


What is Deep Learning?

BSDS 100, Spring 2021
Michael Ruddy

A dark blue diagonal gradient bar that starts from the bottom left and extends towards the top right, covering the lower half of the slide.

What is Deep Learning?

- **Deep Learning** often refers to a subset of Machine Learning algorithms that work by extracting *high-level features* from datasets that are often gigantic and/or largely unstructured
- **Neural Networks** are the workhorse behind many Deep Learning algorithms
 - Computer Vision
 - Natural Language Processing

Deep Learning works

- Image generation by DeepMind AI

Result of partial training



(a) 128×128



(b) 256×256



(c) 512×512



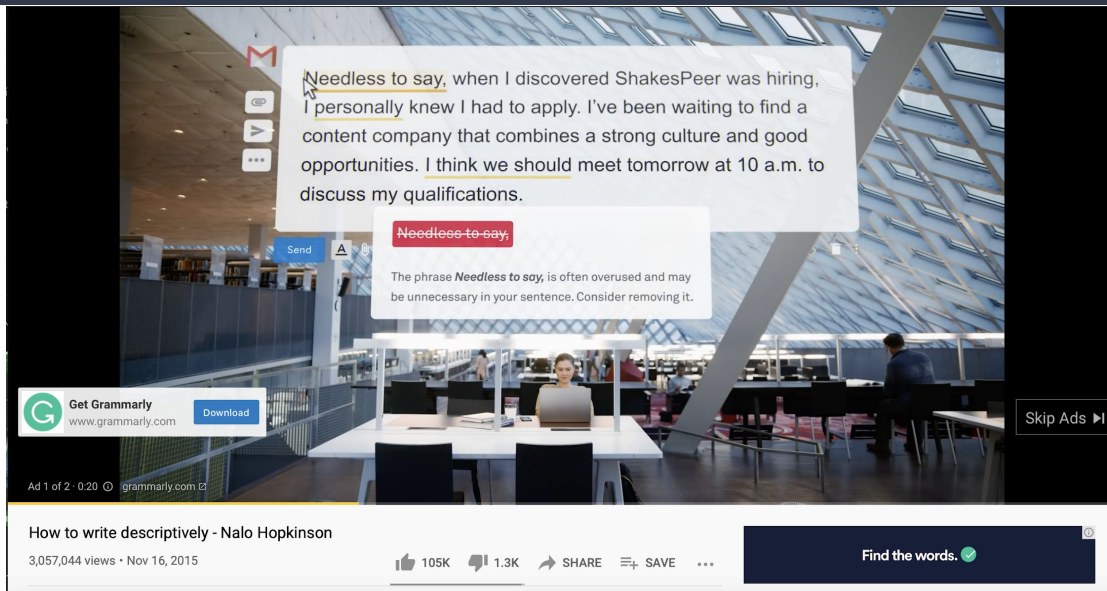
(d)

Deep Learning works



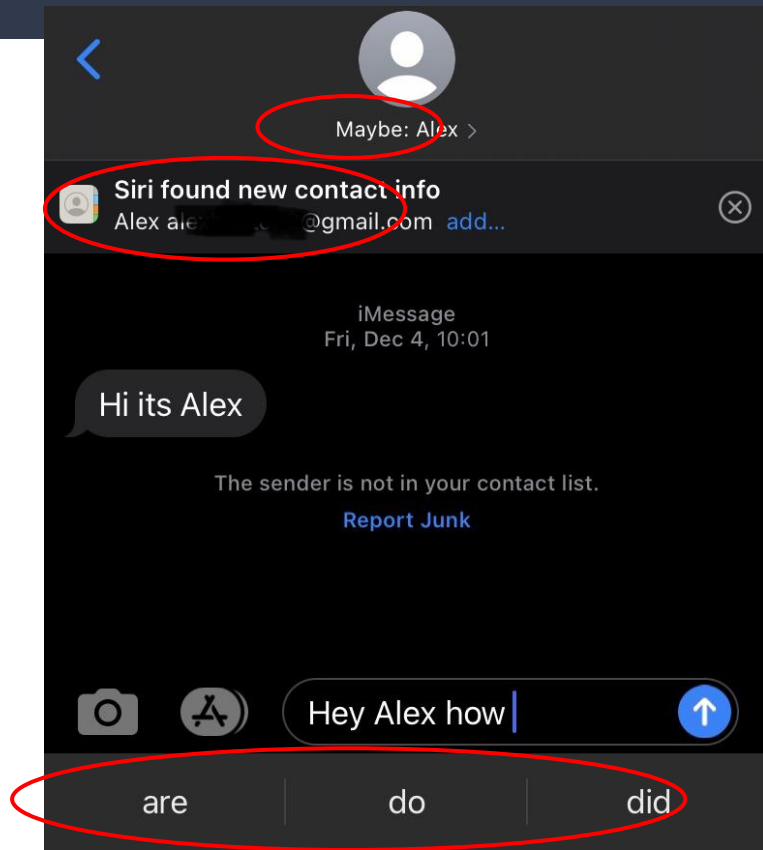
- Tom Cruise Deepfake by @deeptomcruise on Tik Tok

Deep Learning works



The video player shows a scene of a modern office with a large glass ceiling. A white text box is overlaid on the video, containing the text: "Needless to say, when I discovered ShakesPeer was hiring, I personally knew I had to apply. I've been waiting to find a content company that combines a strong culture and good opportunities. I think we should meet tomorrow at 10 a.m. to discuss my qualifications." Below this text, a red box highlights the phrase "Needless to say," with a tooltip that reads: "The phrase *Needless to say*, is often overused and may be unnecessary in your sentence. Consider removing it." At the bottom left, there is a Grammarly logo and the text "Get Grammarly www.grammarly.com Download". At the bottom right, there is a "Skip Ads" button. Below the video player, the video title "How to write descriptively - Nalo Hopkinson" is displayed, along with the view count "3,057,044 views" and the date "Nov 16, 2015". There are also icons for likes (105K), comments (1.3K), share, save, and a "Find the words" button.

Some or all of the content shared in this Tweet conflicts with guidance from public health experts regarding COVID-19. [View](#) [Learn more](#)



The screenshot shows an iMessage conversation on an iPhone. At the top, there is a back arrow, a profile picture, and the name "Maybe: Alex >". Below this, a system message reads: "Siri found new contact info Alex alex...@gmail.com add...". The message history shows an iMessage from "Fri, Dec 4, 10:01" with the text "Hi its Alex". Below this, a system message states: "The sender is not in your contact list. Report Junk". At the bottom, there is a text input field with the text "Hey Alex how" and a send button. Below the input field, a keyboard is visible with the words "are", "do", and "did" highlighted in red circles.

