Introducing Deep Learning with MATLAB

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What is Deep Learning?

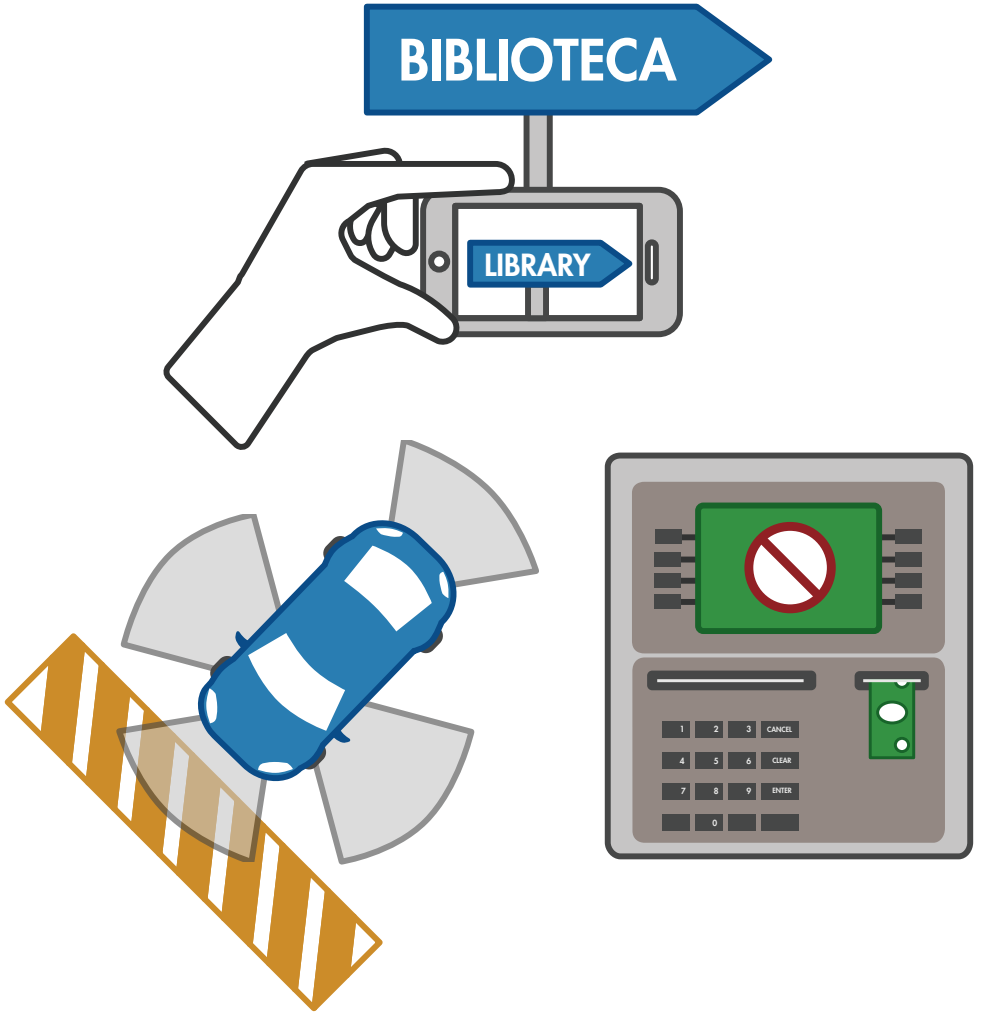
Deep learning is a type of machine learning in which a model learns to perform classification tasks directly from images, text, or sound. Deep learning is usually implemented using a neural network architecture. The term “deep” refers to the number of layers in the network—the more layers, the deeper the network. Traditional neural networks contain only 2 or 3 layers, while deep networks can have hundreds.

