INSTITUTE OF VISUAL COMPUTING

TU Graz

SCIENCE
PASSION
TECHNOLOGY

Research Insight: PRESENT

Innovative Data Analysis for Time Series

Julian Rakuschek and Tobias Schreck

11.Dezember 2024

Who are we?

Julian Rakuschek

julian.rakuschek@tugraz.at

PhD Student in Visual Analytics

Prof. Dr. Tobias Schreck

tobias.schreck@tugraz.at

Professor in Visual Analytics

Agenda

Introduction to PRESENT

Vibrana - Vibration Analysis

AnoScout - Anomalies in Time Series

Project PRESENT

PREdictions for Science, Engineering N' Technology

Funded by
FFG Austria

Coordinated by
Fraunhofer Austria

Forecasts and analyses of time series

Research in the field of visual analytics

Goal: A toolbox for tasks in the analysis of time series in three application areas (buildings, health, production)

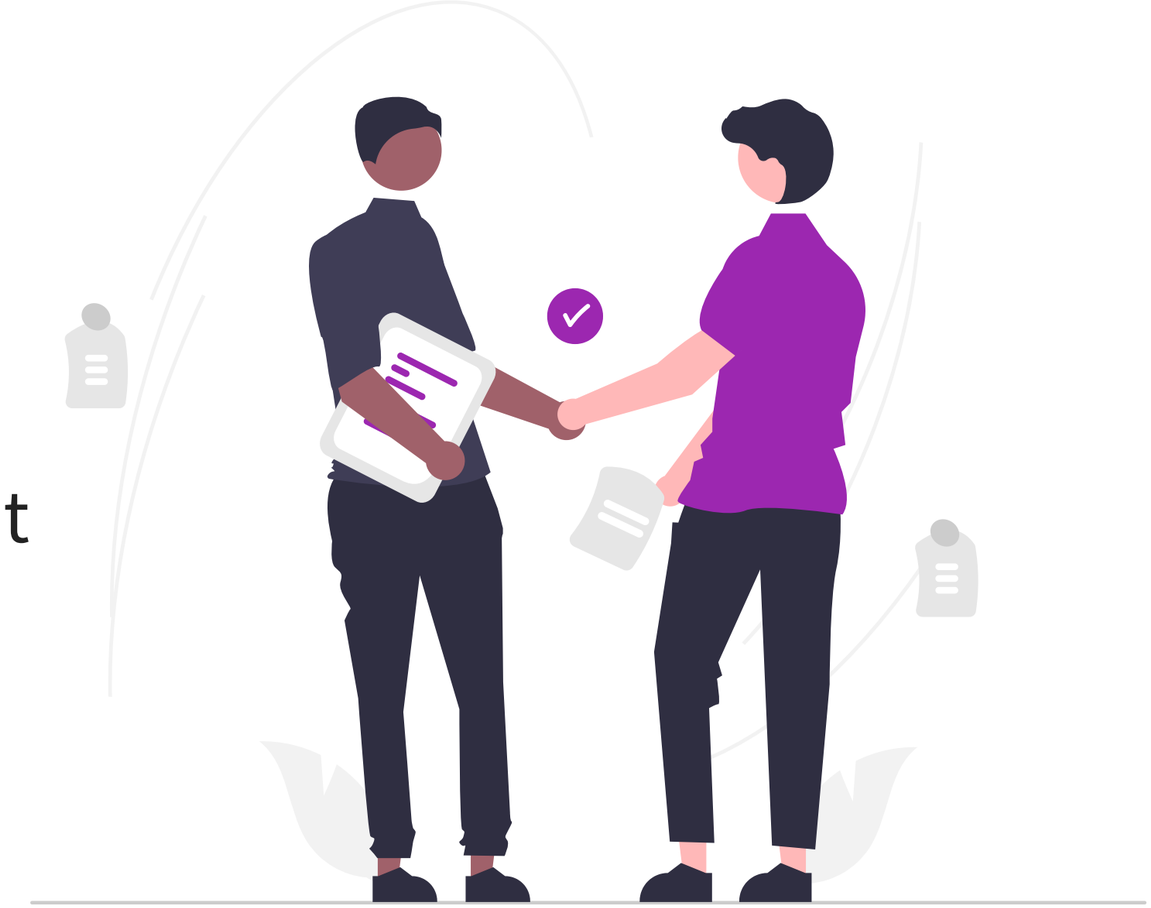
How does it work?

Industry delivers data and problems

We develop prototypes

Sometimes something useful comes out

A beautiful synergy



The Consortium - Industry Meets Science

Scientific Consortium

Fraunhofer AUSTRIA
AIT Austrian Institute of Technology
JOANNEUM RESEARCH
TU Graz
Medizinische Universität Innsbruck

Use Case: Production

ARTI Autonomy for Robots
mcp d+p dankl+partner consulting gmbh MCP Deutschland GmbH
Messfeld Kompetenz in Condition Monitoring
SENSOLLIGENT
INDUSTRIE 4.0 ÖSTERREICH

Use Case: Health

bhs
Solgenium Pioneers of the new healthcare
human. technology. styria.

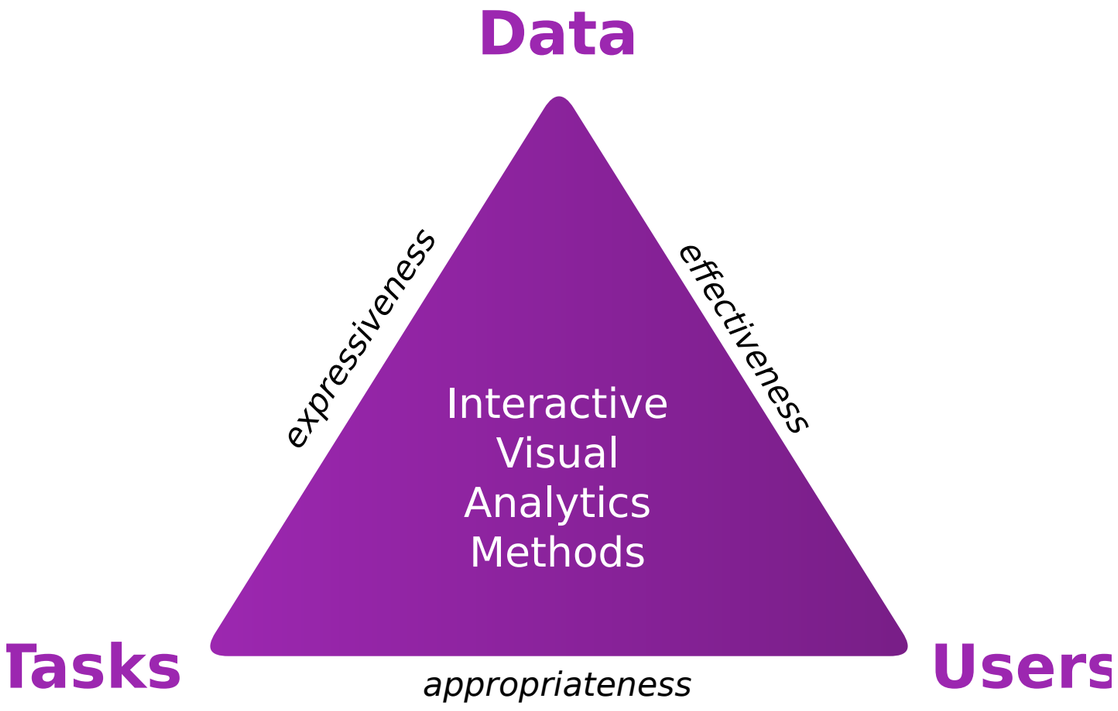
Use Case: Buildings

AO NULL Development GmbH
VIE Vienna International Airport
caFM ENGINEERING
buildingSMART Austria

Ethics and Integration

Compunity
Meets Tech Legal

Our Approach



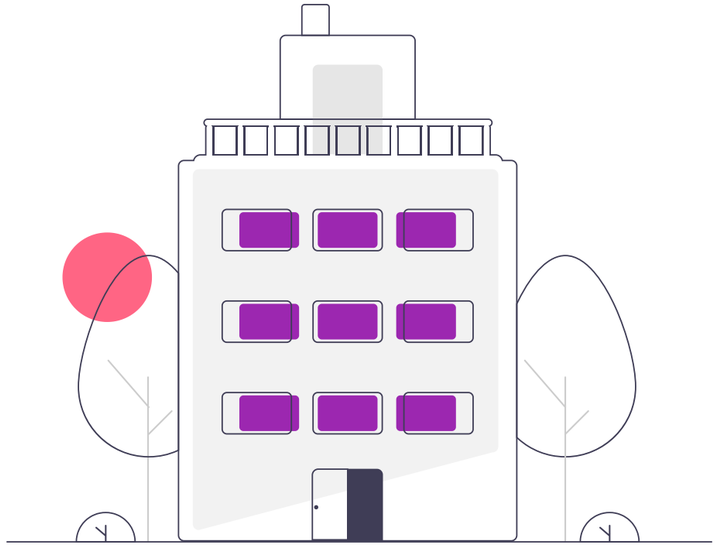
Design Triangle Approach

S. Miksch et al. "A matter of time: Applying a data-users-tasks design triangle to visual analytics of time-oriented data" Comput. Graph. 38 (2014): 286-290

