Introduction to Neural networks (NNDL-Lecture -02)

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Outline

- Types of machine learning
- Introduction of Neural Networks

Types of machine learning

- **Supervised learning (Task Driven):**
- All data is labeled and the algorithms learn to predict the output from the input data.

- **Unsupervised learning (Data Driven):**
- All data is unlabeled and the algorithms learn to inherent structure from the input data

- **Reinforcement learning (Learn from Mistake):**
- Some data is labeled but most of it is unlabeled and a mixture of supervised and unsupervised techniques can be used.

Supervised learning examples

- **Example: Handwritten digit classification with the MNIST dataset**
- **Task:** given an image of a handwritten digit, predict the digit class
  - **Input: the image**
  - **Target: the digit class**
- **Data:** 70,000 images of handwritten digits labeled by humans
- **Training set:** First 60,000 images, used to train the network
- **Test set:** last 10,000 images, not available during training, used to evaluate performance

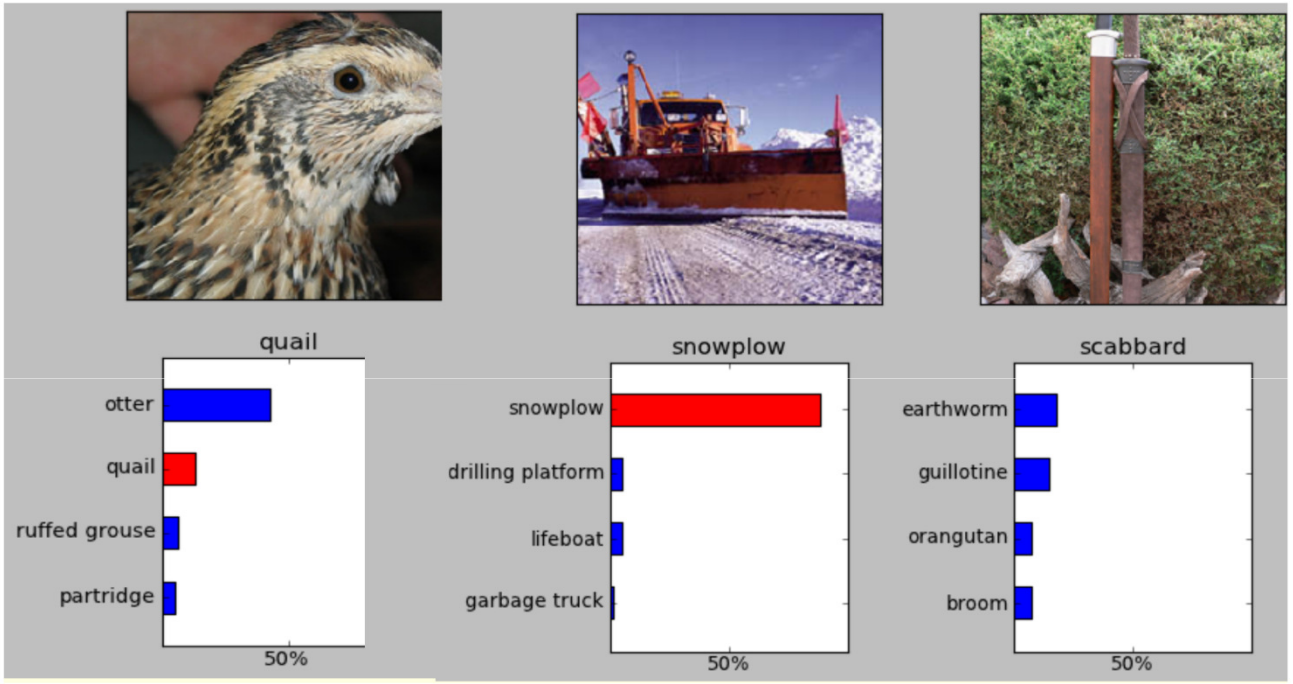
Supervised learning examples

- This dataset is the “fruit Fly" of neural network research.
- Neural networks already achieved > 99% accuracy in the 1990s, but we still continue to learn a lot from it.

- What makes a “2"?

Supervised learning examples

- **Object recognition:**



- **ImageNet dataset:** thousands of categories, millions of labeled images
- Lots of variability in viewpoint, lighting, etc.
- Error rate dropped from 25.7% to 5.7% over the course of a few years!

Unsupervised learning examples

Unsupervised learning examples

- In generative modeling, we want to learn a distribution over some dataset, such as natural images.
- We can evaluate a generative model by sampling from the model and seeing if it looks like the data.
- These results were considered impressive in 2014:

- Denton et al., 2014, Deep generative image models using a Laplacian pyramid of adversarial networks/

Unsupervised learning examples

❑**Recent exciting result:** **a model called the CycleGAN takes lots of**
❑**images of one category (e.g. horses) and lots of images of another category (e.g. zebras) and learns to translate between them.**

https://github.com/junyanz/CycleGAN

Reinforcement Learning Examples

- It is semi-supervised learning model in machine learning.

- **What is reinforcement learning?**

- **What is the workflow I should follow to solve my reinforcement learning problem?**

- **What are the Important Applications of reinforcement learning**

Reinforcement Learning Examples

❑**What is reinforcement learning (RL) ?**

❑It is a technique to allow an agent to take actions and interact with an environment so as to maximize the total rewards.

❑It is a type of machine learning in which a computer learns to perform a task through repeated trial-and-error interactions with a dynamic environment.

❑This learning approach enables the computer to make a series of decisions that maximize a reward metric for the task without human intervention and without being explicitly programmed to achieve the task.

