INTERNATIONAL AUDIO LABORATORIES ERLANGEN

AUDIO LABS

Die Vermessung der Tonart – klingt vermessen?

Meinard Müller
International Audio Laboratories Erlangen
meinard.mueller@audiolabs-erlangen.de

Kolloquium für Prof. Auhagen
Universität Halle-Wittenberg
8. Februar 2019

FAU FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

Fraunhofer IIS

Meinard Müller

- Mathematics (Diplom/Master)
  Computer Science (PhD)
  Information Retrieval (Habilitation)
  Bonn University
- Combinatorics (Postdoc)
  Keio University, Japan
- Senior Researcher
  Max-Planck Institute, Saarland
- Professor: Semantic Audio Processing
  Erlangen-Nürnberg University

universitätbonn

慶應義塾 Keio University

mpi max planck institut informatik

FAU FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

Group Members

- Christof Weiß
- Frank Zalkow
- Patricio López-Serrano
- Sebastian Rosenzweig
- Hendrik Schreiber





International Audio Laboratories Erlangen

Fraunhofer IIS

mp3

FAU FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

AUDIO LABS

International Audio Laboratories Erlangen

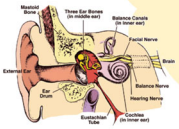
Audio

International Audio Laboratories Erlangen

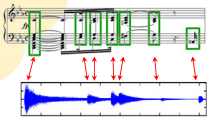
Audio Coding

3D Audio

Audio



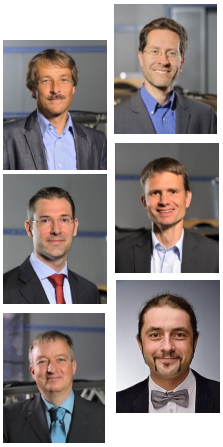
Psychoacoustics



Music Processing

AudioLabs – FAU

- Prof. Dr. Jürgen Herre
  Audio Coding
- Prof. Dr. Bernd Edler
  Audio Signal Analysis
- Prof. Dr. Meinard Müller
  Semantic Audio Processing
- Prof. Dr. Emanuël Habets
  Spatial Audio Signal Processing
- Prof. Dr. Frank Wefers
  Virtual Reality
- Dr. Stefan Turowski
  Coordinator AudioLabs-FAU



Music

Music Information Retrieval (MIR)

Sheet Music (Image)

CD / MP3 (Audio)

MusicXML (Text)

Dance / Motion (Mocap)

Music

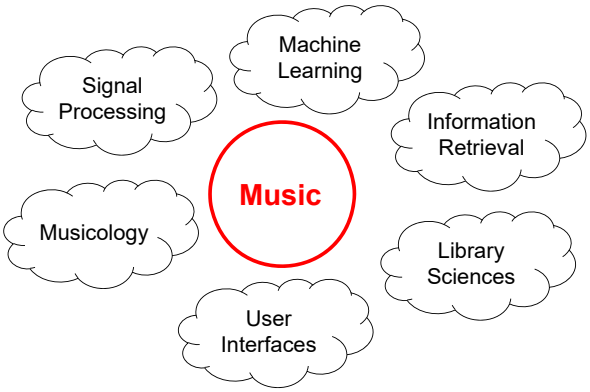
MIDI

Singing / Voice (Audio)

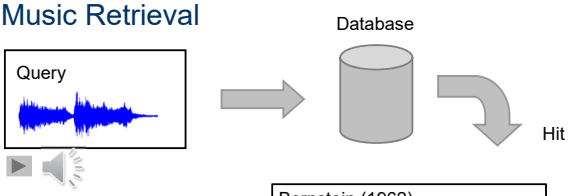
Music Film (Video)

Music Literature (Text)

Music Information Retrieval (MIR)



Music Retrieval



Audio-ID

Bernstein (1962)
Beethoven, Symphony No. 5

Version-ID

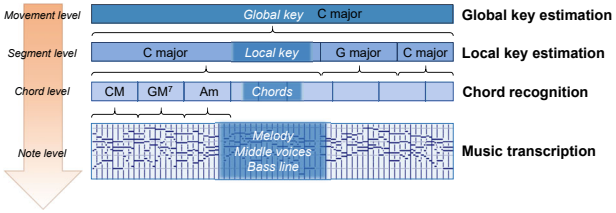
Beethoven, Symphony No. 5:
- Bernstein (1962)
- Karajan (1982)
- Gould (1992)

