

# Introduction

CISC 7026: Introduction to Deep Learning

University of Macau

# Overview

1. Brief chat
2. Course Information
3. Course Structure
4. Lecture

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# Brief Chat

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I taught a course on Deep Reinforcement Learning at Cambridge

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- Chat after class

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The best way to learn is to **ask questions** and have **discussions**

# Brief Chat

I will tell you about myself, and why I am interested in deep learning

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I will tell you about myself, and why I am interested in deep learning

Then, **you** will tell me why you are interested in deep learning

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It will help me alter the course towards your goals

# Brief Chat

I was always interested in space and robotics

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After school, I realized much of the classical robotics that we learn in school **does not work** in reality

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Today's robots are stupid – important robots are human controlled

Since then, I have focused on creating less stupid robots

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Since then, I have focused on creating less stupid robots



Robots that **learn** from their mistakes

I am interested in **deep learning** because I want to make smarter robots

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There are many tasks that humans do not like to do, that robots can do

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What do you want to learn? Why?

## Brief Chat

I am starting a lab, and looking for research students focusing on deep reinforcement learning and robotics

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I am starting a lab, and looking for research students focusing on deep reinforcement learning and robotics

If you finish the course and find it too easy, send me an email!

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- Grading

## Prerequisites:

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- Programming in python

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## Good to Know:

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## Good to Know:

- Probability
  - ▶ Bayes rule, conditional probabilities  $P(a \mid b) = \frac{P(b \mid a)P(a)}{P(b)}$

**Grading (subject to change):**

## Grading (subject to change):

- 70% assignments

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- 20% quiz

## Grading (subject to change):

- 70% assignments
- 20% quiz
- 10% attendance and participation
  - ▶ Name plates

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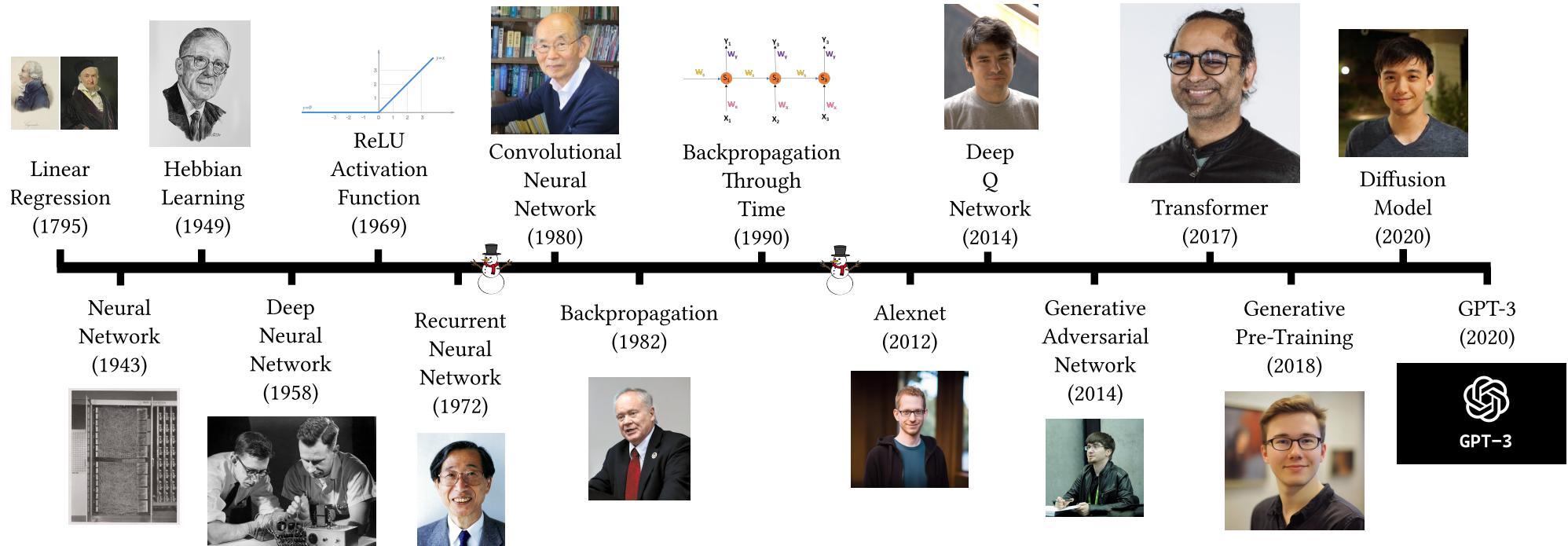
This format is subject to change

# Course Structure

We will be following the history of machine learning

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## 1. Deep Learning Successes