Reinforcement learning examples

- **Example: Real-world equivalent situation**

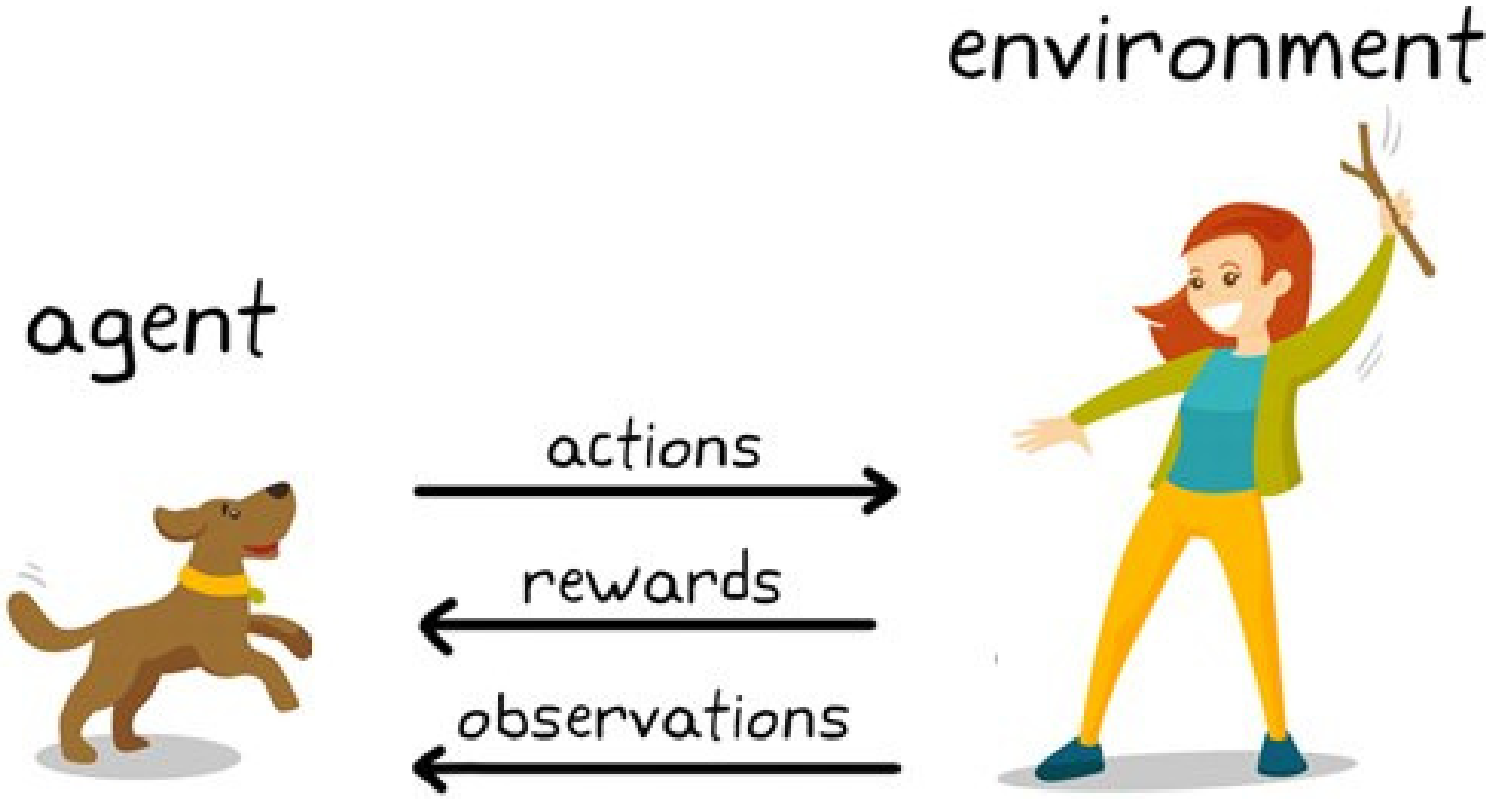


Figure. Reinforcement learning in dog training.

