

MATLAB EXPO

Data-Centric AI for Signal Processing Applications

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MathWorks ✓

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#MATLABEXPO



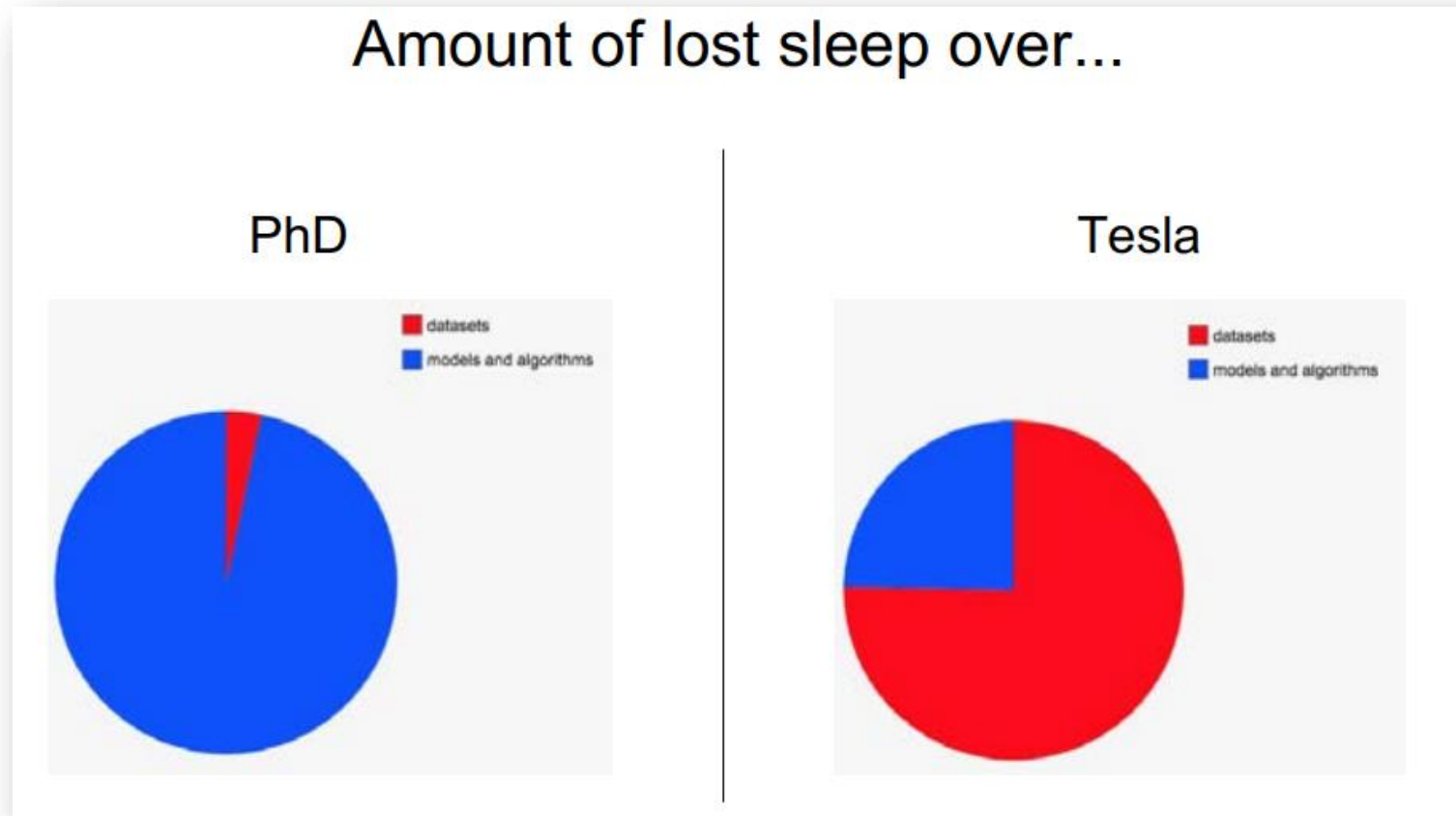
[linkedin.com/in/gabrielebunkheila/](https://www.linkedin.com/in/gabrielebunkheila/)



[linkedin.com/in/frantz-bouchereau-1673375/](https://www.linkedin.com/in/frantz-bouchereau-1673375/)

Industry and Research Invest in AI in Different Ways

Better Models or Better Data?



Andrej Karpathy – [Building the Software 2.0 Stack](#) (Spark+AI Summit 2018)

Data-Centric AI in 2022 – Trend Gaining Pace and Visibility



<https://spectrum.ieee.org/andrew-ng-data-centric-ai>

Most existing AI resources support few applications



Autonomous driving



Language modeling



Computer vision

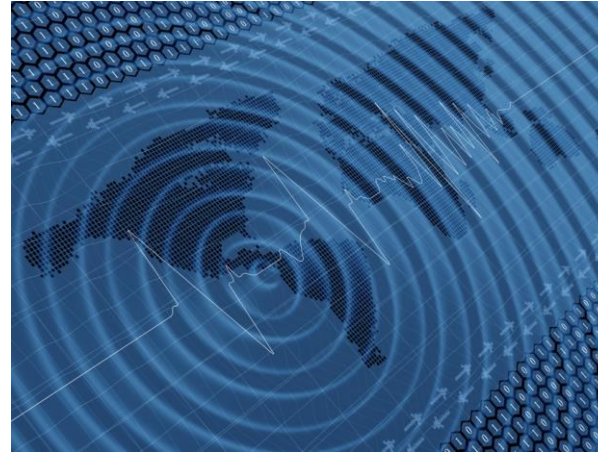


Speech recognition

Most signal processing applications cannot count on many AI resources



Vibration analysis



Seismic analysis



Predictive maintenance



Digital health



Machine health

...

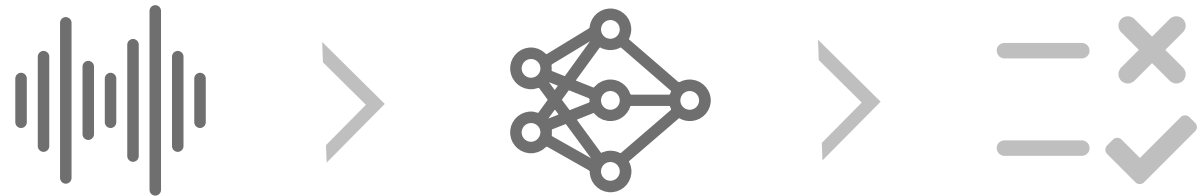
Time for a survey...

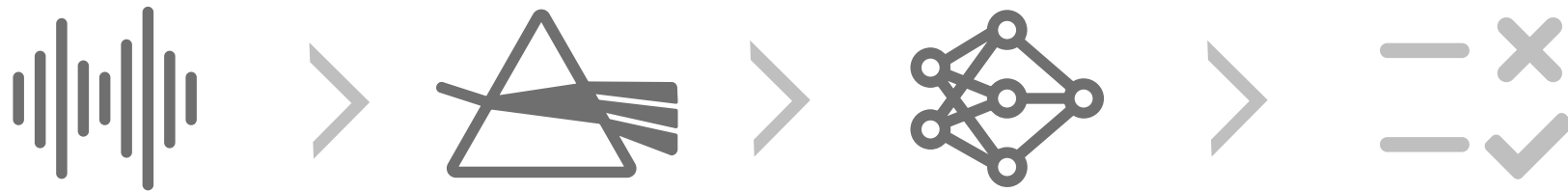
Which of these best describes your AI-related challenges?

