Machine Learning

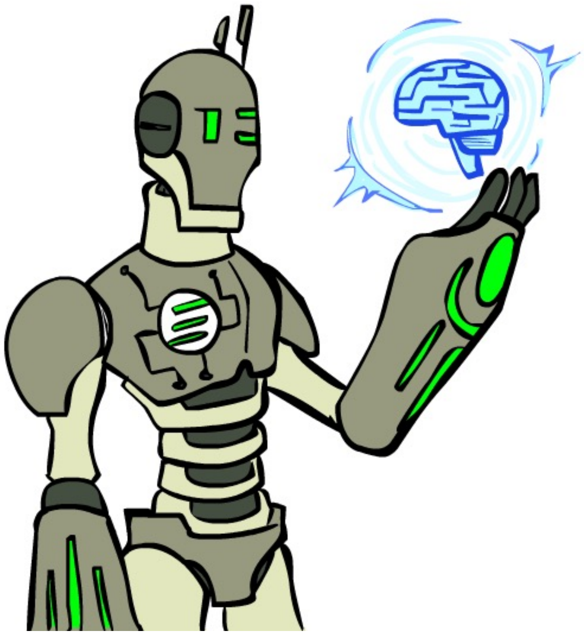
Chapter 10: Deep Learning

Fall 2021

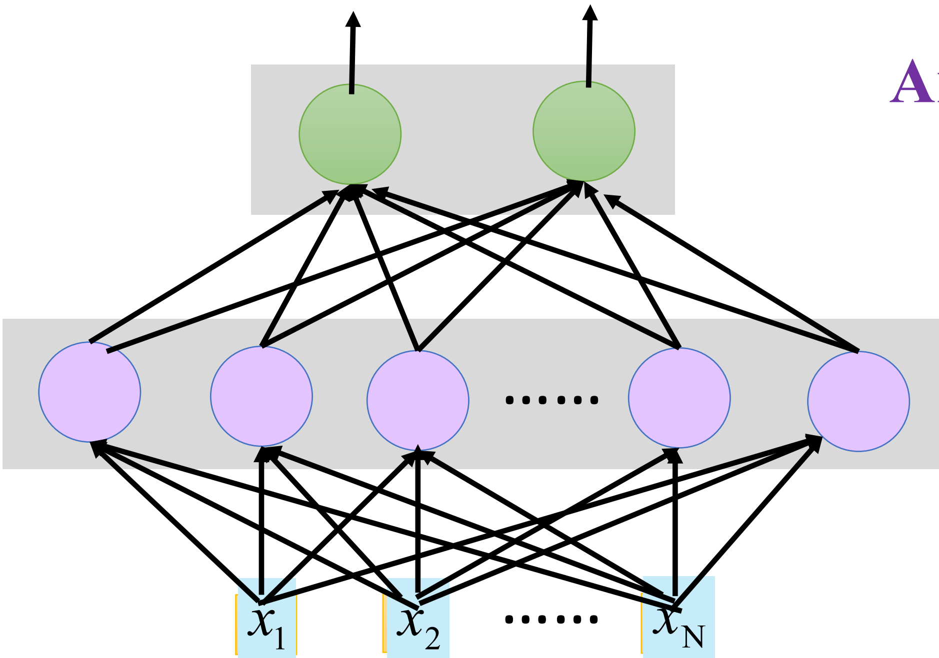
Instructor: Xiaodong Gu

Today

- Deep Learning



Recall: Neural Networks



Any continuous function f

$$f : R^N \to R^M$$

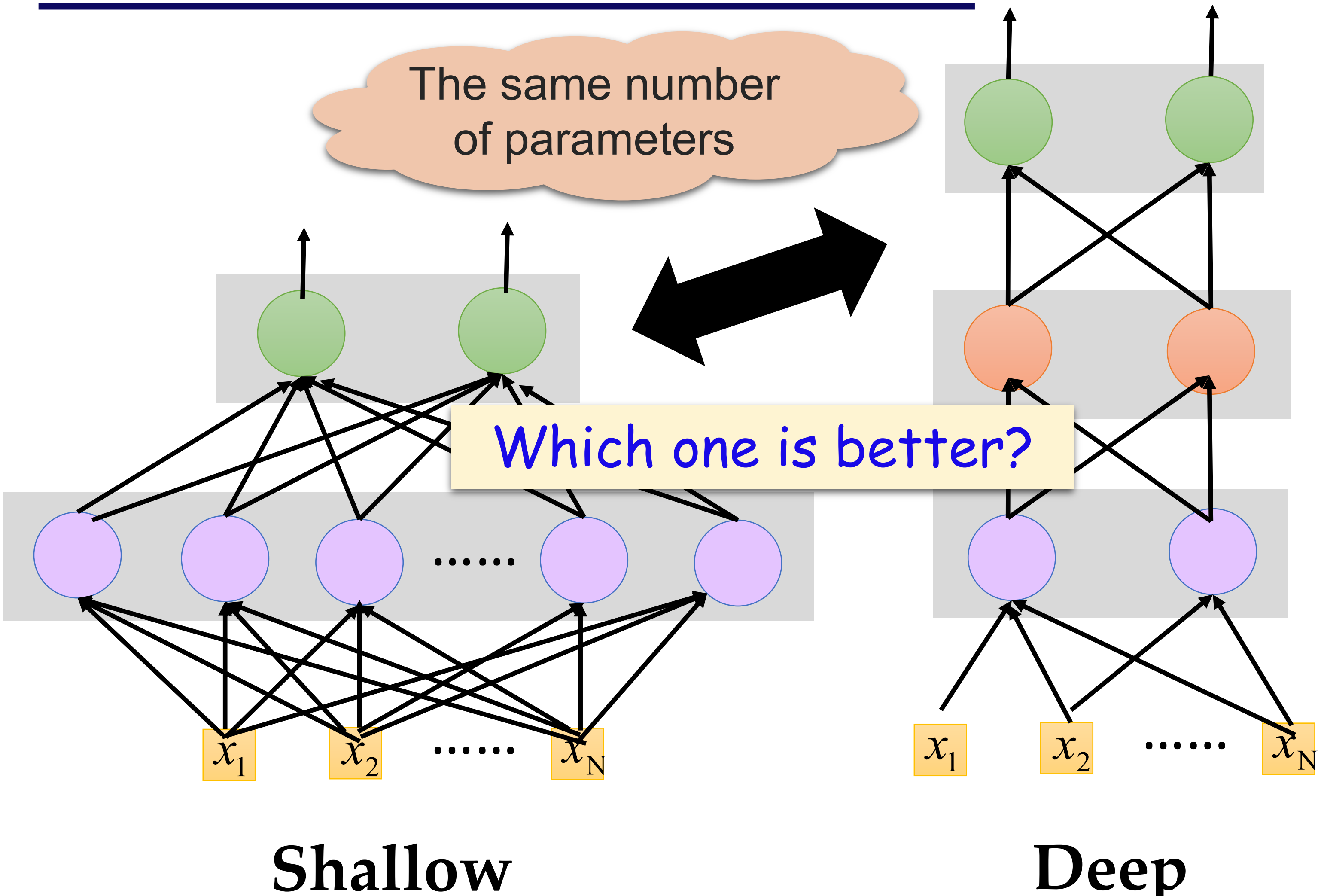
can be realized by an NN with one hidden layer.