Deep Learning works

- **Deep Learning** often refers to a subset of Machine Learning algorithms that work by extracting *high-level features* from datasets that are often gigantic and/or largely unstructured



- Two Ears
- Two Eyes
- A nose
- Fluffiness $\sim .8$

Deep Learning works

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$$\begin{bmatrix} 1 & .5 & 1 & 0 \\ 0 & .25 & .5 & 1 \\ 1 & .25 & 0 & 1 \\ .5 & 0 & 1 & 1 \end{bmatrix}$$

- Two Ears = ???
- Two Eyes = ???
- A nose = ???
- Fluffiness = ???

Deep Learning works

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Low level Geometric features

$\begin{bmatrix} 1 & .5 & 1 & 0 \\ 0 & .25 & .5 & 1 \\ 1 & .25 & 0 & 1 \\ .5 & 0 & 1 & 1 \end{bmatrix}$	- Edge detection
	- Noisiness
	- Blob detection

Deep Learning works

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Deep Learning

$$\begin{bmatrix} 1 & .5 & 1 & 0 \\ 0 & .25 & .5 & 1 \\ 1 & .25 & 0 & 1 \\ .5 & 0 & 1 & 1 \end{bmatrix}$$

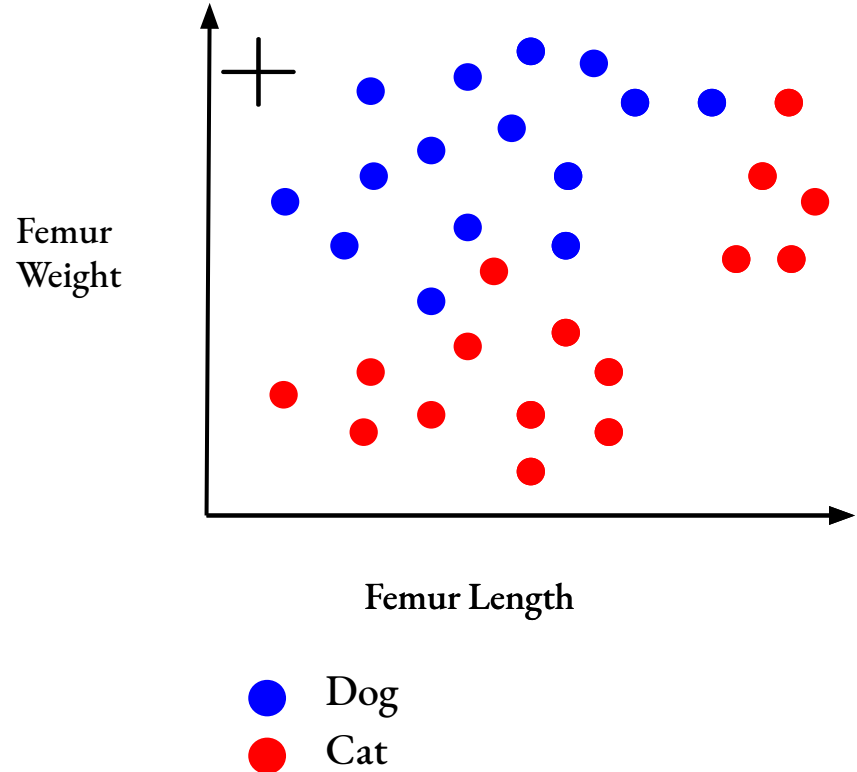
- High-level features
- Not always interpretable!!!!!!

What is a Neural Network?

- Task: Classify as Cat or Dog
- Data:
 - Femur Weight
 - Femur Length



*Sabre Tooth Tiger
Femurs,
U of FL*



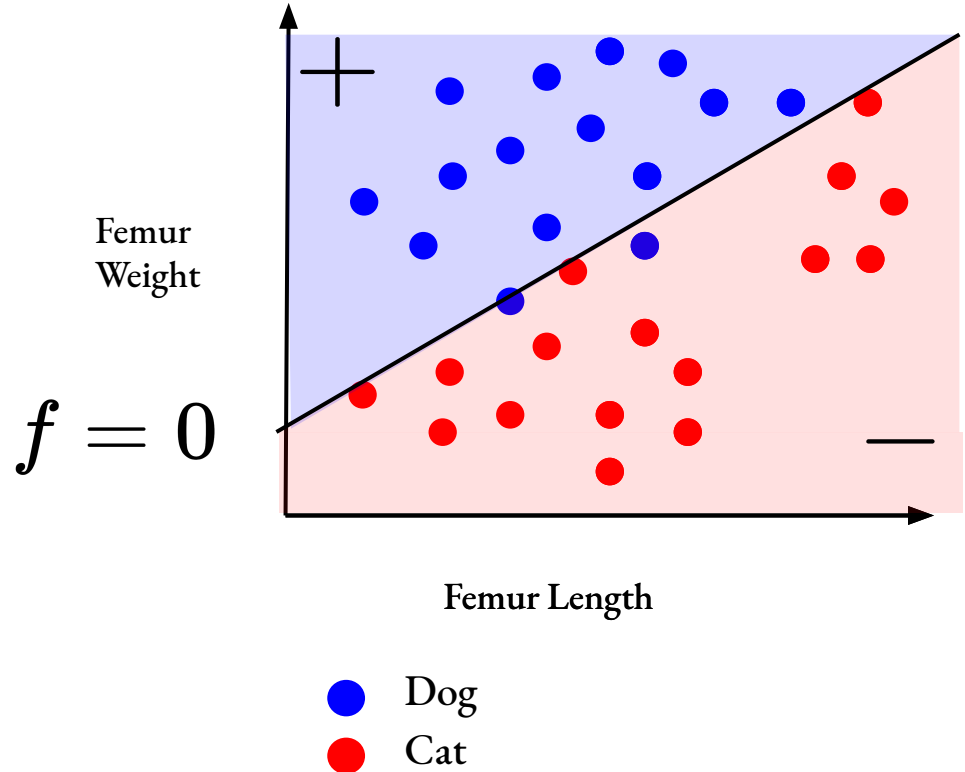
What is a Neural Network?

