NYCU DLP
Lab1 - Backpropagation

2021 Summer

李美慧

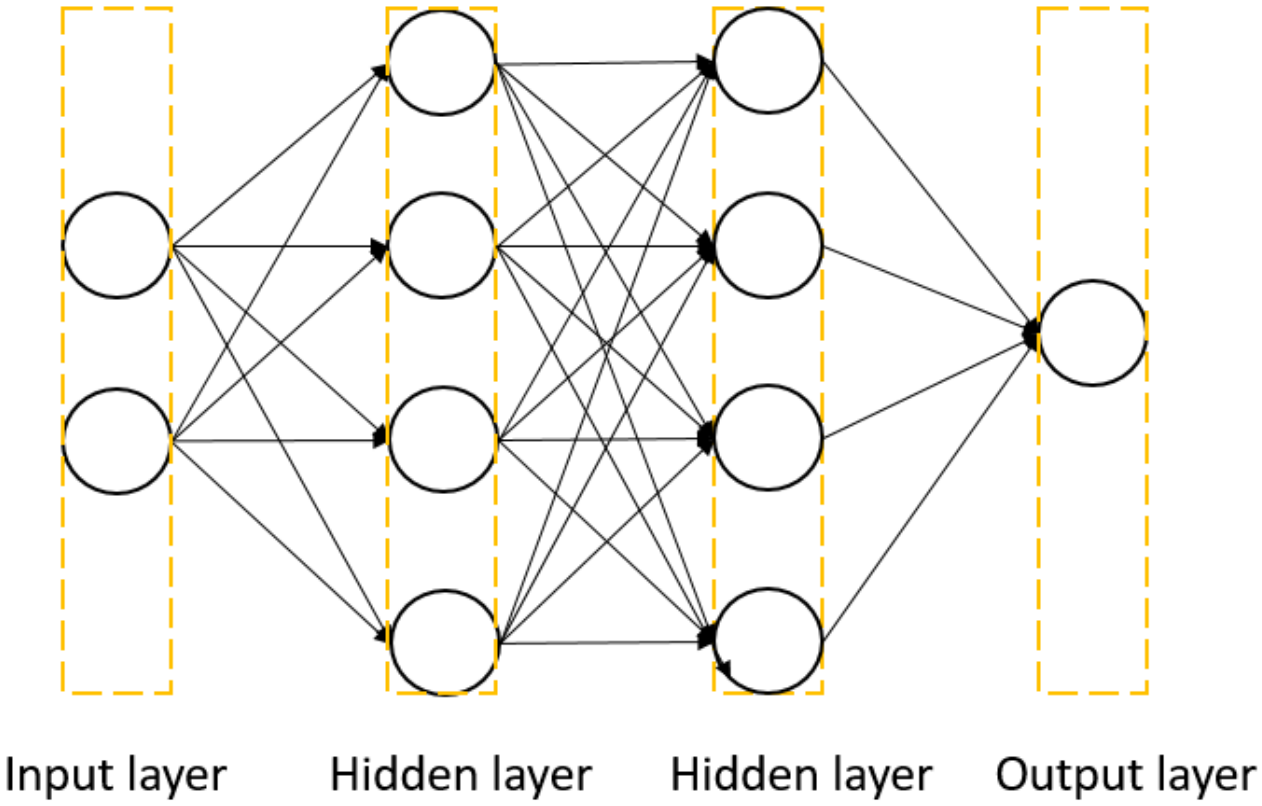
July 13, 2021

Outline

- Lab Objective
- Important Date
- Lab Description
- Scoring Criteria

Lab Objective

- In this lab, you will need to understand and implement a simple neural network with forward and backward pass using two hidden layers



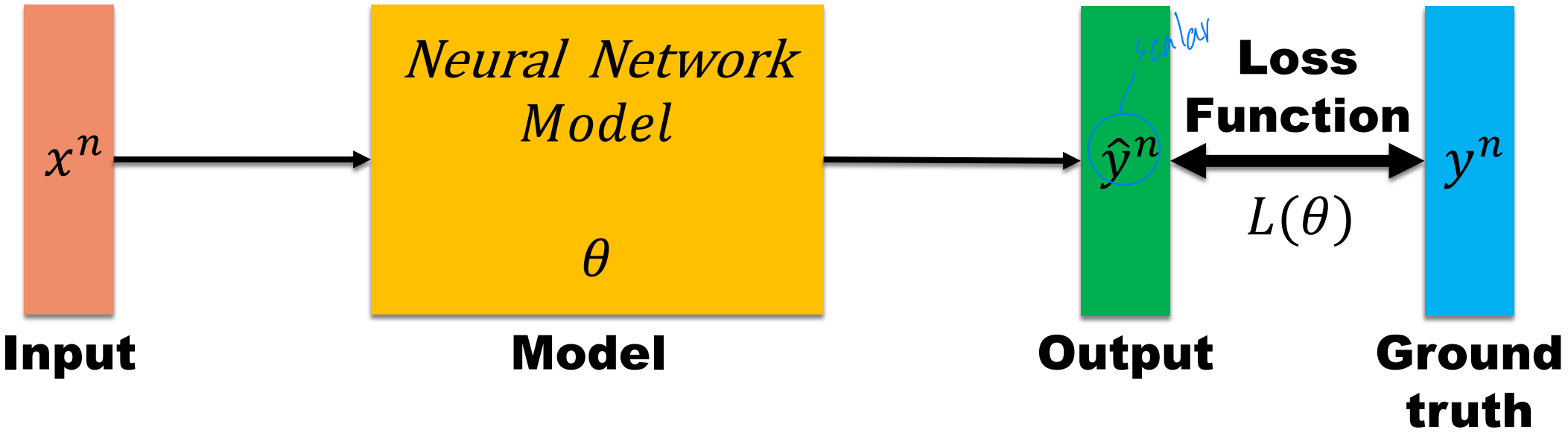
Important Date

- Report Submission Deadline: 7/20 (Tue.) 12:00 p.m. 是中午12點，不是半夜12點!!!
- Demo date: 7/20 (Tue.)
- Zip all files into one file
  - Report (.pdf)
  - Source code
- Name it like「DLP_LAB1_yourstudentID_name.zip」
  - ex:「DLP_LAB1_309551027_李美慧.zip」

Lab Description

- Implement a simple neural network with two hidden layers
- You can only use Numpy and other python standard libraries.
- Plot your comparison figure showing the predictions and ground truth.
- Plot your learning curve (loss, epoch).
- Print the accuracy of your predictions.

