

MATLAB EXPO 2018

Demystifying Deep Learning

“Let the computers do the hard work”

Pitambar Dayal

Product Marketing

Deep Learning, Image Processing



The background of the slide is a close-up photograph of a wooden surface, showing the natural grain and texture of the wood. Two overlapping rectangular boxes are centered on the page. The top box is dark gray with white text, and the bottom box is white with teal text.

Deep Learning Demo

Image Classification

Why MATLAB for Deep Learning?

- MATLAB is Productive
- MATLAB Supports the Entire Deep Learning Workflow
- MATLAB Integrates with Open Source

What is Deep Learning?

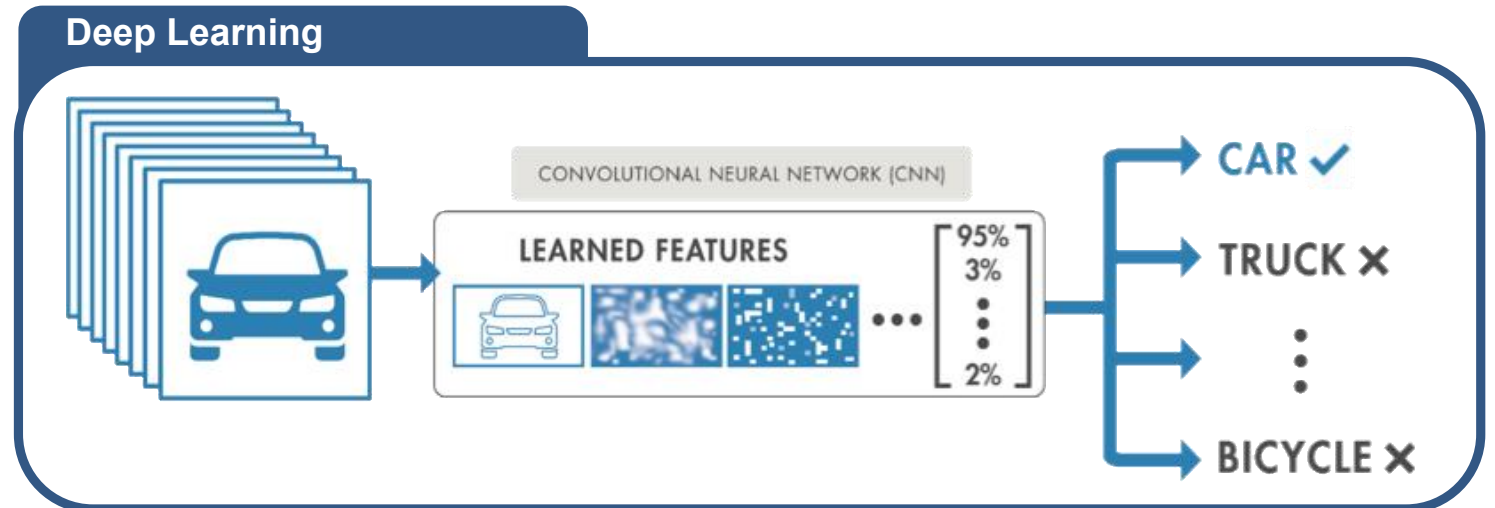
- A. Deep learning is learning done really far underground.
- B. I don't know, I'm just here for the free snacks.
- C. Deep learning is machine learning with automatic feature extraction. It uses a neural network architecture to perform tasks like classification, detection, and regression.

What is Deep Learning?

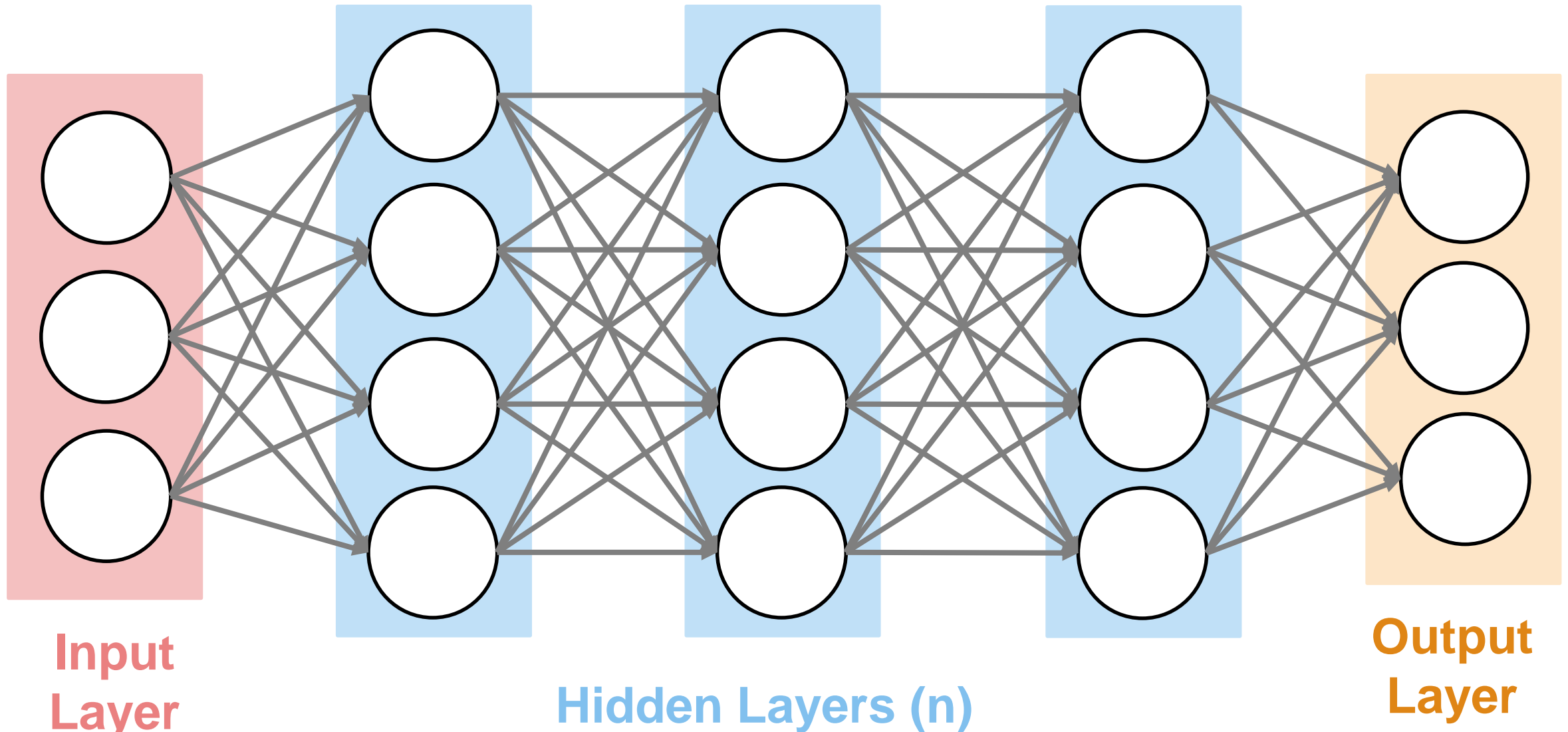
- Subset of machine learning with **automatic feature extraction**
 - Learns features and tasks directly from data
 - More Data = better model

