Advanced Machine Learning and Deep Learning

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Deep Learning

What is Deep Learning?

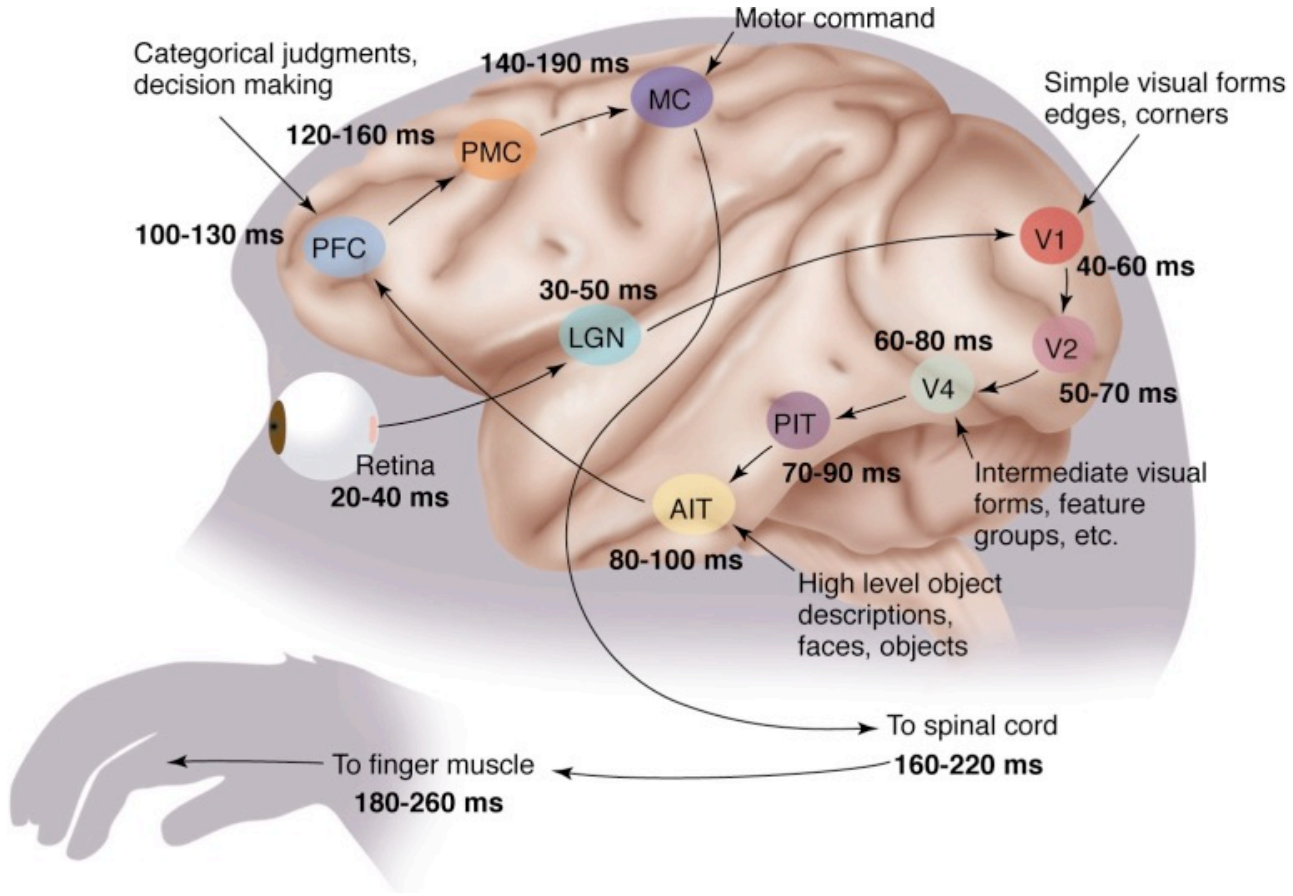
- **What is Deep learning?**
- **Short (inaccurate) Answer:** A **wide** and **deep** ***Neural Network*** with many hidden layers and neurons.
- **General Answer:** A type of Machine Learning that tries to learn ***multiple levels of features or representations*** of the data. Higher level features are derived from lower level features to form a hierarchical representation (the input of each layer is the output from previous layer).

Why Deep Learning?

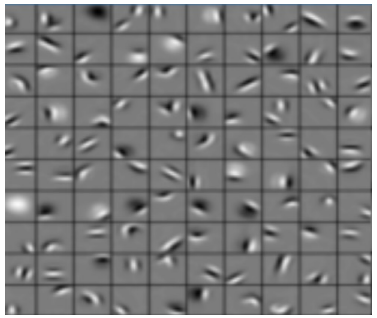
- **Motivations**:
- Most of machine learning algorithms work based on human-designed input features (**handcrafted features**).
  - E.g. HOG, SIFT, SURF features for computer vision and object detection
- One of the promises of **deep learning** is to replace handcrafted features with efficient algorithms for **feature learning** and **hierarchical feature extraction**.
- Deep learning tries to use a series of layers between input and output to ***learn*** and ***extract*** the best features.
- **This is how our Brain works!!!**

This is what happens in our Brain too!!!

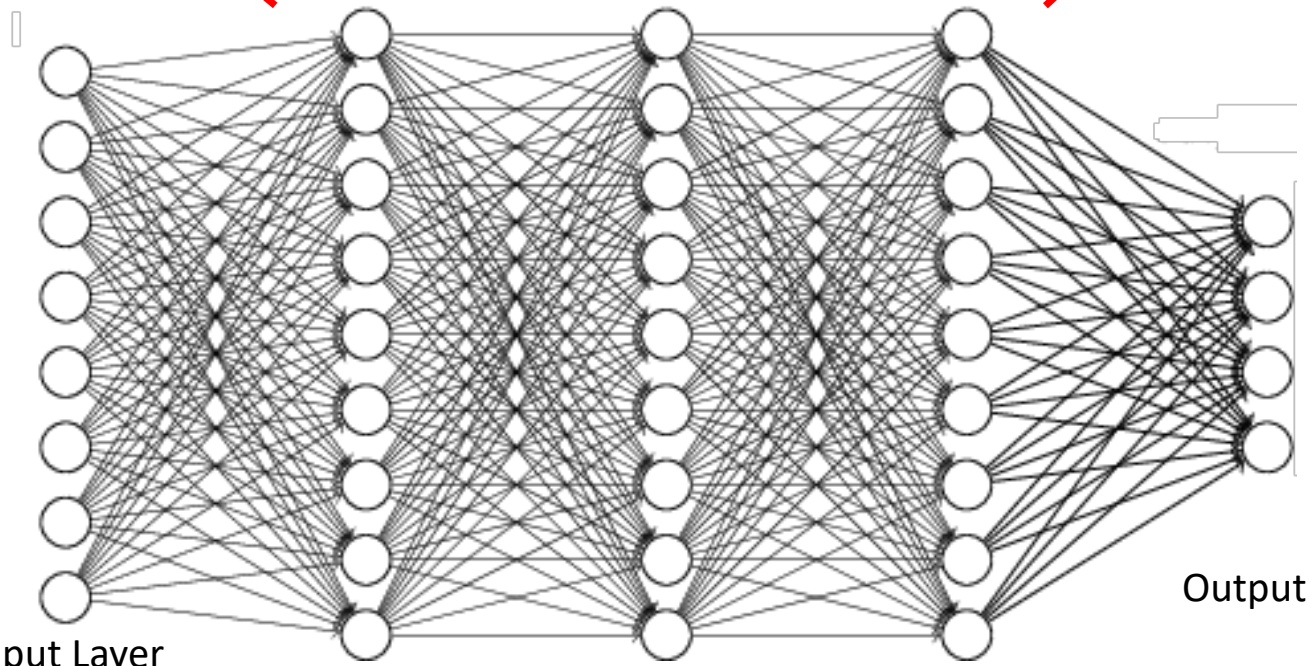
- The first layer of neurons in the cortex that receives visual signals from retina are sensitive to detect edges. The next brain layers in the visual pipeline are sensitive to detect more complex patterns such as face.



