

Machine Learning

CSE 142

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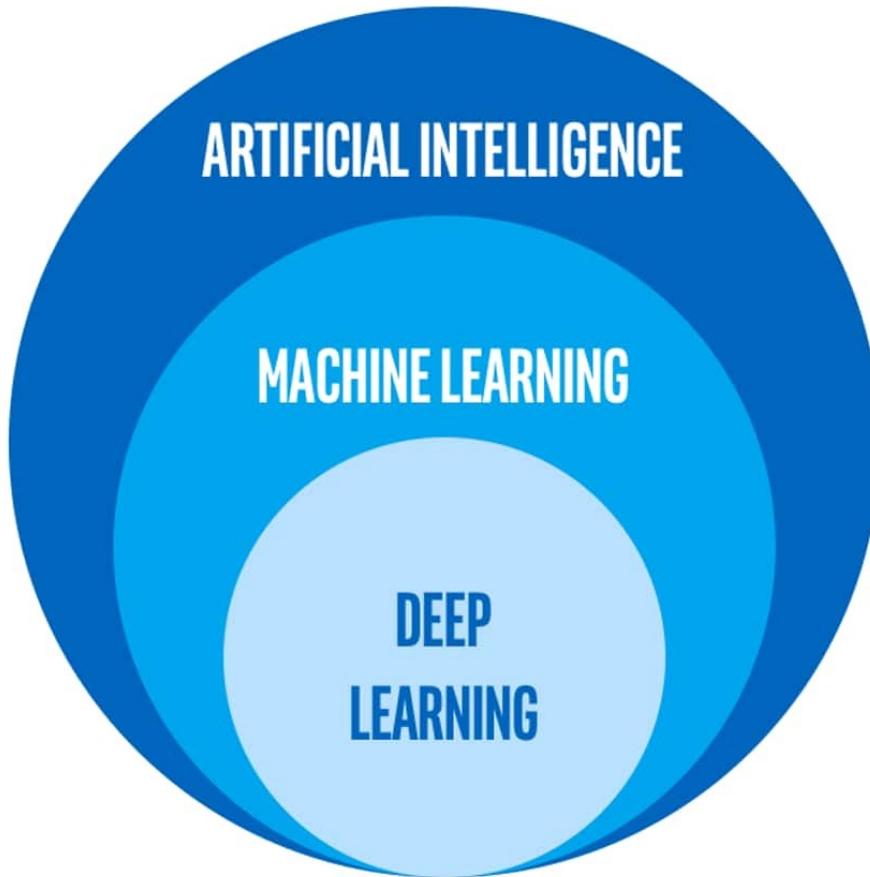
Wednesday, November 24, 2021

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- Neural networks and deep learning

Notes

- HW#4 due December 1 (next Wednesday)
 - One problem – boosting classifier
 - At each iteration t , a new “weak classifier” M_t is learned from weighted training data
 - Weighted simple classifier
 - Computing the class exemplar: $\frac{1}{k} \sum_{i=1}^k x_i \longrightarrow \frac{1}{\sum w_i} \sum_{i=1}^k w_i x_i$
 - Then:
 - Compute weighted error ϵ_t
 - Compute α_t
 - Update weights w_i
 - Done when $\epsilon_t \geq 0.5$ or $t > T$
 - Final classifier: $M(x) = \sum_{t=1}^T \alpha_t M_t(x)$
 - After training, apply M to test data
 - Other base classifiers (logistic regression, perceptron, SVM) can be used as well



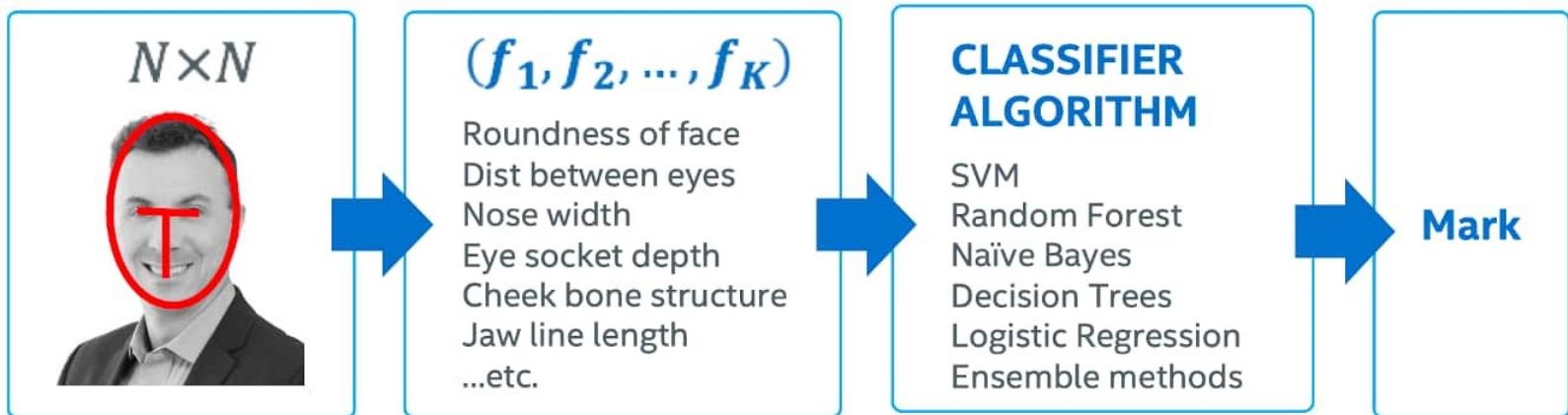
Artificial Intelligence: any technique which enables machines to learn, reason, and behave like humans.

Machine Learning: the design and analysis of algorithms that improve their performance at some task with experience.

Deep Learning: subset of machine learning which make the computation of multi-layer neural networks feasible.

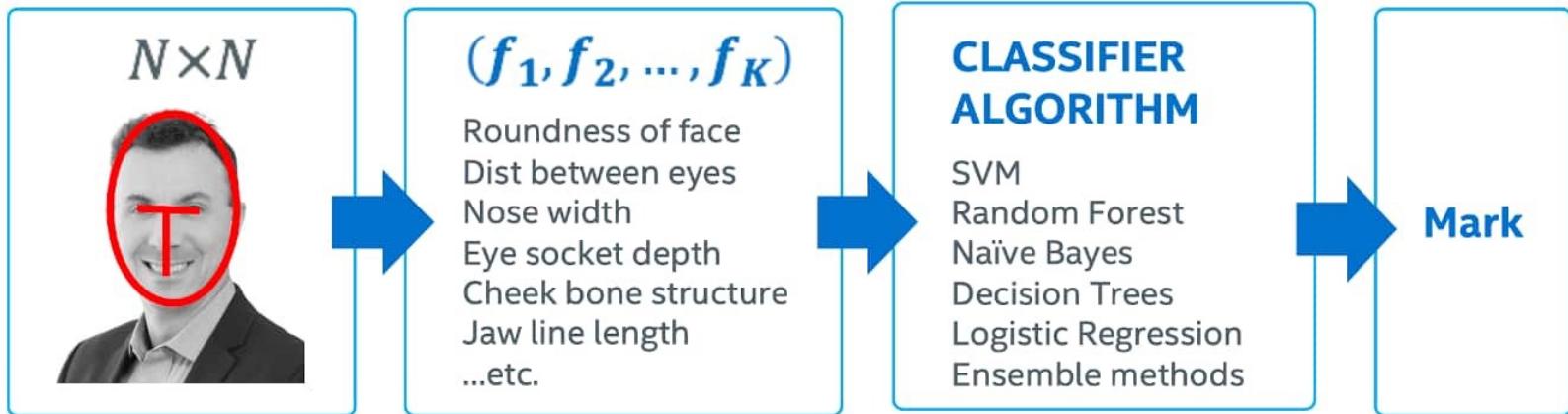
Face recognition via traditional machine learning