Category-ID

- Beethoven, Symphony No. 9
- Beethoven, Symphony No. 3
- Haydn Symphony No. 94

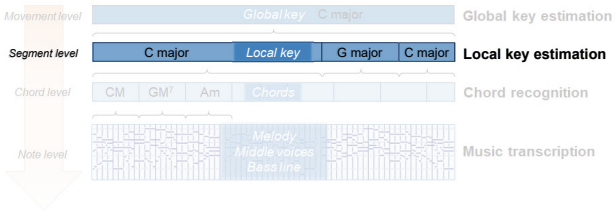
Harmony Analysis

- Different concepts
- Different temporal levels



Harmony Analysis

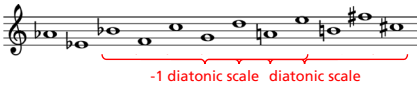
- Different concepts
- Different temporal levels



Local Key Estimation

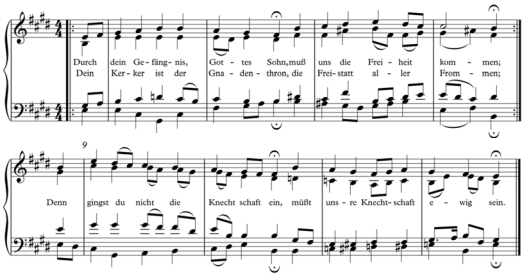
Assumption: Music based on **diatonic scales**

- Heptatonic scales
- Ordering of scales according to the circle of fifths
- Each scale consists of chain of six perfect fifth
- Fifth-neighboring scales share 6 of 7 notes



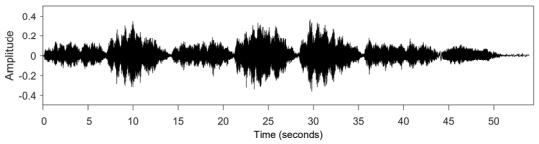
Local Key Estimation

Example: J.S. Bach, Choral "Durch Dein Gefängnis" (*Johannespassion*)
Score representation (piano reduction)



Local Key Estimation

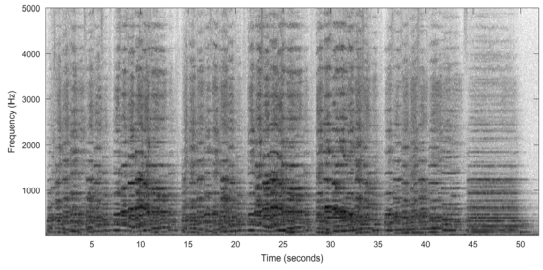
Example: J.S. Bach, Choral "Durch Dein Gefängnis" (*Johannespassion*)
Audio recording (Scholars Baroque Ensemble, Naxos 1994)



Waveform

Local Key Estimation

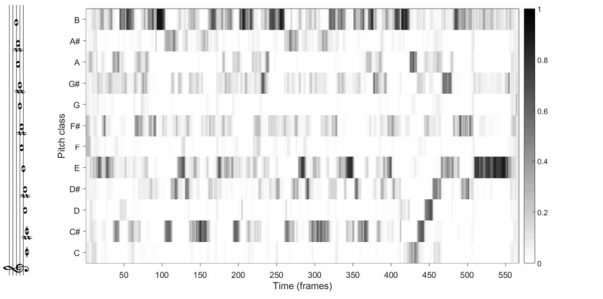
Example: J.S. Bach, Choral "Durch Dein Gefängnis" (*Johannespassion*)
Audio recording (Scholars Baroque Ensemble, Naxos 1994)



Spectrogram

Local Key Estimation

Example: J.S. Bach, Choral "Durch Dein Gefängnis" (*Johannespassion*)
Audio recording (Scholars Baroque Ensemble, Naxos 1994)

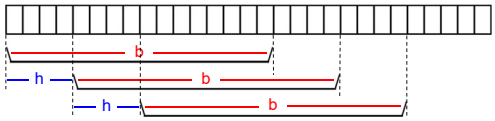


Chromagram

Local Key Estimation

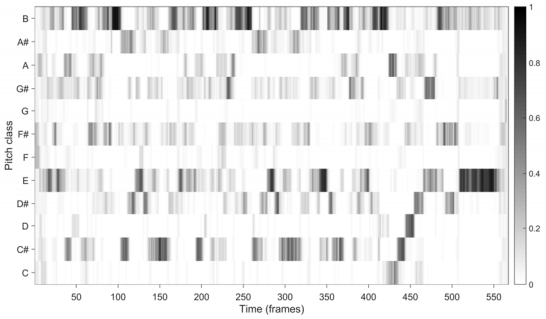
Summarize pitch class (chroma) content over a certain time period

