INSTITUTE OF VISUAL COMPUTING

TU Graz

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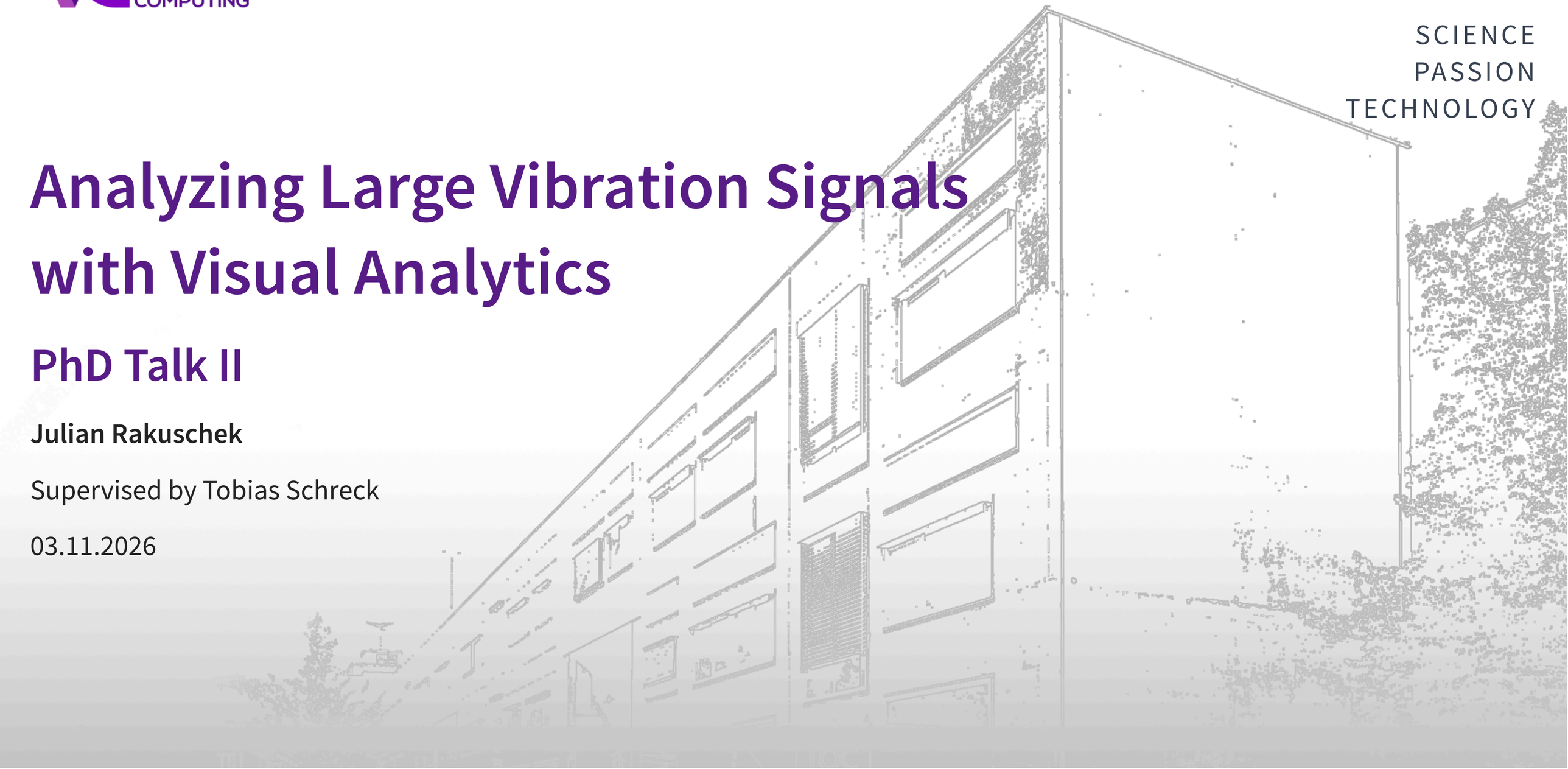


Analyzing Large Vibration Signals with Visual Analytics

PhD Talk II

Julian Rakuschek

Supervised by Tobias Schreck

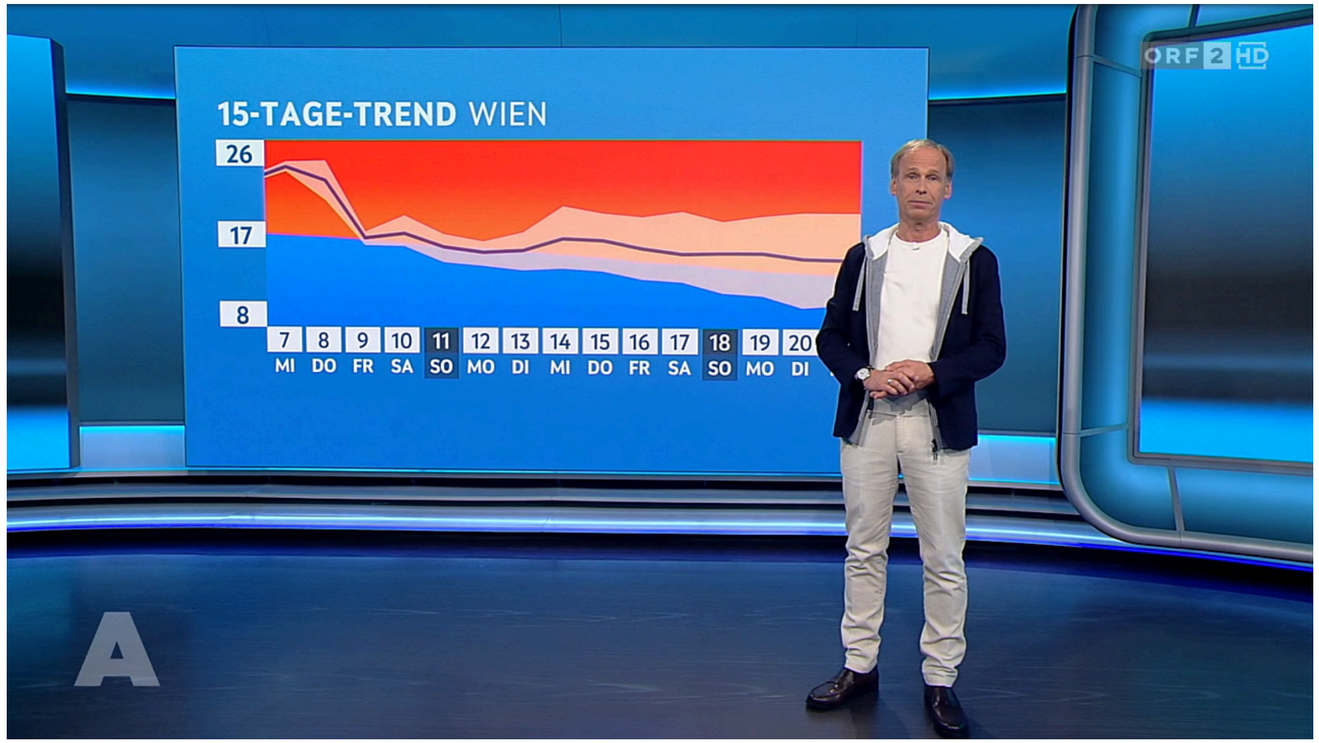
03.11.2026

Have you ever watched a weather report?



ORF weather report (7.10.2026). Source: https://on.orf.at/video/14342094/16166217/wetter-aktuell-nach-eins-vom-07102026

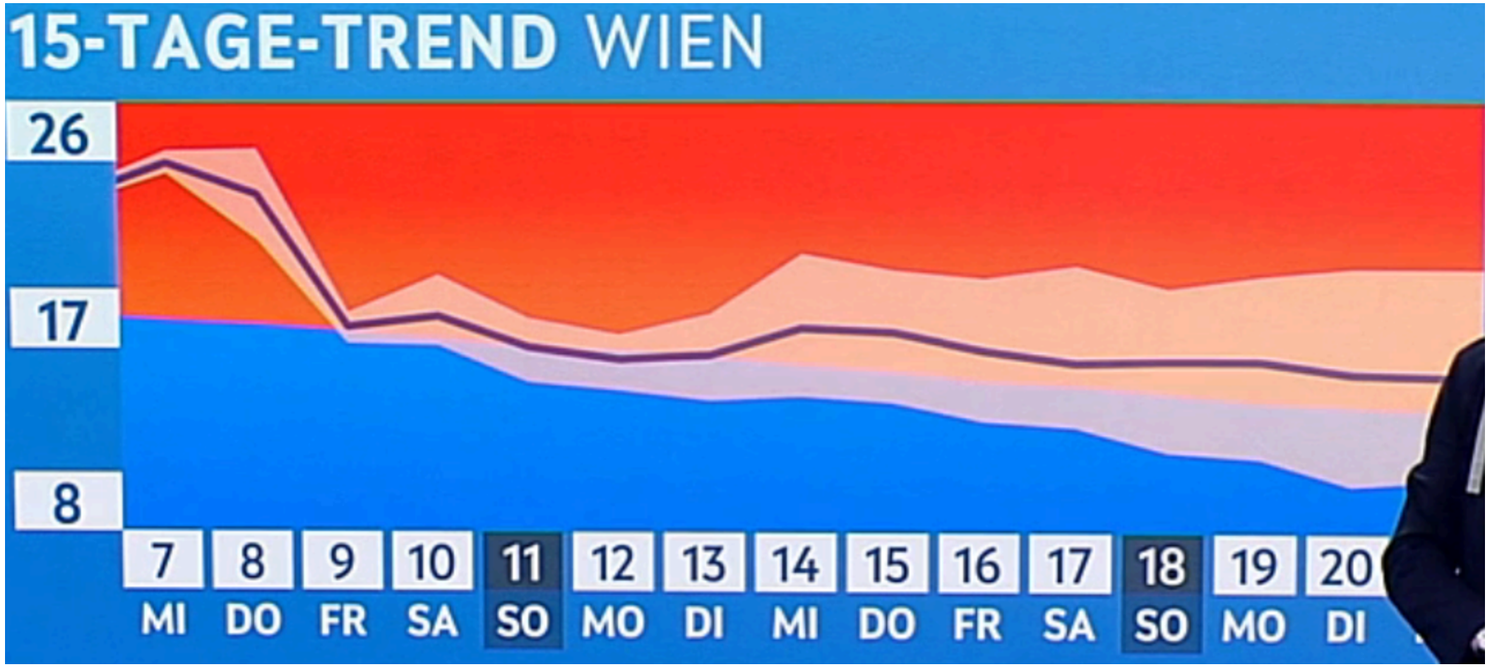
Interesting for us: The Forecast



A time series visualized with the common line chart

ORF weather report (7.10.2026). Source: https://on.orf.at/video/14342094/16166217/wetter-aktuell-nach-eins-vom-07102026

Why is this chart easy to read?



- Only few values
- Not super complex data
- Only one line

This line chart is much harder to read!



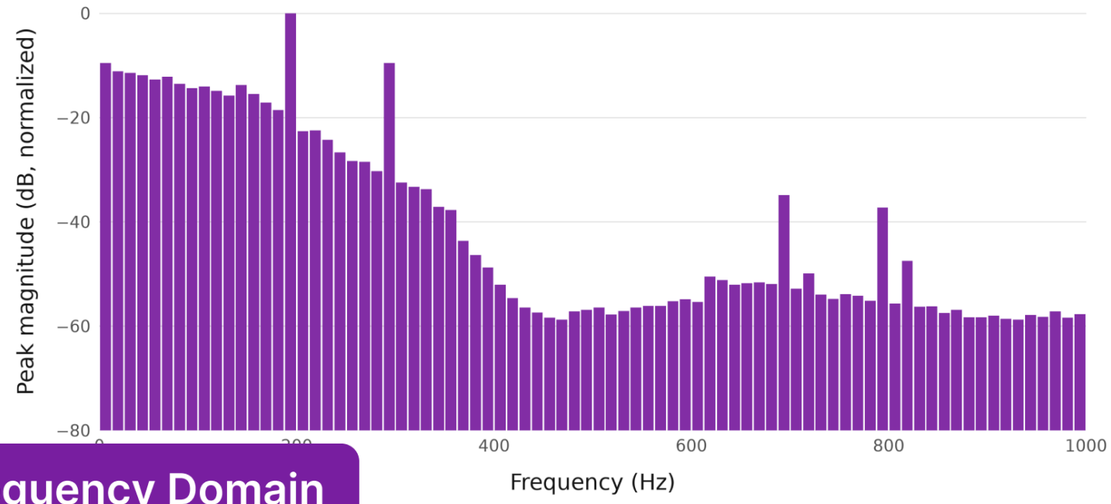
- Dense chart
- Large time series
- Complex patterns (oscillations)

The classic solution: FFT



Time Domain

Fast Fourier Transform



Frequency Domain

Can we also stay in the time domain?

Yes, using time series projections

Visual Fingerprints of Vibration Signals Using Time Delay Embeddings

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

[1] TU Graz, Institute of Visual Computing, Austria
[2] Binder+Co AG, Austria
[3] TU Wien, Institute of Visual Computing & Human-Centered Technology, Austria

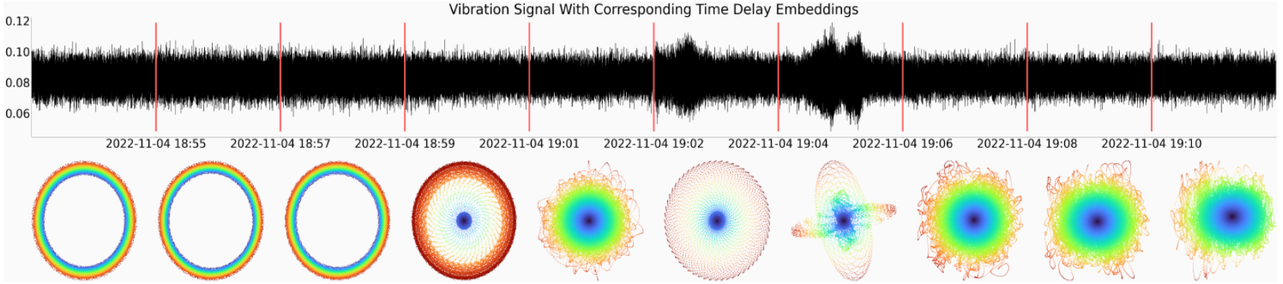


Figure 1: *Vibration measurements from a hydro power plant with the corresponding time delay embeddings per segment. The time delay embedding visualizations evolve over time and can be used as a fingerprint to highlight significant changes in the vibration data.*

EuroVis 2025 (Short Paper)

Time Curves (1)

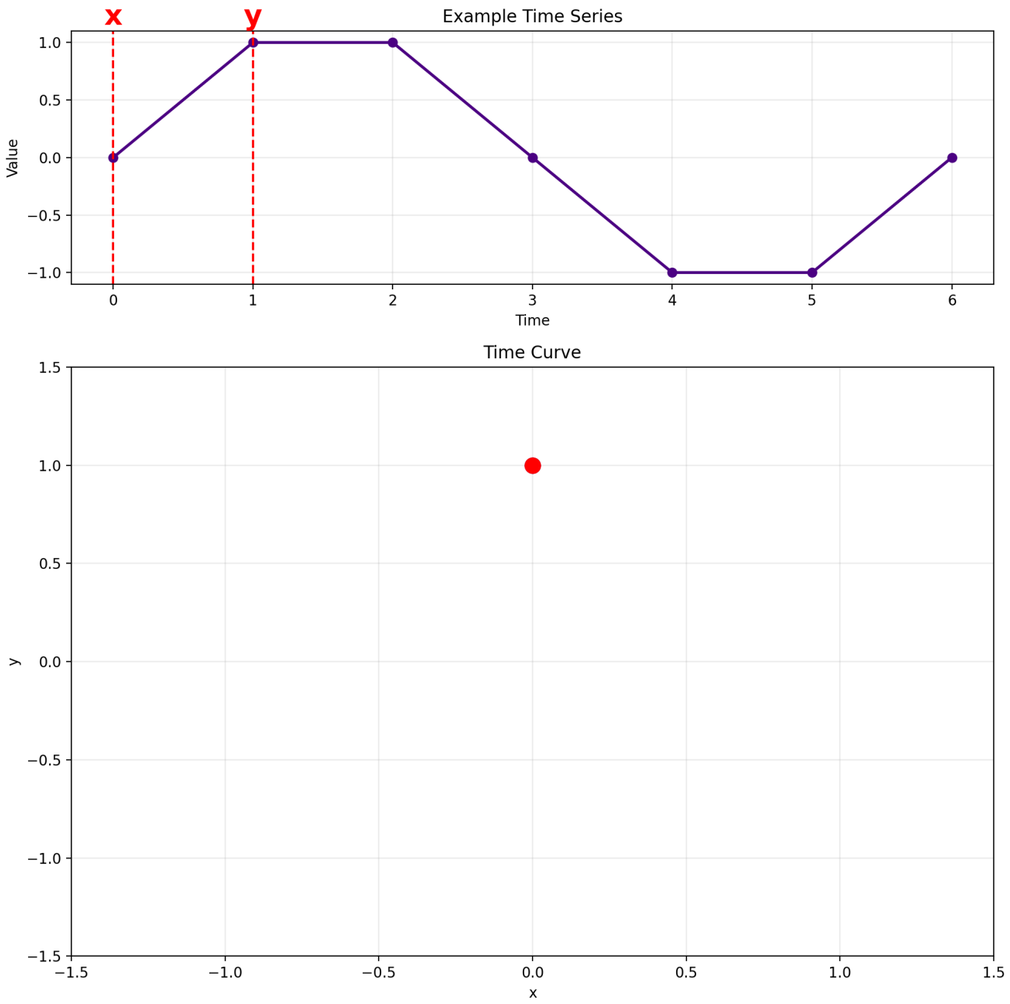
Given a time series as follows:

$$\mathbf{x} = \begin{bmatrix} 0 & 1 & 1 & 0 & -1 & -1 & 0 \end{bmatrix}$$

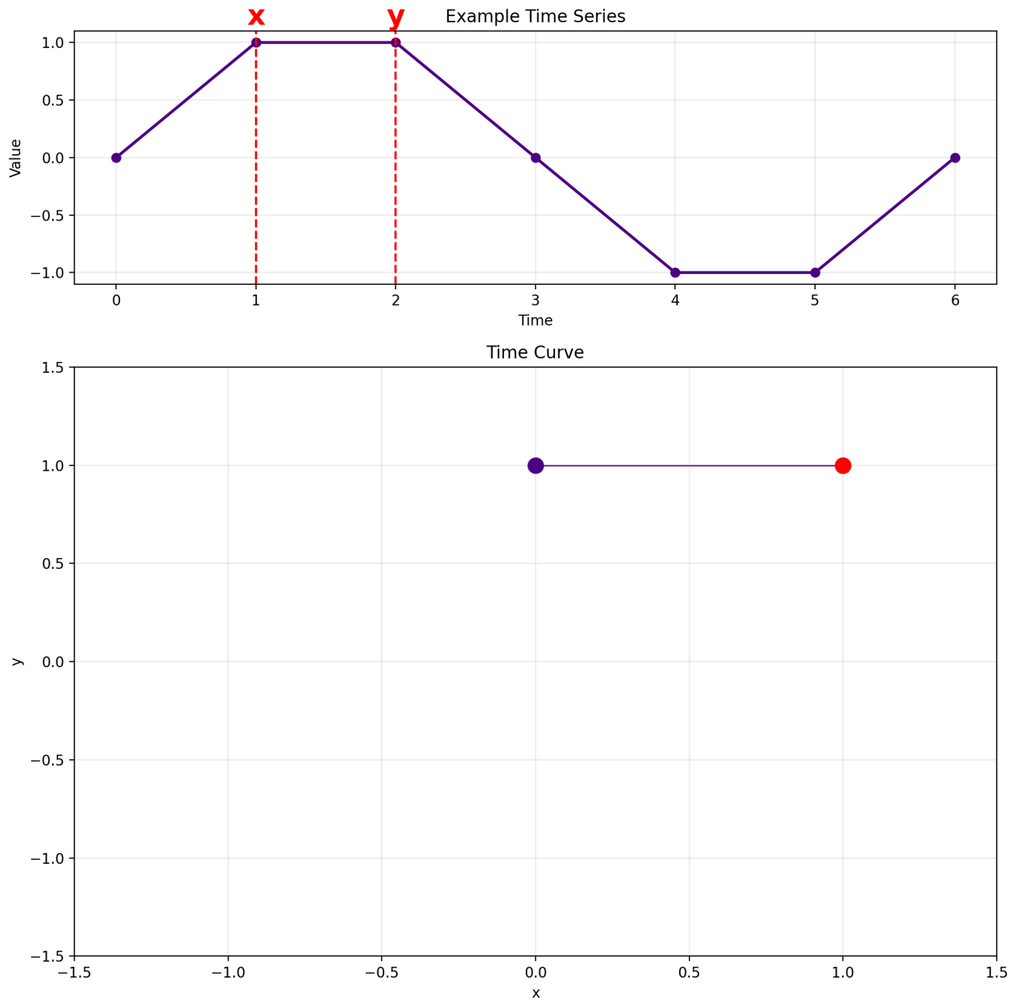
Sliding window view with $w = 2$:

$$SW_{\mathbf{x}} = \begin{bmatrix} 0 & 1 \\ 1 & 1 \\ 1 & 0 \\ 0 & -1 \\ -1 & -1 \\ -1 & 0 \end{bmatrix}$$