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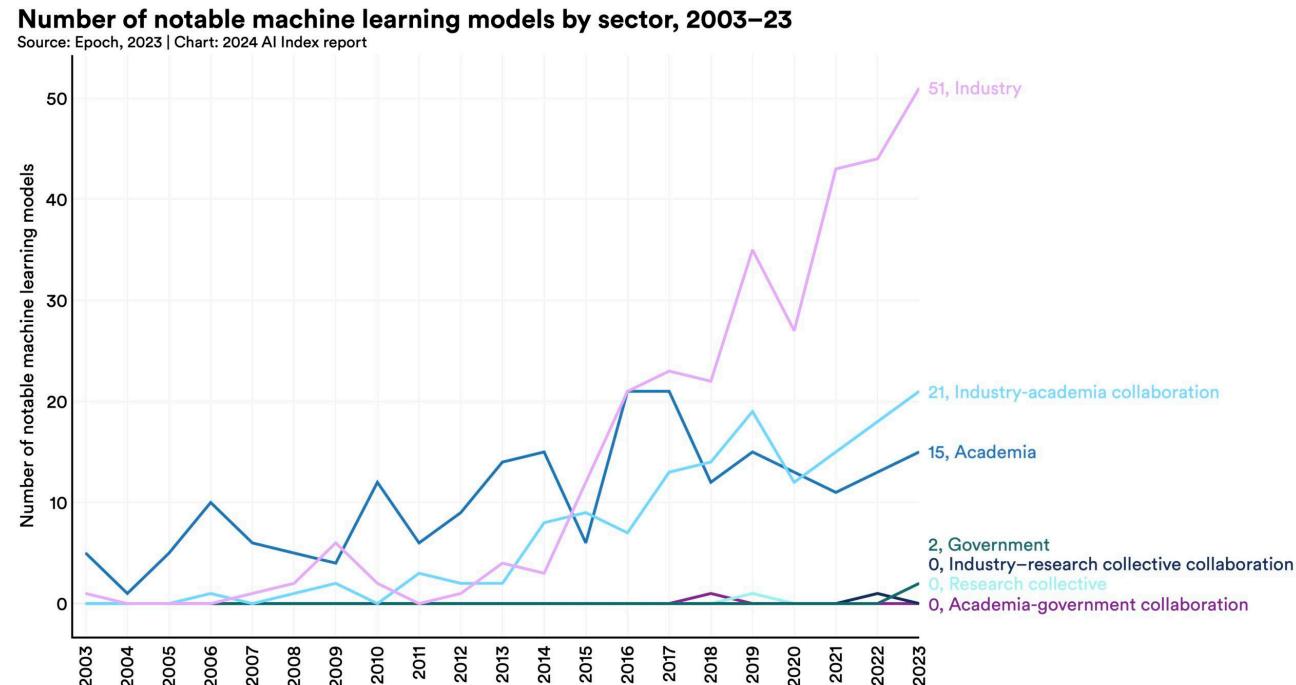
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# Successes

Deep learning is becoming very popular worldwide



Credit: Stanford University 2024 AI Index Report

# Successes

Many things that were once considered science fiction are now possible through deep learning. It can draw pictures for us

Create an image expressing how far deep learning has come



Here is the image depicting the advancements in deep learning. It showcases a futuristic cityscape with various elements symbolizing the integration of AI and deep learning into society. Let me know if you need any adjustments or further details!

# Successes

It can beat the world champions at difficult video games like DotA 2



<https://www.youtube.com/watch?v=UZHTNBMAfAA>

# Successes

It is learning to use tools and break rules

<https://youtu.be/kopoLzvh5jY?si=keH4i8noY4zUVNrP>

# Successes

It is operating fully autonomous taxis in four cities



<https://www.youtube.com/watch?v=Zeyv1bN9v4A>

# Successes

Maybe it is doing your homework, then explaining itself

Write a stack implementation in python

Certainly! Below is a simple stack implementation in Python using a list. The stack will support typical operations such as push, pop, peek, and checking if the stack is empty.



```
python
class Stack:
    def __init__(self):
        self.items = []

    def is_empty(self):
        return len(self.items) == 0

    def push(self, item):
        self.items.append(item)

    def pop(self):
        if self.is_empty():
            raise IndexError("pop from empty stack")
        return self.items.pop()

    def peek(self):
        if self.is_empty():
            raise IndexError("peek from empty stack")
        return self.items[-1]

    def size(self):
        return len(self.items)

    def __str__(self):
        return str(self.items)

# Example usage:
if __name__ == "__main__":
    stack = Stack()
    stack.push(1)
    stack.push(2)
    stack.push(3)
    print("Stack after pushes:", stack)
    print("Peek:", stack.peek())
    print("Pop:", stack.pop())
    print("Stack after pop:", stack)
    print("Is stack empty?", stack.is_empty())
    print("Stack size:", stack.size())
```

**Explanation:**

1. **Initialization:** The stack is initialized with an empty list `self.items`.
2. **is\_empty:** Checks if the stack is empty by returning `True` if the length of `self.items` is 0.

