

csci 1470

Eric Ewing

Thursday, 9/4

Deep Learning

Day 1: Introduction to Deep Learning

Chimborazo, Ecuador. The farthest point from the center of the earth

About Your Instructor

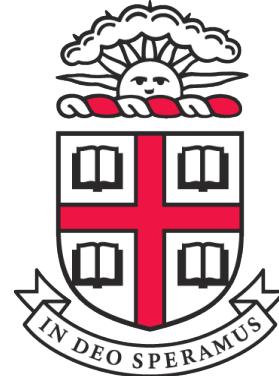


2012-2016 B.A. in
Computer Science
+ Classics



USC

2018-2022
Began Ph.D.



2022-2024
Finished Ph.D.

Office: Arnold Lab 305

Office Hours:
• Tu/W 2-4pm

Enter from Waterman St., near Metcalf!



Research Interests:

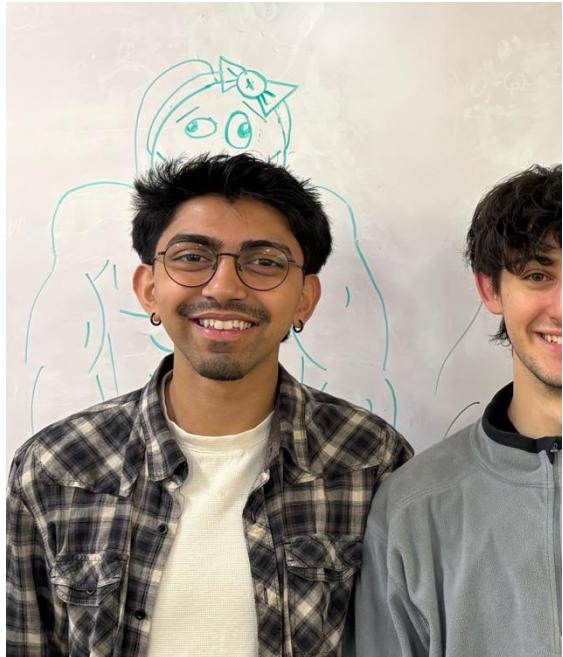
- Multi-Robot Systems
- Deep Learning for Optimization
- Interface between classical AI systems and Deep Learning

UTAs

Your Tas!

HTA

Armaan Patankar



Maria Wang



Narek Harutyunyan



Johnny Elias

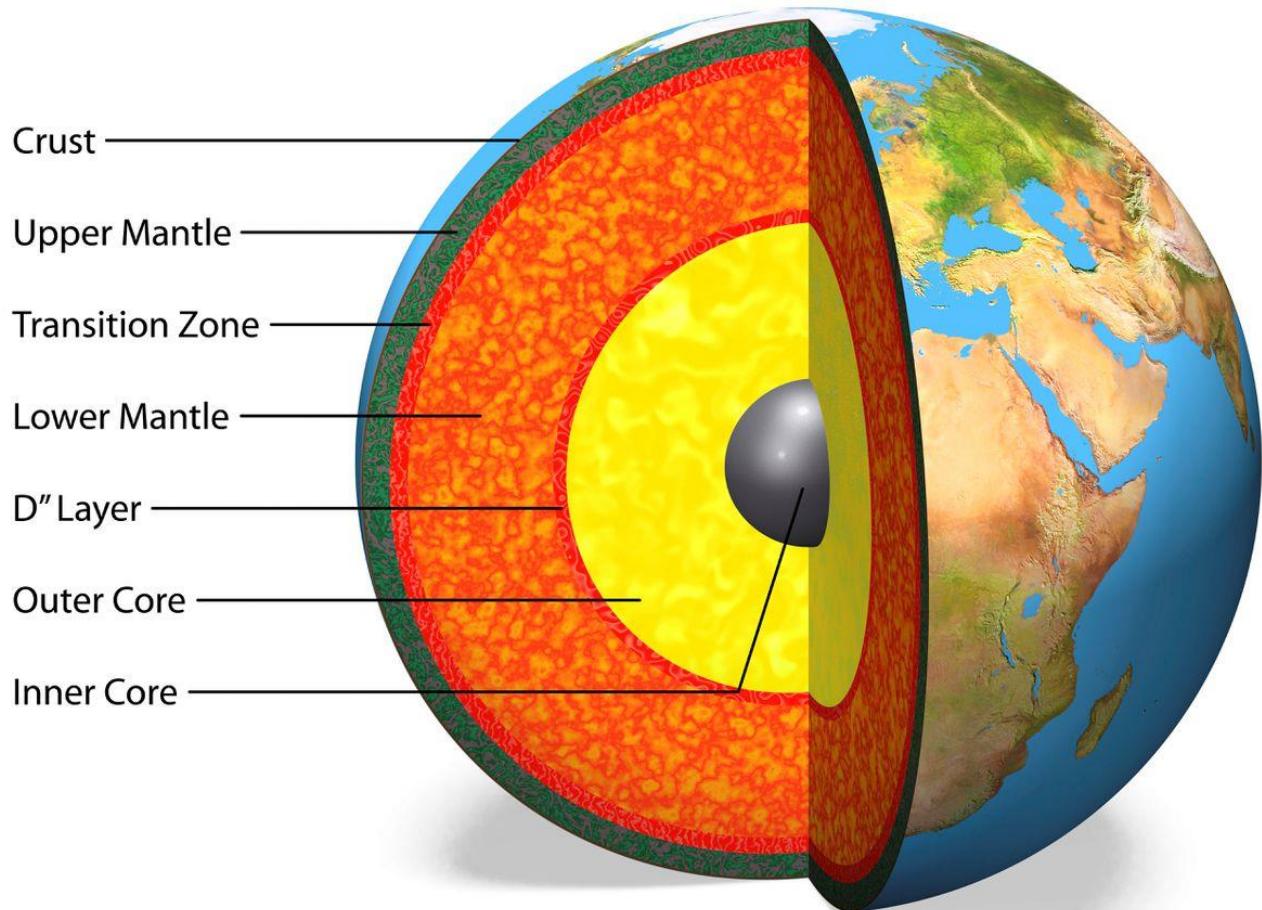


Sreedevi Prasad



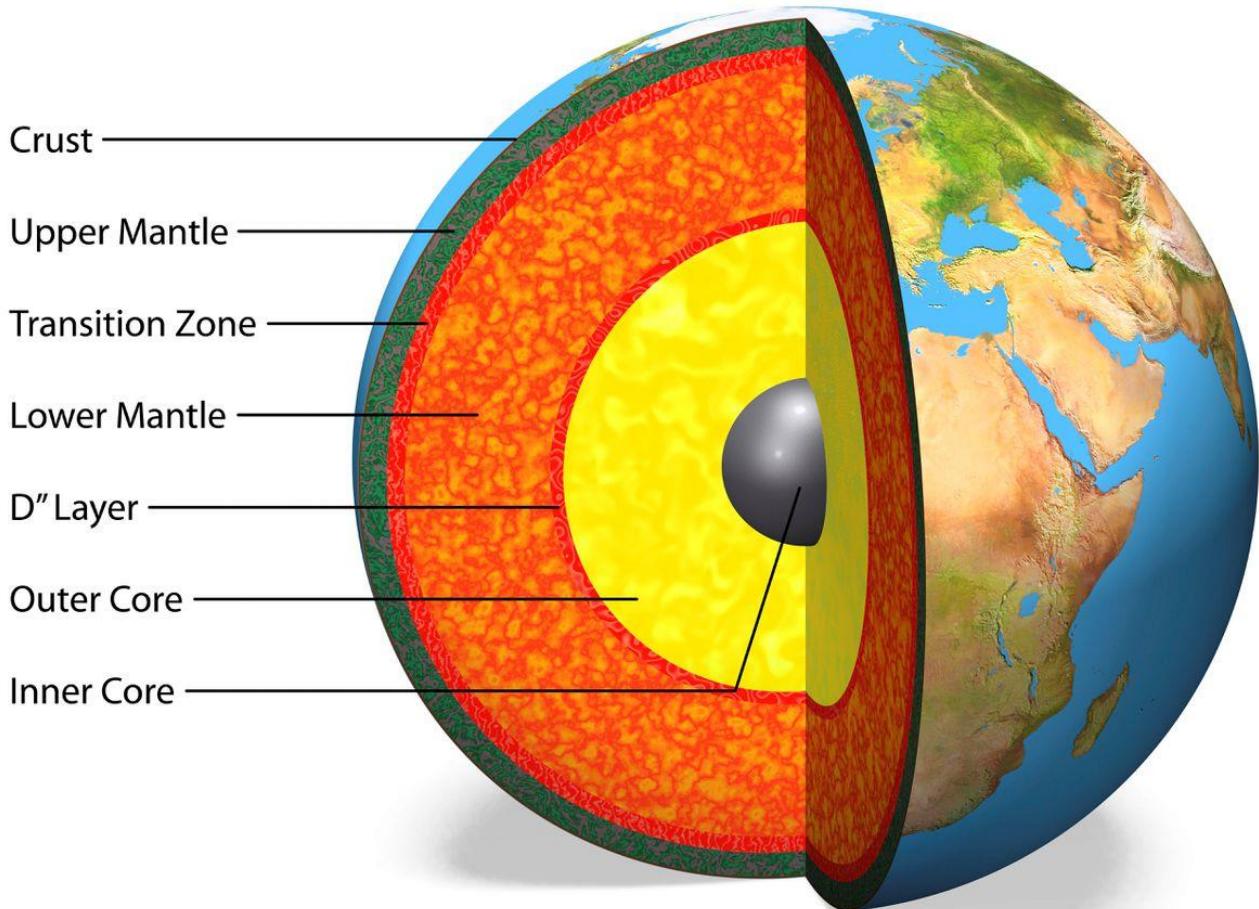
Course Theme

Deep Earth



Course Theme

Deep Earth



Course website: <https://dl-website-f25.vercel.app/>
Accessible through Canvas

Why take this course?

You may have heard of “Deep Learning”



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EE Why should students take a course in deep learning?

There are several compelling reasons for students to take a deep learning course:

Deep learning has become a fundamental technology that powers many of the tools and services we use daily - from recommendation systems and virtual assistants to medical imaging and autonomous vehicles. Understanding how these systems work gives students insight into the technology shaping our world.

The field teaches valuable technical and analytical skills that extend beyond AI. Students learn to think systematically about complex problems, work with large datasets, implement and debug sophisticated algorithms, and evaluate results critically. These skills are valuable across many technical and quantitative fields.

Deep learning also provides an excellent framework for understanding modern software development practices. Students gain hands-on experience with popular tools and frameworks like PyTorch or TensorFlow, version control, cloud computing, and optimization techniques.

From a career perspective, the skills learned in deep learning courses are highly sought after across industries. Companies increasingly need people who can develop and deploy AI systems, or who simply understand their capabilities and limitations well enough to integrate them effectively into products and workflows.

Perhaps most importantly, deep learning offers an exciting way to explore fundamental questions about intelligence, learning, and pattern recognition. Students get to build systems that can recognize speech, generate images, or solve complex games - providing concrete insights into how machines can learn to perform tasks that once seemed uniquely human.

What aspects of deep learning interest you most? Are you considering taking a course in it?