Machine Learning

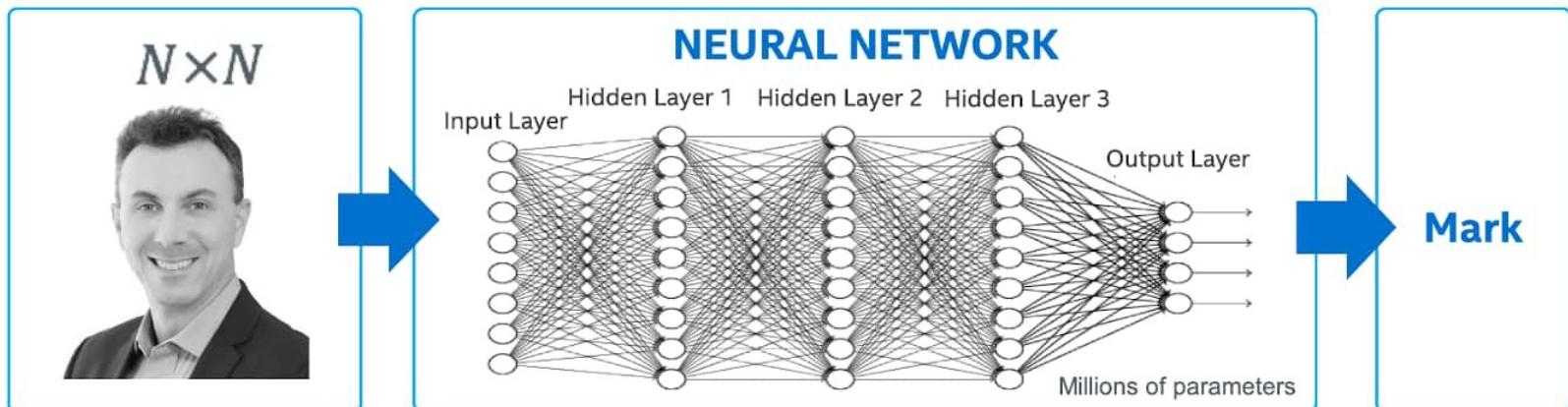


Face recognition via deep learning

Machine Learning



Deep Learning



Machine learning vs. deep learning

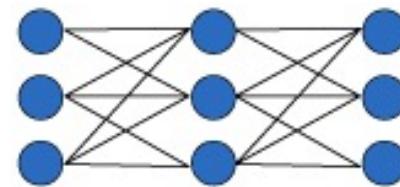


Machine Learning

Input



Feature extraction



Classification

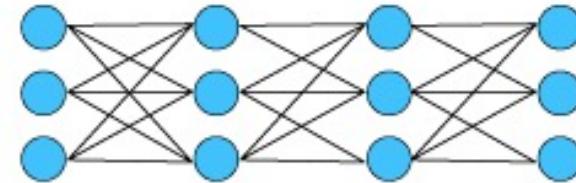


Output



Deep Learning

Input



Feature extraction + Classification



Output

Deep learning success: speech recognition

www.technewsworld.com/story/84013.html

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Microsoft AI Beats Humans at Speech Recognition

By Richard Adhikari Oct 20, 2016 11:40 AM PT

G+ 5
Twitter 25
Facebook Share 45
LinkedIn Share 11
Reddit Share 0
Email share 104



Print Email

How do you feel about Black Friday and Cyber Monday?

- They're great -- I get a lot of bargains!
- The deals are too spread out -- I'd prefer just one day.
- They're a fun way to kick off the holiday season.
- I don't like the commercialization of Thanksgiving Day.
- They're crucial for the retail industry and the economy.
- The deals typically aren't that good.

Vote to See Results

E-Commerce Times

Black Friday Shoppers Hungry for New Experiences, New Tech

Pay TV's Newest Innovation: Giving Users Control

Apple Celebrates Itself in \$300 Coffee Table Tome

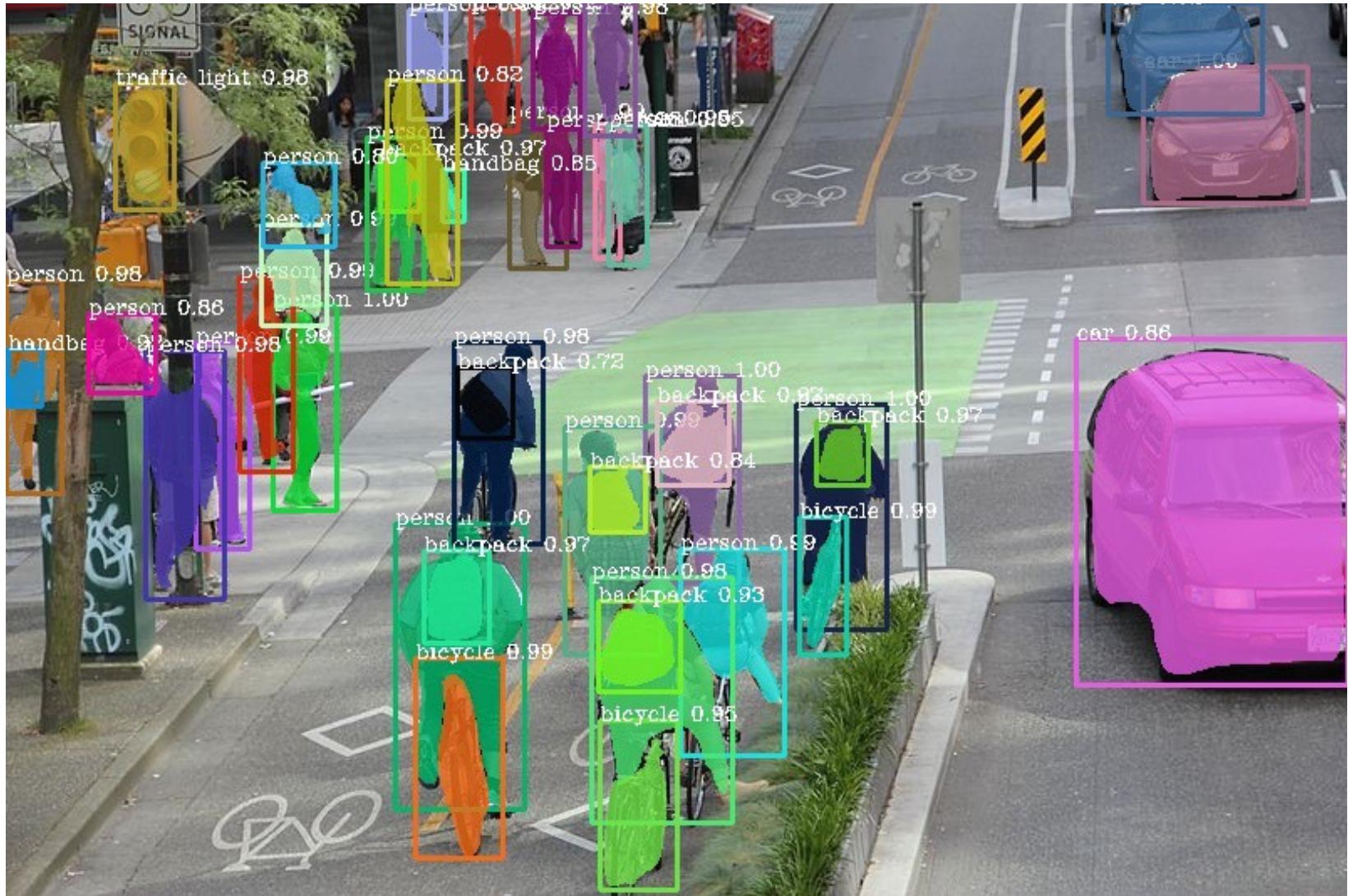
AWS Enjoys Top Perch in IaaS, PaaS Markets

