ISMIR

**ISMIR Tutorial**

Abu Dhabi, UAE, November 08, 2026

ISMIR ABU DHABI 2026

# Introduction to Music Information Retrieval: Three Perspectives

## Part 2: A Computational Musicology Perspective


**Meinard Müller**

International Audio Laboratories Erlangen

Friedrich-Alexander Universität Erlangen-Nürnberg

meinard.mueller@audiolabs-erlangen.de

**Christof Weiß**

Center for Artificial Intelligence and Data Science

Julius-Maximilians-Universität Würzburg

christof.weiss@uni-wuerzburg.de


AUDIO LABS FAU Fraunhofer IIS Julius-Maximilians-Universität Würzburg CAIDAS zpd

# Computational Musicology

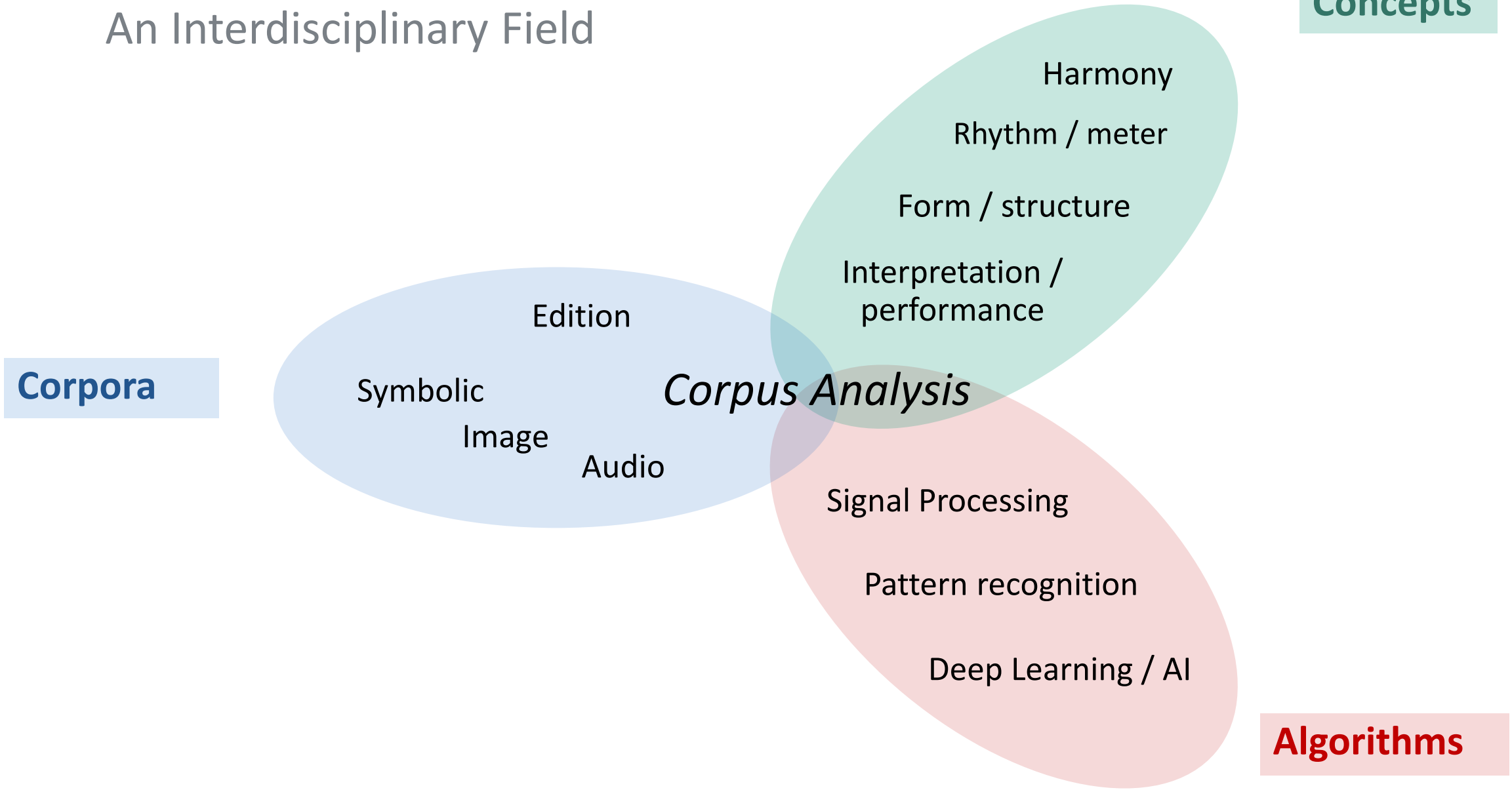
## Application Scenarios for MIR

- New strategies for musicology and humanities
  - **Objective** (measurements)
  - **Scalable** to large databases (corpus analysis)



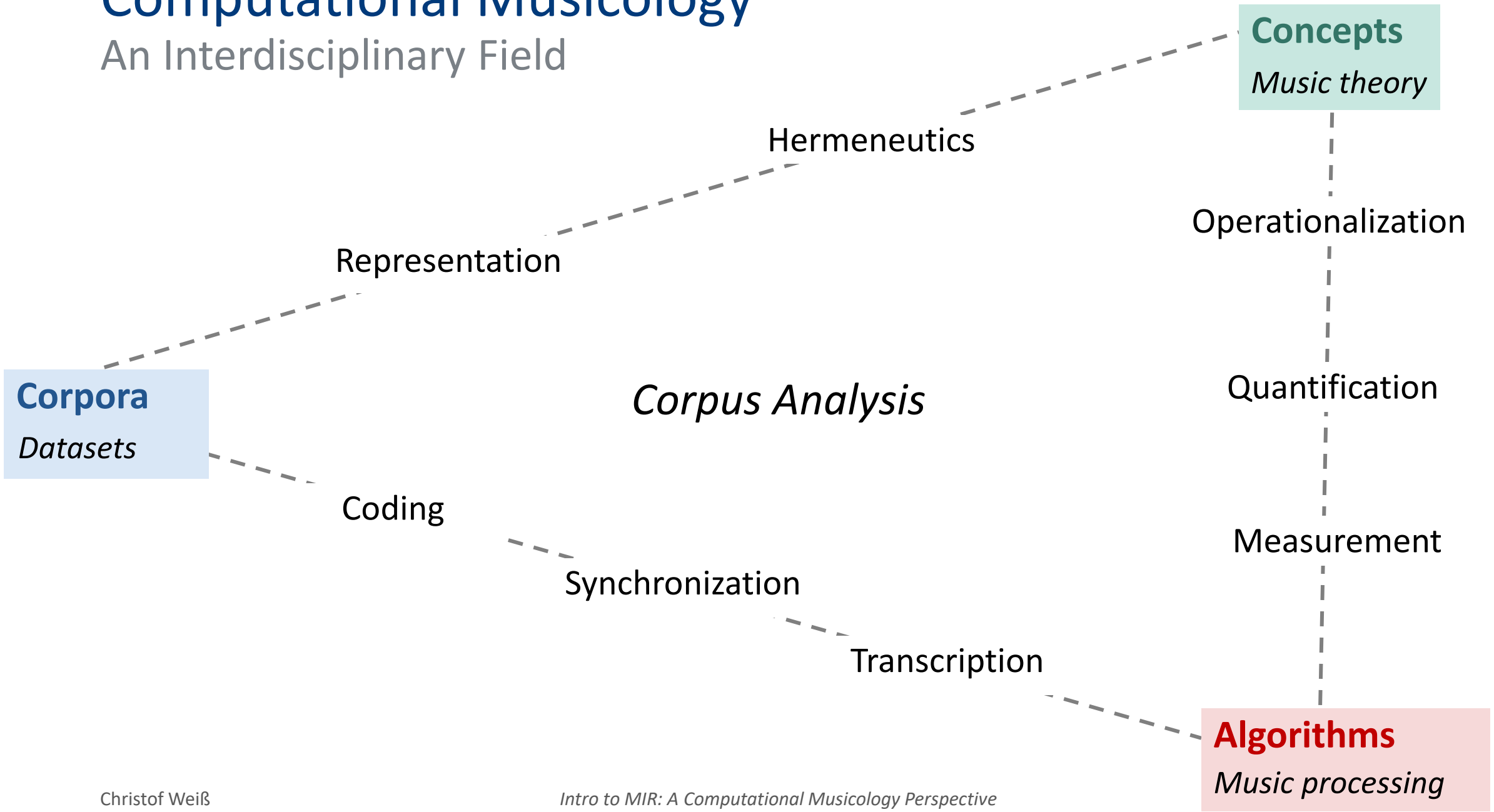
# Computational Musicology

## An Interdisciplinary Field



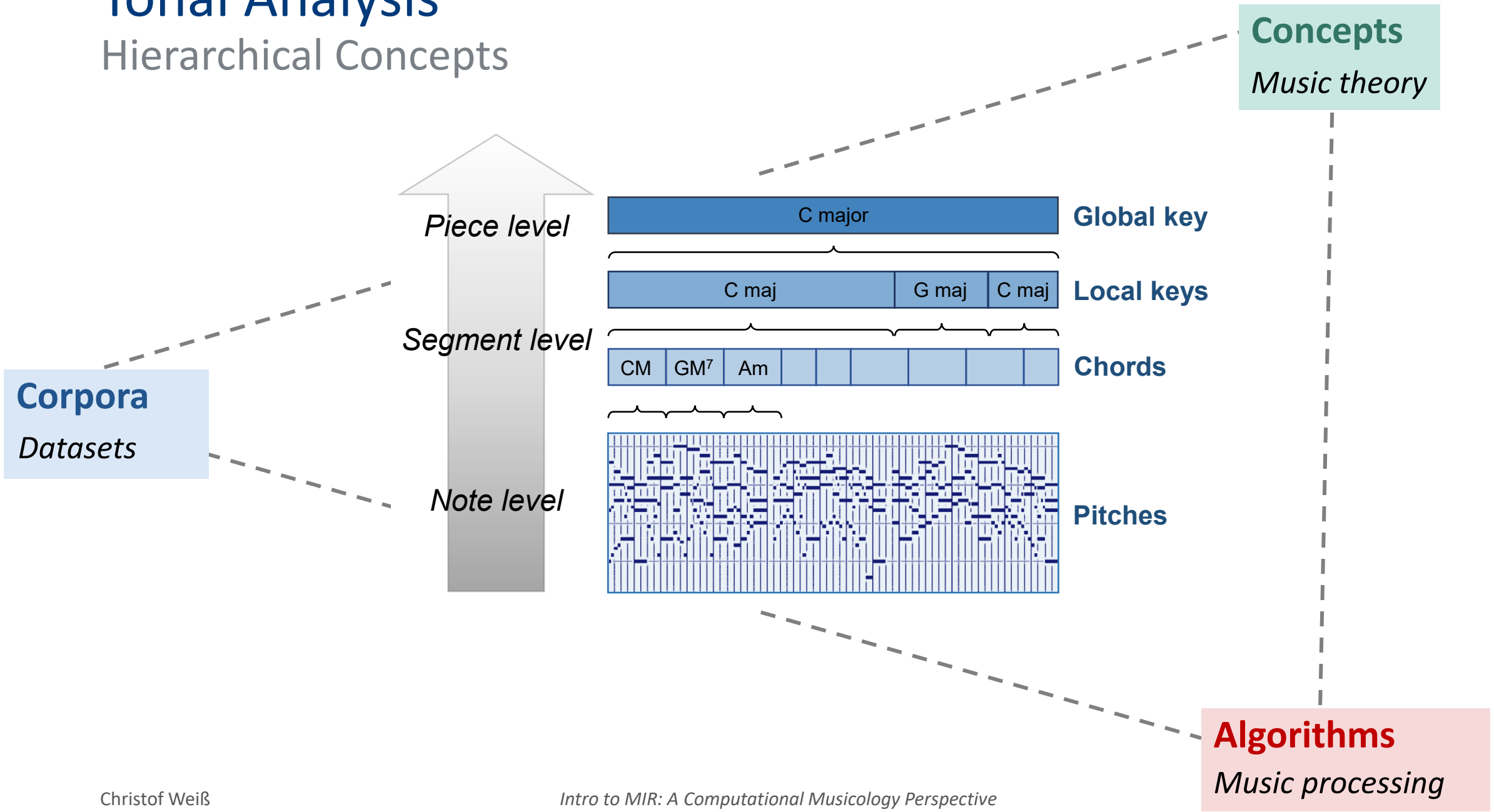
# Computational Musicology

## An Interdisciplinary Field



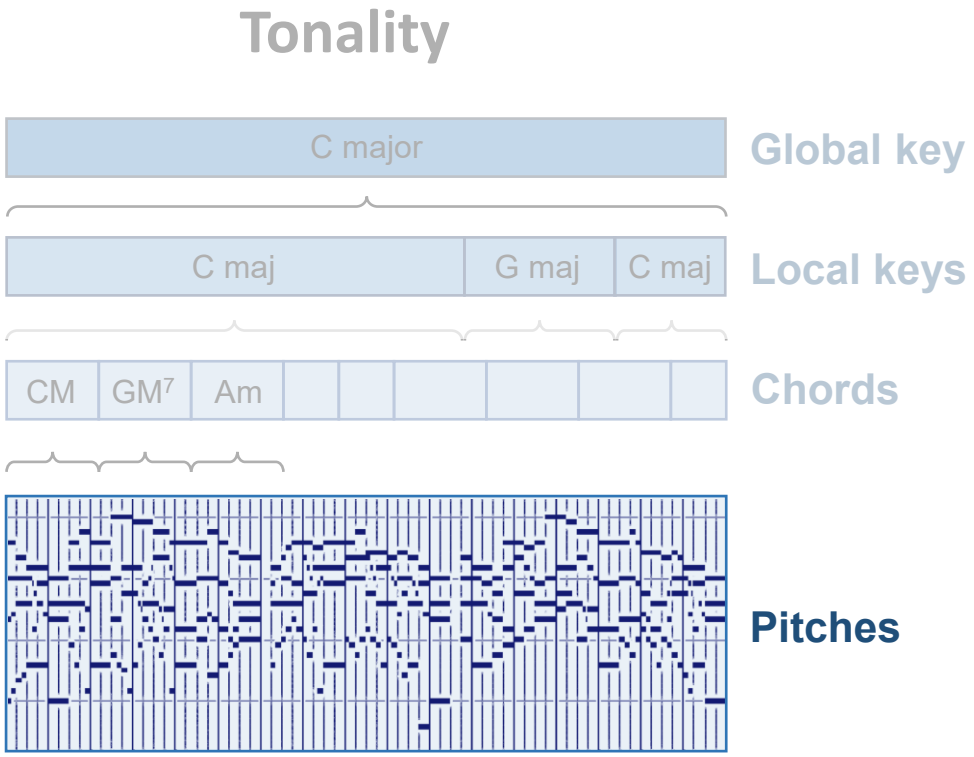
# Tonal Analysis

## Hierarchical Concepts



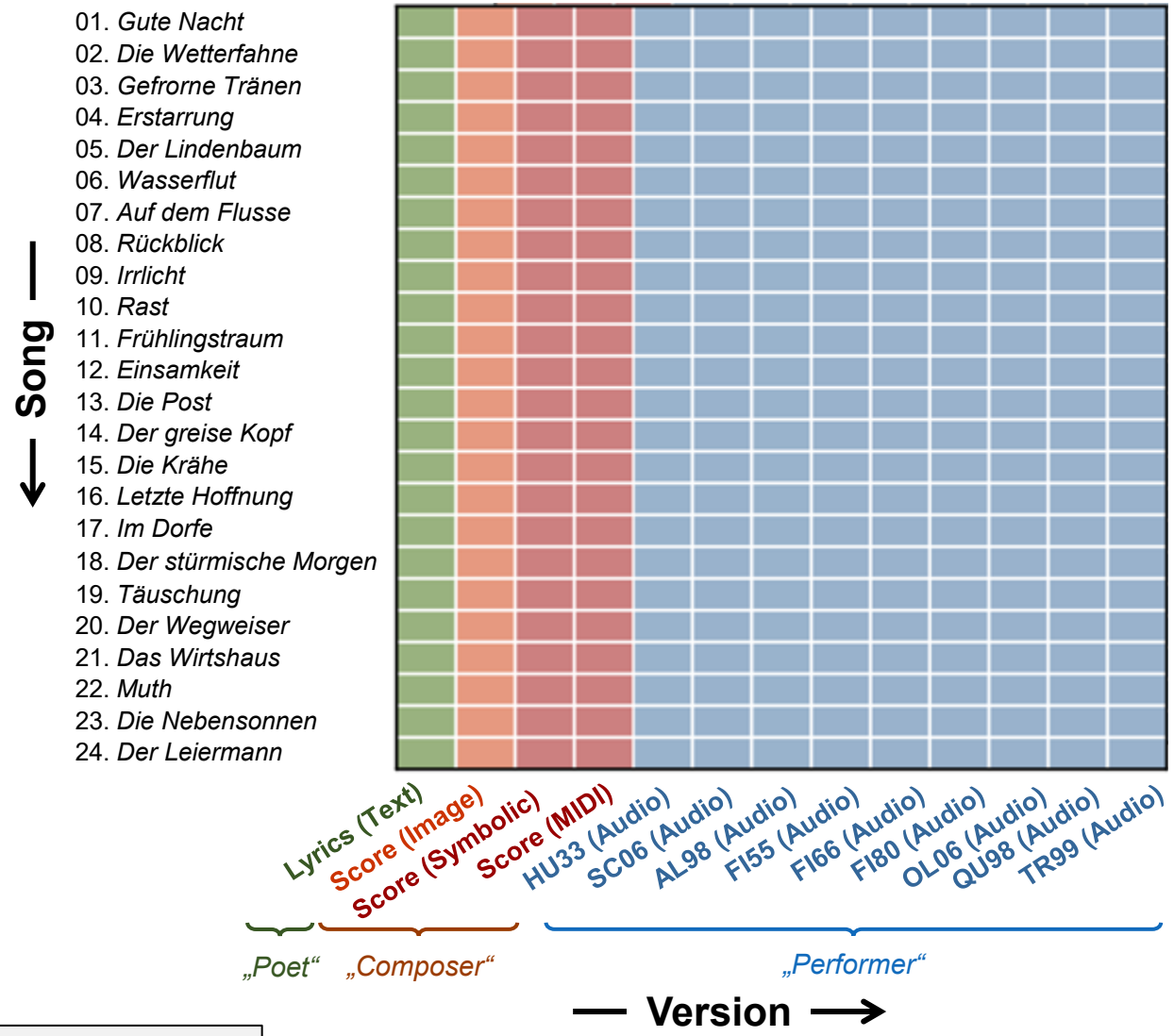
# Outline

1. **Extracting Pitch Information**
2. Measuring Tonal Structures
3. Analyzing Musical Style



## Corpus

Franz Schubert:
*Winterreise*




Weiß et al., **Schubert Winterreise Dataset: A Multimodal Scenario for Music Analysis**
*ACM J. Computing and Cultural Heritage* 2021

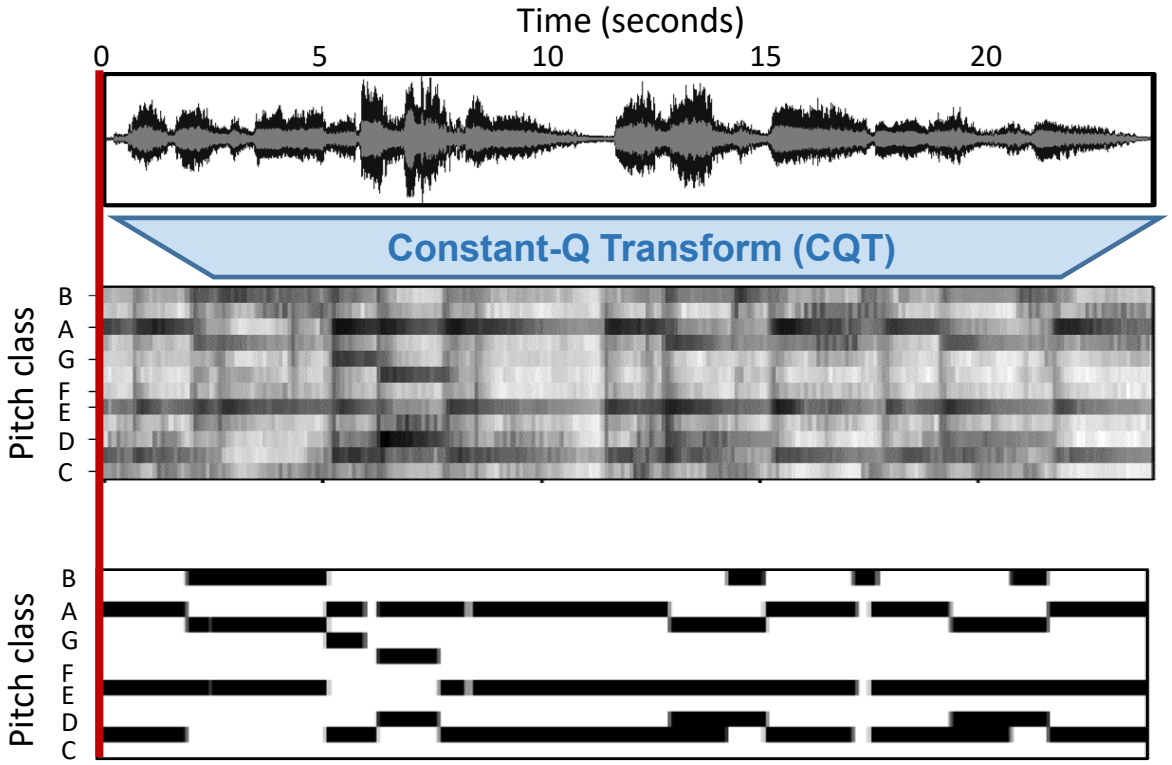
## Music theory

Tonal Analysis
Representations

## Algorithms

Deep Learning
Signal Processing

Nr. 23, *Die Nebensonnen (Trekel 1999)*







## Corpus

Franz Schubert:
*Winterreise*

## Music theory

Tonal Analysis
Representations



## Algorithms

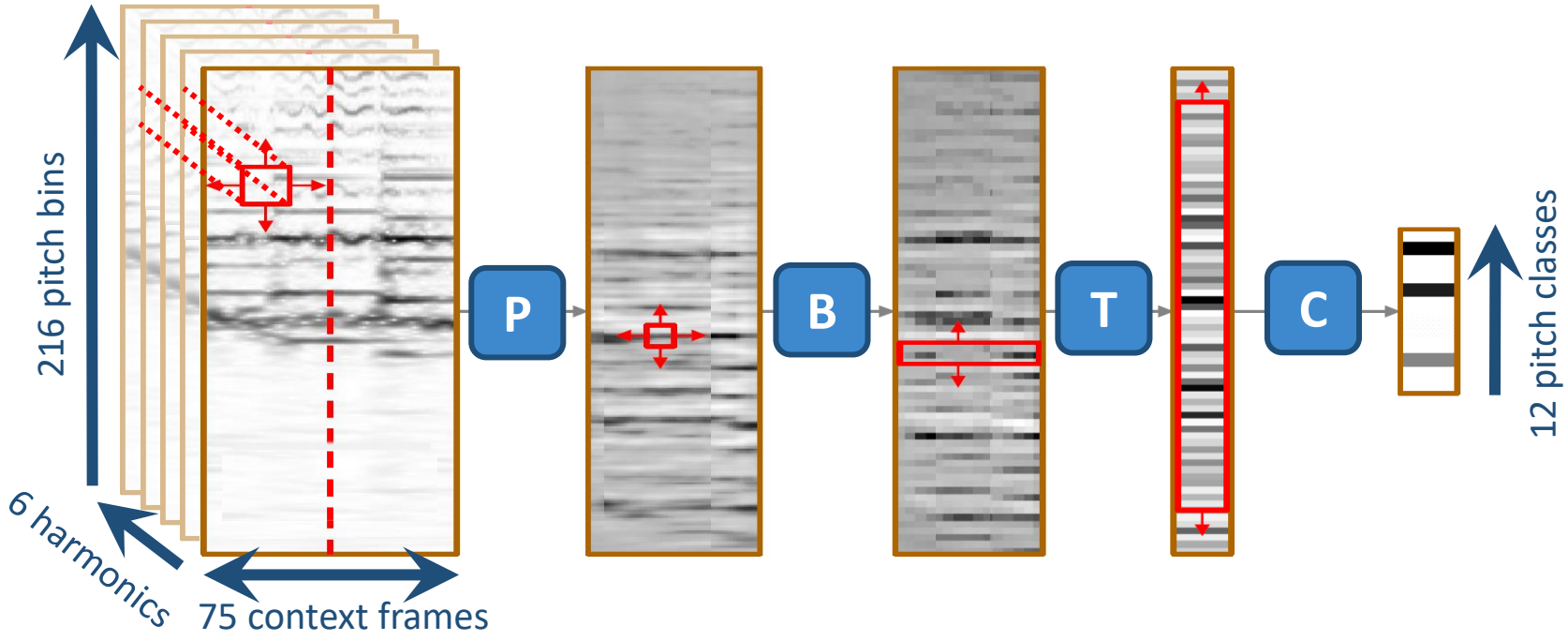
Deep Learning
Signal Processing

# Pitch Class Representations

## Deep-Learning Approach

- 5-layer CNN
- **P**re-filtering, **B**inning, **T**emporal reduction, **C**hroma reduction

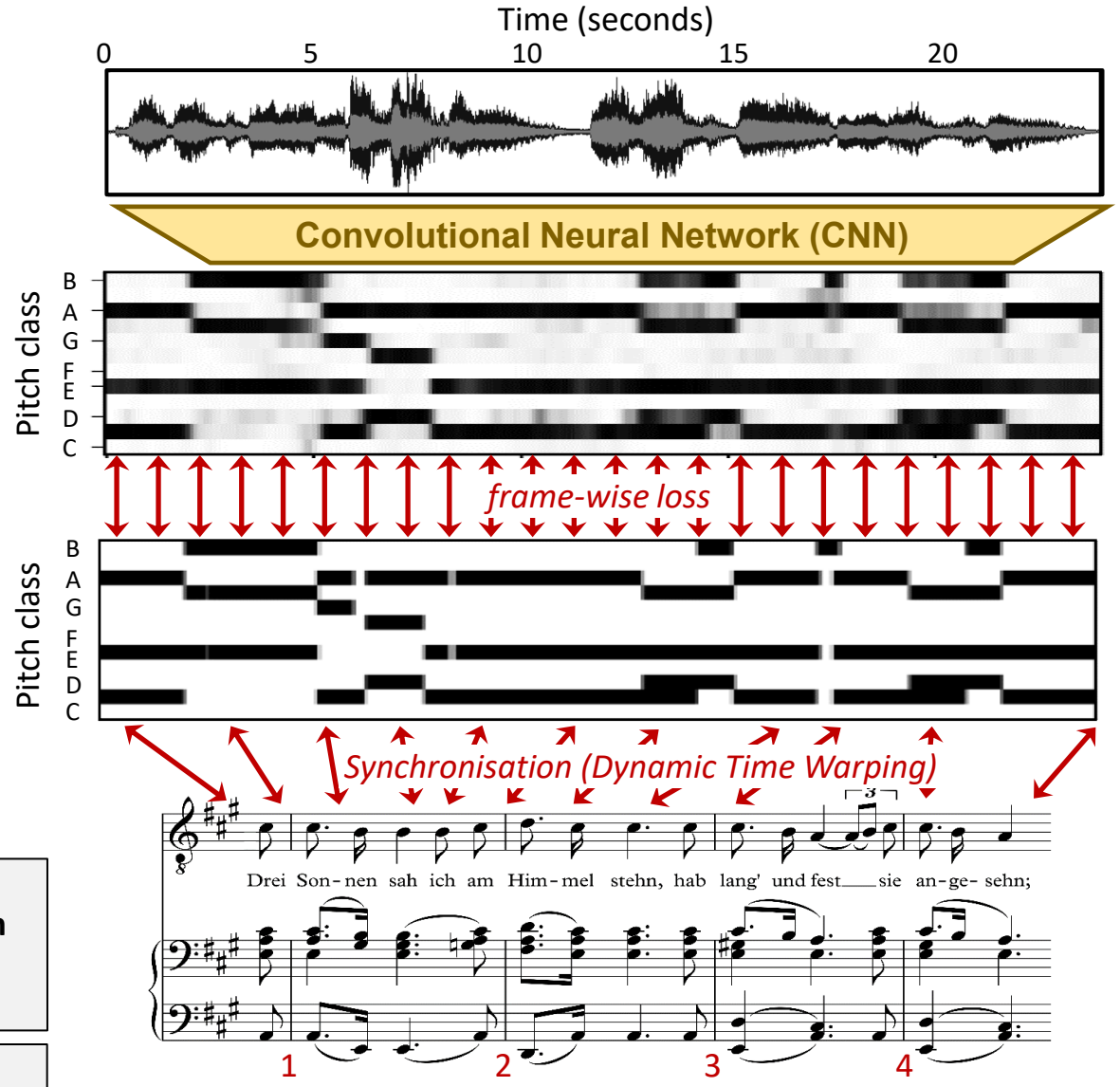
| Layer | Kernel size | Output shape | # Parameters |
|---|---|---|---|
| Layer norm. | | $(T+74, 216, 6)$ | 2592 |
| Conv2D, MaxPool | $15 \times 15$ | $(T+74, 216, 20)$ | 27020 |
| Conv2D, MaxPool | $3 \times 3$ | $(T+74, 72, 20)$ | 3620 |
| Conv2D | $75 \times 1$ | $(T, 72, 10)$ | 15010 |
| Conv2D | $1 \times 1$ | $(T, 72, 1)$ | 11 |
| Conv2D | $1 \times 61$ | $(T, 12+P, Q)$ | $Q(62+73 \cdot P)$ |
| **Total** | | | 48253 $+Q(62+73 \cdot P)$ |




Bittner et al., **Deep Salience Representations for F0 Estimation in Polyphonic Music**, Proc. ISMIR 2017.

## Corpus

Franz Schubert:
*Winterreise*




Weiß, Zeitler, Zunner, Schuberth, Müller, **Learning Pitch-Class Representations from Score–Audio Pairs of Classical Music**, Proc. ISMIR 2021.

Weiß & Peeters, **Training Deep Pitch-Class Representations With a Multi-Label CTC Loss**, Proc. ISMIR 2021.

## Music theory

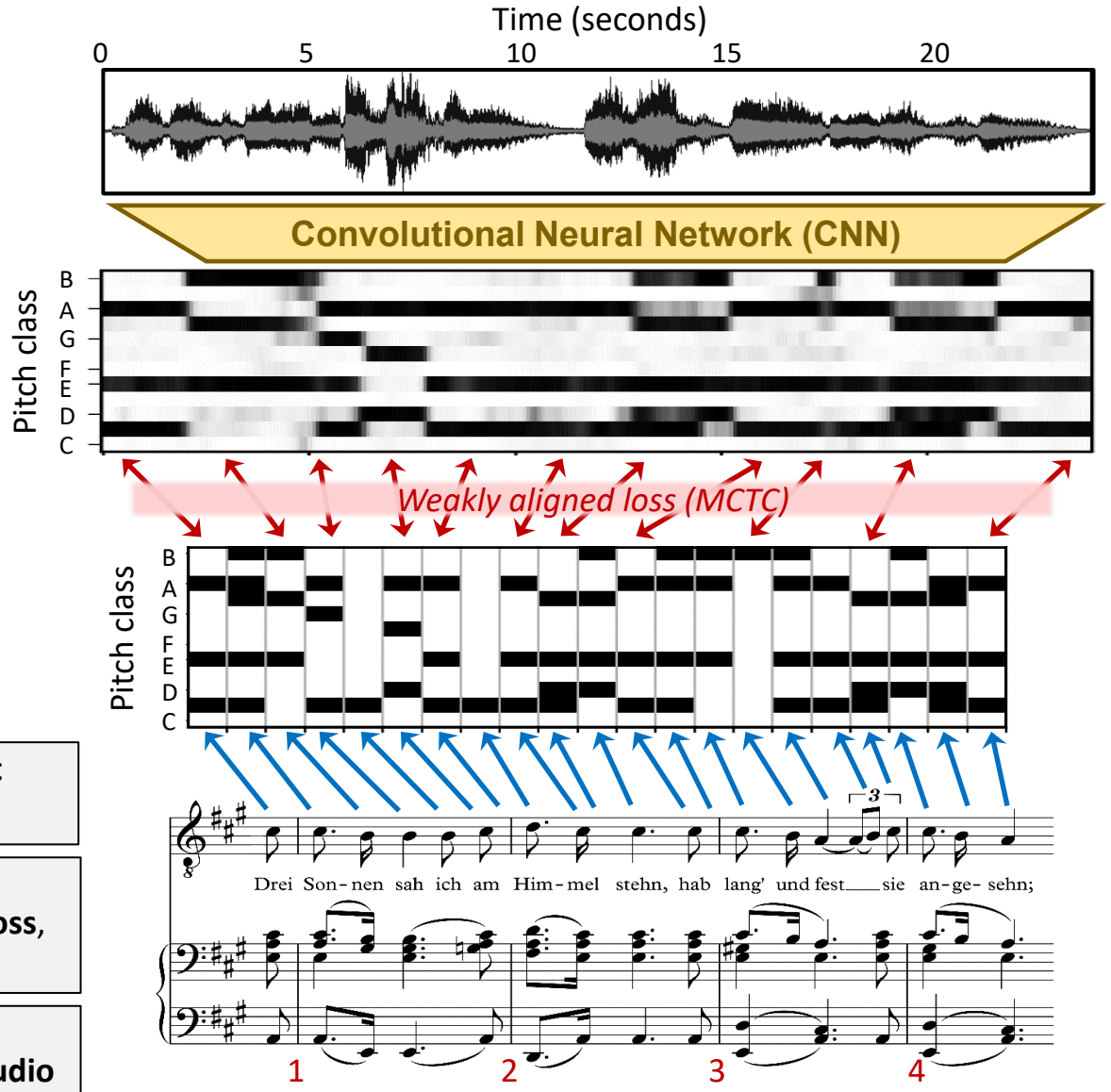
Tonal Analysis
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Wigington et al.: **Multi-label Connectionist Temporal Classification.** Proc. ICDAR 2019.

Weiß & Peeters, **Training Deep Pitch-Class Representations With a Multi-Label CTC Loss**, Proc. ISMIR 2021.

Weiß & Peeters, **Learning Multi-Pitch Estimation From Weakly Aligned Score–Audio Pairs Using A Multi-label CTC Loss**, IEEE WASPAA 2021.