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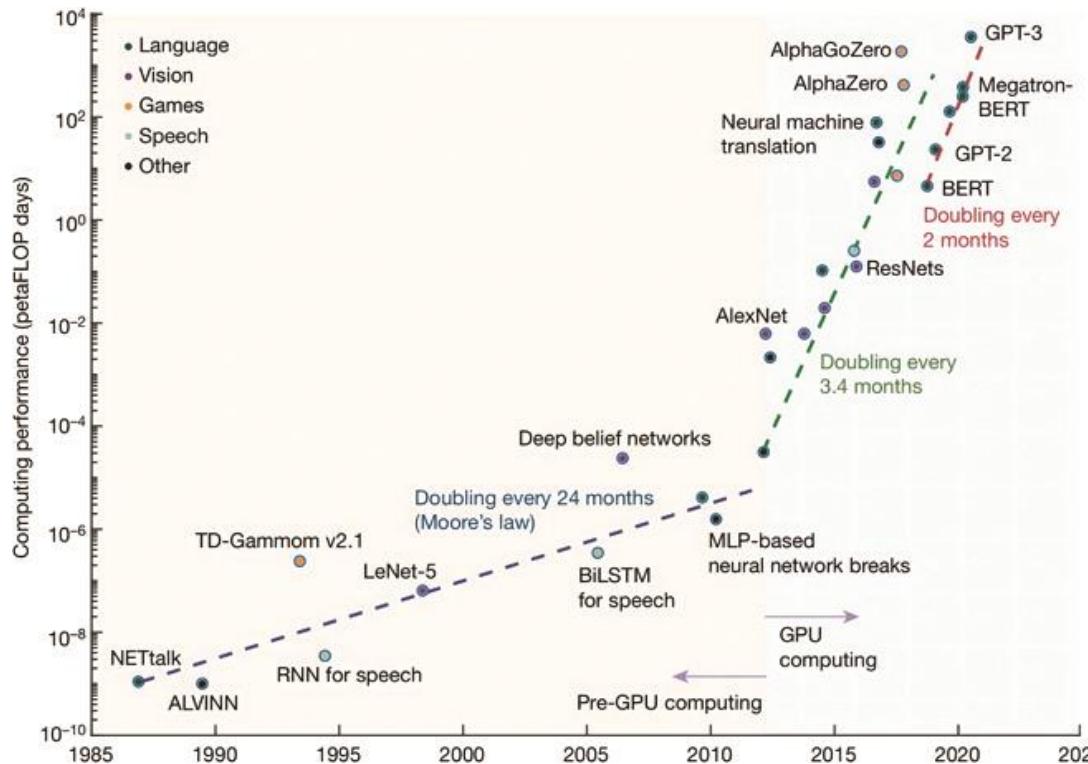
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4. Explore questions about intelligence and learning

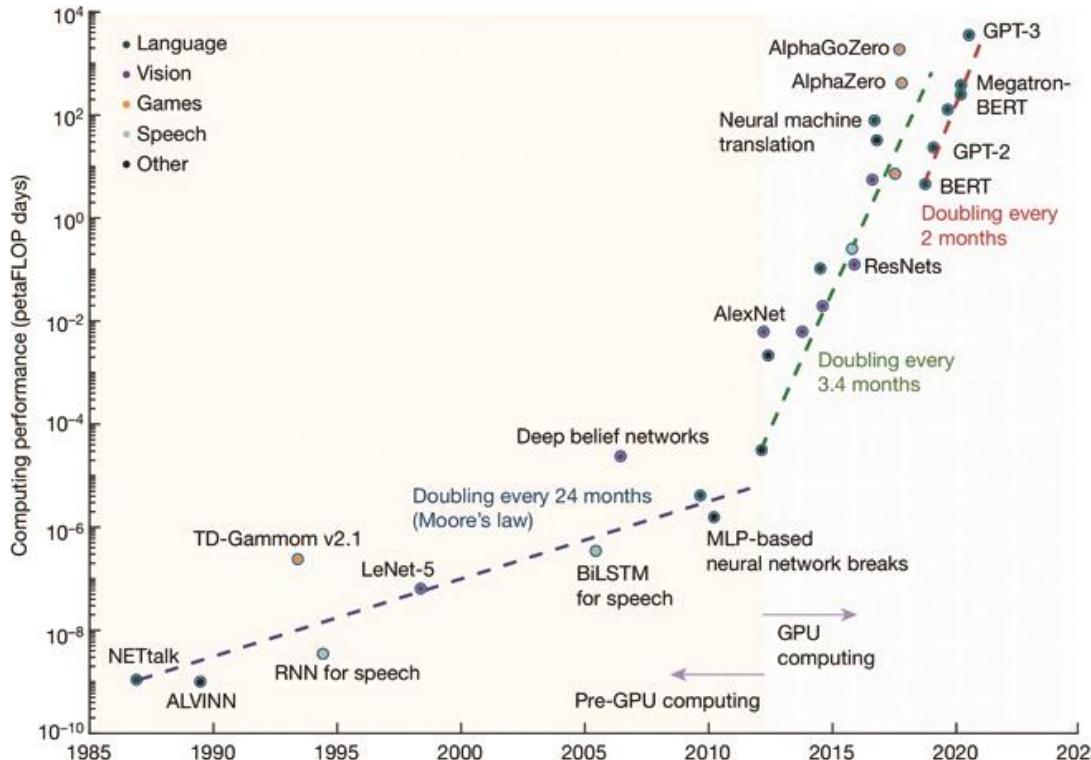
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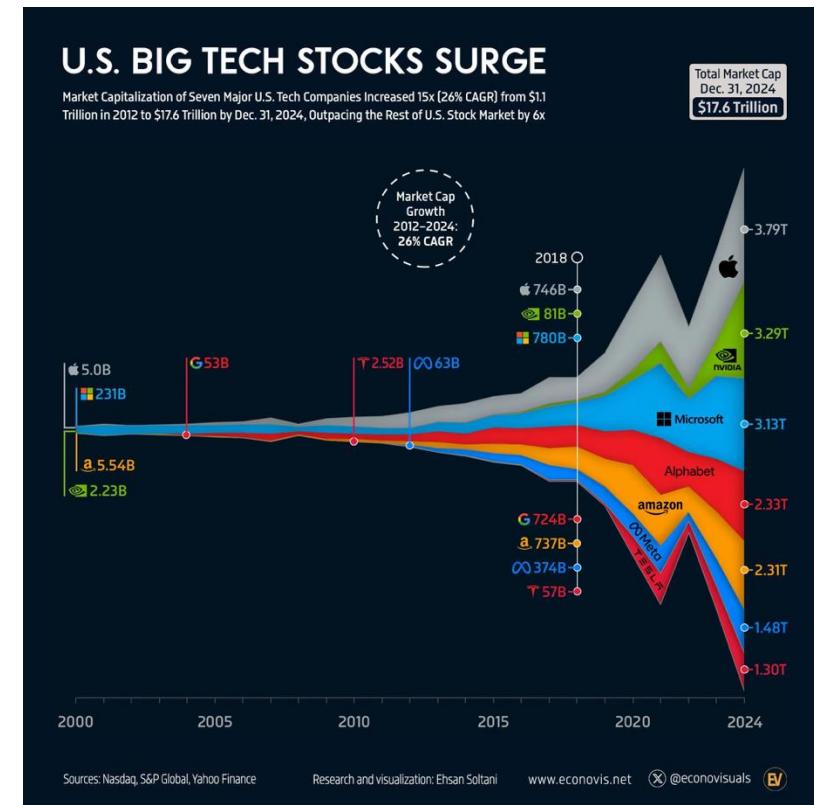


The amount of compute required for powering generative AI doubles every 100 days

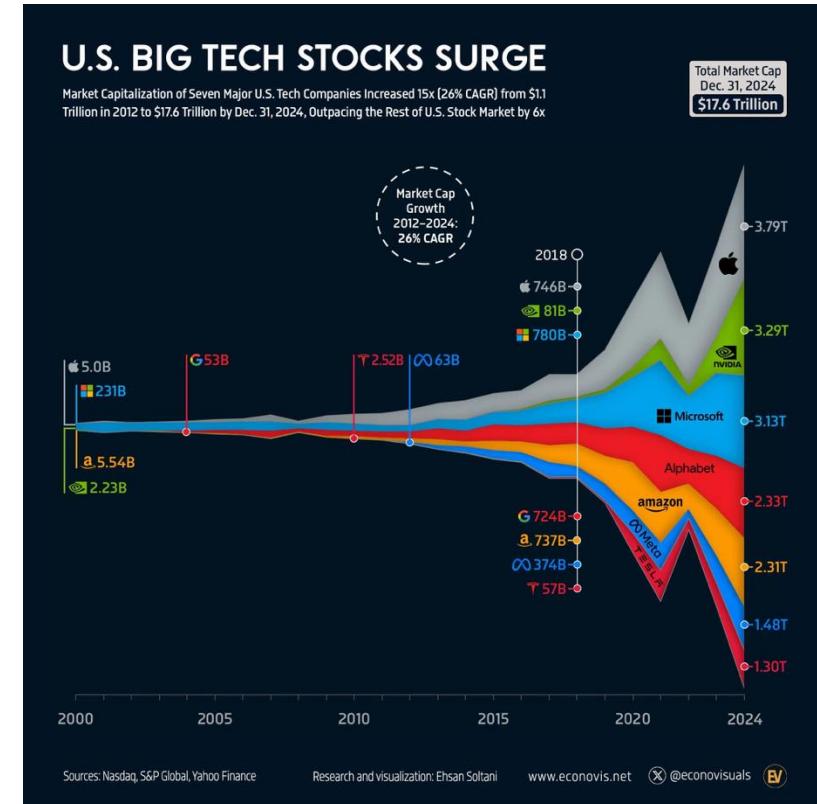
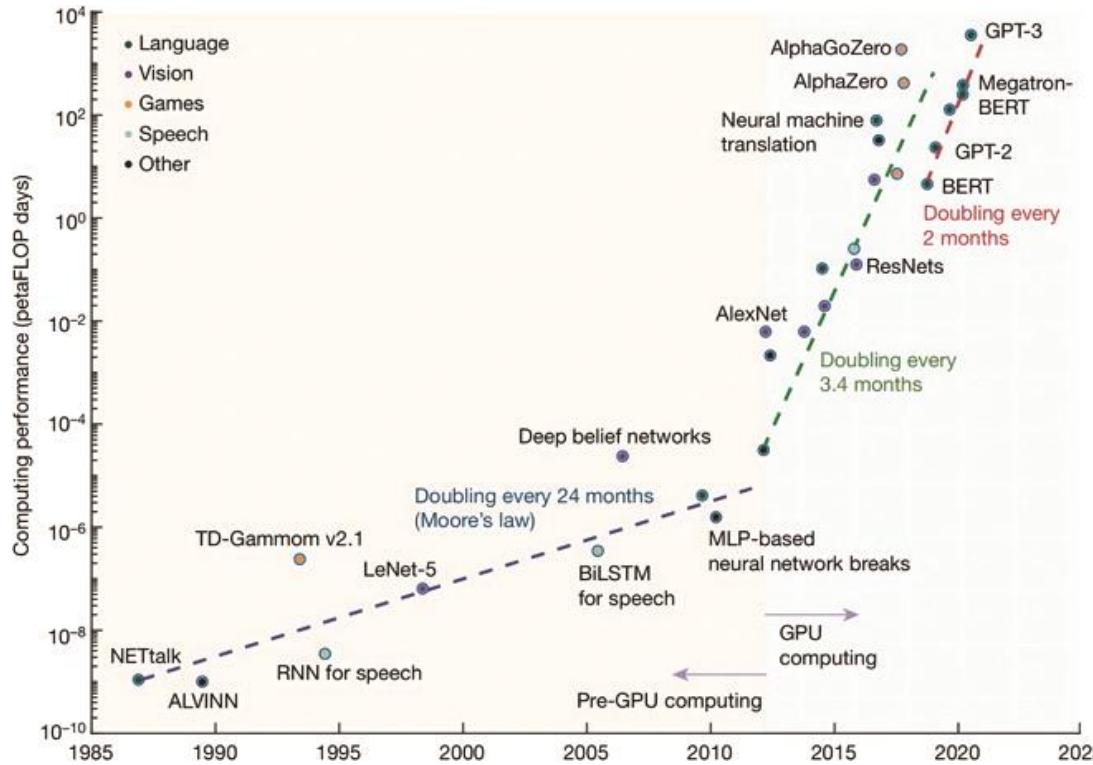
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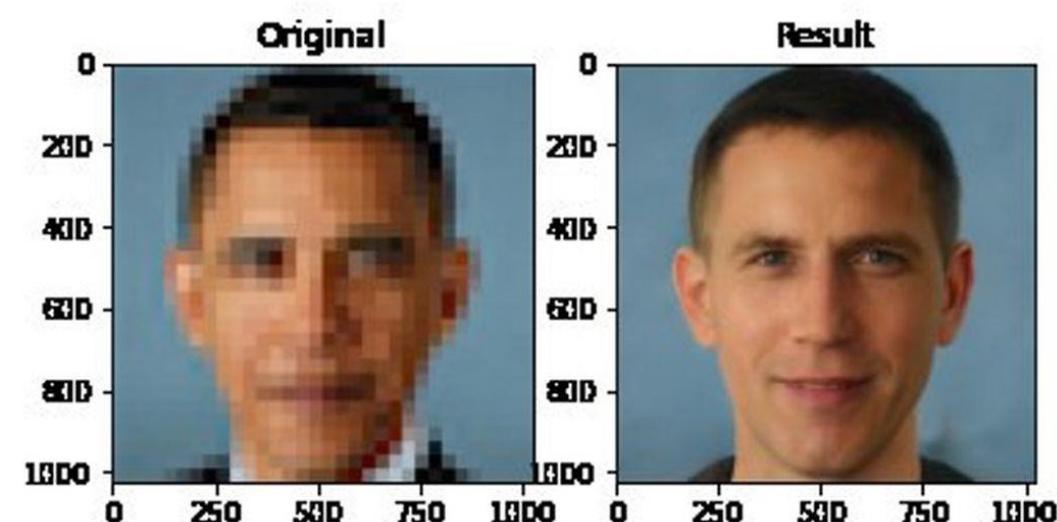


41% of companies worldwide plan to reduce workforces by 2030 due to AI

By Olesya Dmitracova, CNN

⌚ 2 minute read · Published 7:57 AM EST, Wed January 8, 2025

You may have heard of “Deep Learning” or “Artificial Intelligence (AI)”



Grok's antisemitic outbursts reflect a problem with AI chatbots



By [Allison Morrow](#) and [Lisa Eadicicco](#), CNN

⌚ 5 min read · Updated 10:59 AM EDT, Thu July 10, 2025

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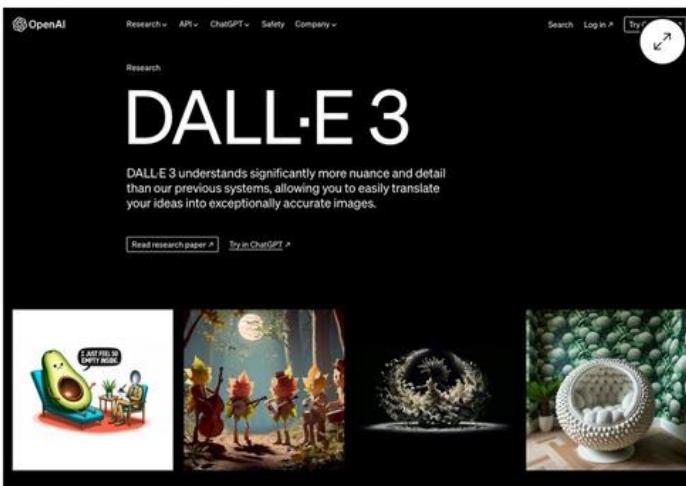
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Technology
AI

Dall-E 3 Is So Good It's Stoking an Artist Revolt Against AI Scraping

Artists are worried AI will take their jobs — so they're getting creative.