Deep Learning Applications

Here are just a few examples of deep learning at work:

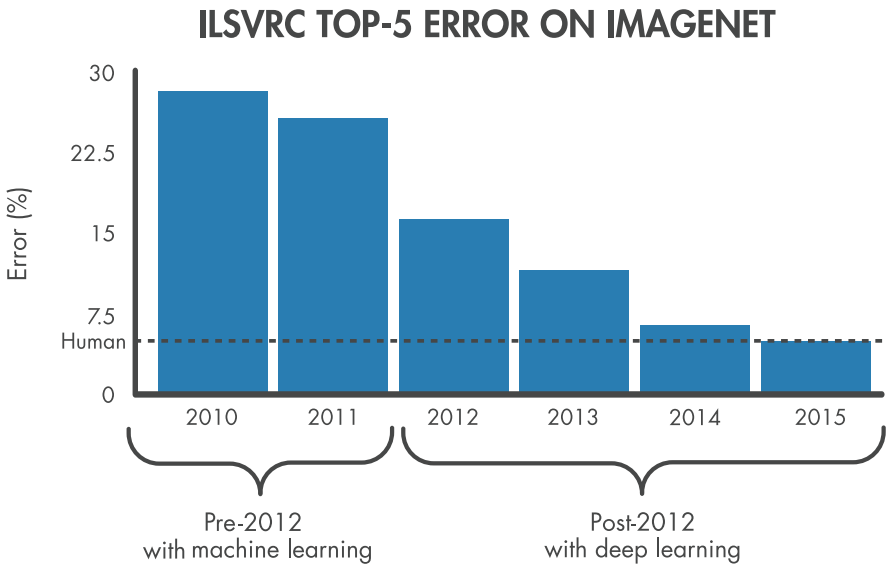
- A self-driving vehicle slows down as it approaches a pedestrian crosswalk.
- An ATM rejects a counterfeit bank note.
- A smartphone app gives an instant translation of a foreign street sign.

Deep learning is especially well-suited to identification applications such as face recognition, text translation, voice recognition, and advanced driver assistance systems, including, lane classification and traffic sign recognition.

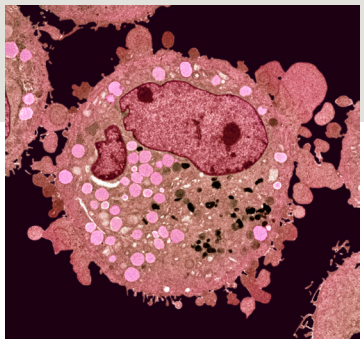


What Makes Deep Learning State-of-the-Art?

In a word, accuracy. Advanced tools and techniques have dramatically improved deep learning algorithms—to the point where they can outperform humans at classifying images, win against the world's best GO player, or enable a voice-controlled assistant like Amazon Echo® and Google Home to find and download that new song you like.



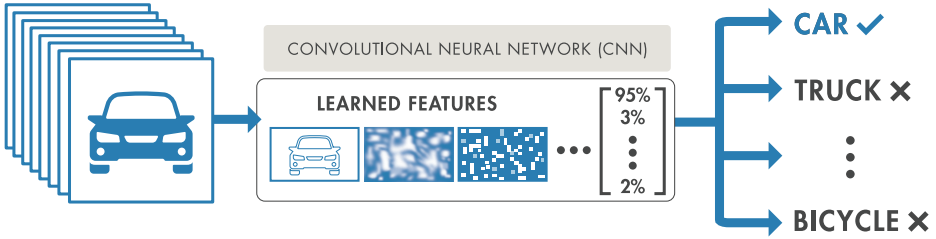
UCLA researchers built an advanced microscope that yields a high-dimensional data set used to train a deep learning network to identify cancer cells in tissue samples.



What Makes Deep Learning State-of-the-Art?
continued

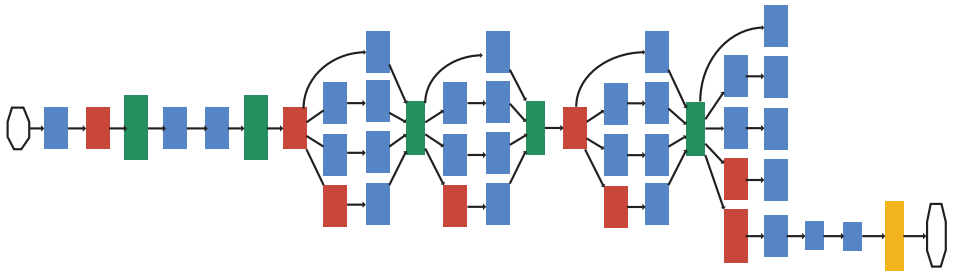
Three technology enablers make this degree of accuracy possible:

Easy access to massive sets of labeled data
Data sets such as ImageNet and PASCAL VoC are freely available, and are useful for training on many different types of objects.