Model Complexity

Data Complexity

AI Expertise

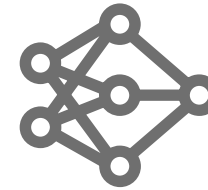




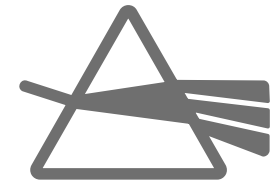
Data-Centric AI in Signal Processing Applications

Agenda – Three Practical Engineering Approaches

1. Transfer learning with pre-trained AI models



2. Feature extraction with simpler and smaller AI models

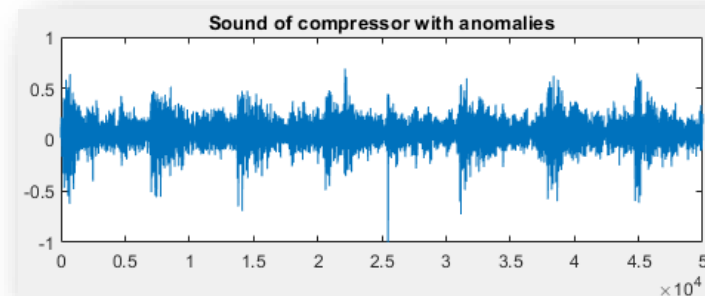
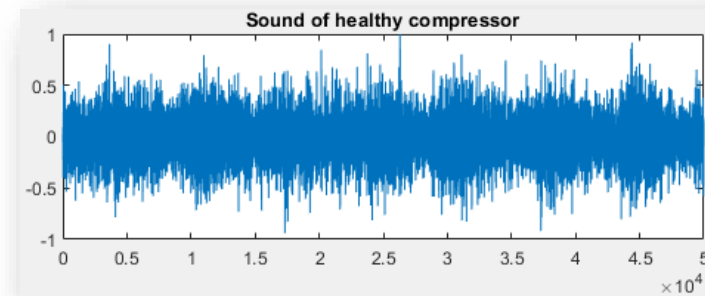


3. Better signal datasets, real or simulated



How can I apply transfer learning to detecting faults in an air compressors based on their noise

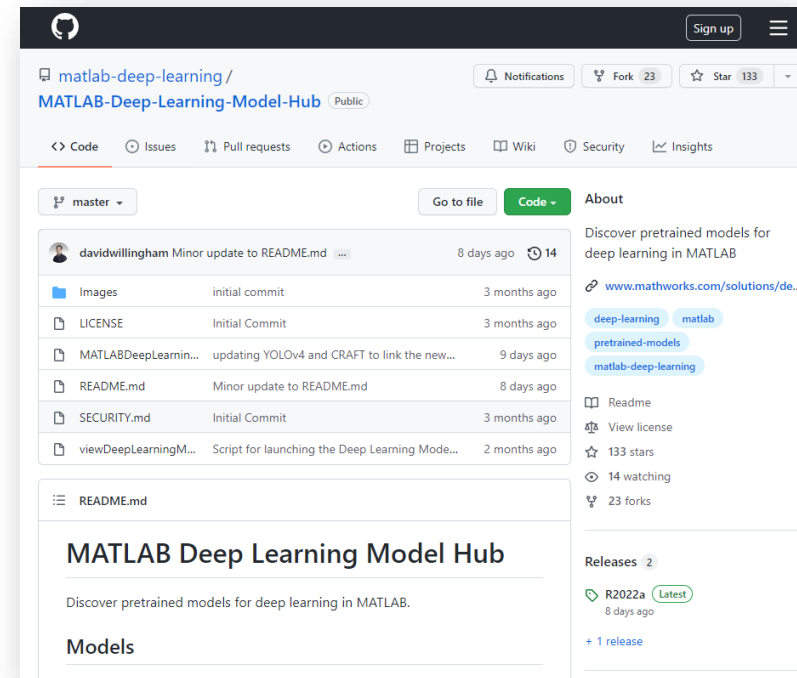
- Have dataset with labeled sound recordings
- One “healthy” class
- 7 different classes of faults
- 1800.wav files, 225 per class



[Example: Transfer Learning with Pretrained Audio Networks in Deep Network Designer](#)

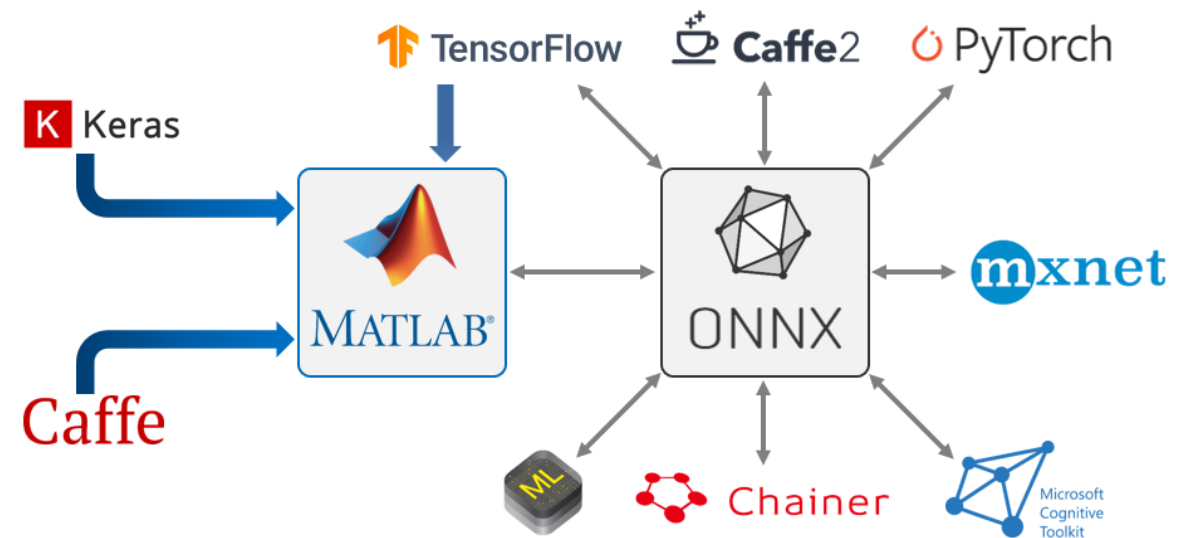
Finding a pre-trained deep learning network for Transfer Learning

- Find one directly in MATLAB



<https://github.com/matlab-deep-learning/MATLAB-Deep-Learning-Model-Hub>

- Import it from a known non-MATLAB repository



Demo – Transfer Learning with YAMNet for Fault Detection

The image shows a series of screenshots from the MATLAB Deep Network Designer interface, illustrating the process of transfer learning for audio classification using a pre-trained YAMNet model.

- Deep Network Designer Start Page:** Shows the 'Pretrained YAMNet network model for sound classification' with details: Depth: 28, Size: 15.5 MB, Parameters: 3.75 M, Input Size: 96x64x1. An 'Open' button is visible.
- Layer Library:** Displays various layer types under 'Audio Networks (Pretrained)', including CREPE, OpenL3, VGGish, and YAMNet.
- Designer Network Diagram:** Shows a sequence of layers: imageInputLayer, image3dInputLayer, sequenceInputLayer, featureInputLayer, rollInputLayer, activation_25 (reluLayer), conv2d_13 (convolution2d), L132 (batchNormaliza), activation_28 (reluLayer), global_averag... (globalAverage), dense (fullyConnected), softmax (softmaxLayer), and Sound classificationLa... (Sound classificationLayer).
- Live Script:** Shows a workspace with variables like accuracy (0.9909), audioDataStore, and a confusion matrix plot.

The confusion matrix plot shows the relationship between True Classes and Predicted Classes. The True Classes are Bearing, Flywheel, Healthy, LIV, LOV, NRV, Piston, and Riderbelt. The Predicted Classes are the same. The matrix shows high diagonal values, indicating accurate predictions.

True Class \ Predicted Class	Bearing	Flywheel	Healthy	LIV	LOV	NRV	Piston	Riderbelt
Bearing	106	2						2
Flywheel	2	108						
Healthy			110					
LIV				109		1		
LOV					110			
NRV						110		
Piston	1						109	
Riderbelt								110

Example: Transfer Learning with Pretrained Audio Networks in Deep Network Designer

Transfer Learning – Handouts

Choosing the right model for transfer learning

Journal of Sensor and Actuator Networks

Article
Comparison of Pre-Trained CNNs for Audio Classification Using Transfer Learning
 Eleni Tsalera¹, Andreas Papadakis^{2,*} and Maria Samarakou¹

MDPI

Table 1. Selected CNNs.

CNN	Type	Trained in	Number of Layers	Millions of Parameters
GoogleNet	Image	ImageNet	22	7
SqueezeNet	Image	ImageNet	18	1.24
ShuffleNet	Image	ImageNet	50	1.4
VGGish	Sound	YouTube	24	72.1
Yamnet	Sound	YouTube	28	3.7

Table 4. The classes, the number of files, and the file types of the selected datasets.

