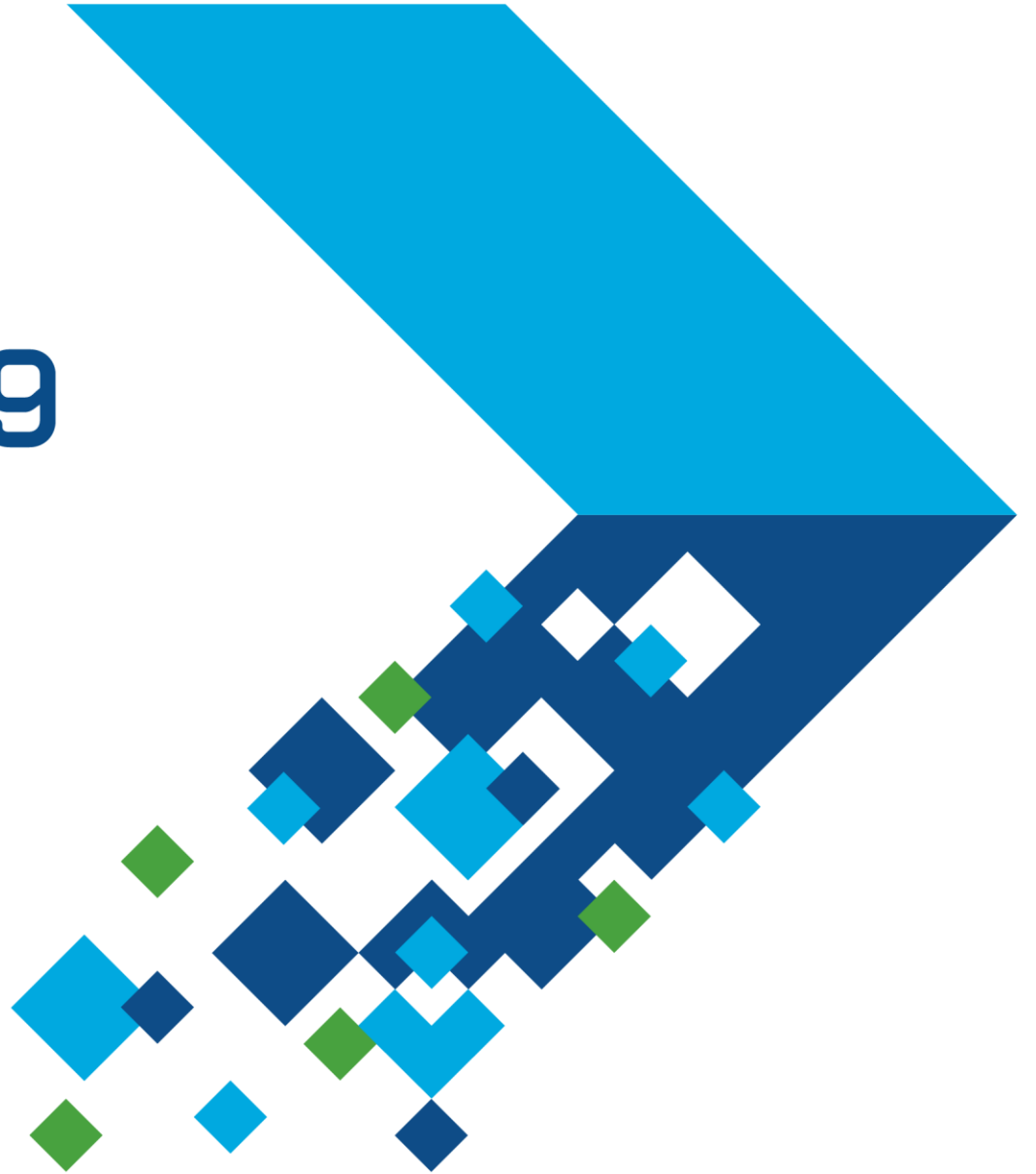# MATLAB EXPO 2019

신호 및 시계열 데이터를 위한 딥러닝

송완빈

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

Recommending music on Spotify with deep learning

AUGUST 05, 2014

This summer, I'm interning a

A Smart Stethoscope Puts AI in Medics' Ears

Engineers from Johns Hopkins reinvent the humble stethoscope to save lives

CNN World » The biomedical smart jacket that diagnoses pneumonia using Bluetooth

Live TV · U.S. Edition +

smart jacket that monia using Bluetooth

Video: Johns Hopkins University

Tech for a Noisy World: Researchers simulated an extremely noisy environment in the lab (the sound meter shows levels of around 70 decibels). They compared the audio heard through a top-notch commercial stethoscope, in which the breathing sounds are mixed with ambient noise, to that heard through the Johns Hopkins smart stethoscope, which uses active acoustic filtering to isolate the breathing sounds.

The Use of Deep Learning is Growing Across Industries

Aerospace, Defense and Communications

Communications devices, security
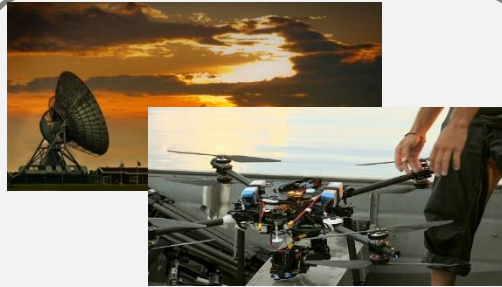
Multi-standard communications receivers, drone recognition

Consumer Electronics and Digital Health

Voice assistants

Digital health

Automotive

Voice control enabled Infotainment

Sensor processing, automated driving

Industrial Automation

Condition monitoring

Predictive maintenance

MATLAB EXPO 2019

Application Examples Using MATLAB – Audio and Speech

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

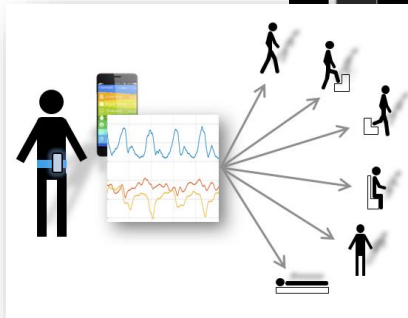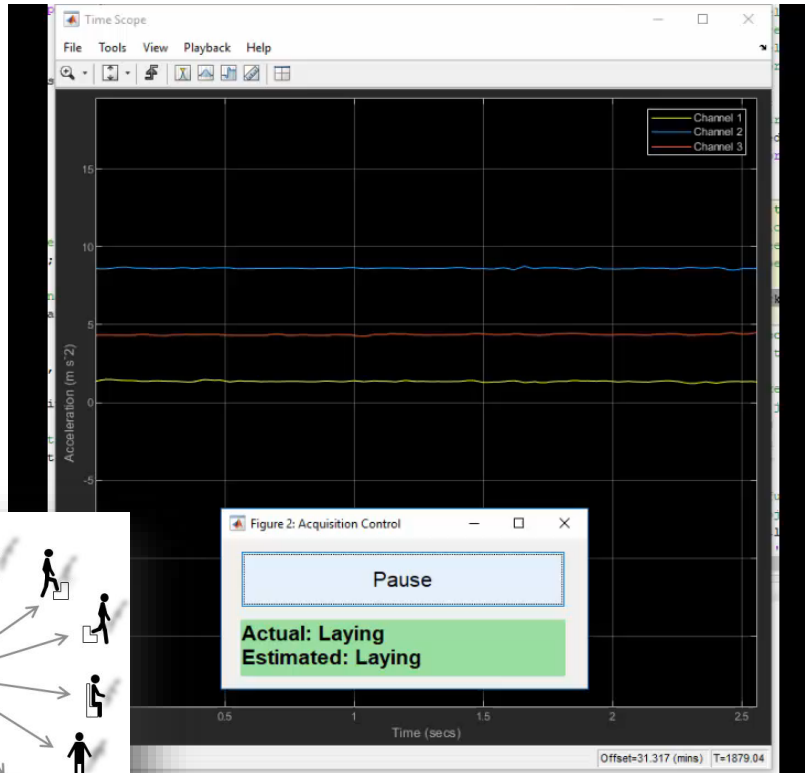https://www.mathworks.com/help/deeplearning/examples/deep-learning-speech-recognition.html
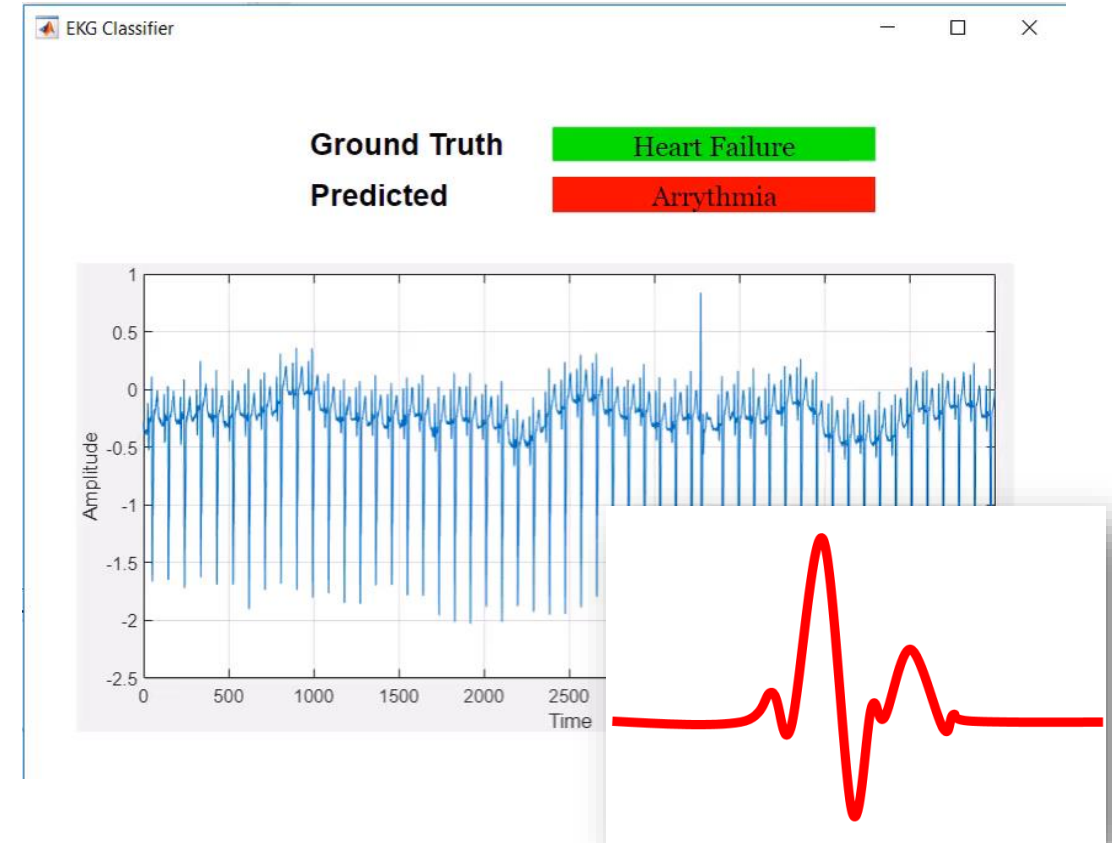
Music Genre Classification

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

Application Examples Using MATLAB – Industrial and physiological sensors
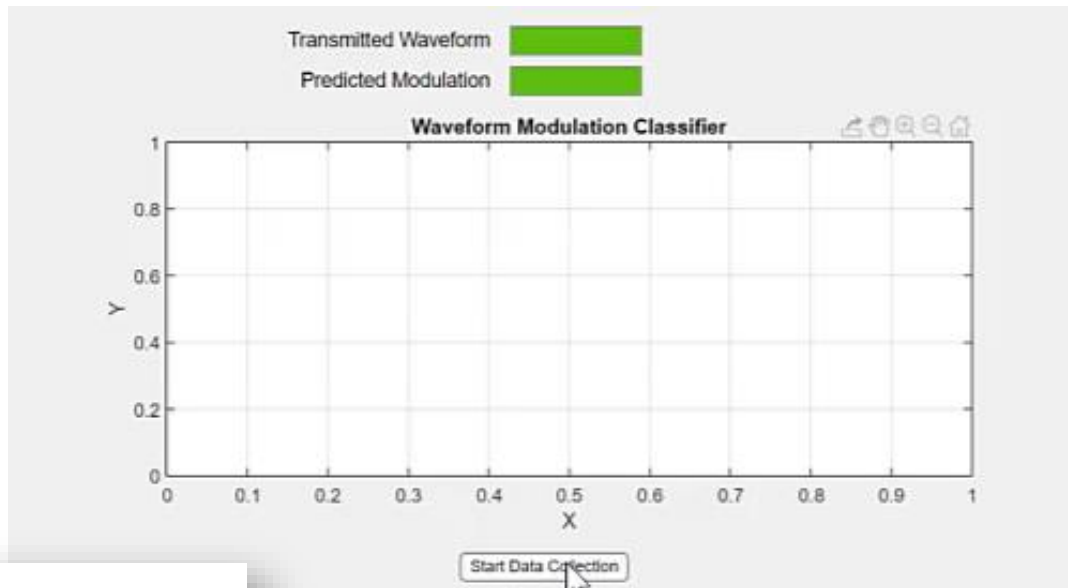