The Dall-E 3 website.

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Bloomberg

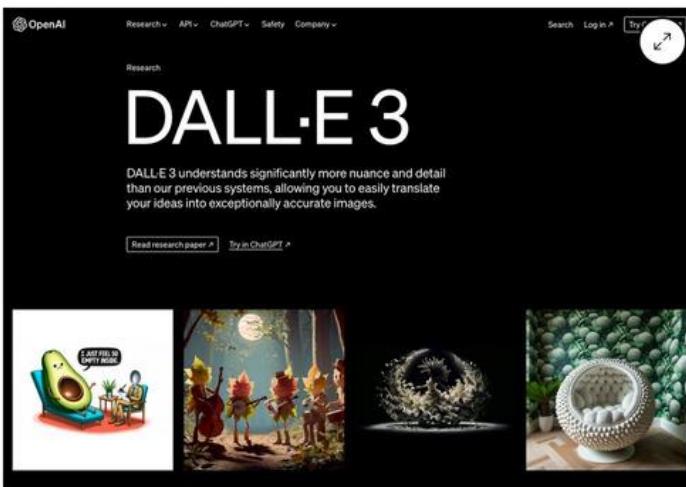
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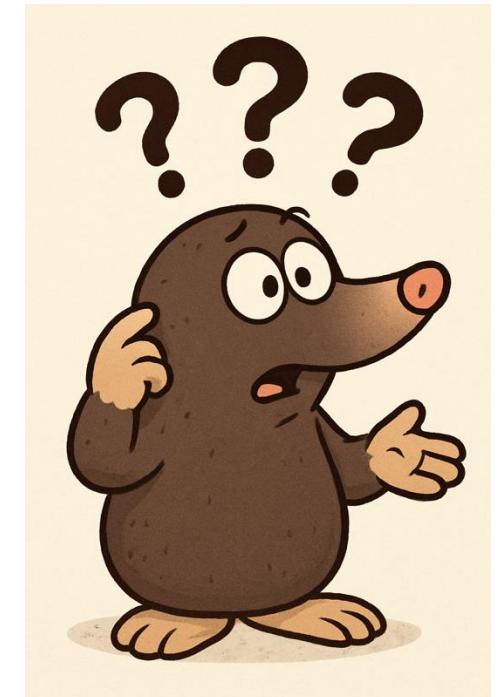
SANDER VAN DER LINDEN IDEAS JAN 22, 2024 7:00 AM

AI-Generated Fake News Is Coming to an Election Near You

Targeted, AI-generated political misinformation is already out there—and humans are falling for it.



Our goal is to answers some important questions



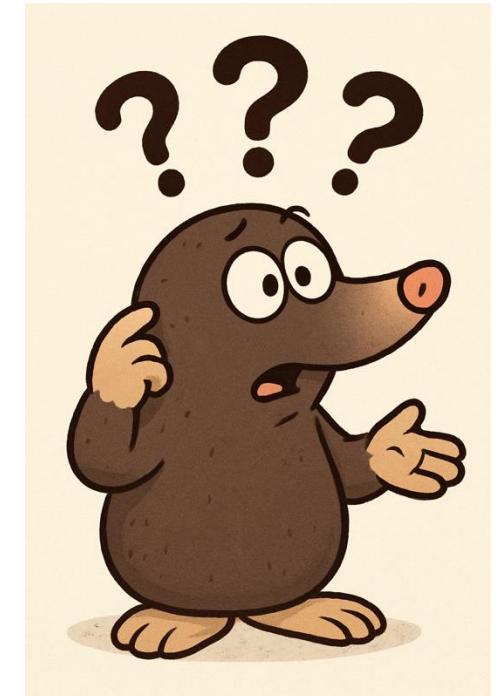
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- What is Deep Learning?



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 - What are the different deep learning architectures and **when are they appropriate to use?**



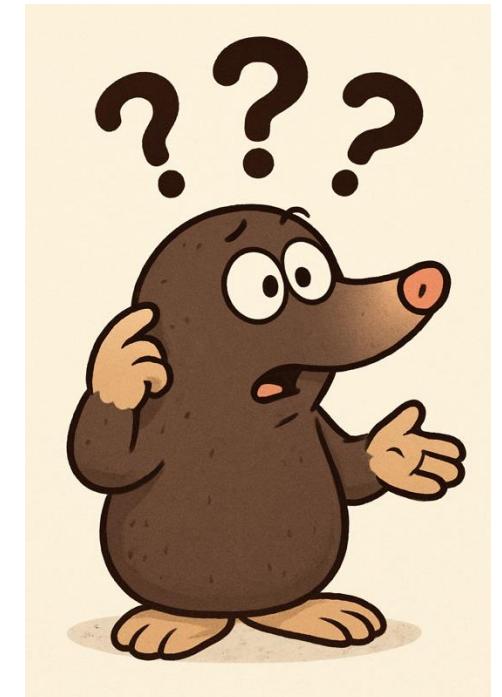
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- **Why Now?**



Today's Goals:

What is Deep Learning?

- (1) What is Machine Learning?
- (2) How Does Deep Learning fit in?
- (3) What is NOT Deep Learning?

What is Machine Learning?

Input: X

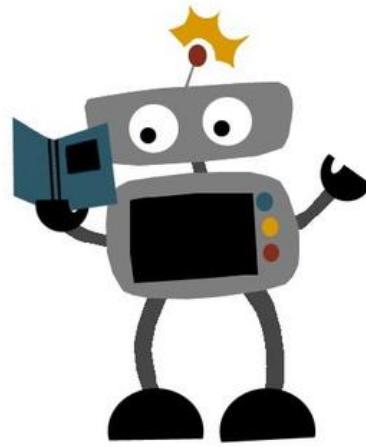


Function: f



Output: Y

"Cooking?"



What is Machine Learning?

Input: X



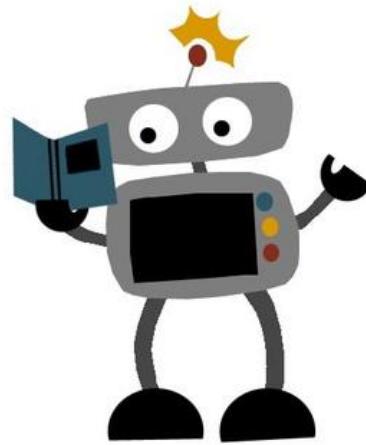
Function: f



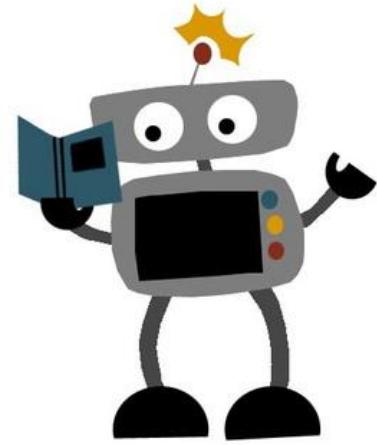
$$f(X) \rightarrow Y$$

Output: Y

"Cooking?"



What is Machine Learning?



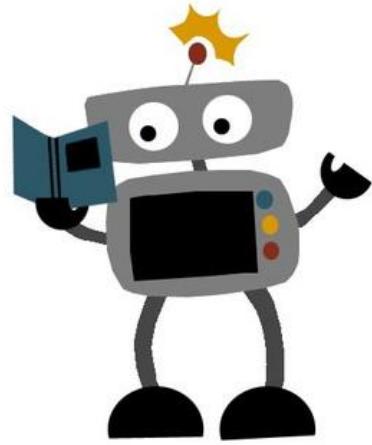
"Cooking?"



→ Function: $f \rightarrow$



What is Machine Learning?



Function: f →

"Cooking?"



Input: X



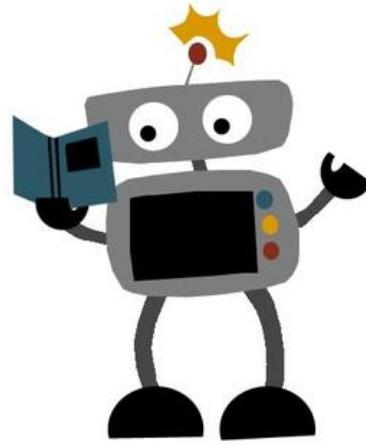
Learned
function: f

$$f(X) \rightarrow Y$$

Output: Y
"Cooking?"



What is Machine Learning?



Supervised
Learning



Function: $f \rightarrow$

"Cooking?"



Input: X



Learned
function: f

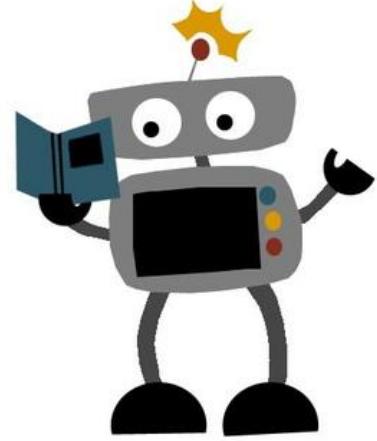


Output: Y
"Cooking?"



$f(X) \rightarrow Y$

What is Machine Learning?



Input: X

I do not want
sour cream in my
burrito

Learned
function: f

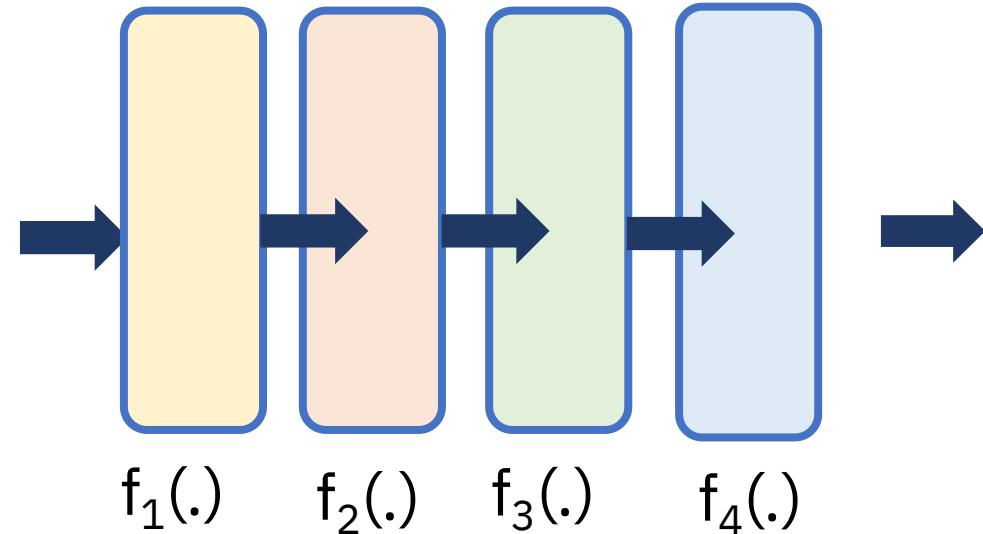
Output: Y

No quiero crema
agreya en mi
burrito

$$f(X) \rightarrow Y$$

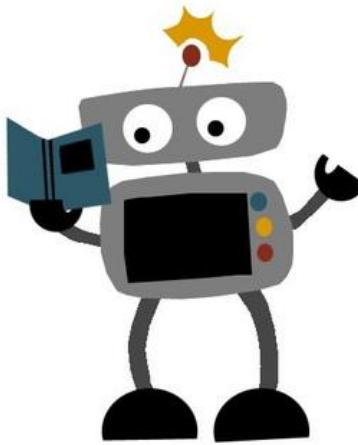
What is Deep Learning?

