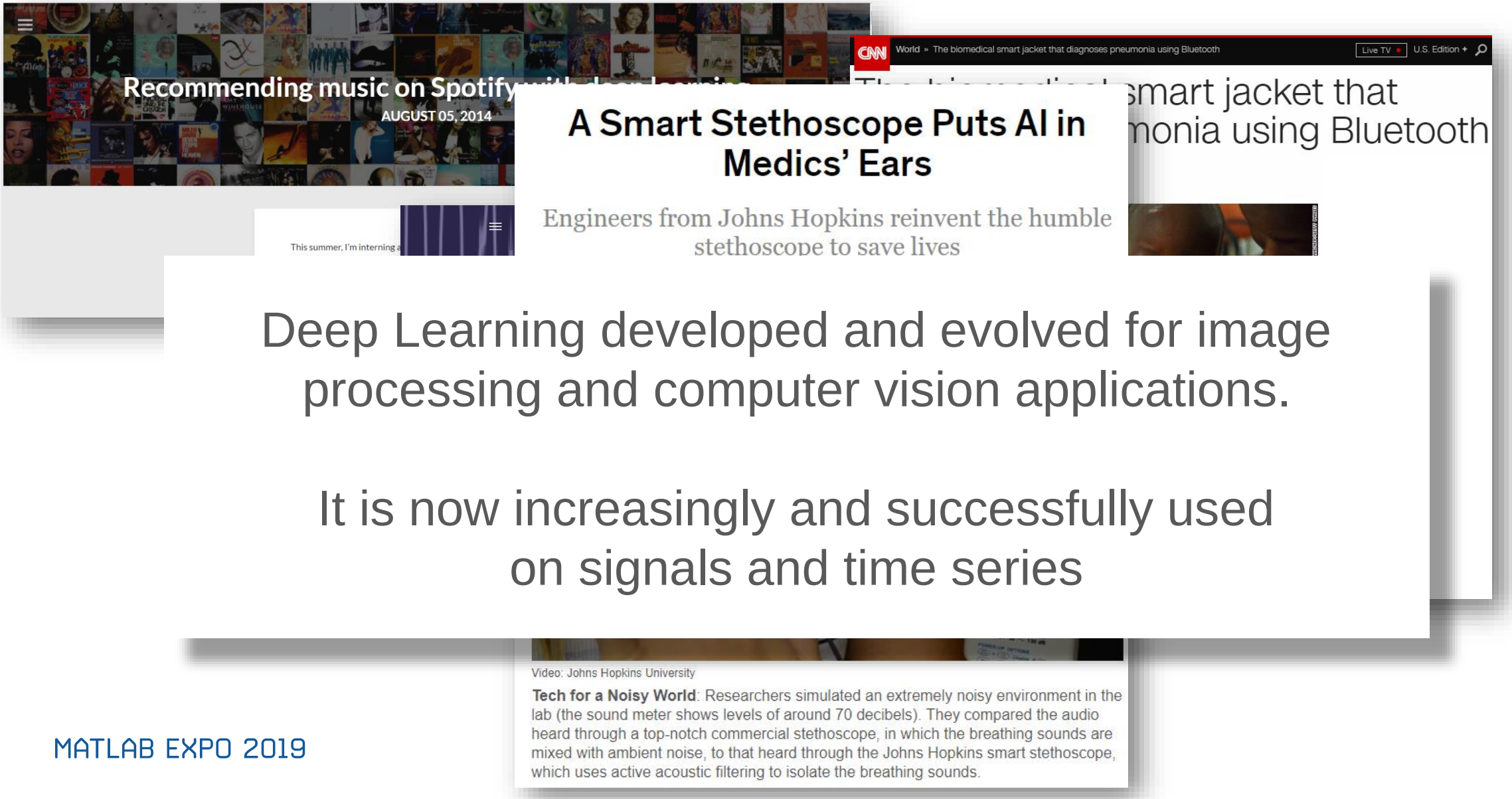
MATLAB EXPO 2019

AI Techniques in MATLAB for Signal, Time-Series, and Text Data

Bryan Perfetti

AI and Deep Learning for Signals in the News



Deep Learning developed and evolved for image processing and computer vision applications.

It is now increasingly and successfully used on signals and time series

The Use of Deep Learning is Growing Across Industries

Aerospace, Defense and Communications

Communications devices, security

Multi-standard communications receivers, drone recognition

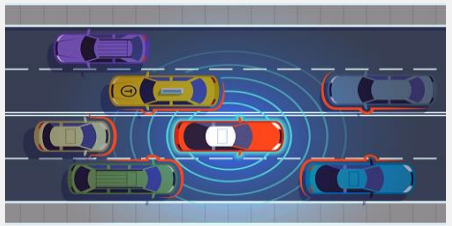
Consumer Electronics and Digital Health

Voice assistants

Digital health

Automotive

Voice control enabled Infotainment



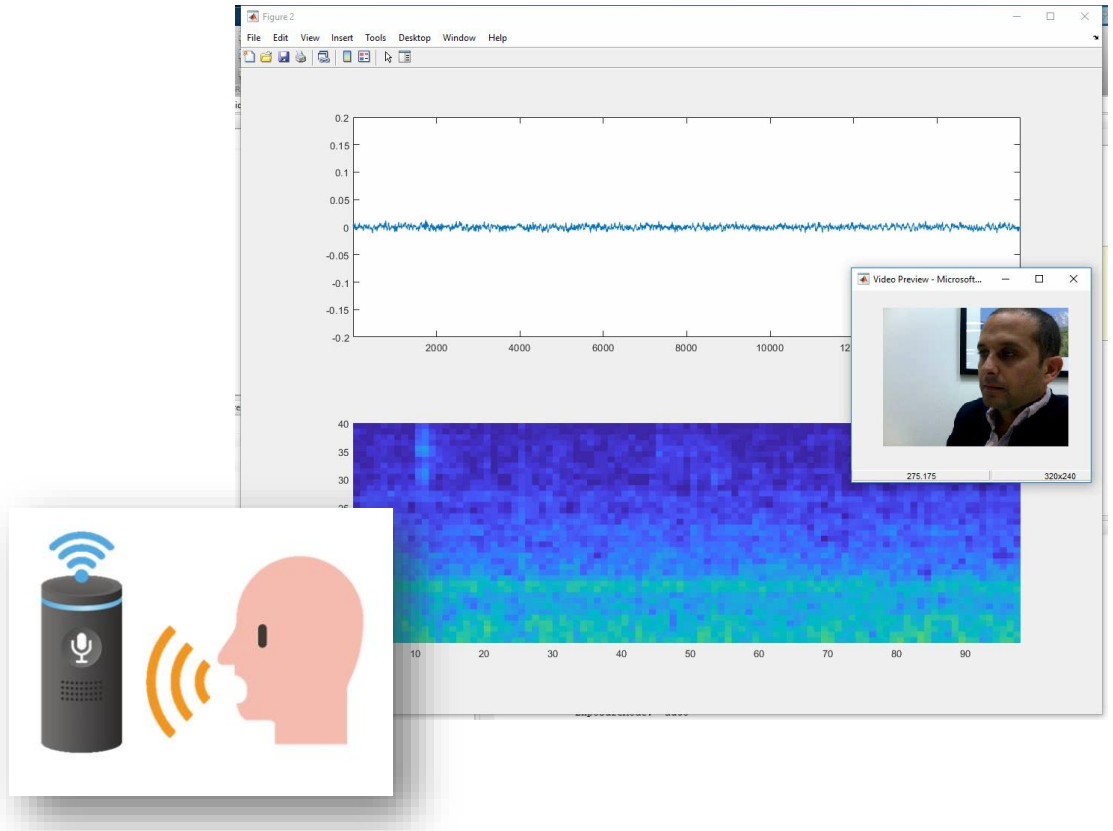
Sensor processing, automated driving

Industrial Automation

Condition monitoring

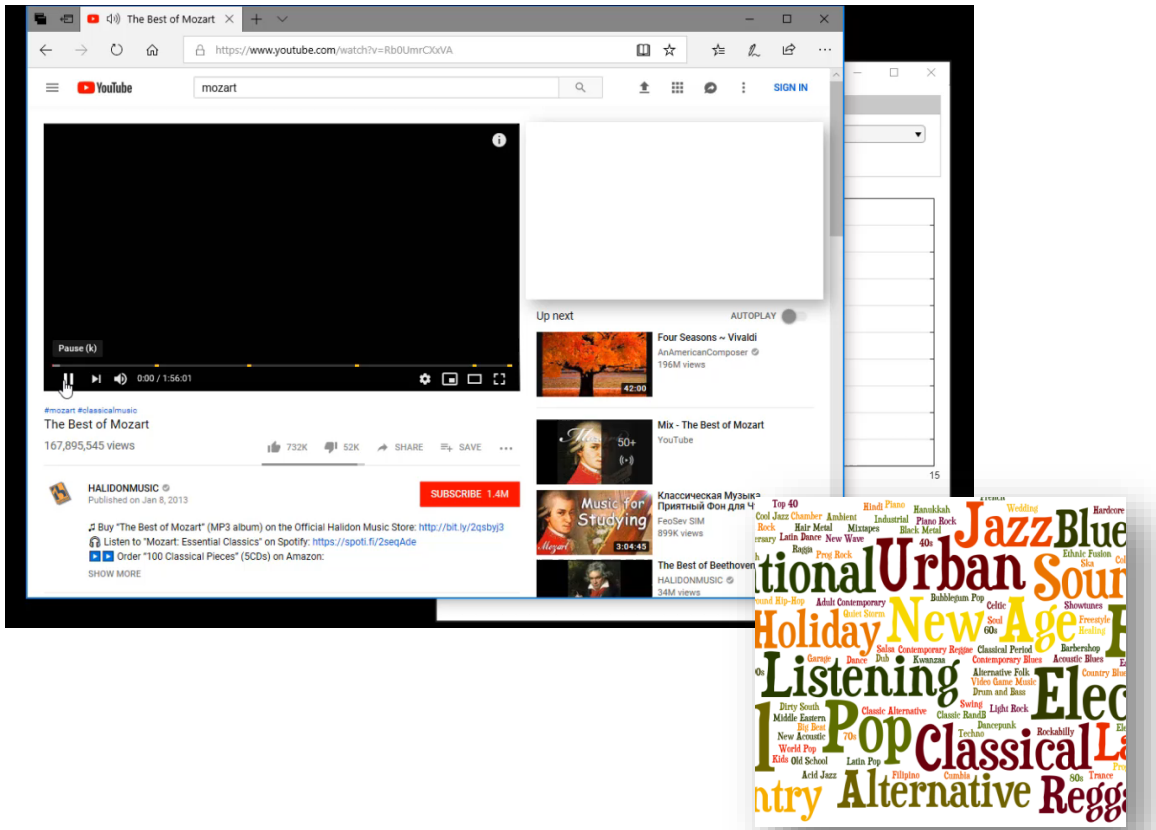
Predictive maintenance

Application Examples Using MATLAB – Audio and Speech



Speech Command Recognition
(a.k.a. "Keyword Spotting")

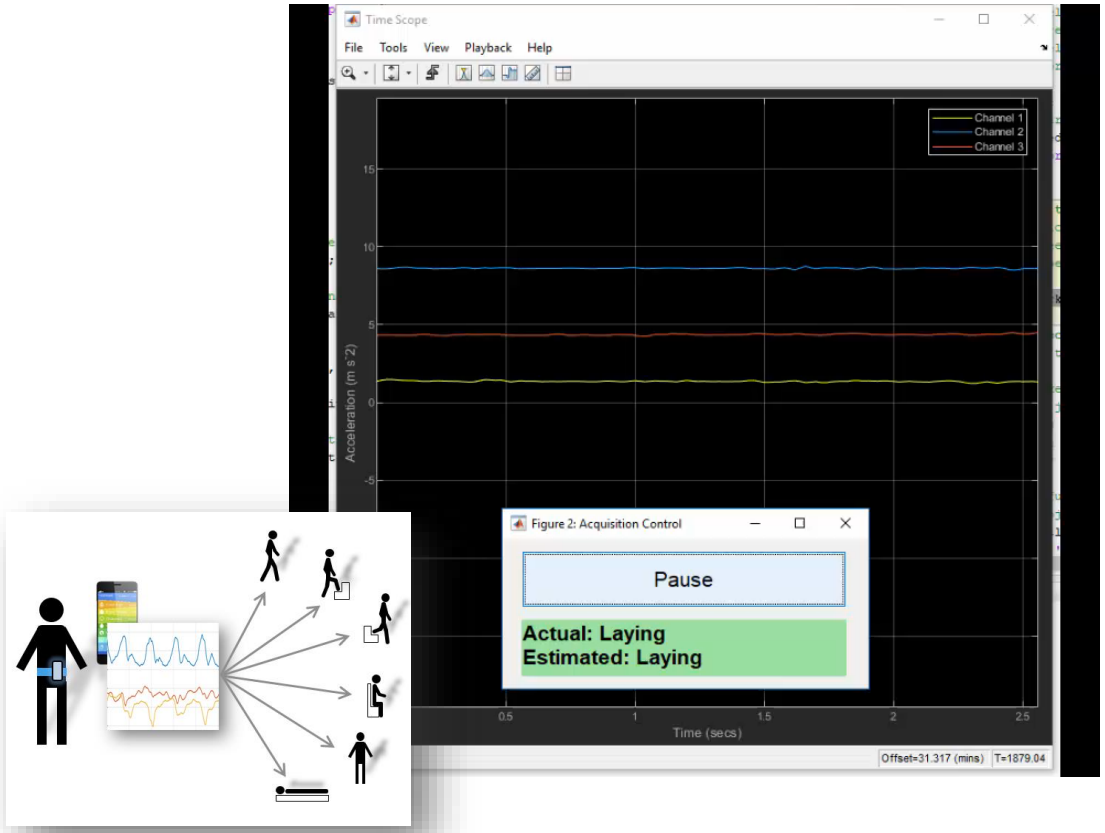
https://www.mathworks.com/help/deeplearning/examples/deep-learning-speech-recognition.html