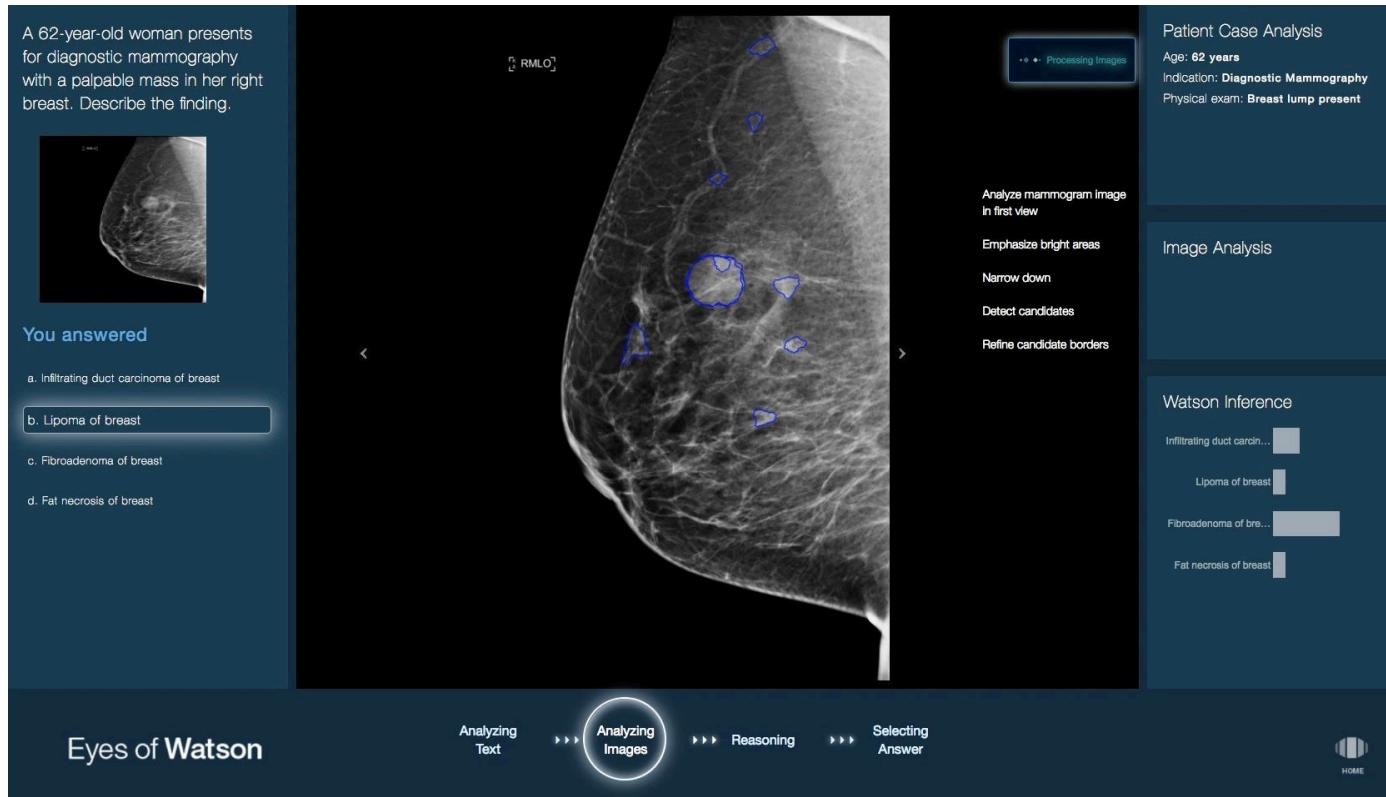
# Successes

It is making you lose money in the stock market



# Successes

It is telling your doctor if you have cancer



# Successes

We are solving more and more problems using deep learning

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Our deep models keep improving as we get more data

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**Opinion:** In the next 10-20 years, our lives will look very different

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Throughout this course, you will be training your own deep models

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After the course, you will be experts at deep learning

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Deep learning is a powerful tool

Like all powerful tools, deep learning can be used for evil

**Request:** Before you train a deep model, ask yourself whether it is good or bad for the world

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At a high level, how does deep learning work?

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It consists of four parts:

1. Dataset
2. Deep neural network
3. Loss function
4. Optimization procedure

# DL at a Glance

The dataset provides a set inputs and associated outputs



Dog



Muffin

# DL at a Glance

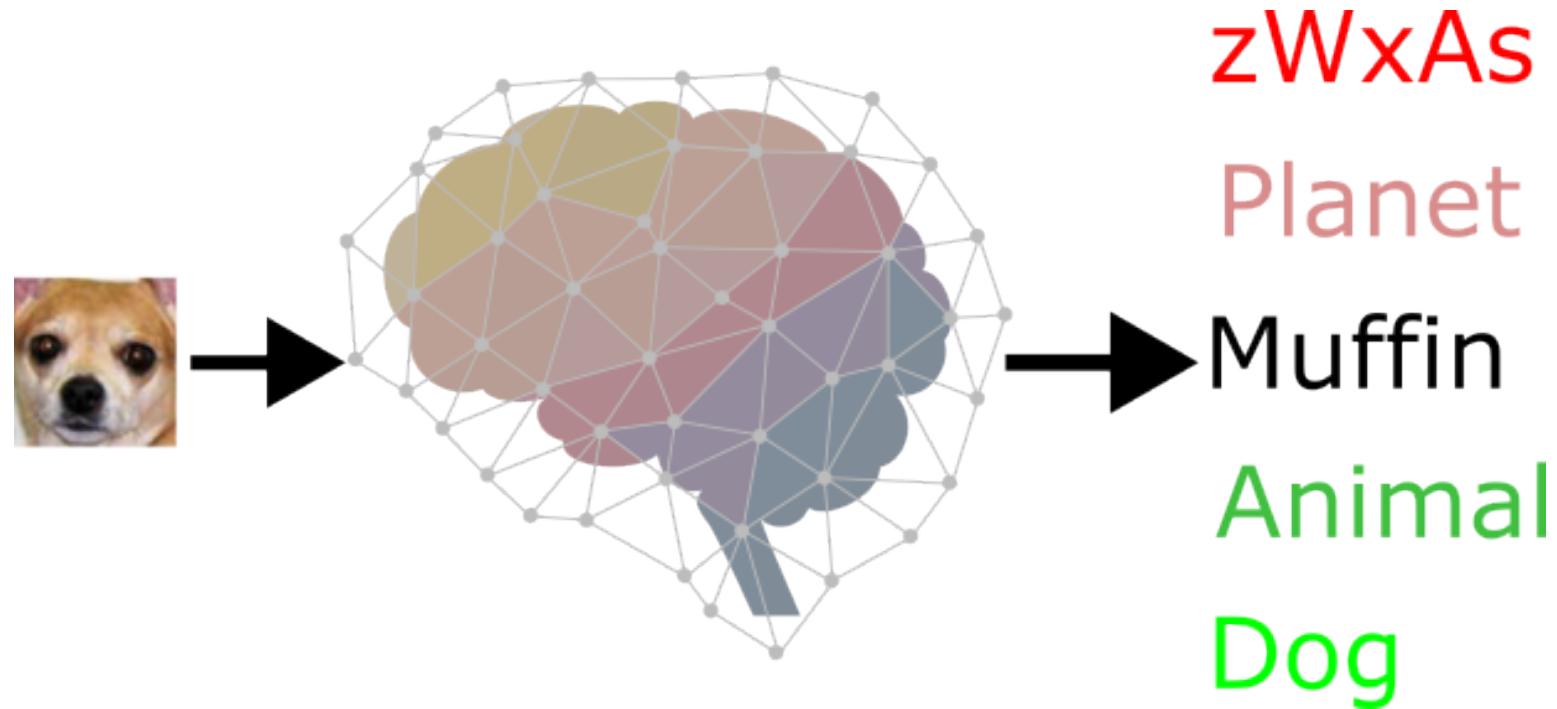
The **neural network** learns to map the inputs to outputs



