MATLAB EXPO 2017

Preprocessing & Feature Extraction in Signal Processing Applications

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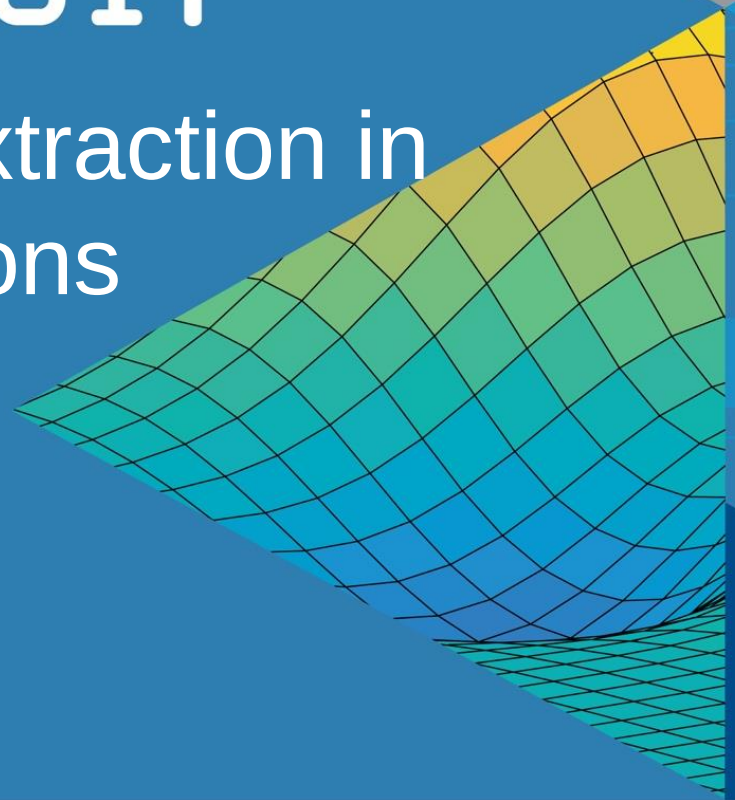
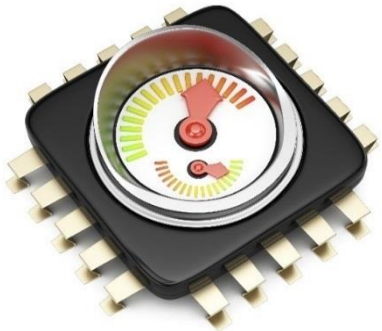
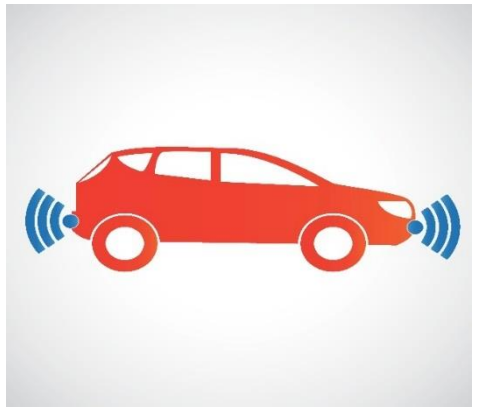
Signal Processing and Communications



Signals and Data are Everywhere





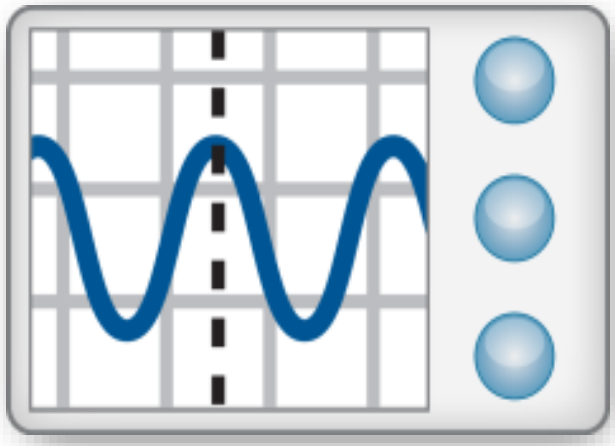
phase noise **motion**

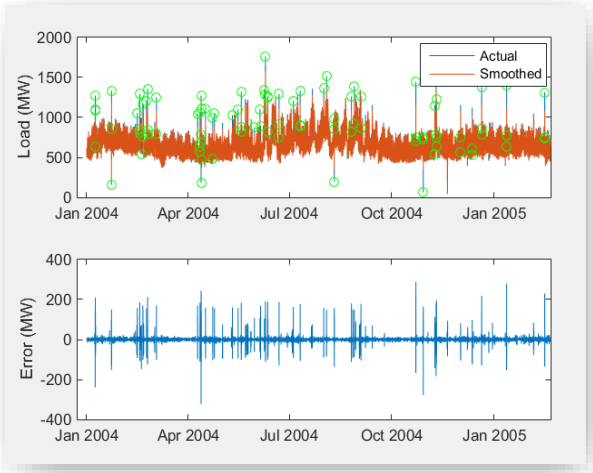
acceleration position

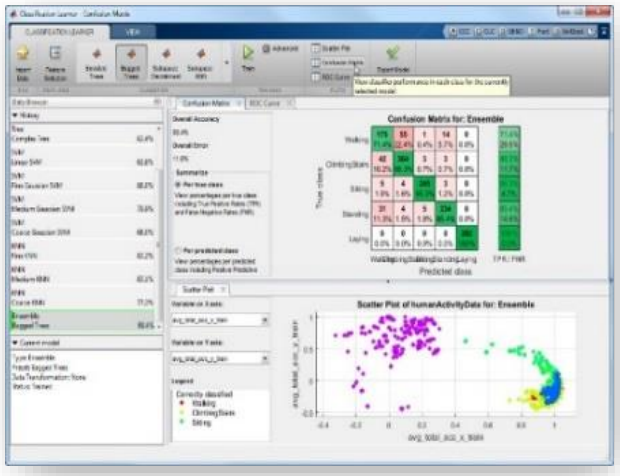
pressure **vibration** strain

temperature **tilt** rotation

Preprocess and Extract Features for Data Analysis







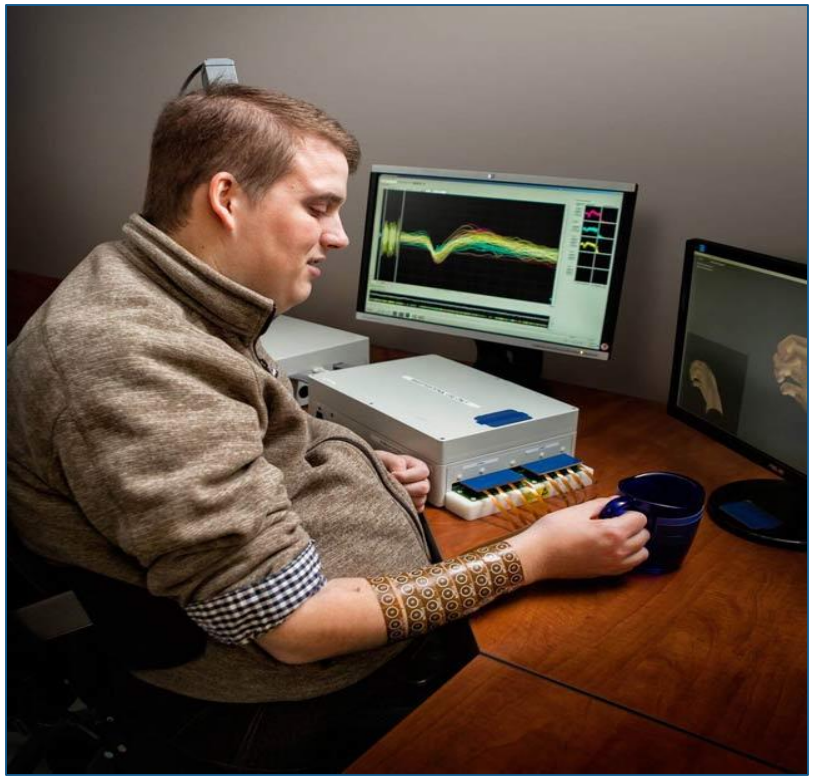
Connect and Acquire → **Signal Processing** → **Data Analysis**

Preprocess → **Extract Features**

Challenge: Gain insights to improve data analysis

Feature Extraction Techniques Help to Restore Arm Movement

- Multichannel electrode implanted in the brain to record brain signals
- Wavelet techniques isolate frequency bands of brain signals that govern movement
- Wavelets help transform 3000 features per channel into a single value