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Tonal Analysis
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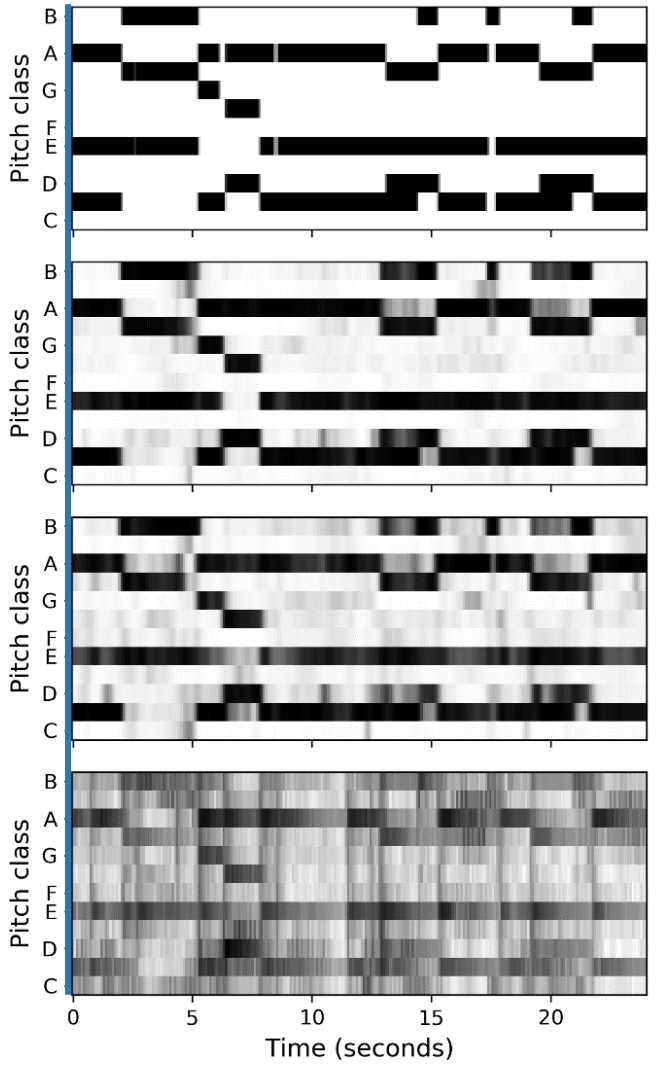
Franz Schubert:
*Winterreise*

Annotations

CNN, supervised

CNN, weakly-aligned (MCTC)

Signal Processing (CQT)




CS = 1

CS = 0.95

CS = 0.93

CS = 0.71

## Music theory

Tonal Analysis
Representations

## Algorithms

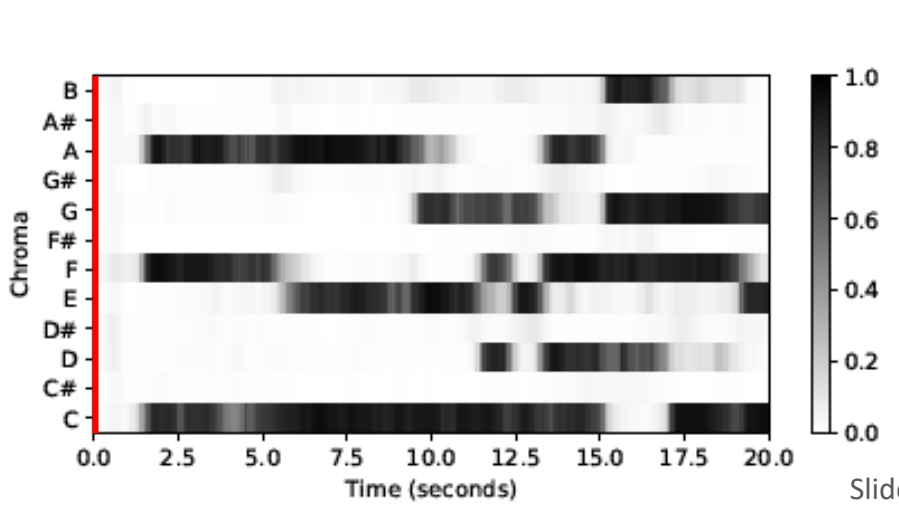
Pitch-Class
Estimation

**Music theory**

Tonal Analysis Representations

**Example**: “Abendlied”, Josef Gabriel Rheinberger (1855)




**Signal Processing**

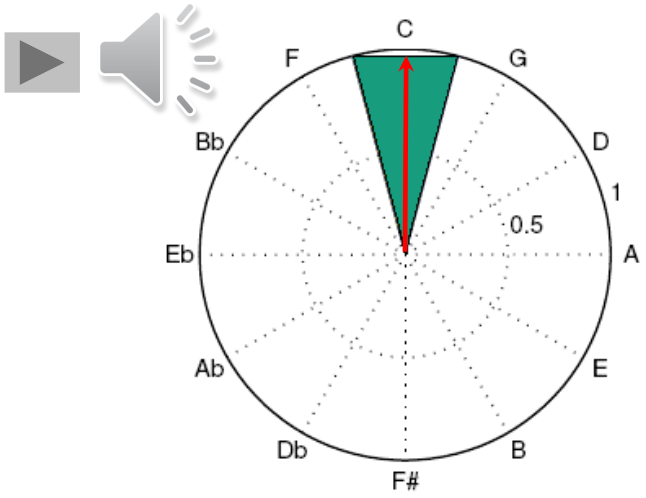



**Deep Learning**

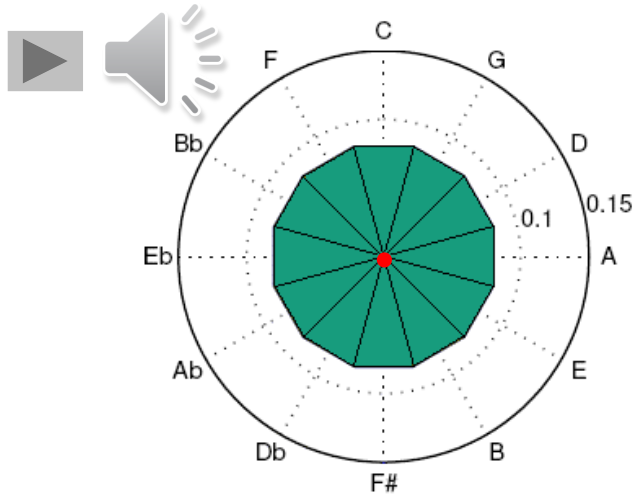
## Music theory

Fifth Width
Tonal Complexity

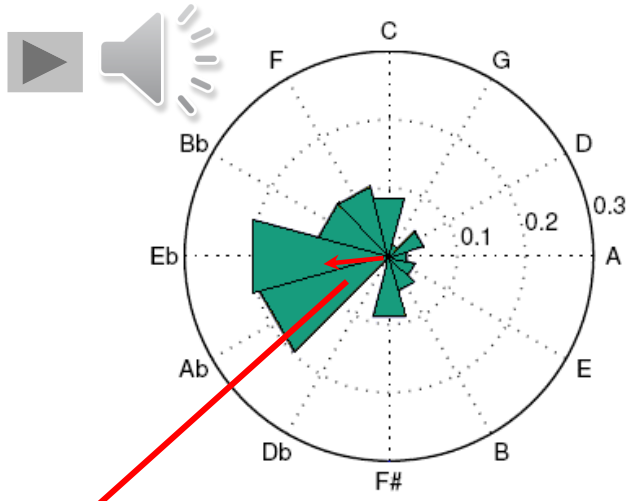
$Complexity = 0$




$Complexity = 1$




$Complexity = 0.6$



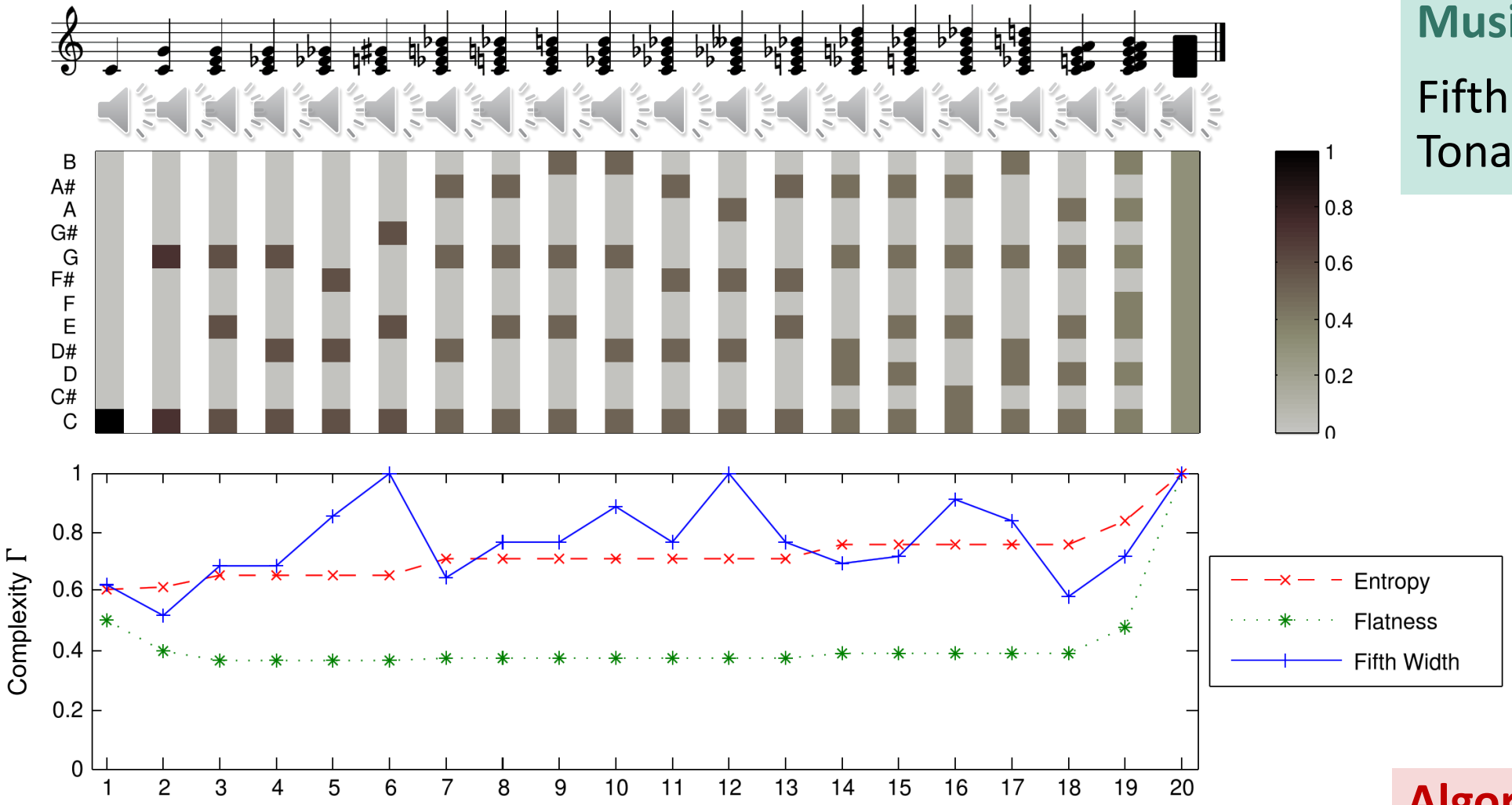

$$Complexity = \sqrt{1 - r_{\text{fifth}}(\mathbf{c})}$$

Weiß & Müller, **Quantifying and Visualizing Tonal Complexity**, Proc. Conf. on Interdisciplinary Musicology, 2014.

Weiß & Müller, **Tonal Complexity Features for Style Classification of Classical Music**, Proc. IEEE ICASSP 2015.

## Algorithms

Geometry
Circular Statistics




## Music theory

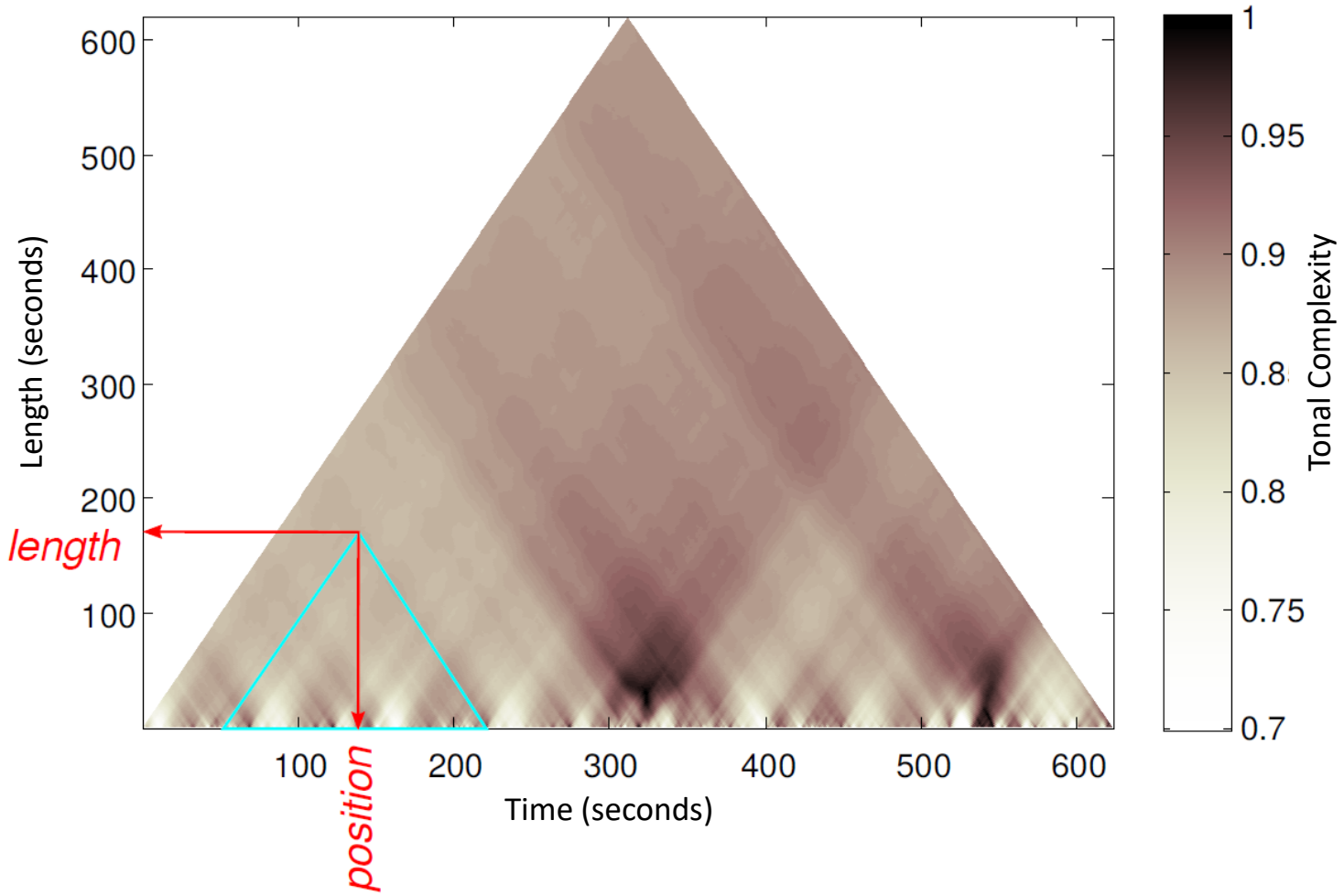
Fifth Width
Tonal Complexity

## Algorithms

Geometry
Circular Statistics

Weiß & Müller, **Quantifying and Visualizing Tonal Complexity**, Proc. Conf. on Interdisciplinary Musicology, 2014.

Complexity relates to multiple time scales
Multi-scale visualization technique: Scape plot




**Music theory**

Fifth Width
Tonal Complexity

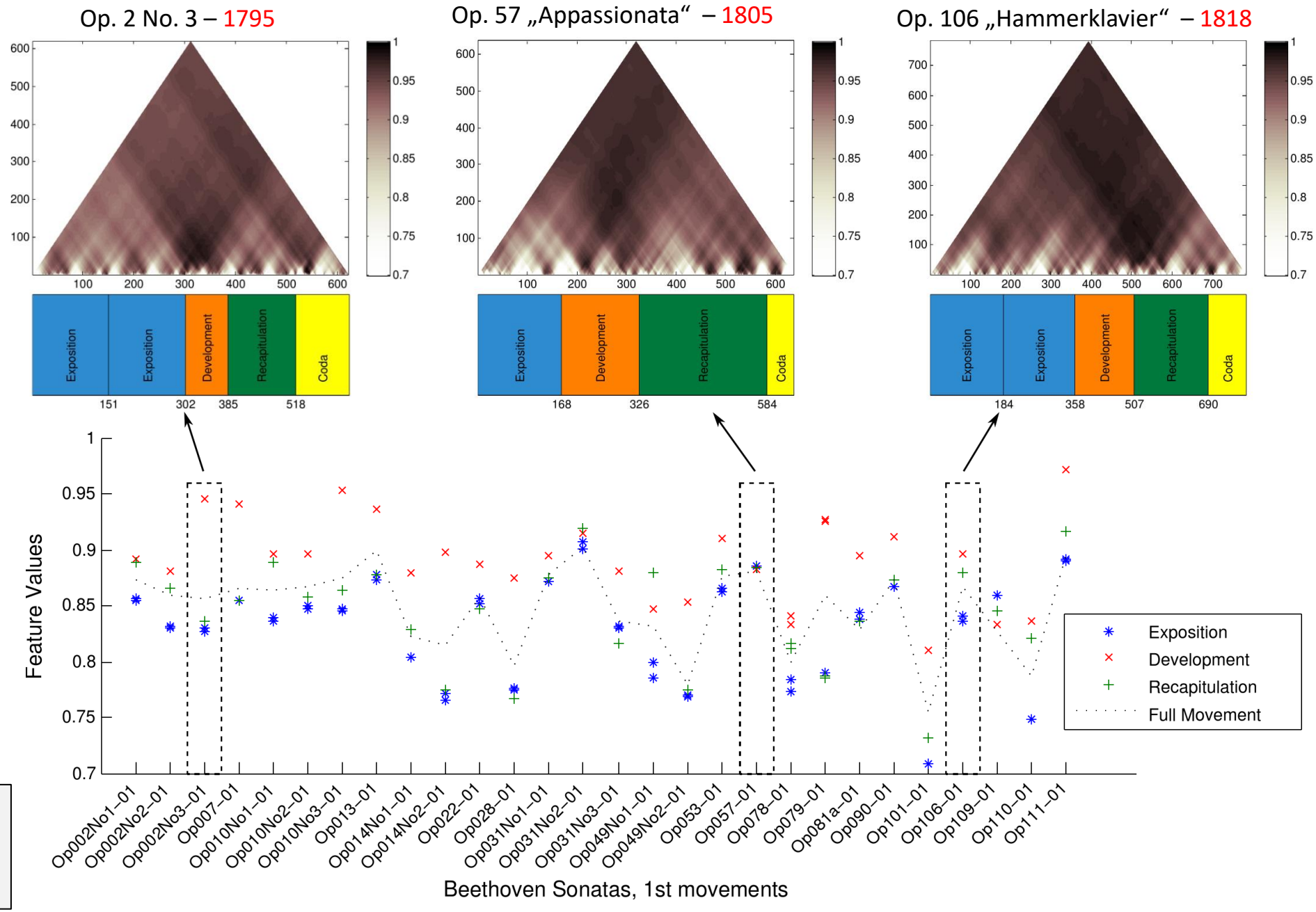
**Algorithms**

Geometry
Circular Statistics

Craig Sapp. **Harmonic Visualizations of Tonal Music**. ICMC 2001

## Corpus

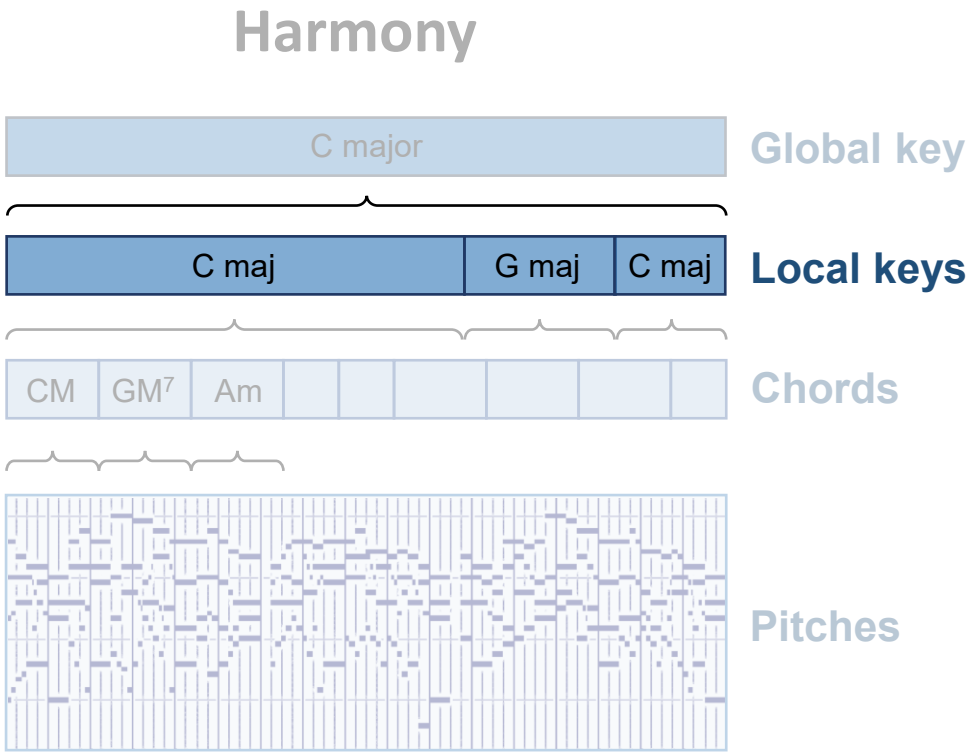
L. v. Beethoven, Piano Sonatas (Expositions)




Zeitler, Weiß, Arifi-Müller, Müller, **BPSD: A Coherent Multi-Version Dataset for Analyzing the First Movements of Beethoven's Piano Sonatas**, TISMIR 2024.

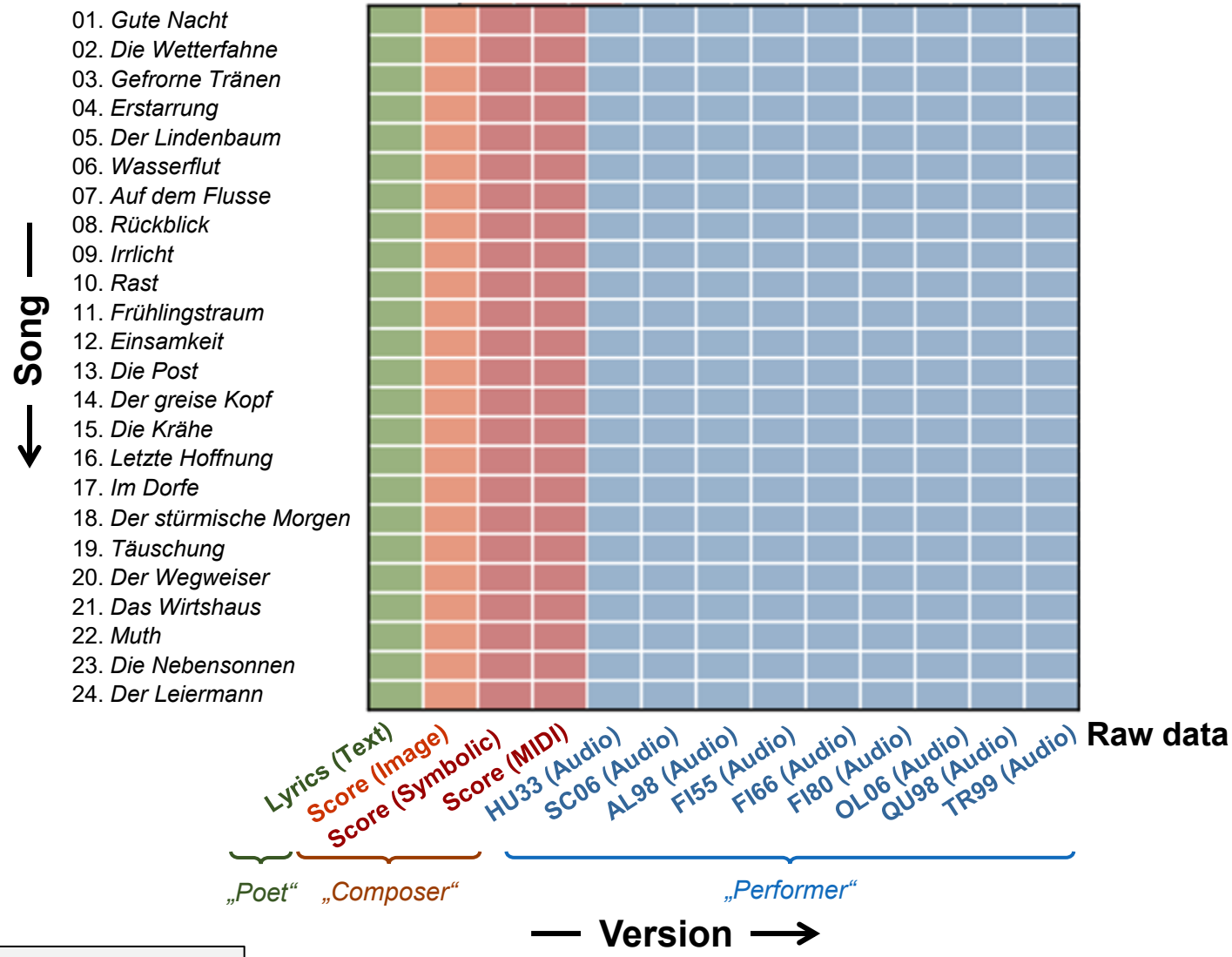
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## Music theory

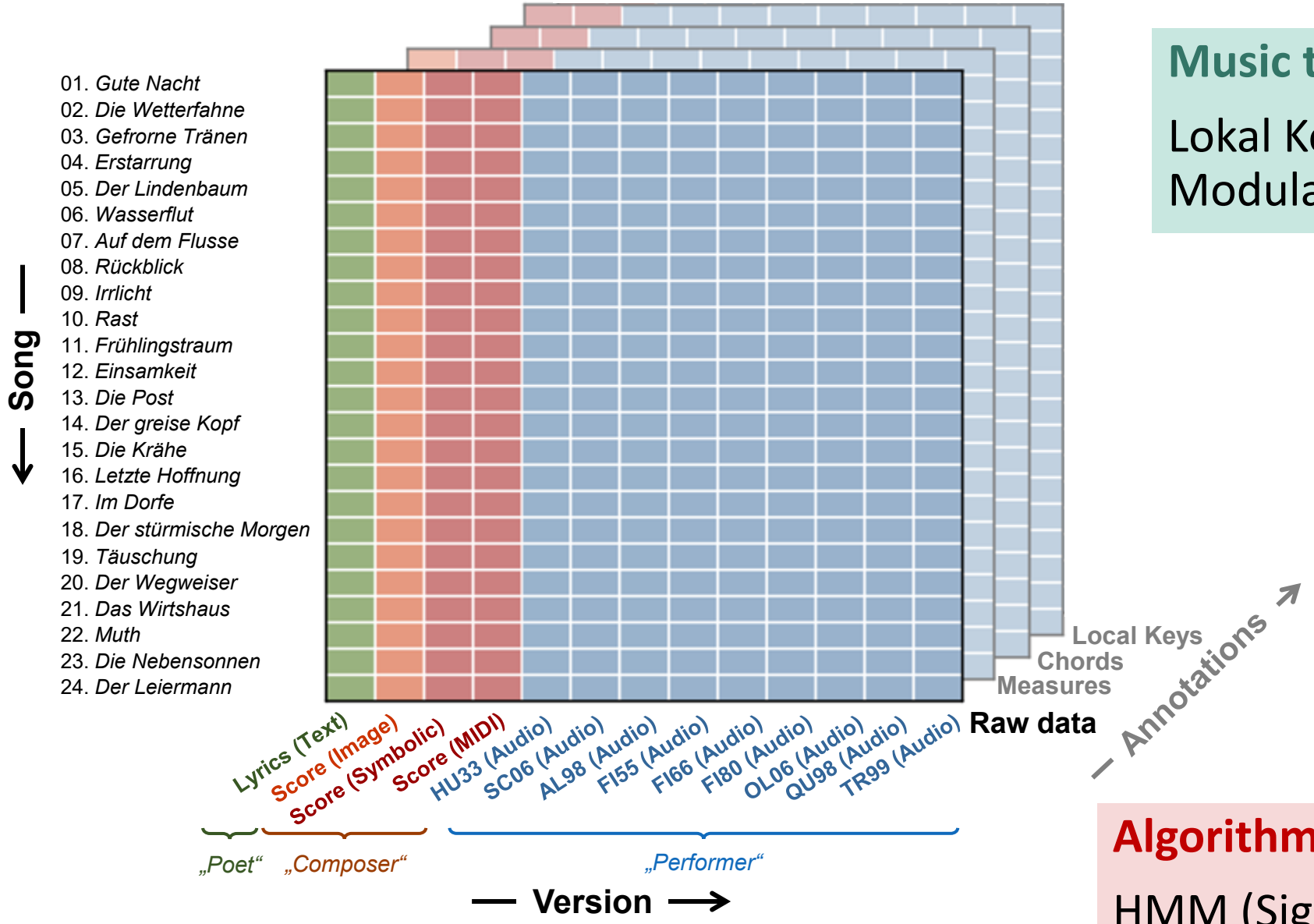
Tonal Analysis
Representations

## Algorithms

Deep Learning
Signal Processing

## Corpus

Franz Schubert:
*Winterreise*




## Music theory

Lokal Keys
Modulations

## Algorithms

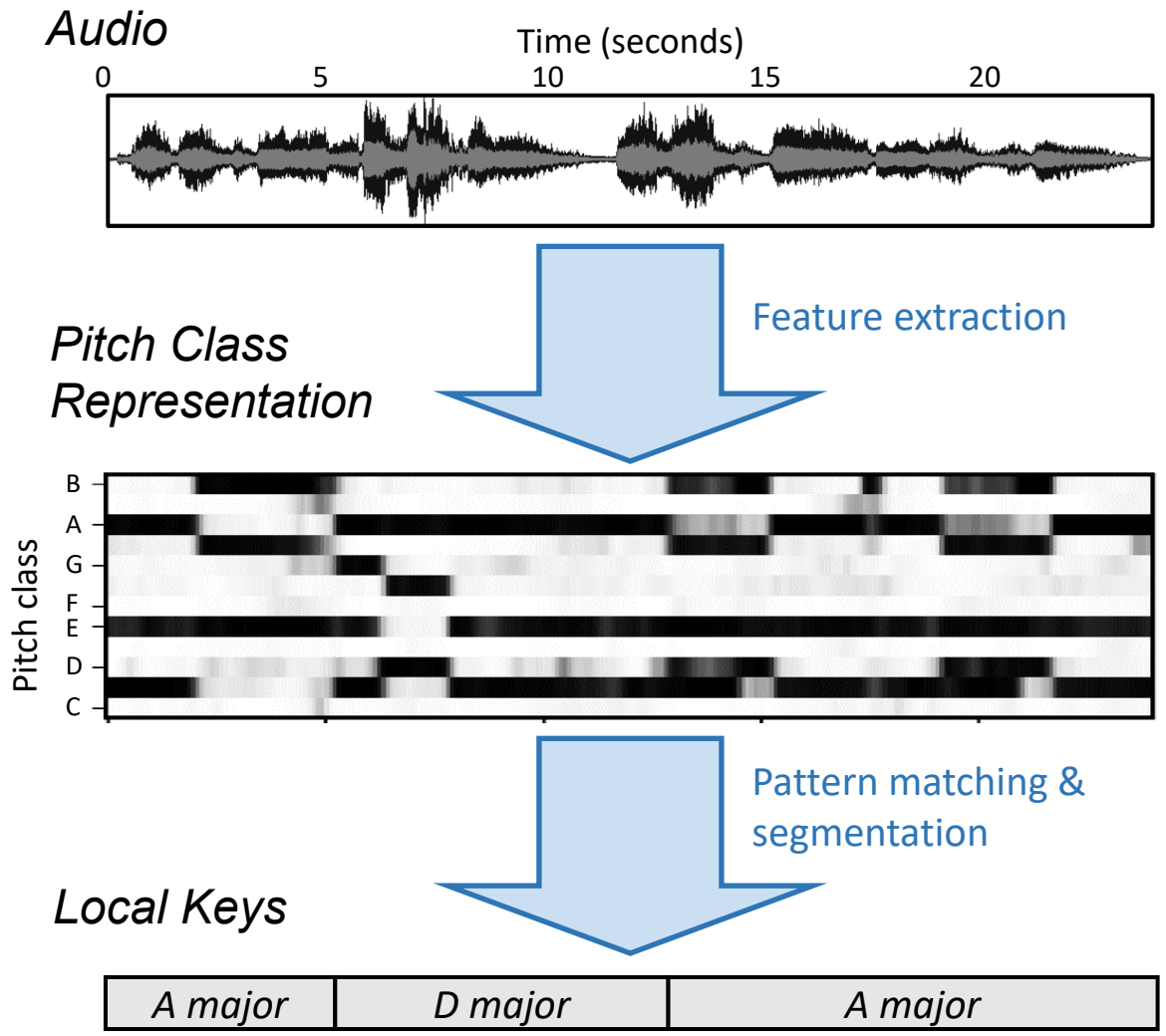
HMM (Signal Proc.)
CNN (Deep Learning)

## Music theory

Lokal Keys
Modulations

## Corpus

Franz Schubert:
*Winterreise*




## Algorithms

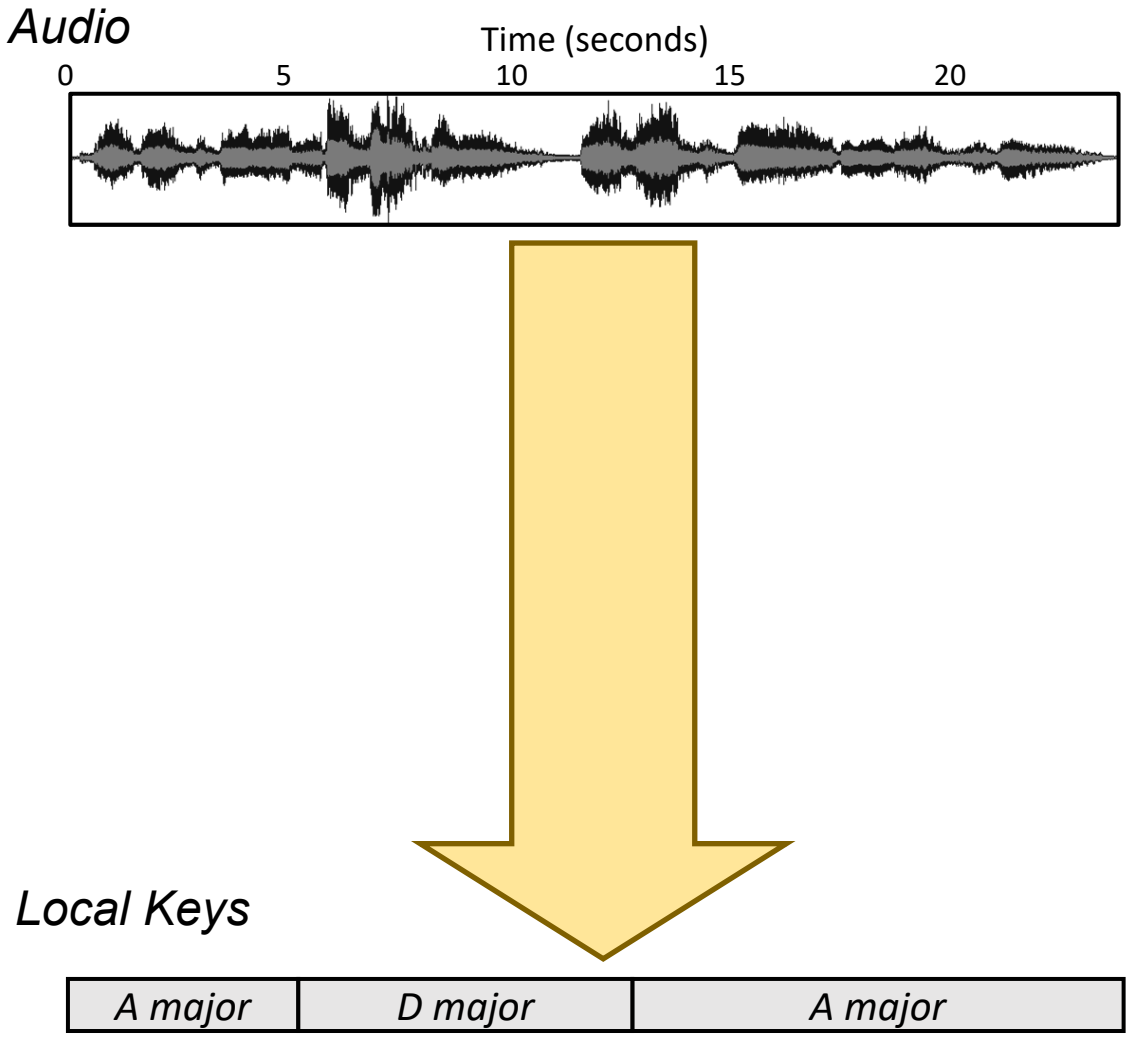
HMM (Signal Proc.)
Gaussian Modeling

## Music theory

Lokal Keys
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## Corpus

Franz Schubert:
*Winterreise*




## Algorithms

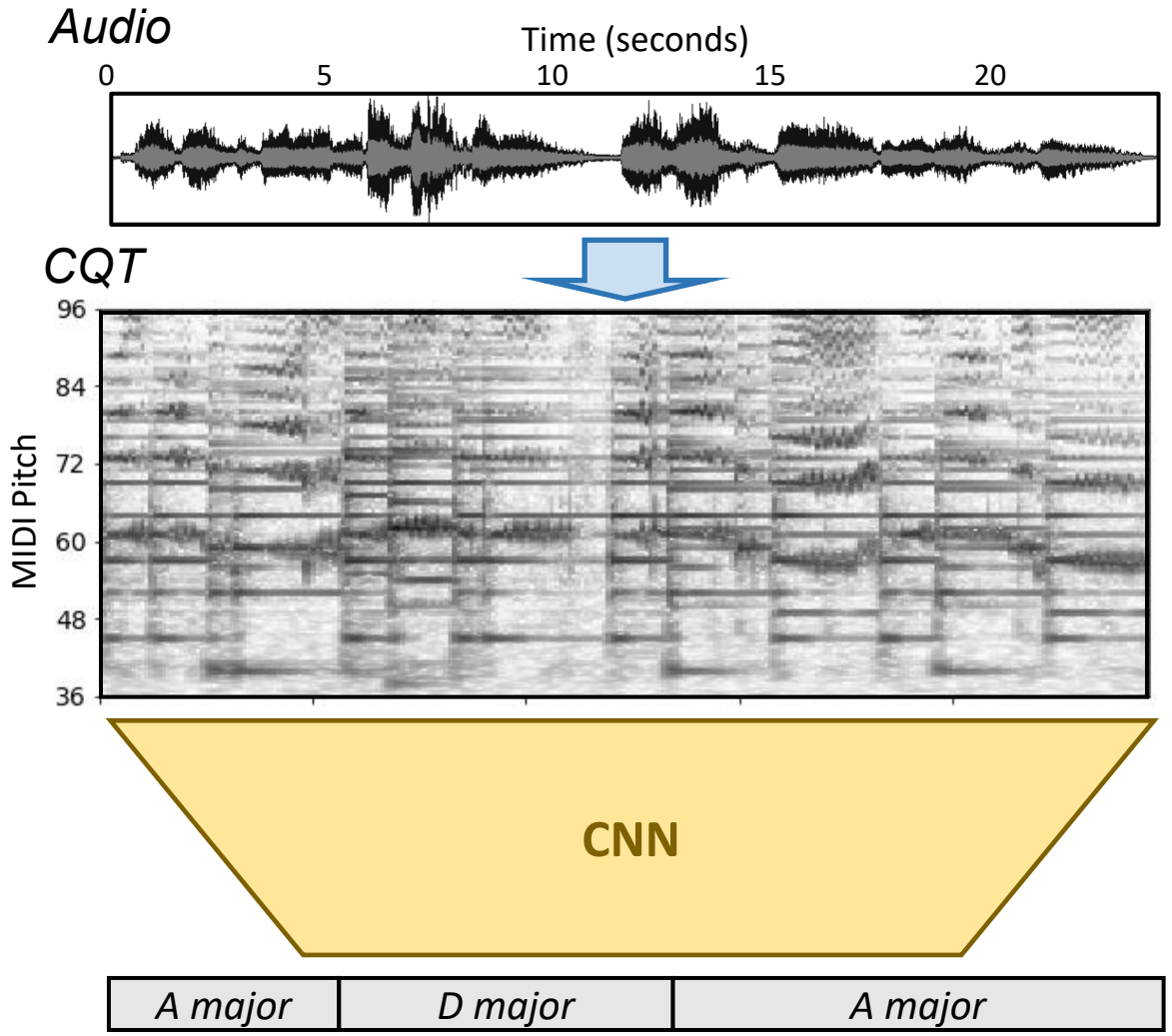
Conv. Neural Network
(Deep Learning)