Lab Description



$$\theta = \{w_1, w_2, w_3, w_4, \cdots\}$$

$$\boldsymbol{\nabla L(\theta)} = \begin{bmatrix} \partial L(\theta)/\partial w_1 \\ \partial L(\theta)/\partial w_2 \\ \partial L(\theta)/\partial w_3 \\ \vdots \\ \vdots \end{bmatrix}$$

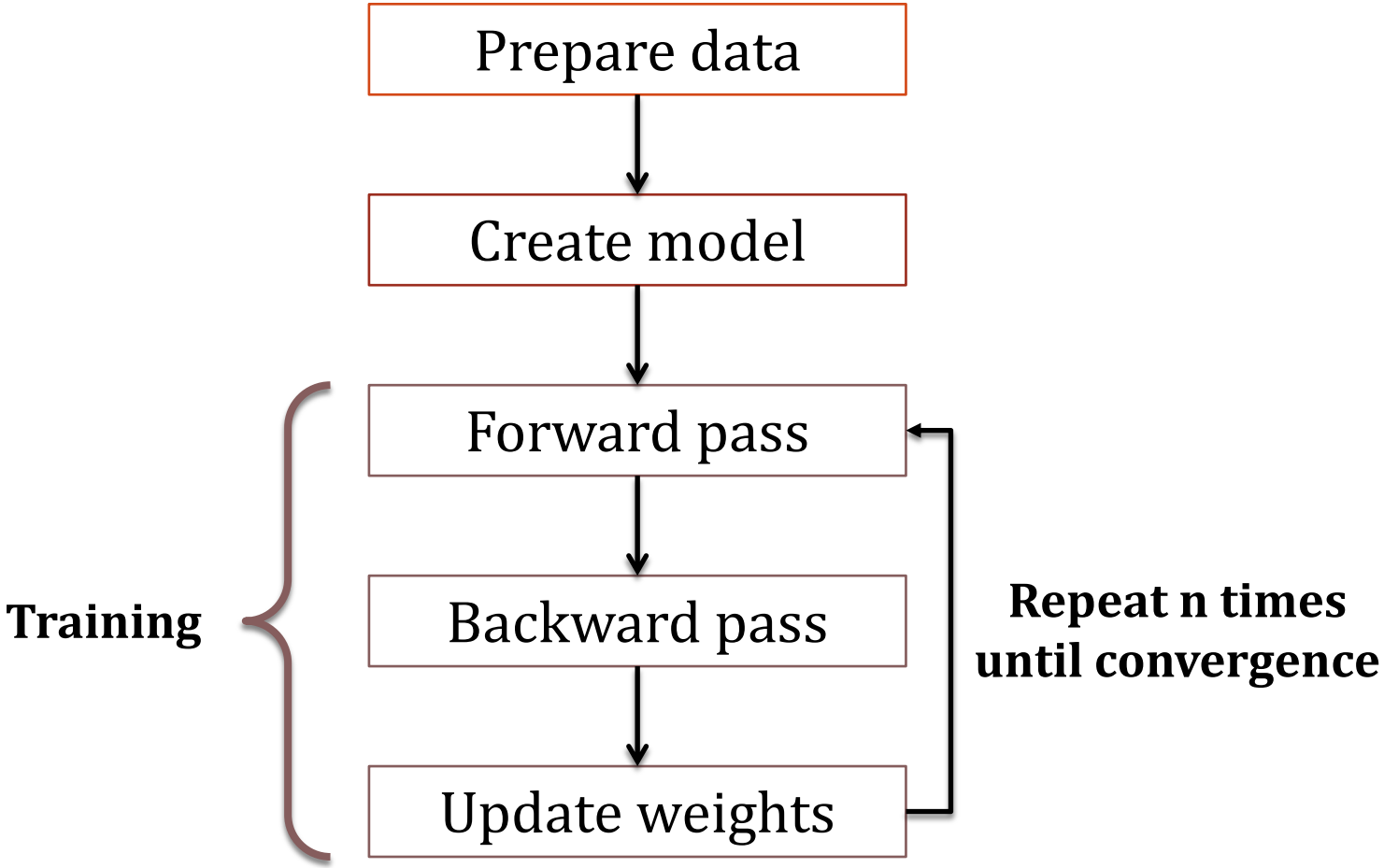
Compute $\nabla L(\theta^0)$ $\quad \theta^1 = \theta^0 - \rho\, \nabla L(\theta^0)$

Compute $\nabla L(\theta^1)$ $\quad \theta^2 = \theta^1 - \rho\, \nabla L(\theta^1)$