The **loss function** describes how “wrong” the neural network is. We call this “wrongness” the **loss**.

# DL at a Glance

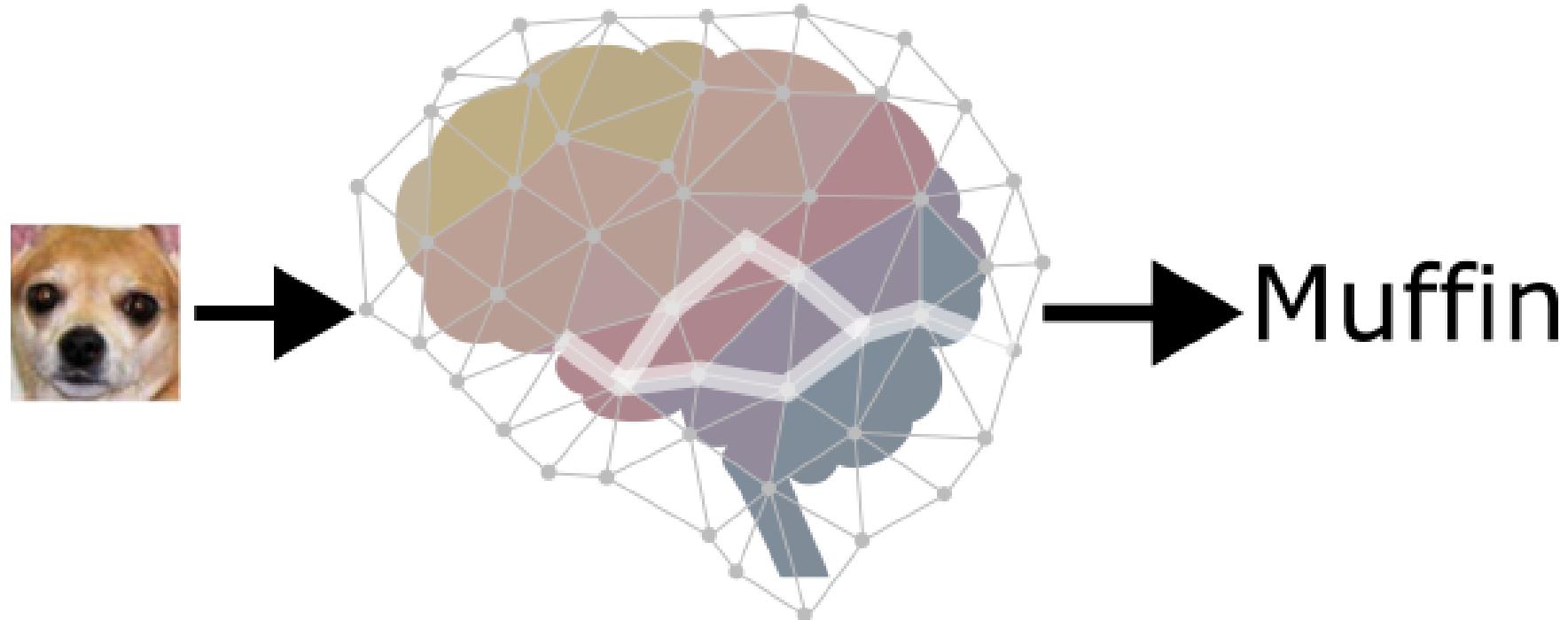
The **loss function** describes how “wrong” the neural network is. We call this “wrongness” the **loss**.