Our Time Series Sources

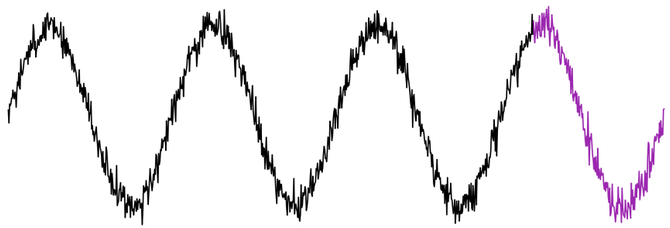
Medical

Production

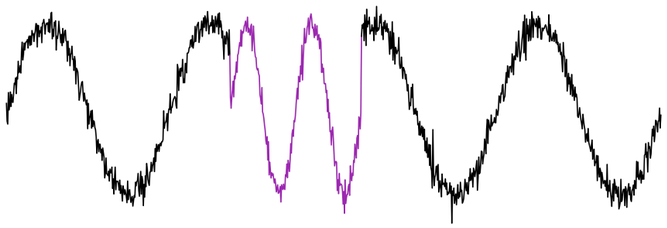


Facility

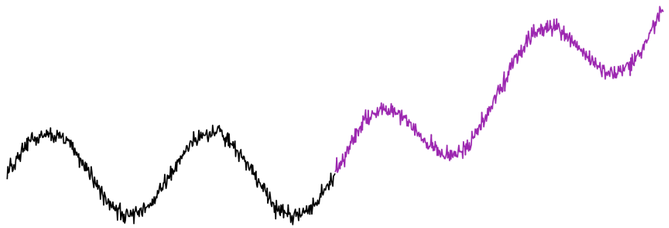
Time Series Tasks



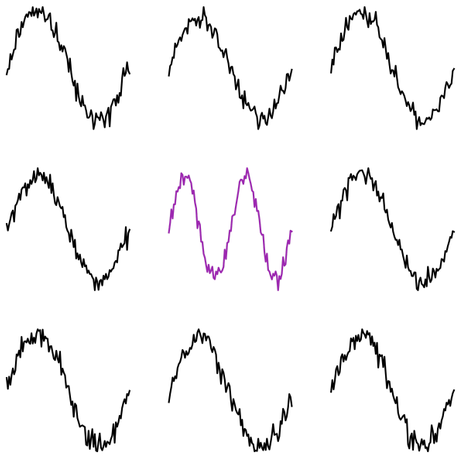
Forecasting



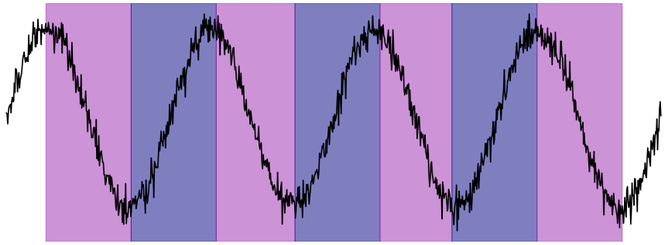
Anomaly Detection



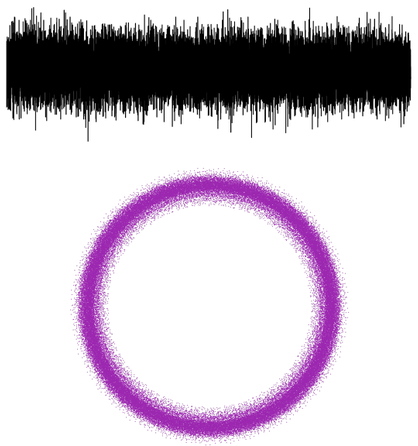
Drift Detection



Classification

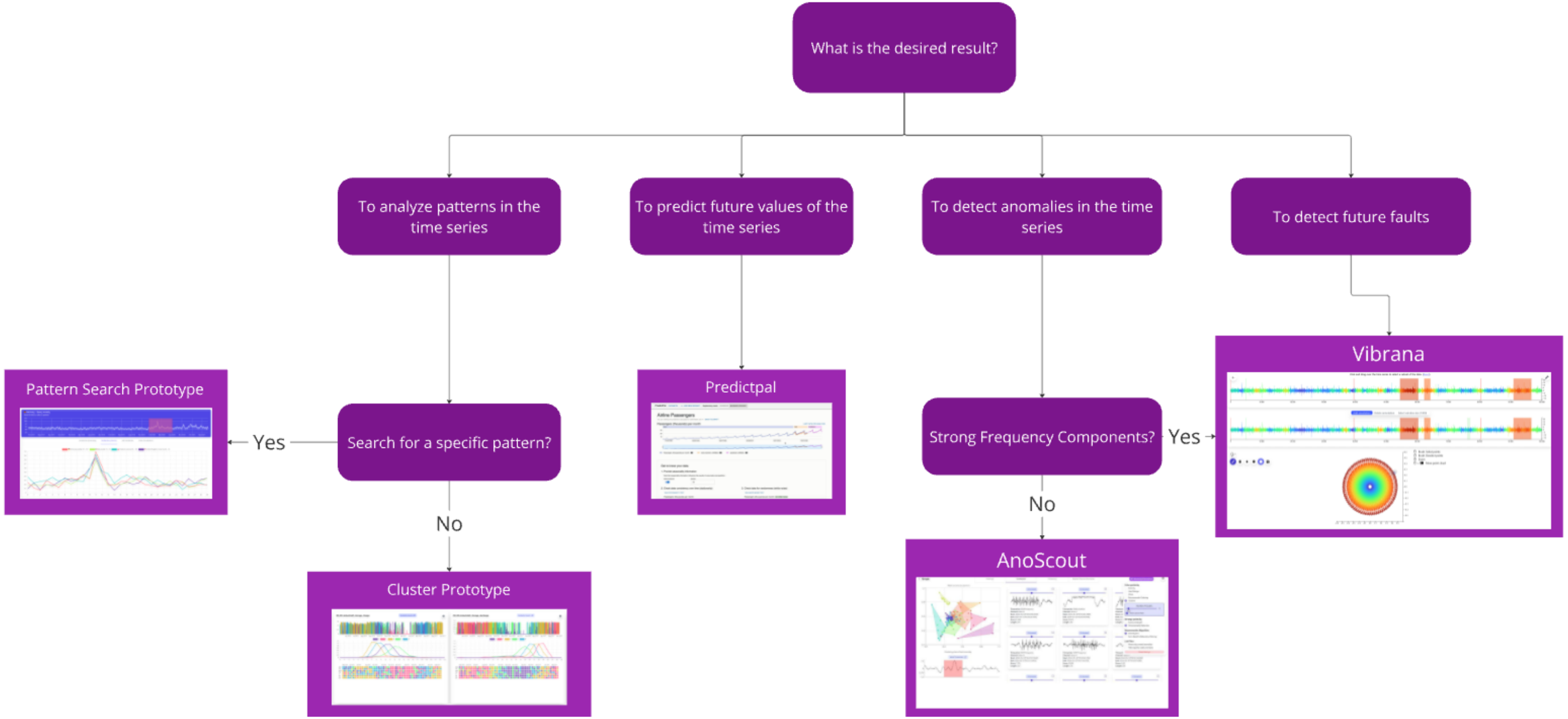


Segmentation



Vibration Analysis

Goal: A Tool-Driven Decision Tree



Summary - What do we do?

- Our Data Domains
  - Production
  - Building Management
  - Healthcare
- Our Research Targets
  - Statistical and AI-based Methods
  - Interactive Data Visualization
- Results
  - Decision Tree for Method Selection
  - Toolbox for Visualizations
  - Happy industry partners :)

Vibrana

Vibrationen messen

+

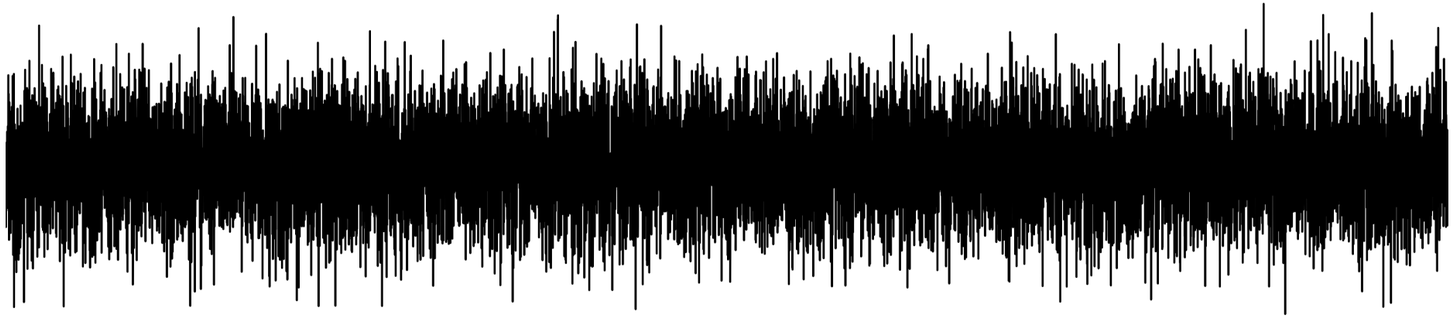
=

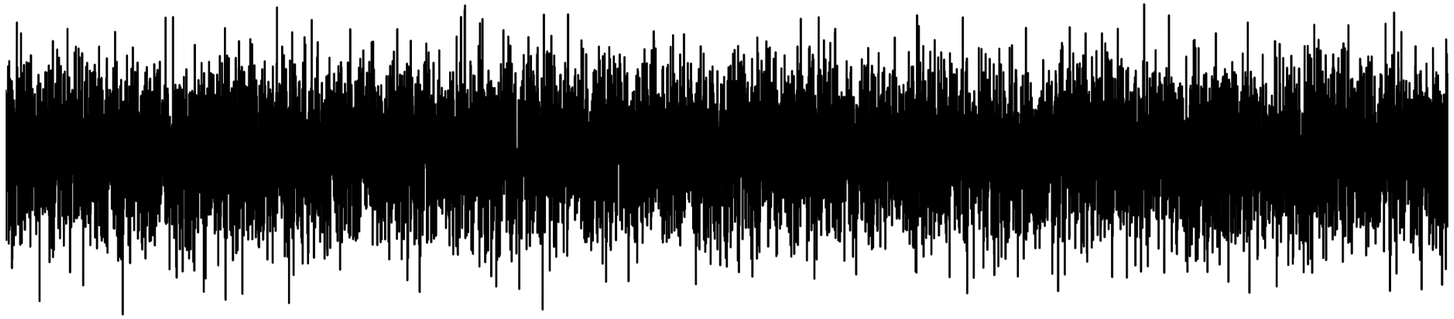
Motor

Accelerometer

Vibrationssignal

Das Problem



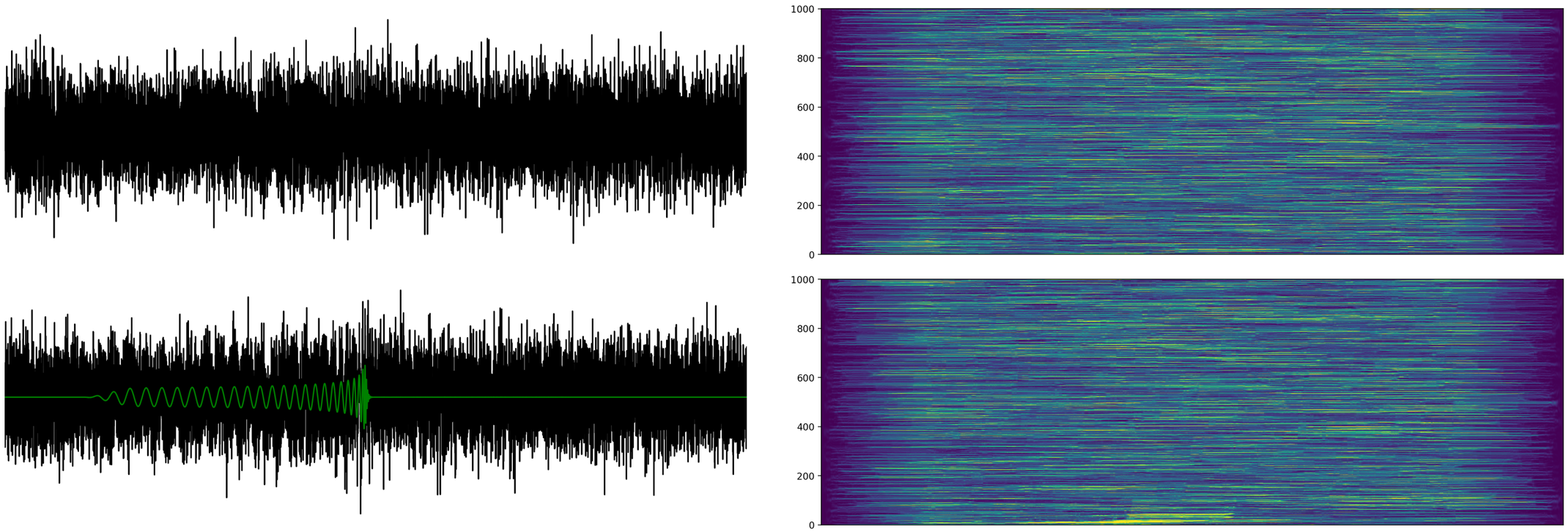


Was ist der Unterschied?

Ein verborgenes Signal

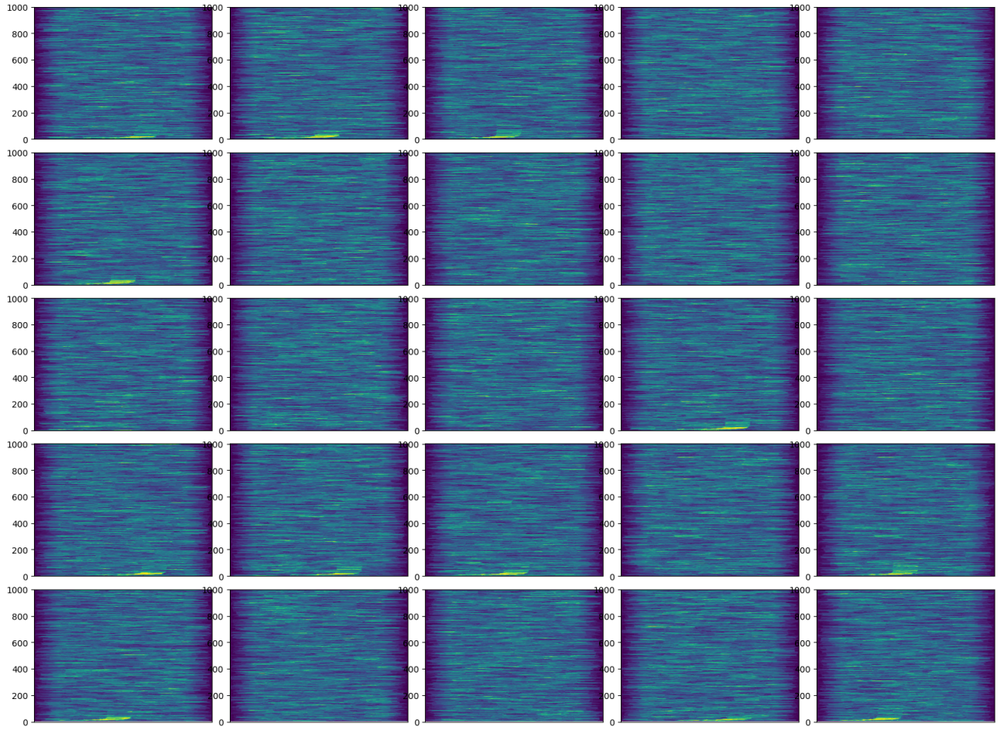
Durch den Line Chart nicht erkennbar!