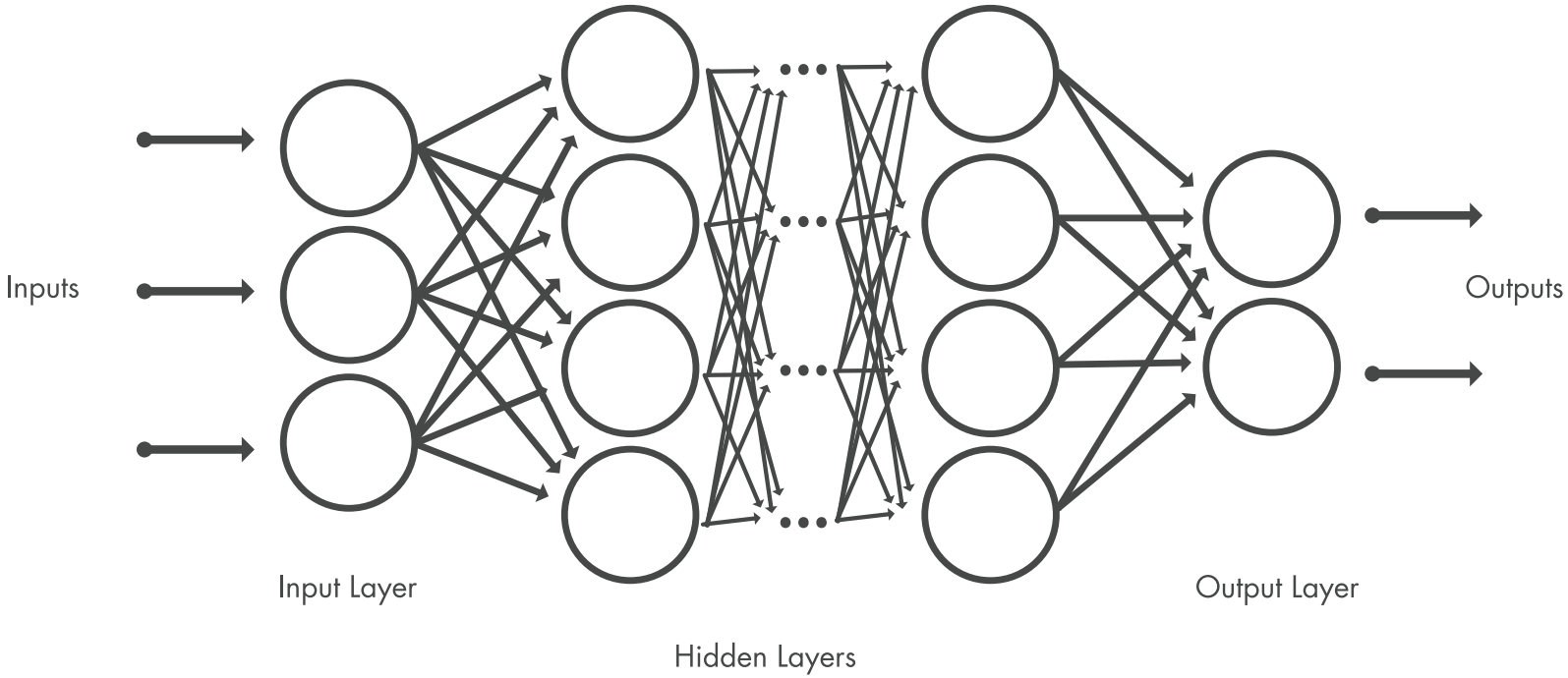
Increased computing power
High-performance GPUs accelerate the training of the massive amounts of data needed for deep learning, reducing training time from weeks to hours.

Pretrained models built by experts
Models such as AlexNet can be retrained to perform new recognition tasks using a technique called *transfer learning*. While AlexNet was trained on 1.3 million high-resolution images to recognize 1000 different objects, accurate transfer learning can be achieved with much smaller datasets.