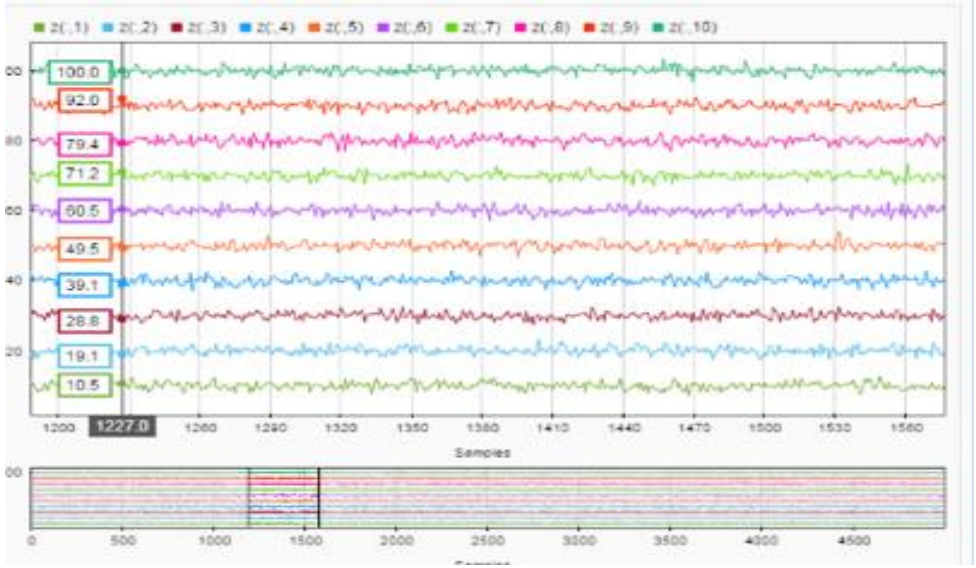


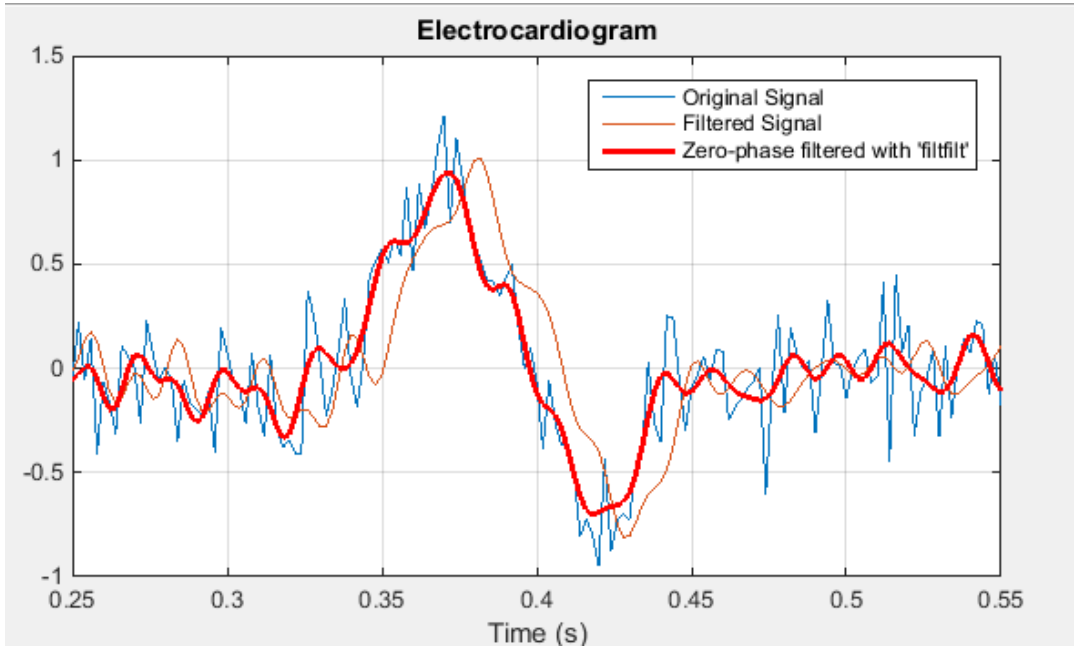
User Story: Battelle Neural Bypass Technology Restores Movement to a Paralyzed Man's Arm and Hand

Developed by Battelle Memorial Institute entirely in MATLAB and Wavelet Toolbox

Real-World Signals are Challenging to Analyze

- Large amounts of data
  - Wide data ➡ multiple streams, many sensors
  - Tall data ➡ long signals
- "Messy" time series
  - Noise
  - Non-uniform sampling
  - Lack of alignment between signals
  - Missing data
  - Data outliers





Signal Processing for Engineers and Scientists

Is this a signal or just noise?

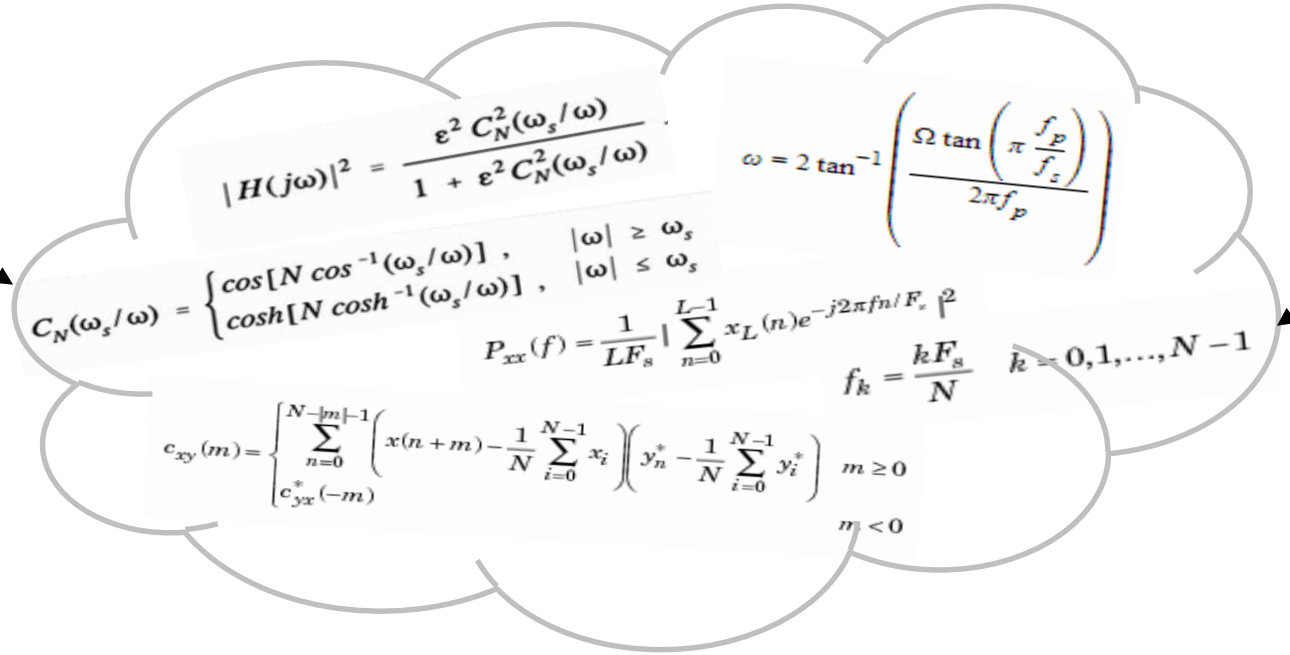
How do I align different signals?

How do I compare signals?

How do I measure a delay between signals?

Are these signals related?

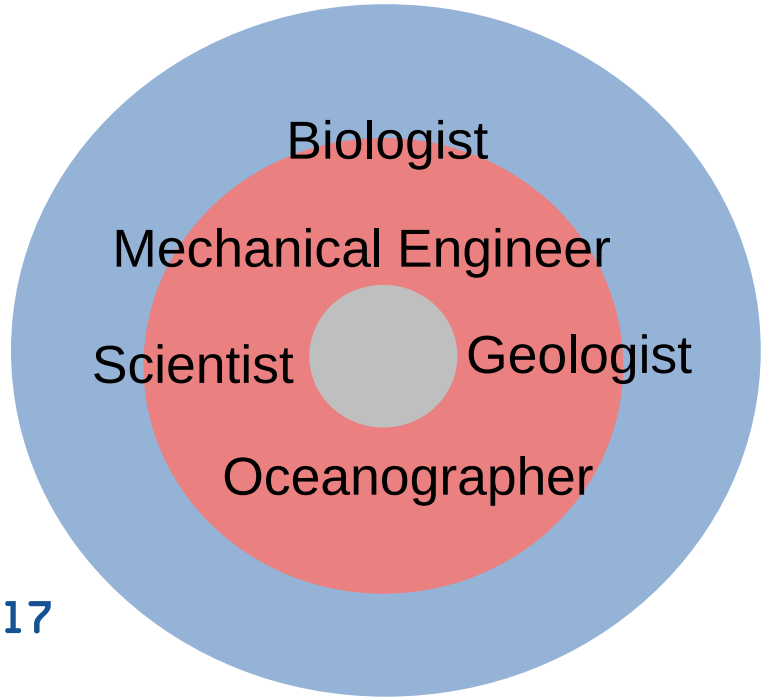
Signal Modeling, Generation & Preprocessing	Measurements & Feature Extraction	Digital & Analog Filter Design	Transforms & Spectral Analysis	Vibration Analysis



Support for Real-World Applications

Signal Processing Toolbox | Wavelet Toolbox

- Traditional users: Electrical Engineer with Signal Processing background
- Expanded focus over recent releases:
  - Scientists require signal processing techniques but may not be proficient in this area