Frequenzanalyse durch Spektrogramme



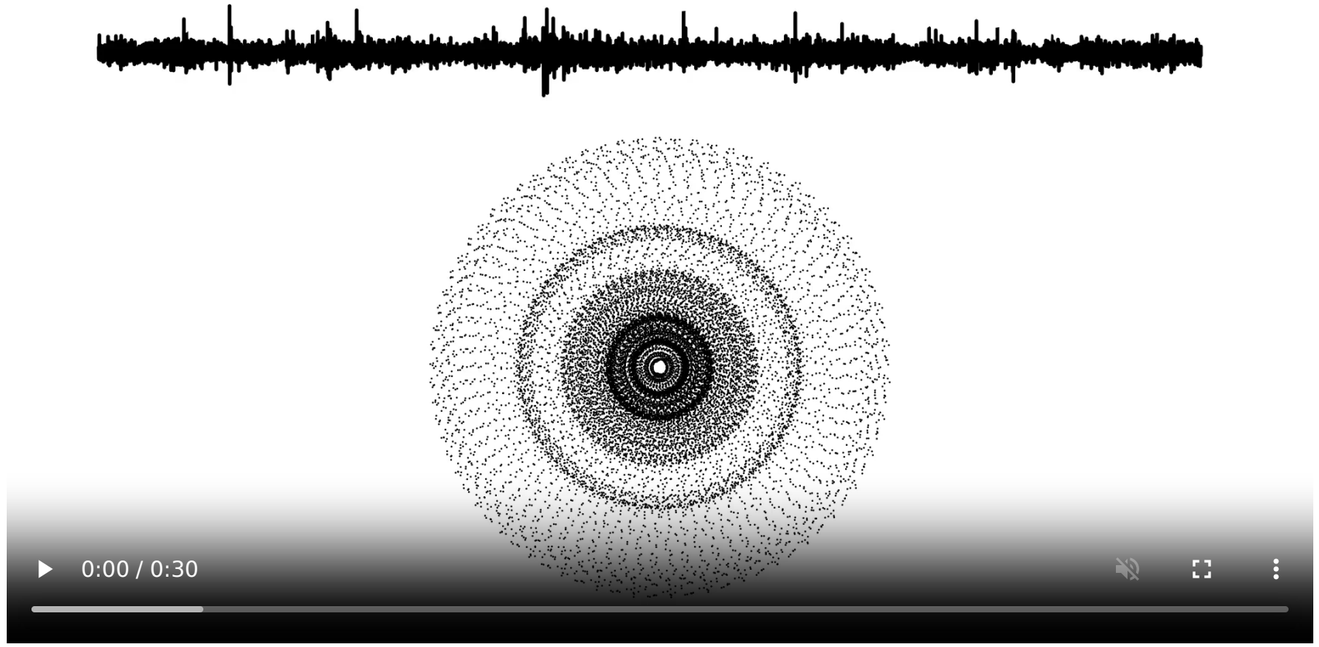
Unterschied zwar erkennbar, aber man muss genau schauen.

Wenn viele Signale den Überblick erschweren

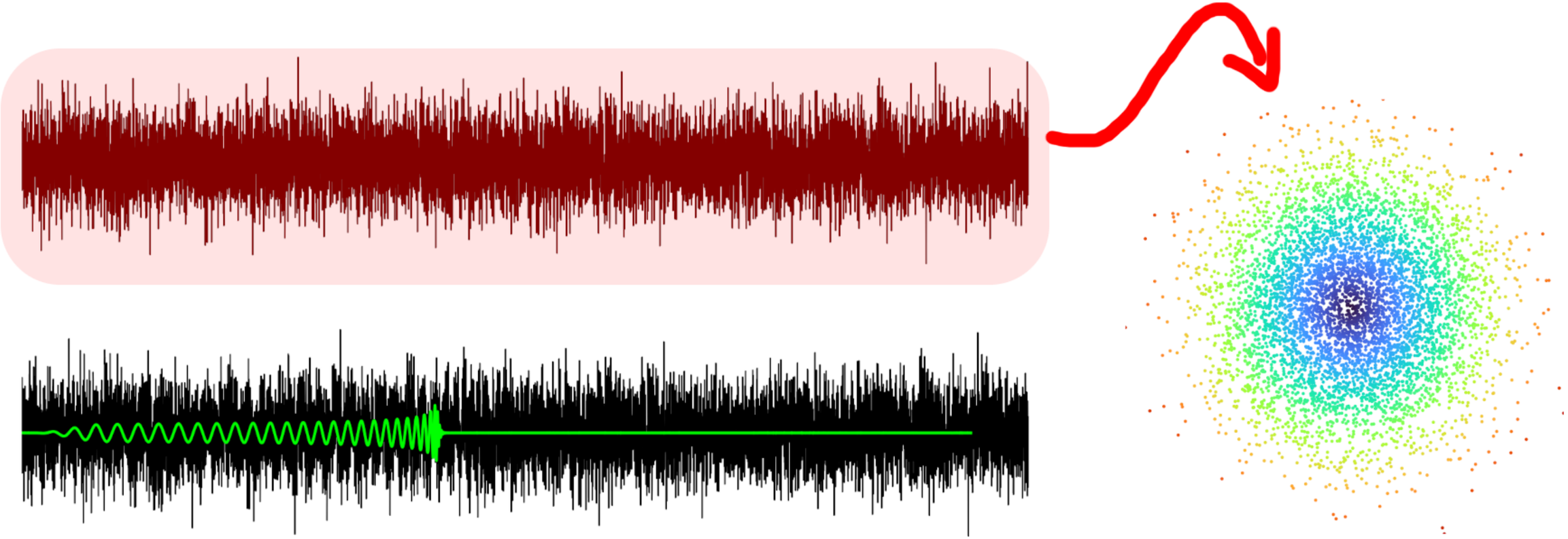


Wir suchen nach einer Visualisierung, die eindeutig Unterschiede aufzeigt!

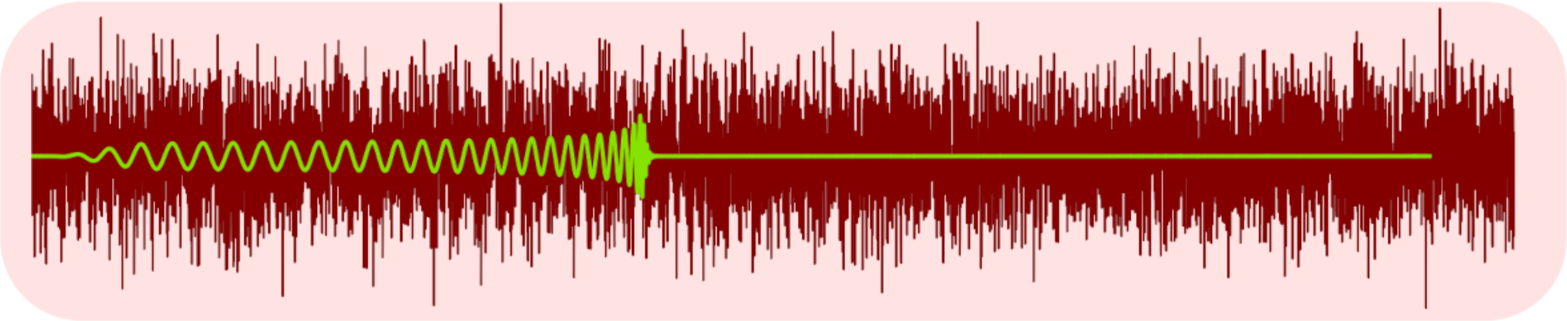
Das Time Delay Embedding (TDE)

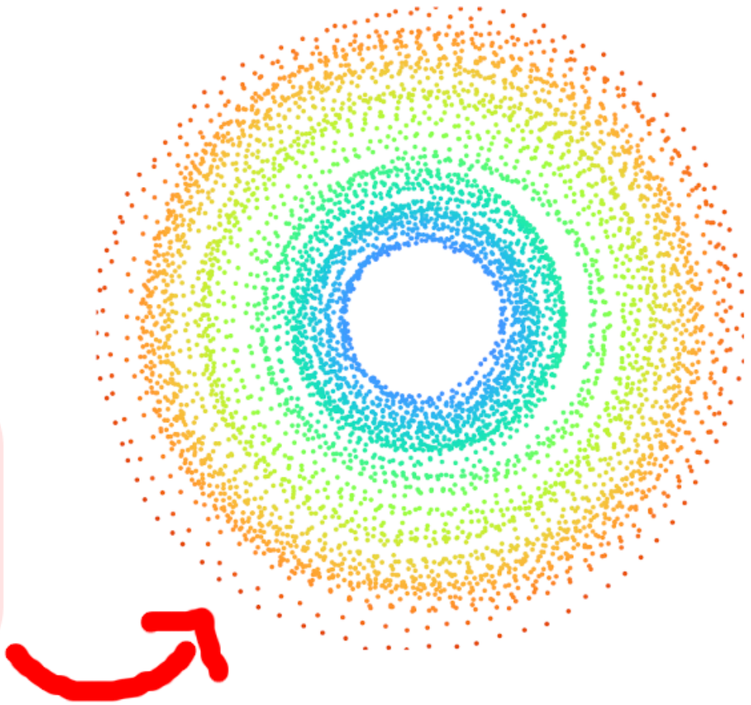


Rauschen ist nicht spektakulär ...

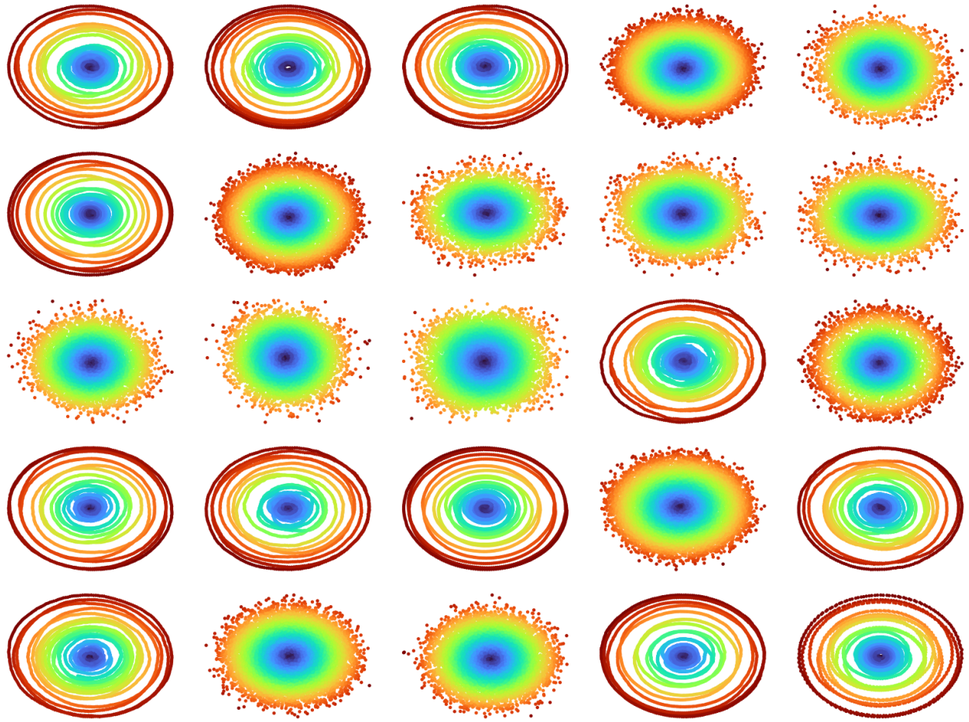


... Schwingungen hingegen führen zu Kreisen!





Sehen Sie die Unterschiede?



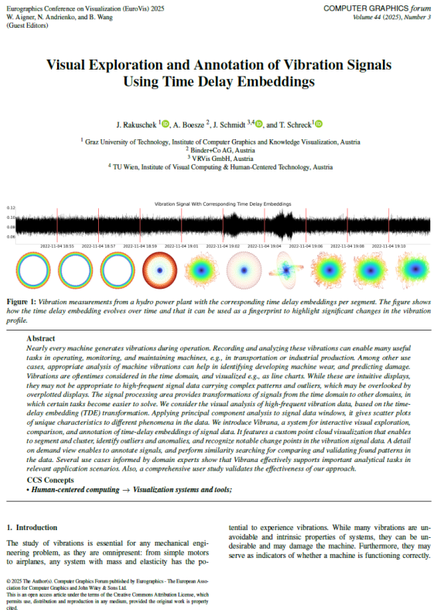
Was wollen wir damit machen?