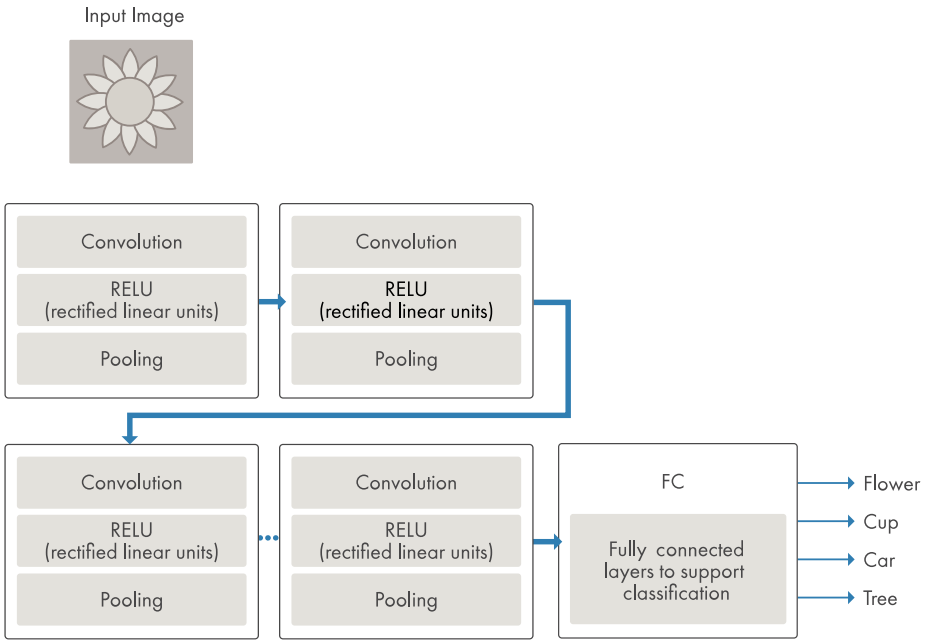
Inside a Deep Neural Network

A deep neural network combines multiple nonlinear processing layers, using simple elements operating in parallel and inspired by biological nervous systems. It consists of an input layer, several hidden layers, and an output layer. The layers are interconnected via nodes, or neurons, with each hidden layer using the output of the previous layer as its input.



How A Deep Neural Network Learns

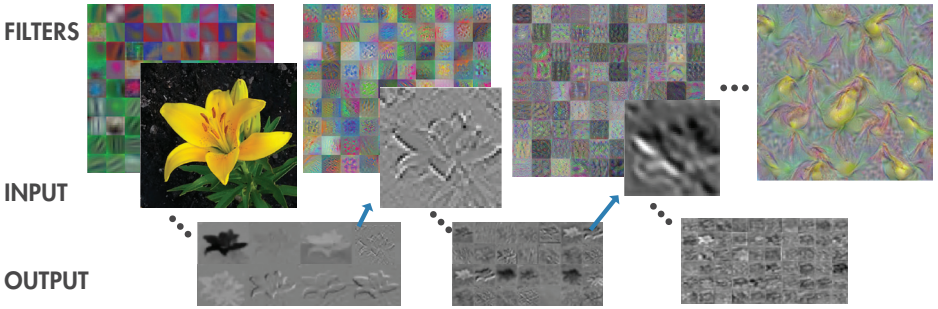
Let's say we have a set of images where each image contains one of four different categories of object, and we want the deep learning network to automatically recognize which object is in each image. We label the images in order to have training data for the network.



Using this training data, the network can then start to understand the object's specific features and associate them with the corresponding category.

Each layer in the network takes in data from the previous layer, transforms it, and passes it on. The network increases the complexity and detail of what it is learning from layer to layer.

Notice that the network learns directly from the data—we have no influence over what features are being learned.



About Convolutional Neural Networks

A convolutional neural network (CNN, or ConvNet) is one of the most popular algorithms for deep learning with images and video.

Like other neural networks, a CNN is composed of an input layer, an output layer, and many hidden layers in between.