The **optimization procedure** changes the neural network to reduce the loss

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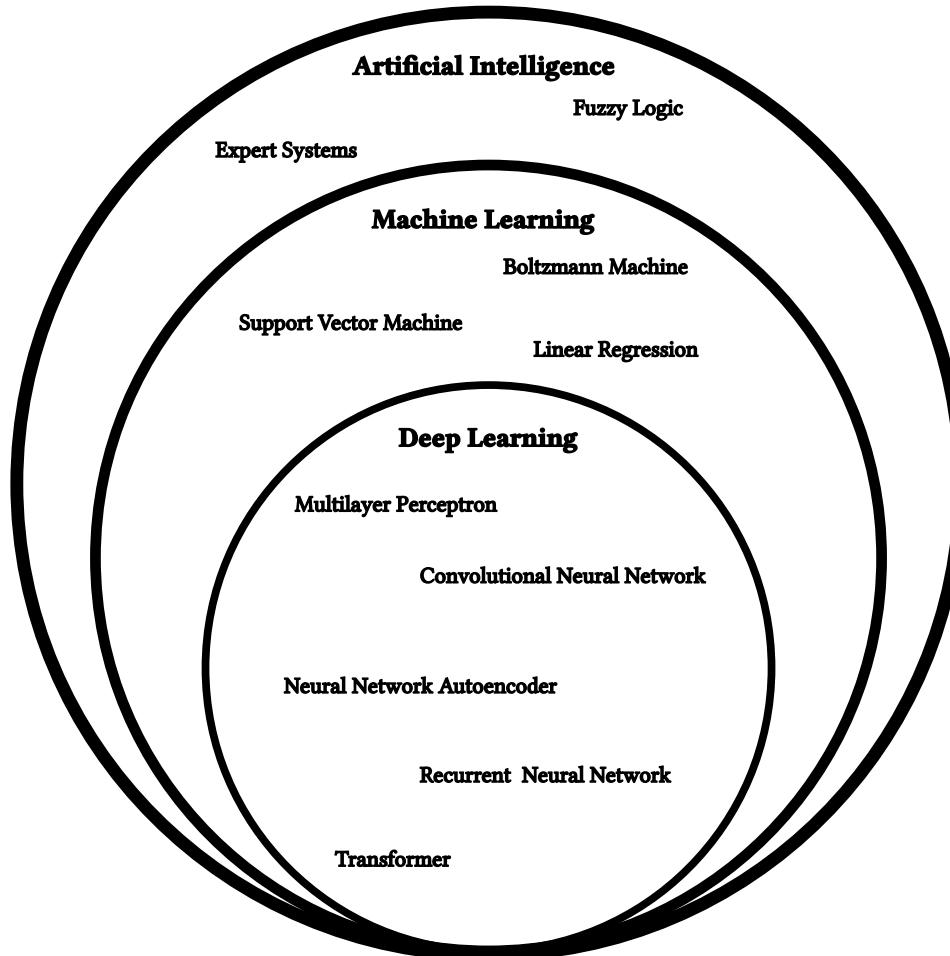
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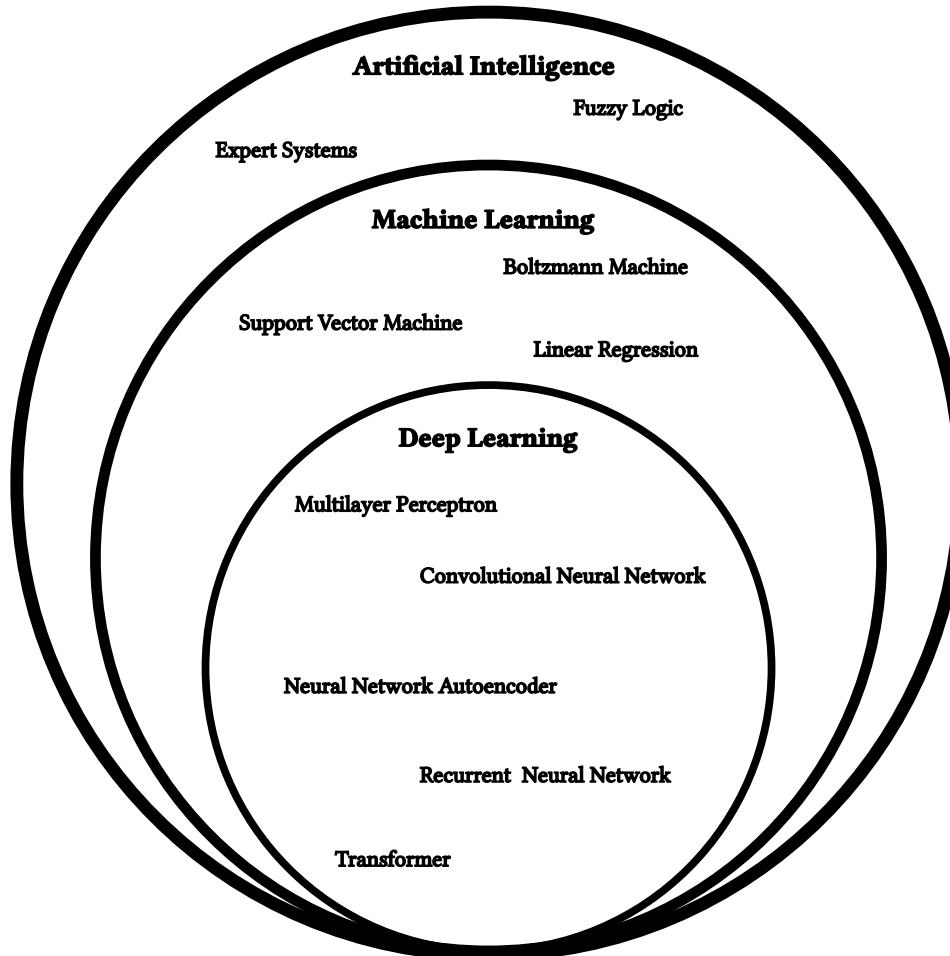
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Relax