## Music theory

Lokal Keys
Modulations

## Corpus

Franz Schubert:
*Winterreise*



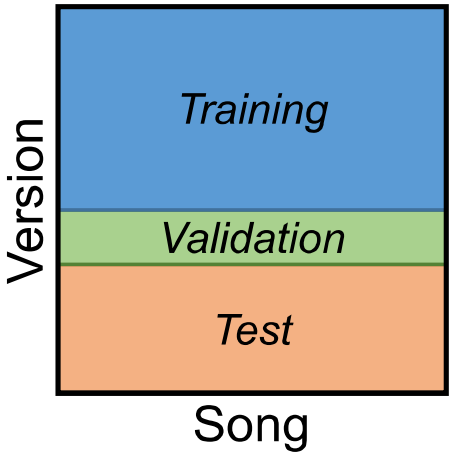

## Algorithms

HMM (Signal Proc.)
CNN (Deep Learning)

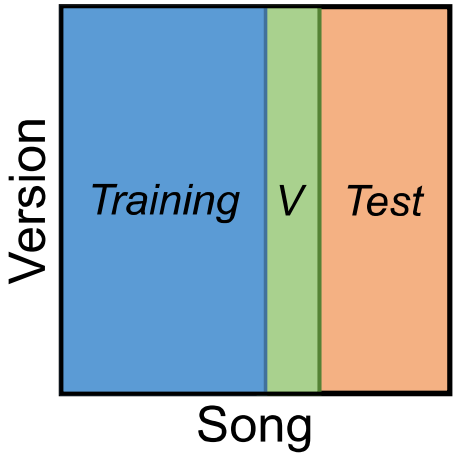
# Local Key Estimation

## Cross-Version Evaluation

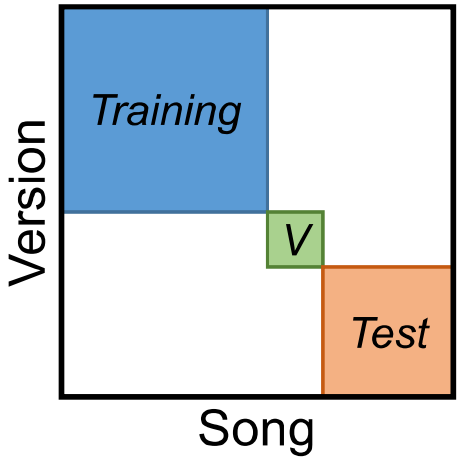
**Version split**




**Song split**




**Neither split**



# Local Key Estimation

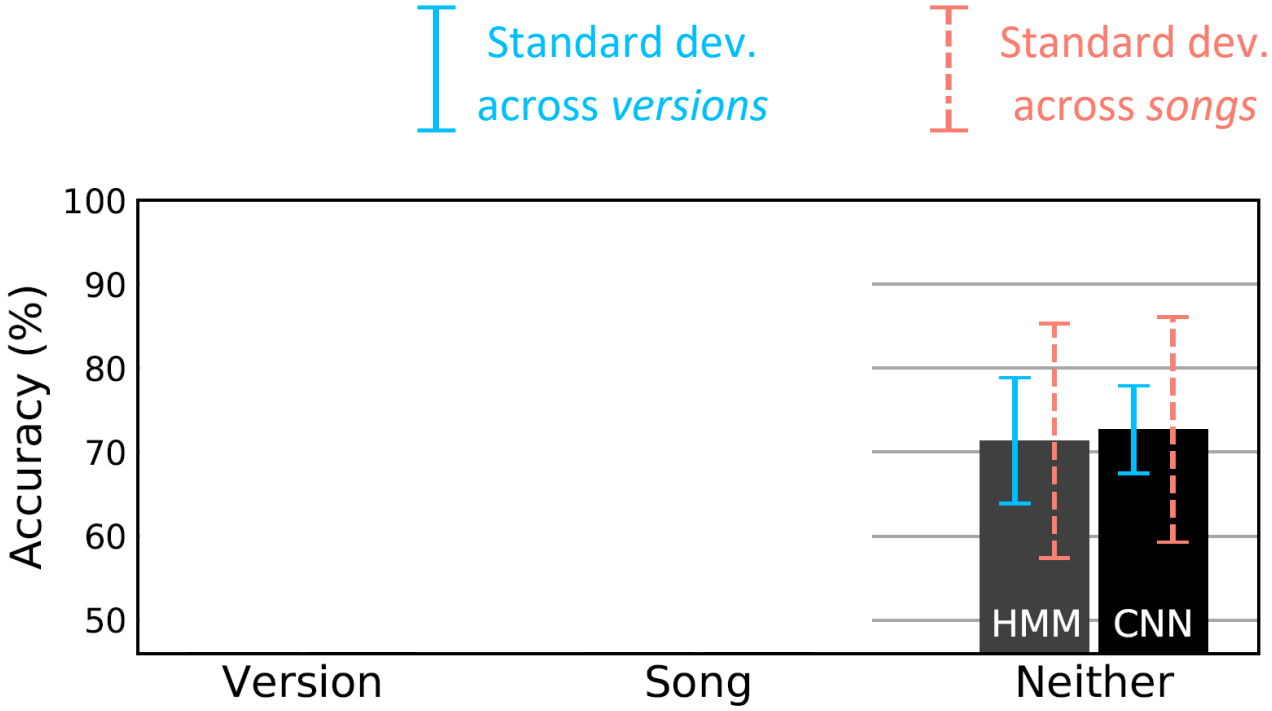
## Cross-Version Evaluation

**Music theory**

Lokal Keys
Modulations

**Corpus**

Franz Schubert:
*Winterreise*




**Algorithms**

HMM (Signal Proc.)
CNN (Deep Learning)

Schreiber, Weiß & Müller, **Local Key Estimation in Classical Music Recordings: A Cross-Version Study on Schubert's Winterreise**, Proc. IEEE ICASSP 2020.

# Local Key Estimation

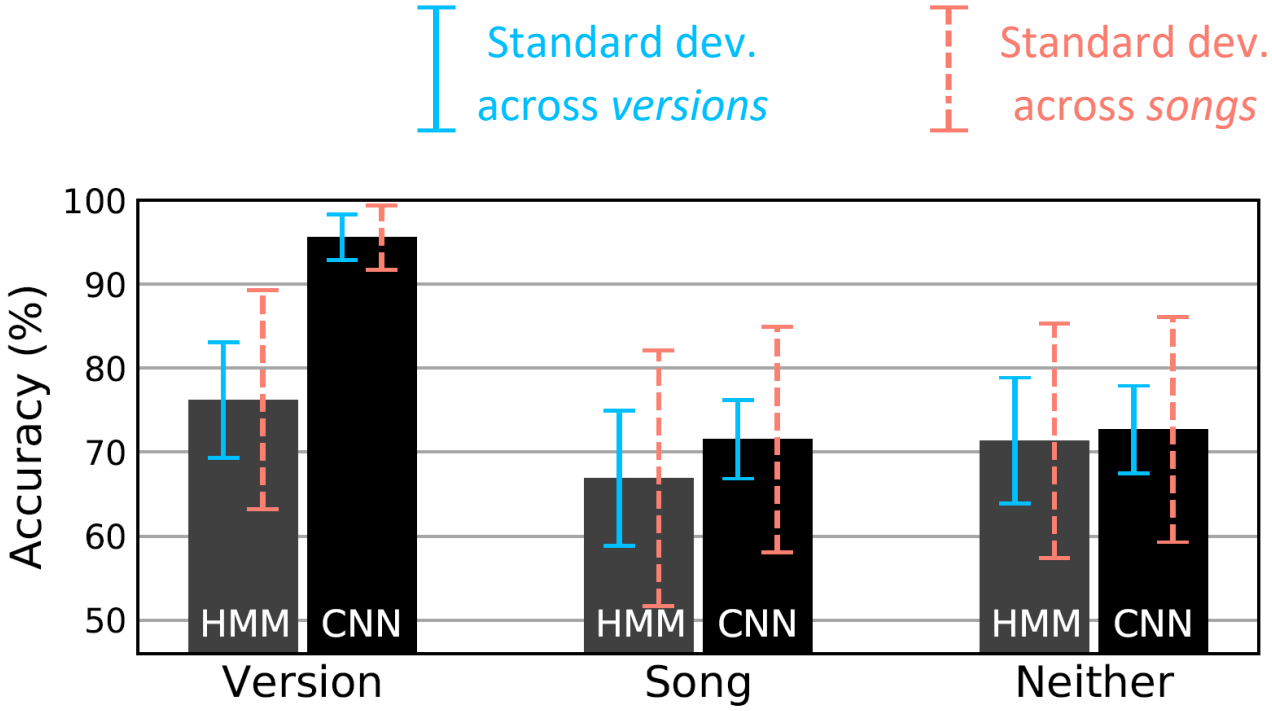
## Cross-Version Evaluation

**Music theory**

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# Local Key Estimation

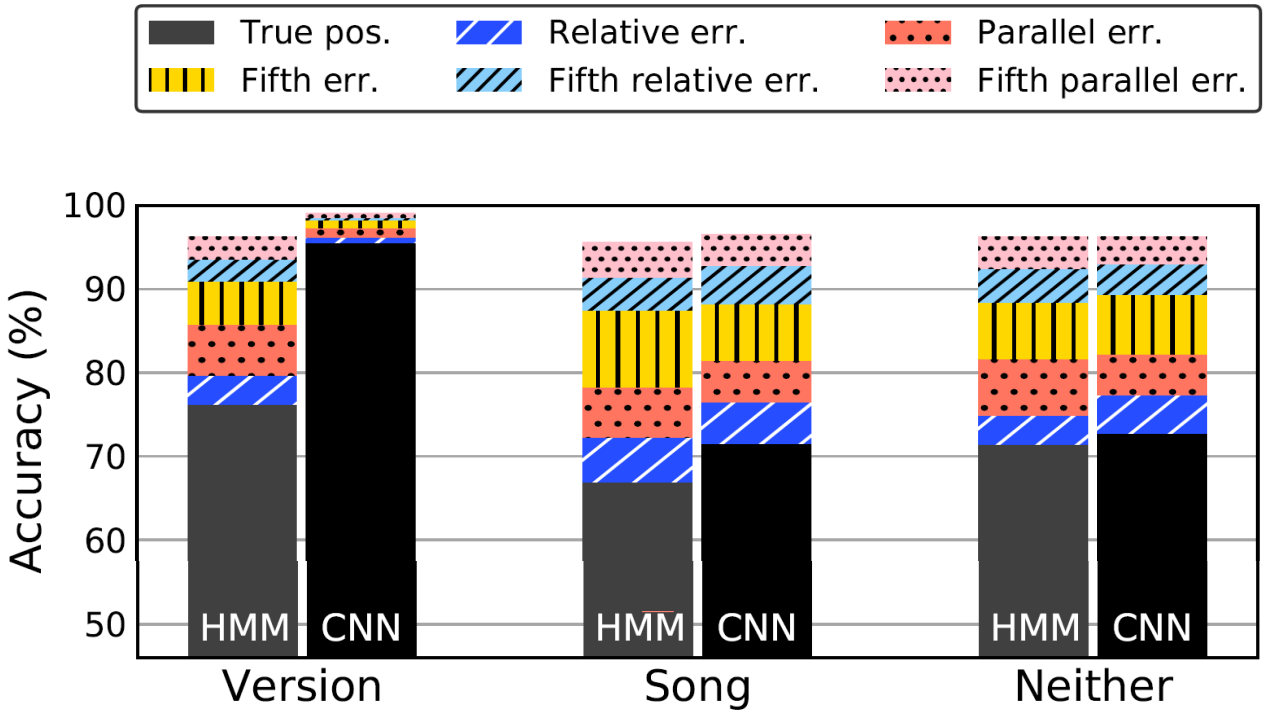
## Cross-Version Evaluation

**Music theory**

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Franz Schubert:
*Winterreise*



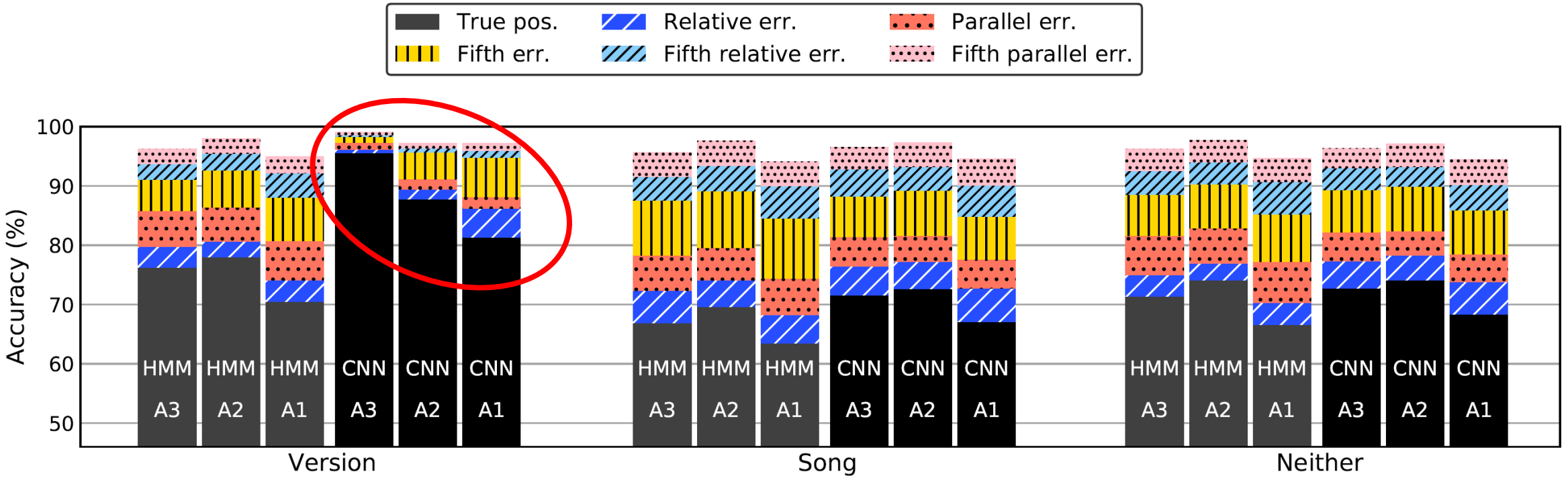

Schreiber, Weiß & Müller, **Local Key Estimation in Classical Music Recordings: A Cross-Version Study on Schubert's Winterreise**, Proc. IEEE ICASSP 2020.

**Algorithms**

HMM (Signal Proc.)
CNN (Deep Learning)

# Local Key Estimation

## Cross-Annotator Evaluation

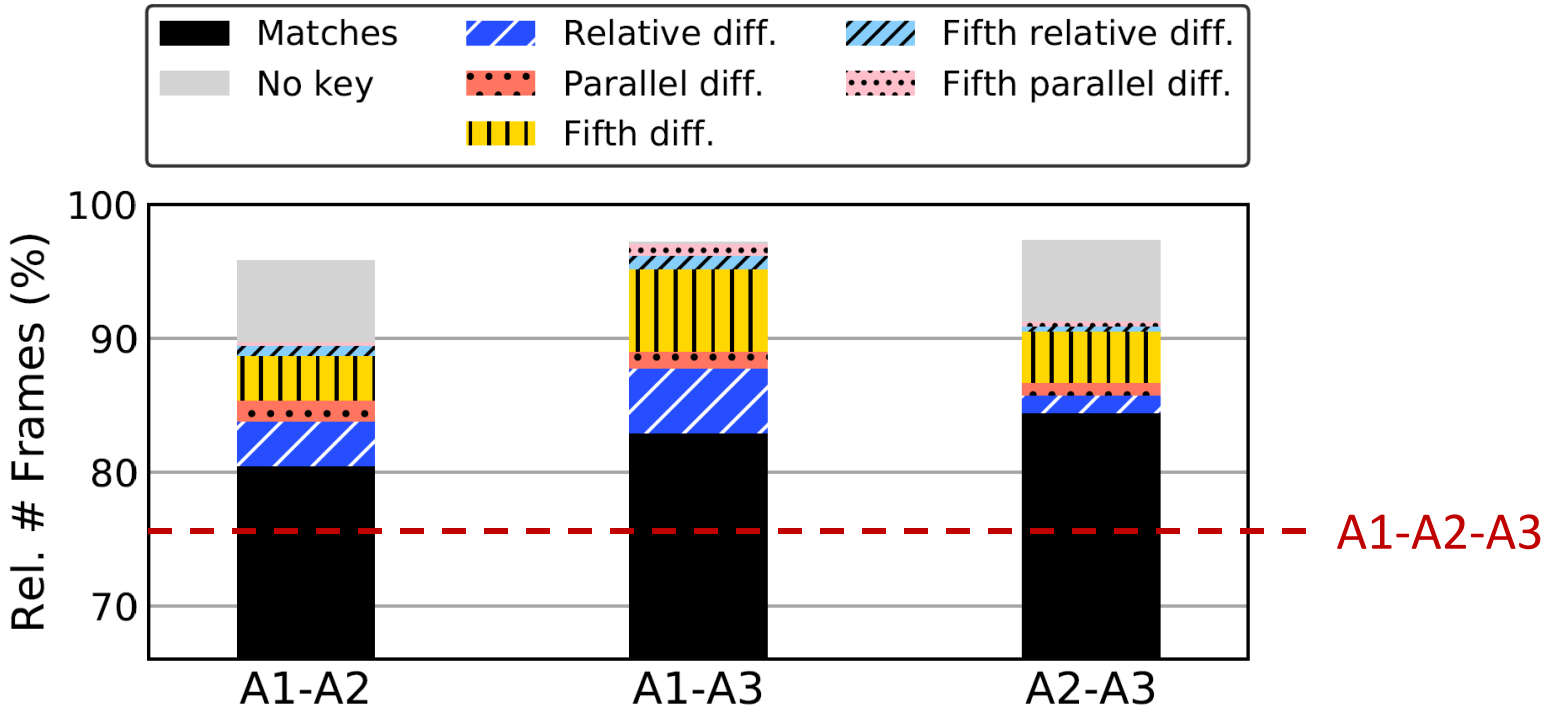



Weiß, Schreiber, Müller, **Local Key Estimation in Music Recordings: A Case Study Across Songs, Versions, and Annotators**, IEEE/ACM Transactions ASLP, 2020.

# Local Key Estimation

## Cross-Annotator Evaluation

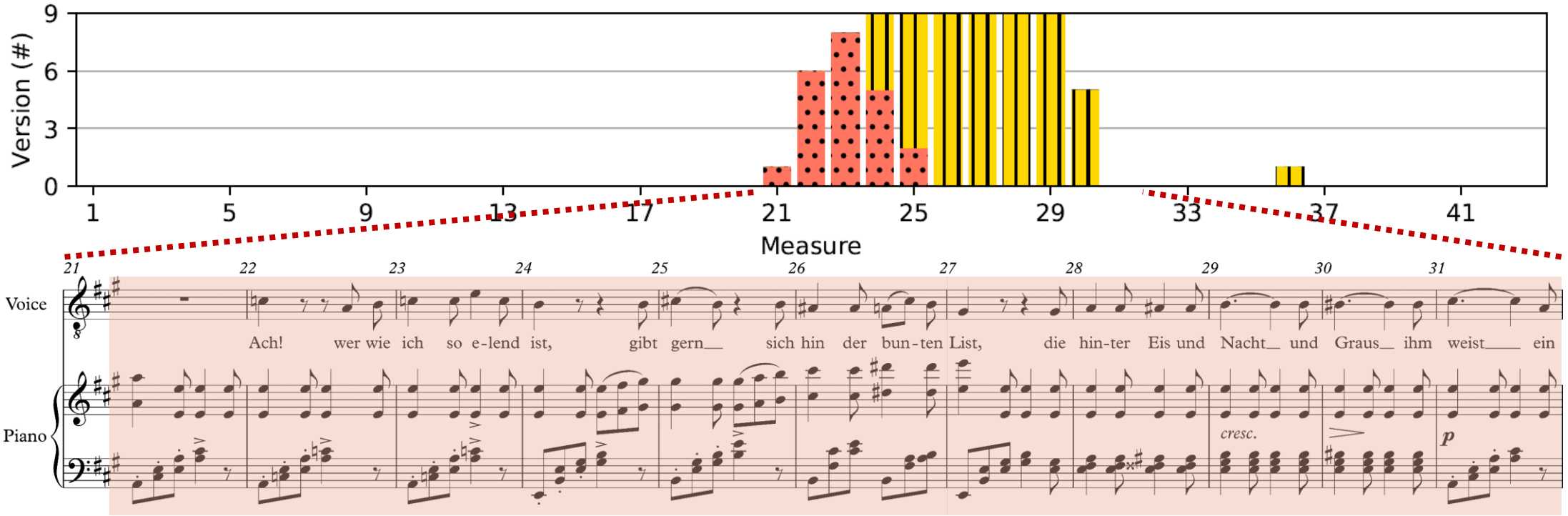
- Consistency between different annotators



# Local Key Estimation

## Cross-Annotator Evaluation

Song No. 19 “Täuschung”

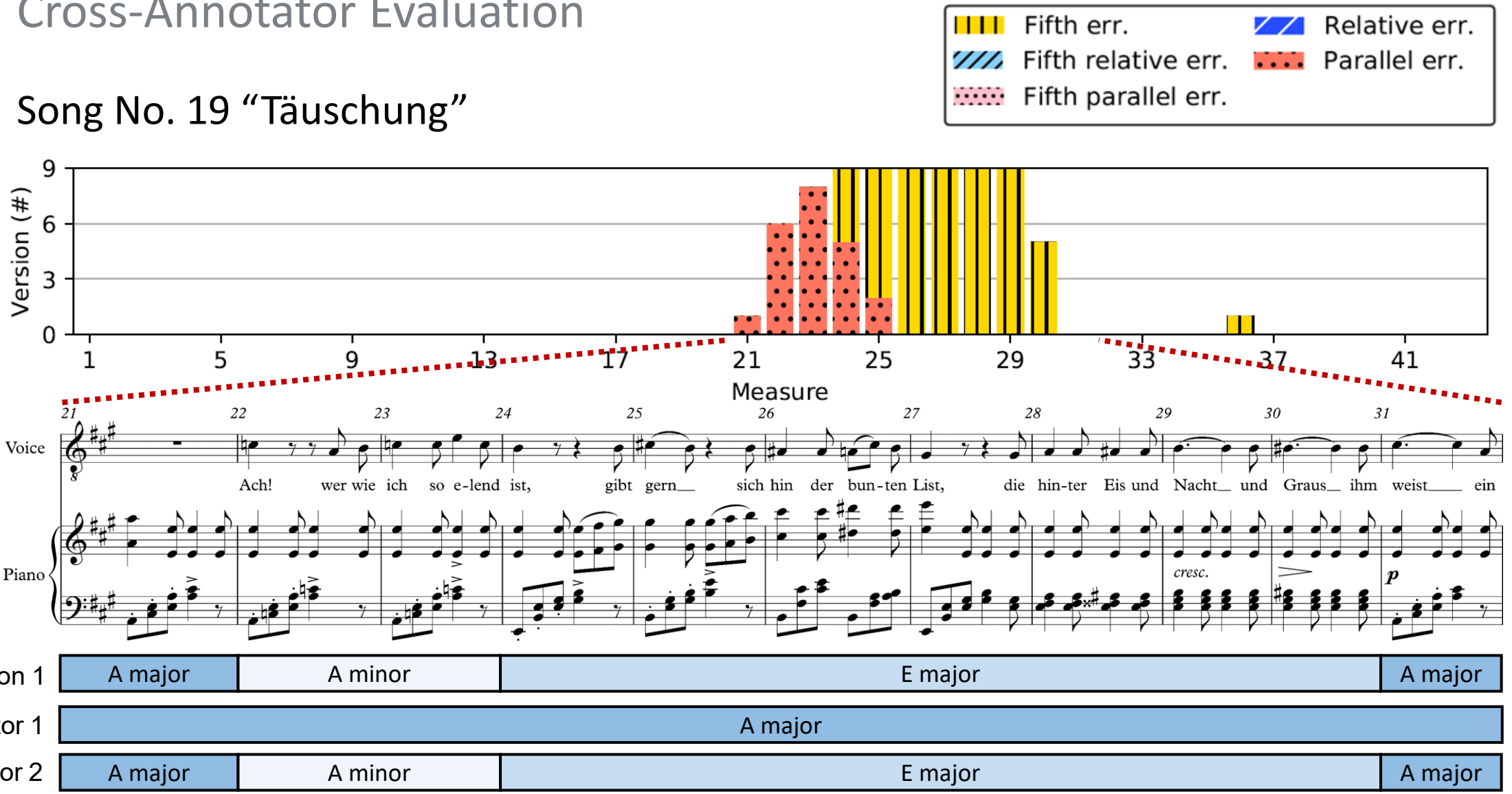



Weiß/Schreiber/Müller, *Local Key Estimation in Music Recordings: A Case Study Across Songs, Versions, and Annotators*, **IEEE/ACM Transactions Audio, Speech, Language Proessing**, 2020.

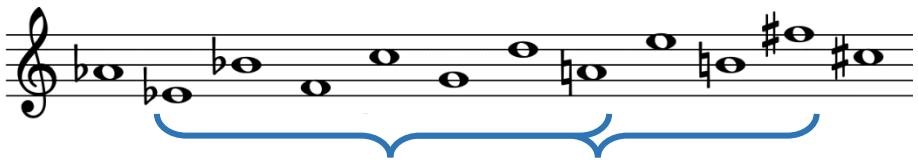
# Local Key Estimation

## Cross-Annotator Evaluation

Song No. 19 “Täuschung”



## Series of Fifths



*–2 diatonic  1 diatonic*

## Music theory

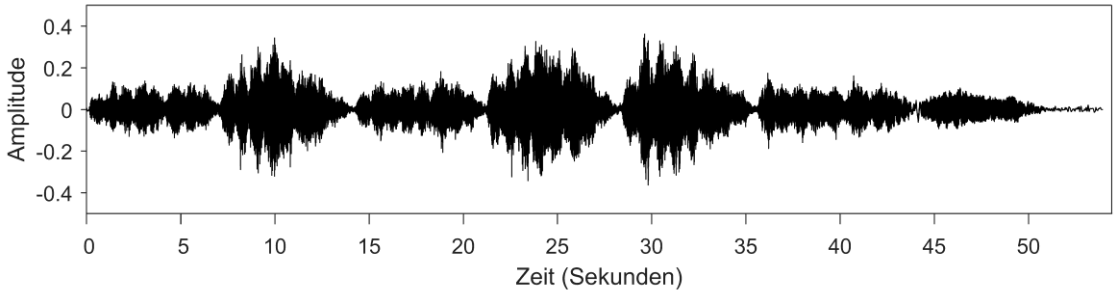
Diatonic Scales
Series of Fifths

## Corpus

J. S. Bach:
*Johannespassion*
Choral „Durch dein Gefängnis“

*Scholars Baroque, Naxos 1994*




## Algorithms

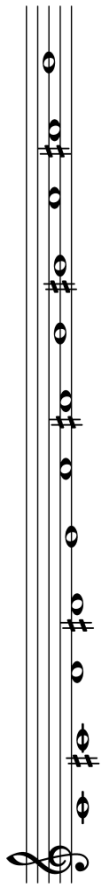
Template Matching
Visualization

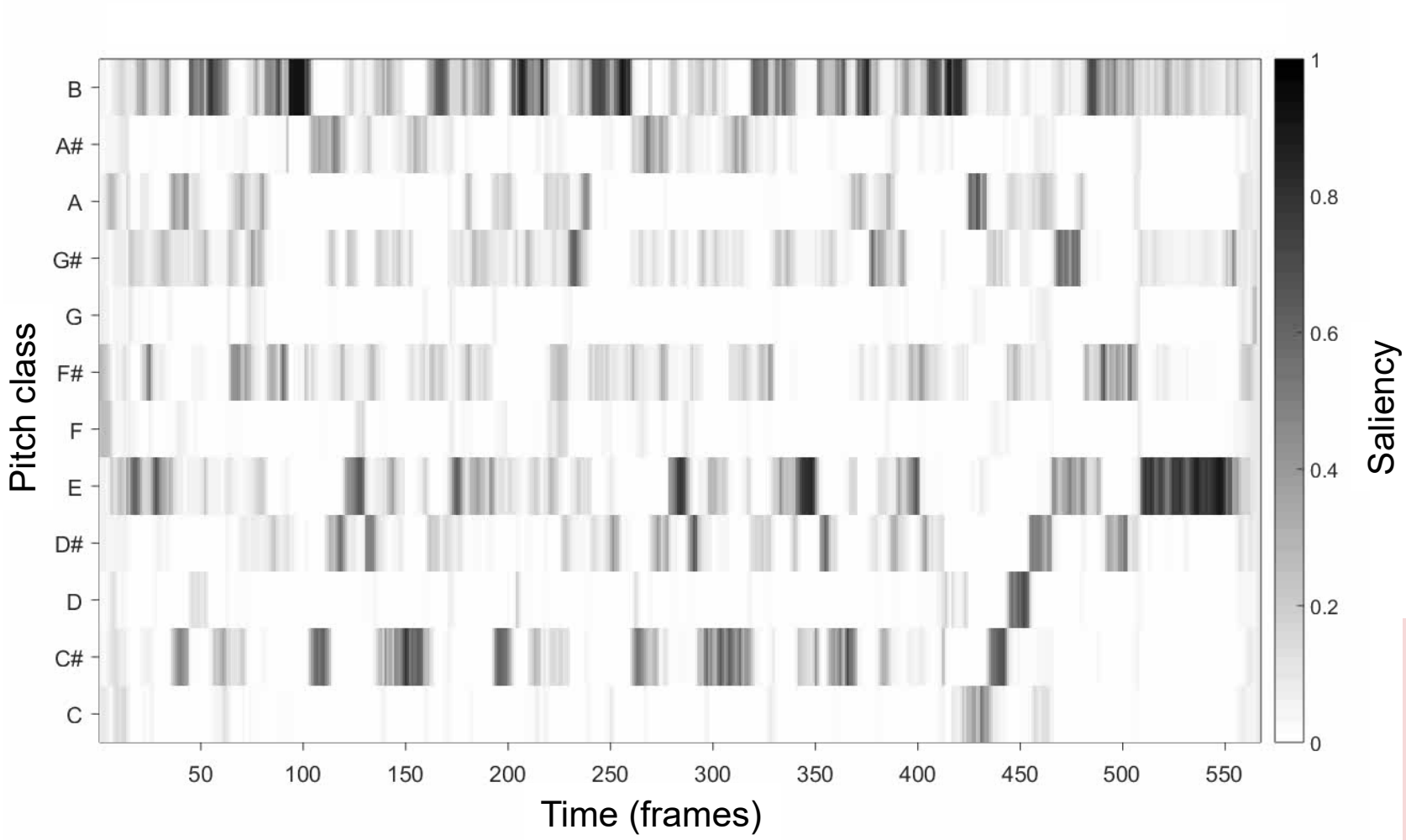
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J. S. Bach:
*Johannespassion*