(given **enough** hidden neurons)

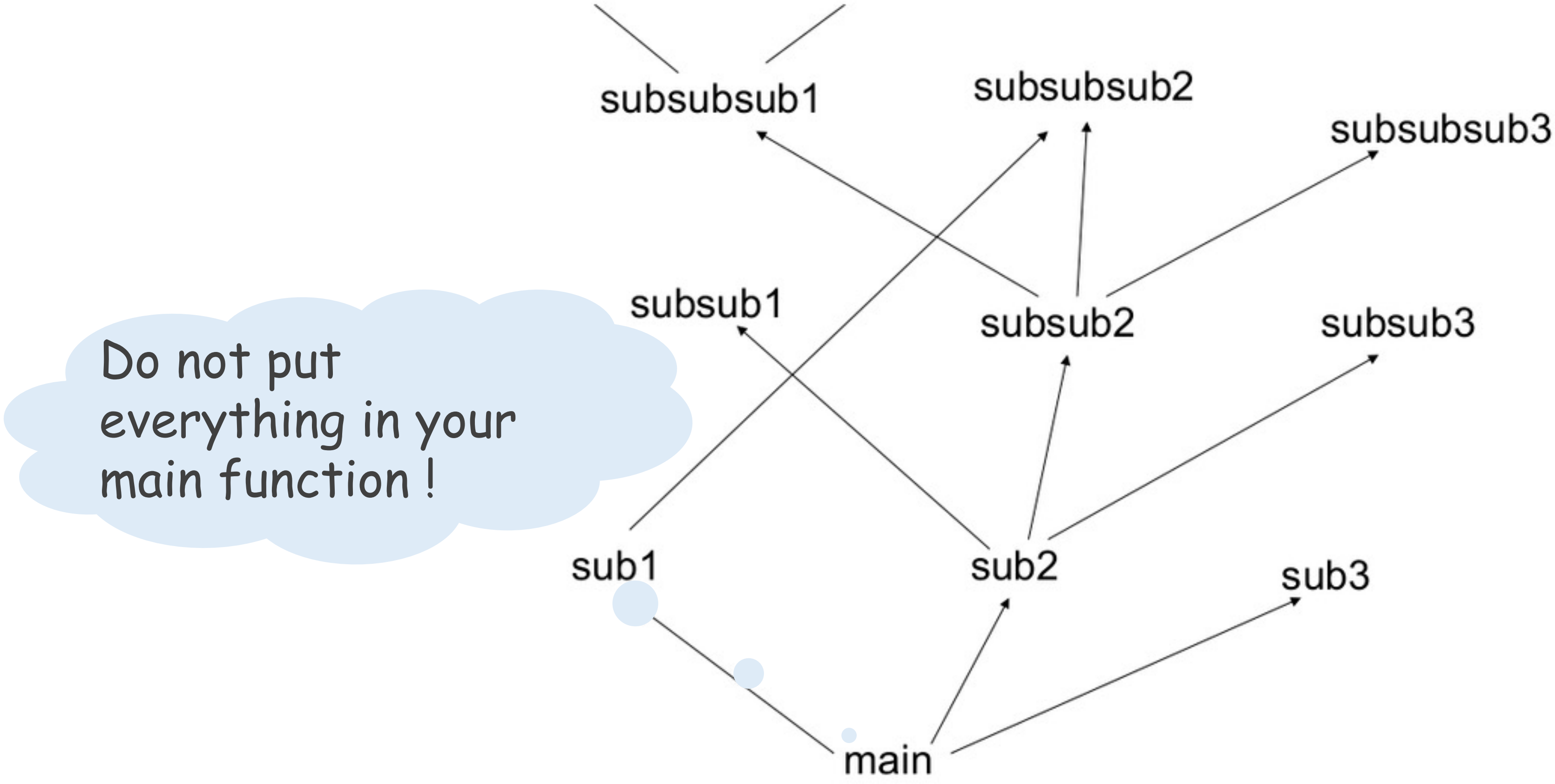
NNs with one hidden layer can represent **every** function.

So?

The Deeper, The Better?