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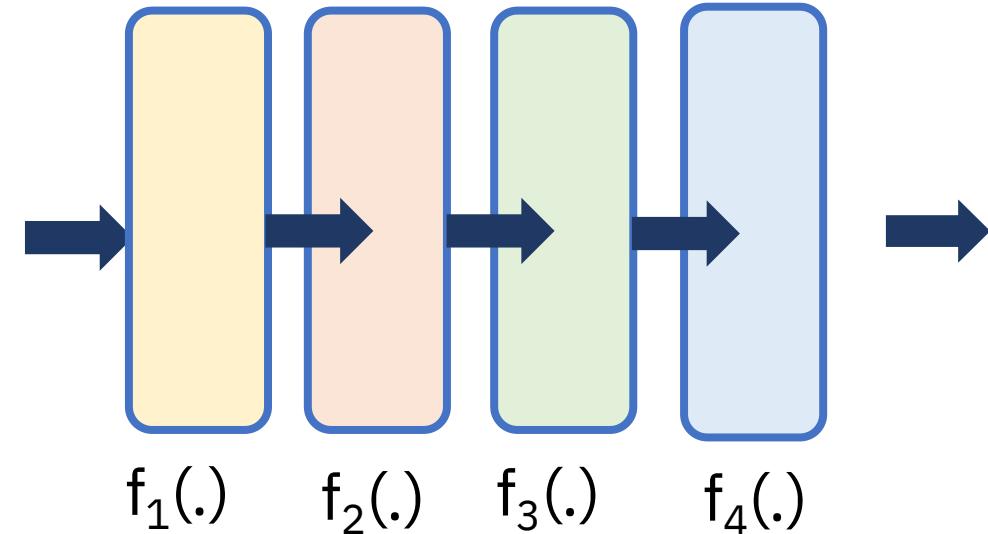
"Cooking?"



$$f_4(f_3(f_2(f_1(X)))) \rightarrow Y$$

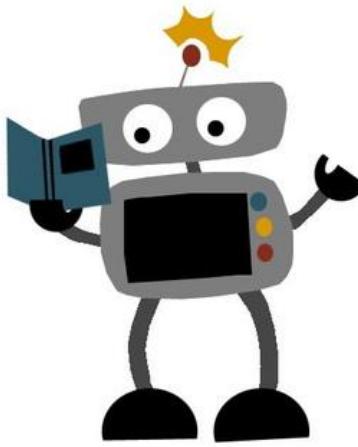
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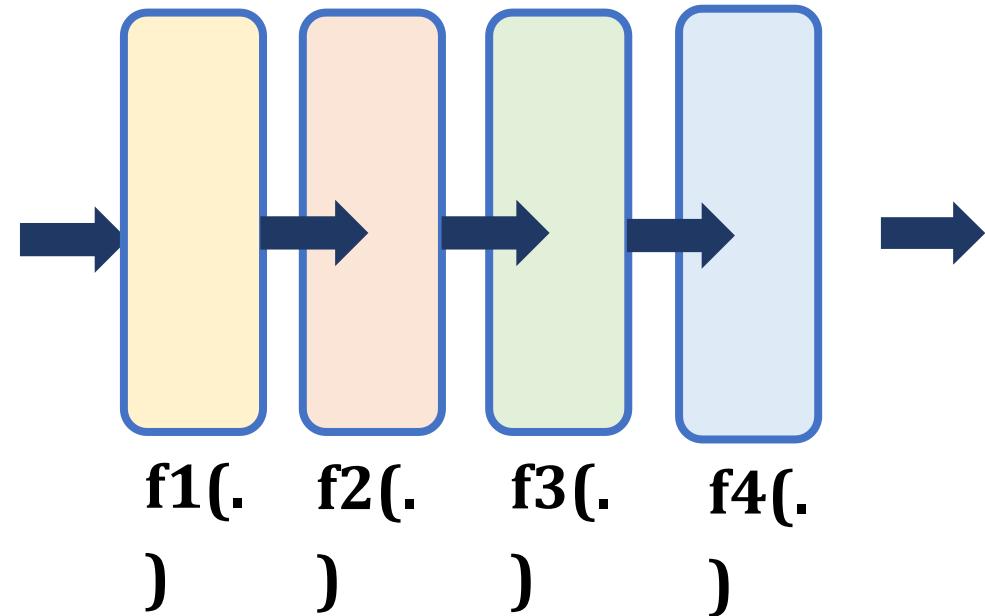
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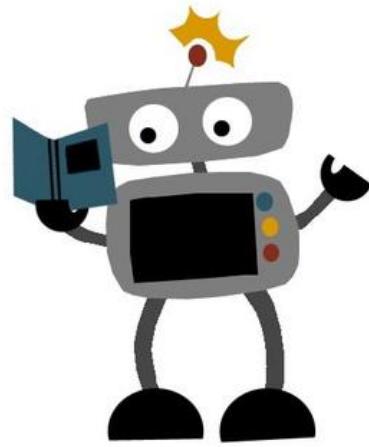
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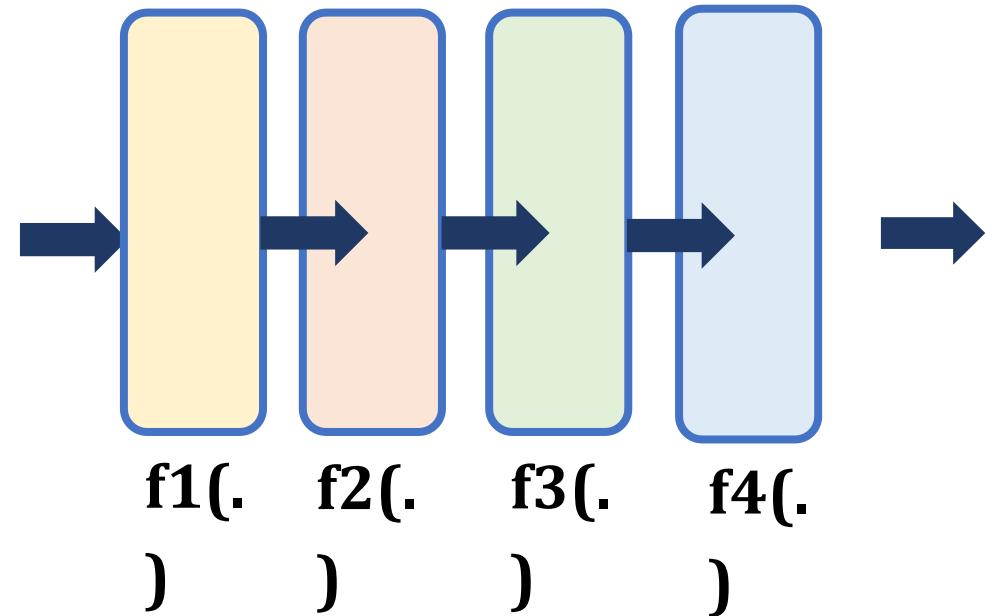
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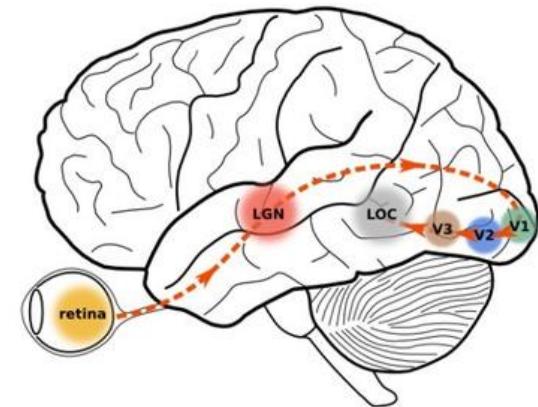
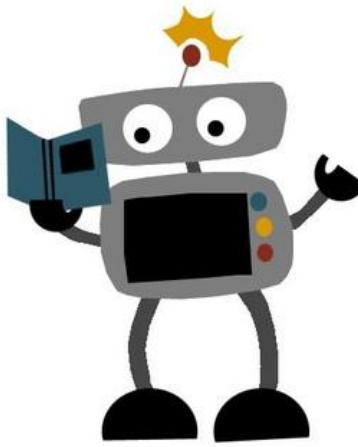
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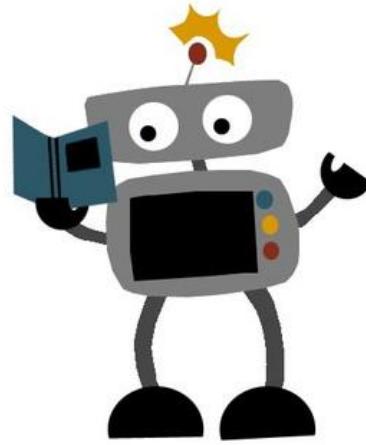
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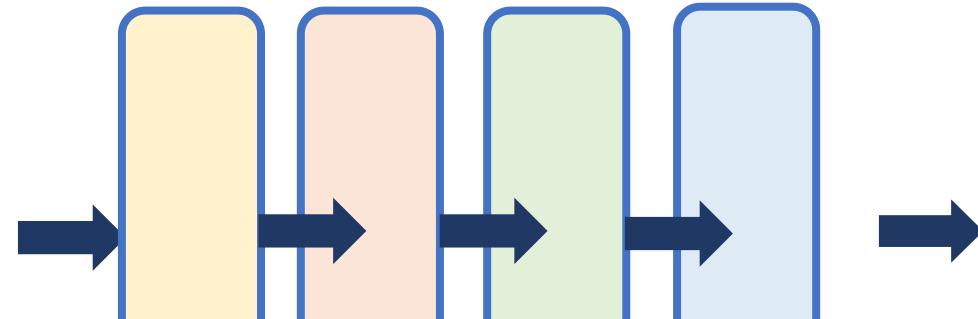


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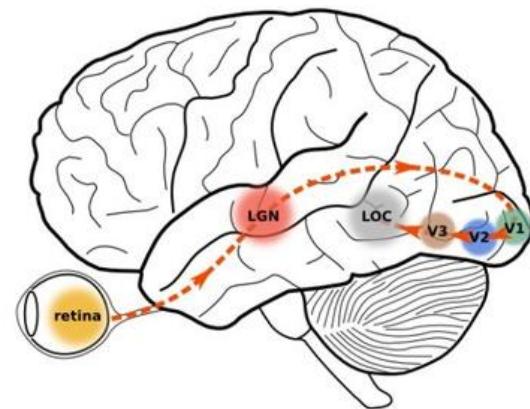
"Cooking?"



TURN ANY PHOTO INTO AN ARTWORK – FOR FREE!

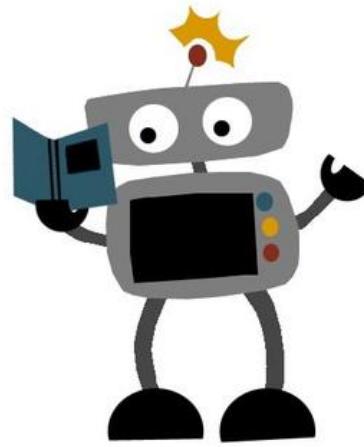
We use an algorithm inspired by the human brain. It uses the stylistic elements of one image to draw the content of another. Get your own artwork in just three steps.

[<https://deepart.io>]

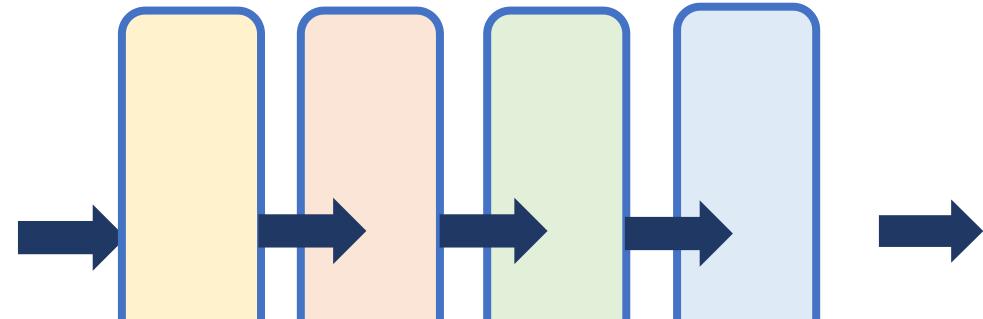


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WHAT IS DEEP LEARNING?

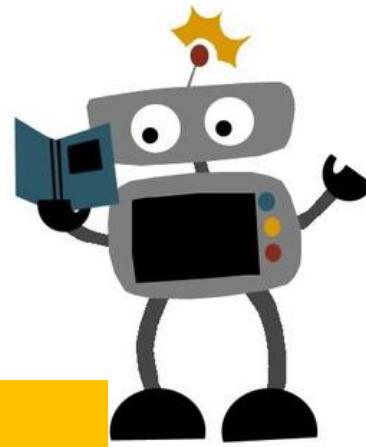


A newly re-invigorated form of machine learning, which is itself a subset of artificial intelligence, deep learning employs powerful computers, massive data sets, “supervised” (trained) neural networks and an algorithm called back-propagation (backprop for short) to recognize objects and translate speech in real time **by mimicking the layers of neurons in a human brain’s neocortex**.

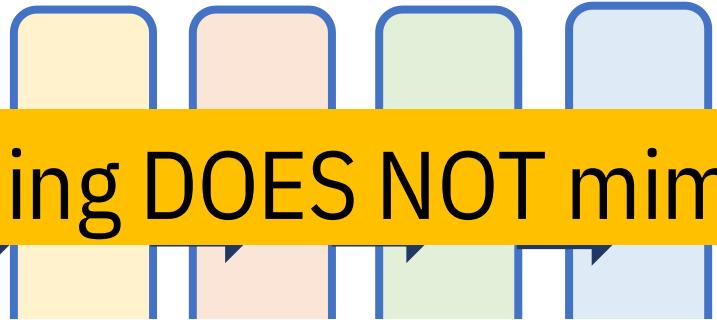
[<https://builtin.com/artificial-intelligence/deep-learning>]

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Deep Learning DOES NOT mimic the brain!