## Music theory

Diatonic Scales
Series of Fifths






## Algorithms

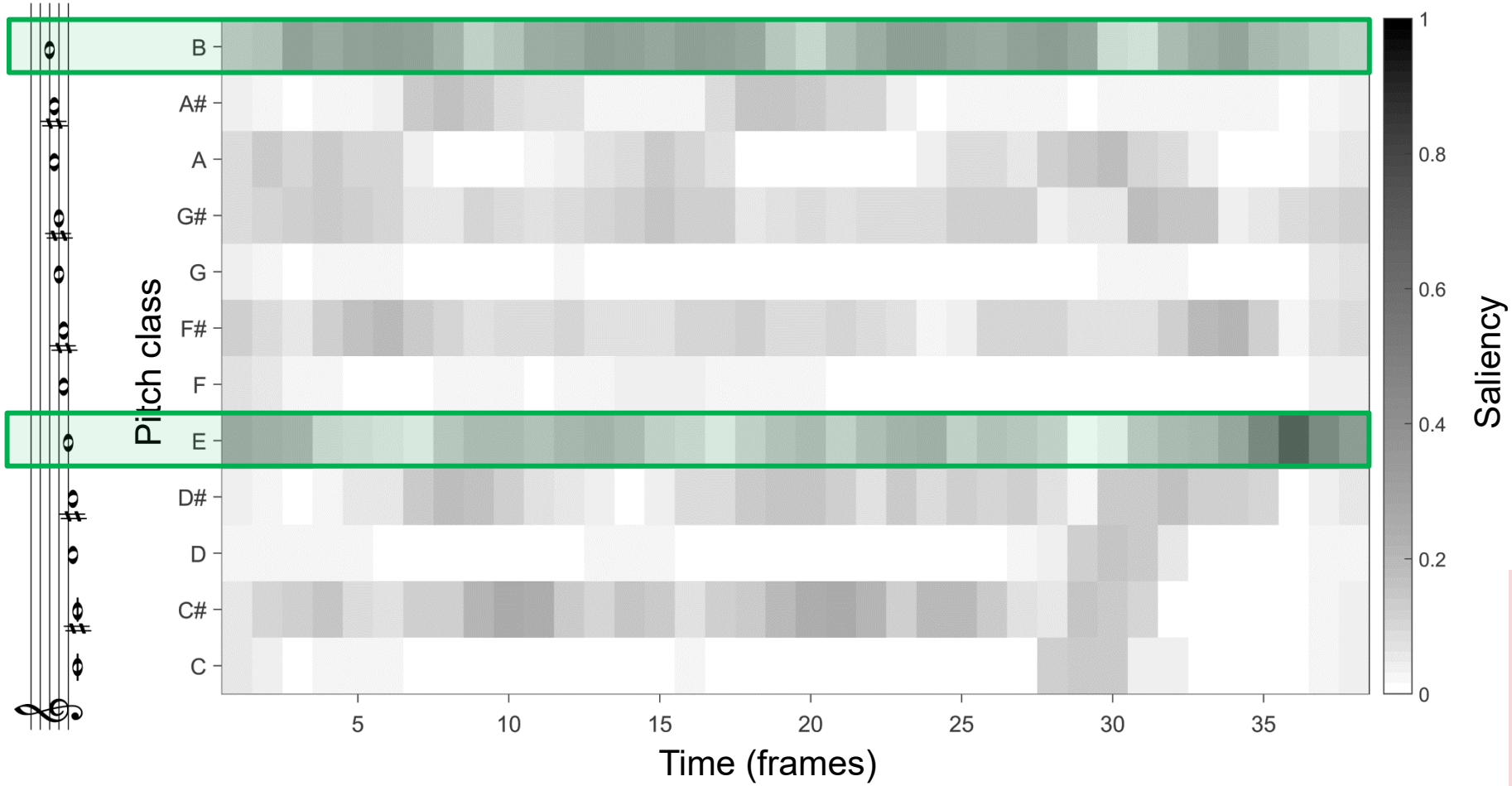
Template Matching
Visualization

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J. S. Bach:
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Diatonic Scales
Series of Fifths




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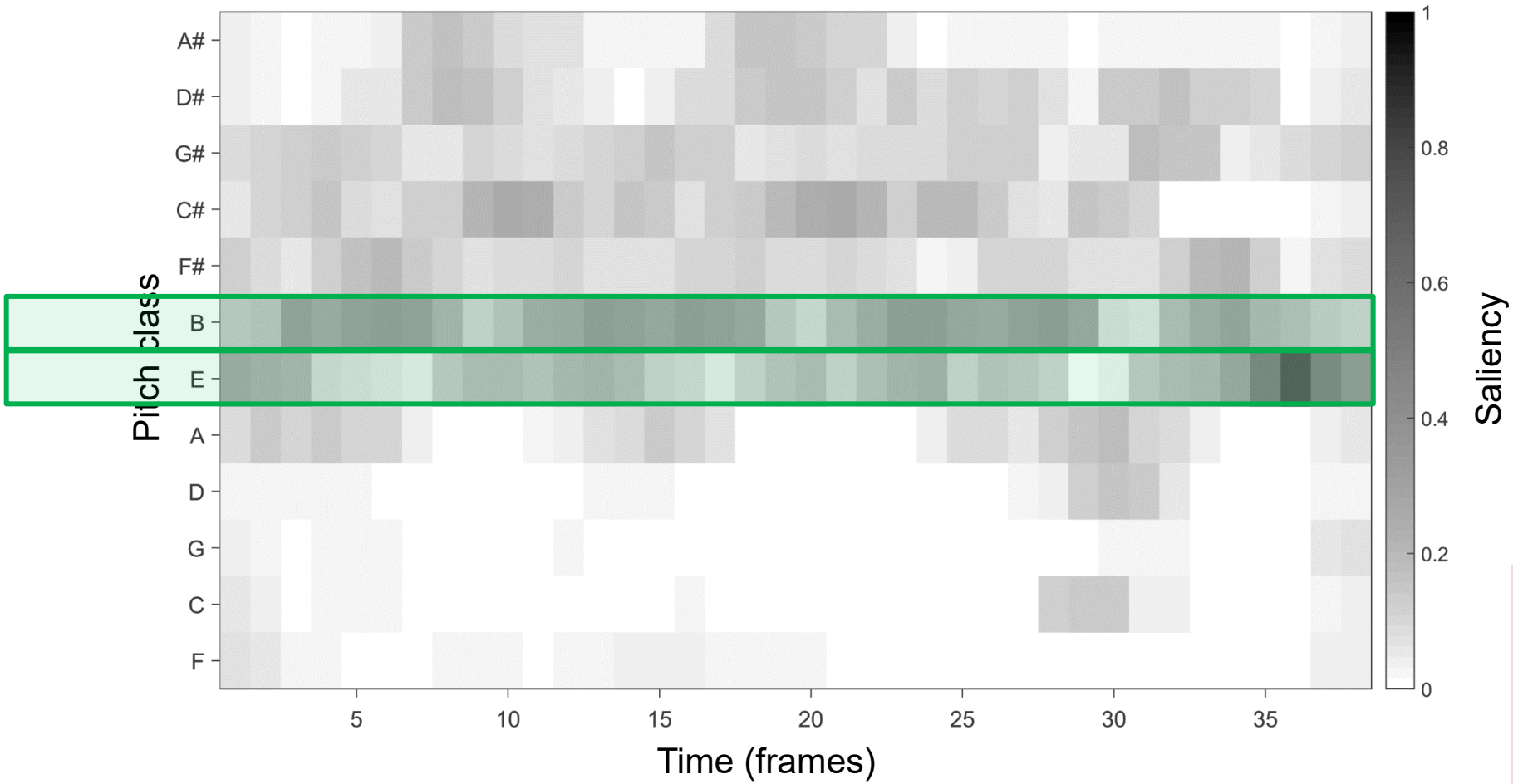
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Series of Fifths




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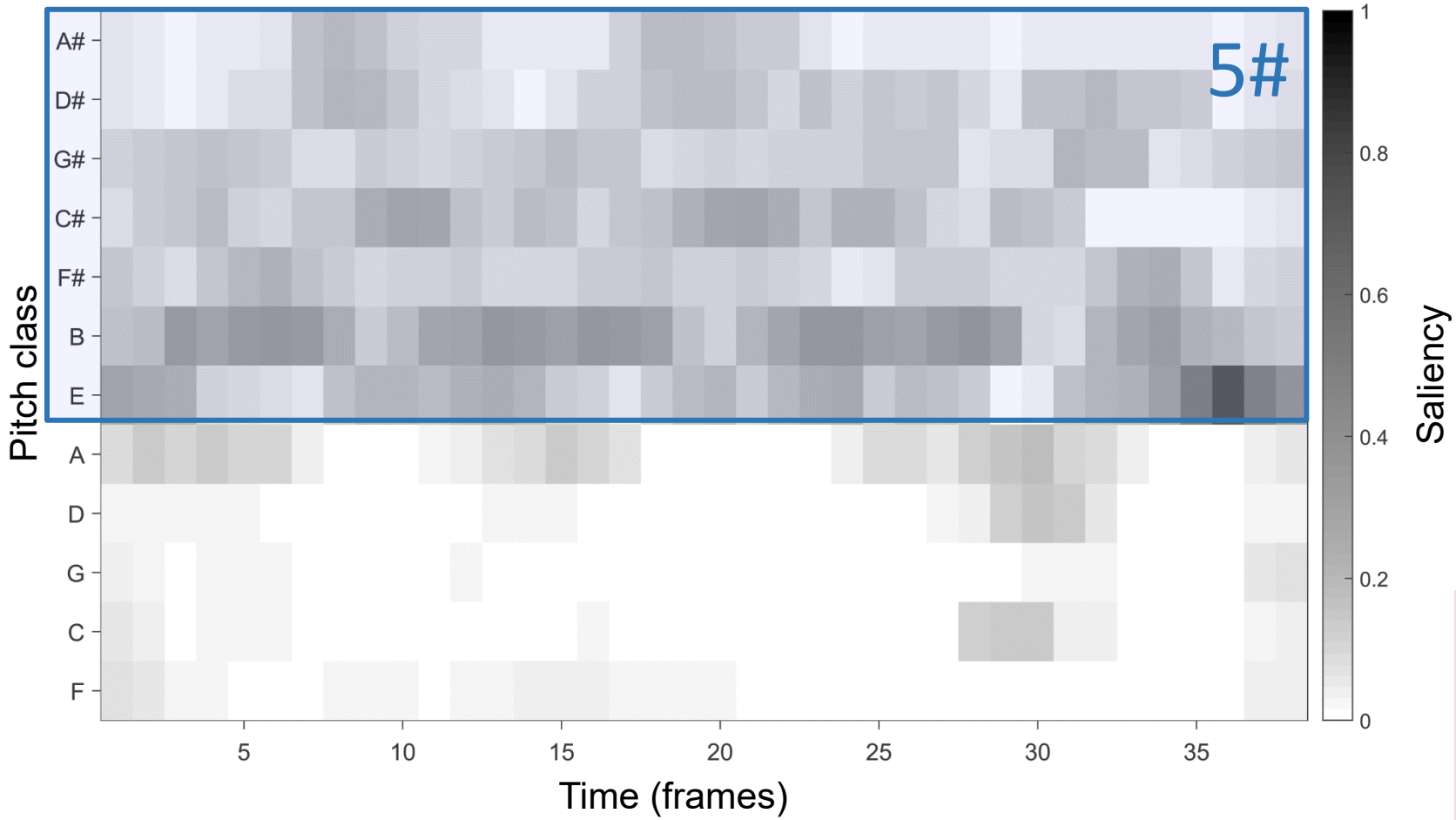
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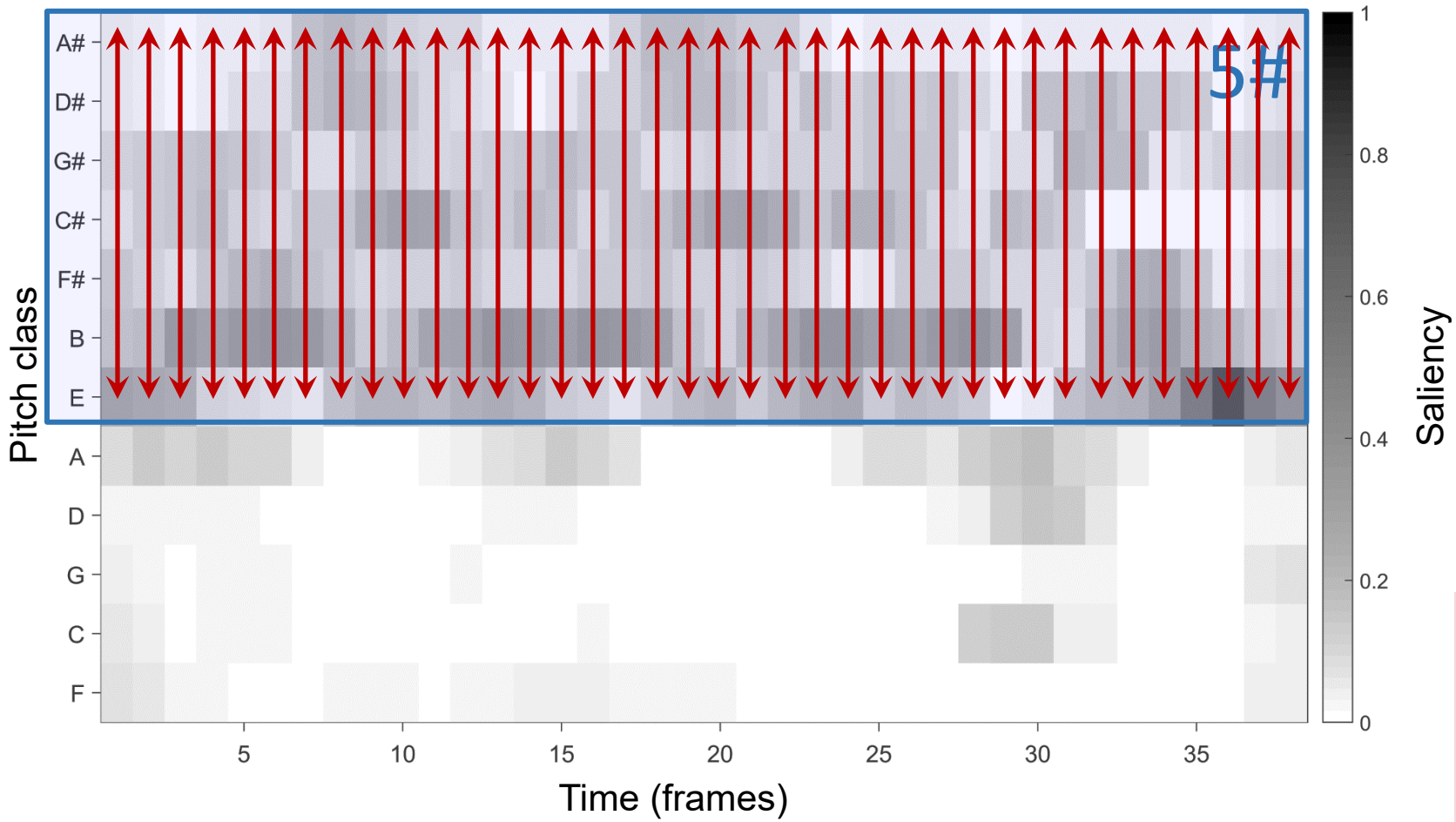
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Series of Fifths




## Algorithms

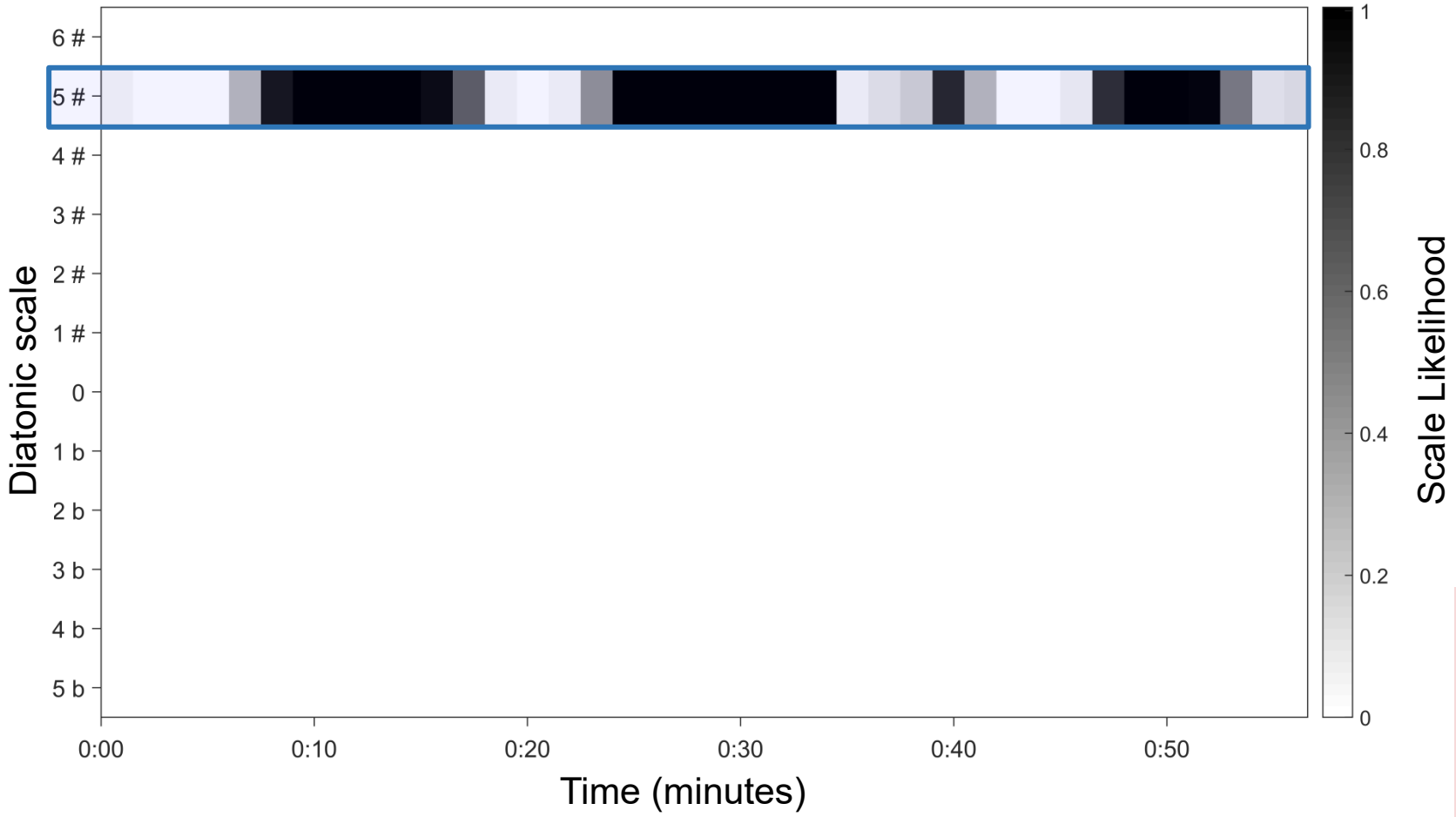
Template Matching
Visualization

## Corpus

J. S. Bach:
*Johannespassion*

## Music theory

Diatonic Scales
Series of Fifths




## Algorithms

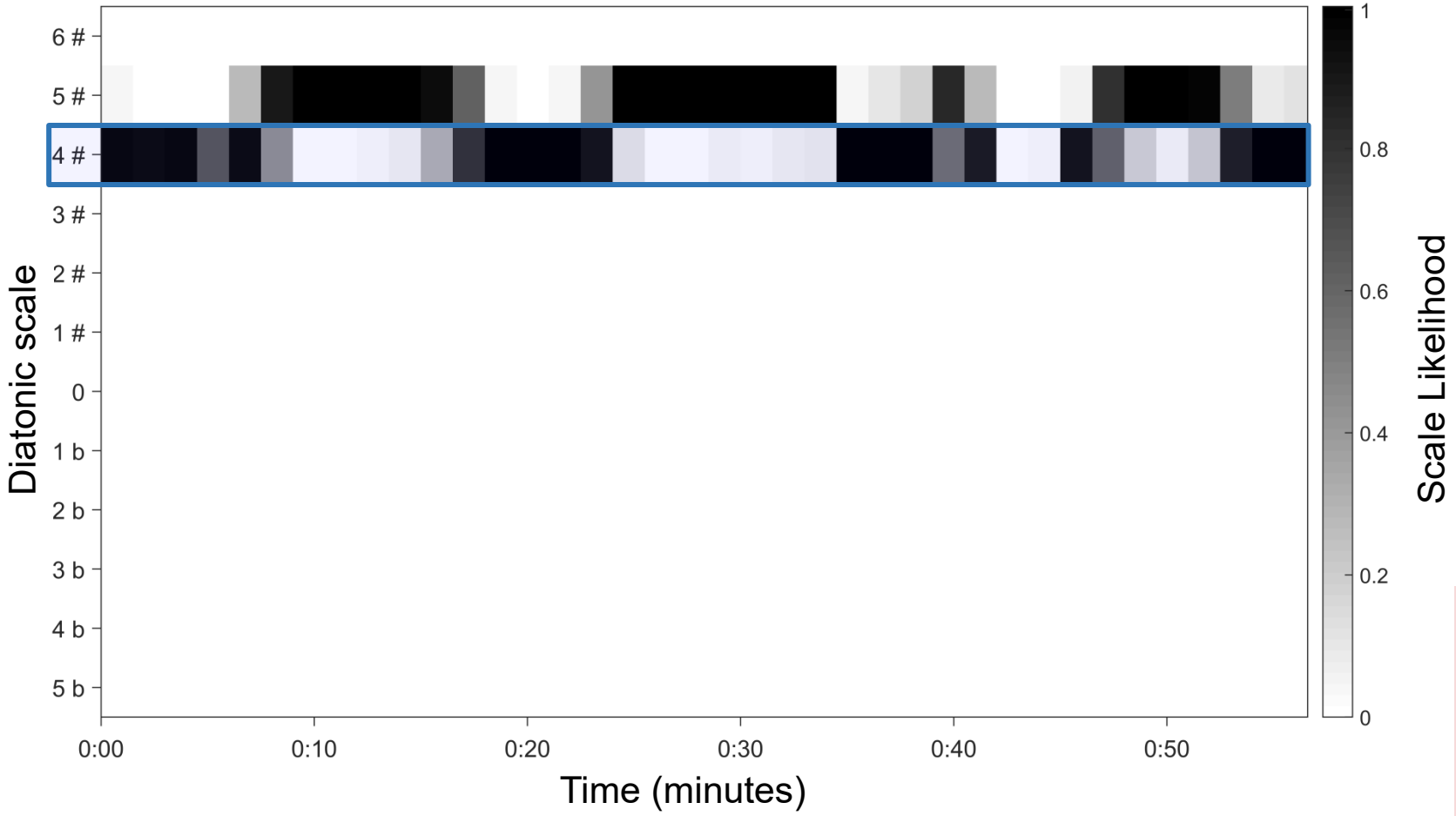
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## Corpus

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Diatonic Scales
Series of Fifths




## Algorithms

Template Matching
Visualization

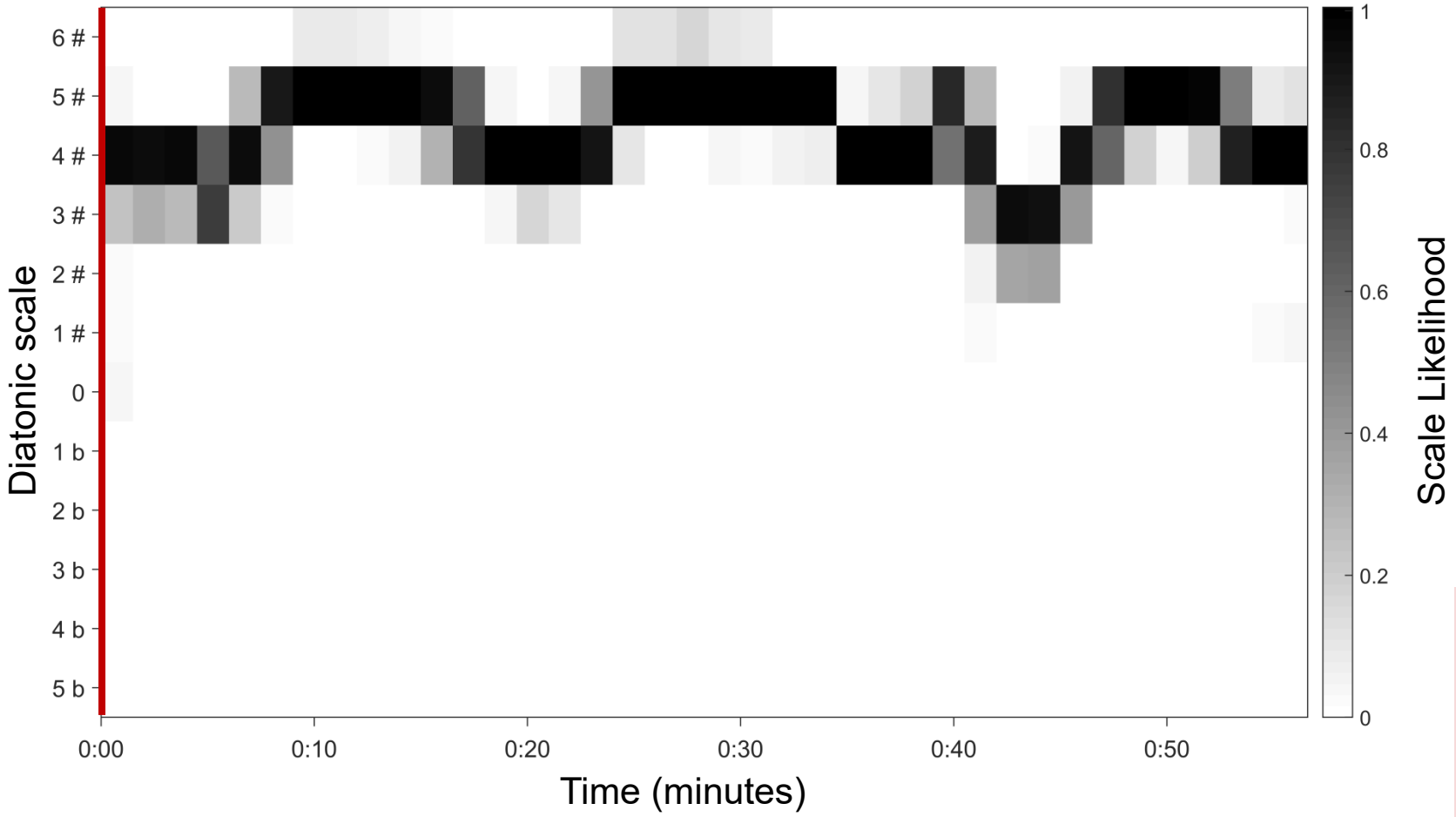
## Corpus

J. S. Bach:
*Johannespassion*

[5] Weiß & Habryka, **Chroma-Based Scale Matching for Audio Tonality Analysis**, Proc. Conf. on Interdisciplinary Musicology, 2014.

## Music theory

Diatonic Scales
Series of Fifths




## Algorithms

Template Matching
Visualization

## Corpus

J. S. Bach:
*Johannespassion*

## Music theory

Diatonic Scales
Series of Fifths



## Algorithms

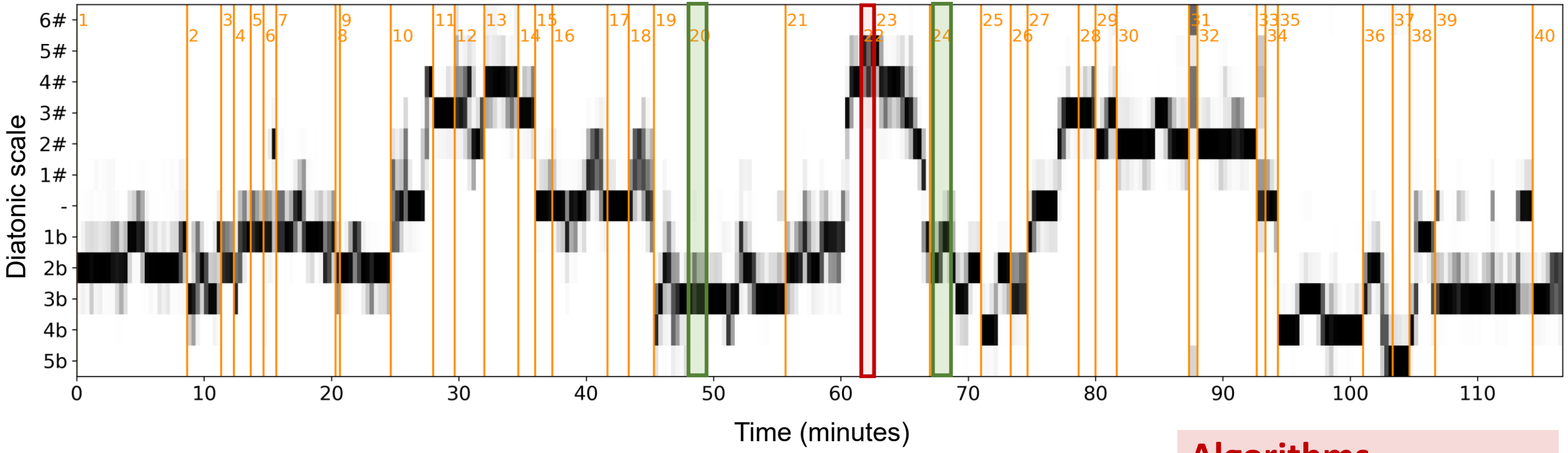
Template Matching
Visualization

## Corpus

J. S. Bach:
*Johannespassion*

## Music theory

Diatonic Scales
Series of Fifths




## Algorithms

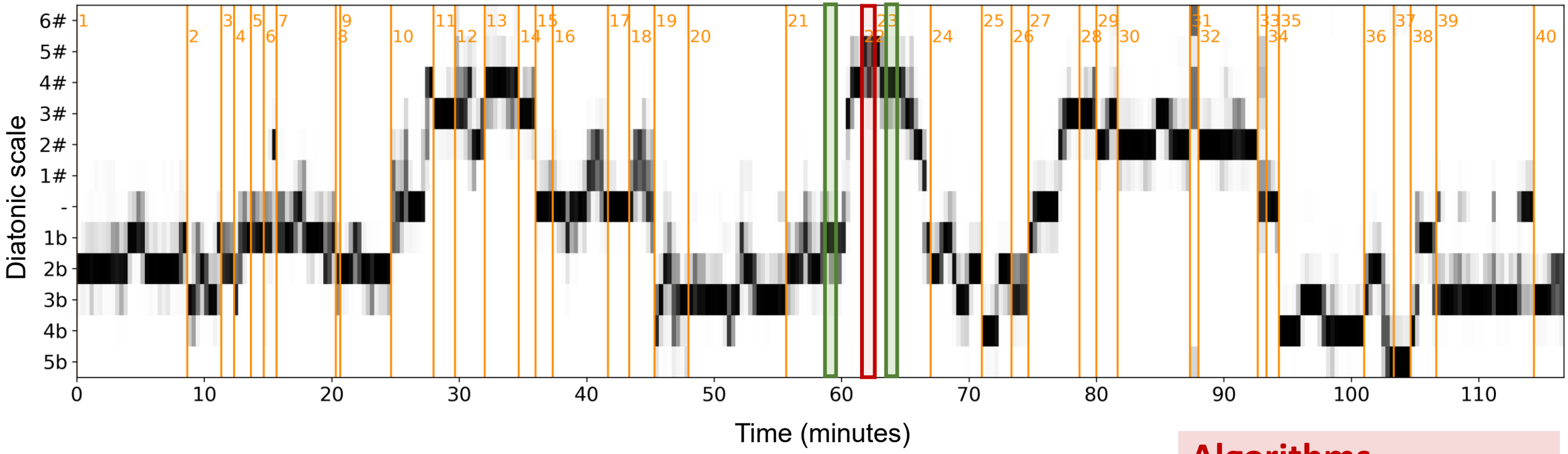
Template Matching
Visualization

## Corpus

J. S. Bach:
*Johannespassion*

## Music theory

Diatonic Scales
Series of Fifths

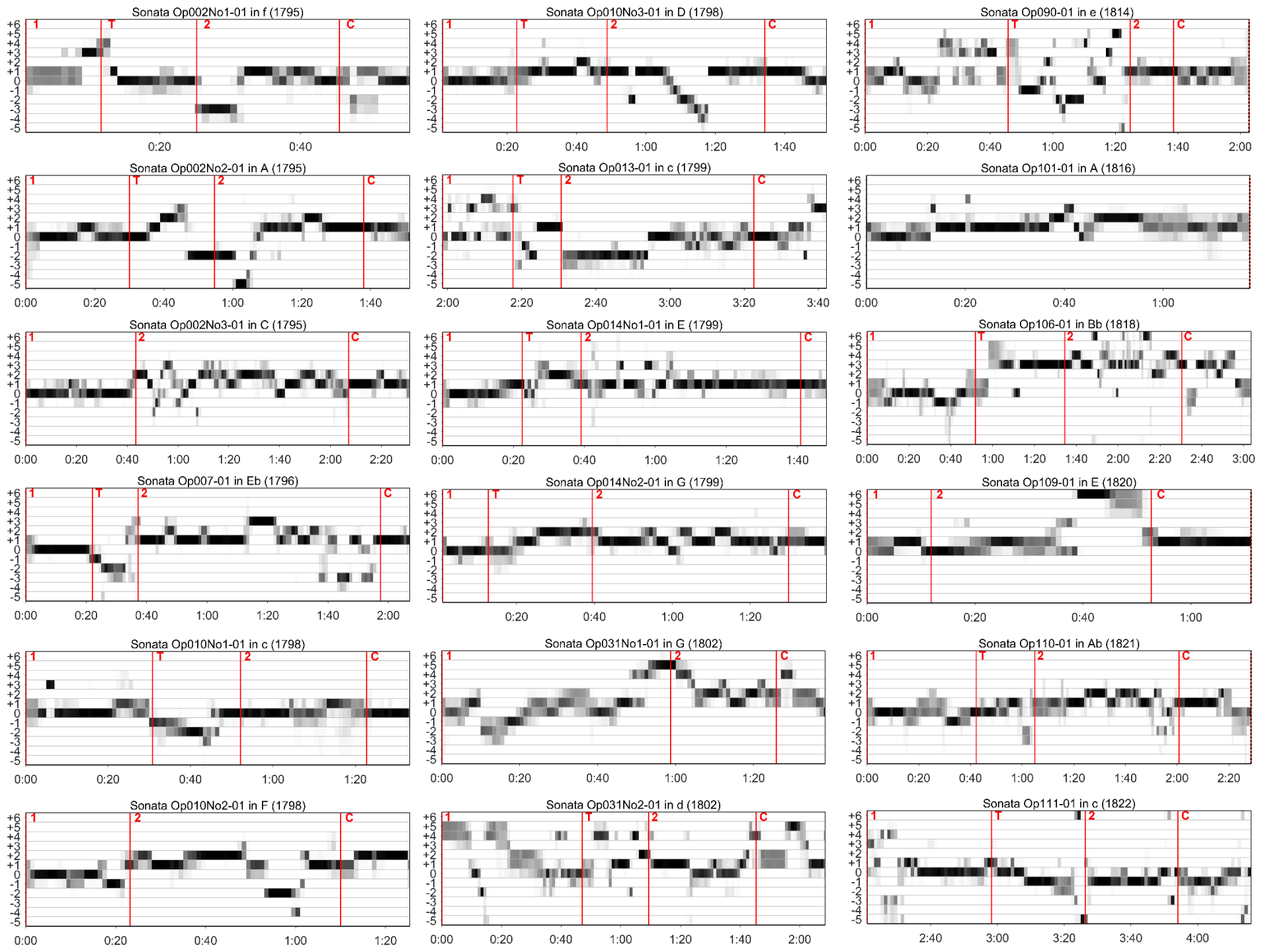



## Algorithms

Template Matching
Visualization

## Corpus

L. v. Beethoven, Piano Sonatas (Expositions)




Weiß, Klauk, Gotham, Müller, Kleinertz, **Discourse Not Dualism: An Interdisciplinary Dialogue On Sonata Form in Beethoven's Early Piano Sonatas**, ISMIR 2020.