US Comptroller Gears Up for Blockchain and

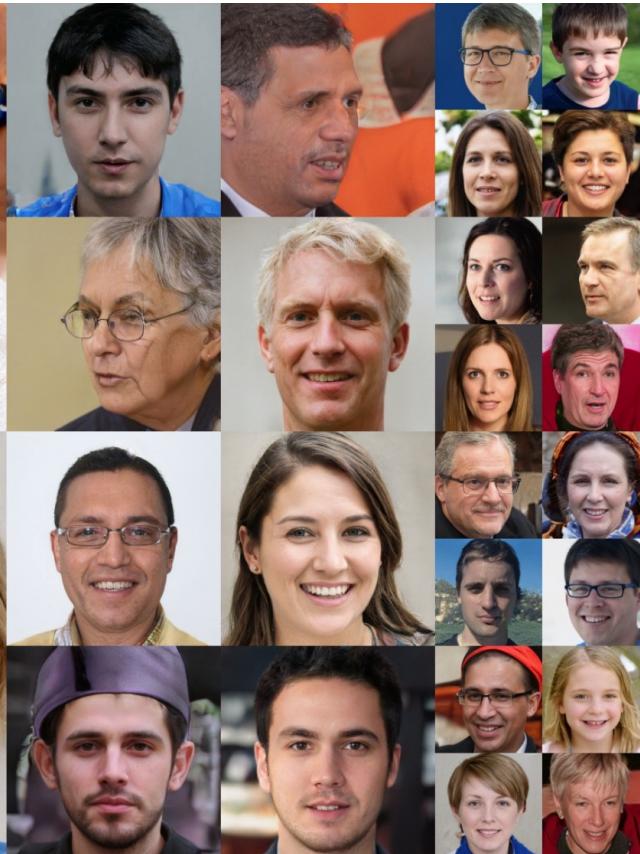
Image: Adobe Stock

Microsoft's Artificial Intelligence and Research Unit earlier this week reported that its speech recognition technology had surpassed the performance of human transcriptionists.

Deep learning success: object detection



Deep learning success: image generation



Deep learning success: language generation

Human: Hello, who are you?

AI: I am an AI created by OpenAI. How can I help you today?

Human: Are you ready to write some Ruby code? We're going to do a phone screen.

AI: Sure! Let's go.

Human: Write code to reverse an array.

AI: Can I use a method that already exists?

Human: Sure.

AI: Array.reverse

Human: Good work. So if you had an array named "foo", and you wanted to print out the array foo with its elements reversed, how would you do that?

AI: I would call Array.reverse on "foo".

Human: You also have to print it. Can you write code for it?

AI: Sure. print(foo.reverse)

Human: Nice! Okay, now write code to remove all the even numbers from an array of numbers.

AI: Sounds like I should remove all the elements that are divisible by 2.

Human: Yes.

AI: my_array.gsub(/\d+(?:\d\d)/) { |x| x % 2 == 0 ? '_' : x }

Human: Interesting. It looks like you're assuming the input is an array of strings. You can make the code simpler if you just assume it's an array of numbers.

AI: ok. my_array.gsub(/\d+(?:\d\d)/) { |x| x % 2 == 0 ? '' : x }

Human: Well, you don't need to do a gsub at all. Try doing it without regular expressions.

AI: my_array.select { |x| x % 2 == 0 }.reverse

Human: Does this code return just the even numbers, or does it remove all the even numbers?

AI: It returns just the even numbers.

Human: Ah, ok. We wanted to remove all the even numbers, rather than returning them. Can you write code for that?

AI: Sure. my_array.delete(x) if x % 2 == 0

Human: You have the right idea, but I think there's a syntax error in your code.

AI: ok, what am I missing?