1. Ab wann sieht man eine Änderung?
2. Unterteilung von Signalen in Gruppen
3. Labels finden zur Anomalieerkennung

Unser Prototyp:

Vibrana

Basis dazu unser Paper



Eurographics Conference on Visualization (EuroVis) 2025
W. Aigner, N. Andrienko, and B. Wang
(Guest Editors)

COMPUTER GRAPHICS forum
Volume 44 (2025), Number 3

Visual Exploration and Annotation of Vibration Signals Using Time Delay Embeddings

J. Rakuschek [1], A. Boesze [2], J. Schmidt [3,4], and T. Schreck [1]

[1] Graz University of Technology, Institute of Computer Graphics and Knowledge Visualization, Austria
[2] Binder+Co AG, Austria
[3] VRVis GmbH, Austria
[4] TU Wien, Institute of Visual Computing & Human-Centered Technology, Austria

Figure 1: *Vibration measurements from a hydro power plant with the corresponding time delay embeddings per segment. The figure shows how the time delay embedding evolves over time and that it can be used as a fingerprint to highlight significant changes in the vibration profile.*

Abstract

Nearly every machine generates vibrations during operation. Recording and analyzing these vibrations can enable many useful tasks in operating, monitoring, and maintaining machines, e.g., in transportation or industrial production. Among other use cases, appropriate analysis of machine vibrations can help in identifying developing machine wear, and predicting damage. Vibrations are oftentimes considered in the time domain, and visualized e.g., as line charts. While these are intuitive displays, they may not be appropriate to high-frequent signal data carrying complex patterns and outliers, which may be overlooked by overplotted displays. The signal processing area provides transformations of signals from the time domain to other domains, in which certain tasks become easier to solve. We consider the visual analysis of high-frequent vibration data, based on the time-delay embedding (TDE) transformation. Applying principal component analysis to signal data windows, it gives scatter plots of unique characteristics to different phenomena in the data. We introduce Vibrana, a system for interactive visual exploration, comparison, and annotation of time-delay embeddings of signal data. It features a custom point cloud visualization that enables to segment and cluster, identify outliers and anomalies, and recognize notable change points in the vibration signal data. A detail on demand view enables to annotate signals, and perform similarity searching for comparing and validating found patterns in the data. Several use cases informed by domain experts show that Vibrana effectively supports important analytical tasks in relevant application scenarios. Also, a comprehensive user study validates the effectiveness of our approach.

CCS Concepts

• ***Human-centered computing*** → ***Visualization systems and tools;***

1. Introduction

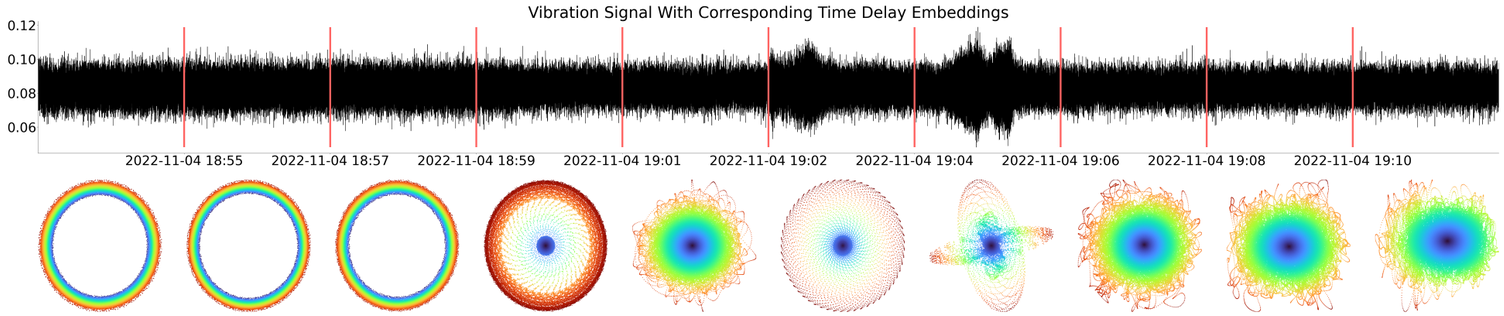
The study of vibrations is essential for any mechanical engineering problem, as they are omnipresent: from simple motors to airplanes, any system with mass and elasticity has the potential to experience vibrations. While many vibrations are unavoidable and intrinsic properties of systems, they can be undesirable and may damage the machine. Furthermore, they may serve as indicators of whether a machine is functioning correctly.

EuroVis 2025 Einreichung

Aktuell in Begutachtung 🤞

Ab wann sieht man eine Änderung?

Vibrationen in einem Wasserkraftwerk

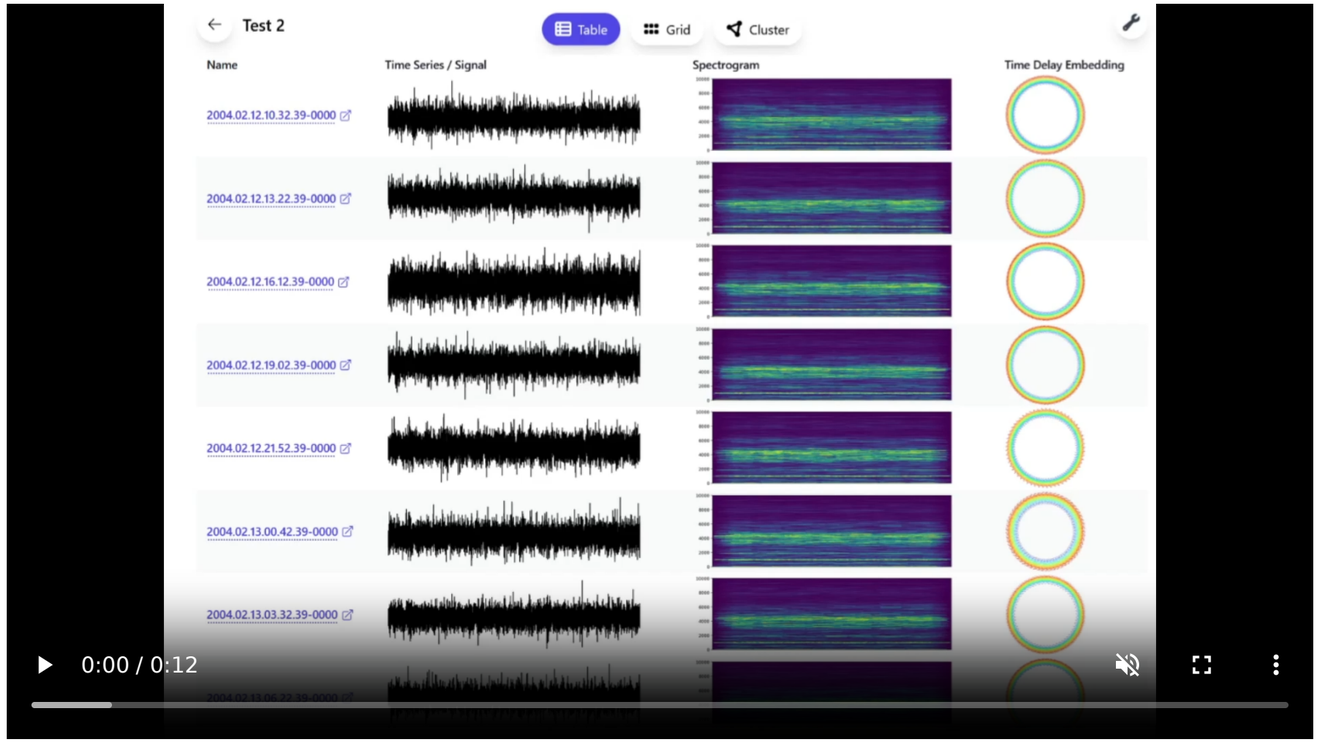


Das TDE als Fingerabdruck, der sich über die Zeit hinweg entwickelt.

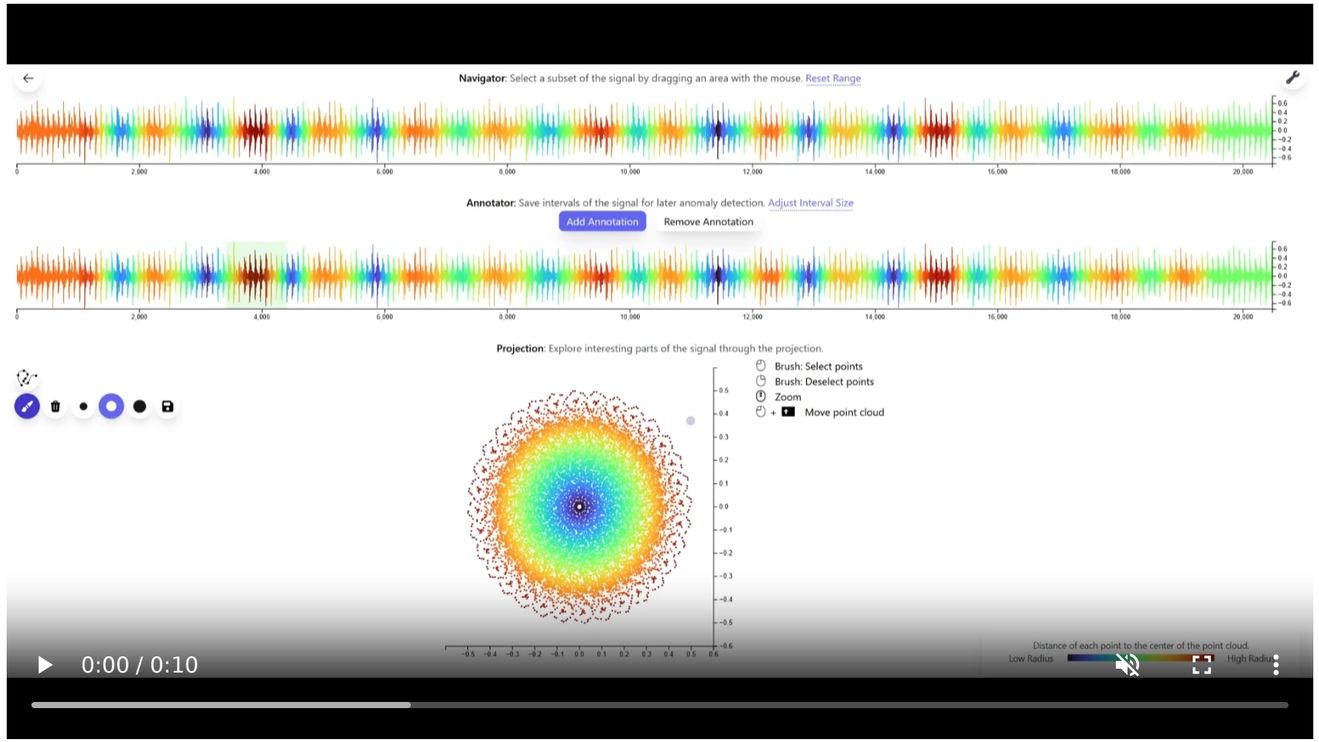
Anwendungsfall: Motor Verschleiß

Ab wann ist Verschleiß erkennbar?

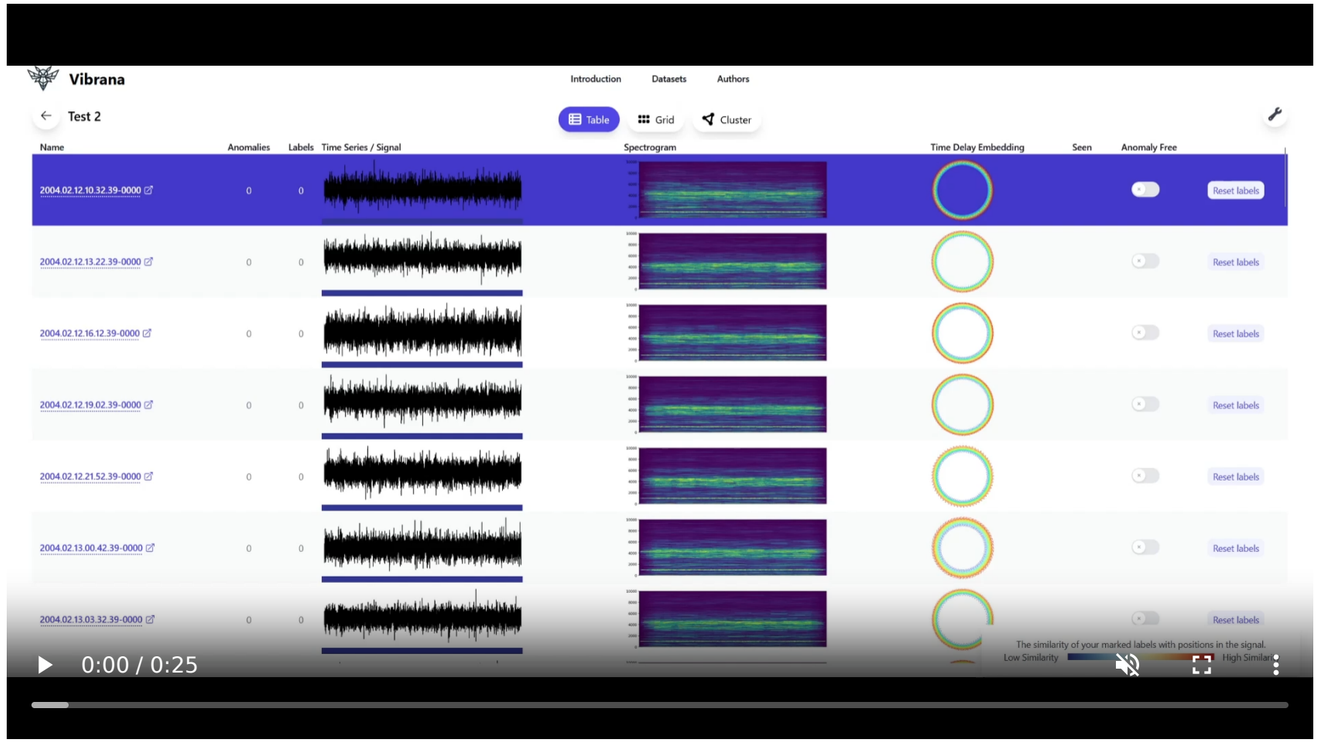
In der Tabelle wird die Änderung sichtbar



Das TDE als Guide für Labels



Wozu die Labels? Similarity Search!

