Deep Learning
Machine Learning

What is Machine Learning?

"Field of study that gives computers the ability to learn without being explicitly programmed"

---Arthur Samuel
**Machine Learning**

**Types of Machine Learning**

- **Supervised**: Task driven (Regression / Classification)
- **Unsupervised**: Data driven (Clustering)
- **Reinforcement**: Algorithm learns to react to an environment
Machine Learning

Supervised Learning Model

$H_\theta(x) = \theta_0 + \theta_1 x$

How to choose $\theta_i$?

<table>
<thead>
<tr>
<th>Size of House</th>
<th>Price of House</th>
</tr>
</thead>
<tbody>
<tr>
<td>950</td>
<td>$123,325</td>
</tr>
<tr>
<td>1,535</td>
<td>$156,570</td>
</tr>
<tr>
<td>1,605</td>
<td>$158,895</td>
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<tr>
<td>1,905</td>
<td>$200,025</td>
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<tr>
<td>2,057</td>
<td>$230,384</td>
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<tr>
<td>2,227</td>
<td>$233,835</td>
</tr>
<tr>
<td>3,150</td>
<td>$261,420</td>
</tr>
<tr>
<td>3,620</td>
<td>$433,500</td>
</tr>
</tbody>
</table>

Housing Price Prediction

(Credit: Andrew Ng/Stanford University)
Deep Learning

Deep learning (also known as deep structured learning, hierarchical learning or deep machine learning) is a branch of machine learning based on a set of algorithms that attempt to model high-level abstractions in data by using multiple processing layers, with complex structures or otherwise, composed of multiple non-linear transformations.

--- from WIKI
Deep Learning in industry

Driverless car  Face identification  Speech recognition  Web search

Google  Facebook  Alibaba  Huawei  Intel

Microsoft  Baidu  Tencent  AMD
Deep Learning

Good **features** essential for successful machine learning: 90% effort

Handcrafting features VS learning features?

Deep learning allows computational models that are composed of multiple processing layers to learn representations of data with multiple levels of abstraction.

Extracting local features and combining them to form higher order features.
Why going deep?

- Data are often high-dimensional.
- There is a huge amount of structure in the data, but the structure is too complicated to be represented by a simple model.
- Insufficient depth can require more computational elements than architectures whose depth matches the task.
- Deep nets provide simpler but more descriptive models of many problems.
Layered Visual System

David Hubel and Torsten Wiesel found the animal’s visual system is layered:

Retina $\rightarrow$ Area V1 $\rightarrow$ Area V2 $\rightarrow$ Area V4 $\rightarrow$ ...

Orientation Selective Cell: be activated when pupils sensing the edges of the object and the edges pointing to the specific orientation.
Why not use features with pixels scale?

The features with pixels scale have almost no value for us.
Shallow feature representation

Consistent with David Hubel and Torsten Wiesel’s finding
Feature abstraction

Features learned from training on different object classes.
Example

Deep Neural Network

Input Layer

Hidden Layer 1

Hidden Layer 2

Hidden Layer 3

Output Layer

edges

combinations of edges

object models
Deep Learning

Conventional machine-learning techniques were limited in their ability to process natural data in their raw form.

Deep-learning methods are representation-learning methods with multiple levels of representation, obtained by computing simple but non-linear modules that each transform the representation at one level (staring with the raw input) into a representation at a higher, slightly more abstract level.

Deep learning discovers intricate structure in large data sets by using the backpropagation algorithm to indicate how a machine should change its internal parameters that are used to compute the representation in each layer from the representation in the previous layer.
Deep Learning

Various deep learning architectures such as:

- deep neural networks
- convolutional deep neural networks
- deep belief networks
- recurrent neural networks

have been applied to fields like computer vision, automatic speech recognition, natural language processing, audio recognition and bioinformatics where they have been shown to produce state-of-the-art results on various tasks.

**convolutional deep neural networks**

Predicting the sequence specificities of DNA-and RNA-binding proteins by deep learning (Nature Biotech)
Convolutional Neural Networks

Four key ideas behind convolutional neural networks:

- Local connections
- Shared weights
- Pooling
- Use of many layers
Local connection

- Spatial correlation is local
- Better to put resources elsewhere!

Local receptive field
Shared Weights

What if that 1M hidden units shared a same set of weights called a filter bank?

ONLY 100 parameters!!!

Still too many parameters!
Shared Weights

Only 1 feature was detected
All units in a feature map share the same filter bank, different feature maps in a layer use different filter banks.

Why?
1. Local groups of values are often highly correlated, forming distinctive local motifs that are easily detected
2. The local statistic of images and other signals are invariant to location
**Shared Weights**

If a motif can appear in one part of the image, it could appear anywhere, hence the idea of units at different locations sharing the same weights and detecting the same feature in different parts of the image.

Mathematically, the filtering operation performed by a feature map is a discrete convolution.
Shared Weights

Image

Convolved Feature
**Pooling**

Hidden neurons (output from feature map)

- Simply the information in the output from the convolutional layers
- Merge semantically similar features into one

The relative positions of features forming a motif can vary somewhat, reliably detecting the motif can be done by coarse-graining the position of each feature.

E.g., each unit in the pooling layer may summarize a region of (say) 2x2x2 neurons in the previous layer.

The pooling allows representations to vary very little when elements in the previous layer vary in position and appearance.
Convolutional Neural Networks

Raw data $\rightarrow$ \{Convolution $\rightarrow$ Pooling\}(can be multi-times) $\rightarrow$ fully connected neural network $\rightarrow$ output
Thanks!