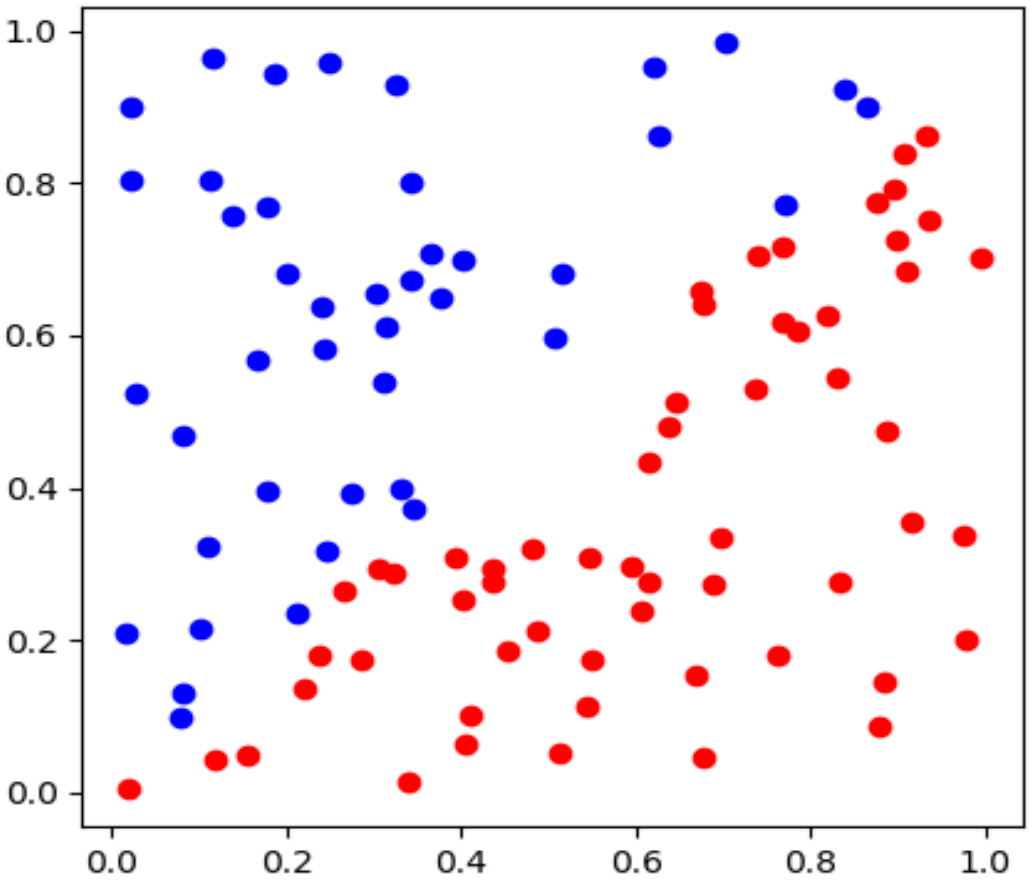
Compute $\nabla L(\theta^2)$ $\quad \theta^3 = \theta^2 - \rho\, \nabla L(\theta^2)$