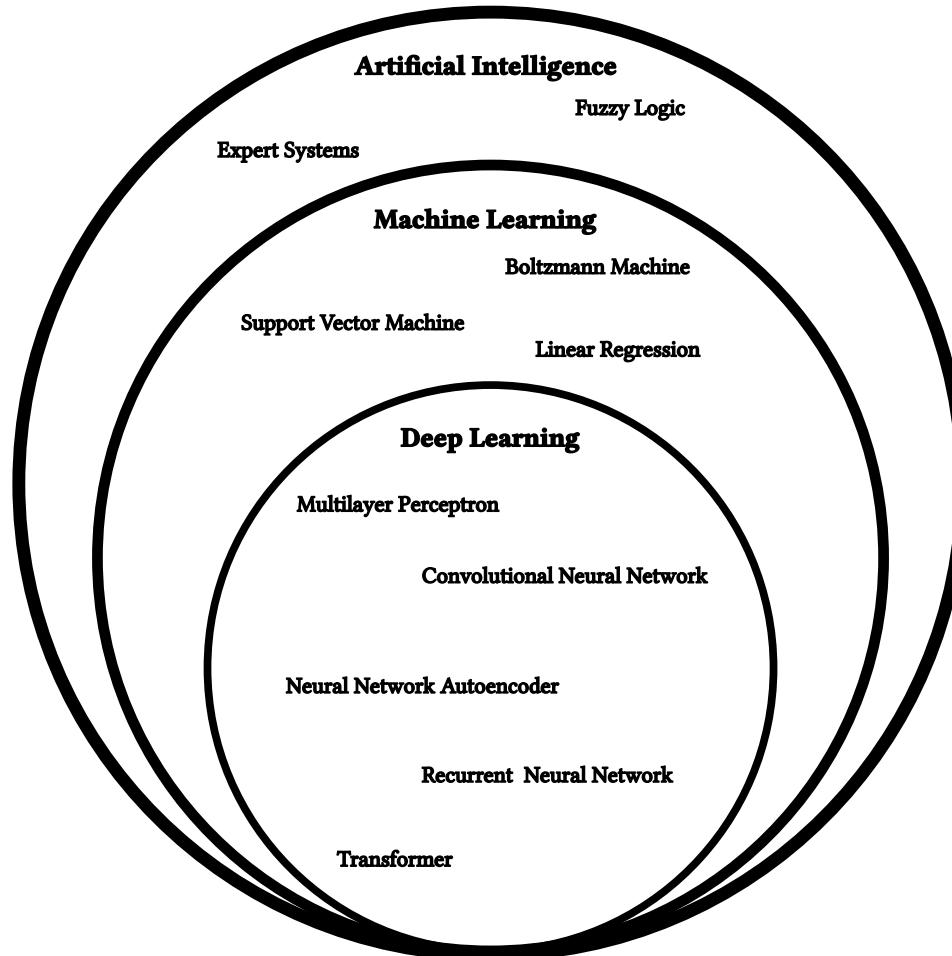
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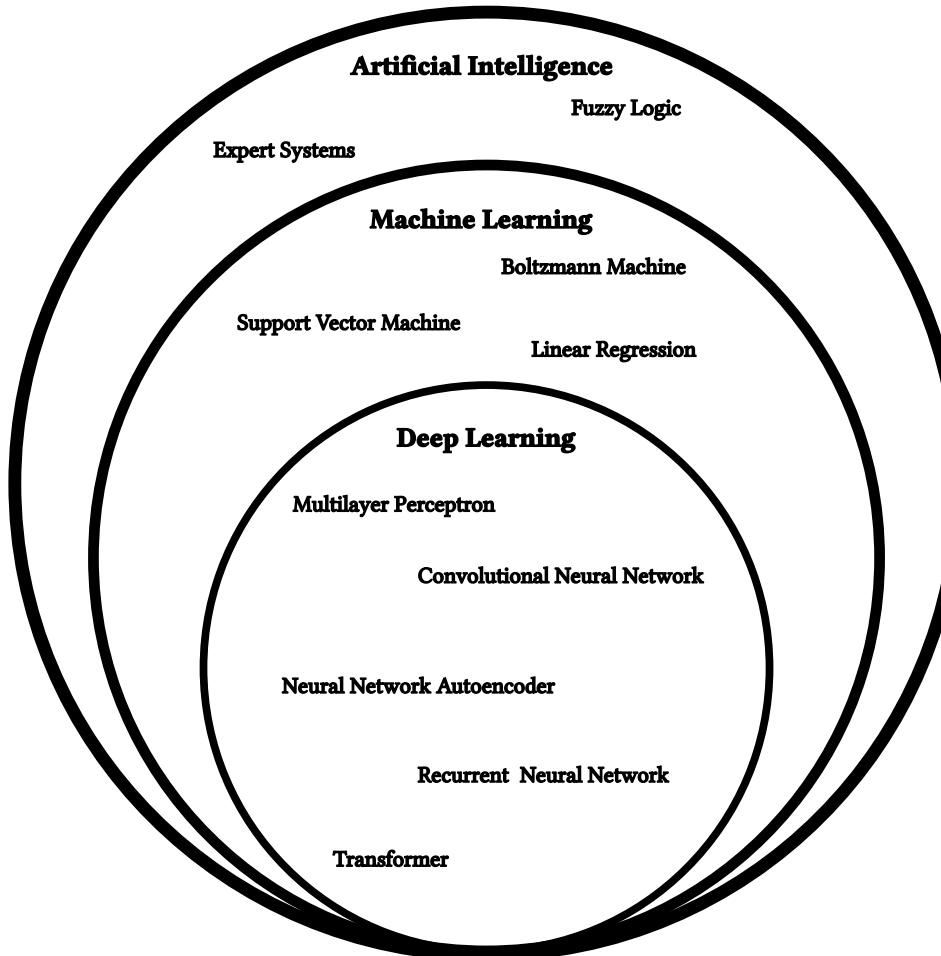


