MATLAB EXPO 2018

Demystifying Deep Learning

“Let the computers do the hard work”

Nilgün Sever, FİGES


Deep Learning Demo
Image Classification

Why MATLAB for Deep Learning?

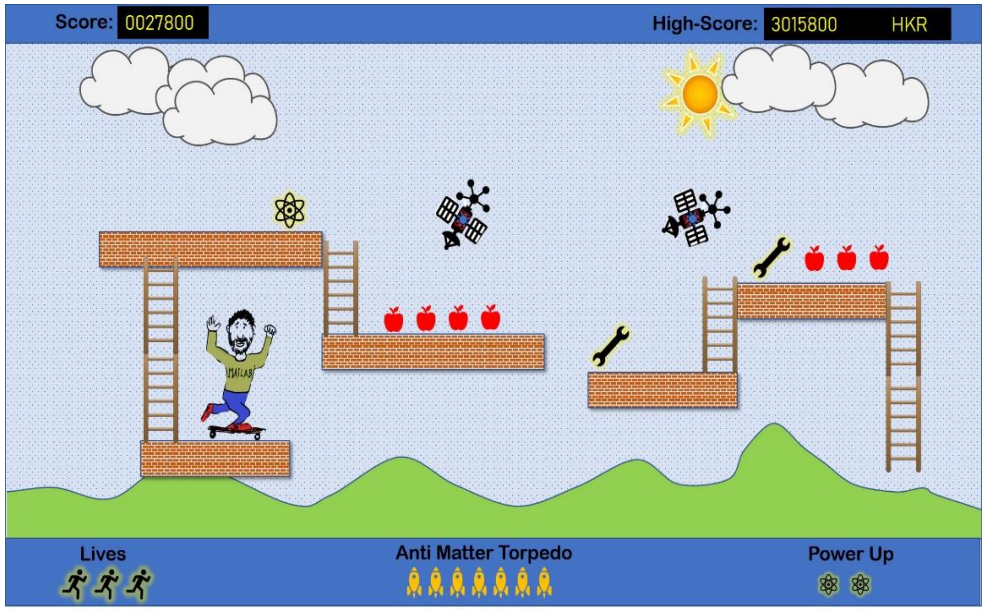
- MATLAB is Productive
- MATLAB is Fast
- MATLAB Integrates with Open Source

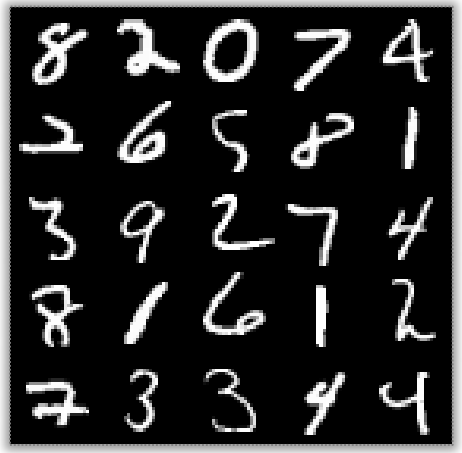
Deep Learning Applications

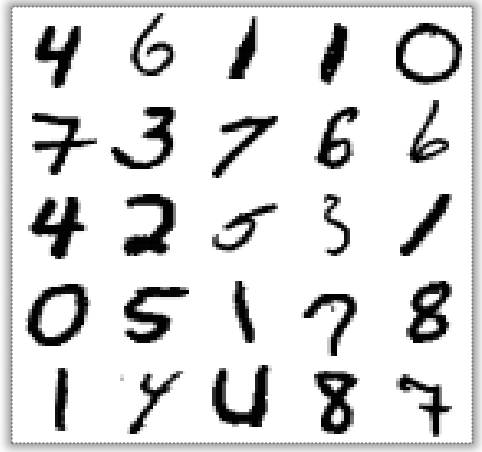
Voice assistants (speech to text)

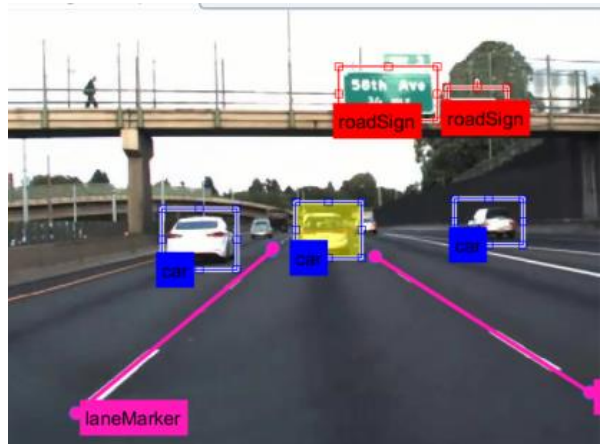
Teaching character to beat video game

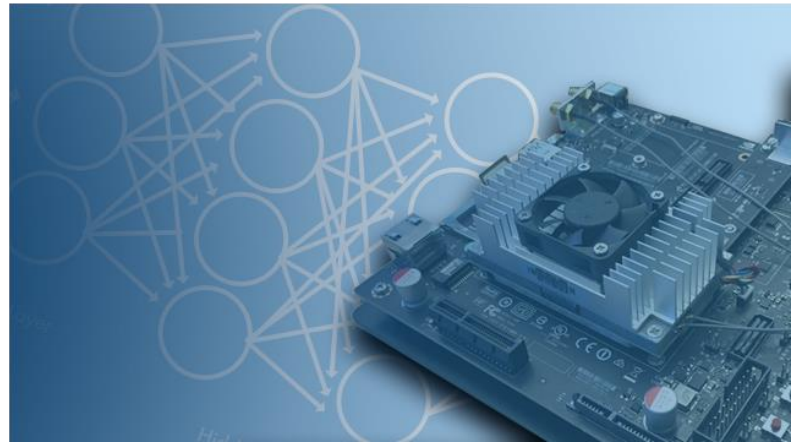
Automatically coloring black-and-white images



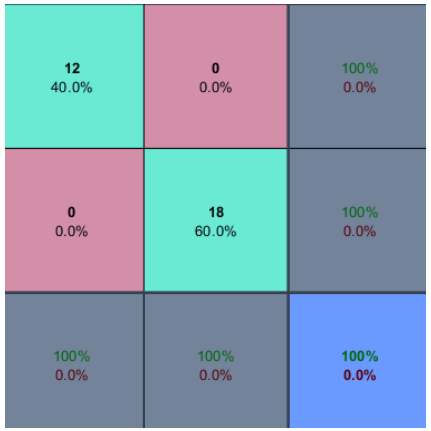






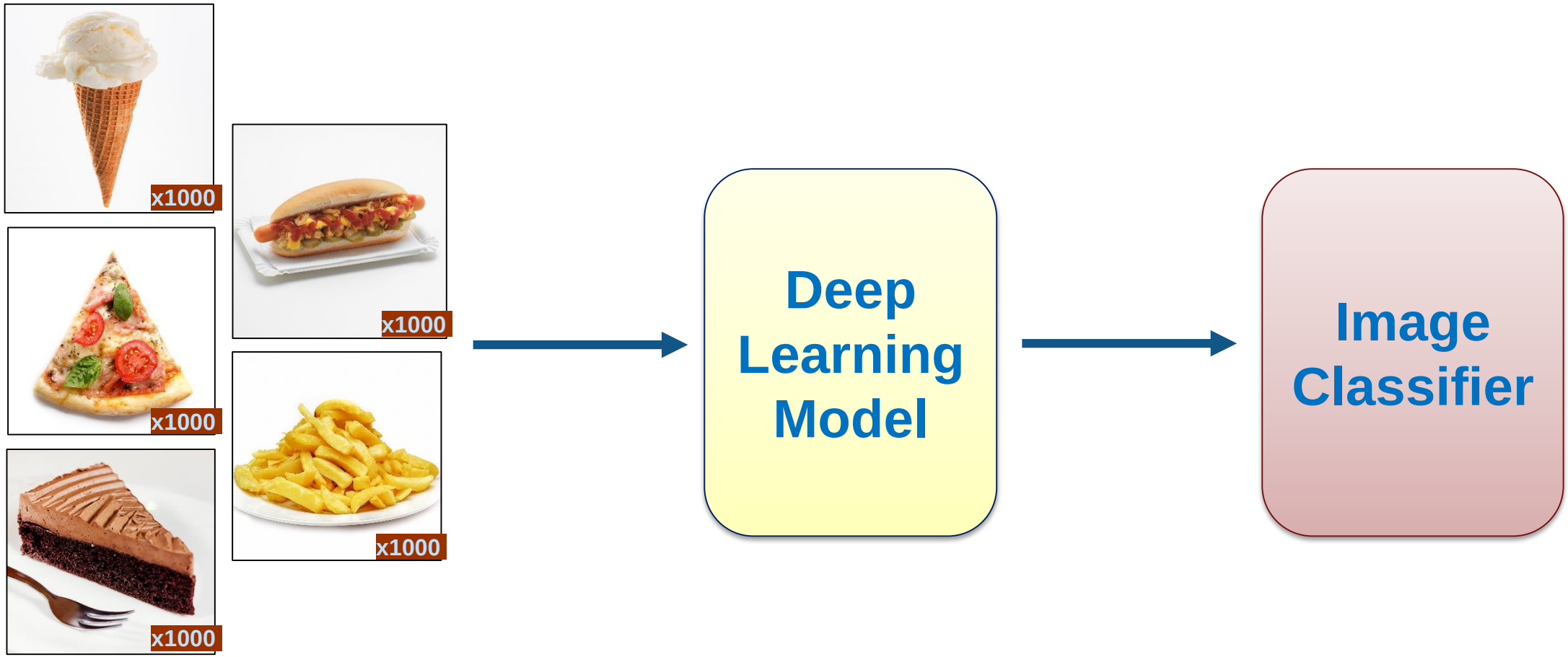


What is Deep Learning?

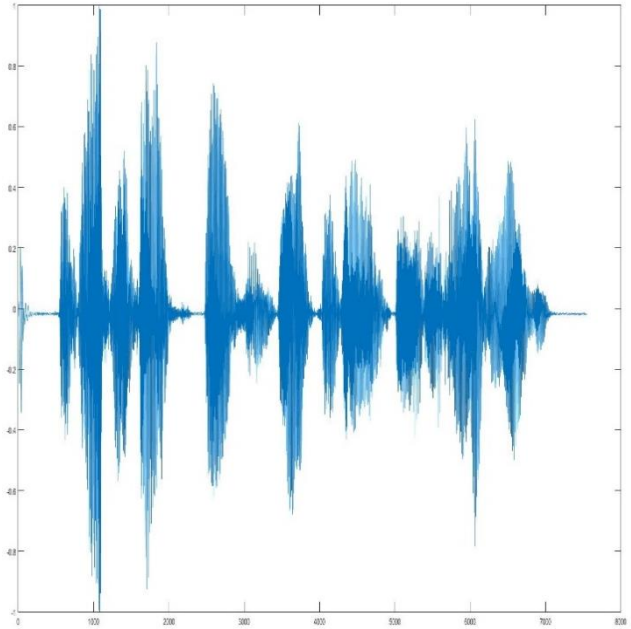


Deep Learning

Model learns to perform classification tasks directly from data.