$$f = a_1 + a_2(\text{length}) + a_3(\text{weight})$$

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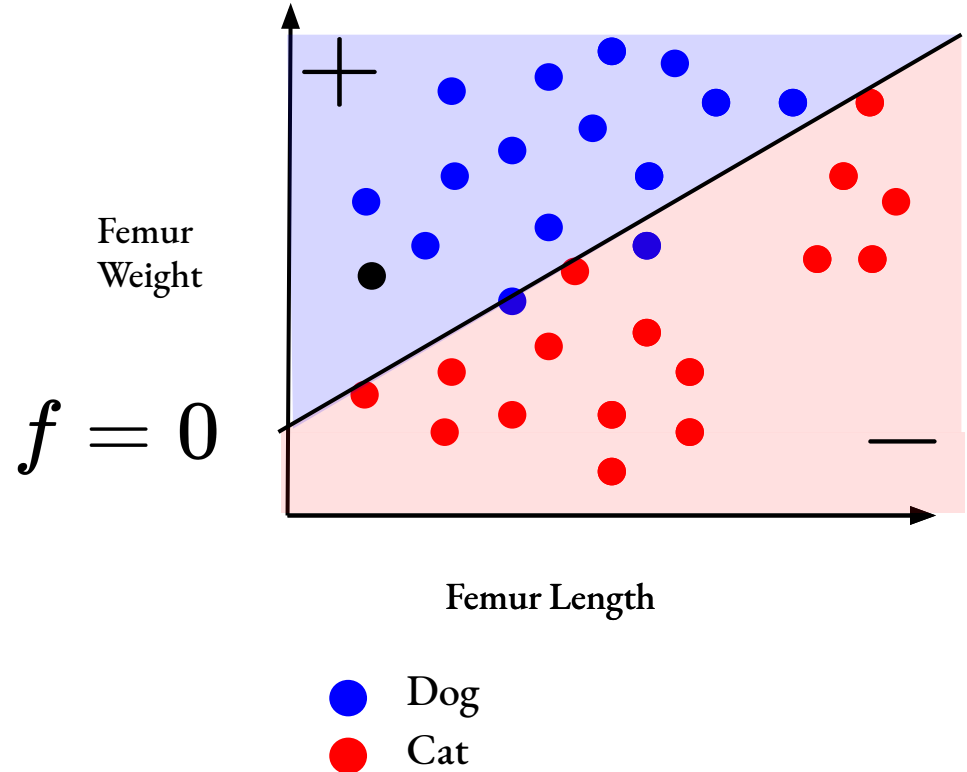
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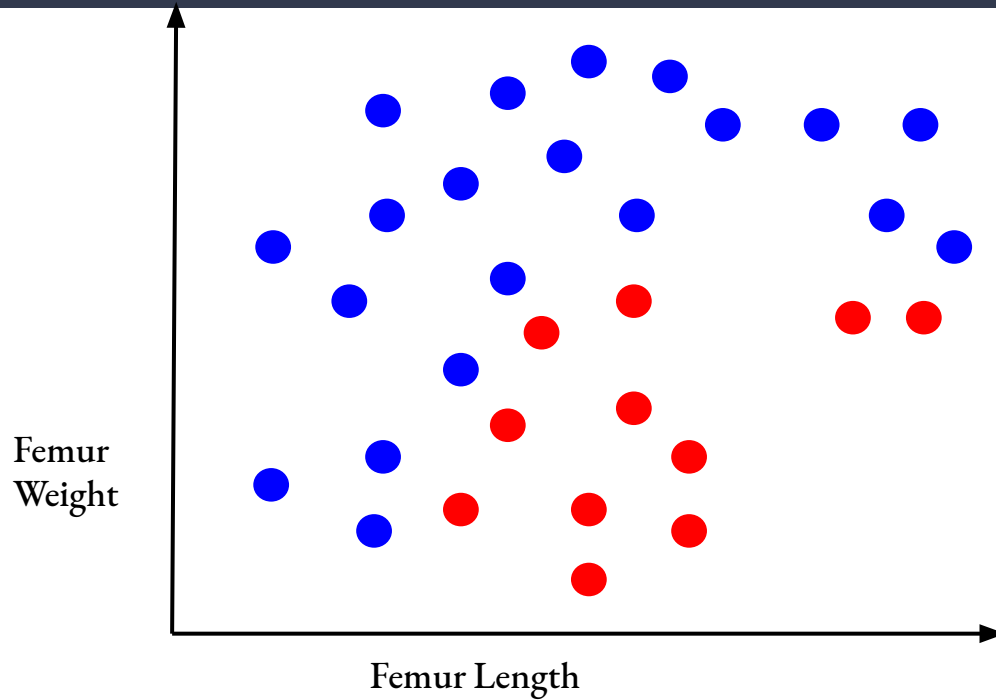
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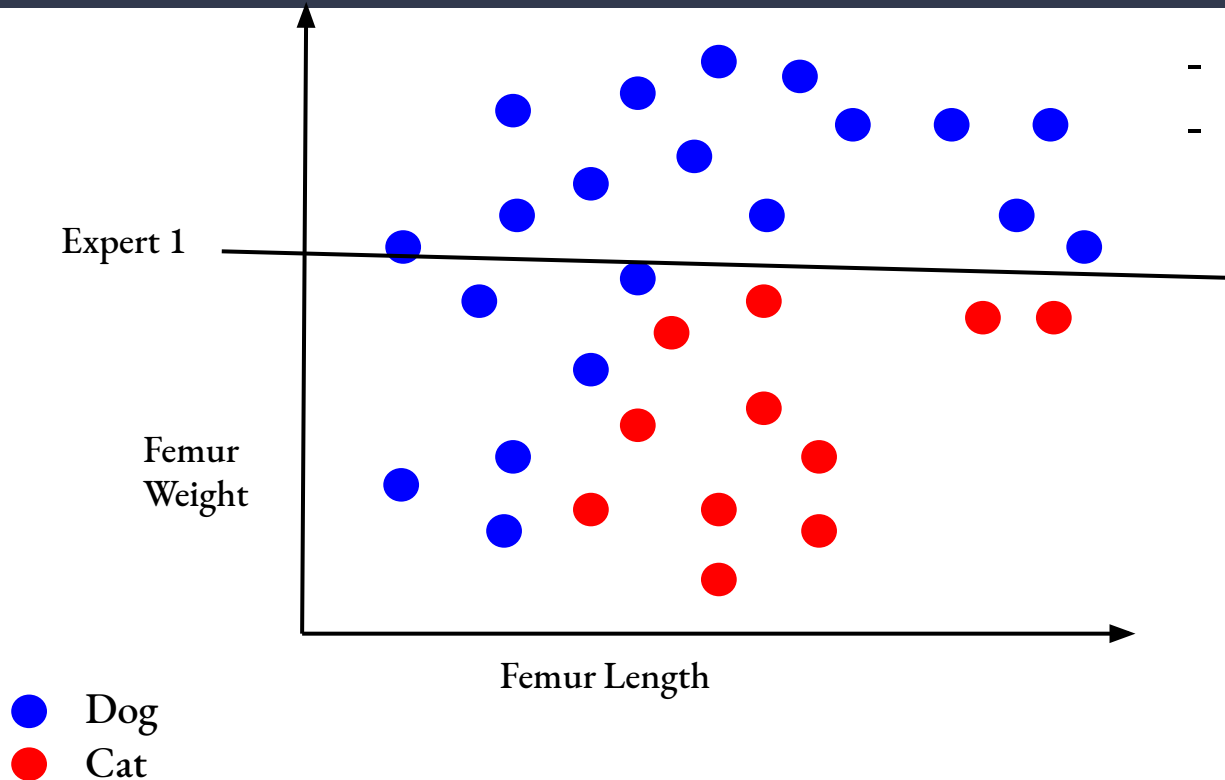
What is a Neural Network?