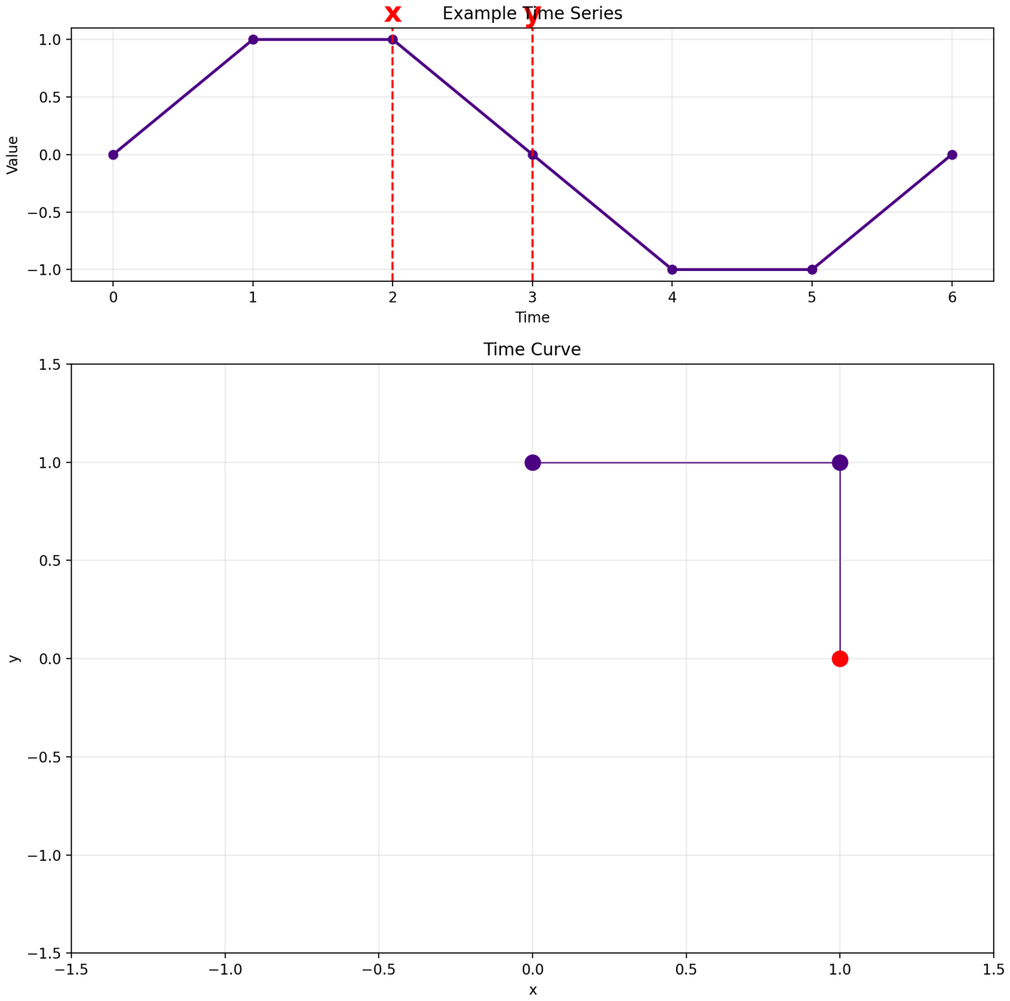
Time Curves (2)



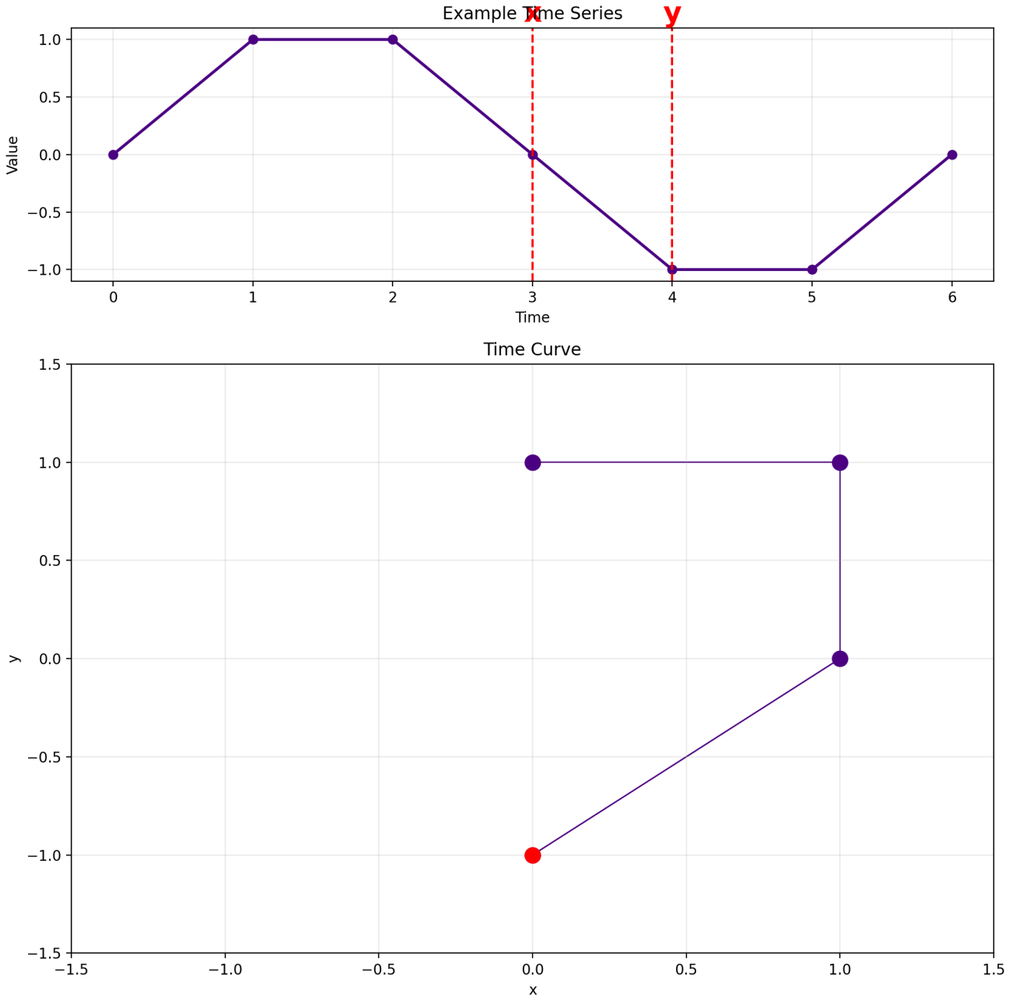
Time Curves (3)



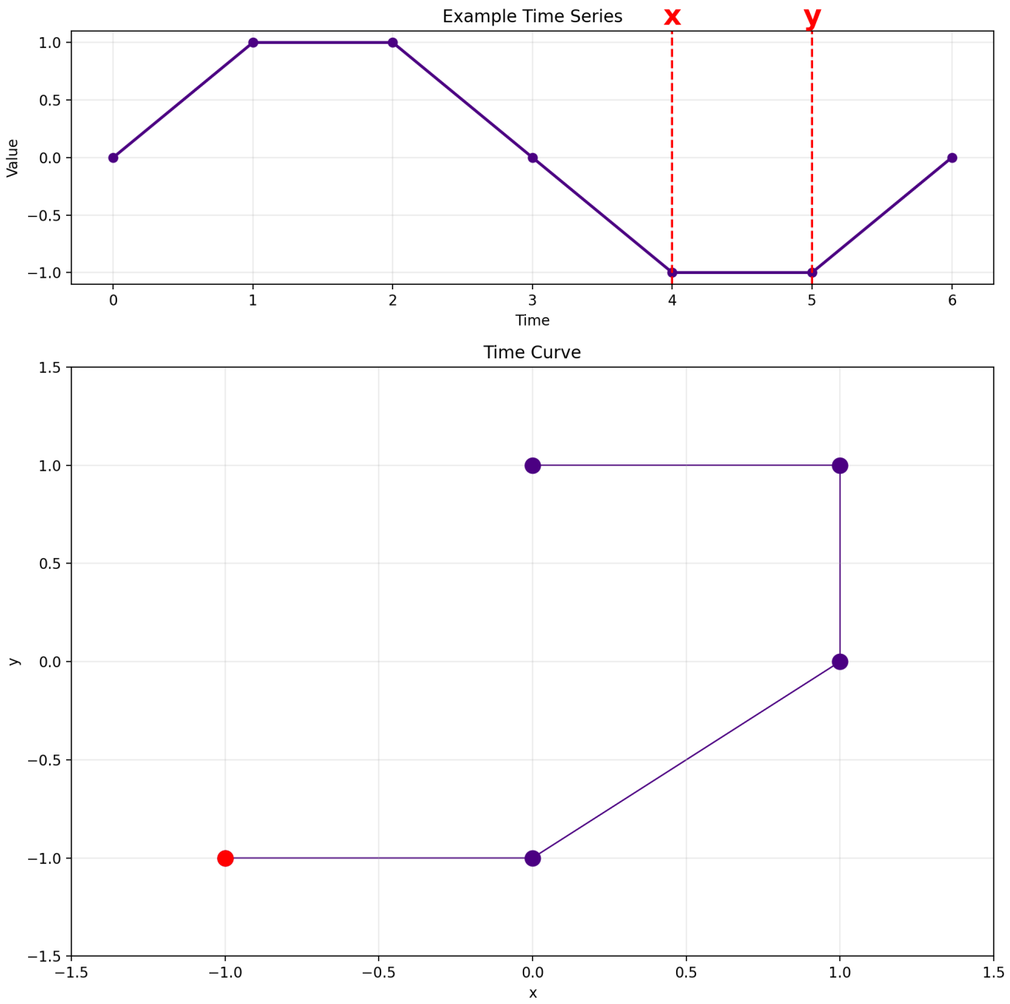
Time Curves (4)



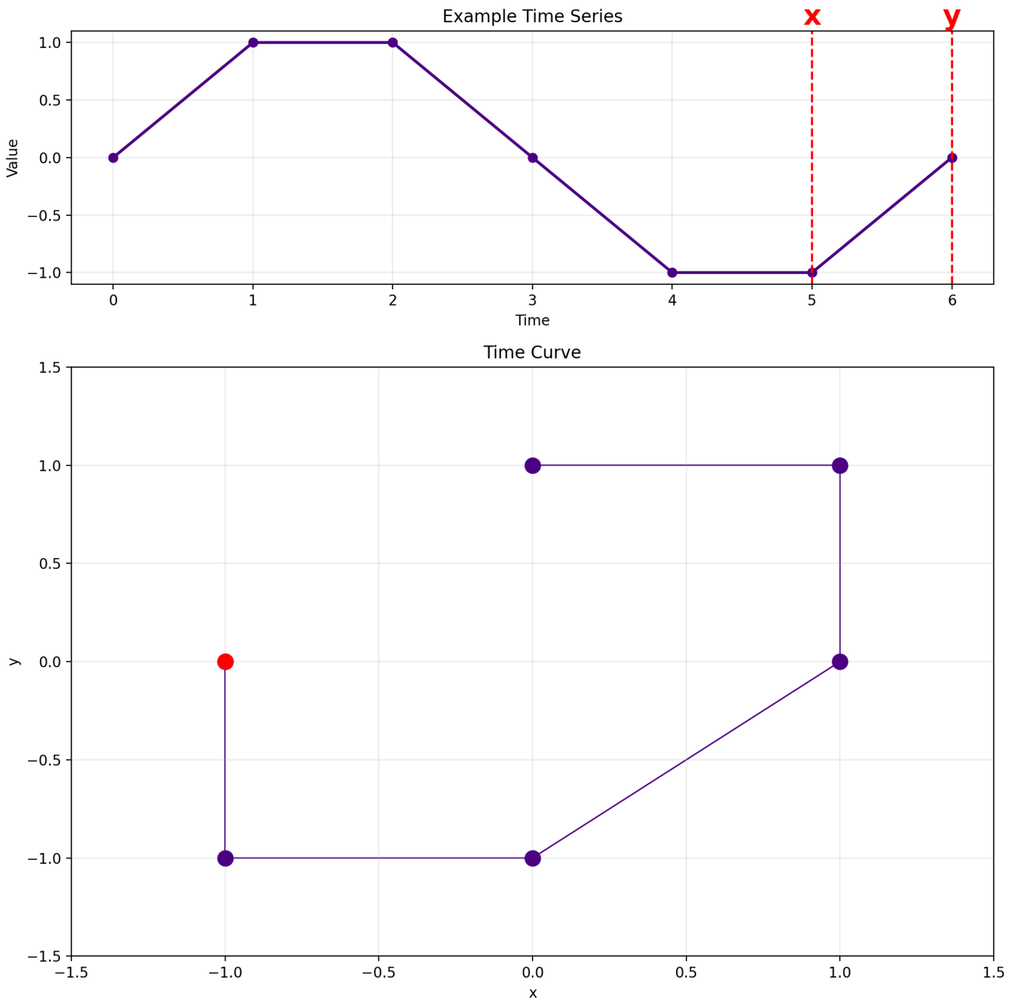
Time Curves (5)



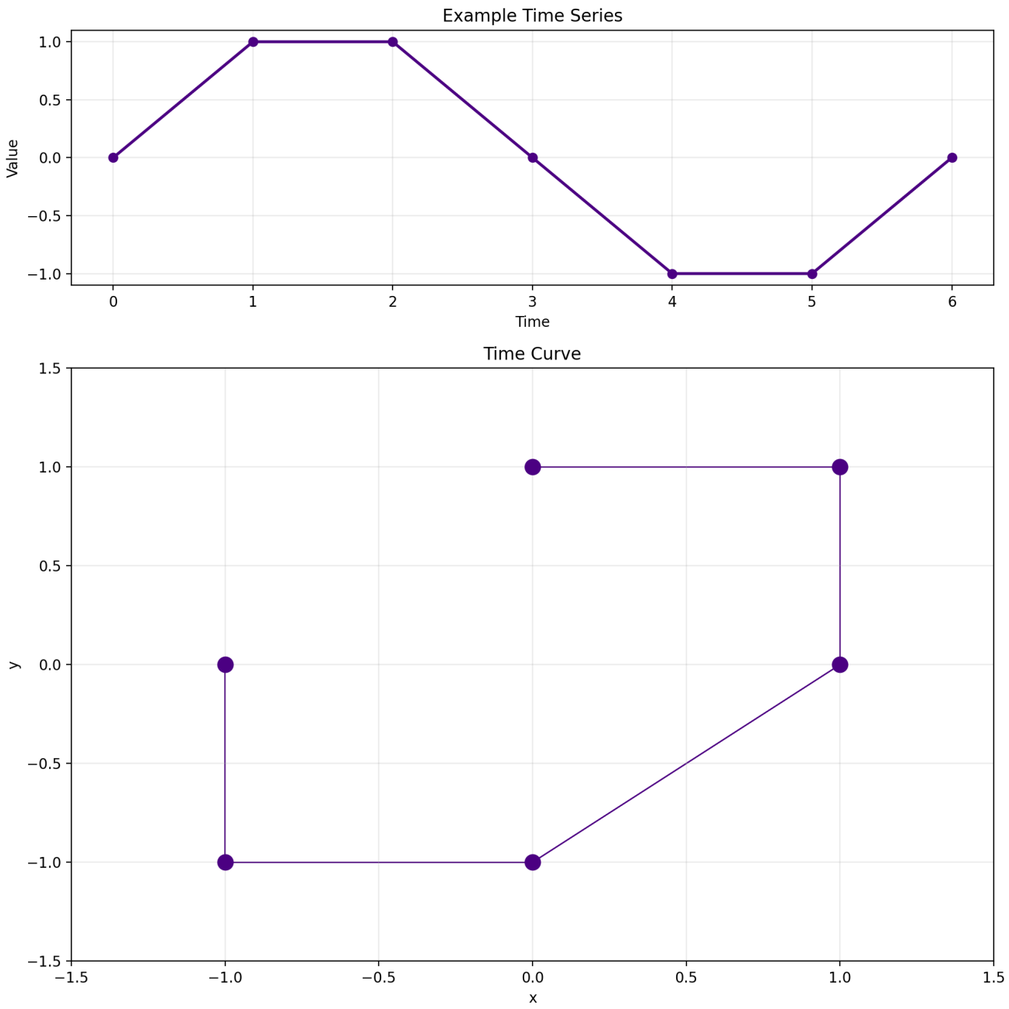
Time Curves (6)



Time Curves (7)



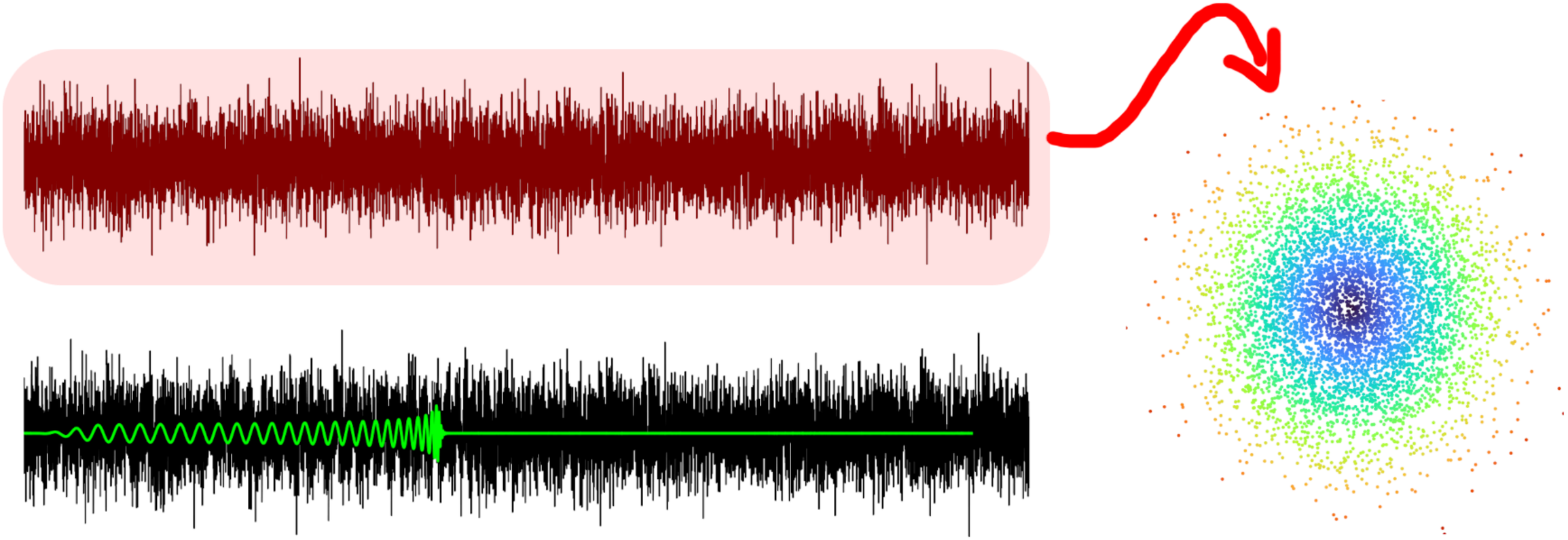
Time Curves (8)



What if $w > 2$?