Music Genre Classification

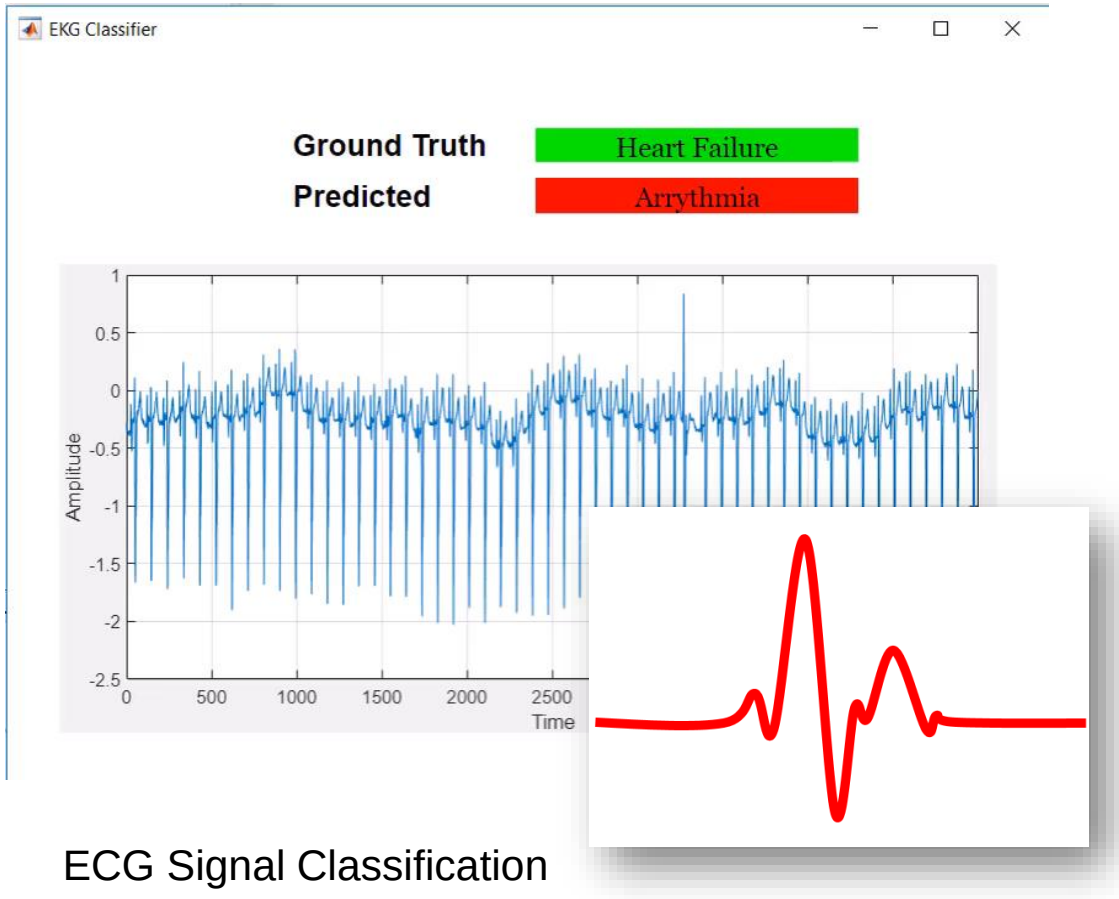
https://www.mathworks.com/help/audio/examples/music-genre-classification-using-wavelet-time-scattering.html

Application Examples Using MATLAB – Industrial and physiological sensors



Human Activity Recognition

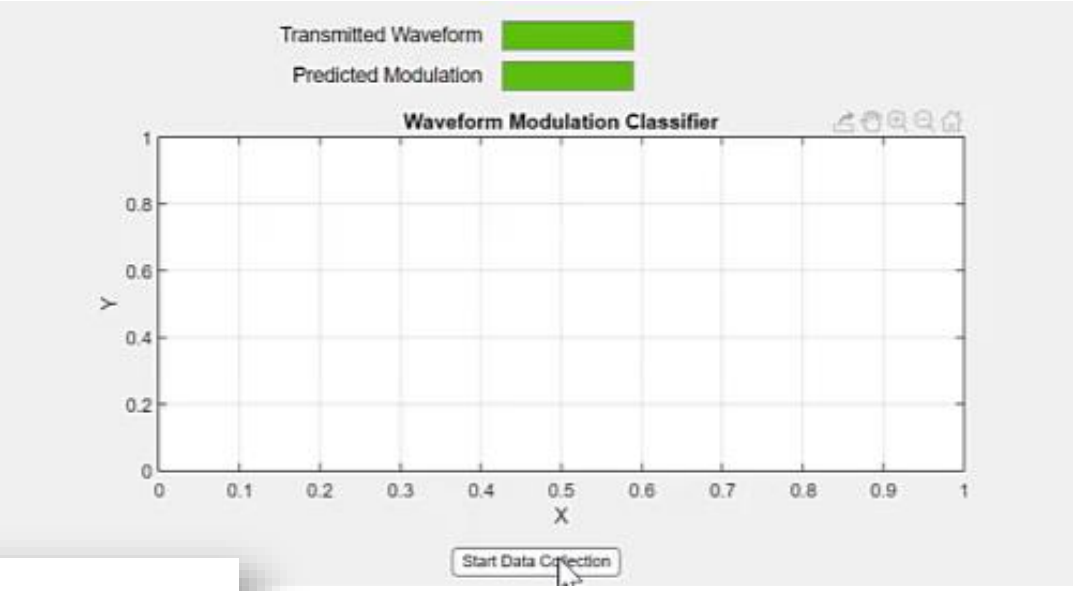
https://www.mathworks.com/help/deeplearning/examples/sequence-to-sequence-classification-using-deep-learning.html

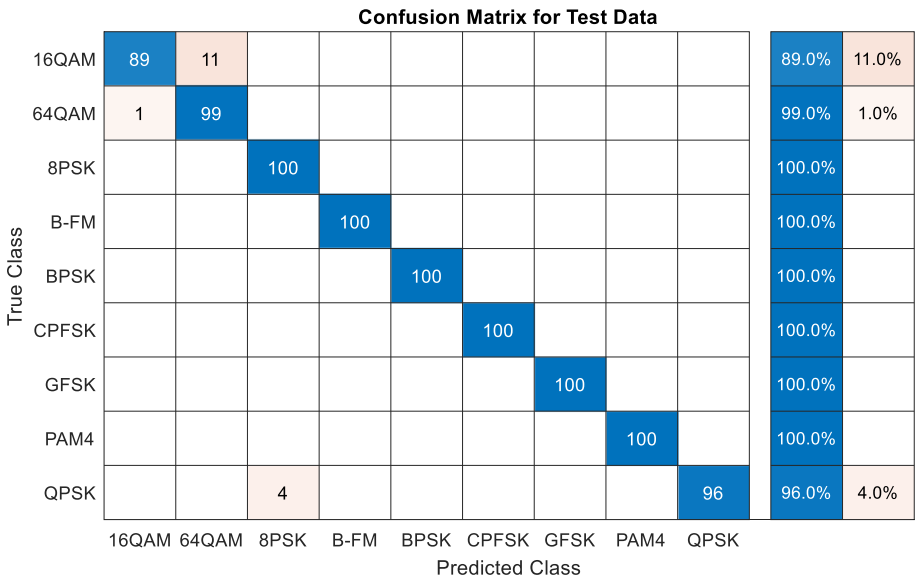


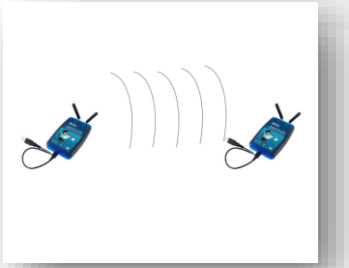
ECG Signal Classification

https://www.mathworks.com/help/signal/examples/classify-ecg-signals-using-long-short-term-memory-networks.html

Application Examples Using MATLAB – Radar and Communications



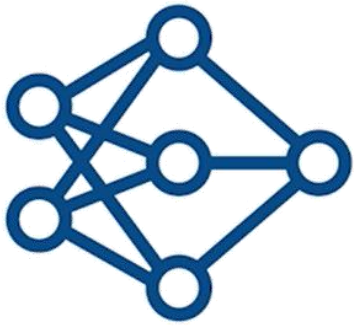




Modulation Classification

http://www.mathworks.com/help/comm/examples/modulation-classification-with-deep-learning.html

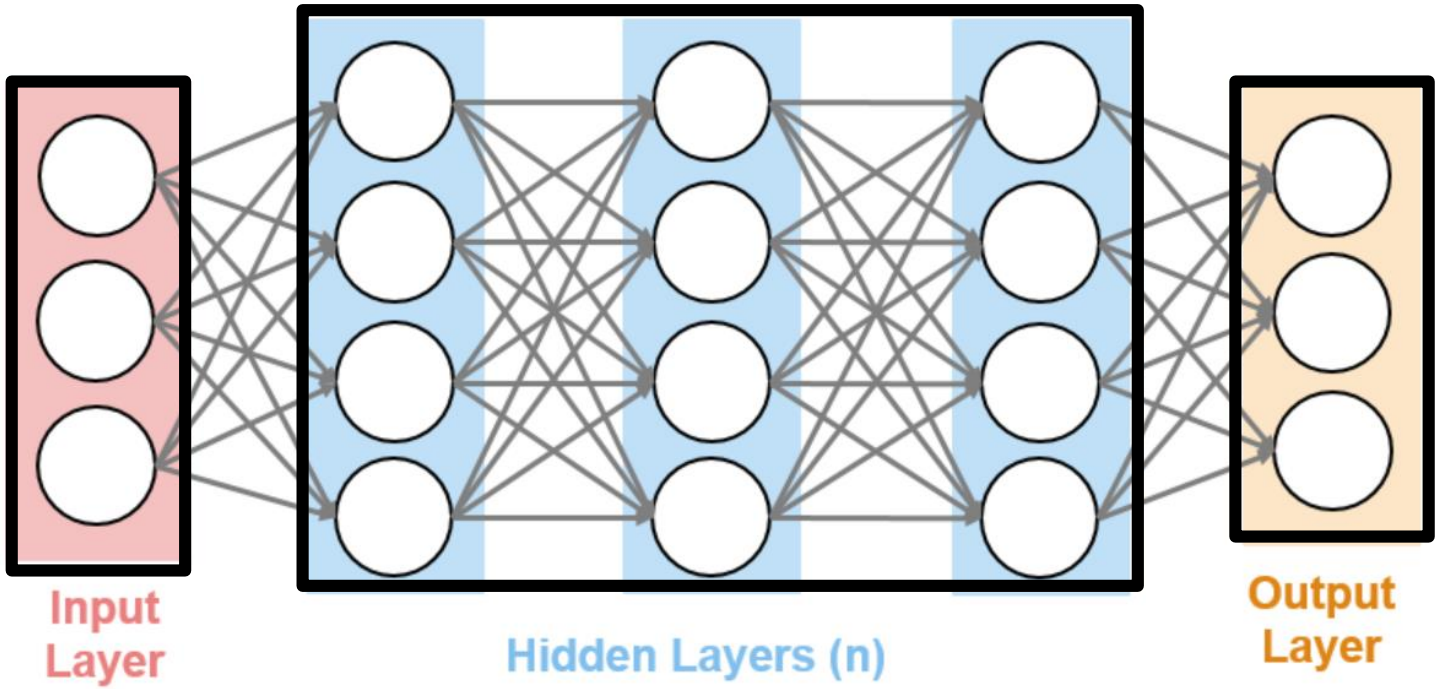
Agenda



- Deep Learning – Basic ideas
- Deep Learning Model Development for Signals, Time Series, and Text
- Conclusions

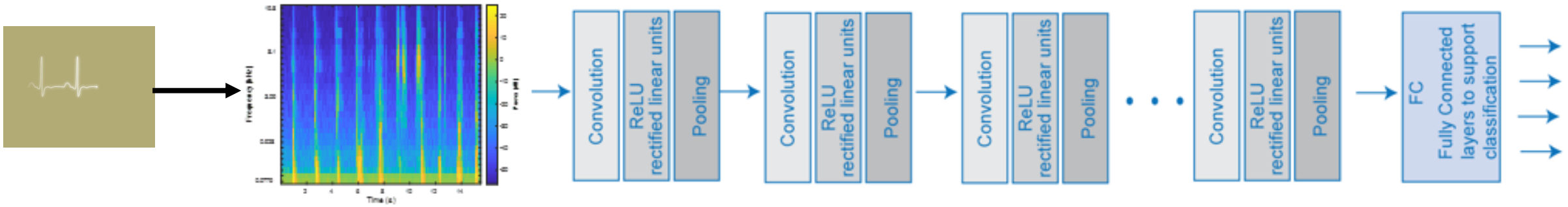
What is Deep Learning?

Deep learning is a type of machine learning in which a model learns from examples.



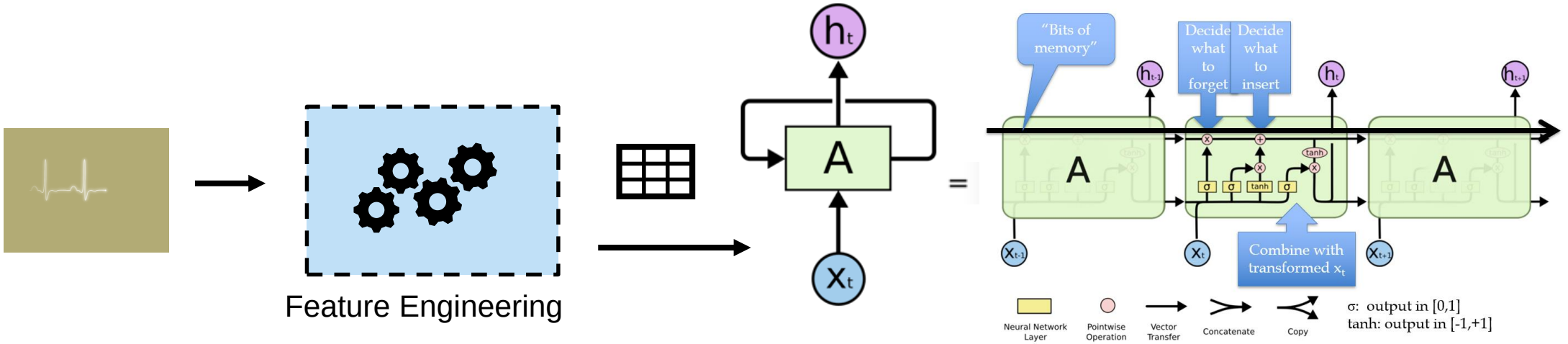
Common Network Architectures - Signal Processing

Convolutional Neural Networks (**CNN**)



Time-Frequency Transformation

Long Short Term Memory (**LSTM**) Networks



Feature Engineering

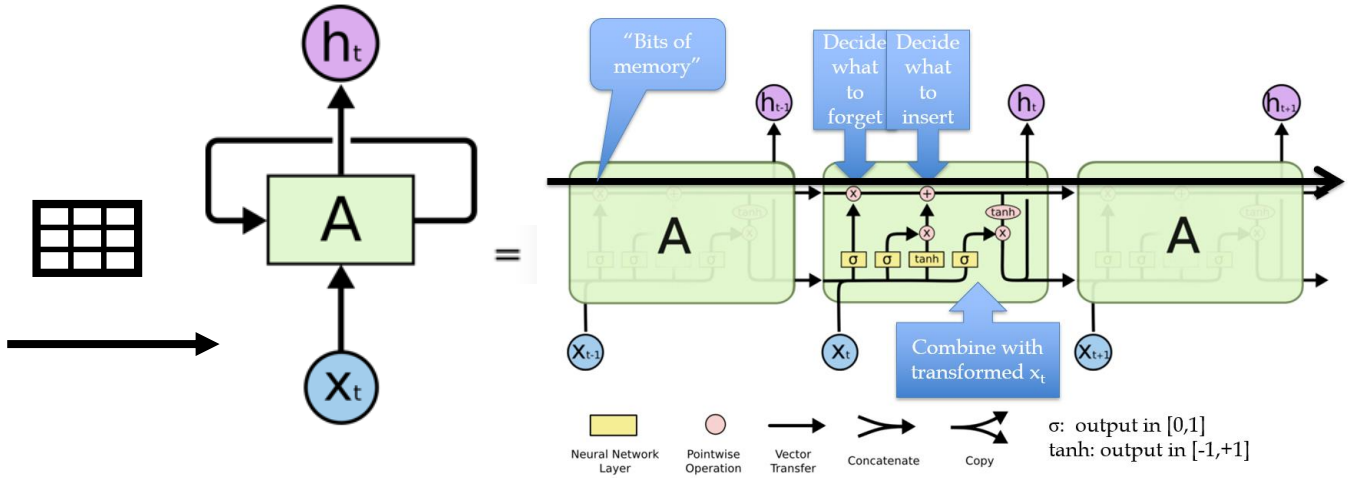
Common Network Architectures – Text Analytics

