Lecture 2

Deep Neural Network

Seoul National University

Human Interface Laboratory

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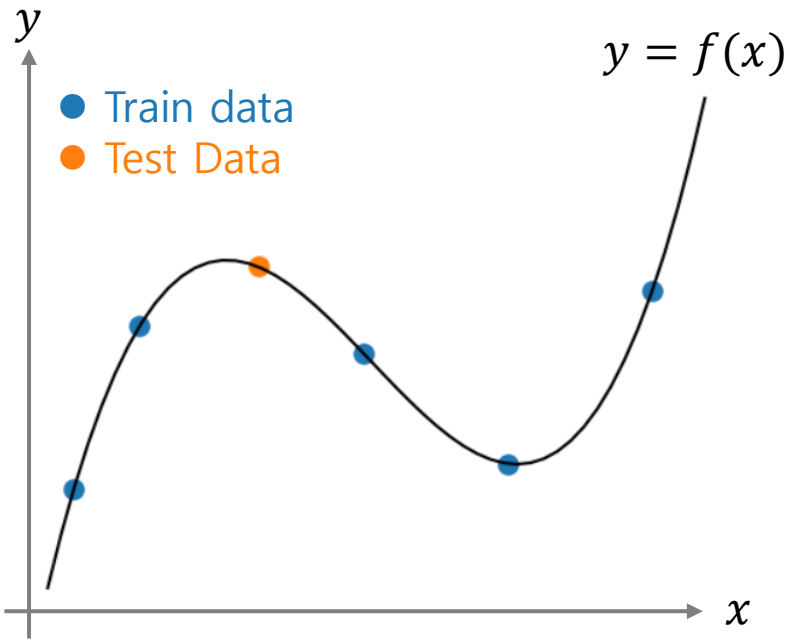
- **Perceptron**
- **Deep Neural Network**

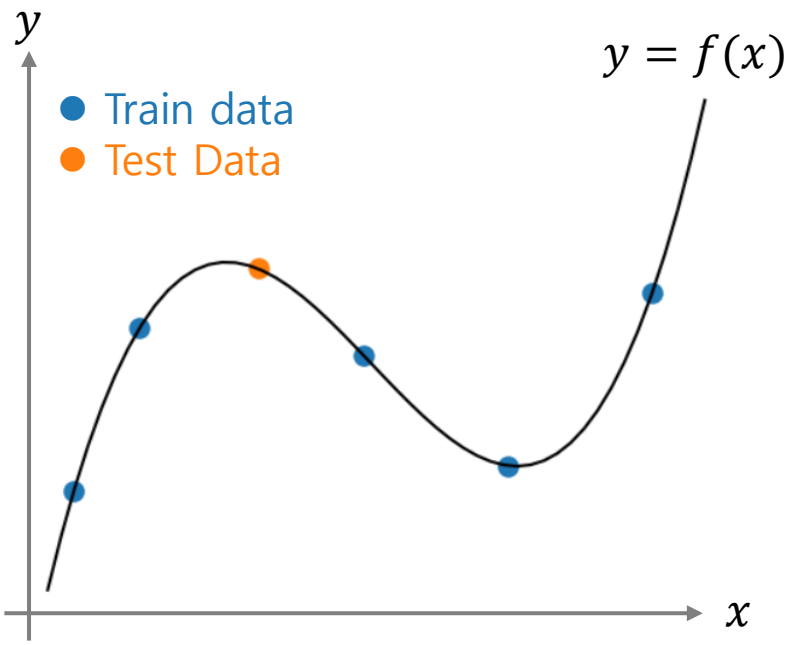
Neural Network is a Function Approximator



➥ Unknown function f를
N.N. (f_θ) 으로 approximate 하겠다!

- 매우 많은 $(x_i, y_i) \in TrainData$가 주어질 때, $y_i \approx f_\theta(x_i)$ 가 되도록 Neural Network f_θ를 학습하겠다
- [희망 사항] 학습때 쓰이지 않은 $(x_i, y_i) \in TestData$ 에 대해서도 $y_i \approx f_\theta(x_i)$ 가 될 것이다!