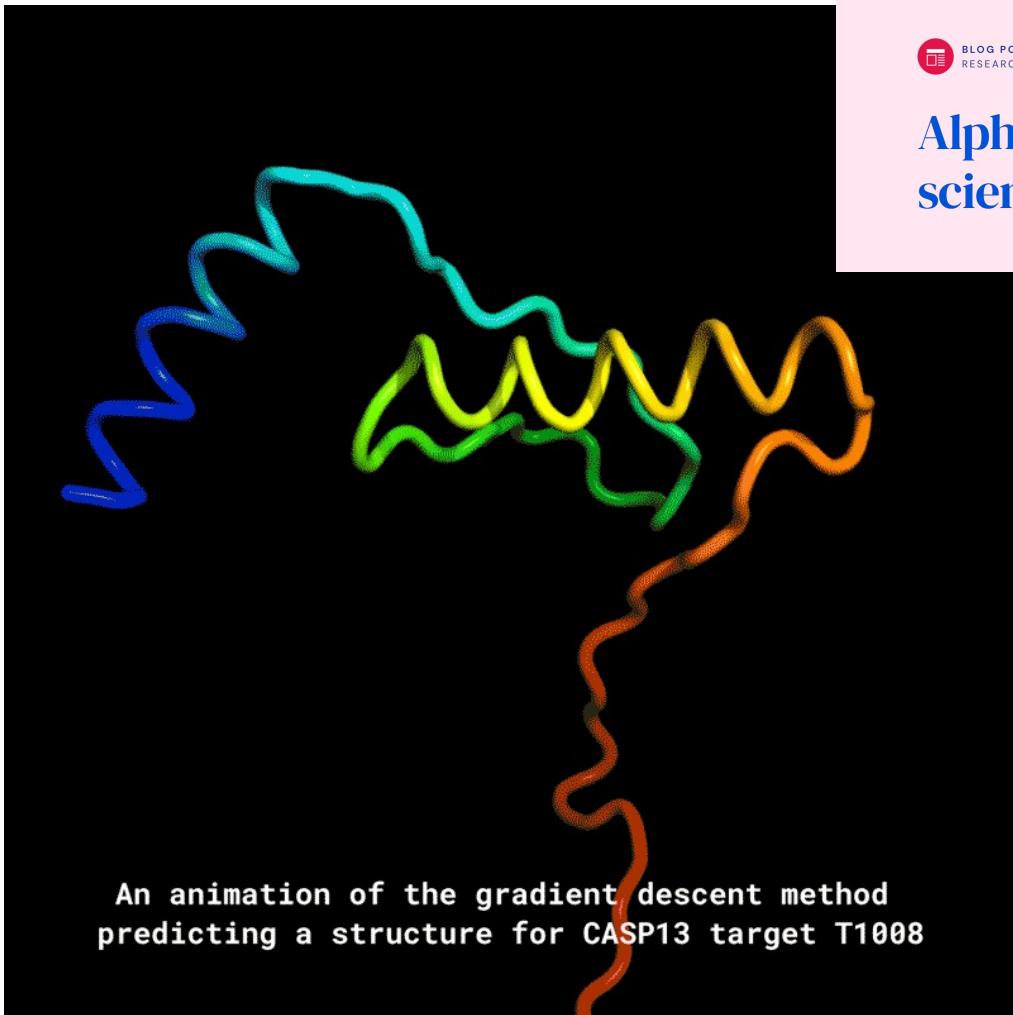
Human: You're using the variable x without defining it.

AI: x = []

Human: Sorry, I don't think you pass this phone screen. Better luck next time.

AI: I had a lot of fun. Let's try again tomorrow!

Deep learning success: protein folding



Some of my deep learning research



Video description:

A man moves all around the net holding the ball and demonstrates how to shoot a hoop.

Storytelling:

Kyrie Irving does not get vaccinated. He cannot play official games now, but he is filming a video to teach others how to play basketball.

Some of my deep learning research



Human

Can you grab the plant for me?

Get out of the room and go towards the kitchen. The plant is on the window near the kitchen.

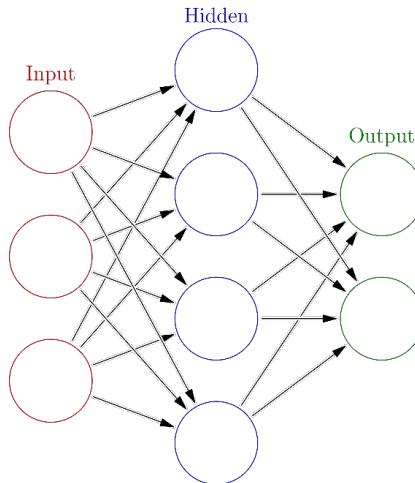
Sure. Where is it?



Gotcha.

Contributors to deep learning success

- Neural network
- Computation
- Data



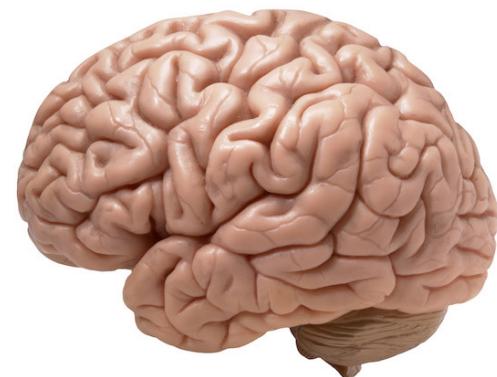
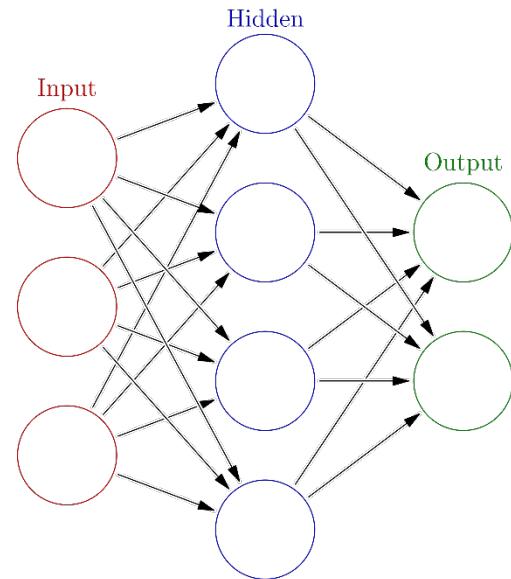
Neural Networks or Artificial Neural Networks (ANNs)

Not covered in the textbook

See assigned reading

Neural networks

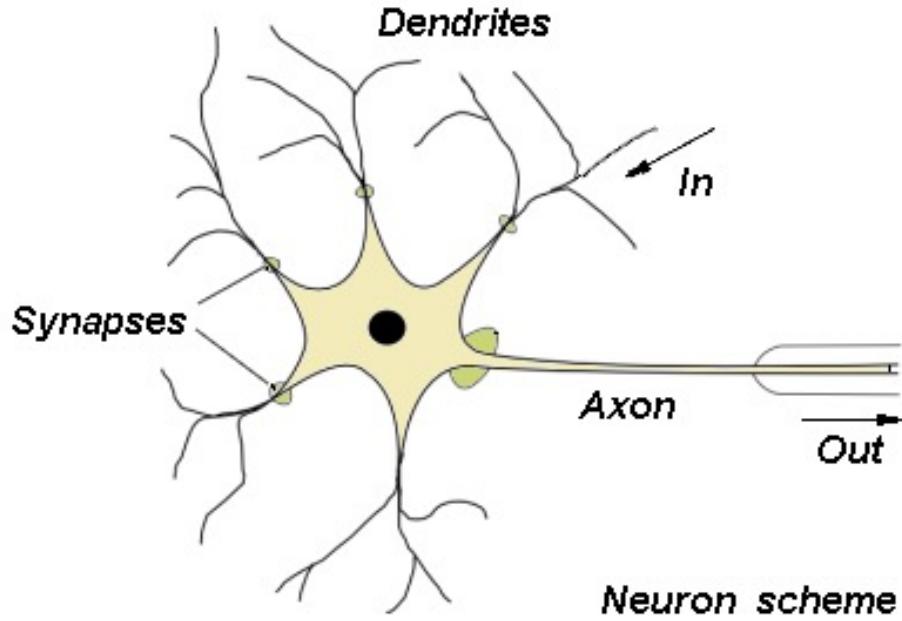
- Networks of processing units (**neurons**) with connections (**synapses**) between them
 - Learning by tuning weights
 - Highly parallel, distributed processing
- Inspired by the brain:
 - Large number of neurons: $\sim 10^{11}$
 - Large connectivity: $\sim 10^{14}$
 - High degree of parallel processing
 - Distributed computation/memory
 - Robust to noise, failures