[Figure Ref]: Simon Thorpe



Training Data



Input Layer

Hidden Layer1

Hidden Layer2

Hidden Layer N

Output Layer

Reasons to Explore Deep Learning

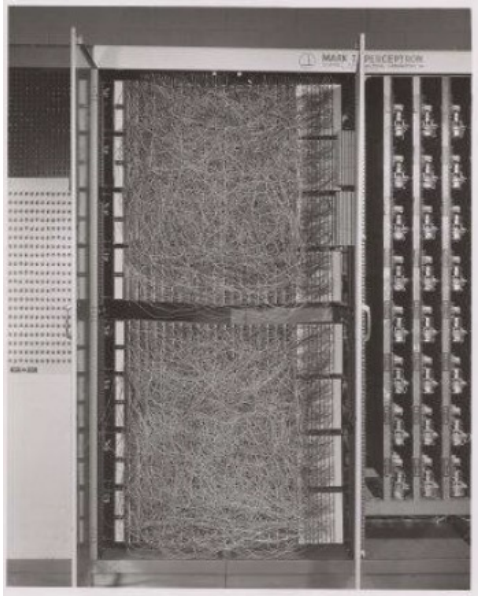
1. We need Feature Learning because Hand-crafted Features are time-consuming and inefficient.
2. Many Deep Learning methods are unsupervised. Unsupervised Learning is important because most of the available data (almost all data!) is unlabeled!
3. Biologically inspired by human brain: The brain has a deep multiple layer architecture.
4. The results have shown that it works very well!

[Ref]: Socher and Manning (Stanford Univ.), Deep Learning for NLP, NAACL.

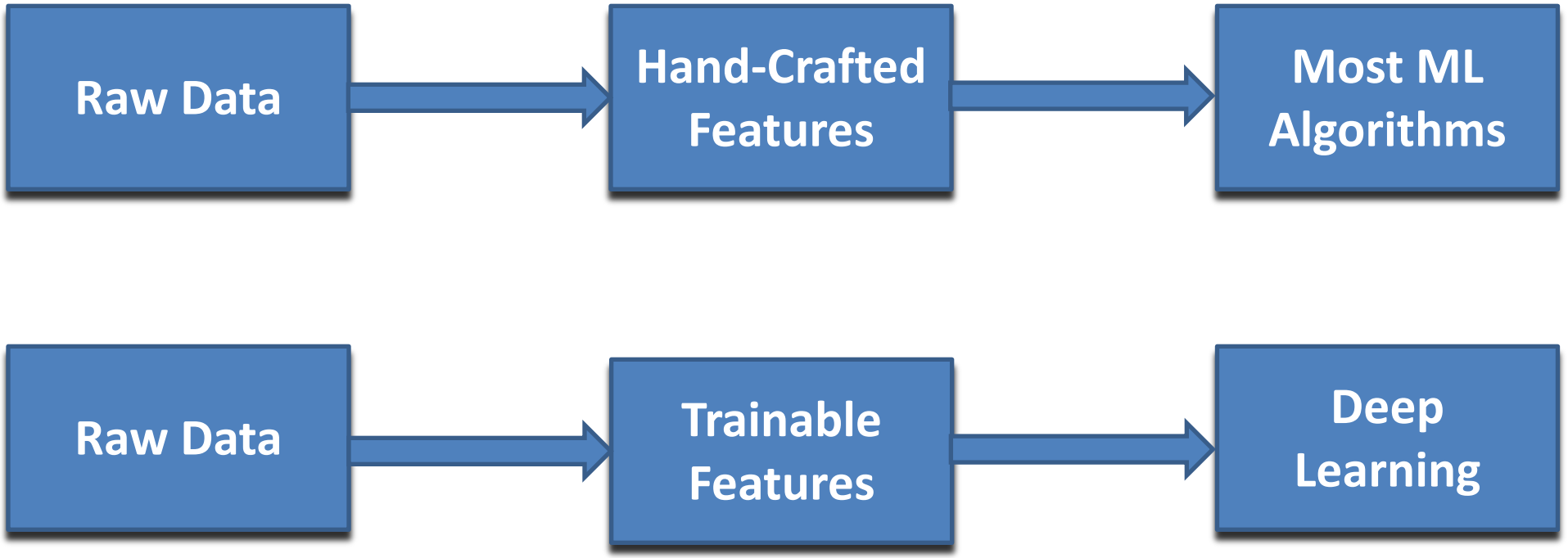
Why Now?

- Why are these algorithms so important now?