Machine Learning

Deep Learning



Deep Learning Uses a Neural Network Architecture

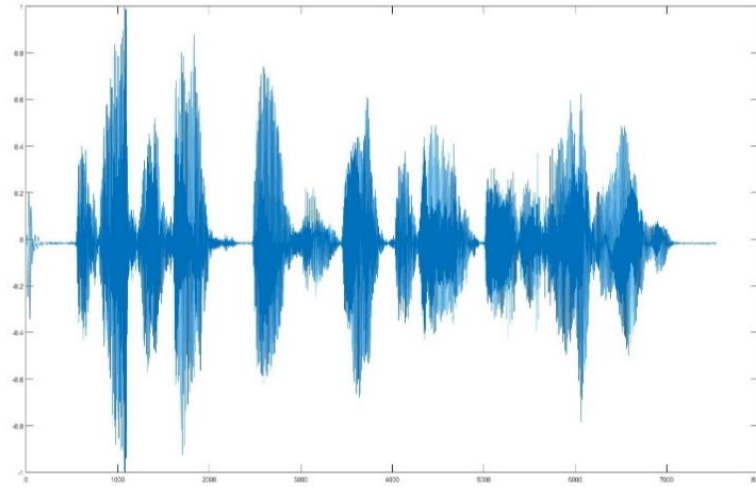


Deep Learning Datatypes

Image



Signal



Numeric

AgeCat	WeightQ	GroupCount	mean_BloodPressure	
Under 30	Q1	6	123.17	79.667
Under 30	Q2	3	120.33	79.667
Under 30	Q3	2	127.5	86.5
Under 30	Q4	4	122	78
30-39	Q1	12	121.75	81.75
30-39	Q2	9	119.56	82.556
30-39	Q3	9	121	83.222
30-39	Q4	11	125.55	87.273
Over 40	Q1	7	122.14	84.714
Over 40	Q2	13	123.38	79.385
Over 40	Q3	14	123.07	84.643
Over 40	Q4	10	124.6	85.1

Text



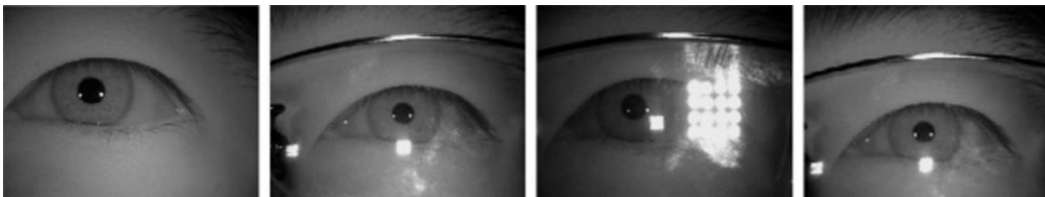
Deep Learning is **Versatile**



Detection of cars and road in autonomous driving systems



Rain Detection and Removal¹



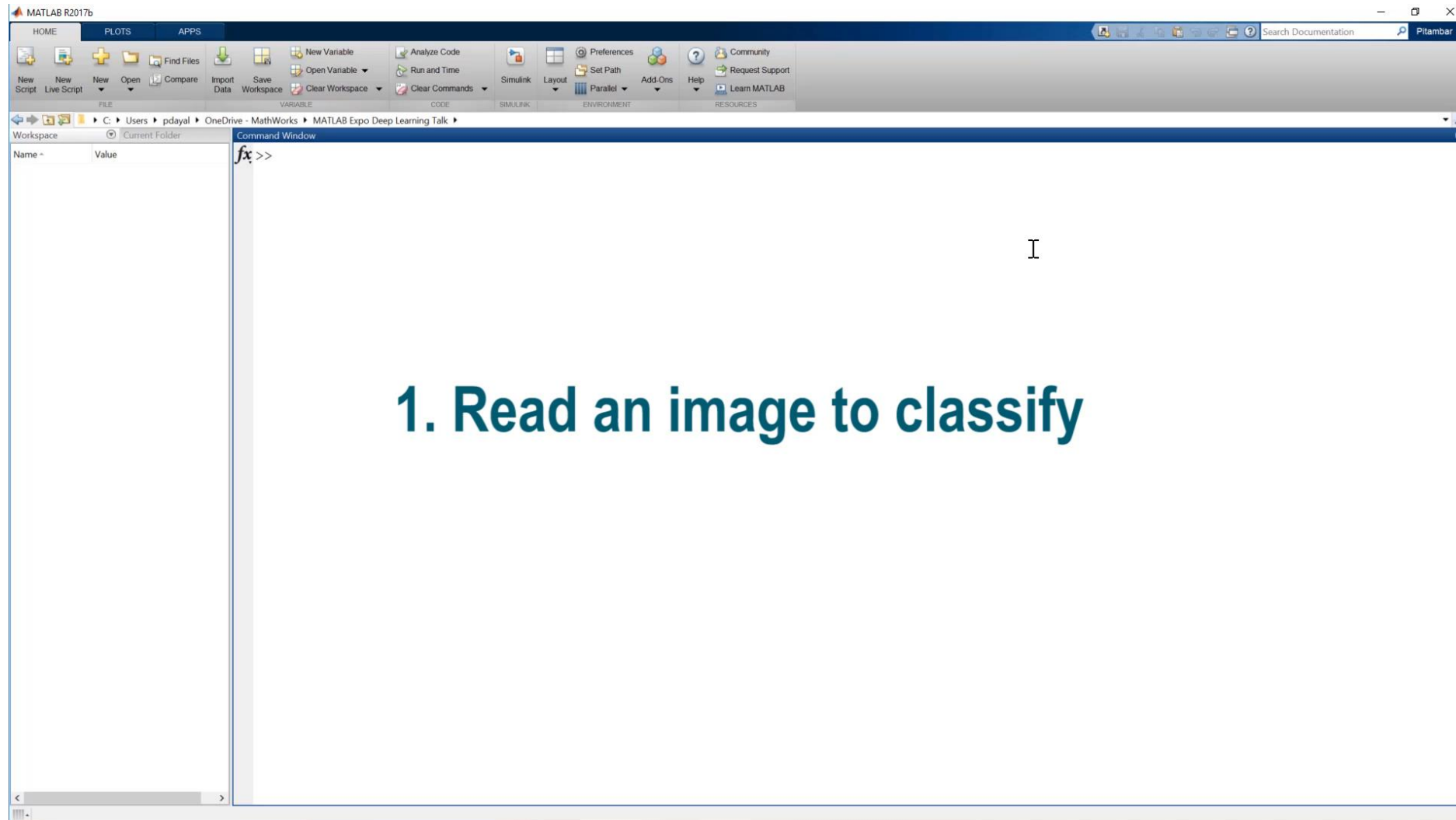
Iris Recognition – 99.4% accuracy²

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

Why MATLAB for Deep Learning?