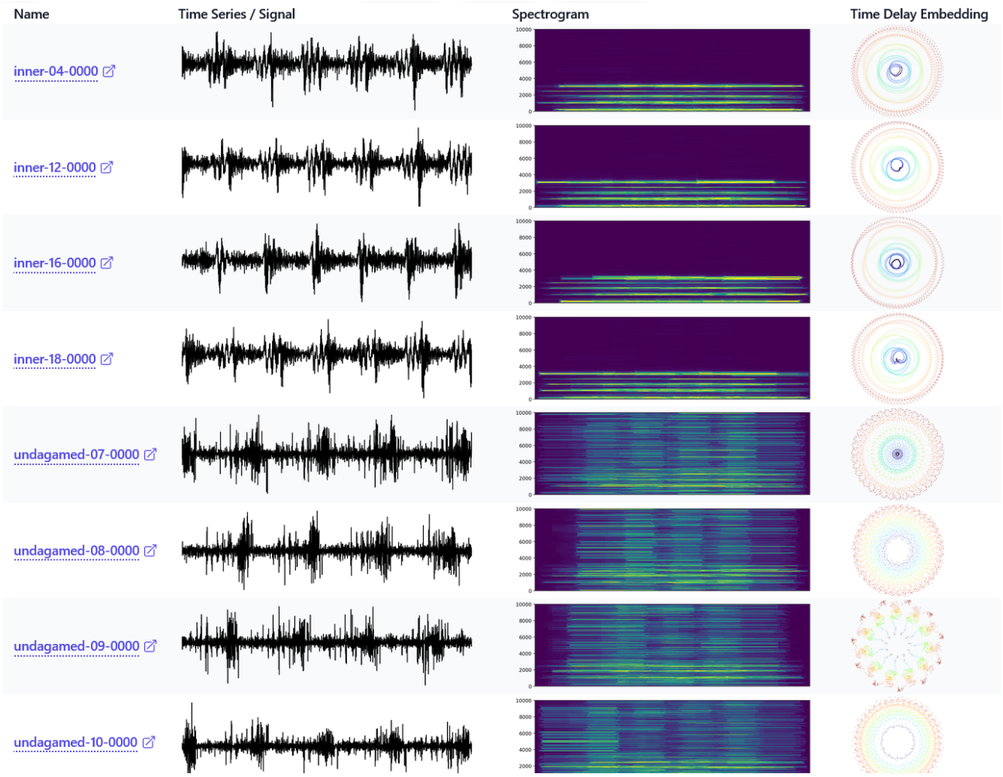


Überraschung: Der Verschleiß kann früher gefunden werden!

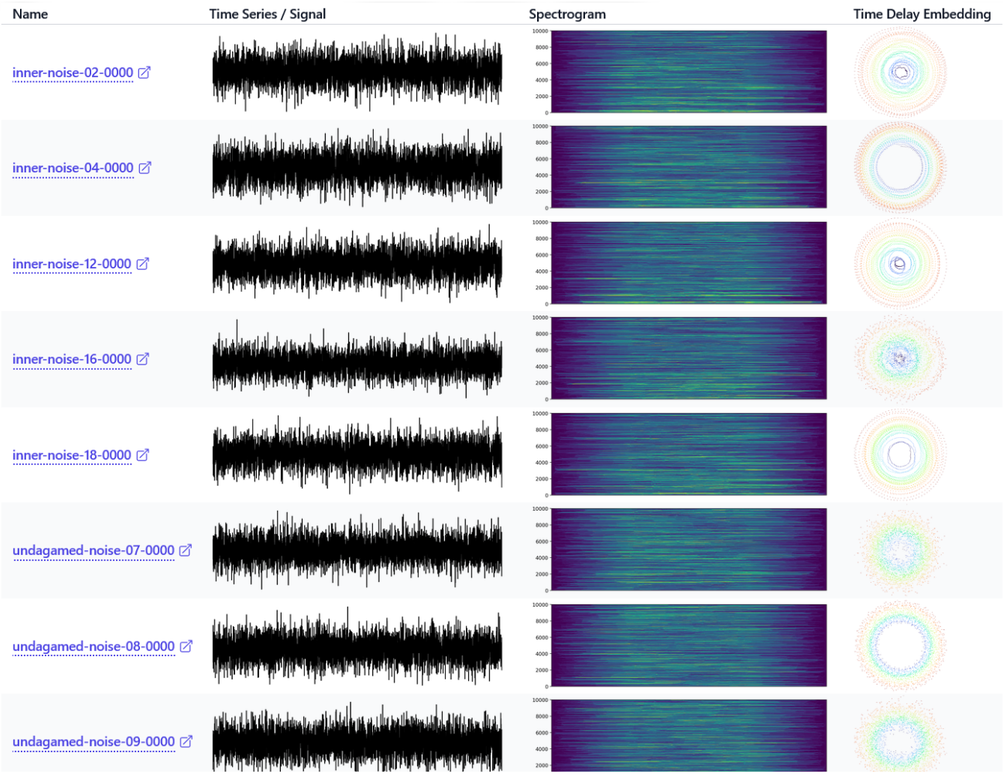
Anwendungsfall: Lager klassifizieren

Welche sind fehlerhaft?

Hier ist das Spektrogramm zwar besser ...

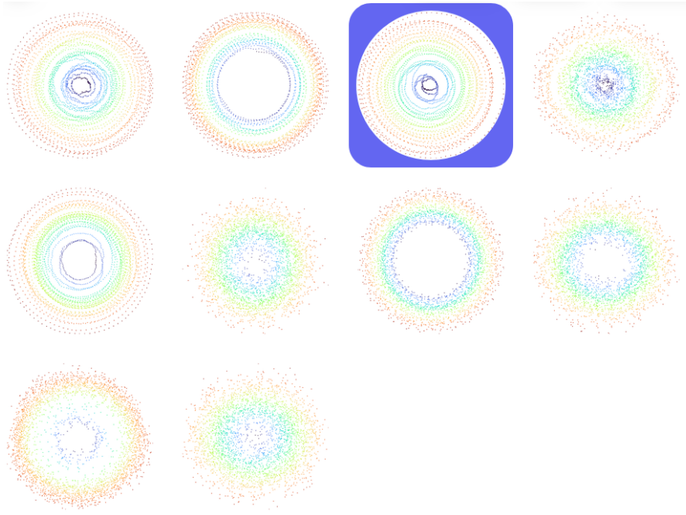


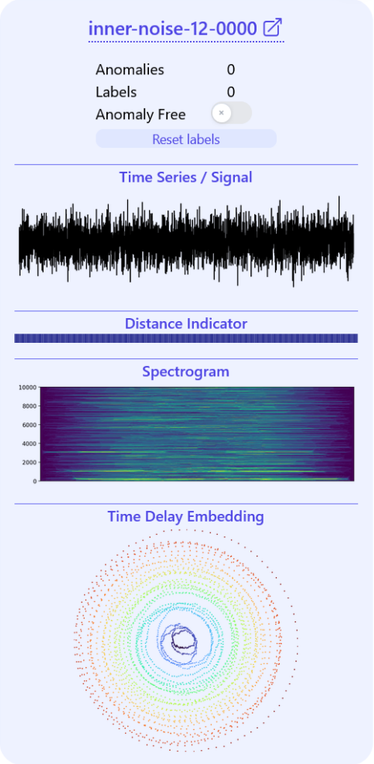
... aber wie sieht es mit Rauschen aus?



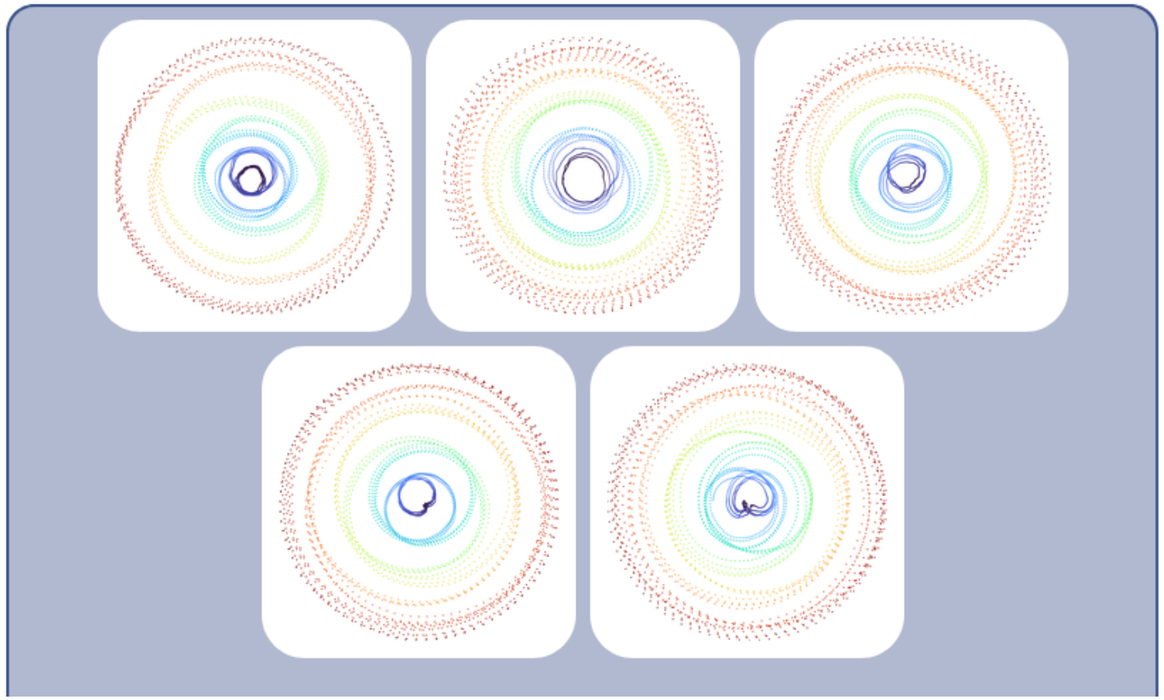
Welche sind fehlerhaft?

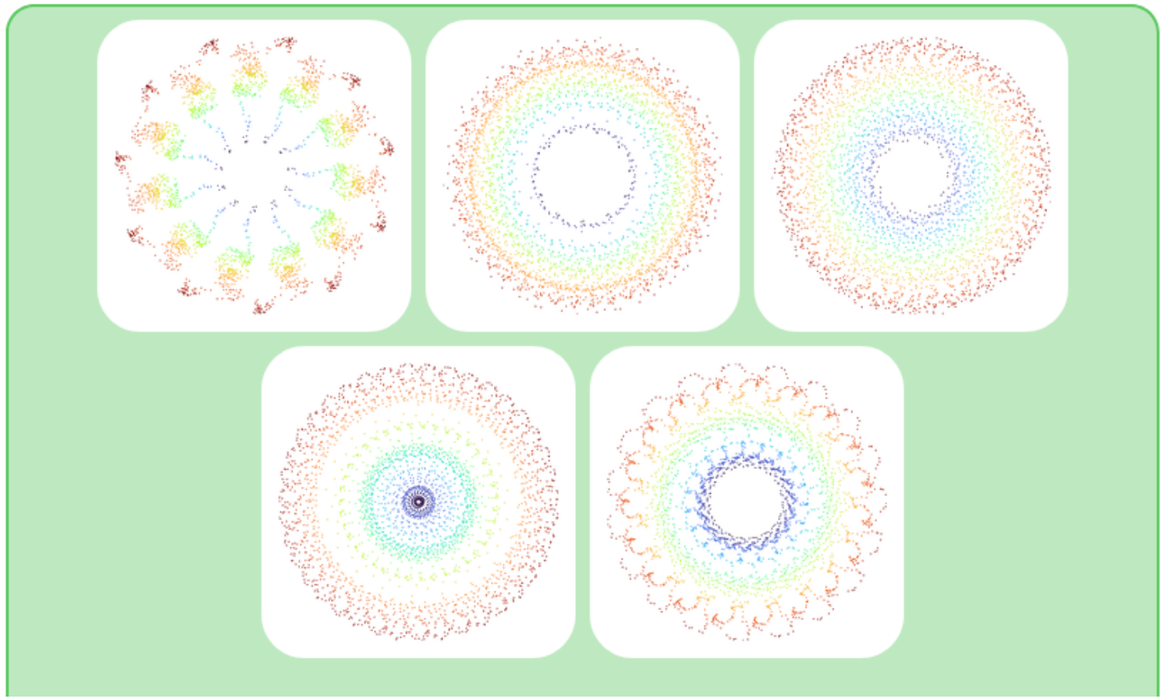
TDEs vergleichen: Matrix





Automatisch Clustern



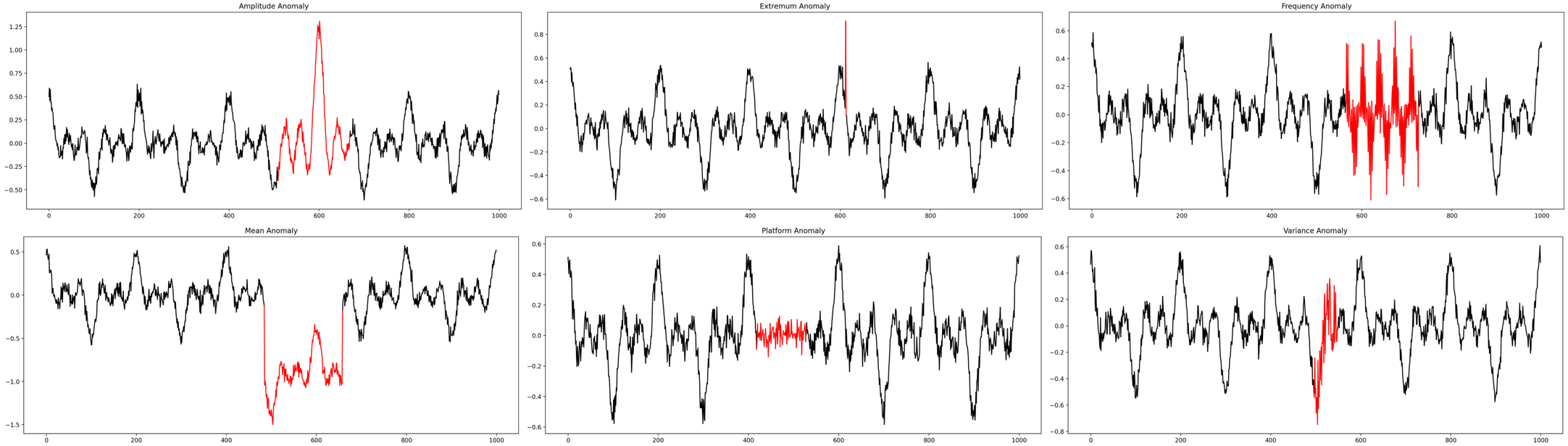


Was wollen wir damit machen?

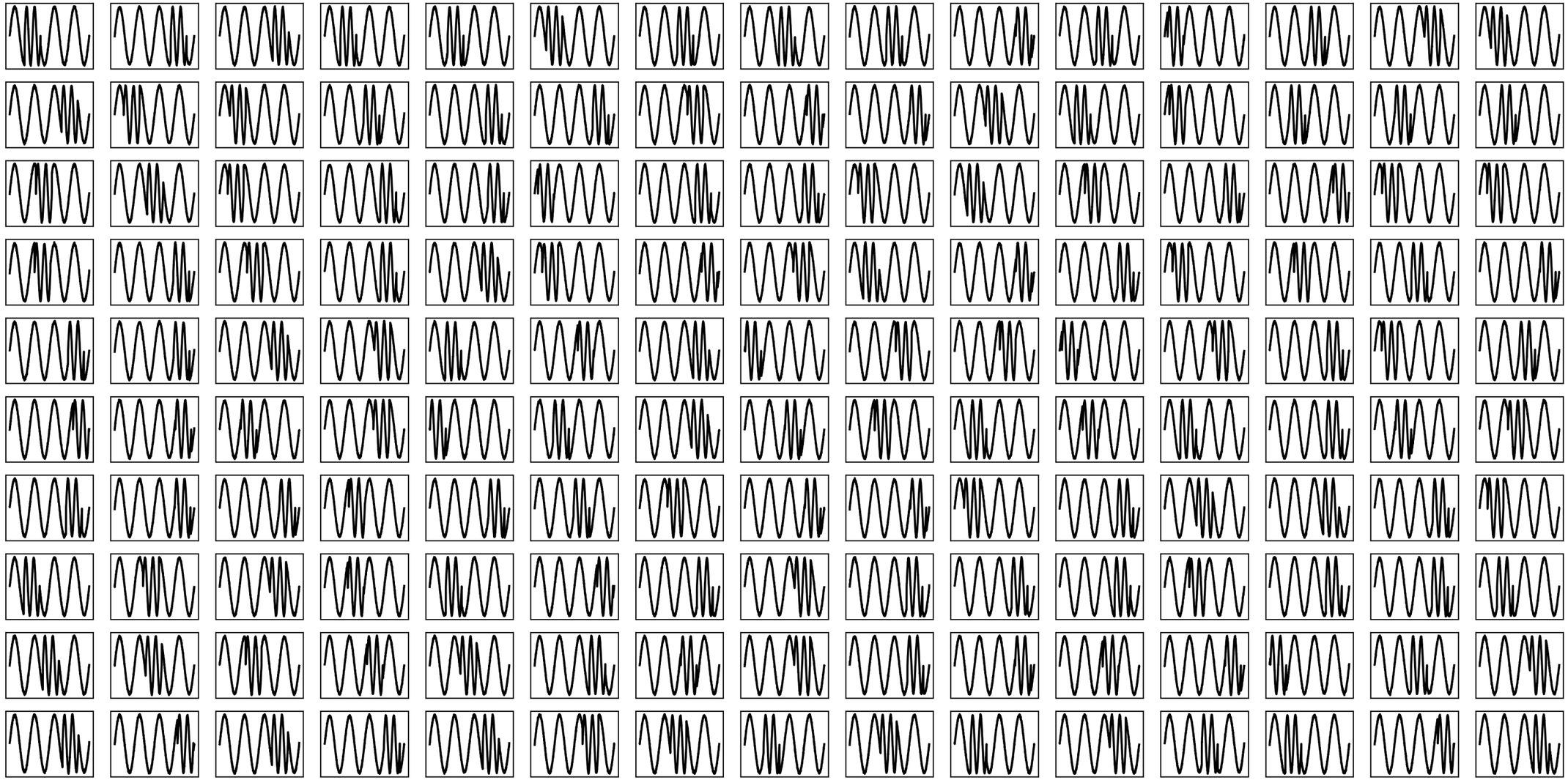
1. Ab wann sieht man eine Änderung?
   Motor Verschleiß (Tabelle)
2. Unterteilung von Signalen in Gruppen
   Lager klassifizieren (Clustering)
3. Labels finden zur Anomalieerkennung
   Motor Verschleiß (Labeling)

AnoScout

Anomalien in Zeitreihen (Auswahl)

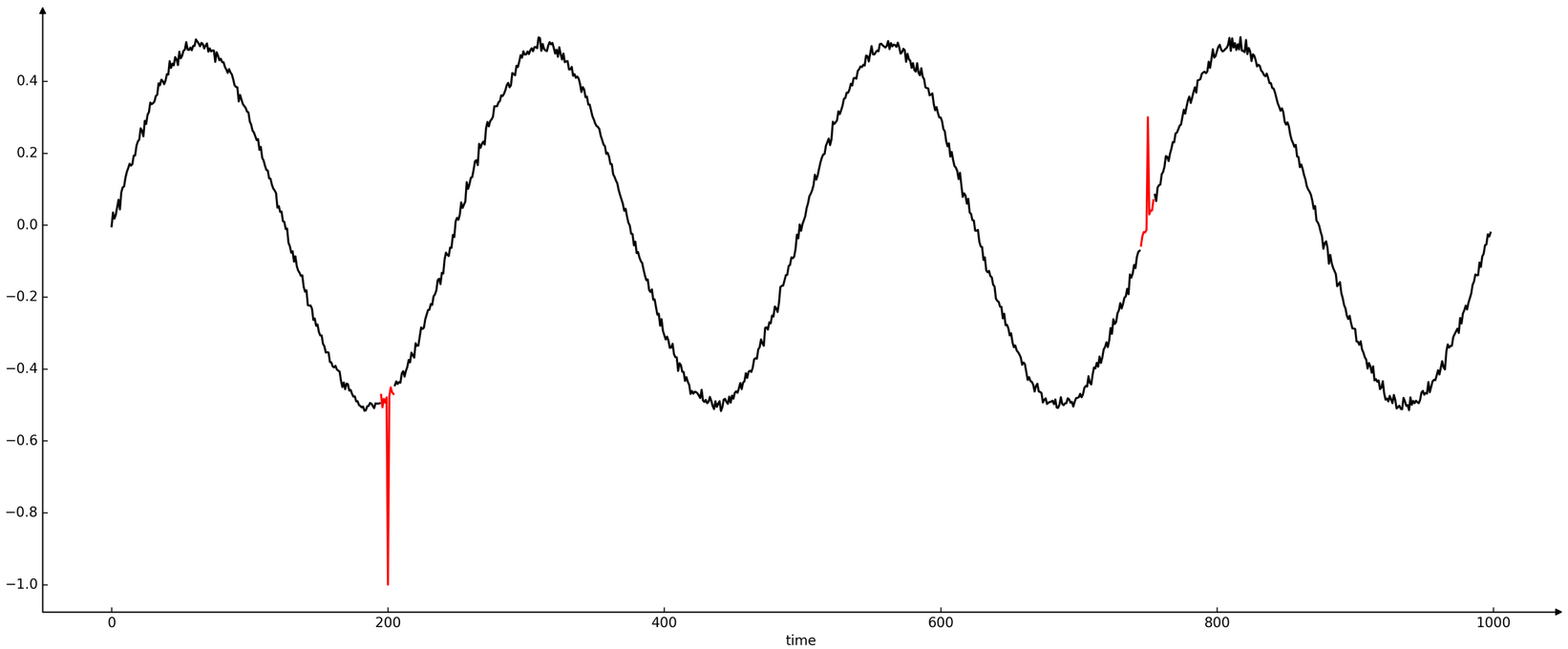


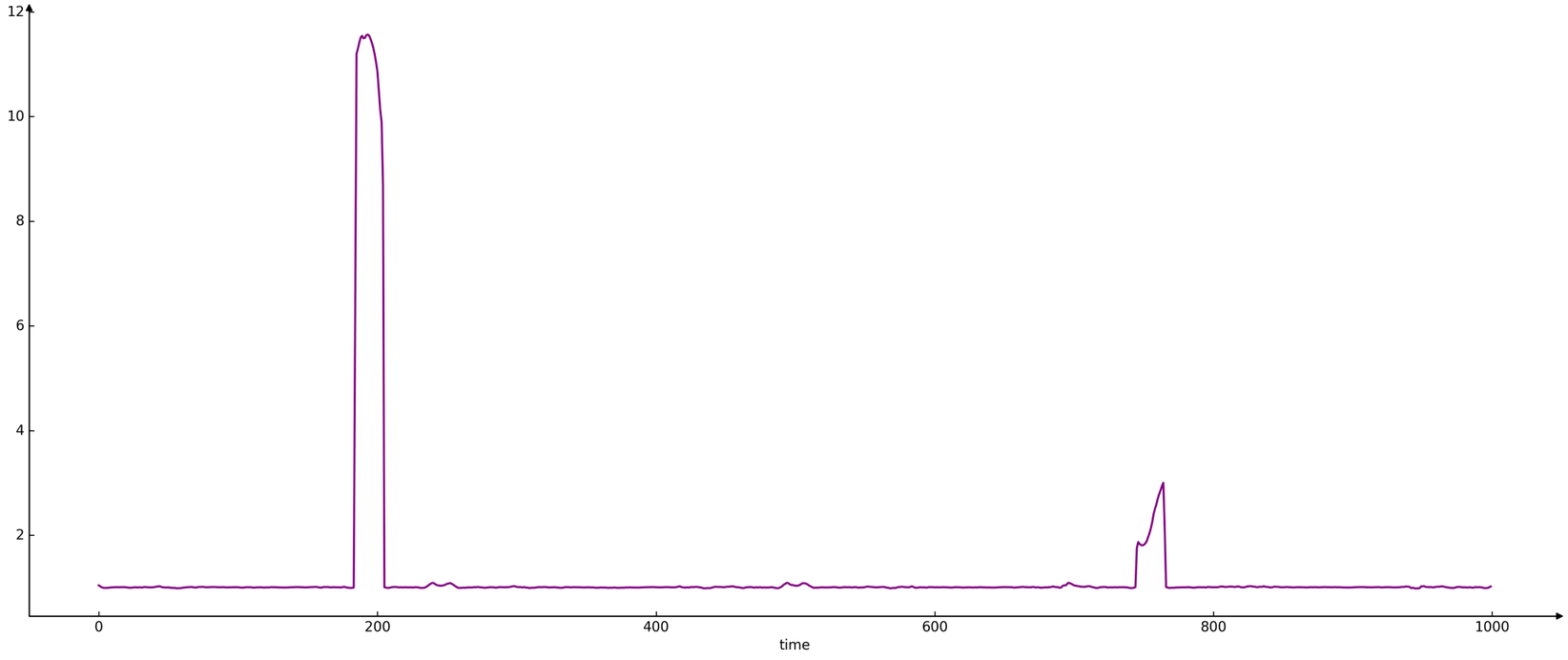
Jede Zeitreihe manuell begutachten?