Neural networks

- Biological evidence of connectionism/parallelism:
 - Physical structure of brain:
 - **Neuron switching time**: 10^{-3} second (1 millisecond)
 - Complex, short-time computations:
 - **Scene recognition time**: 10^{-1} second
 - $100 (= 0.1/0.001)$ inference steps doesn't seem like enough
 - There must be much **parallel computation**
- Artificial Neural Networks (ANNs)
 - Many neuron-like threshold switching units
 - Many weighted interconnections among units
 - Highly parallel, distributed process
 - Emphasis on tuning weights (learning) automatically (searching in weight space)

Biological neurons



Dendrites

- Nerve fibers carrying electrical signals **to the cell**

Cell body (soma)

- “Computes” a non-linear function of its inputs

$$o = f(\text{inputs})$$

Axon

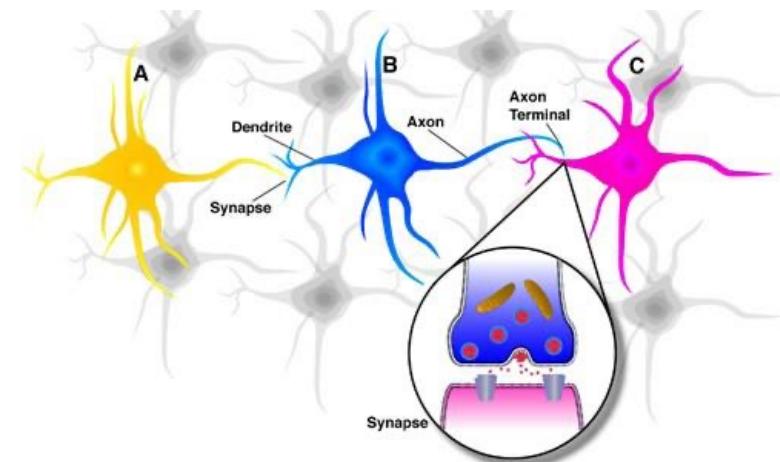
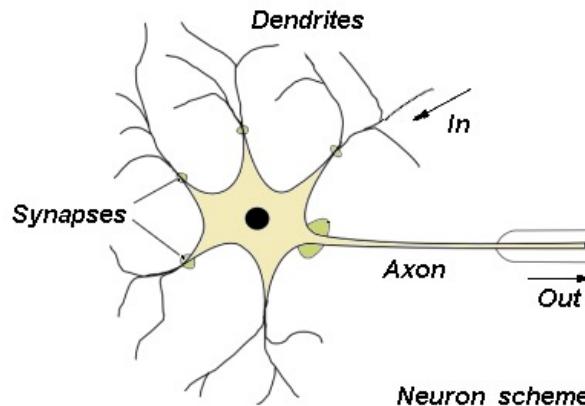
- Single long fiber that carries the electrical signal **from the cell body** to other neurons

Synapse

- The point of contact between the **axon** of one cell and the **dendrite** of another, regulating a chemical connection whose strength affects the input to the **cell**

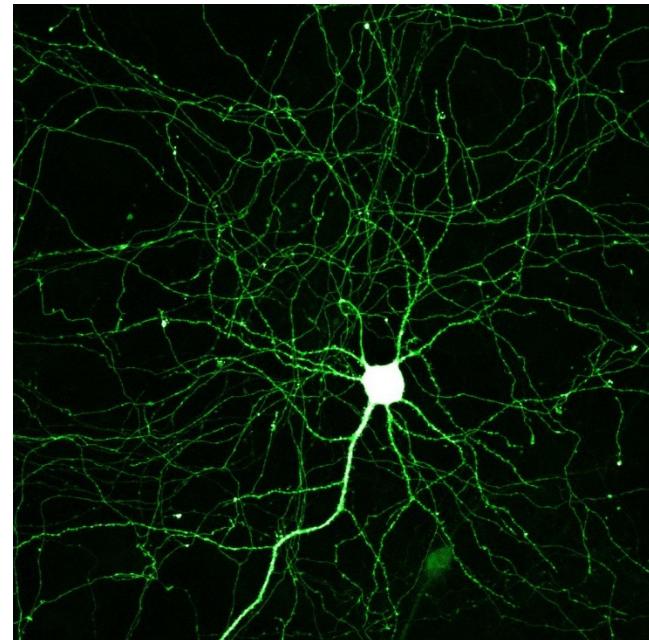
Biological neurons

- The **spikes** travelling along the **axon** of the pre-synaptic neuron trigger the release of **neurotransmitter substances** at the **synapse**
- The neurotransmitters cause excitation or inhibition in the **dendrite** of the post-synaptic neuron.
- The integration of the **excitatory** and **inhibitory** signals may produce **spikes** in the post-synaptic neuron.
- The contribution of the signals depends on the strength of the **synaptic connection**