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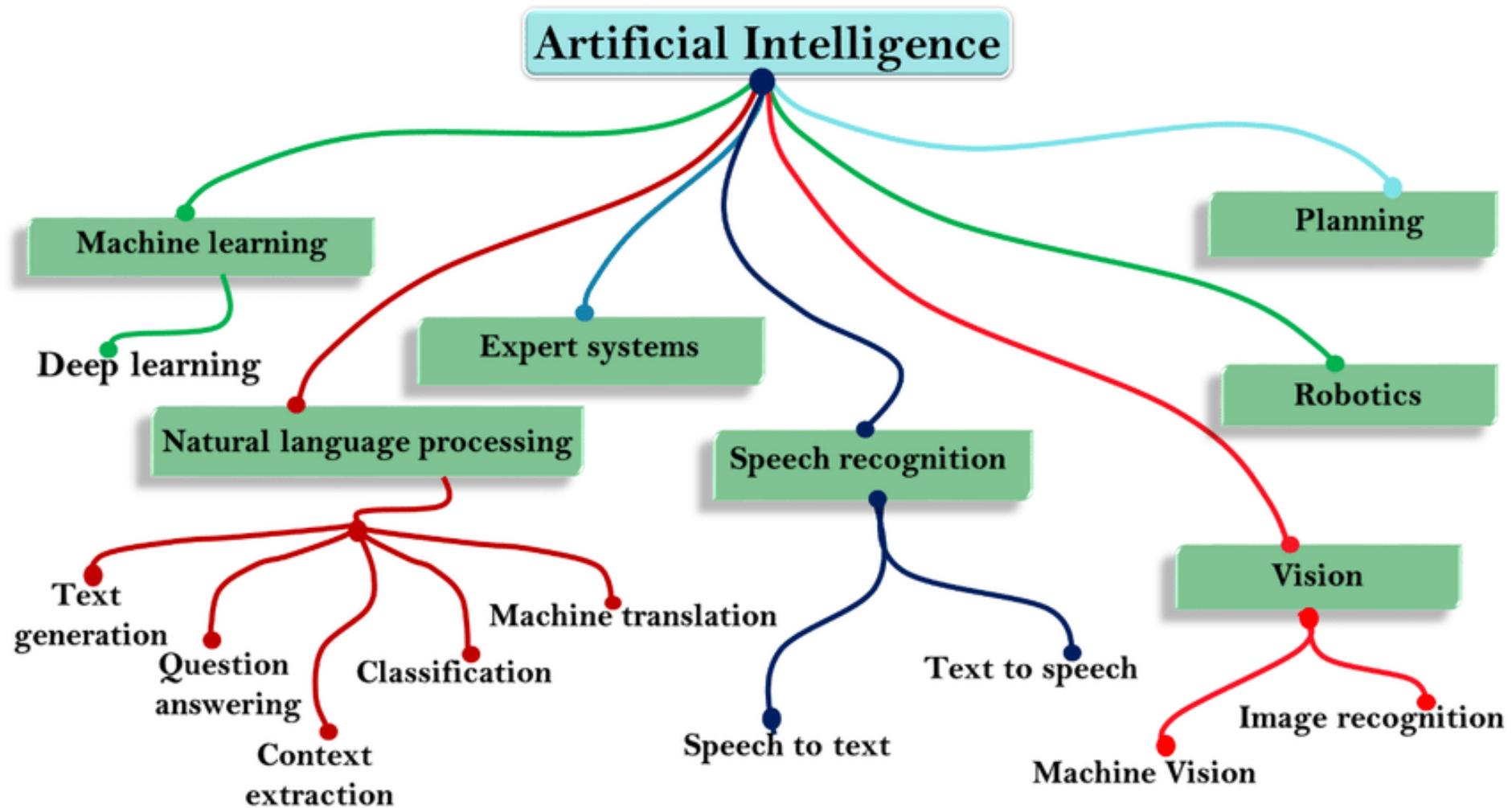


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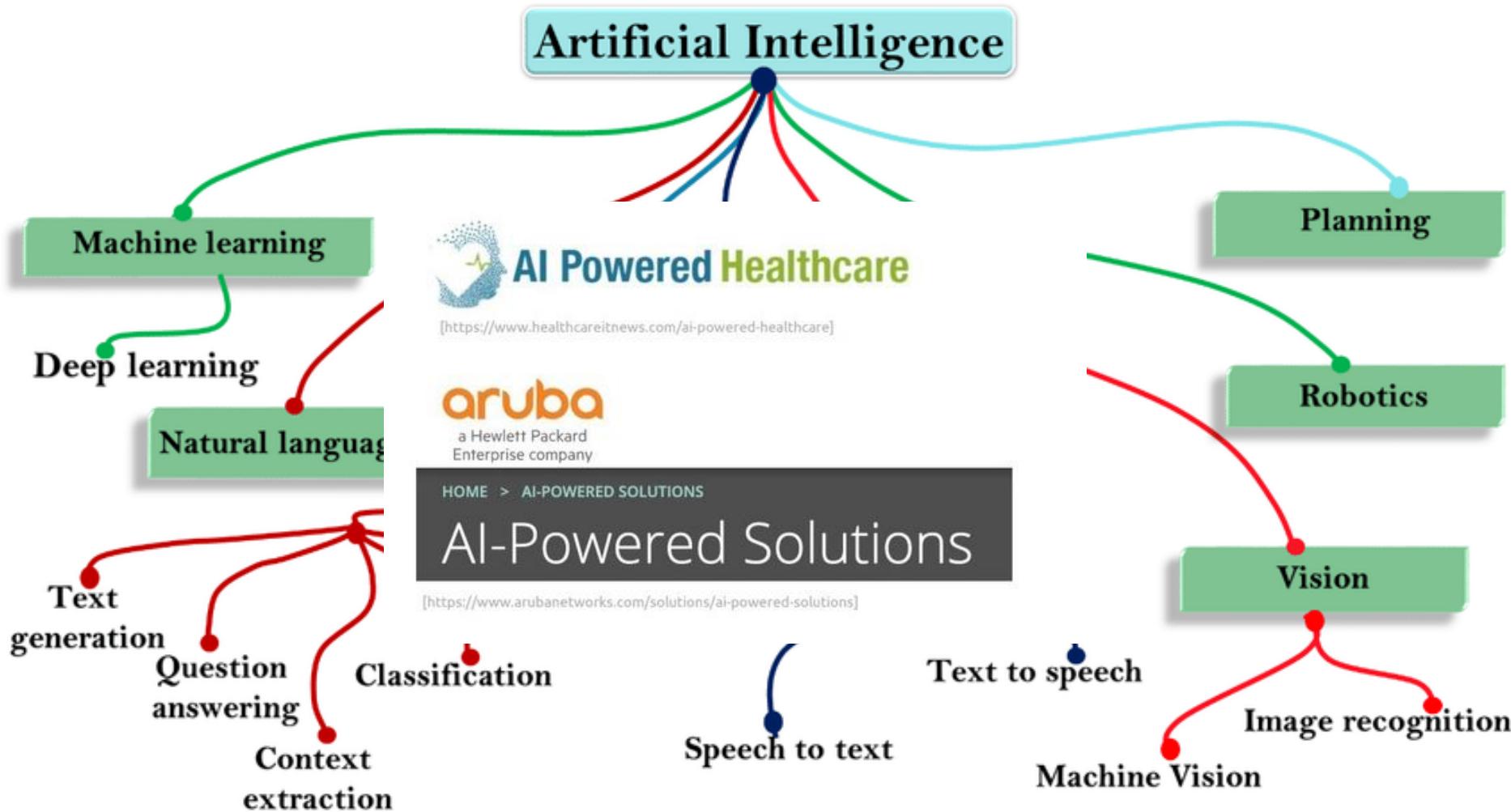
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“Cooking?”

What is NOT Deep Learning

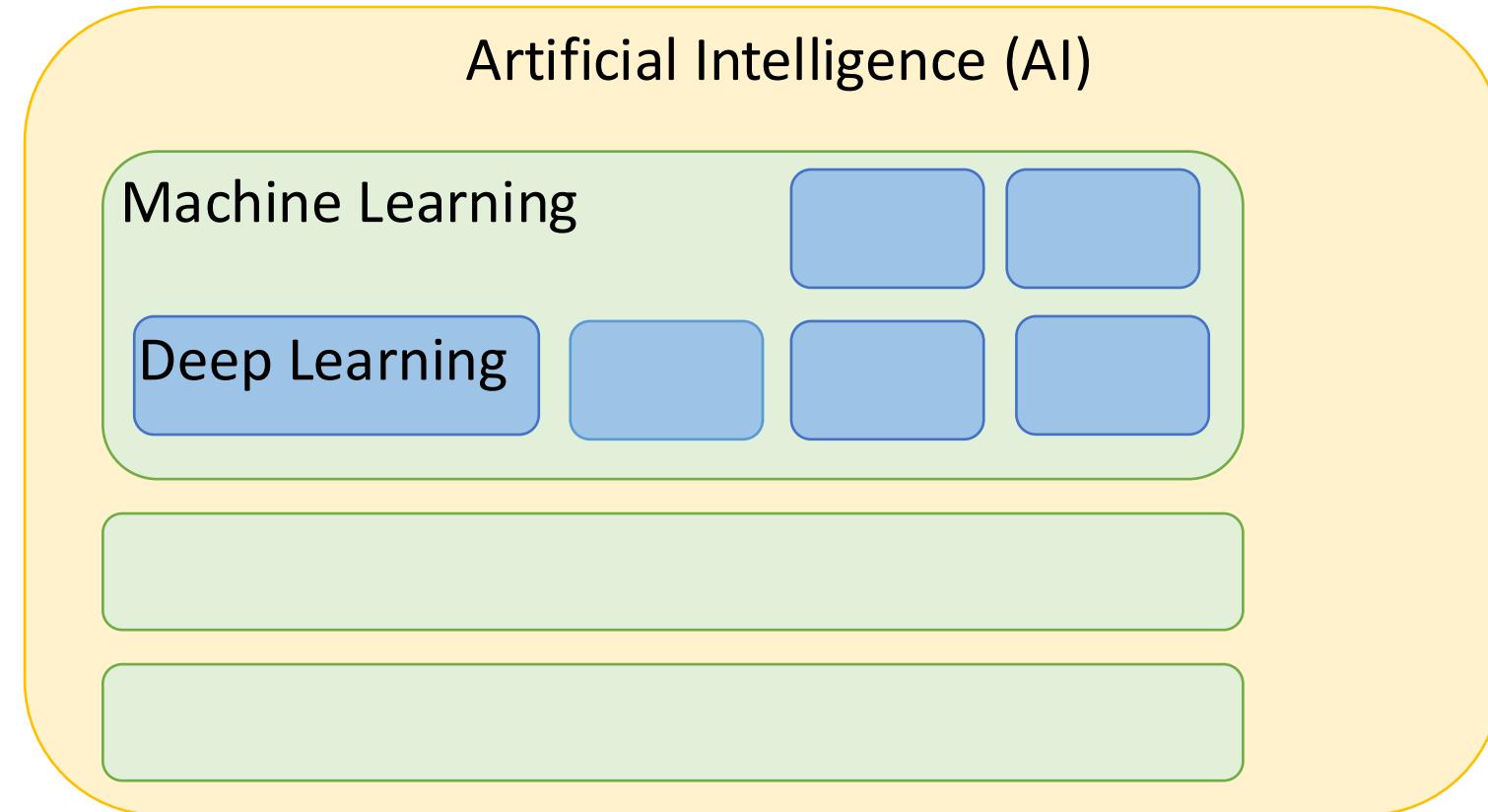


What is NOT Deep Learning



What is NOT Deep Learning?

Deep Learning is NOT equivalent to AI

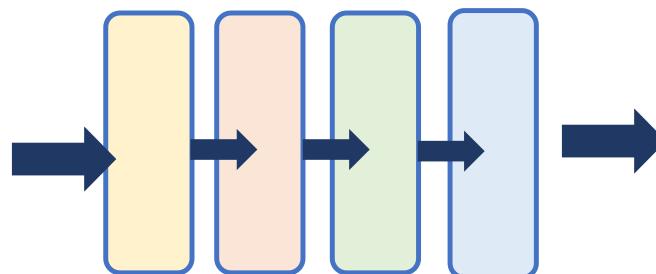


Recap

Input: X

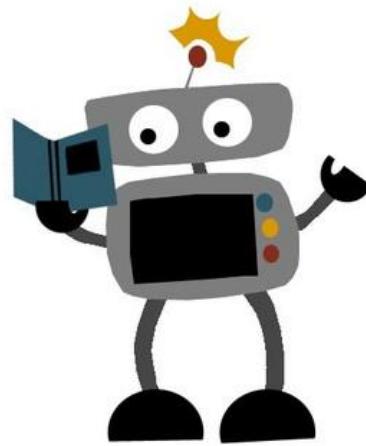


Machine Learning



Output: Y

"Cooking?"