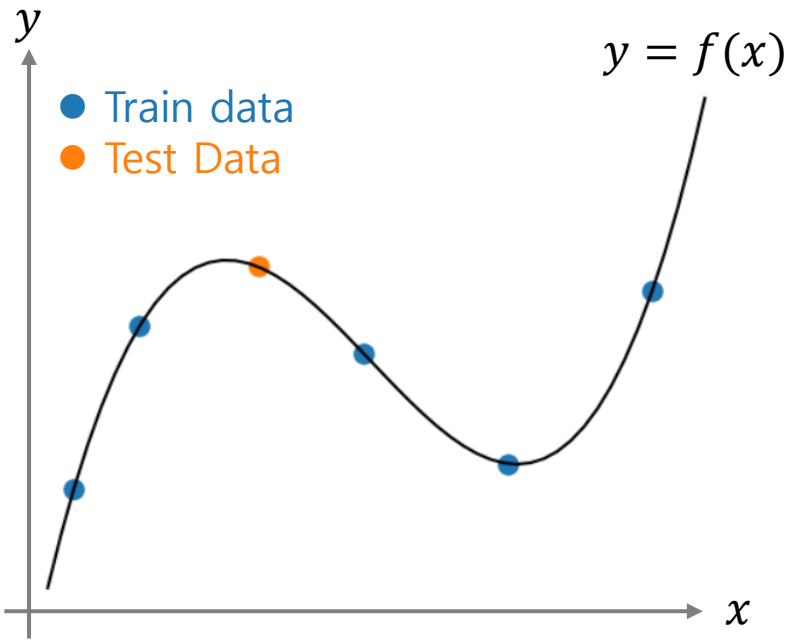
Neural Network is a Function Approximator



↳ Unknown function f를
N.N. (f_θ) 으로 approximate 하겠다!

f (함수)	x (입력)	y (출력)
$f(x) = x^3$	1.1	1.331
	-0.3	-0.027
And Gate	(1, 1)	1
	(1, 0)	0
Image Classifier		*"강아지"*
Language Model (ex. ChatGPT)	*"안녕하세"*	*"요"*
	"Question"	*"Answer"*