Dataset	Classes	Number of Files	File Type
UrbanSound8k	10	8732	wav
ESC-10	10	494	wav
Air Compressor	8	1800	wav

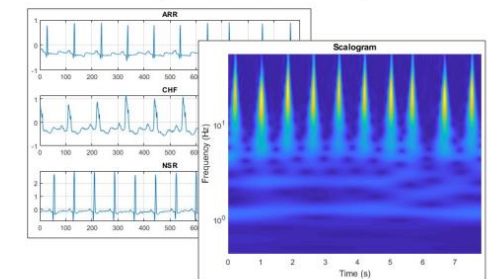
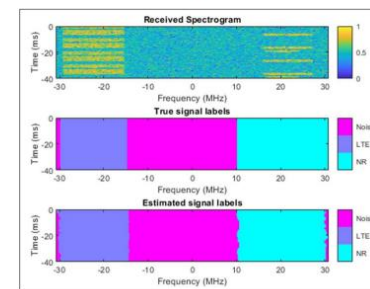
Classification accuracy per CNN per dataset

Training from Scratch vs. Transfer Learning

<https://www.mdpi.com/2224-2708/10/4/72>

Transfer Learning with models pre-trained on different types of data

- [Spectrum Sensing with Deep Learning to Identify 5G and LTE Signals](#)
- Network: ResNet-50 (Image segmentation)
- Input: 256-by-256-by-3 images
- Features: spectrogram of baseband waveforms
- [Classify Time Series Using Wavelet Analysis and Deep Learning](#)
- Network: GoogLeNet (Image object classification)
- Input: 224-by-224-by-3 images
- Features: cwt (scalogram) of ECG signals

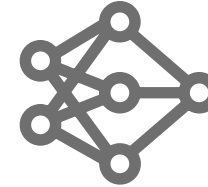


[Download @ Journal of Sensors and Actuator Networks](#)

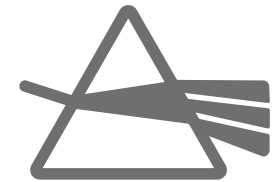
Data-Centric AI in Signal Processing Applications

Agenda – Three Practical Engineering Approaches

1. Transfer learning with pre-trained AI models



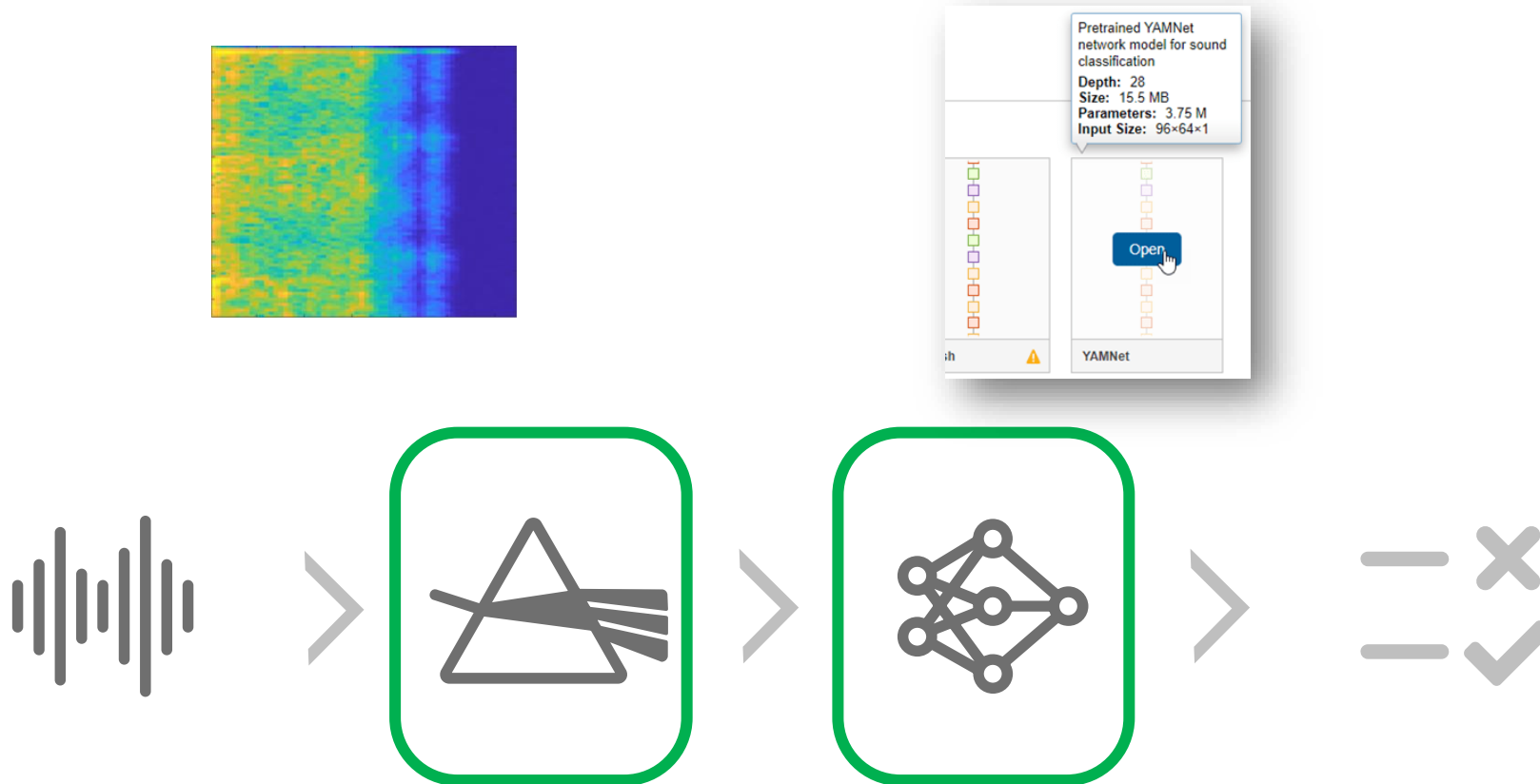
2. Feature extraction with simpler and smaller AI models



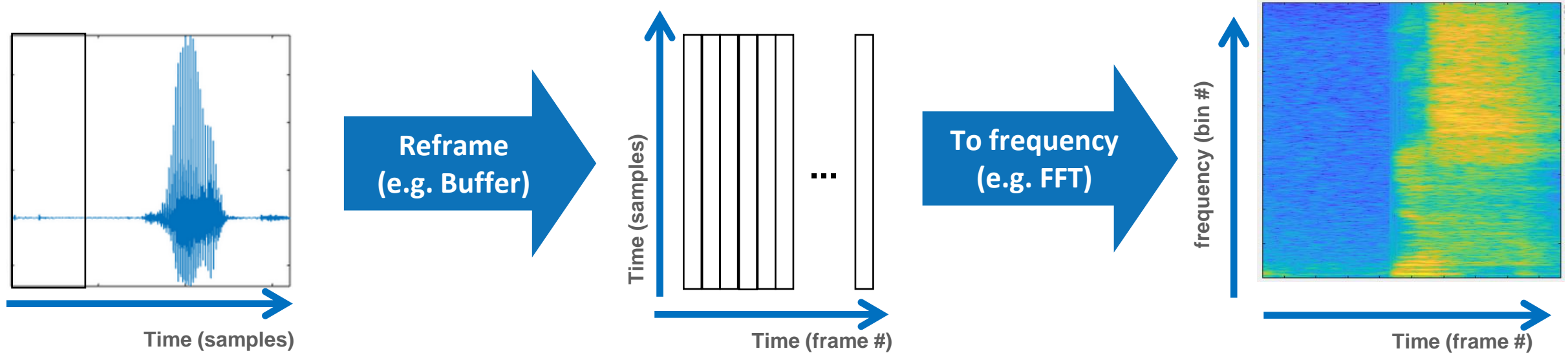
3. Better signal datasets, real or simulated