Data Types for Deep Learning



Signal

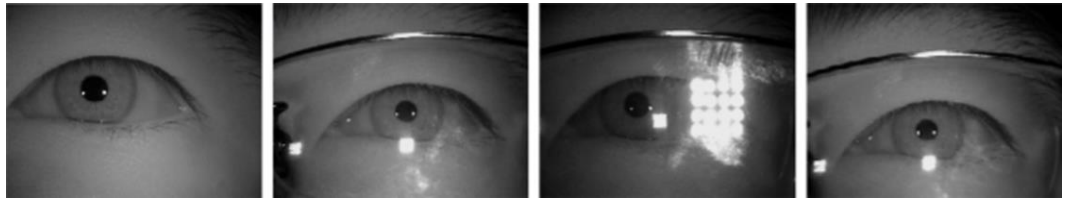
Text

Image

Deep Learning is Versatile

Detection of cars and road in autonomous driving systems

Rain Detection and Removal[1]

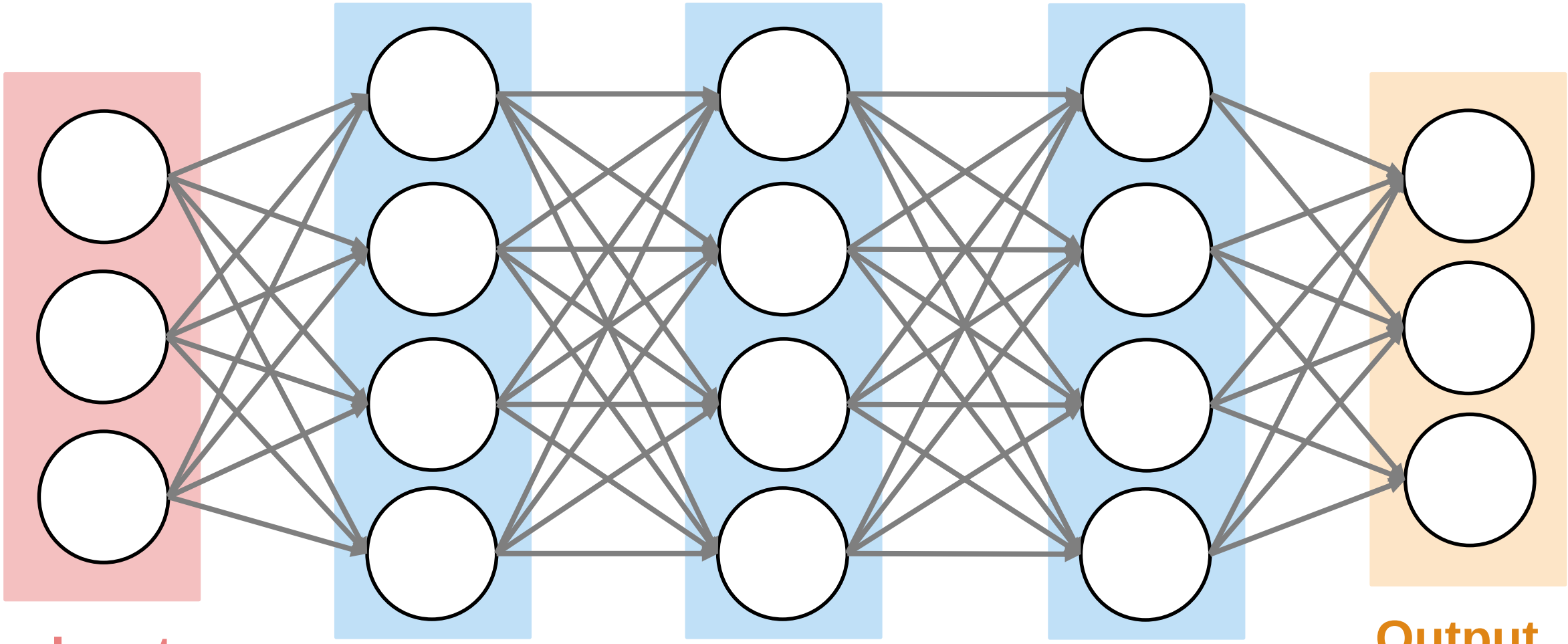


Iris Recognition – 99.4% accuracy[2]

1. *Deep Joint Rain Detection and Removal from a Single Image" Wenhan Yang, Robby T. Tan, Jiashi Feng, Jiaying Liu, Zongming Guo, and Shuicheng Yan*
2. *Source: An experimental study of deep convolutional features for iris recognition Signal Processing in Medicine and Biology Symposium (SPMB), 2016 IEEE Shervin Minaee ; Amirali Abdolrashidiy ; Yao Wang; An experimental study of deep convolutional features for iris recognition*

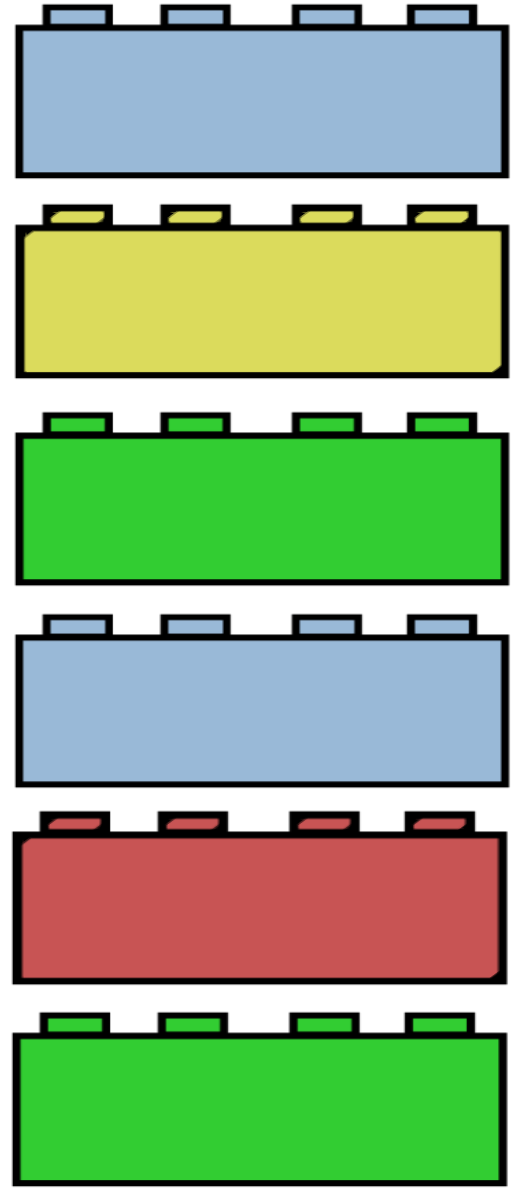
How is deep learning performing so well?

Deep Learning Uses a Neural Network Architecture



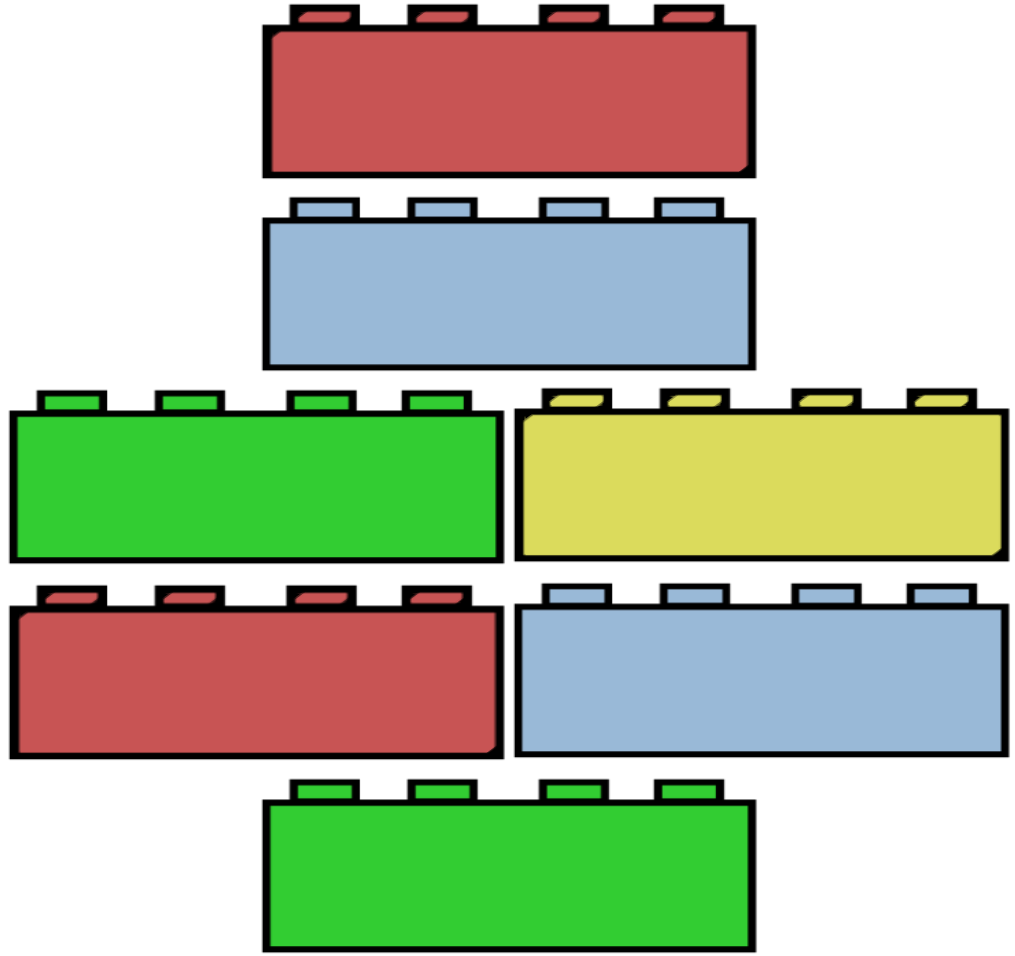
Thinking about Layers

- Layers are like blocks
  - Stack on top of each other
  - Replace one block with a different one
- Each hidden layer processes the information from the previous layer