Feature Detection Layers

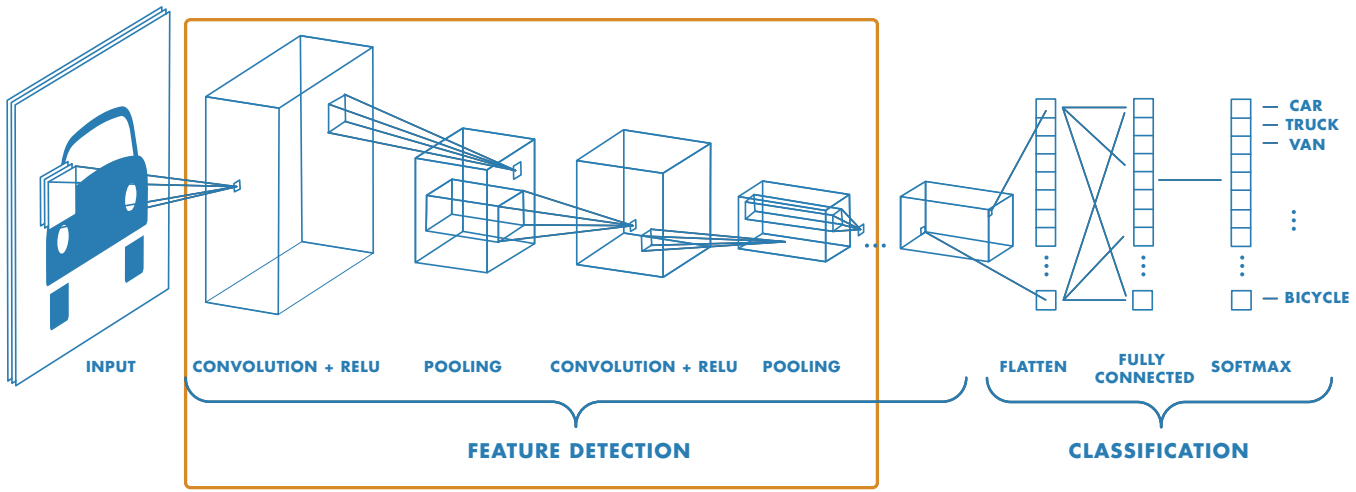
These layers perform one of three types of operations on the data: convolution, pooling, or rectified linear unit (ReLU).

Convolution puts the input images through a set of convolutional filters, each of which activates certain features from the images.

Pooling simplifies the output by performing nonlinear downsampling, reducing the number of parameters that the network needs to learn about.

Rectified linear unit (ReLU) allows for faster and more effective training by mapping negative values to zero and maintaining positive values.

These three operations are repeated over tens or hundreds of layers, with each layer learning to detect different features.



About Convolutional Neural Networks *continued*

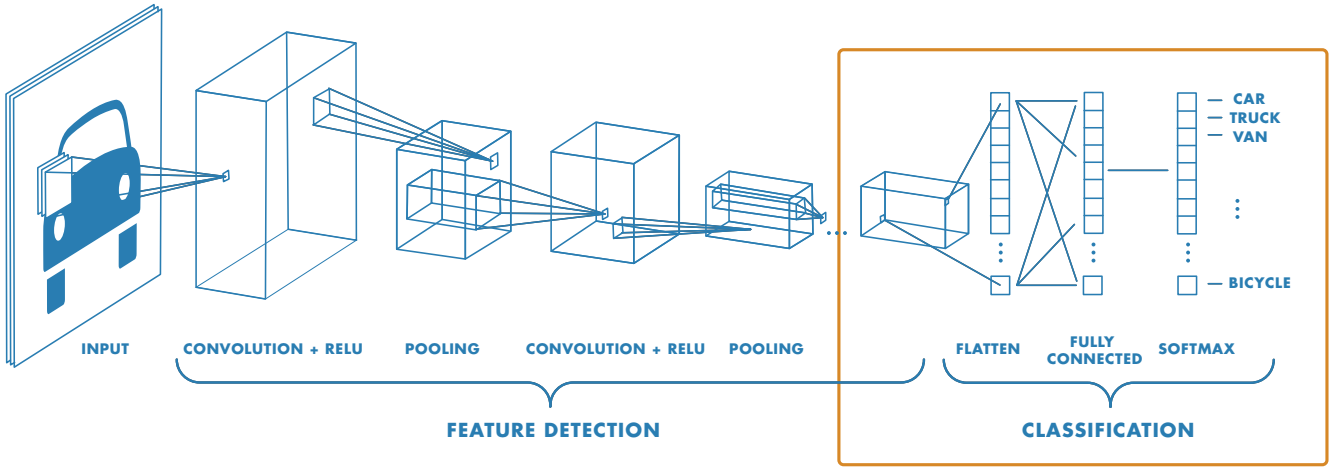
Classification Layers

After feature detection, the architecture of a CNN shifts to classification.