Reinforcement Learning Examples

- **Example: Automated driving system**

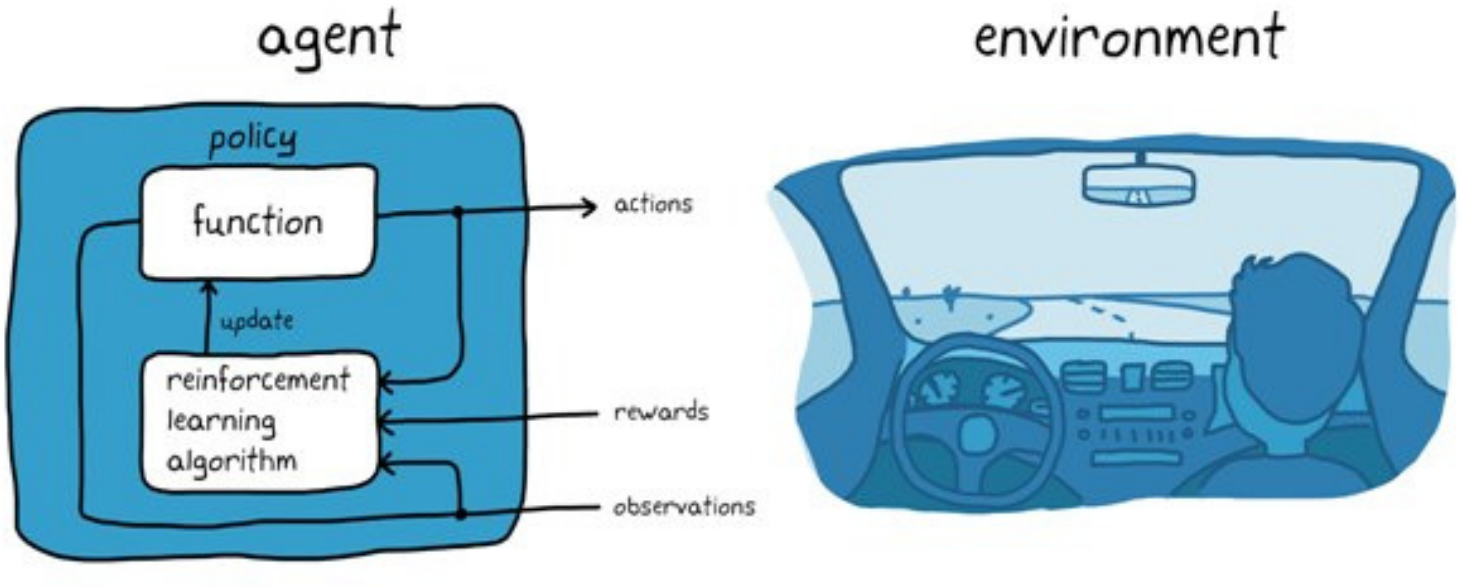


Figure. Reinforcement learning in autonomous parking..

Reinforcement Learning Examples

❑What is the workflow I should follow to solve my reinforcement learning problem?

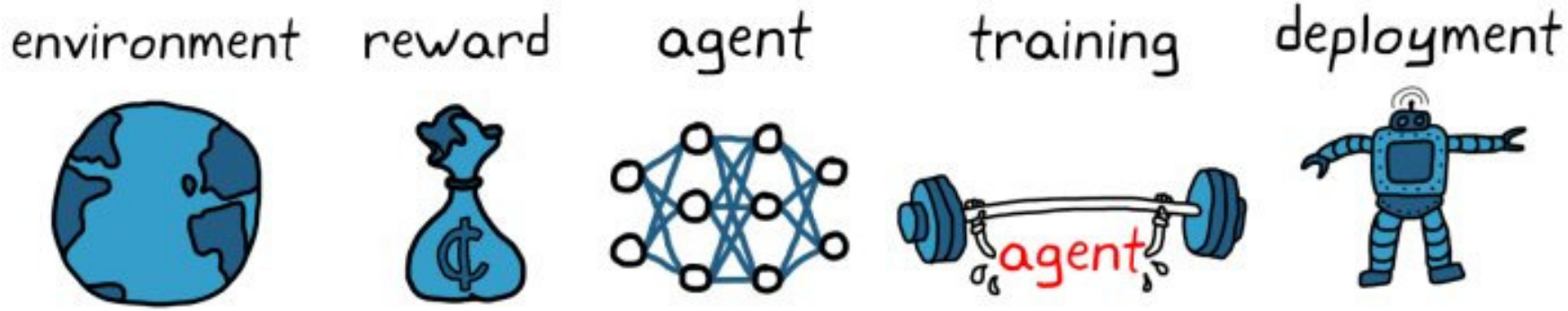


Figure. Reinforcement learning workflow.

❑**Steps:(1). Create the Environment (2). Define the Reward (3) Create the Agent (4)Train and Validate the Agent (5) Deploy the Policy**

Reinforcement Learning Examples

❑Important applications of RL

❑RL is widely used in building AI for playing computer games.

❑**Games- AlphaGo Zero** is the first computer program to defeat a world champion in the ancient Chinese game of Go (**AlphaGo).** Others include ATARI games (2015), Backgammon ,etc

https://www.youtube.com/watch?v=V1eYniJ0Rnk

❑**In robotics and industrial automation-** RL is used to enable the robot to create an efficient adaptive control system for itself which learns from its own experience and behavior.

❑**DeepMind's** work on Deep Reinforcement Learning **for Robotic Manipulation with Asynchronous Policy updates** is a good example of the same.

❑Watch this interesting demonstration video.

https://www.youtube.com/watch?v=Q4bMcUk6pcw&feature=emb_rel_end

Reinforcement Learning Examples

- **Other Important applications of RL**
  - **Resources management in computer clusters**
  - **Traffic Light Control**
  - **Web System Configuration**
  - **Chemistry**
  - **Personalized Recommendations**
  - **Bidding and Advertising**