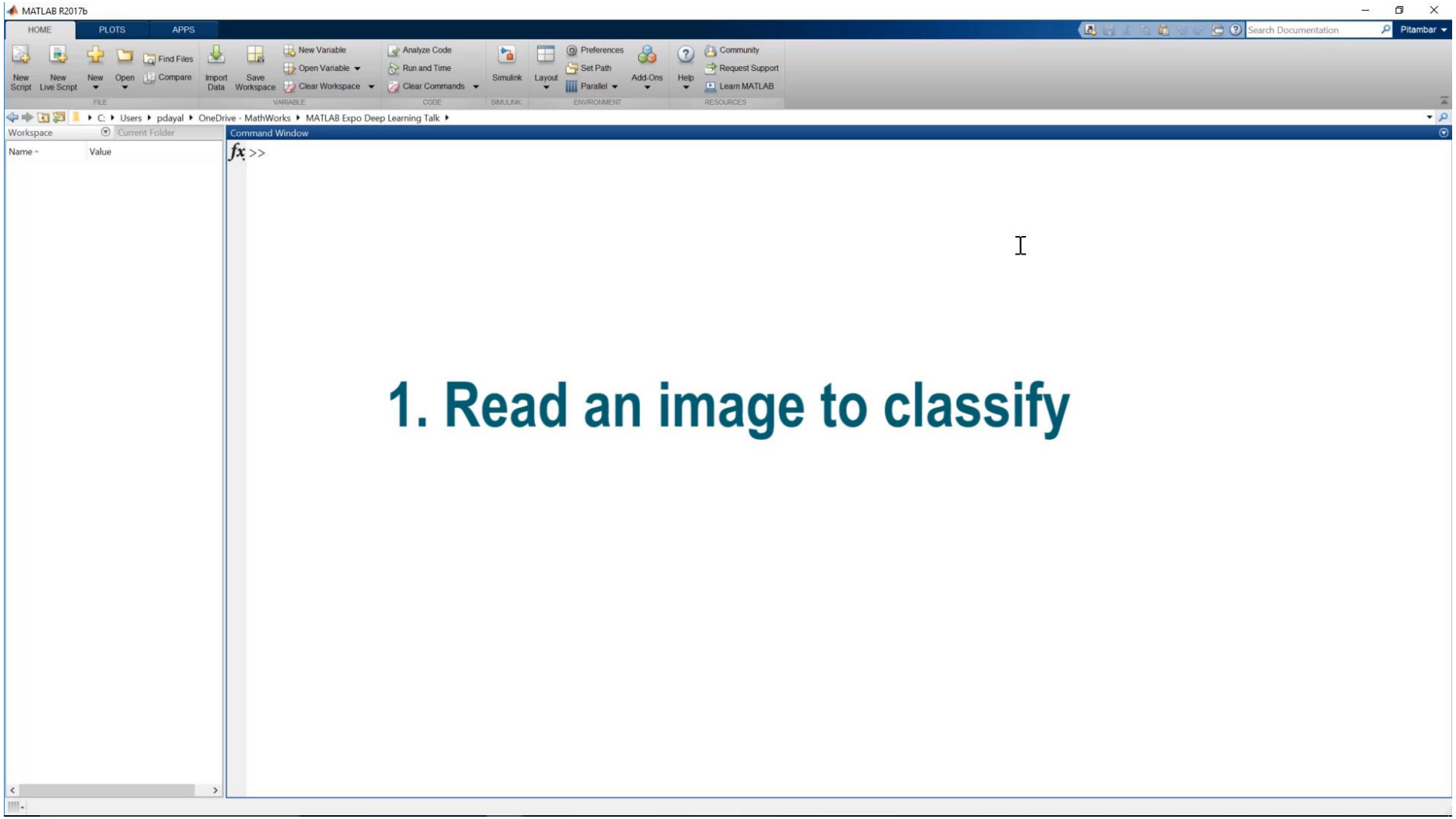


Thinking about Layers

- Layers are like blocks
  - Stack them on top of each other
  - Replace one block with a different one
- Each hidden layer processes the information from the previous layer
- Layers can be ordered in different ways



Deep Learning in 6 Lines of MATLAB Code



Why MATLAB for Deep Learning?

- MATLAB is Productive
- MATLAB is Fast
- MATLAB integrates with Open Source

“I love to label and preprocess my data”

~ Said no engineer, ever.

Caterpillar Case Study

- World's leading manufacturer of construction and mining equipment.
- Similarity between these projects?
  - Autonomous haul trucks
  - Pedestrian detection
  - Equipment classification
  - Terrain mapping

Computer Must Learn from Lots of Data

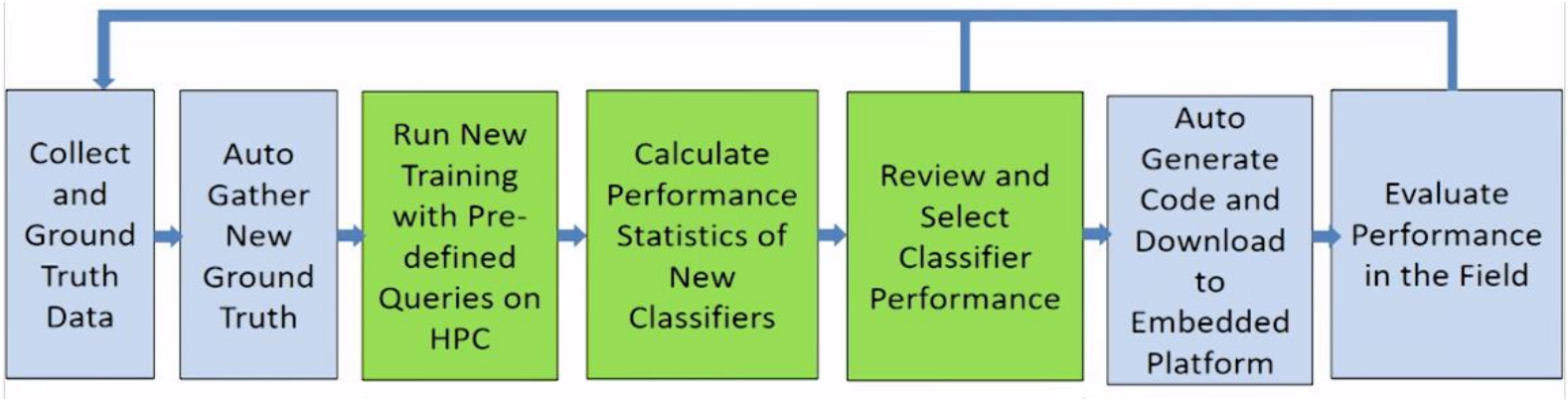
- ALL data must first be labeled to create these autonomous systems.

“We were spending way too much time ground-truthing [the data]”