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

Deep Learning in 6 Lines of MATLAB Code



**“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.

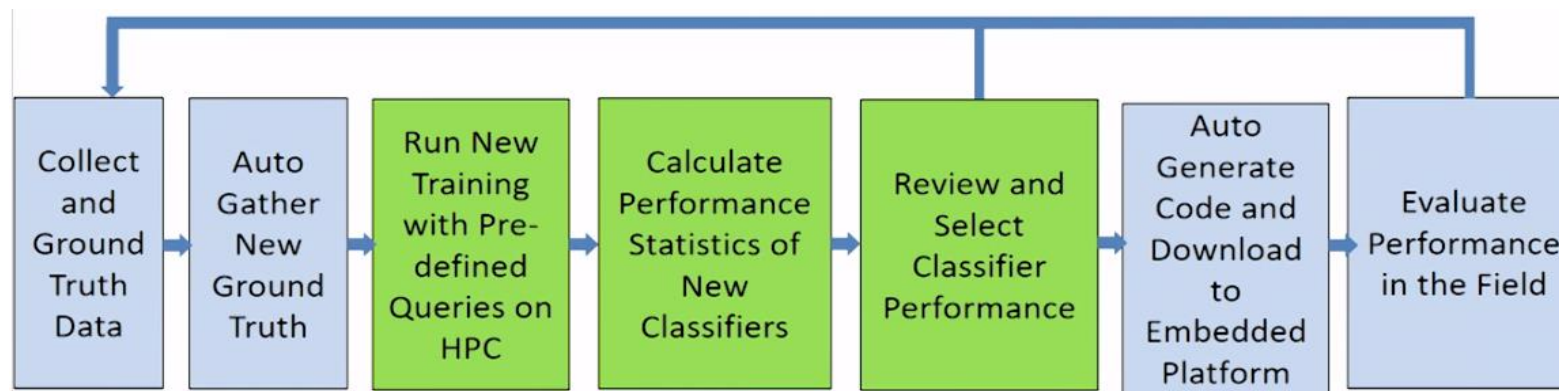


“We were spending way too much time ground-truthing [the data]”