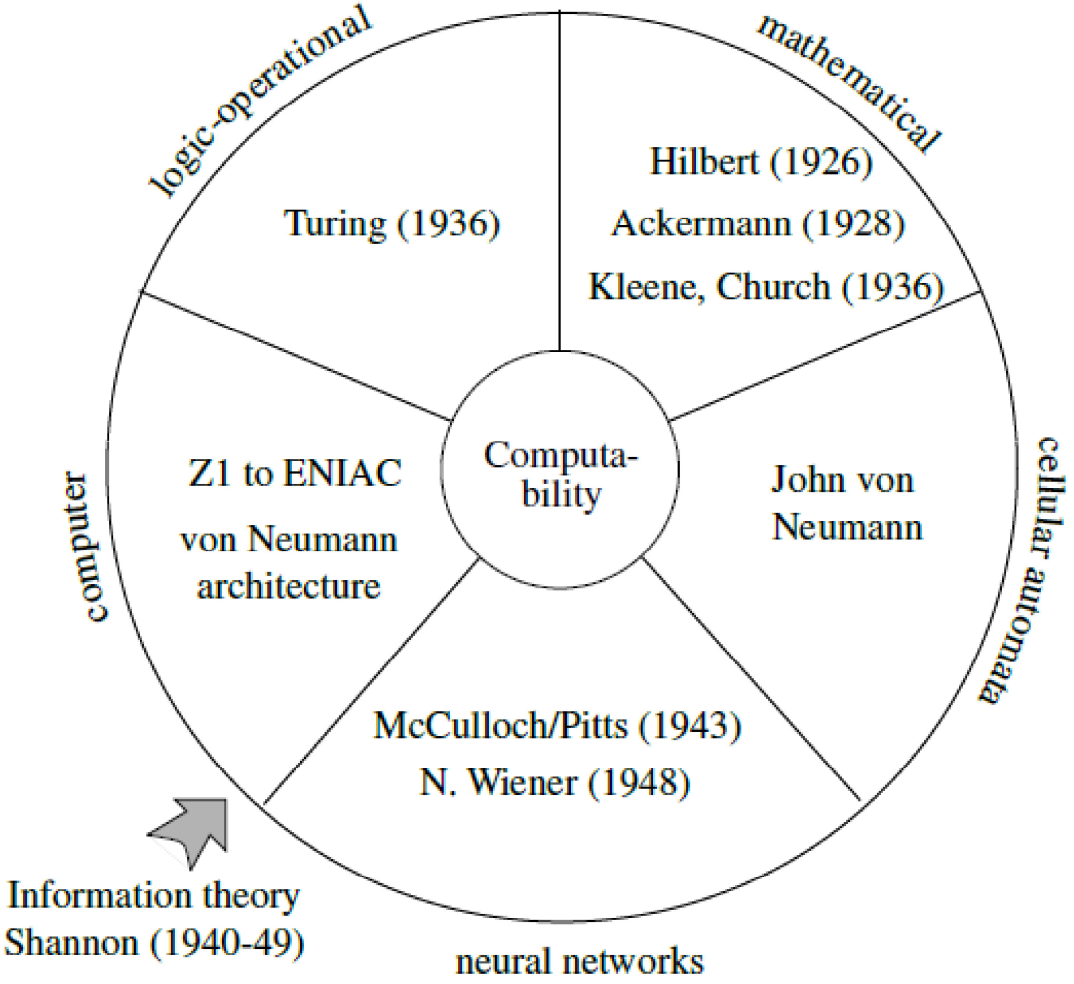
https://towardsdatascience.com/applications-of-reinforcement-learning-in-real-world-1a94955bcd12

https://github.com/aikorea/awesome-rl

What are neural networks?

❑**Neural computation:**

Computation=
Storage +Transmission
+Processing



What are neural networks?

- The study of neurons, their interconnections, and their role as the brain's elementary building blocks is one of the most dynamic and important research fields in modern biology.

- Between 1901 and 1991 approximately ten percent of the **Nobel Prizes for Physiology and Medicine** were awarded to scientists who contributed to the understanding of the brain.

- Artificial neural networks are an attempt at modeling the information processing capabilities of nervous systems.

- Artificial neural networks can be considered as another approach to the problem of computation.

Ref: R. Rojas: Neural Networks, Springer-Verlag, Berlin, 1996

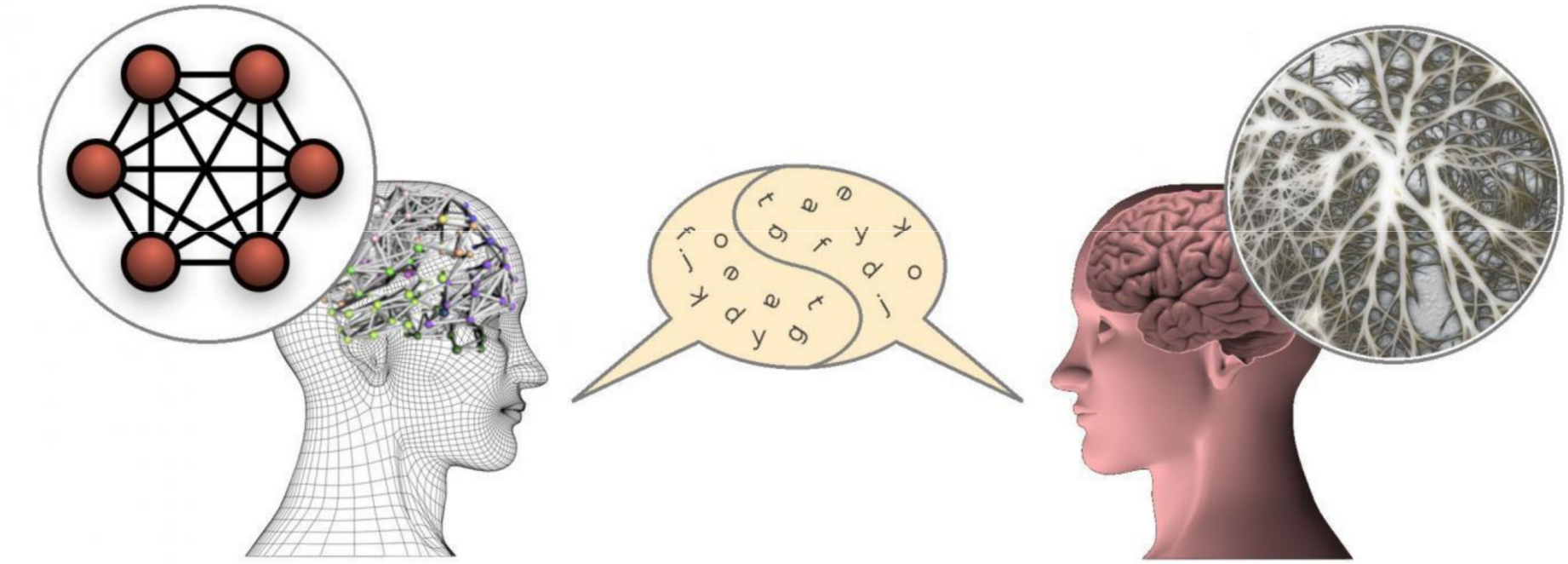
What are neural networks?