- Real data not so easy!

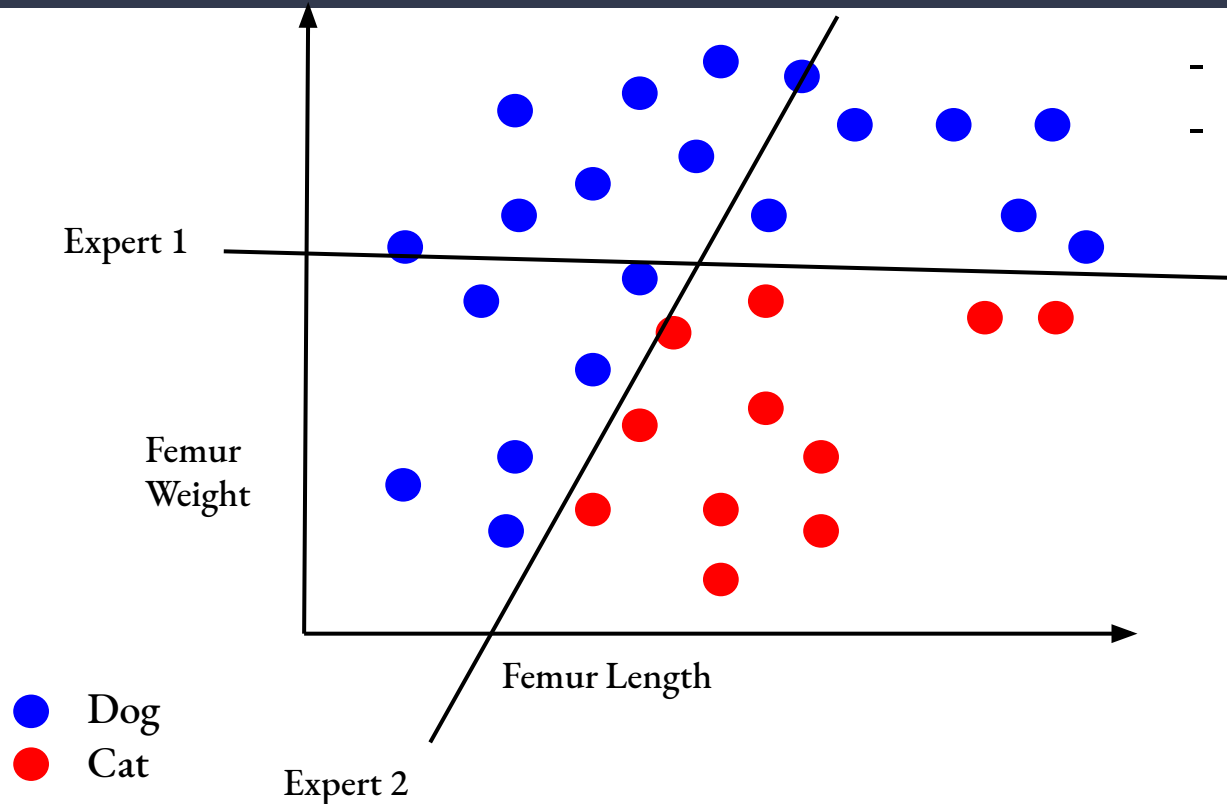
● Dog
● Cat

What is a Neural Network?



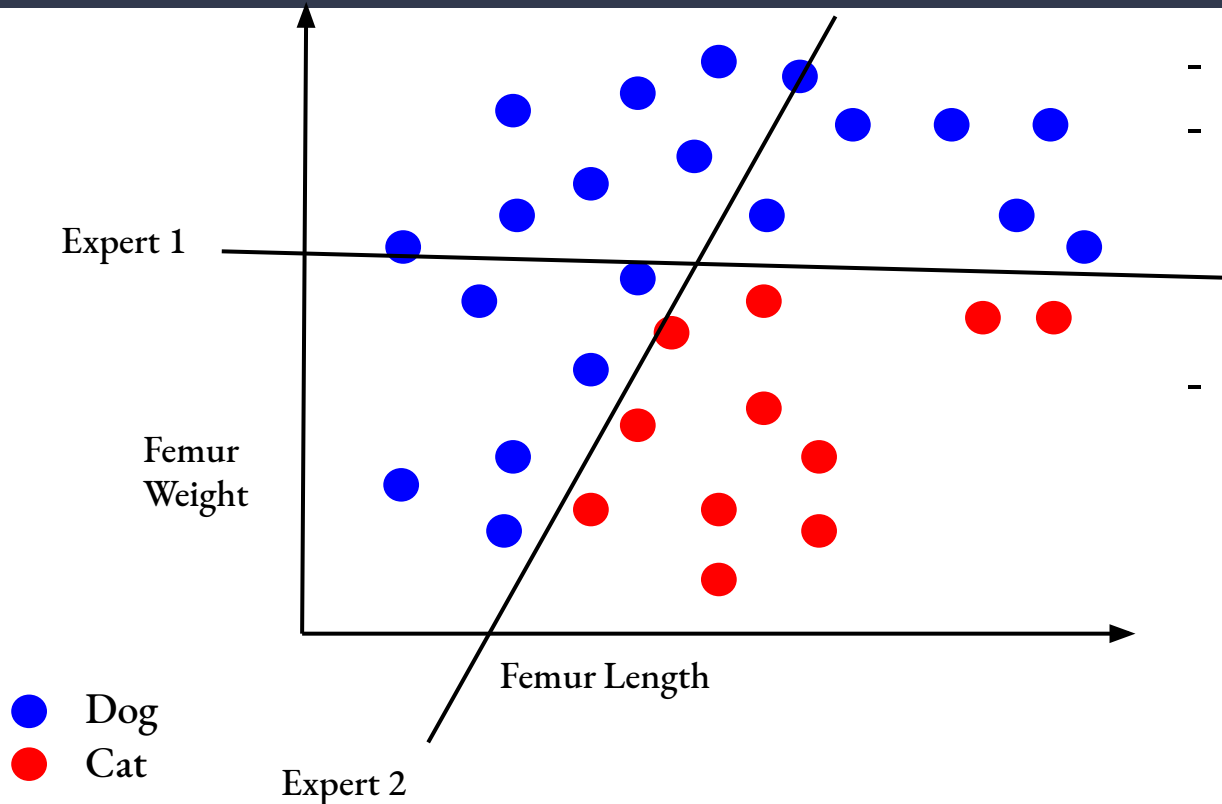
- Real data not so easy!
- Two expert opinions:
Zooarchaeologists

What is a Neural Network?