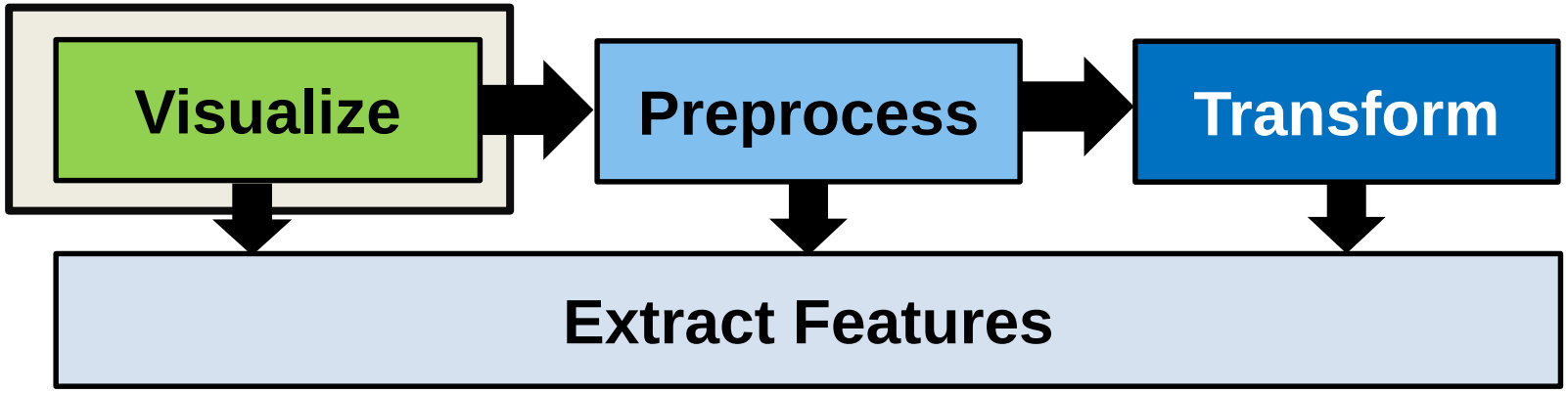
Apps to work with data

Intuitive function names

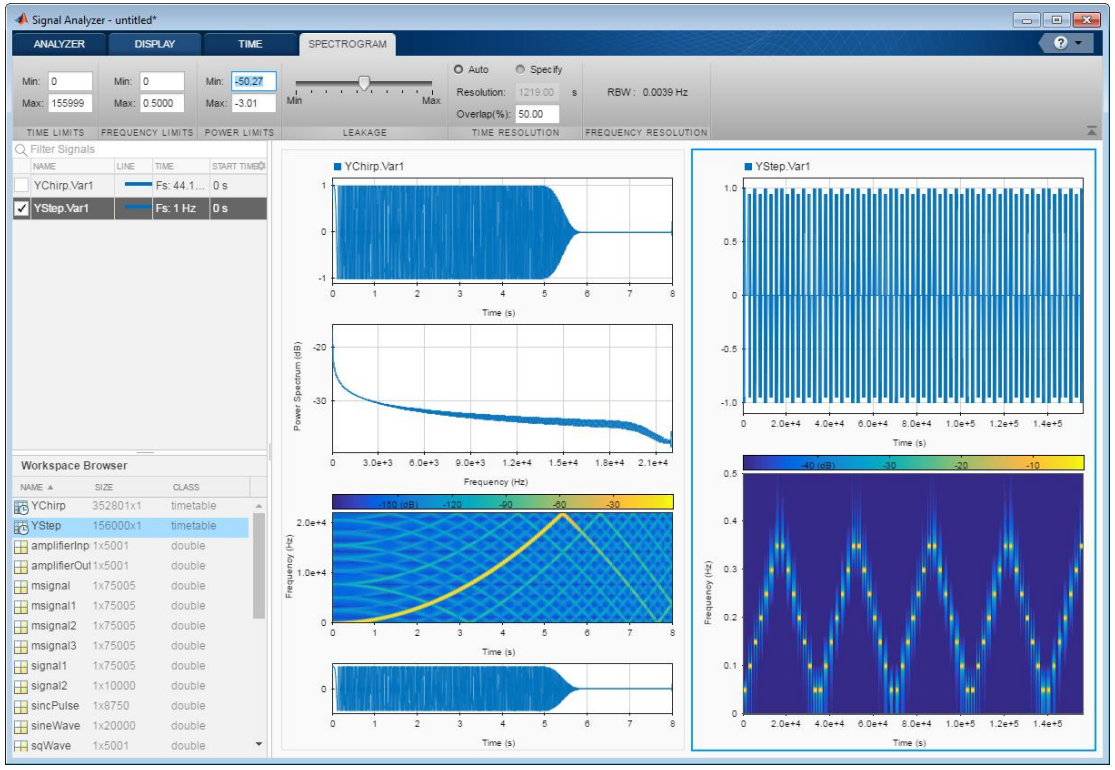
Domain friendly defaults

Easy path to deeper analysis

Signal Preprocessing and Feature Extraction



Signal Analyzer App

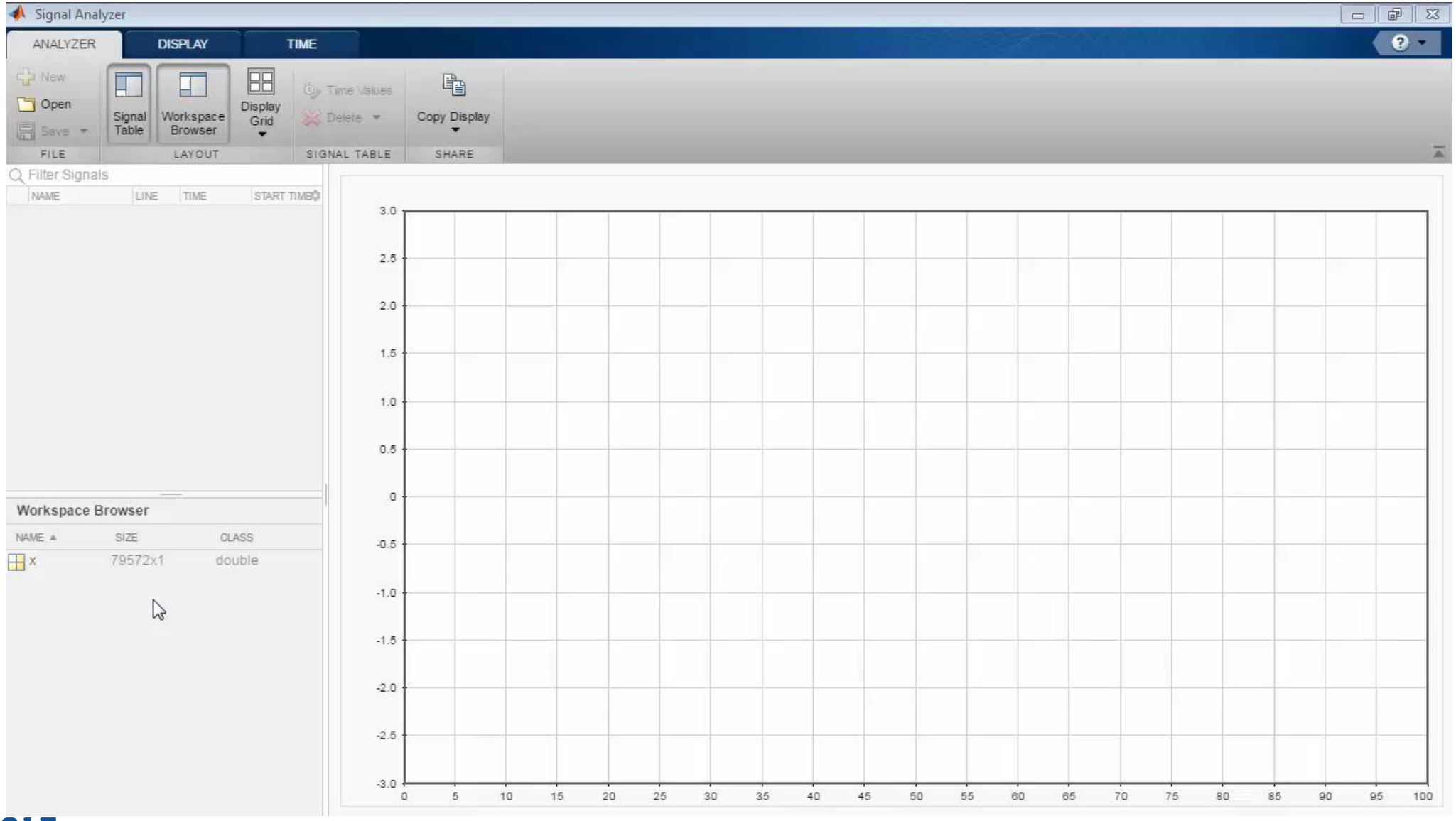


Viewing and Exploring Signals with Signal Analyzer App

Visualize

Extraction Features

- Time and frequency
- Navigate, pan, & zoom
- Compare multiple signals
- Extract regions of interest