Deep networks most often don't learn directly from raw signals

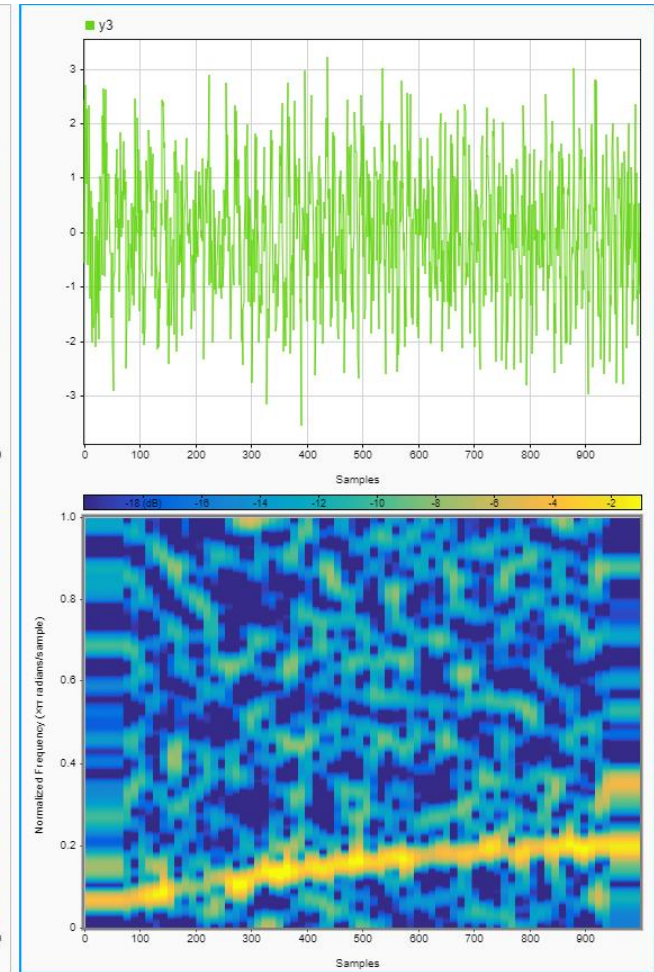
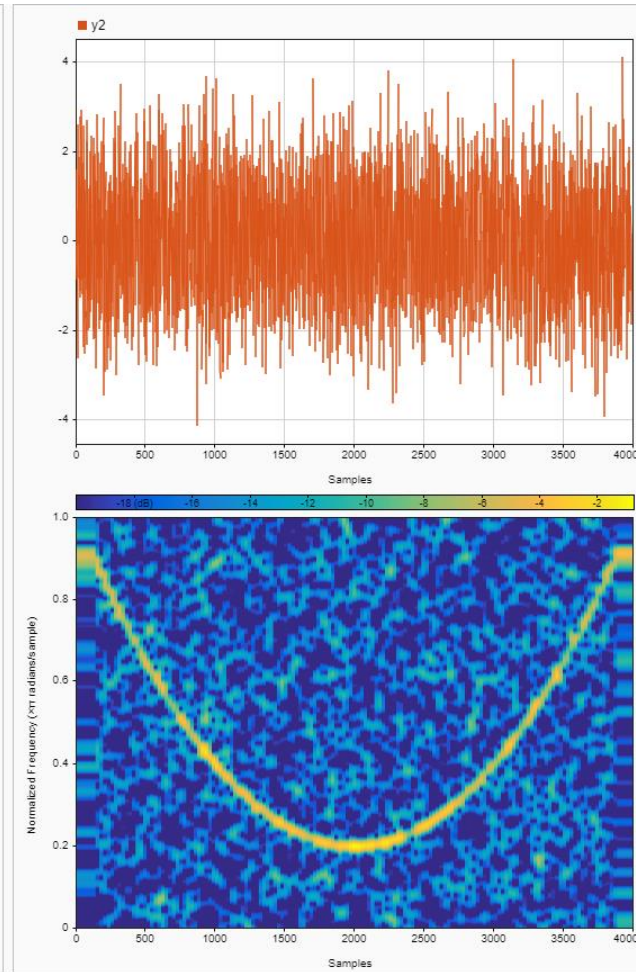
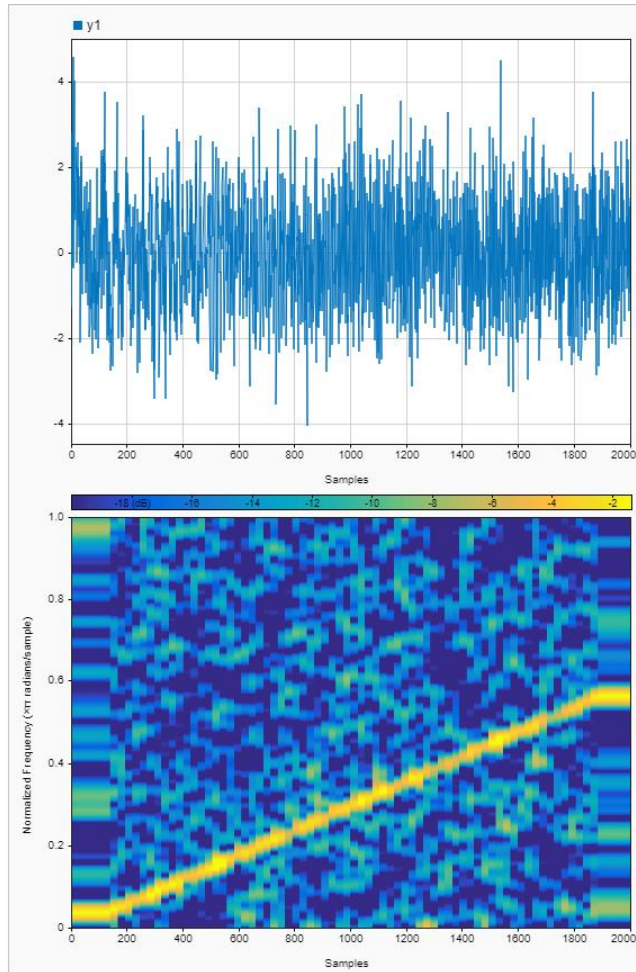


Time-frequency transformations are popular feature extraction methods



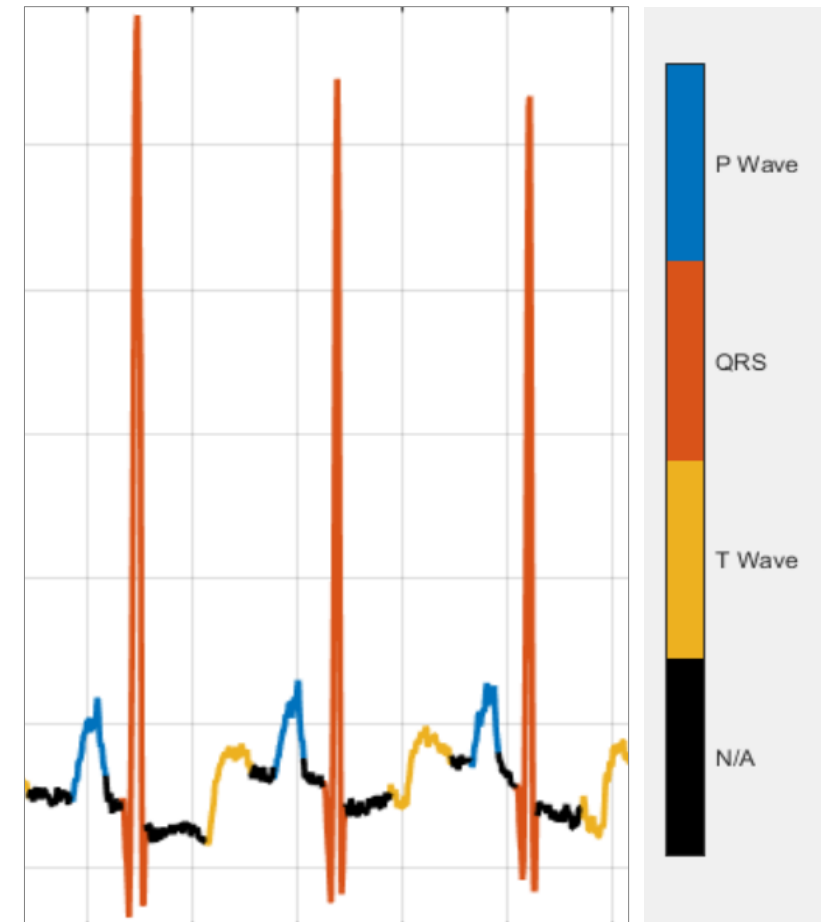
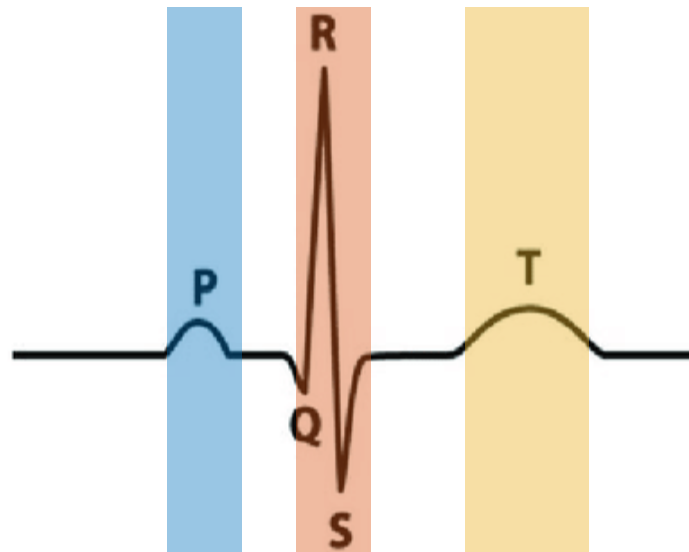
Time-frequency transforms make signal characteristics more evident