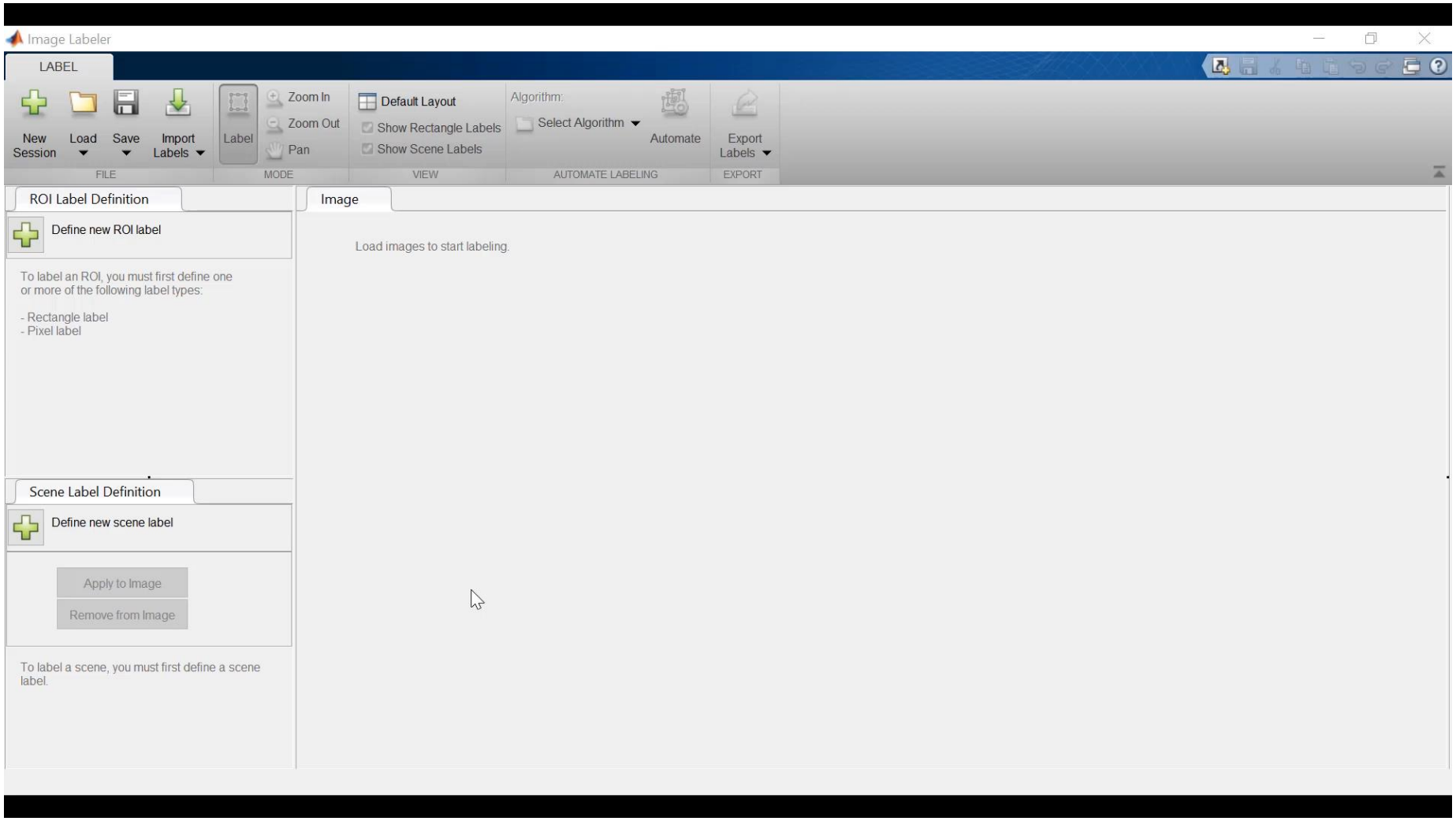
--Larry Mianzo, Caterpillar

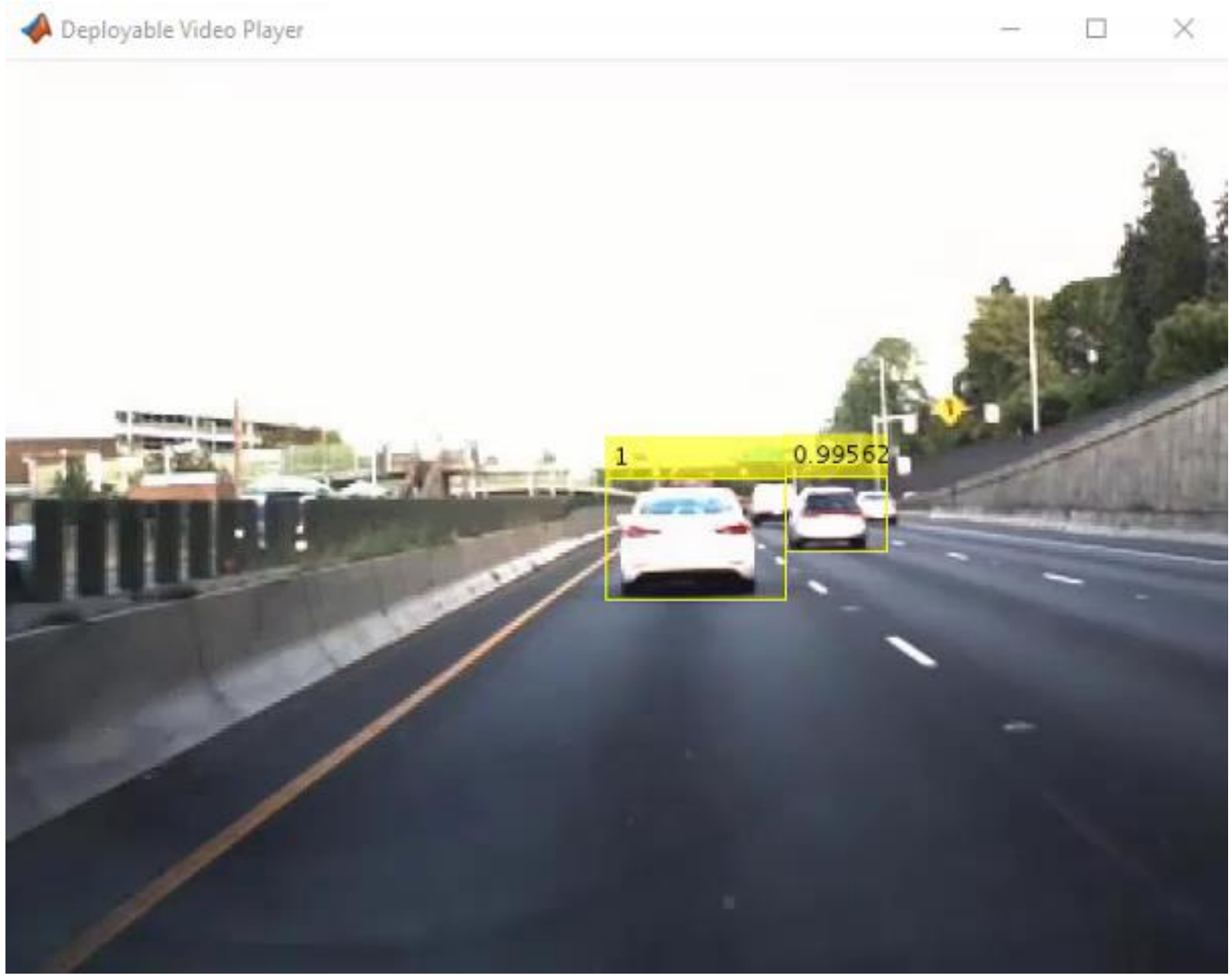
How Did Caterpillar Do with Our Tools?

- Semi-automated labeling process
  - *"We go from having to label 100 percent of our data to only having to label about 80 to 90 percent"*
- Used MATLAB for entire development workflow.
  - *"Because everything is in MATLAB, development time is short"*



How Does MATLAB Come into Play?




Deployable Video Player
1
0.99562

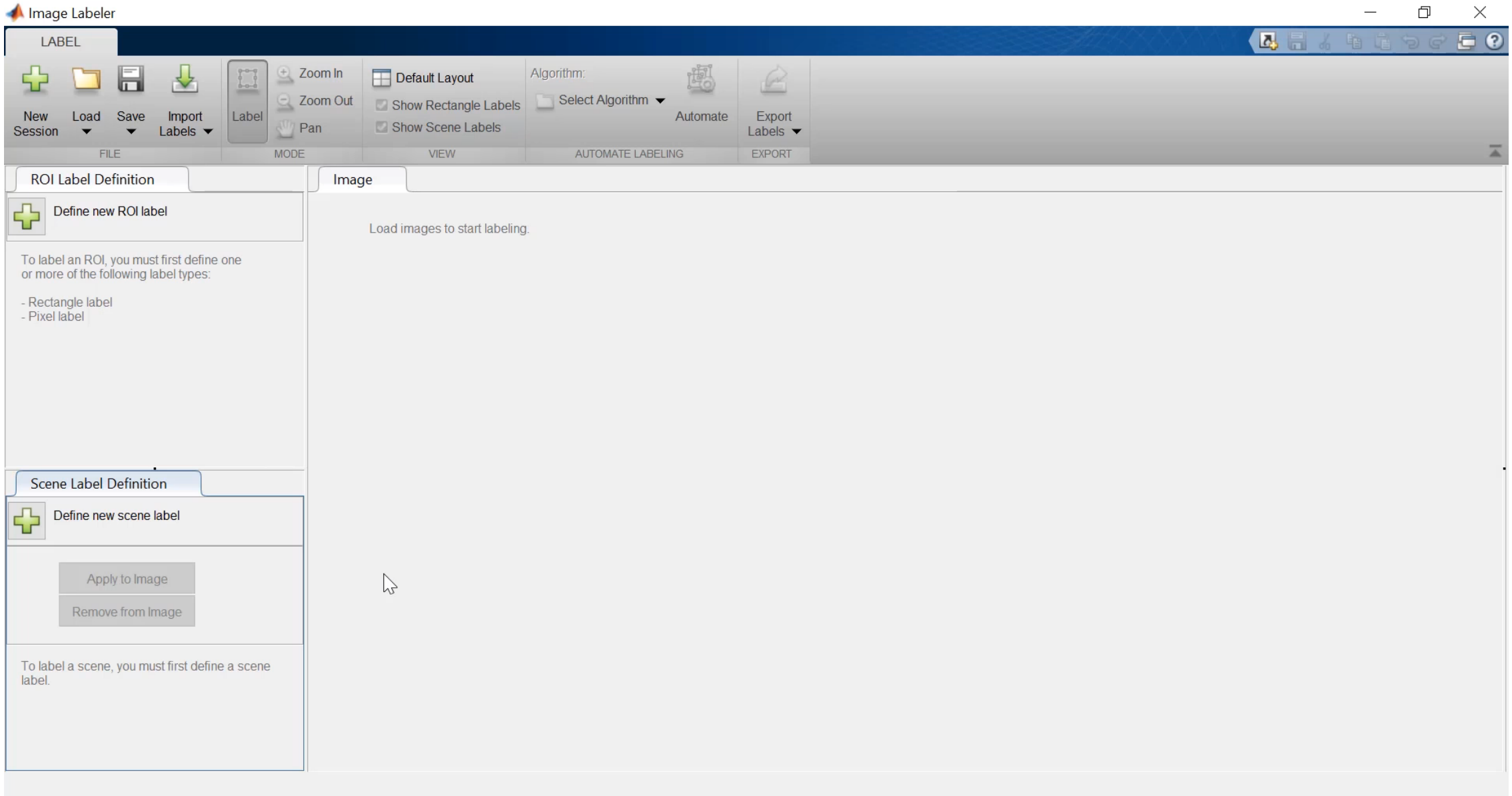


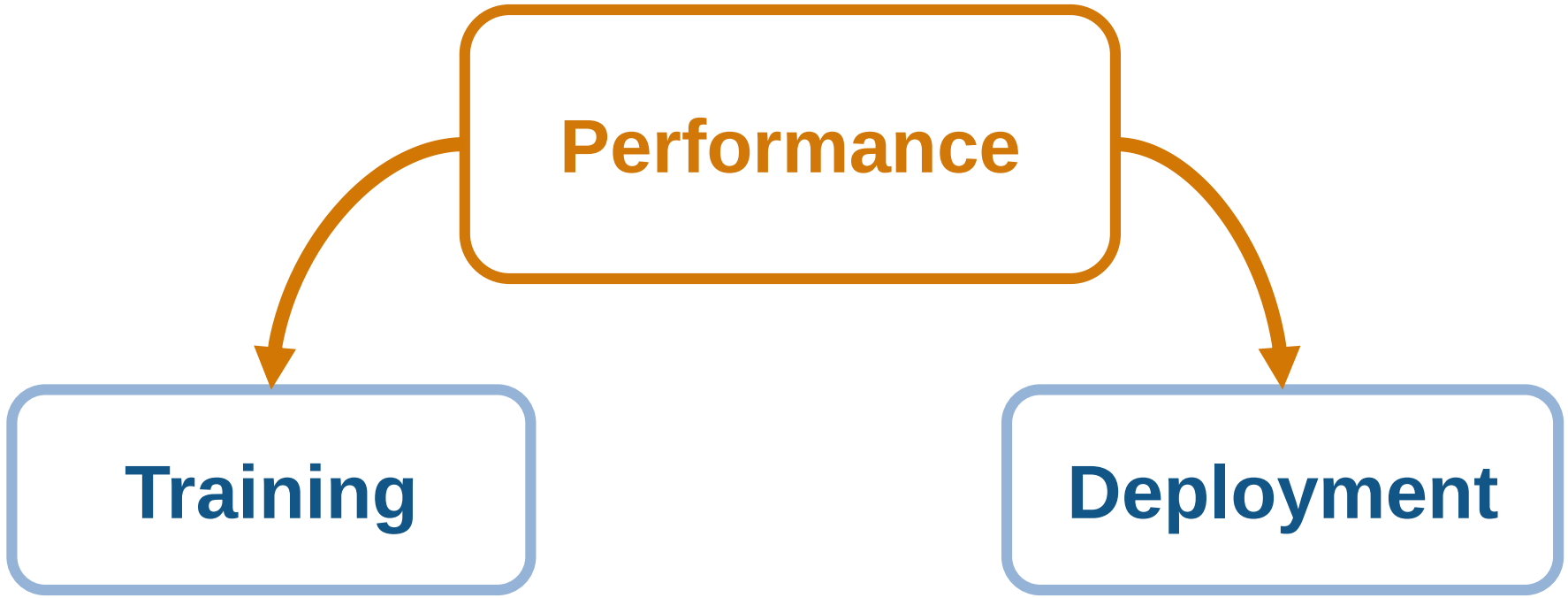
Image Labeler
LABEL
New Session
Load
Save
Import Labels
Label
Zoom In
Zoom Out
Pan
Default Layout
Show Rectangle Labels
Show Scene Labels
Algorithm:
Select Algorithm
Automate
Export Labels
FILE
MODE
VIEW
AUTOMATE LABELING
EXPORT
ROI Label Definition
Define new ROI label
To label an ROI, you must first define one or more of the following label types:
- Rectangle label
- Pixel label
Scene Label Definition
Define new scene label
Apply to Image
Remove from Image
To label a scene, you must first define a scene label.
Image
Load images to start labeling.