- **What changed?**
  - **Computational Power**
  - **Data Size**
  - **More Importantly: New Techniques for training Deep Neural Networks.**

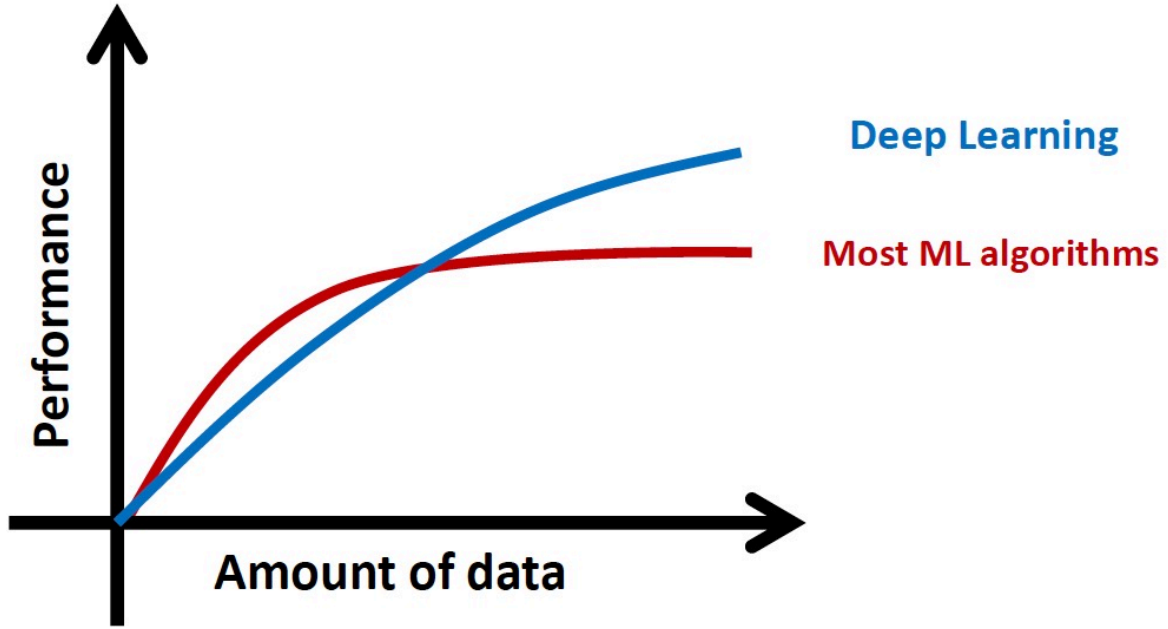


Deep Learning vs. Others!



Deep Learning vs. Others!

- **So, Why not always Deep Learning?**
  1. **For low to medium size data, other ML algorithms beat deep learning!**
  2. **Deep Learning is computationally expensive (sometimes it is not practical for some applications! Sometimes it is not worth it!)**



[Figure Source]: Andrew Ng.

Some Famous Examples

Example: Google Brain

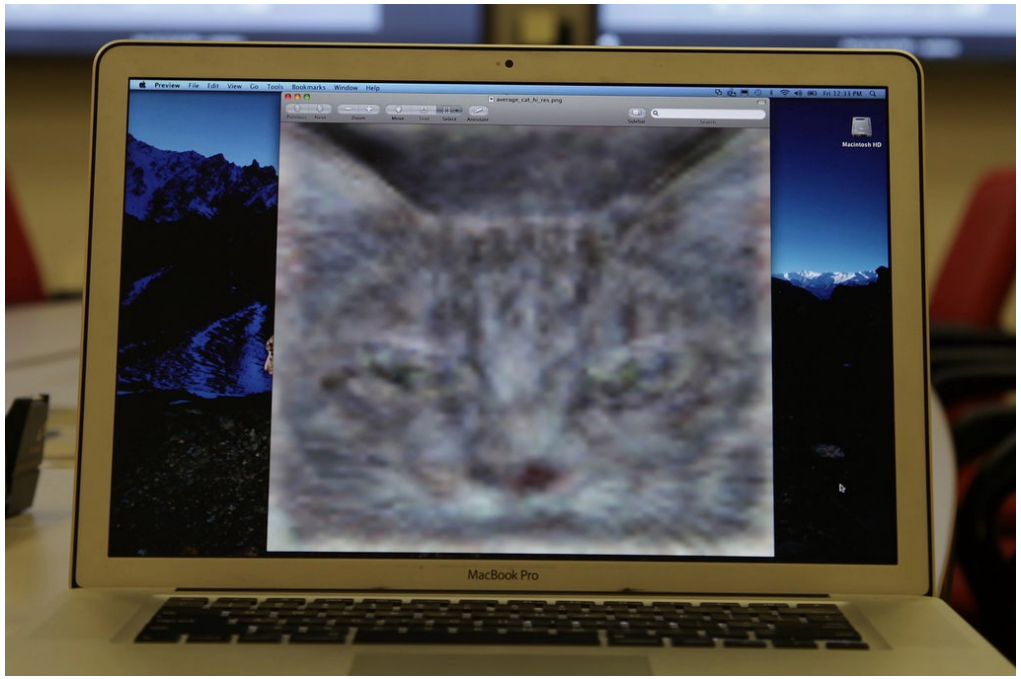
- The "**Google Brain**" project began in 2011 as a research collaboration on **deep learning** between *Google Fellow Jeff Dean* and *Stanford University professor Andrew Ng*.
- In 2012, the **New York Times** reported that a group of 16,000 computers dedicated to mimicking human brain had successfully trained itself to recognize a “cat” based on 10 million **unlabeled** images taken from YouTube videos.

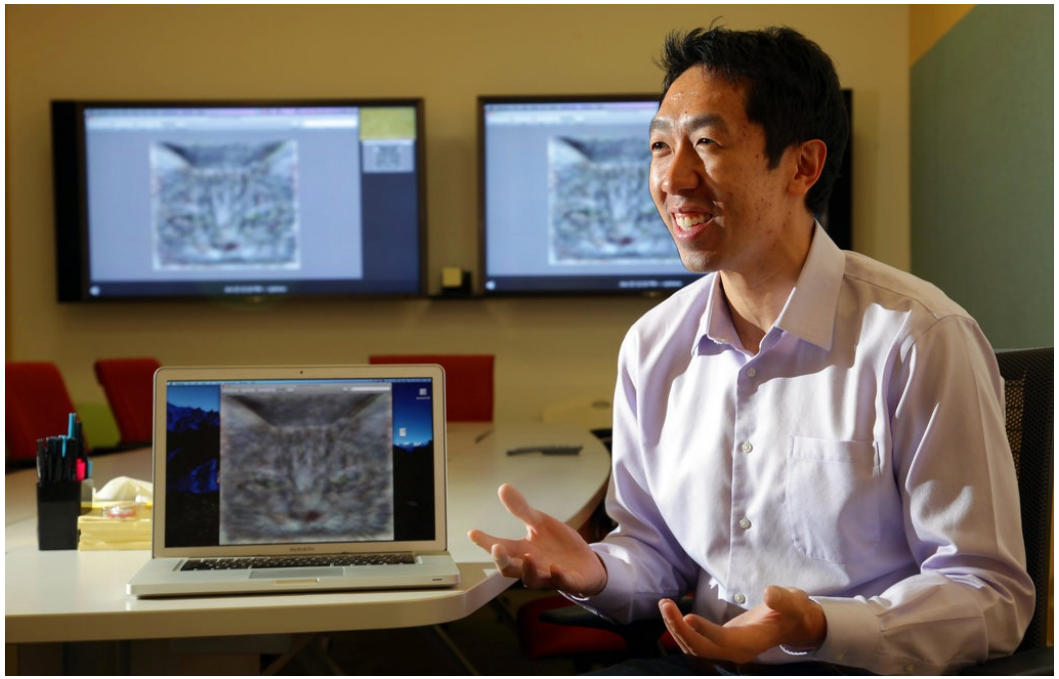
- **They used Unsupervised Learning! (the images were unlabeled!)**
- **So, no one told the algorithm during training that which image was the image of a cat!**
- **But, the algorithm could still learn the concept of a cat !!!!!!!**

[Ref]: https://en.wikipedia.org/wiki/Google_Brain

Example: Google Brain

"We never told it during the training, 'This is a cat,' " said Dr. Dean.