- Feature smoothing
- Parameters: blocksize b and hopsize h



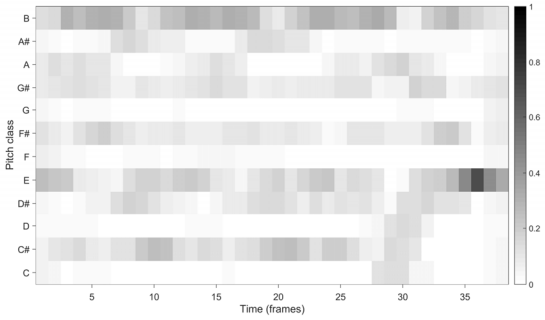
Local Key Estimation

Chromagram



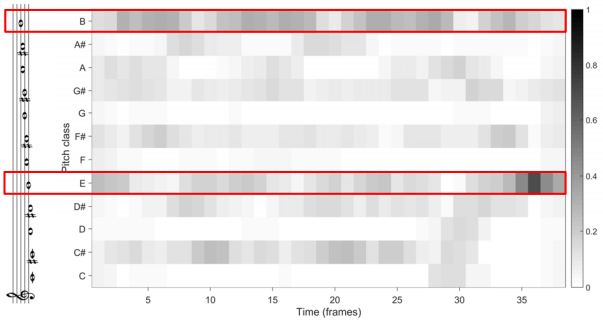
Local Key Estimation

Chromagram after smoothing (b = 42, h = 15)



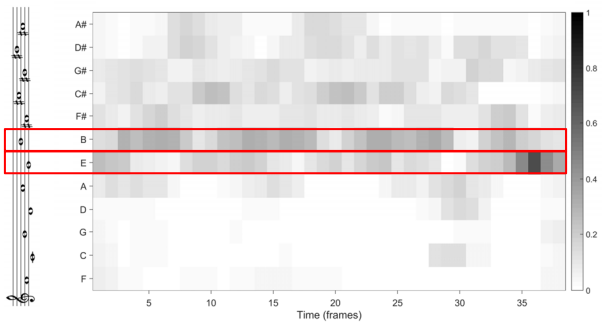
Local Key Estimation

Arrange pitch classes according to **perfect fifth** series



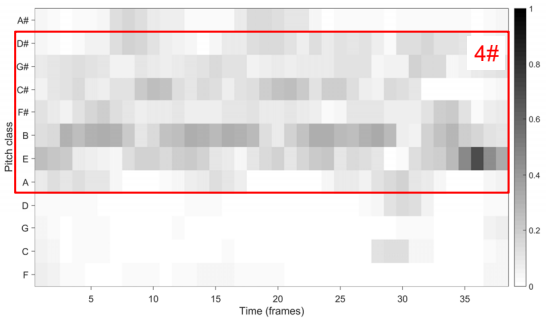
Local Key Estimation

Arrange pitch classes according to **perfect fifth** series



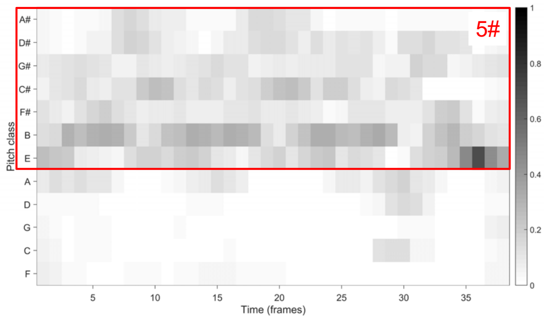
Local Key Estimation

Summarize pitch class content according to **diatonic scales**



Local Key Estimation

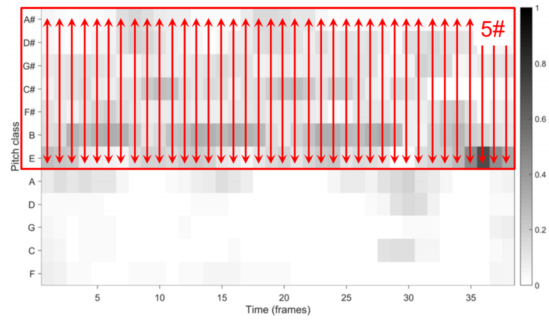
Summarize pitch class content according to **diatonic scales**



Local Key Estimation

Summarize pitch class content according to **diatonic scales**

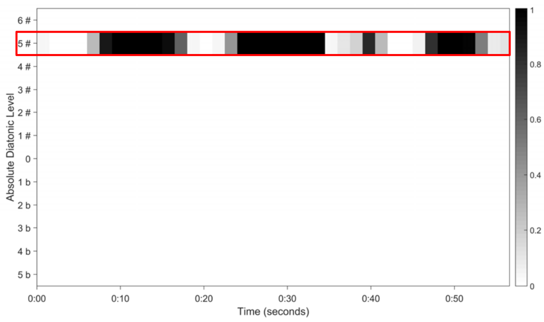
Multiply chroma values (in each column)