RICE HOUSE

MATLAB is Productive

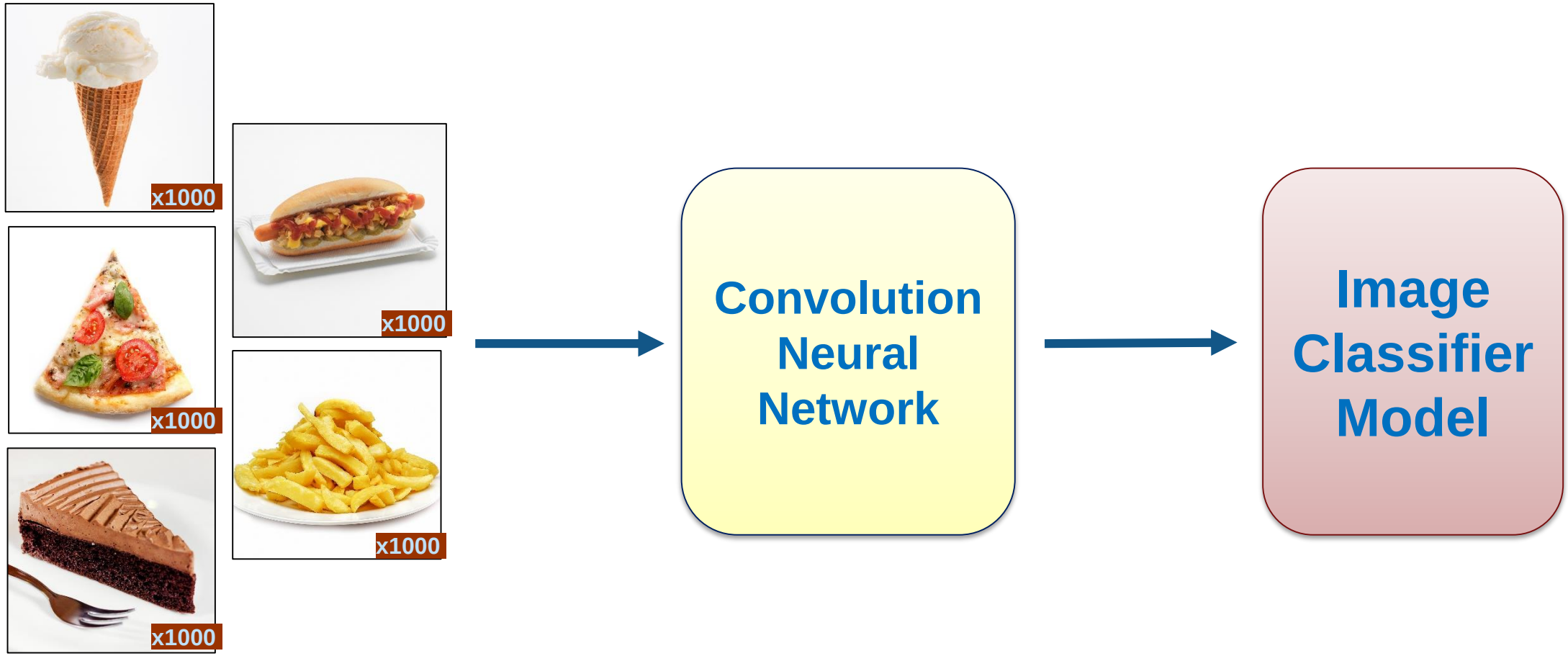
- Image Labeler App semi-automates labeling workflow
- Bootstrapping
  - Improve automatic labeling by updating algorithm as you label more images correctly.
- Easy to load metadata even when labeling manually

MATLAB is Fast



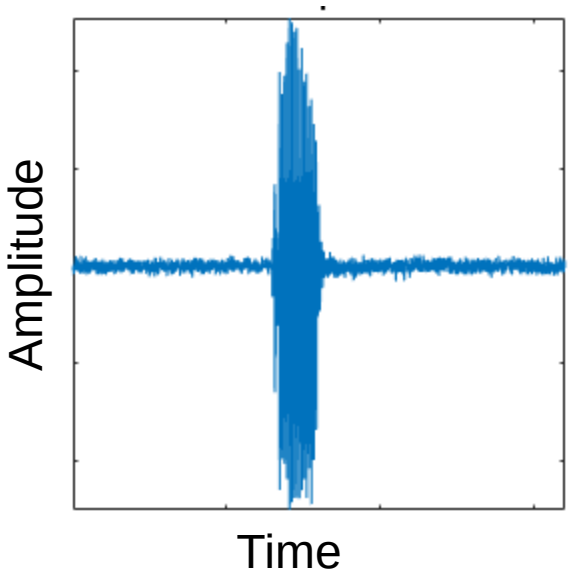
What is Training?

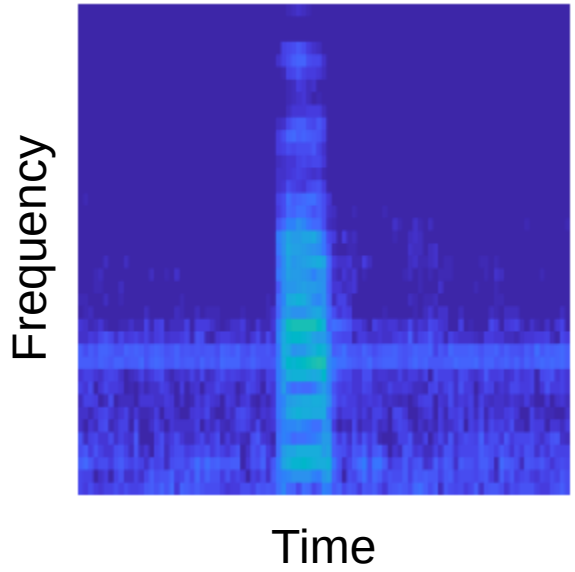
Feed labeled data into neural network to create working model

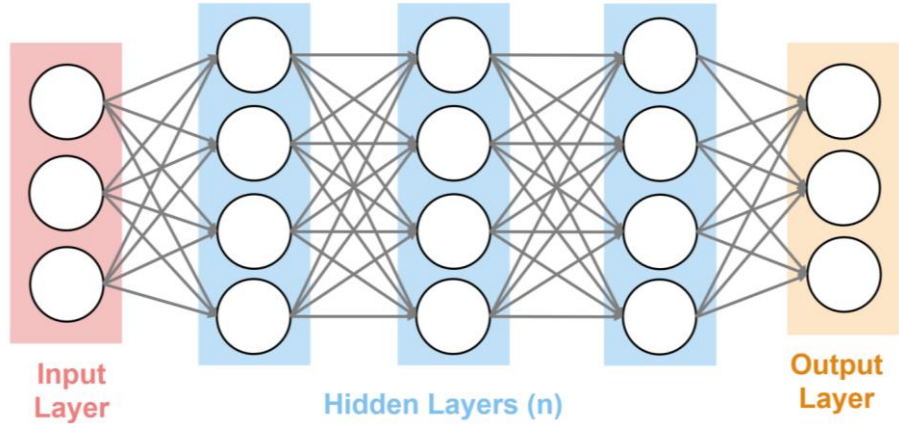


Speech Recognition Example

Audio signal → Spectrogram → Image Classification algorithm

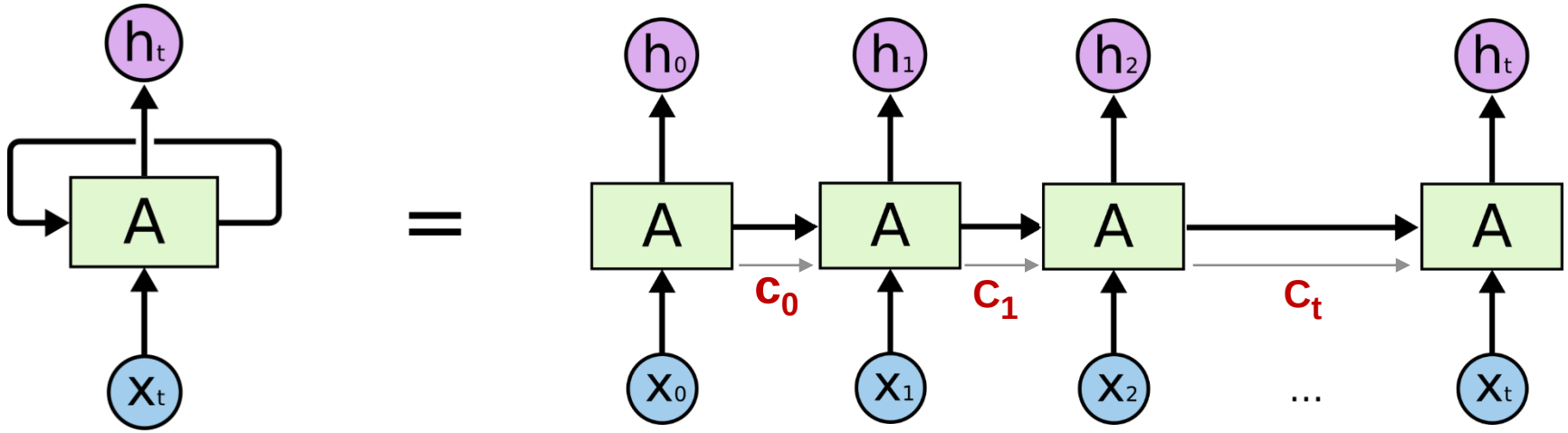






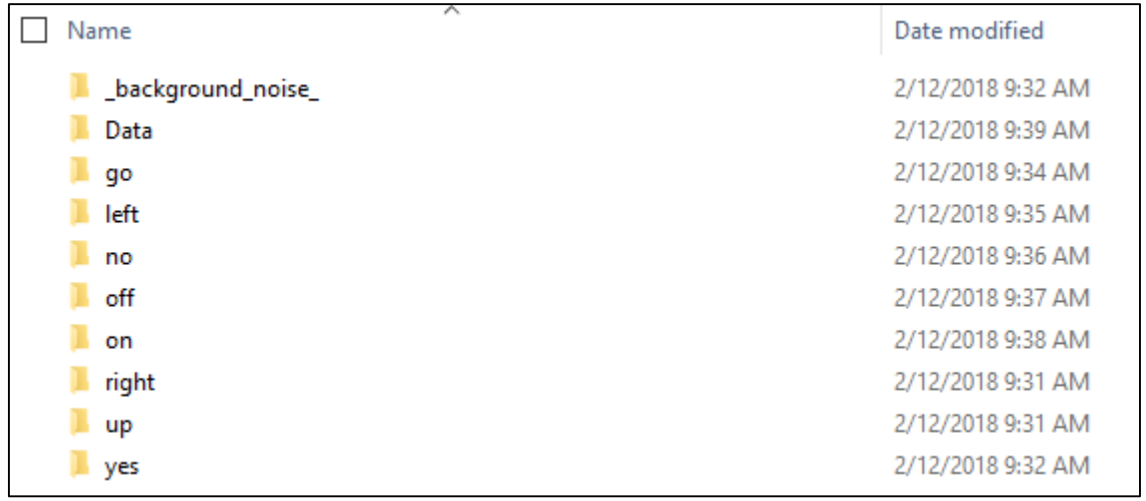
Another Network for Signals - LSTM

- LSTM = Long Short Term Memory (Networks)
  - Signal, text, time-series data
  - Use previous data to predict new information
- I live in France. I speak _____.