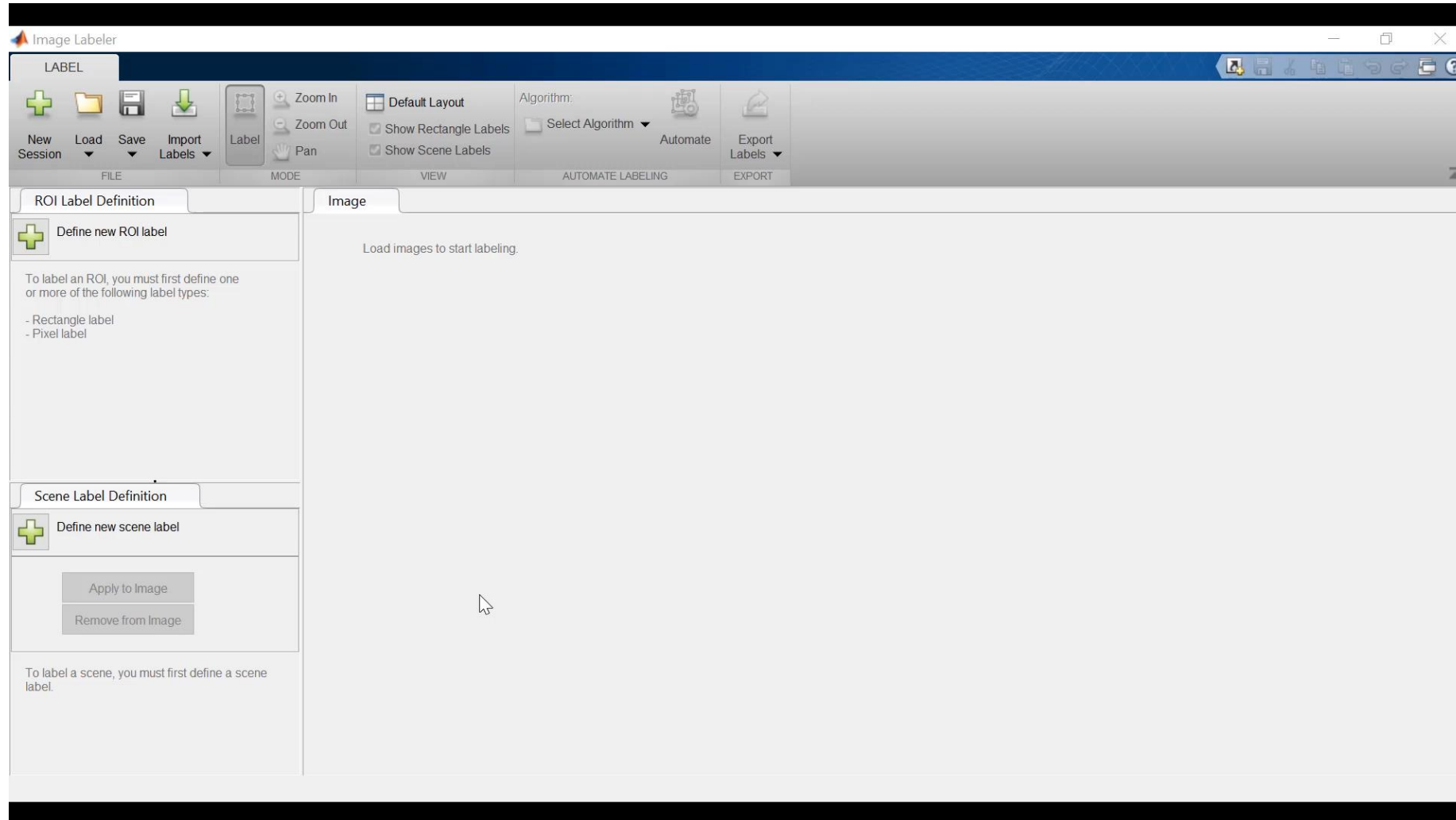
--Larry Mianzo, Caterpillar

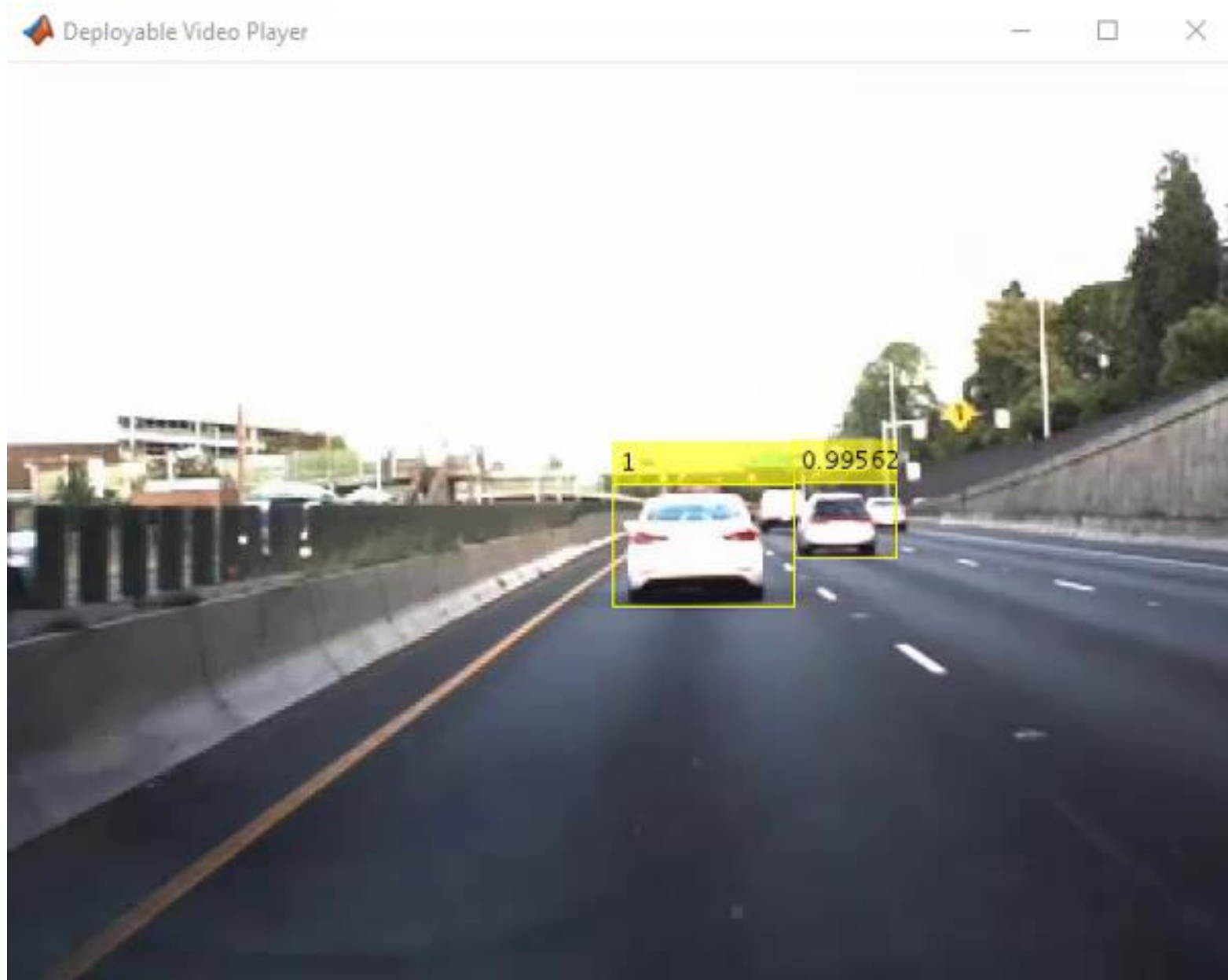
How Did Caterpillar Do with Our Tools?

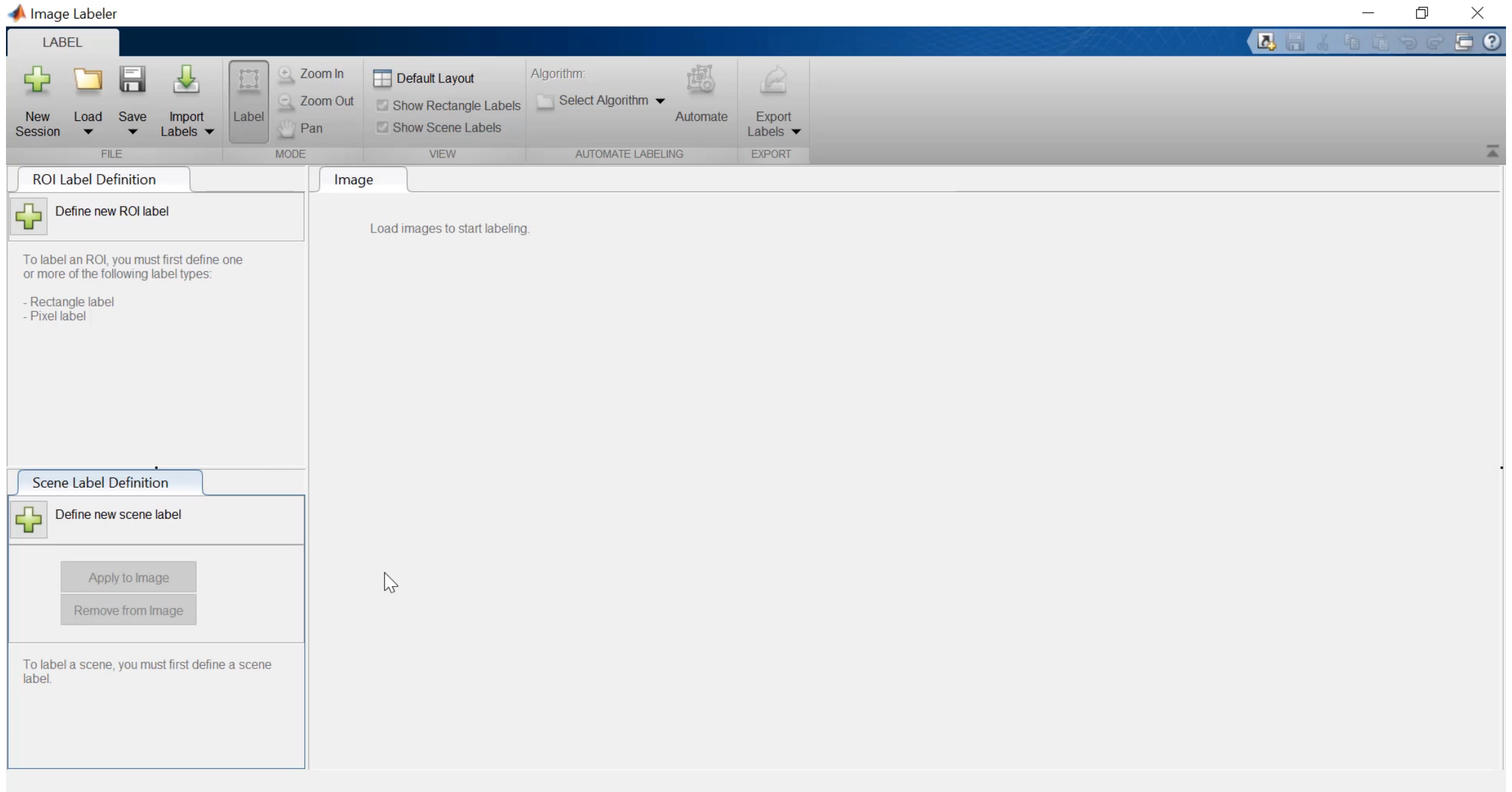
- Semi-automated labeling process
 - *“We go from having to label 100 percent of our data to only having to label about 80 to 90 percent”*
- Used MATLAB for entire development workflow.
 - *“Because everything is in MATLAB, development time is short”*



How Does MATLAB Come into Play?









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

Why MATLAB for Deep Learning?