Local Key Estimation

Summarize pitch class content according to **diatonic scales**

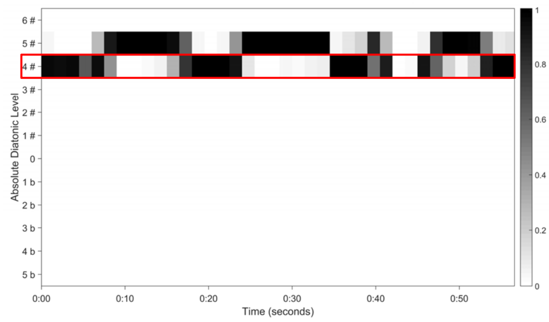
Multiply chroma values



Local Key Estimation

Summarize pitch class content according to **diatonic scales**

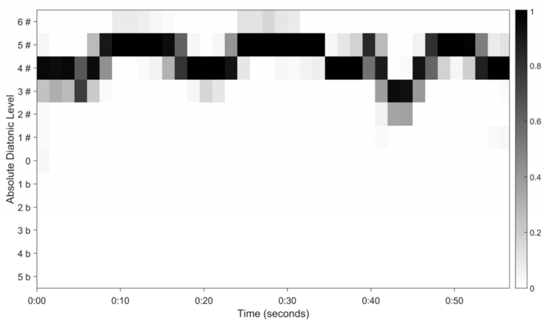
Multiply chroma values



Local Key Estimation

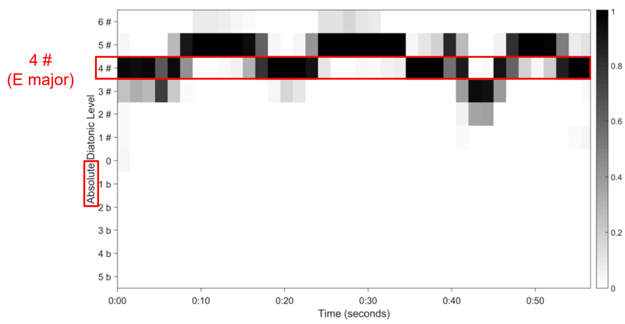
Summarize pitch class content according to **diatonic scales**

Multiply chroma values



Local Key Estimation

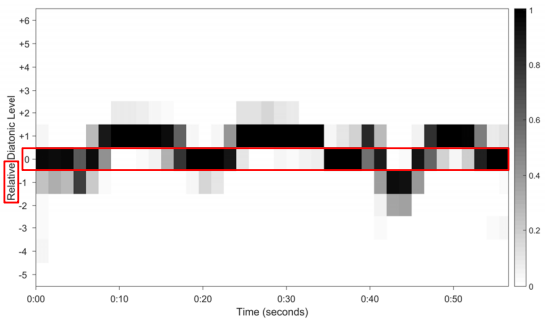
Normalize representation relative to global key



Local Key Estimation

Normalize representation relative to global key

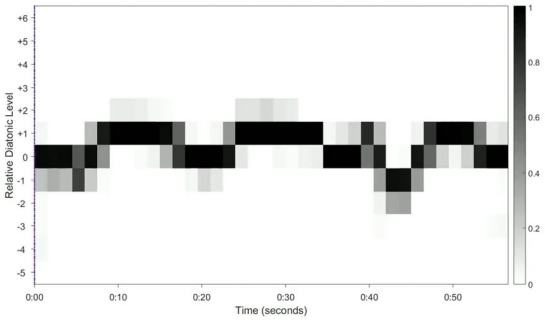
4 #
(E major)



Visualization of Diatonic Scales

J.S. Bach: Choral "Durch Dein Gefängnis" (*Johannespassion*)
Recording: Scholars Baroque Ensemble, Naxos 1994

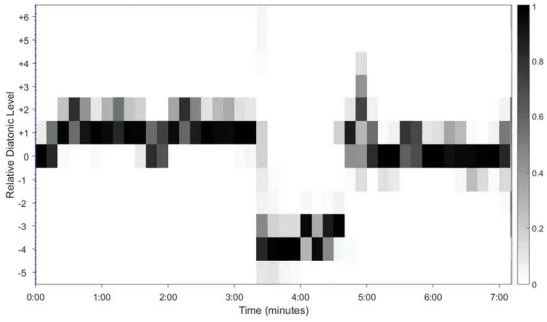
4 #
(E major)