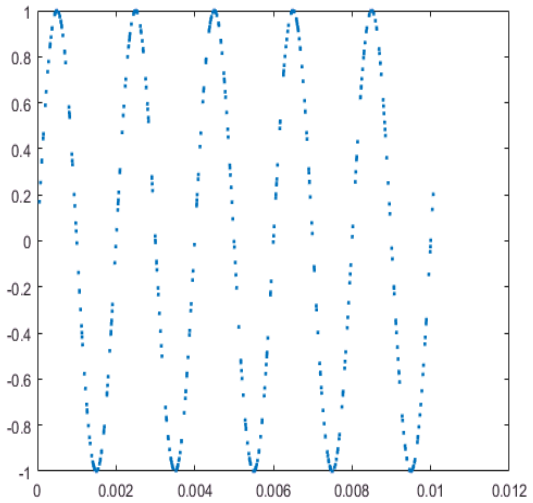


Preprocess Messy Signals

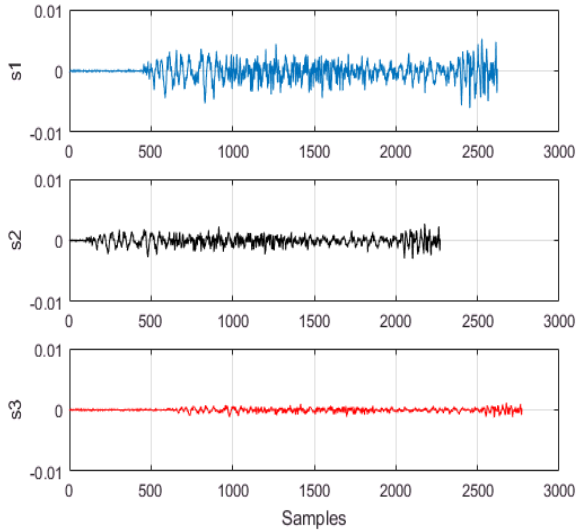
Visualize

↓

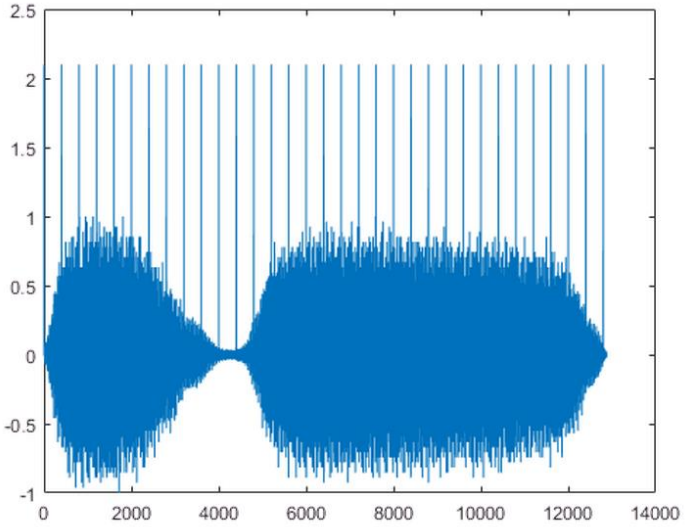
Preprocess

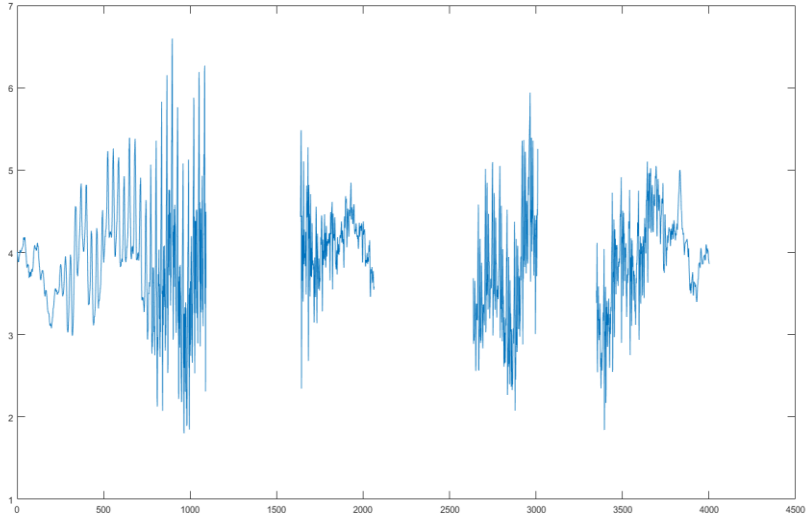


Non-uniformly sampled signals

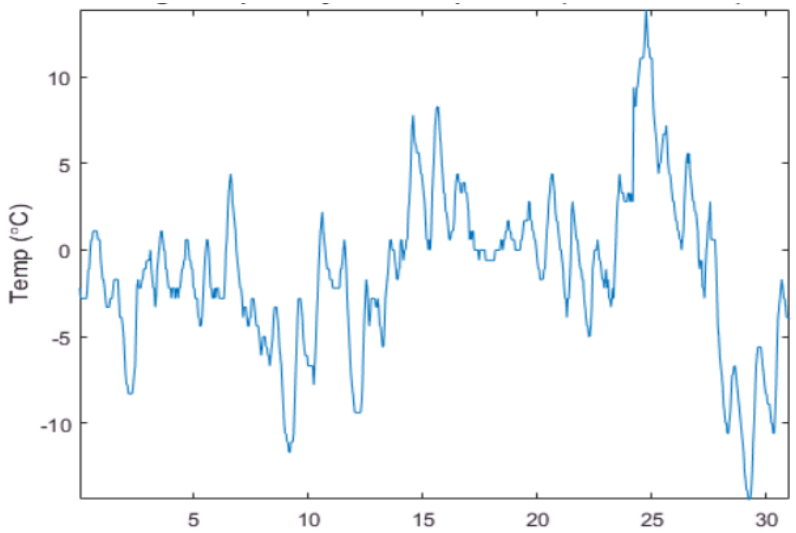


Misaligned signals



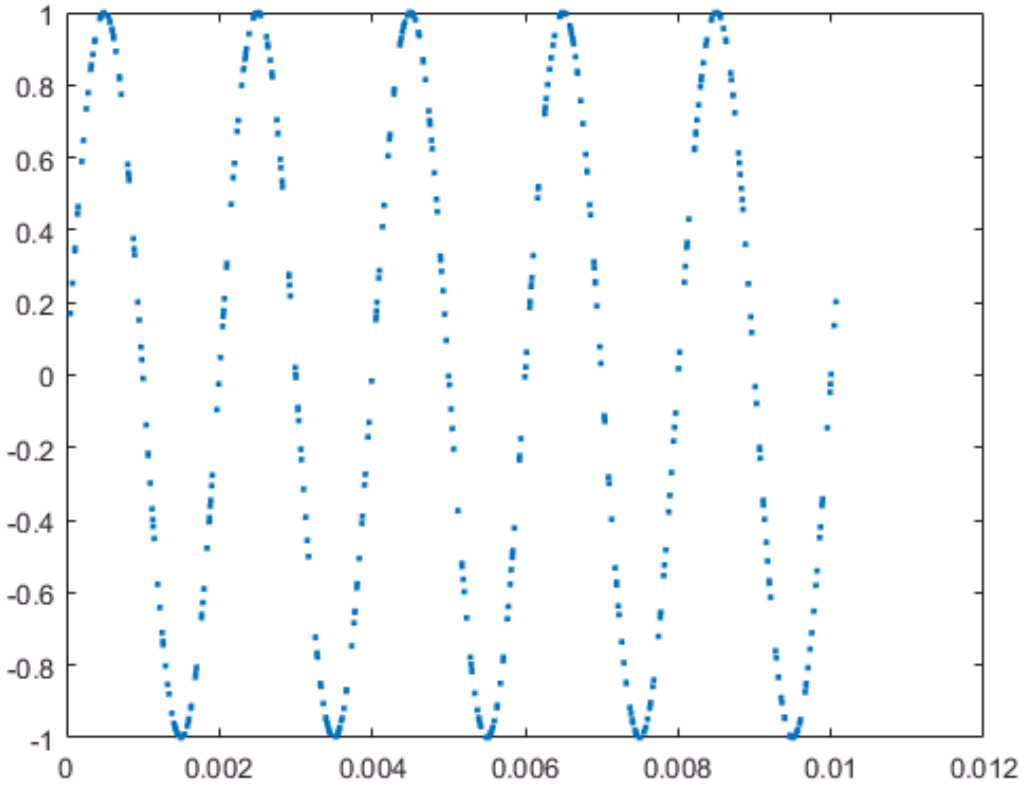


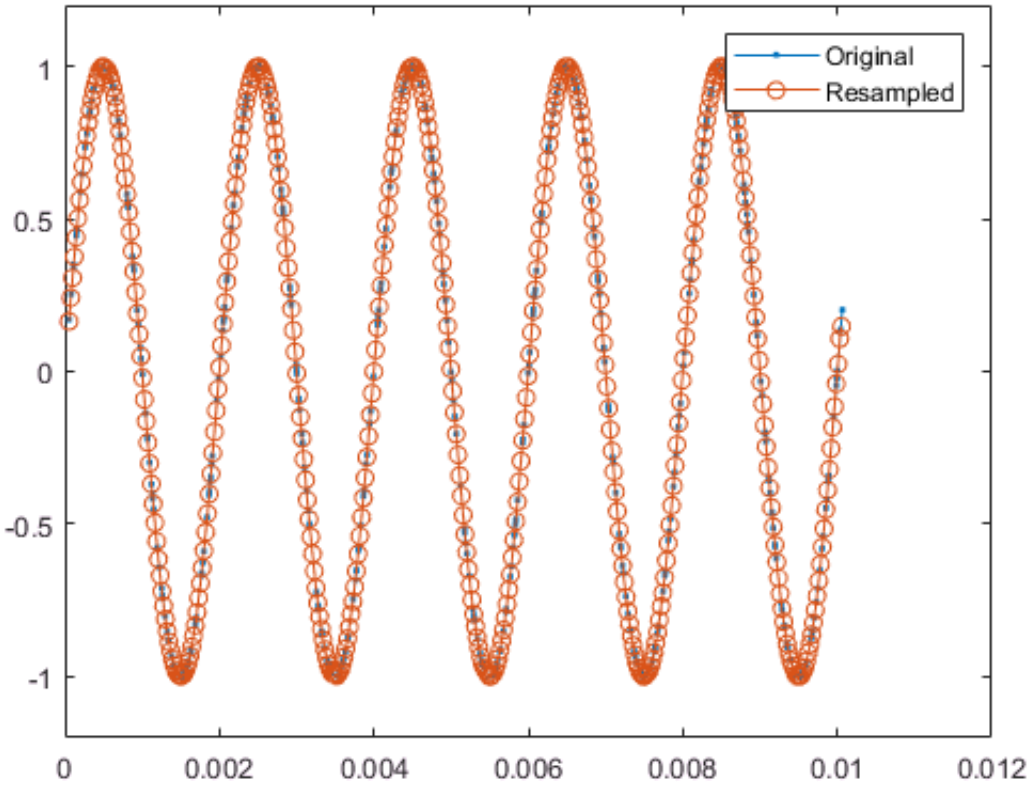
Outliers & data gaps



Noise or unwanted frequency content

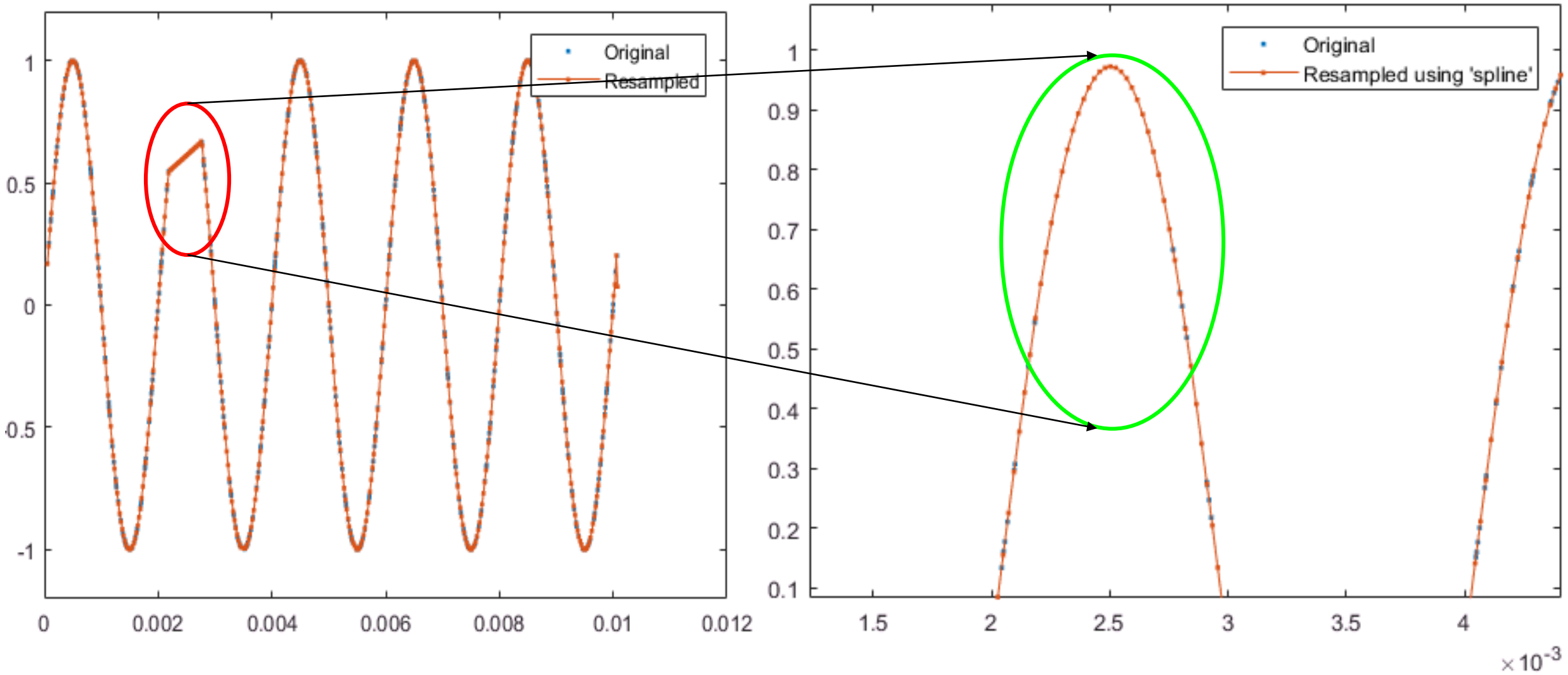
Resample Non-uniformly Sampled Signals





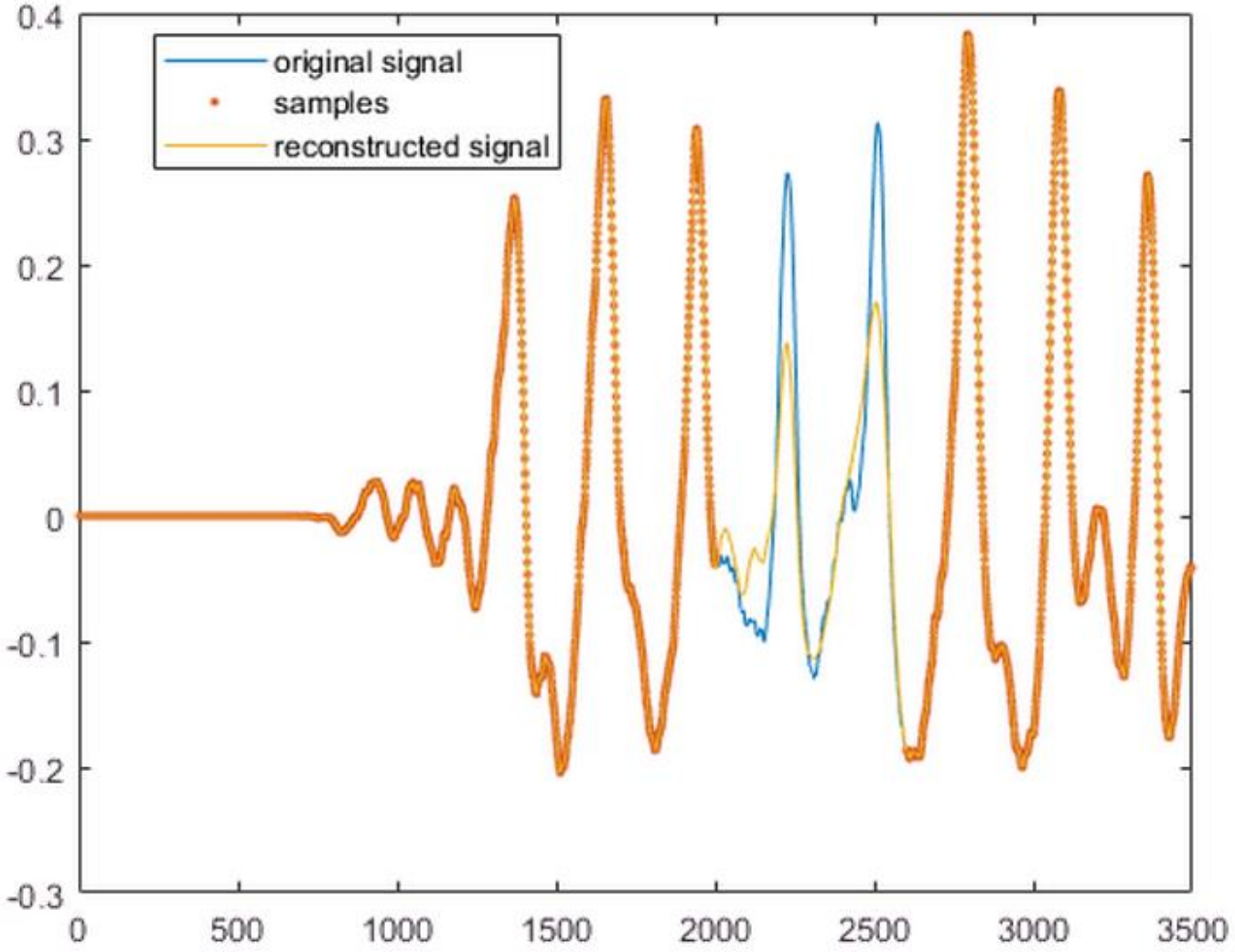

```
>>[y, Ty] = resample(x,nonUniformSig,desiredFs);
```