Deep Learning is a type of  
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Deep Learning is a type of Machine Learning

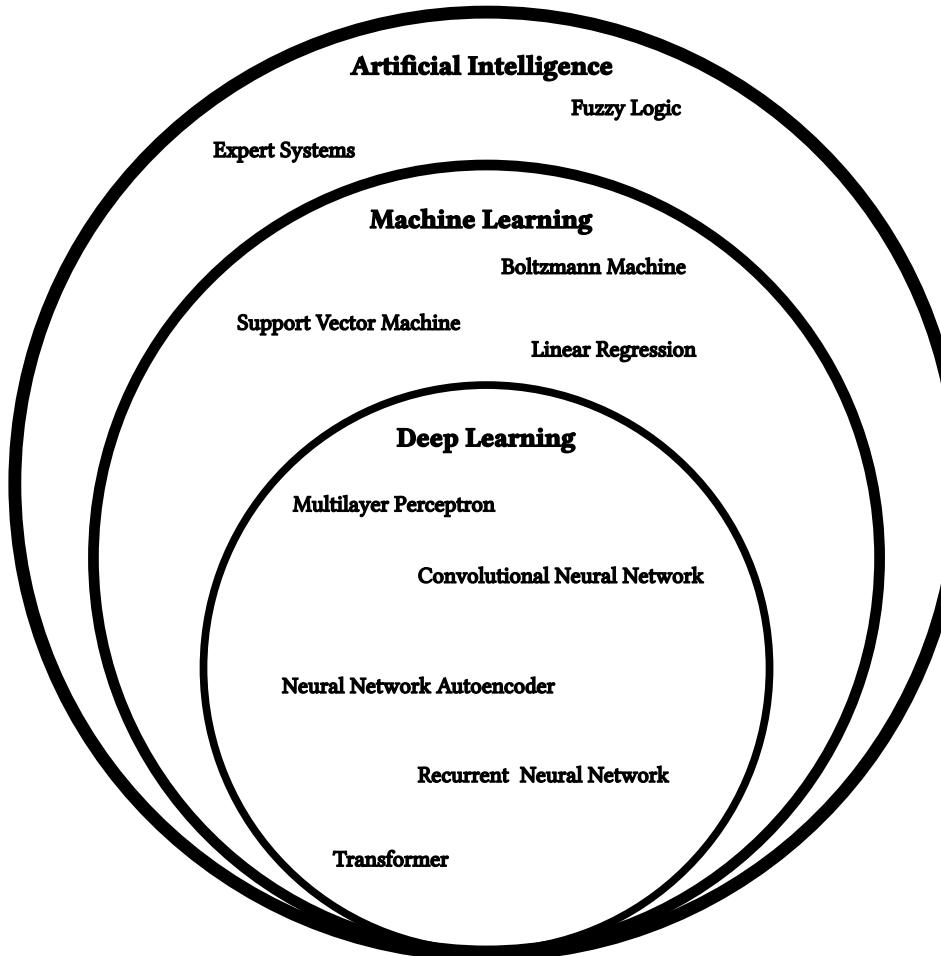
Machine learning defines **what** we are trying to do



Deep Learning is a type of Machine Learning

Machine learning defines **what** we are trying to do

Deep learning defines **how** we do it



Deep Learning is a type of Machine Learning

Machine learning defines **what** we are trying to do

Deep learning defines **how** we do it

Before we can understand deep learning, we must become familiar with machine learning

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**Task:** Write a program to determine if a picture contains a dog.

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**Question:** How would you program this?

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**Question:** How would you program this?



Would your method still work?

**Task:** Write a program to determine if a picture contains a dog.

**Question:** How would you program this?



Would your method still work?

We often know **what** we want, but we do not know **how**

We give machine learning the **what**

We give machine learning the **what**

And it tells us the **how**

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And it tells us the **how**

In other words, we tell an ML model **what** we want it to do

We give machine learning the **what**

And it tells us the **how**

In other words, we tell an ML model **what** we want it to do

And it learns **how** to do it

We often know **what** we want, but we do not know **how**

We often know **what** we want, but we do not know **how**

We have many pictures of either dogs or muffins  $x \in X$

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We have many pictures of either dogs or muffins  $x \in X$

We want to know if the picture is [dog | muffin]  $y \in Y$

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$$f : X \mapsto Y$$

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Machine learning tells us how to find  $f$

$$f(\text{dog}) = \text{dog}$$
$$f(\text{muffin}) = \text{muffin}$$

Consider some more interesting functions

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$$f : \text{image} \mapsto \text{caption}$$

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$$f : \text{image} \mapsto \text{caption}$$

$$f : \text{caption} \mapsto \text{image}$$

$$f : \text{English} \mapsto \text{Chinese}$$

$$f : \text{law} \mapsto \text{change in climate}$$

Consider some more interesting functions

$$f : \text{image} \mapsto \text{caption}$$
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$$f : \text{English} \mapsto \text{Chinese}$$
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$$f : \text{voice command} \mapsto \text{robot action}$$

Consider some more interesting functions

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**Question:** Can anyone suggest other interesting functions?