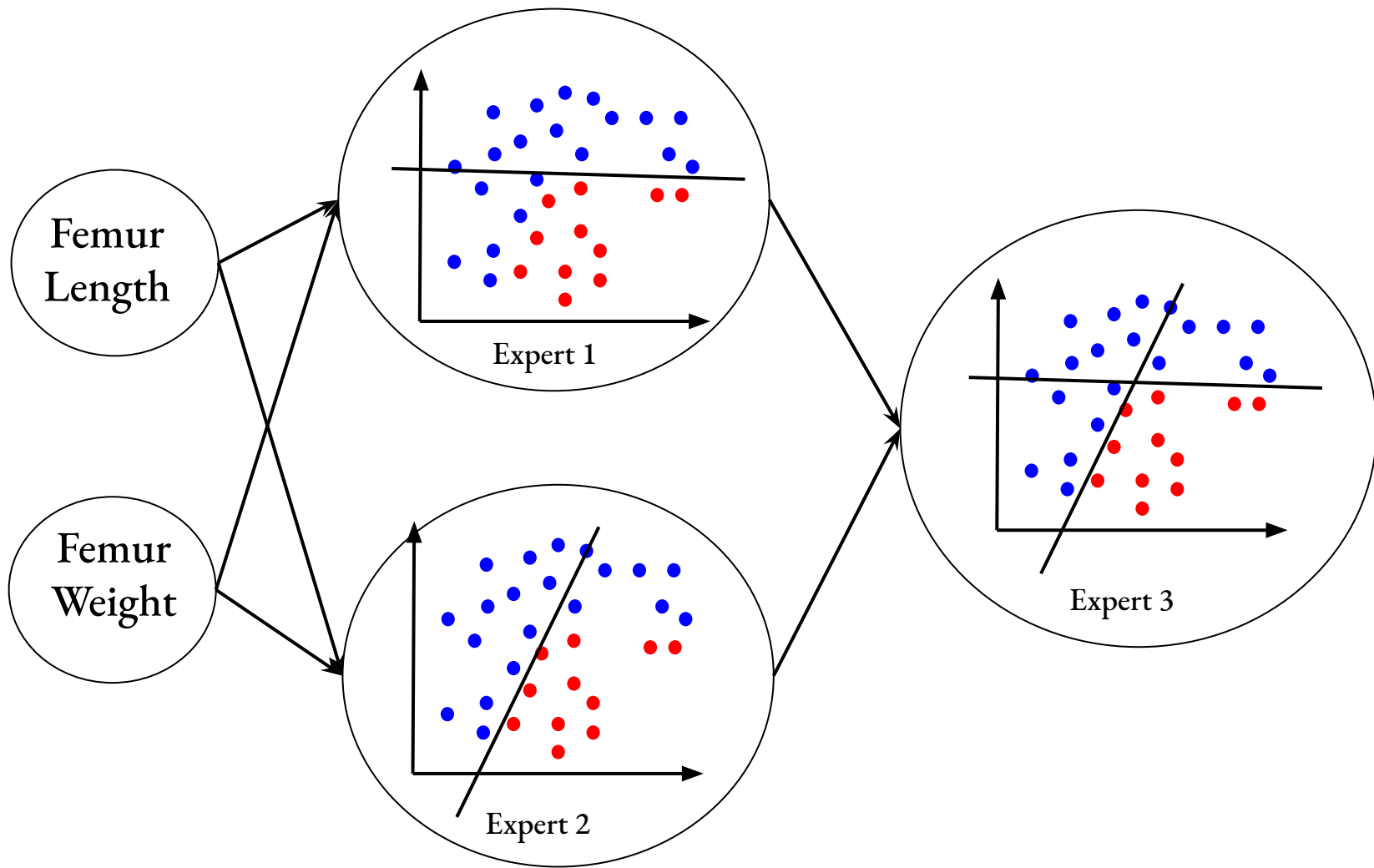


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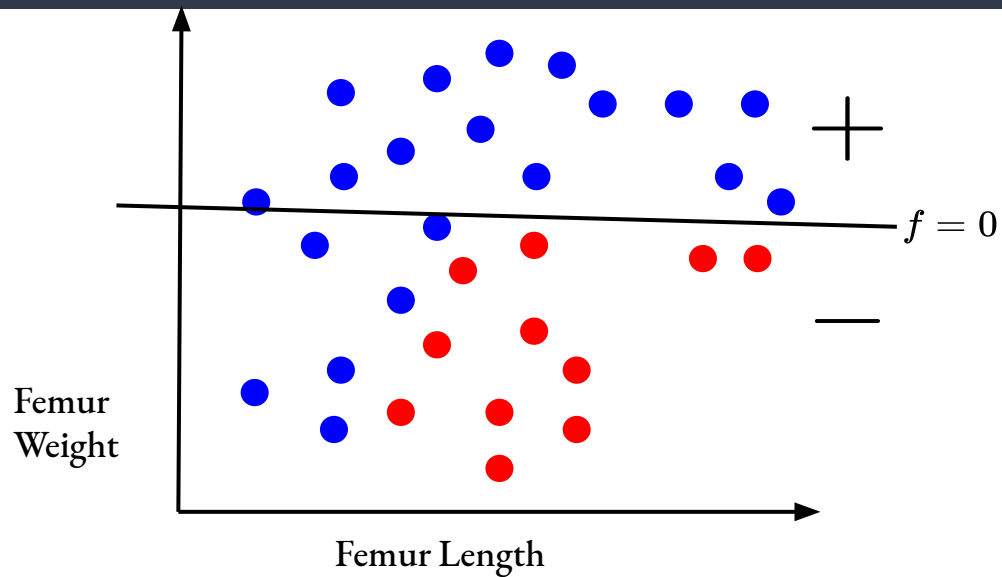
What is a Neural Network?