- **What are Neural Networks used for?**
- There are two basic goals for neural network research:
- **Brain modelling:**
- The biological goal of constructing models of how real brains work.
- This can potentially help us understand the **nature of perception, actions, learning and memory, thought and intelligence** and/or formulate medical solutions to brain damaged patients
- **Artificial System Construction:**
- The engineering goal of building efficient systems for real world applications.
- This may make machines more powerful and intelligent, relieve humans of tedious tasks, and may even improve upon human performance.

What are neural networks?

Neural Network

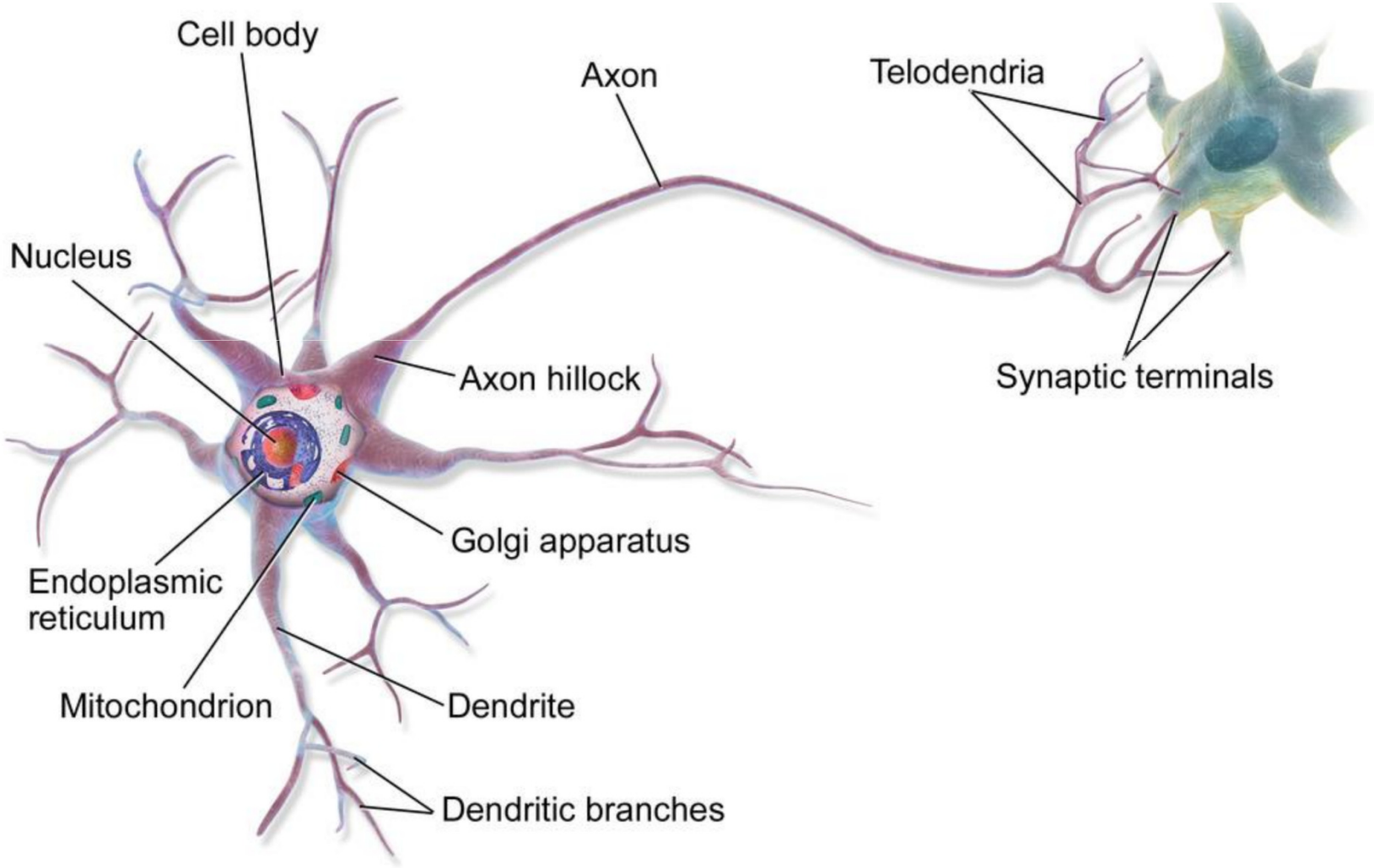
Human Brain



What are neural networks?

- **The human body is made up of trillions of cells.**
- **Cells of the nervous system, called nerve cells or neurons, are specialized to carry "messages" through an electrochemical process.**
- **Neurons come in many different shapes and sizes.**
- Some of the smallest neurons have cell bodies that are only 4 microns wide.
- **Some of the biggest neurons have cell bodies that are 100 microns wide.**

What are neural networks?



What are neural networks?

- **Typically, a neuron contains three important parts**:

- a **cell body** that directs all activities of the neuron.

- **dendrites** (the part that looks like tree branches), which are short fibers that receive messages from other neurons and relay those messages to the cell body.