ρ : Learning rate

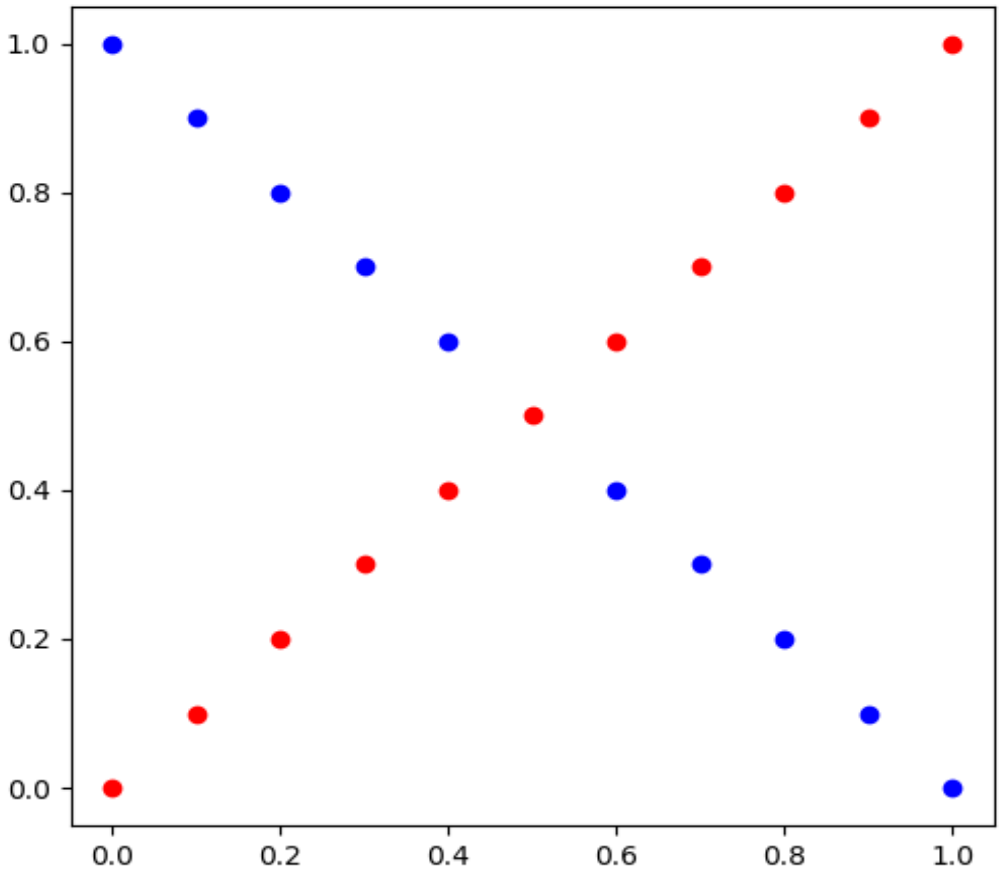
Lab Description – Flowchart



Lab Description - Data

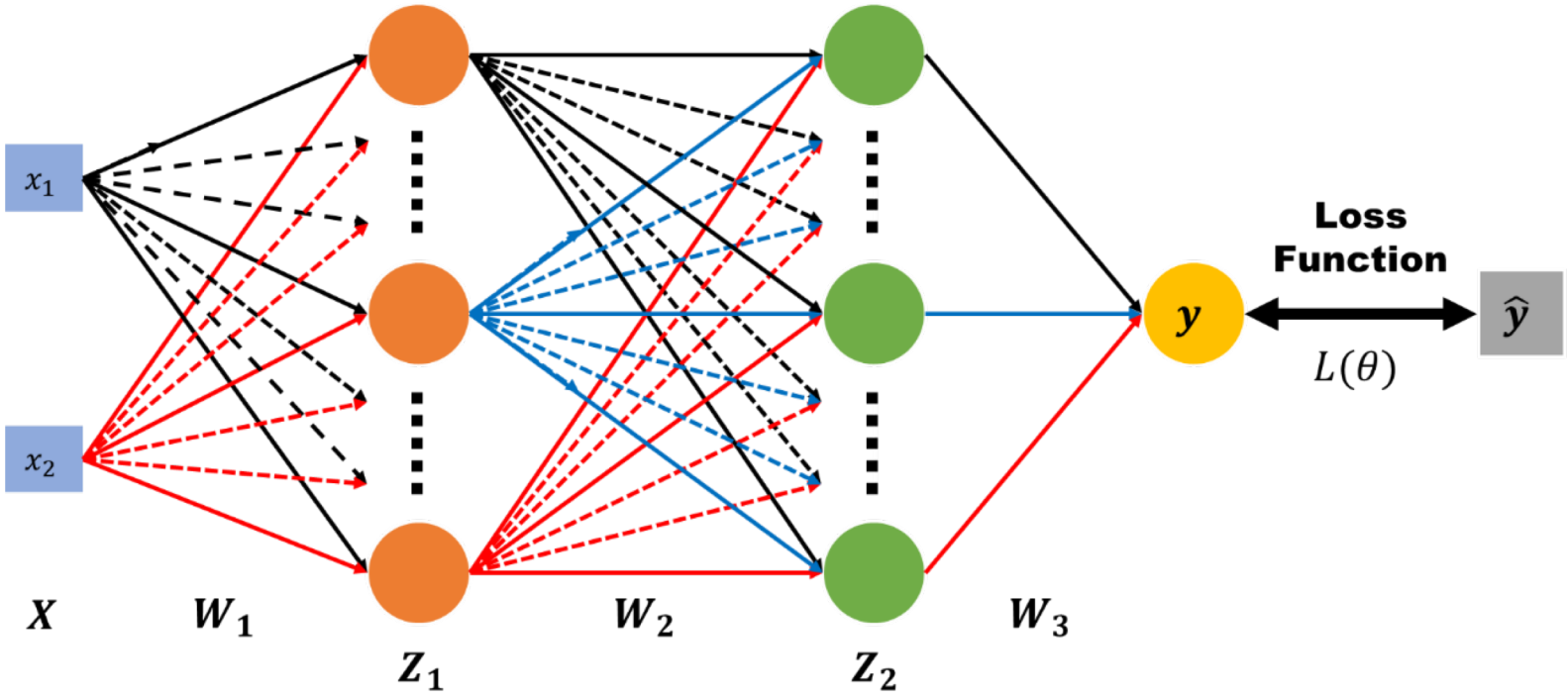


Linear



XOR

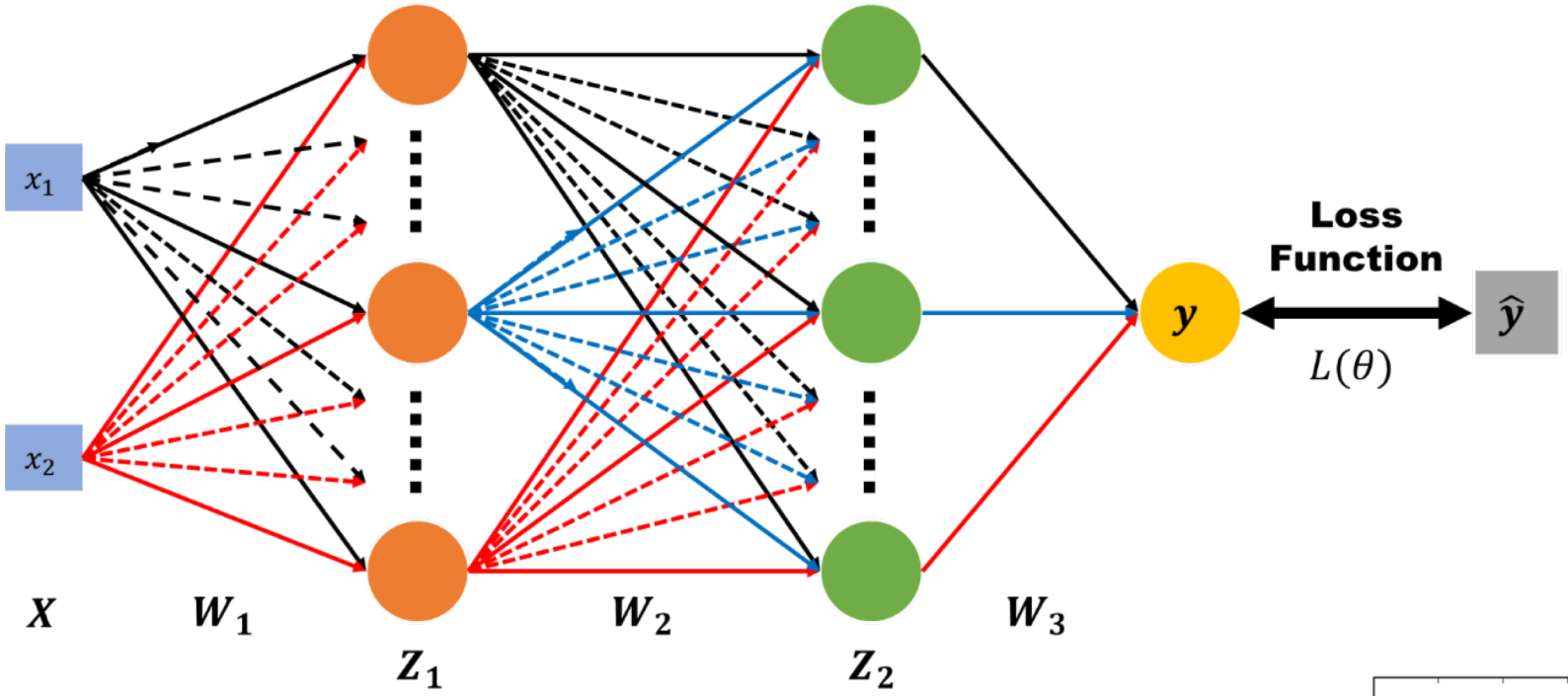
Lab Description – Architecture



X : $[x_1, x_2]$ $\quad$ y : *output* $\quad$ $\hat{y}$: *ground truth*

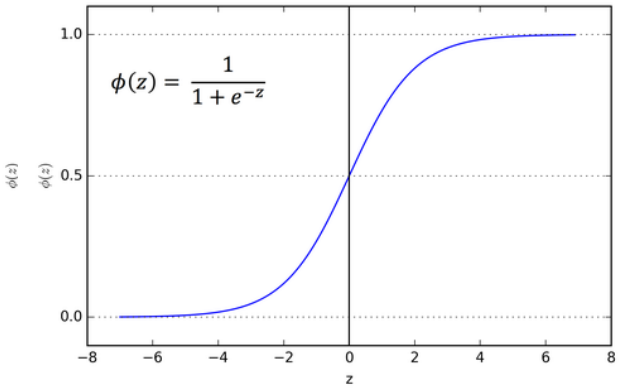
W_1, W_2, W_3 : *weight matrix of network layers*

Lab Description – Forward

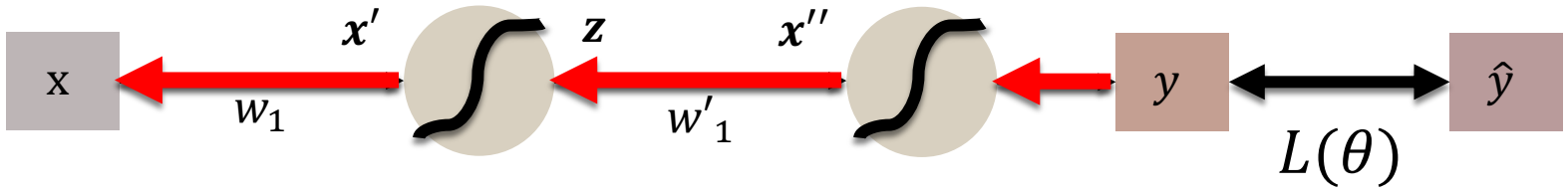


$$Z_1 = \sigma(XW_1) \qquad Z_2 = \sigma(Z_1W_2) \qquad y = \sigma(Z_2W_3)$$

$$\sigma(\mathrm{x}) = \frac{1}{1+e^{-x}}$$



Lab Description – Backward



$\boldsymbol{x' = xw_1}$ $\quad$ $\boldsymbol{z = \sigma(x')}$ $\quad$ $\boldsymbol{x'' = zw'_1}$ $\quad$ $\boldsymbol{y = \sigma(x'')}$

Chain rule