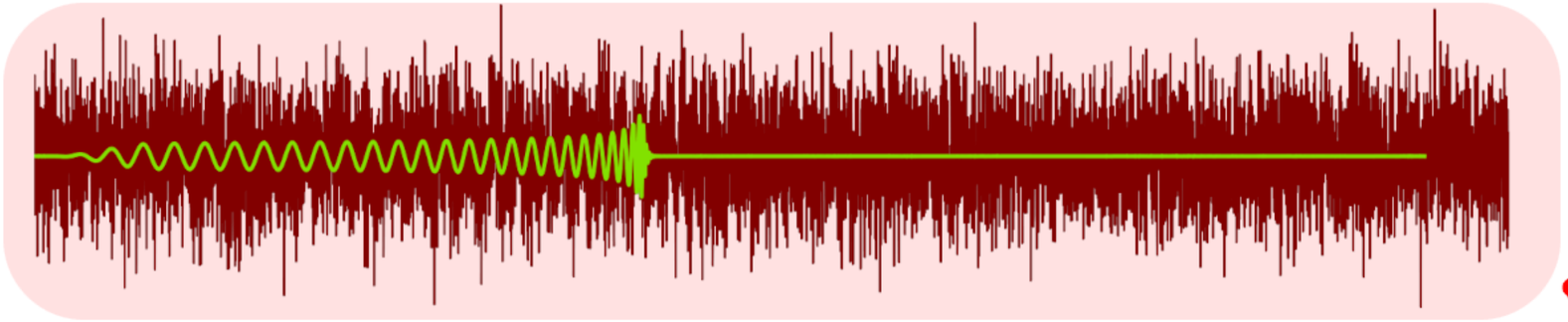
Apply PCA!

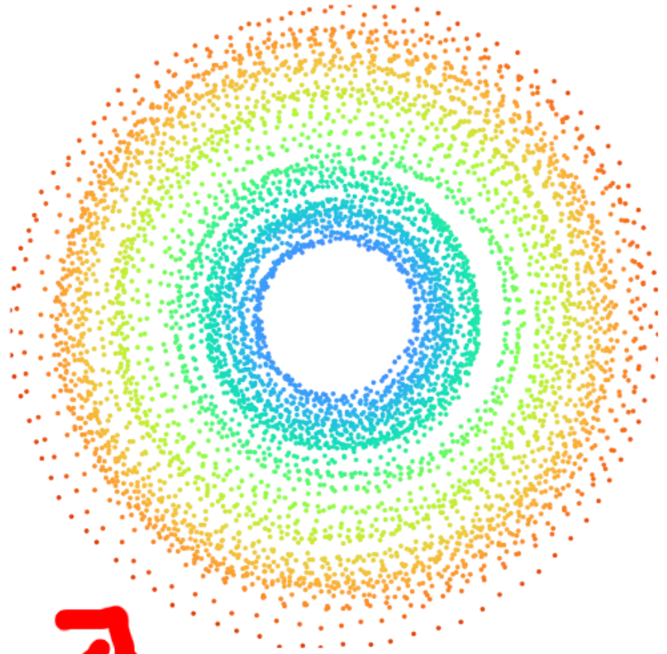
Noise is not exciting ...



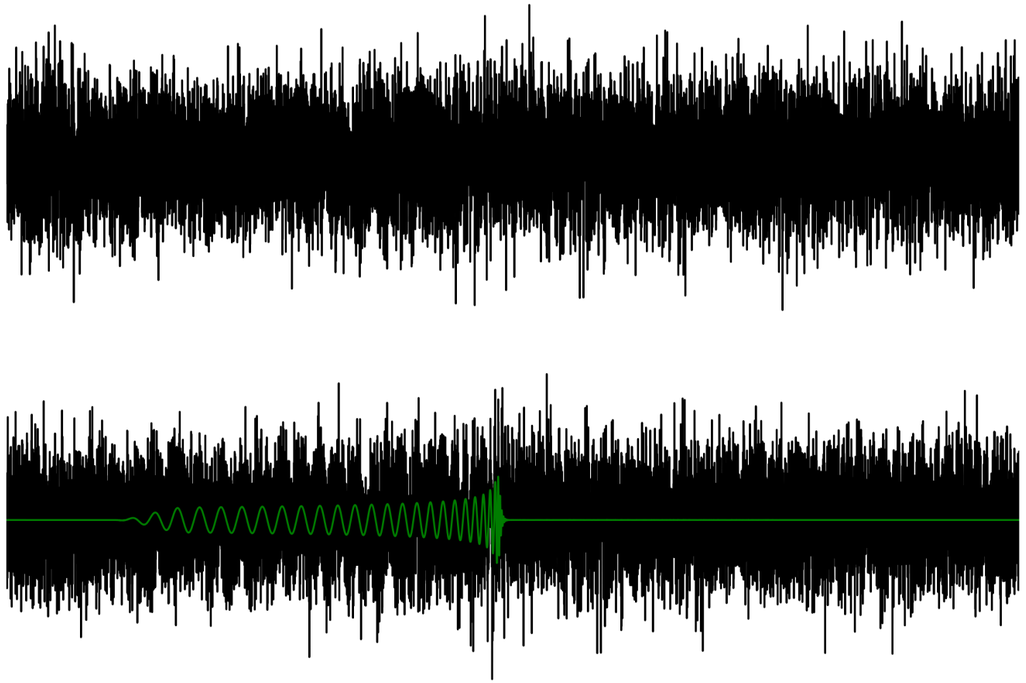
... but oscillations result in circles!

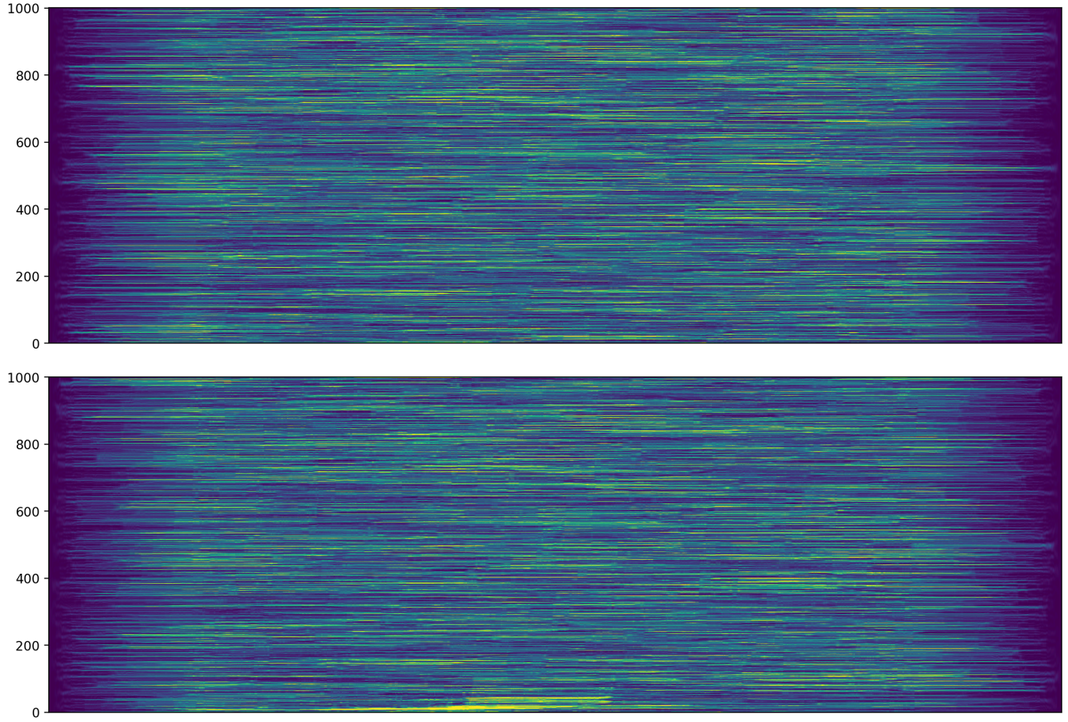




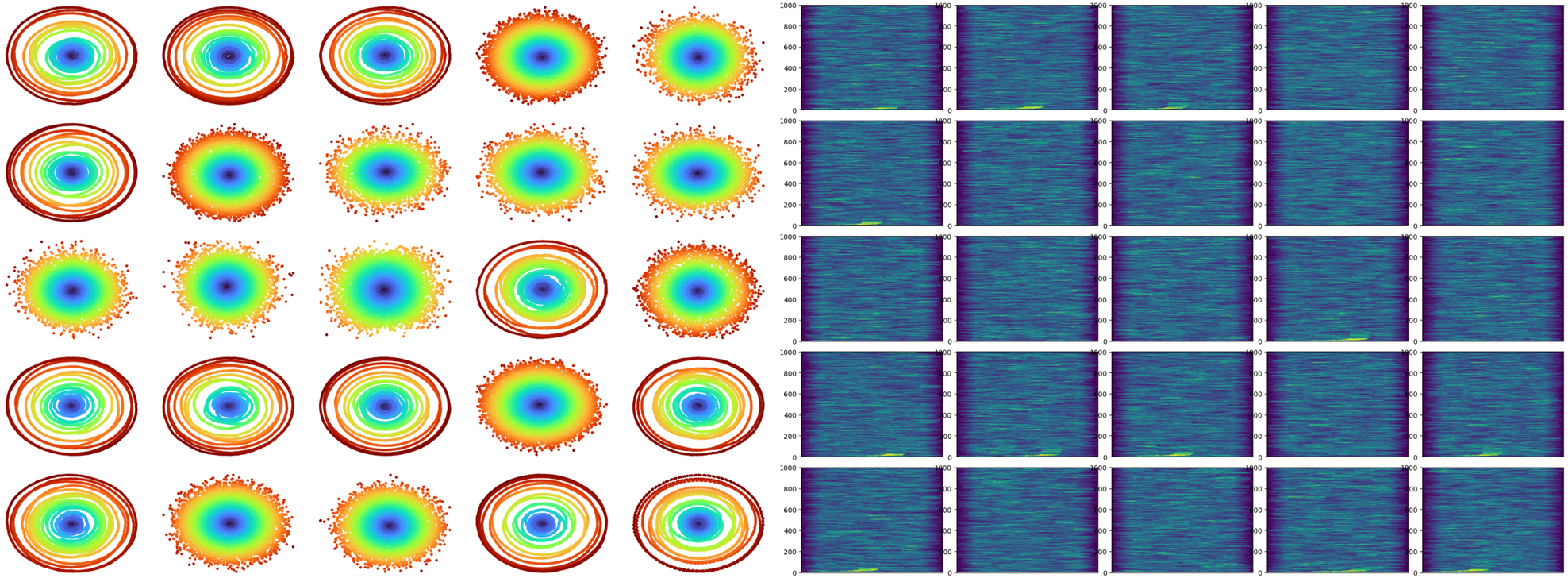


Yes, this is also detectable with spectrograms, but ...



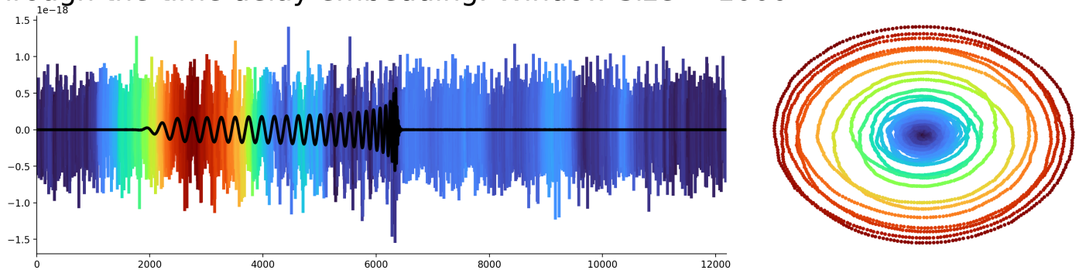


... the TDE is suitable to gain an overview!

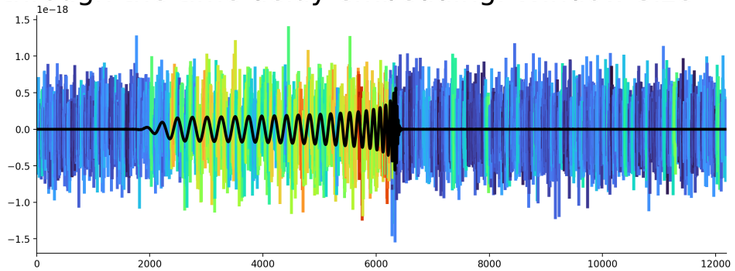


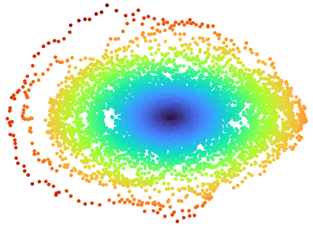
Why the coloring?

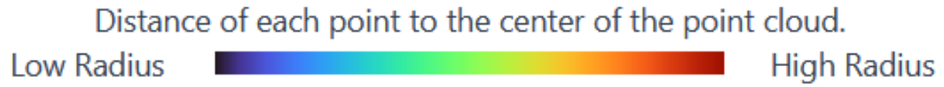
The hidden signal (black) in the noise is revealed through the time delay embedding. Window Size = 1000



The hidden signal (black) in the noise is revealed through the time delay embedding. Window Size = 70





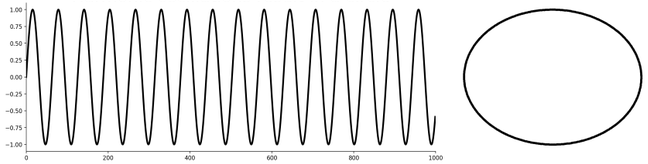


Through the turbo coloring, the fingerprint guides users towards vibrations within the signal.

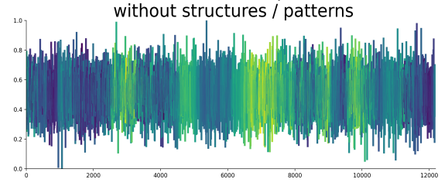
Press "Arrow Down" to see other colormaps

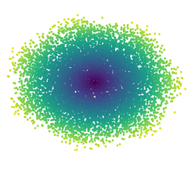
Viridis

Harmonic oscillations result in a circle

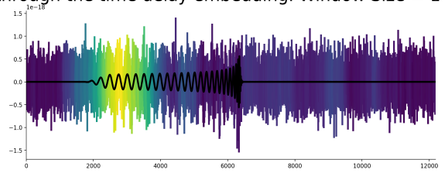


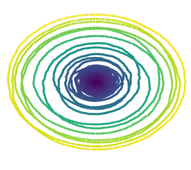
Pure noise results in a point cloud without structures / patterns





The hidden signal (black) in the noise is revealed through the time delay embedding. Window Size = 1000





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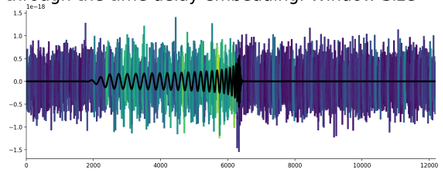
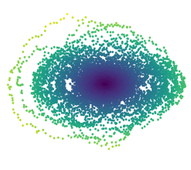
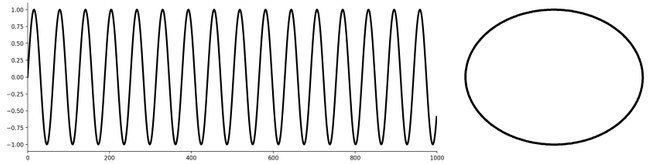


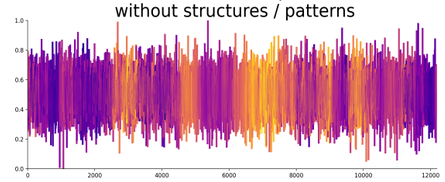


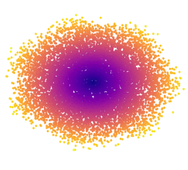
Plasma

Harmonic oscillations result in a circle

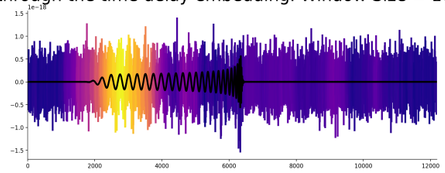


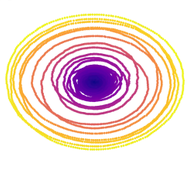
Pure noise results in a point cloud without structures / patterns



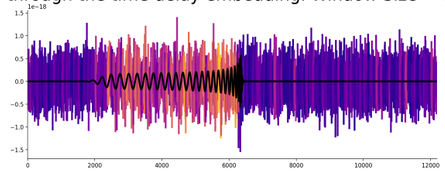


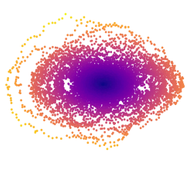
The hidden signal (black) in the noise is revealed through the time delay embedding. Window Size = 1000