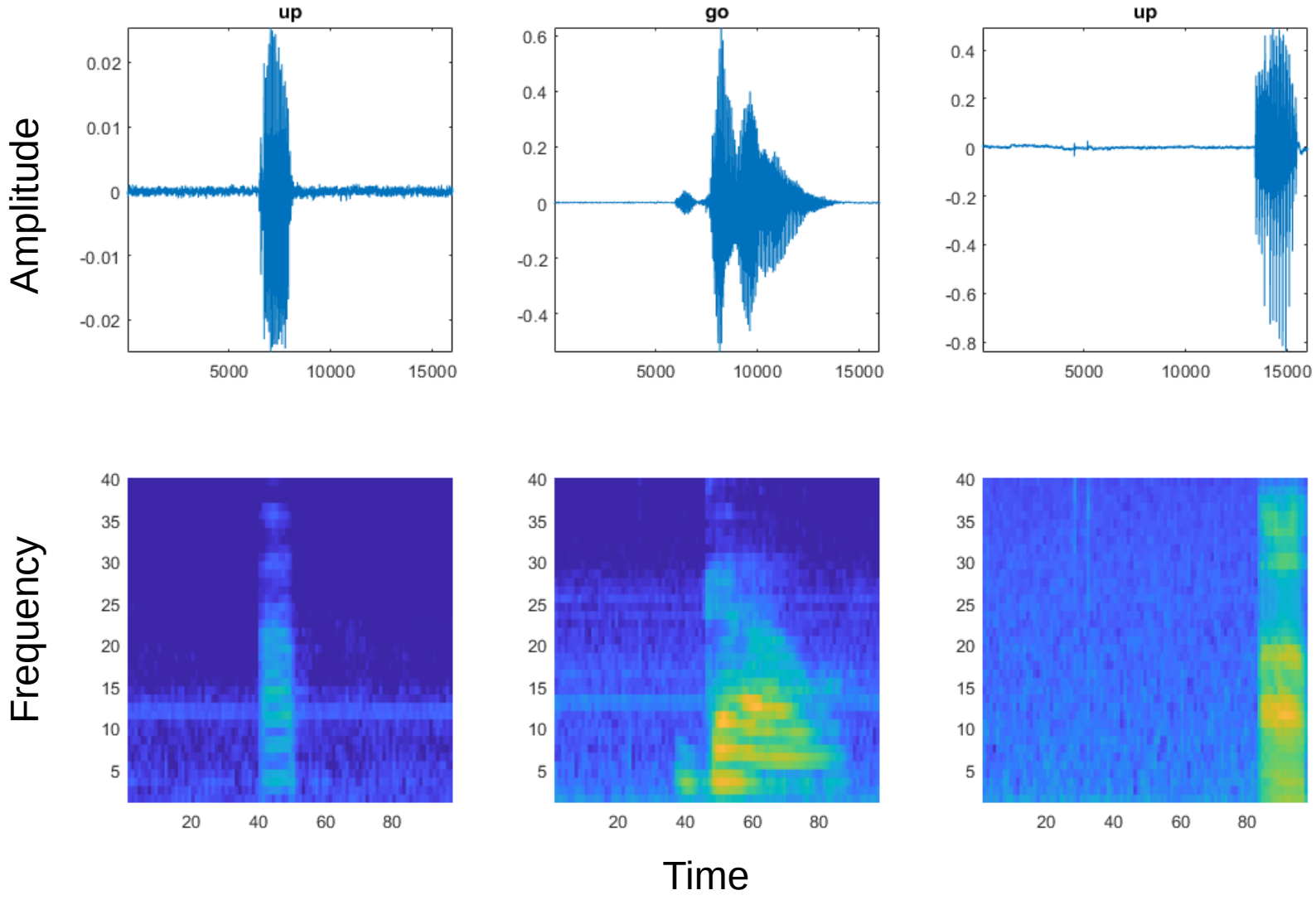
1. Create Datastore

- Datastore creates reference for data
- Do not have to load in all objects into memory




```
datafolder = fullfile(tempdir,'speech_commands_v0.01');

addpath(fullfile(matlabroot,'toolbox','audio','audiodemos'))
ads = audioexample.Datastore(datafolder, ...
    'IncludeSubfolders',true, ...
    'FileExtensions','.wav', ...
    'LabelSource','foldernames', ...
    'ReadMethod','File')
```

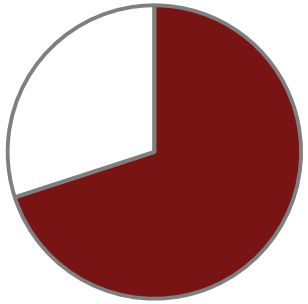
2. Compute Speech Spectrograms



3. Split datastores

Training

70%



- Trains the model
- Computer “learns” from this data

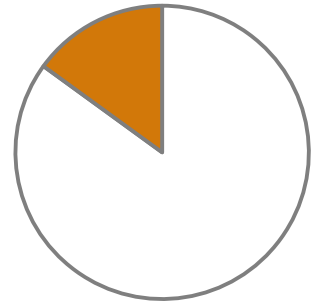
Validation

15%

- Checks accuracy of model during training

Test

15%



- Tests model accuracy
- Not used until validation accuracy is good

4. Define Architecture and Parameters

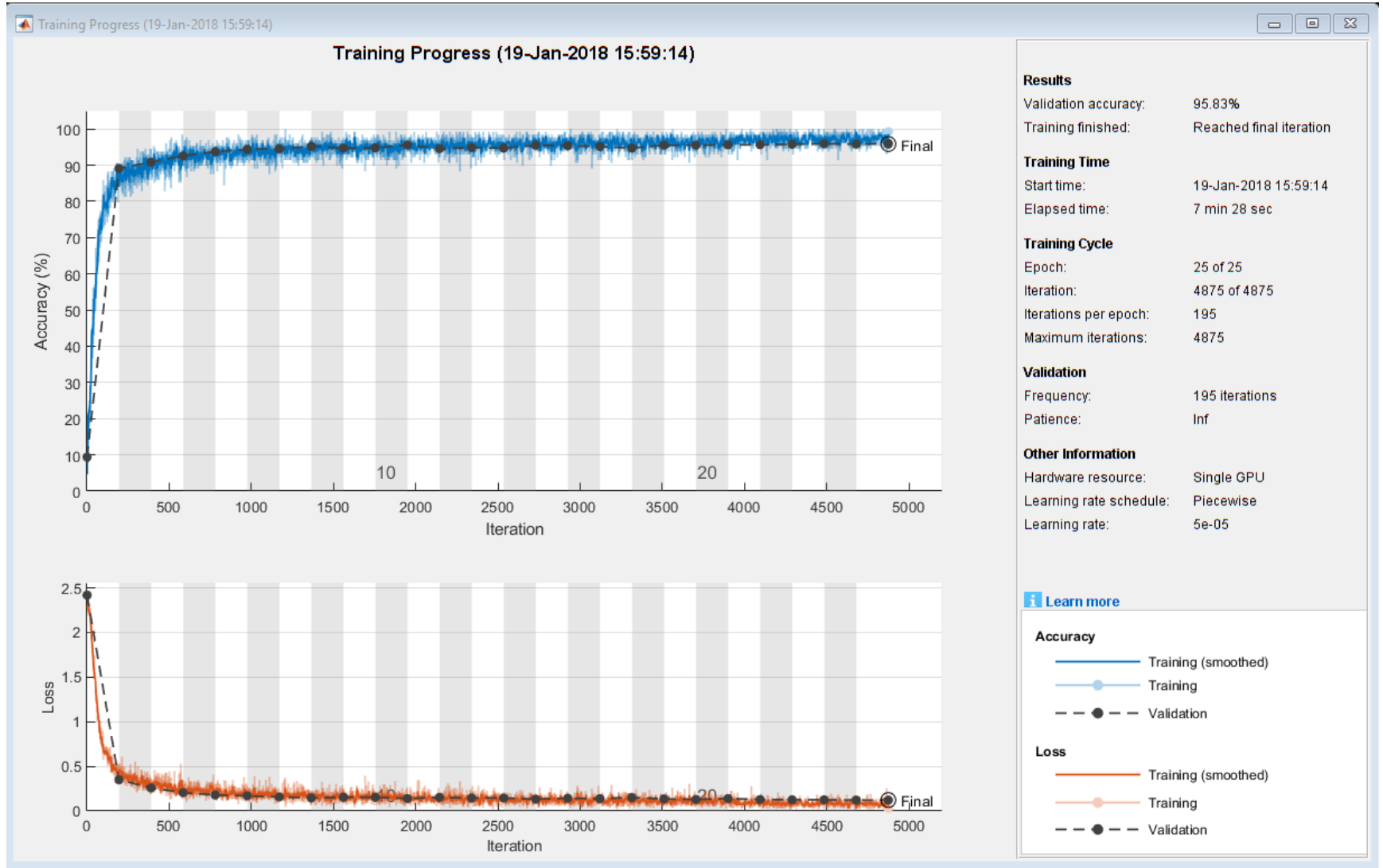
```
layers = [
    imageInputLayer(imageSize)

    convolution2dLayer(3,16,'Padding','same')
    batchNormalizationLayer
    reluLayer

    maxPooling2dLayer(2,'Stride',2)

    convolution2dLayer(3,32,'Padding','same')
    batchNormalizationLayer
    reluLayer

    maxPooling2dLayer(2,'Stride',2,'Padding',[0,1])

    dropoutLayer(dropoutProb)
    convolution2dLayer(3,64,'Padding','same')
    batchNormalizationLayer
    reluLayer

    dropoutLayer(dropoutProb)
    convolution2dLayer(3,64,'Padding','same')
    batchNormalizationLayer
    reluLayer

    maxPooling2dLayer(2,'Stride',2,'Padding',[0,1])

    dropoutLayer(dropoutProb)
    convolution2dLayer(3,64,'Padding','same')
    batchNormalizationLayer
    reluLayer

    maxPooling2dLayer([1 13])

    fullyConnectedLayer(numClasses)
    softmaxLayer
    weightedCrossEntropyLayer(classNames,classWeights)];
```