Feature Engineering

Convolutional Neural Networks (**CNN**)

Feature Engineering

Long Short Term Memory (**LSTM**) Networks



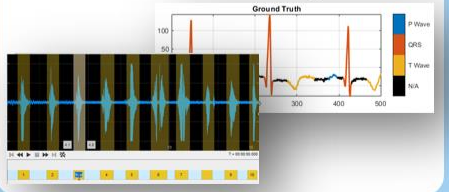
Deep Learning Workflow

Create and Access Datasets

Data sources

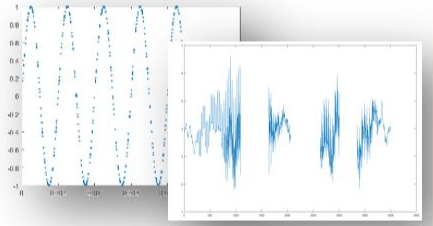
Simulation and augmentation

Data Labeling

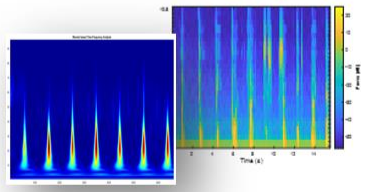


Preprocess and Transform Data

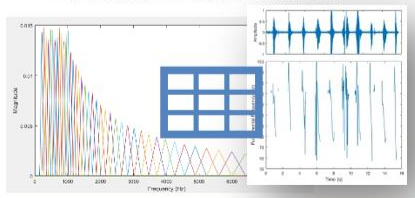
Pre-Processing



Transformation



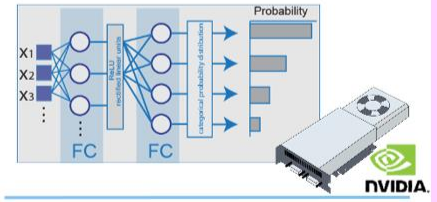
Feature extraction



Develop Predictive Models

Import Reference Models/ Design from scratch

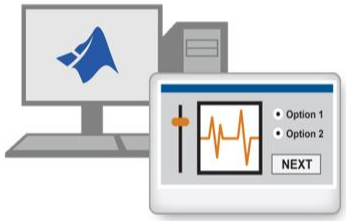
Hardware-Accelerated Training



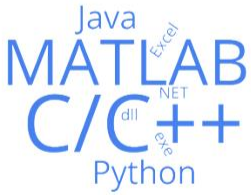
Analyze and tune hyperparameters

Accelerate and Deploy

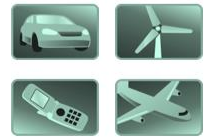
Desktop Apps



Enterprise Scale Systems

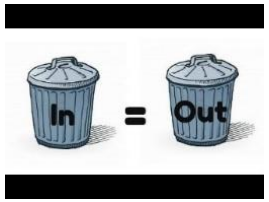


Embedded Devices and Hardware



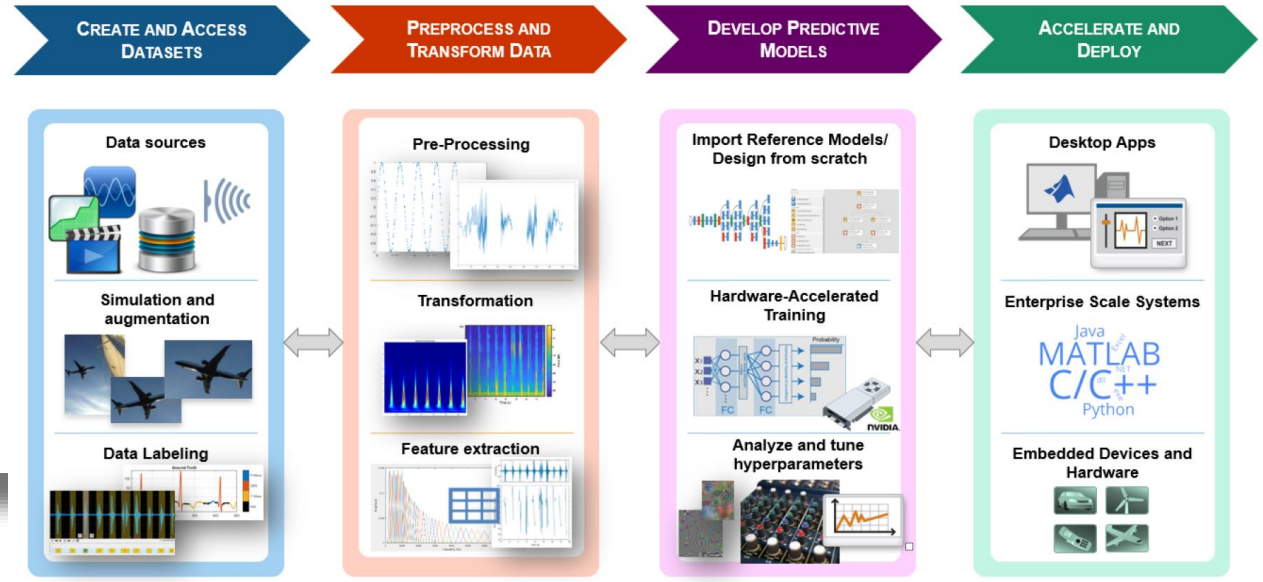
Deep Learning Workflow Challenges – Signals and Time Series

Deep learning models only as good as training data



Data Labeling

Limited Data Availabiliy

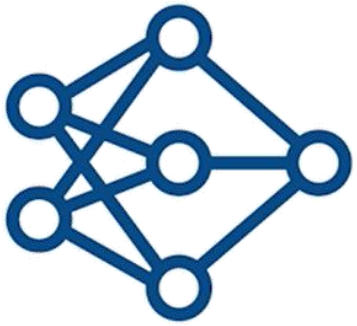


Domain-specific data processing desirable

Limited reference research

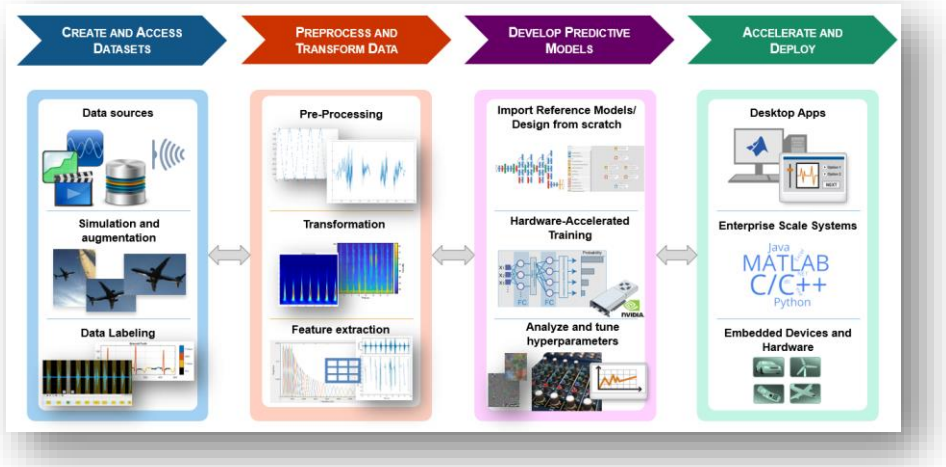
Deployment and Scaling to various platforms

Agenda



- Deep Learning – Basic ideas

- **Deep Learning Model Development for Signals, Time Series, and Text**
  - Data
  - Processing and transformation
  - Model design and optimization
  - Acceleration, prototyping, and deployment



- Conclusions

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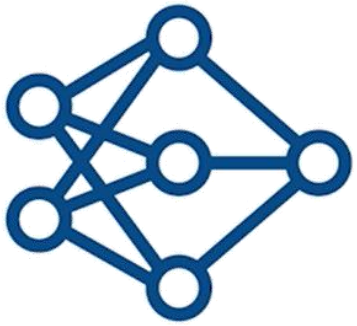

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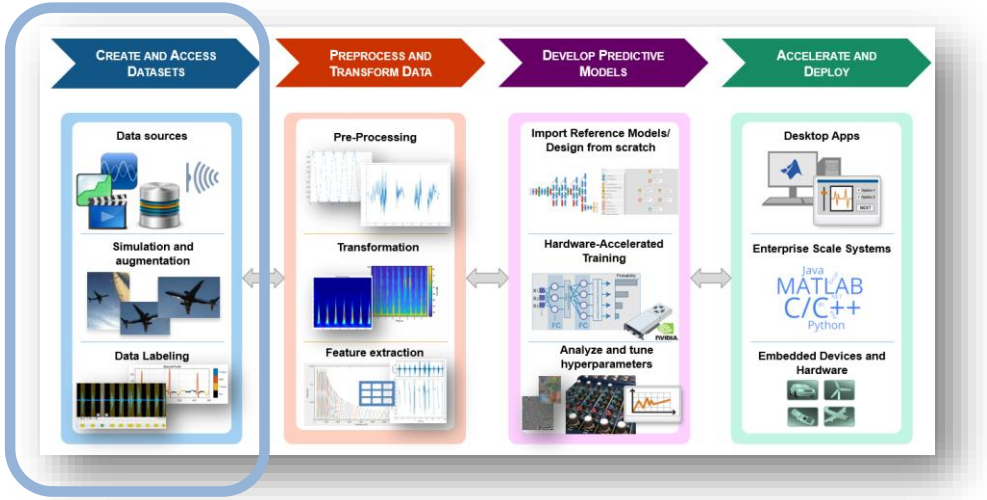
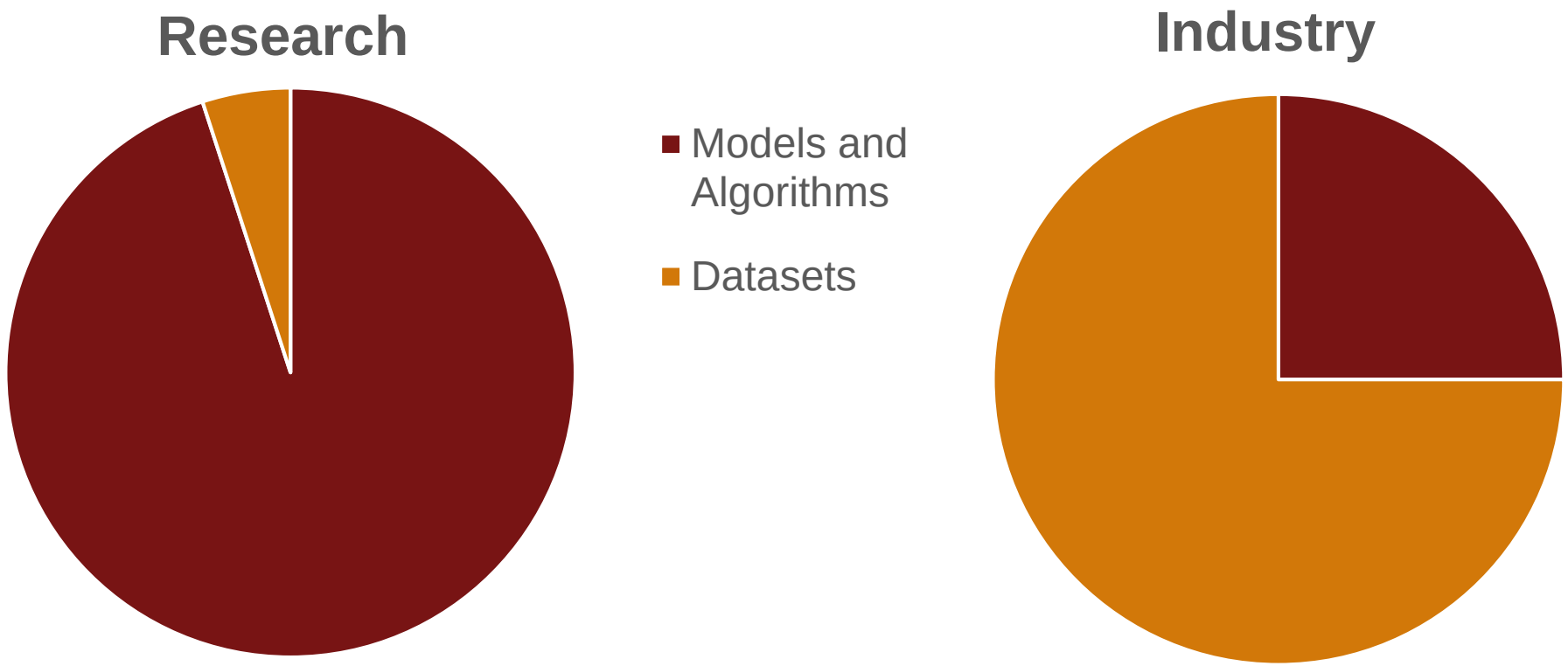


- Conclusions

Current Investments – Models vs. Data



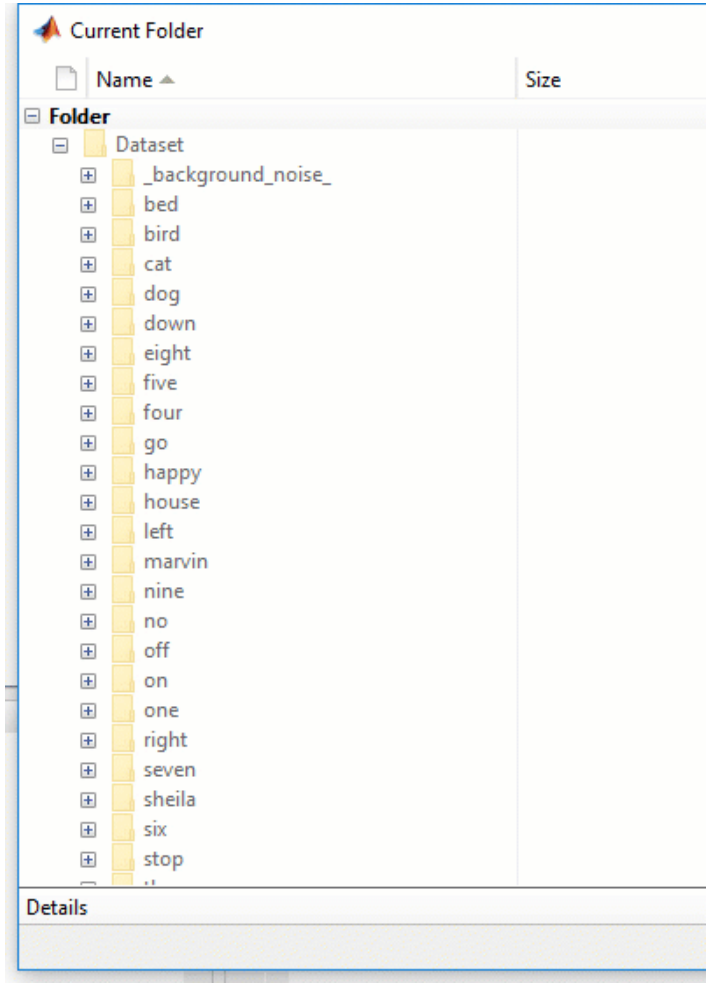
From "Troubleshooting deep neural networks" (Josh Tobin et al., Jan 2019)