# Why do we call it machine **learning**?

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More specifically, we learn function **parameters**  $\Theta$

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We learn the function  $f$  from the **data**  $x \in X, y \in Y$

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$$f : X, \Theta \mapsto Y$$

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$$f : X, \Theta \mapsto Y$$

$$f\left(\text{你好吗}, \begin{bmatrix} \theta_1 \\ \theta_2 \\ \vdots \end{bmatrix}\right) = \text{You good?}$$

More specifically, we learn function **parameters**  $\Theta$

$$f : X, \Theta \mapsto Y$$

$$f\left(\text{dog image}, \begin{bmatrix} \theta_1 \\ \theta_2 \\ \vdots \end{bmatrix}\right) = \text{Dog}$$

More specifically, we learn function **parameters**  $\Theta$

$$f : X, \Theta \mapsto Y$$

$$f\left(\text{Muffin}, \begin{bmatrix} \theta_1 \\ \theta_2 \\ \vdots \end{bmatrix}\right) = \text{Muffin}$$

More specifically, we learn function **parameters**  $\Theta$

$$f : X, \Theta \mapsto Y$$

$$f\left(\text{Dog}, \begin{bmatrix} \theta_1 \\ \theta_2 \\ \vdots \end{bmatrix}\right) = \img[alt="A small brown dog's face." data-bbox="568 368 662 525]$$

More specifically, we learn function **parameters**  $\Theta$

$$f : X, \Theta \mapsto Y$$

$$f\left(\text{Dog}, \begin{bmatrix} \theta_1 \\ \theta_2 \\ \vdots \end{bmatrix}\right) = \img[alt="A small brown dog's face." data-bbox="568 368 662 525]$$

Machine learning learns the parameters that solve difficult problems

# Summary:

**Summary:**

1. Certain problems are difficult to solve with programming

## Summary:

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  - Dog or muffin?

## Summary:

1. Certain problems are difficult to solve with programming
  - Dog or muffin?
2. Machine learning provides a framework to solve difficult problems

## Summary:

1. Certain problems are difficult to solve with programming
  - Dog or muffin?
2. Machine learning provides a framework to solve difficult problems
  - We learn the parameters  $\theta$  for some function  $f(x, \theta) = y$

Relax

You will use Python with machine learning libraries in this course

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We will specifically focus on:

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We will specifically focus on:

- JAX

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- JAX
- PyTorch

You will use Python with machine learning libraries in this course

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- PyTorch

You should become comfortable using these libraries

You will use Python with machine learning libraries in this course

We will specifically focus on:

- JAX
- PyTorch

You should become comfortable using these libraries

- Read tutorials online

You will use Python with machine learning libraries in this course

We will specifically focus on:

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- PyTorch

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- `pip install torch`
- `pip install jax jaxlib`

## Create vectors, matrices, or tensors in jax

```
import jax.numpy as jnp
a = jnp.array(1) # Scalar
b = jnp.array([1, 2]) # Vector
C = jnp.array([[1,2], [3,4]]) # 2x2 Matrix
D = jnp.ones((3,3,3)) # 3x3x3 Tensor
```

You can determine the dimensions of a variable using `shape`

```
b.shape # Prints (2,)
C.shape # Prints (2,2)
D.shape # prints (3,3,3)
```

## Create vectors, matrices, or tensors in pytorch

```
import torch  
a = torch.tensor(1) # Scalar  
b = torch.tensor([1, 2]) # Vector  
C = torch.tensor([[1,2], [3,4]]) # 2x2 Matrix  
D = torch.ones((3,3,3)) # 3x3x3 Tensor
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```
import jax.numpy as jnp

s = 5 * jnp.array([1, 2])
print(s) # jnp.array(5, 10)
x = jnp.array([1, 2]) + jnp.array([3, 4])
print(x) # jnp.array([4, 6])
y = jnp.array([1, 2]) * jnp.array([3, 4]) # Careful!
print(y) # jnp.array([3, 8])
z = jnp.array([[1], [2]]) @ jnp.array([[3, 4]])
print(z) # A^t B (dot product), jnp.array([[11]])
```

pytorch is very similar to jax

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```

You can also call various methods on arrays/tensors

```
import jax.numpy as jnp

x = jnp.array([[1, 2], [3, 4]]).sum(axis=0)
print(x) # Sum across leading axis, array([4, 6])
y = jnp.array([[1, 2], [3, 4]]).mean()
print(y) # Mean across all axes, array(2.5)
z = jnp.array([[1, 2], [3, 4]]).reshape(4, 1)
print(z) # jnp.array([[1], [2], [3], [4]])
```

## Same thing for pytorch

```
import torch

x = torch.tensor([[1, 2], [3, 4]]).sum(axis=0)
print(x) # Sum across leading axis, array([4, 6])
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print(z) # torch.tensor([[1], [2], [3], [4]])
```

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```
>>> jnp.array([[1,2]]) @ jnp.array([[3,4]]) # (1, 2) x (1, 2)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
    File "/local/scratch/sm2558/miniconda3/envs/jax/lib/python3.11/site-
packages/jax/_src/numpy/array_methods.py", line 256, in deferring_binary_op
        return binary_op(*args)
               ^^^^^^^^^^^^^^^^^^

  File "/local/scratch/sm2558/miniconda3/envs/jax/lib/python3.11/site-
packages/jax/_src/numpy/lax_numpy.py", line 3192, in matmul
    out = lax.dot_general(
           ^^^^^^^^^^^^^^

TypeError: dot_general requires contracting dimensions to have the same
shape, got (2,) and (1,).
```

# Let us do a Google Colab tutorial!

# Let us set up a local conda environment

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There might be a quiz on jax and pytorch operations next lecture