

INTERNATIONAL AUDIO LABORATORIES ERLANGEN
A joint institution of Fraunhofer IIS and Universität Erlangen-Nürnberg





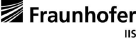


ISMIR Tutorial
Daejeon, Korea, September 21, 2025

Differentiable Alignment Techniques for Music Processing: Techniques and Applications

Part 0: Overview

Meinard Müller, Johannes Zeitler
International Audio Laboratories Erlangen
{meinard.mueller, johannes.zeitler}@audiolabs-erlangen.de



Meinard Müller

- Mathematics (Diplom/Master, 1997)
- Computer Science (PhD, 2001)
- Information Retrieval (Habilitation, 2007)
- Senior Researcher at the MPI for Informatics (2007 to 2012)
- Professor Semantic Audio Processing (since 2012)
- Former Board Member and President of ISMIR (2009 to 2021)
- Editor-in-Chief for TISMIR (since 2024)
- IEEE Fellow for contributions to Music Signal Processing



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Part 0: Overview, Slide 2



Johannes Zeitler

- Electrical Engineering (Bachelor, 2019)
- Signal Processing and Communications Engineering (Master, 2021)
- PhD at AudioLabs under supervision of Meinard Müller (since 2022)
- DFG Project: Differentiable Alignment Techniques for MIR
- Fourth time attending the ISMIR conference (2021, 2023, 2024, 2025)



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Part 0: Overview, Slide 3



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Fraunhofer Institute for Integrated Circuits IIS
Largest Fraunhofer institute with > 1000 members
Applied research for sensor, audio, and media technology

Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)
One of Germany's largest universities with ~ 40,000 students
Strong Technical Faculty

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Audio

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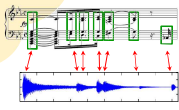
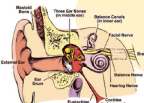
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Part 0: Overview, Slide 5



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Audio



Audio Coding
3D Audio
Psychoacoustics
Internet of Things
Music Processing

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Part 0: Overview, Slide 6



Meinard Müller: Research Group



- Ben Maman
- Simon Schwär
- Johannes Zeitler
- Abhirup Saha
- Sebastian Strahl
- Uli Berendes
- Vlora Arifi-Müller
- Stefan Balke



- Ching-Yu Chiu (Sunny)
- Peter Meier
- Yigitcan Özer
- Michael Krause
- Christof Weiß
- Sebastian Rosenzweig
- Frank Zalkow
- Hendrik Schreiber
- Christian Dittmar
- Stefan Balke
- Jonathan Driedger
- Thomas Prätzlich
- ...



Overview

Part 0: Overview

Part 1: Introduction to Alignment Techniques

Coffee Break

Part 2: Theoretical Foundations & Implementation



- Slides/Material
https://audiolabs-erlangen.de/resources/MIR/2025_TutorialDiffAlign_ISMIR
- DFG Project
<https://www.audiolabs-erlangen.de/fau/professor/mueller/projects/dat4mir>

Literature

Differentiable

- Boyd, Vandenberghe: Convex Optimization. Cambridge University Press, 2004.
- Graves et al.: Connectionist Temporal Classification: Labelling Unsegmented Sequence Data with Recurrent Neural Networks. ICML, 2006.
- Mensch, Blondel: Differentiable Dynamic Programming for Structured Prediction and Attention. ICML, 2018.
- Wigington et al.: Multi-Label Connectionist Temporal Classification. ICDAR, 2019.
- Weiß, Peeters: Learning Multi-Pitch Estimation from Weakly Aligned Score-Audio Pairs Using a Multi-Label CTC Loss. WASPAA, 2021.
- Blondel, Roulet: The Elements of Differentiable Programming. Arxiv preprint, 2025.
- Cuturi, Blondel: Soft-DTW: A Differentiable Loss Function for Time-Series. ICML, 2017.
- Blondel, Mensch, Vert: Differentiable Divergences Between Time Series. AISTATS, 2021.
- Zalkow, Müller: CTC-Based Learning of Chroma Features for Score-Audio Music Retrieval. IEEE TASLP, 2021.
- Krause, Weiß, Müller: Soft Dynamic Time Warping For Multi Pitch Estimation And Beyond. Proc. ICASSP, 2023.
- Zeitler, Deniffel, Krause, Müller: Stabilizing Training with Soft Dynamic Time Warping: A Case Study for Pitch Class Estimation with Weakly Aligned Targets. Proc. ISMIR, 2023.
- Zeitler, Krause, Müller: Soft Dynamic Time Warping with Variable Step Weights. Proc. ICASSP, 2024.
- Zeitler, Müller: Reformulating Soft Dynamic Time Warping: Insights Into Target Artifacts and Prediction Quality. Proc. ISMIR, 2025.
- Zeitler, Müller: A Unified Perspective on CTC and SDTW using Differentiable DTW. Submitted to IEEE TASLP, 2025
- Zeitler, Müller: Subsequence SDTW: A Framework for Differentiable Alignment with Flexible Boundary Conditions. Submitted to ICASSP 2026

Sources

Datasets ...

- Schubert Winterreise Dataset (SWD)
https://zenodo.org/records/4122060#X_gZA9hKIUK
- Wagner Ring Dataset (WRD)
<https://zenodo.org/records/7672157>
- Beethoven Piano Sonata Dataset (BPSD)
<https://zenodo.org/records/12783403>
- Musical Theme Dataset (MTD)
<https://www.audiolabs-erlangen.de/resources/MIR/MTD>
- Dagstuhl ChoirSet
<https://www.audiolabs-erlangen.de/resources/MIR/2020-DagstuhlChoirSet>

Further Resources:

<https://www.audiolabs-erlangen.de/fau/professor/mueller/resources>