Time-frequency transform



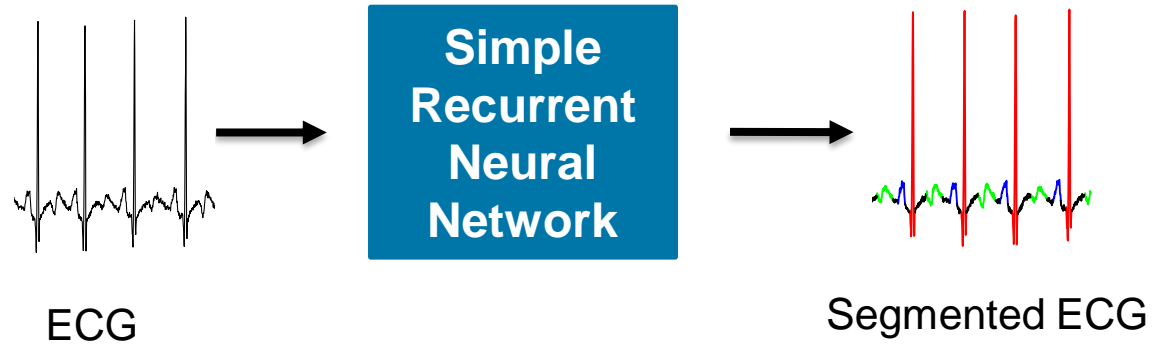
How to use feature extraction to segment ECG signals?

- Have dataset with signals labeled by cardiologists
- 3 types of wave events
- 210 ECG recordings (total ~15 minutes)



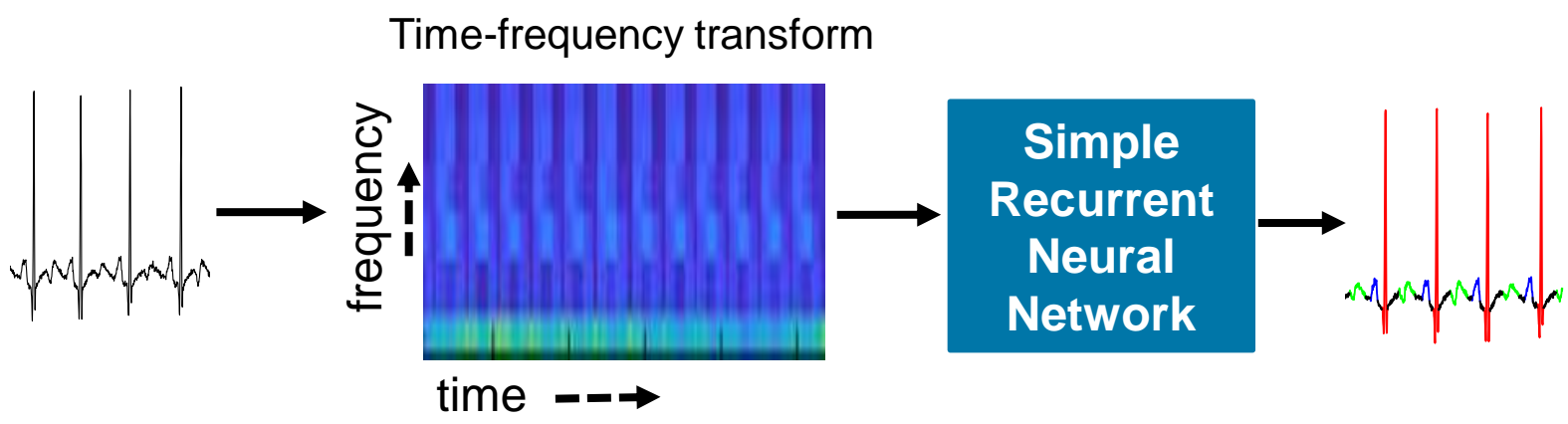
[Example: Waveform Segmentation Using Deep Learning](#)

Feature extraction allows getting high accuracy from simple AI models



	P	QRS	T	n/a
P	37.4%	2.3%	1.1%	2.1%
QRS	4.1%	61.4%	0.6%	4.3%
T	2.5%	1.4%	58.7%	7.3%
n/a	56.0%	34.8%	39.6%	86.2%
	P	QRS	T	n/a