Visualization of Diatonic Scales

L. v. Beethoven: Piano Sonata No. 10 (Op. 14 Nr. 2), 1. Allegro
Recording: Barenboim, EMI 1998

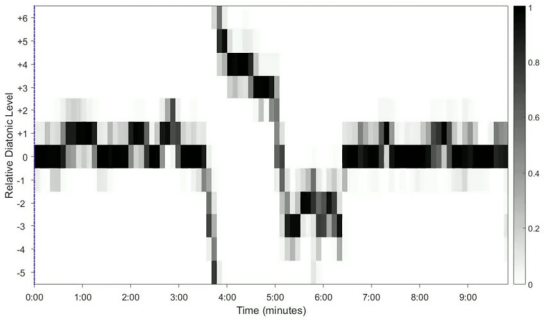
1 #
(G major)



Visualization of Diatonic Scales

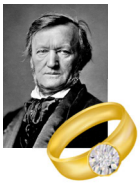
R. Wagner, *Die Meistersinger von Nürnberg*, Vorspiel
Recording: Polish National Radio Symphony Orchestra,Naxos 1993

0 #
(C major)



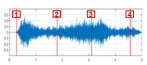
Cooperation: Musicology

- Partner: Prof. Rainer Kleinertz
  Saarland University
- Duration: 2014 – 2018
- Objectives
  - Harmony-based structural analysis
  - Visualization techniques
  - Exploration of interdisciplinary research
- Application to Wagner's *Ring*



Cross-Version Analysis

- 16 different versions (audio recordings)
- Measure annotations (manual for 3 versions, automatic for 13 versions)



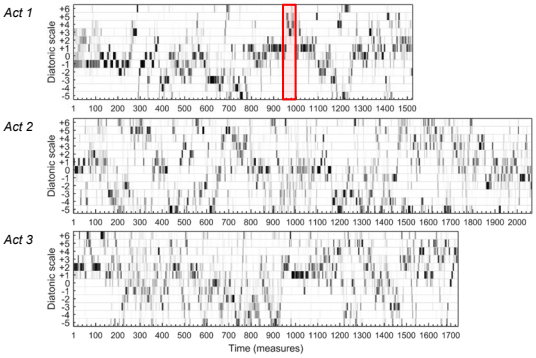
No.	Conductor	Recording	hh:mm:ss
1	Barenboim	1991–92	14:54:55
2	Boulez	1980–81	13:44:38
3	Böhm	1967–71	13:39:28
4	Furtwängler	1953	15:04:22
5	Haitink	1988–91	14:27:10
6	Janowski	1980–83	14:08:34
7	Karajan	1967–70	14:58:08
8	Keilberth/Furtwängler	1952–54	14:19:56
9	Krauss	1953	14:12:27
10	Levine	1987–89	15:21:52
11	Neuhold	1993–95	14:04:35
12	Sawallisch	1989	14:06:50
13	Solti	1958–65	14:36:58
14	Swarowsky	1968	14:56:34
15	Thielemann	2011	14:31:13
16	Weigle	2010–12	14:48:46

Cross-Version Analysis

- Hypothesis:
  Harmonic characteristics should not depend on version
- Strategy:
  Use consistency of analysis results across different versions as indicator of “reliability” or “stability”
- Application:
  Visualize consistency with gray scheme

