Deep Learning in MATLAB:
A Brief Overview

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Principal Application Engineer
What is can Deep Learning do for us?
(An example)
Example 1:
Object recognition using deep learning
Object recognition using deep learning

<table>
<thead>
<tr>
<th>Training (GPU)</th>
<th>Prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Millions of images from 1000 different categories</td>
<td>Real-time object recognition using a webcam connected to a laptop</td>
</tr>
</tbody>
</table>
What is Deep Learning?
Machine Learning vs Deep Learning

We specify the nature of the features we want to extract…

…and the type of model we want to build.

Machine Learning

MANUAL FEATURE EXTRACTION

CLASSIFICATION

CAR

TRUCK

BICYCLE
Machine Learning vs Deep Learning

We need only specify the architecture of the model...
- **Deep learning** is a type of machine learning in which a model learns to perform tasks like classification – directly from images, texts, or signals.
- Deep learning performs **end-to-end learning**, and is usually implemented using a **neural network architecture**.
- Deep learning algorithms also **scale with data** – traditional machine learning **saturates**.
Why is Deep Learning So Popular Now?

Source: ILSVRC Top-5 Error on ImageNet
Two Approaches for Deep Learning

1. Train a Deep Neural Network from Scratch

2. Fine-tune a pre-trained model (transfer learning)
Pains In Deep Learning

Expertise

Time to Train

Data

```matlab
layers = [
    imageInputLayer([28 28 1])
    convolution2dLayer(3,16,'Padding',1)
    batchNormalizationLayer
    reluLayer
    maxPooling2dLayer(2,'Stride',2)
    convolution2dLayer(3,32,'Padding',1)
    batchNormalizationLayer
    reluLayer
    maxPooling2dLayer(2,'Stride',2)
    convolution2dLayer(3,64,'Padding',1)
    batchNormalizationLayer
    reluLayer
    fullyConnectedLayer(10)
    softmaxLayer
    classificationLayer];
```
Example: Vehicle recognition using deep transfer learning
Import the Latest Models for Transfer Learning

Pretrained Models*

- AlexNet
- VGG-16
- VGG-19
- GoogLeNet
- Inception-v3
- ResNet50
- ResNet-101
- Inception-resnet-v2
- SqueezeNet
- MobileNet (coming soon)

* single line of code to access model

Import Models from Frameworks

- Caffe Model Importer
- TensorFlow-Keras Model Importer
- Onnx - Importer/Exporter (Coming Soon)
Detection and localization using deep learning

Regions with Convolutional Neural Network Features (R-CNN)
What is semantic segmentation?
Localization using deep learning

Original Image

ROI detection

Pixel classification
Semantic Segmentation Network

Boat
Airplane
Other classes
Semantic Segmentation Network
Semantic Segmentation Demo

CamVid Dataset
1. Segmentation and Recognition Using Structure from Motion Point Clouds, ECCV 2008
2. Semantic Object Classes in Video: A High-Definition Ground Truth Database, Pattern Recognition Letters
Semantic Segmentation

CamVid Dataset
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“I love to label and preprocess my data”

~ Said no engineer, ever.
Ground truth Labeling

“How do I label my data?”

New App for Ground Truth Labeling

Label pixels and regions for semantic segmentation
Attributes and Sublabels
Types of Datasets

Numeric Data

ML or LSTM

Time Series/Text Data

LSTM or CNN

Image Data

CNN
Analyzing signal data using deep learning

Signal Classification using LSTMs

Speech Recognition using CNNs
Deep learning features overview

- Classification
- Regression
- Semantic segmentation
- Object detection
- Scalability
  - Multiple GPUs
  - Cluster or cloud
- Custom network layers
- Import models
  - Caffe
  - Keras/TensorFlow
- Data augmentation
- Hyperparameter tuning
  - Bayesian optimization
- Python ↔ MATLAB interface
- LSTM networks
  - Time series, signals, audio
- Custom labeling
  - API for ground-truth labeling automation
  - Superpixels
- Data validation
  - Training and testing
Prediction Performance: Fast with GPU Coder

Why is GPU Coder so fast?
- Analyzes and optimizes network architecture
- Invested 15 years in code generation

Images/Sec

<table>
<thead>
<tr>
<th>Images/Sec</th>
<th>Prediction (V100 GPU)</th>
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<tbody>
<tr>
<td></td>
<td>AlexNet</td>
</tr>
<tr>
<td></td>
<td>ResNet-50</td>
</tr>
<tr>
<td></td>
<td>VGG-16</td>
</tr>
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TensorFlow
MATLAB
MXNet
GPU Coder

Using CUDA v9 and cuDNN v7
Overview of deep learning deployment options

“How do I deploy my model?”

- Create Desktop Apps
- Run Enterprise Solution
- Generate C and C++ Code
- Target GPUs
- Generate C and C++ Code

Introducing:
GPU Coder - Convert to NVIDIA CUDA code

Deploy / Share
GPU Coder Fills a Gap in Our Deep Learning Solution

Access Data → Preprocess → Select Network → Train → Deploy

Image Acq. → Image Processing → Neural Network → PCT → GPU Coder

Computer Vision → Training → Inference

MathWorks
Deploying to CPUs

Deep Learning Networks → GPU Coder →

- Intel MKL-DNN Library
- NVIDIA TensorRT & cuDNN Libraries
- ARM Compute Library
MATLAB products for deep learning

Required products

- Neural Network Toolbox
- Parallel Computing Toolbox
- Image Processing Toolbox
- Computer Vision System Toolbox

Recommended products

- Statistics and Machine Learning Toolbox
- MATLAB Coder
- GPU Coder
- Automated Driving System Toolbox
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  - Training and testing

* We can cover in more detail outside this presentation
Thank you!
Deep learning in automated driving…
Deep Learning Onramp

- Get started using deep learning methods to perform image recognition.
- Free access for everyone
- Interactive exercises and short video demonstrations
- Work on real-life image recognition problems
- Topics include:
  - Convolutional neural networks
  - Working with pre-trained networks
  - Transfer learning
  - Evaluating network performance
Convolutional Neural Networks (CNN)

Edges

Shapes

Objects

→ Flower
→ Cup
→ Car
→ Tree