Deep Learning for Computer Vision Applications Using MATLAB

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Agenda

What is deep learning?- Overview

Why deep learning?

Pretrained networks and Network layers

Building your own network

Transfer learning with CNNs
Traditional Machine Learning vs Deep Learning

**Traditional Machine Learning**

- **Feature Extraction**
  - Handcrafted Features

- **Classification**
  - Machine Learning
    - Car ✓
    - Truck ×
    - Bicycle ×

**Deep Learning**

- **Convolutional Neural Network (CNN)**
  - End-to-end learning

- **Feature learning + Classification**
  - Car ✓
  - Truck ×
  - Bicycle ×

Deep learning performs **end-end learning** by learning **features, representations and tasks** directly from **images, text and sound**.
Deep learning Applications

Semantic Segmentation

Vehicle Detection
Agenda

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Transfer learning with CNNs
Deep learning models can surpass human accuracy.

Source: ILSVRC Top-5 Error on ImageNet
Deep Learning Enablers

Labeled public datasets

World-class models

AlexNet
PRETRAINED MODEL

VGG-16
PRETRAINED MODEL

ResNet
PRETRAINED MODEL

Caffe
MODELS

GoogLeNet
PRETRAINED MODEL

TensorFlow/Keras
MODELS

Increased GPU acceleration
Let’s try it out!

Exercise: SS_DeepLearningIn5Linesmlx
What is deep learning? - Overview

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# Pre-Trained Models and Network Architectures

## Pretrained Models

- AlexNet
- VGG-16
- VGG-19
- GoogLeNet
- Resnet50
- Resnet101

```matlab
net = alexnet;
net = vgg16;
net = vgg19;
net = googlenet;
net = resnet50;
net = resnet101
```

## Import Models from Frameworks

- Caffe Model Importer (including Caffe Model Zoo)
  - `importCaffeLayers`
  - `importCaffeNetwork`

- TensorFlow-Keras Model Importer
  - `importKerasLayers`
  - `importKerasNetwork`
Deep Learning Uses a Neural Network Architecture

Input Layer

Hidden Layers (n)

Output Layer
Convolutional Neural Network

Feature Learning

Classification

Input

Convolution + ReLU
Pooling

Convolution + ReLU
Pooling

Flatten
Fully Connected
Softmax

goldfish ✓
cat ❌
dog ❌
Takeaways

- Pre-trained networks have a pre-determined layer order that makes them effective for classifying images
  - Typically trained to classify lots of images
- Great starting point, but not consistently accurate
  - We’ll fix this later with transfer learning!
Agenda

- What is deep learning? - Overview
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- Pretrained networks and Network layers
  - Building your own network
- Transfer learning with CNNs
Deep Learning Workflow

Repeat these steps until network reaches desired level of accuracy:

- Preprocess Images
- Define Layers in CNN
- Set training options
- Train the network
- Test/deploy trained network
Let’s try it out!

Exercise: SS_MNIST_HandwritingRecognitionmlx
Takeaways

- Deep learning for image classification uses CNNs
- CNNs can have different combinations of initial layers but usually end with:
  - Fully Connected Layer
  - Softmax Layer
  - Classification Layer
- Important factors that affect accuracy and training time
  - Network architecture
  - Mini Batch Size
  - Initial learning rate
Agenda

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Transfer learning with CNNs
Two Approaches for Deep Learning

1. Train a Deep Neural Network from Scratch

2. Fine-tune a pre-trained model (transfer learning)
## Two Approaches for Deep Learning

### Fine-tune a pre-trained model (transfer learning)

Recommended when:

<table>
<thead>
<tr>
<th>Training data</th>
<th>100s to 1000s of labeled images (small)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computation</td>
<td>Moderate computation (GPU optional)</td>
</tr>
<tr>
<td>Training Time</td>
<td>Seconds to minutes</td>
</tr>
<tr>
<td>Model accuracy</td>
<td>Good, depends on the pre-trained CNN model</td>
</tr>
</tbody>
</table>

### Train a deep neural network from scratch

Recommended when:

<table>
<thead>
<tr>
<th>Training data</th>
<th>1000s to millions of labeled images</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computation</td>
<td>Compute intensive (requires GPU)</td>
</tr>
<tr>
<td>Training Time</td>
<td>Days to Weeks for real problems</td>
</tr>
<tr>
<td>Model accuracy</td>
<td>High (can over fit to small datasets)</td>
</tr>
</tbody>
</table>
Transfer Learning Workflow

Load pretrained network
- Early layers that learned low-level features (edges, blobs, colors)
- Last layers that learned task specific features
- 1 million images
- 1000s classes

Replace final layers
- New layers to learn features specific to your data
- Fewer classes
- Learn faster

Train network
- Training images
- Training options
- 100s images
- 10s classes

Predict and assess network accuracy
- Test images
- Trained Network

Deploy results
- Probability
- Boat
- Plane
- Car
- Train
Transfer Learning Workflow – Step 1

Load pretrained network

Early layers learn low-level features (edges, blobs, colors)

Last layers learn task-specific features

1 million images
1000s classes
Transfer Learning Workflow – Step 2

Load pretrained network

Early layers that learned low-level features (edges, blobs, colors)

Last layers that learned task specific features

1 million images
1000s classes

Replace final layers

New layers learn features specific to your data

Fewer classes
Learn faster
Transfer Learning Workflow – Step 3

Load pretrained network
- Early layers that learned low-level features (edges, blobs, colors)
- Last layers that learned task specific features
- 1 million images
- 1000s classes
- Fewer classes
- Learn faster

Replace final layers
- New layers to learn features specific to your data
- Replace final layers
- 100s images
- 10s classes

Train network
- Training images
- Training options
- 100s images
- 10s classes
- Train network
Transfer Learning Workflow – Step 4

Predict and assess network accuracy

Test images

Load pretrained network

Early layers that learned low-level features (edges, blobs, colors)

1 million images
1000s classes

Replace final layers

New layers to learn features specific to your data

Fewer classes
Learn faster

100s images
10s classes

Train network

Transfer Learning Workflow

Training images

Training options

1 million images
1000s classes

100s images
10s classes

1 million images
1000s classes

Transfer Learning Workflow

Training images

Training options

1 million images
1000s classes

Early layers that learned low-level features (edges, blobs, colors)

1 million images
1000s classes

Replace final layers

New layers to learn features specific to your data

Fewer classes
Learn faster

100s images
10s classes

Load pretrained network

Last layers that learned task specific features

1 million images
1000s classes

Predict and assess network accuracy

Test images
Transfer Learning Workflow – Step 5

- **Load pretrained network**
  - Early layers that learned low-level features (edges, blobs, colors)
  - Last layers that learned task-specific features
  - 1 million images
  - 1000s classes

- **Replace final layers**
  - Fewer classes
  - Learn faster

- **Train network**
  - 100s images
  - 10s classes

- **Test images**

- **Deploy results**
  - Predict and assess network accuracy

- **Trained Network**

- **Probability**
  - Boat
  - Plane
  - Car
  - Train
Let’s try it out!

Exercise: SS_SeeFoodTransferLearning.mlx
Takeaways – Transfer Learning

- Replace last layers with our own layers
- Efficient way to modify pre-trained models to our needs
- Use an Image datastore when working with lots of images
One Step Left – Deployment!

1. Access Data
   - Image Acquisition
   - Image Processing
   - Computer Vision System

2. Preprocess
   - Image Processing

3. Select Network
   - Neural Network

4. Train
   - Parallel Computing

5. Deploy
   - GPU Coder
What Next?

Deep Learning Onramp

This free self-paced tutorial provides an interactive introduction to practical deep learning. It focuses on using MATLAB® to apply deep learning methods to perform image recognition. The tutorial consists of hands-on exercises and short videos. In the exercises, you will enter commands in an online version of MATLAB and receive contextual feedback that will help you correct common mistakes. Topics include:

- Convolutional neural networks
- Preprocessing images
- Using pretrained networks
- Transfer learning
- Evaluating network performance

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Thank You!
Questions?