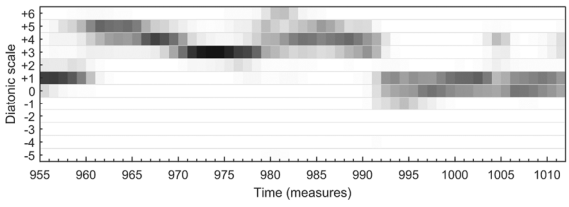
Cross-Version Visualization

R. Wagner: WWV 86 B (*Die Walküre*)



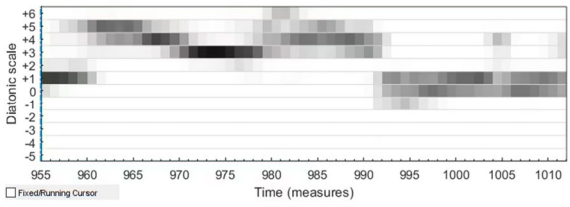
Cross-Version Visualization

R. Wagner: WWV 86 B (*Die Walküre*)
Act 1, measure 955–1012 (*Sieglinde’s narration*)



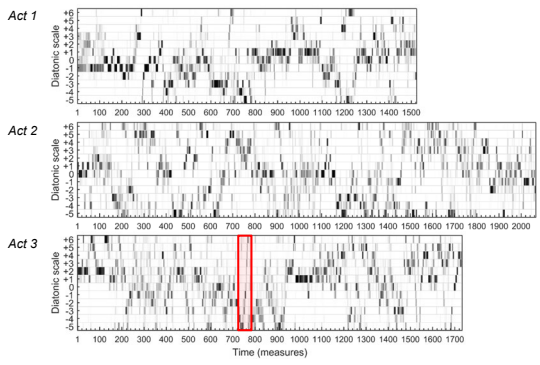
Cross-Version Visualization

R. Wagner: WWV 86 B (*Die Walküre*)
Act 1, measure 955–1012 (*Sieglinde’s narration*)



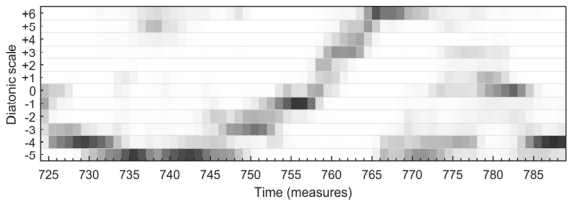
Cross-Version Visualization

R. Wagner: WWV 86 B (*Die Walküre*)



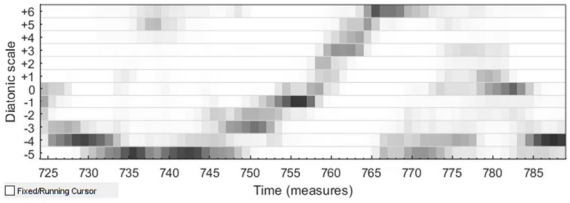
Cross-Version Visualization

R. Wagner: WWV 86 B (*Die Walküre*)
Act 3, measure 724–789 (*Wotan’s punishment*)



Cross-Version Visualization

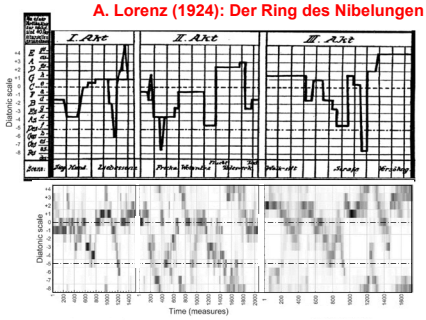
R. Wagner: WWV 86 B (*Die Walküre*)
Act 3, measure 724–789 (*Wotan's punishment*)



Cross-Version Visualization

R. Wagner: WWV 86 B (*Die Walküre*)

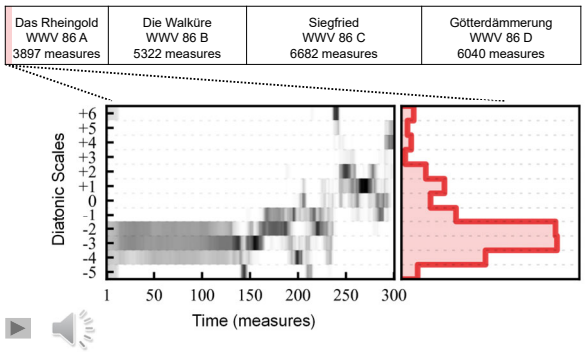
A. Lorenz (1924): Der Ring des Nibelungen