- **axon**, a long single fiber that transmits messages from the cell body to dendrites of other neurons.

What are neural networks?

When will the number of neurons in AI systems equal the human brain?

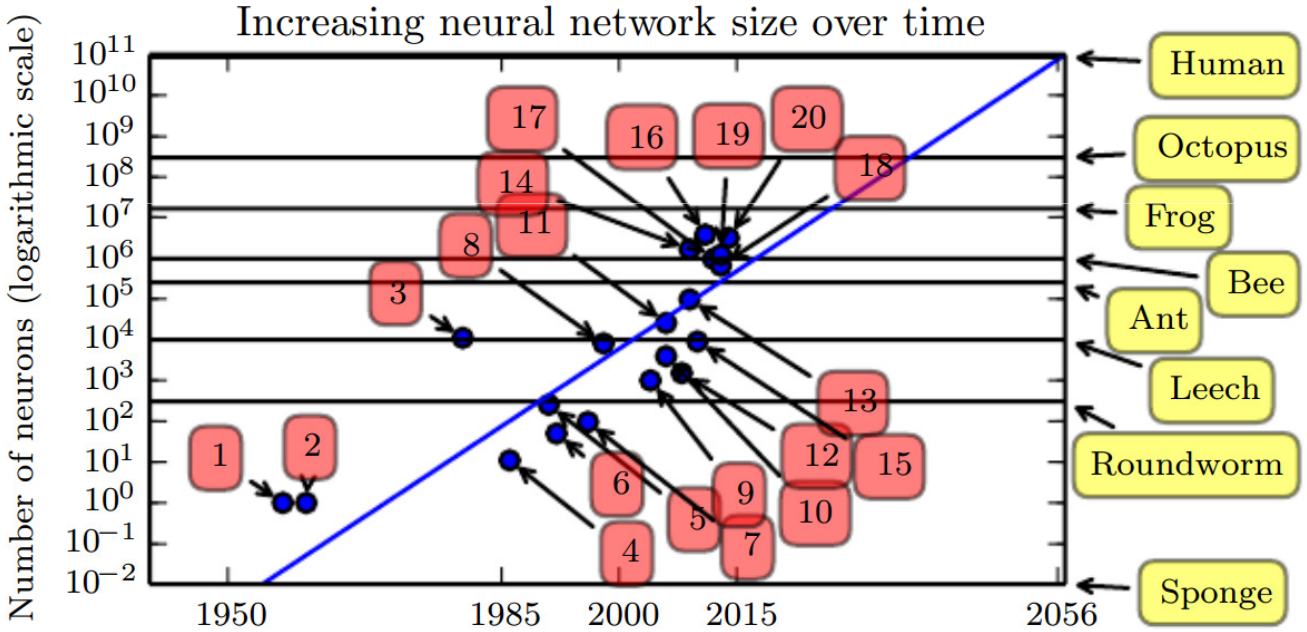


Figure 1.11: Since the introduction of hidden units, artificial neural networks have doubled in size roughly every 2.4 years. Biological neural network sizes from Wikipedia (2015).

Deep Learning Book has the above figure on page 27:http://www.deeplearningbook.org/

What are neural networks?

The referenced neural networks are:

1. Perceptron (Rosenblatt, 1958, 1962)
2. Adaptive linear element (Widrow and Hoff, 1960)
3. Neocognitron (Fukushima, 1980)
4. Early back-propagation network (Rumelhart *et al.*, 1986b)
5. Recurrent neural network for speech recognition (Robinson and Fallside, 1991)
6. Multilayer perceptron for speech recognition (Bengio *et al.*, 1991)
7. Mean field sigmoid belief network (Saul *et al.*, 1996)
8. LeNet-5 (LeCun *et al.*, 1998b)
9. Echo state network (Jaeger and Haas, 2004)
10. Deep belief network (Hinton *et al.*, 2006)
11. GPU-accelerated convolutional network (Chellapilla *et al.*, 2006)
12. Deep Boltzmann machine (Salakhutdinov and Hinton, 2009a)
13. GPU-accelerated deep belief network (Raina *et al.*, 2009)
14. Unsupervised convolutional network (Jarrett *et al.*, 2009)
15. GPU-accelerated multilayer perceptron (Ciresan *et al.*, 2010)
16. OMP-1 network (Coates and Ng, 2011)
17. Distributed autoencoder (Le *et al.*, 2012)
18. Multi-GPU convolutional network (Krizhevsky *et al.*, 2012)
19. COTS HPC unsupervised convolutional network (Coates *et al.*, 2013)
20. GoogLeNet (Szegedy *et al.*, 2014a)

What are neural networks?