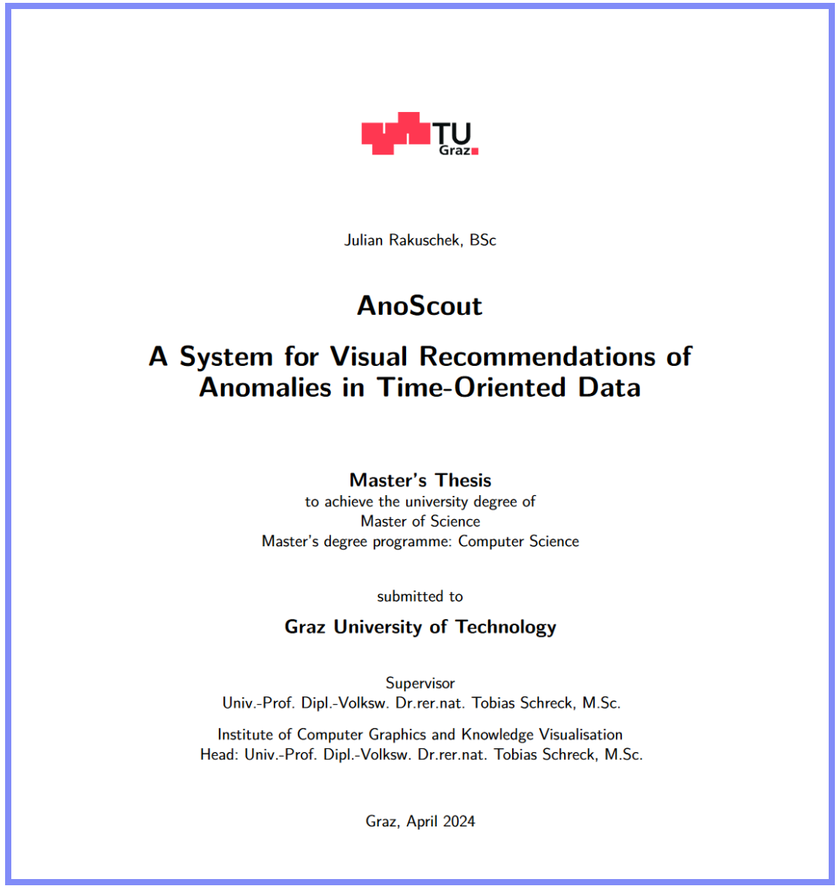
Wir wenden Algorithmen an!

Gewünschter Output vom Algorithmus: Scoring




12
10
8
6
4
2
0
200
400
600
800
1000
time

Introducing AnoScout



Julian Rakuschek, BSc

AnoScout

A System for Visual Recommendations of Anomalies in Time-Oriented Data

Master's Thesis
to achieve the university degree of
Master of Science
Master's degree programme: Computer Science

submitted to

Graz University of Technology

Supervisor
Univ.-Prof. Dipl.-Volksw. Dr.rer.nat. Tobias Schreck, M.Sc.

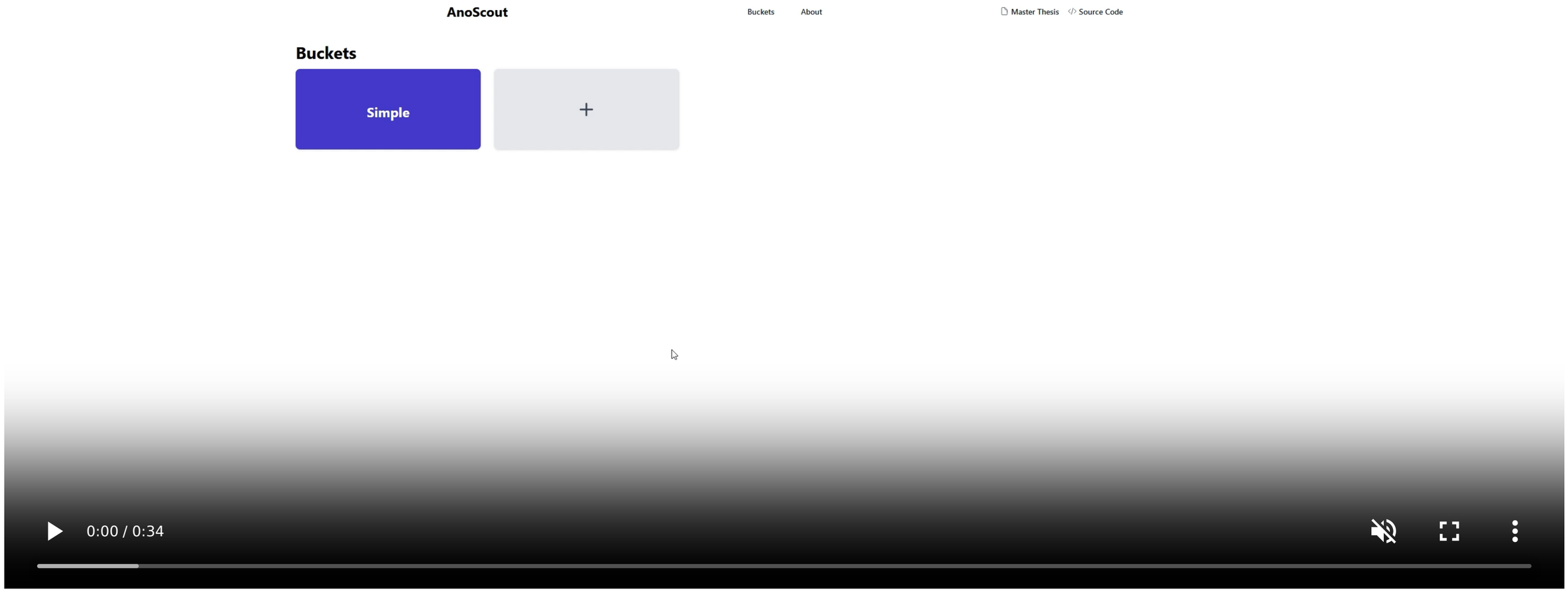
Institute of Computer Graphics and Knowledge Visualisation
Head: Univ.-Prof. Dipl.-Volksw. Dr.rer.nat. Tobias Schreck, M.Sc.

Graz, April 2024

AnoScout implementiert sieben Algorithmen

- AutoEncoder
- Discrete Wavelet Transform
- Subsequence Isolation Forest
- Subsequence Local Outlier Factor
- LSTM Forecasting
- Random Black Forest
- ARIMA

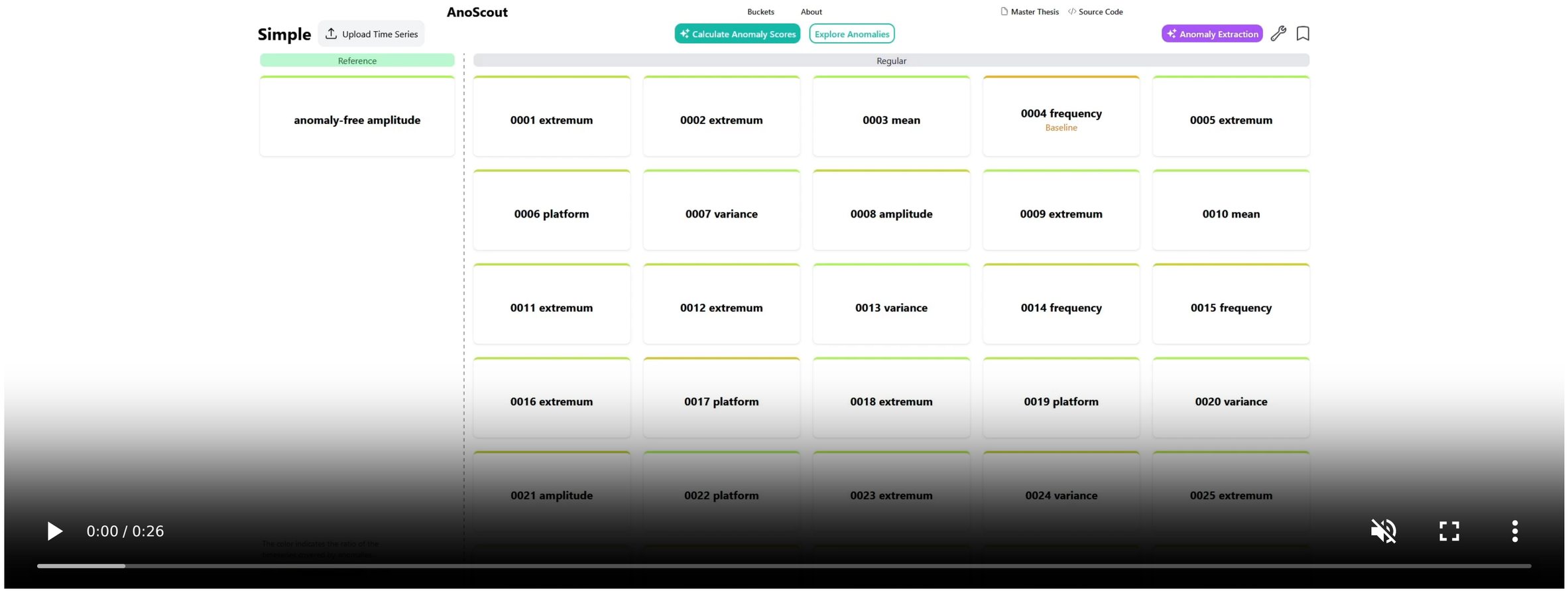
Upload und Scoring Berechnung



Haben wir nun Anomalien?

Noch nicht!

Extraktion der Anomalien

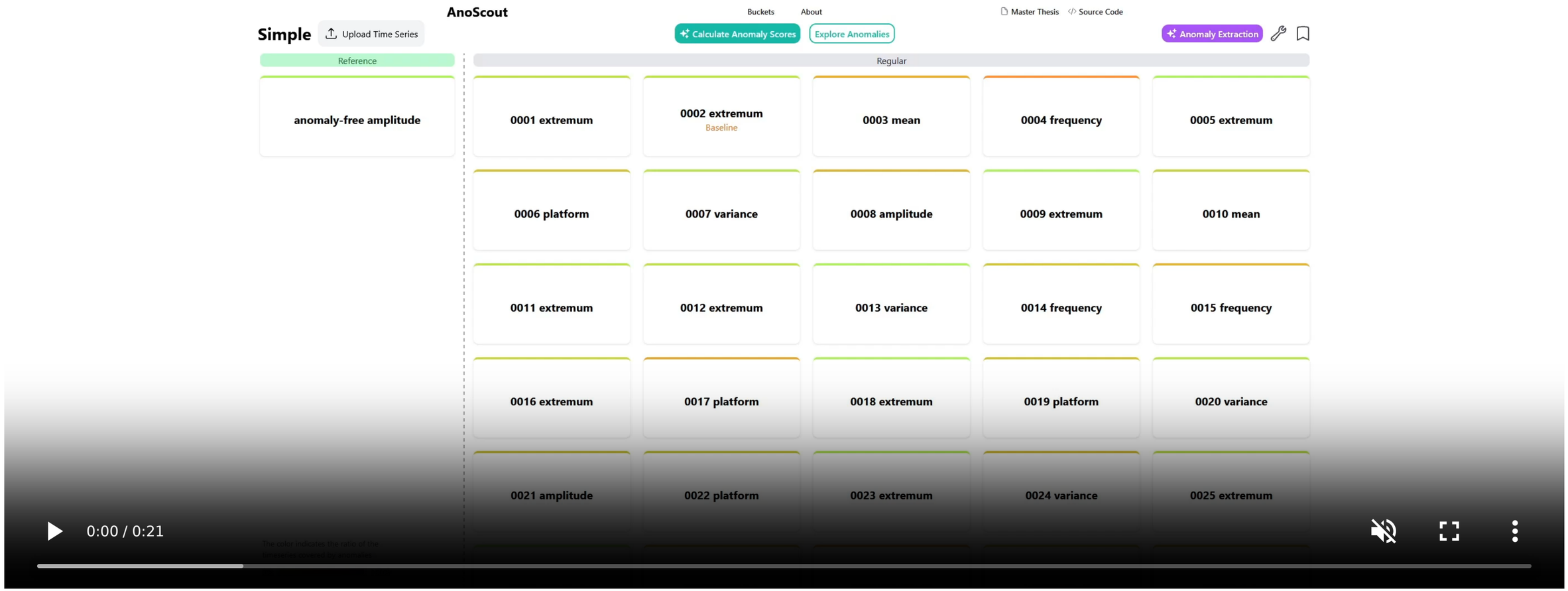


Anomalien als Karten

5 Important verified

Timeseries: 0065 frequency
Channel: value-0
Start: 2024-05-12T19:47:07.943Z
End: 2024-05-12T19:51:13.943Z
Score: 1.178
Length: 247