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Deep Learning Workflow

ACCESS AND EXPLORE
DATA

LABEL AND PREPROCESS
DATA

DEVELOP PREDICTIVE
MODELS

INTEGRATE MODELS WITH
SYSTEMS

Files



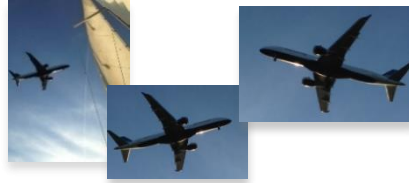
Databases



Sensors



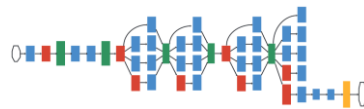
Data Augmentation/
Transformation



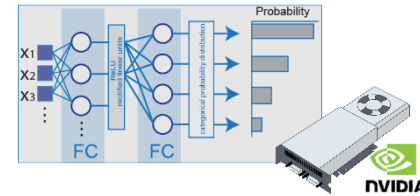
Labeling Automation



Import Reference
Models



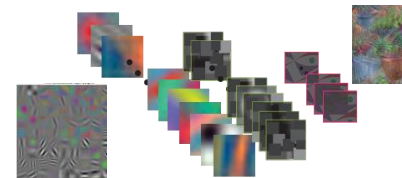
Hardware-Accelerated
Training



Hyperparameter Tuning



Network Visualization



Desktop Apps



Enterprise Scale Systems

Java
MATLAB
C/C++
Python

Embedded Devices and
Hardware



ACCESS AND EXPLORE DATA

Files



Databases



Sensors



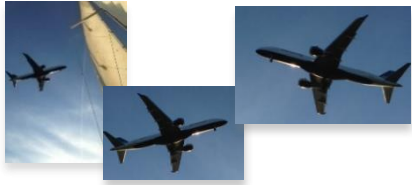
Name	Date modified
_background_noise_	2/12/2018 9:32 AM
Data	2/12/2018 9:39 AM
go	2/12/2018 9:34 AM
left	2/12/2018 9:35 AM
no	2/12/2018 9:36 AM
off	2/12/2018 9:37 AM
on	2/12/2018 9:38 AM
right	2/12/2018 9:31 AM
up	2/12/2018 9:31 AM
yes	2/12/2018 9:32 AM

```
datafolder = fullfile(tempdir, 'speech_commands_v0.01');
ads = audioDatastore(datafolder, ...
    'IncludeSubfolders', true, ...
    'FileExtensions', '.wav', ...
    'LabelSource', 'foldernames')
```

- Datastore useful for large datasets
- Built in read support for many file types

LABEL AND PREPROCESS DATA

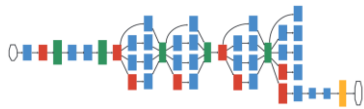
Data Augmentation/ Transformation



Labeling Automation

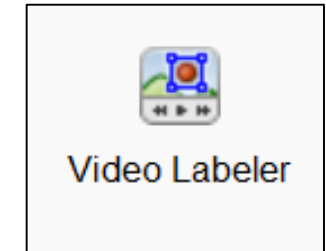
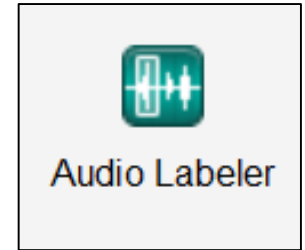


Import Reference Models



The screenshot shows the MATLAB APPS gallery with the following tools visible:

- SIGNAL PROCESSING AND COMMUNICATIONS:**
 - Antenna Designer
 - Audio Labeler
 - Bit Error Rate Analysis
 - Eye Diagram Scope
 - Filter Builder
 - Filter Designer
 - Impulse Response Me...
 - LTE Downlink RMC Generator
 - LTE Test Model Generator
 - LTE Throughput Analyzer
 - LTE Uplink RMC Generator
 - Radar Equation Calculator
 - Radar Waveform Analyzer
 - RF Budget Analyzer
 - Sensor Array Analyzer
 - Signal Analyzer
 - Signal Multiresolution...
 - Sonar Equation Calculator
 - Wavelet Analyzer
 - Wavelet Signal Denoiser
 - Window Designer
 - Wireless Waveform Ge...
- IMAGE PROCESSING AND COMPUTER VISION:**
 - Camera Calibrator
 - Color Thresholder
 - DICOM Browser
 - Image Browser
 - Image Acquisition
 - Image Batch Processor
 - Image Labeler
 - Image Region Analyzer
 - Image Segmenter
 - Image Viewer
 - Map Viewer
 - OCR Trainer
 - Registration Estimator
 - Stereo Camera Calibrator
 - Video Labeler
 - Video Viewer
 - Volume



DEVELOP PREDICTIVE MODELS

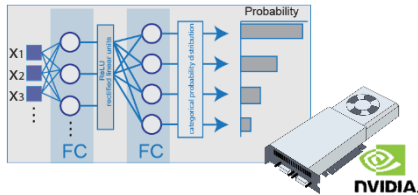
Hardware-Accelerated Training

Hyperparameter Tuning

Network Visualization

DEVELOP PREDICTIVE MODELS

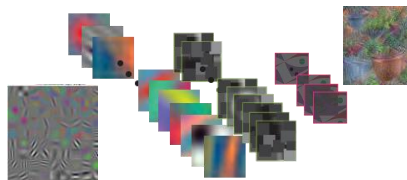
Hardware-Accelerated Training



Hyperparameter Tuning



Network Visualization



Inception-v3

PRETRAINED MODEL

ResNet-101

PRETRAINED MODEL

GoogLeNet

PRETRAINED MODEL

AlexNet

PRETRAINED MODEL

VGG-16

PRETRAINED MODEL

DenseNet-201

PRETRAINED MODEL

ResNet-50

PRETRAINED MODEL

VGG-19

PRETRAINED MODEL

SqueezeNet

PRETRAINED MODEL

ResNet-18

PRETRAINED MODEL

ResNet-50

PRETRAINED MODEL

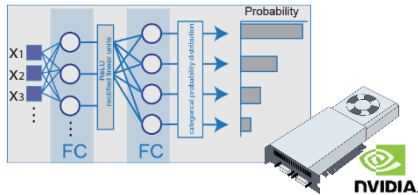
Inception-ResNet-v2

PRETRAINED MODEL

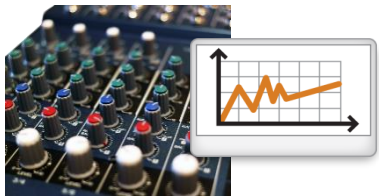
Easy access to many pre-trained models

DEVELOP PREDICTIVE MODELS

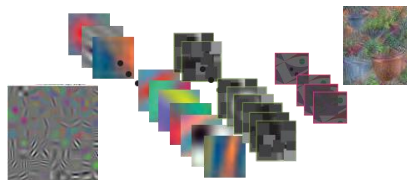
Hardware-Accelerated Training



Hyperparameter Tuning



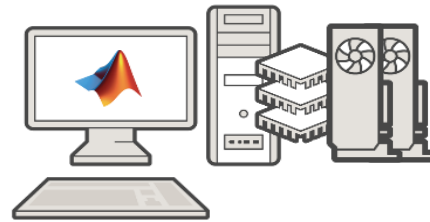
Network Visualization



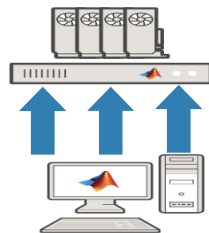
Single CPU



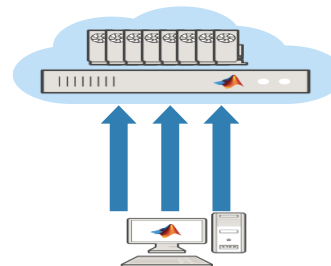
Single CPU
Single GPU



Single CPU, Multiple GPUs



On-prem server with GPUs



Cloud GPUs (AWS)

```
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' );
```