# Interdisciplinary Project

## Computer-assisted Analysis of Harmonic Structures

**Music theory**

Diatonic Scales
Series of Fifths

DFG

**Corpus**

Richard Wagner:
*Der Ring des Nibelungen*

- Rainer Kleinertz, Stephanie Klauk, Christof Weiß, Meinard Müller
- Interdisciplinary project 2014–2025
- Large-scale analysis of harmonic structures



**Algorithms**

Template Matching
Visualization

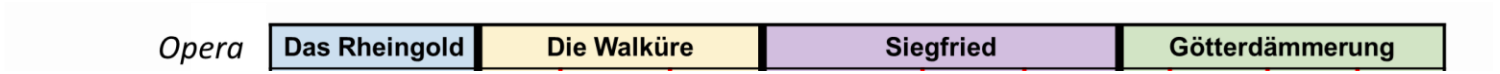
# Wagner Ring Dataset

## Structure

- Tetralogy (four operas)

**Corpus**

Richard Wagner: *Der Ring des Nibelungen*




Weiß, Arifi-Müller, …, Kleinertz, Müller, **Wagner Ring Dataset: A Complex Opera Scenario for Music Processing and Computational Musicology**, TISMIR 2023

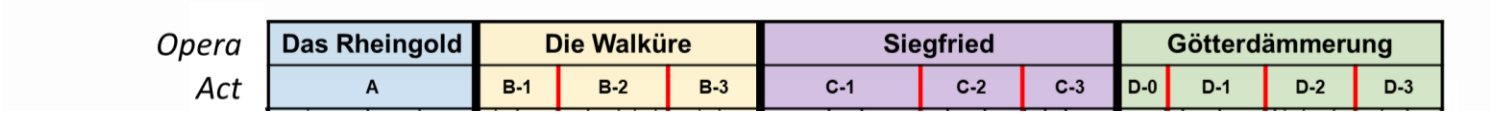
# Wagner Ring Dataset

## Structure

- Tetralogy (four operas)
- 11 Acts

**Corpus**

Richard Wagner: *Der Ring des Nibelungen*

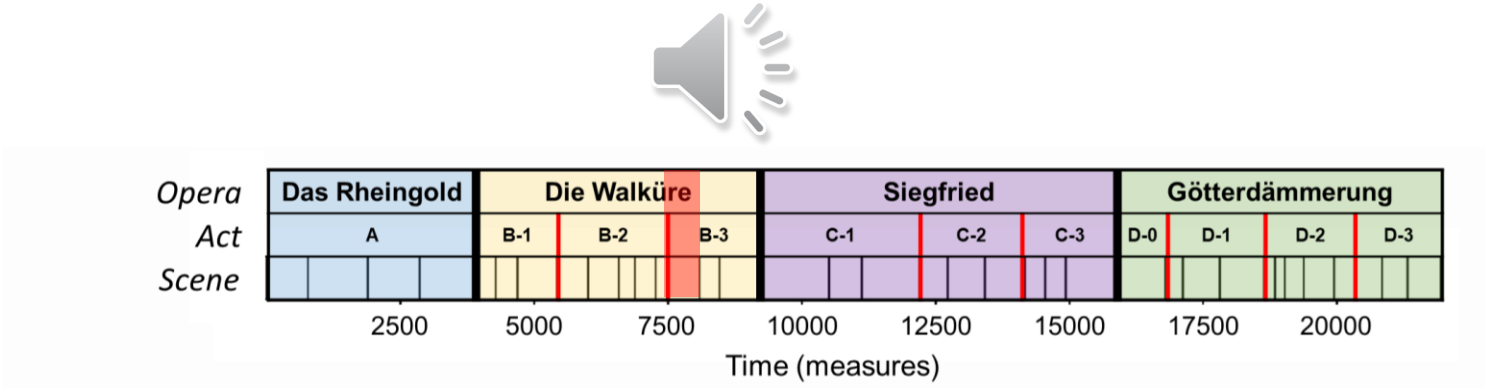



Weiß, Arifi-Müller, …, Kleinertz, Müller, **Wagner Ring Dataset: A Complex Opera Scenario for Music Processing and Computational Musicology**, TISMIR 2023

# Wagner Ring Dataset

## Structure

- Tetralogy (four operas)
- 11 Acts
- 21,939 measures



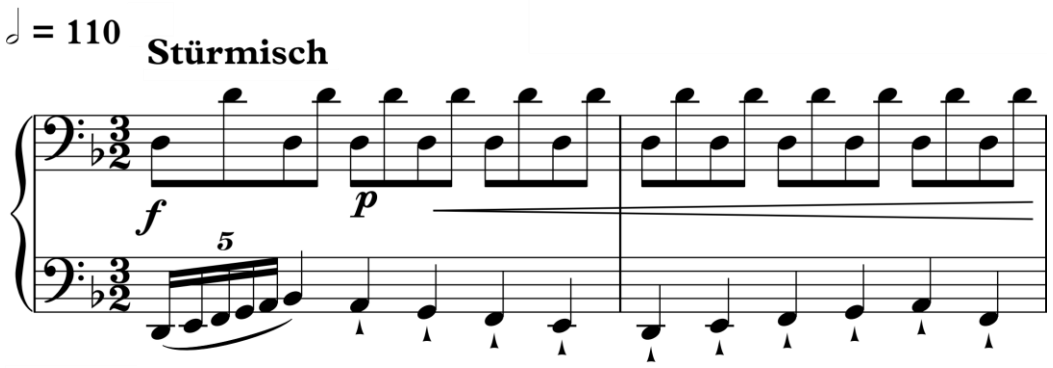

Weiß, Arifi-Müller, …, Kleinertz, Müller, **Wagner Ring Dataset: A Complex Opera Scenario for Music Processing and Computational Musicology**, TISMIR 2023

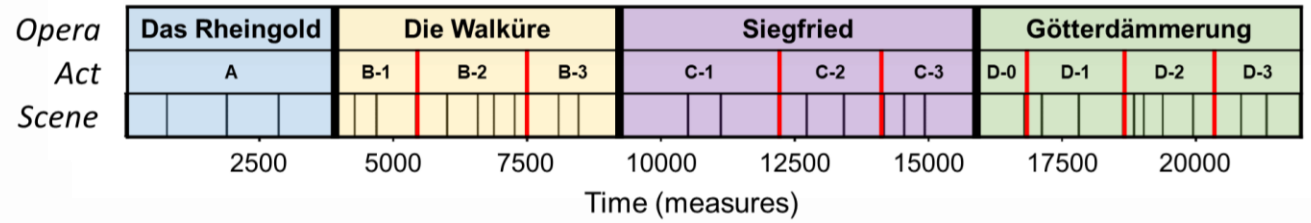
# Wagner Ring Dataset

## Raw Data




- Symbolic score:
  - Piano reduction
  - 822 pages




Weiß, Arifi-Müller, …, Kleinertz, Müller, **Wagner Ring Dataset: A Complex Opera Scenario for Music Processing and Computational Musicology**, TISMIR 2023

# Wagner Ring Dataset

## Raw Data

- Symbolic score:
  - Piano reduction
  - 822 pages
- Audio recordings:
  - 16 performances
  - 232 hours
  - 3 performances in Public Domain (EU)

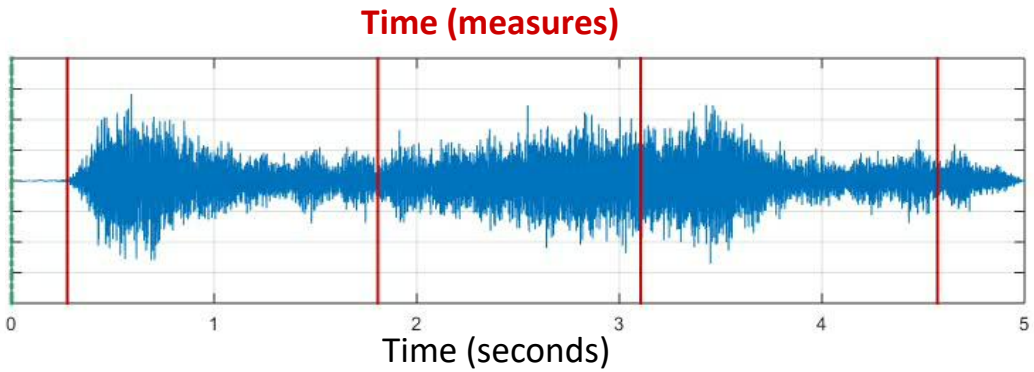



Weiß, Arifi-Müller, …, Kleinertz, Müller, **Wagner Ring Dataset: A Complex Opera Scenario for Music Processing and Computational Musicology**, TISMIR 2023

# Wagner Ring Dataset

## Annotations

- Measure positions





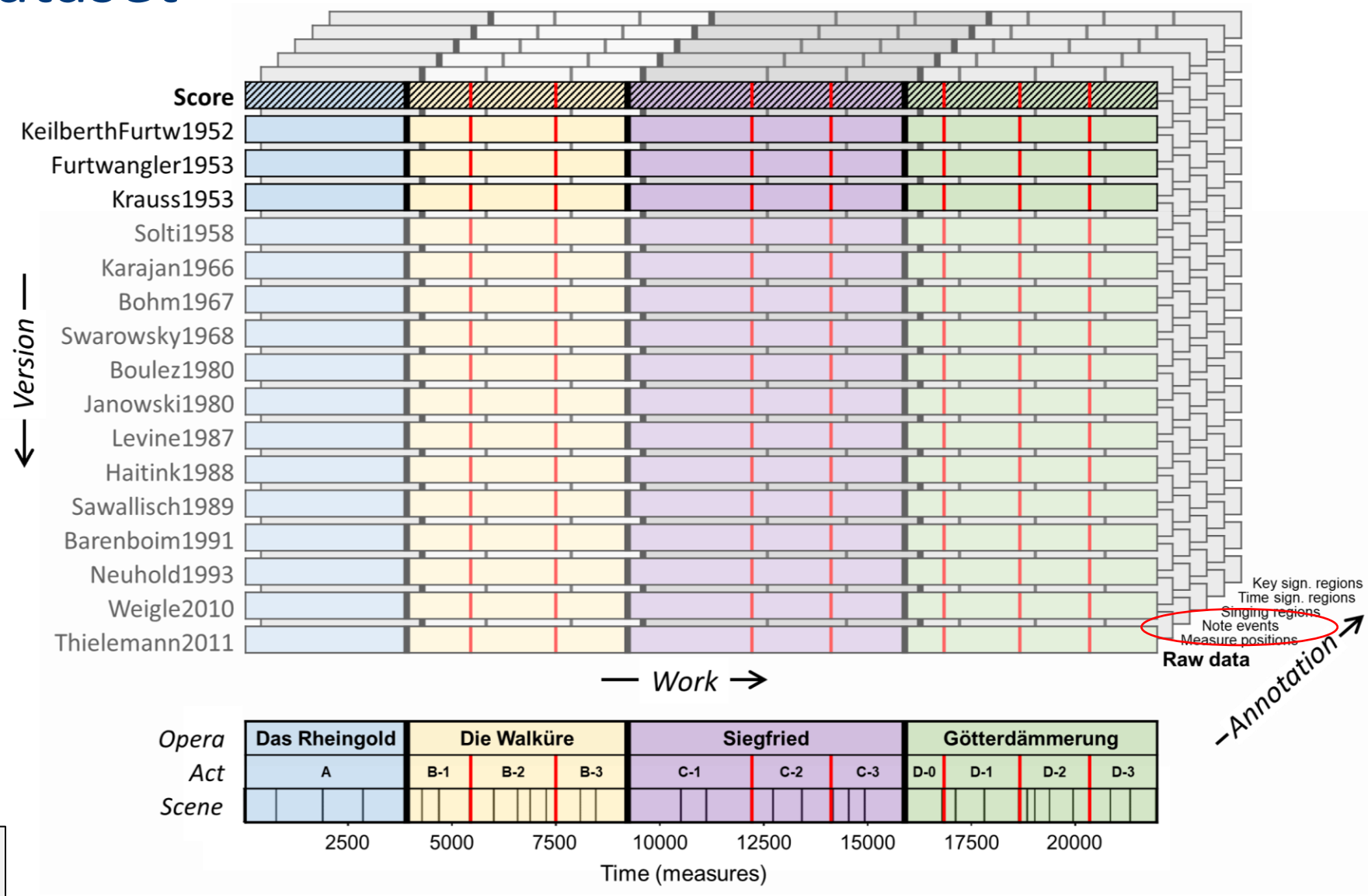


Weiß, Arifi-Müller, …, Kleinertz, Müller, **Wagner Ring Dataset: A Complex Opera Scenario for Music Processing and Computational Musicology**, TISMIR 2023

# Wagner Ring Dataset

## Annotations

- Measure positions
- Note events

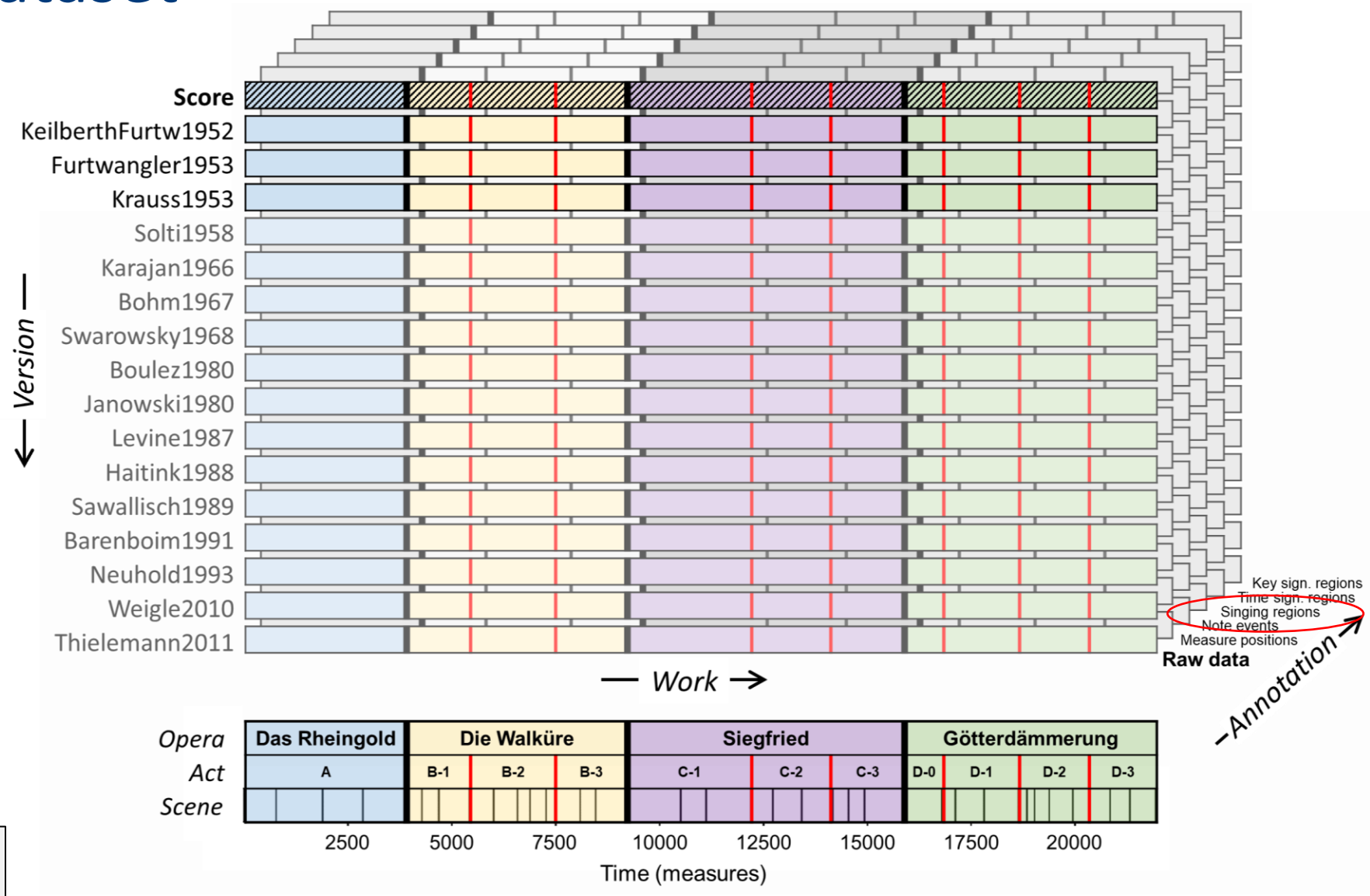



Weiß, Arifi-Müller, …, Kleinertz, Müller, **Wagner Ring Dataset: A Complex Opera Scenario for Music Processing and Computational Musicology**, TISMIR 2023

# Wagner Ring Dataset

## Annotations

- Measure positions
- Note events
- Singing regions

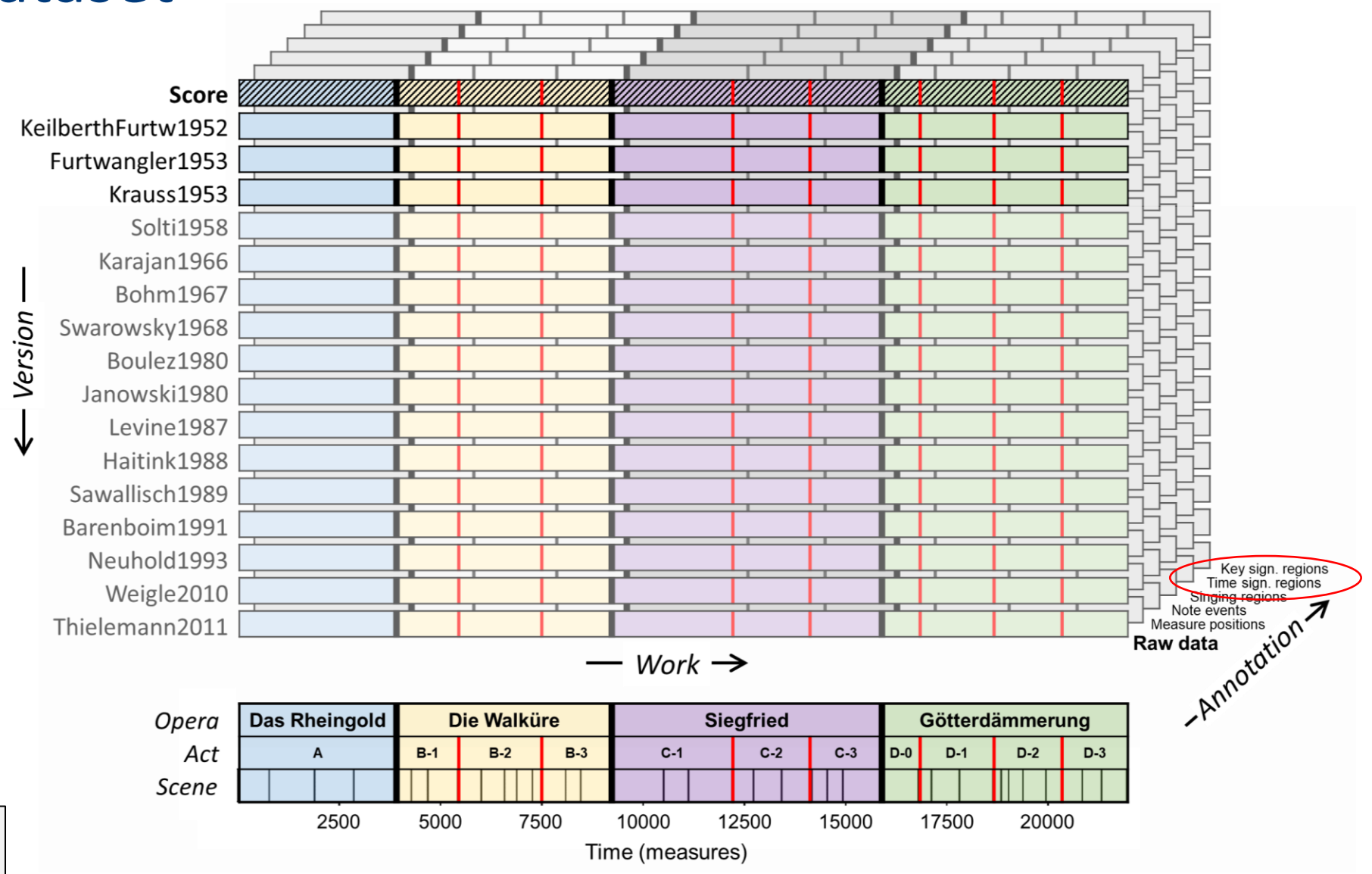



Weiß, Arifi-Müller, …, Kleinertz, Müller, **Wagner Ring Dataset: A Complex Opera Scenario for Music Processing and Computational Musicology**, TISMIR 2023

# Wagner Ring Dataset

## Annotations

- Measure positions
- Note events
- Singing regions
- Time signatures
- Key signatures



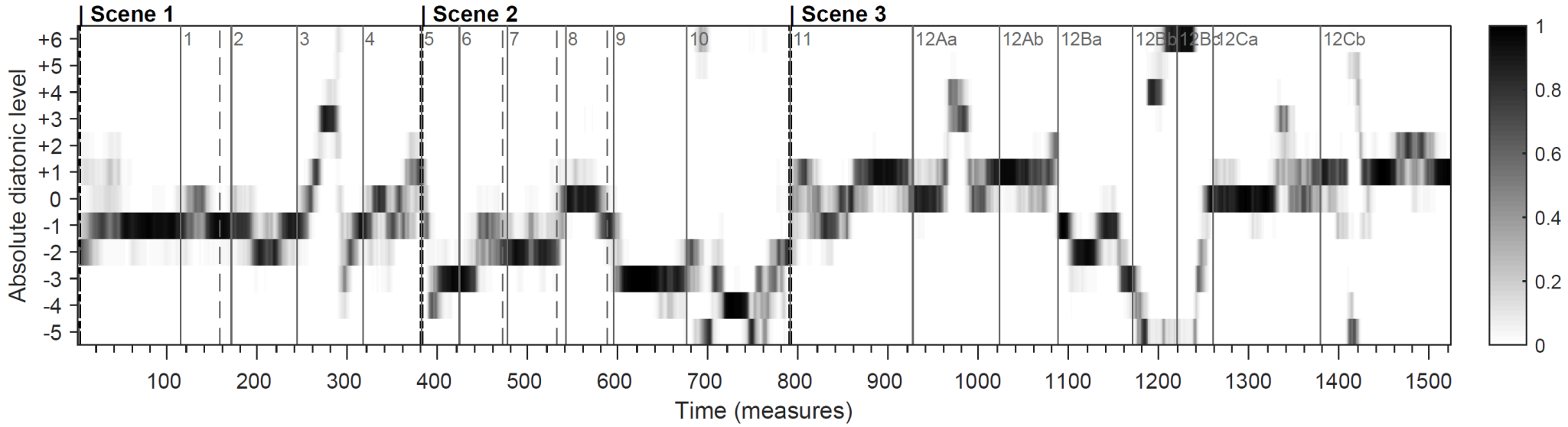

Weiß, Arifi-Müller, …, Kleinertz, Müller, **Wagner Ring Dataset: A Complex Opera Scenario for Music Processing and Computational Musicology**, TISMIR 2023

# Measuring Tonal Structures

## Diatonic Scales

Second opera *Die Walküre*, first act WWV 86 B1

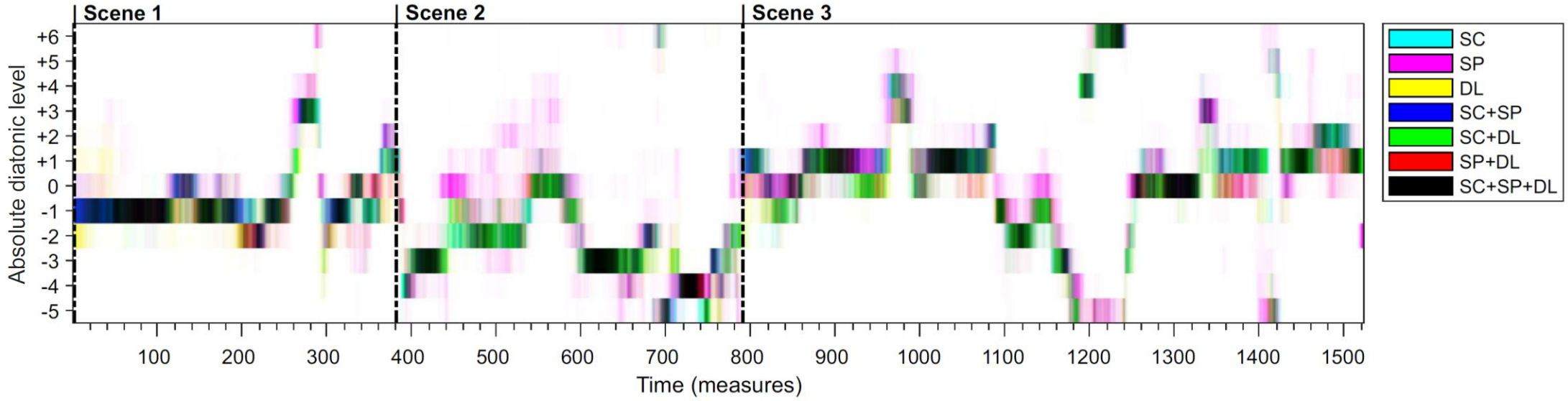
- DL: pitch-class features based on deep learning → diatonic scale likelihoods



# Measuring Tonal Structures

## Diatonic Scales – Comparative Visualization

- SC: based on score data
- SP: pitch-class features based on signal processing
- DL: pitch-class features based on deep learning → diatonic scale likelihoods

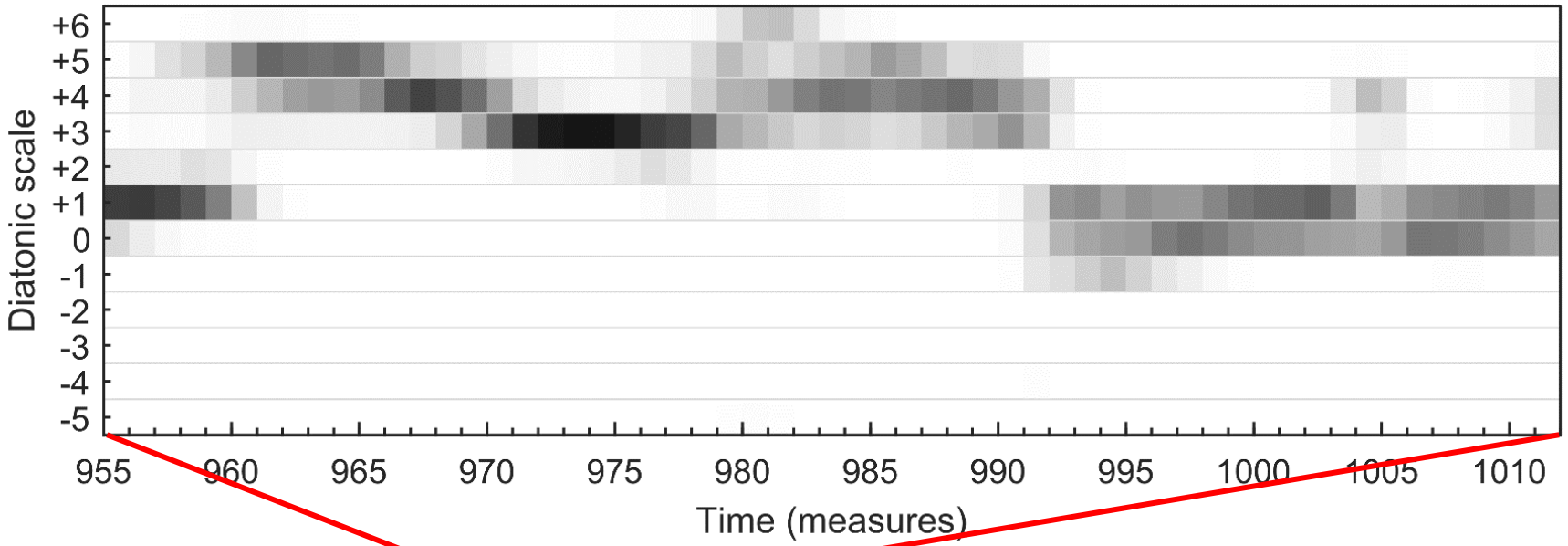


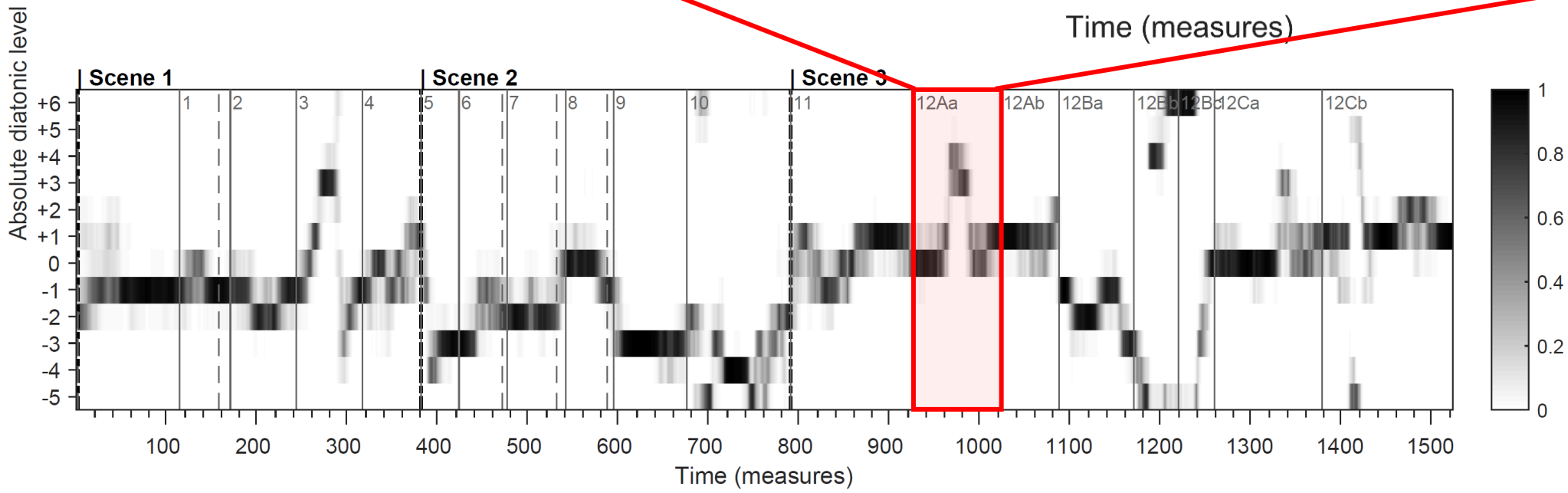

Weiß, Müller, **From Music Scores to Audio Recordings: Deep Pitch-Class Representations for Measuring Tonal Structures**, ACM JOCCH 2024

# Measuring Tonal Structures

## Diatonic Scales

Second opera
*Die Walküre*
first act WWV 86 B1

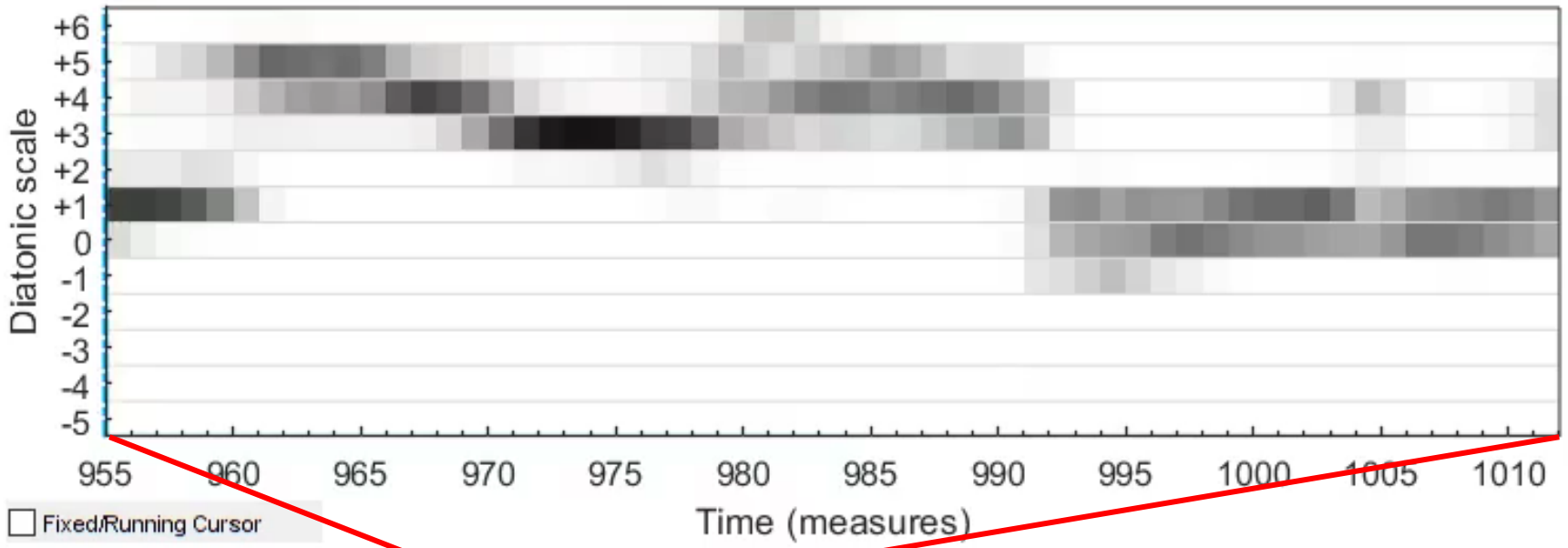


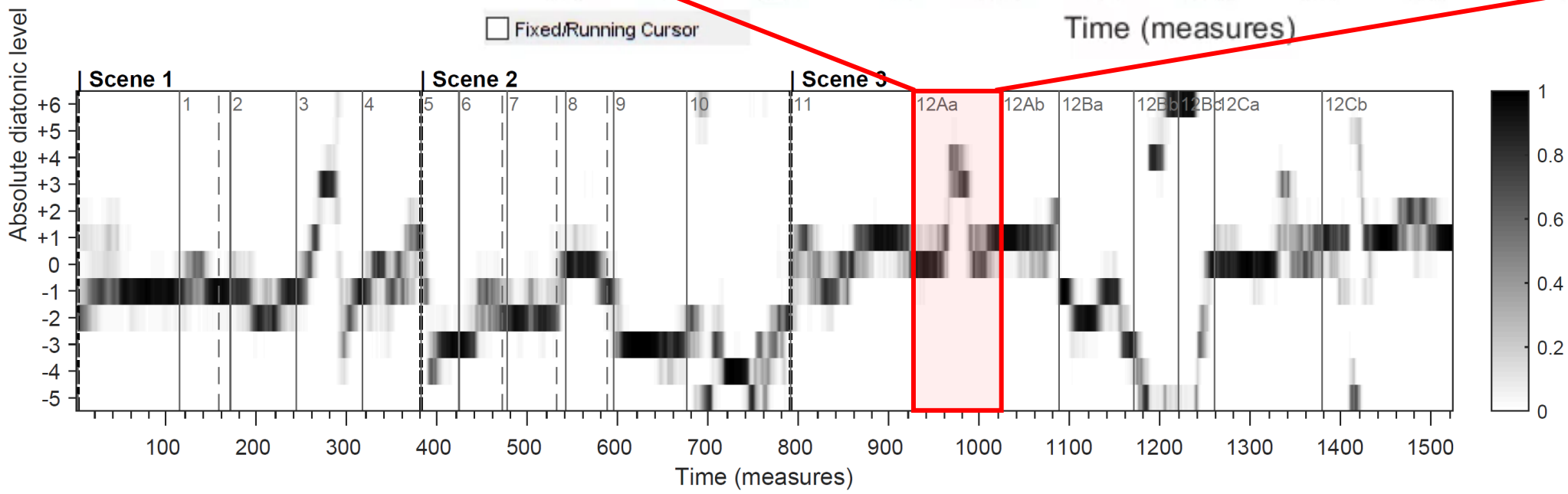



# Measuring Tonal Structures

## Diatonic Scales

Second opera
*Die Walküre*
first act WWV 86 B1



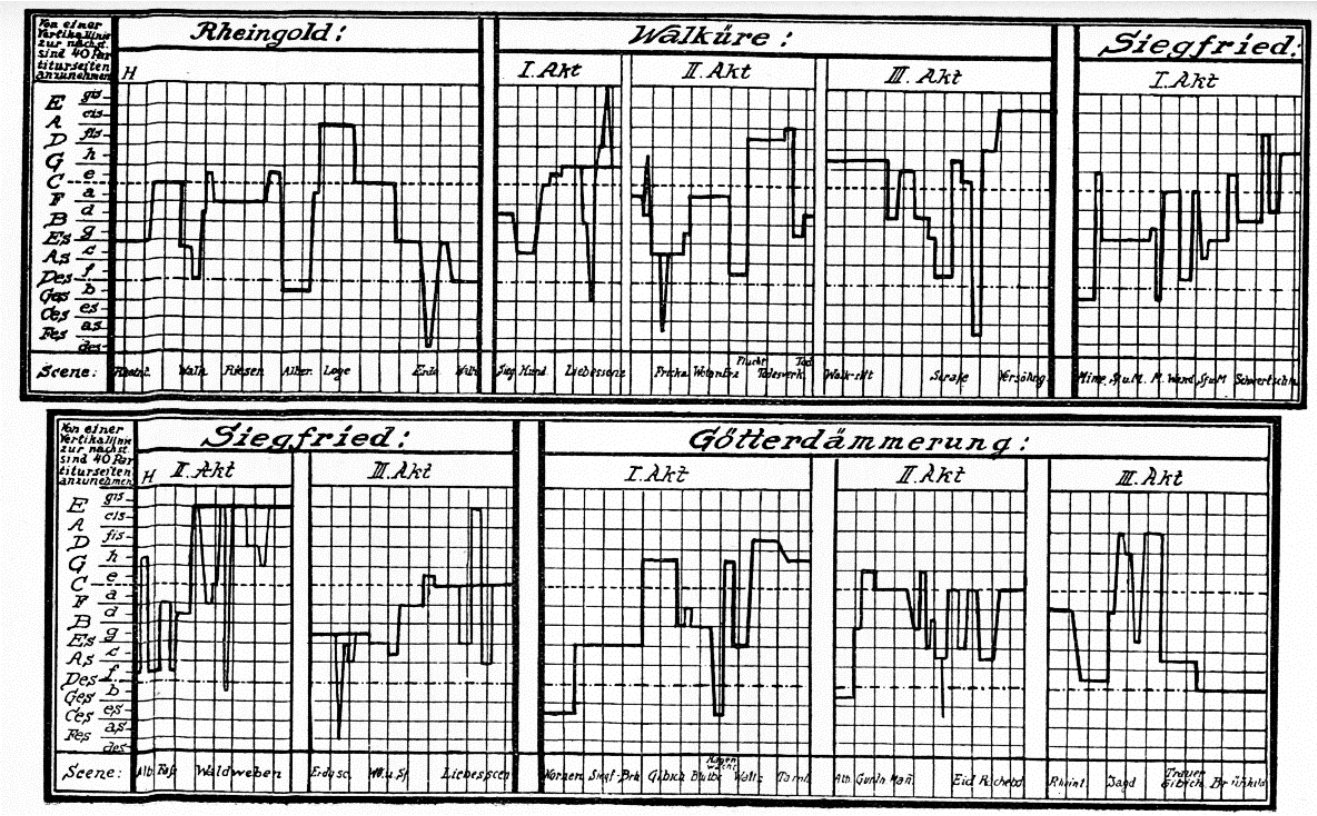
# Measuring Tonal Structures

## Beyond Evaluation – Three Perspectives on the *Ring*

Problem: Local key annotations subjective & ambiguous, hierachical, … Compare with

- Key Signature (KS) regions extracted from the score
- Coarse-scale annotations by musicologist Alfred Lorenz (AL)

Alfred Lorenz, **Das Geheimnis der Form bei R. Wagner**, 1924




**Die Walküre.**

**I. Aufzug.**

Vorspiel: d-moll. Wk. I. 1—20,10 [1—121].
M. I.: Aufstellung des Gewittersturmmotives. Verarbeitung des Gewitterzaubermotives.