Manuelle Inspektion



Explorierung von Anomalien

Heatmap

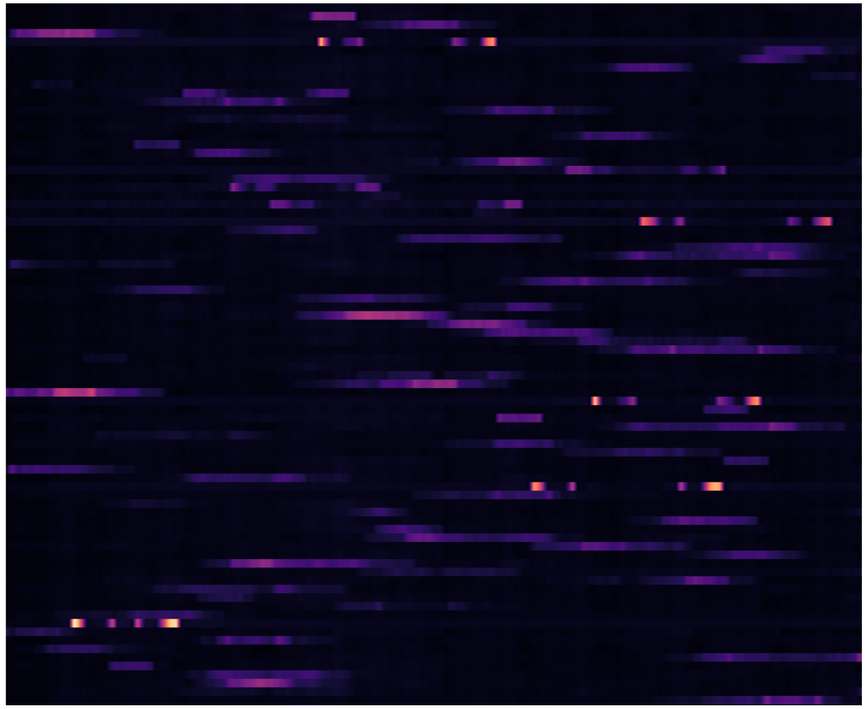
Scatterplot

Cluster Overview

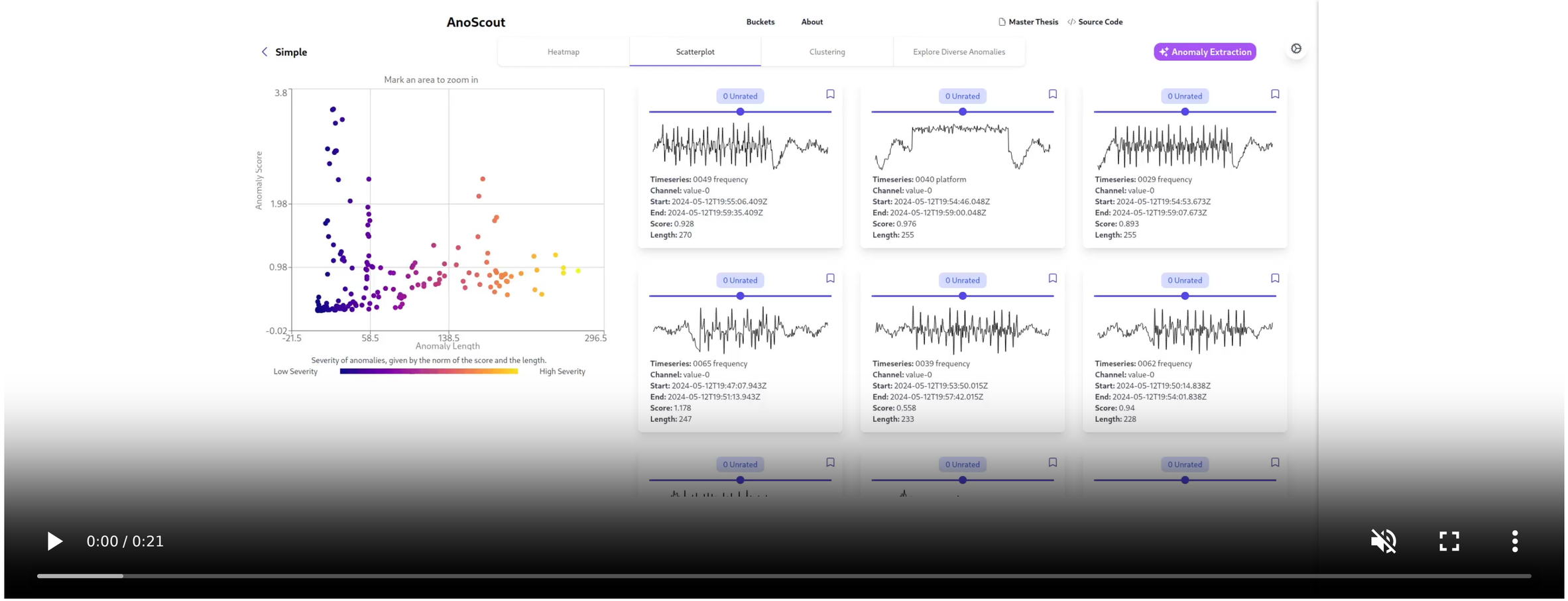
Heatmap

Vogelperspektive

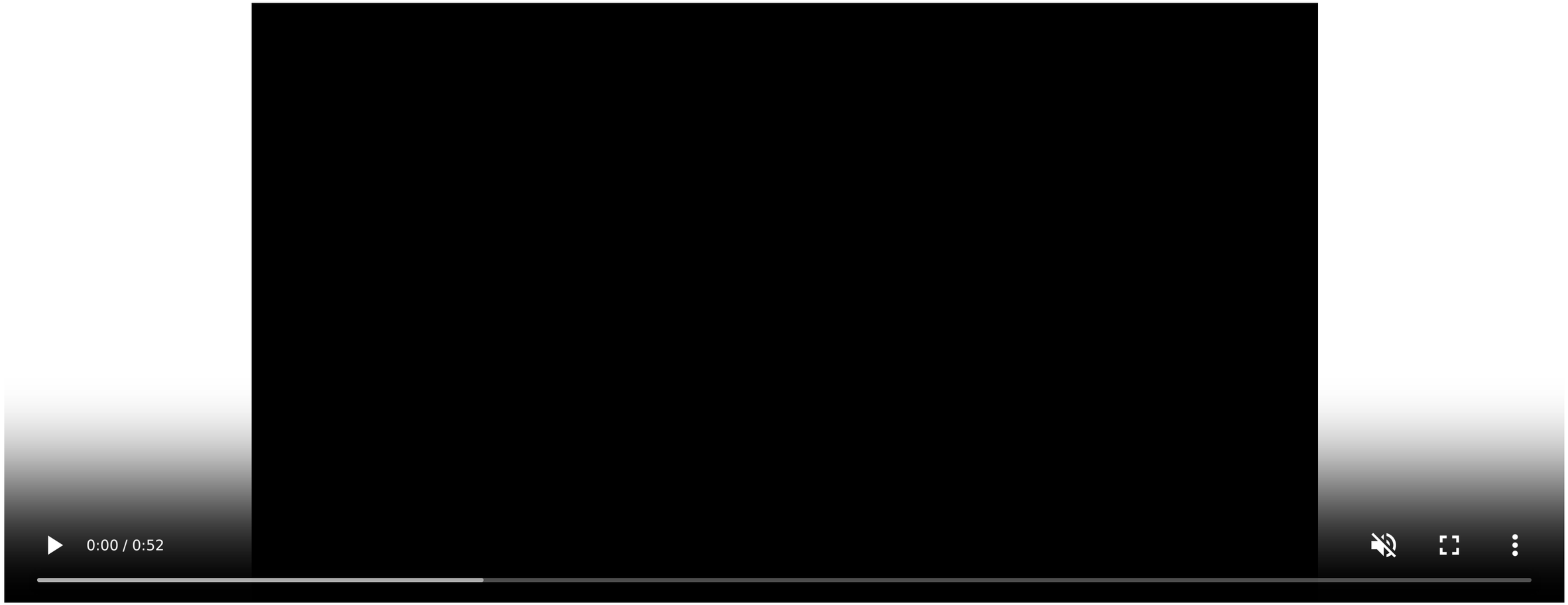
Each horizontal line in the heatmap represents one timeseries



Der Scatterplot als Überblick



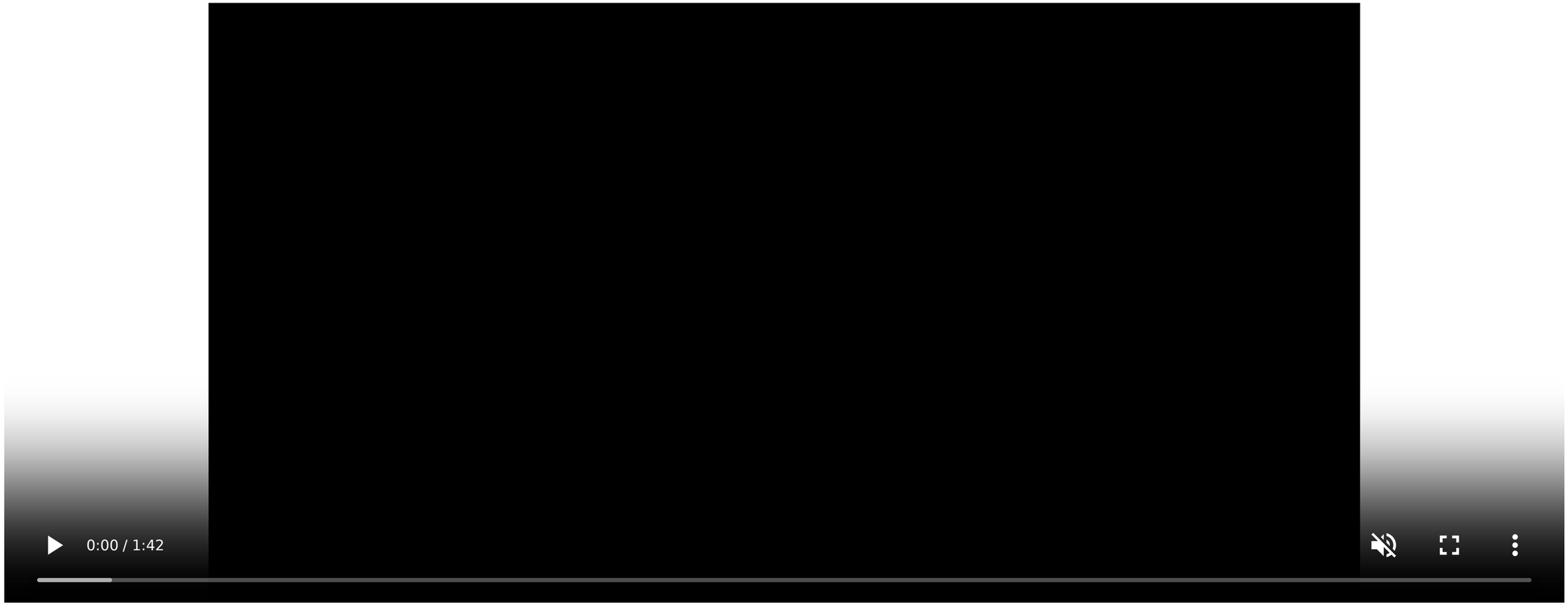
Der Recommender für maßgeschneiderte Empfehlungen



Wie erlangen wir einen Überblick über Arten von Anomalien?

Clustering!

Clustering von Anomalien



Hauptmerkmale von AnoScout zusammengefasst

1. Erkundungs-Pipeline für Anomalien in zeitlich orientierten Daten.
2. 7 Algorithmen zur Berechnung von Anomalien.
3. "Spielplatz" zum Testen verschiedener Algorithmen.
4. Verwendung von Benutzerlabels zur Feinabstimmung des Systems.

Anwendungsszenario

- Ein Unternehmen möchte eine neue Maschine installieren.
- Die Maschine führt Schweißarbeiten durch.
- Jede Schweißnaht wird über einen Sensor aufgezeichnet.
- Wir möchten AnoScout verwenden, um:
  1. Mögliche Anomalie-Muster zu finden.
  2. Zu überprüfen, welche Algorithmen gut funktionieren.

Wir sind auf der Suche nach weiteren Anwendungen!

Kontakt

Julian Rakuschek
julian.rakuschek@tugraz.at

Prof. Dr. Tobias Schreck
tobias.schreck@tugraz.at

Danke!