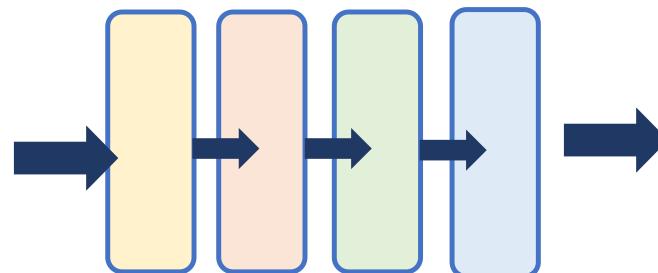
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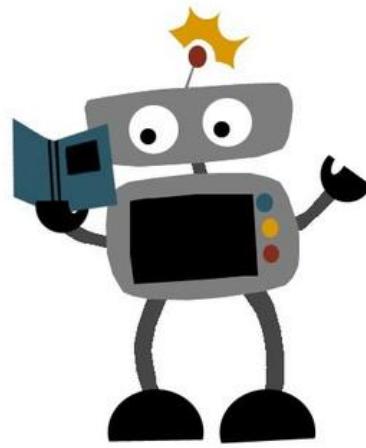
Machine Learning

$$f(X) \rightarrow Y$$



Output: Y

"Cooking?"



Recap

Input: X



Machine Learning

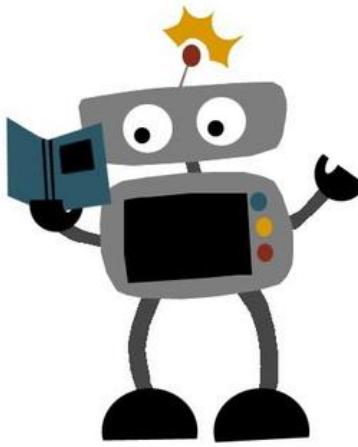
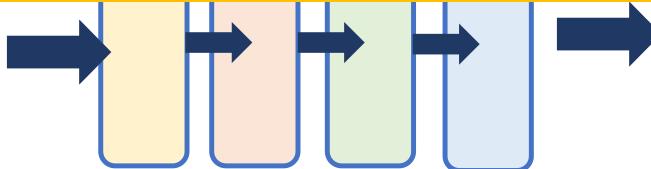
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Deep Learning is NOT equivalent to AI



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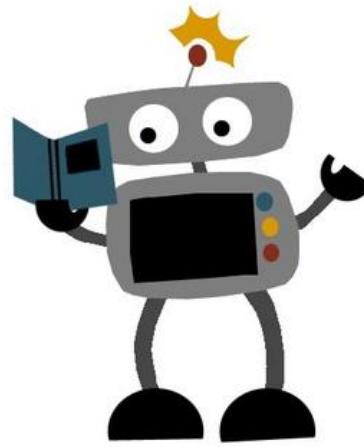


Deep Learning DOES NOT mimic the brain!

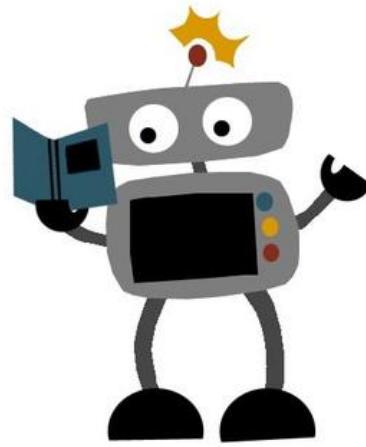


Deep Learning

$$f_4(f_3(f_2(f_1(X)))) \rightarrow Y$$



How do we represent Input/Output?



Input: X



Output: Y

"Cooking?"



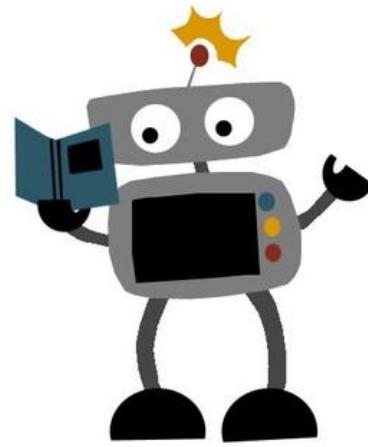
Function: f



$$f(X) \rightarrow Y$$



How do we represent Input/Output?



Input: X



Computers work
with numbers!

Output: Y

"Cooking?"



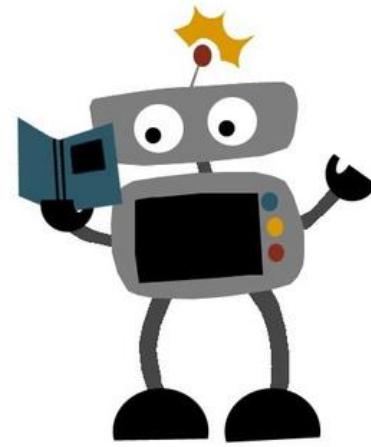
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$$f(X) \rightarrow Y$$

Output: Y

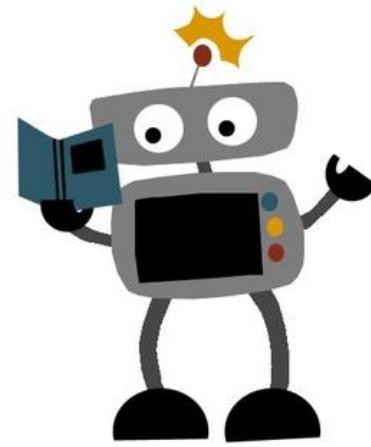
"Cooking?"



How can we represent
output labels as numbers?



How do we represent Input/Output?



Input: X



Computers work
with numbers!



Function: f

$$f(X) \rightarrow Y$$

How can we represent
Input with numbers?



Output: Y

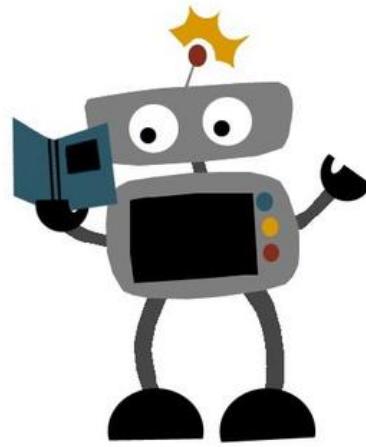
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Input: X



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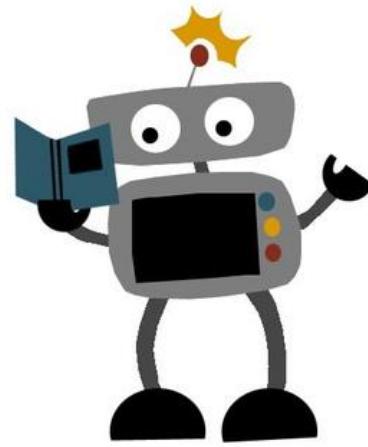
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How do we represent Input/Output?



Input: X



Function: f

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"Cooking?"



1

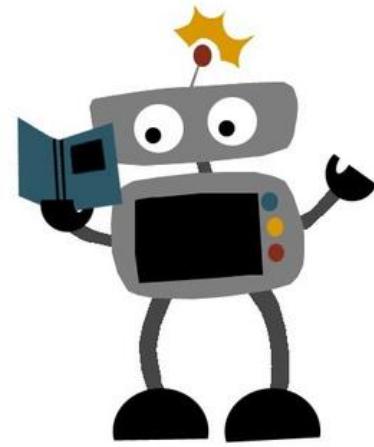


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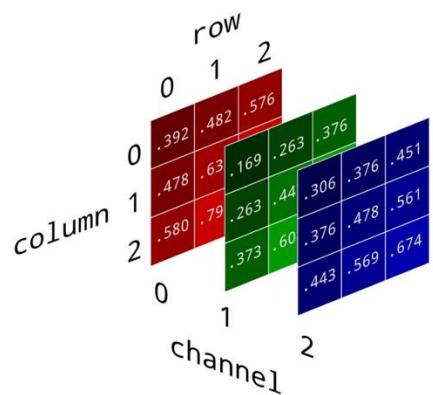


$y \in \{0,1\}$

How do we represent Input/Output?



Input: X



$$X \in \mathbb{R}^{H \times W \times 3}$$



Function: f

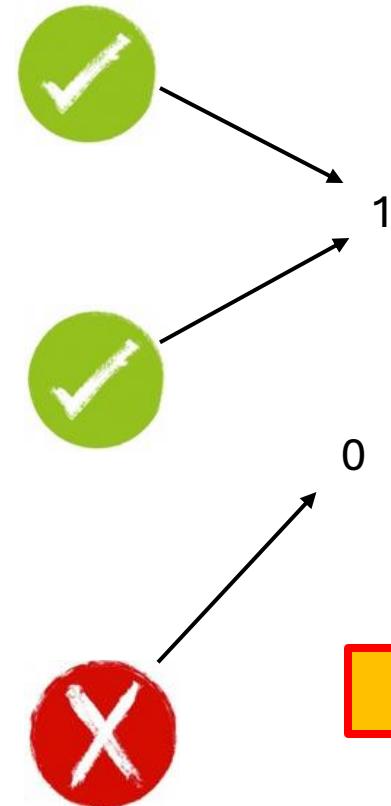


$$f(X) \rightarrow Y$$

Output: Y

"Cooking?"

$$y \in \{0,1\}$$



Classification

When y is discrete, the task is **classification**

Input: X



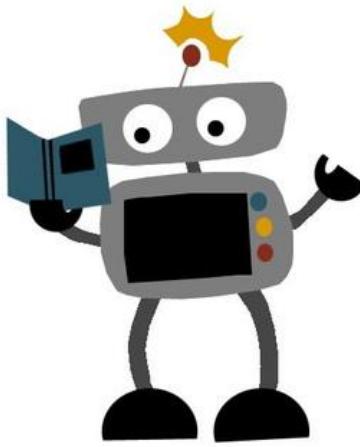
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$$f(X) \rightarrow Y$$

Output: Y

"Cooking?"



Classification

When y is discrete, the task is **classification**

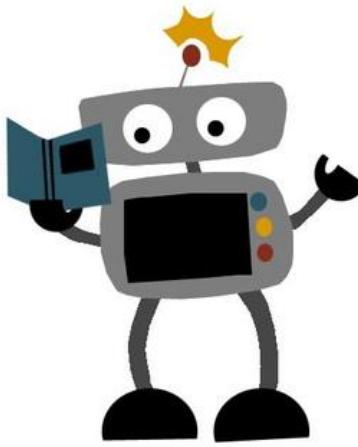
Input: X



When $y \in \{0, 1\}$ the task is **Binary Classification**



Function: f



Output: Y

"Cooking?"



$$f(X) \rightarrow Y$$



Classification

When y is discrete, the task is **classification**

Input: X



When $y \in \{0, 1\}$ the task is **Binary Classification**



What's an example of **multi-class Classification**?

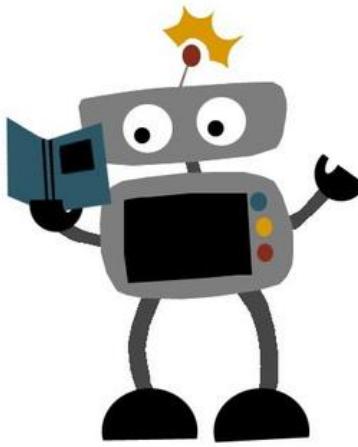


Function: f

$$f(X) \rightarrow Y$$

Output: Y

"Cooking?"



Questions?



Ice Breaker!

- Turn to the person sitting next to you and introduce yourself!
- What do you hope to learn/be able to do by the end of this course?



Ice Breaker!

- Turn to the person sitting next to you and introduce yourself!
- What do you hope to learn/be able to do by the end of this course?



<https://forms.gle/oCY6wZfd7fdEA6HEA>

Course Logistics

The Canvas Website



Your access to:

- Ed Discussion
- GradeScope
- Weekly quizzes

CSCI1470 Fall25 S01 Deep Learning

[Jump to Today](#)

Welcome to Deep Learning! Over the past few years, Deep Learning has become a popular area, with deep neural network methods obtaining state-of-the-art results on applications in computer vision (Self-Driving Cars), natural language processing (Google Translate), and reinforcement learning (AlphaGo). These technologies are having transformative effects on our society, including some undesirable ones (e.g. deep fakes).

This course is there to give students a practical understanding of how Deep Learning works, how to implement neural networks, and how to apply them ethically. We introduce students to the core concepts of deep neural networks and survey the techniques used to model complex processes within the contexts of computer vision and natural language processing.

Throughout the course, we emphasize and require students to think critically about potential ethical pitfalls that can result from mis-application of these powerful models. The course is taught using the Tensorflow deep learning framework.