Neural Network is a Function Approximator



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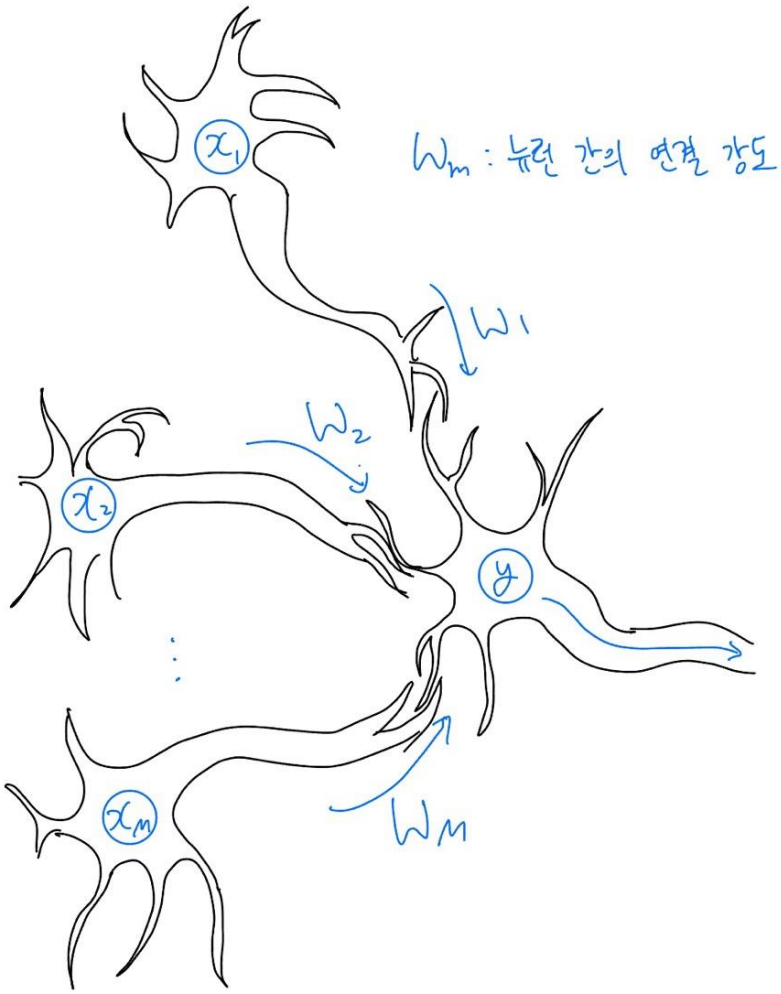
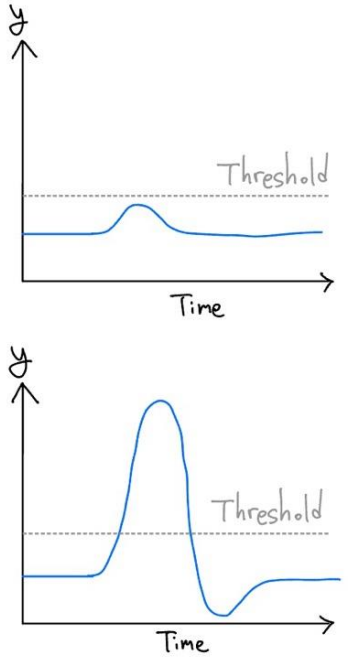
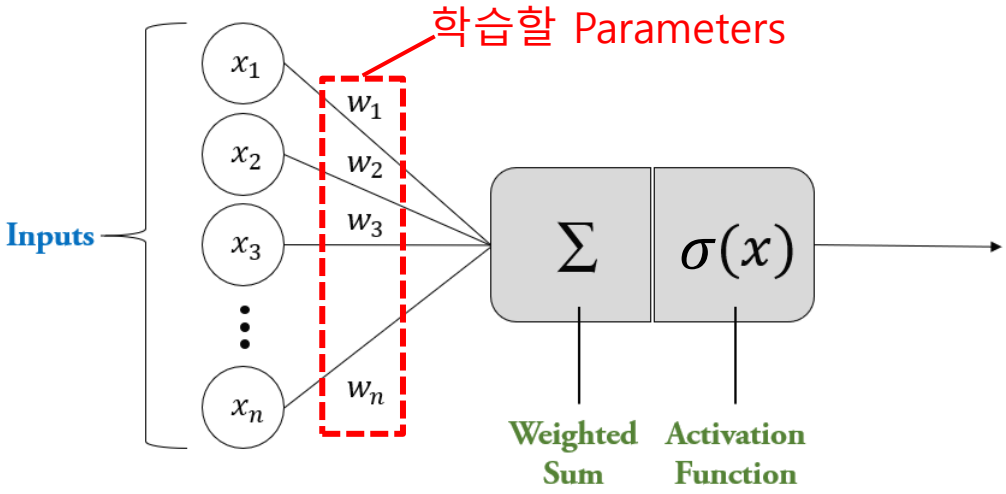
Motivation (Synapse & Neuron)