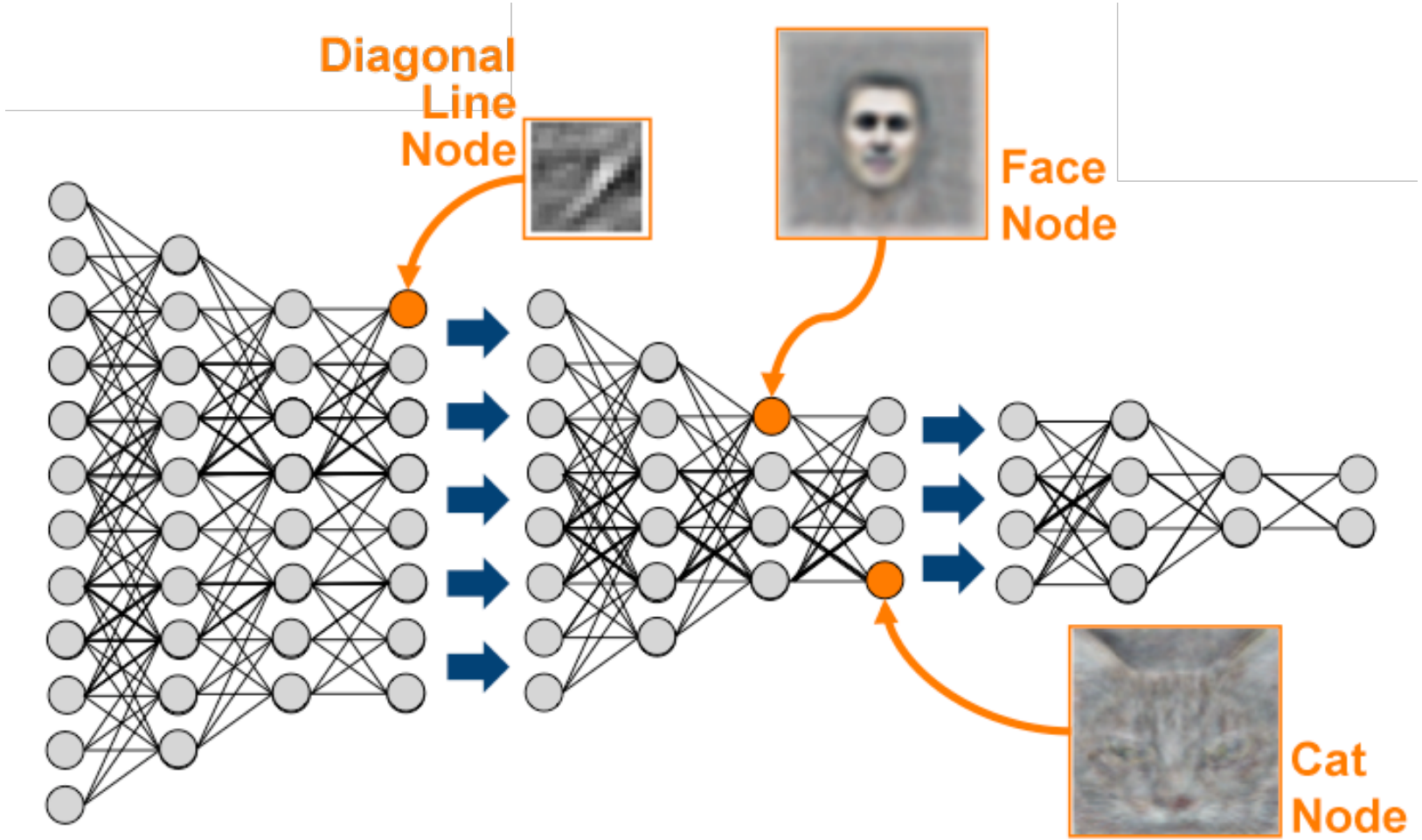


Dr. Andrew Ng, Stanford Univ.

[Ref]: http://www.nytimes.com/2012/06/26/technology/in-a-big-network-of-computers-evidence-of-machine-learning.html?pagewanted=all

Example: Google Brain

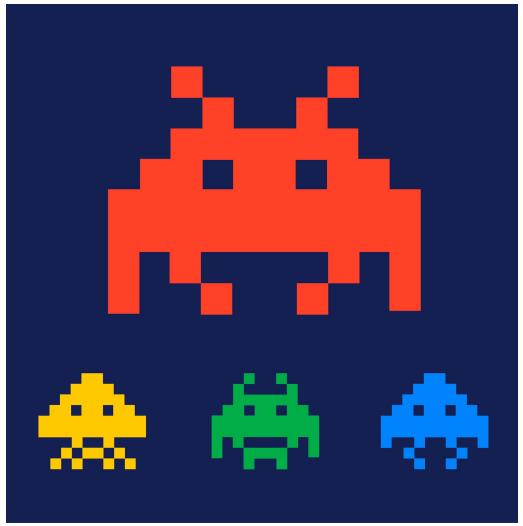
Training Data

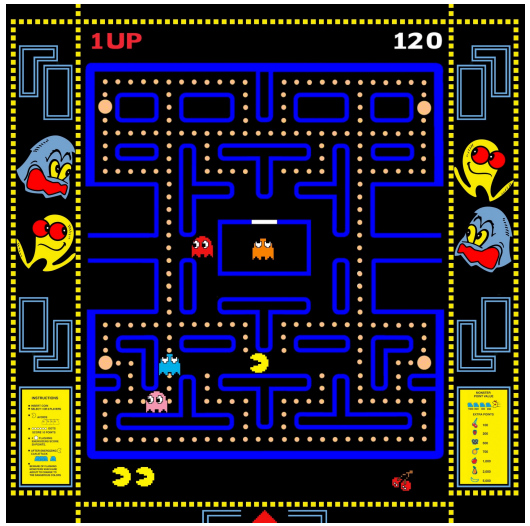


[Figure Source]: Google Brain

Example: Google DeepMind

- **DeepMind Technologies** is an AI company founded in 2010. It was acquired by **Google** in 2014.
- The company has created a **neural network** that learns how to play video games similar to humans, and also mimics the short-term memory of the human brain.