What does a large dataset look

How to navigate, index, read (al

`audioDatastore` `imageDatastore`

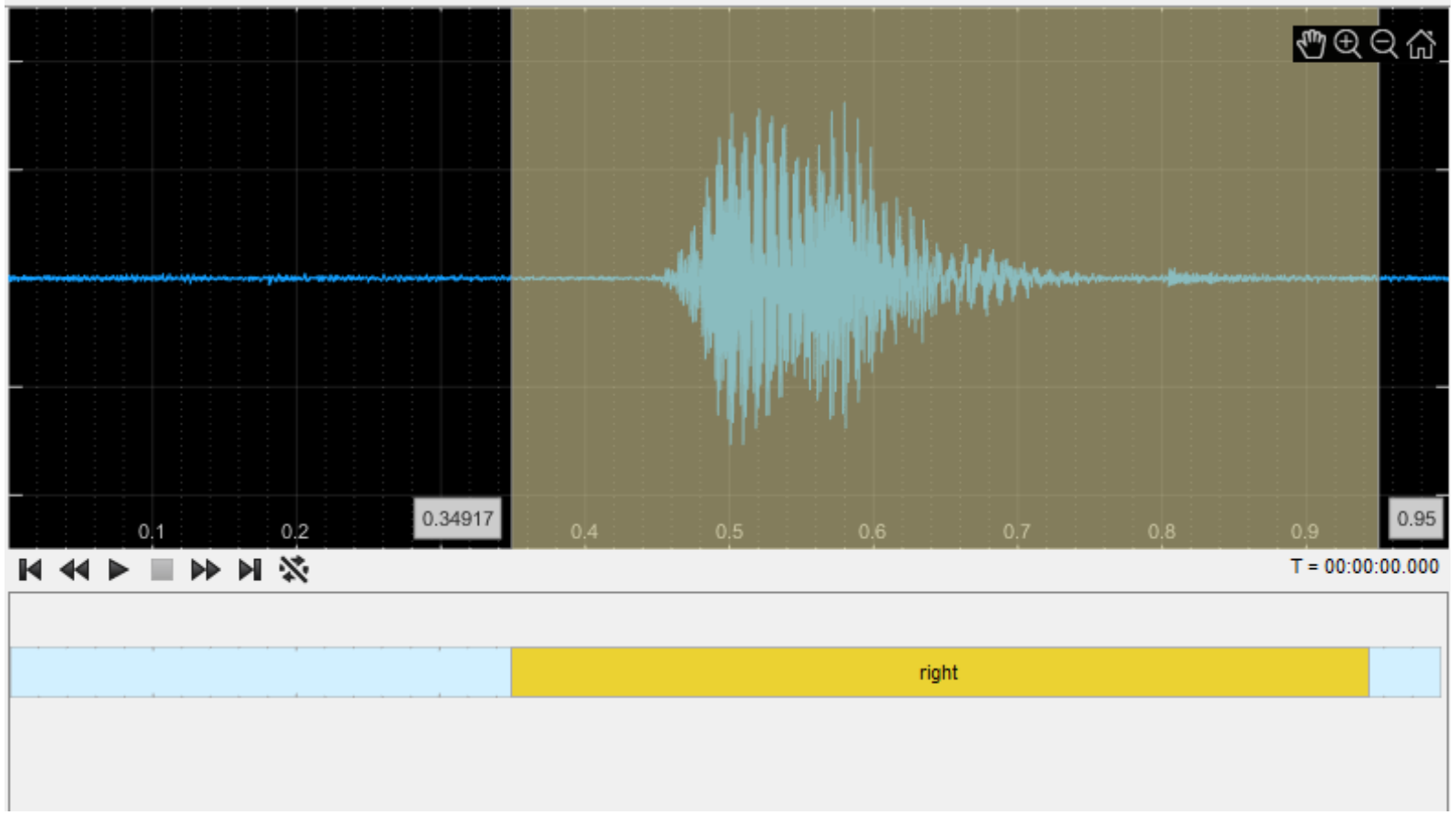
`fileDatastore` Custom Datastores



How to...

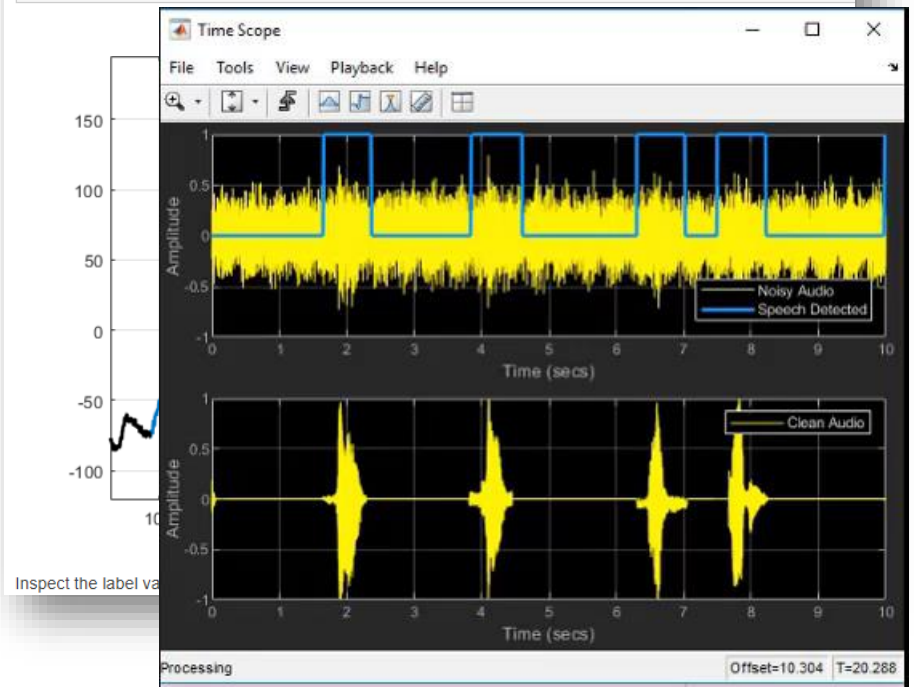
- Build a list of all data and labels?
- Review basic statistics about available data?
- Select data subsets without nested `for` loops, `dir`, `ls`, `what`, ... aplenty?
- Jointly read data and labels?
- Automatically distribute computations?

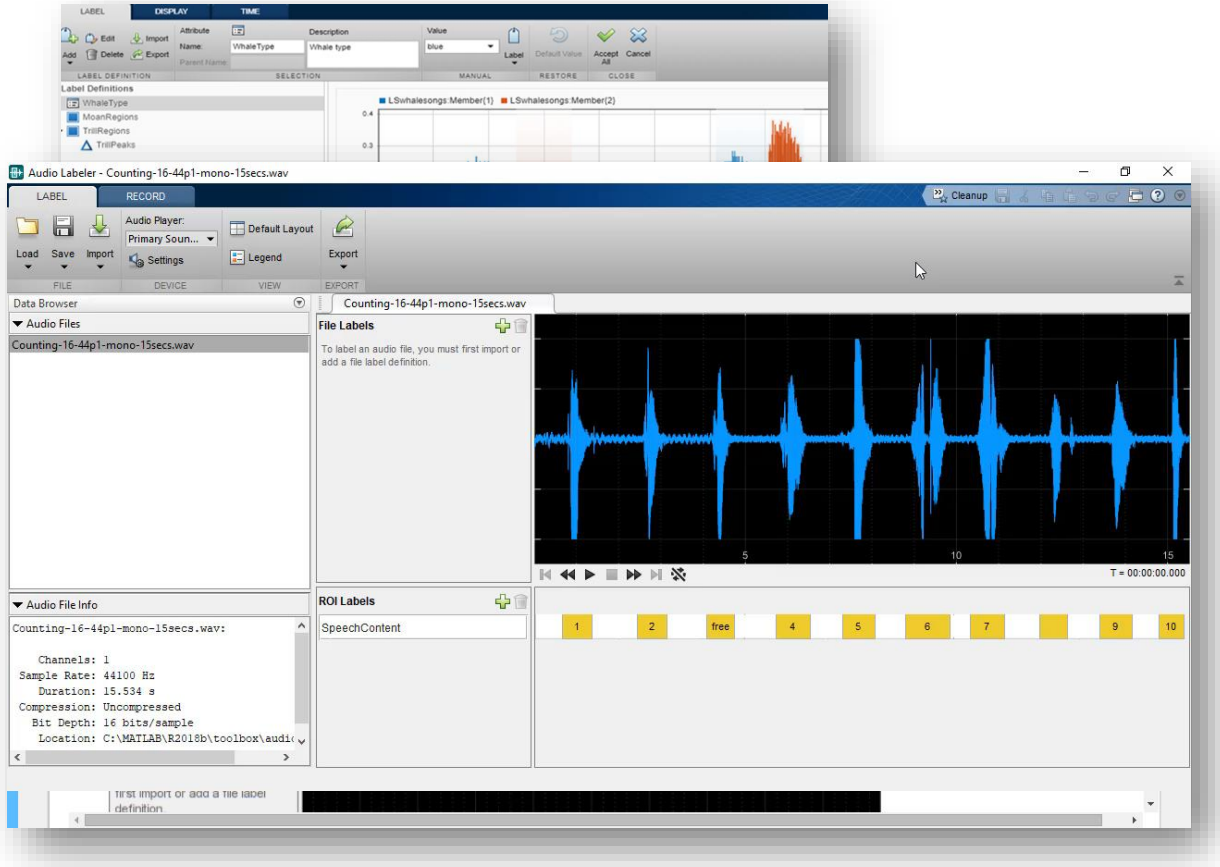
Label quality impacts model performance as much as the quality and quantity of the actual recordings



Use appropriate tools to help you label signals

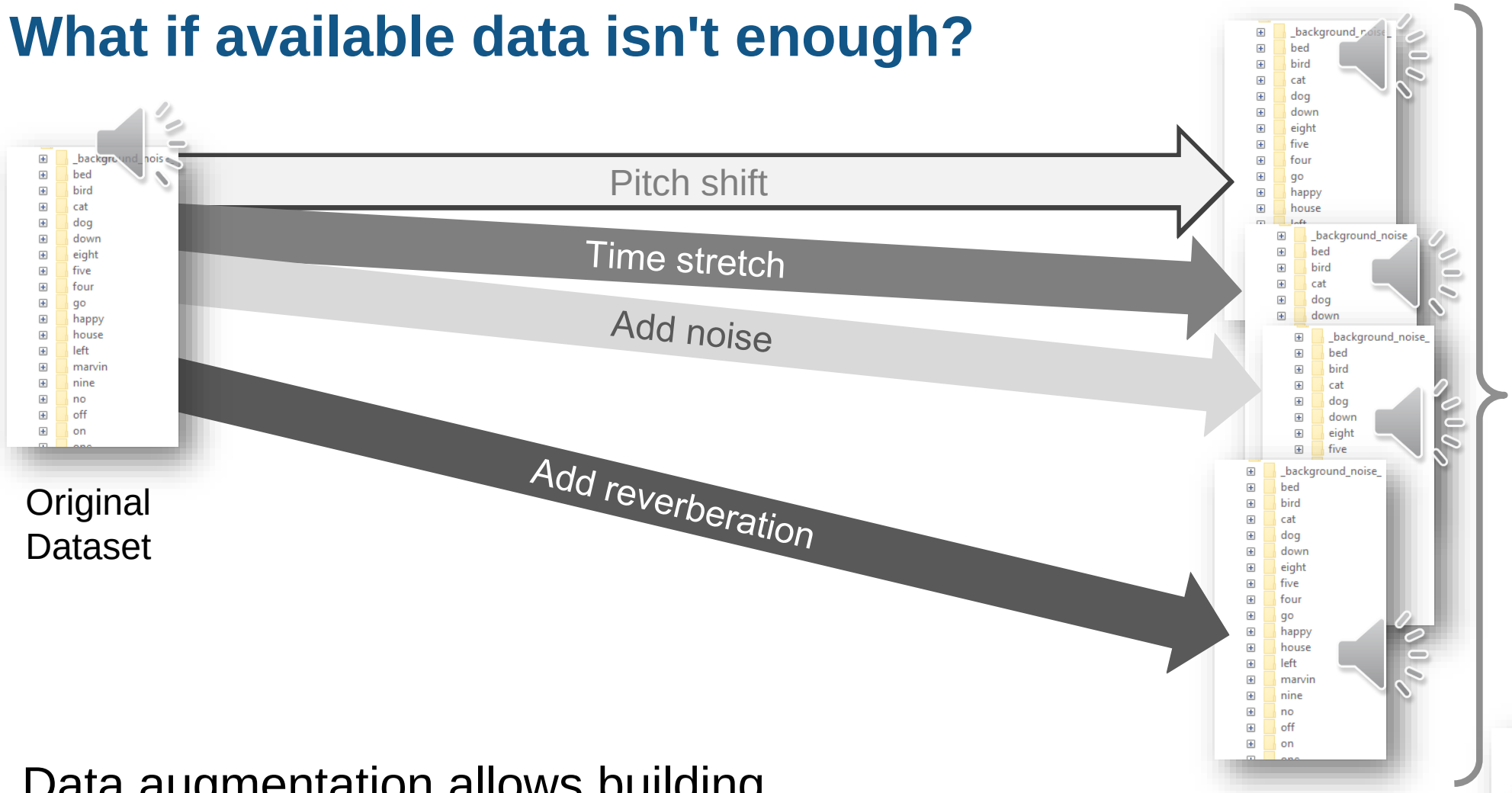
```
patientID = 1;
signalVals = getSignal(QTData,patientID);
labelVals = getLabelValues(QTData,patientID,'WaveformLabels_Chan1');

displayWaveformLabels(signalVals(1,1:1000),labelVals.Value(1:1000))
```



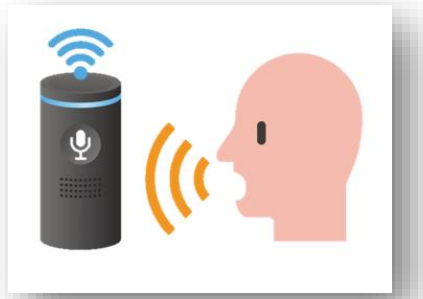


- Programmatically…
- … or via Apps

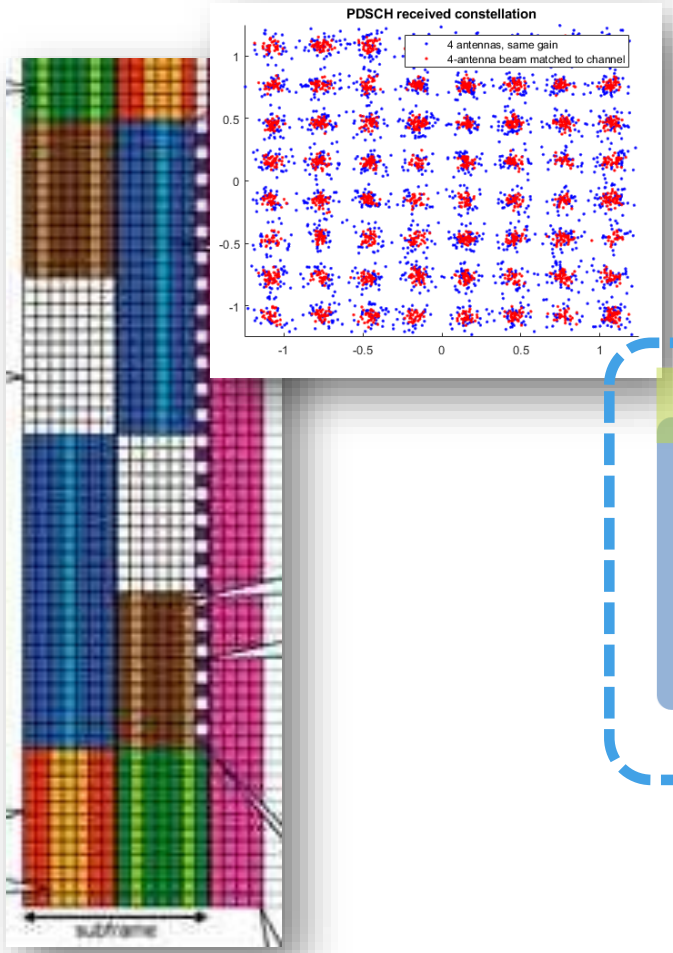
What if available data isn't enough?