Neural Network Architecture

```
miniBatchSize = 128;
validationFrequency = floor(numel(YTrain)/miniBatchSize);
options = trainingOptions('adam', ...
    'InitialLearnRate',5e-4, ...
    'MaxEpochs',25, ...
    'MiniBatchSize',miniBatchSize, ...
    'Shuffle','every-epoch', ...
    'Plots','training-progress', ...
    'Verbose',false, ...
    'ValidationData',{XValidation,YValidation}, ...
    'ValidationFrequency',validationFrequency, ...
    'ValidationPatience',Inf, ...
    'LearnRateSchedule','piecewise', ...
    'LearnRateDropFactor',0.1, ...
    'LearnRateDropPeriod',20);
```

Model Parameters

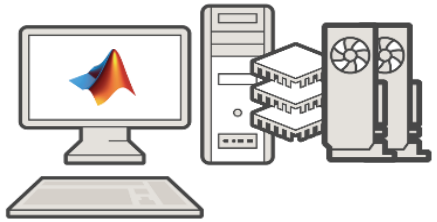
5. Train Network



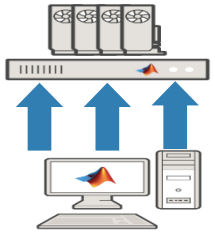
Deep Learning on CPU, GPU, Multi-GPU and Clusters

Single CPU

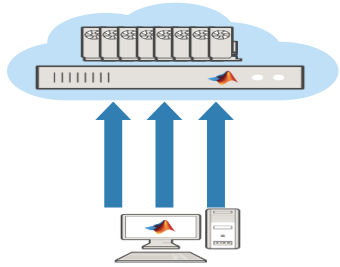
Single CPU
Single GPU



Single CPU, Multiple GPUs



On-prem server with GPUs



Cloud GPUs (AWS)

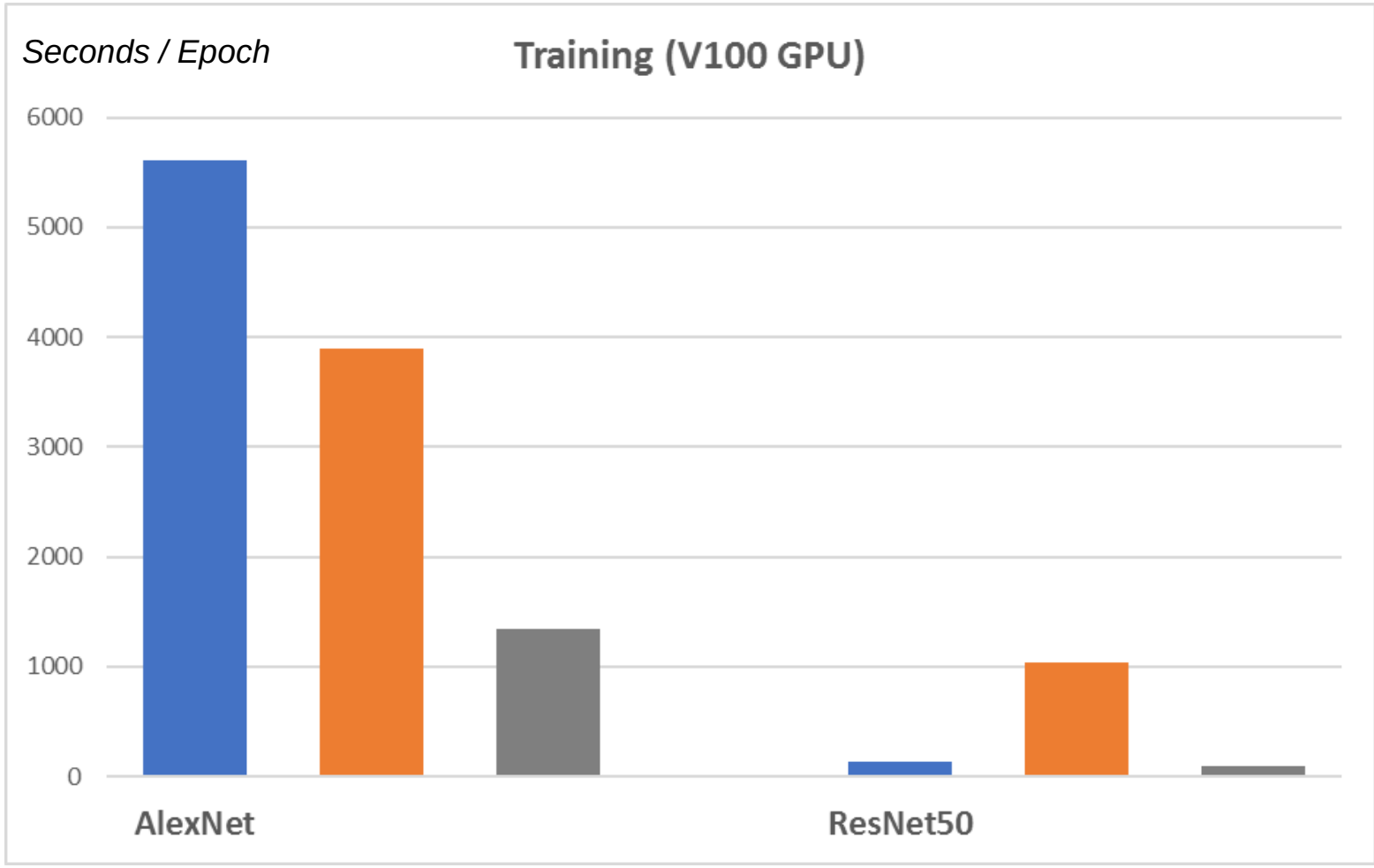
How to target?

```
opts = trainingOptions('sgdm', ...
    'MaxEpochs', 100, ...
    'MiniBatchSize', 250, ...
    'InitialLearnRate', 0.00005, ...
'ExecutionEnvironment', 'auto' );
```

```
opts = trainingOptions('sgdm', ...
    'MaxEpochs', 100, ...
    'MiniBatchSize', 250, ...
    'InitialLearnRate', 0.00005, ...
'ExecutionEnvironment', 'multi-gpu' );
```

```
opts = trainingOptions('sgdm', ...
    'MaxEpochs', 100, ...
    'MiniBatchSize', 250, ...
    'InitialLearnRate', 0.00005, ...
'ExecutionEnvironment', 'parallel' );
```

Training Performance



TensorFlow

MATLAB

MXNet

Batch size 32

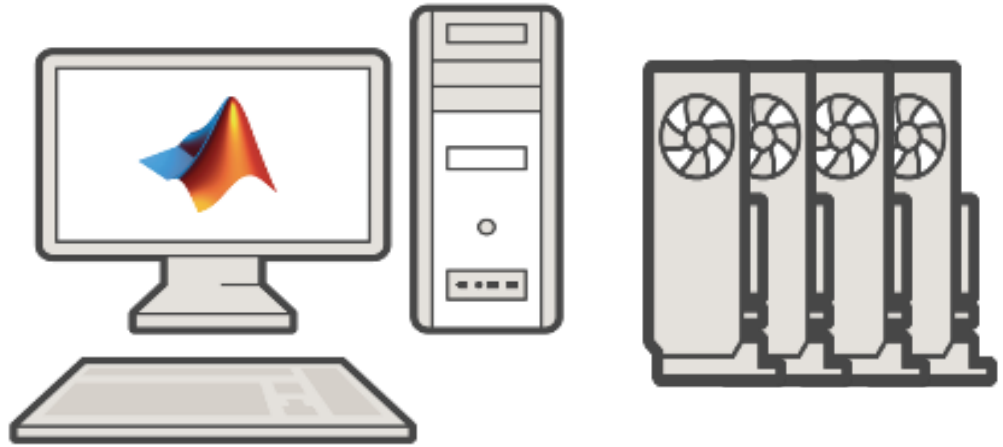
Training is an Iterative Process

```
miniBatchSize = 128;
validationFrequency = floor(numel(YTrain)/miniBatchSize);
options = trainingOptions('adam', ...
    'InitialLearnRate',5e-4, ...
    'MaxEpochs',25, ...
    'MiniBatchSize',miniBatchSize, ...
    'Shuffle','every-epoch', ...
    'Plots','training-progress', ...
    'Verbose',false, ...
    'ValidationData',{XValidation,YValidation}, ...
    'ValidationFrequency',validationFrequency, ...
    'ValidationPatience',Inf, ...
    'LearnRateSchedule','piecewise', ...
    'LearnRateDropFactor',0.1, ...
    'LearnRateDropPeriod',20);
```

Parameters adjusted according to performance

MATLAB is Fast for Deployment

- Target a GPU for optimal performance
- NVIDIA GPUs use CUDA code
- We only have MATLAB code. Can we translate this?