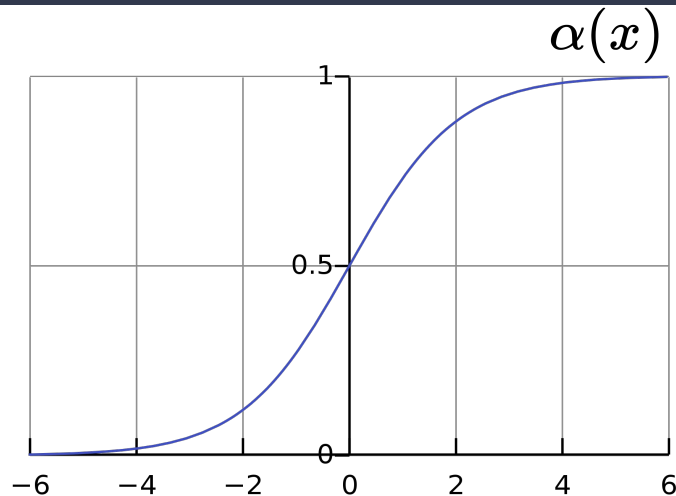
- Real data not so easy!
- Two expert opinions: Zooarchaeologists
- Expert 3:
If 1 & 2 think it's a cat, then it's a cat.
Otherwise it's a dog



What is a Neural Network?



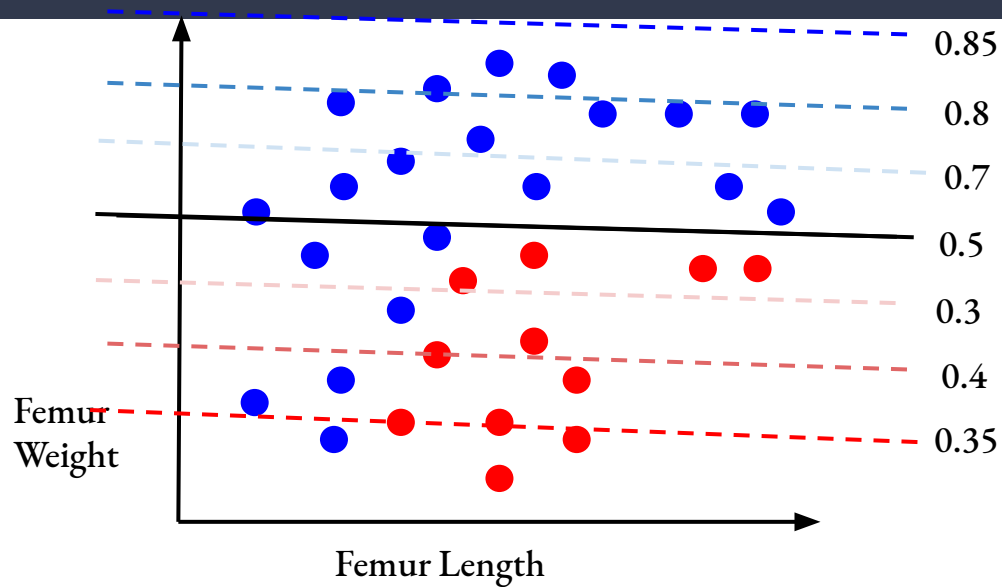
- Dog
- Cat



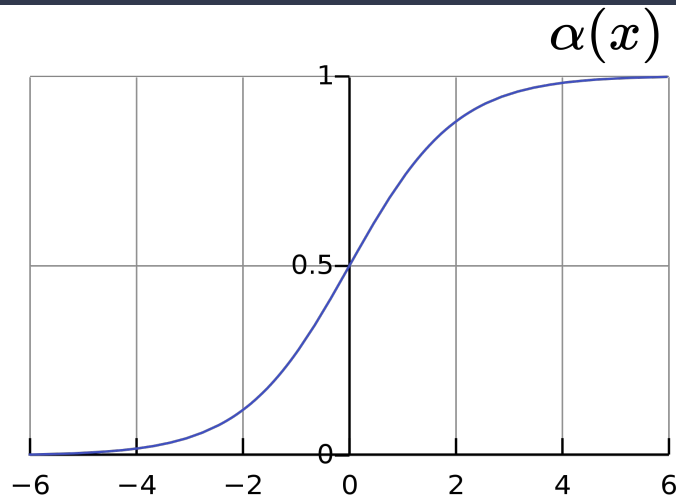
Sigmoid function

What is a Neural Network?

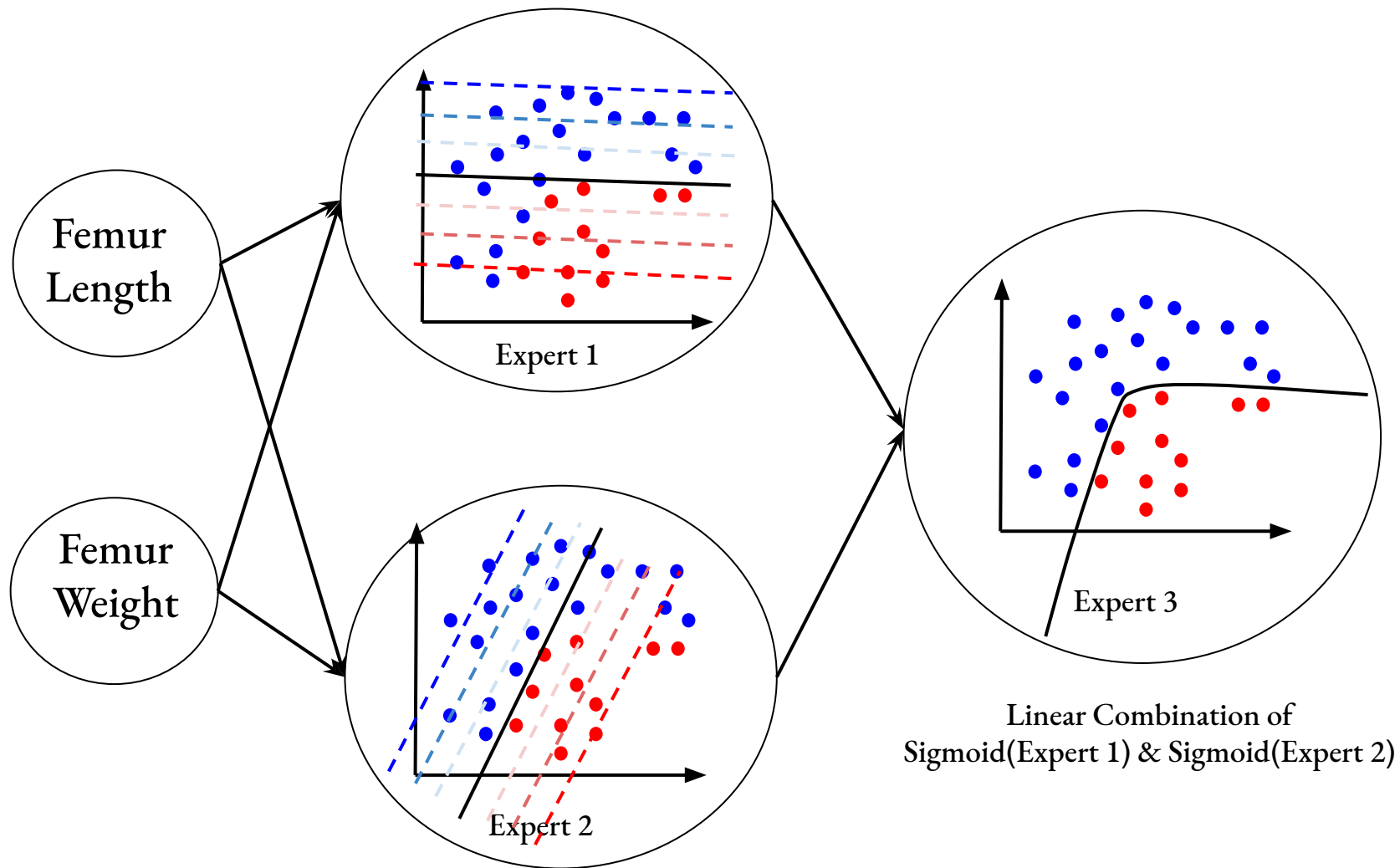
$$\alpha[a_1 + a_2(\text{length}) + a_2(\text{weight})]$$