Human Activity Recognition

ECG Signal Classification
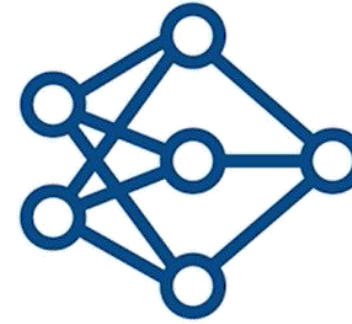
Application Examples Using MATLAB – Radar and Communications

Modulation Classification

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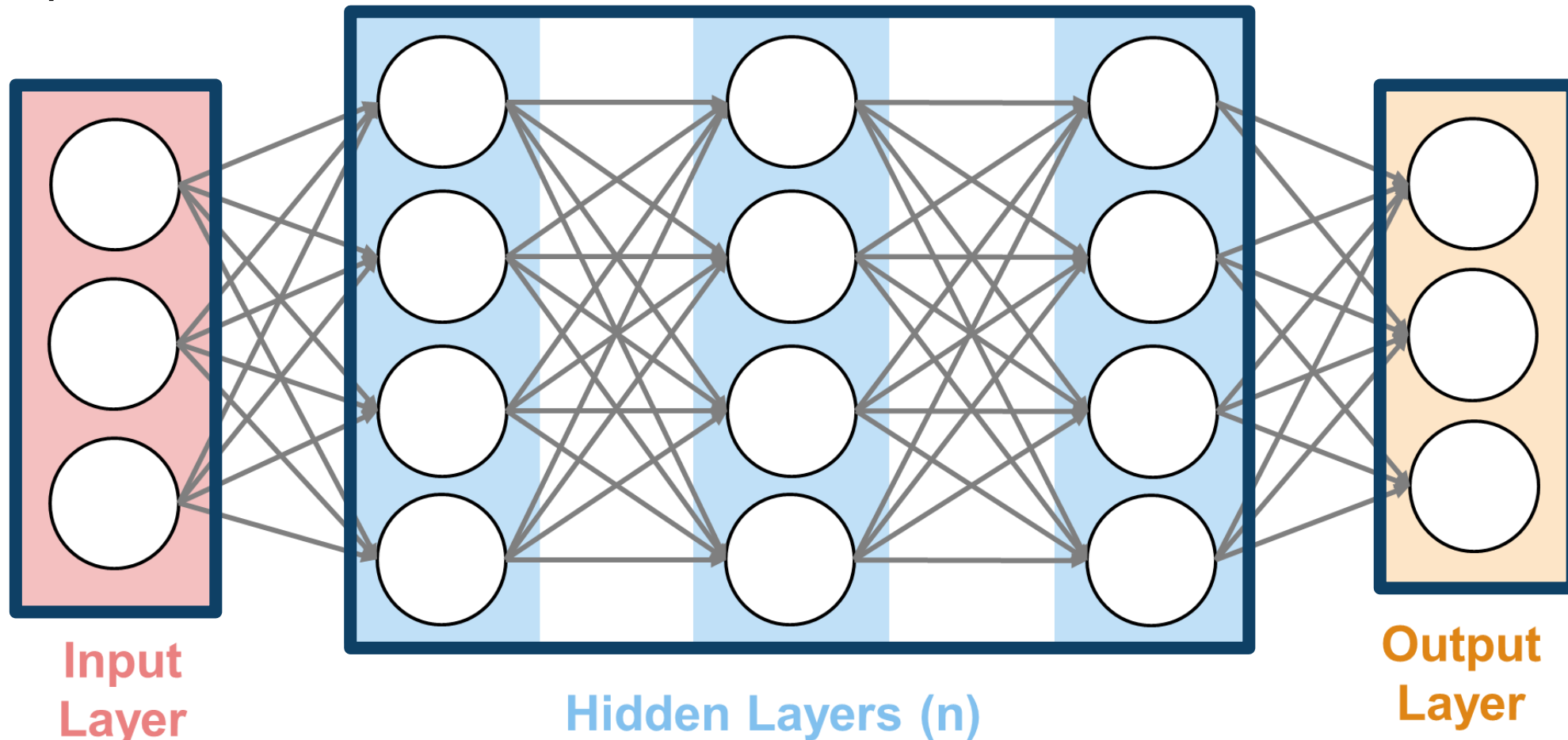
Agenda

- Deep Learning – Basic ideas

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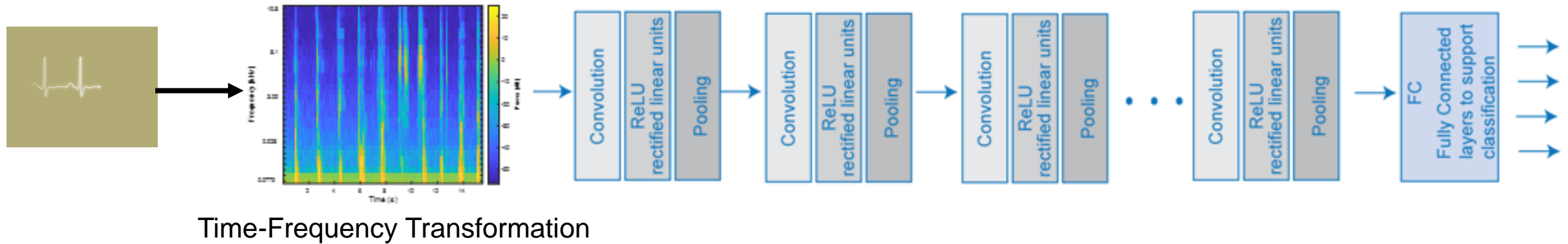
- Conclusions

What is Deep Learning?

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

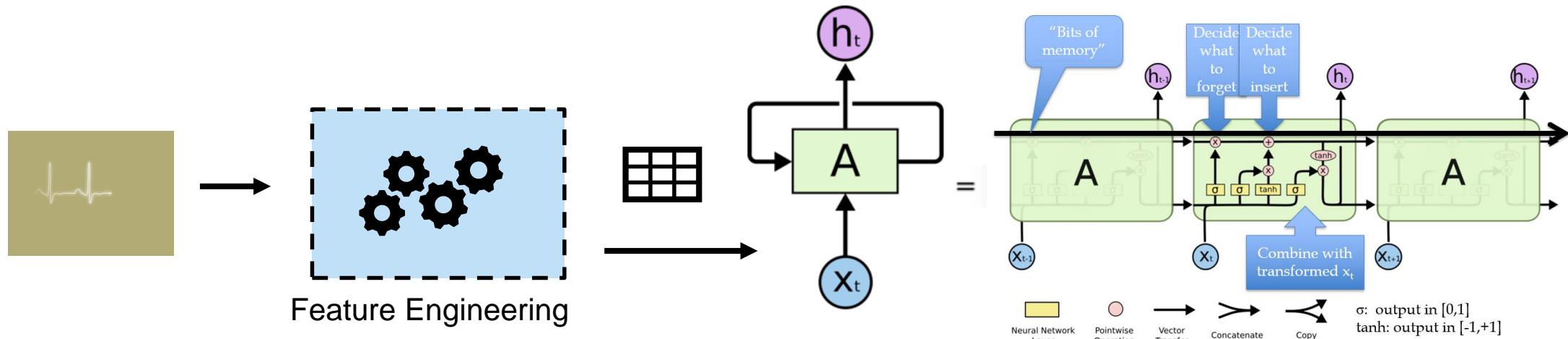**Input Layer**

Hidden Layers (n)

Output Layer

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

Convolutional Neural Networks (**CNN**)

Feature Engineering

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

Feature Engineering

Deep Learning Workflow

CREATE AND ACCESS DATASETS

PREPROCESS AND TRANSFORM DATA

DEVELOP PREDICTIVE MODELS

ACCELERATE AND DEPLOY

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
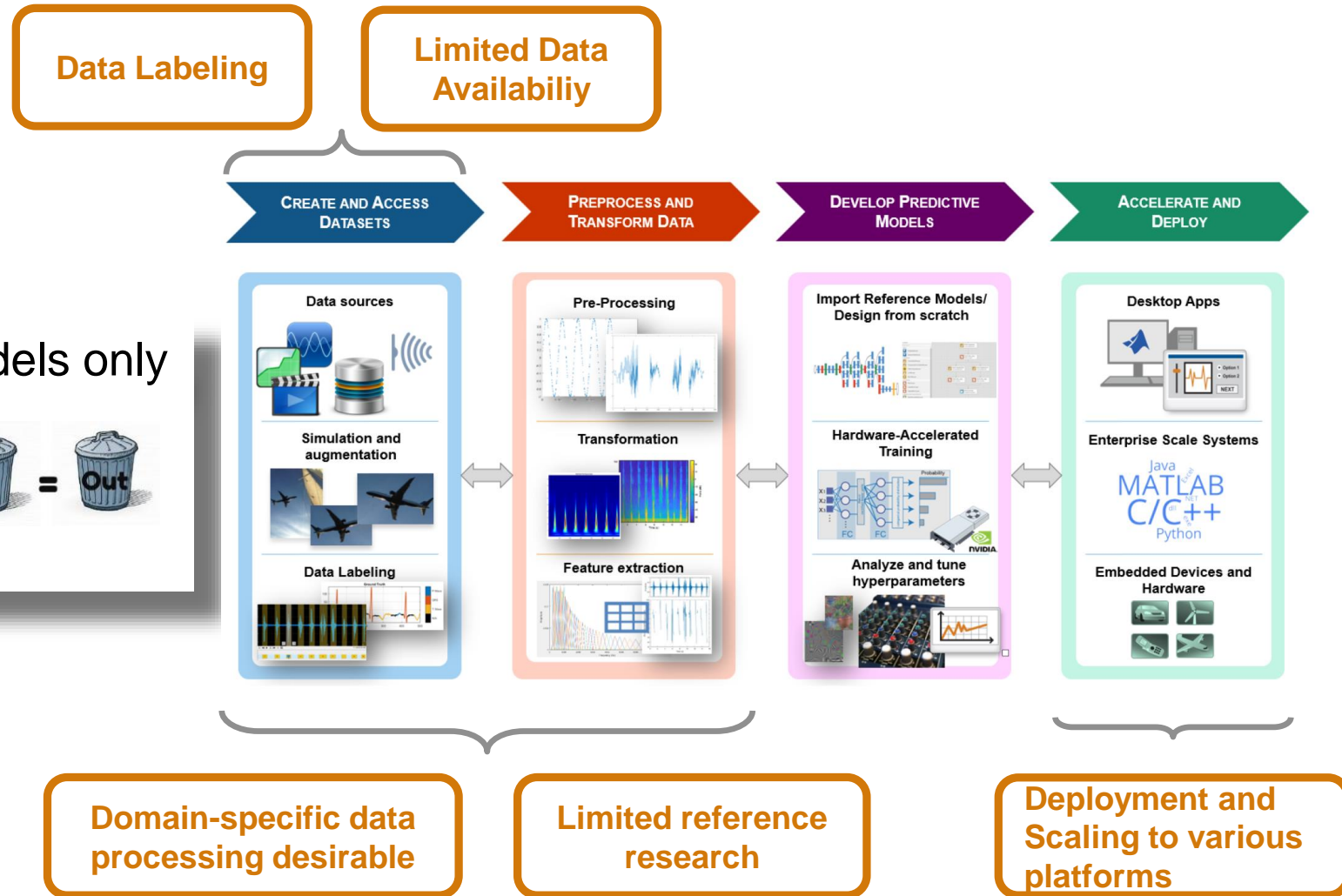
Desktop Apps

Enterprise Scale Systems

Java
MATLAB
C/C++
Python

Embedded Devices and Hardware

Deep Learning Workflow Challenges – Signals and Time Series

Data Labeling

Limited Data Availabiliy

Deep learning models only as good as training data

In = Out

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

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
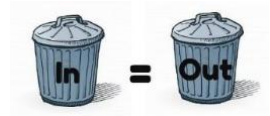- Hardware-Accelerated Training
- Analyze and tune hyperparameters

Accelerate and Deploy
- Desktop Apps
- Enterprise Scale Systems
- Java MATLAB C/C++ Python
- Embedded Devices and Hardware