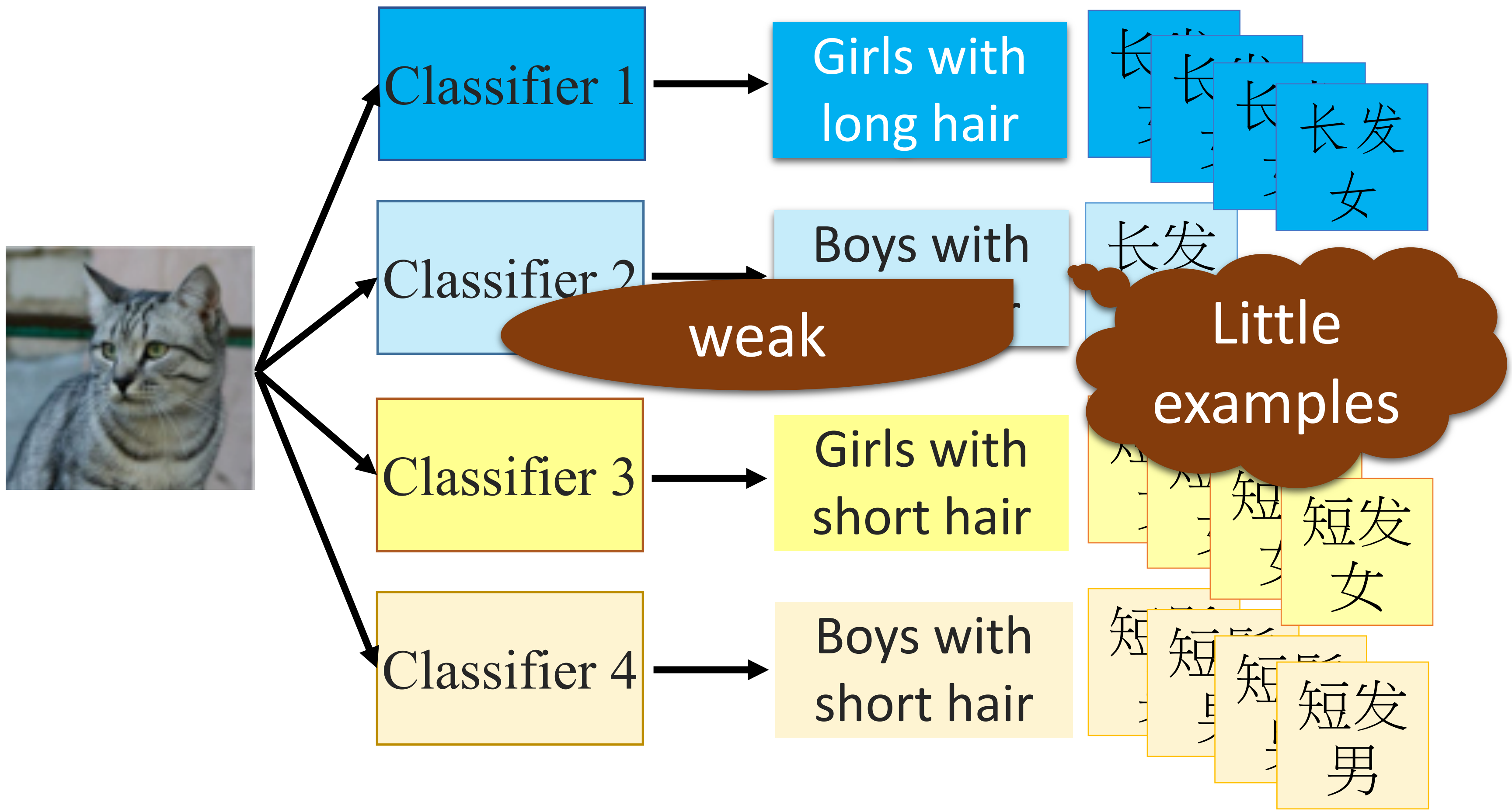


Idea: Modularization



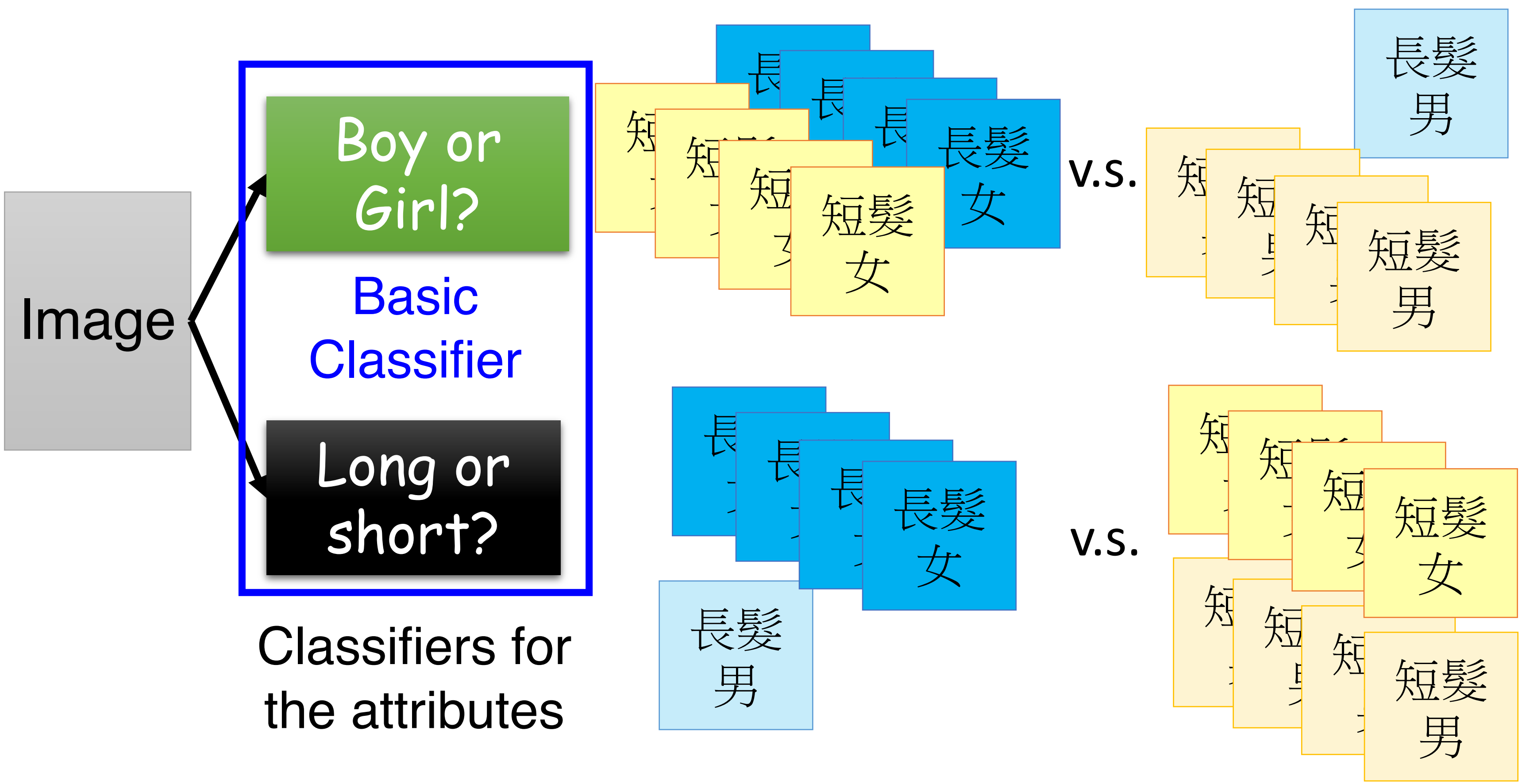
http://rinuboney.github.io/2015/10/18/theoretical-motivations-deep-learning.html

Idea: Modularization



Idea: Modularization

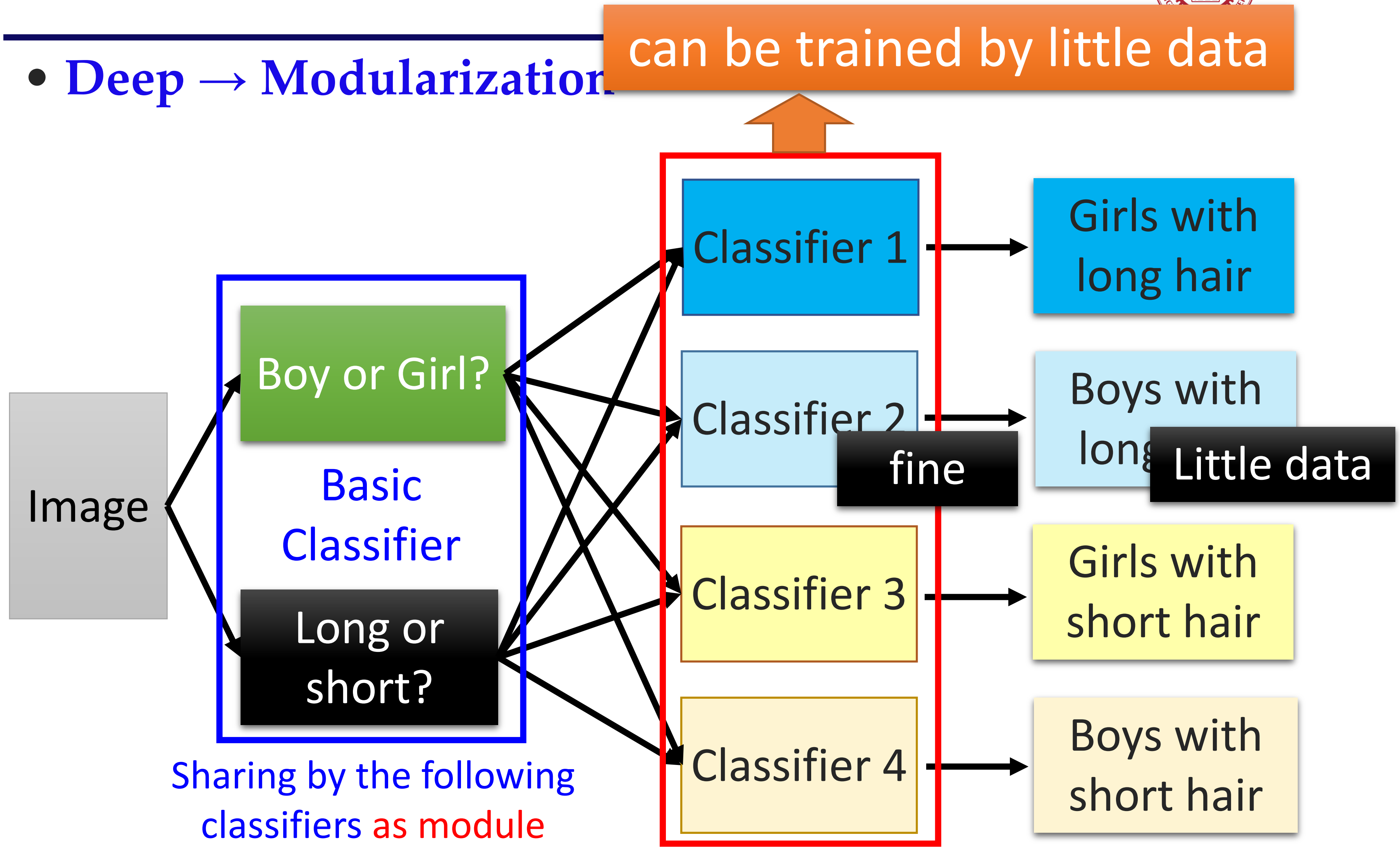
Each basic classifier can have sufficient training examples.