Example: Google DeepMind

- The most important thing is that the algorithm does NOT know the concept of the game and rules. Nobody told the algorithm how to play!
- The neural network based algorithm (deep reinforcement learning) trains itself how to play just by receiving the pixels on the screen with the goal to maximize the score!!!
- Outperforms humans in over 30 Atari games!

- Demo: www.youtube.com/watch?v=V1eYniJ0Rnk

Example: Google DeepMind

- **In 2016, the DeepMind's neural network based program AlphaGo beat a human professional Go player for the first time!!!**

[Image Source]: The Guardian

The Big Players!

Geoffrey Hinton, University of Toronto, Google.

Yann LeCun, New York University, Facebook.

Andrew Ng, Stanford, Coursera, Baidu, Google, Landing AI.

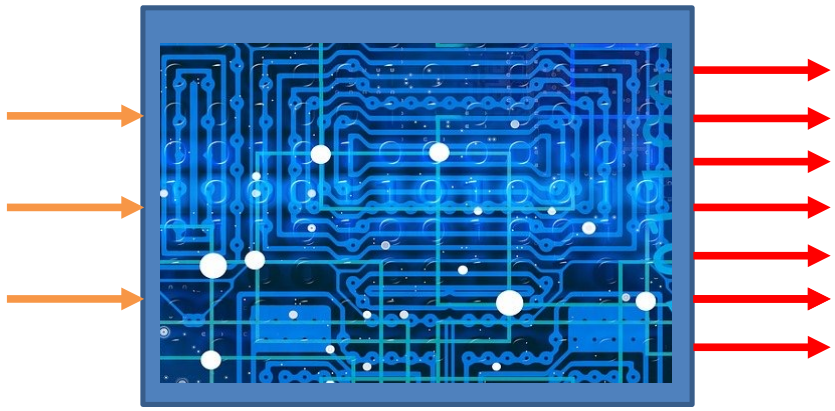
Yoshua Bengio, Université de Montréal.

The Big Players!

Review: Artificial Neural Networks

- **Artificial Neural Networks (ANN)**, or simply called **Neural Networks** are a family of Artificial Intelligence models/methods **inspired by the human's nervous system, particularly the brain.**
- **Neural Network** algorithms try to mimic the brain!
- **Neural Networks** are able to learn from data and generate models that get a number of inputs and map them to the desired outputs in an optimal way.

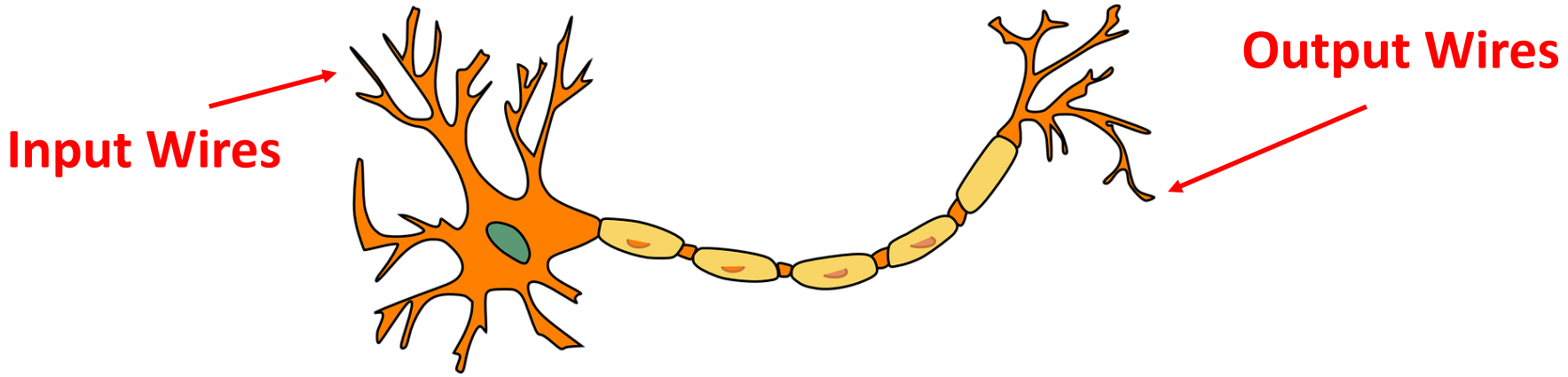
ANN



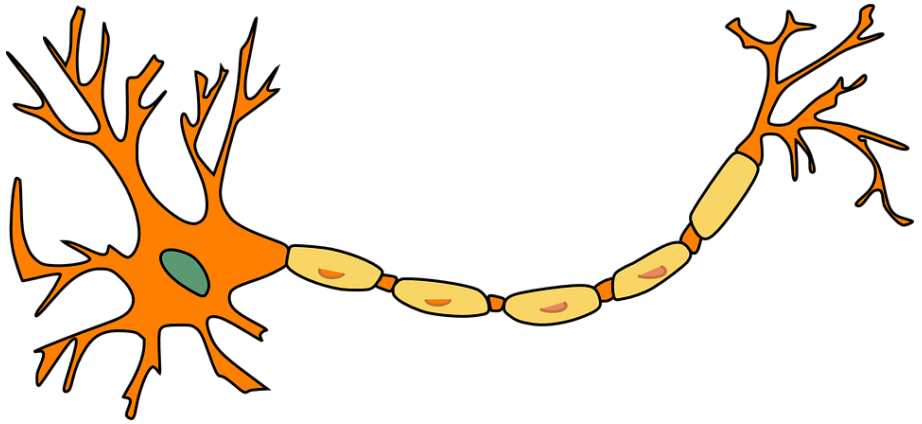
The Brain

Review: Neurons

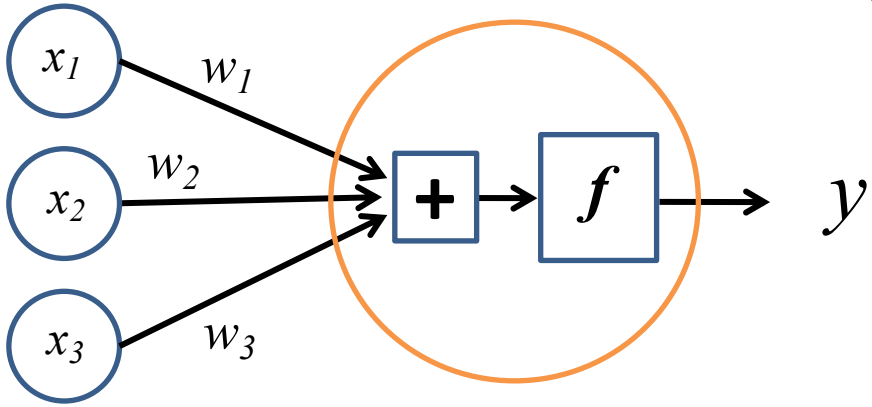
- **Artificial Neural Networks** are developed by **simulating of Neurons** (nerve cells), and then **Network of Neurons** in the human nervous system.