Domain-specific data processing desirable

Limited reference research

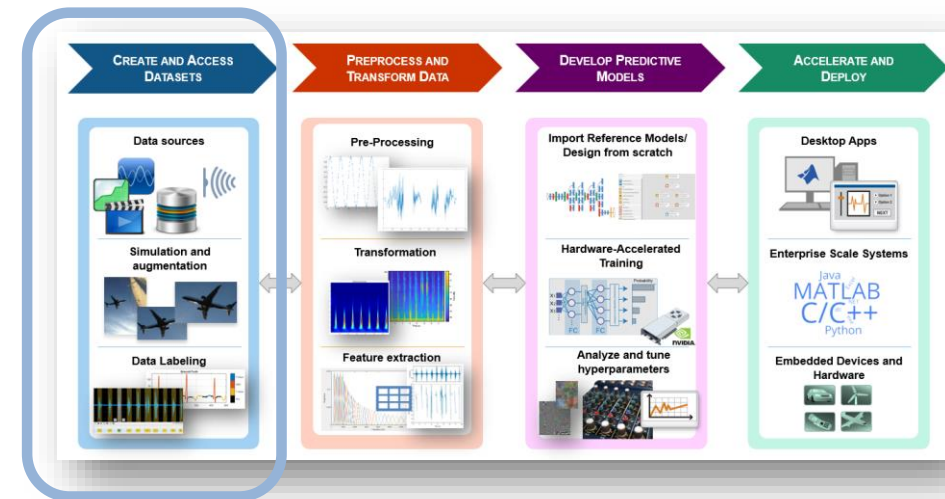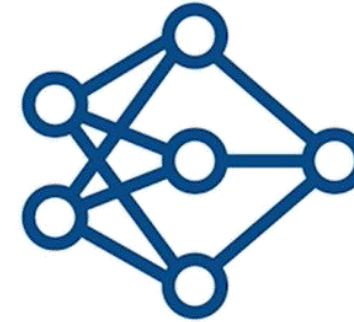**Deployment and Scaling to various platforms**

Agenda

- Deep Learning – Basic ideas

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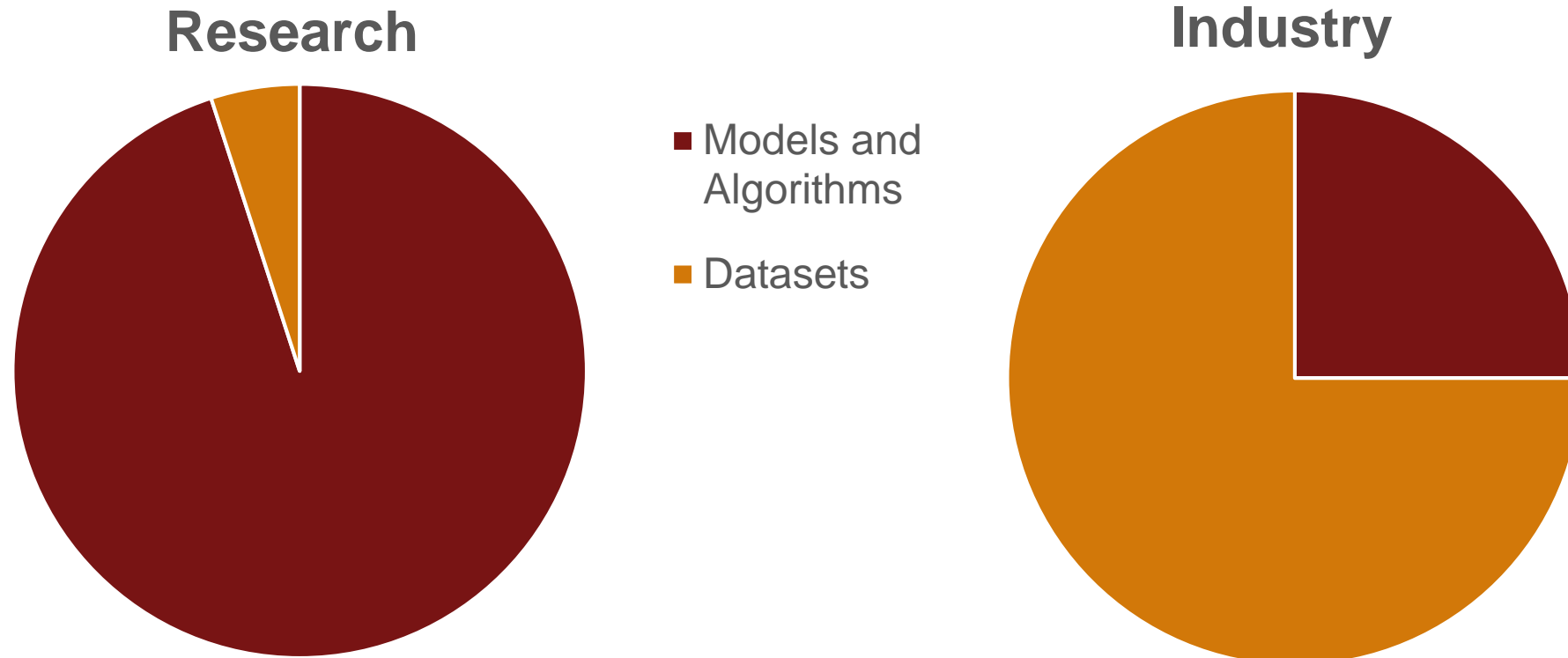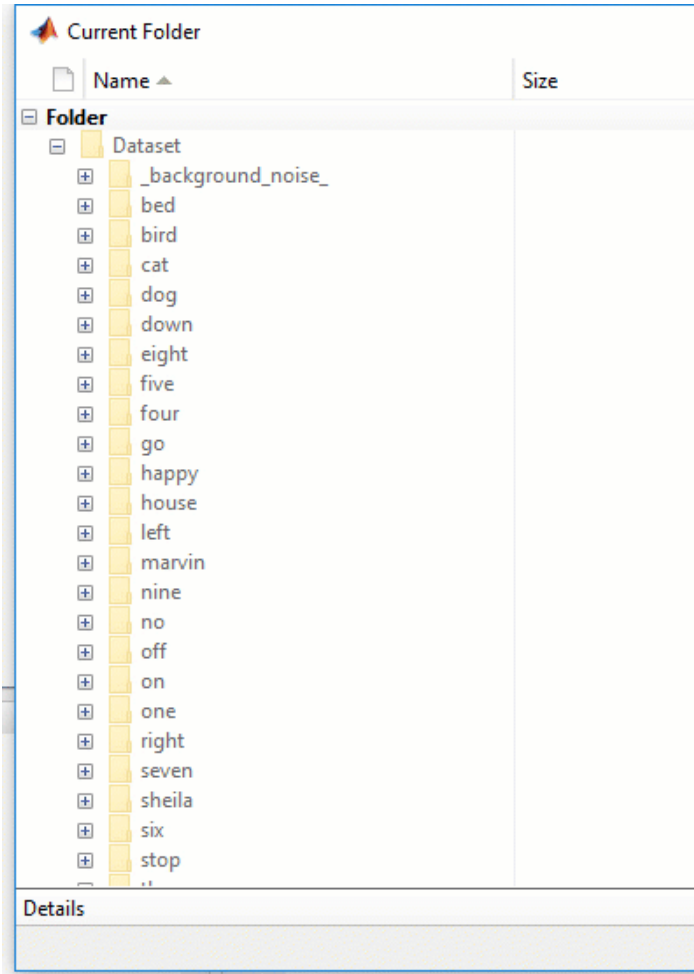 - Acceleration, prototyping, and deployment

- Conclusions

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

Current Investments – Models vs. Data

Research

Industry

- Models and Algorithms
- Datasets

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

What does a large dataset look ~~like?~~
How to navigate, index, read (a~~ll~~...


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
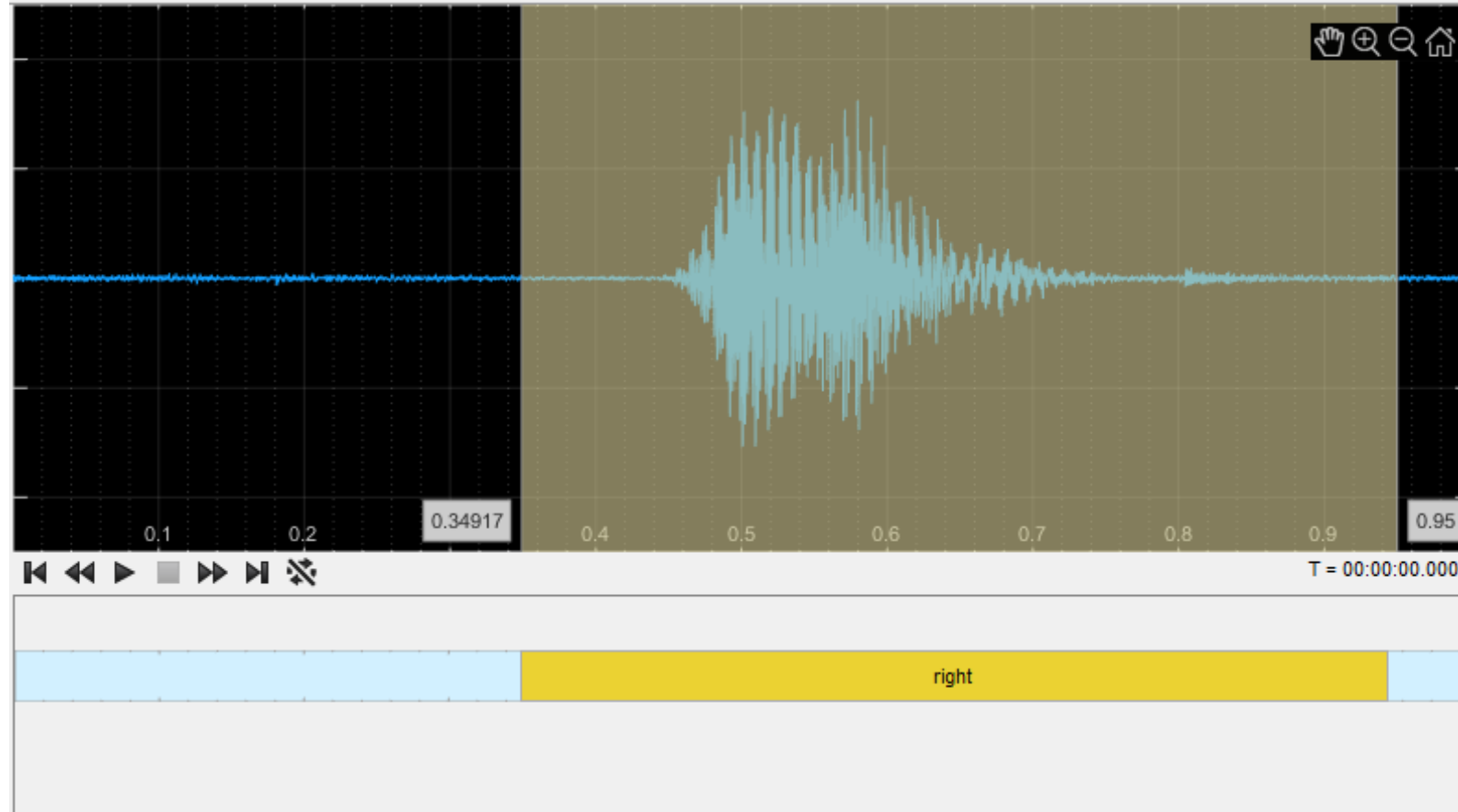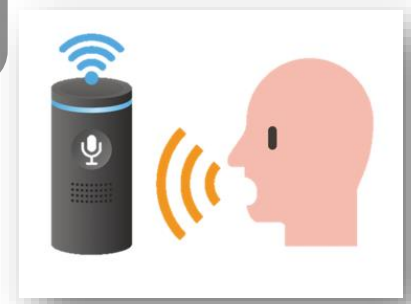
Use appropriate tools to help you label signals

- Programmatically…

- … or via Apps

What if available data isn't enough?