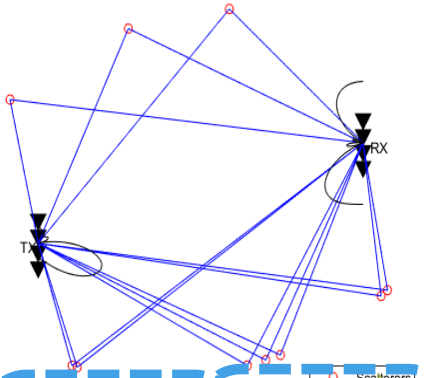


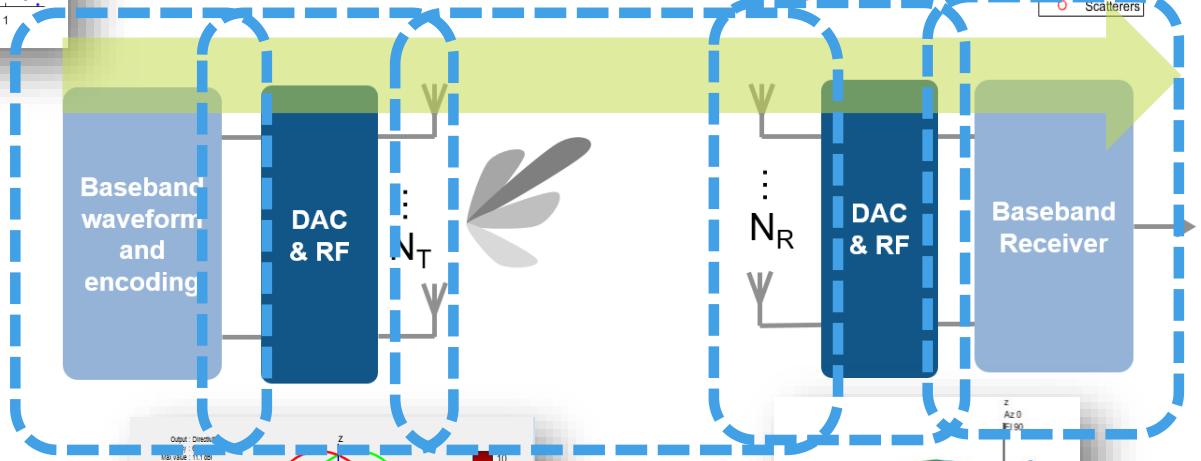
Data augmentation allows building more complex and more robust models

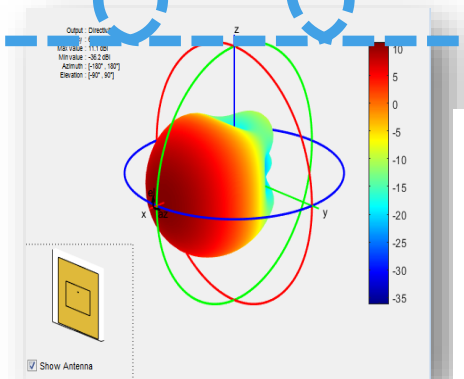


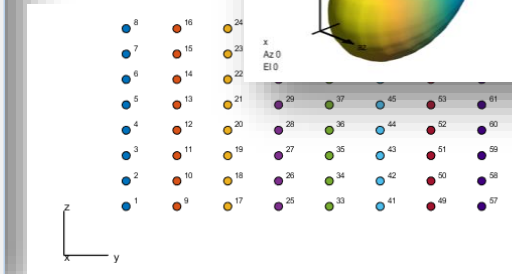
Simulation is key if recording and labelling real-world data is impractical or unreasonable – Communications Signals

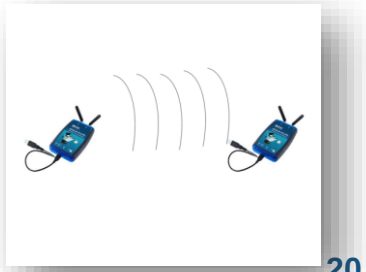




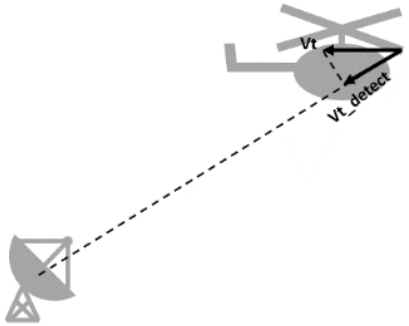


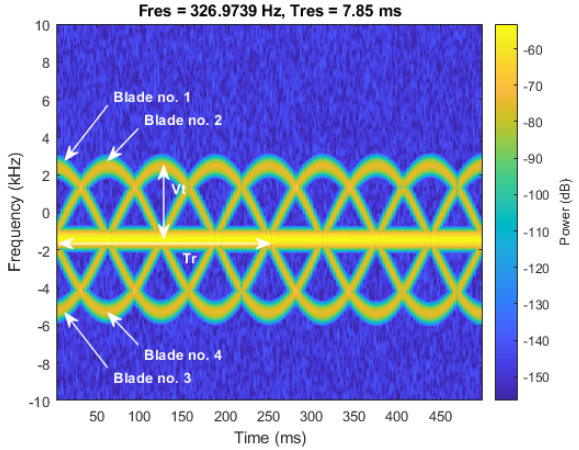






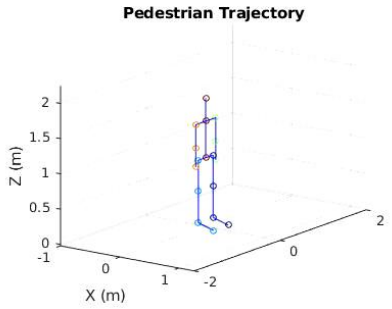
Simulation is key if recording and labelling real-world data is impractical or unreasonable – Radar Signals

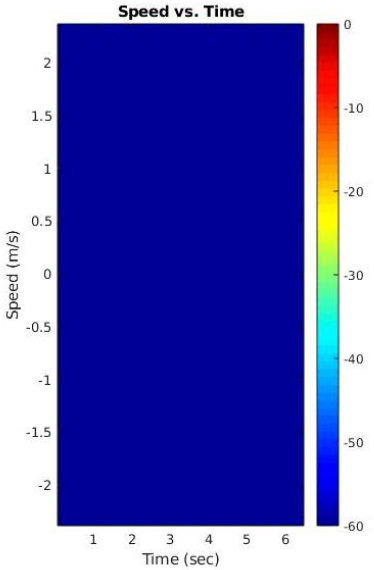




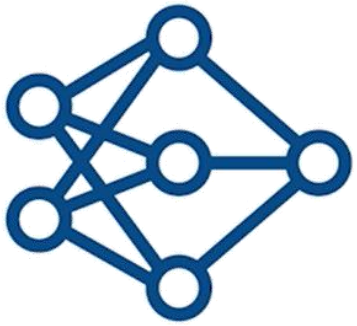
Radar Target Simulation

Micro-Doppler Analysis





Agenda



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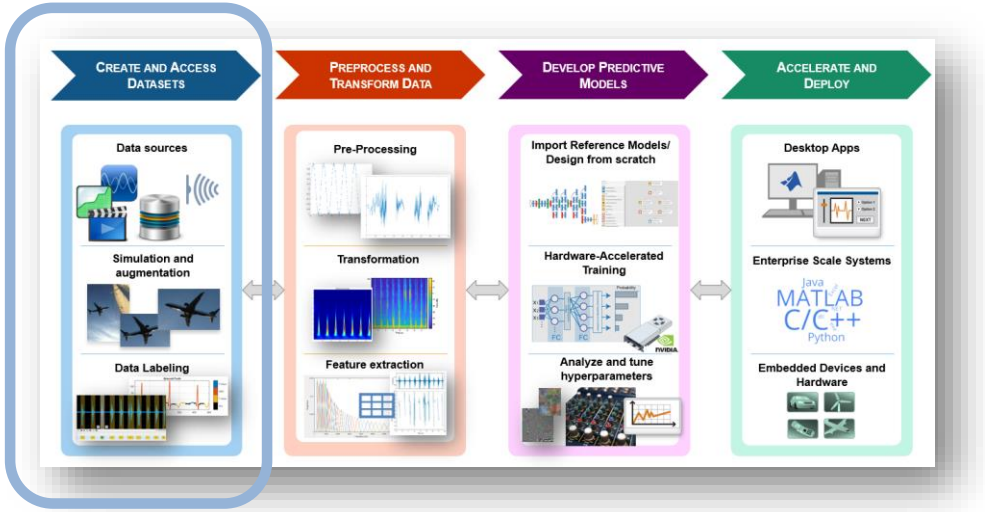
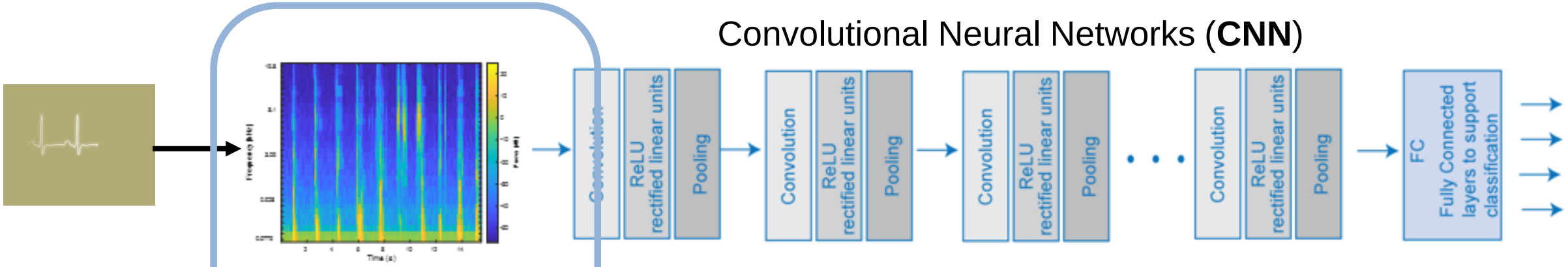


- Conclusions

Common types of network architectures used in signal processing and text analytics applications

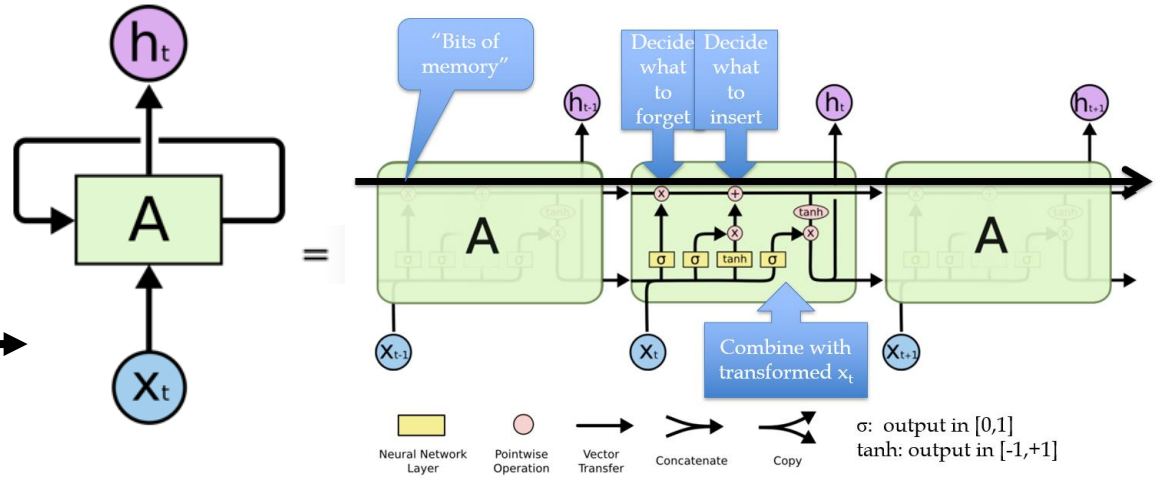
Convolutional Neural Networks (**CNN**)



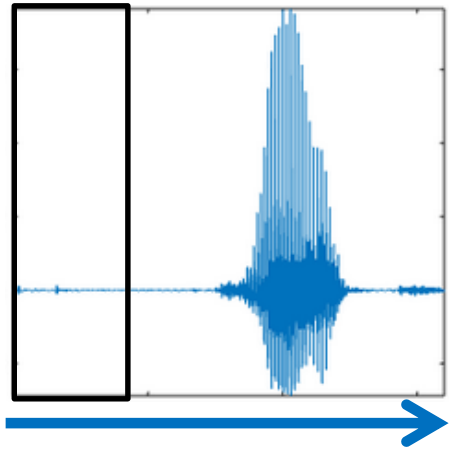
Time-Frequency Transformation

Feature Engineering

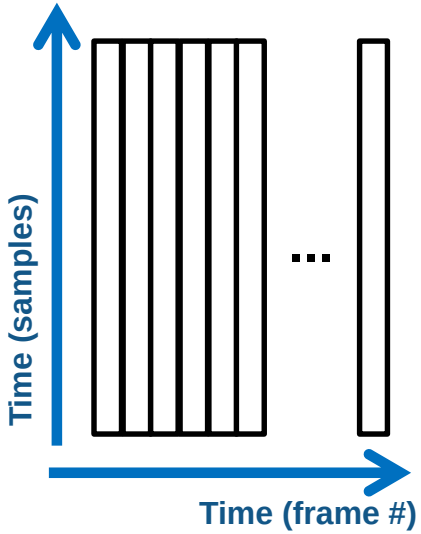
Long Short Term Memory (**LSTM**) Networks



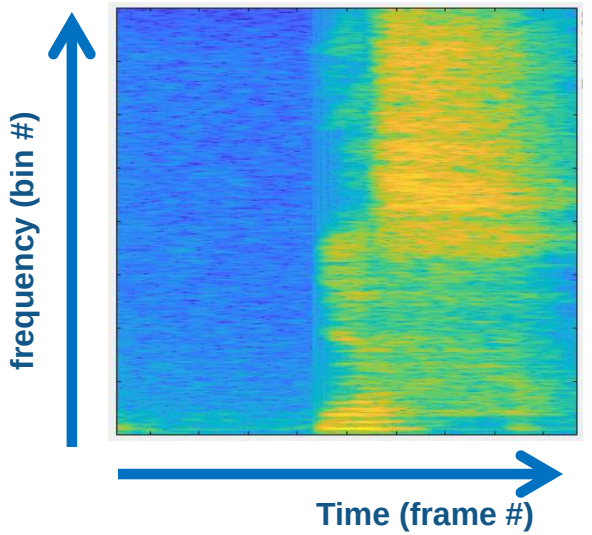
Time-Frequency Transformations



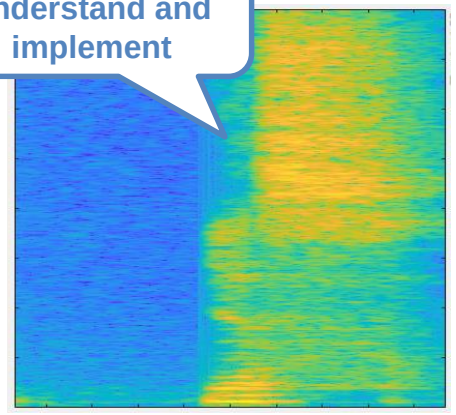
Reframe (e.g. Buffer)