First Step in ANN: Simulating a Neuron

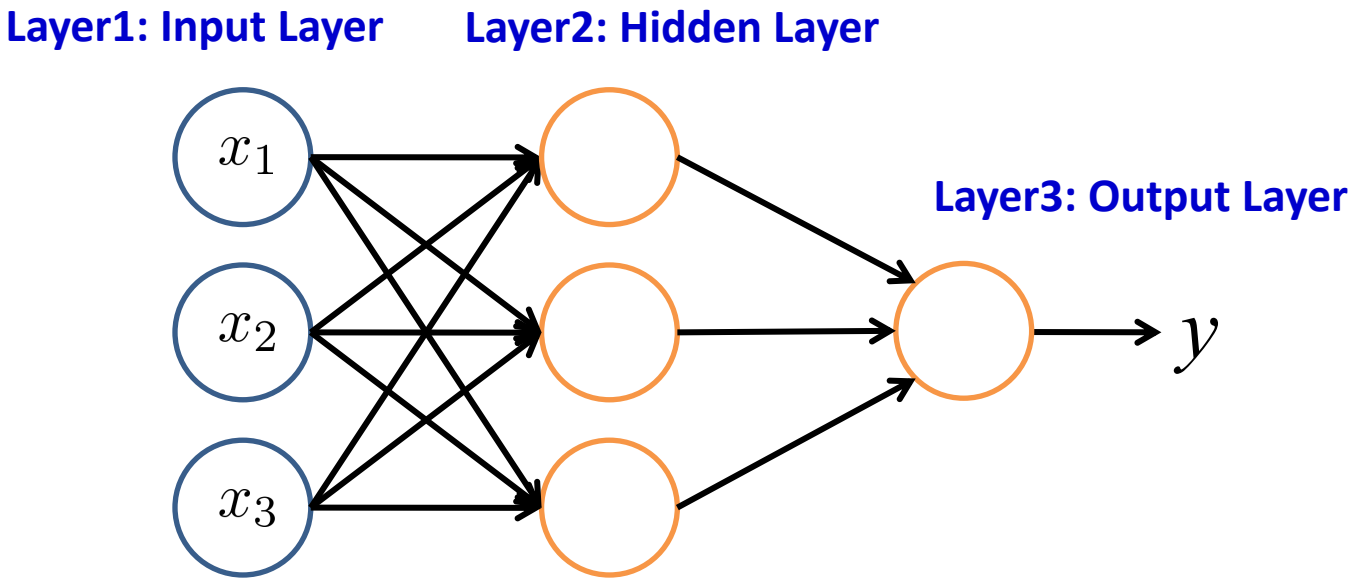


$$y = f(w_0 b + \sum_{i=1}^{N} x_i w_i)$$



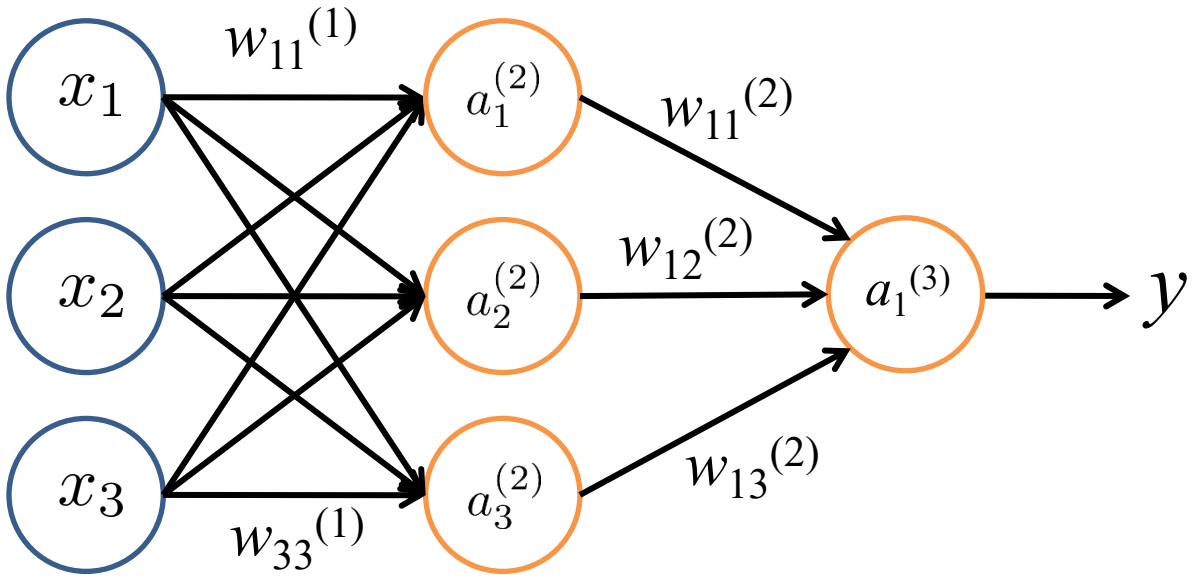
Review: Neural Networks

- Similar to the human brain, an artificial neural network is formed by connecting multiple artificial neurons.
- The first layer is called **Input Layer**. The input layer neurons are to only pass and distribute the inputs and perform no computation.
- The last layer is called **Output Layer**. The middle layers are called **Hidden Layers**.



A Very Cool Interpretation of ANN Model!

- In the following ANN structure, if we forget about the first layer, and just focus on the last two layers, how does it look like?