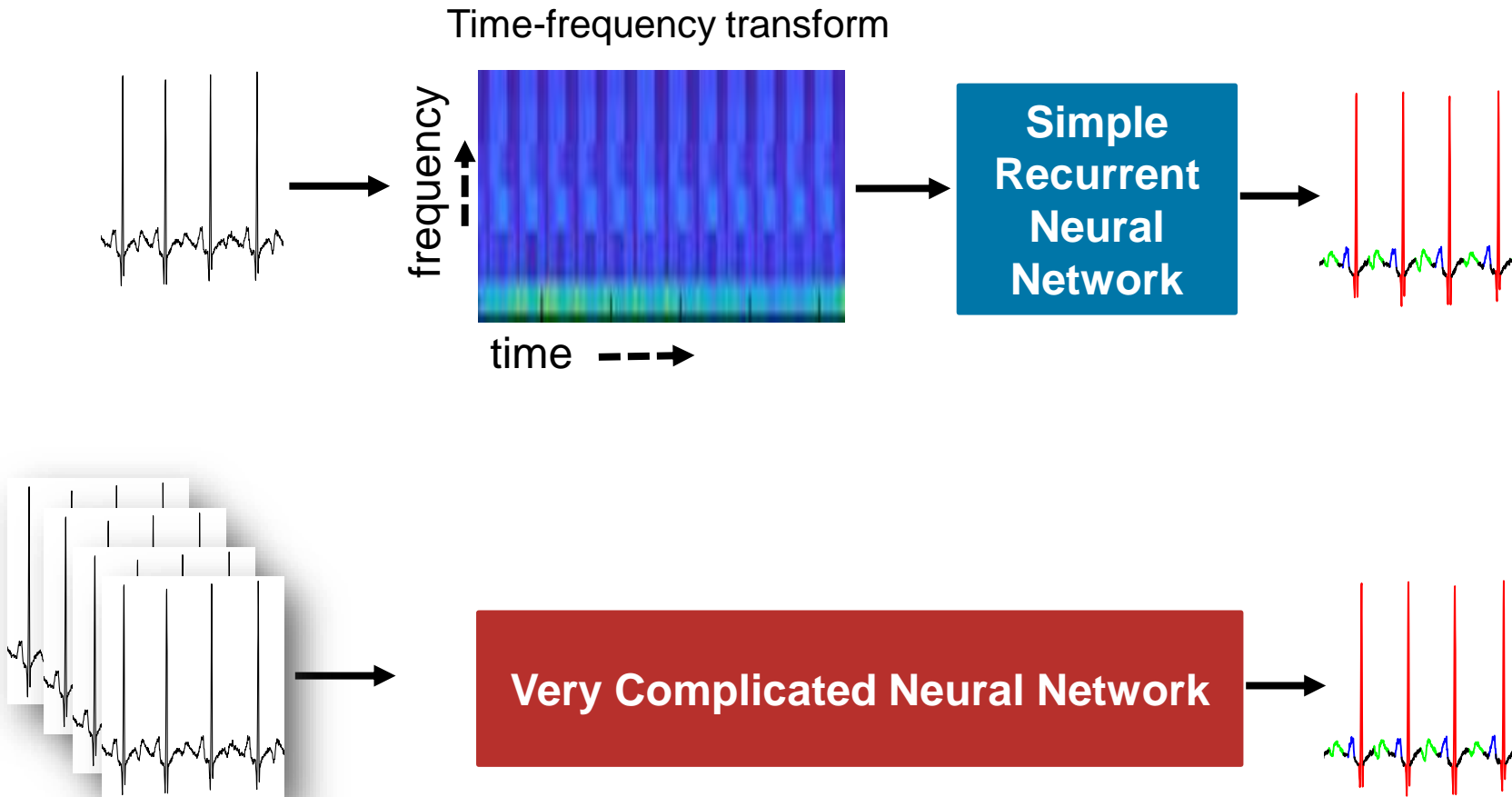
Predicted Class



	P	QRS	T	n/a
P	80.5%	0.4%	0.3%	3.2%
QRS	0.7%	90.7%	0.3%	2.1%
T	1.0%	0.3%	82.2%	7.7%
n/a	17.8%	8.7%	17.2%	87.1%
	P	QRS	T	n/a

Predicted Class

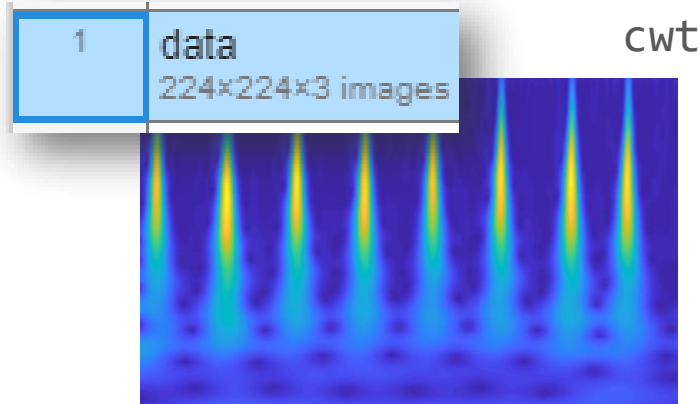
Feature extraction reduces model and data complexity



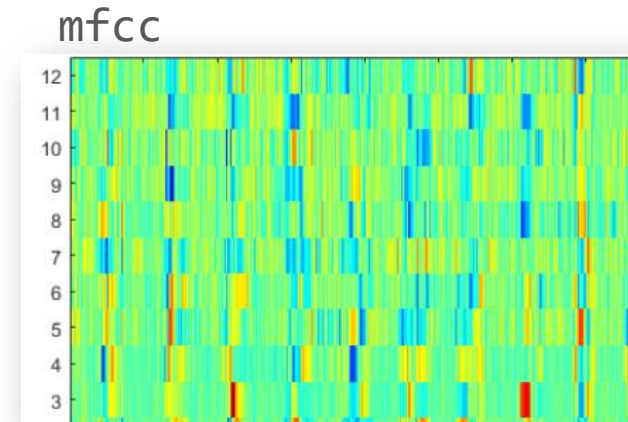
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T	1.0%	0.3%	82.2%	7.7%
n/a	17.8%	8.7%	17.2%	87.1%
	Predicted Class			

Domain experts are best placed to select feature extraction algorithm

Model size, signal patterns

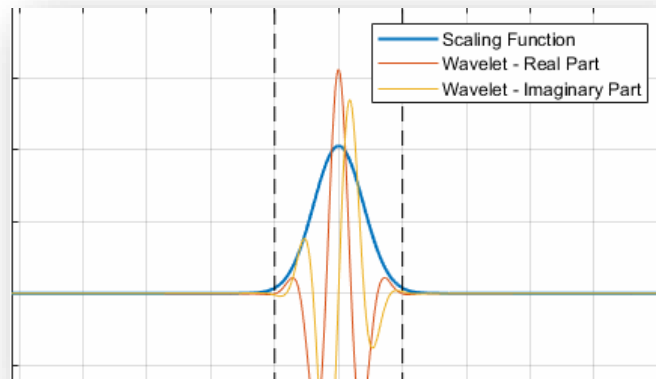


Application and signal type



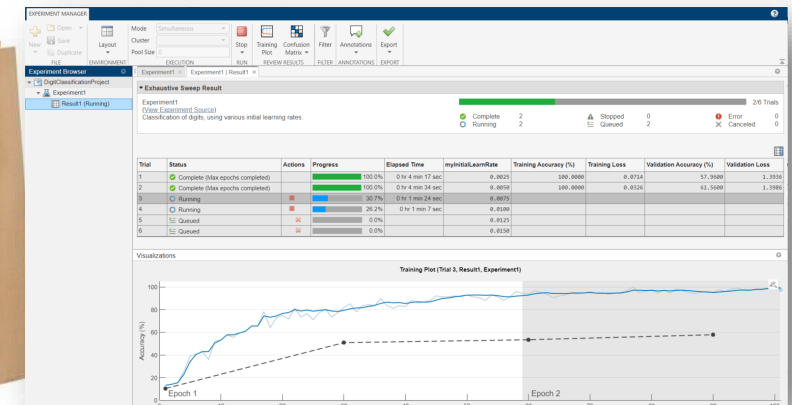
Automated methodology

waveletScattering



Test-based experiments

experimentManager



signalFrequencyFeatureExtractor

Feature Extraction – Handouts

MathWorks Wins Geoscience AI GPU Hackathon

The following post is from Akhilesh Mishra, Mil Shastri and Samwith V. Rao from MathWorks here to talk about their participation and in a Geoscience hackathon. Akhilesh and Mil are Applications Engineers and Samwith is the Industry Marketing Manager supporting the Oil and Gas industry.

Background

SEAM (SEG Advanced Modeling Corp.) is a petroleum geoscience industry body that fosters collaborations among industry, government, and academia to address major Geological challenges. Their latest event was a hackathon (SEAM AI Applied Geoscience GPU Hackathon) that sought to explore the use of AI to improve both qualitative and quantitative interpretation of geophysical images of Earth's interior, and speed up the applications using NVIDIA GPUs.

A total of 7 teams participated from all over the world, including commercial companies (Chevron, Total, Petrobras) and a mix of industry and university students. Each team was assigned a mentor who is an expert geoscientist working for a top oil and gas company.

The Challenge

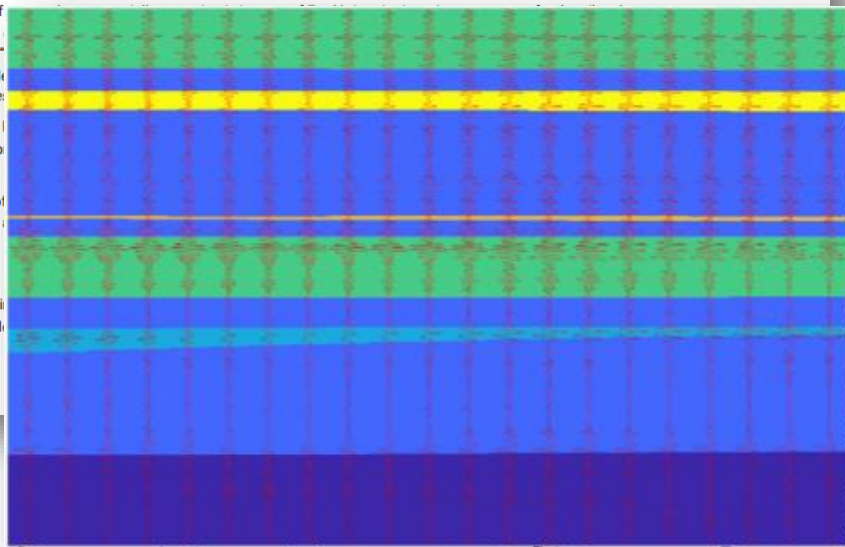
Geologic interpretation of industry. Seismic images summarized by the term "and abandonment of undi often called seismic facie

This process is still done l display. Successful interp features.