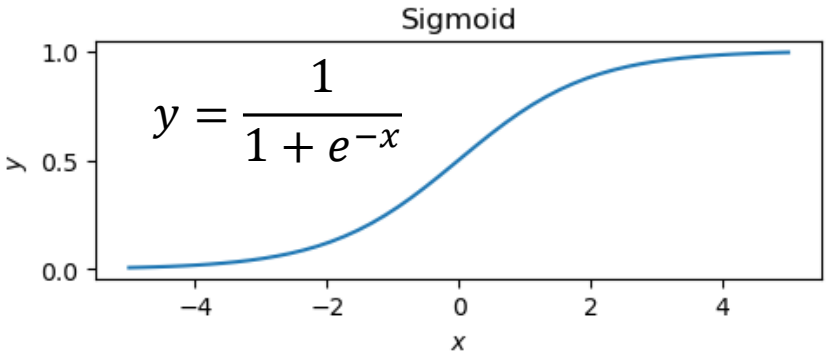


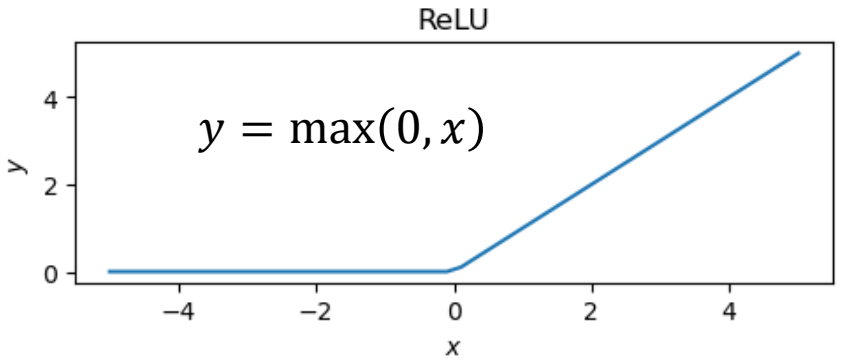
Perceptron



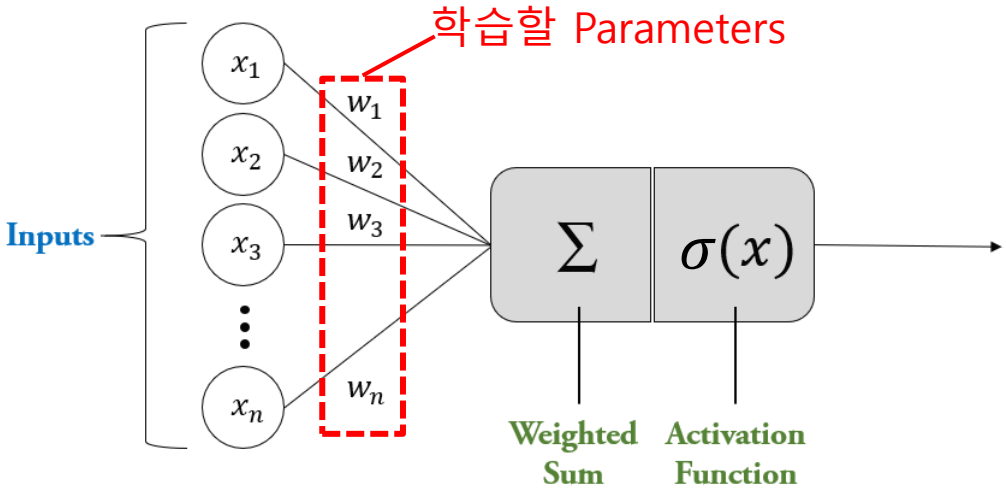
$$y = \sigma\left(\sum_n x_n \cdot w_n + b\right)$$

- $\sigma(\cdot)$: Activation function (비선형 함수)





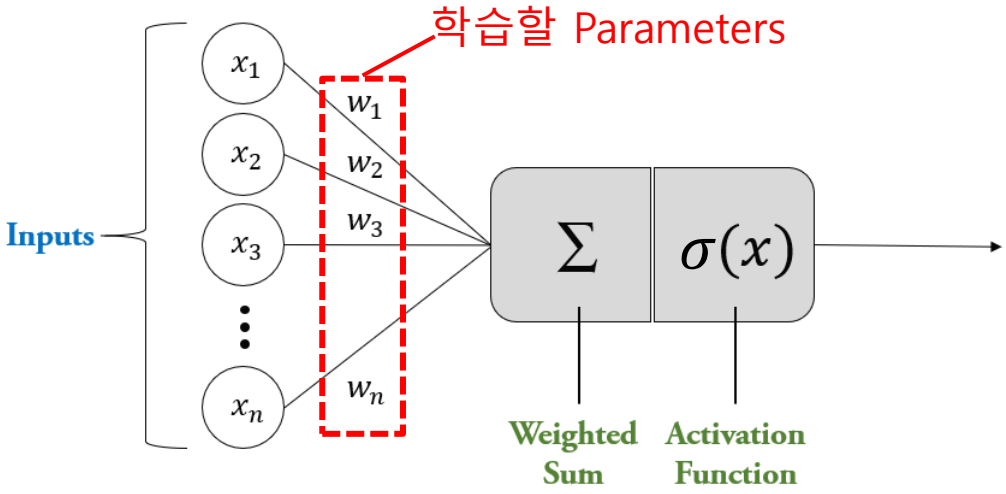
Perceptron 실습 (AND Gate)



$$y = \sigma\left(\sum_n x_n \cdot w_n + b\right)$$

- Lab2-1. PyTorch Tensor
- Lab2-2. Perceptron (AND Gate)