Classifiers for the attributes

Idea: Modularization

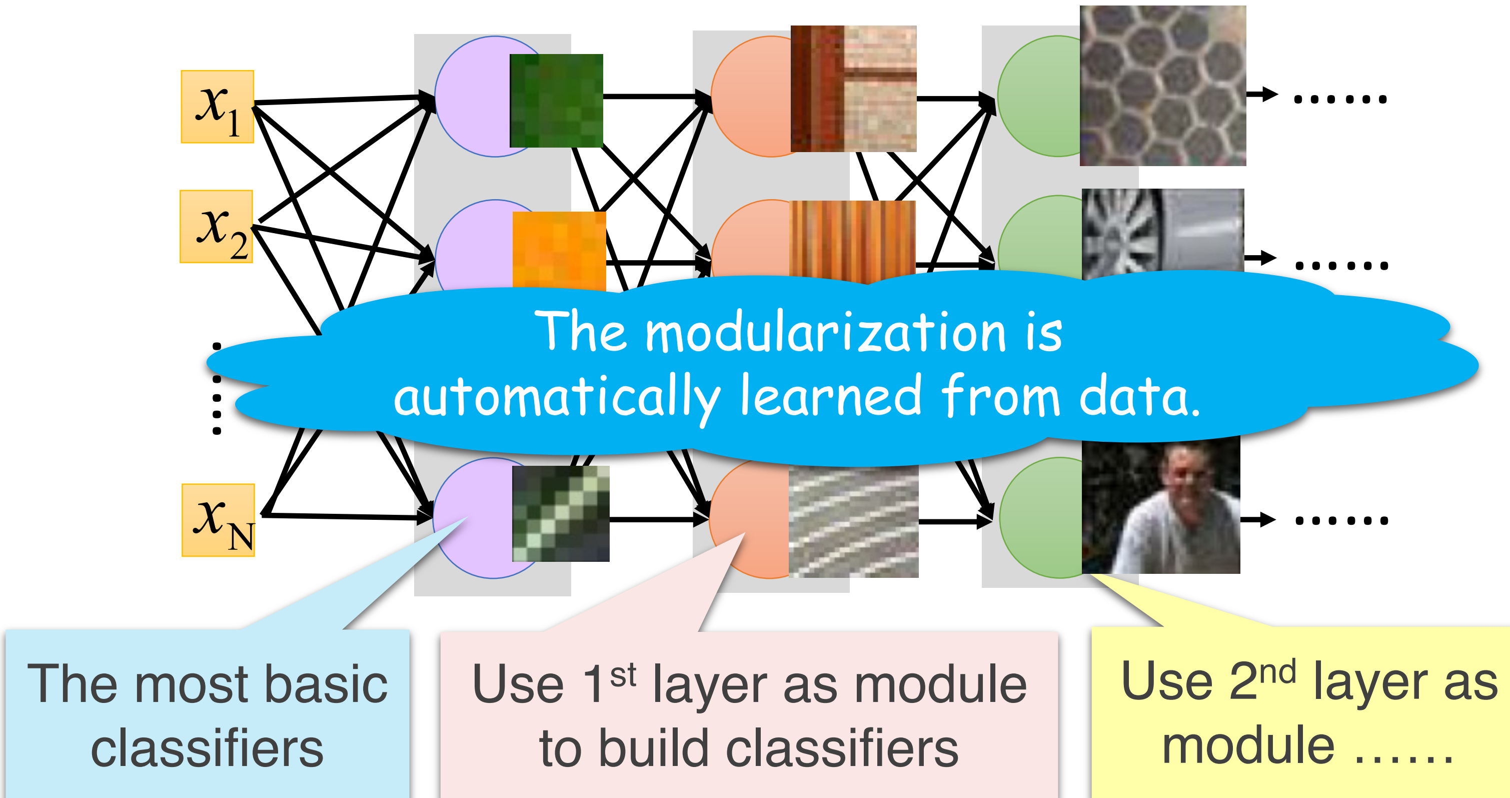
- **Deep → Modularization**



Modularization - Image

- **Deep → Modularization**

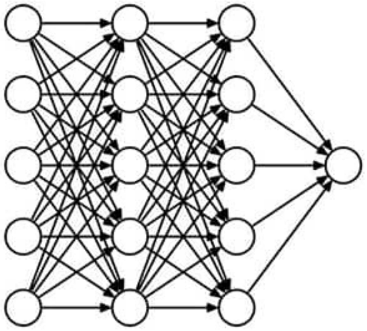
→ Less training data?



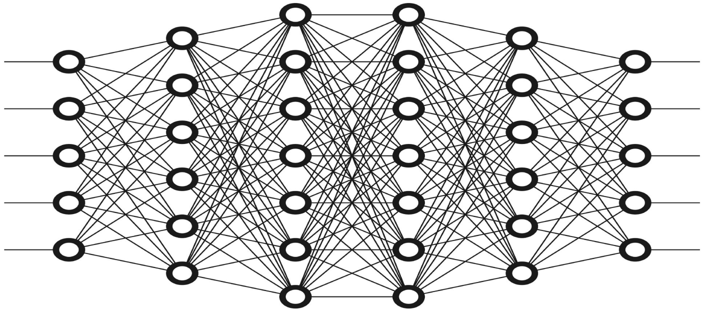
Zeiler, M. D., & Fergus, R. Visualizing and understanding convolutional networks. In *ECCV 2014*

The Deeper, The Better

So, shallow network can represent any functions.



However, using deep structures is more effective.



Reference for the reason: http://neuralnetworksanddeeplearning.com/chap4.html

Deep Learning

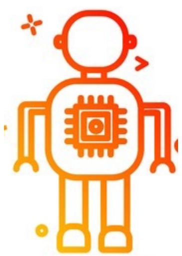
What is Deep Learning?

- **Deep learning** (deep machine learning, or deep structured learning, or hierarchical learning, or sometimes DL) is a branch of machine learning based on a set of algorithms that attempt to <u>model high-level abstractions</u> in data by using model architectures, with complex structures or otherwise, composed of multiple non-linear transformations.

What is Deep Learning ?

Artificial Intelligence

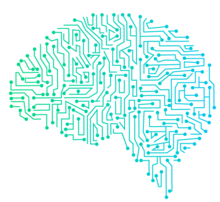
Computer systems that perform tasks that would usually require human intelligence



Machine Learning

Statistical techniques that learn from a series of inputs and outputs

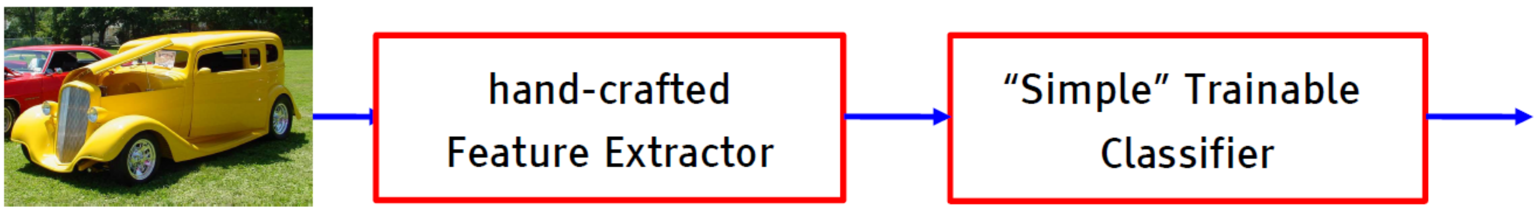
Deep Learning



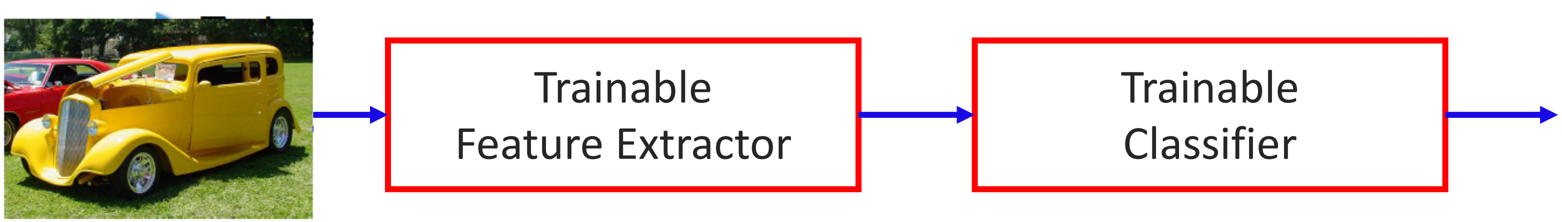
Machine learning algorithms that enable self learning of data representations