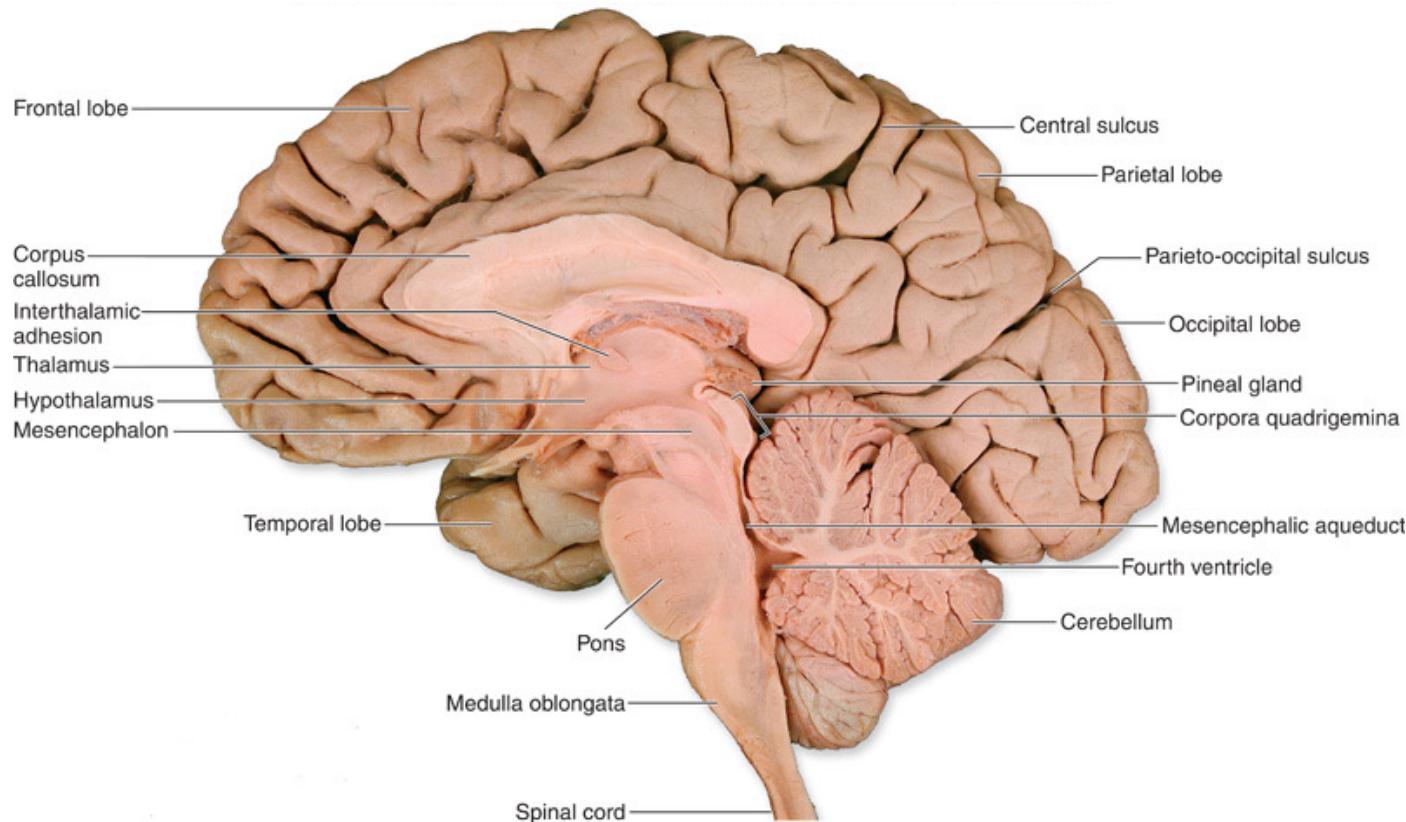


Biological neurons

- A variety of different neurons exist (motor neurons, various visual neurons, etc.), with different branching structures
- The **connections** of the network and the **strengths** of the individual synapses establish the function of the network.



Brains = Neural networks??



Thoughts

Muscle control

Feelings

Emotions

Sensing

Perception

Language

Reasoning

Decision making

Consciousness

Planning

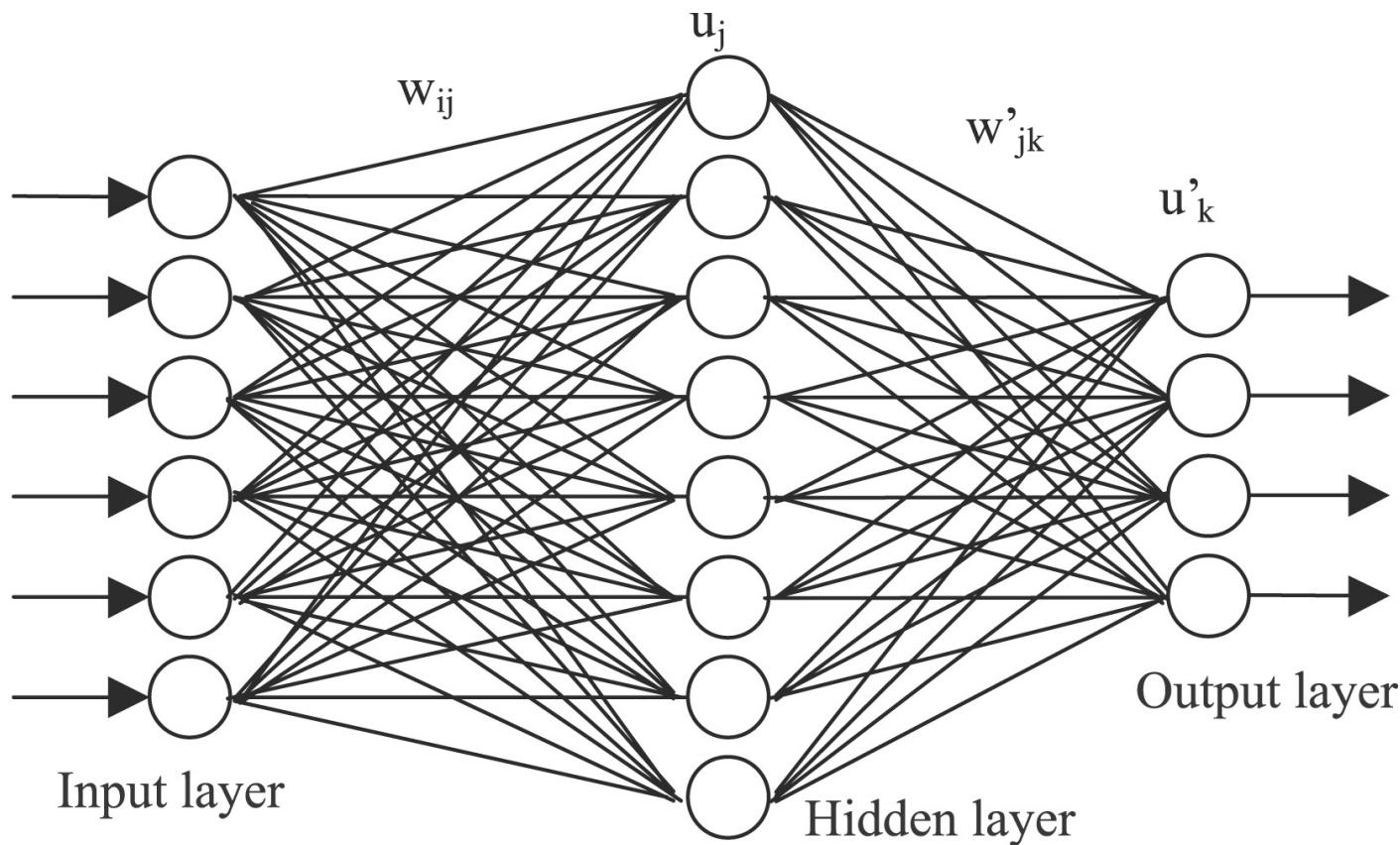
Memory

Balance

Timing

Coordination

Brains = Neural networks??



Note: This is a **two-layer** (not three-layer) neural network, a hidden layer and an output layer. The input layer does not count. There are **two layers of weights**.

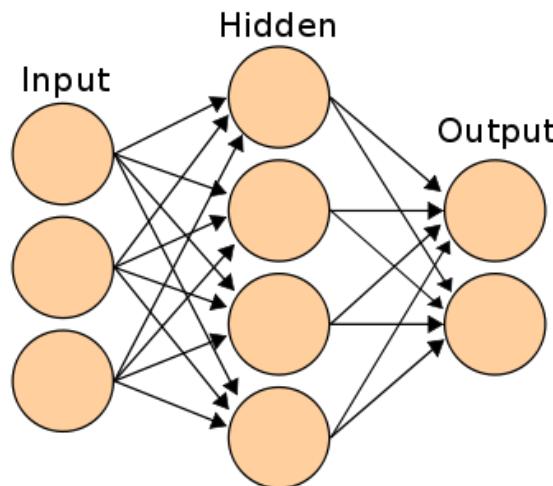
What do neural networks do?