Course Website: <https://dl-website-f25.vercel.app/> ↗

The Course Website

The screenshot shows a dark-themed course website section titled "LECTURES". At the top, there are two orange icons resembling shopping carts. Below the title, the text "WEEKS 1-3: FOUNDATIONS OF NEURAL NETWORKS" is displayed in white. Four lecture items are listed in a vertical stack, each with a date, title, and a small orange circular icon:

- 2025-09-4 Welcome to Deep Learning
- 2025-09-9 Machine Learning
- 2025-09-11 Perceptrons and MLPs
- 2025-09-16 Optimization, Gradients, and Losses

- Your one-stop-shop for:

- Syllabus Lecture, lab, & assignment
- schedules Links to important forms,
- etc. ...

Brown Deep Learning Day!

- Course final project
- In-person mini conference!
- Poster sessions and presentations
 - Grouped by theme: e.g. vision, language, robotics, ...

Details forthcoming!



Deep Learning Day (Spring 2022)

Gen-AI Policy (LLMs)

Help with assignments:

- Submitting AI generated code or problem set answers without attaching a transcript is forbidden unless specifically stated otherwise and is an academic code violation.
- We will provide opportunities for working with AI tools, notably the final project and a few homeworks will allow AI use.

Help with content:

- Use LLMs to help you learn, not to give you the answers.
- Have LLMs quiz you on topics, have them point you to helpful resources, or brainstorm ideas together.

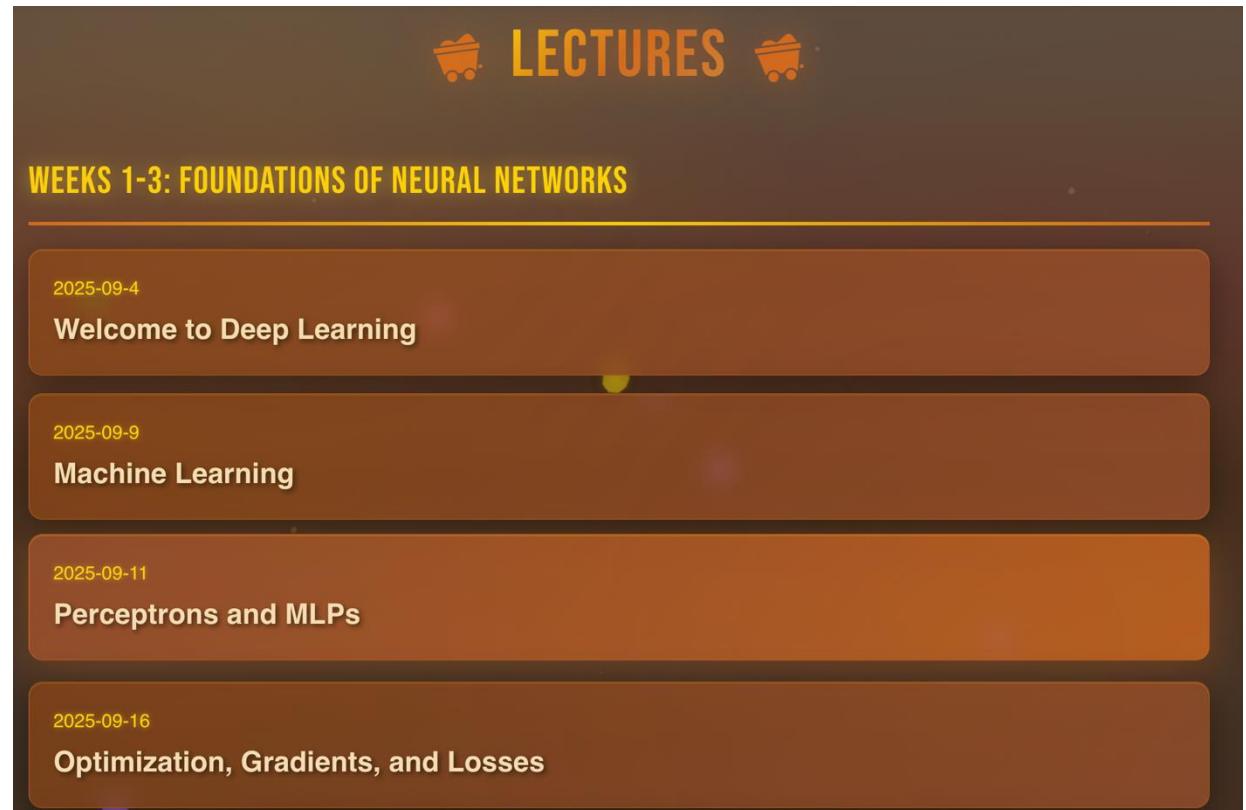
Lectures and class participation

- In-person Lectures

- Lecture recordings available
- Recordings posted to Canvas (Media Library)

- Weekly quiz on Canvas

- Released on Tuesdays in class (starts next week!)
- Due on Tuesday at midnight
- Minimum time/effort if you attend class or watch lectures regularly
- No deadline extensions!



Homework

- Homework 1 (will be released today!)
 - Review of relevant math and probability concepts
 - Setting up programming environment
 - Graded for completion only (**deadline Sept 18th**)

Homeworks

- Homework 2: Introduction to Numpy and Tensorflow
- Homework 3: Beras: Neural networks from scratch
- Homework 4: Convolutional Neural Networks
- Homework 5: Language Modeling (RNNs and LLMs)
- Homework 6: Image Captioning
- Homework 7: Generative Modeling
- Homework 8: Deep Reinforcement Learning

Workshops and SRC Discussions

- SRC Discussion Sections focus on a variety of ethical issues in deep learning and how to overcome them.
- Workshops will important skills/applications of deep learning that we think are useful for working on your final project
 - How to read and implement an academic research paper
 - Other deep learning frameworks/tools
 - Applications (DL for biology, LLMs, theory, etc.)
- Each is an hour long with multiple time slots offered
- Required to attend 3 total, minimum one of each

Acknowledgements



Ritambhara Singh
(taught in Spring 2024)



Professor Chen Sun
(taught 2470 in Fall 2024)



Original course material developed by
Professor Daniel Ritchie and
previous FABULOUS TA staff

Questions?



Machine Learning

What does it mean to **learn**?

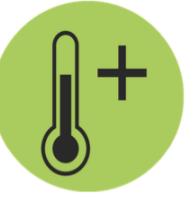
Machine Learning

Machine Learning

What does it mean to **learn**?

- The more information you have available, the better you should do.
- Learning often involves abstracting large amounts of data into smaller “models” of the world

Simpler example: Lemonade Stand



“Temperature”

100.1 °F

“Profit made on selling lemonade”

\$200.0



80.0 °F

\$180.5

30.3 °F

\$115.1

Some Notation

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\mathbb{R} : The set of real numbers

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$v \in \mathbb{R}^d$: A **vector** in dimension d

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\mathbb{X} : A set of **input** data

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\mathbb{Y} : A set of target variables (outputs/labels) for supervised learning

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$x^{(k)}$: k 'th example (input) from dataset

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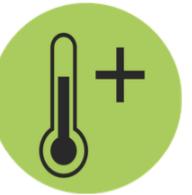
\mathbb{X} : A set of **input** data

\mathbb{Y} : A set of target variables (outputs/labels) for supervised learning

$x^{(k)}$: k 'th example (input) from dataset

$y^{(k)}$: k 'th example (output) associated with $x^{(k)}$

Simpler example: How do we represent input/output?



Input: \mathbb{X}

"Temperature"

$$x^{(1)} \quad 100.1 \text{ °F}$$

$$\mathbb{X} \in \mathbb{R}$$

$$x^{(2)} \quad 80.0 \text{ °F}$$

$$x^{(3)} \quad 30.3 \text{ °F}$$

Target: \mathbb{Y}

"Profit made on selling lemonade"



$$y^{(1)} \quad \$200.0$$

$$y^{(2)} \quad \$180.5$$

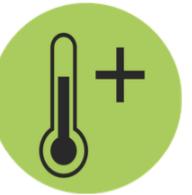
$$y^{(3)} \quad \$115.1$$

→ Function: f →

$$\mathbb{Y} \in \mathbb{R}$$

(Numerical output)

Simpler example: How do we represent input/output?



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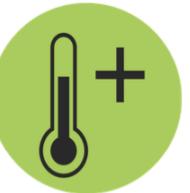
$$\mathbb{Y} \in \mathbb{R}$$

(Numerical output)

→ Function: f →

Do you see a
trend here?

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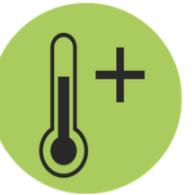
→ Function: f →

Do you see a trend here?

What is different about the output here?

$\mathbb{Y} \in \mathbb{R}$
(Numerical output)

Simpler example: How do we represent input/output?



Input: \mathbb{X}

"Temperature"

$$x^{(1)} \quad 100.1 \text{ °F}$$

$$\mathbb{X} \in \mathbb{R}$$

$$x^{(2)} \quad 80.0 \text{ °F}$$

$$x^{(3)} \quad 30.3 \text{ °F}$$

Regression

Target: \mathbb{Y}

"Profit made on selling lemonade"



$$y^{(1)} \quad \$200.0$$

$$y^{(2)} \quad \$180.5$$

$$y^{(3)} \quad \$115.1$$

Function: f

$f(\mathbb{X}) \rightarrow \mathbb{Y}$

Do you see a trend here?

What is different about the output here?

$$\mathbb{Y} \in \mathbb{R}$$

(Numerical output)

Learning function f



Input: \mathbb{X}

“Temperature”

$$x^{(1)} = 100.1$$

$$\mathbb{X} \in \mathbb{R}$$

$$x^{(2)} = 80.0$$

$$x^{(3)} = 30.3$$



$$y^{(1)} = 200.0$$

$$y^{(2)} = 180.5$$

$$y^{(3)} = 115.1$$

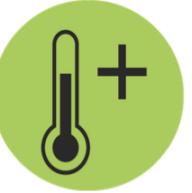
$\mathbb{Y} \in \mathbb{R}$
(Numerical output)



Target: \mathbb{Y}

“Profit made on selling lemonade”

Learning function f



Input: \mathbb{X}

“Temperature”

$$x^{(1)} = 100.1$$

$$\mathbb{X} \in \mathbb{R}$$

$$x^{(2)} = 80.0$$

$$x^{(3)} = 30.3$$



Target: \mathbb{Y}

“Profit made on selling lemonade”



$$y^{(1)} = 200.0$$

$$y^{(2)} = 180.5$$

$$y^{(3)} = 115.1$$

$$\mathbb{Y} \in \mathbb{R}$$

(Numerical output)

Step 1: Model Hypothesis:
What function do we think
best fits the data

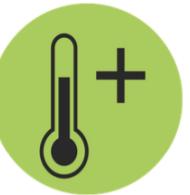
Learning function f



$X \in \mathbb{R}$

$$x^{(2)} = 80.0$$

$$x^{(3)} = 30.3$$



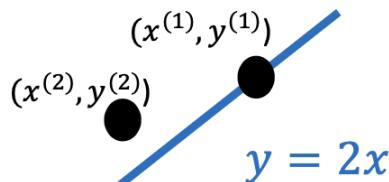
Input: \mathbb{X}

"Temperature"

$$x^{(1)} = 100.1$$

Linear function

$$y = wx + b$$



Target: \mathbb{Y}

"Profit made on selling lemonade"



$$y^{(1)} = 200.0$$

$$y^{(2)} = 180.5$$

$$y^{(3)} = 115.1$$

$\mathbb{Y} \in \mathbb{R}$
(Numerical output)

Learning function f

Have you seen this
equation before?