To frequency (e.g. FFT)



Easiest to understand and implement

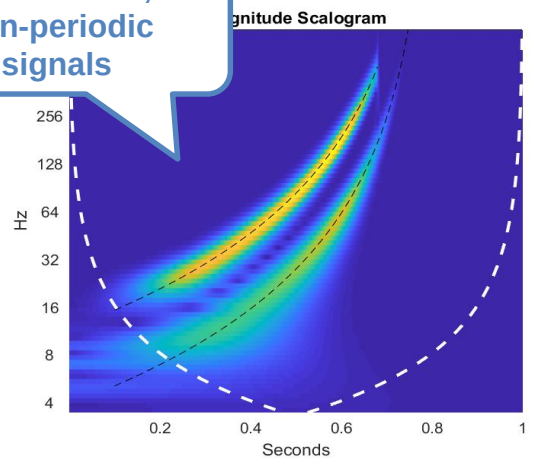


Basic spectrogram

More compact for speech & audio applications

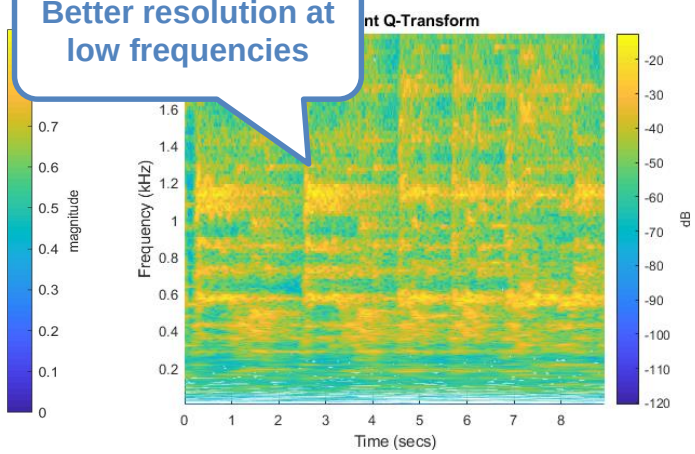
Perceptually-spaced (e.g. Mel, Bark) Spectrogram

Best resolution, for non-periodic signals



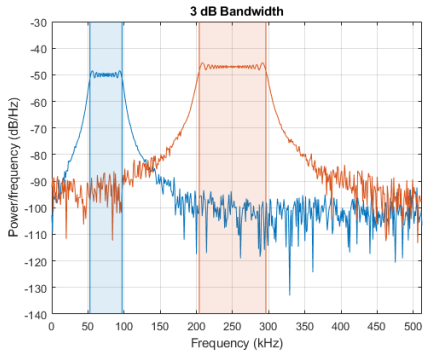
Wavelet scalogram

Better resolution at low frequencies

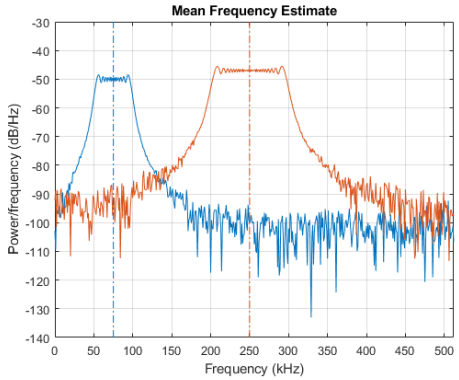


Constant Q transform

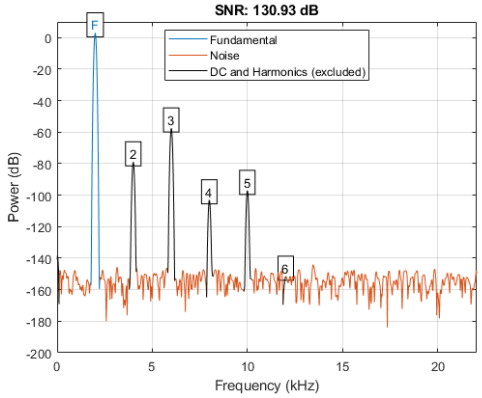
Extracting Features from Signals: Application-Agnostic Examples



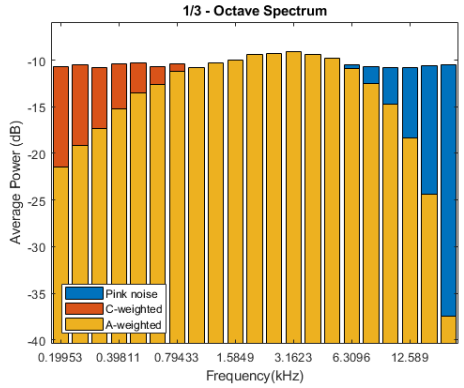
BW measurements



Spectral statistics



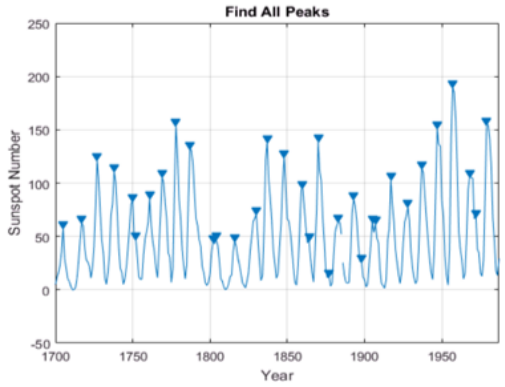
Harmonic analysis



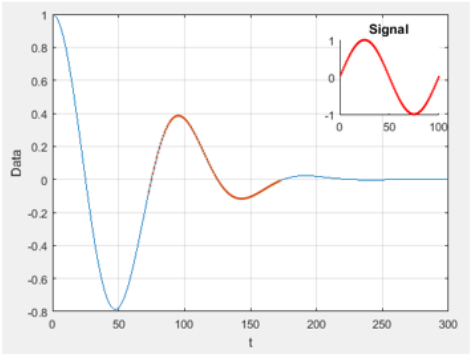
Octave spectrum

Frequency domain

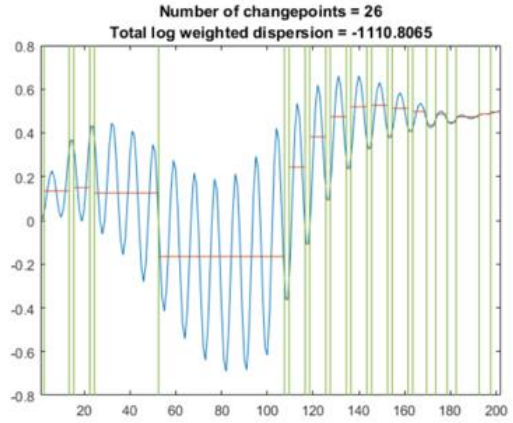
Time domain



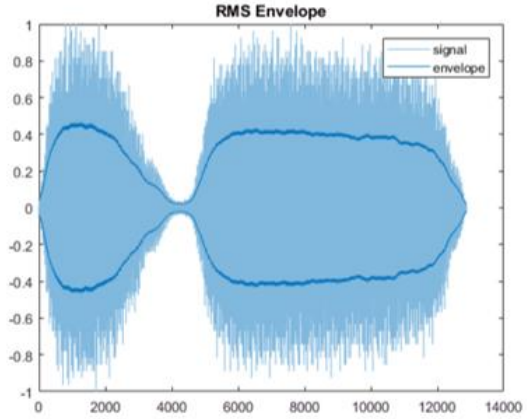
Find peaks



Find signal patterns



Detect change points

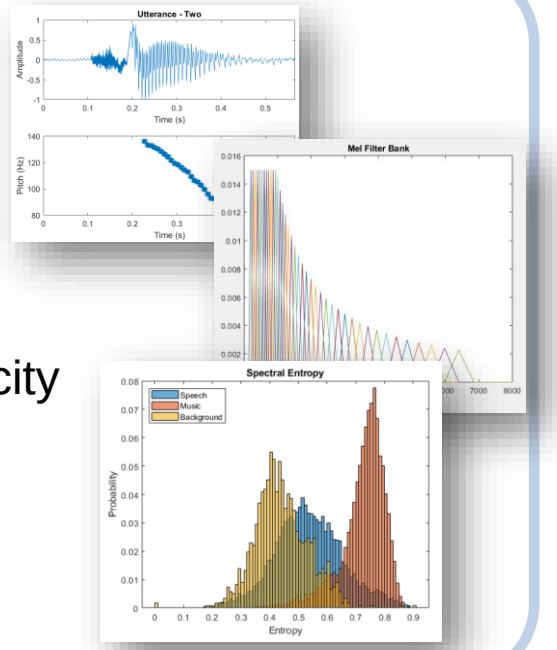


Find signal envelope

Domain-Specific Features and Transformations – Examples

Speech and Audio

- MFCC
- GTCC
- MDCT
- Pitch, harmonicity
- Spectral shape descriptors
- ...



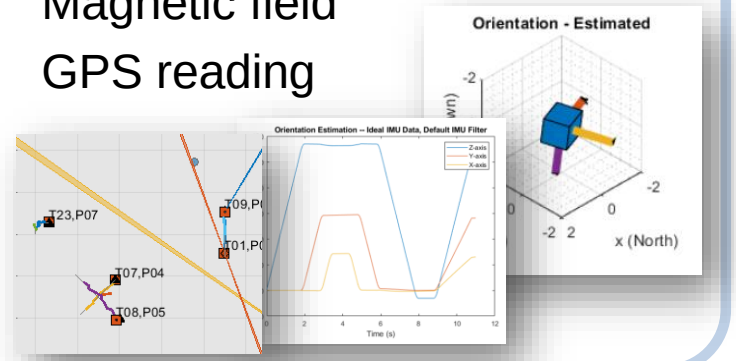
Navigation and Sensor Fusion

- Orientation
- Height
- Position

from

- Acceleration, angular velocity
- Magnetic field
- GPS reading

- Multi-object tracking
- ...

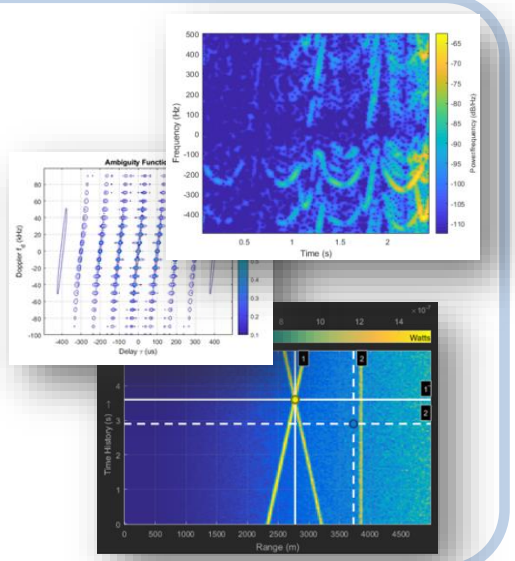


Text Analytics

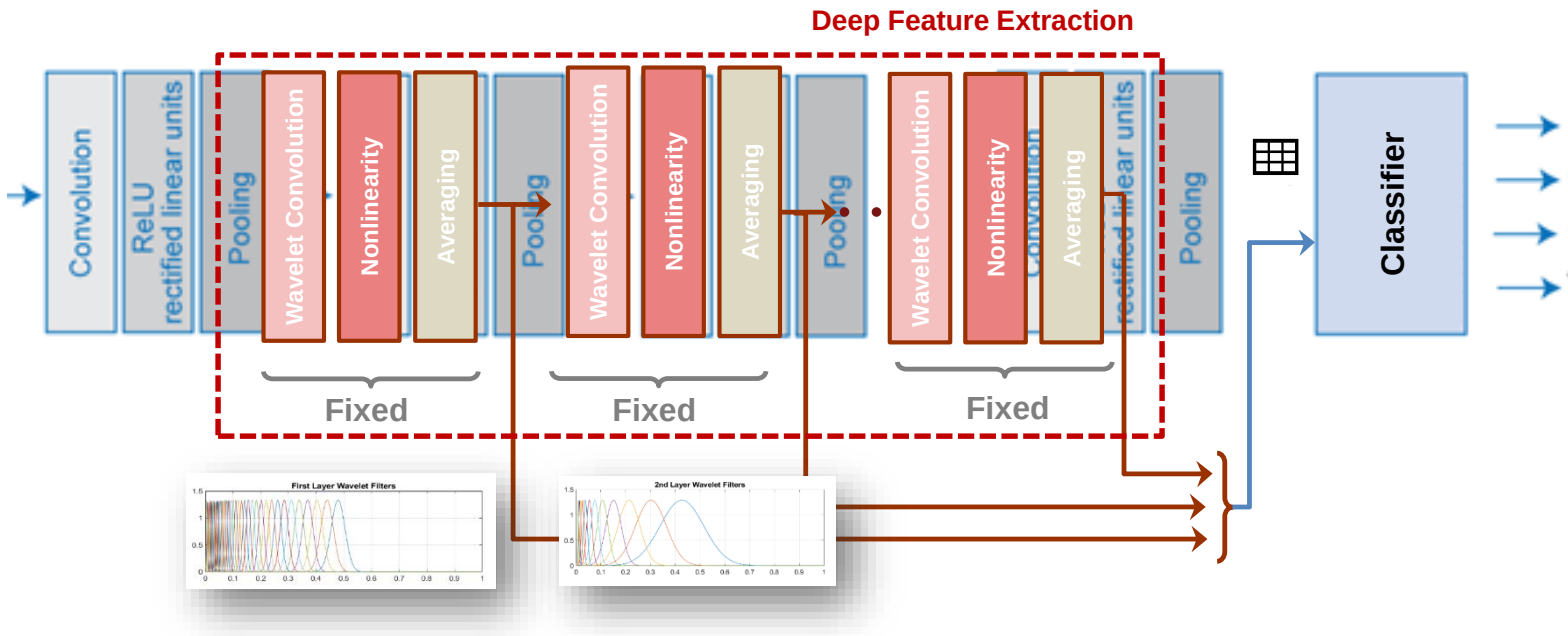
- Train Word Embeddings
- Word2Vec
- Topic Modeling
- ...

Radar

- Micro-Doppler analysis
- Range-Doppler processing
- Synthetic aperture imaging
- Spectral analysis
- Waveform ambiguity
- ...