INTEGRATE MODELS WITH SYSTEMS

Coder Products

Desktop Apps

Enterprise Scale Systems

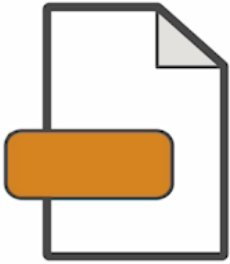
Java
MATLAB
C/C++
Python

Excel
NET
dll
Java

Embedded Devices and Hardware



MATLAB Code

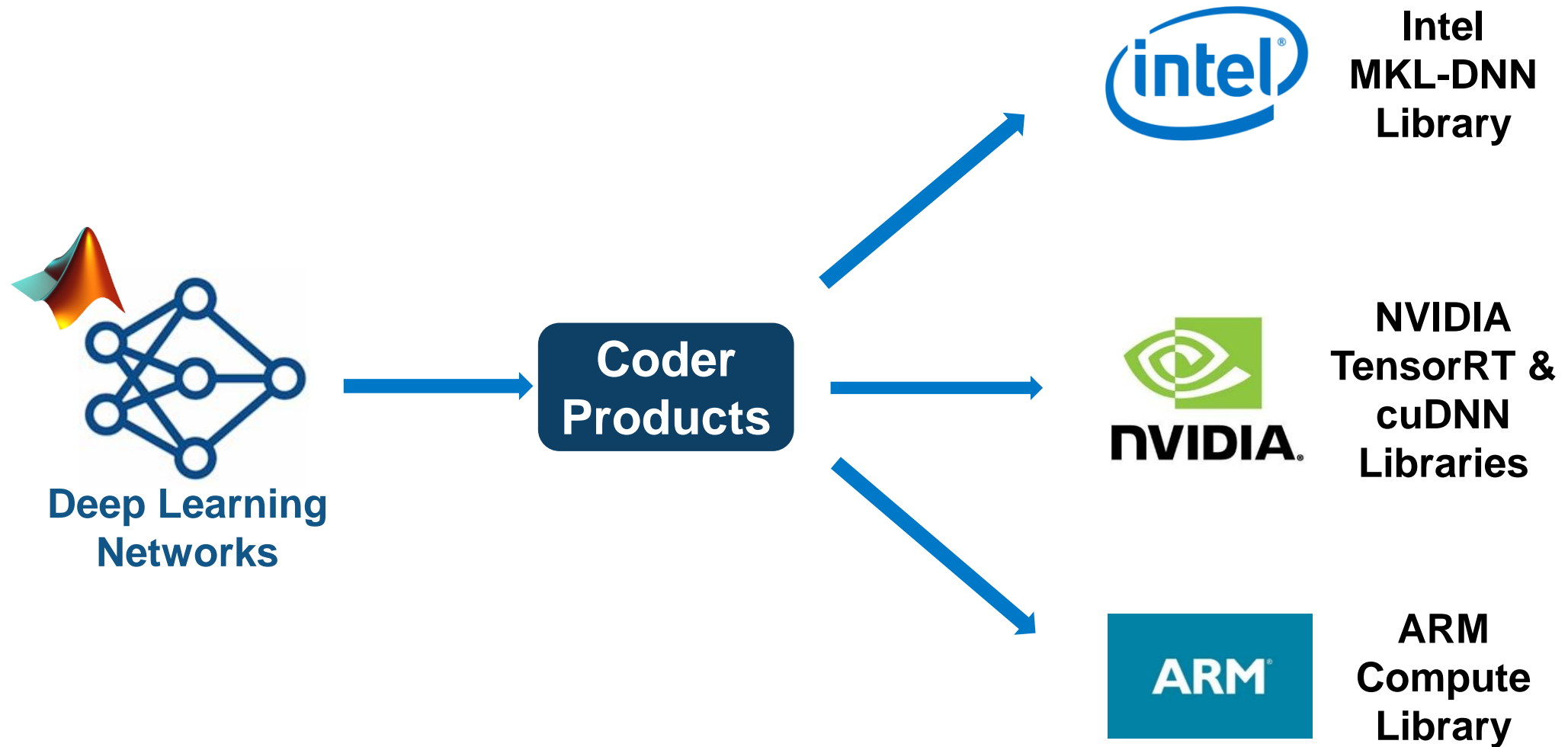


C/C++/HDL/etc.

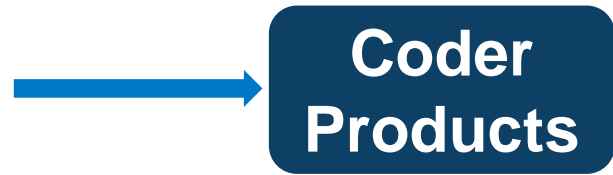
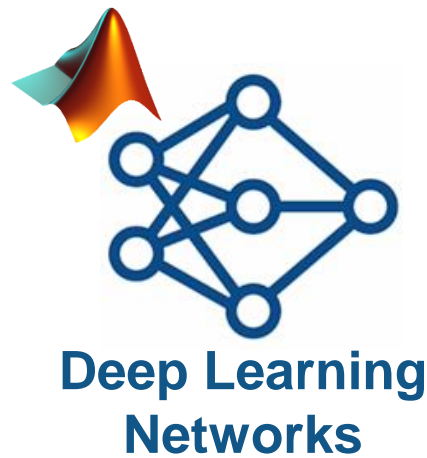