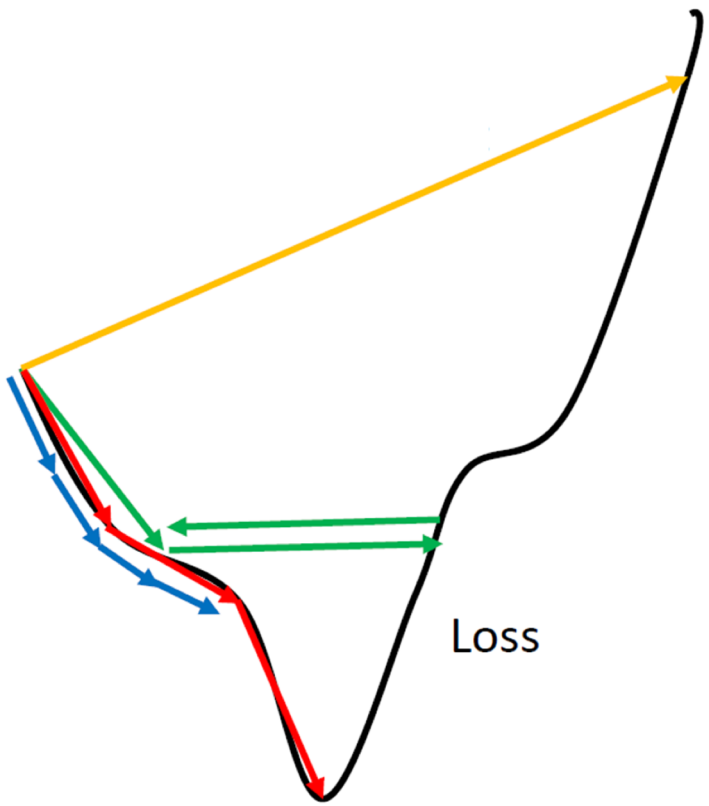
$$y = g(x) \qquad z = h(y)$$

$$\mathbf{x} \xrightarrow{\mathbf{g}()} \boldsymbol{y} \xrightarrow{\boldsymbol{h}()} \boldsymbol{z} \qquad \frac{dz}{dx} = \frac{dz}{\cancel{dy}}\frac{\cancel{dy}}{dx}$$

$$\begin{aligned}
\frac{\partial L(\theta)}{\partial w_1} &= \frac{\partial y}{\partial w_1}\frac{\partial L(\theta)}{\partial y} \\
&= \frac{\partial x''}{\partial w_1}\frac{\partial y}{\partial x''}\frac{\partial L(\theta)}{\partial y} \\
&= \frac{\partial z}{\partial w_1}\frac{\partial x''}{\partial z}\frac{\partial y}{\partial x''}\frac{\partial L(\theta)}{\partial y} \\
&= \frac{\partial x'}{\partial w_1}\frac{\partial z}{\partial x'}\frac{\partial x''}{\partial z}\frac{\partial y}{\partial x''}\frac{\partial L(\theta)}{\partial y}
\end{aligned}$$