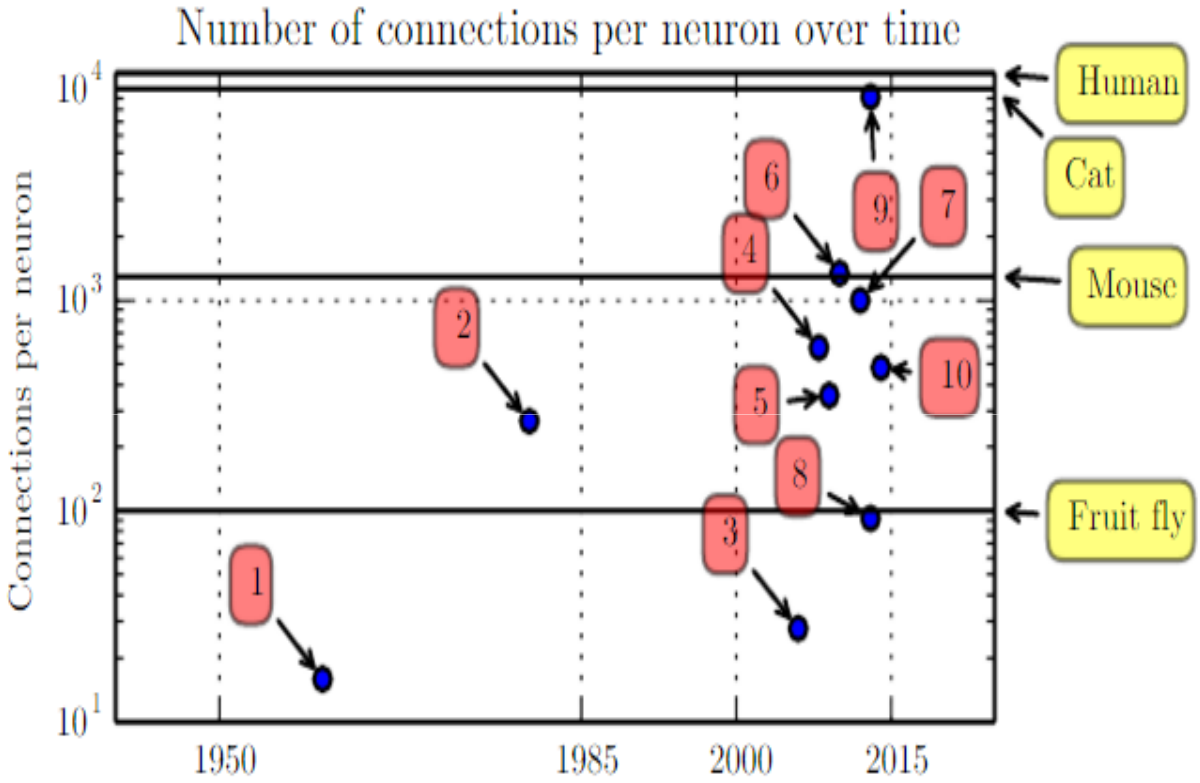


Figure 1.10: Initially, the number of connections between neurons in artificial neural networks was limited by hardware capabilities.

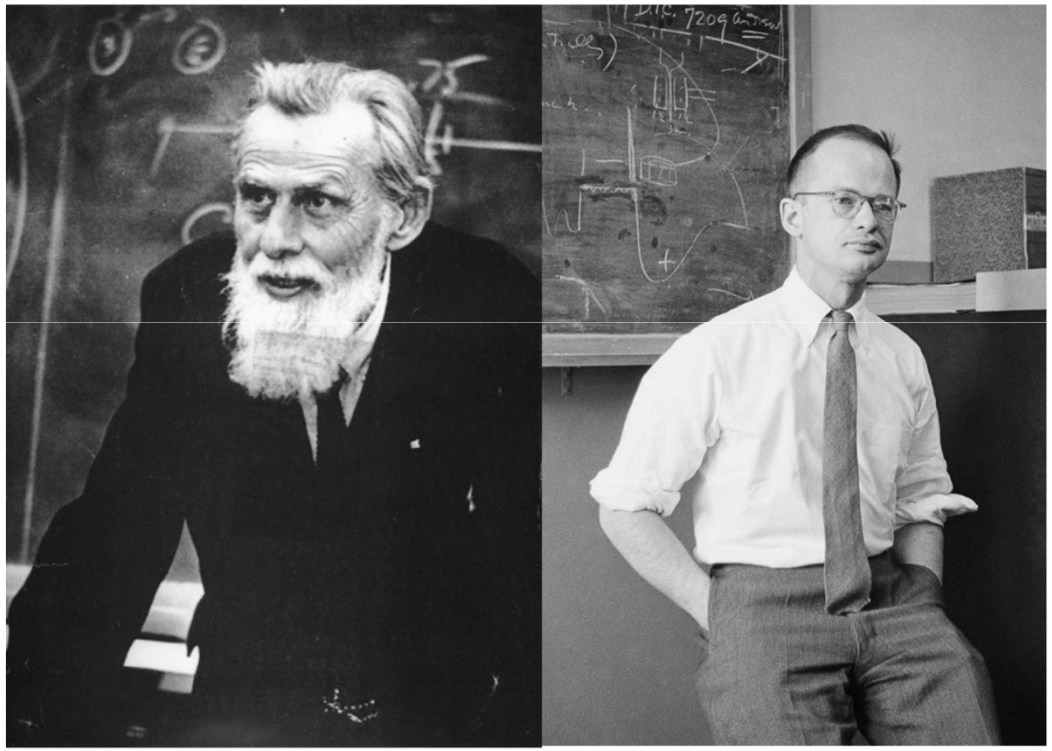
What are neural networks?

- Some artificial neural networks have nearly as many connections per neuron as a cat, and it is quite common for other neural networks to have as many connections per neuron as smaller mammals like mice.
- Even the human brain does not have an exorbitant amount of connections per neuron. Biological neural network sizes from Wikipedia (2015)

- Neural networks are collections of thousands (or millions) of these simple processing units that together perform useful computations.

What are neural networks?