The next-to-last layer is a **fully connected layer** (FC) that outputs a vector of K dimensions where K is the number of classes that the network will be able to predict. This vector contains the probabilities for each class of any image being classified.

The final layer of the CNN architecture uses a **softmax** function to provide the classification output.

There is no exact formula for selecting layers. The best approach is to try a few and see how well they work—or to use a pretrained network.

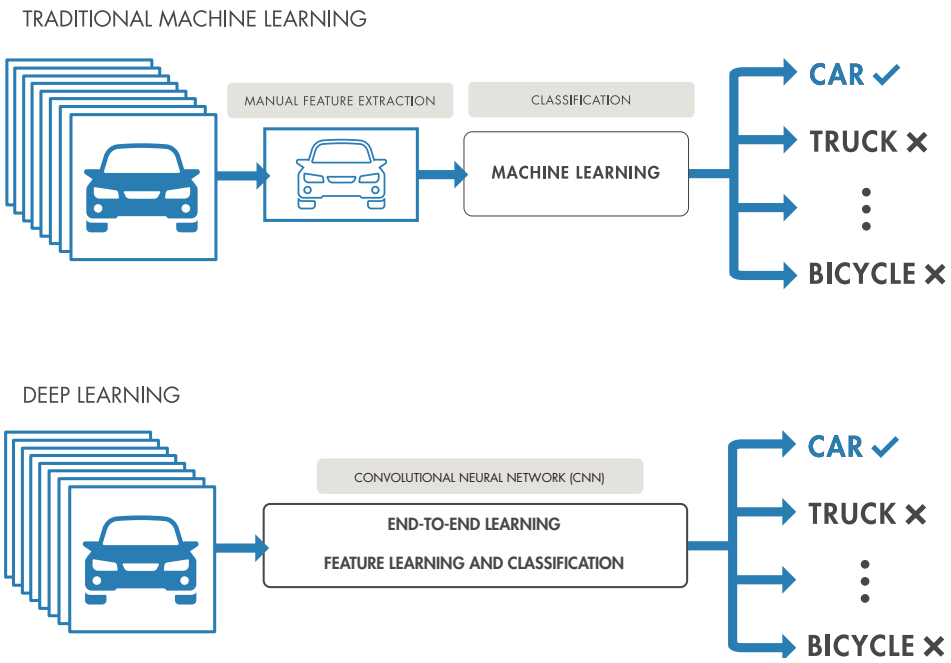


» Explore the architecture of a CNN

What is the Difference Between Deep Learning and Machine Learning?

Deep learning is a subtype of machine learning. With machine learning, you manually extract the relevant features of an image. With deep learning, you feed the raw images directly into a deep neural network that learns the features automatically.

Deep learning often requires hundreds of thousands or millions of images for the best results. It's also computationally intensive and requires a high-performance GPU.