The problem statement of automatically, producing ; up human interpretation.

The Data

We were given the followi public and has been label



Daihatsu Uses AI to Classify Engine Sounds

Challenge

Develop an AI solution that can judge the level of engine knocking sound, which only skilled workers could judge

Solution

Create classification models and easy-to-use interface with MATLAB, making it possible to examine features multiple times

Key Outcomes

- Performed knocking sound analysis with the same accuracy as skilled workers
- Increased AI expertise through MATLAB training
- Promoted visualization of AI and increased awareness of AI

[Link to case study](#)



Daihatsu used AI to identify knocking sounds from its engines.

"Although we tried other programming languages, it was hard to implement. We decided to use MATLAB, which allows us to easily import the necessary data by dragging and dropping, and we could easily see the result by ourselves."

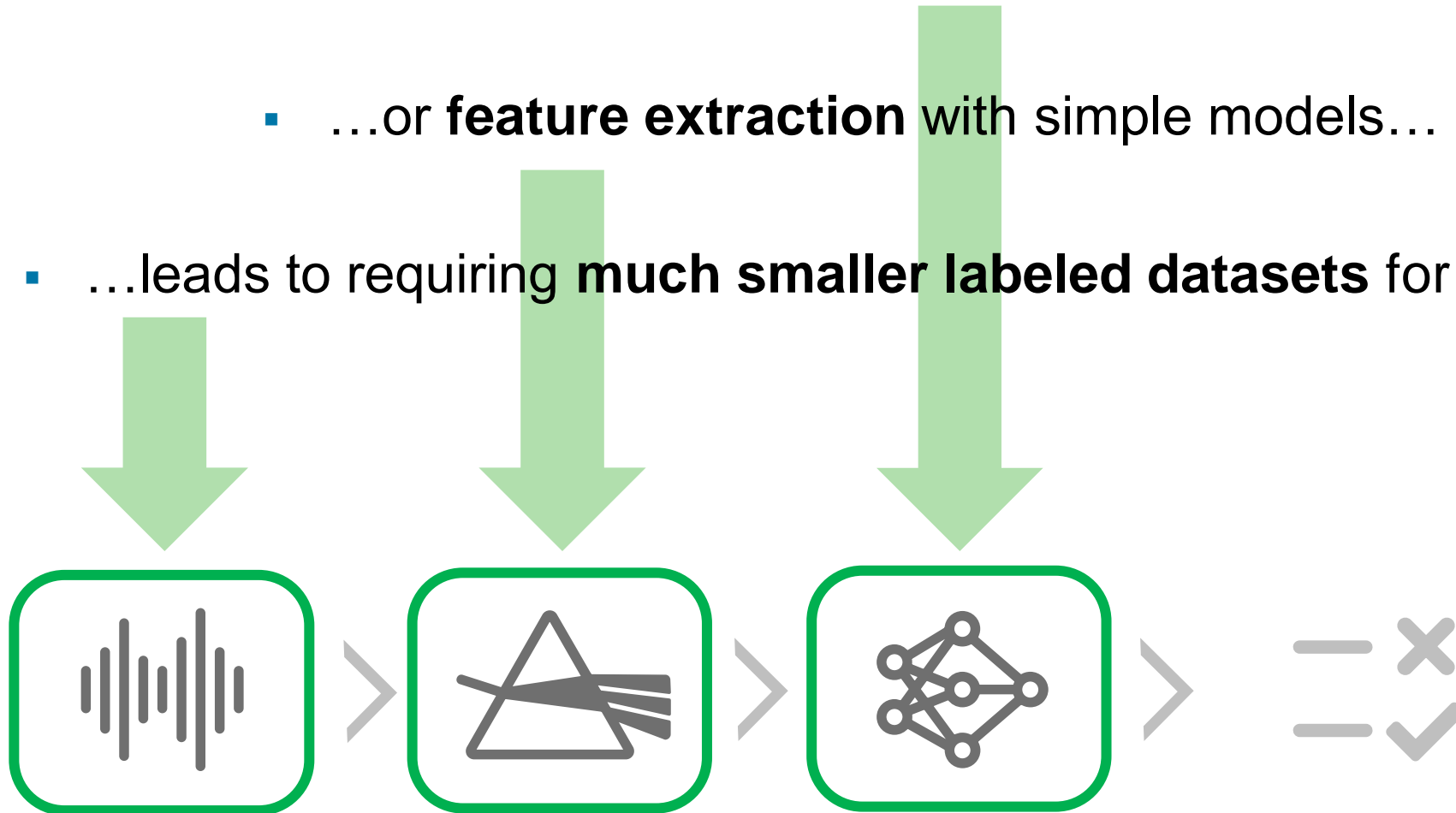
- Takuya Kumagae, Daihatsu Motor Co., Ltd.

[MathWorks Deep Learning Blog Post](#)

[Daihatsu User Story](#)

Requiring smaller datasets multiplies the impact of data engineering

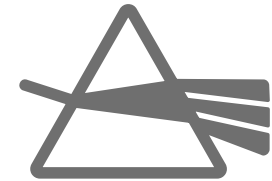
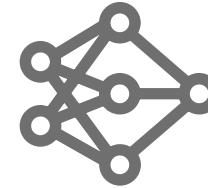
- Using **transfer learning**...
- ...or **feature extraction** with simple models...
- ...leads to requiring **much smaller labeled datasets** for model training



Data-Centric AI in Signal Processing Applications

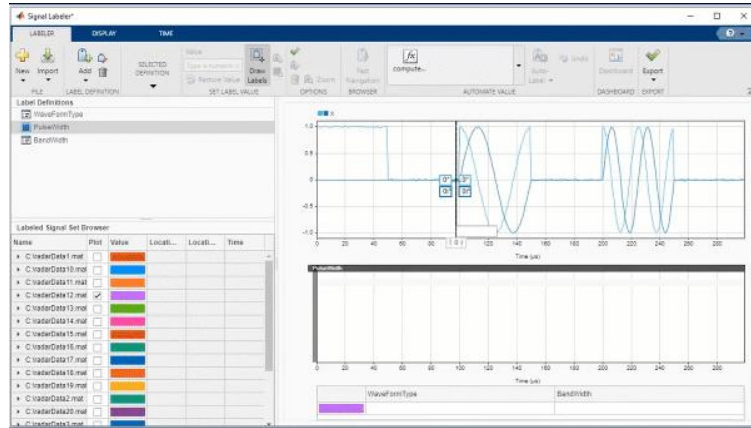
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2. Feature extraction with simpler and smaller AI models
3. Better signal datasets, real or simulated



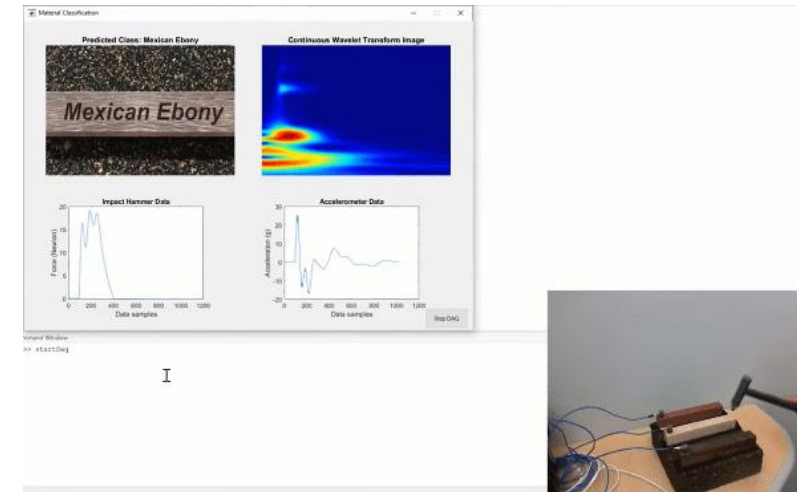
How can I enhance the quality of my training signal data?

