is higher?**



# tuning frequency estimation

## quick example



**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

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

- tuning frequency can be far from 440 Hz

⇒ wrong tuning frequency assumption can significantly impact pitch detection reliability

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# tuning frequency estimation

## assumptions and limits

- 1 **key is unknown**, i.e., deviation  $> 50$  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

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# tuning frequency estimation

## typical processing steps

- 1 estimate fundamental frequencies** or frequencies of tonal components
- 2 calculate deviation  $\Delta C$**  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:

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

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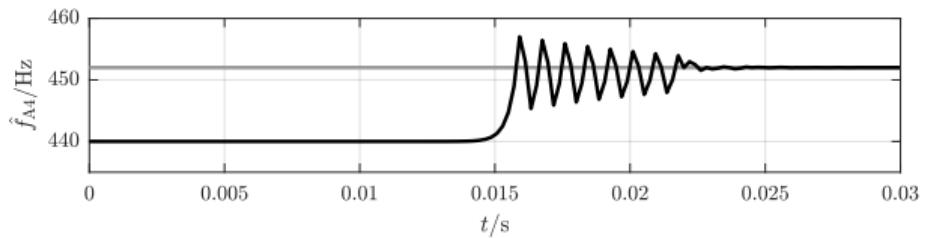
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# tuning frequency estimation

## adaption example



overview  
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intro  
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task  
ooo●

summary  
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# tuning frequency estimation

## adaption example

Georgia Tech | Center for Music Technology  
College of Design



matlab source: [matlab/animate/FA4FilterBank.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