Lab Description – Gradient descent

Network Parameters $\theta = \{w_1, w_2, w_3, w_4, \cdots\}$

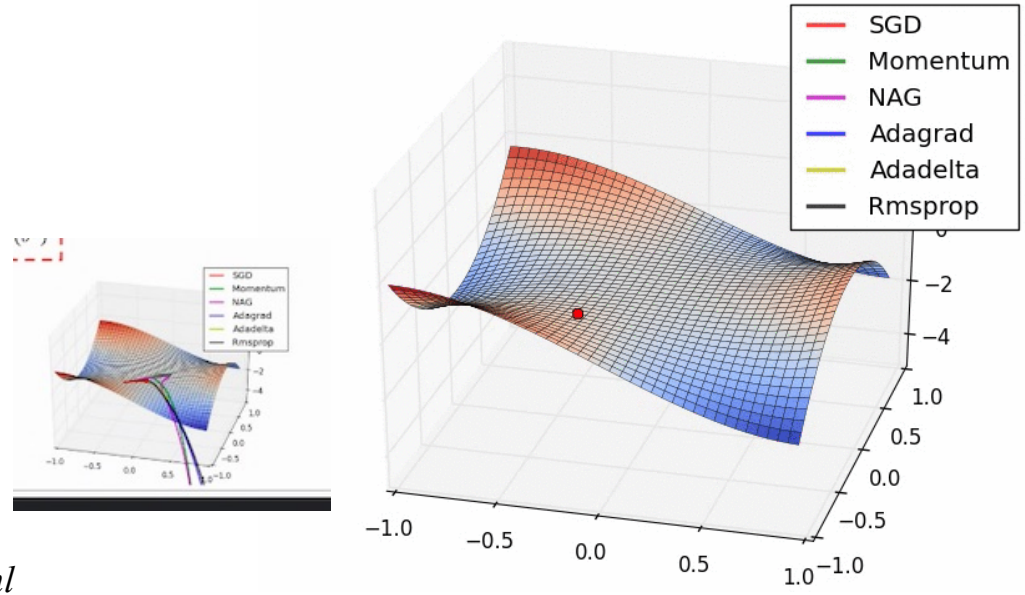


$$\theta^1 = \theta^0 - \rho\,\nabla L(\theta^0)$$

$$\theta^2 = \theta^1 - \rho\,\nabla L(\theta^1)$$

$$\theta^3 = \theta^2 - \rho\,\nabla L(\theta^2)$$

ρ : Learning rate



http://www.denizyuret.com/2015/03/alec-radfords-animations-for.html

Lab Description - Prediction

- In the training, you need to print loss

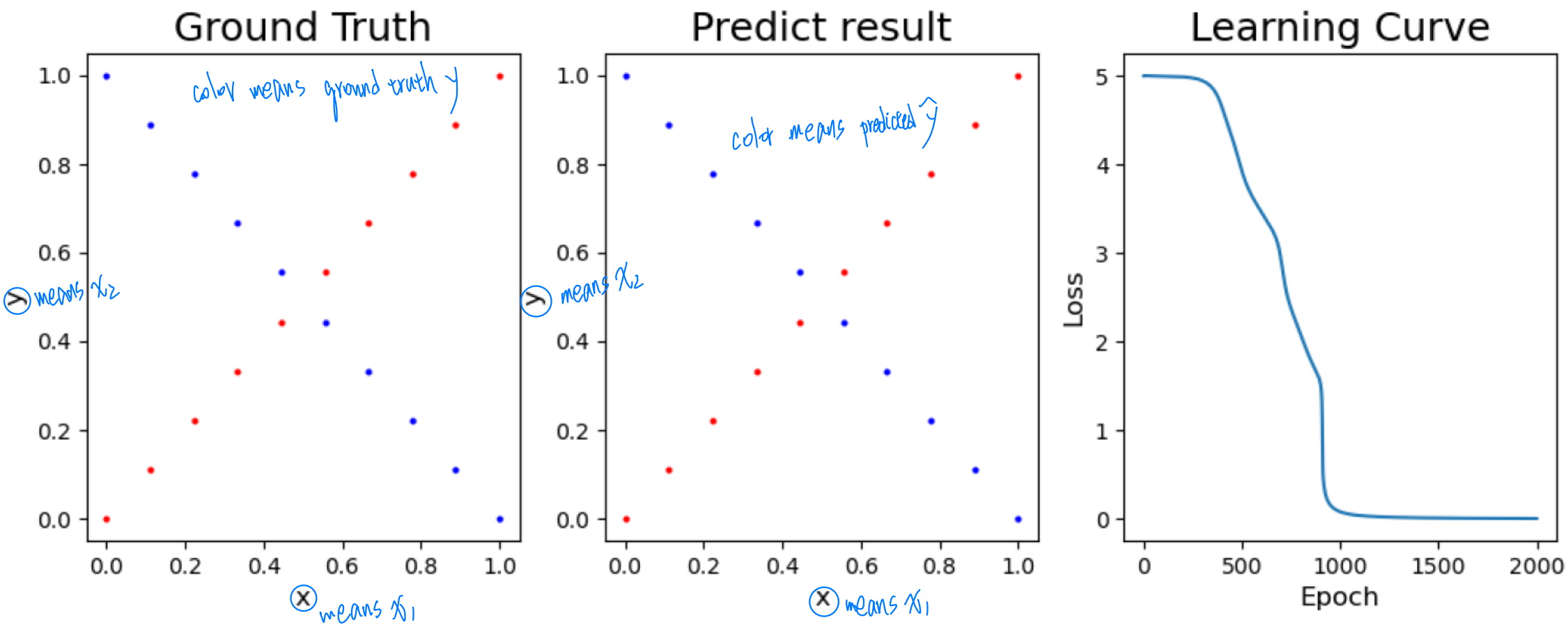
```
epoch 10000 loss : 0.16234523253277644
epoch 15000 loss : 0.2524336634177614
epoch 20000 loss : 0.1590783047540092
epoch 25000 loss : 0.22099447030234853
epoch 30000 loss : 0.3292173477217561
epoch 35000 loss : 0.40406233282426085
epoch 40000 loss : 0.43052897480298924
epoch 45000 loss : 0.4207525735586605
epoch 50000 loss : 0.3934759509342479
epoch 55000 loss : 0.3615008372106921
epoch 60000 loss : 0.33077879872648525
epoch 65000 loss : 0.30333537090819584
epoch 70000 loss : 0.2794858089741792
epoch 75000 loss : 0.25892812312991587
epoch 80000 loss : 0.24119780823897027
epoch 85000 loss : 0.22583656353511342
epoch 90000 loss : 0.21244497028971704
epoch 95000 loss : 0.2006912468389013
```