1. Periode: d-moll. Wk. I. 20,3—22,17 [114—156].
D. I.: Siegmunds Erschöpfung.
M. I.: Aufstellung des Siegmundmotivs.

Übergang: Wk. I. 22,18—23,9 [157—169].
D. I.: Sieglinde erblickt den Fremden.

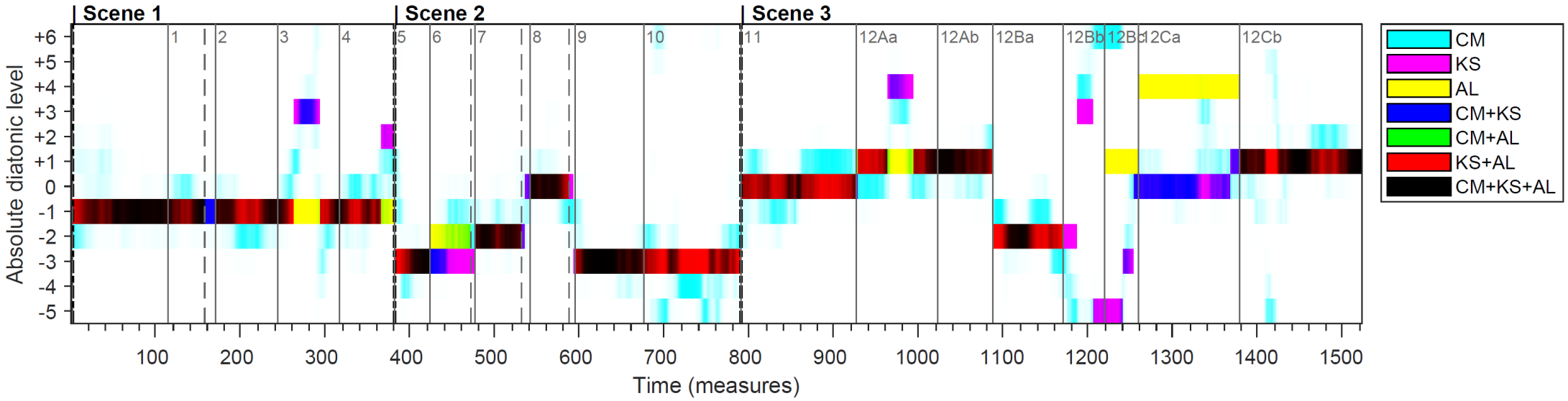
2. Periode: d-moll. Wk. I. 23,10—28,3 [170—242].
D. I.: Sieglinde labt den Gast.
M. I.: Aufstellung von Mitleids-, Flucht- und Liebesmotiv.

3. Periode: d-moll. Wk. I. 28,4—35,13 [243—315].
D. I.: Siegmund erkennt seine Liebe und will fort.
M. I.: Steigerung der bisherigen Motive.

# Measuring Tonal Structures

## Beyond Evaluation – Three Perspectives on the *Ring*

- CM: Computational Measurement from DL-based pitch-class features
- KS: Key Signature regions extracted from the score
- AL: Coarse-scale annotations by musicologist Alfred Lorenz

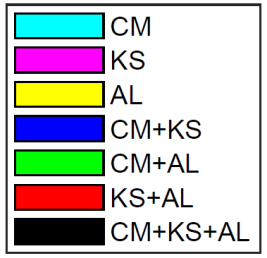


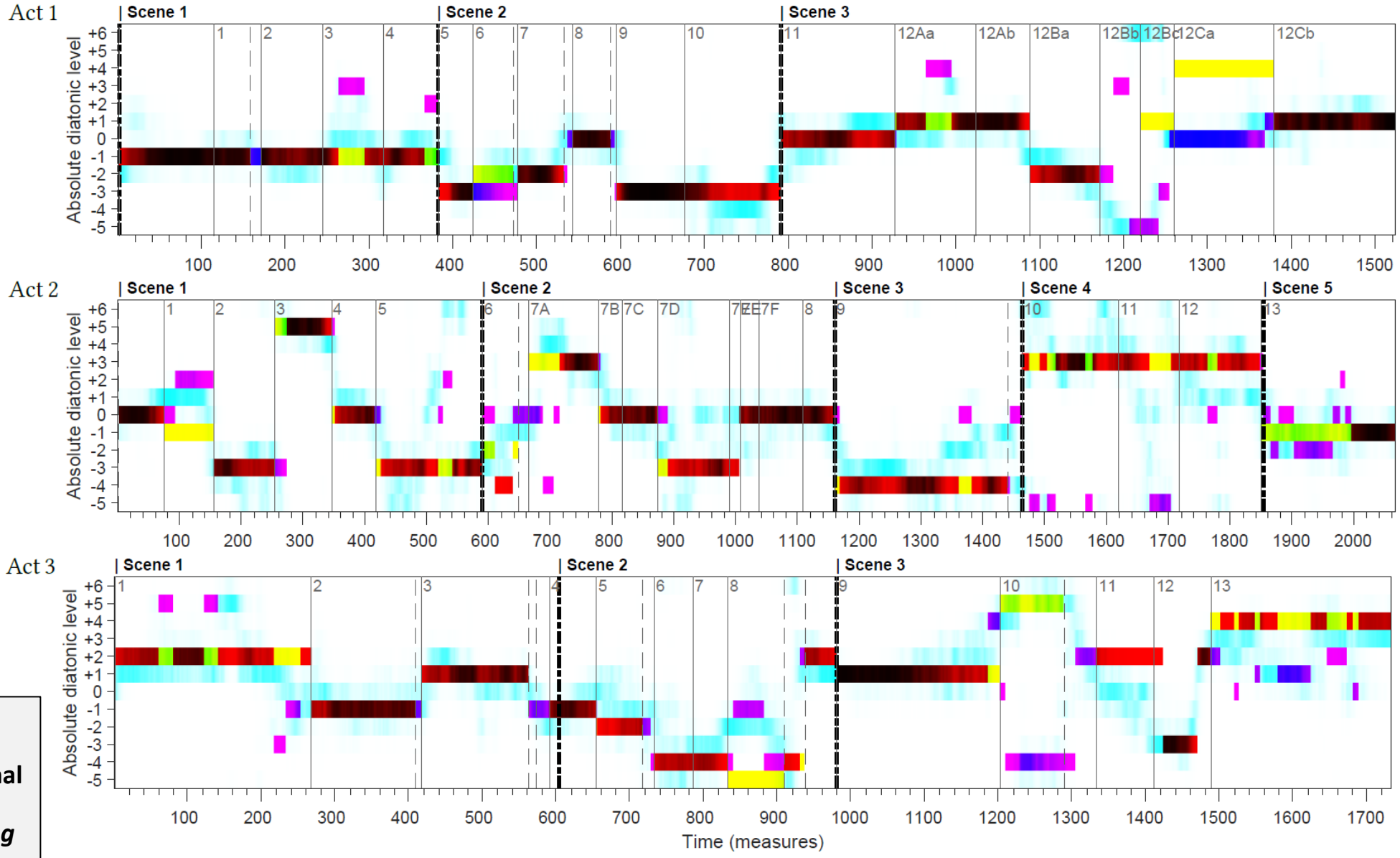

Weiß, Kleinertz, Klauk Müller, **Computational Strategies for Measuring and Visualizing Tonal Structures: Towards a Large-Scale Analysis of Wagner's *Ring* Cycle**, ACM JOCCH 2026

# Full Opera

*Die Walküre,*

WWV 86 B




Weiß, Kleinertz, Klauk Müller, **Computational Strategies for Measuring and Visualizing Tonal Structures: Towards a Large-Scale Analysis of Wagner's *Ring* Cycle**, ACM JOCCH 2026

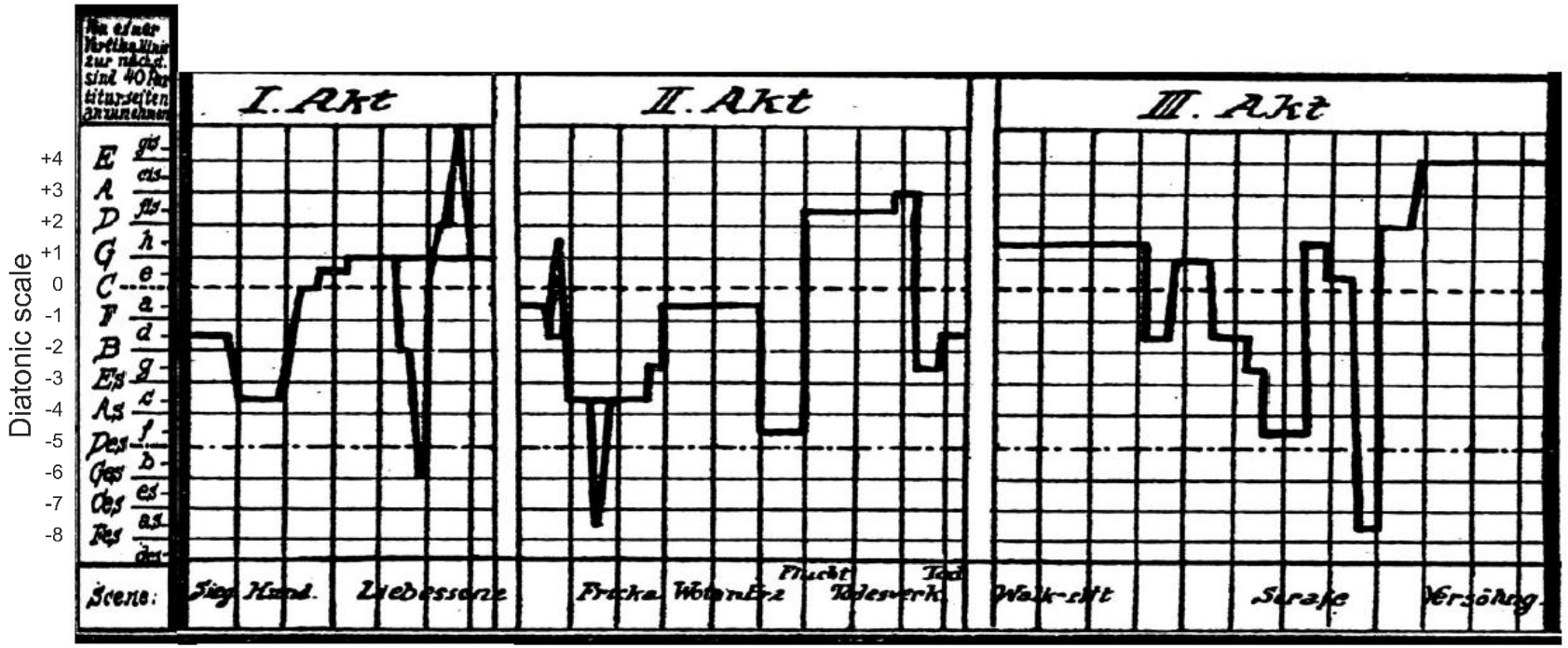
# Full Opera

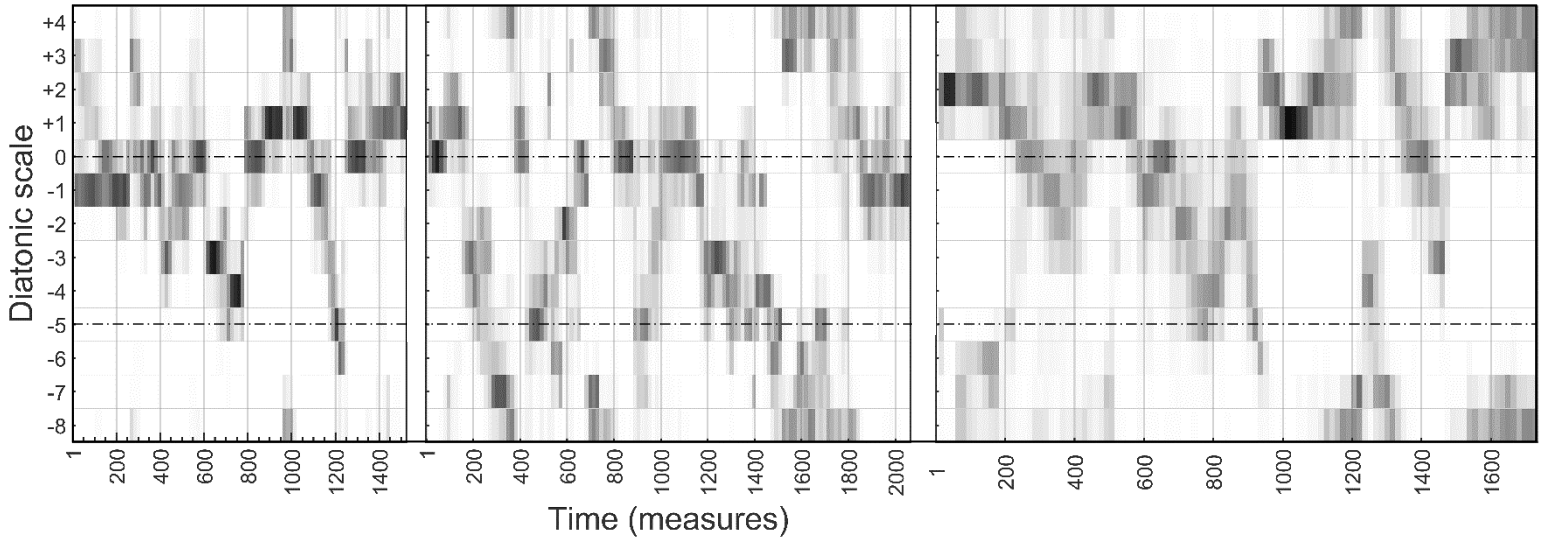
*Die Walküre,*

WWV 86 B

Alfred Lorenz, 1924

Computational Measurement



# Exploring Tonal-Dramatic Relationships

**Special Thanks**



**Frank Zalkow**

**Corpus**

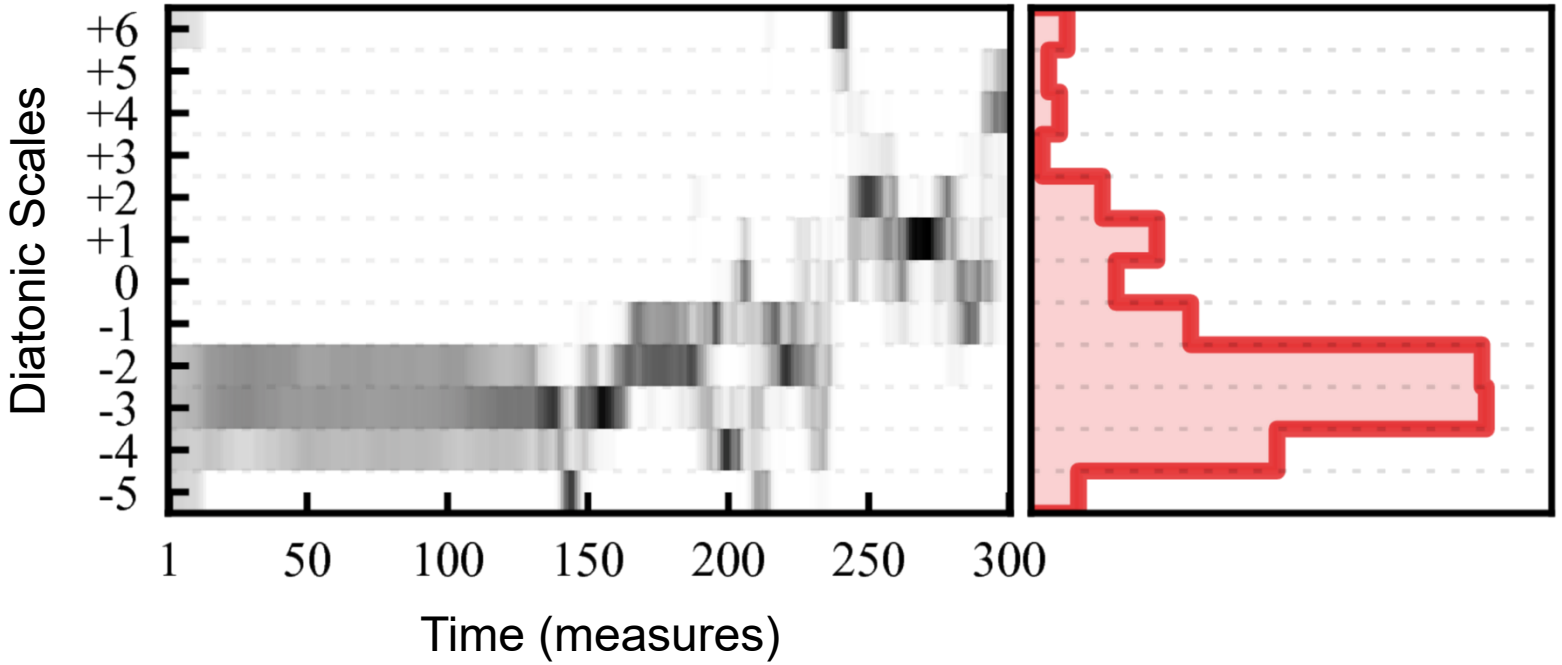
Richard Wagner:
*Der Ring des Nibelungen*

**Music theory**

Diatonic Scales
Chords

Histograms of scale analysis over time

| Das Rheingold<br>WWV 86 A<br>3897 measures | Die Walküre<br>WWV 86 B<br>5322 measures | Siegfried<br>WWV 86 C<br>6682 measures | Götterdämmerung<br>WWV 86 D<br>6040 measures |
|---|---|---|---|



# Exploring Tonal-Dramatic Relationships

## Leitmotifs

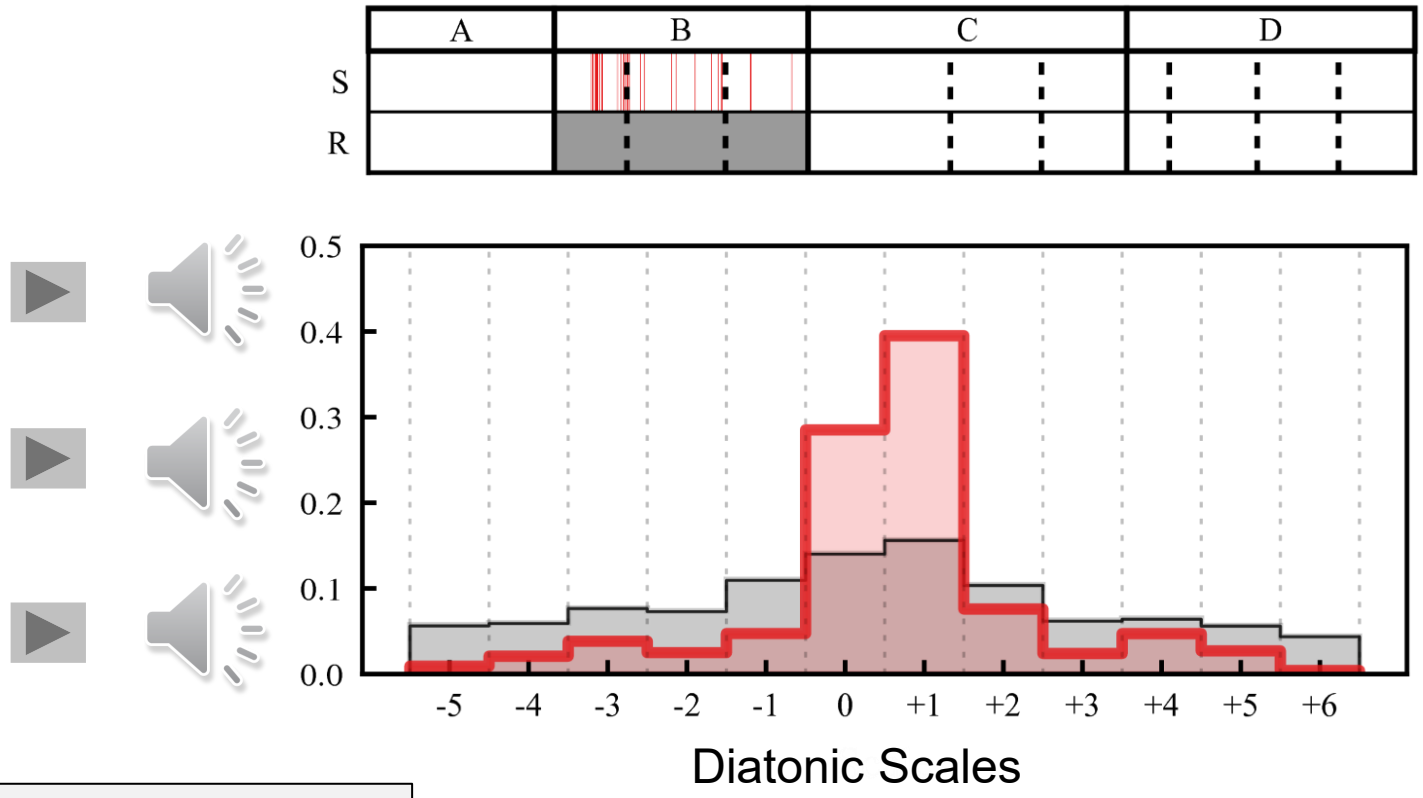
**Music theory**

Diatonic Scales
Chords

**Corpus**

Richard Wagner:
*Der Ring des Nibelungen*

**Die Walküre – Sword motif**




Zalkow, Weiß, Müller, **Exploring Tonal-Dramatic Relationships in Richard Wagner's Ring Cycle**, ISMIR 2017.

# Exploring Tonal-Dramatic Relationships

## Leitmotifs

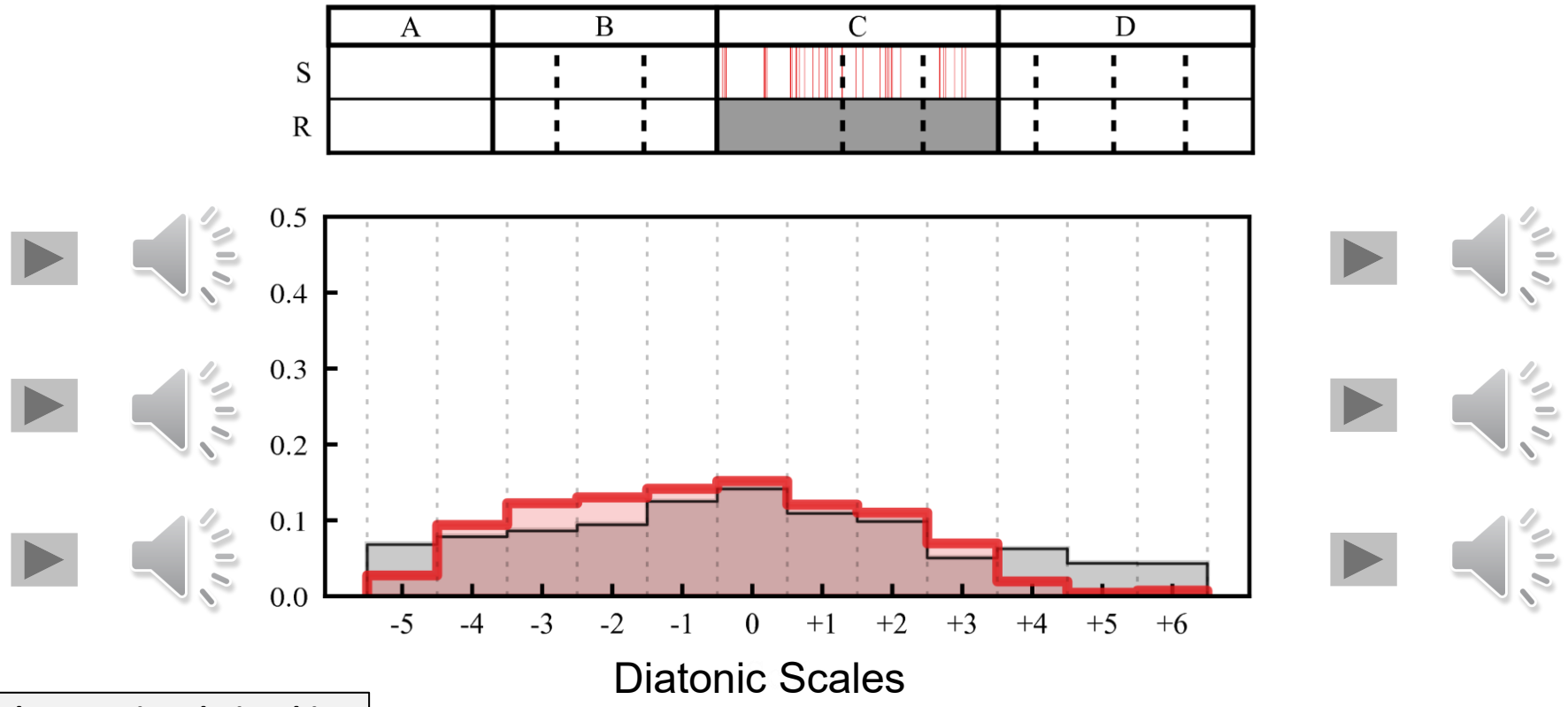
**Music theory**

Diatonic Scales
Chords

**Corpus**

Richard Wagner:
*Der Ring des Nibelungen*

**Siegfried – Sword motif**




Zalkow, Weiß, Müller, **Exploring Tonal-Dramatic Relationships in Richard Wagner's Ring Cycle**, ISMIR 2017.

# Exploring Tonal-Dramatic Relationships

## Leitmotifs

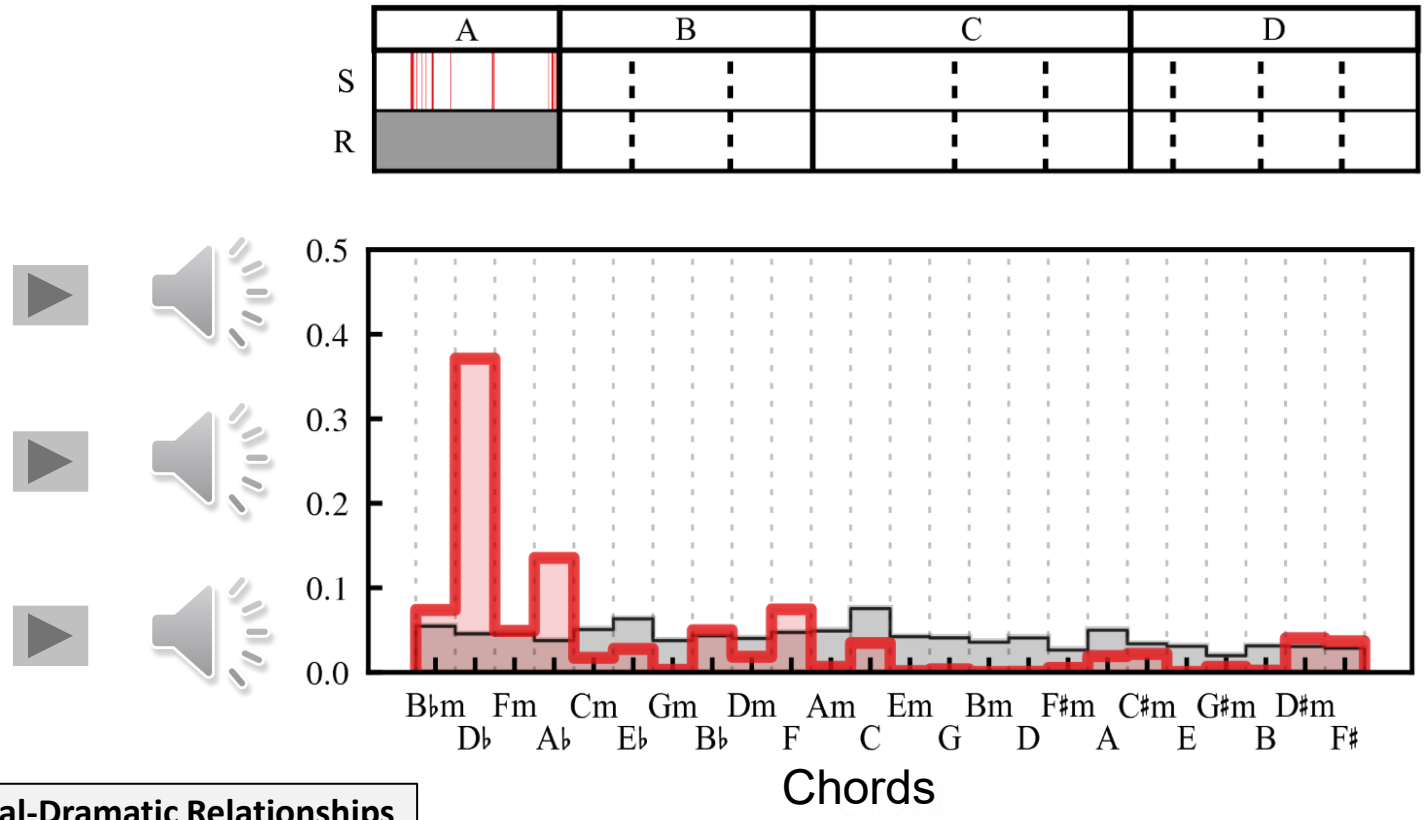
**Music theory**

Diatonic Scales
Chords

**Corpus**

Richard Wagner:
*Der Ring des Nibelungen*

**Das Rheingold – Valhalla motif**




Zalkow, Weiß, Müller, **Exploring Tonal-Dramatic Relationships in Richard Wagner's Ring Cycle**, ISMIR 2017.

# Exploring Tonal-Dramatic Relationships

## Leitmotifs

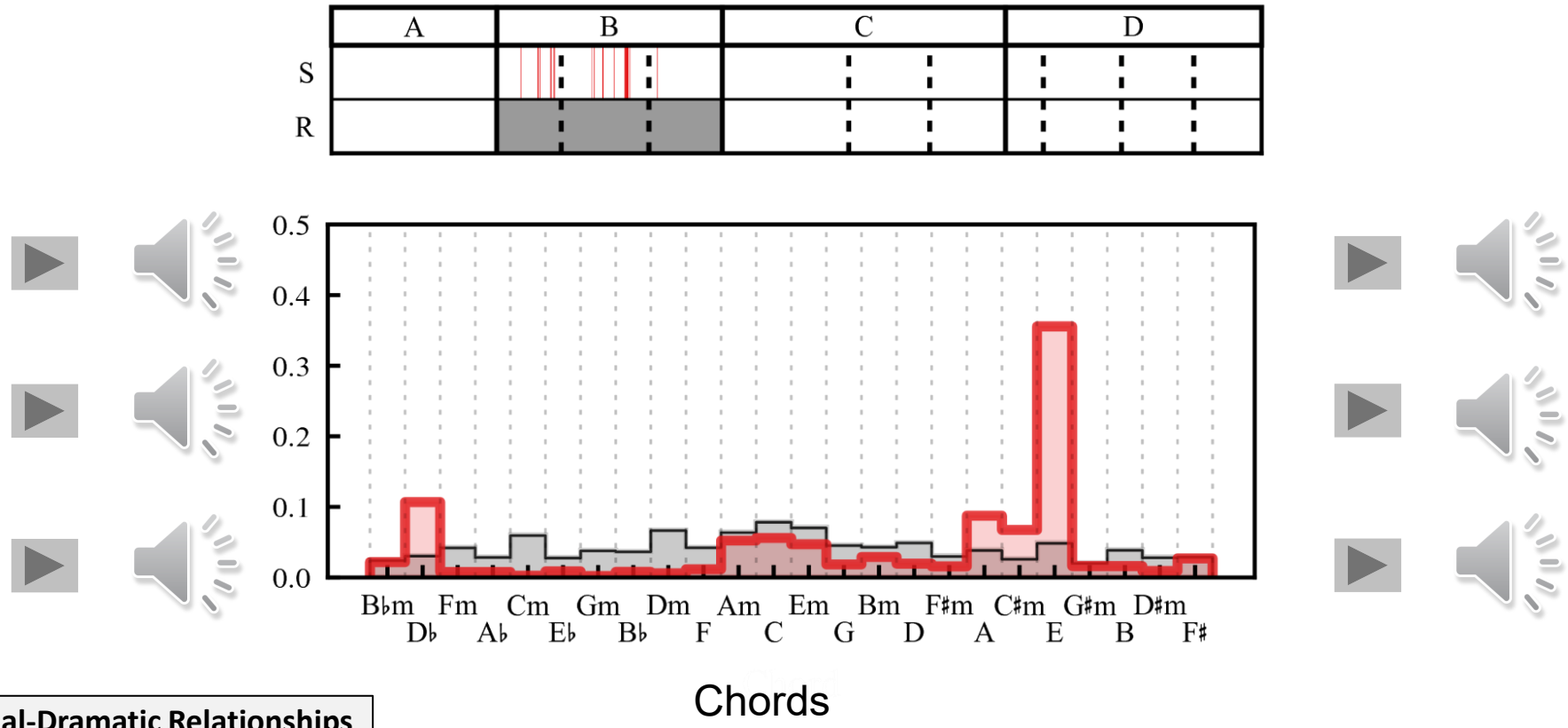
**Music theory**

Diatonic Scales
Chords

**Corpus**

Richard Wagner:
*Der Ring des Nibelungen*

**Die Walküre – Valhalla motif**

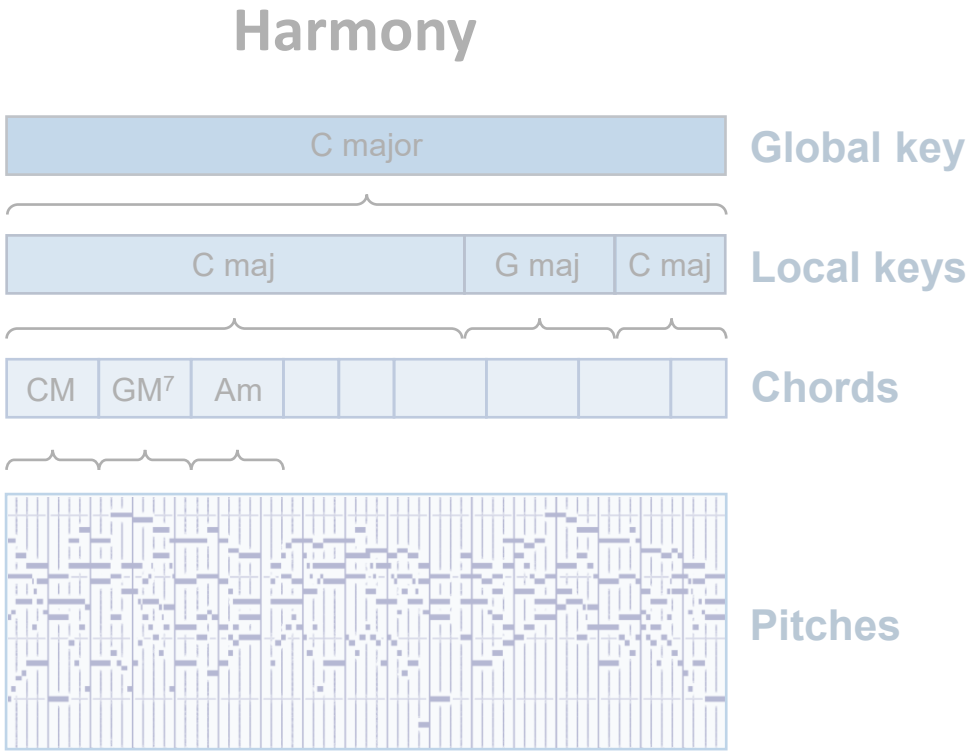




Zalkow, Weiß, Müller, **Exploring Tonal-Dramatic Relationships in Richard Wagner's Ring Cycle**, ISMIR 2017.

# Outline

1. Extracting Pitch Information
2. Measuring Tonal Structures
3. **Analyzing Musical Style**



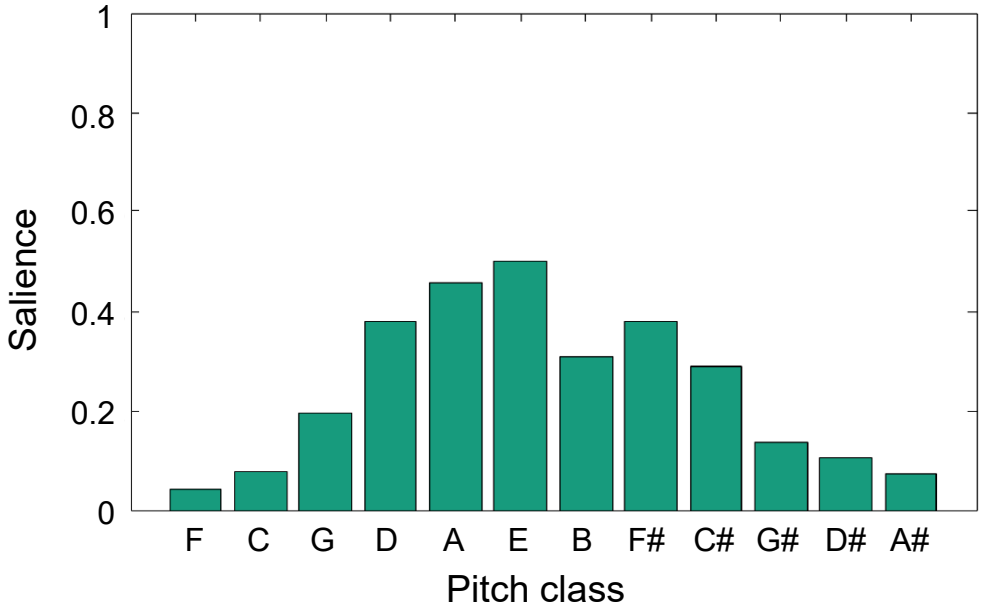
# Corpus Analysis

## Tonal Complexity

**Music theory**

Fifth Width
Tonal Complexity

- **1725** – J. S. Bach, Orchestral Suite BWV 1068, 1st movement




*Series of fifths →*

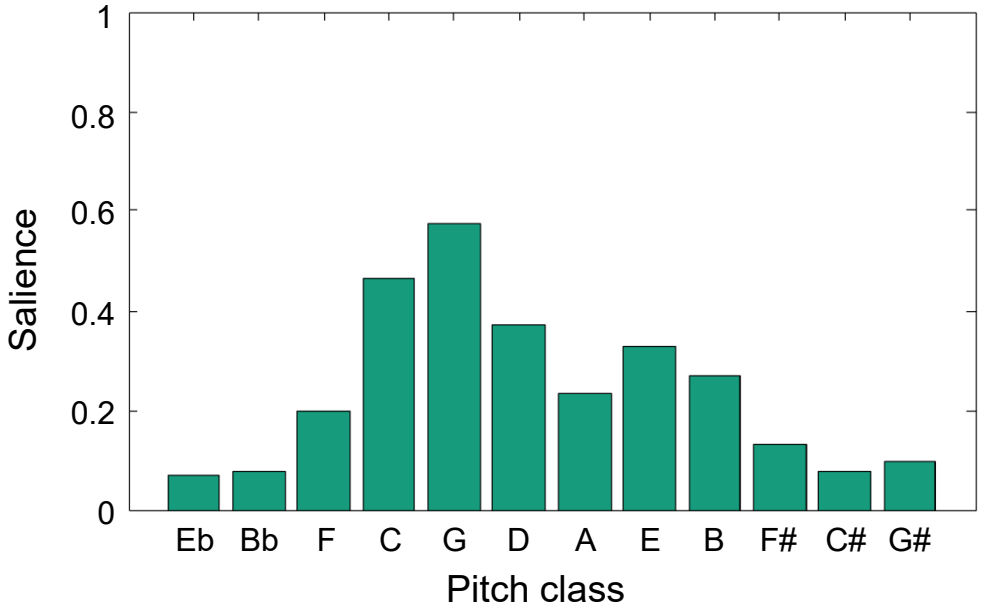
**Algorithms**

Geometry
Circular Statistics

# Corpus Analysis

## Tonal Complexity

- **1783** – W. A. Mozart, Symphony KV 425, 1st movement




*Series of fifths →*

**Music theory**

Fifth Width
Tonal Complexity

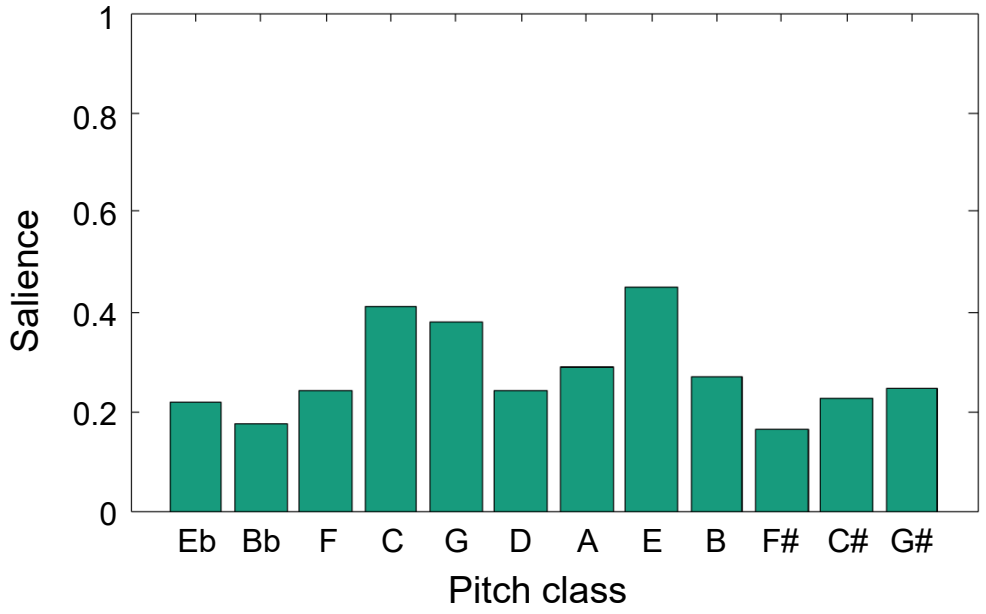
**Algorithms**

Geometry
Circular Statistics

# Corpus Analysis

## Tonal Complexity

- **1883** – J. Brahms,  Symphony No. 3, 1st movement




*Series of fifths →*

**Music theory**

Fifth Width
Tonal Complexity

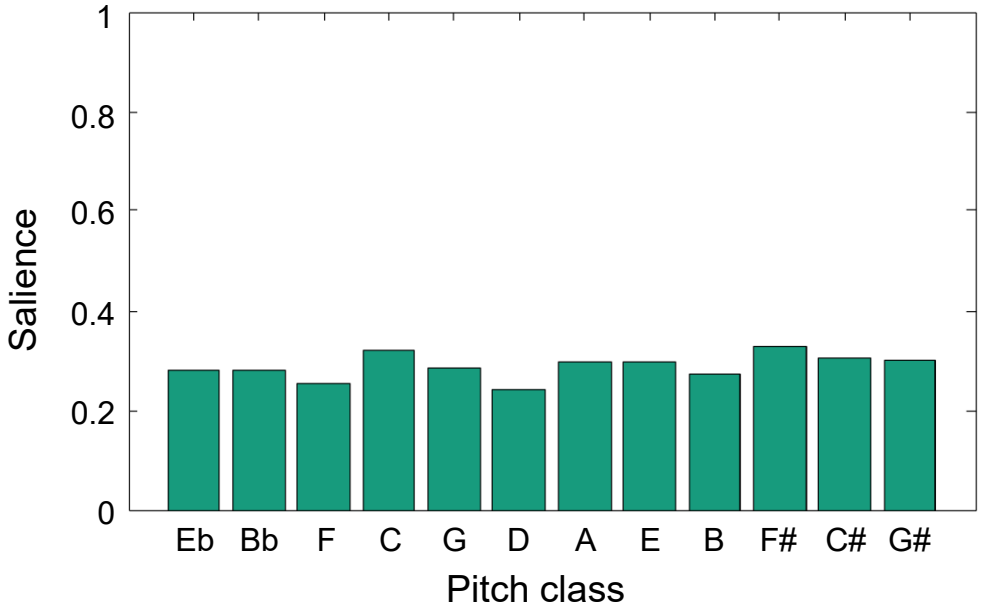
**Algorithms**

Geometry
Circular Statistics

# Corpus Analysis

## Tonal Complexity

- **1940** – A. Webern, Variations for Orchestra op. 30




*Series of fifths →*

**Music theory**

Fifth Width
Tonal Complexity

**Algorithms**

Geometry
Circular Statistics

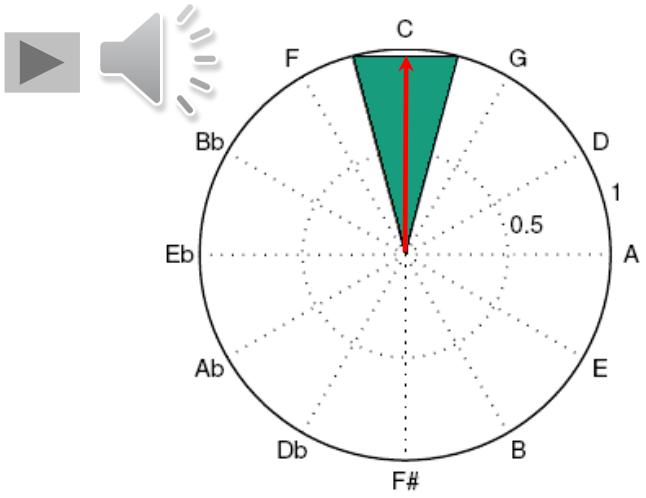
# Corpus Analysis

## Tonal Complexity

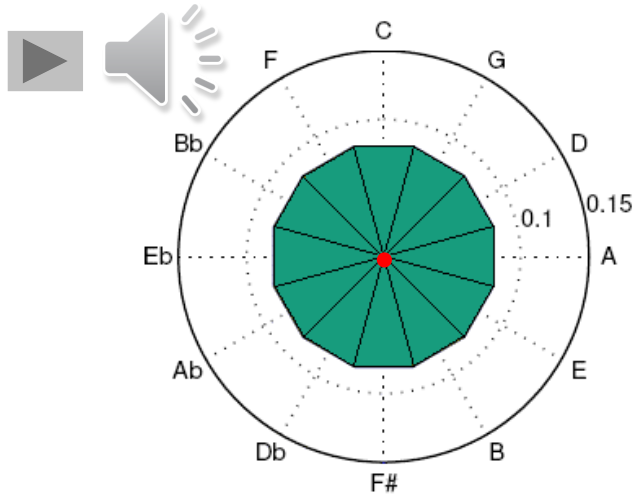
**Music theory**

Fifth Width
Tonal Complexity

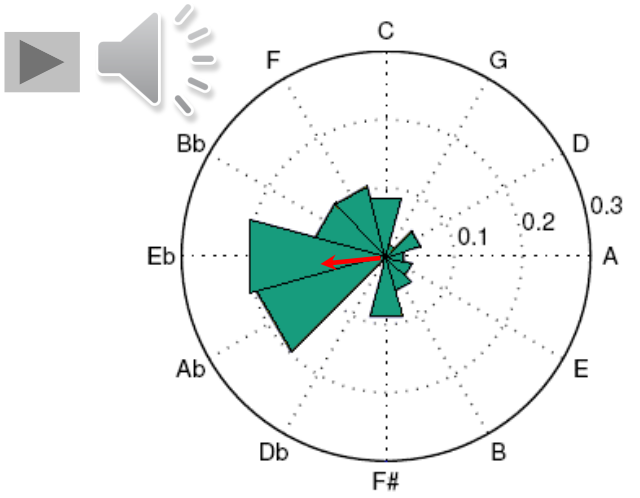
$Complexity = 0$




$Complexity = 1$




$Complexity = 0.6$




Weiß & Müller, **Quantifying and Visualizing Tonal Complexity**, Proc. Conf. on Interdisciplinary Musicology, 2014.

Weiß & Müller, **Tonal Complexity Features for Style Classification of Classical Music**, Proc. IEEE ICASSP 2015.

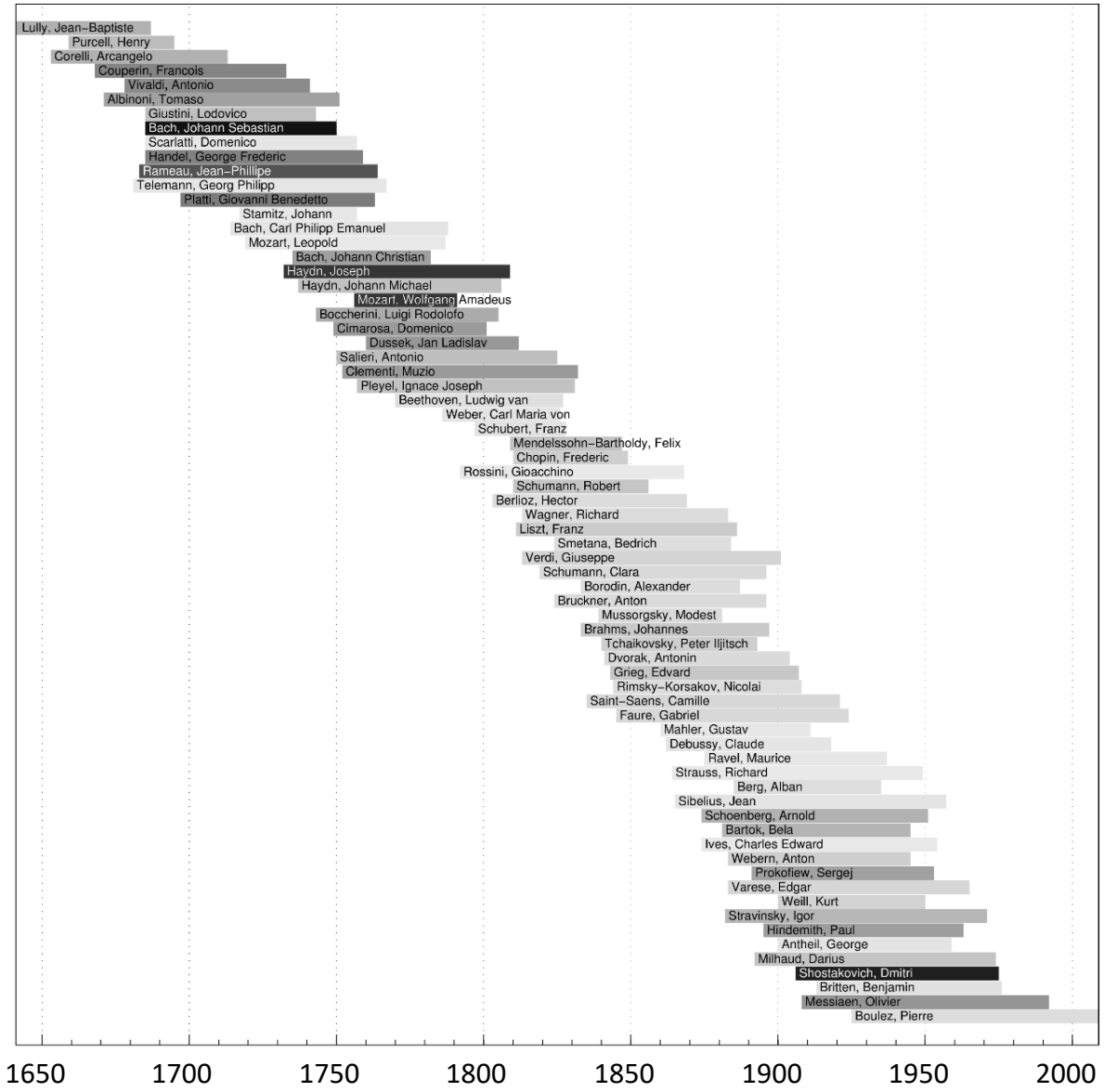
**Algorithms**

Geometry
Circular Statistics

## Corpus

„Cross-Era“

2000 Piano and Orchestra Recordings




## Music theory

Fifth Width
Tonal Complexity

## Algorithms

Geometry
Circular Statistics

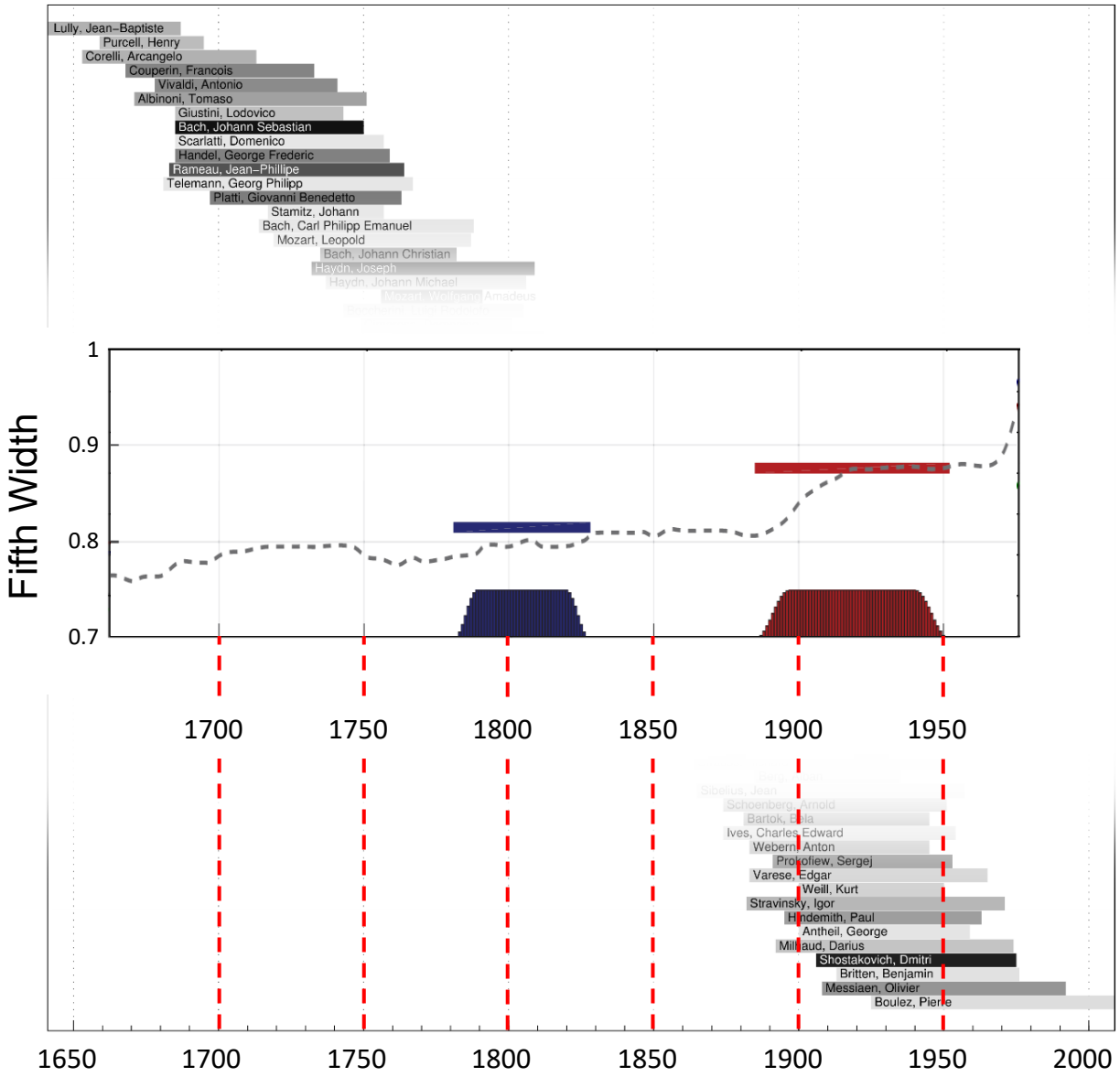
## Music theory

Fifth Width
Tonal Complexity

## Corpus

„Cross-Era“

2000 Piano and Orchestra Recordings




Beethoven, Piano Sonata
Schoenberg, Orchestral Piece
Evolution Curve

Weiß, Mauch, Dixon, Müller, **Investigating Style Evolution of Western Classical Music: A Computational Approach**, Musicae Scientiae 2019.

## Algorithms

„Evolution curves“

## Music theory

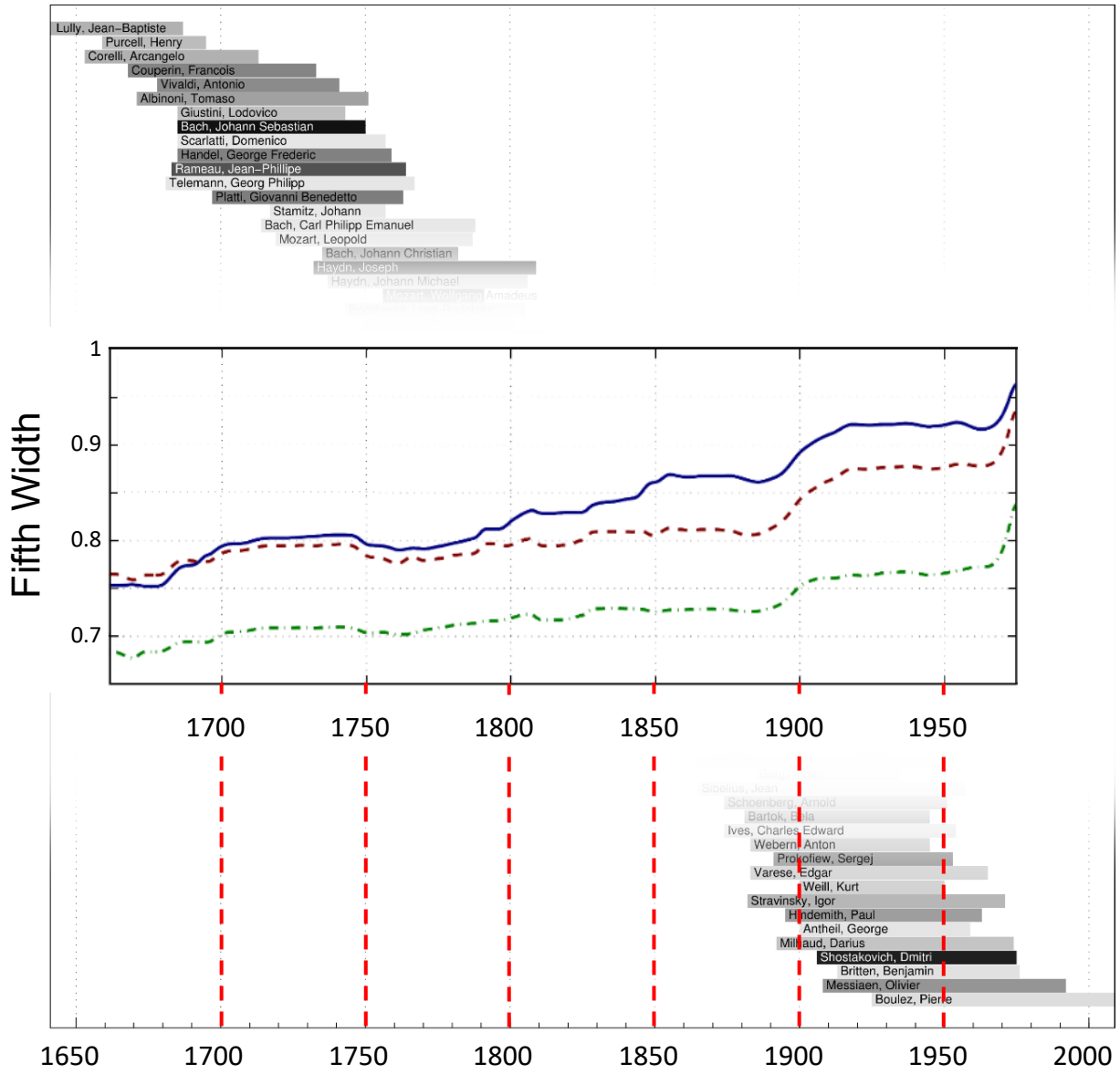
Fifth Width
Tonal Complexity

## Corpus

„Cross-Era“

2000 Piano and Orchestra Recordings

350 years




Global (*piece*)
Medium (*segment*)
Local (*chord*)

Weiß, Mauch, Dixon, Müller, **Investigating Style Evolution of Western Classical Music: A Computational Approach**, Musicae Scientiae 2019.

## Algorithms

Geometry
Circular Statistics

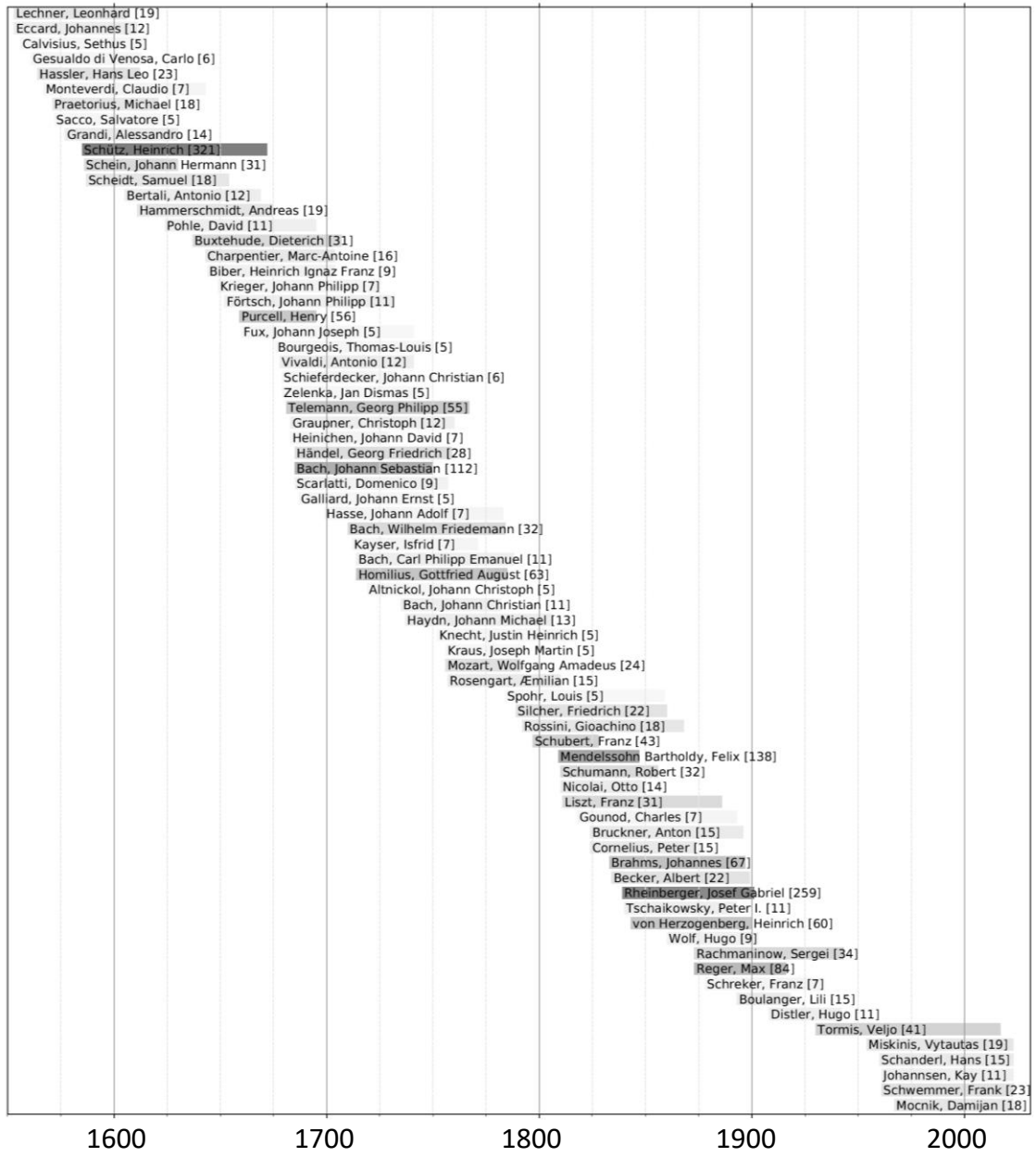
Carus

## Corpus

Carus Audio Corpus

5773 Choral and Sacred Music Recordings

450 years




Weiß, Müller, **Studying Tonal Evolution of Western Choral Music: A Corpus-Based Strategy**, Computational Humanities Research, 2023.

## Music theory

Fifth Width
Tonal Complexity

## Algorithms

Geometry
Circular Statistics

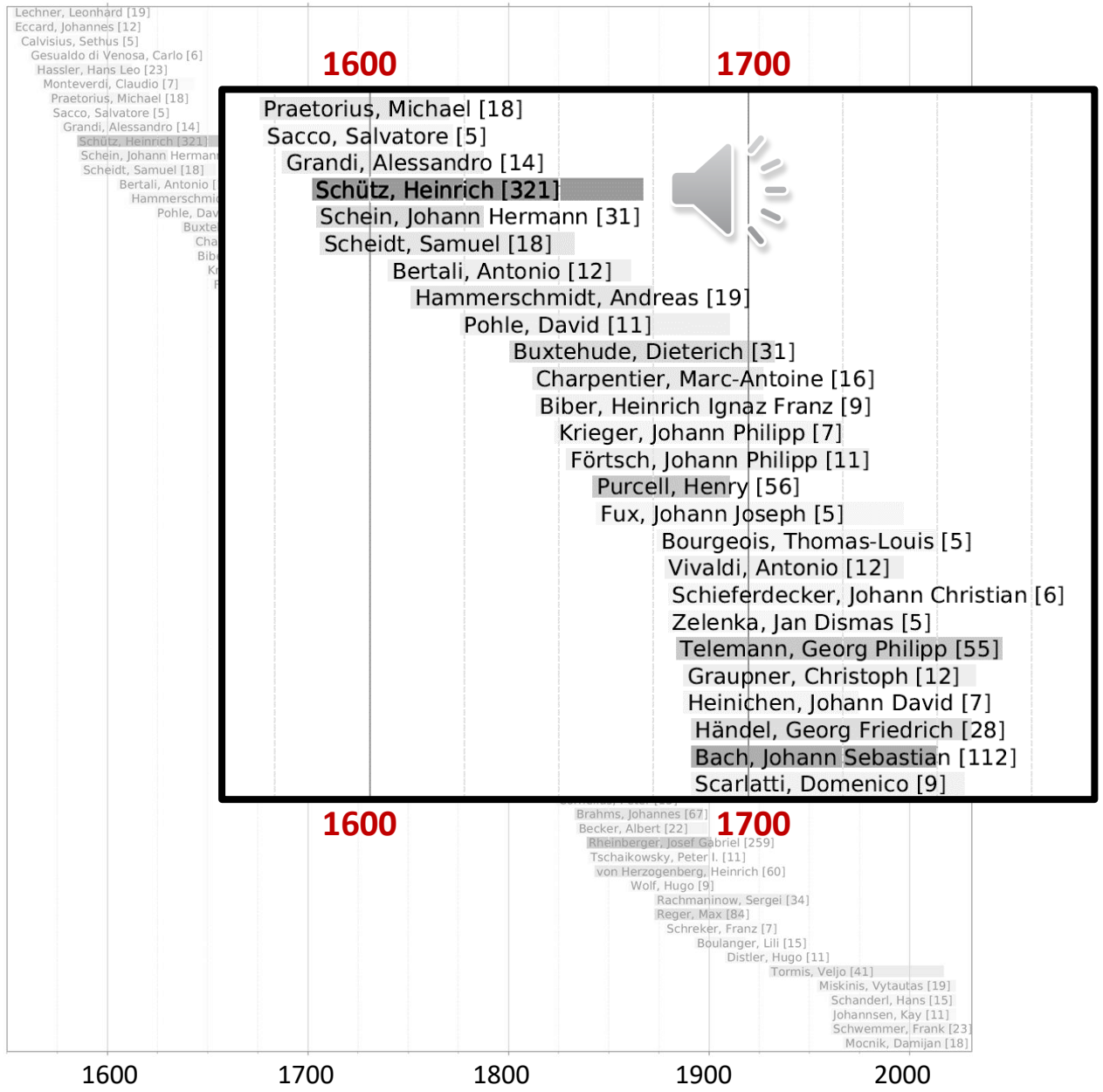
Carus

## Corpus

Carus Audio Corpus

5773 Choral and Sacred Music Recordings

450 years




Weiß, Müller, **Studying Tonal Evolution of Western Choral Music: A Corpus-Based Strategy**, Computational Humanities Research, 2023.

## Music theory

Fifth Width
Tonal Complexity

## Algorithms

Geometry
Circular Statistics

## Special Thanks

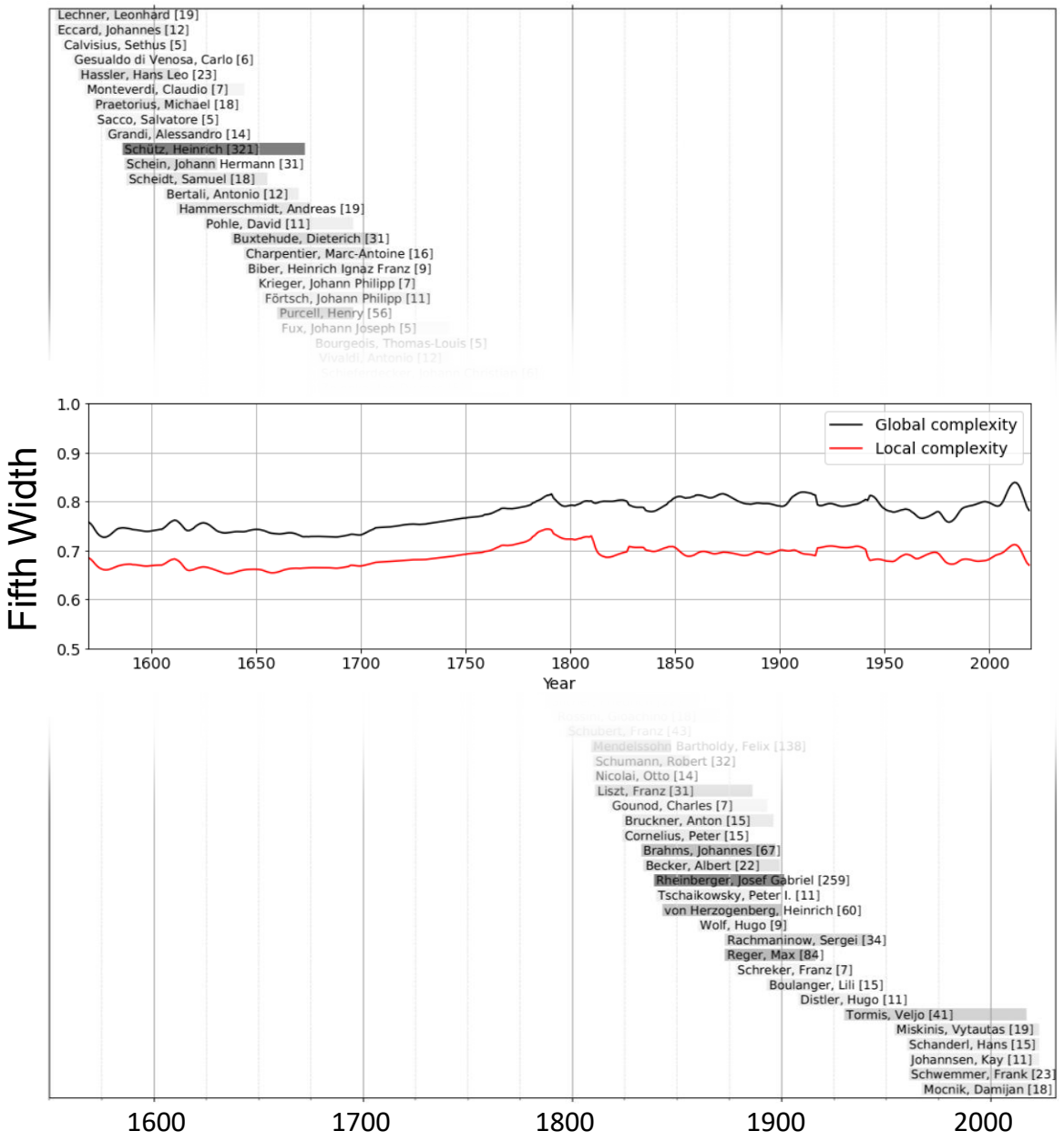


Benjamin Henzel

## Corpus

Carus Audio Corpus

5773 Choral and Sacred Music Recordings




## Music theory

Fifth Width
Tonal Complexity

— Global (*piece*)
— Local (*chord*)

## Algorithms

Pitch-Class CNN
Circular Statistics

Weiß, Müller, **Studying Tonal Evolution of Western Choral Music: A Corpus-Based Strategy**, Computational Humanities Research, 2023.