Pitch shift

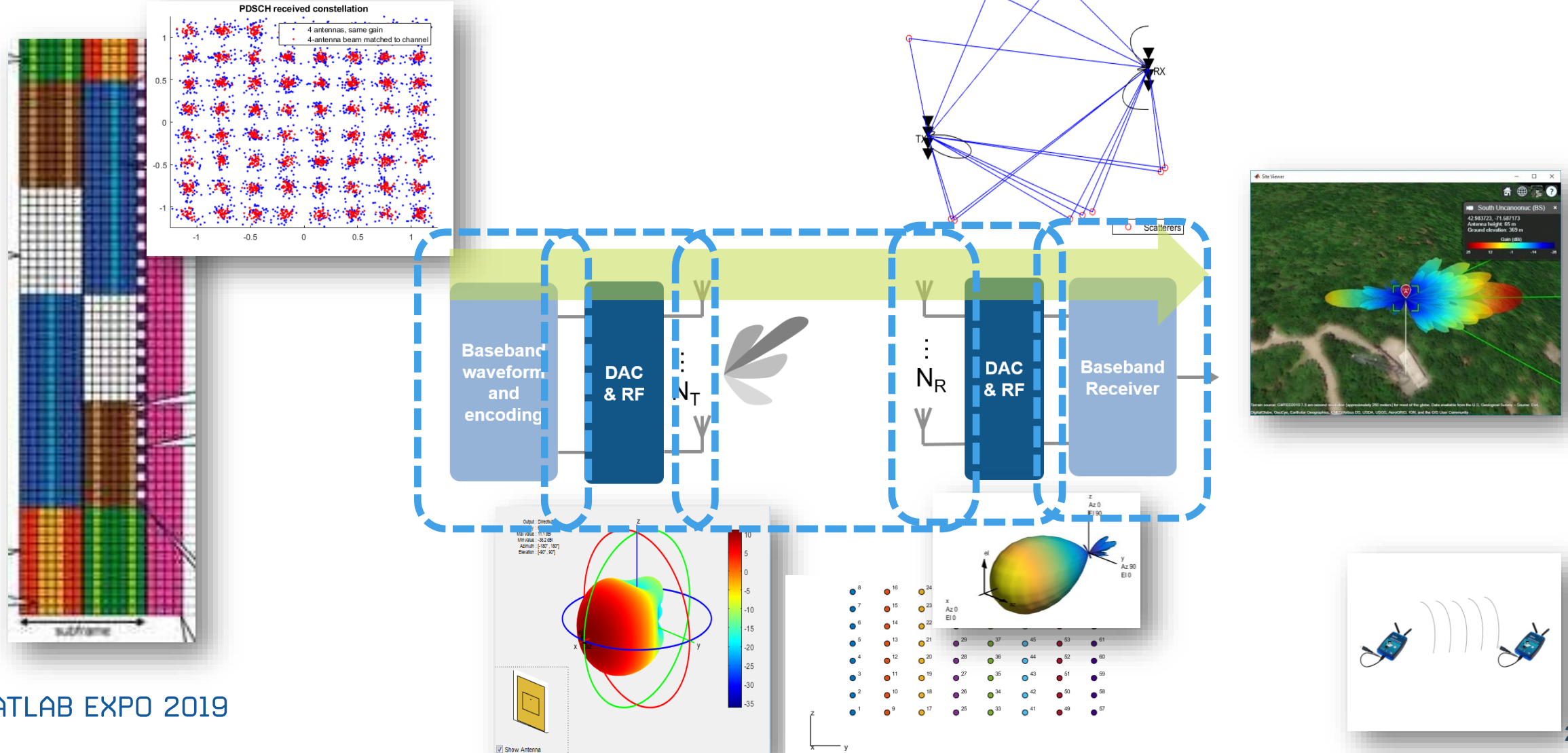Time stretch

Add noise

Add reverberation

Original Dataset

Augmented Dataset

N times as much data
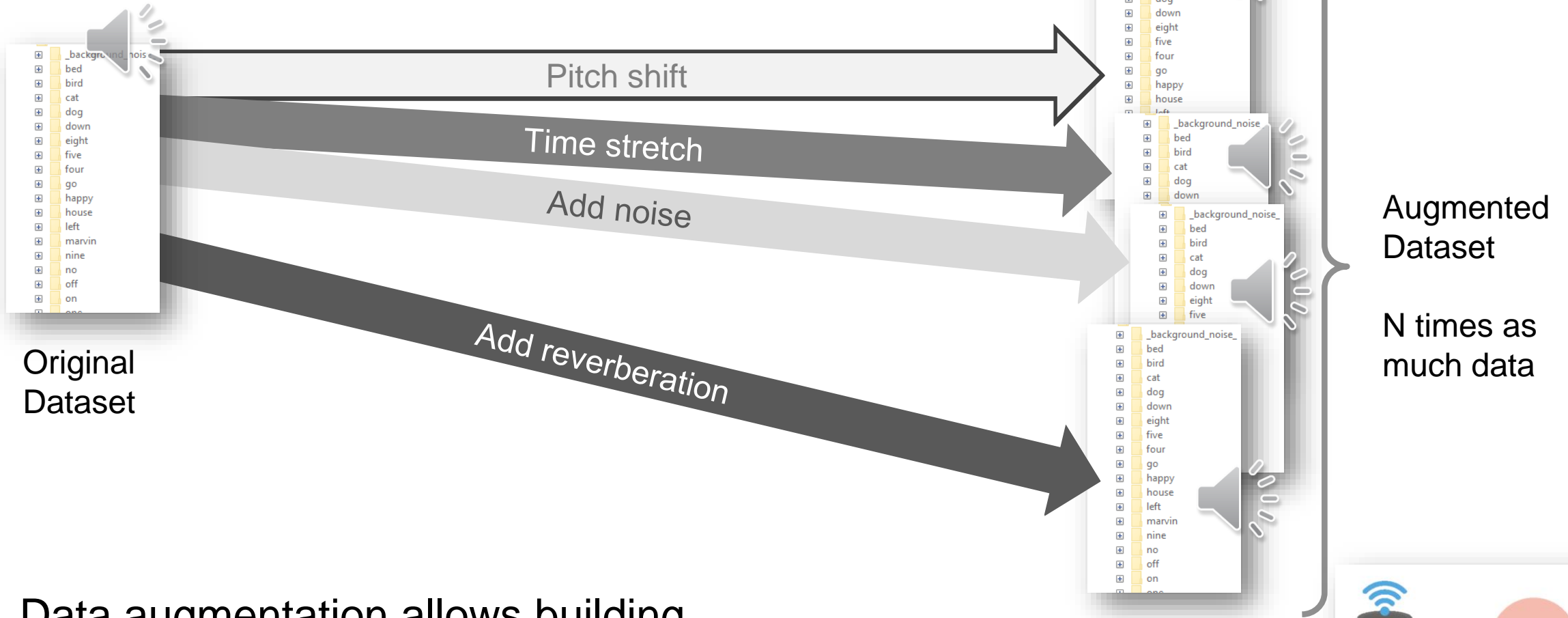
Data augmentation allows building more complex and more robust models

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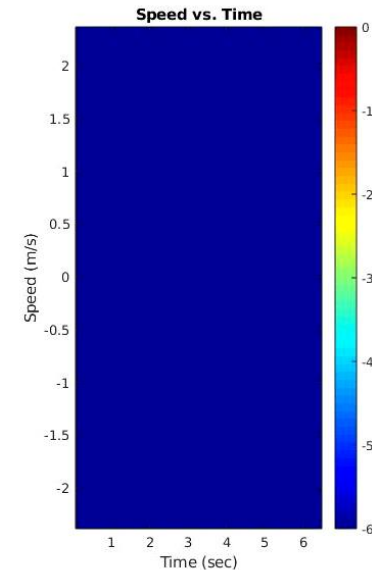

PDSCH received constellation

- 4 antennas, same gain
- 4-antenna beam matched to channel

Baseband waveform and encoding
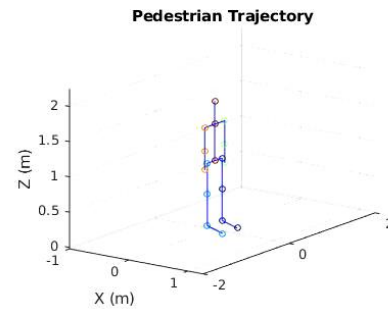
DAC & RF

N_T

N_R

DAC & RF

Baseband Receiver

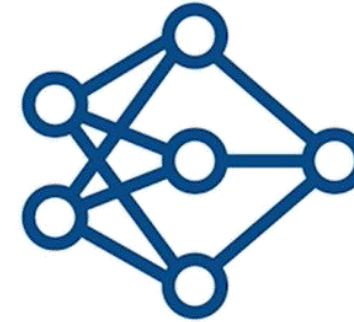# Simulation is key if recording and labelling real-world data is impractical or unreasonable – Radar Signals
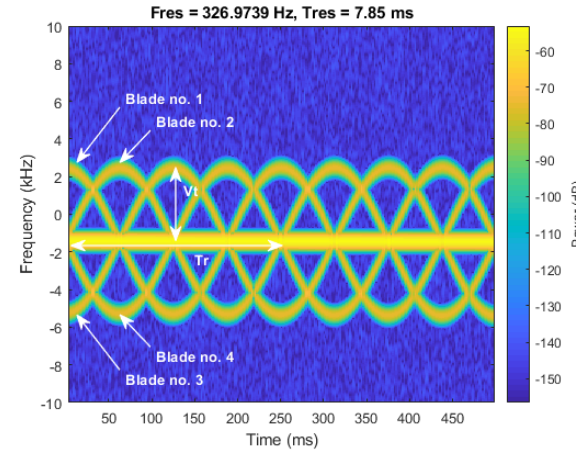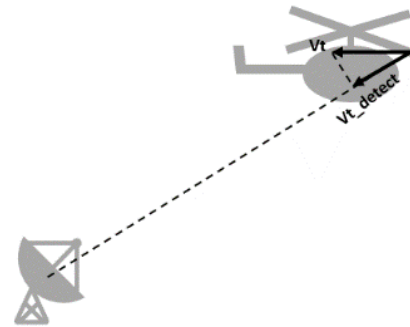
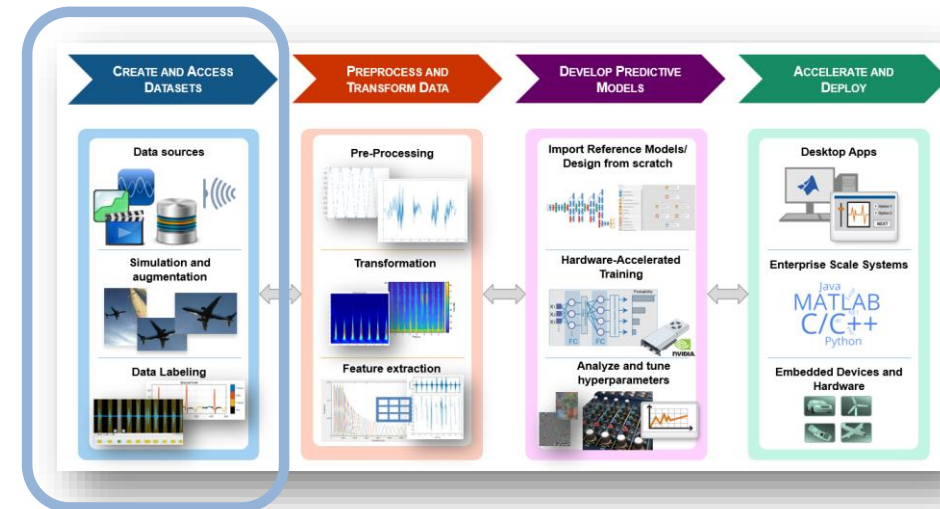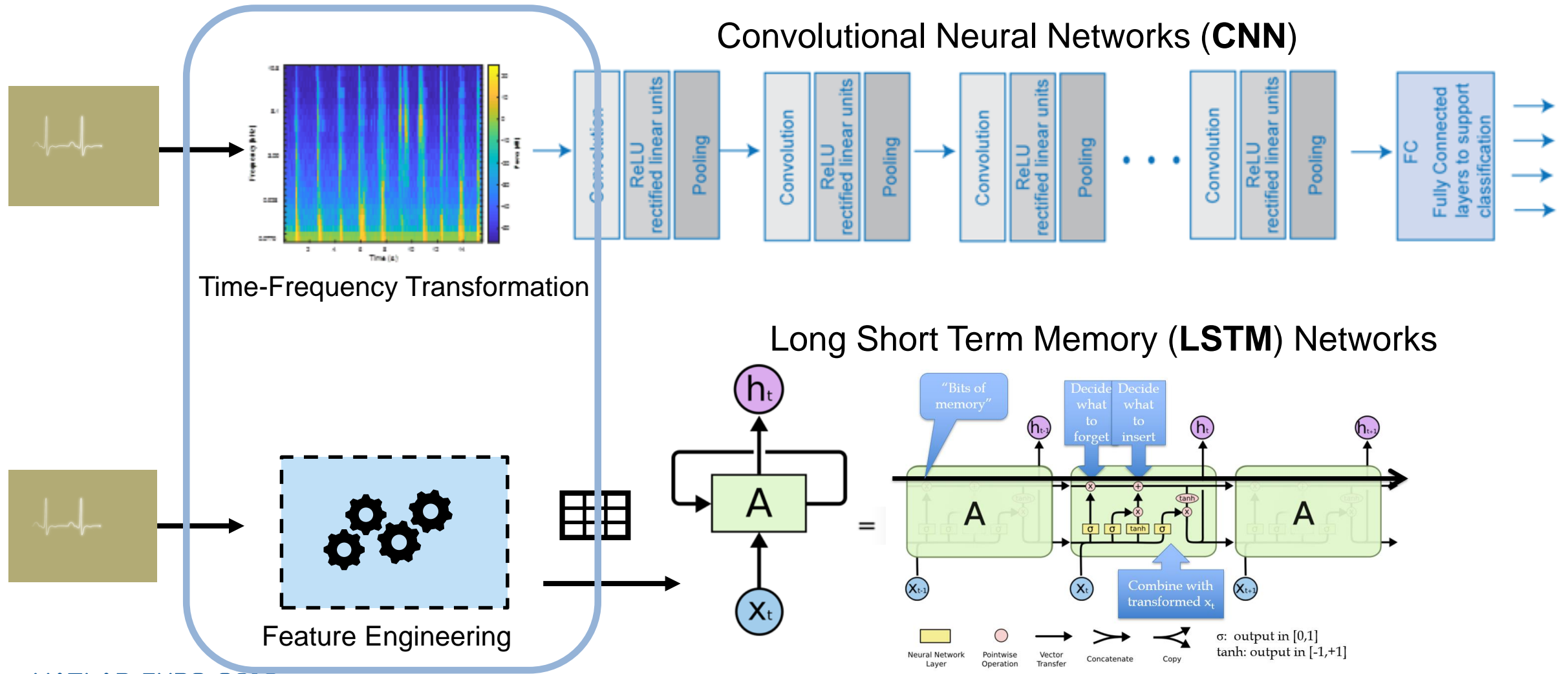Radar Target Simulation