Perceptron 학습

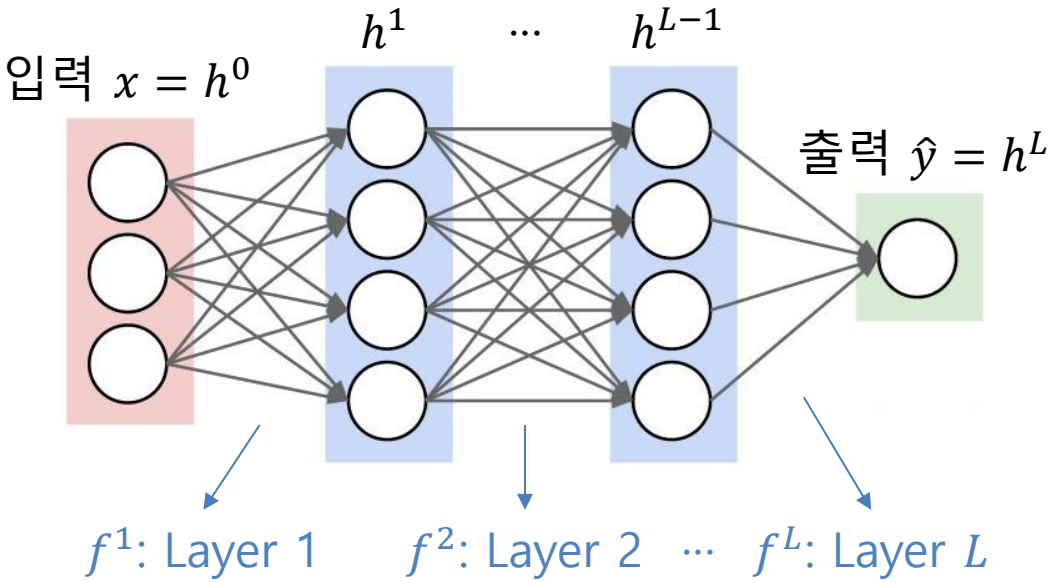


$$y = \sigma\left(\sum_n x_n \cdot w_n + b\right)$$

1. Parameter $\theta = [w, b]$ 를 random한 값으로 초기화
2. $(x_i, y_i) \in TrainData$ 에 대해 $y_i \approx f_\theta(x_i)$ 되도록 모델의 parameter θ를 학습

➢ [한계] 매우 간단한 함수 (ex. AND gate)만 approximate 가능. 조금만 복잡해져도 (ex. XOR gate) approximate 불가능.

Deep Neural Network



- Deep Neural Network (DNN)는 여러 Layer들로 이루어져 있음

$$\hat{y} = f(x) = f^L\left(f^{L-1}\left(\cdots f^1(x)\right)\right)$$

- Layer 종류: Fully Connected Layer, Convolutional Layer, Recurrent Layer, Transformer, …

Neural Network 학습 알고리즘

1. $\hat{y} = f_\theta(x)$: Forward Propagation
2. $Loss = \mathcal{L}(\hat{y}, y)$: 정답과의 차이 계산

   Ex) Mean squared error (MSE) loss = $\frac{1}{B}\sum_{i=1}^{B}(y_i - \hat{y}_i)^2$
3. $\frac{\partial \mathcal{L}}{\partial \theta}$ 계산 : Backpropagation
4. $\theta \leftarrow \theta - \eta \cdot \frac{\partial \mathcal{L}}{\partial \theta}$: Gradient descent

   Learning rate, 충분히 작은 상수 (ex. 0.001)

위 1~4를 계속 반복하면 Loss가 줄어든다

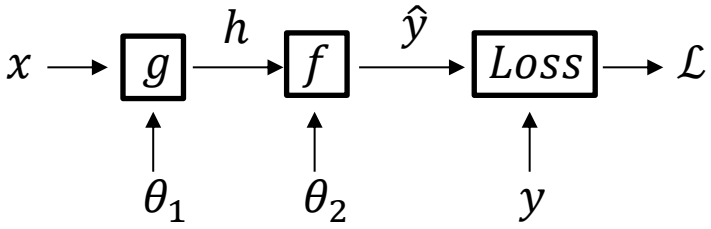
- $(x_i, y_i) \in TrainData$ 에 대해 $y_i \approx f_\theta(x_i)$ 가 된다
- $(x_i, y_i) \in TestData$ 에 대해서도 $y_i \approx f_\theta(x_i)$ 가 되길 희망

Chain Rule

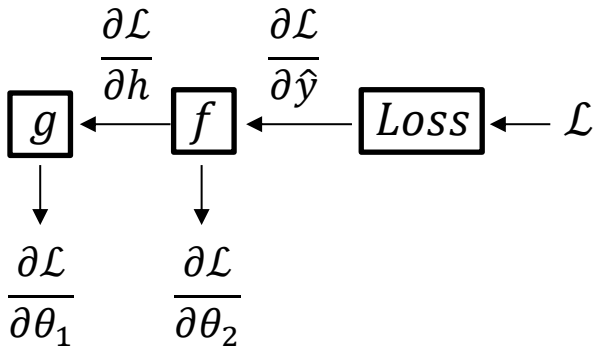
- $y = g\big(f(x)\big)$
- $y' = g'\big(f(x)\big) \cdot f'(x)$
- $\Leftrightarrow \frac{\partial y}{\partial x} = \frac{\partial g}{\partial f} \cdot \frac{\partial f}{\partial x}$

Backpropagation Using Chain Rule

- $h = g_{\theta_1}(x)$
- $\hat{y} = f_{\theta_2}(h)$
- $\mathcal{L} = Loss(\hat{y}, y)$



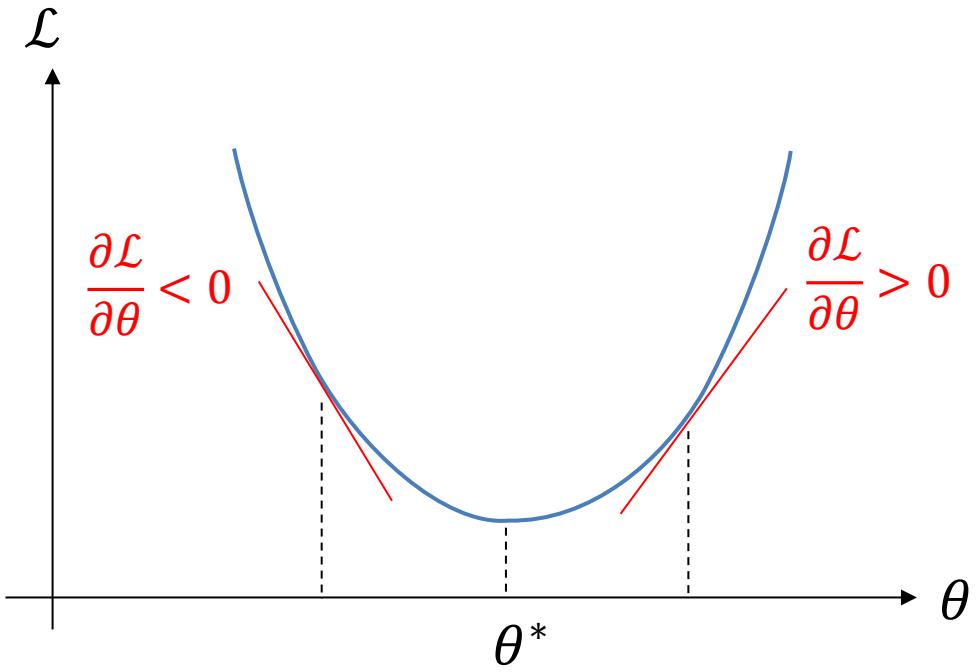
- $\frac{\partial \mathcal{L}}{\partial \theta_2} = \frac{\partial \mathcal{L}}{\partial \hat{y}} \cdot \frac{\partial \hat{y}}{\partial \theta_2}$
- $\frac{\partial \mathcal{L}}{\partial \theta_1} = \frac{\partial \mathcal{L}}{\partial \hat{y}} \cdot \frac{\partial \hat{y}}{\partial h} \cdot \frac{\partial h}{\partial \theta_1}$



Gradient Descent

$$\theta \leftarrow \theta - \eta \cdot \frac{\partial \mathcal{L}}{\partial \theta}$$

Learning rate, 충분히 작은 상수 (ex. 0.001)



Neural Network 학습을 위한 준비물

- **Data**
  - 학습을 위한 $(x_i, y_i) \in TrainData$
  - 검증을 위한 $(x_i, y_i) \in TestData$
- **Model**
  - Fully Connected Layer, Convolutional Layer, Recurrent Layer, Transformer, …
- **Training Algorithm**
  - Loss
  - Backpropagation
  - Optimizer (ex. Gradient descent)

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Neural Network 실습 (Regression)

- Lab2-3 ~ 2-5. Training a Perceptron (AND Gate)
- Lab2.6 Deep Neural Network (Regression)