Deep Learning = Learning Representations/Features of Data

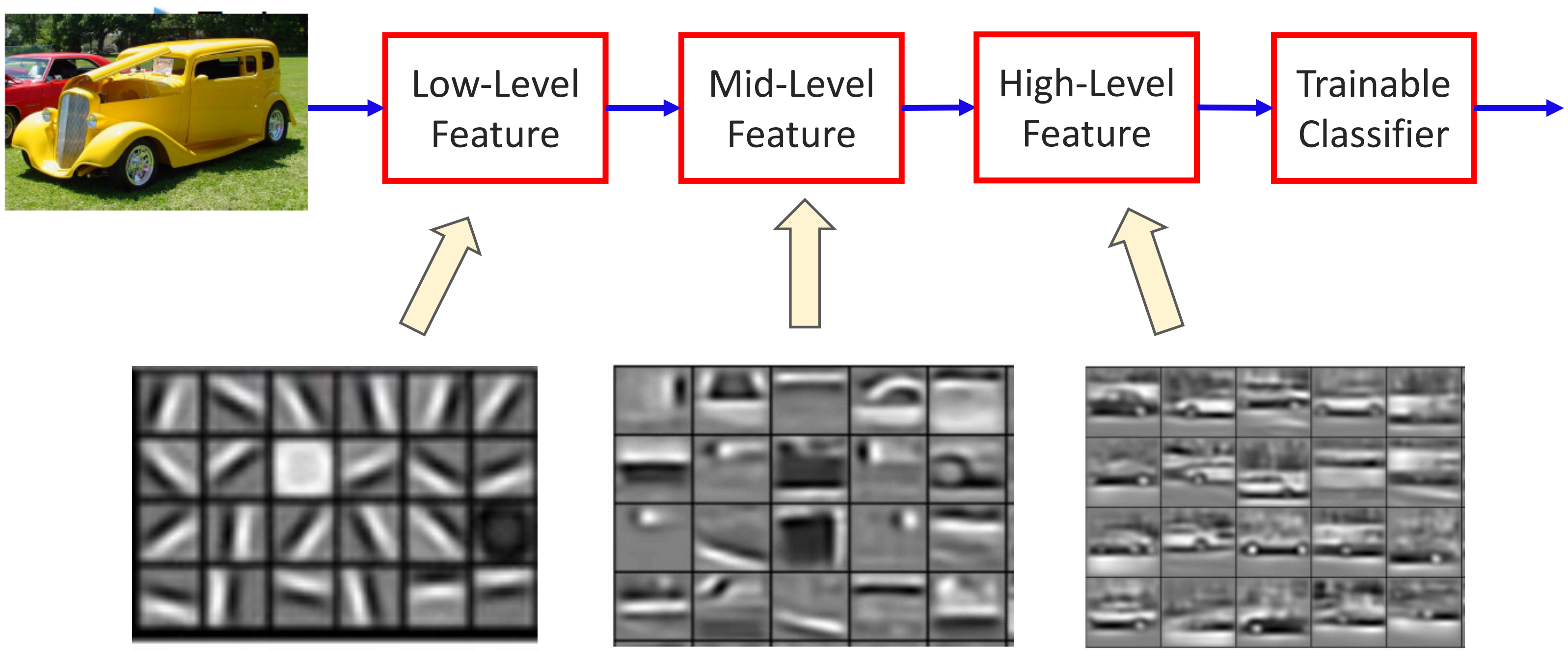
- The traditional model of pattern recognition (since the late 50's)
  - ▶ **fixed/engineered** features + **trainable** classifier



- Deep Learning/ Feature learning / End-to-end Learning
  - ▶ **trainable** features + **trainable** classifier



Deep Learning = Learning Hierarchical Representations



Hierarchical Representations with Increasing Level of Abstraction

- Image recognition

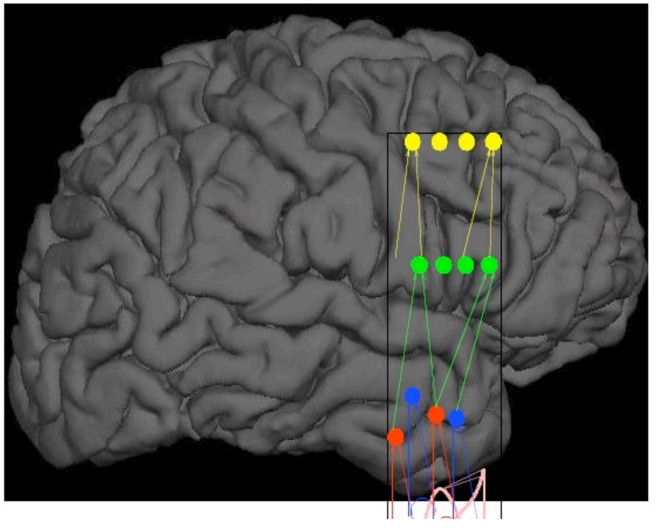
  pixel → edge → texton → motif → part → object

- Speech

  sample → spectral band → sound → phone → word…

- Text

  character → word → phrase → clause → sentence → paragraph → document



Human brains also has a deep architecture.

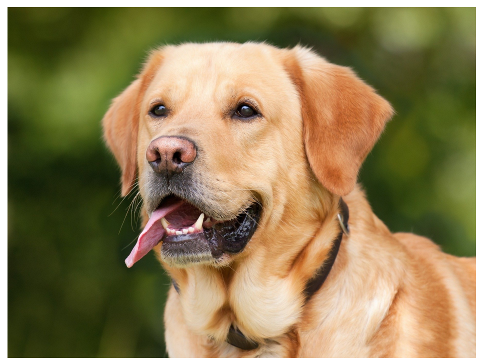
Humans first learn simpler concepts and then compose them into complicated ones.

From concepts to consciousness?

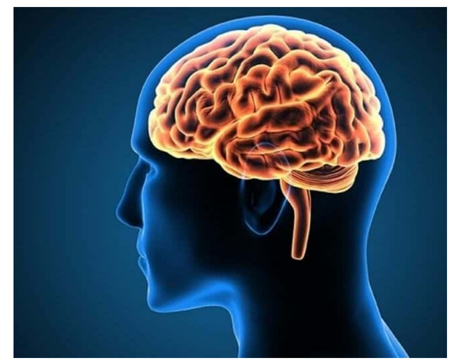
- The worlds of different species.

leaves,
wetness,…

self-awareness、
color, taste,
movement



happiness, sorrow,
anxiety, depression

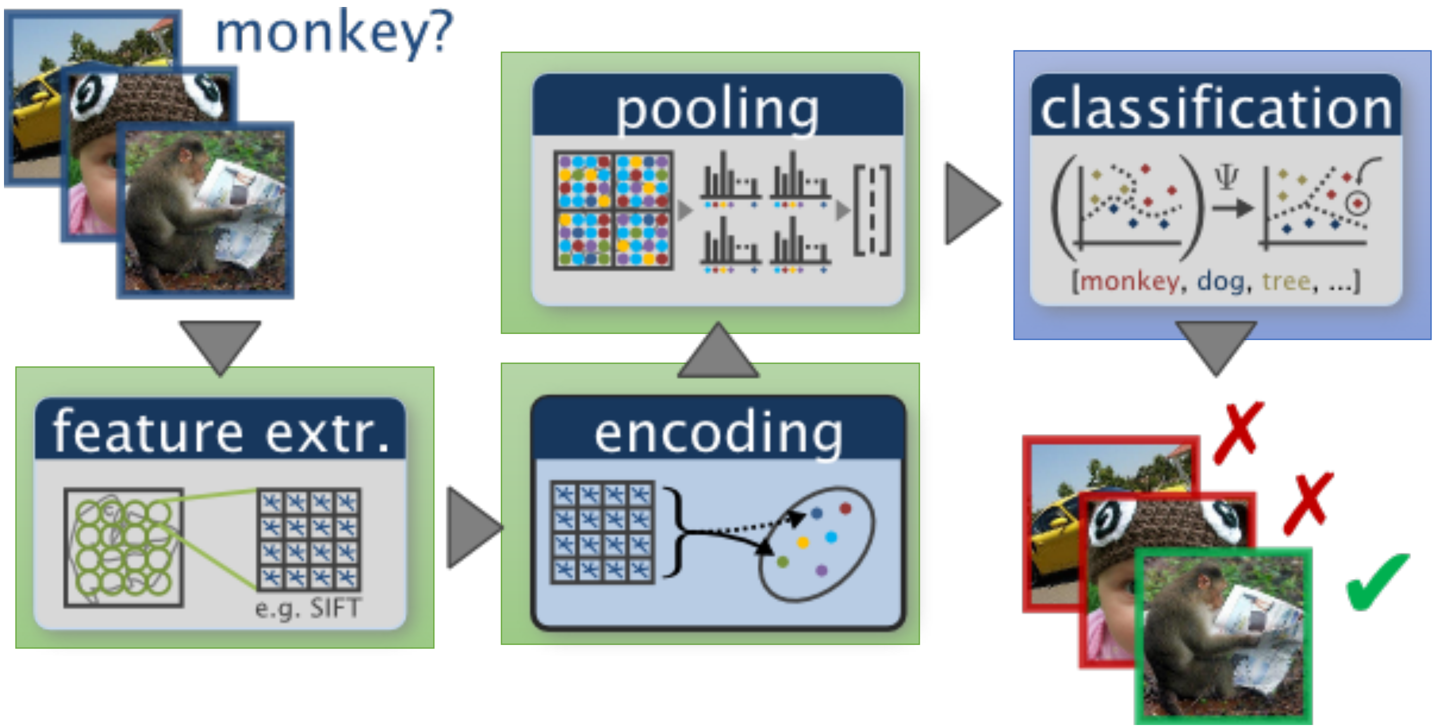


(complexity of neurons)