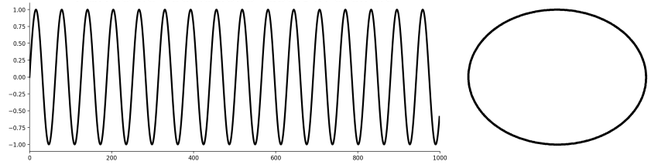
The hidden signal (black) in the noise is revealed through the time delay embedding. Window Size = 70



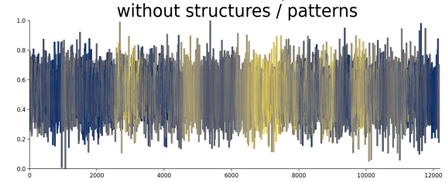


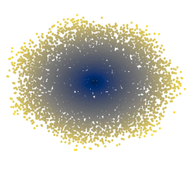
Cividis

Harmonic oscillations result in a circle

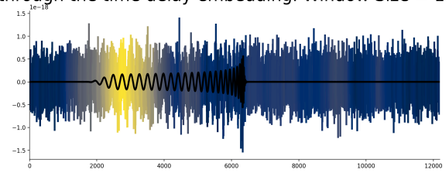


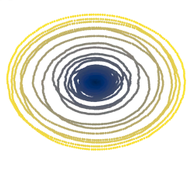
Pure noise results in a point cloud without structures / patterns



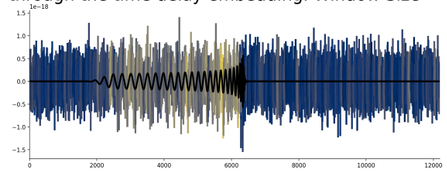


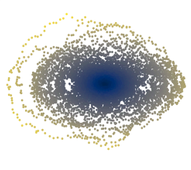
The hidden signal (black) in the noise is revealed through the time delay embedding. Window Size = 1000





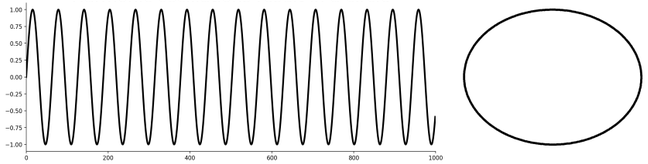
The hidden signal (black) in the noise is revealed through the time delay embedding. Window Size = 70



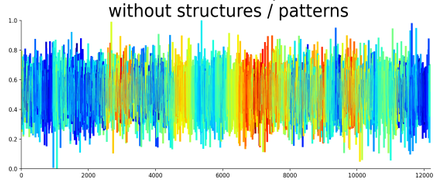


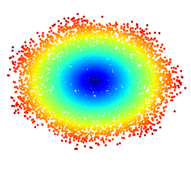
Jet

Harmonic oscillations result in a circle

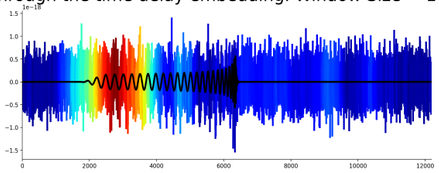


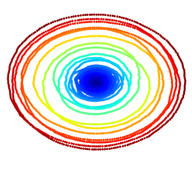
Pure noise results in a point cloud without structures / patterns



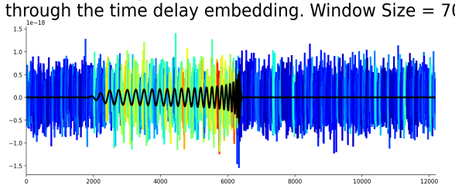


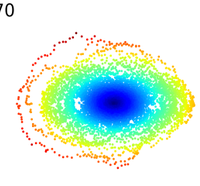
The hidden signal (black) in the noise is revealed through the time delay embedding. Window Size = 1000





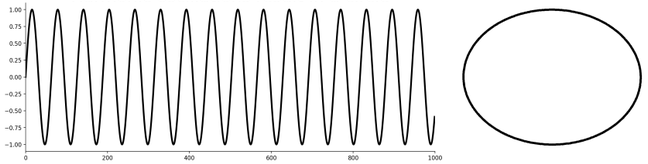
The hidden signal (black) in the noise is revealed through the time delay embedding. Window Size = 70



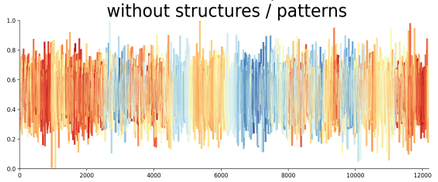


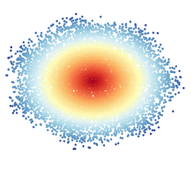
RdYlBu

Harmonic oscillations result in a circle

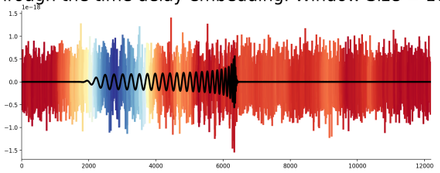


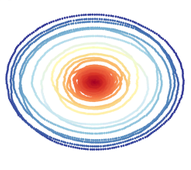
Pure noise results in a point cloud without structures / patterns



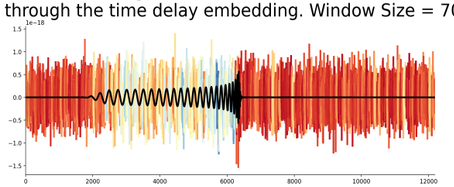


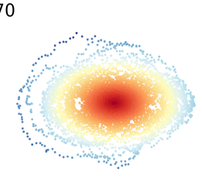
The hidden signal (black) in the noise is revealed through the time delay embedding. Window Size = 1000





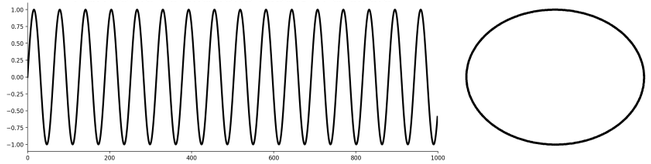
The hidden signal (black) in the noise is revealed through the time delay embedding. Window Size = 70



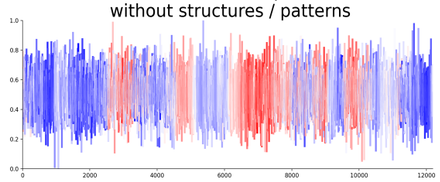


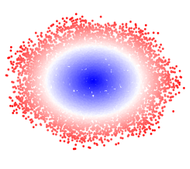
bwr

Harmonic oscillations result in a circle

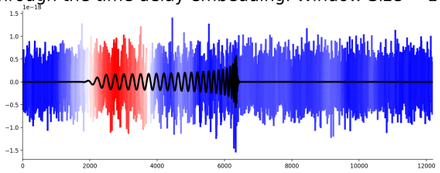


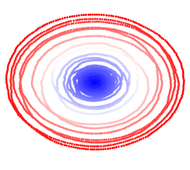
Pure noise results in a point cloud without structures / patterns



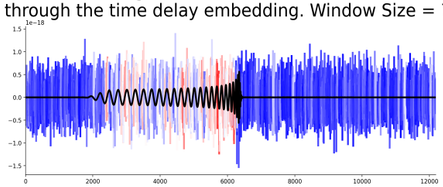


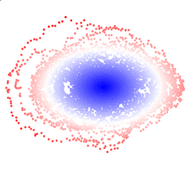
The hidden signal (black) in the noise is revealed through the time delay embedding. Window Size = 1000



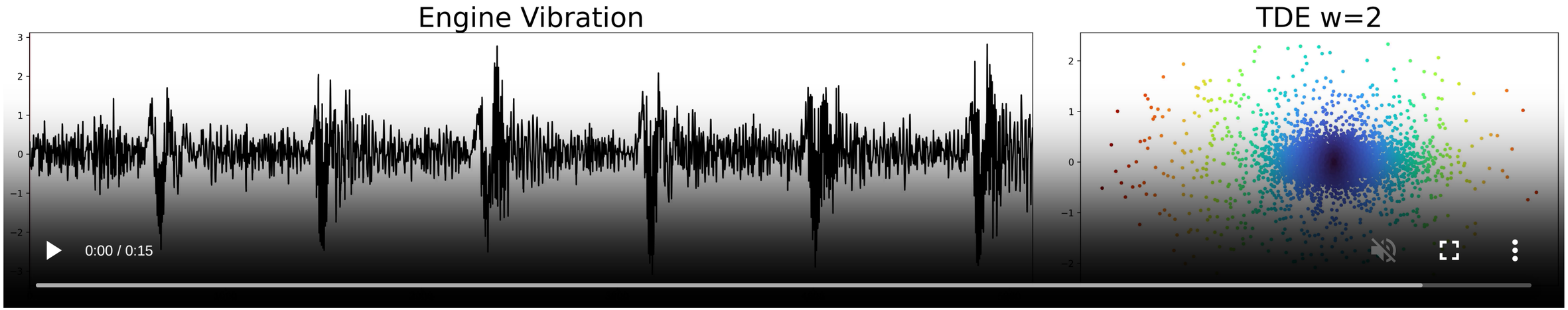


The hidden signal (black) in the noise is revealed through the time delay embedding. Window Size = 70



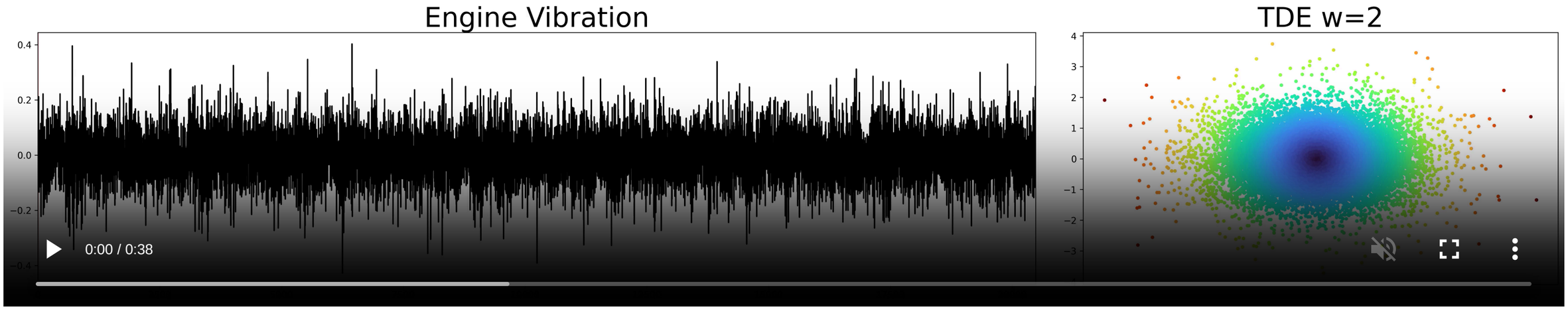


The only parameter: Window Size



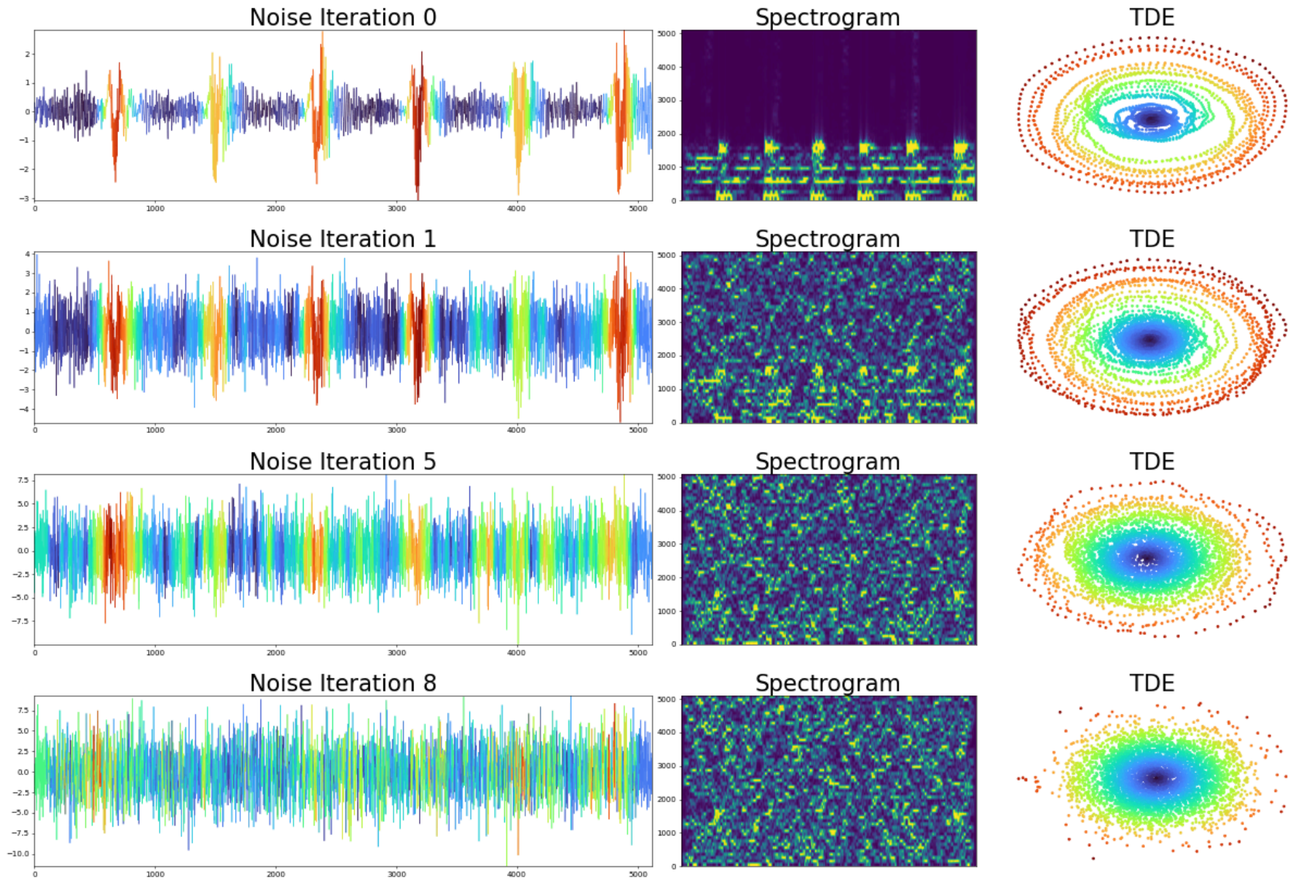
Large window sizes in general advisable

The only parameter: Window Size

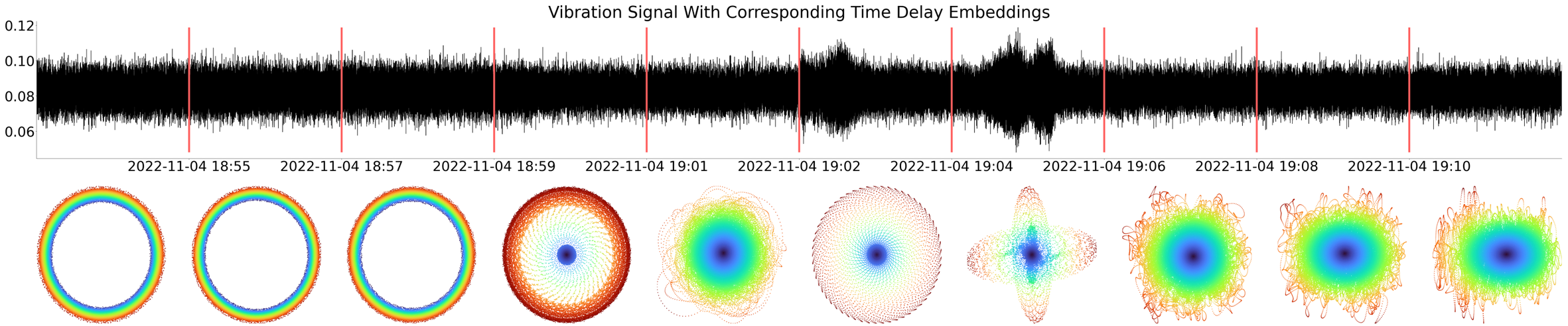


Large window sizes in general advisable

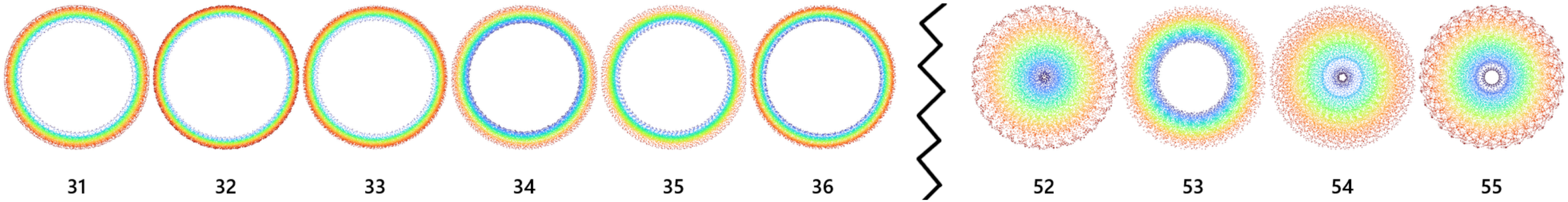
TDE under Noise Influence



We can use the fingerprints to observe change ...



... and to observe wear in a machine.