- Dog
- Cat



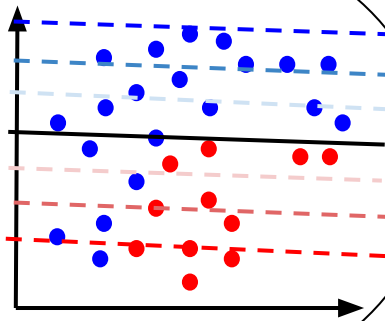
Sigmoid function



Input Layer

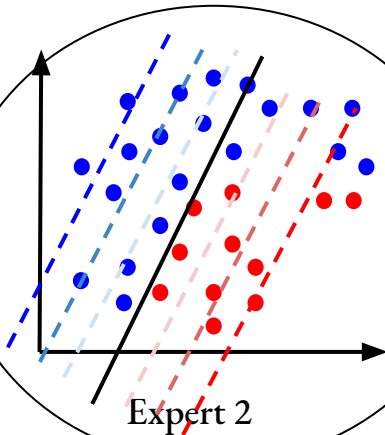
Femur
Length

Femur
Weight



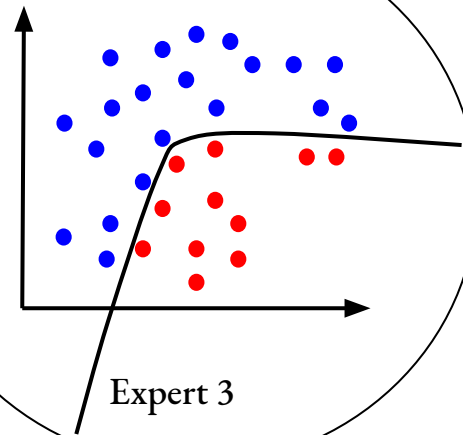
Expert 1

Hidden Layer

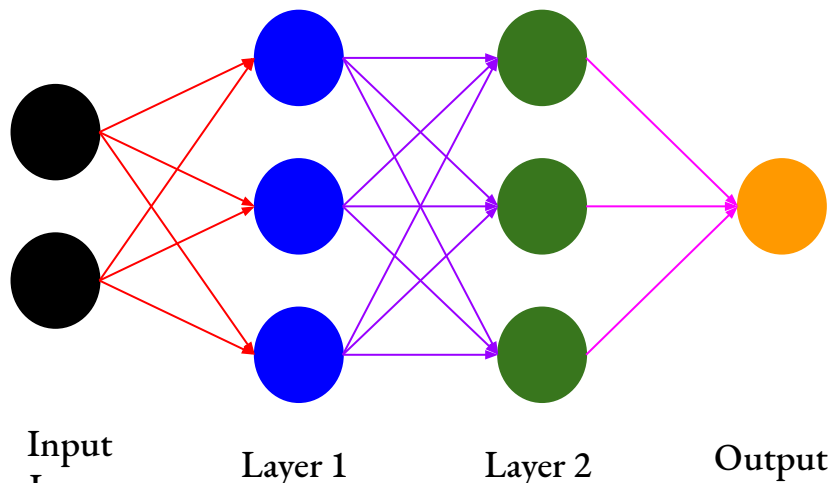


Expert 2

Output Layer



Expert 3


 \vec{x}
 \vec{a}_1
 \vec{a}_2
 \vec{y}

$$\vec{a}_1 = \alpha(A_1 \vec{x} + \vec{b}_1)$$

$$\vec{a}_2 = \alpha(A_2 \vec{a}_1 + \vec{b}_2)$$

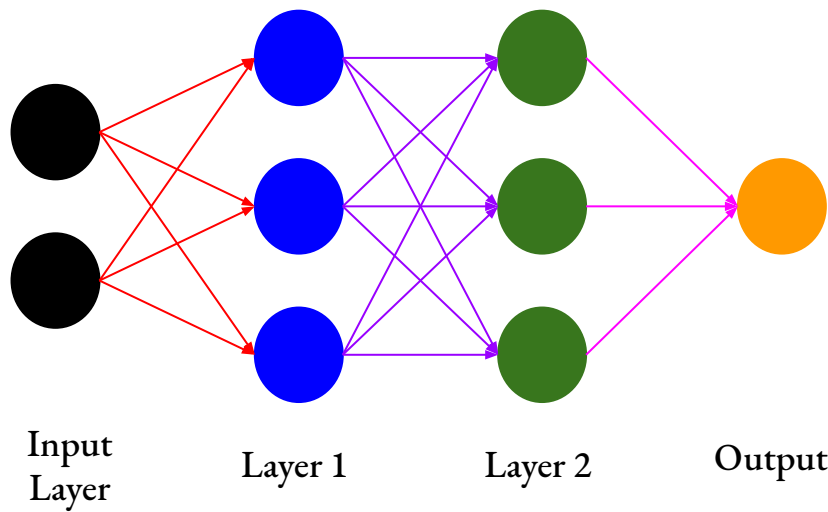
$$\vec{y} = \alpha(A_3 \vec{a}_2 + \vec{b}_3) = f(\vec{x})$$

In general:

- Linear function followed by nonlinearity
- Can approximate *any* function this way
- 'Deeper' = more layers

Why?