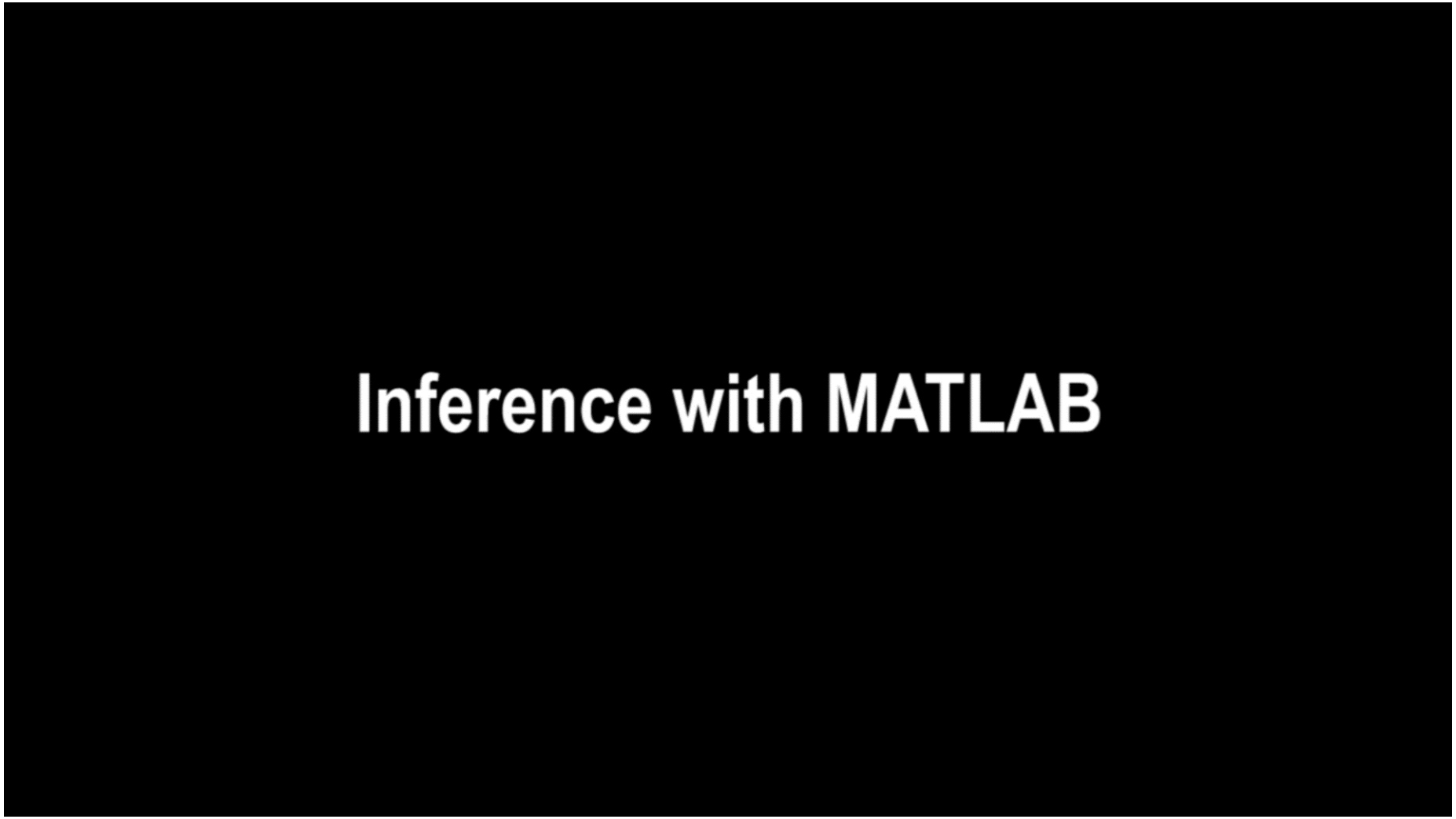


GPU Coder

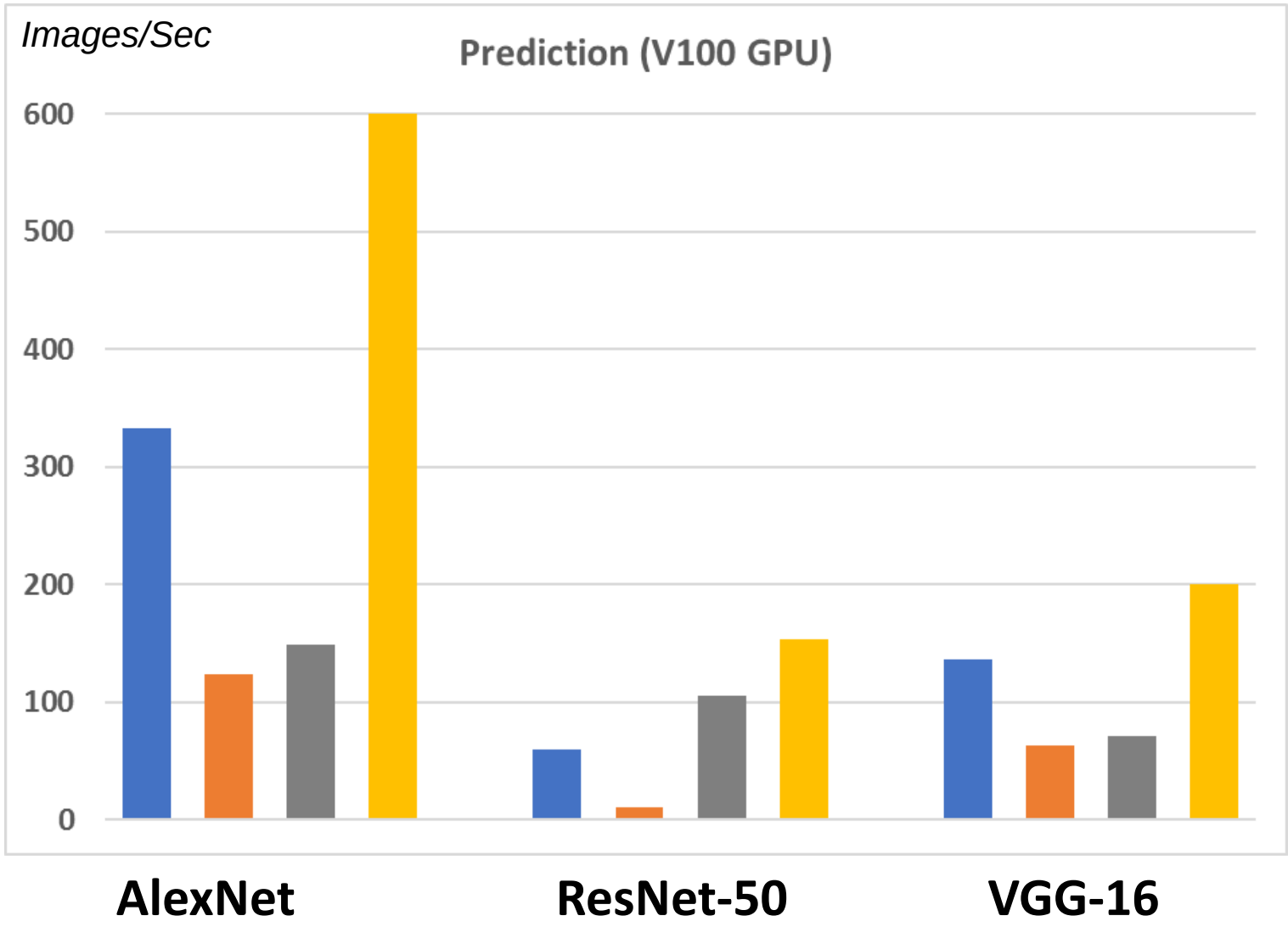
- Automatically generates **CUDA** Code from MATLAB Code
  - can be used on NVIDIA GPUs

- CUDA extends C/C++ code with constructs for parallel computing

GPU Coder Performance



Prediction Performance: Fast with GPU Coder



Why is GPU Coder so fast?

- Analyzes and optimizes network architecture
- Invested 15 years in code generation

TensorFlow

MATLAB

MXNet

GPU Coder

Why MATLAB?

- MATLAB is Productive
- MATLAB is Fast
- MATLAB Integrates with Open Source

Used MATLAB and Open Source Together

- Used Caffe and MATLAB together
- Achieved significantly better results than an engineered rain model.

- Use our tools where it makes your workflow easier!

1. Deep Joint Rain Detection and Removal from a Single Image" Wenhan Yang, Robby T. Tan, Jiashi Feng, Jiaying Liu, Zongming Guo, and Shuicheng Yan

MATLAB Integrates with Open Source Frameworks

- Access to many pretrained models through add-ons
- Users wanted to import latest models

- Import models directly from Tensorflow or Caffe
  - Allows for improved collaboration

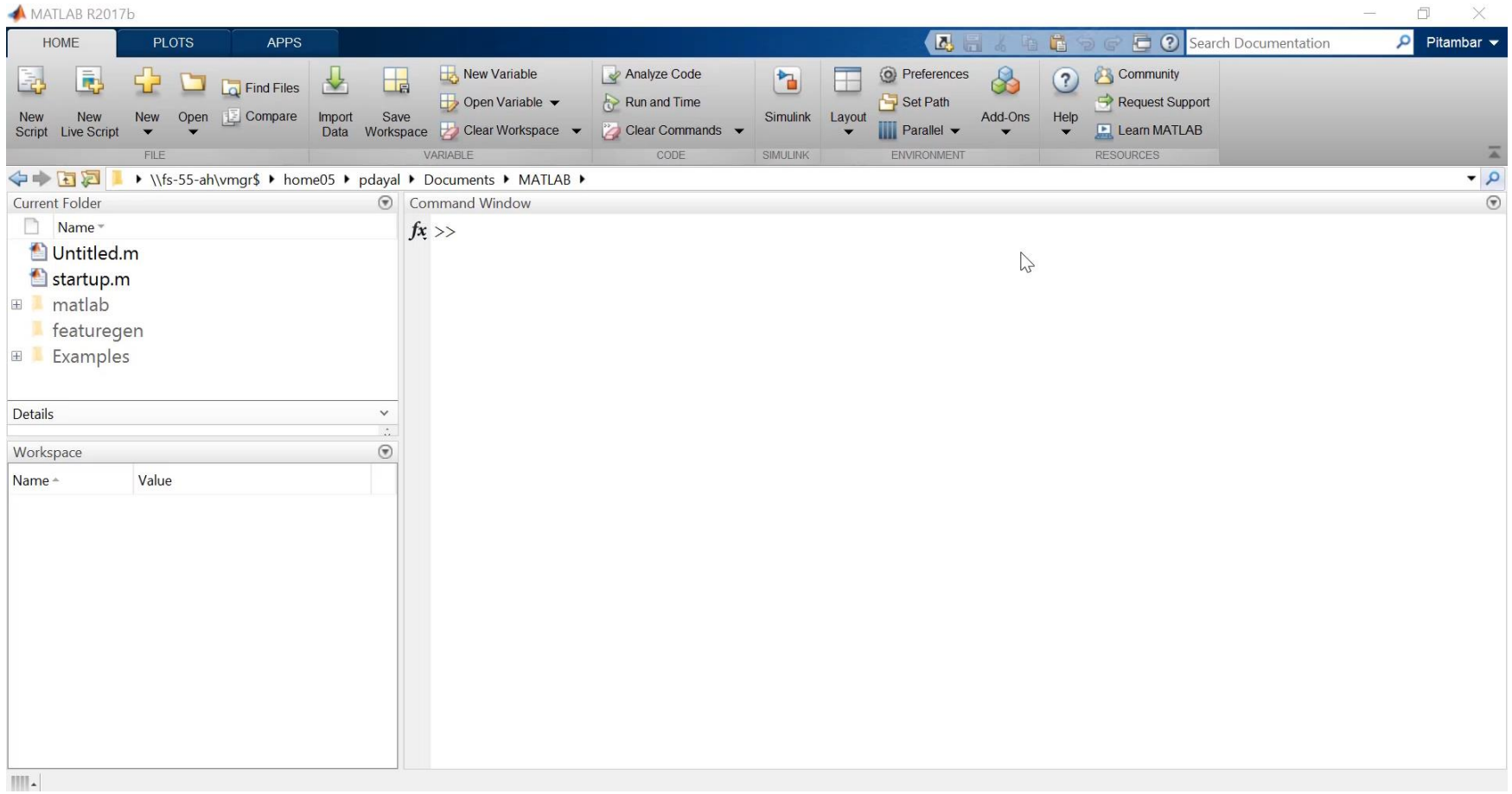
KERAS IMPORTER

Importer for TensorFlow-Keras Models

Caffe

MODELS

Keras-Tensorflow Importer



MATLAB Integrates with Open Source Frameworks

- MATLAB supports entire deep learning workflow
  - Use when it is convenient for your workflow
- Access to latest models
- Improved collaboration with other users

Why MATLAB for Deep Learning?

- MATLAB is Productive
- MATLAB is Fast (*Performance*)
- MATLAB Integrates with Open Source *(Frameworks)*