The big problem with vibrations:

Large data volumes

High sampling rate = large data volumes

Example: 30 kHz (30 000 samples per second)

Assumption: 8 byte per sample

After one minute: 14,4 MB

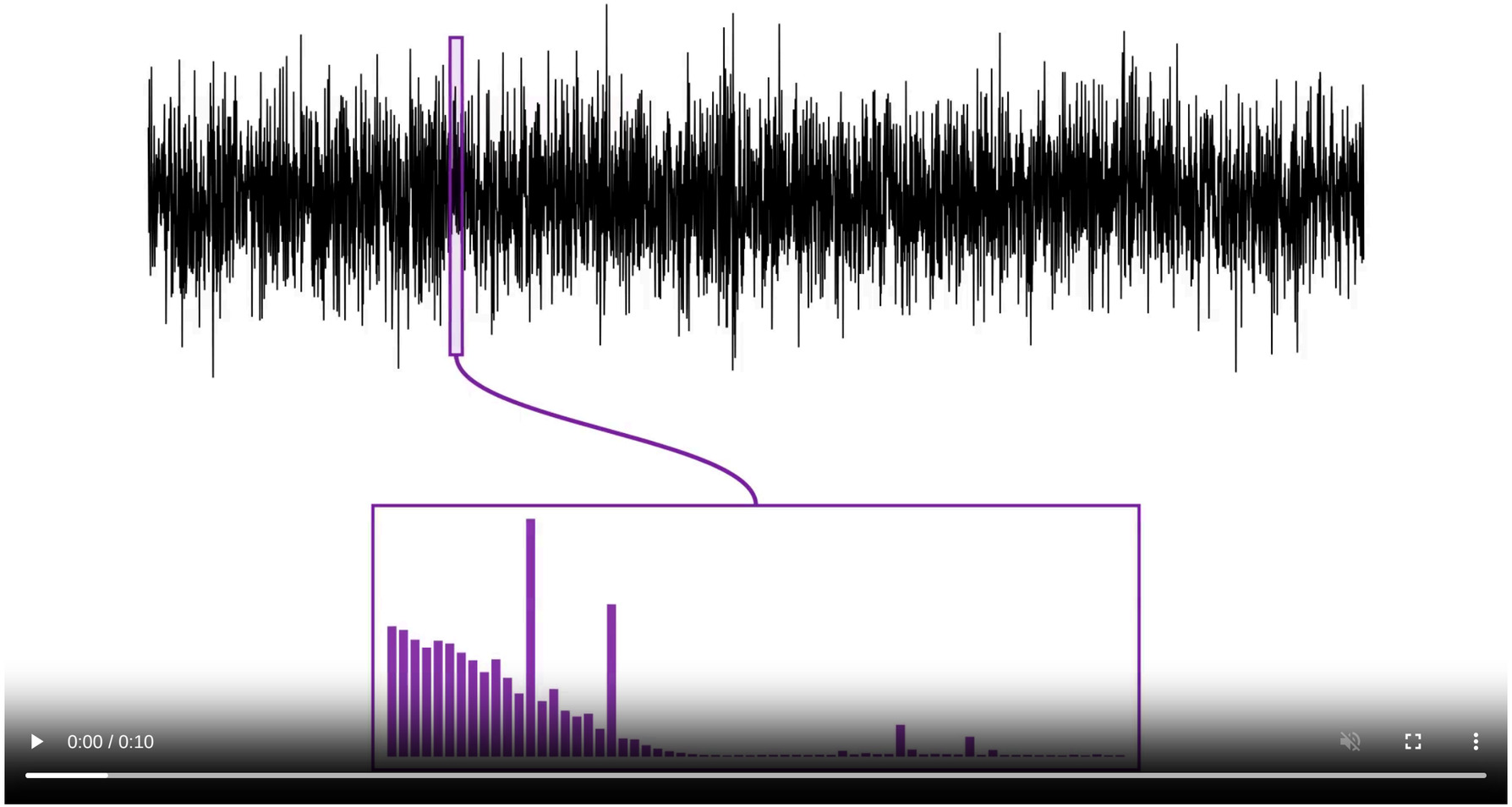
After one hour: 864 MB

After one day: 20,7 GB

After a year: 7,5 TB

How do domain experts approach this?

Signal Analysis via Manual Window Positioning



How about 10TB?

Manual scanning is tedious!

Progressive Visual Segmentation of Vibration Signals to Detect Change Points

J. Rakuschek[1], J. Schmidt[1,2], U. Schlegel[3], M. Posch[4], J. Isopp[4], and T. Schreck[1]

[1] TU Graz, Institute of Visual Computing, Austria
[2] TU Wien, Institute of Visual Computing & Human-Centered Technology, Austria
[3] LMU Munich & Munich Center for Machine Learning, Germany
[4] Messfeld GmbH, Austria

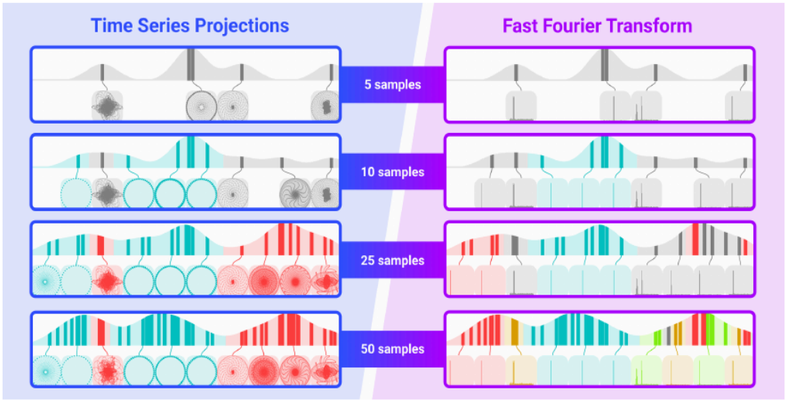
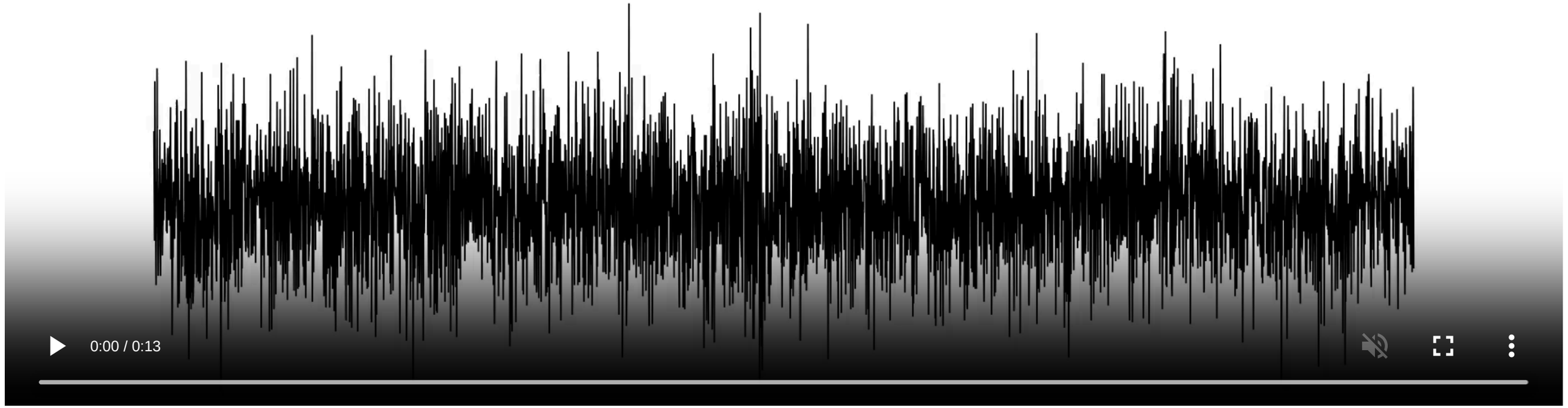


Figure 1: *Our progressive visual analytics approach samples from a vibration signal and represents each sample either as a time series projection (left) or as a fast Fourier transform (right). The representations are used to visualize key properties of the signal windows and act as feature descriptors to incrementally cluster the signal, resulting in a segmentation that improves over time.*

VMV 2026

Our approach: Sampling

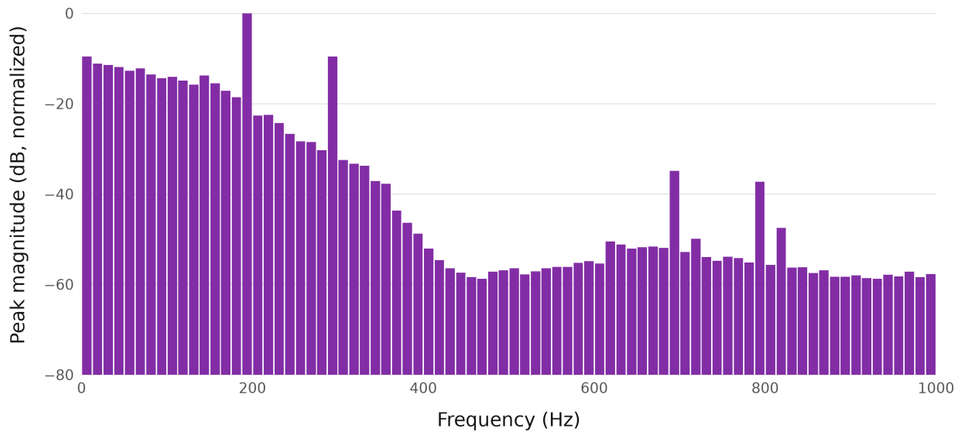
We iteratively construct an overview



In many cases a small fraction of the data suffices!

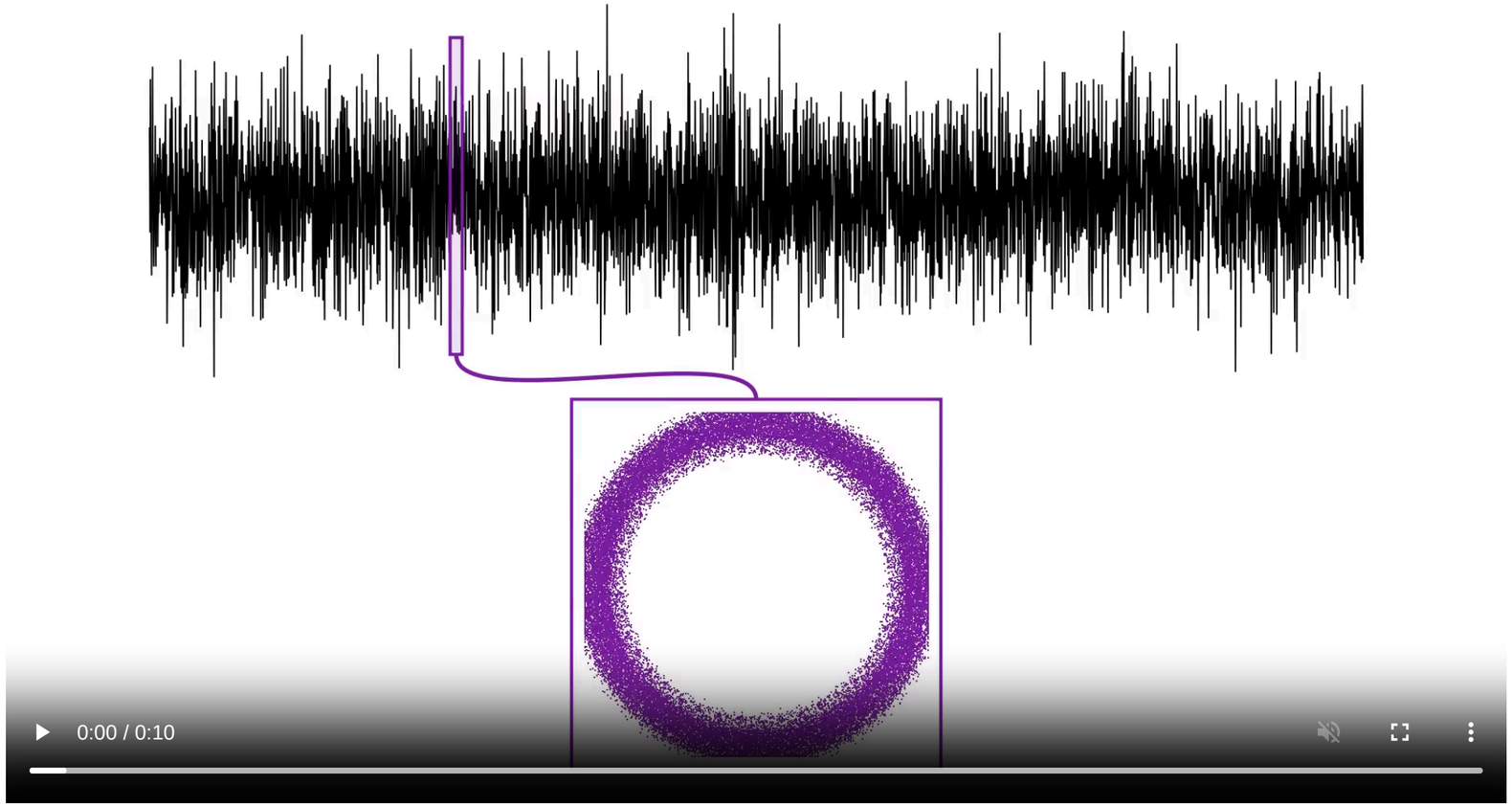
Do we need to save the full signal?

No!



We only save a FFT histogram per sample into the database.

Also the time series projections are feasible!



We only need to save the first two eigenvectors and project on demand!

We start with an empty timeline



Next we randomly draw samples



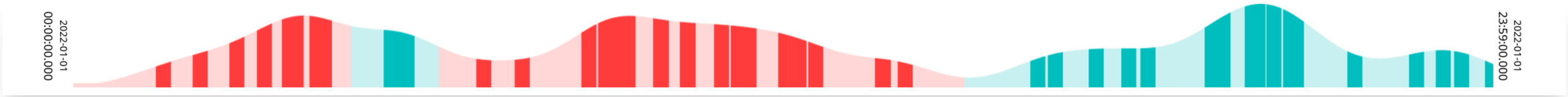
The subsequences are grouped by similarity



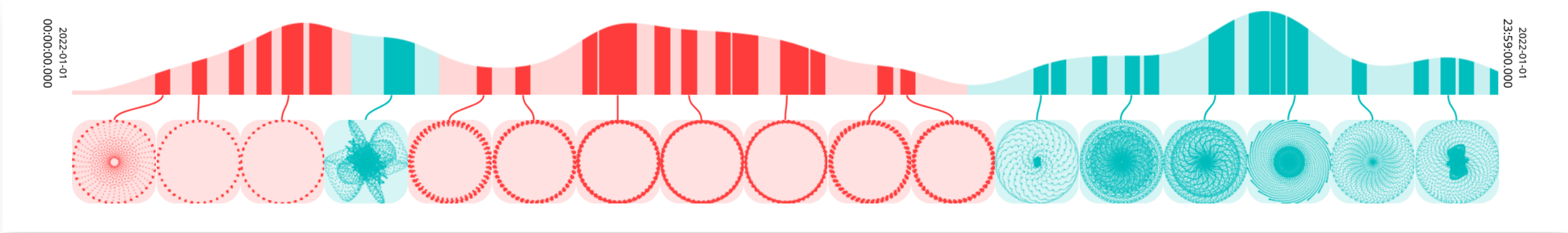
The background is colored by closest label



The height is adjusted based on the density



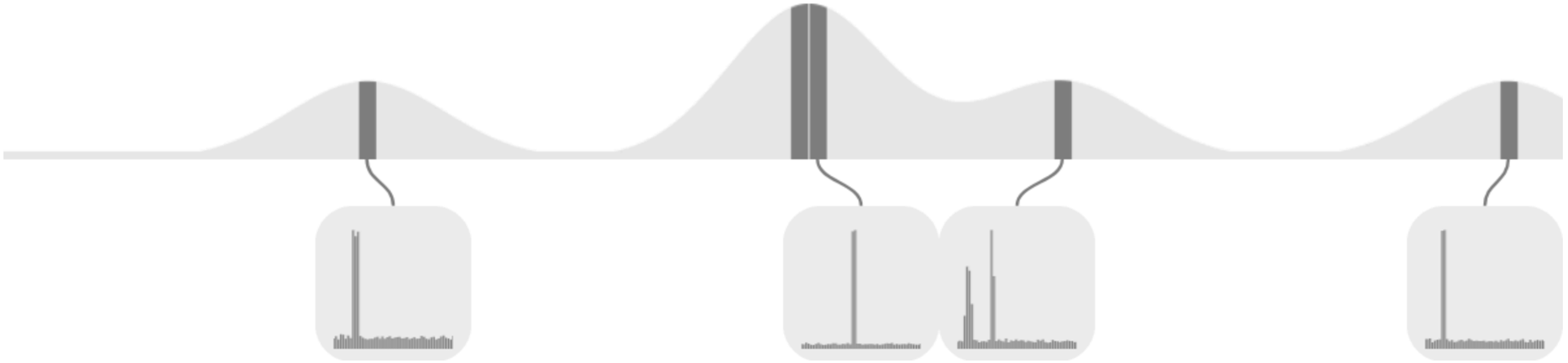
For a subset of samples we can show representations as thumbnails.



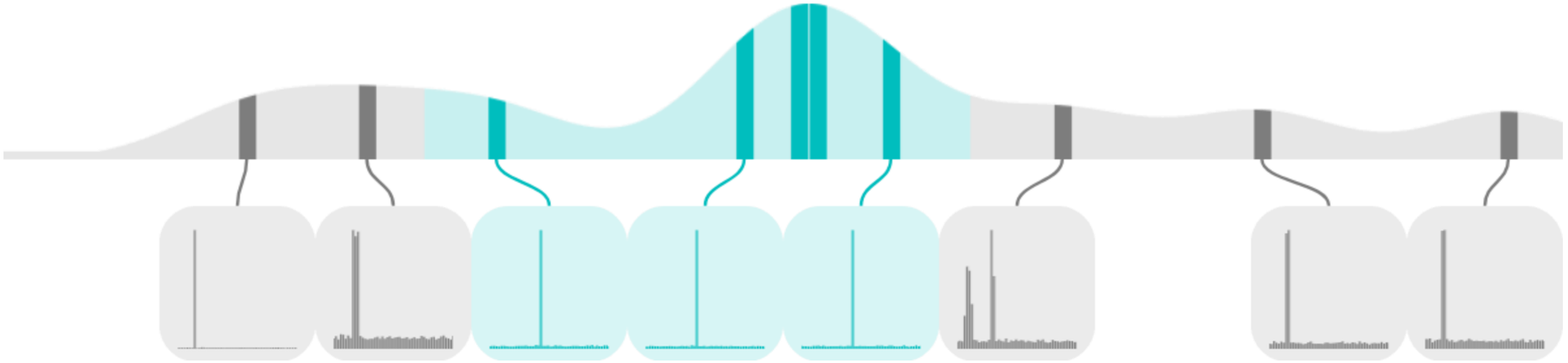
We obtain a segmentation

With more samples, the segmentation becomes more accurate.