- Neural networks provide a way to **learn functions**, which are used for the types of machine learning problems we've been discussing: classification, clustering, regression, etc.
- NNs provide a **family of techniques** to address ML problems:
 - Feedforward neural network
 - Convolutional neural network
 - Recurrent neural network
 - Learning Vector Quantization
 - Hopfield network
 - Boltzmann machine
 - Associative neural network
 - Cascading neural network
 - Transformer (self-attention neural network)
 - Etc., etc.

Artificial neural networks

- Inspired by our understanding of the brain, a basic ANN is a set of simple processing elements (nodes or neurons) connected together to form a network that shares some properties with connected networks of neurons in the brain
- Neural networks typically have these characteristics:
 - Node connections with adaptive (learnable) weights
 - Can approximate nonlinear functions of the inputs
 - Highly parallel (conceptually – may be implemented serially)

A simple 2-layer
neural network

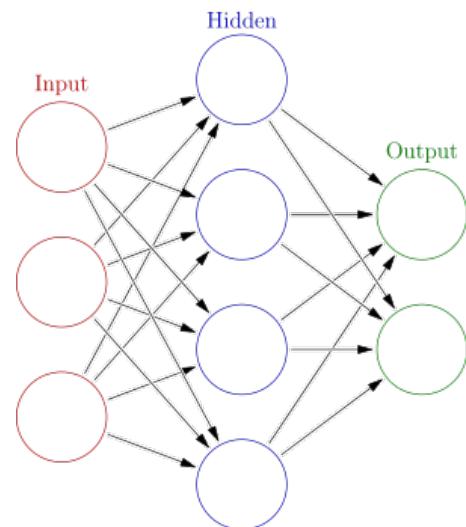


The NN learning problem:
from training data, learn the
weights.

So the ML model comprises
the network architecture and
the weights.

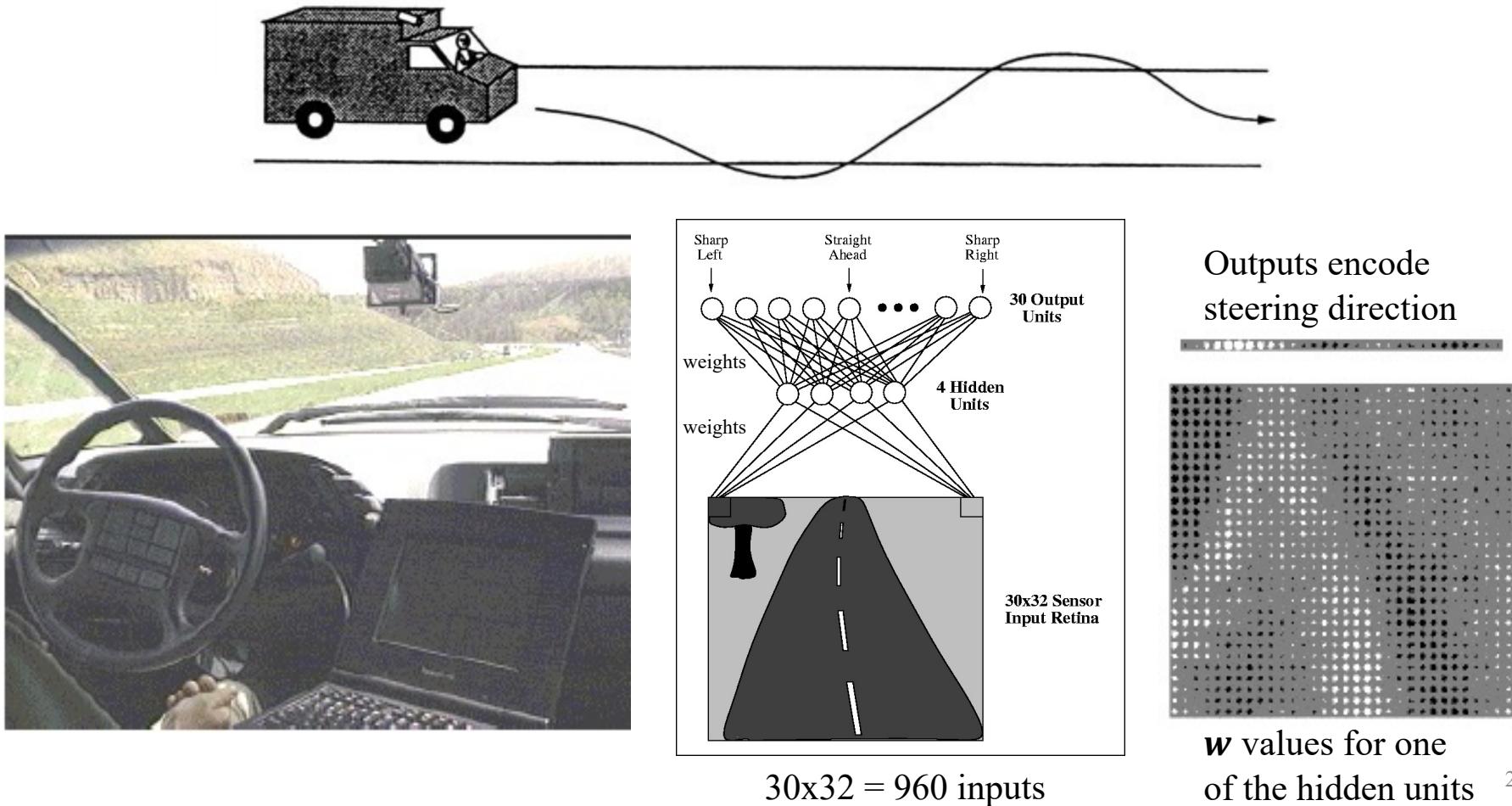
When to consider using an ANN

- When the **input** is
 - High-dimensional
 - Not well understood
 - Noisy
- Form of **target function** is unknown
- Long **training times** are acceptable
- **Human readability** is unimportant
 - Don't need to understand what's "under the hood"
- Especially necessarily good for **complex pattern recognition** problems, such as:
 - Speech recognition
 - Image classification
 - Financial prediction



Problems “too hard to program”

ALVINN (mid-1990s): a NN perception system which learned to control the CMU NAVLAB vehicles, trained by observing a person drive