Automated Feature Extraction: Wavelet Scattering

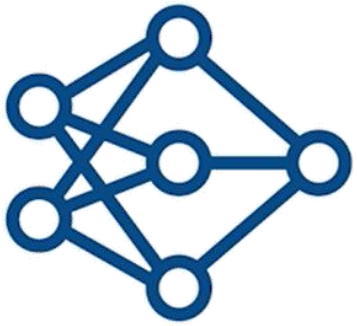


- Can relieve requirements on amount of data and model complexity
  - Featured in leader-boards a number of research competitions

- Framework for extracting features [1]

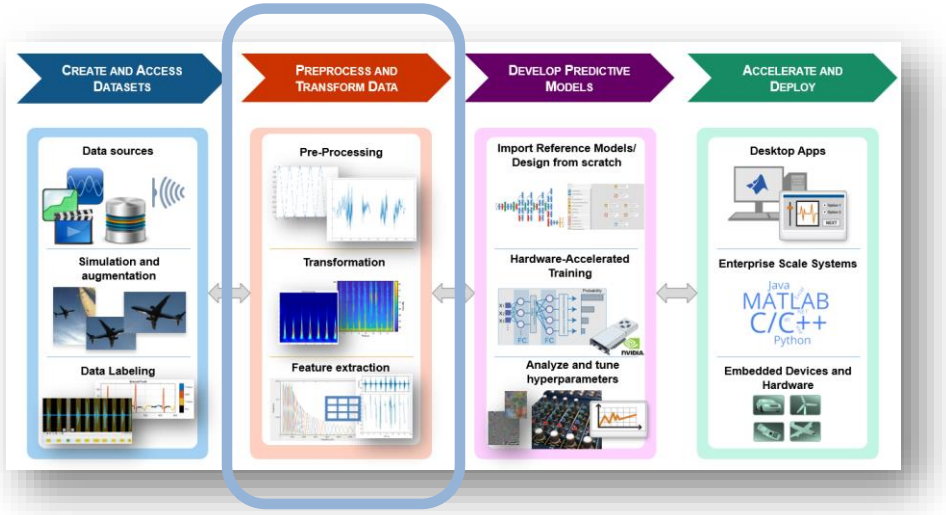
[1] Joan Bruna, and Stephane Mallat, P. 2013. Invariant Scattering Convolution Networks. IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 35, No. 8, pp. 1872-1886.

Agenda



- Deep Learning – Basic ideas

- Deep Learning Model Development for Signals, Time Series, and Text
  - Data
  - Processing and transformation
  - **Model design and optimization**
  - Acceleration, prototyping, and deployment

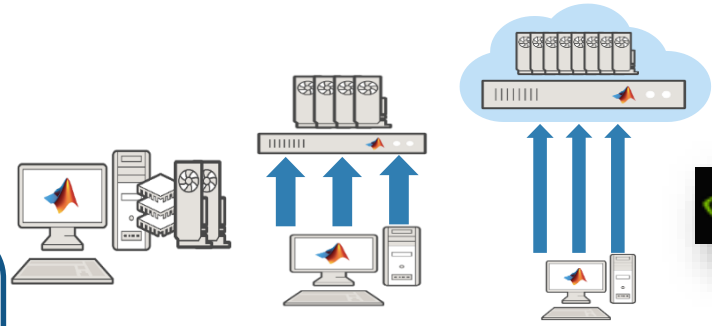


- Conclusions

Developing Deep Learning Models

Design Network

Train



Accelerate Training

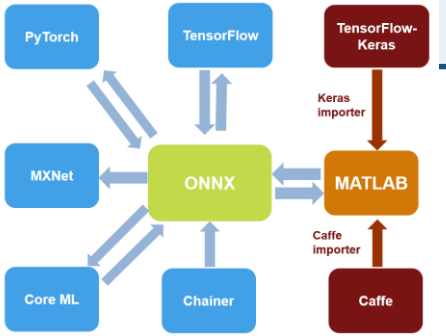
NVIDIA GPU CLOUD

MATLAB as a container on NGC

Design

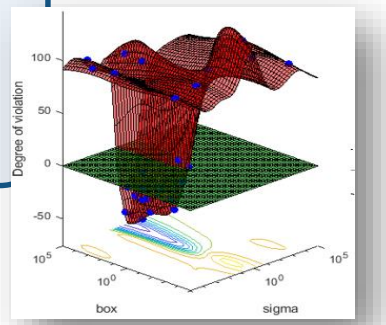
Optimize

Model Exchange



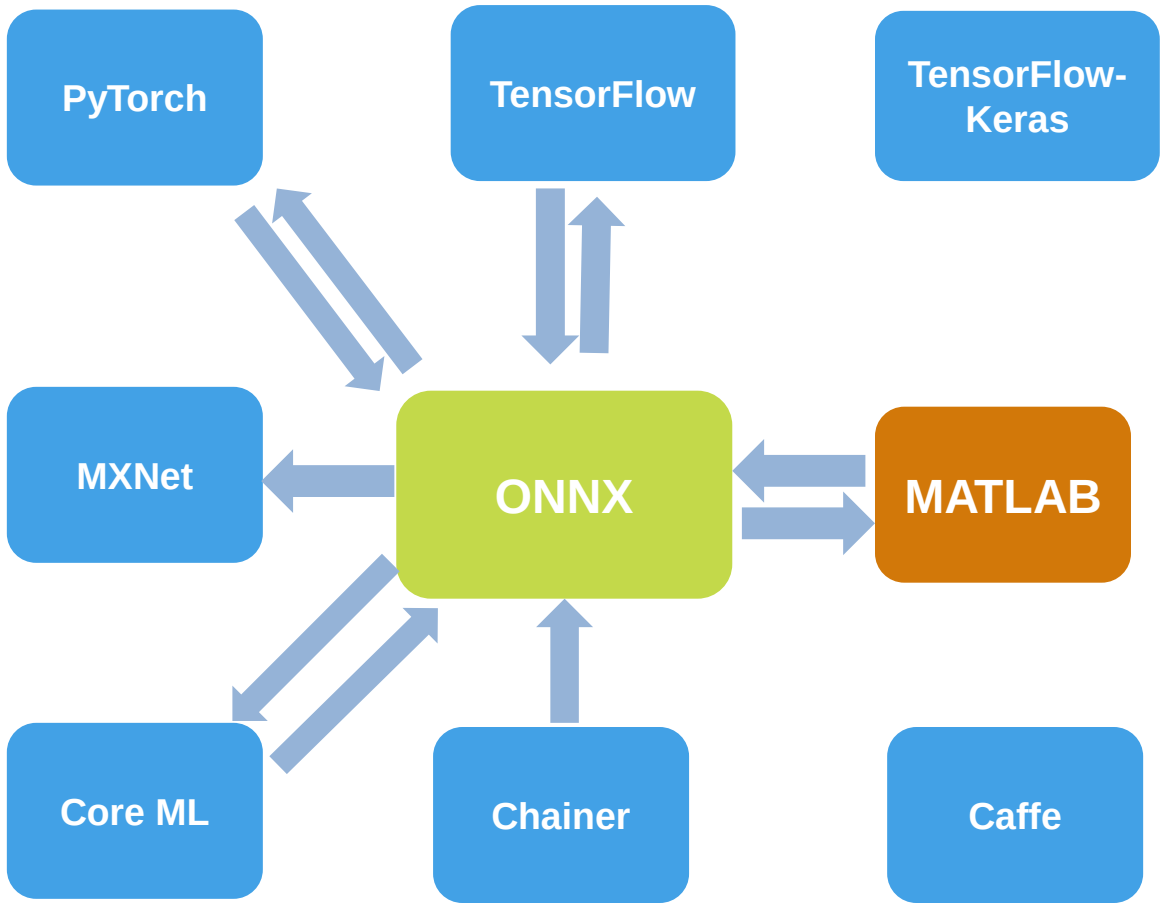
Pre-trained Networks

AlexNet PRETRAINED MODEL	VGG-16 PRETRAINED MODEL	ResNet-50 PRETRAINED MODEL	ONNX Converter MODEL CONVERTER
Caffe IMPORTER	GoogLeNet PRETRAINED MODEL	TensorFlow-Keras IMPORTER	Inception-v3 MODELS



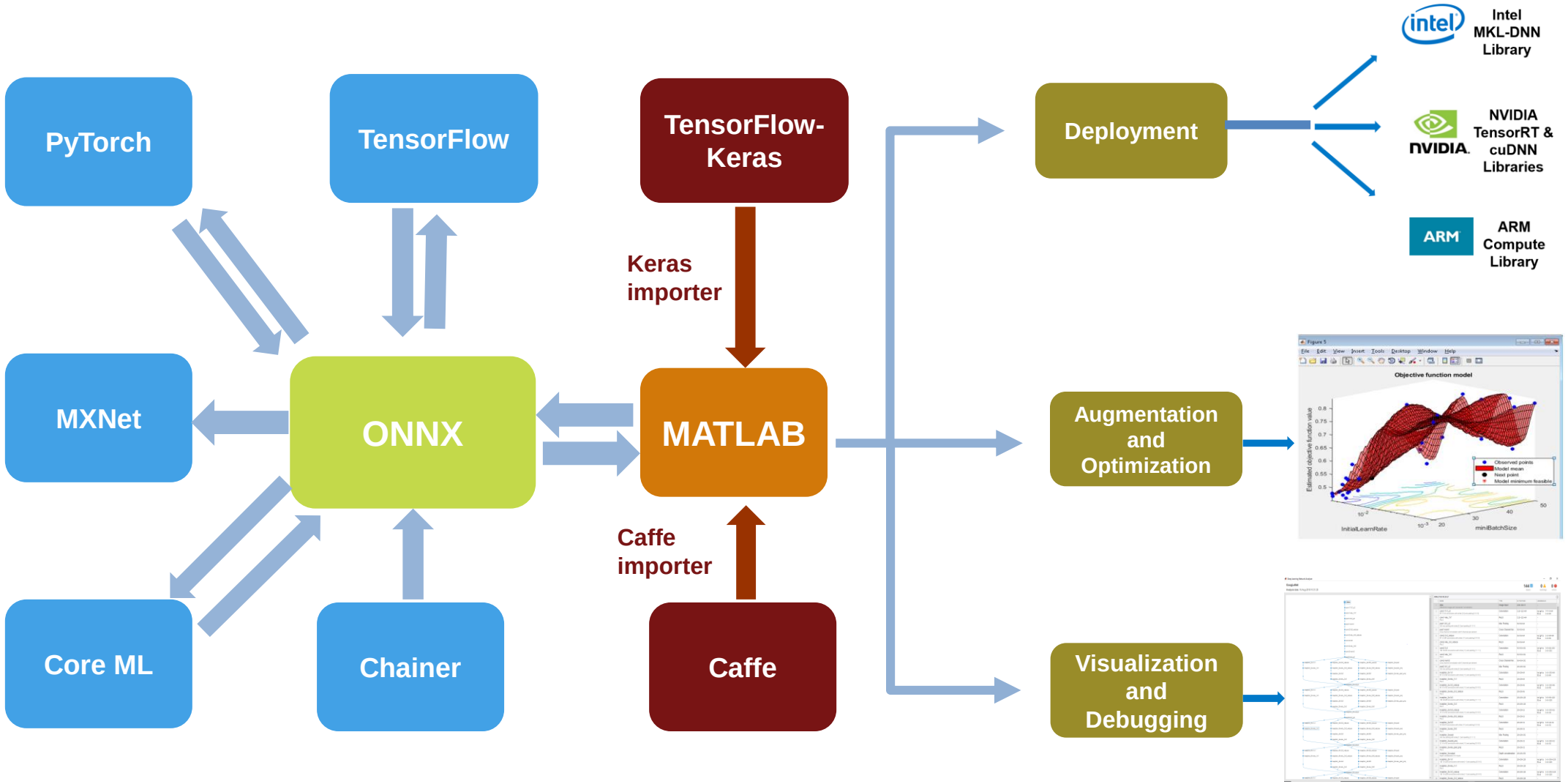
Bayesian Hyperparameter Optimization

Exchange Models With Deep Learning Frameworks



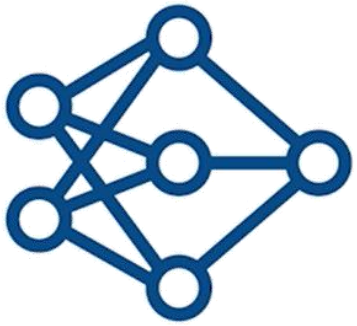
ONNX = Open Neural Network Exchange Format

Exchange Models With Deep Learning Frameworks



ONNX = Open Neural Network Exchange Format

Agenda



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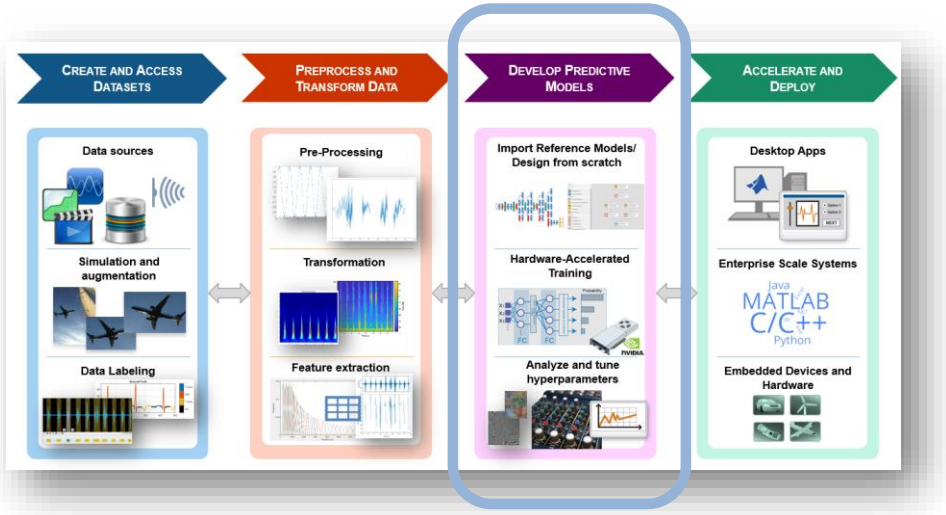
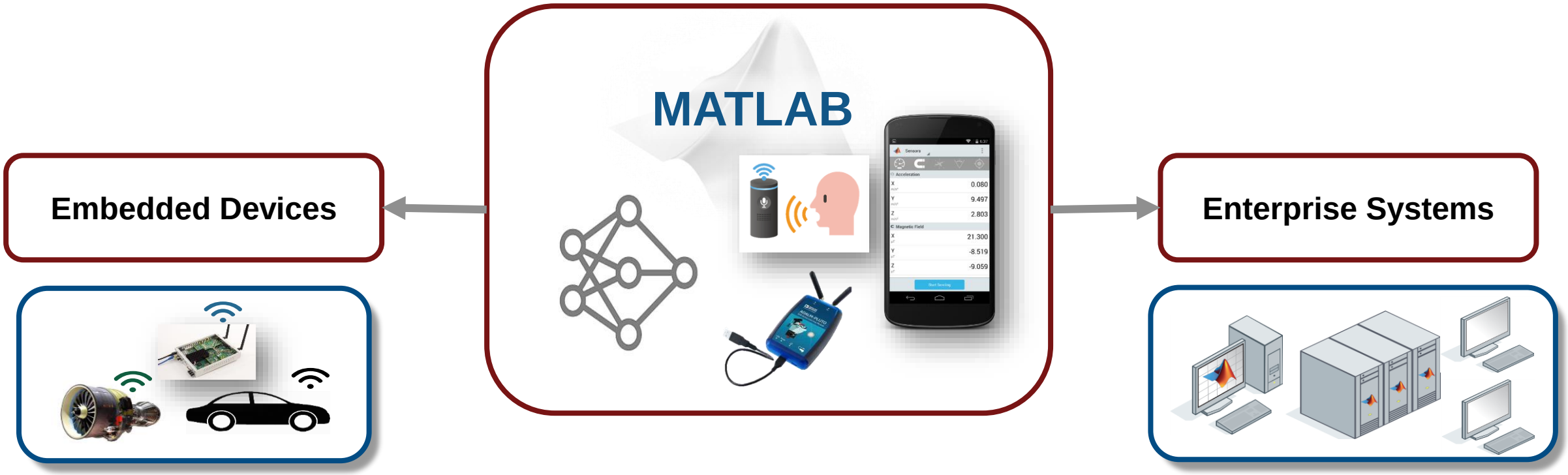
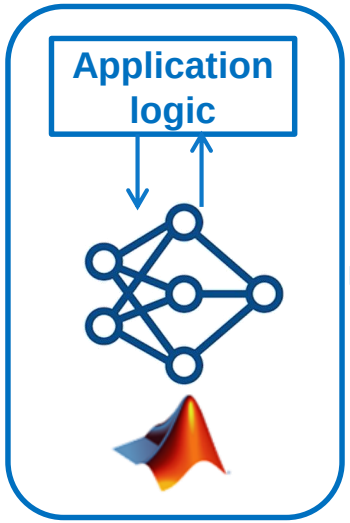


- Conclusions

Deployment and Scaling for A.I.