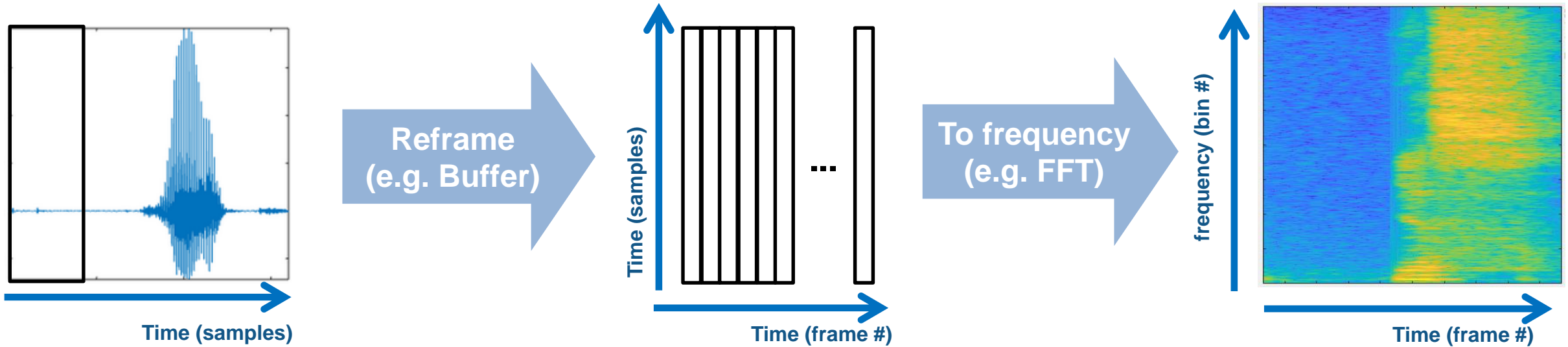Micro-Doppler Analysis

Agenda

- Deep Learning – Basic ideas

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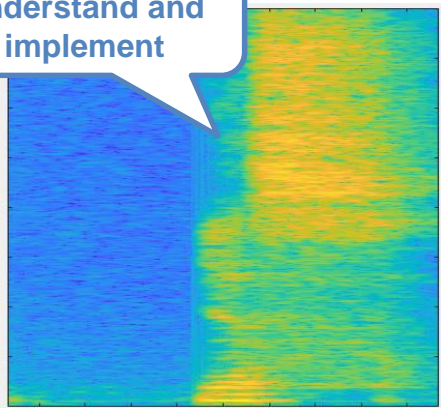 - Acceleration, prototyping, and deployment

- Conclusions

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

Convolutional Neural Networks (**CNN**)
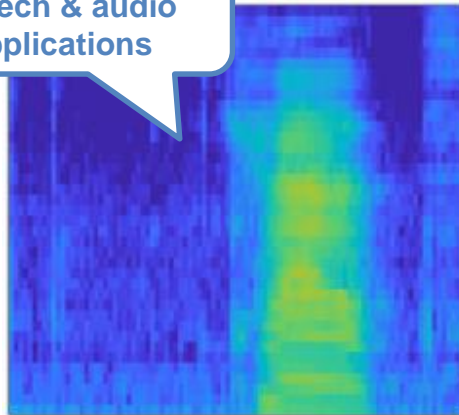
Time-Frequency Transformation

Feature Engineering

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

Time-Frequency Transformations

Reframe (e.g. Buffer)

To frequency (e.g. FFT)

Time (samples)

Time (samples)

Time (frame #)

frequency (bin #)

Time (frame #)

Easiest to understand and implement

More compact for speech & audio applications

Best resolution, for non-periodic signals

Better resolution at low frequencies

Basic spectrogram
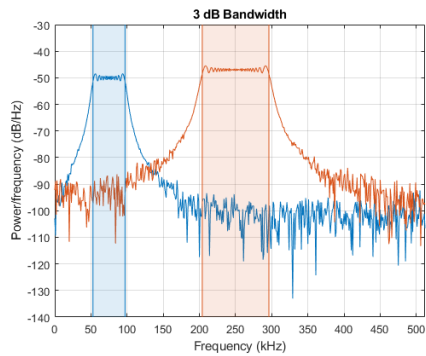MATLAB EXPO 2019

Perceptually-spaced (e.g. Mel, Bark) Spectrogram
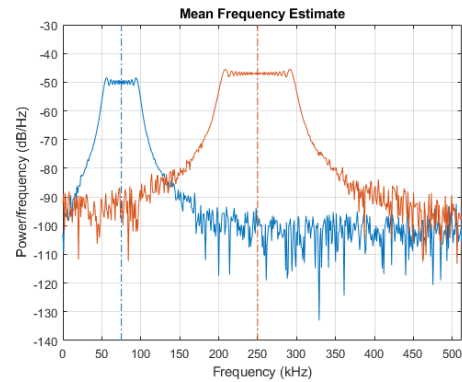
Wavelet scalogram
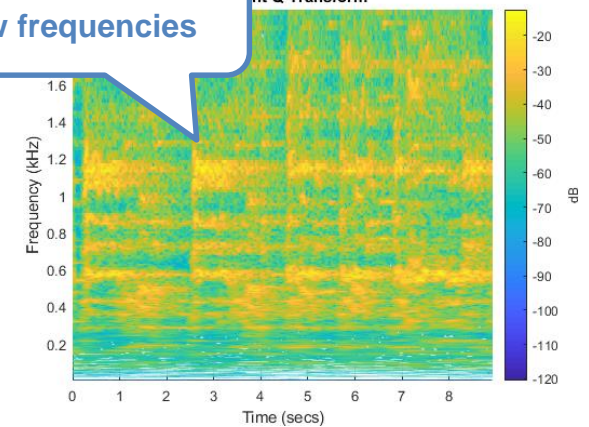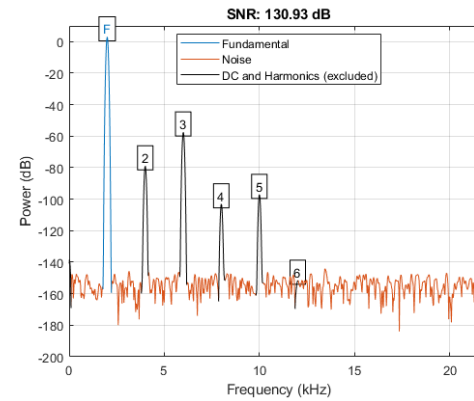
Constant Q transform

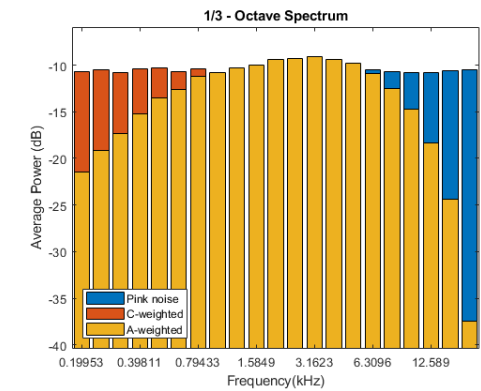# Extracting Features from Signals: Application-Agnostic Examples
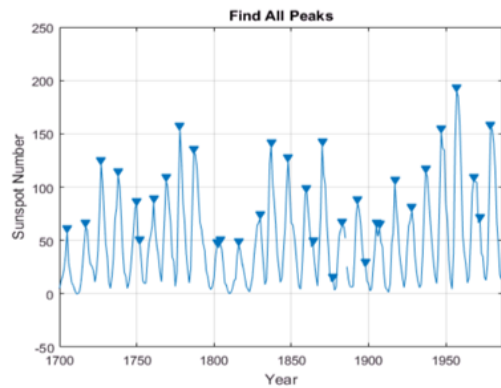

BW measurements
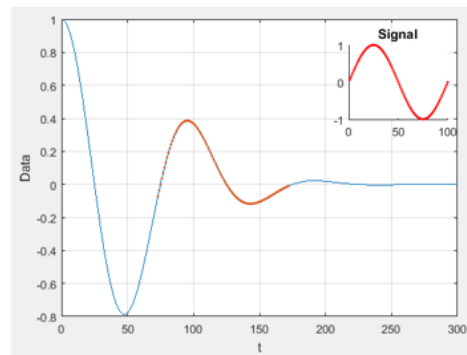

Spectral statistics

Harmonic analysis
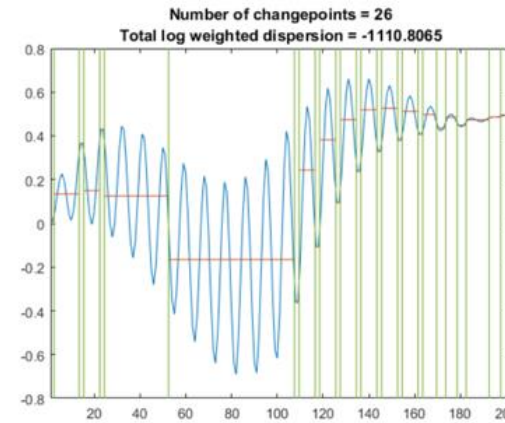

Octave spectrum
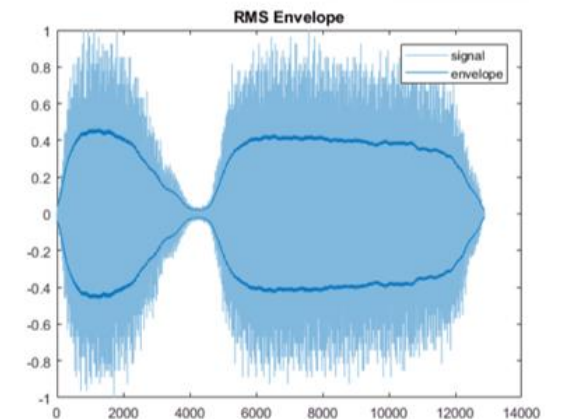
Frequency domain

Time domain

Find peaks

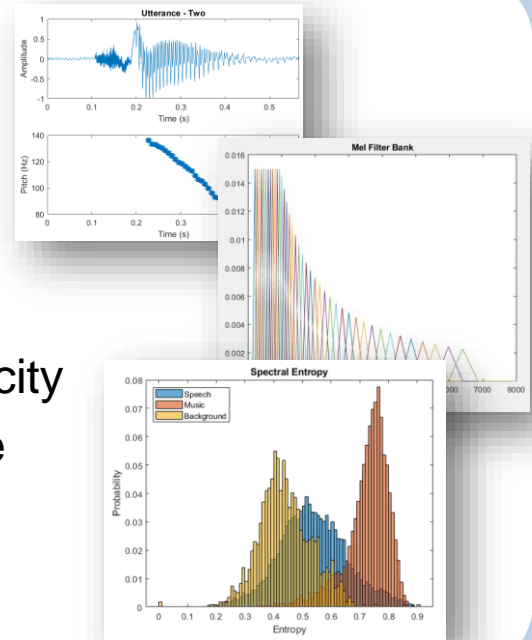
Find signal patterns

Detect change points

Find signal envelope

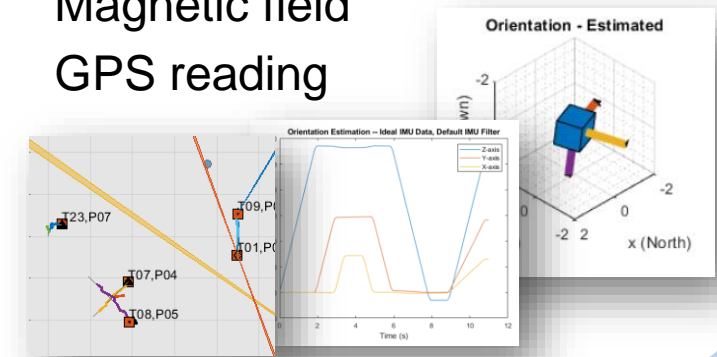# Domain-Specific Features and Transformations – Examples

Speech and Audio

- MFCC
- GTCC
- MDCT
- Pitch, harmonicity
- Spectral shape descriptors
- ...
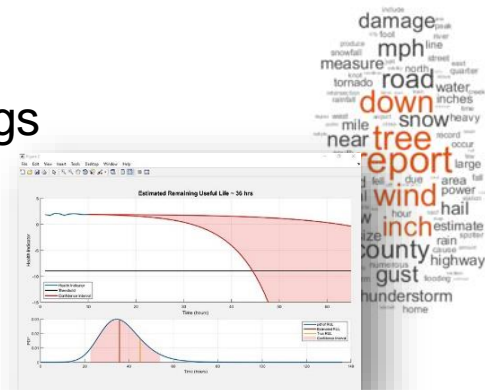
Navigation and Sensor Fusion

- Orientation
- Height
- Position

from

- Acceleration, angular velocity
- Magnetic field
- GPS reading
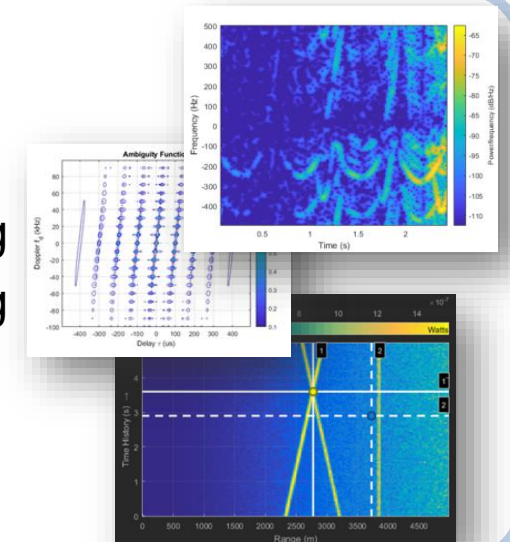
- Multi-object tracking
- ...

