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What is Deep Learning?

Deep learning is a type of machine learning that performs end-to-end learning by learning tasks directly from images, text, and sound.
Why is Deep Learning So Popular Now?

Unparalleled Accuracy

1000 Class Image Recognition

Machine Learning

Deep Learning

Error Rate

0% 10% 20% 30%

2010 2011 2012 2013 2014 2015

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

Acceleration with GPU’s

Massive sets of labeled data

Availability of state of the art models from experts
Deep Learning Workflow

- **Training Data**
  - Large open datasets
  - Recorded labeled data (e.g., images, video)

- **Pre-Processed Models**
  - Access state-of-art networks already trained on large datasets

- **Data Augmentation**
  - Crop, resize and rotate images – create more training data

- **Label Training Data**
  - For image data: draw ROI’s, label individual pixels with labels

- **Train from Scratch**
  - Configure and train a deep network with massive amount of training data

- **Transfer Learning**
  - Tune pre-trained model for a different task with smaller datasets

- **Preprocess Data**

- **Develop Predictive Models**

- **Integrate Analytics to Systems**
  - Publish models for others to use

- **Share Models**
  - Embedded Deployment
    - Embedded processors
    - FPGA

- **HPC**
  - Servers (multi-GPU)
  - Clusters

- **Access & Explore**

- **Leverages MATLAB Platform Strengths**
Convolutional Neural Networks

- Train “deep” neural networks on structured data (e.g. images, signals, text)
- Implements Feature Learning: Eliminates need for “hand crafted” features
- Trained using GPUs for performance

```
Convolution + ReLu
Pooling
Convolution + ReLu
Pooling
Flatten
Fully Connected
Softmax
```

Feature Learning

Classification
Convolution Layer

- Core building block of a CNN
- Convolve the filters sliding them across the input, computing the dot product
- Intuition: learn filters that activate when they “see” some specific feature
Rectified Linear Unit (ReLU) Layer

- Frequently used in combination with Convolution layers
- Do not add complexity to the network
- Most popular choice: \( f(x) = \max(0, x) \), activation is thresholded at 0
Pooling Layer

- Perform a **downsampling** operation across the spatial dimensions
- Goal: progressively decrease the size of the layers
- Max pooling and average pooling methods
- Popular choice: Max pooling with 2x2 filters, Stride = 2
Image Classification Using Pre-trained Network (Video)
Approaches for Deep Learning

1. Train a Deep Neural Network from Scratch

- **Convolutional Neural Network (CNN)**
  - Learned features
  - Classification probabilities:
    - Car: 95%
    - Truck: 3%
    - Bicycle: 2%

2. Fine-tune a pre-trained model (transfer learning)

- **Pre-trained CNN**
  - Fine-tune network weights

- Target new tasks:
  - Cake: ✔
  - Cookies: ✗
Example: Fine-tune a pre-trained model (Transfer learning)

Pre-trained CNN
(AlexNet – 1000 Classes)

New Task – 5 Class Classification
Why Perform Transfer Learning

- Requires less data and training time
- Reference models (like AlexNet, VGG-16, VGG-19) are great feature extractors
- Leverage best network types from top researchers
Transfer Learning in MATLAB

Fine Tuning A Deep Neural Network

This example shows how to fine tune a pre-trained deep convolutional neural network (CNN) for a new recognition task.

Load Image Data

Data is 5 different categories of food. Create an imageDatastore to read images. Please download the categories of objects you want to use as a good source of data can be found here:


load(location, 'bar_food');
ims = imageDatastore(location, 'IncludeSubfolders', 1, ...
    'LabelSource', 'foldername', ...
    'tol', countEachLabel(inms));

Load Pre-trained CNN

The CNN model is saved in MatConvNet’s format [3]. Load the MatConvNet network data into convnet, a SeriesNetwork object from Neural Network Toolbox™, using the helper function helperImportMatConvNet. A SeriesNetwork object can be used to inspect the network architecture, classify new data, and extract network activations from specific layers.
Manipulate Deep Learning Networks Easily

Perform net surgery

Modify the existing network by deleting later layers and adding new ones.

% Here we only need to keep everything except the last 3 layers.
layers = net.Layers(1:end-3)

% Add new fully-connected layer for 2 categories.
layers(end+1) = fullyConnectedLayer(64, 'Name', 'special 2');
layers(end+1) = reluLayer;

% the new layer adding non-linearity and improves the network's ability to handle data
layers(end+1) = fullyConnectedLayer(height(tol), 'Name', 'fc62');

% Add the softmax layer and the classification layer
layers(end+1) = softmaxLayer;
layers(end+1) = classificationLayer();
**Manipulate Deep Learning Networks Easily**

**Set options for training**
```matlab
opts = trainingOptions('sgdm');
```

**Train the network**
```matlab
net = trainNetwork(imds, layers, opts);
```

**Make predictions**
```matlab
label = classify(net, im);
```

**Extract features**
```matlab
features = activations(net, Xtrain, 'fc7');
```
MATLAB makes Deep Learning Easy and Accessible

Learn about new MATLAB capabilities to

- Handle and label large sets of images
- Accelerate deep learning with GPU’s
- Visualize and debug deep neural networks
- Access and use models from experts

```matlab
imageDS = imageDatastore(dir)  
Easily manage large sets of images
```
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**Training modes supported:**

- Auto Select GPU
- Multi GPU (local)
- Multi GPU (cluster)

**Acceleration with Multiple GPUs**
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**Curated Set of Pretrained Models**

Access Models with 1-line of MATLAB Code

Net1 = alexnet
Net2 = vgg16
Net3 = vgg19
Regression Support for Deep Learning

Classification vs. Regression

- Classification – outputs categories/labels
- Regression – outputs numbers

Supported by new regression layer:
```
outputlayer = regressionLayer('Name','output')
```

Example predict facial key-points: