Machine Learning to Language Model

Topic 01 - Introduction to Machine Learning

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https://jaihuayen.github.io/

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- Gradient Descent
- Demo
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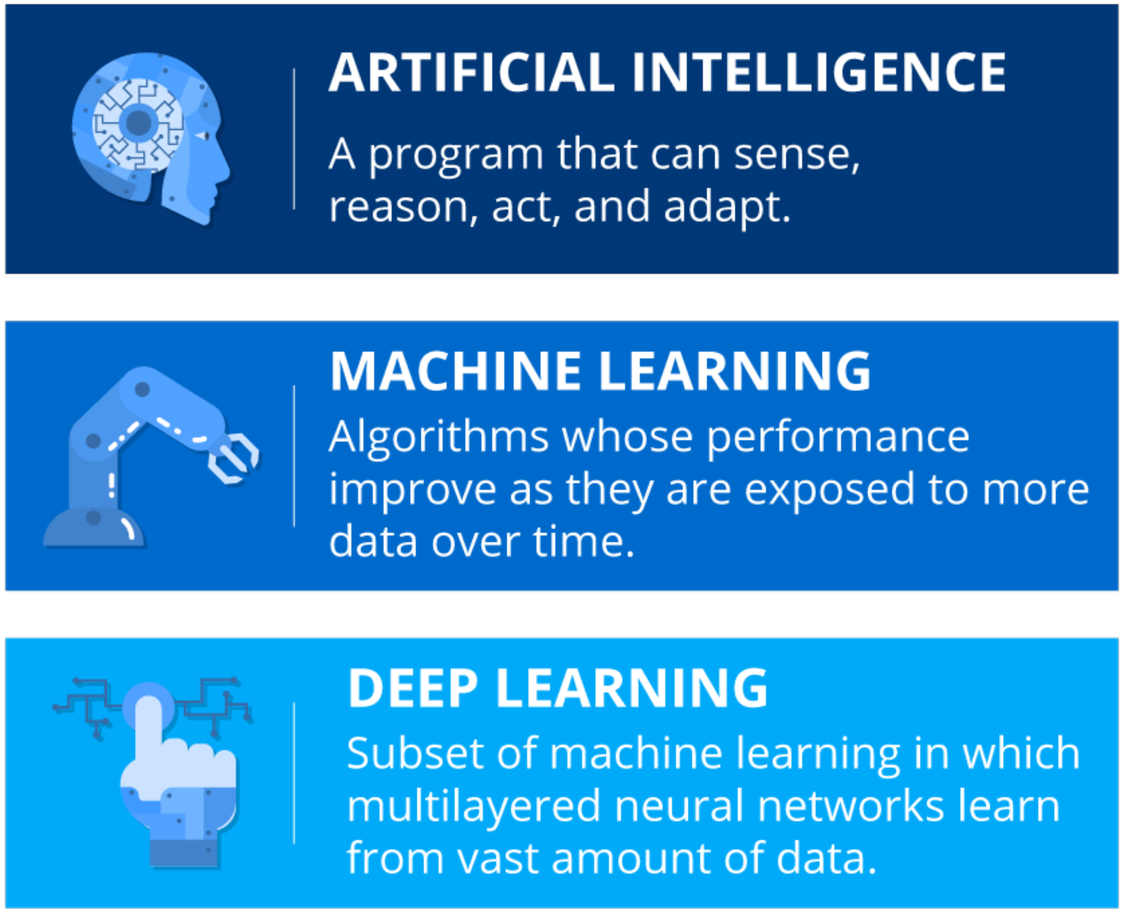
AI Models

AI Models



https://www.globaltechcouncil.org/artificial-intelligence/clearing-the-confusion-ai-vs-machine-learning-vs-deep-learning/

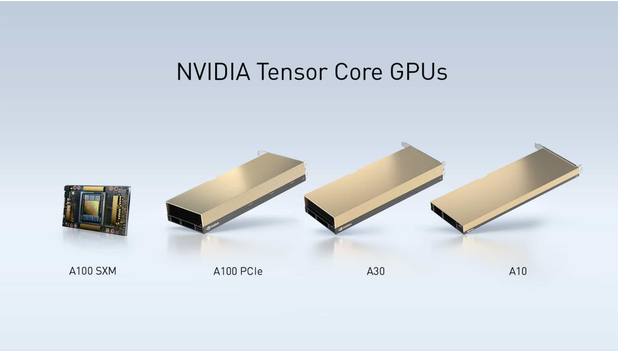
The Era of AI

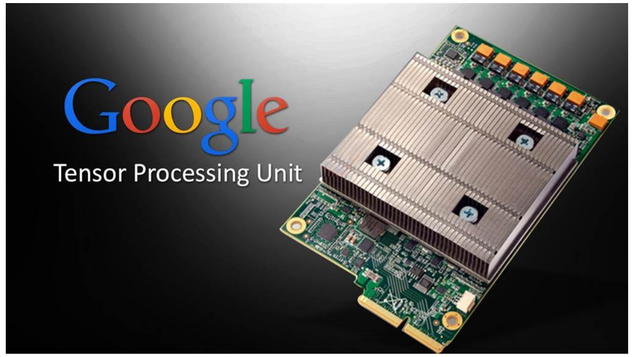
AI could finally be introduced into practice in general tasks!

- Tremendous improvement in computational resources.
- Enhancement of model architecture for model efficiency.
- Release open-source large pre-trained general models.
- Development of novel model training algorithms.

Hugging Face

PyTorch 2.0





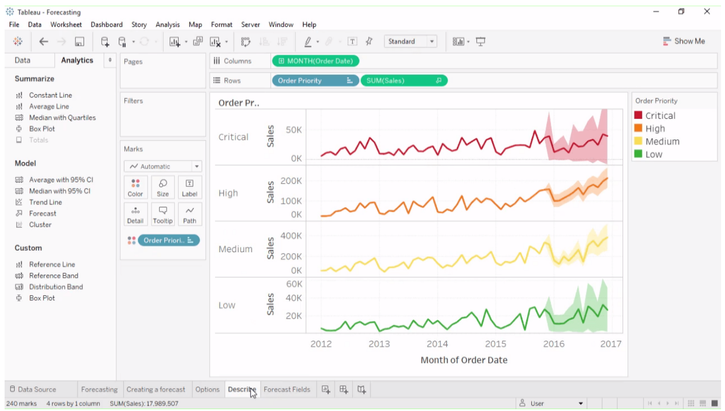
	ResNet Cloud AI	MobileNet Mobile AI	MCUNet Tiny AI
Memory (Activation)	16GB	4GB ← 13,000x smaller	320kB
Storage (Weights)	~TB/PB	256GB	1MB

[MCUNet: Tiny Deep Learning on IoT Devices, Han et al. 2020]

AI Models

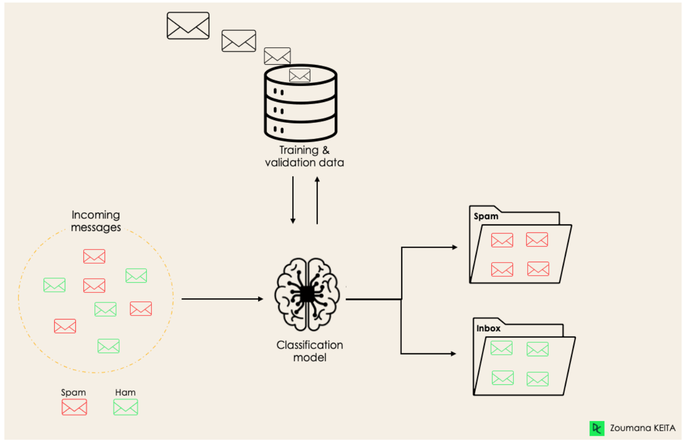
AI models could be used in these tasks:

Forecasting



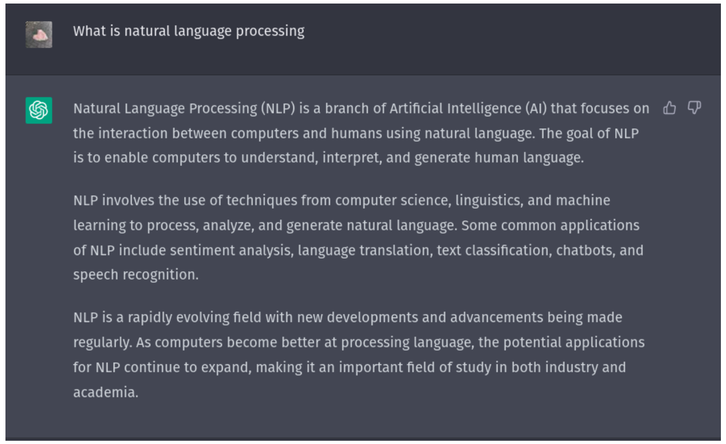
https://www.tableau.com/learn/articles/time-series-forecasting

Classification



https://www.datacamp.com/blog/classification-machine-learning

Generating



https://openai.com/blog/chatgpt

AI Models

AI models are functions!

AI

The image of dog.

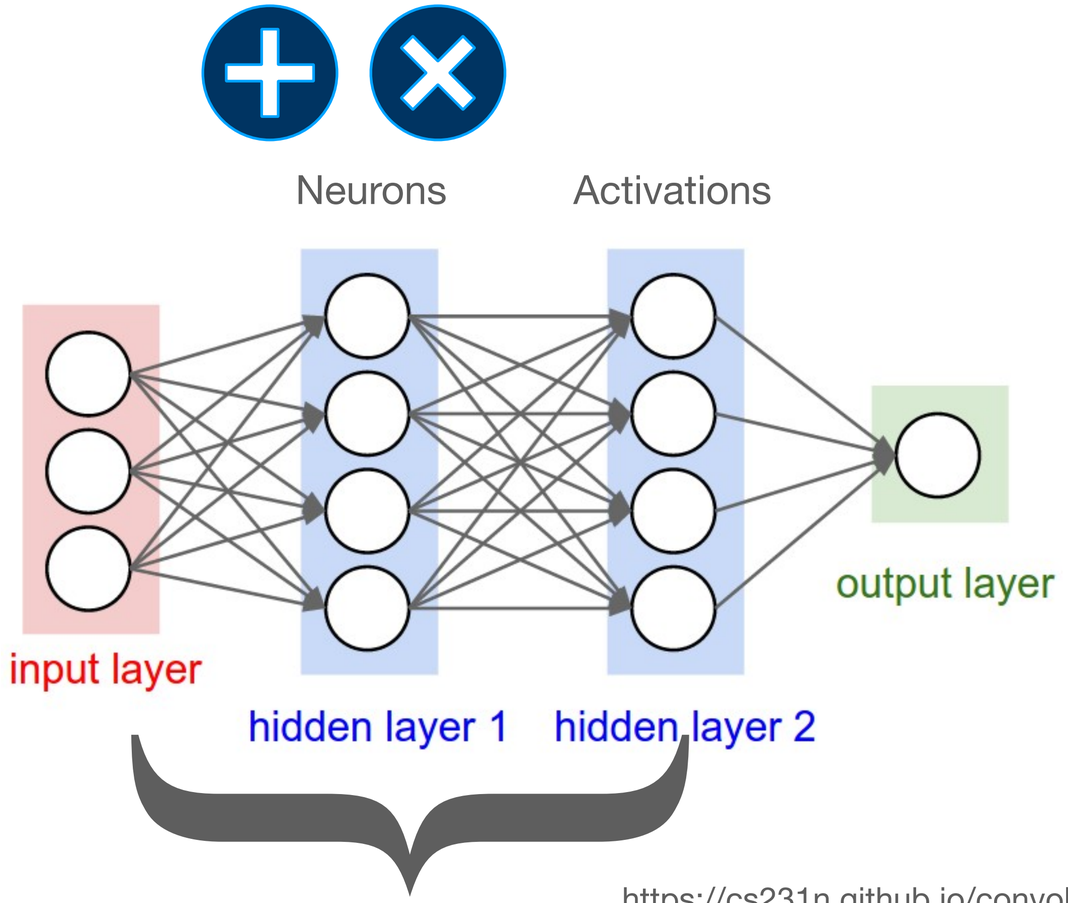
Translate “你好” in English.

$f(x)$

Hello

AI Models

AI models are functions built by neural networks



Universal Approximation Theorem

$$g(x) \approx f(x)$$

Any function can be approximated by neural network!

https://cs231n.github.io/convolutional-networks/

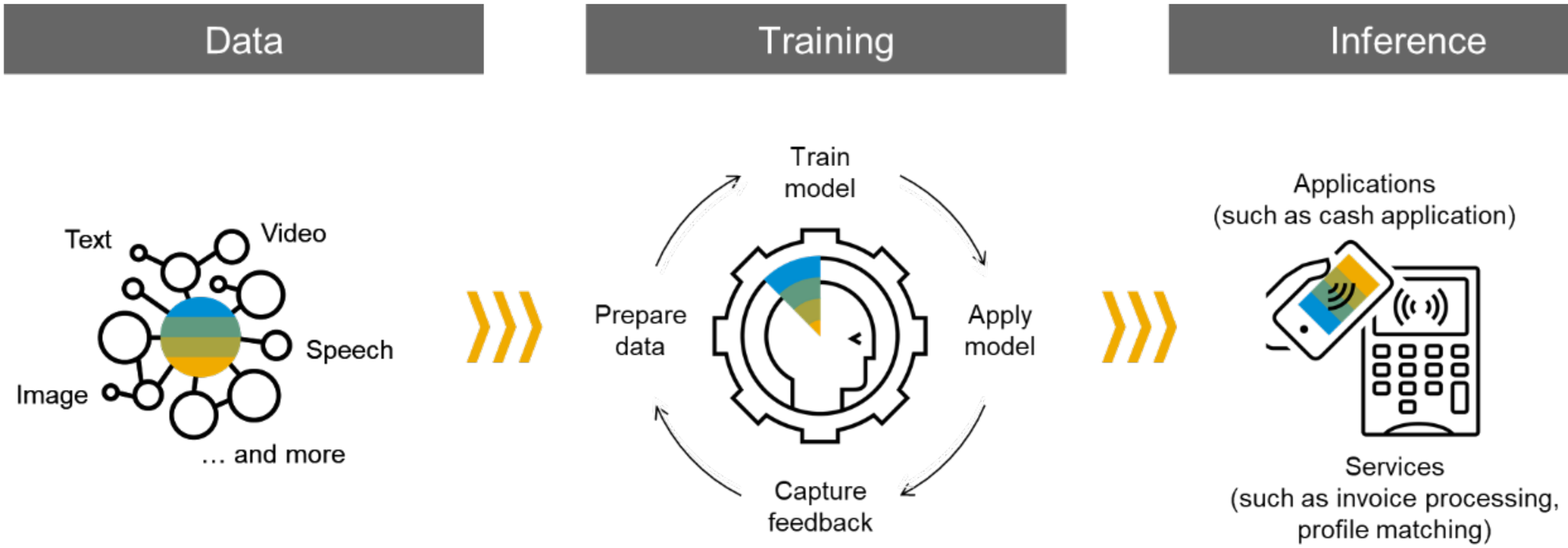
$g(x)$

The function we want to learn from data by training

How to Train AI Models?

Machine Learning

Mathematical Fundations of Model Training

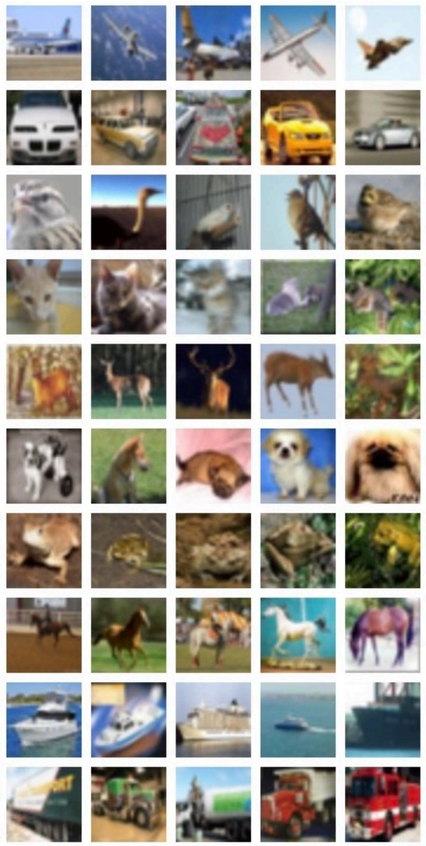


https://blogs.sap.com/2019/04/05/machine-learning-in-sap-strategy/

Training Dataset

Given datasets and tags to train AI model.

x



$$y = g(x)$$

y

airplane

automobile

bird

cat

deer

dog

frog

horse

ship

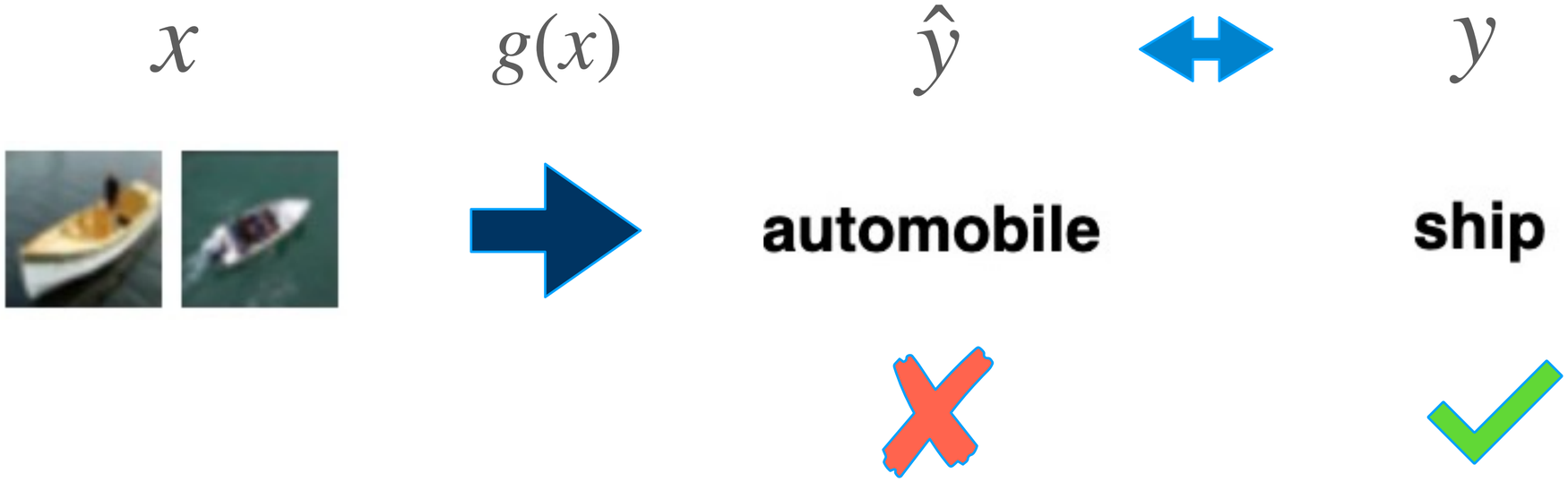
truck

https://www.cs.toronto.edu/~kriz/cifar.html

Model Training

Cannot perfectly predict the true label in the first time

The difference between the true label and predicted label



We want to improve the model output in order to have better performance!

Loss Function

Measurement of model performance

The difference between the true label and predicted label

$\hat{y}$ ⟷ y

automobile **ship**

[0,0.4,0,0,0,0,0,0,0,0.6,0] [0,0,0,0,0,0,0,0,1,0]

Loss function (Cross Entropy Loss)

$$L = -\sum_{i=1} y_i \log \hat{y}_i$$

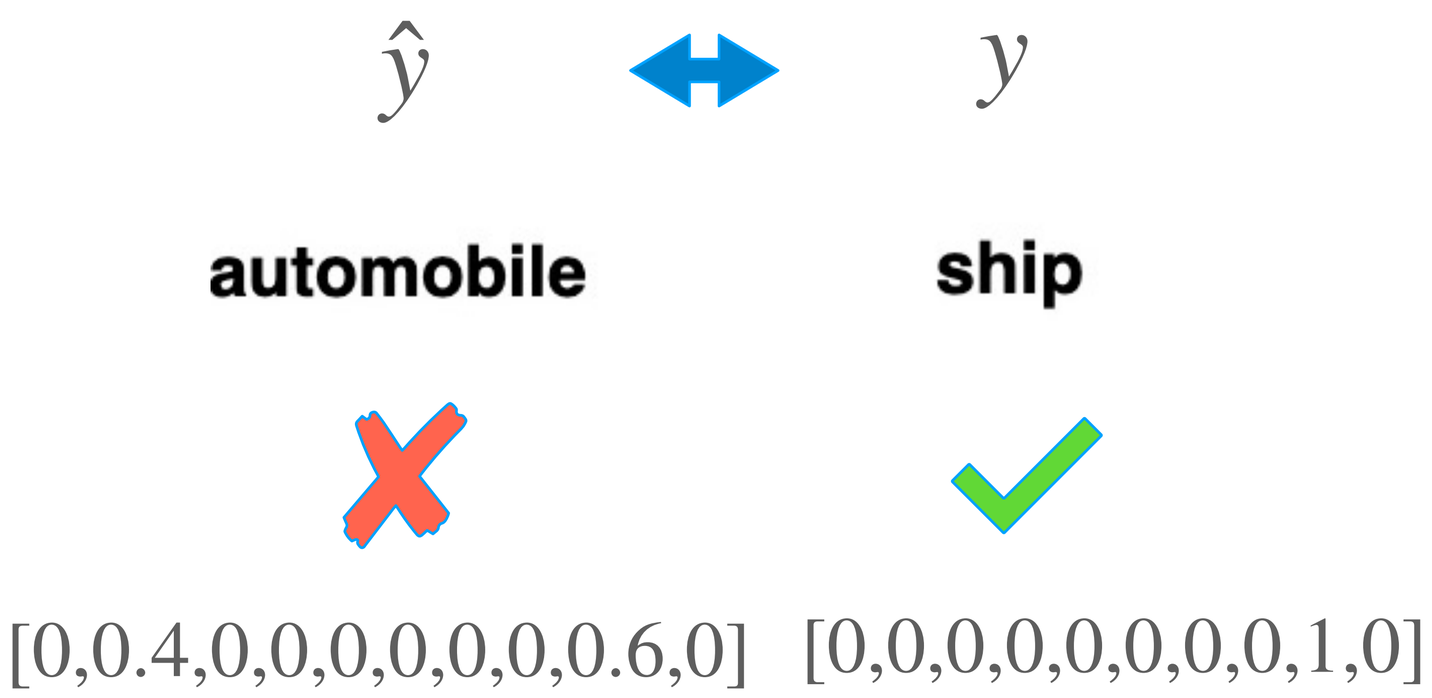
$y_i = 1$ The higher the predicted probability the lower the loss you will get

$y_i = 0$ The whole term will be 0 so it doesn't matter

Loss Function

Measurement of model performance

The difference between the true label and predicted label



Loss function (Cross Entropy Loss)

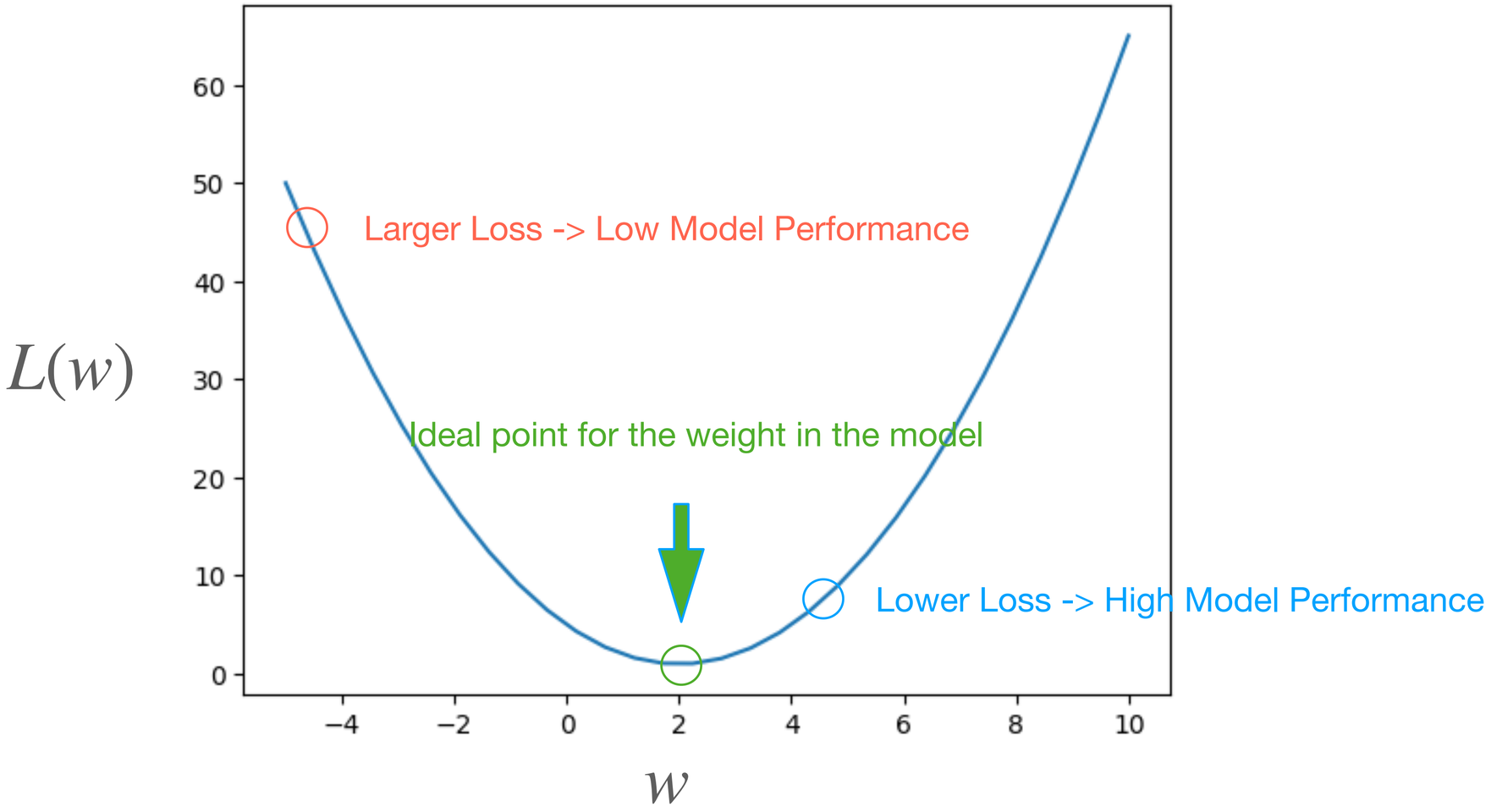
$$L = -\sum_{i=1} y_i \log \hat{y}_i$$

$$= -\sum_{i=1} y_i \log g(x_i)$$

$$L(w) \triangleq -\sum_{i=1} y_i \log(wx_i)$$

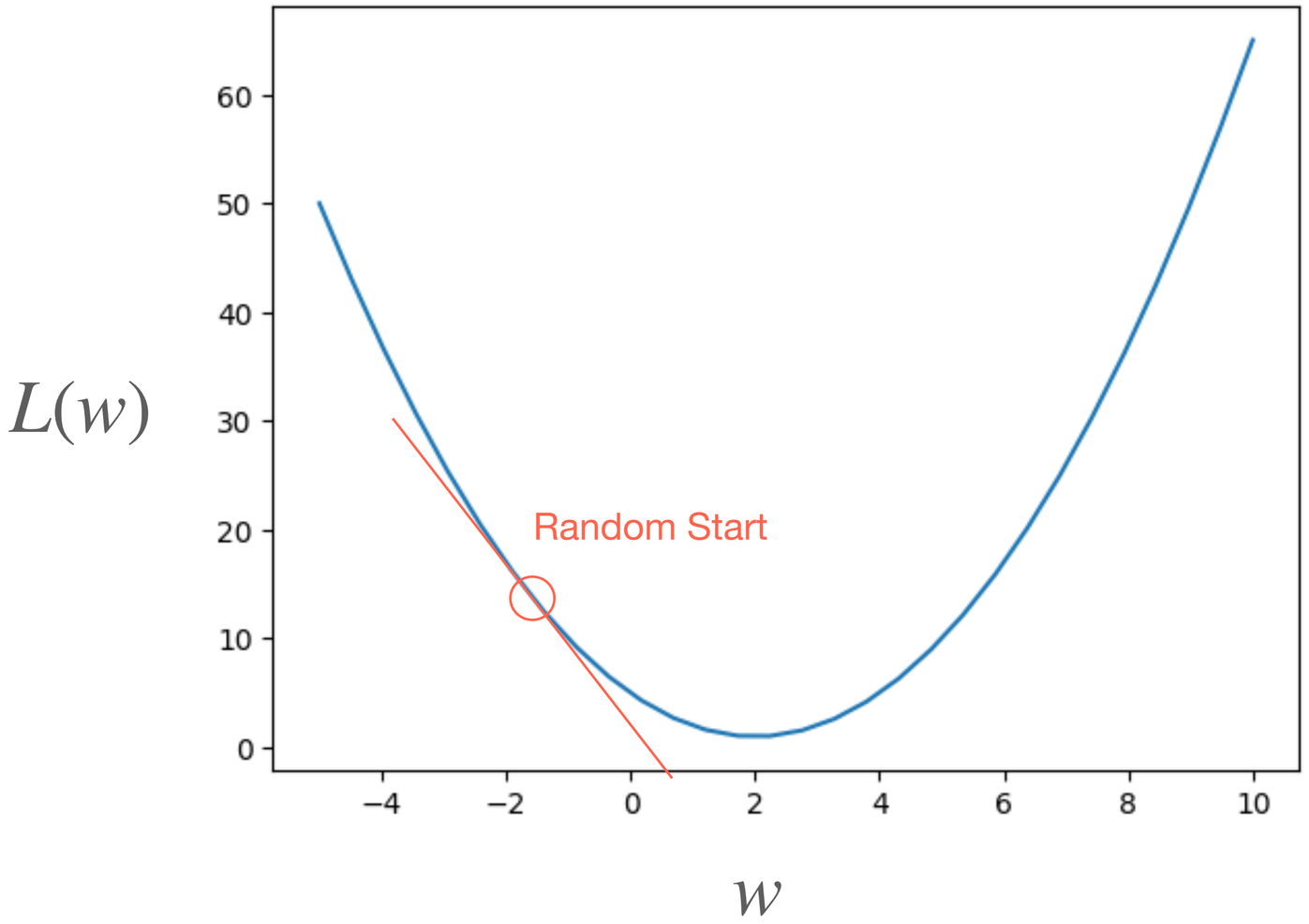
Loss Function

Measurement of model performance



Training Procedure

Start for Random Initialization of Weight



Intuition:
Walk to the lower point of the loss function

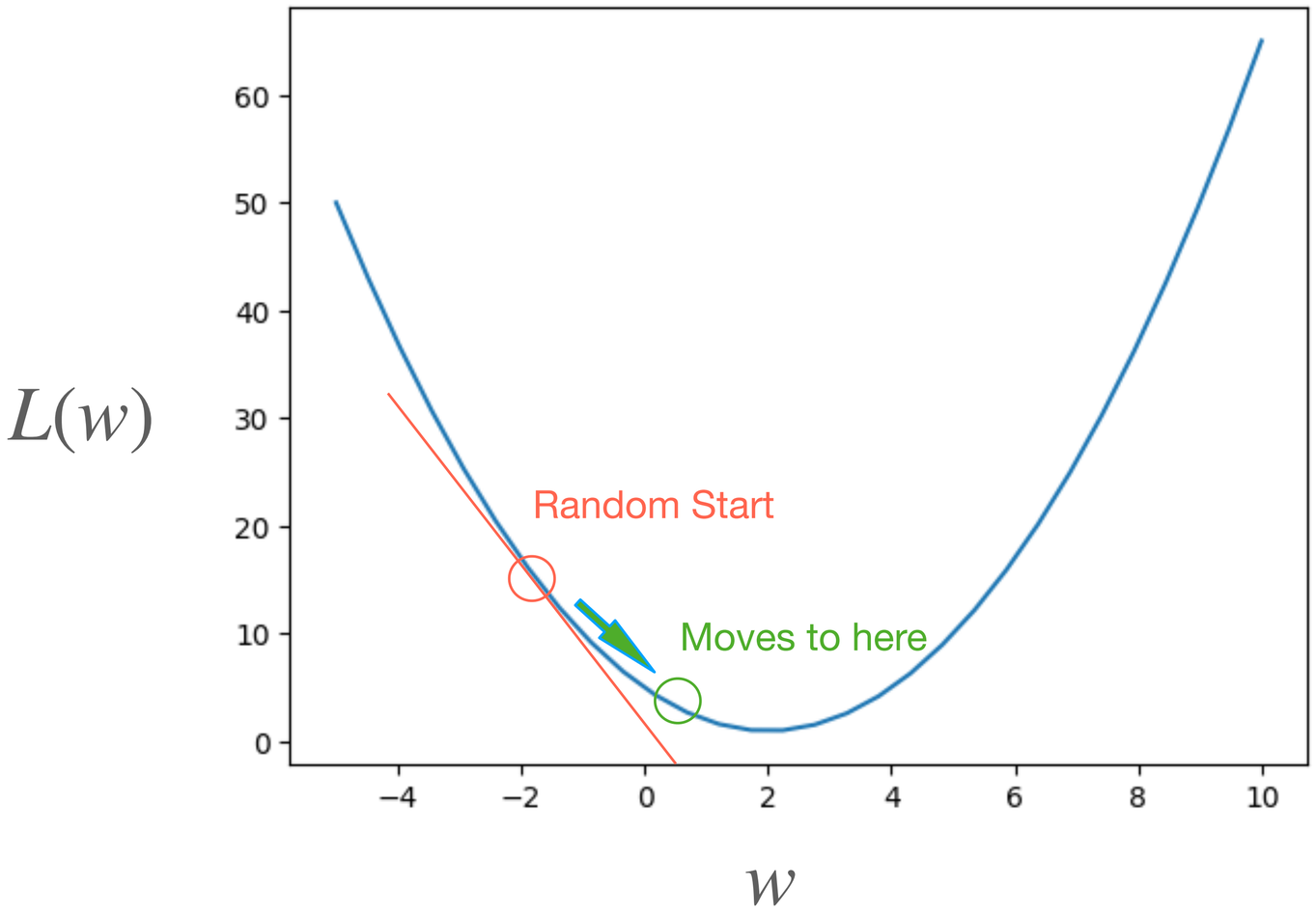
In mathematical language:
Find the direction where the loss will decrease
i.e. Slope < 0

$$Slope = \frac{L(w+h) - L(w)}{h}$$

$$\frac{dL}{dw} = \lim_{h \to 0} \frac{L(w+h) - L(w)}{h}$$

Gradient Descent

A Approach to lower the function value



learning rate

$$w_t = w_{t-1} - r \underbrace{\frac{dL}{dw_{t-1}}}$$

If < 0, this term will be < 0 and w increases
If > 0, this term will be > 0 and w decreases

The procedure continues until some given threshold

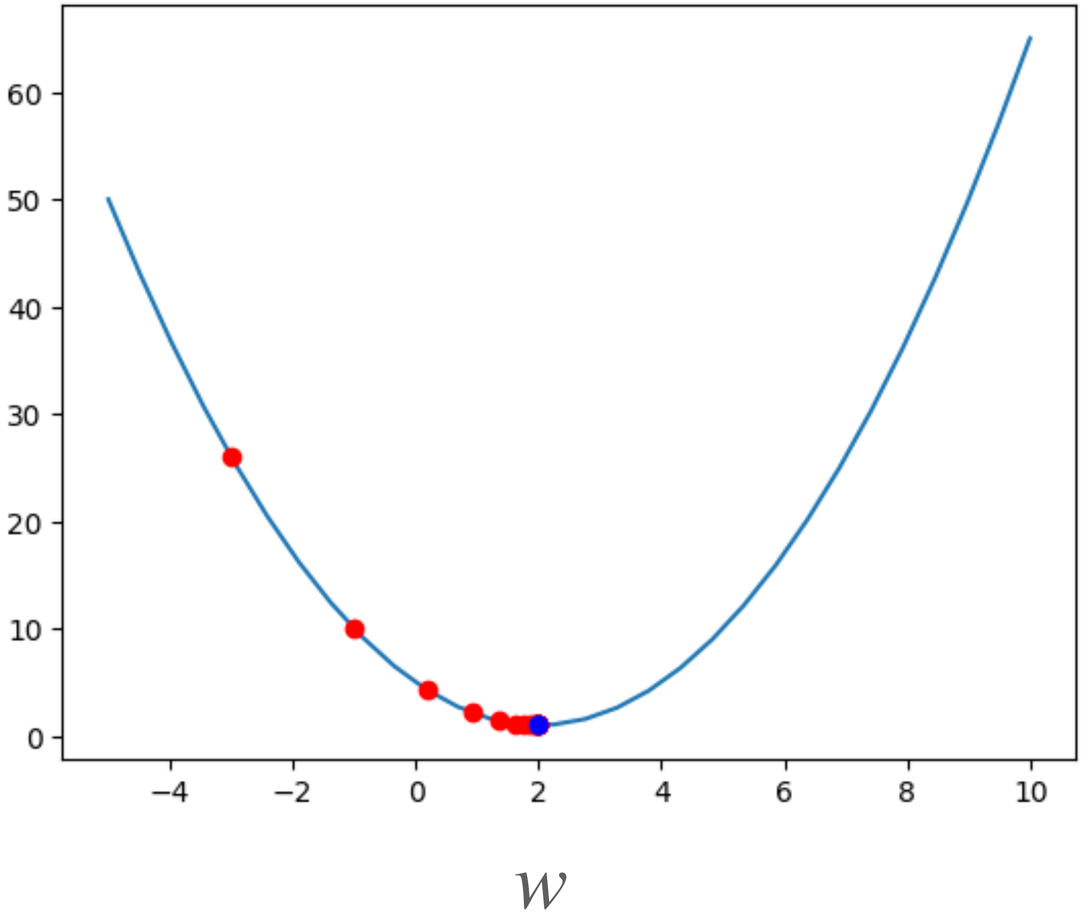
$$|L(w_t) - L(w_{t-1})| < \epsilon$$

or given update steps t

Gradient Descent

A Approach to lower the function value

$L(w)$



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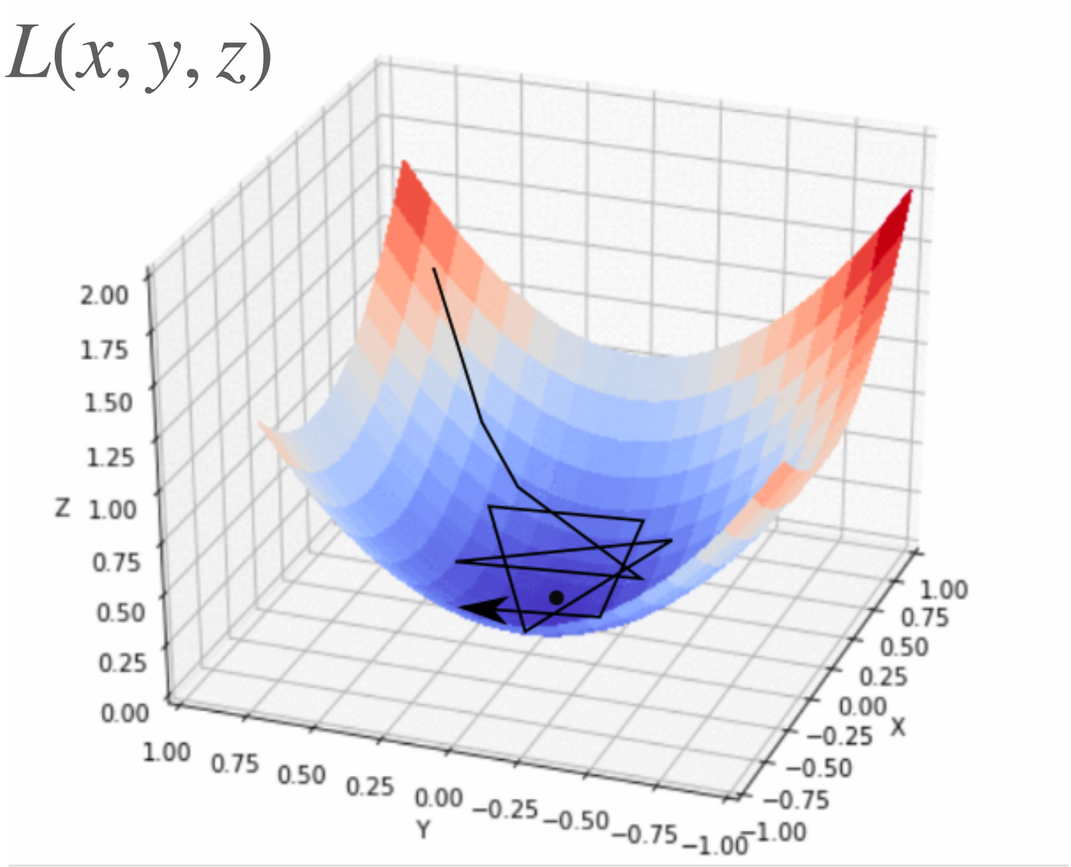
Gradient Descent

A High-Dimension Overview



https://blog.paperspace.com/intro-to-optimization-in-deep-learning-gradient-descent/

Update the three parameters at the same time!

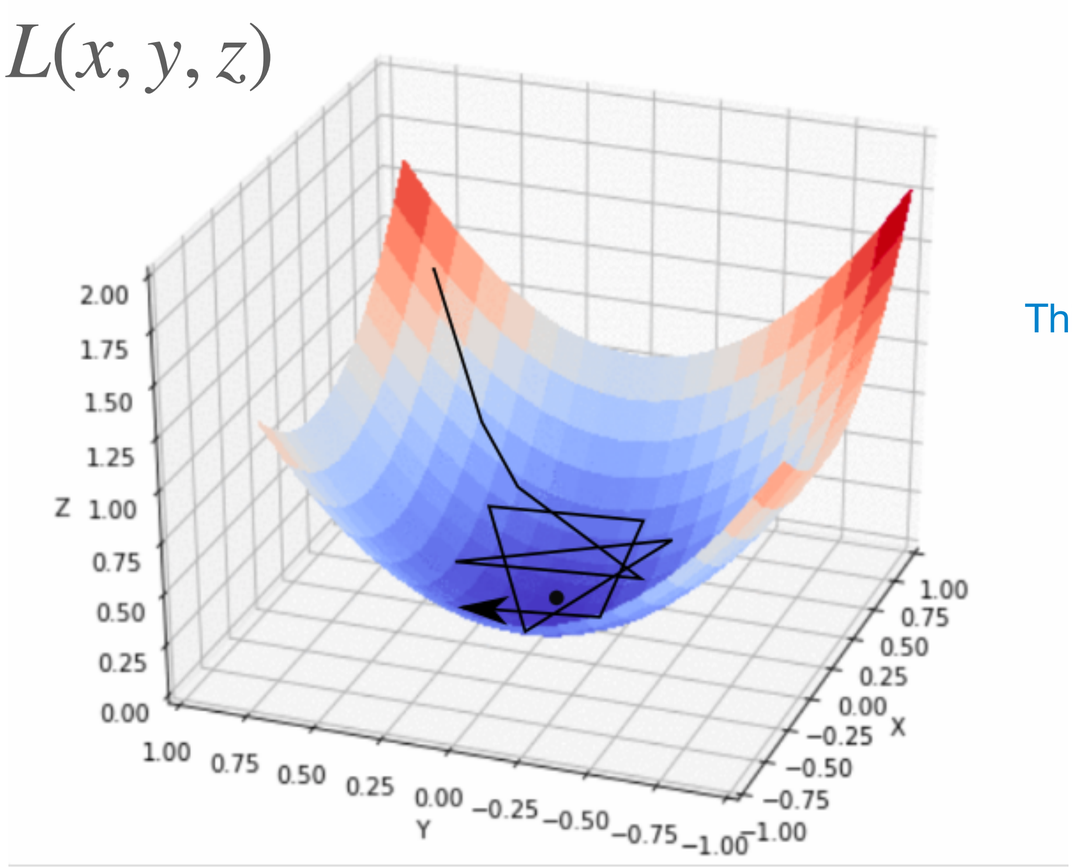
$$x_t = x_{t-1} - r\frac{\partial L(x, y, z)}{\partial x_{t-1}}$$

$$y_t = y_{t-1} - r\frac{\partial L(x, y, z)}{\partial y_{t-1}}$$

$$z_t = z_{t-1} - r\frac{\partial L(x, y, z)}{\partial z_{t-1}}$$

Gradient Descent

A High-Dimension Overview



https://blog.paperspace.com/intro-to-optimization-in-deep-learning-gradient-descent/

$$w = [x, y, z]$$

$$w_t = w_{t-1} - r\nabla L(x, y, z)$$

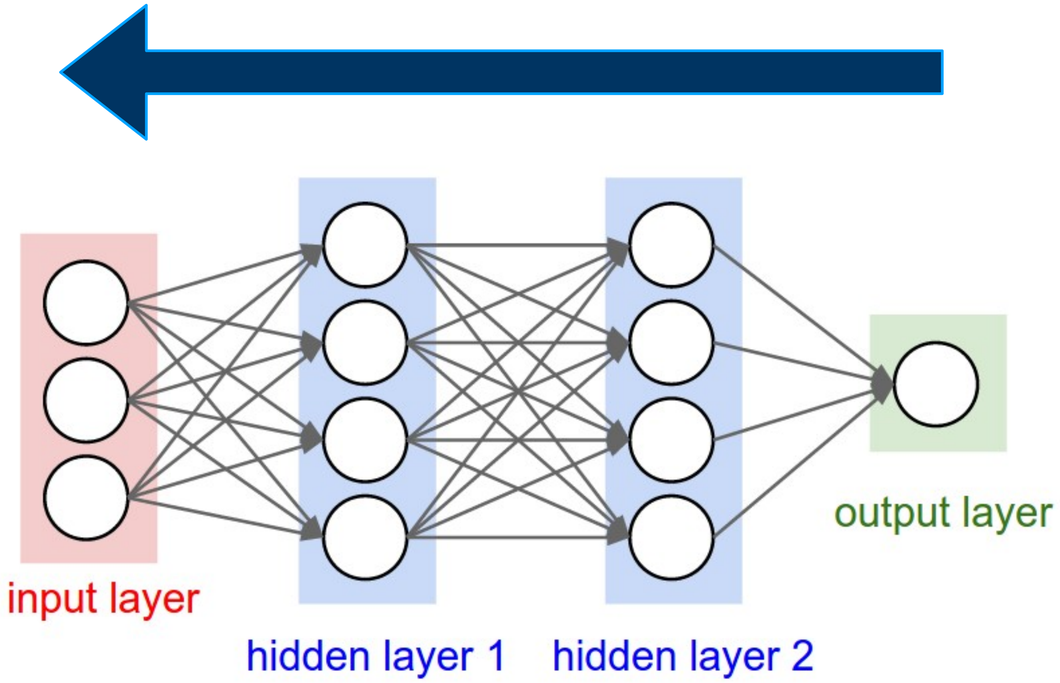
This is called gradient, which makes this method called **gradient descent**!

$$\begin{bmatrix} x_t \\ y_t \\ z_t \end{bmatrix} = \begin{bmatrix} x_{t-1} \\ y_{t-1} \\ z_{t-1} \end{bmatrix} - r \begin{bmatrix} \frac{\partial L}{\partial x_{t-1}} \\ \frac{\partial L}{\partial y_{t-1}} \\ \frac{\partial L}{\partial z_{t-1}} \end{bmatrix}$$

Backpropogation

A High-Dimension Overview

Use loss to update the weights in backward order



https://cs231n.github.io/convolutional-networks/

$$w = [x, y, z]$$

$$w_t = w_{t-1} - r \nabla L(x, y, z)$$

$$\begin{bmatrix} x_t \\ y_t \\ z_t \end{bmatrix} = \begin{bmatrix} x_{t-1} \\ y_{t-1} \\ z_{t-1} \end{bmatrix} - r \begin{bmatrix} \frac{\partial L}{\partial x_{t-1}} \\ \frac{\partial L}{\partial y_{t-1}} \\ \frac{\partial L}{\partial z_{t-1}} \end{bmatrix}$$

Let’s do this in Colab!