Life is about hierarchical representations

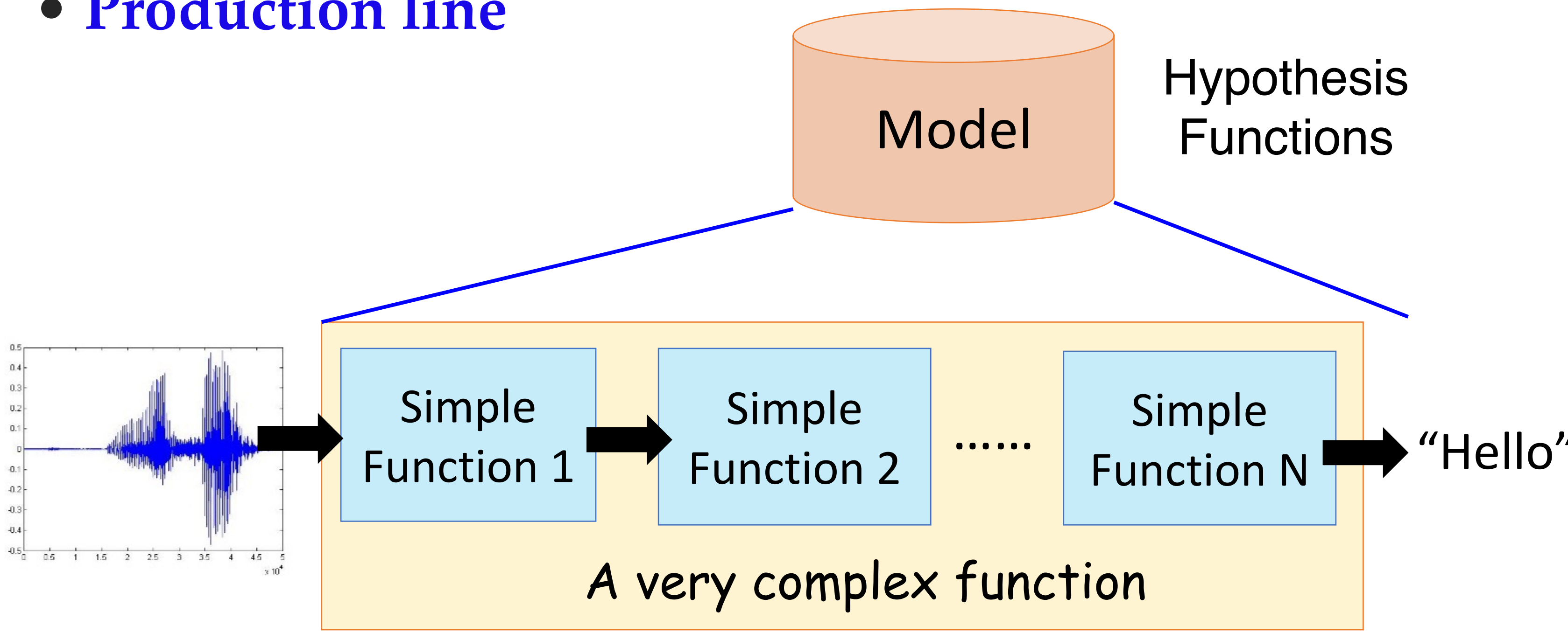
End-to-end Learning

- **Shallow Approach** http://www.robots.ox.ac.uk/~vgg/research/encoding_eval/



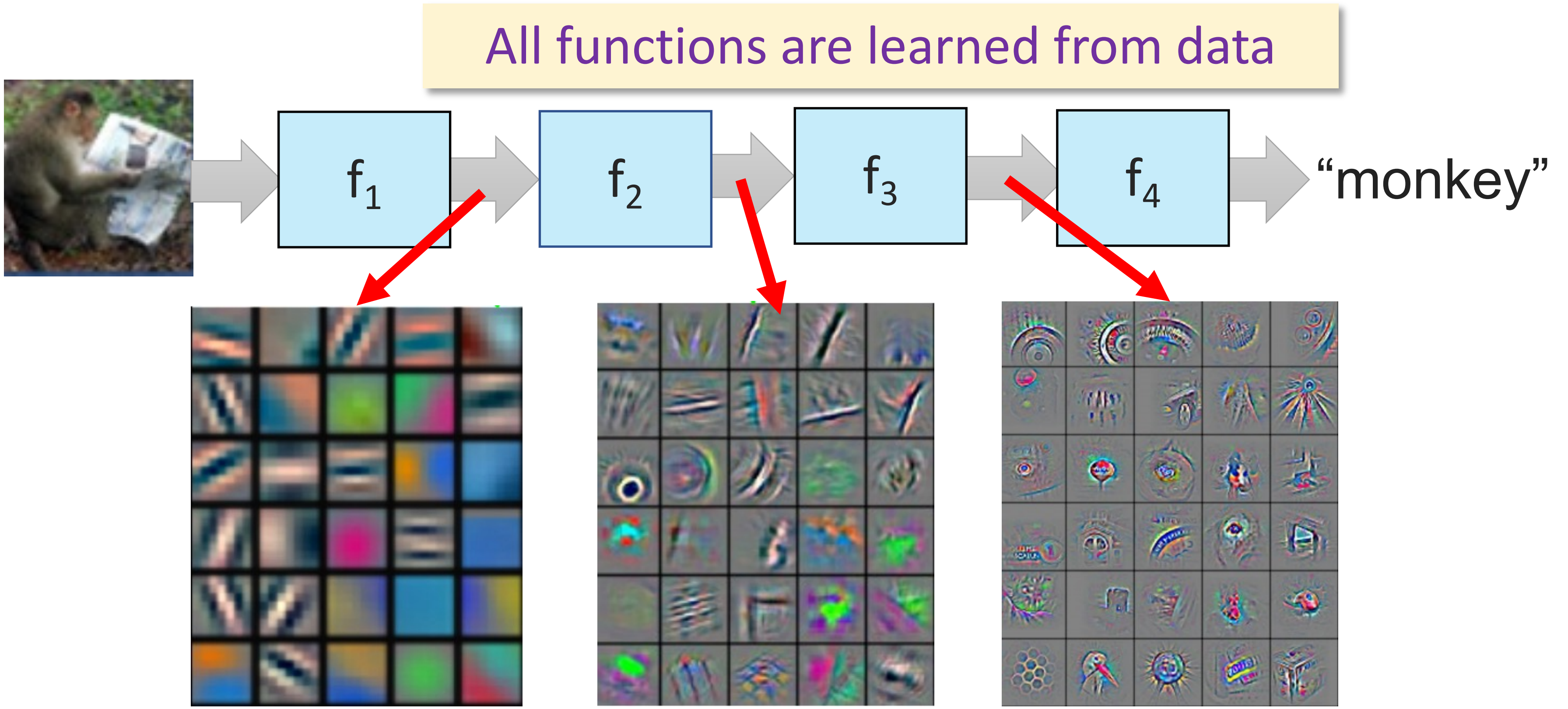
End-to-end Learning

- **Production line**



End-to-end training: What each function should do is learned automatically.

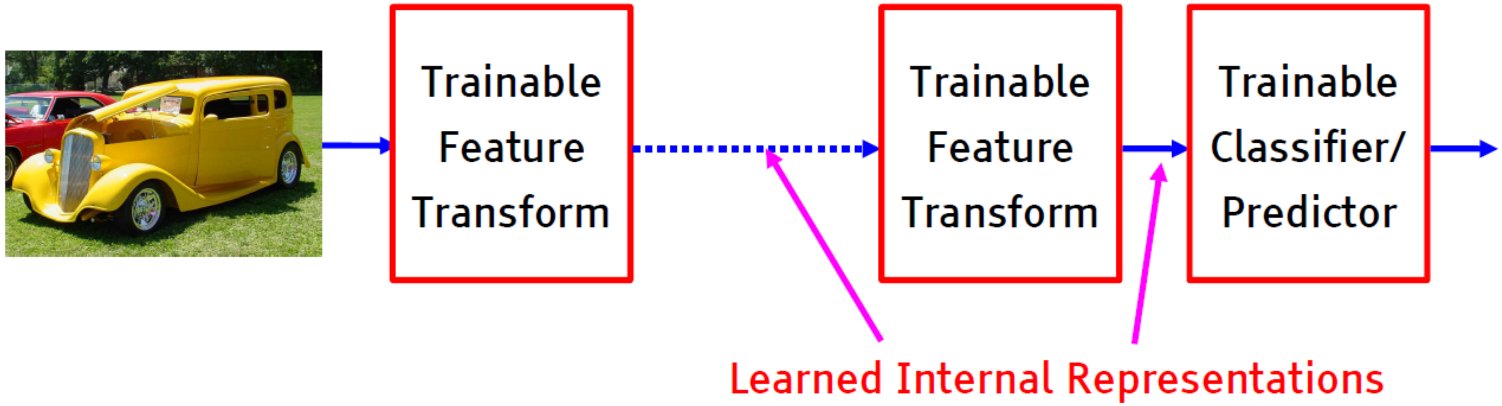
End-to-end Learning



Zeiler, M. D., & Fergus, R. (2014). Visualizing and understanding convolutional networks. In *Computer Vision–ECCV 2014* (pp. 818-833)