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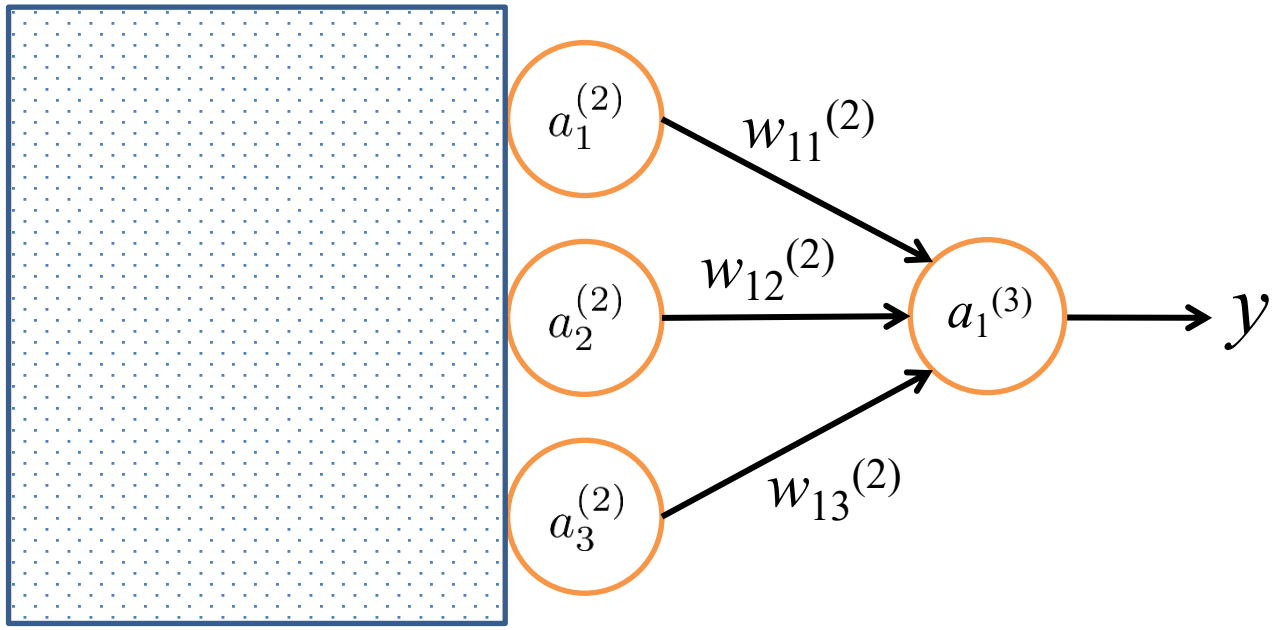


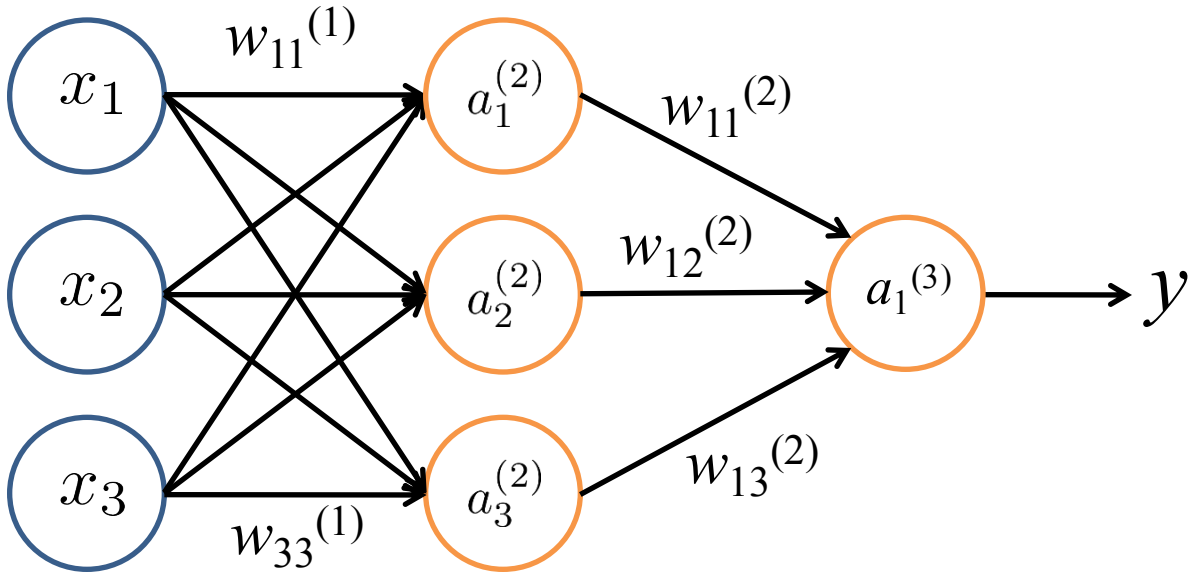
$$y = g\left(w_{10}^{(2)} b^{(2)} + w_{11}^{(2)} a_1^{(2)} + w_{12}^{(2)} a_2^{(2)} + w_{13}^{(2)} a_3^{(2)}\right)$$

What does it look like?

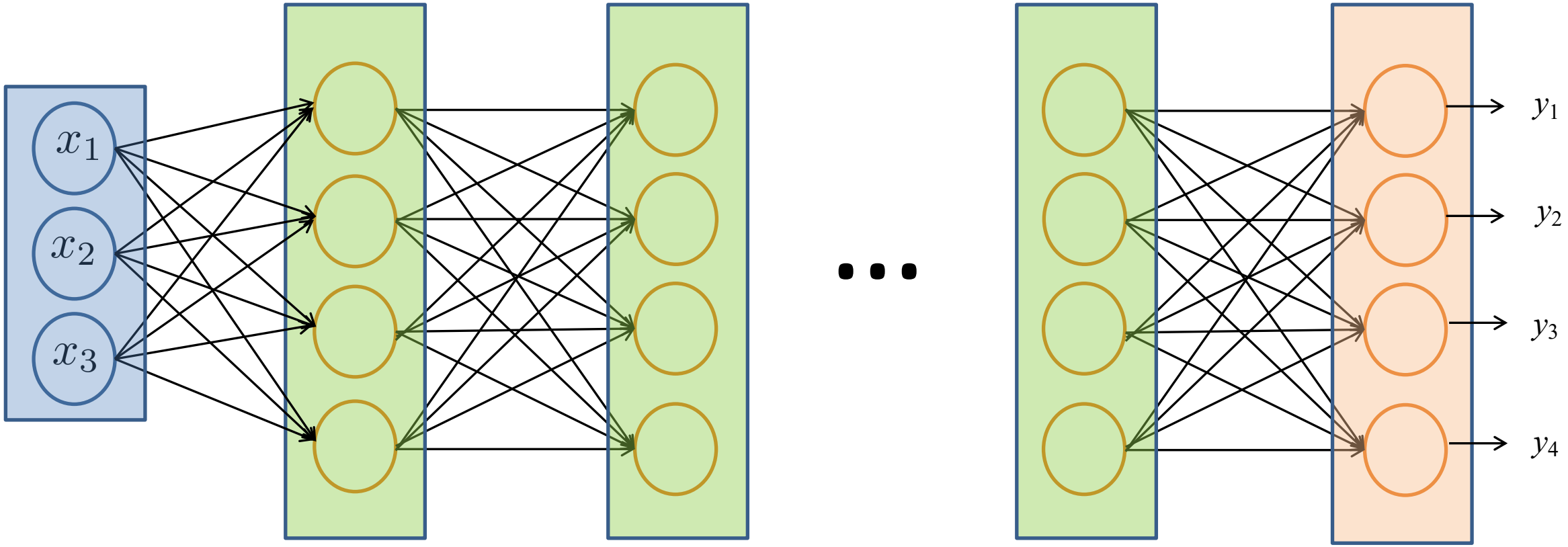
Answer: Logistic Regression!!!!