Demo

Bi-Gram Model

A Very Simple Language Model

- We only predict the next word based on the previous word.
- Model the predicted probability of a certain word based on a given word.

$$P(c_i \mid c_{i-1})$$

c_i is the word in the i position.

- Here we give an example of a sentence:

<s> AI could finally be introduced into practice in general tasks <e>

Bi-Gram Model

A Very Simple Language Model

<s> AI could finally be introduced into practice in general tasks <e>

c_{i-1} c_i

<s> AI

Bi-Gram Model

A Very Simple Language Model

<s> AI could finally be introduced into practice in general tasks <e>

c_{i-1} c_i

AI could

Bi-Gram Model

A Very Simple Language Model

<s> AI could finally be introduced into practice in general tasks <e>

c_{i-1} c_i

tasks <e>

Bi-Gram Model

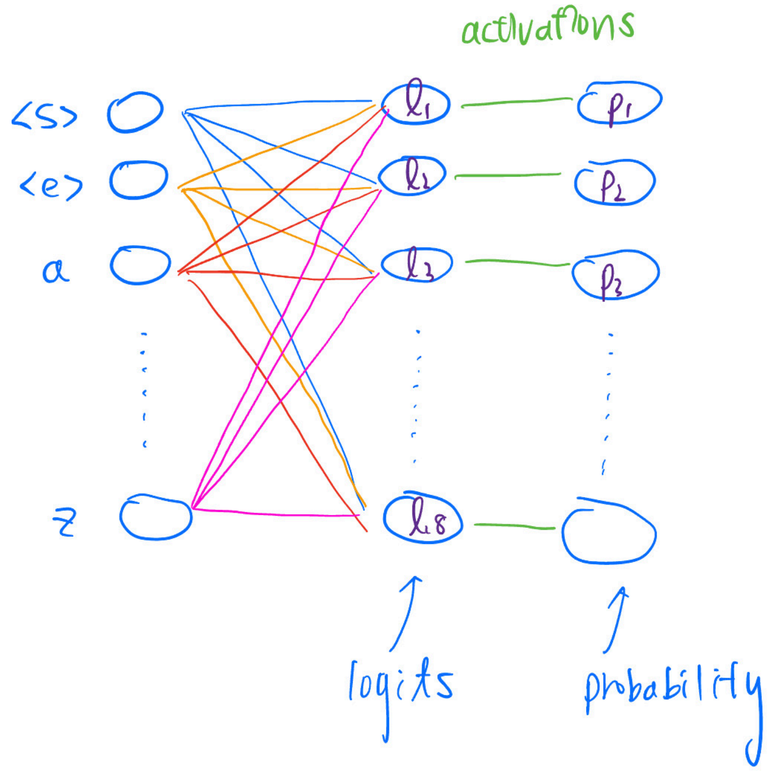
A Very Simple Language Model

We want to train the following neural network

One-hot Encoding

$$v_{<s>} = \begin{bmatrix} 1 \\ 0 \\ \vdots \\ 0 \end{bmatrix}$$

$$v_{<z>} = \begin{bmatrix} 0 \\ 0 \\ \vdots \\ 1 \end{bmatrix}$$



$$p_i = \frac{e^{l_i}}{\sum_{i=1}^{28} e^{l_i}}$$

Let’s also do this in Colab!

Questions

- What if having too large/small learning rate (r)?
- What if we cannot cover all the cases so that some conditional probability is zero?
- What if we also consider the penalty of the loss of predicting the class that does not contain the ground truth label?

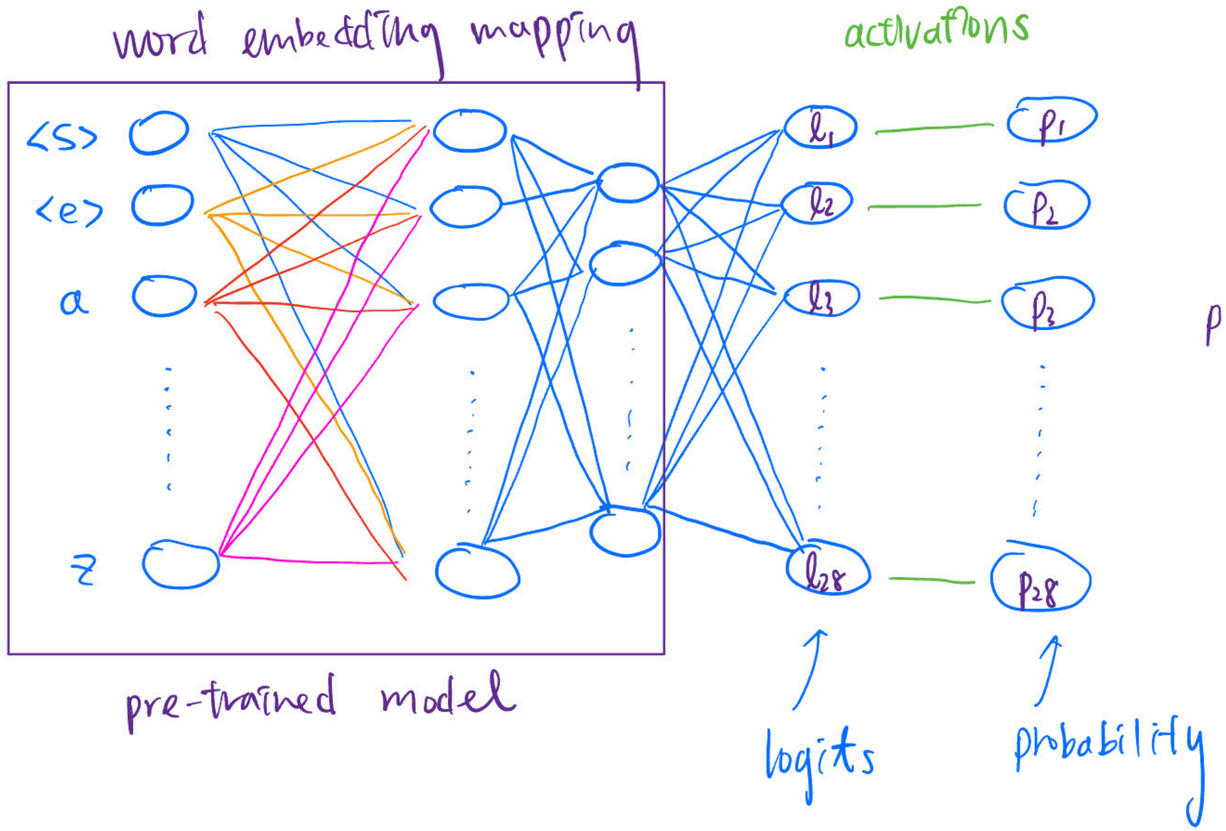
Wrap Up

What We Have Gone Through

- Applications in machine learning
- Training a machine learning model
- Gradient descent
- Bi-gram language model

What's Next

- Deep Neural Network
- Word Embedding
- Transfer Learning



Q & A