End-to-end Learning

- A hierarchy of trainable feature transforms
  - each module transforms its input representations into a higher-level one.
  - high-level features are more global and more invariant
  - low-level features are shared among categories

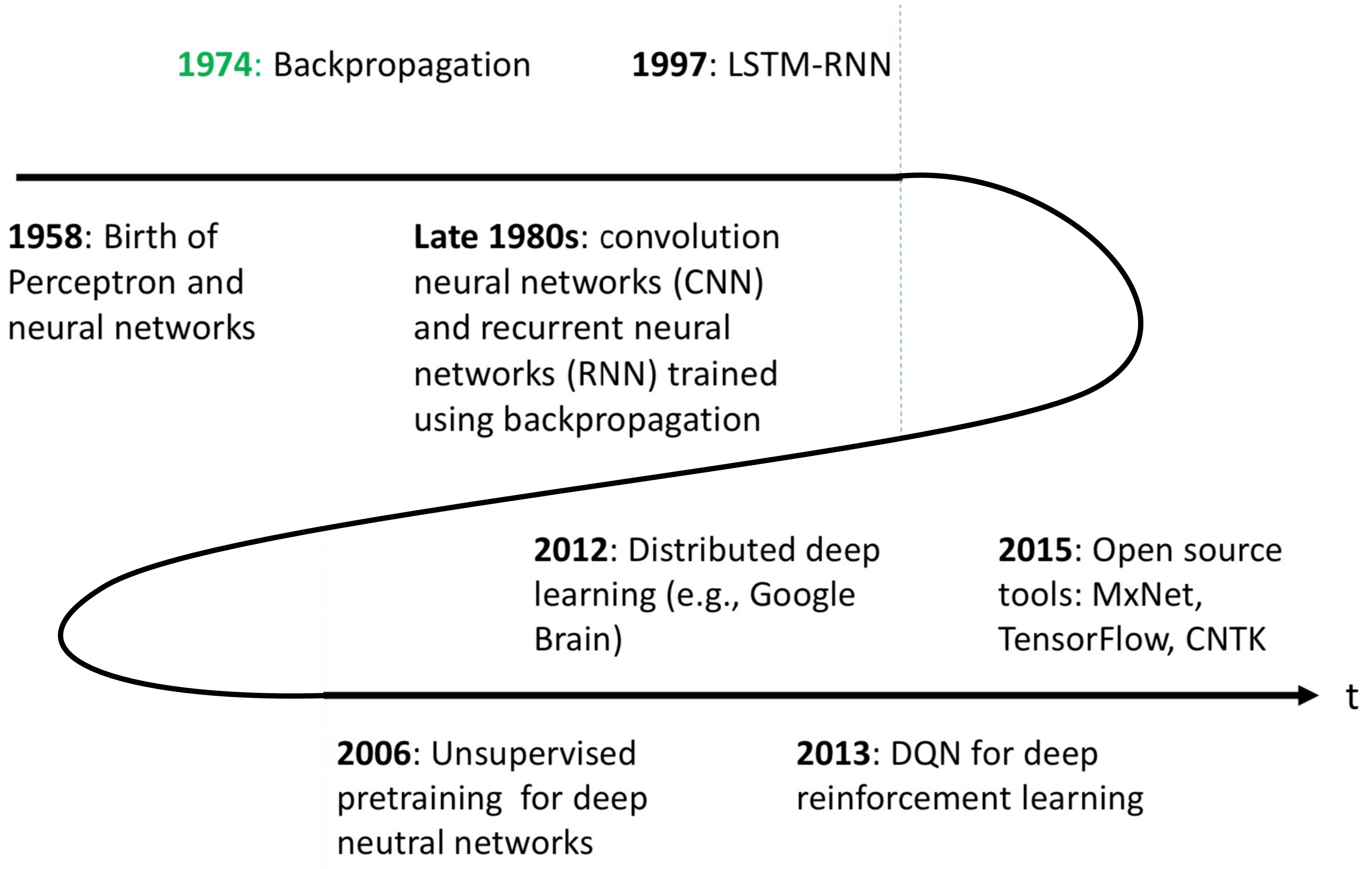


All in all: Why Deep Learning?

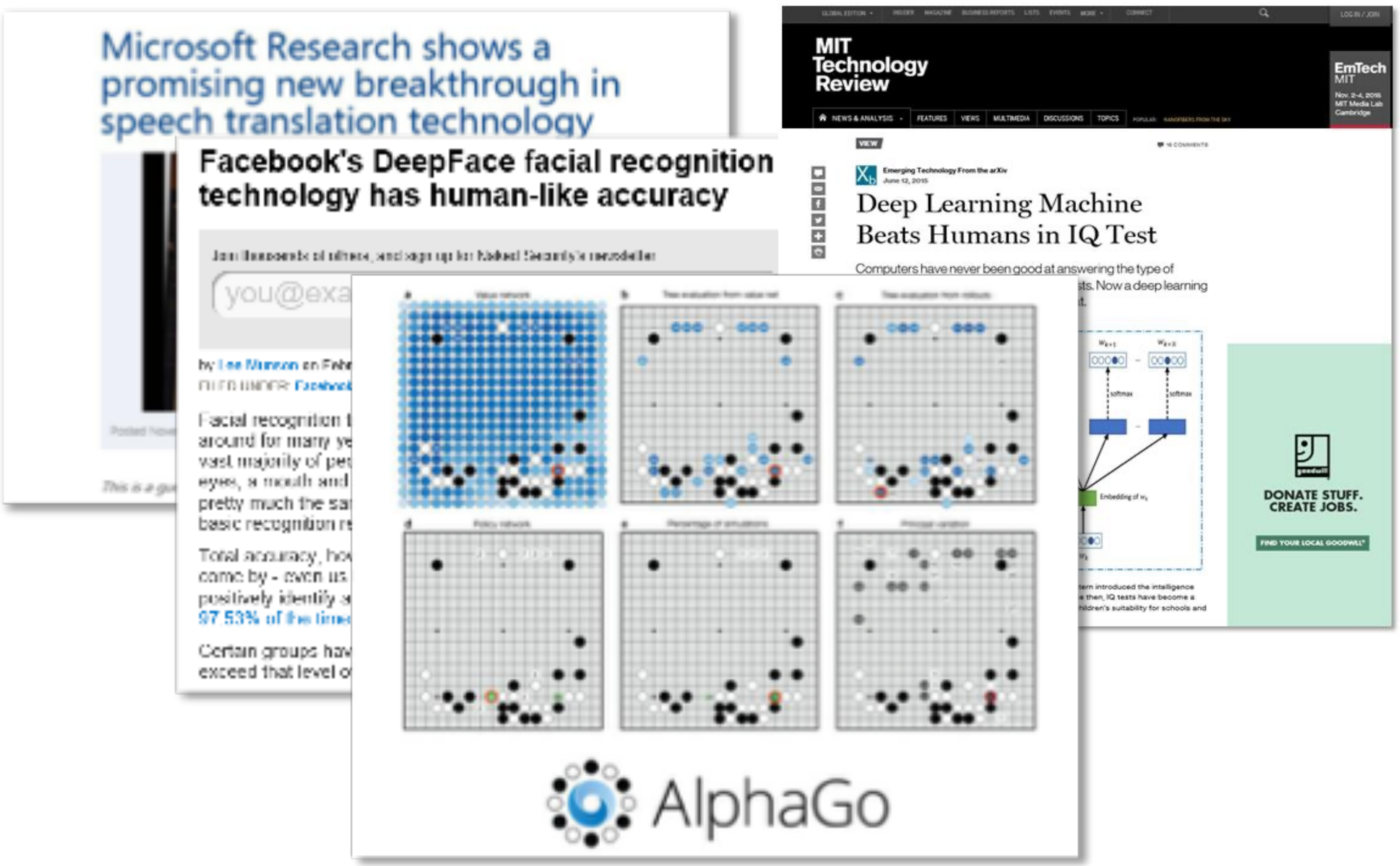
- huge amount of training data – **Big Data**
- sufficient computational power – **Big Machine (GPU and Cloud)**
- highly complicated models – **Big Model**
  - Deep structure reduces the number of parameters while achieving high model complexity
  - Layered structure is very natural