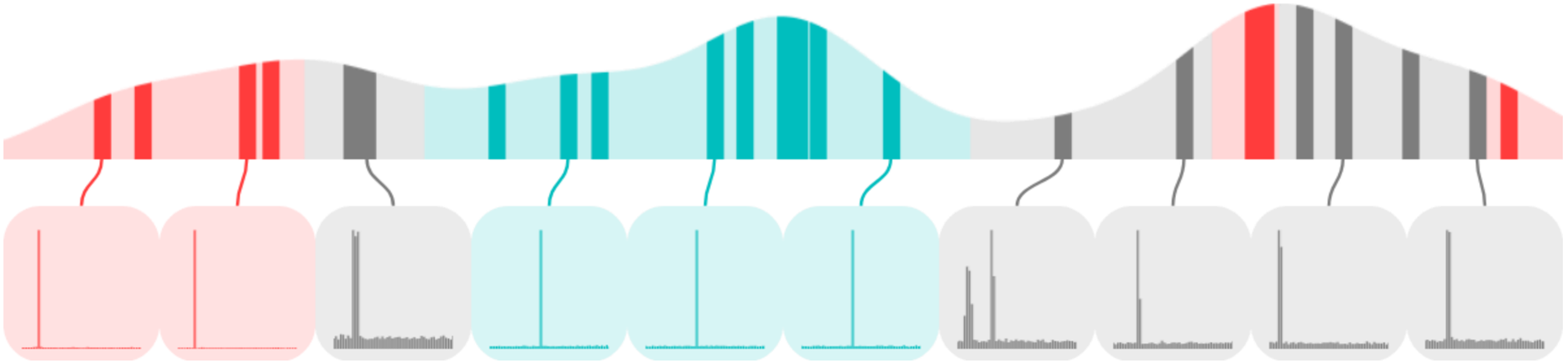
5 samples



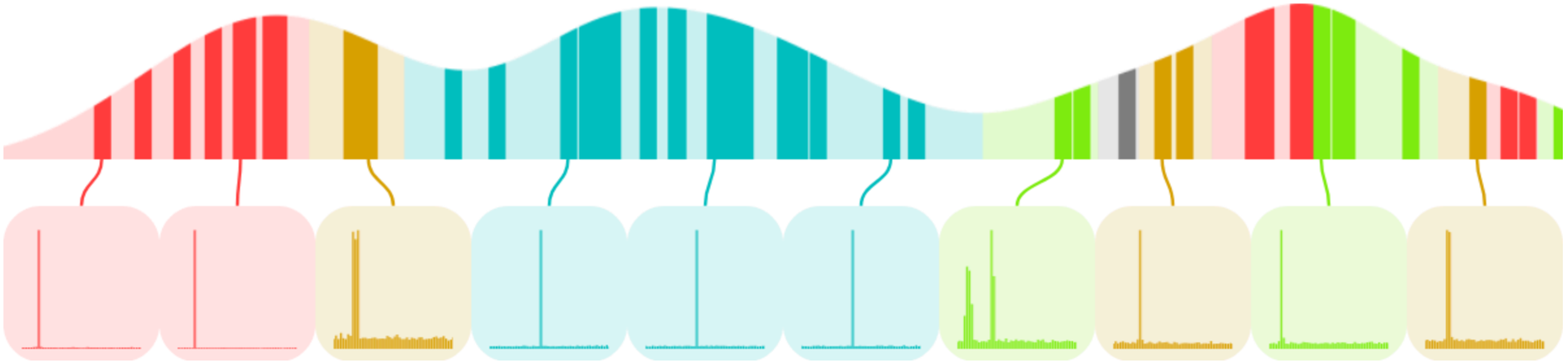
10 samples



25 samples



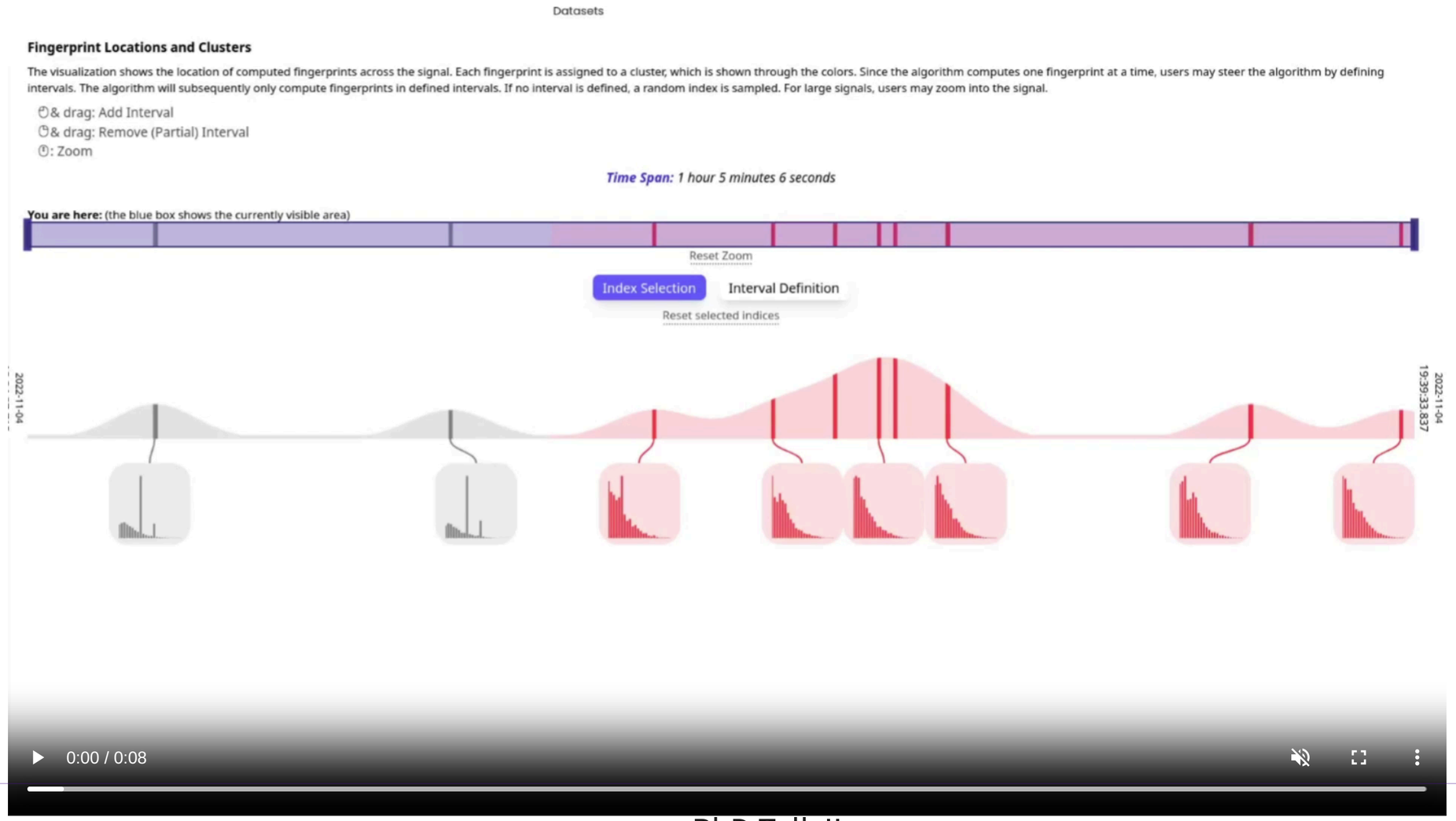
50 samples



How can users steer the sampling?

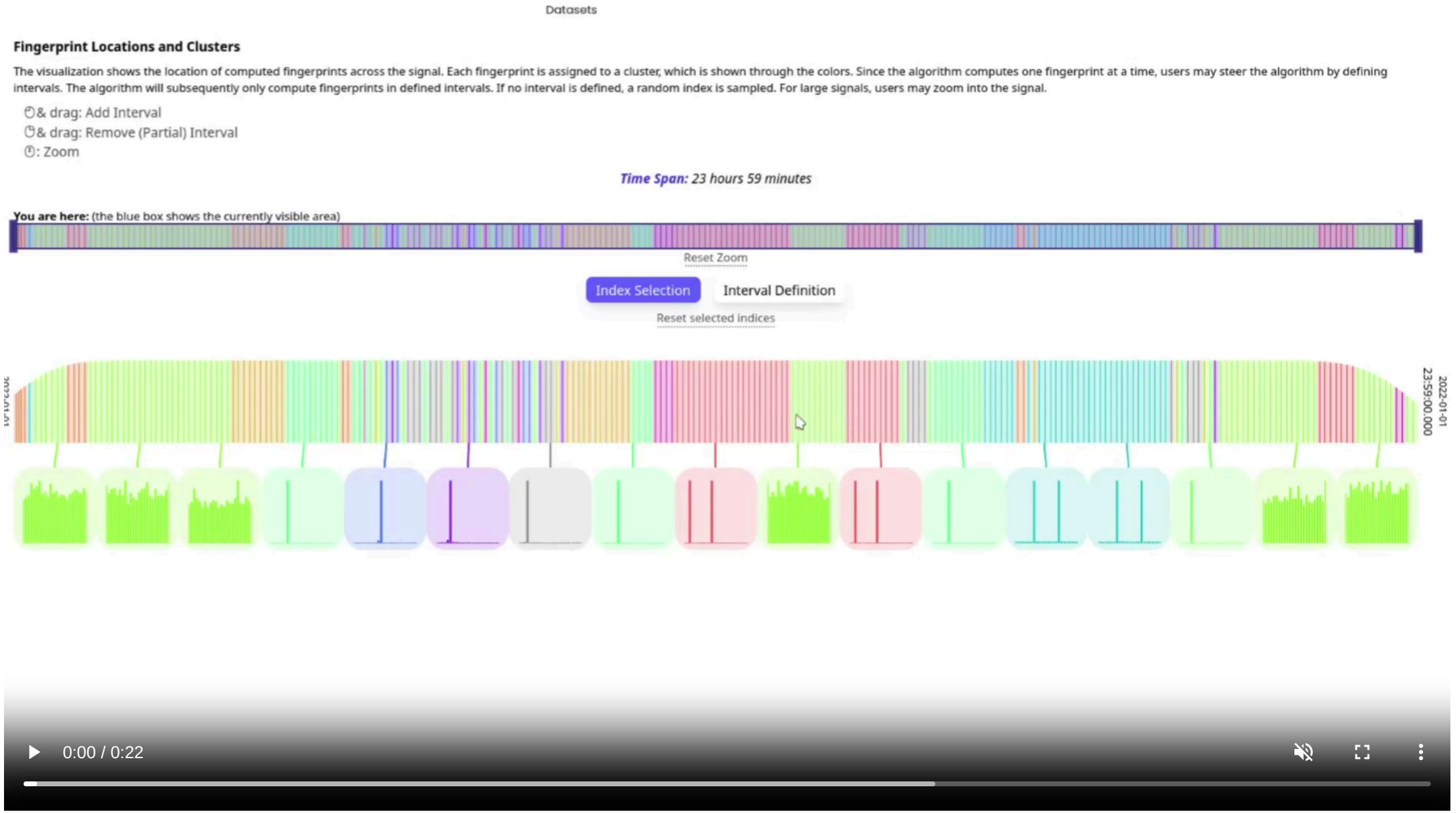
Defining intervals to constrain the sampling

(Accelerated video footage)

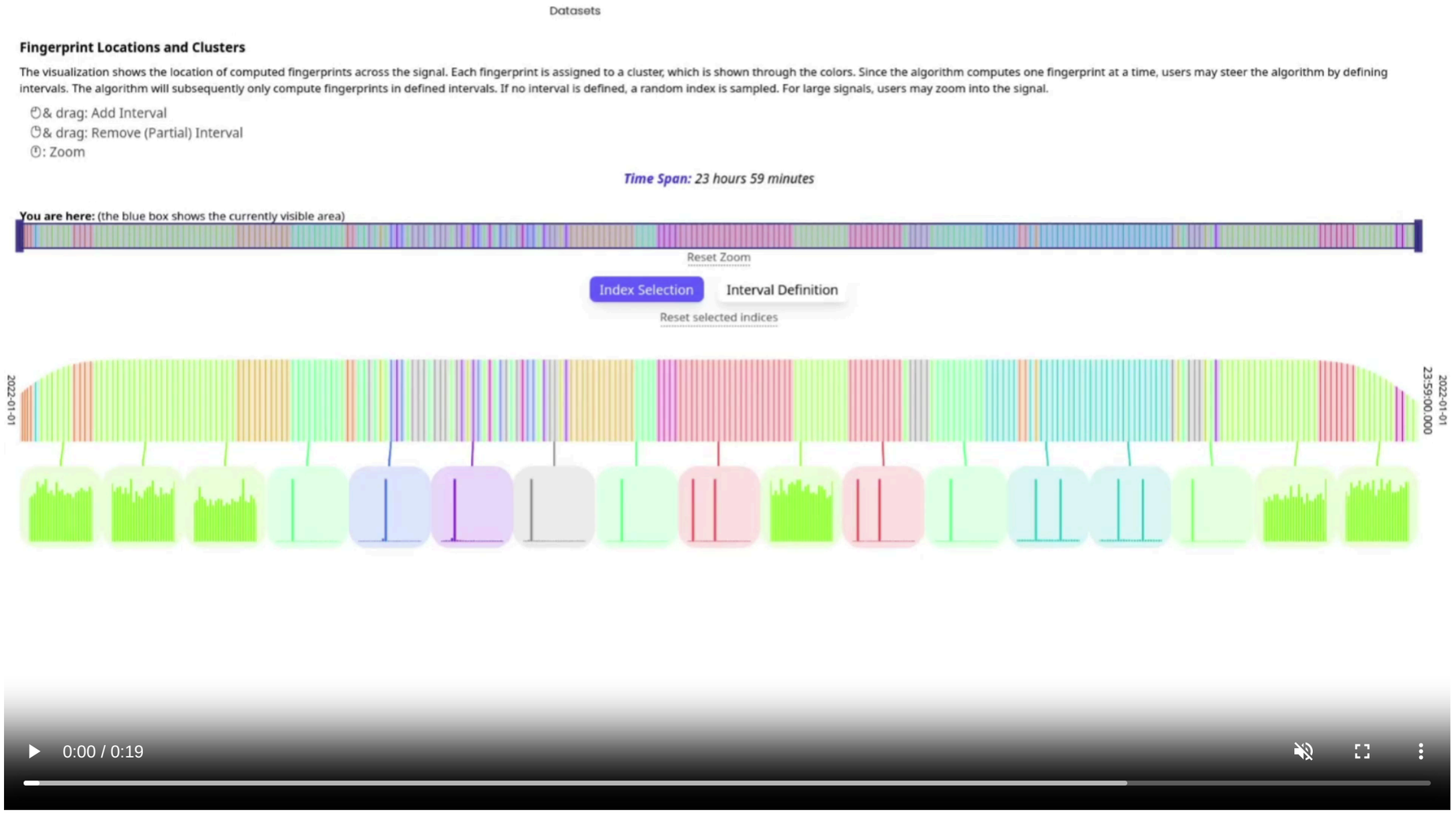


How can users explore the result?

Classic zooming and panning

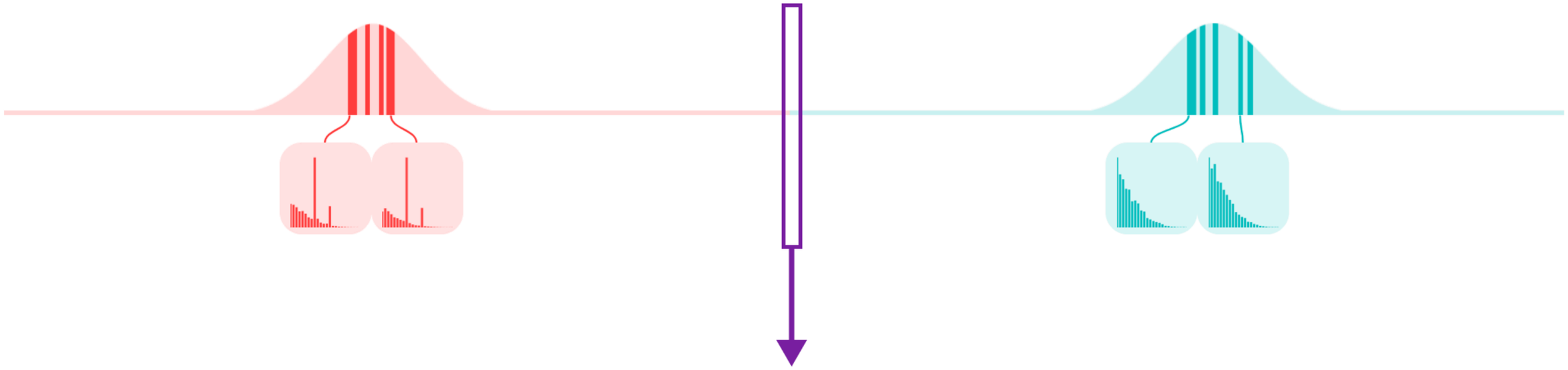


Inspecting samples in detail



Other sampling strategies

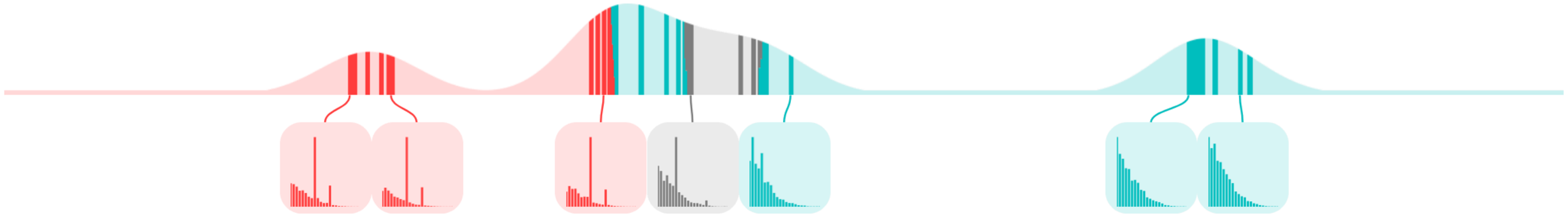
Binary Sampling (1)



Sample between different segments

Binary Sampling (2)

The result: Sharp boundaries

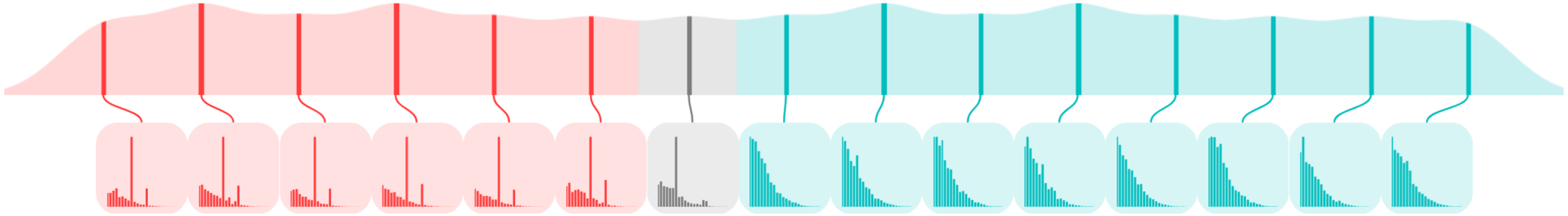


Gap Filling (1)



Gap Filling (2)

The result is a uniform distribution of samples



Linear Sampling

Pick samples in chronological order



(Accelerated video footage)

Formative Evaluation (1)

With two **domain experts** from the field of vibration analysis

Round 1 / 3

Discussion and Requirements

Formative Evaluation (2)

Round 2 / 3

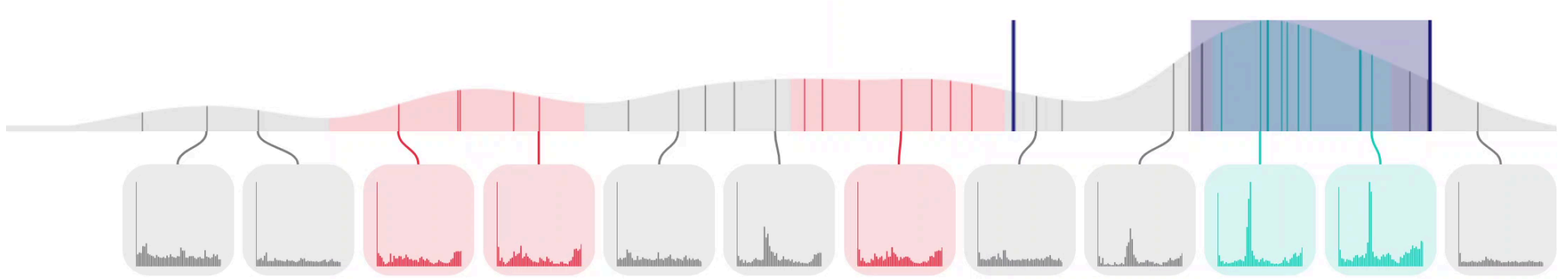
- Experts used the system
- Identify a change point
- Feedback

Formative Evaluation (3)

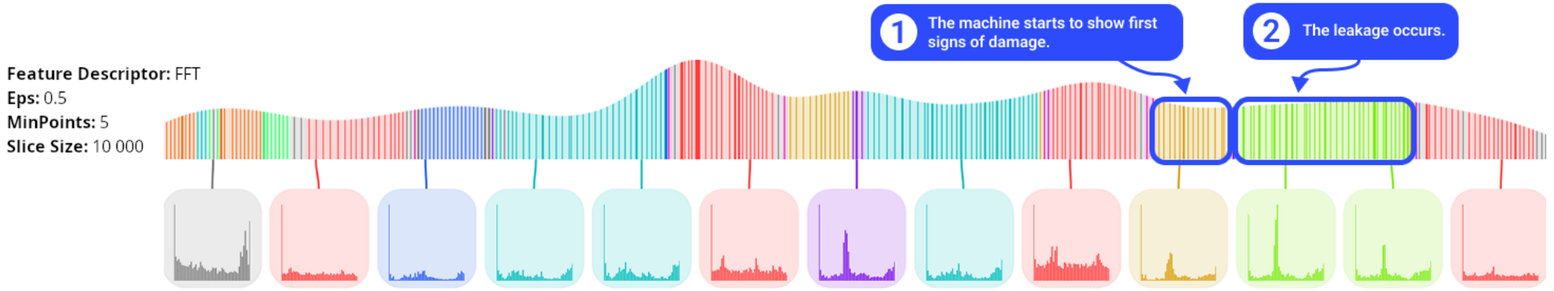
Round 3 / 3

- Experts used own dataset.
- Tried to replicate a finding.
- Successfully used system to identify leakage in a machine.