Define accurate data labels



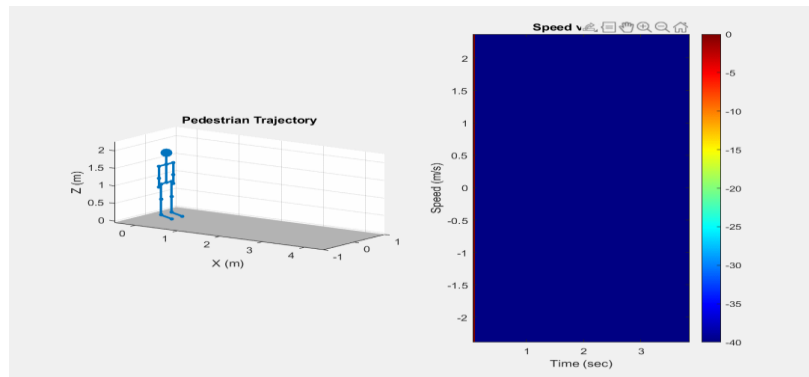
signalLabeler

Record and label new data via Apps and Hardware

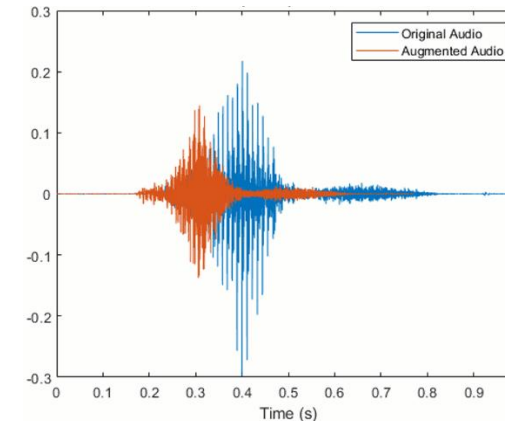


App Designer

Synthesize data via simulation



Augment data via signal processing



audioDataAugmenter

MATLAB EXPO 2022 Talk – Honeywell Technology Solutions

Automating Audio Labeling Workflow Using Pre-Trained Deep Learning Models for Voice Activity Detection



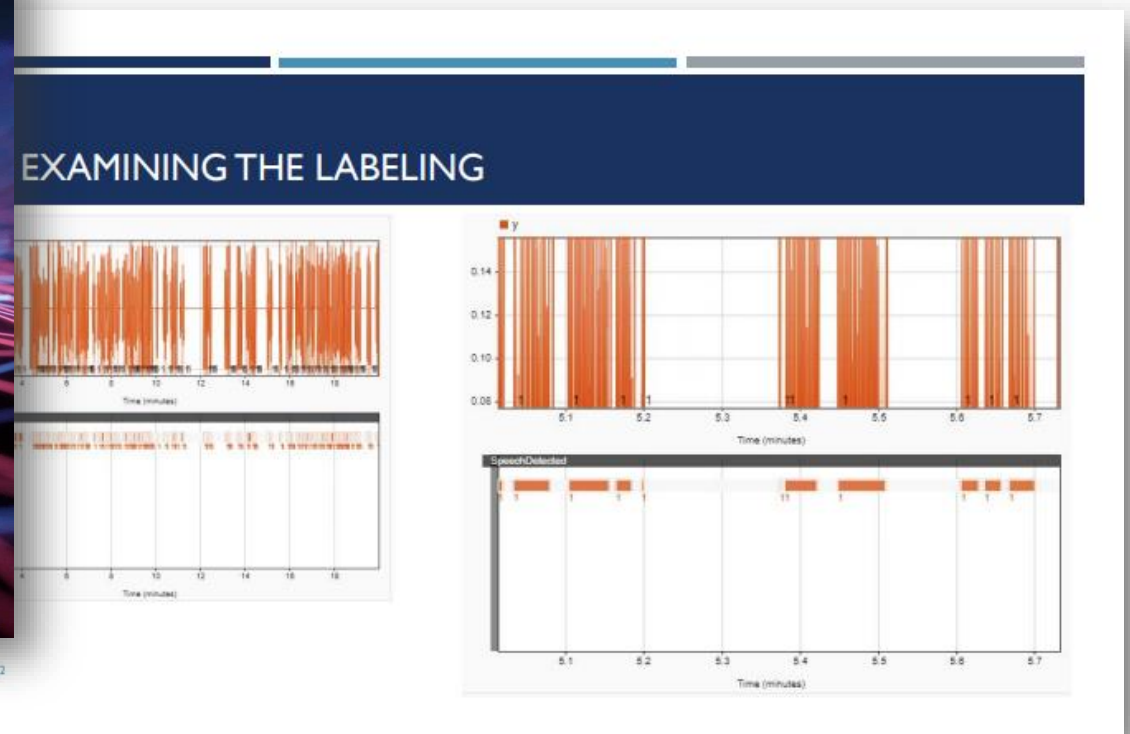
AUTOMATING AUDIO LABELING WORKFLOW USING
DEEP LEARNING FOR VOICE ACTIVITY DETECTION

RAMAKRISHNAN RAMAN
FELLOW
HONEYWELL TECHNOLOGY SOLUTIONS

VASANTHA SELVI PAULRAJ
LEAD EMBEDDED ENGINEER
HONEYWELL TECHNOLOGY SOLUTIONS

MATLAB EXPO 2022

Paulraj, Vasantha Selvi



Track: **AI in Engineering**

Data-Centric AI accelerates AI adoption by domain experts

The “unbiggen AI” effect

○ ~~Model Complexity~~

» MATLAB

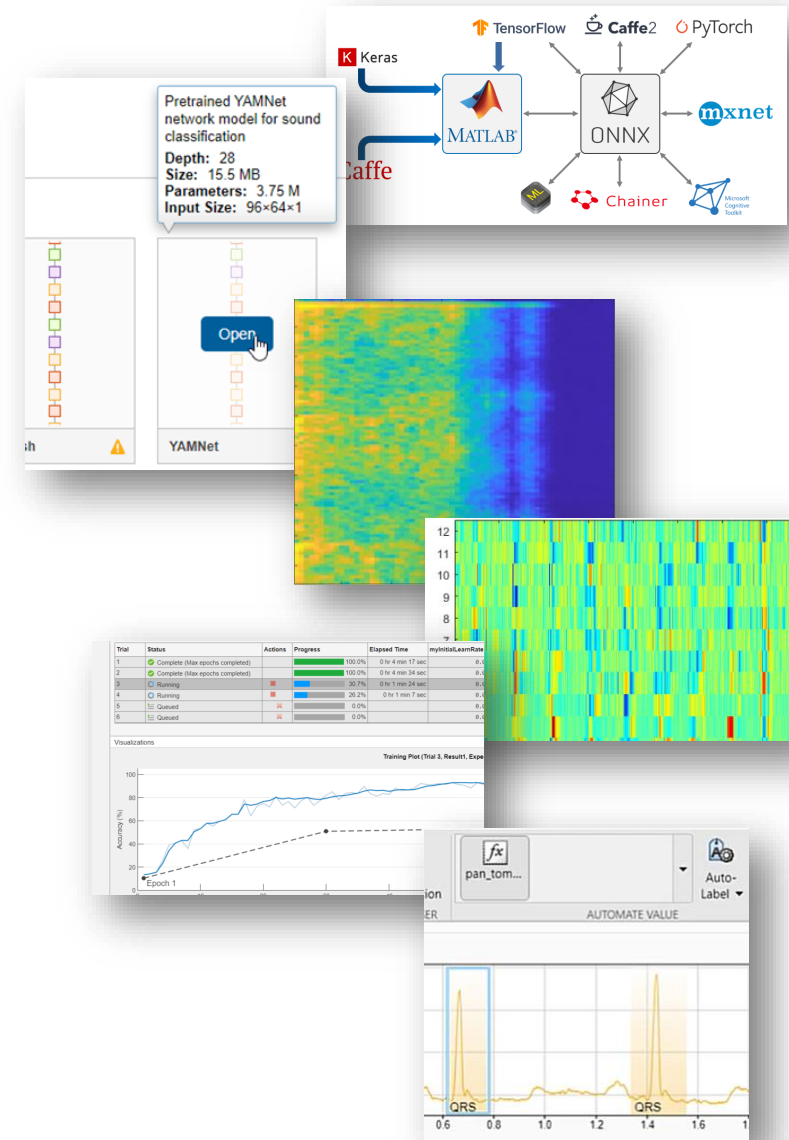
○ ~~Data Complexity~~

» Signal Processing

○ ~~AI Expertise~~

» Domain Expertise

AI + Signal Processing



MATLAB EXPO

Thank you