Image: Pixel → edge → texton → motif → part → object
Speech: Sample → spectral band → sound → phone → word...
Text: Character → word → phrase → clause → sentence → paragraph → document

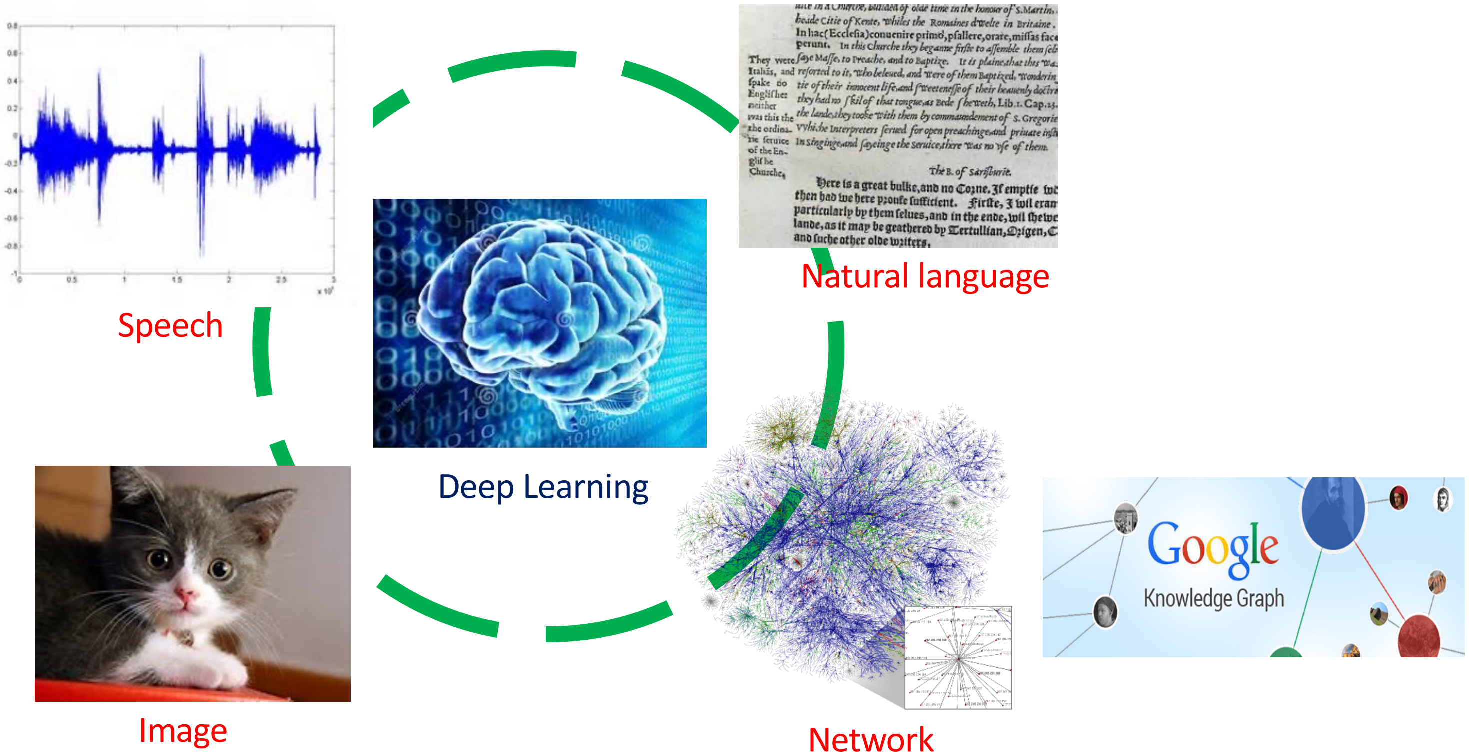
History of Deep Learning



Success of Deep Learning



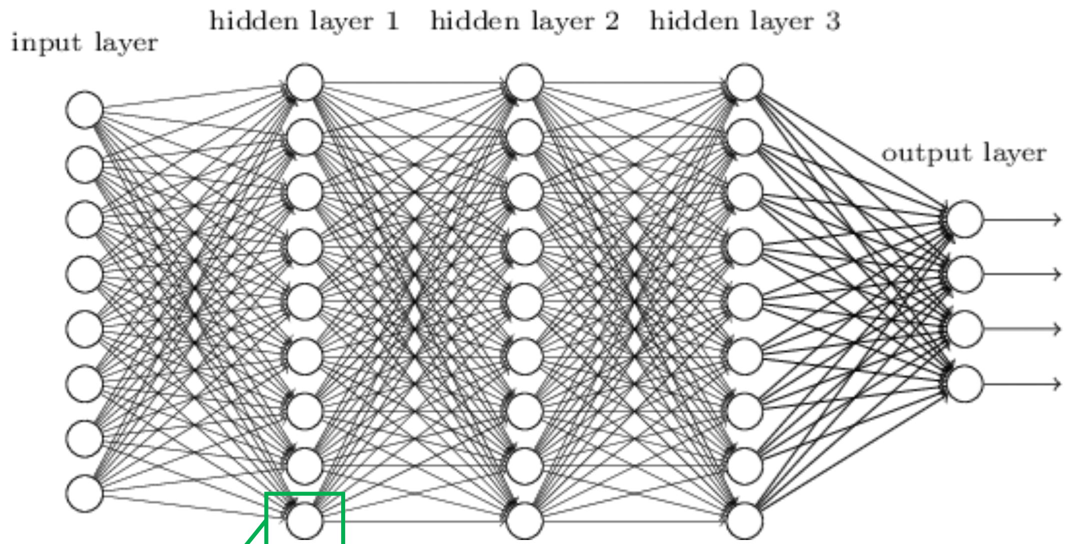
Applications in Various Domains



Deep Neural Networks

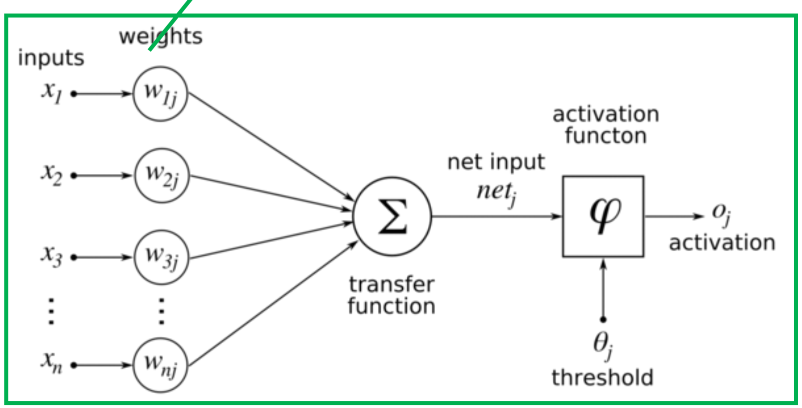
- Feedforward neural networks
- Convolutional neural networks
- Recurrent neural networks

Deep (Feedforward) Neural Networks

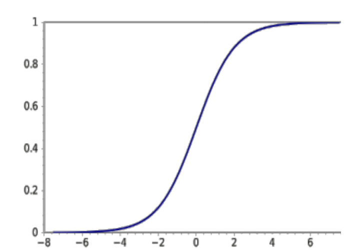


Loss functions:
- Square error
- Cross entropy
- Hinge loss
- Ranking loss
- …

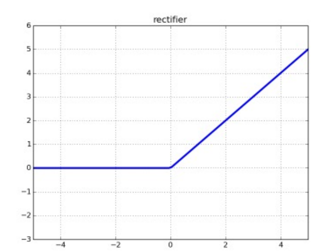
Training:
Backpropagation



Activation functions



Sigmoid



ReLU

Other Structures?

- Convolutional Neural Networks (CNN)
- Recurrent Neural Networks (RNN)
- Transformer
- …