- In the testing, you need to show your predictions, also the accuracy

```
[[0.01025062]
 [0.99730607]
 [0.02141321]
 [0.99722154]
 [0.03578171]
 [0.99701922]
 [0.04397049]
 [0.99574117]
 [0.04162245]
 [0.92902792]
 [0.03348791]
 [0.02511045]
 [0.94093942]
 [0.01870069]
 [0.99622948]
 [0.01431959]
 [0.99434455]
 [0.01143039]
 [0.98992477]
 [0.00952752]
 [0.98385905]]
```

Lab Description - Prediction

- Visualize ground truth, your predictions, and learning curve



Scoring Criteria

- Report (40%)
- Demo (60%)
  - Experimental results (40%)
  - Questions (20%)
- Late report or demo
  - Before 8/31

Supplementary Materials

Optimizers

- SGD – minibatch
- Momentum
- AdaGrad
- Adam

Momentum

$$V_t \leftarrow \beta V_{t-1} - \eta \frac{\partial L}{\partial W}$$

$$W \leftarrow W + V_t$$

AdaGrad

$$W \leftarrow W - \eta \frac{1}{\sqrt{n+\epsilon}} \frac{\partial L}{\partial W}$$

$$n = \sum_{r=1}^{t} \left(\frac{\partial L_r}{\partial W_r}\right)^2$$

Adam

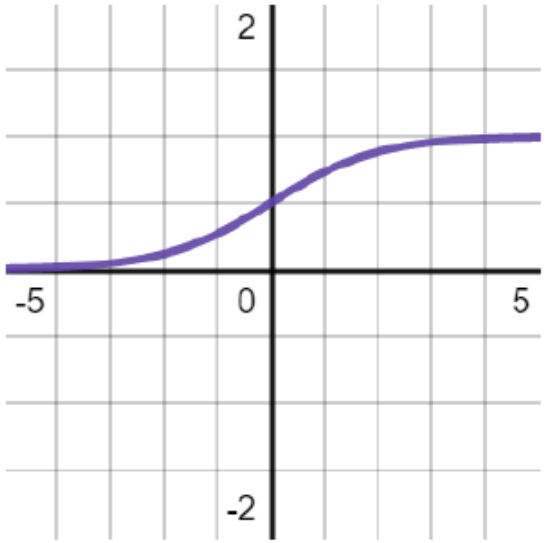
$$m_t = \beta_1 m_{t-1} + (1-\beta_1) \frac{\partial L_t}{\partial W_t} \qquad \hat{m}_t = \frac{m_t}{1-\beta_1^t}$$

$$v_t = \beta_1 v_{t-1} + (1-\beta_2) \left(\frac{\partial L_t}{\partial W_t}\right)^2 \qquad \hat{v}_t = \frac{v_t}{1-\beta_2^t}$$

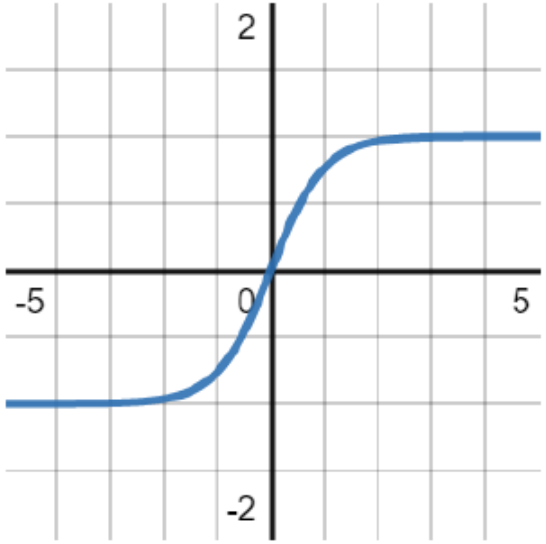
$$W \leftarrow W - \eta \frac{\hat{m}_t}{\sqrt{\hat{v}_t} + \epsilon}$$

https://medium.com/%E9%9B%9E%E9%9B%9E%E8%88%87%E5%85%94%E5%85%94%E7%9A%84%E5%B7%A5%E7%A8%8B%E4%B8%96%E7%95%8C/%E6%A9%9F%E5%99%A8%E5%AD%B8%E7%BF%92ml-note-sgd-momentum-adagrad-adam-optimizer-f20568c968db