- Linear = simple, fast
- Optimization



\vec{x}

\vec{a}_1

\vec{a}_2

\vec{y}

$$\vec{a}_1 = \alpha(A_1\vec{x} + \vec{b}_1)$$

$$\vec{a}_2 = \alpha(A_2\vec{a}_1 + \vec{b}_2)$$

$$\vec{y} = \alpha(A_3\vec{a}_2 + \vec{b}_3) = f(\vec{x})$$

Linear
Algebra

+

Calculus

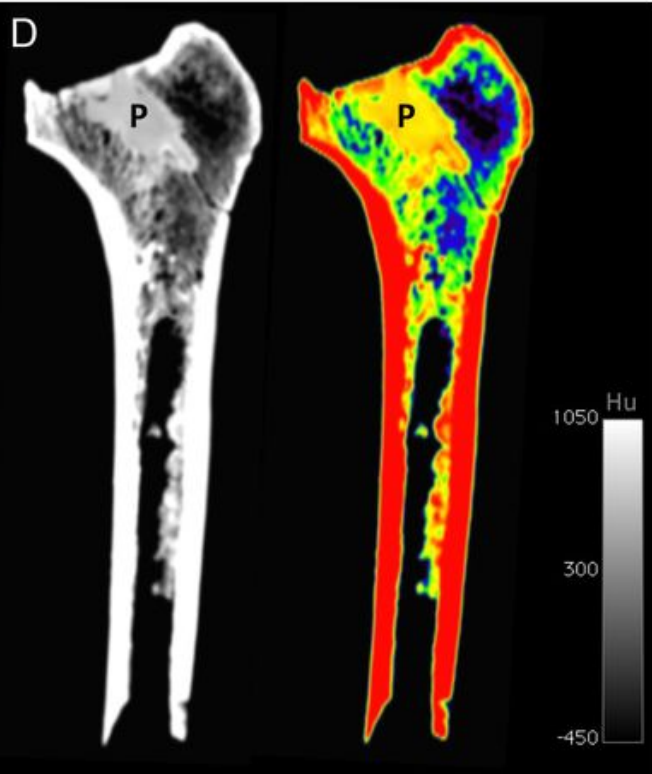
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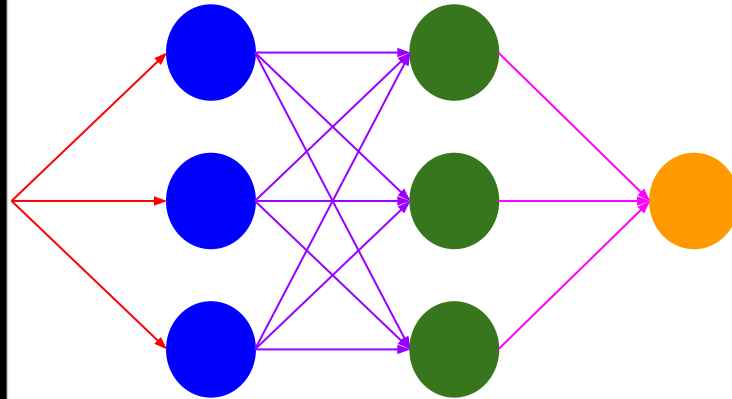
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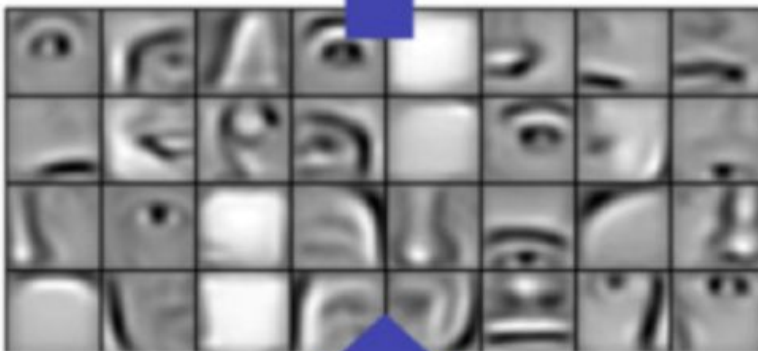
Let model decide what features are important from raw image data



A Hominin Femur with Archaic Affinities from the Late Pleistocene of Southwest China, Curnoe D., Ji X., Liu W., Bao Z. Tacon P., Ren L.



Layer 3



Layer 2



Layer 1

Why now?

- To build a high-performance Neural Network model you need:
 - Lots of Data
 - Lots of Computing Power
- The sheer amount of data prevents overfitting and helps Neural Networks learn complicated patterns in data
- GPUs perform small computations extremely quickly and in parallel, incidentally they are great for training Neural Networks

Benefits of Recent Progress in Deep Learning

- Explosion of performance capability
 - Computer Vision: from fun Snapchat features to self-driving
 - NLP: Conquered simple language tasks, conversation/Q&A is next?
 - AI that can beat humans at games like Go
- Upends many traditional modelling frameworks
- Gives mathematicians/statisticians something to do...

Careful!

- Neural Networks are generally **not interpretable**.
 - We don't know why/how a particular model comes to its decision
 - Hard to know exactly what it will do in outlier situations
 - Wholly dependent on data it has access to

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 - Wholly dependent on data it has access to
- Can be **dangerous** when used carelessly with real world consequences
 - Can reinforce systemic biases (yes algorithms can learn to be racist)
 - Liability issues for AI

Careful! – Examples

- *Man is to Computer Programmer as Woman is to Homemaker? Debiasing Word Embeddings* by Bolukbasi, Chang, Zou, Saligrama, Kalai
- *Examining the Modelling Framework of Crime Hotpot Models in Predictive Policing* by Goodson, Hoyer-Leitzel
- *Face Recognition: Too Bias or Not Too Bias?* by Robinson, Livitz, Henon, Qin, Fu, Timoner

Summary

- Deep learning works by combining simple computations to create a complicated network with many parameters then using tons of data to train a high-performing model
- These algorithms are becoming increasingly common
- Can be extraordinarily helpful
- Can also be extremely harmful if not used carefully and if developers do not think deeply about their impact
- Still largely a “black box” method with more study desperately needed!