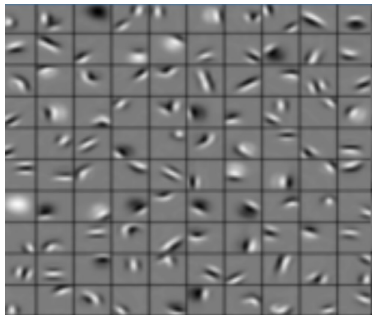
A Very Cool Interpretation of ANN Model!

- In fact, **ANN** acts like **logistic regression**. The important difference is that, rather than just using raw input features, ANN processes the input features, find the best combination of them as new features (**learns and extract its own features**), and eventually use them for classification!



- **A *Deep Neural Network* usually includes several hidden layers:**





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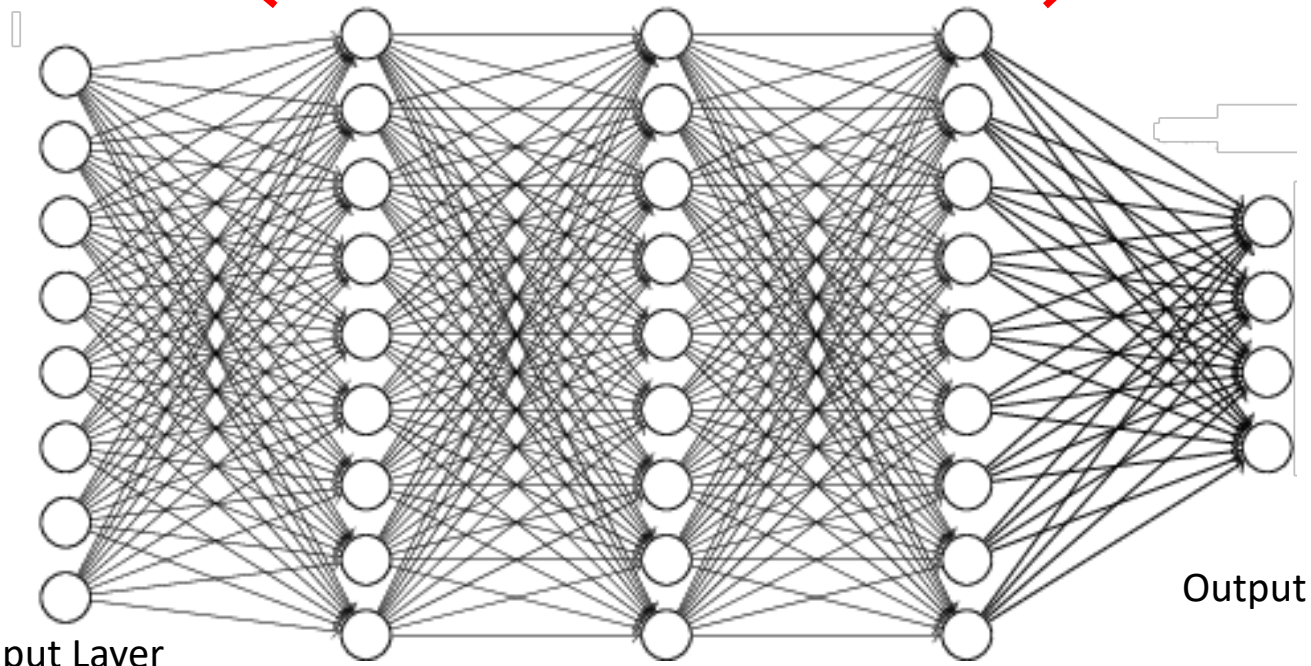


Input Layer

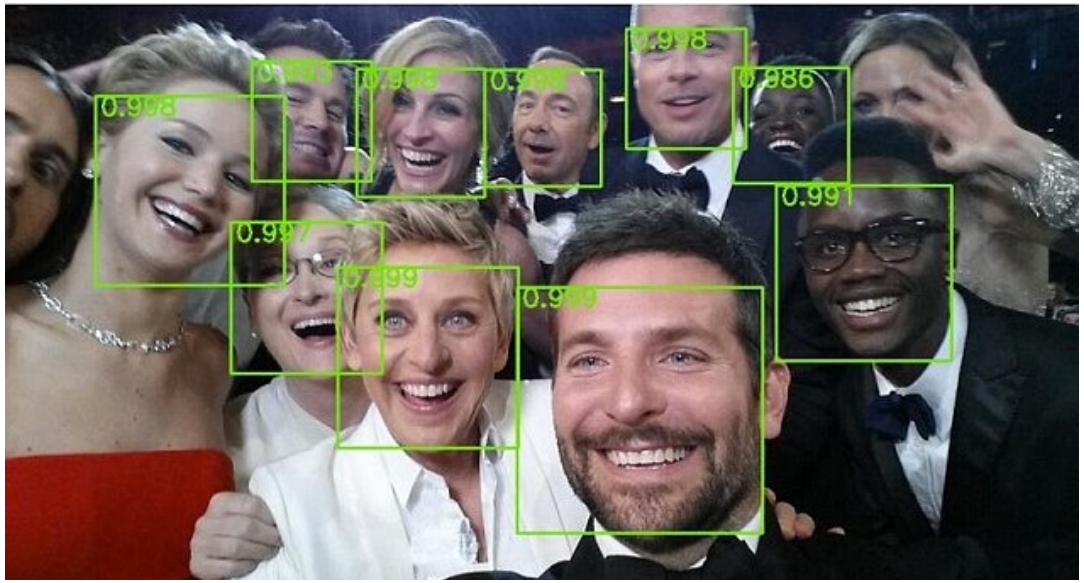
Hidden Layer1

Hidden Layer2

Hidden Layer N

Output Layer

Example: Face Recognition



[Image Source]: Ellen DeGeneres on Twitter

Thank You!

Questions?