Early analysis results:

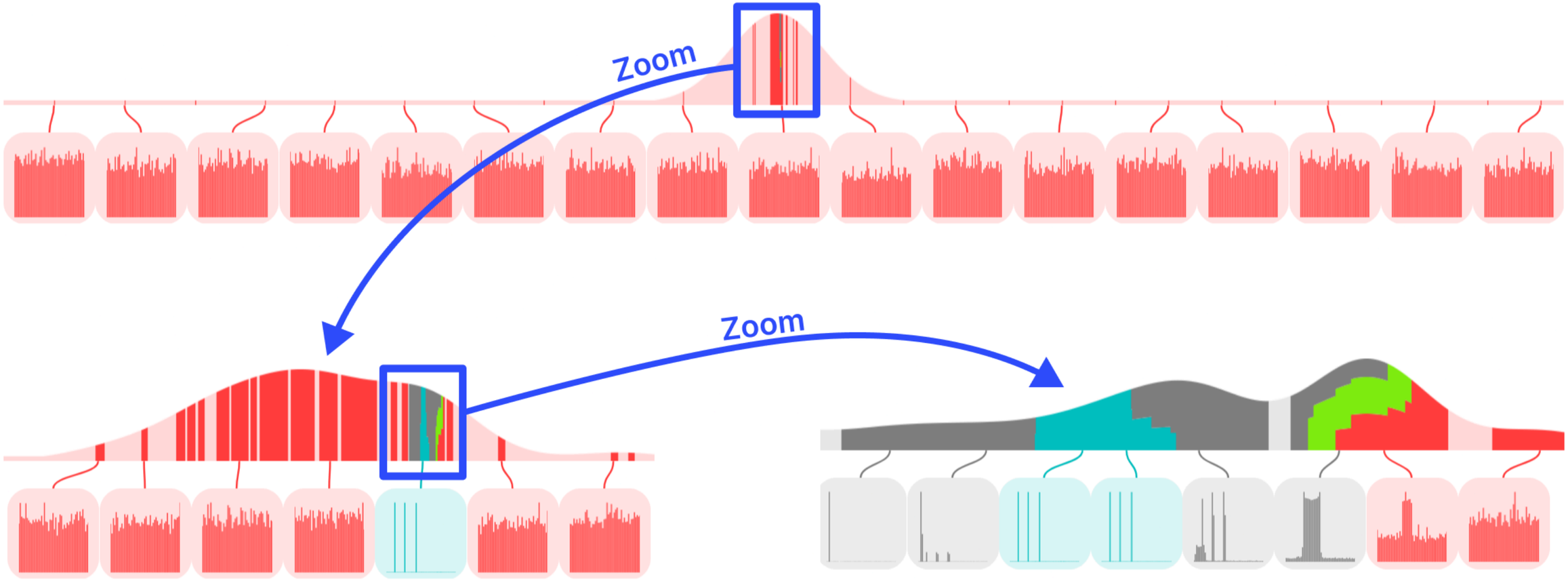


Final analysis results:

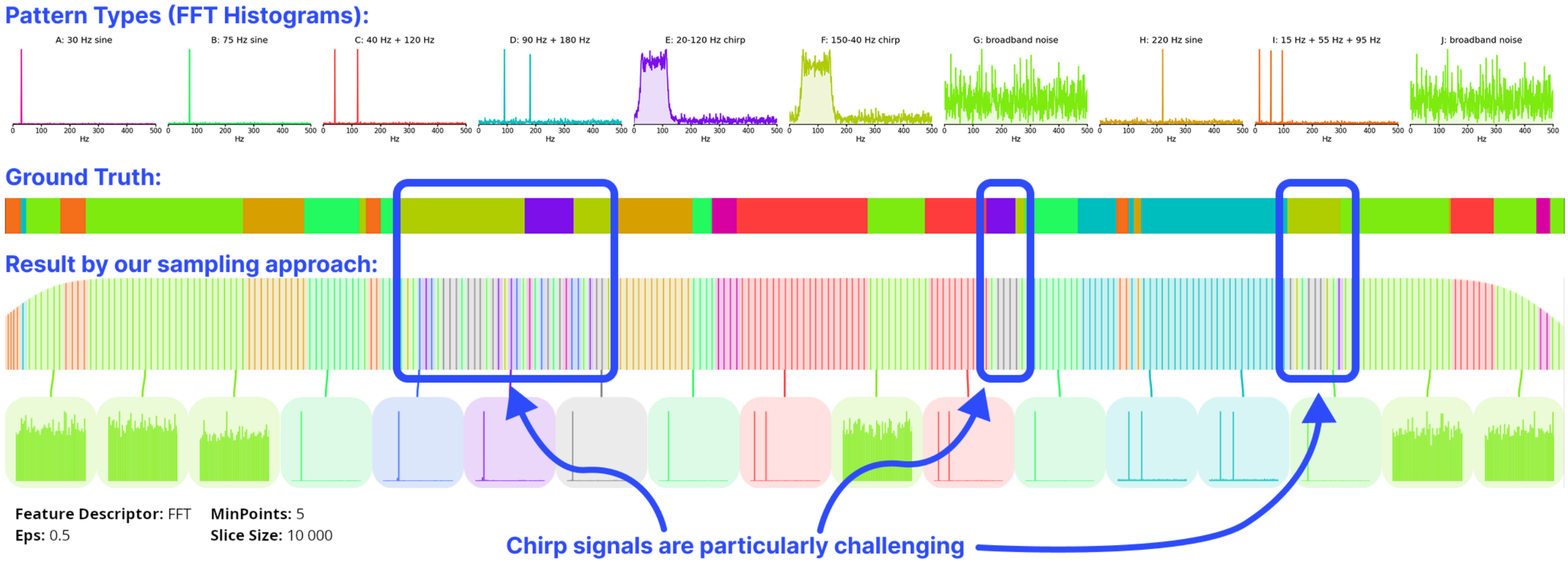


Where does it not work?