Text Analytics

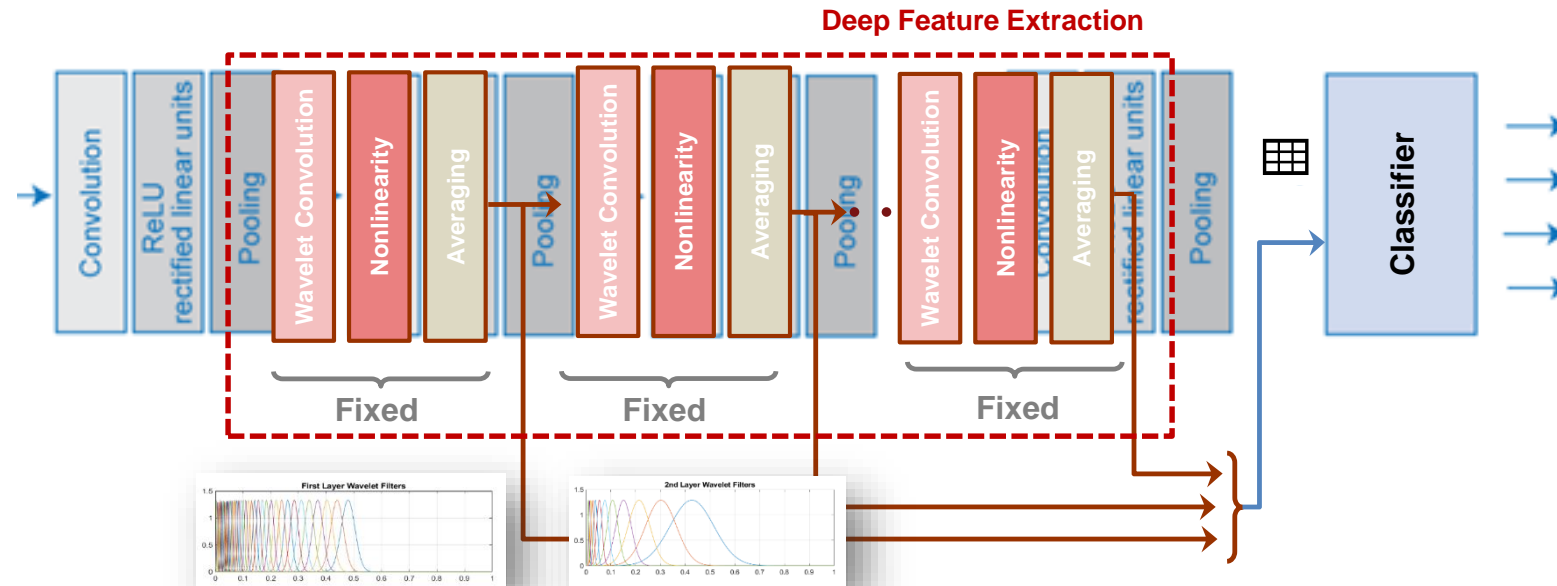- Train Word Embeddings
- Word2Vec
- Topic Modeling
- ...

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
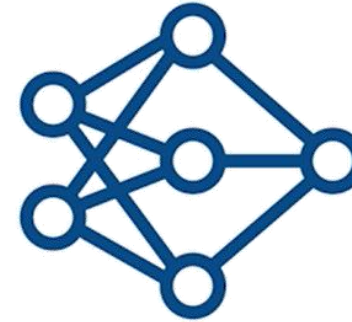
- Deep Learning – Basic ideas

- Deep Learning Model Development for Signals, Time Series, and Text

  - Data

  - Processing and transformation

  - **Model design and optimization**

  - Acceleration, prototyping, and deployment
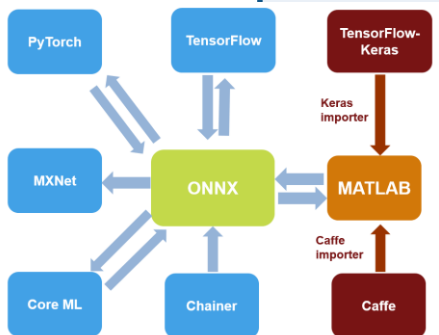
- Conclusions
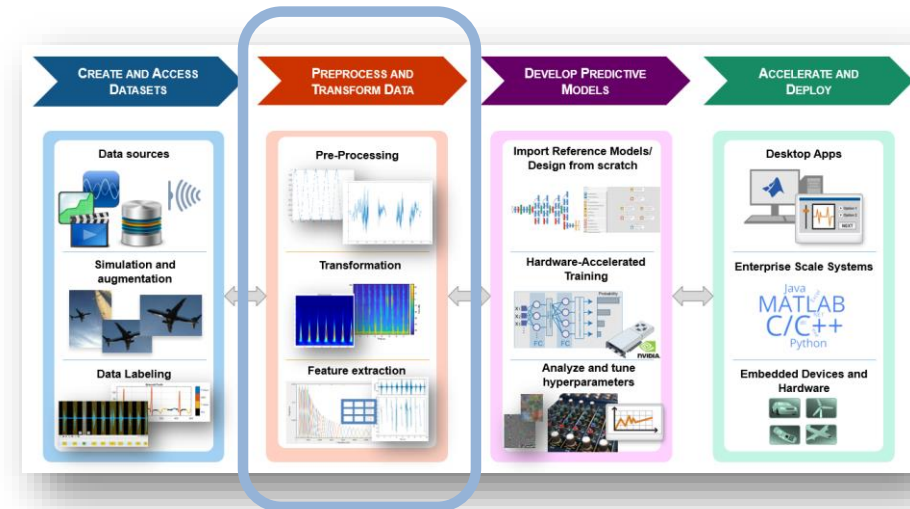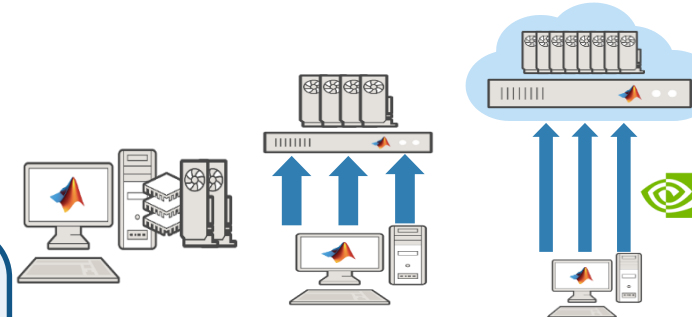
Developing Deep Learning Models

Design Network

Train

Accelerate Training

MATLAB as a container on NGC

NVIDIA. GPU CLOUD

Design

Optimize

Model Exchange

PyTorch
TensorFlow
TensorFlow-Keras

Keras importer

MXNet
ONNX
MATLAB

Caffe importer

Core ML
Chainer
Caffe

Pre-trained Networks

AlexNet
PRETRAINED MODEL

VGG-16
PRETRAINED MODEL

ResNet-50
PRETRAINED MODEL

ONNX Converter
MODEL CONVERTER

Caffe
IMPORTER

GoogLeNet
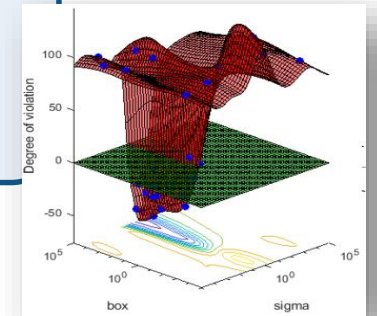PRETRAINED MODEL

TensorFlow-Keras
IMPORTER

Inception-v3
MODELS

Bayesian Hyperparameter Optimization

MATLAB EXPO 2019

29

Exchange Models With Deep Learning Frameworks

PyTorch

TensorFlow

TensorFlow-Keras

MXNet
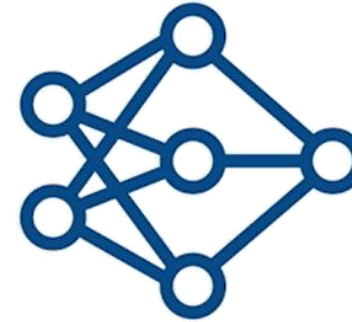
ONNX

MATLAB

Core ML

Chainer

Caffe
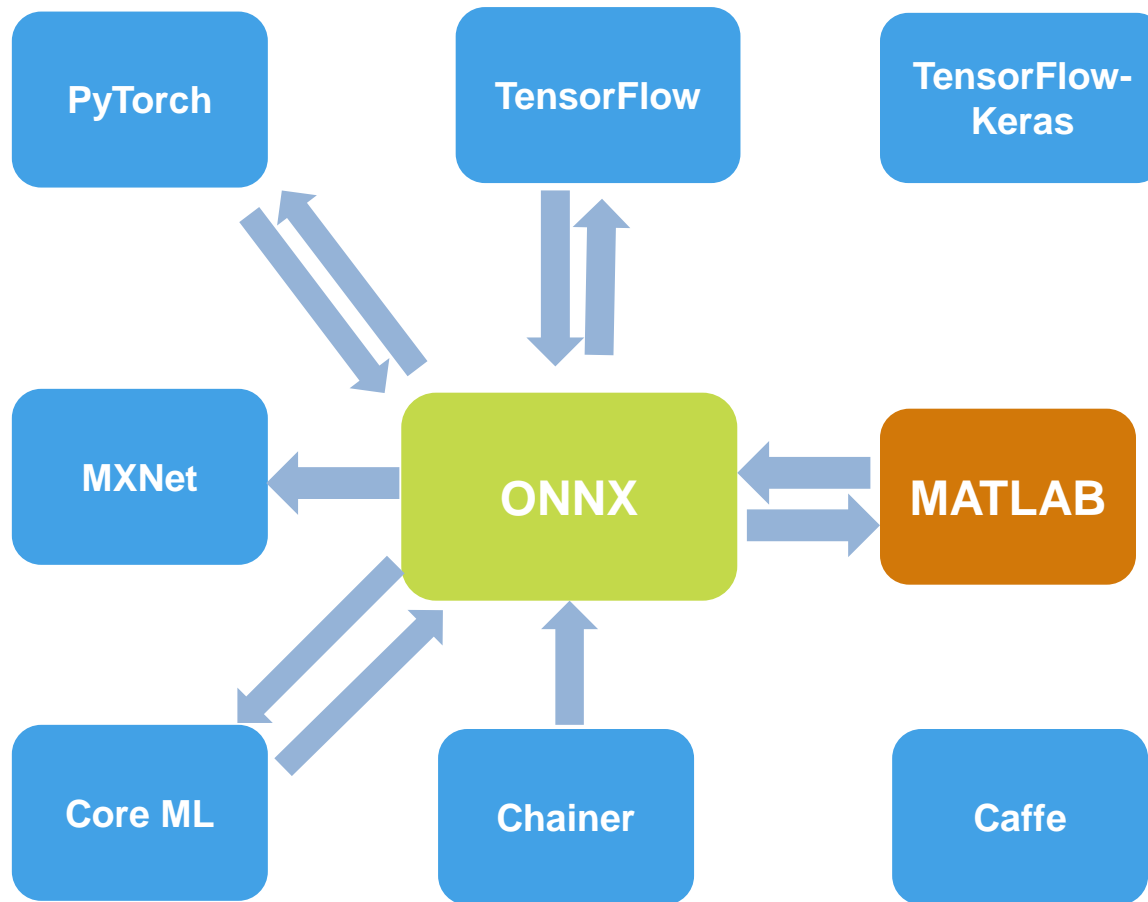
ONNX = Open Neural Network Exchange Format