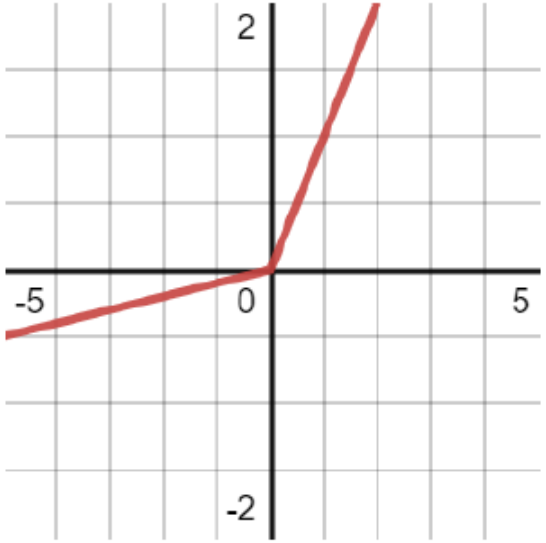
Activation functions



Sigmoid



Tanh



Leaky Relu

Backpropagation in Convolutional NN

$$\begin{bmatrix} O_{11} & O_{12} \\ O_{21} & O_{22} \end{bmatrix} = \text{Convolution}\left(\begin{bmatrix} X_{11} & X_{12} & X_{13} \\ X_{21} & X_{22} & X_{23} \\ X_{31} & X_{32} & X_{33} \end{bmatrix}, \begin{bmatrix} F_{11} & F_{12} \\ F_{21} & F_{22} \end{bmatrix} \right)$$

$$O_{11} = F_{11}X_{11} + F_{12}X_{12} + F_{21}X_{21} + F_{22}X_{22}$$

$$O_{12} = F_{11}X_{12} + F_{12}X_{13} + F_{21}X_{22} + F_{22}X_{23}$$

$$O_{21} = F_{11}X_{21} + F_{12}X_{22} + F_{21}X_{31} + F_{22}X_{32}$$

$$O_{22} = F_{11}X_{22} + F_{12}X_{23} + F_{21}X_{32} + F_{22}X_{33}$$

$$\begin{bmatrix} \partial E/\partial F_{11} & \partial E/\partial F_{12} \\ \partial E/\partial F_{21} & \partial E/\partial F_{22} \end{bmatrix} = \text{Convolution}\left(\begin{bmatrix} X_{11} & X_{12} & X_{13} \\ X_{21} & X_{22} & X_{23} \\ X_{31} & X_{32} & X_{33} \end{bmatrix}, \begin{bmatrix} \partial E/\partial O_{11} & \partial E/\partial O_{12} \\ \partial E/\partial O_{21} & \partial E/\partial O_{22} \end{bmatrix} \right)$$

$$\begin{bmatrix} \partial E/\partial X_{11} & \partial E/\partial X_{12} & \partial E/\partial X_{13} \\ \partial E/\partial X_{21} & \partial E/\partial X_{22} & \partial E/\partial X_{23} \\ \partial E/\partial X_{31} & \partial E/\partial X_{32} & \partial E/\partial X_{33} \end{bmatrix} = \text{Full_Convolution}\left(\begin{bmatrix} \partial E/\partial O_{11} & \partial E/\partial O_{12} \\ \partial E/\partial O_{21} & \partial E/\partial O_{22} \end{bmatrix}, \begin{bmatrix} F_{22} & F_{21} \\ F_{12} & F_{11} \end{bmatrix} \right)$$

Reference : https://medium.com/@2017csm1006/forward-and-backpropagation-in-convolutional-neural-network-4dfa96d7b37e

Announcement

1. Machine

- Just refer to the installation document

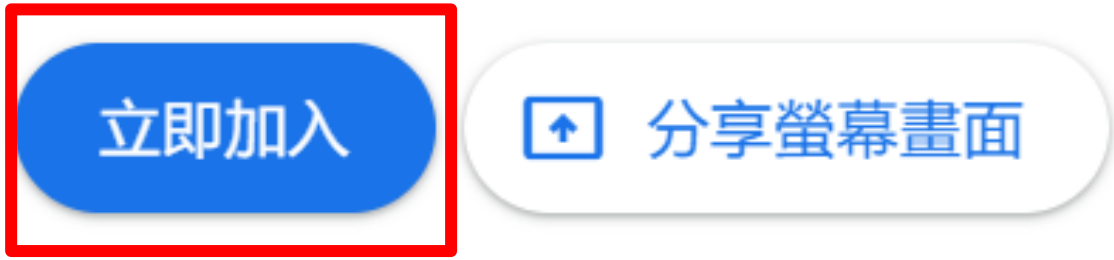
CUDA_conda_installation.pdf

```
ubuntu@ec        :~$ nvidia-smi
Unable to determine the device handle for GPU 0000:01:00.0: Unknown Error
```

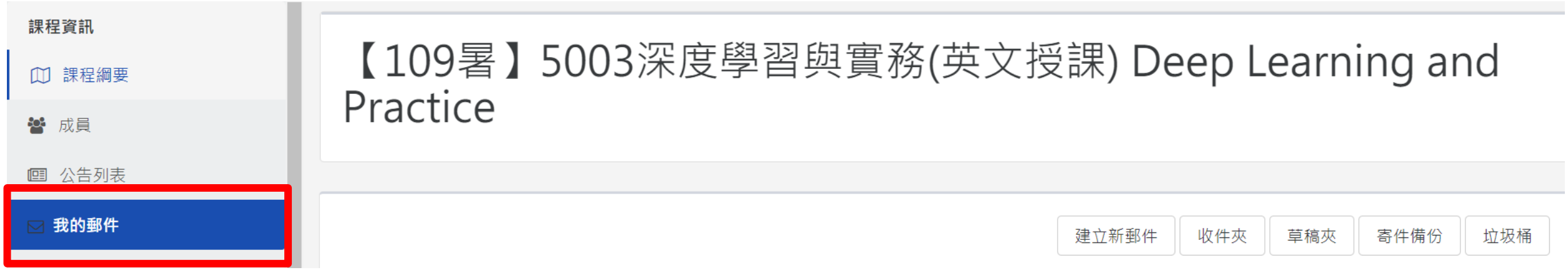
2. Google Meet

- Attend Google Meet using **NYCU** account

NYCU



Not NYCU

3. Email via new E3

- Use the **new e3** email system to send email to me
- If you do not use the new e3 email system, I may not reply to you.