Small patterns (e.g. Anomalies) can be hard to detect

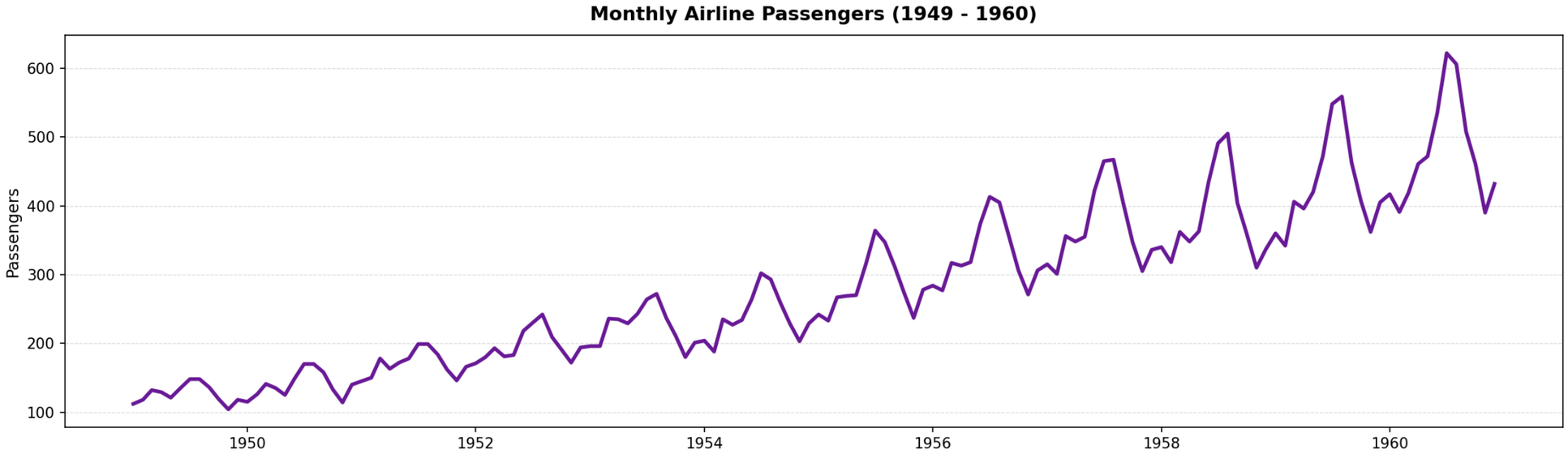


Chirp signals are challenging

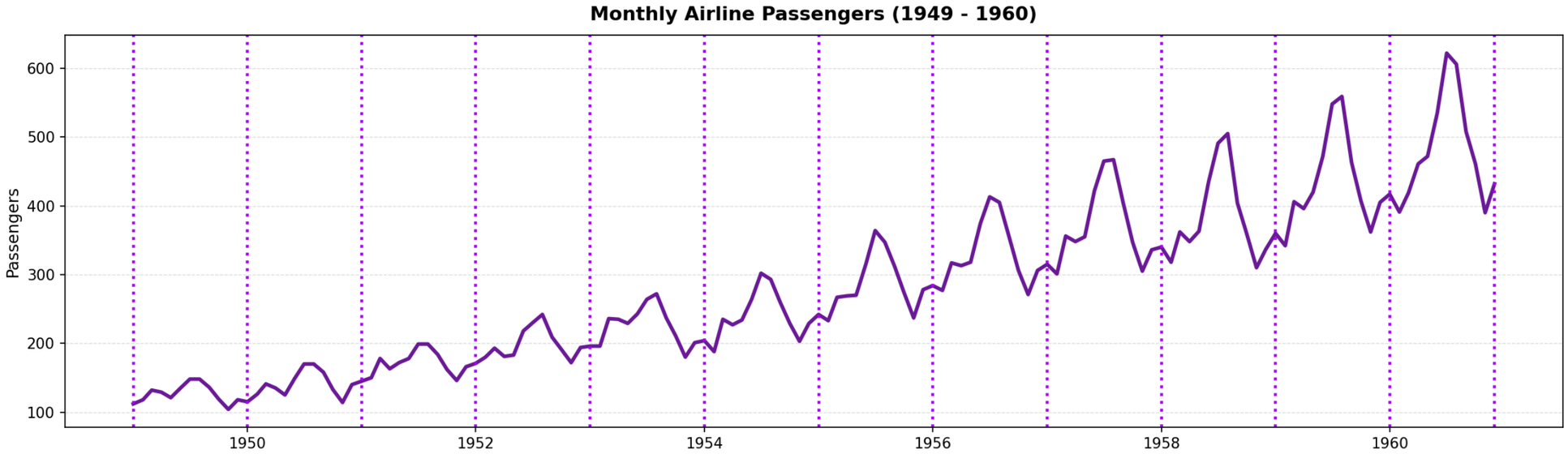


Visualizing Periodic Time Series

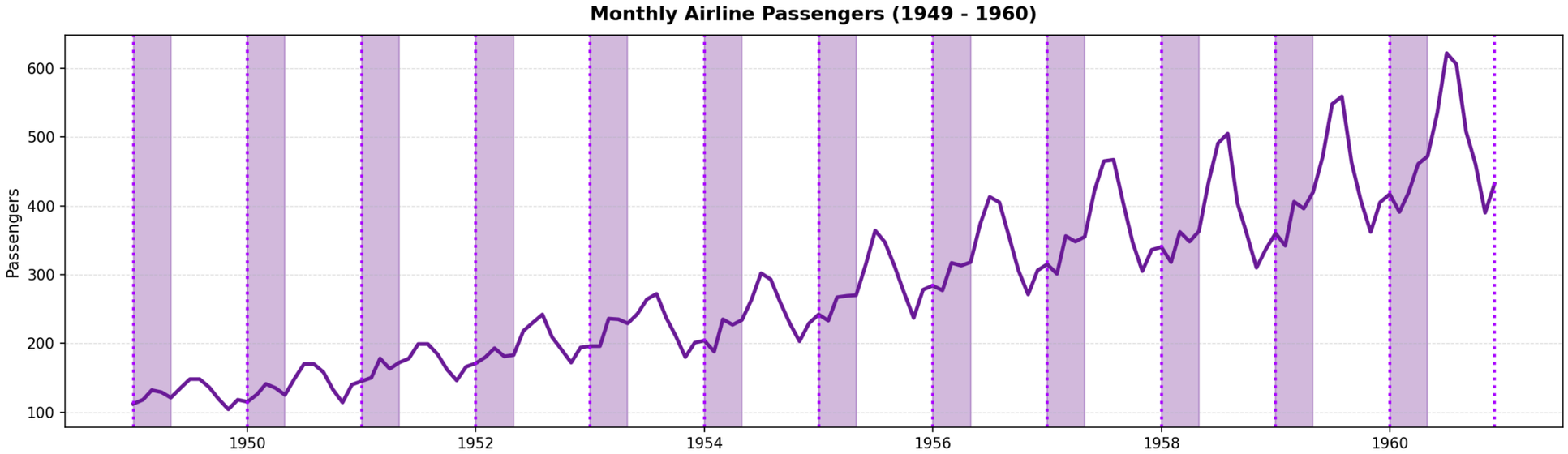
Periodic Time Series



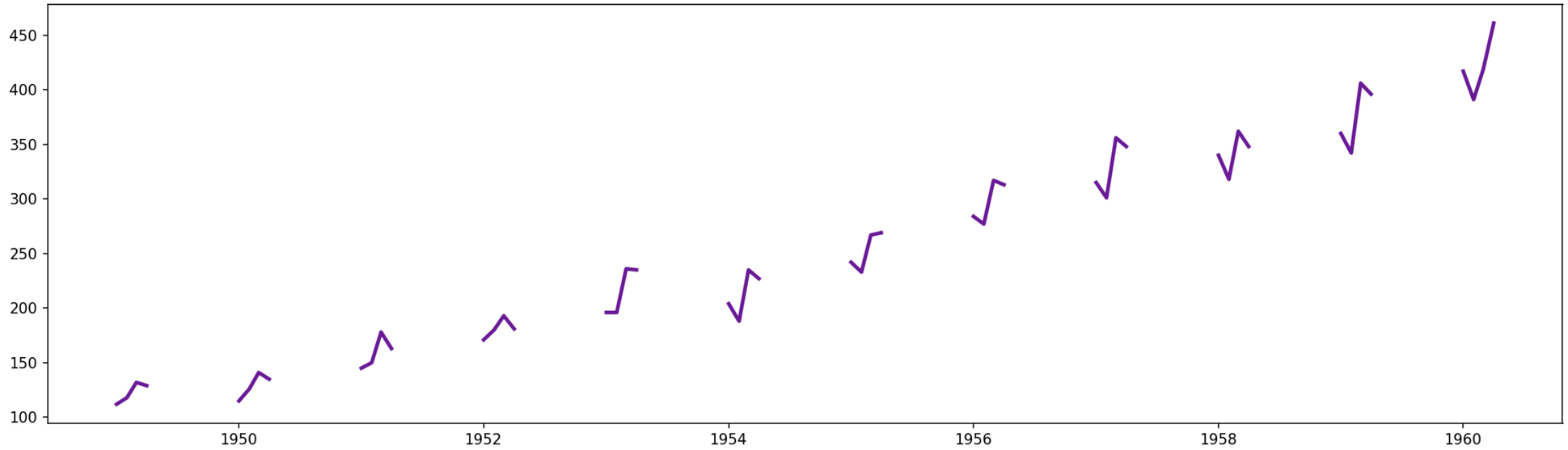
Segment by Year



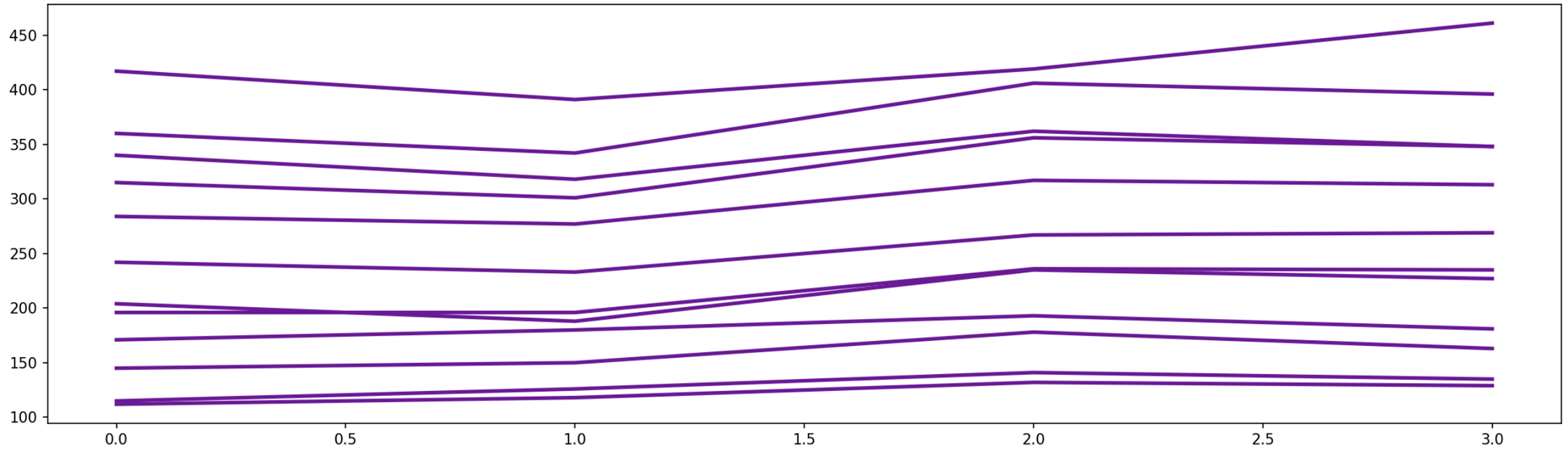
We want to compare each springtime



Result: Subsequences

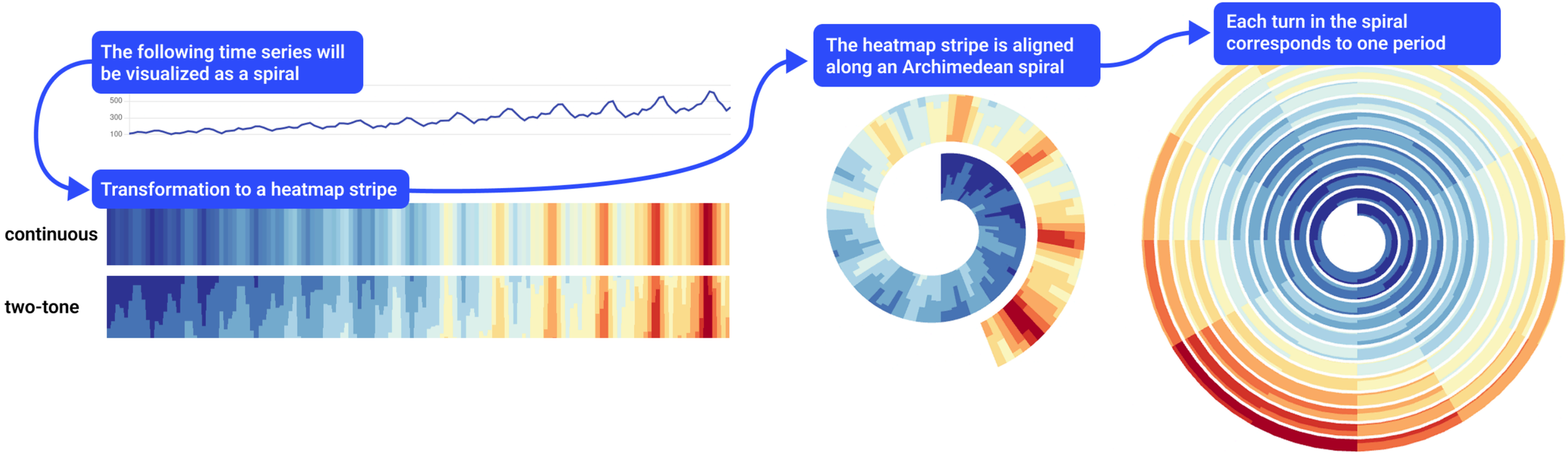


Comparison via Superposition

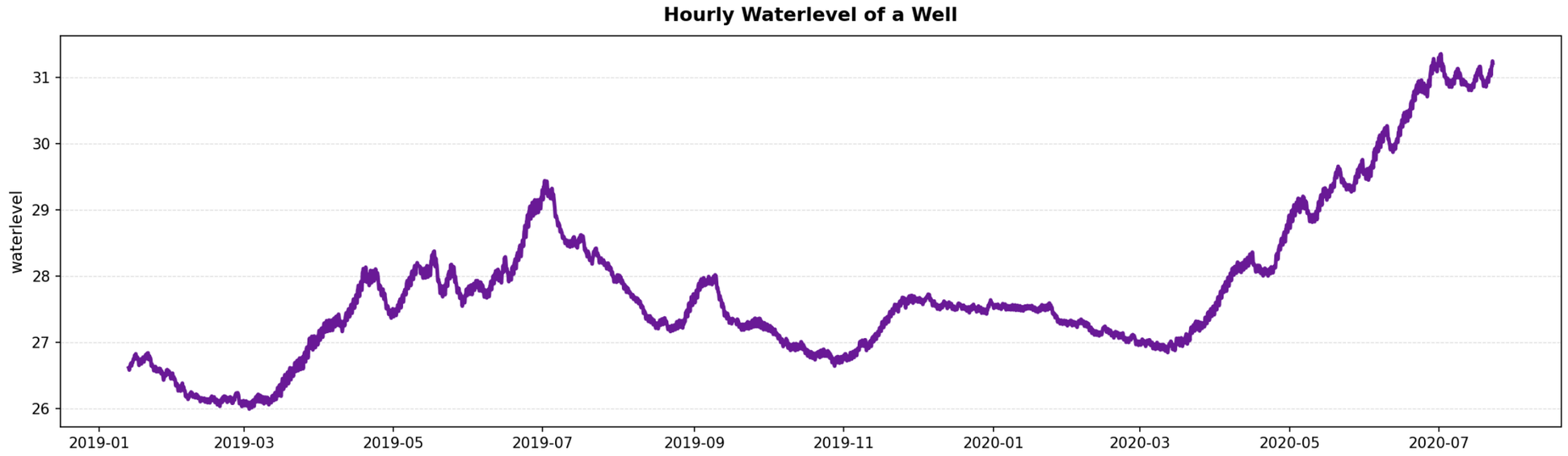


Can we do better?

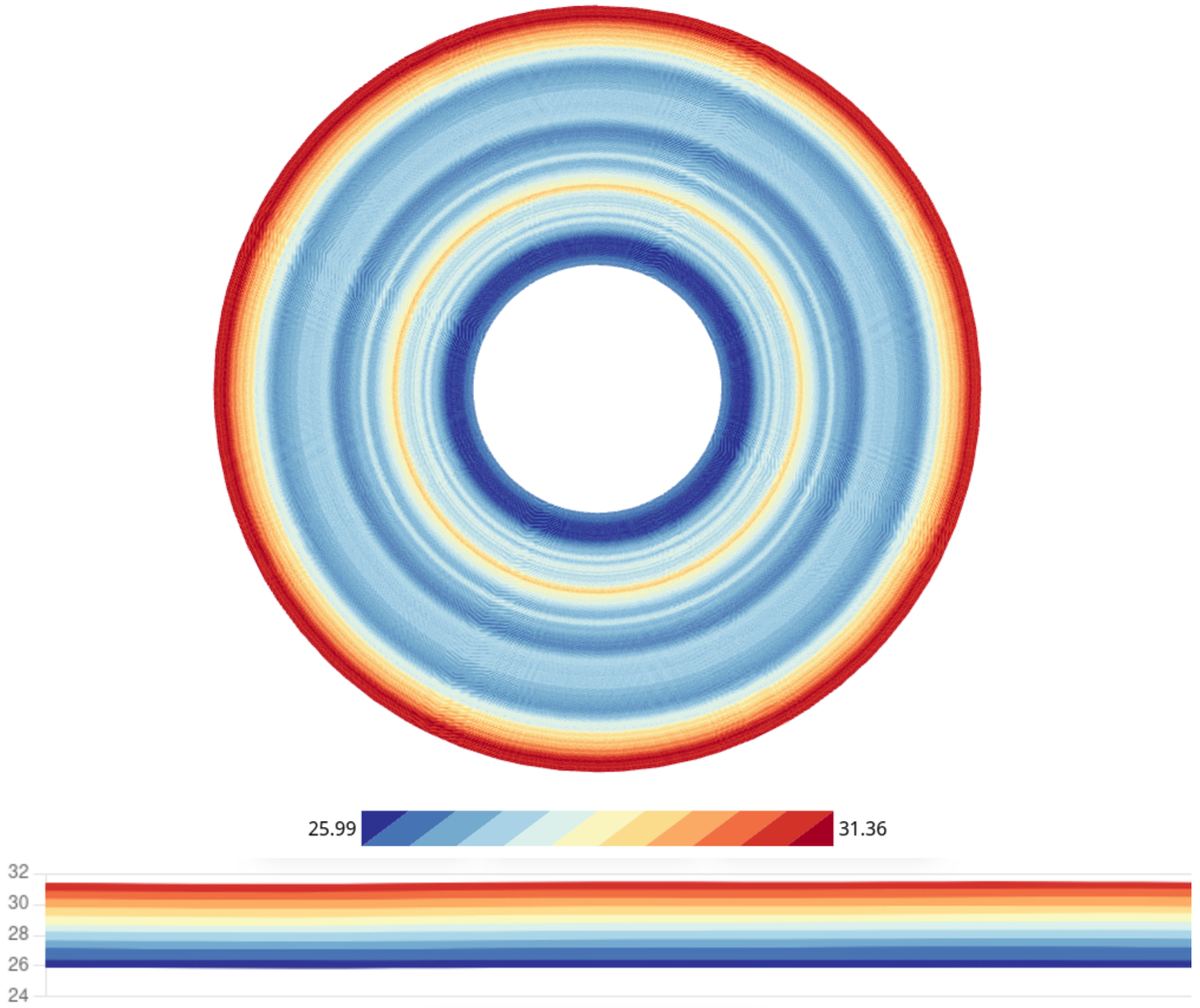
The Time Series Spiral



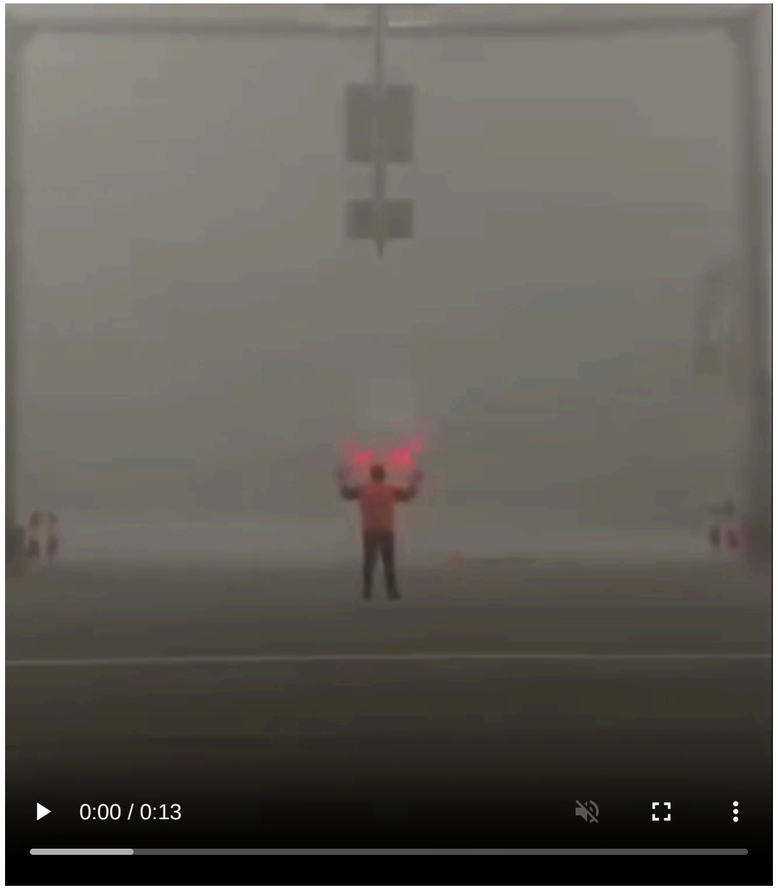
Complex Time Series are challenging!



No differences in sectors visible.

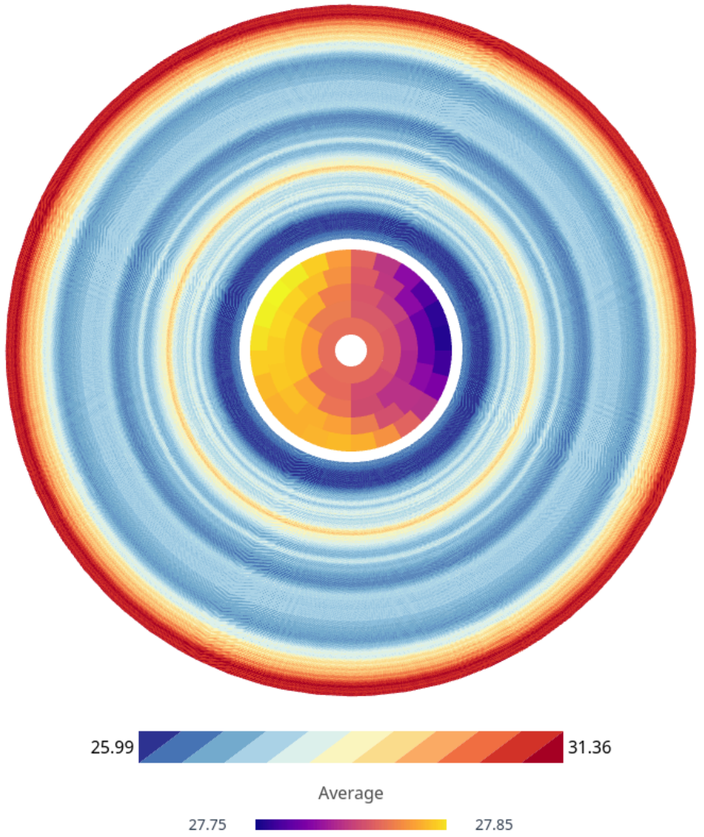


Visual Guidance can help



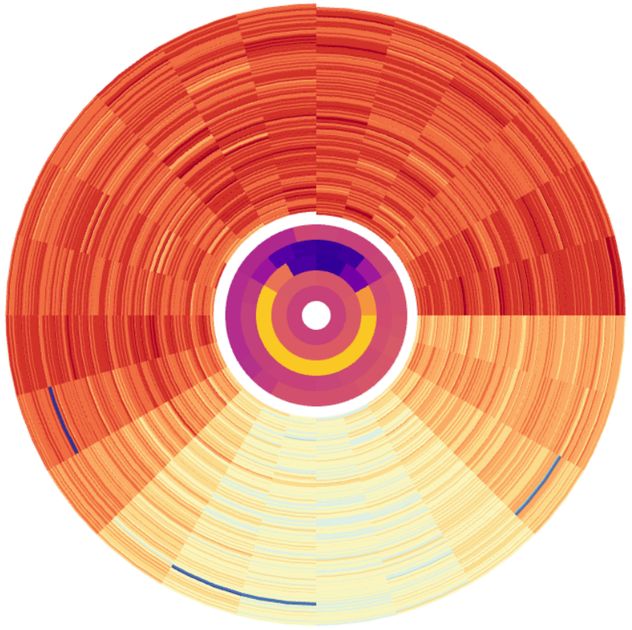
We need to navigate through a foggy data swamp.

Average Guidance



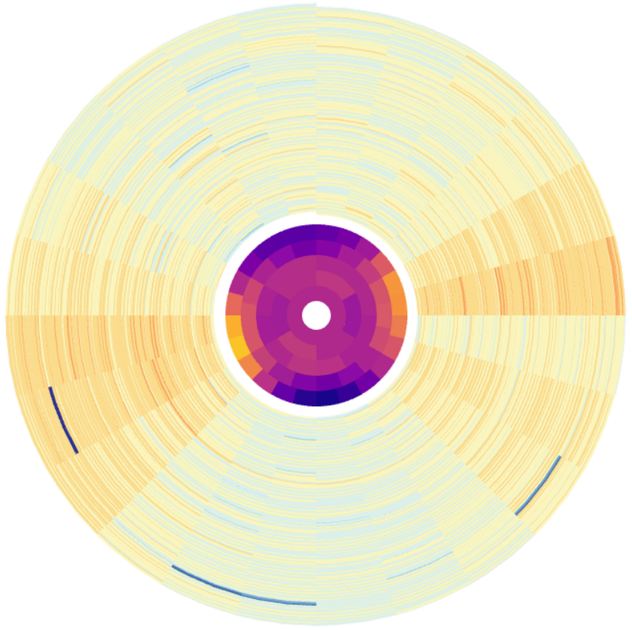
Another Example: Traffic

1 Average vehicle speed at a busy US highway





2 Using the residuals of a regression model, a secondary pattern emerges

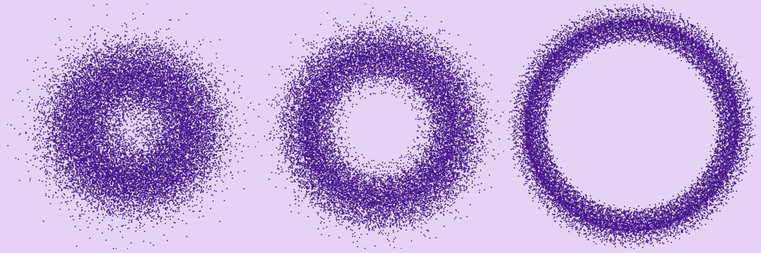




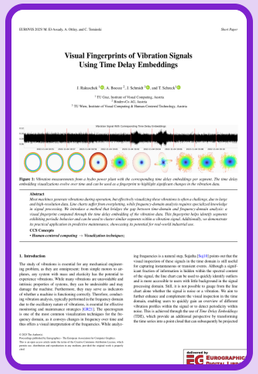
Summary

More than just vibrations

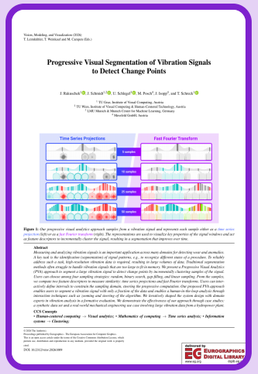
Vibration Signals



Large Time Series

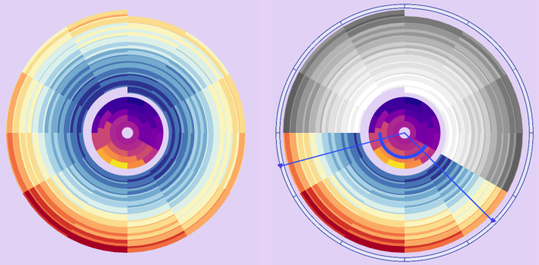


EuroVis Short 2025



VMV 2026

Periodic Time Series

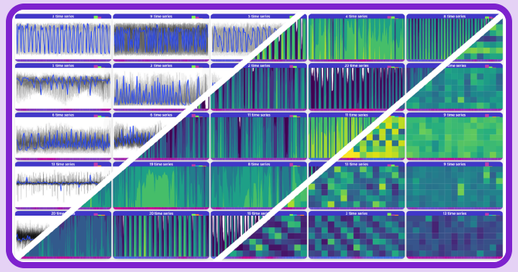


Complex Time Series

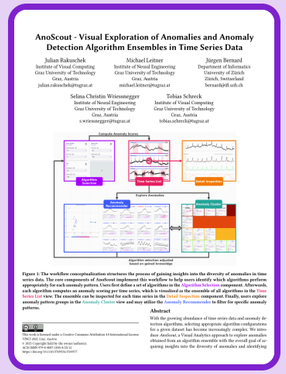


C&G Journal 2026

Anomalies



Many Time Series



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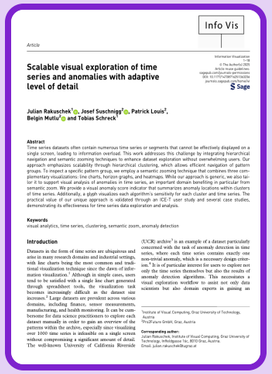

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Thank you!

Questions?