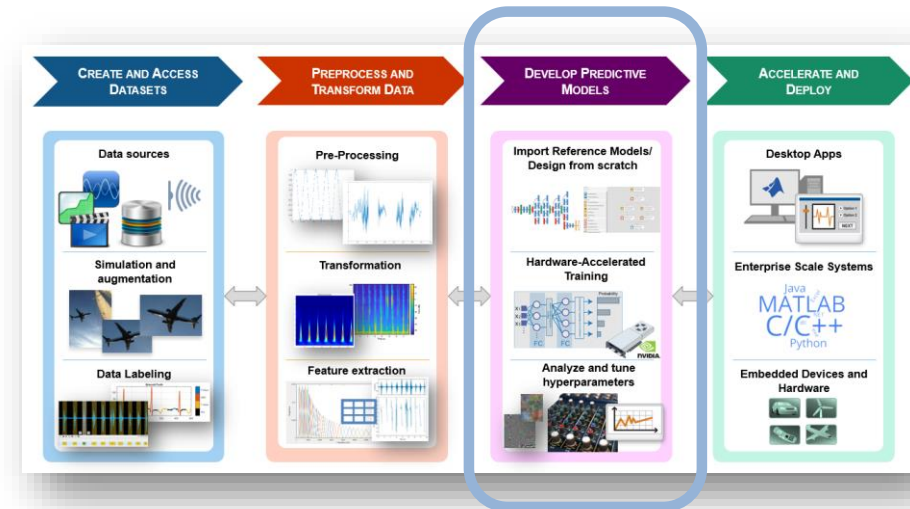# Exchange Models With Deep Learning Frameworks
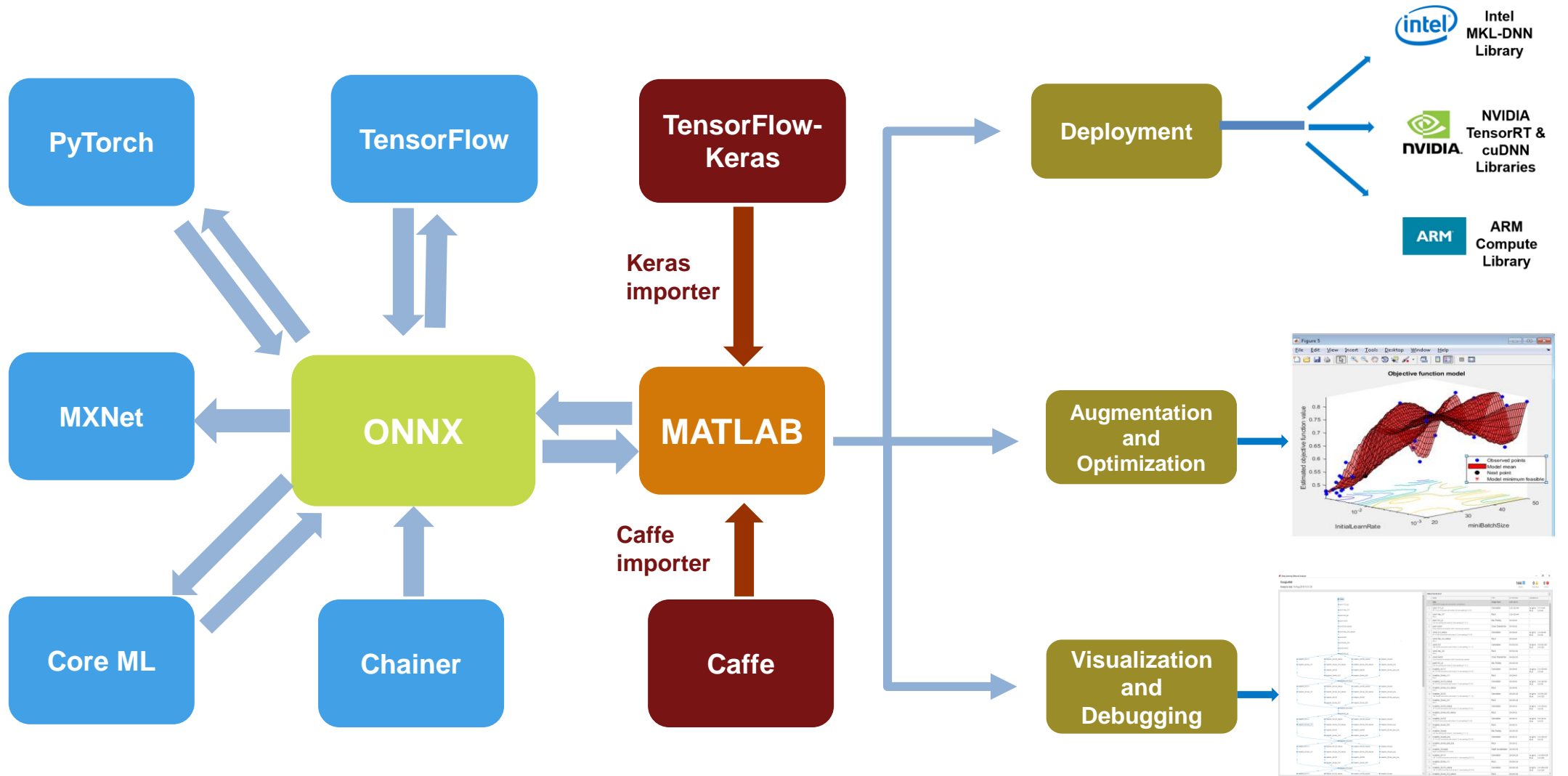
ONNX = Open Neural Network Exchange Format
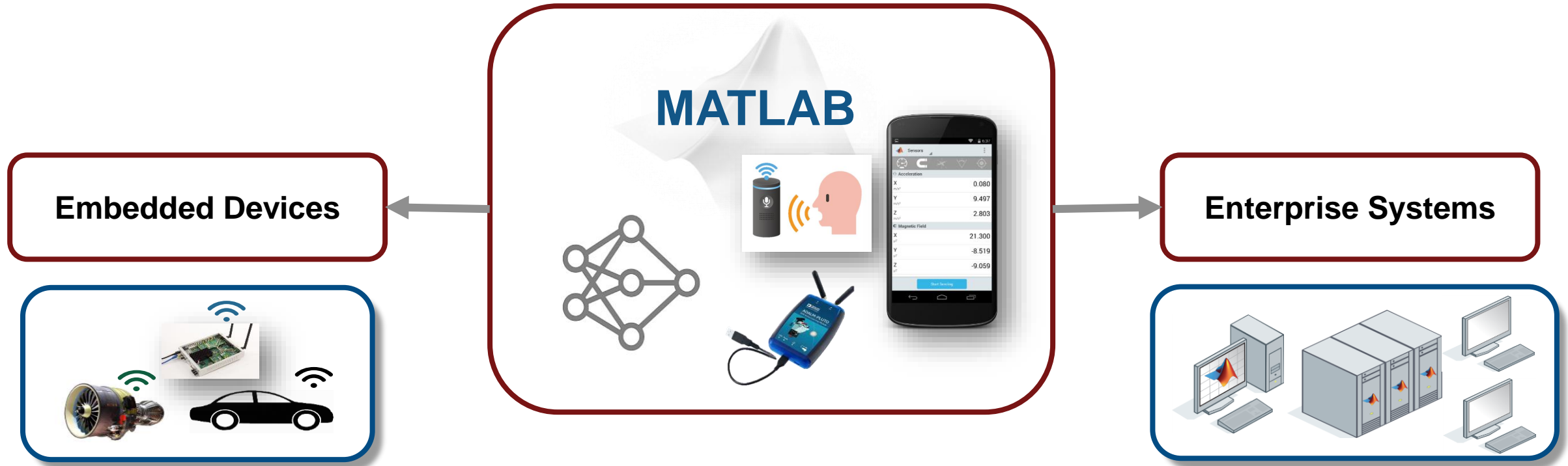
Agenda

- 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

Deployment and Scaling for A.I.

Embedded Devices

MATLAB

Enterprise Systems

Deploying Deep Learning Models for Inference

Application logic

Code Generation

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

Intel MKL-DNN Library

NVIDIA TensorRT & cuDNN Libraries

ARM Compute Library

With **GPU Coder**, MATLAB is fast

Single Image Inference (Titan V, Linux)

R2019a

Legend:
- **TensorFlow** (blue)
- **MXNet** (gray)
- **GPU Coder** (yellow)
- **PyTorch** (green)

GPU Coder is faster than TensorFlow, MXNet and Pytorch

Intel® Xeon® CPU 3.6 GHz - NVIDIA libraries: CUDA10 - cuDNN 7 - Frameworks: TensorFlow 1.13.0, MXNet 1.4.0 PyTorch 1.0.0