Large-Scale Harmonic Analysis

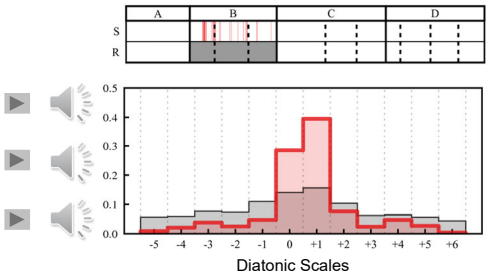
Exploring Tonal-Dramatic Relationships

Tonal analysis representations and **local histograms**



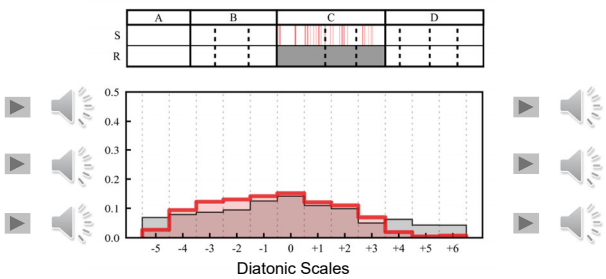
Exploring Tonal-Dramatic Relationships

Die Walküre – **Sword motif**



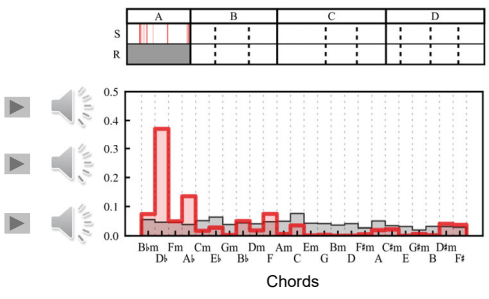
Exploring Tonal-Dramatic Relationships

Siegfried – **Sword motif**



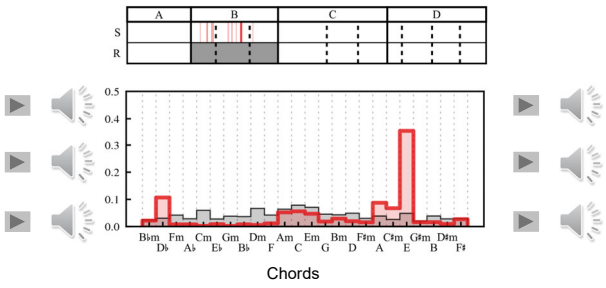
Exploring Tonal-Dramatic Relationships

Das Rheingold – **Valhalla motif**



Exploring Tonal-Dramatic Relationships

Die Walküre – **Valhalla motif**



Computational Analysis of Traditional Georgian Vocal Music

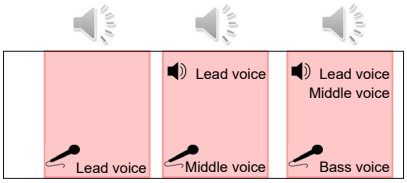
- Partner: Prof. Frank Scherbaum
  Potsdam University
- Duration: 2018 – 2021
- Objectives
  - Harmonic, tonal and performance analysis
  - New sensors (larynx microphones)
  - Digital humanities

https://www.audiolabs-erlangen.de/resources/MIR/2017-GeorgianMusic-Erkomaishvili
https://www.audiolabs-erlangen.de/resources/MIR/2018-ISMIR-LBD-ThroatMics

Traditional Georgian Vocal Music

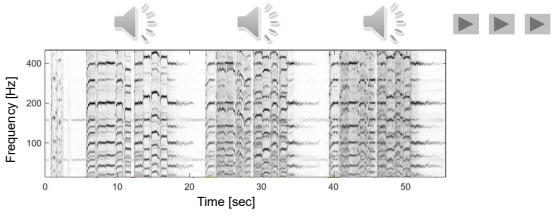
Which scale? Harmonic/melodic intervals? Singer interaction?

Traditional Georgian Vocal Music



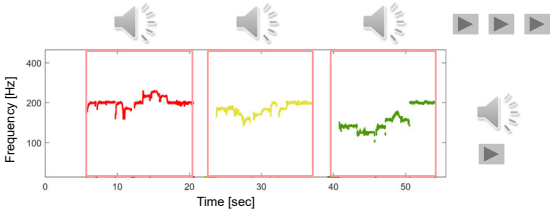
- Master chanter: Artem Erkomaishvili
- Recordings of 100 songs (1966)
- Example song: Da sulisatsa (#87)

Traditional Georgian Vocal Music



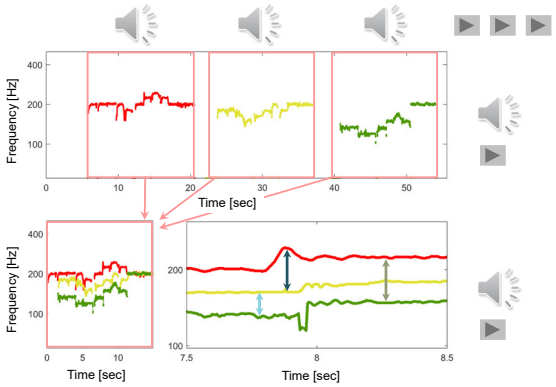
- Master chanter: Artem Erkomaishvili
- Recordings of 100 songs (1966)
- Example song: Da sulisatsa (#87)

Traditional Georgian Vocal Music

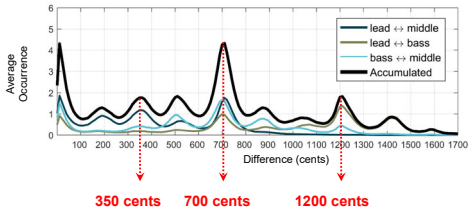


- Master chanter: Artem Erkomaishvili
- Recordings of 100 songs (1966)
- Example song: Da sulisatsa (#87)

Traditional Georgian Vocal Music



Traditional Georgian Vocal Music



- Peak at 350 cents (between minor and major third)
- **Non-western temperament**

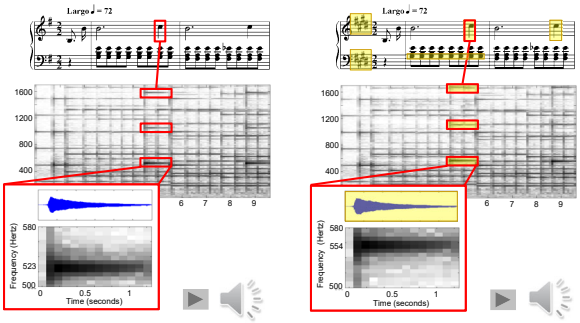
Automated Methods and Tools for Analyzing and Structuring Choral Music