Input: \mathbb{X}

"Temperature"

$$x^{(1)} = 100.1$$

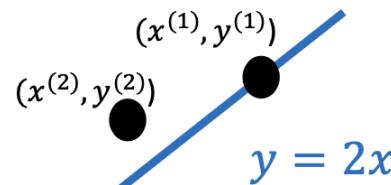
$$\mathbb{X} \in \mathbb{R}$$

$$x^{(2)} = 80.0$$

$$x^{(3)} = 30.3$$

Linear function

$$y = wx + b$$



Profit (\mathbb{Y})

Temperature (\mathbb{X})

Target: \mathbb{Y}

"Profit made on selling
lemonade"



$$y^{(1)} = 200.0$$

$$y^{(2)} = 180.5$$

$$y^{(3)} = 115.1$$

$\mathbb{Y} \in \mathbb{R}$
(Numerical output)

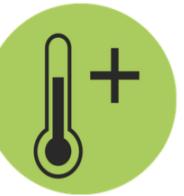
Learning function f



$X \in \mathbb{R}$

$$x^{(2)} = 80.0$$

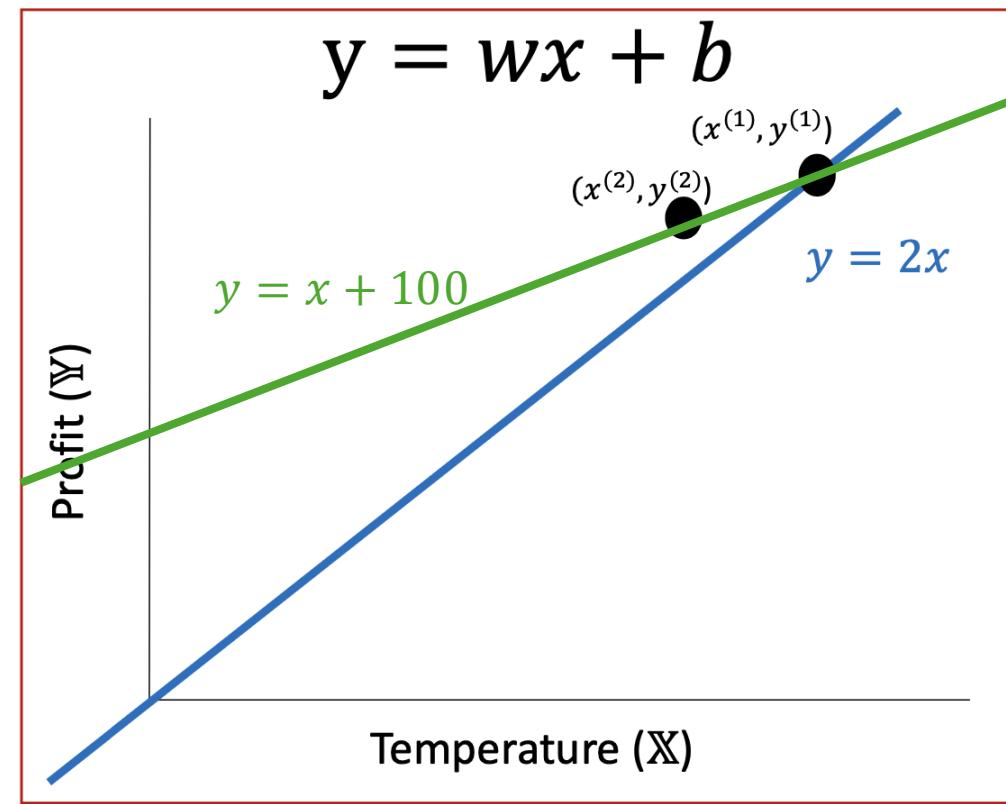
$$x^{(3)} = 30.3$$



Input: \mathbb{X}

"Temperature"

$$x^{(1)} = 100.1$$



Target: \mathbb{Y}

"Profit made on selling lemonade"



$$y^{(1)} = 200.0$$

$$y^{(2)} = 180.5$$

$$y^{(3)} = 115.1$$

$\mathbb{Y} \in \mathbb{R}$
(Numerical output)

Learning function f



$X \in \mathbb{R}$

$$x^{(1)} = 100.1$$

$$x^{(2)} = 80.0$$

$$x^{(3)} = 20.2$$

Input: \mathbb{X}

"Temperature"



Linear function

$$y = wx + b$$

$$y = x + 100$$

 $(x^{(1)}, y^{(1)})$ $(x^{(2)}, y^{(2)})$

$$y = 2x$$

Profit (\mathbb{Y})

Temperature (\mathbb{X})

Bias term is necessary for
best fit line to fit the data
well

Target: \mathbb{Y}

"Profit made on selling
lemonade"



$$y^{(1)} = 200.0$$

$$y^{(2)} = 180.5$$

$$y^{(3)} = 115.1$$

$\mathbb{Y} \in \mathbb{R}$
(Numerical output)

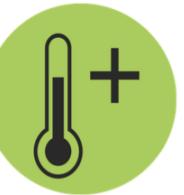
Learning function f



$X \in \mathbb{R}$

$$x^{(2)} = 80.0$$

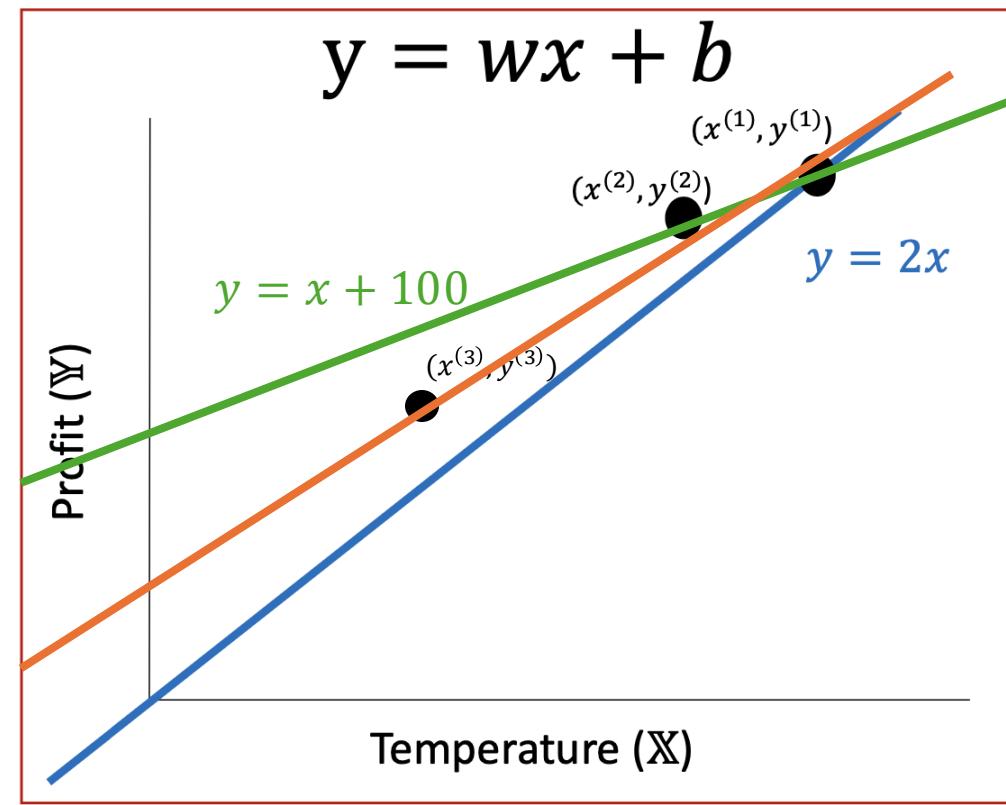
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Input: \mathbb{X}

"Temperature"

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Target: \mathbb{Y}

"Profit made on selling lemonade"



$$y^{(1)} = 200.0$$

$$y^{(2)} = 180.5$$

$$y^{(3)} = 115.1$$

$\mathbb{Y} \in \mathbb{R}$
(Numerical output)

Learning function f



$X \in \mathbb{R}$

$$x^{(2)} = 80.0$$

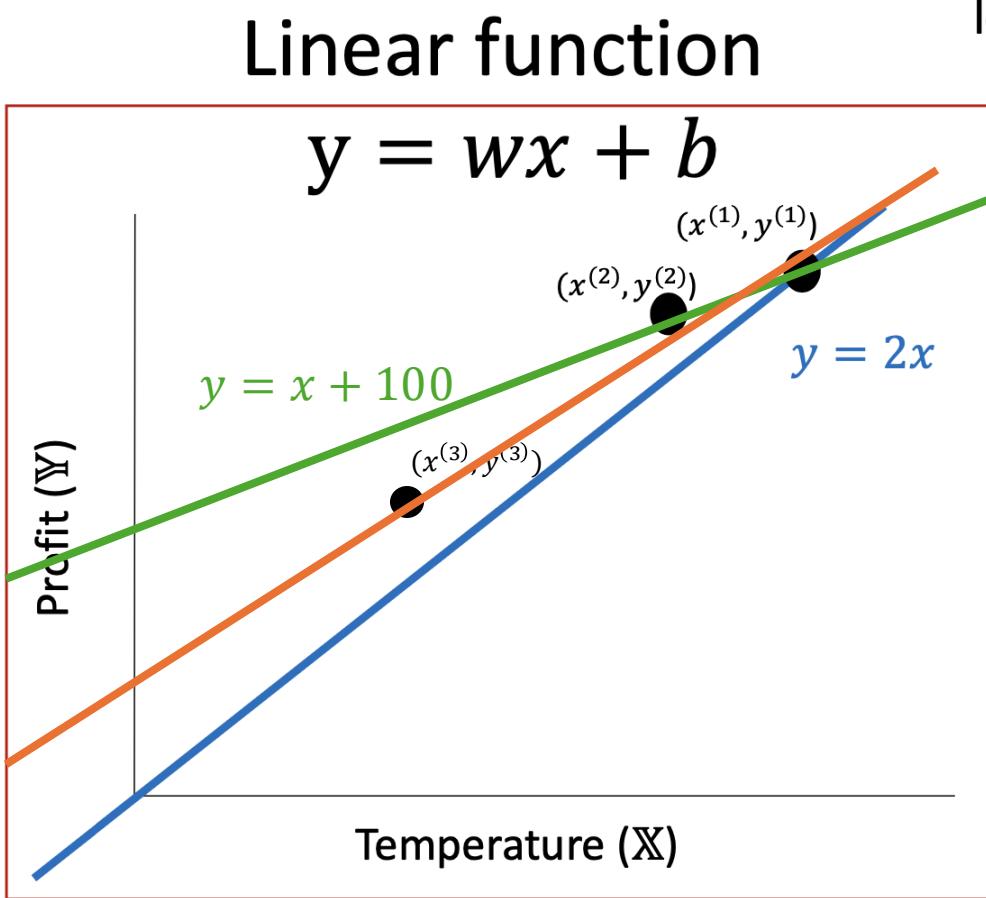
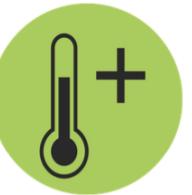
$$x^{(3)} = 30.3$$

Hard to find these functions by hand...

Input: \mathbb{X}

"Temperature"

$$x^{(1)} = 100.1$$



Target: \mathbb{Y}

"Profit made on selling lemonade"



$$y^{(1)} = 200.0$$

$$y^{(2)} = 180.5$$

$$y^{(3)} = 115.1$$

$\mathbb{Y} \in \mathbb{R}$
(Numerical output)

Learning function f



$X \in \mathbb{R}$

$$x^{(1)} = 100.1$$

$$x^{(2)} = 80.0$$

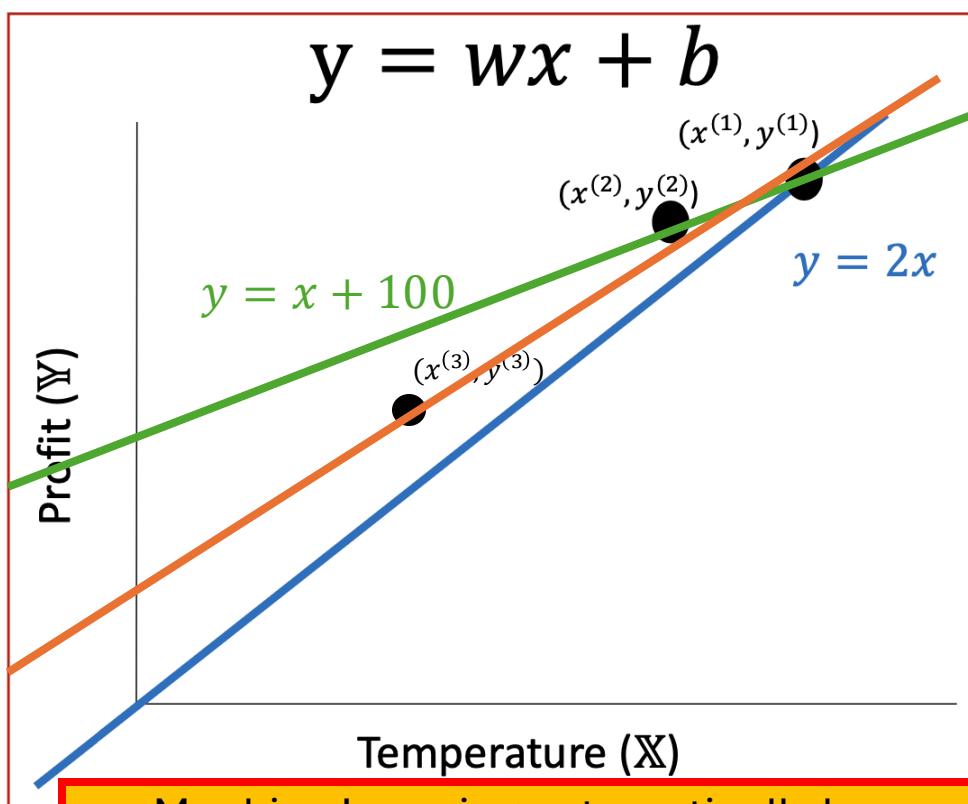
$$x^{(3)} = 30.3$$

Hard to find these functions by hand...



Input: \mathbb{X}

"Temperature"



Target: \mathbb{Y}

"Profit made on selling lemonade"



$$y^{(1)} = 200.0$$

$$y^{(2)} = 180.5$$

$$y^{(3)} = 115.1$$

$\mathbb{Y} \in \mathbb{R}$
(Numerical output)

Machine Learning automatically learns good approximations of f from data (or at least tries to)

Recap

ML Goal: Learn to approximate f ,
where $f(X) \rightarrow Y$

Deep Learning: $f_4(f_3(f_2(f_1(X)))) \rightarrow Y$

Discrete Outputs \rightarrow Classification

Continuous Outputs \rightarrow Regression

Remaining Questions:

How do we determine if one approximation of f is better than another?