What if Data is Missing?




```
>>  [y, Ty] = resample(x,irregTx,desiredFs,'spline');
```

Multiple Ways to Reconstruct Missing Data

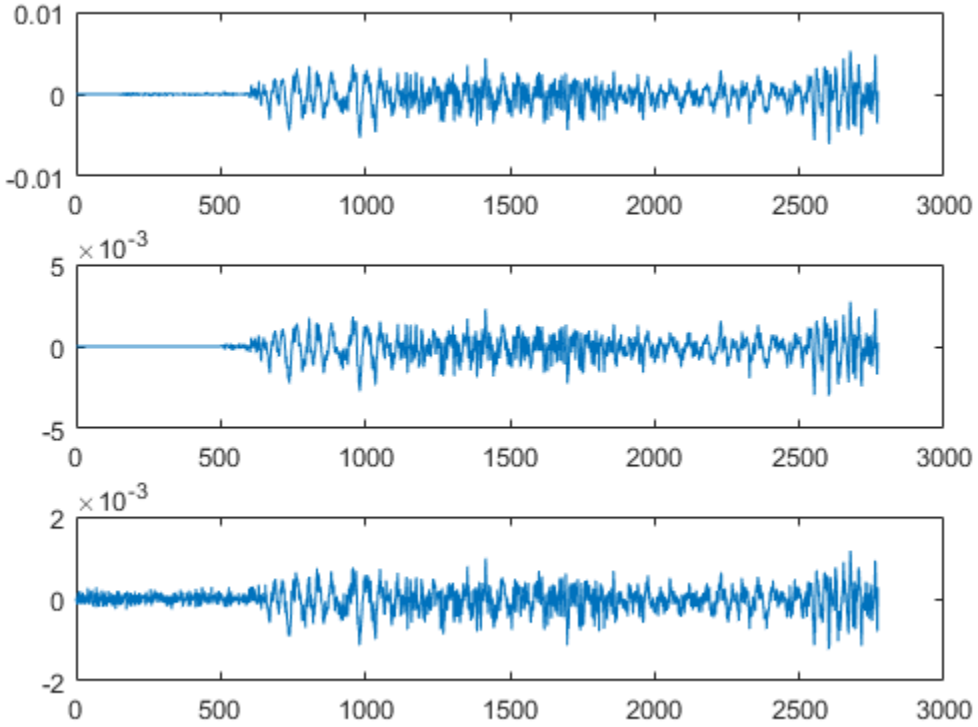


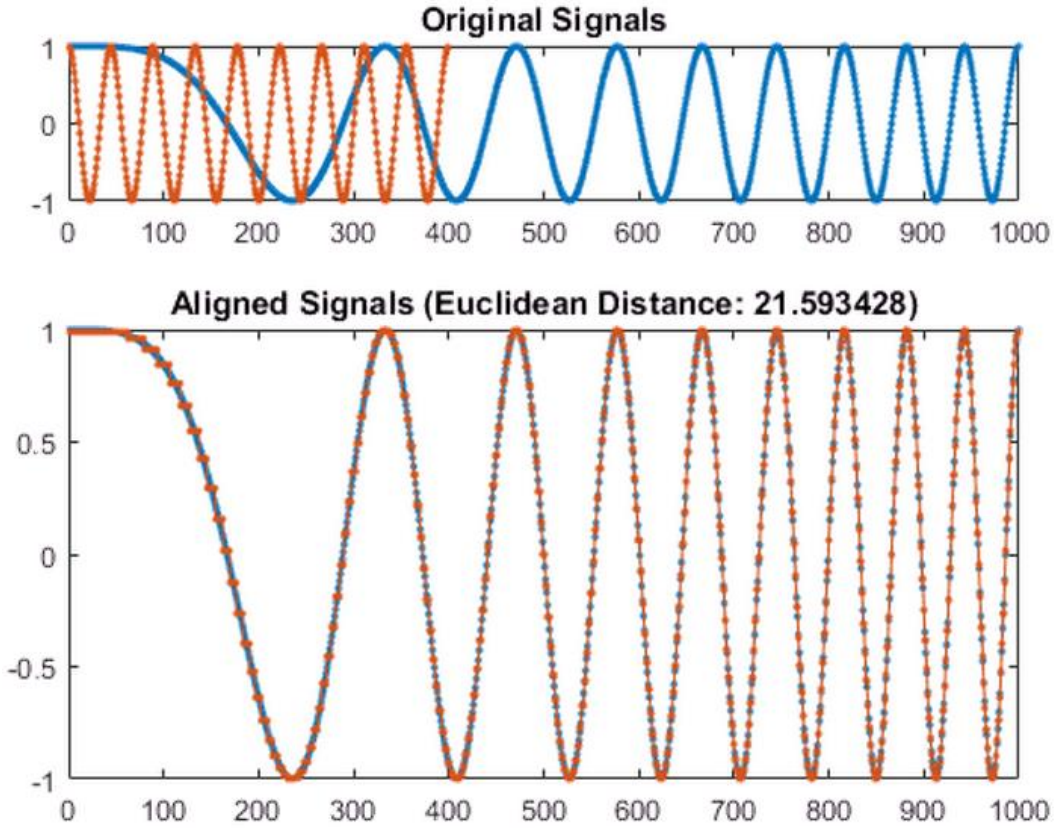
- Resampling often best for low frequency components
- For large gaps in wideband signals, autoregressive modeling is more effective

```
>> x = y(1:3500);
>> x(2000:2600) = NaN;
>> y2 = fillgaps(x);
```

Synchronizing Signals from Multiple Sensors

Data collected asynchronously by multiple sensors may require alignment



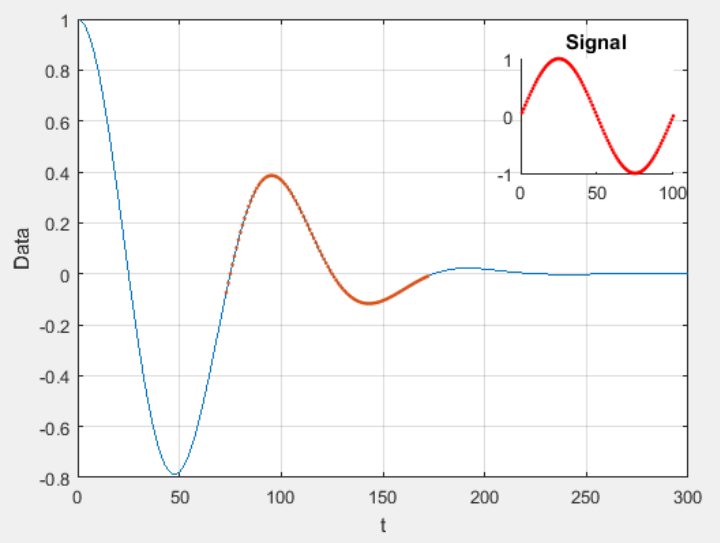



```
»[x1,x3] = alignsignals(s1,s3)
»x2 = alignsignals(s2,s3);
```