- Partner: Carus-Verlag
- Duration: 2018 – 2021
- Objectives
  - Navigation, visualization, sonification of musical structures
  - Practicability & applications (music education, musicology)
  - Web-based prototypes for interactive interfaces

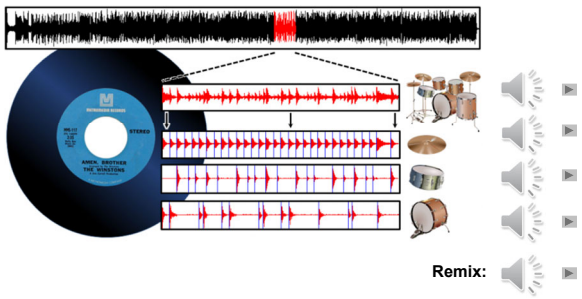
https://www.audiolabs-erlangen.de/resources/MIR/2018-ISMIR-LBD-Carus

Score-Informed Audio Decomposition

Application: Audio editing



Informed Drum-Sound Decomposition

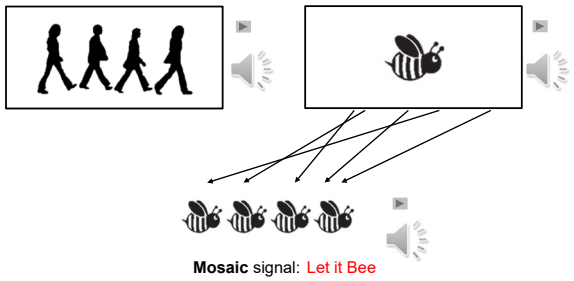


Literature: [Dittmar/Müller, IEEE/ACM-TASLP 2016]
Demo: https://www.audiolabs-erlangen.de/resources/MIR/2016-IEEE-TASLP-DrumSeparation

Audio Mosaicing

Target signal: Beatles–Let it be

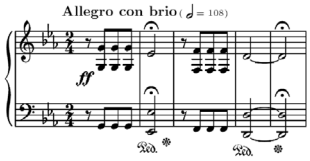
Source signal: Bees



Mosaic signal: Let it Bee

Literature: [Driedger/Müller, ISMIR 2015]
Demo: https://www.audiolabs-erlangen.de/resources/MIR/2015-ISMIR-LetItBee

Motivic Similarity

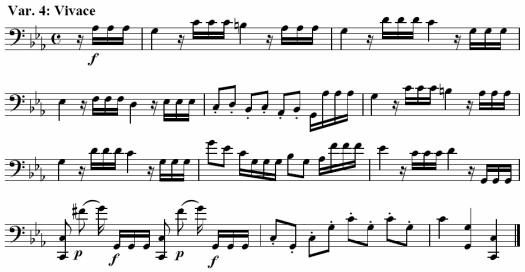


Beethoven's Fifth (1st Mov.)

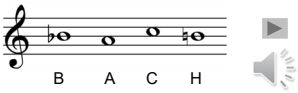
Beethoven's Fifth (3rd Mov.)

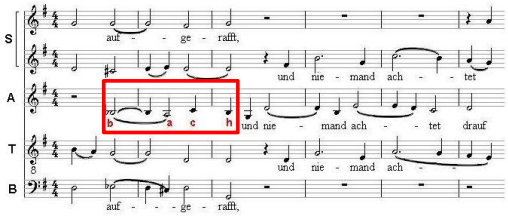
Beethoven's Appassionata

Motivic Similarity

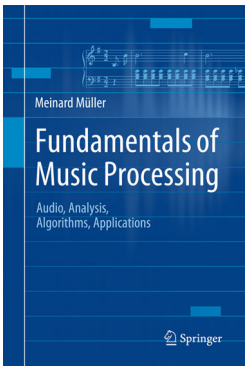


Motivic Similarity





Book: Fundamentals of Music Processing



Meinard Müller
Fundamentals of Music Processing
Audio, Analysis, Algorithms, Applications
483 p., 249 illus., hardcover
ISBN: 978-3-319-21944-8
Springer, 2015

Accompanying website:
www.music-processing.de

Book: Fundamentals of Music Processing

Chapter		Music Processing Scenario
1		Music Represenations
2		Fourier Analysis of Signals
3		Music Synchronization
4		Music Structure Analysis
5		Chord Recognition
6		Tempo and Beat Tracking
7		Content-Based Audio Retrieval
8		Musically Informed Audio Decomposition

Meinard Müller
Fundamentals of Music Processing
Audio, Analysis, Algorithms, Applications
483 p., 249 illus., hardcover
ISBN: 978-3-319-21944-8
Springer, 2015

Accompanying website:
www.music-processing.de