# Corpus Analysis

## Vocal vs. Instrumental Music Evolution

**Music theory**

Fifth Width
Tonal Complexity

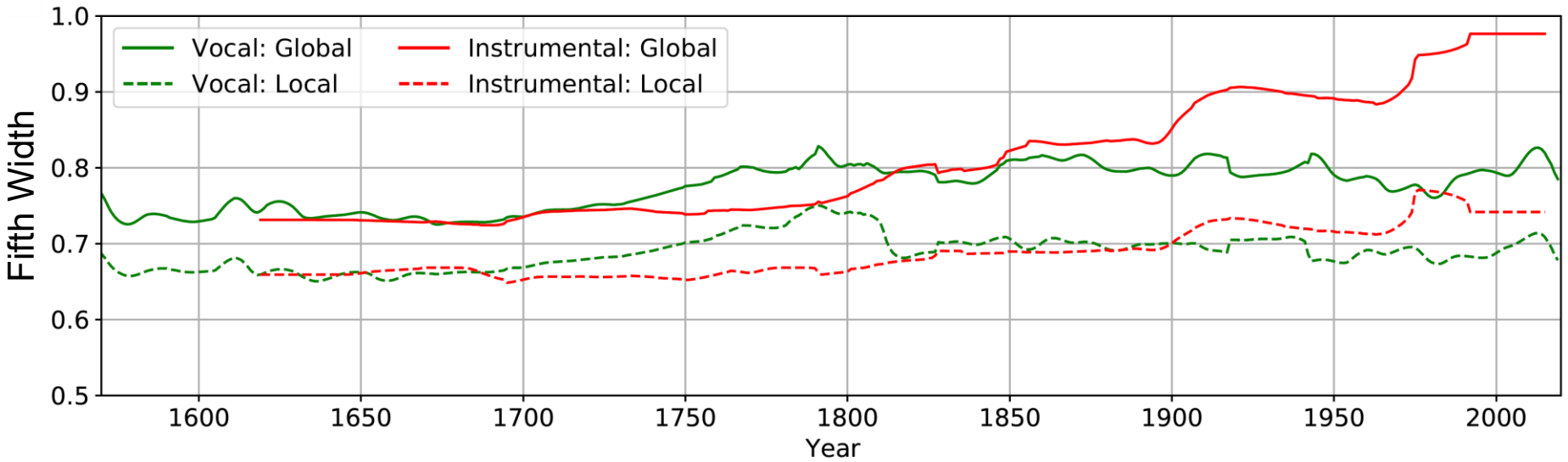
**Corpus**

„Cross-Era“

2000 Piano and Orchestra Recordings

Carus Audio Corpus

5773 Choral and Sacred Music Recordings




**Algorithms**

Pitch-Class CNN
Circular Statistics

Henzel, Müller, Weiß, *Style Evolution in Western Choral Music: A Corpus-Based Strategy,* **Computational Humanities Research 1**, 2025.

# Corpus Analysis

## Individual Composer Evolution

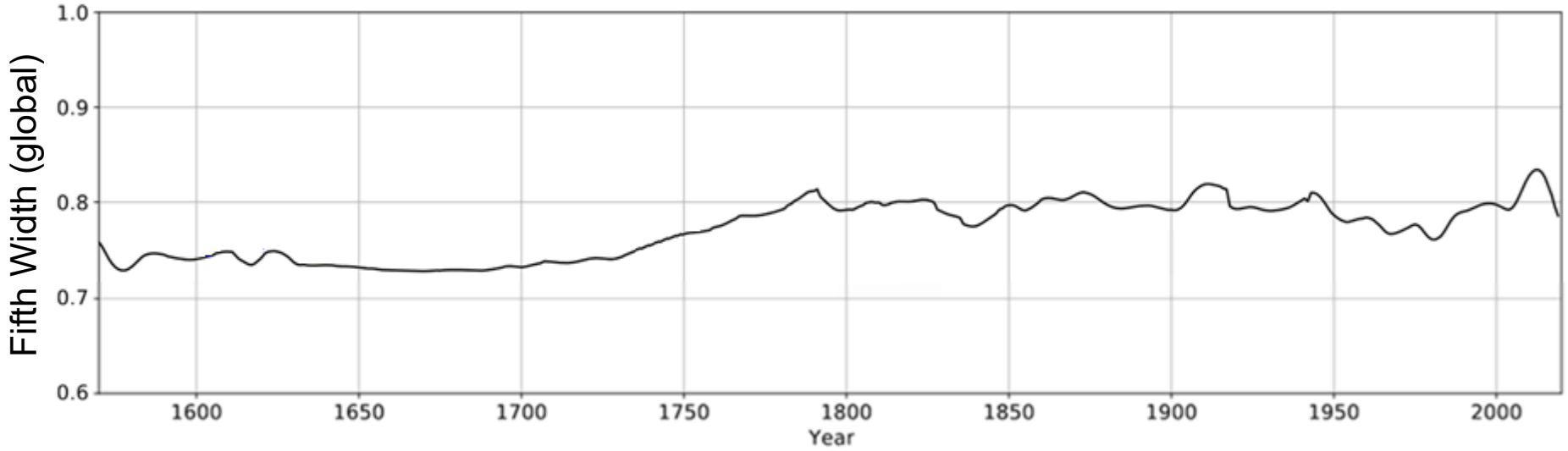
**Music theory**

Fifth Width
Tonal Complexity

**Corpus**

Carus Audio Corpus

5773 Choral and Sacred Music Recordings




**Algorithms**

Pitch-Class CNN
Circular Statistics

Henzel, Müller, Weiß, *Style Evolution in Western Choral Music: A Corpus-Based Strategy,* **Computational Humanities Research 1**, 2025.

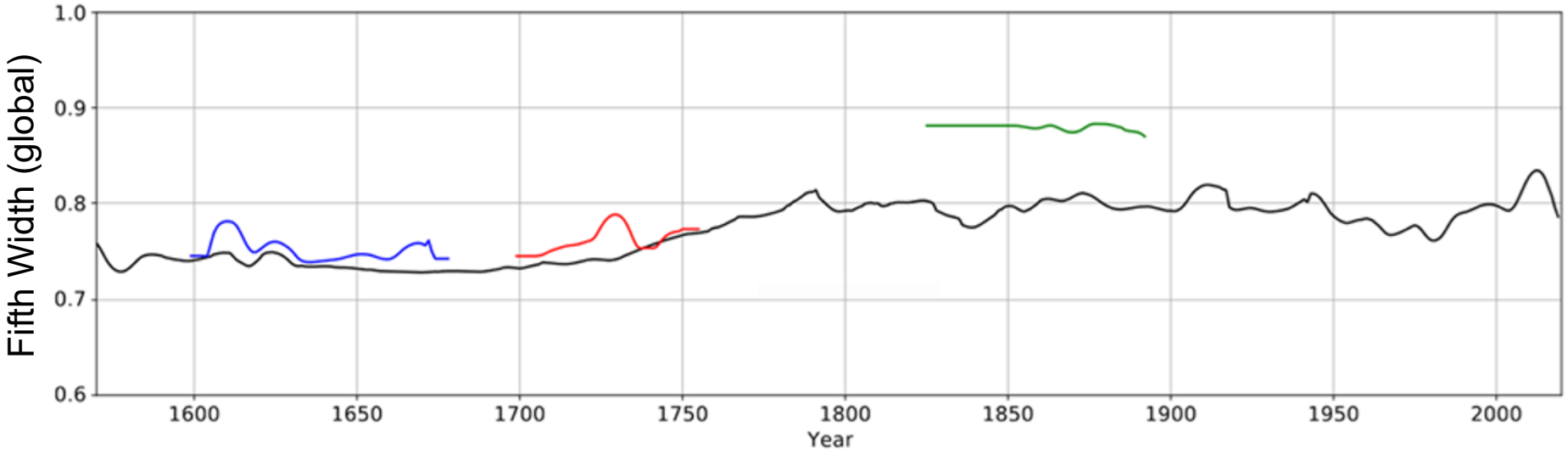
# Corpus Analysis

## Individual Composer Evolution

**Music theory**

Fifth Width
Tonal Complexity

**Heinrich Schütz (1585–1672)**
**Johann Sebastian Bach (1685–1750)**
**Franz Liszt (1811–1886)**




**Corpus**

Carus Audio Corpus

5773 Choral and Sacred Music Recordings

**Algorithms**

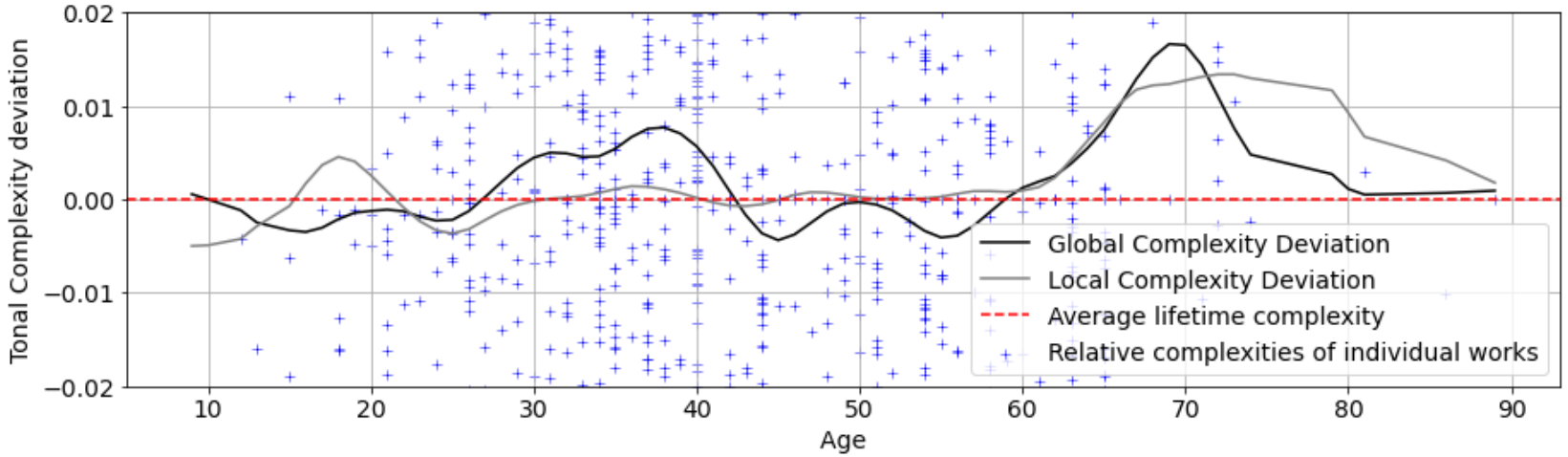
Pitch-Class CNN
Circular Statistics

Henzel, Müller, Weiß, *Style Evolution in Western Choral Music: A Corpus-Based Strategy,* **Computational Humanities Research 1**, 2025.

# Corpus Analysis

## Complexity Deviation vs. Composer Average

All Composers

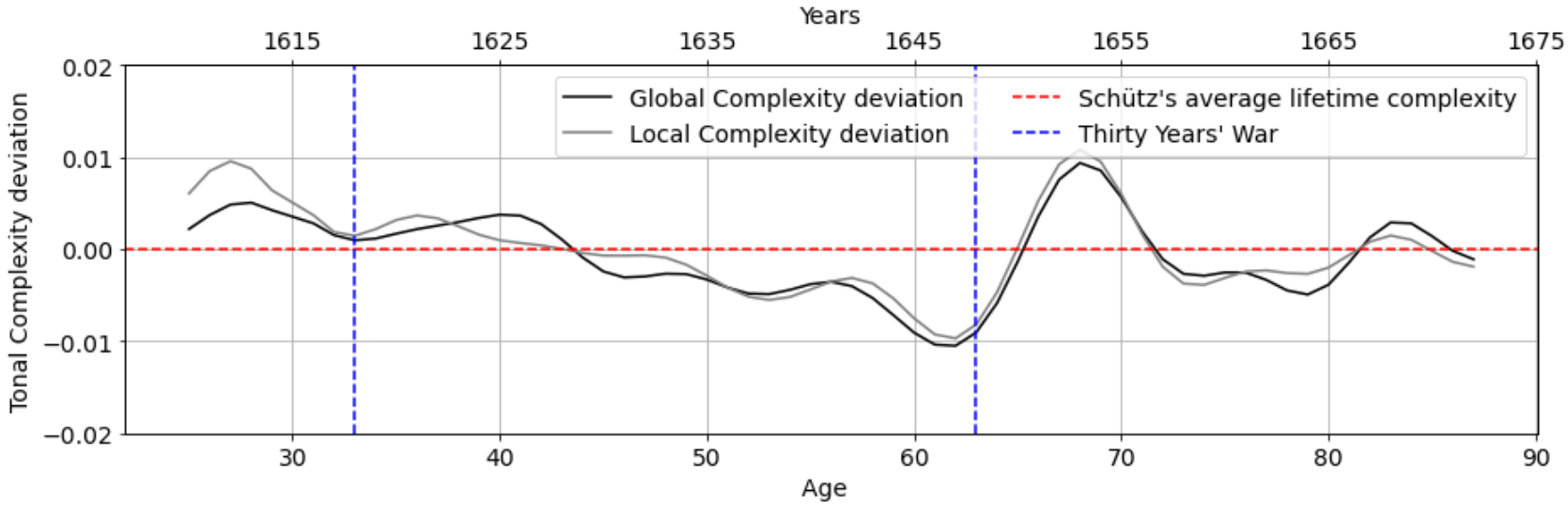



**Corpus**

Carus Audio Corpus

5773 Choral and Sacred Music Recordings

Heinrich Schütz (1585–1672)




Henzel, Müller, Weiß, *Style Evolution in Western Choral Music: A Corpus-Based Strategy,* **Computational Humanities Research 1**, 2025.

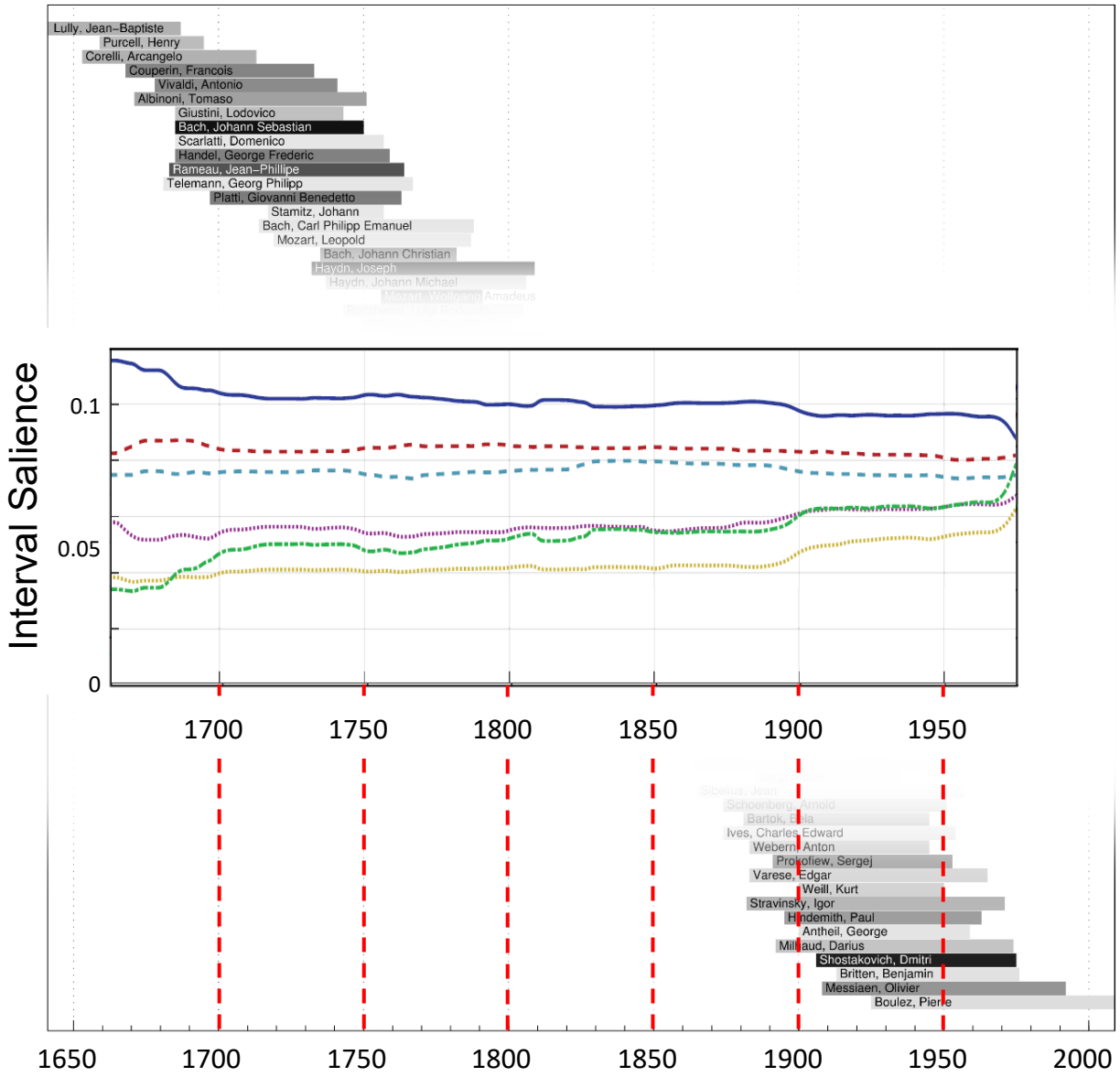
## Music theory

Interval types
PC set theory

## Corpus

„Cross-Era“

2000 Piano and Orchestra Recordings




$F_1$ (Minor Second)
$F_2$ (Major Second)
$F_3$ (Minor Third)
$F_4$ (Major Third)
$F_5$ (Fifth)
$F_6$ (Tritone)

[11] Weiß, Mauch, Dixon, Müller, **Investigating Style Evolution of Western Classical Music: A Computational Approach**, Musicae Scientiae 2019.

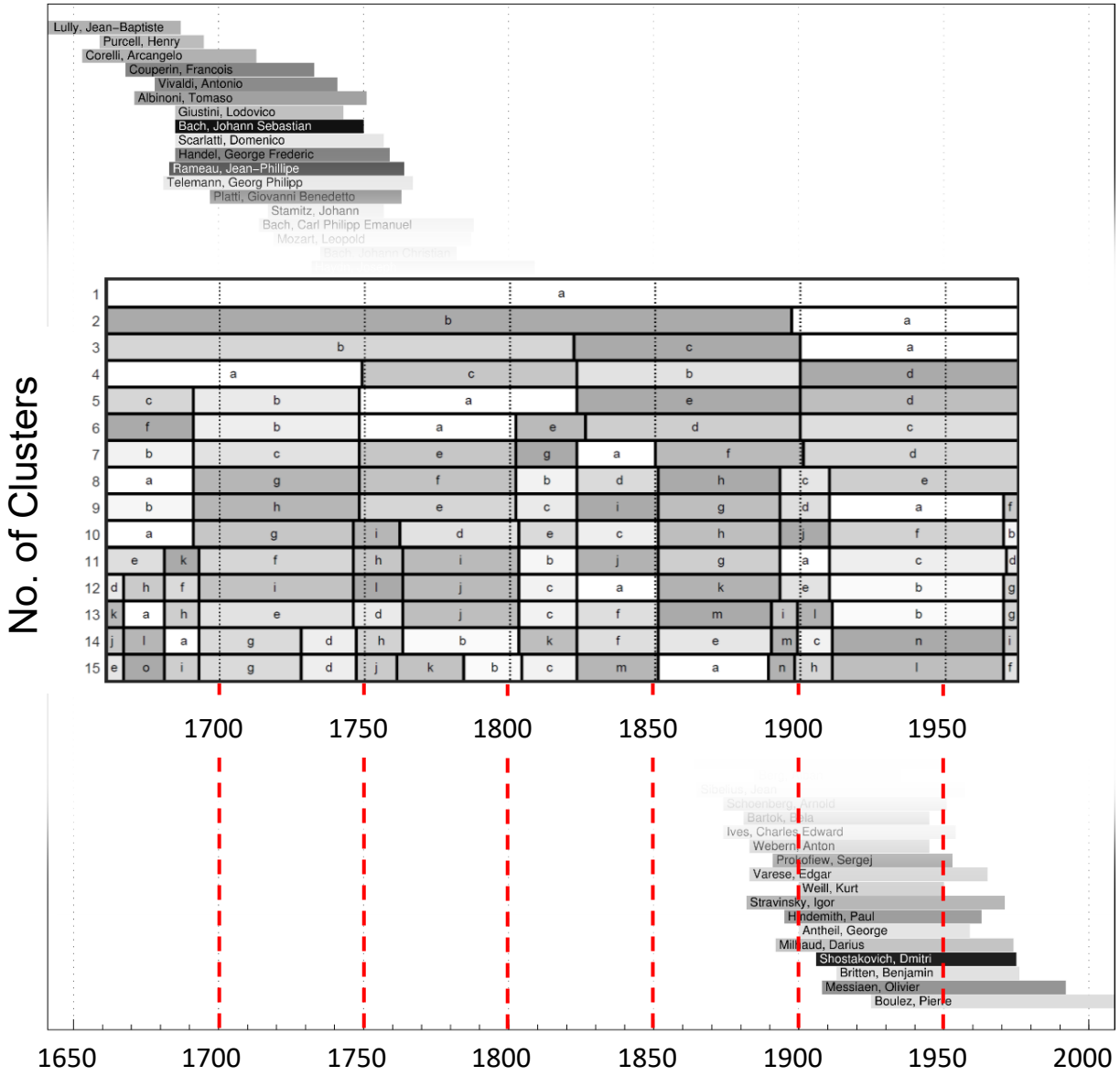
## Algorithms

Template Matching

## Corpus

„Cross-Era“

2000 Piano and Orchestra Recordings




Weiß, Mauch, Dixon, Müller, **Investigating Style Evolution of Western Classical Music: A Computational Approach**, Musicae Scientiae 2019.

## Music theory

Fifth Width
Intervals
Chord progressions

## Algorithms

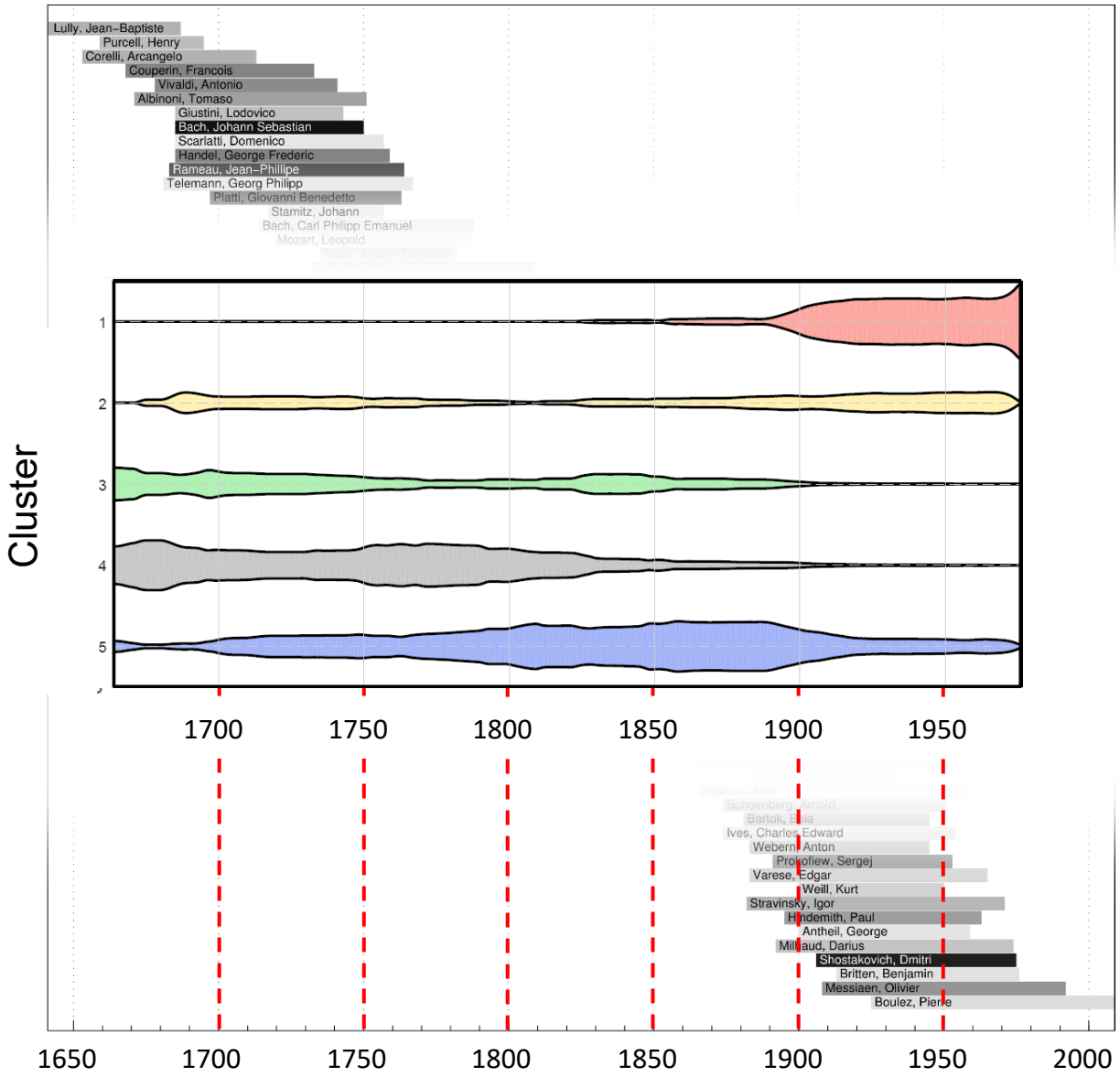
Tonal Features
k-Means Clustering

## Corpus

„Cross-Era“

2000 Piano and Orchestra Recordings

Weiß, Mauch, Dixon, Müller, **Investigating Style Evolution of Western Classical Music: A Computational Approach**, Musicae Scientiae 2019.

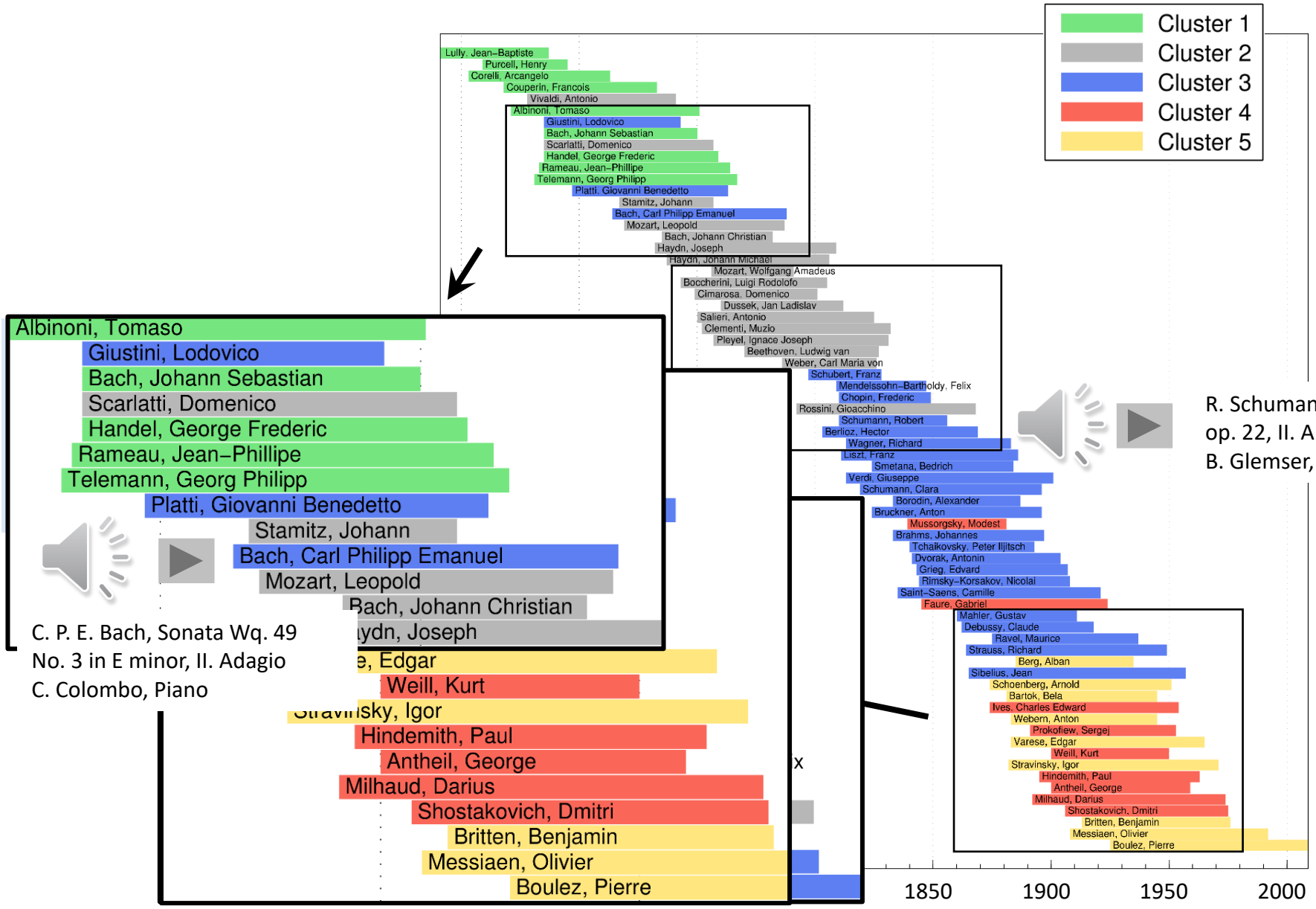



## Music theory

Fifth Width
Intervals
Chord progressions

## Algorithms

Tonal Features
k-Means Clustering




C. P. E. Bach, Sonata Wq. 49
No. 3 in E minor, II. Adagio
C. Colombo, Piano

R. Schumann, Sonata No. 2
op. 22, II. Andantino
B. Glemser, Piano

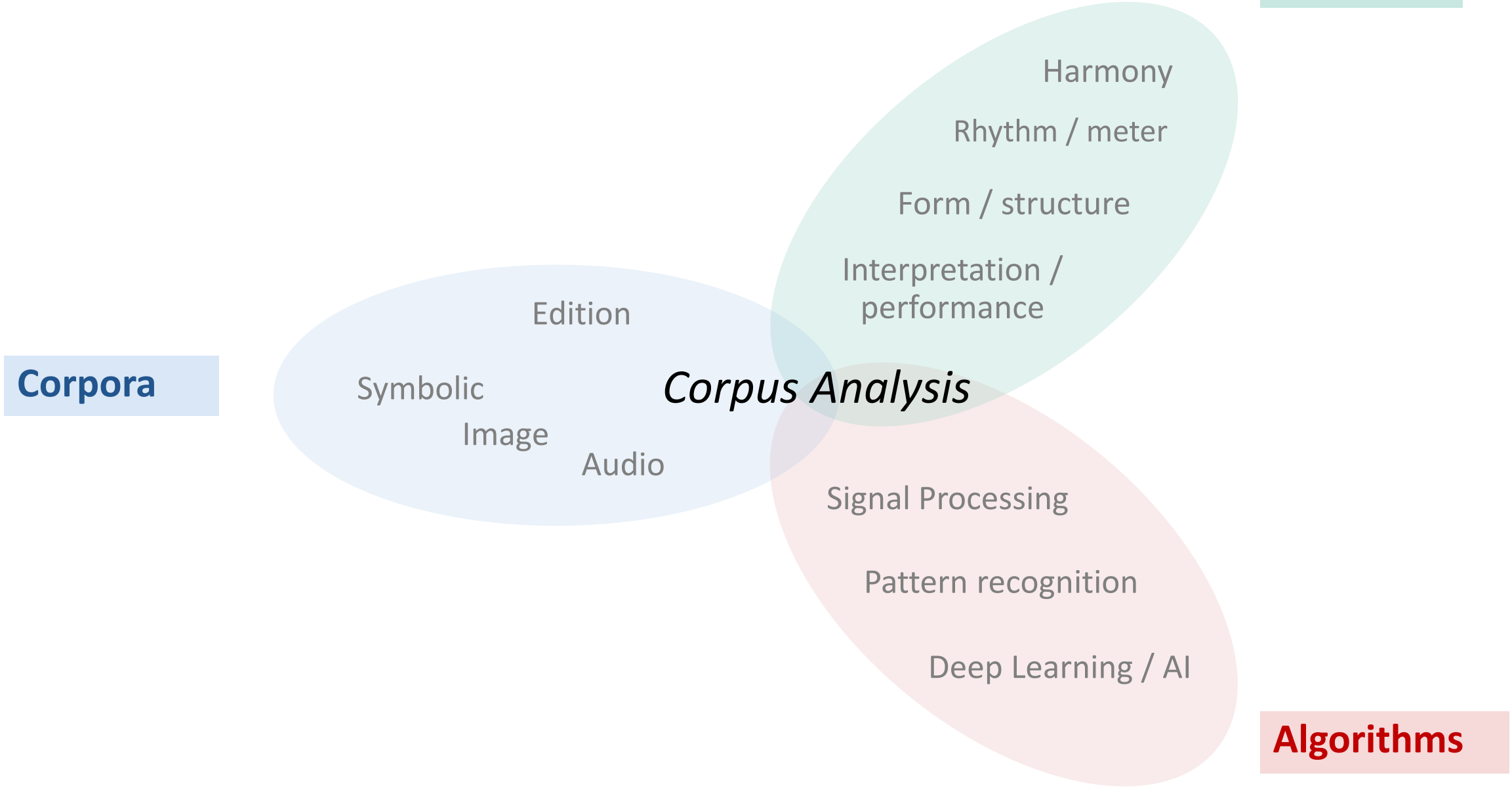
## Music theory

Fifth Width
Intervals
Chord progressions

## Algorithms

Tonal Features
k-Means Clustering

# Conclusion


Concepts
Harmony
Rhythm / meter
Form / structure
Interpretation / performance
Corpora
Edition
Symbolic
Image
Audio
Corpus Analysis
Signal Processing
Pattern recognition
Deep Learning / AI
Algorithms