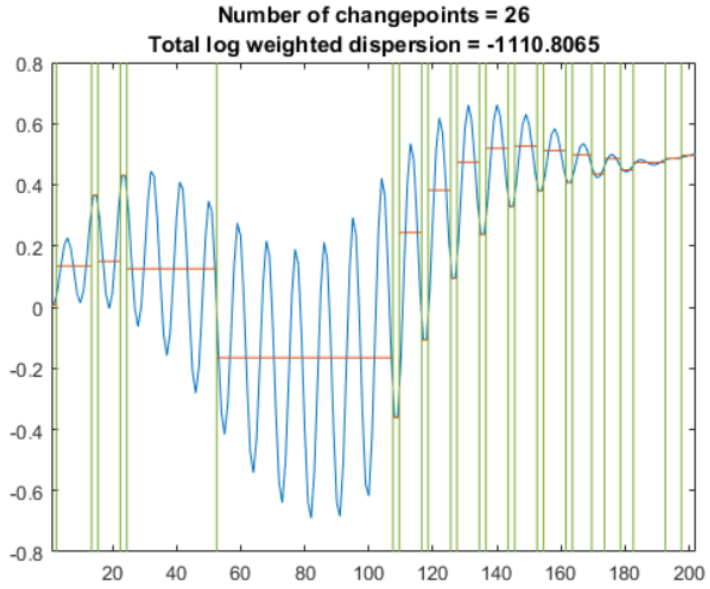
```
» dtw(s1,s2)
```

Extract Features

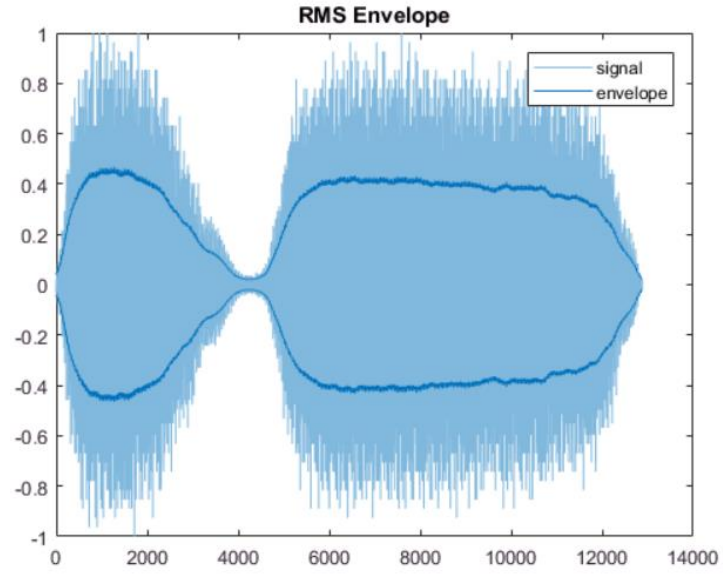
Extract Features



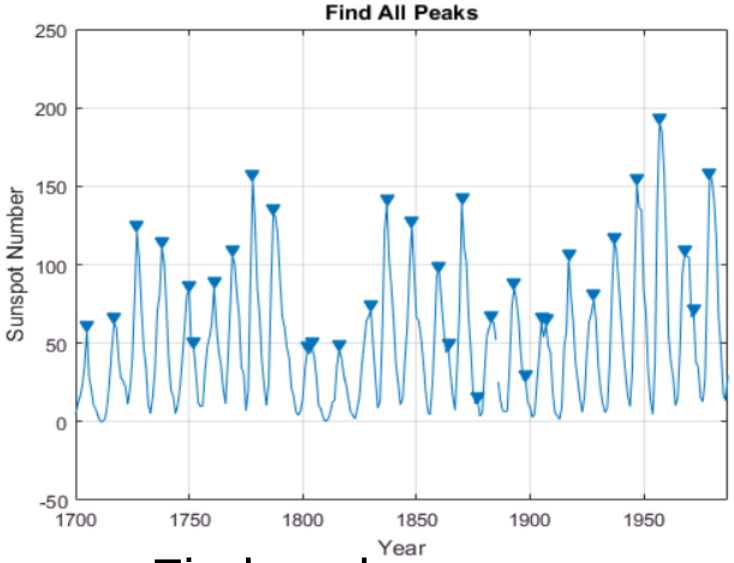
Find desired signal from patterns



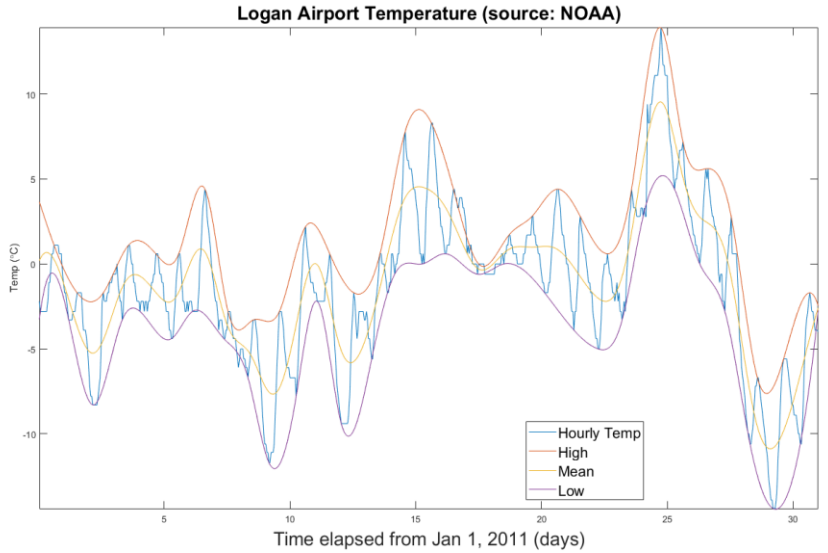
Detect change points



Find signal envelope



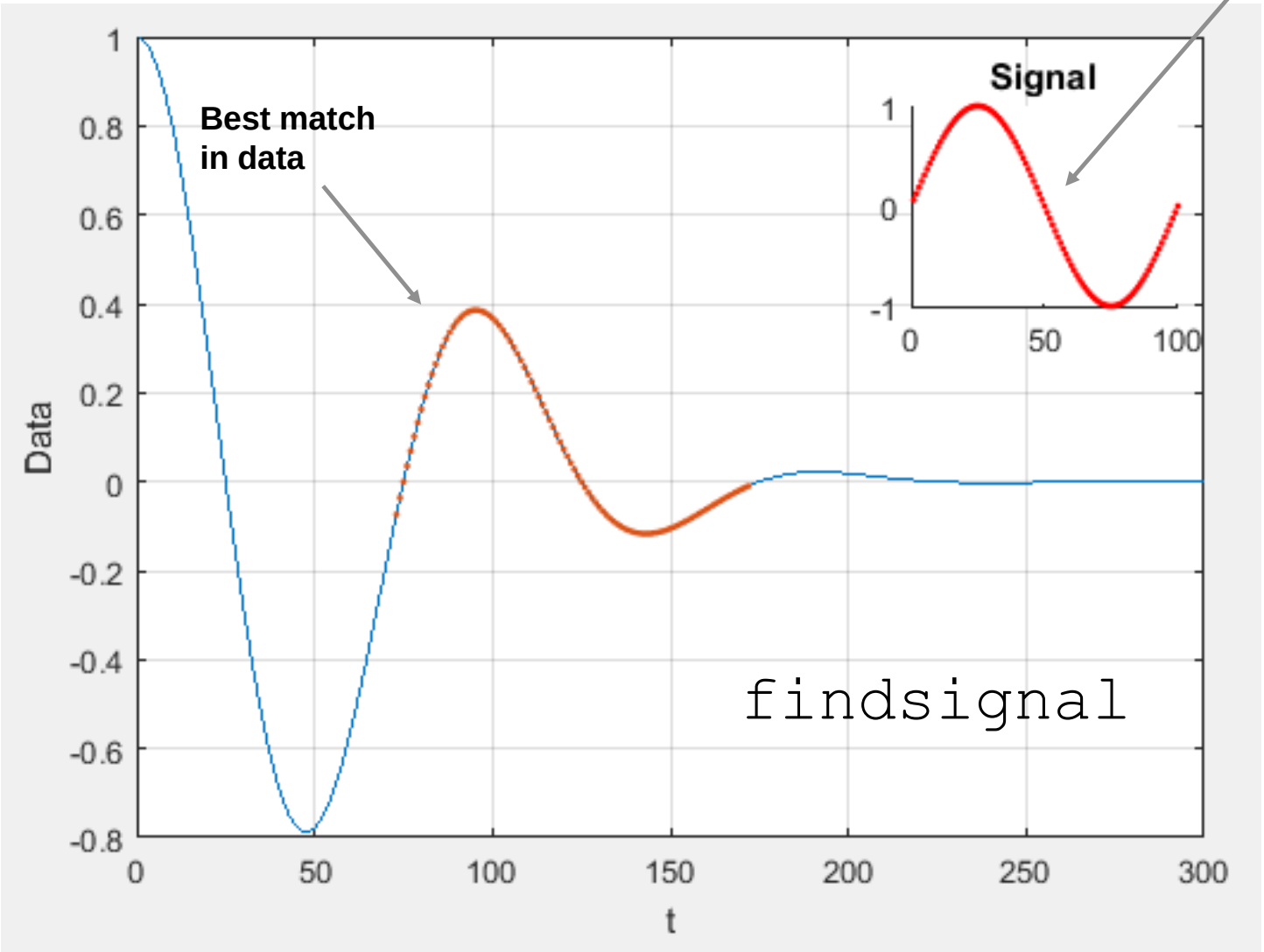
Find peaks



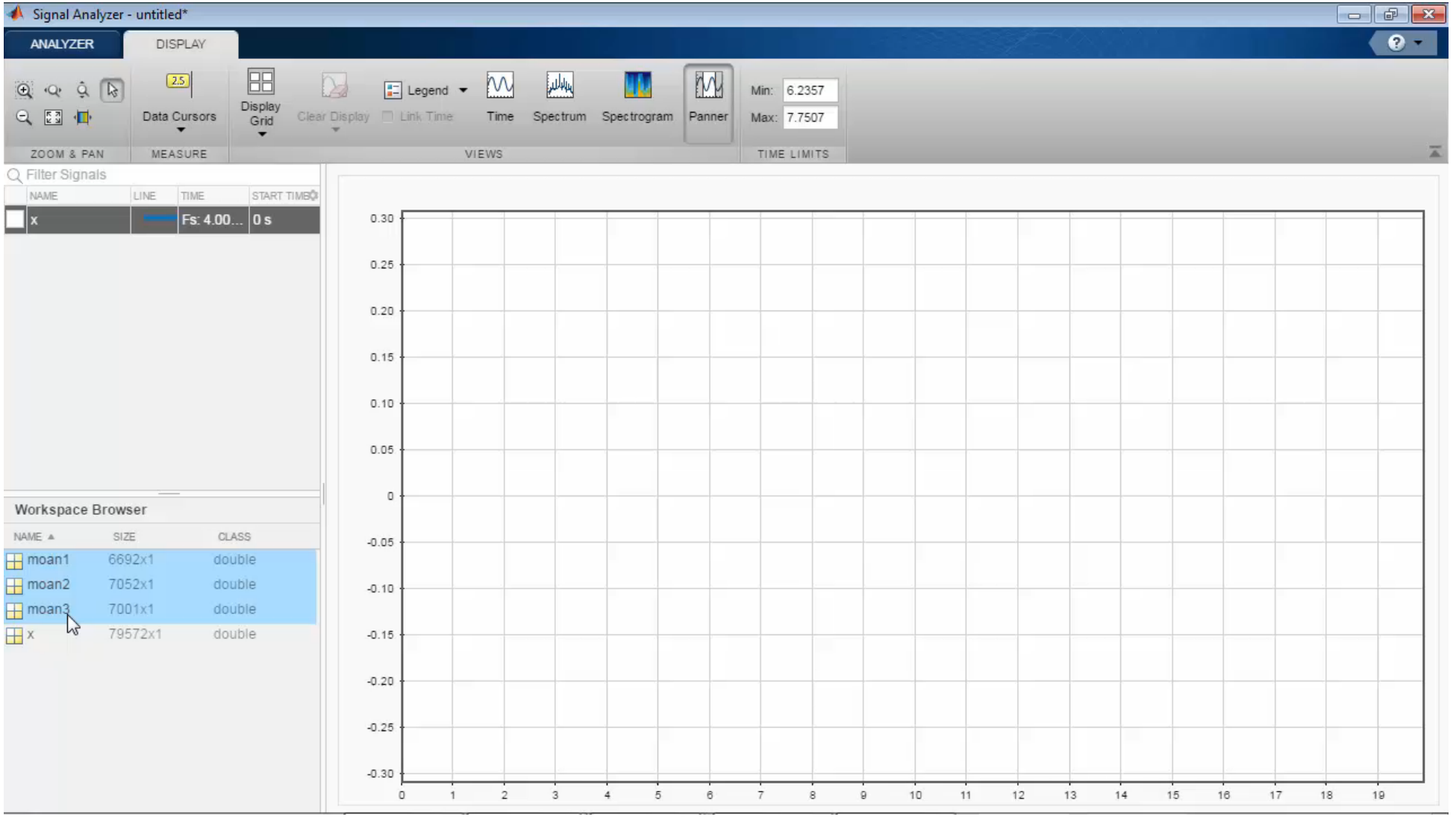
Determine signal statistics

Finding Signals and Patterns of Interest

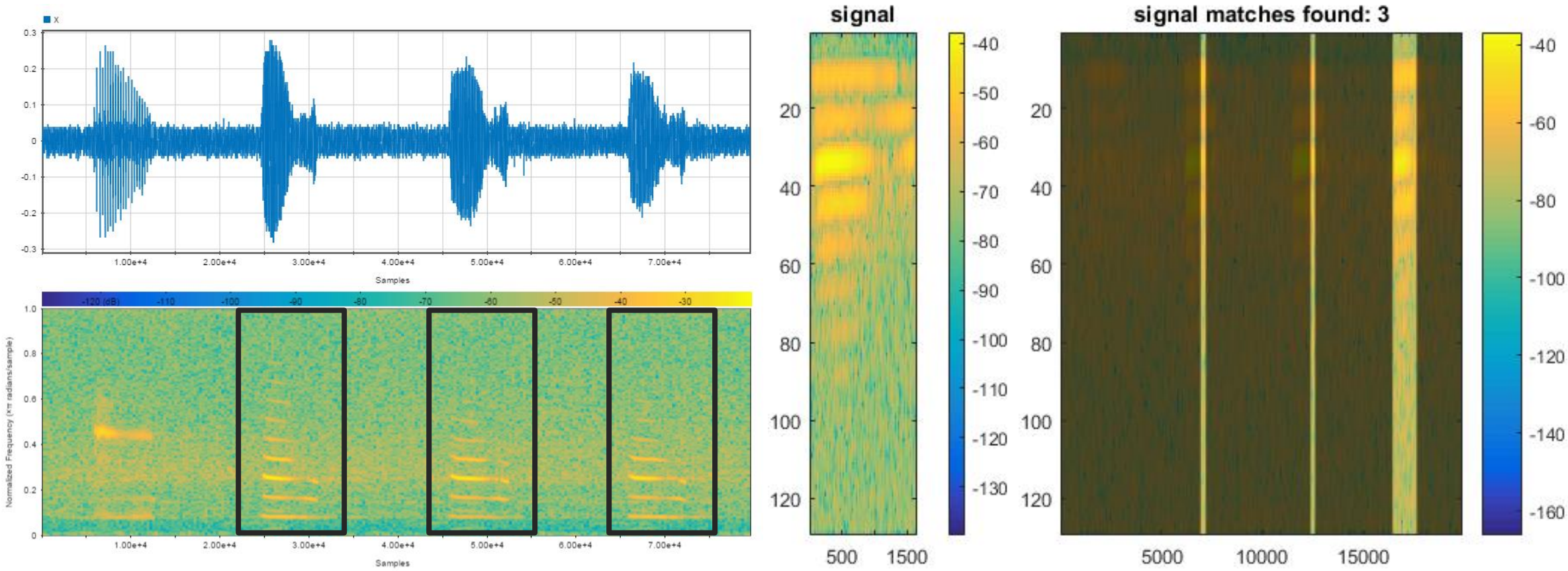
- Similarity search for finding repeat occurrences
- `findsignal` can be used with time or frequency data



Searching the Spectral Content