1995

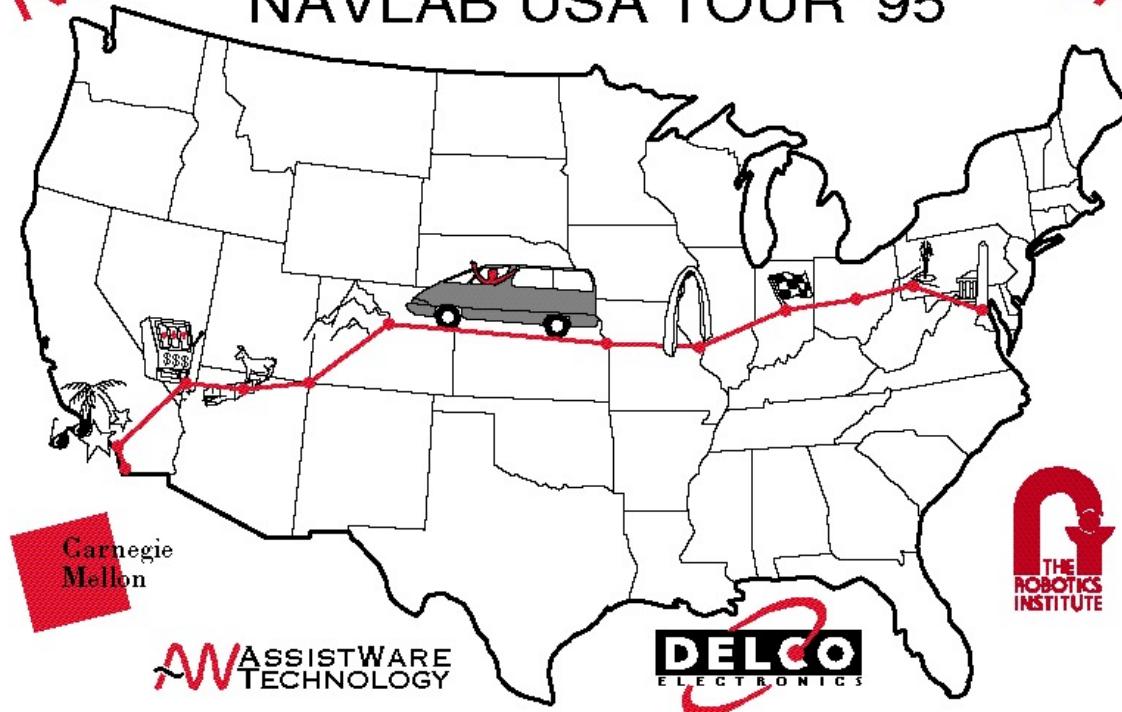


2797/2849 miles

(98.2%)

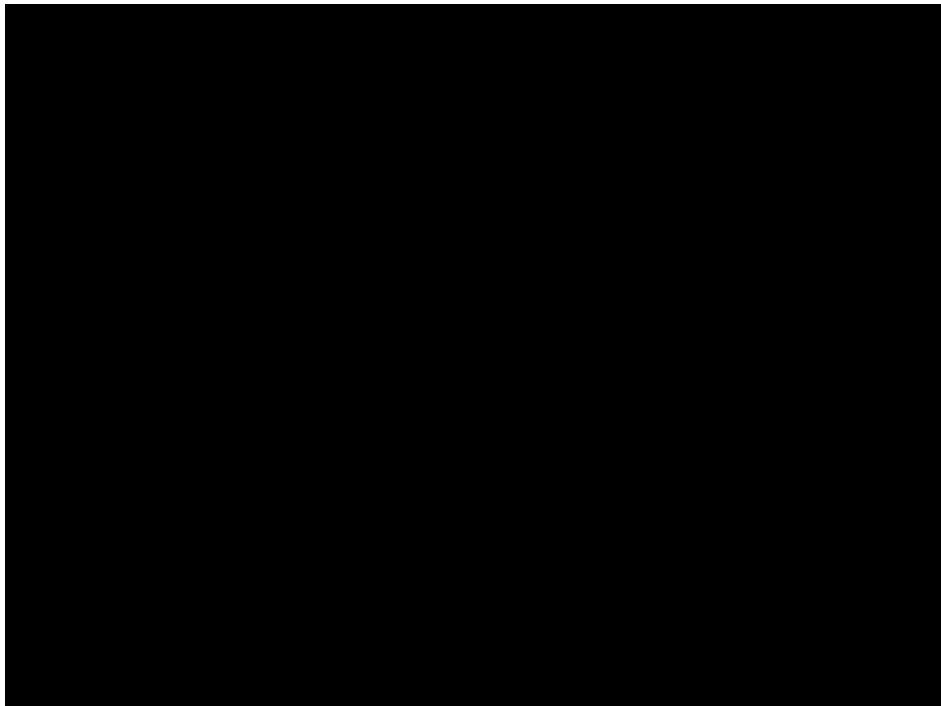
Speeds up to 70 mph

NO HANDS ACROSS AMERICA NAVLAB USA TOUR '95



- Washington DC ● Pittsburgh PA ● Columbus OH ● Indianapolis IN ● Kokomo IN
- Saint Louis MO ● Kansas City KA ● Denver CO ● Four Corners
- Grand Canyon ● Las Vegas NV ● Los Angeles CA
- San Diego CA

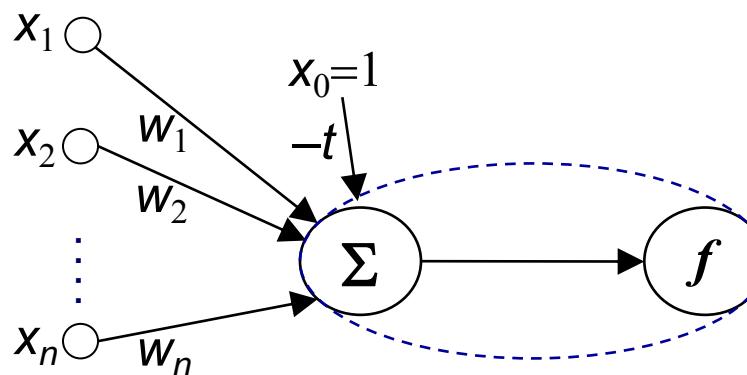
NavLab 1997 video



https://www.youtube.com/watch?v=xkJVV1_4l8E

More details: <https://www.youtube.com/watch?v=Tat70DqpKw8>

A simple neural network



What's this neural network called?
A linear **perceptron**!

$$o = f\left(\sum_{i=0}^n w_i x_i\right) = \begin{cases} 1 & \text{if } > 0 \\ -1 & \text{else} \end{cases}$$

Inputs x	Weights w	Sum of weighted inputs	Threshold function
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$-t$: threshold value or **bias**

$$\left(\sum_{i=0}^n w_i x_i \right) = \left(\sum_{i=1}^n w_i x_i \right) - t = w^T x - t$$

Homogeneous Non-homogeneous

f : activation function – may be a thresholding unit (binary output):

$$f(x) = \begin{cases} 1 & x > 0 \\ -1 & \text{otherwise} \end{cases} \quad \text{or} \quad f(x) = \begin{cases} 1 & x > 0 \\ 0 & \text{otherwise} \end{cases}$$

HAPPY
THANKSGIVING