❑The McCulloch-Pitts Model of Neuron (1942 model)

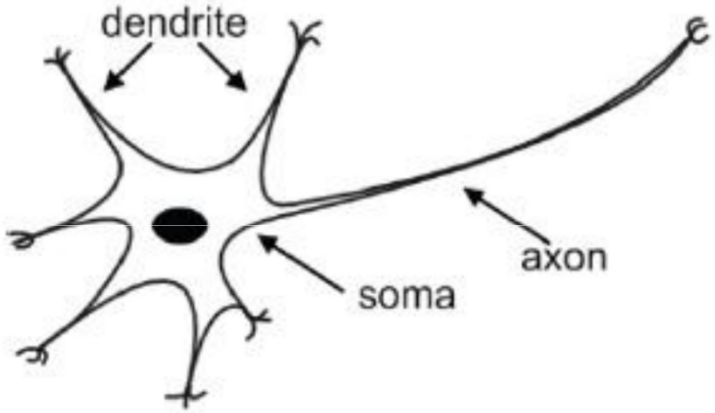


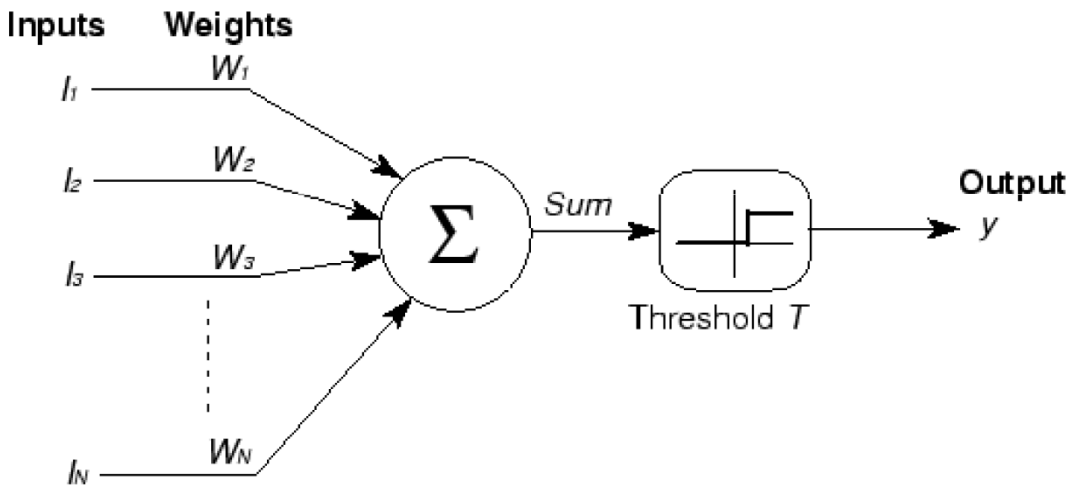
Warren McCulloch Walter Pitts

1943, "A Logical Calculus of the Ideas Immanent in Nervous Activity". With Walter Pitts. In: *Bulletin of Mathematical Biophysics* Vol 5, pp 115–133.

What are neural networks?

- The early model of an artificial neuron is introduced by Warren McCulloch and Walter Pitts in 1943.



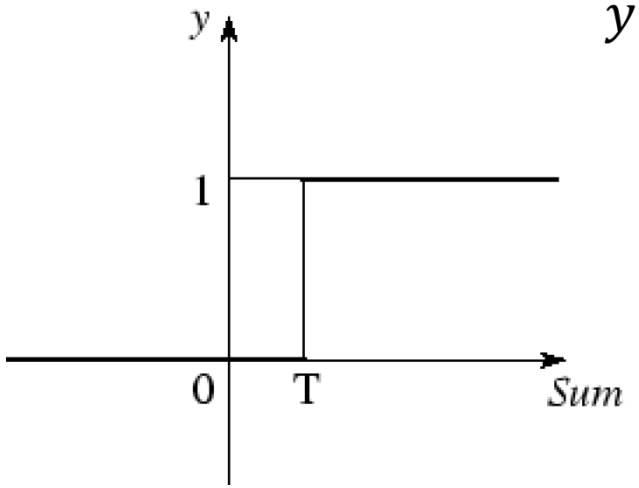


- $Sum = \sum_{i=1}^{N} I_i W_i$ and $Output = \begin{cases} 0 & \text{if Sum} \leq T \\ 1 & \text{if Sum} > T \end{cases}$

What are neural networks?

- **The main feature of their neuron model is that a weighted sum of input signals is compared to a threshold to determine the neuron output.**
- **When the sum is greater than or equal to the threshold, the output is 1.**
- When the sum is less than the threshold, the output is 0.

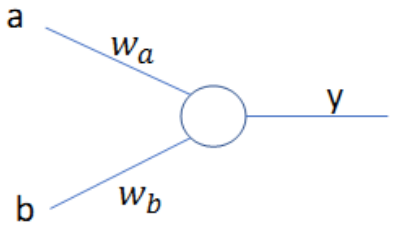
$$y = f(Sum)$$



What are neural networks?

- They demonstrated that networks of these neurons could, in principle, compute any arithmetic or logical function.
- Unlike biological networks, the parameters of their networks had to be designed, as no training method was available.
- However, the perceived connection between biology and digital computers generated a great deal of interest.

2 Input AND gate		
A	B	A.B
0	0	0
0	1	0
1	0	0
1	1	1



$$y = \begin{cases} 0 & \text{if Sum} \leq T \\ 1 & \text{if Sum} > T \end{cases}$$

$T \geq 0$

$w_b \leq T$

$w_a \leq T$

$w_a + w_b > T$

$T = 1.5, w_b = 1, w_b = 1$

What are neural networks?

- McCulloch and Pitts were pioneers of neural networks who wrote a research article on the model with two inputs and single output in 1943.

- The following were the features of that McCulloch and Walter Pitts model:

- A neuron would only be activated if:
  - One of the inputs is active
  - The weights for each input is equal
  - The output of the model is binary