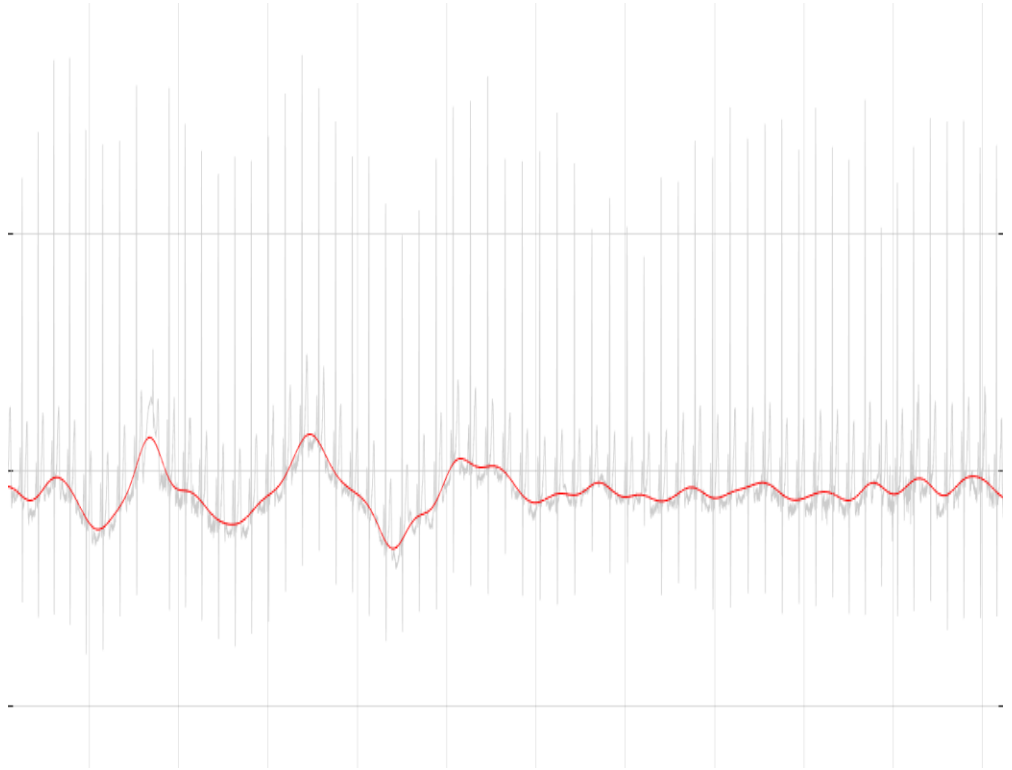
Finding a Signal of Interest




```
>>findsignal(PxxSignal,PxxMoan,'Normalization','power‘,'TimeAlignment','dtw',…
'Metric','symmkl','MaxNumSegments',3);
```

Challenges of Time-Frequency Analysis

- Fixed spectral windows can limit time-frequency resolution
- Features occurring at different scales may be missed
- Sinusoids may not be well localized in frequency



May need a different class of functions to analyze real world signals

Time-Frequency Analysis

Transform

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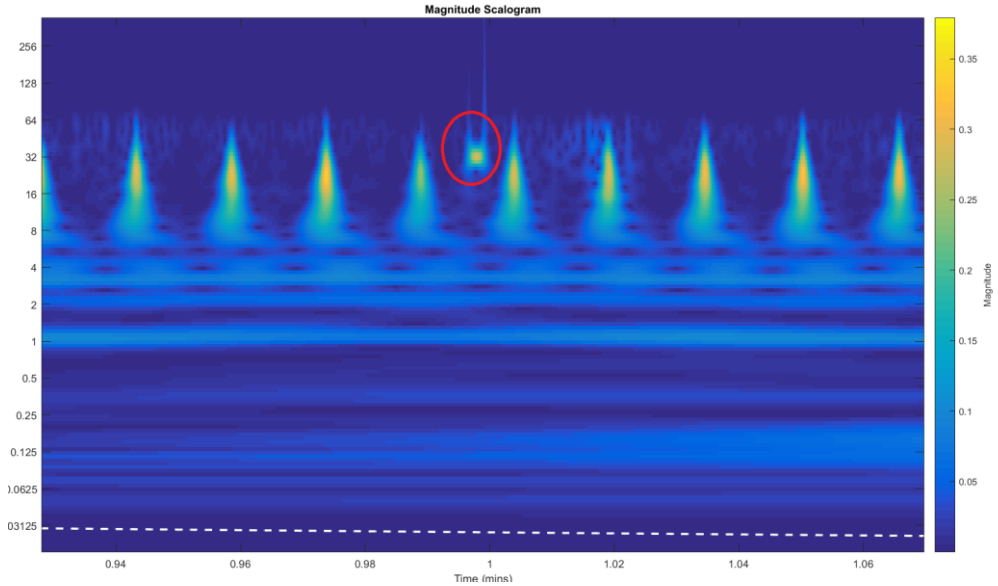
Extract Features