Deploying Deep Learning Models for Inference



Code Generation

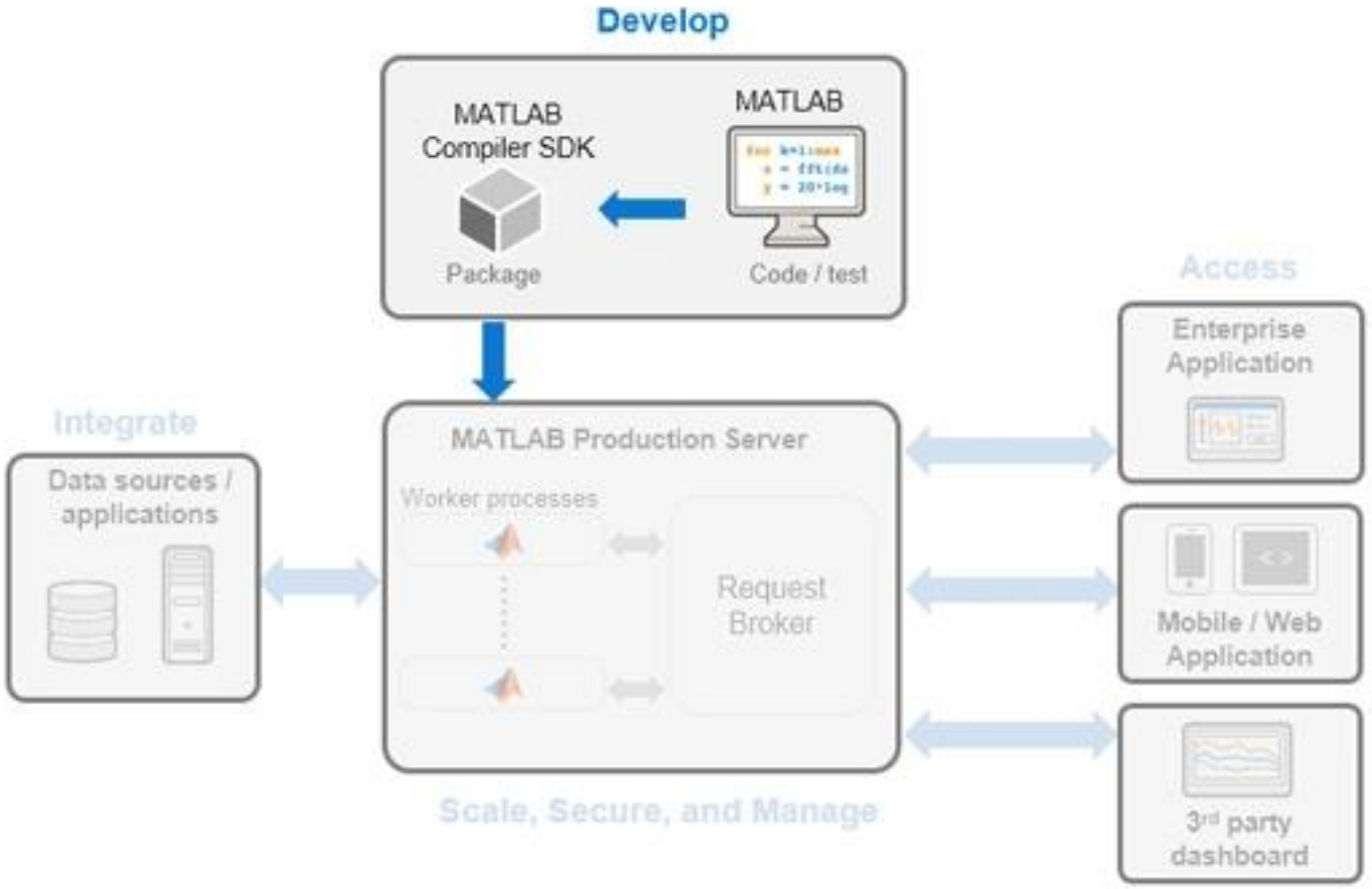
Auto-generated Code (C/C++/CUDA)

Intel MKL-DNN Library

NVIDIA TensorRT & cuDNN Libraries

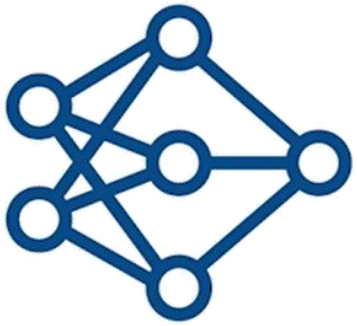
ARM Compute Library

Enterprise Deployment



Deployment to the cloud with MATLAB Compiler and MATLAB Production Server

Agenda



- Deep Learning – Basic ideas

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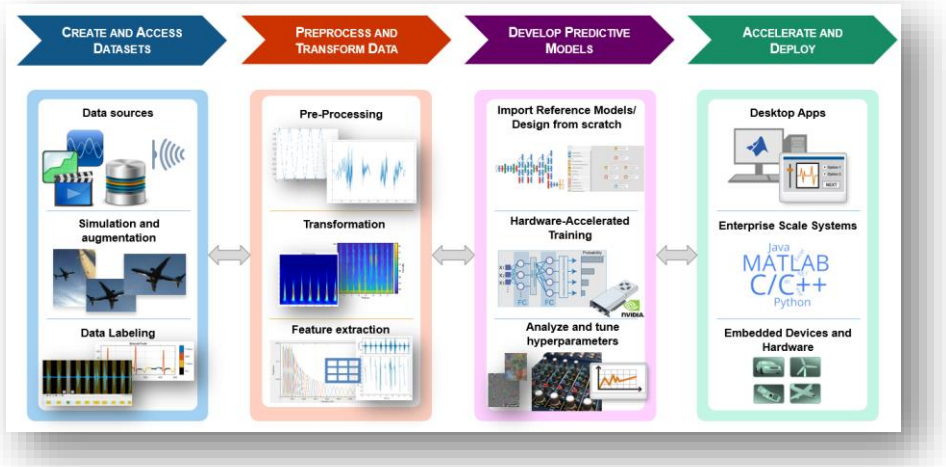
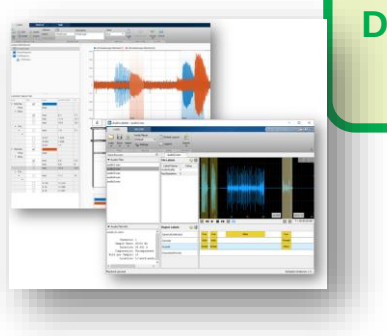
  - Model design and optimization
  - Acceleration, prototyping, and deployment



- **Conclusions**

Deep Learning Workflow Challenges – Signals and Time Series



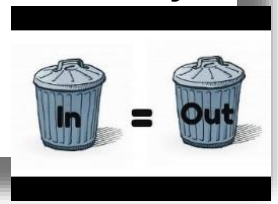
Data-labeling Apps and Examples

Augmentation and simulation algorithms

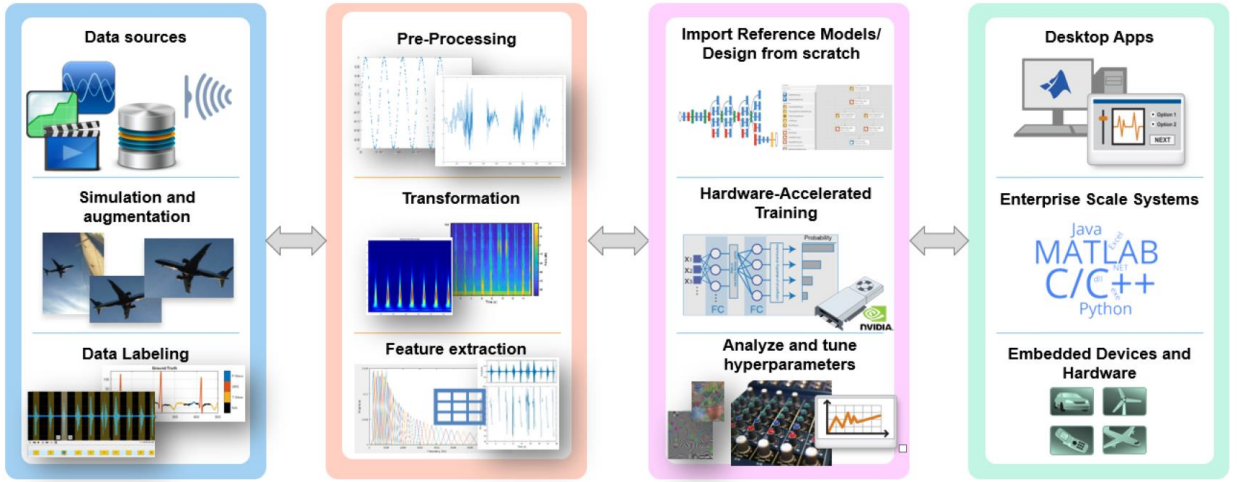
Deployment and Scaling to various platforms

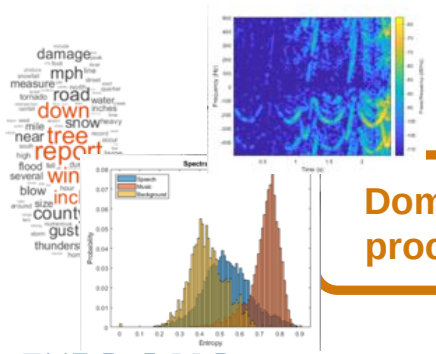
- Intel MKL-DNN Library
- NVIDIA TensorRT & cuDNN Libraries
- ARM Compute Library

Deep learning models only as good as training data



CREATE AND ACCESS DATASETS | PREPROCESS AND TRANSFORM DATA | DEVELOP PREDICTIVE MODELS | ACCELERATE AND DEPLOY

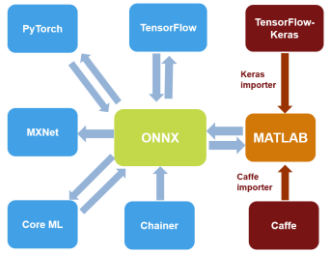




Dom... proc...

Application-specific algorithms and tools

Collaboration in the AI ecosystem



Domain-Specific Features and Transformations – Examples

Audio
Speech Command Recognition
Voice Activity Detection in Noise
Denoise Speech
Classify Gender

Time-Series and Text
Classify Time Series Using Wavelet Analysis
Sequence-to-Sequence Classification
Classify Text Data Using LSTMs
Classify Text Data Using CNNs

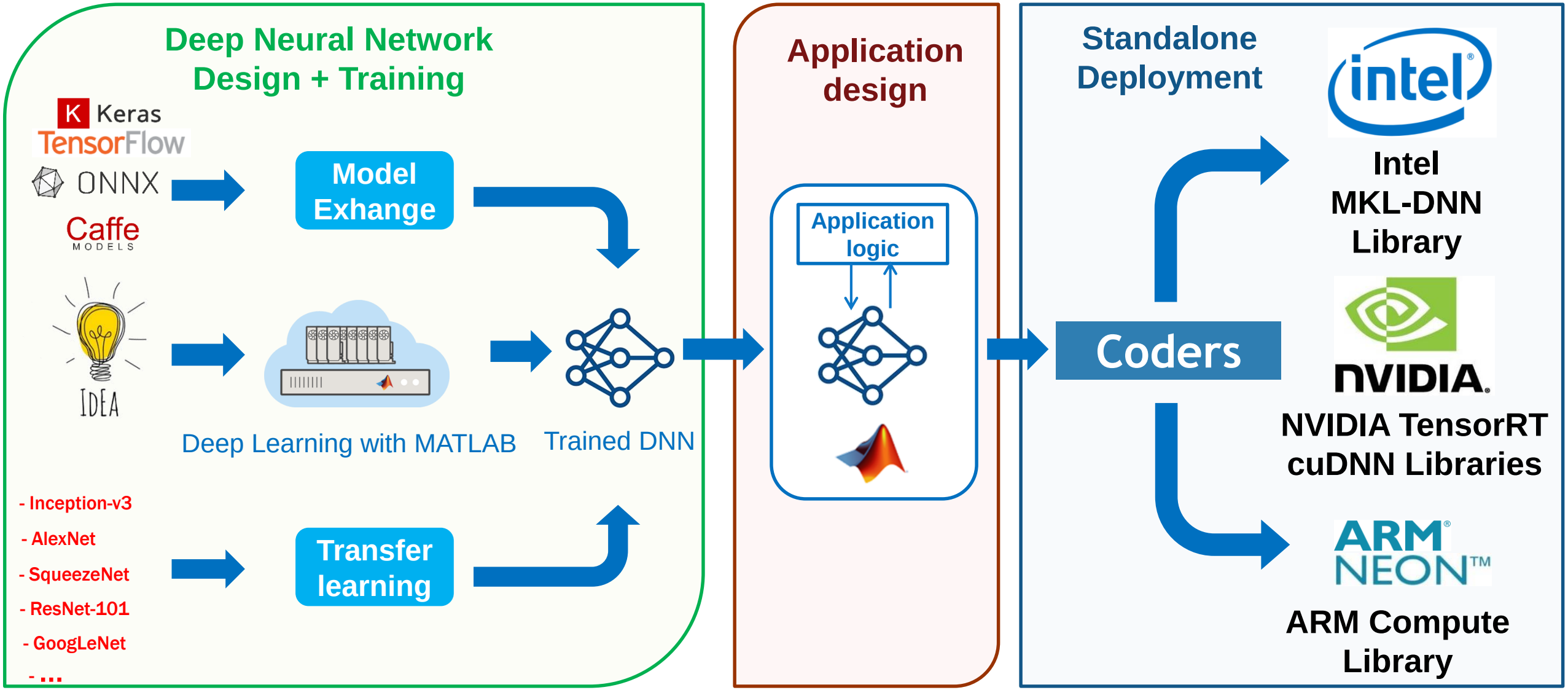
Signal
Music Genre Classification
Human Activity Recognition
ECG Signal Classification
Waveform Segmentation

Comms and Radar
Radar Waveform Classification
Modulation Classification

To Learn More

- **Visit us at the booth** to discuss your specific application

- **Attend the talk on** Deploying Deep Neural Networks to Embedded GPUs and CPUs

Back up

Summary - Deep learning workflow in MATLAB