Enterprise Deployment

Deployment to the cloud with MATLAB Compiler and MATLAB Production Server

Agenda

- Deep Learning – Basic ideas

- Deep Learning Model Development for Signals, Time Series, and Text

  – Data

  – Processing and transformation

  – Model design and optimization

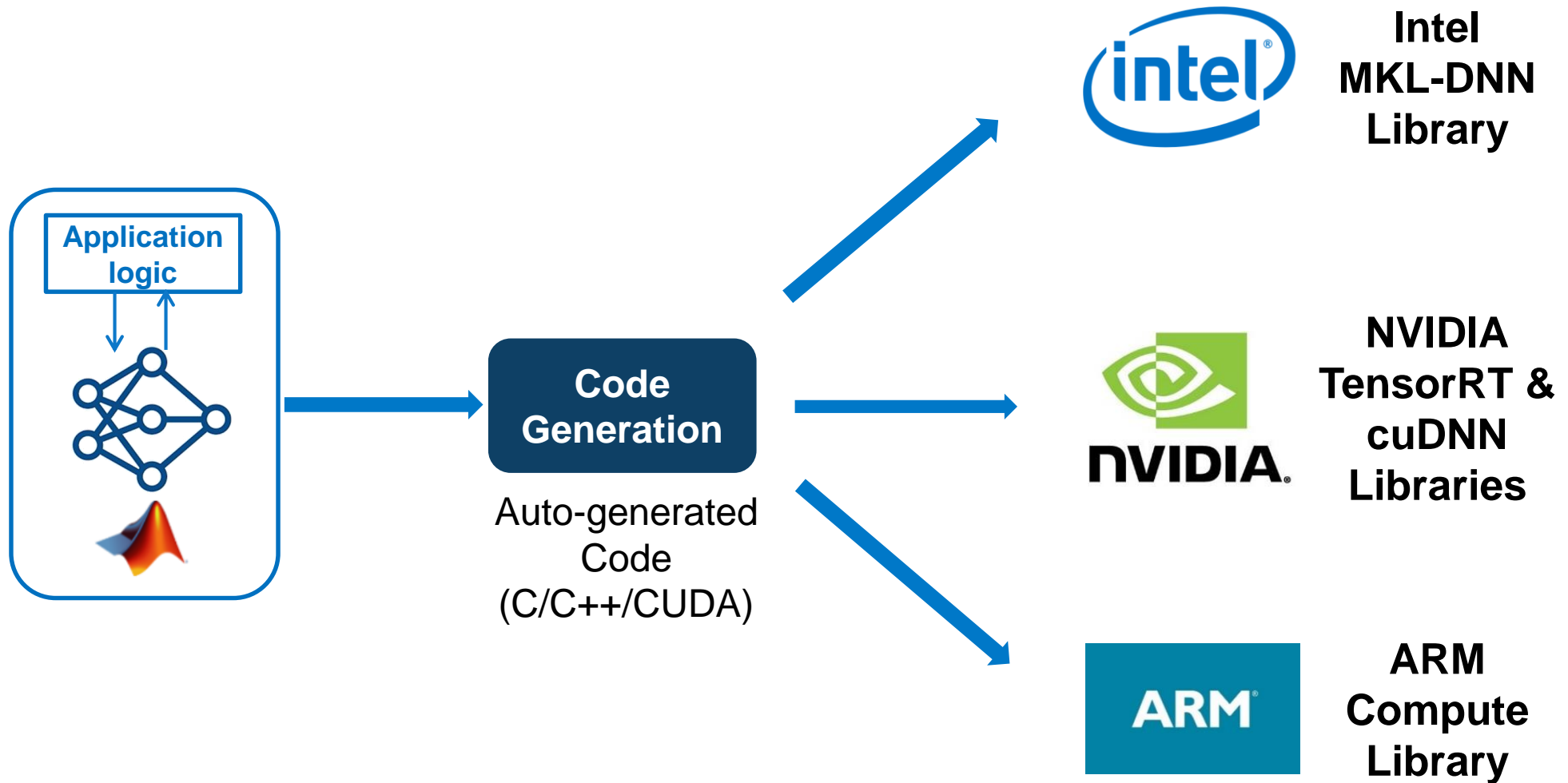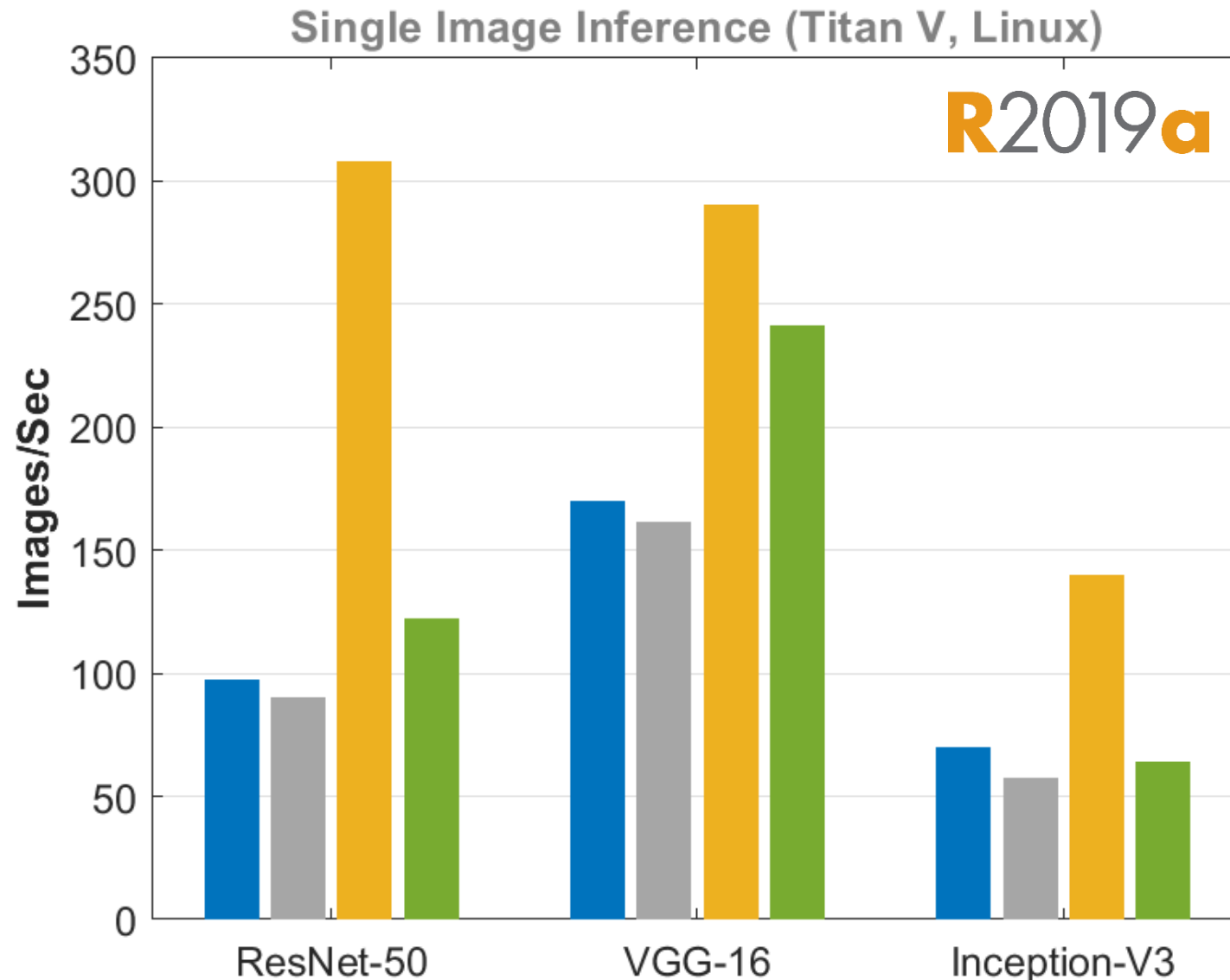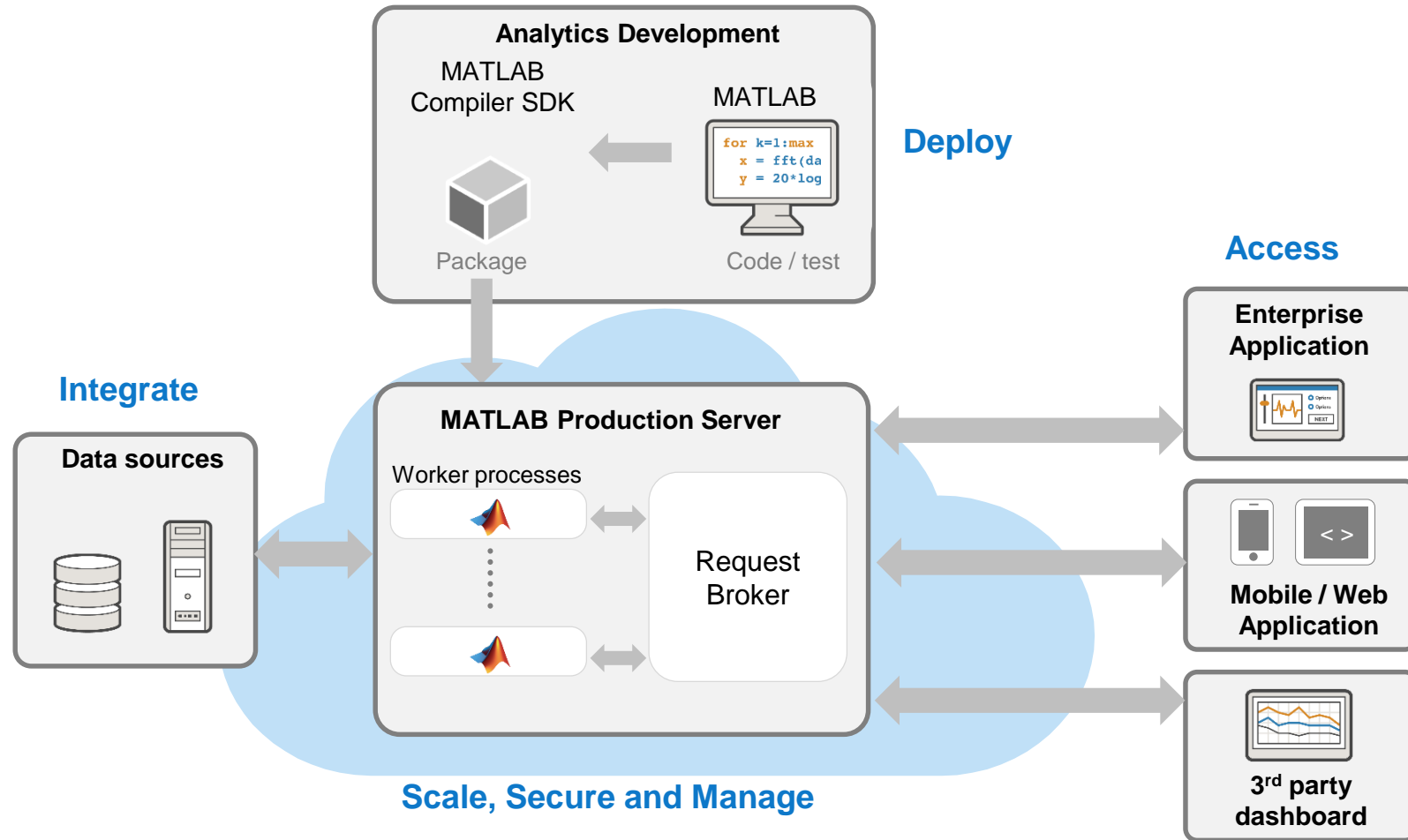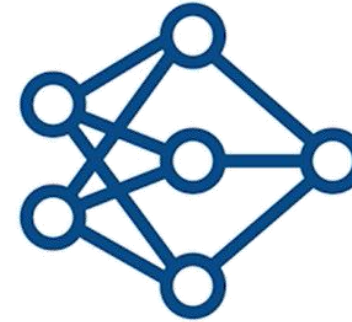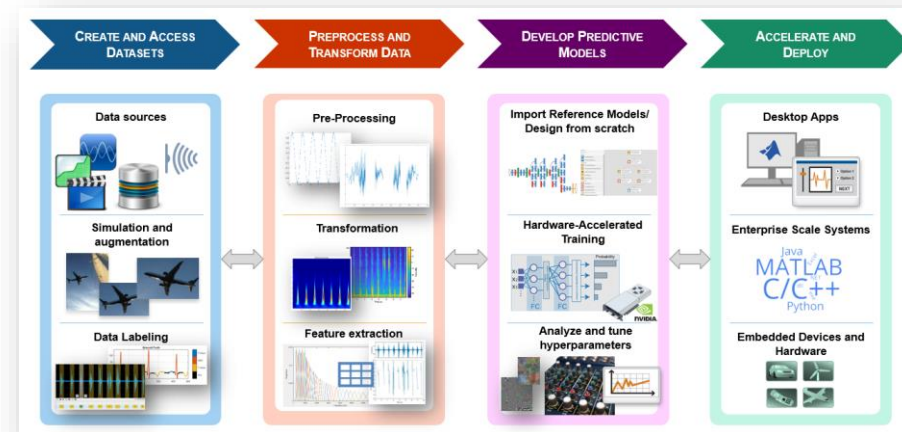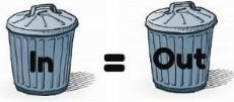 – Acceleration, prototyping, and deployment

- **Conclusions**

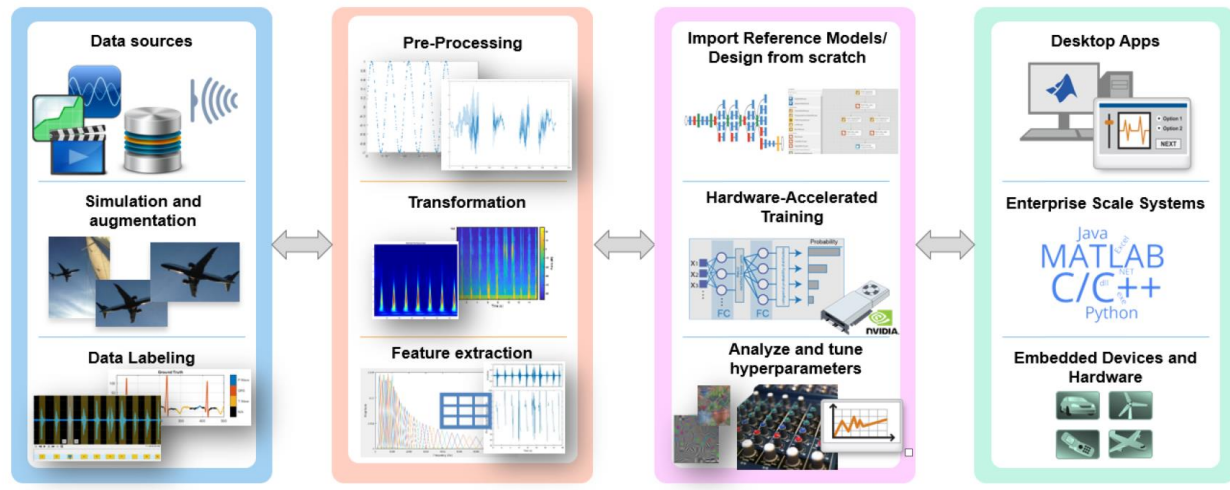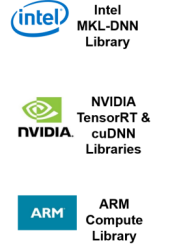# Deep Learning Workflow Challenges – Signals and Time Series

Data-labeling Apps and Examples

Augmentation and simulation algorithms

Deployment and Scaling to various platforms

Deep learning models only as good as training data

CREATE AND ACCESS DATASETS

PREPROCESS AND TRANSFORM DATA

DEVELOP PREDICTIVE MODELS

ACCELERATE AND DEPLOY

Data sources
Simulation and augmentation
Data Labeling

Pre-Processing
Transformation
Feature extraction

Import Reference Models/ Design from scratch
Hardware-Accelerated Training
Analyze and tune hyperparameters

Desktop Apps
Enterprise Scale Systems
Embedded Devices and Hardware

Application-specific algorithms and tools

Collaboration in the AI ecosystem

Intel MKL-DNN Library

NVIDIA TensorRT & cuDNN Libraries

ARM Compute Library

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38
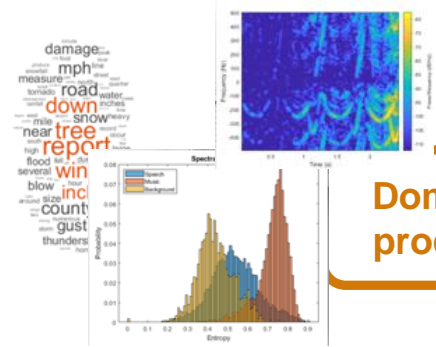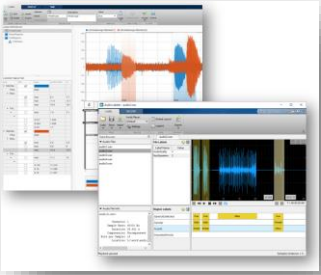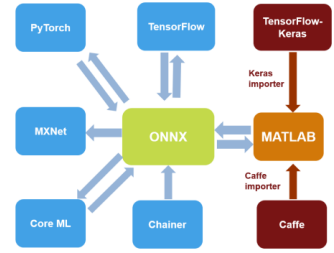
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감사합니다