Signal Processing Toolbox

- Spectrogram
- Fourier Synchrosqueezed Transform

Wavelet Toolbox

- Continuous Wavelet Analysis
- Discrete Wavelet Analysis
- Denoising and Compression
- Filter Banks

Localizing Unwanted Frequency Components

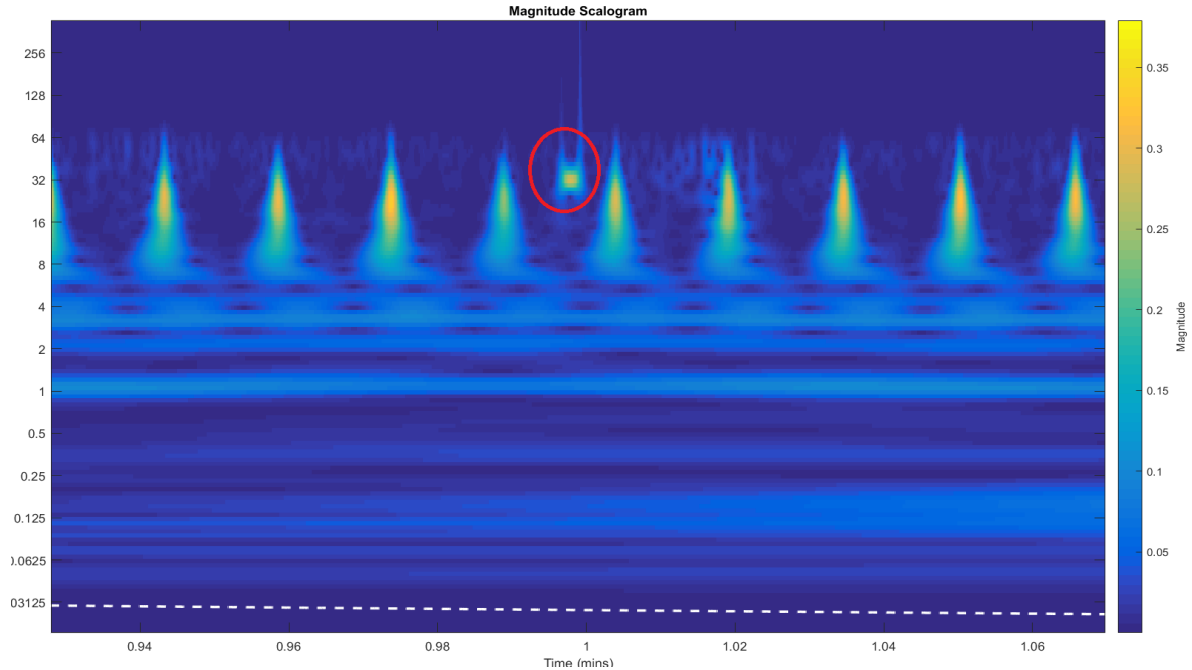
- Wavelets used to localize & remove unwanted spectral components

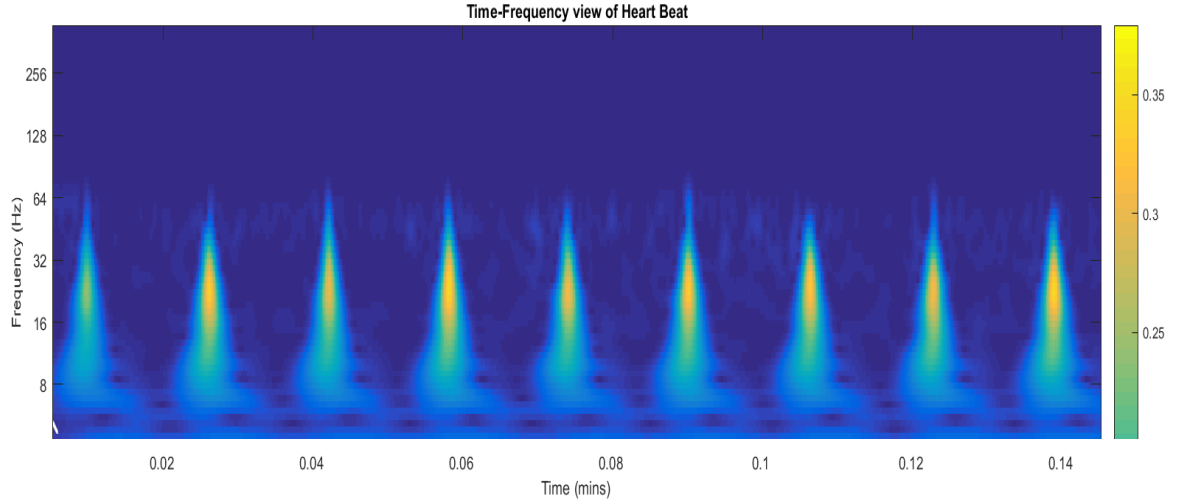
Wavelet transform

Localize noise frequency

Remove noise

Reconstruct signal

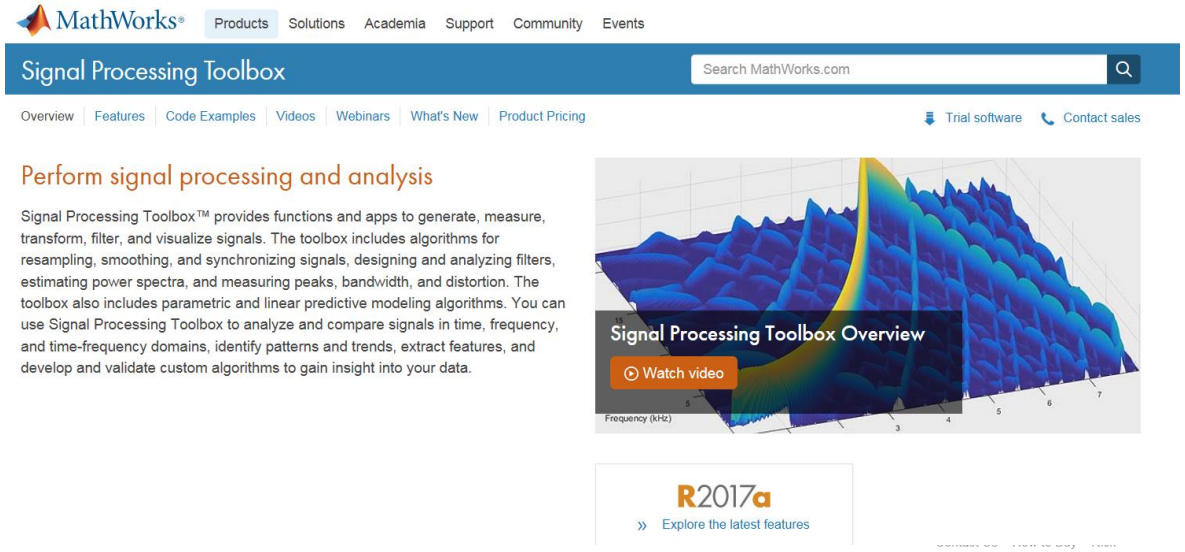




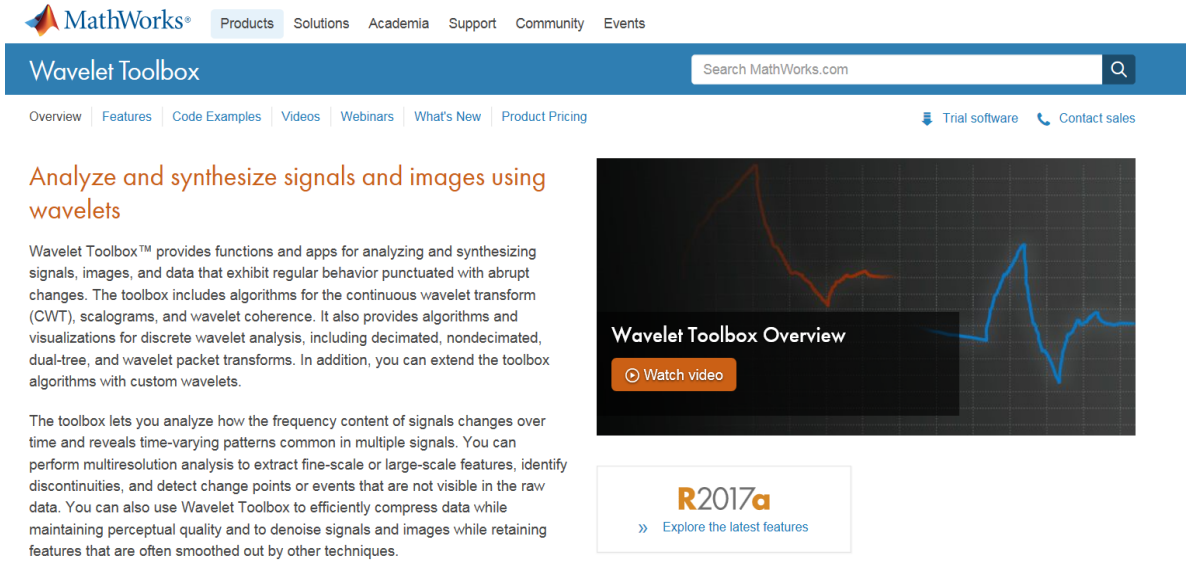
Summary

- Real world signals are challenging
  - MathWorks tools make preprocessing and feature extraction easy
- MathWorks website includes many examples to get started with
  - Data Analytics, Industrial, Automotive, Medical, Noise and Vibration, and many others
- Thank you for attending

More Resources



https://www.mathworks.com/products/signal.html



https://www.mathworks.com/products/wavelet.html

Wavelet Tech Talks

- Series of 4 short videos on wavelet concepts including MATLAB-based examples