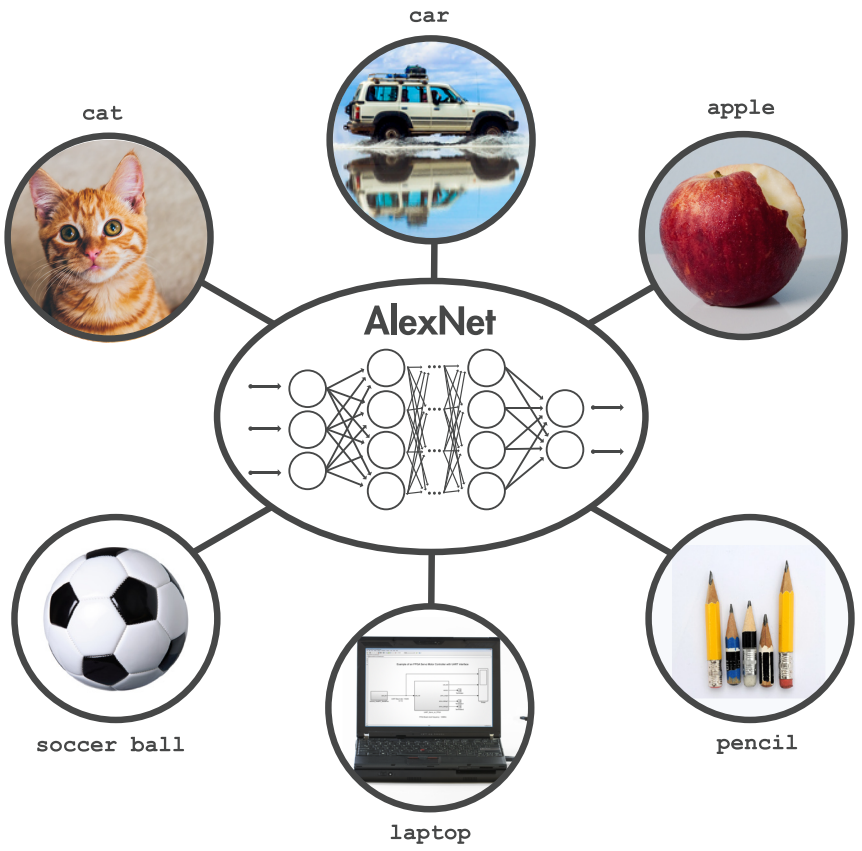


Machine Learning	Deep Learning
+ Good results with small data sets	— Requires very large data sets
+ Quick to train a model	— Computationally intensive
— Need to try different features and classifiers to achieve best results	+ Learns features and classifiers automatically
— Accuracy plateaus	+ Accuracy is unlimited

Getting Started with Deep Learning

If you're new to deep learning, a quick and easy way to get started is to use an existing network, such as AlexNet, a CNN trained on more than a million images. AlexNet is most commonly used for image classification. It can classify images into 1000 different categories, including keyboards, computer mice, pencils, and other office equipment, as well as various breeds of dogs, cats, horses, and other animals.

AlexNet was first published in 2012, and has become a well-known model in the research community.



» Learn more about pretrained networks

An Example Using AlexNet

You can use AlexNet to classify objects in any image. In this example, we'll use it to classify objects in an image from a webcam installed on a desktop. In addition to MATLAB®, we'll be using the following:

- Neural Network Toolbox™
- Support package for using webcams in MATLAB
- Support package for using AlexNet

After loading AlexNet we connect to the webcam and capture a live image.

```
camera = webcam; % Connect to the camera

nnet = alexnet;  % Load the neural net

picture = camera.snapshot;
% Take a picture
```

Next, we resize the image to 227x227 pixels, the size required by AlexNet.

```
picture = imresize(picture,[227,227]);
% Resize the picture
```

AlexNet can now classify our image.

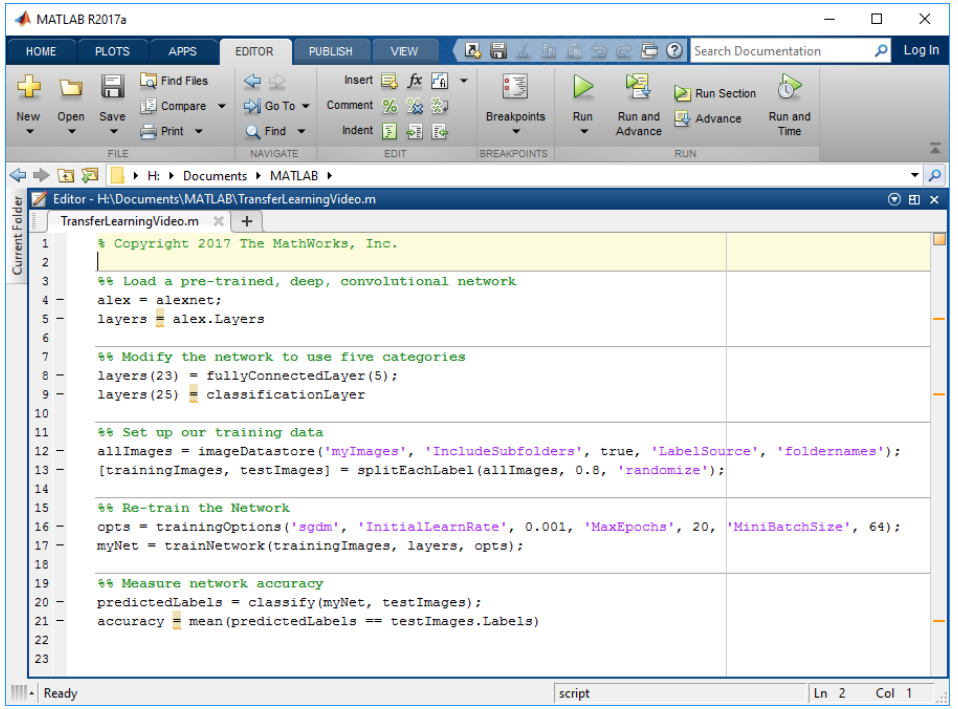
```
label = classify(nnet, picture);
% Classify the picture

image(picture);      % Show the picture

title(char(label)); % Show the label
```