Deployment Target

Deploying Deep Learning Models for Inference



Deploying to Various Targets



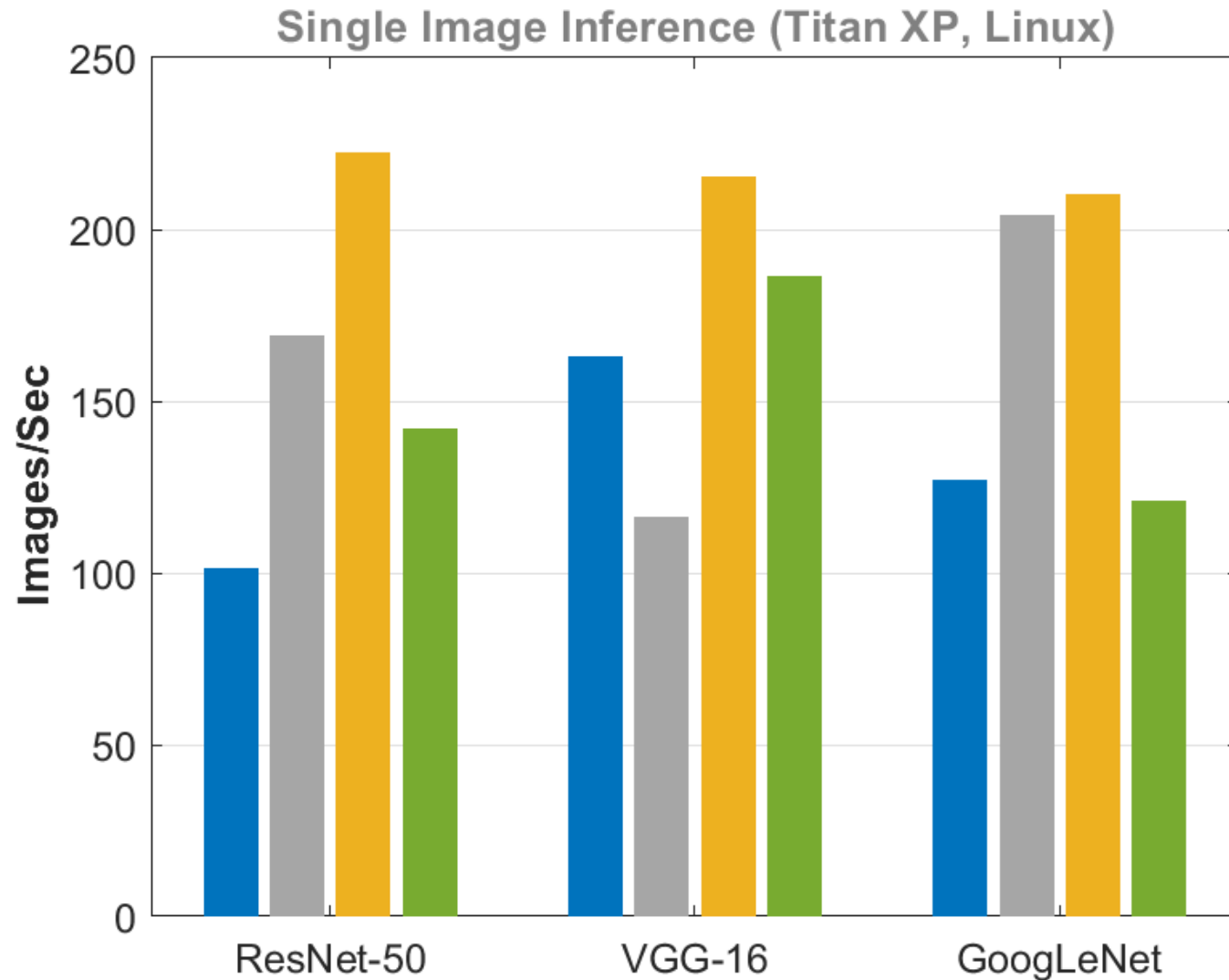
23.88 FPS
89.7% computer keyboard
8.6% space bar
1.7% typewriter keybo
0.0% mouse
0.0% notebook

Desktop CPU

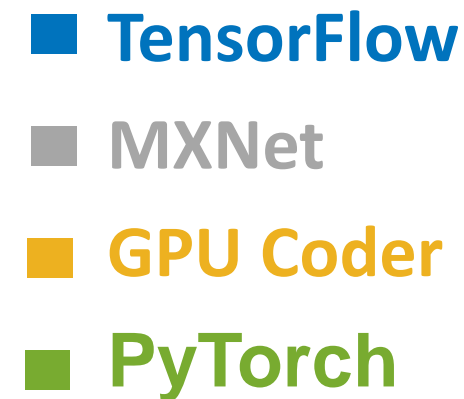
NVIDIA
TensorRT &
cuDNN
Libraries

Raspberry Pi board

With GPU Coder, MATLAB is fast



GPU Coder is faster than TensorFlow, MXNet and Pytorch



Deep Learning Workflow

ACCESS AND EXPLORE
DATA

LABEL AND PREPROCESS
DATA

DEVELOP PREDICTIVE
MODELS

INTEGRATE MODELS WITH
SYSTEMS

Files



Databases



Sensors



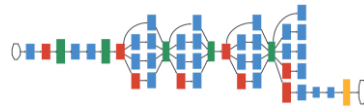
Data Augmentation/
Transformation



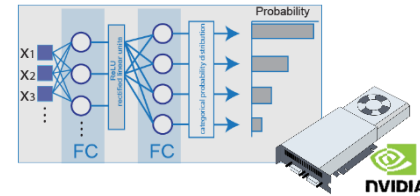
Labeling Automation



Import Reference
Models



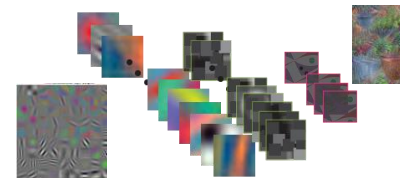
Hardware-Accelerated
Training



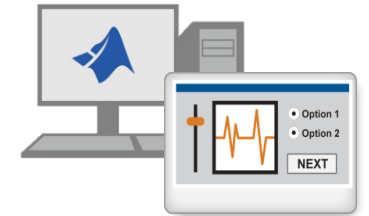
Hyperparameter Tuning



Network Visualization



Desktop Apps



Enterprise Scale Systems



Embedded Devices and
Hardware



Why MATLAB?

- MATLAB is Productive
- MATLAB Supports the Entire Deep Learning Workflow
- **MATLAB Integrates with Open Source**

Used MATLAB and Open Source Together



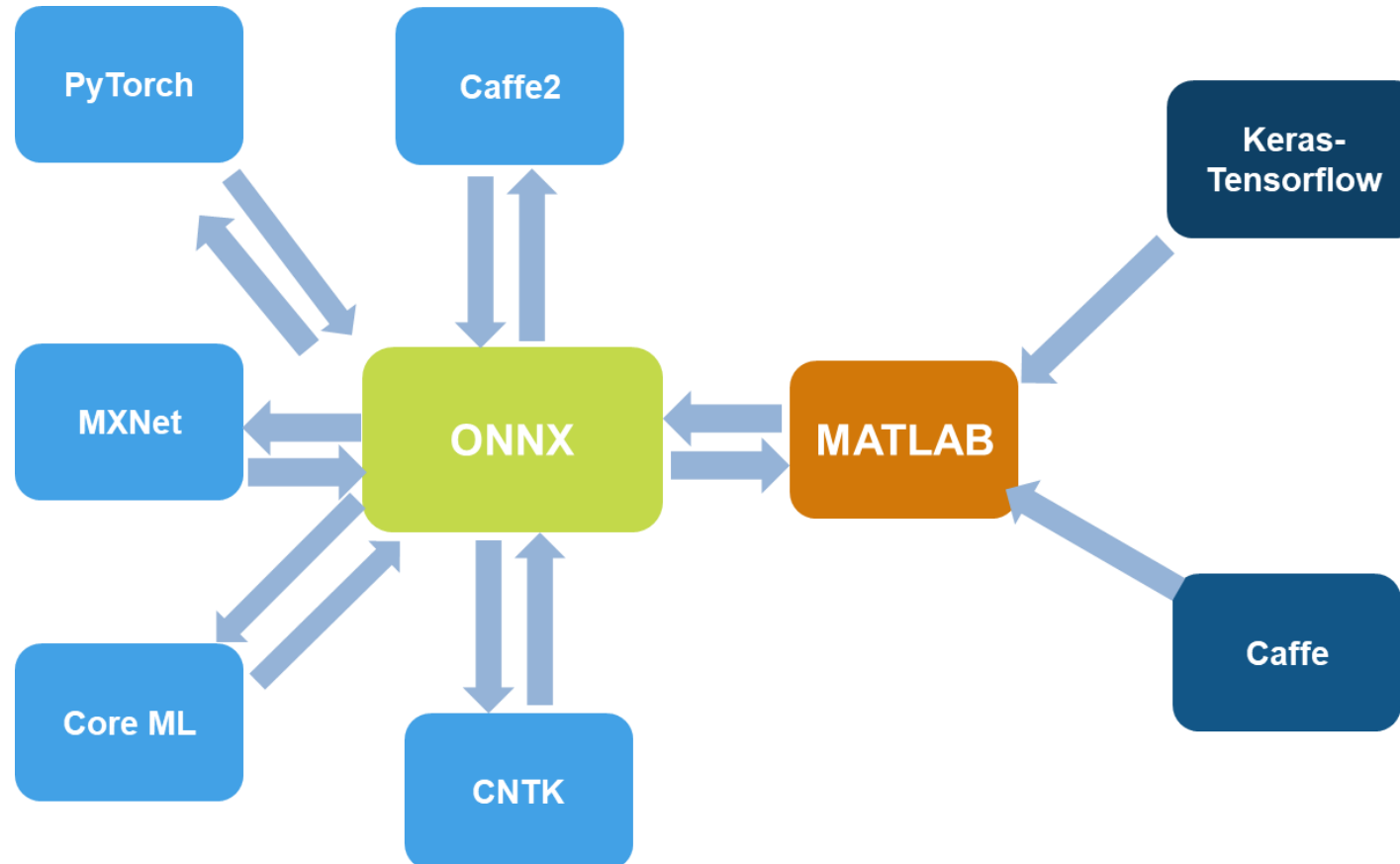
- Used Caffe and MATLAB together
- Achieved significantly better results than an engineered rain model.
- Use our tools where it makes your workflow easier!

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

The screenshot shows the MathWorks Community Profile for the Deep Learning Toolbox Team. The page features a navigation bar with links to Products, Solutions, Academia, Support, Community, and Events. A search bar is located in the top right. Below the navigation, there are tabs for MATLAB Answers, File Exchange, Cody, Blogs, ThingSpeak, and Maker Community. The main content area displays a list of contributions, with a large blue box highlighting the text: "Import models from other frameworks via ONNX or direct from Keras-TensorFlow and Caffe". To the right of this text, four contribution items are listed: ONNX Converter (Export to ONNX model format), KERAS IMPORTER (Importer for TensorFlow-Keras Models), ResNet-50 (PRETRAINED MODEL), and SqueezeNet (PRETRAINED MODEL). The left sidebar includes the team name, a staff badge, and a contact button.

ONNX is an open format to represent deep learning models

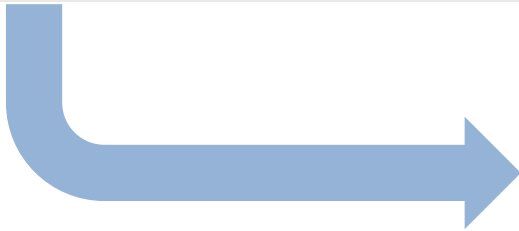


ONNX = Open Neural Network Exchange Format

ONNX Converter

Import from ONNX format

```
modelfile = 'cifarResNet.onnx';
classes = ["airplane" "automobile" "bird"];
net = importONNXNetwork(modelfile, 'Output');
analyzeNetwork(net)
```



Export to ONNX format

```
filename = 'fishdetector.onnx';
exportONNXNetwork(net, filename)
```

net
Analysis date: 04-Jul-2018 08:16:54

77 layers 0 warnings 0 errors

	NAME	TYPE	ACTIVATIONS	LEARNABLES
1	Input_input 32x32x3 images	Image Input	32x32x3	-
2	input_Sub Layer adds bias to the input	Bias	32x32x3	-
3	conv1np 16 3x3x3 convolutions with stride [1 1] and padding [1 1 1 1]	Convolution	32x32x16	Weights 3x3x3x16 Bias 1x1x16
4	BN1np Batch normalization with 16 channels	Batch Normalization	32x32x16	Offset 1x1x16 Scale 1x1x16
5	relu1np ReLU	ReLU	32x32x16	-
6	S1U1_conv1 16 3x3x16 convolutions with stride [1 1] and padding [1 1 1 1]	Convolution	32x32x16	Weights 3x3x16x16 Bias 1x1x16
7	S1U1_BN1 Batch normalization with 16 channels	Batch Normalization	32x32x16	Offset 1x1x16 Scale 1x1x16
8	S1U1_relu1 ReLU	ReLU	32x32x16	-
9	S1U1_conv2 16 3x3x16 convolutions with stride [1 1] and padding [1 1 1 1]	Convolution	32x32x16	Weights 3x3x16x16 Bias 1x1x16
10	S1U1_BN2 Batch normalization with 16 channels	Batch Normalization	32x32x16	Offset 1x1x16 Scale 1x1x16
11	add11 Element-wise addition of 2 inputs	Addition	32x32x16	-
12	relu11 ReLU	ReLU	32x32x16	-
13	S1U2_conv1 16 3x3x16 convolutions with stride [1 1] and padding [1 1 1 1]	Convolution	32x32x16	Weights 3x3x16x16 Bias 1x1x16
14	S1U2_BN1 Batch normalization with 16 channels	Batch Normalization	32x32x16	Offset 1x1x16 Scale 1x1x16
15	S1U2_relu1 ReLU	ReLU	32x32x16	-
16	S1U2_conv2 16 3x3x16 convolutions with stride [1 1] and padding [1 1 1 1]	Convolution	32x32x16	Weights 3x3x16x16 Bias 1x1x16
17	S1U2_BN2 Batch normalization with 16 channels	Batch Normalization	32x32x16	Offset 1x1x16 Scale 1x1x16

MATLAB Integrates with Open Source Frameworks

- Use MATLAB for parts of workflow
- Access to latest models
- Improved collaboration with other users

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- MATLAB Integrates with Open Source

Other Deep Learning Expo Events

- Deep Learning Workshops – 1pm, 2pm, 3:30pm
- Deep Learning Booth
- Deep Learning for Signals – 3:30pm