» Watch how-to video: Deep Learning in 11 Lines of MATLAB Code

Retraining an Existing Network

In the previous example, we used the network straight out of the box. We didn't modify it in any way because AlexNet was trained on images similar to the ones we wanted to classify.

To use AlexNet for objects not trained in the original network, we can retrain it through *transfer learning*. Transfer learning is an approach that applies knowledge of one type of problem to a different but related problem. In this case, we simply trim off the last 3 layers of the network and retrain them with our own images.



If transfer learning doesn't suit your application, you may need to train your own network from scratch. This method produces the most accurate results, but it generally requires hundreds of thousands of labeled images and considerable computational resources.

» Get started with transfer learning

Computational Resources for Deep Learning

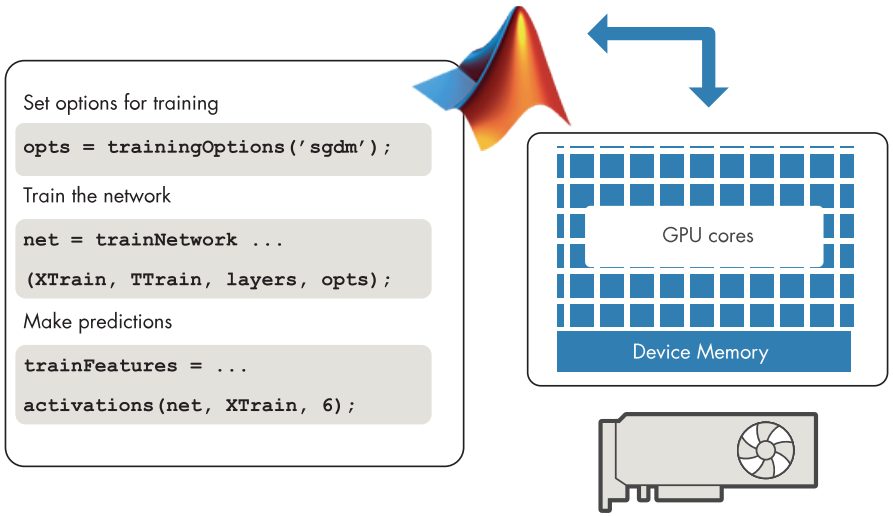
Training a deep learning model can take hours, days, or weeks, depending on the size of the data and the amount of processing power you have available. Selecting a computational resource is a critical consideration when you set up your workflow.

Currently, there are three computation options: CPU-based, GPU-based, and cloud-based.

CPU-based computation is the simplest and most readily available option. The example described in the previous section works on a CPU, but we recommend using CPU-based computation only for simple examples using a pretrained network.

Using a GPU reduces network training time from days to hours. You can use a GPU in MATLAB without doing any additional programming. We recommend an NVidia® 3.0 compute-capable GPU. Multiple GPUs can speed up processing even more.

Cloud-based GPU computation means that you don't have to buy and set up the hardware yourself. The MATLAB code you write for using a local GPU can be extended to use cloud resources with just a few settings changes.



» Learn more about deep learning with big data on GPUs

More Deep Learning Resources

Introduction to Deep Learning

Deep Learning with MATLAB: Quick-Start Videos

Start Deep Learning Faster Using Transfer Learning

Transfer Learning Using AlexNet

Introduction to Convolutional Neural Networks

Create a Simple Deep Learning Network for Classification

Deep Learning for Computer Vision with MATLAB

Cancer Diagnostics with Deep Learning and Photonic Time Stretch

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