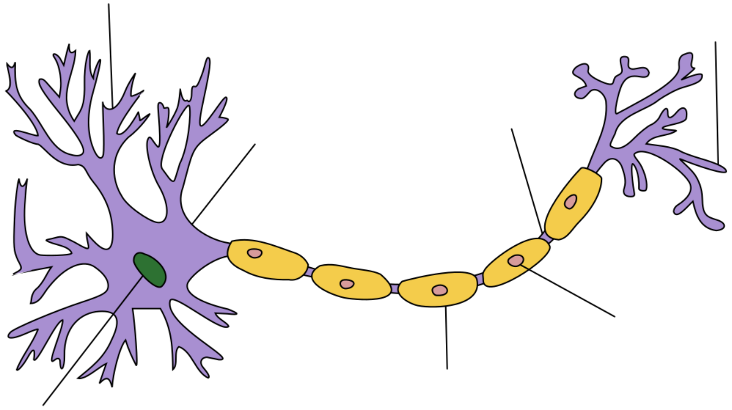
Python Programming

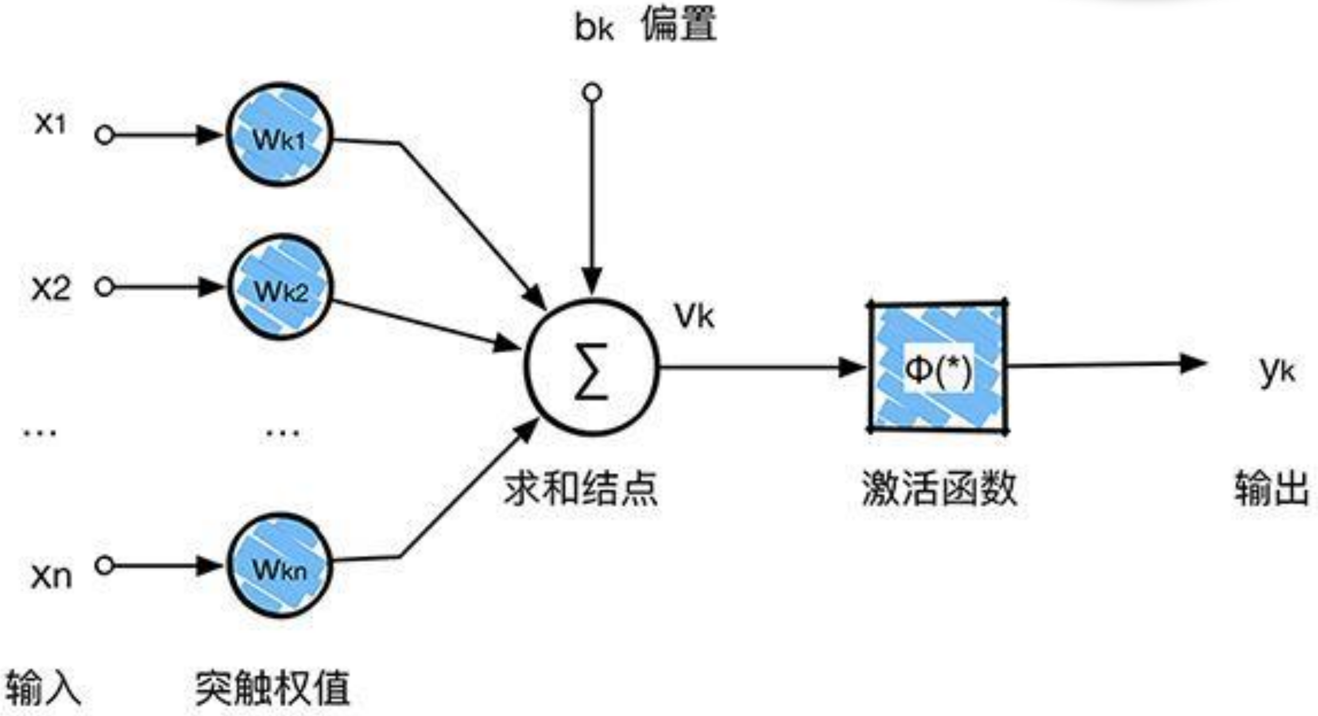
Jian Zhang

Introduction to Deep Learning

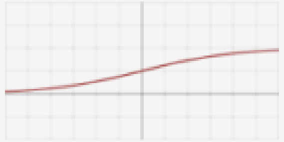
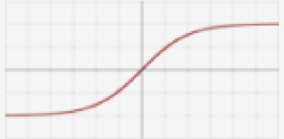
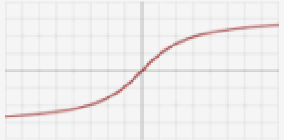
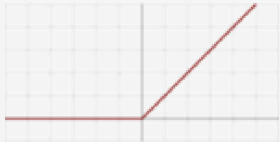
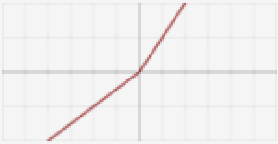
- Fully-Connected Layer
- PyTorch and AutoGrad
- Regression and Classification

Neuron

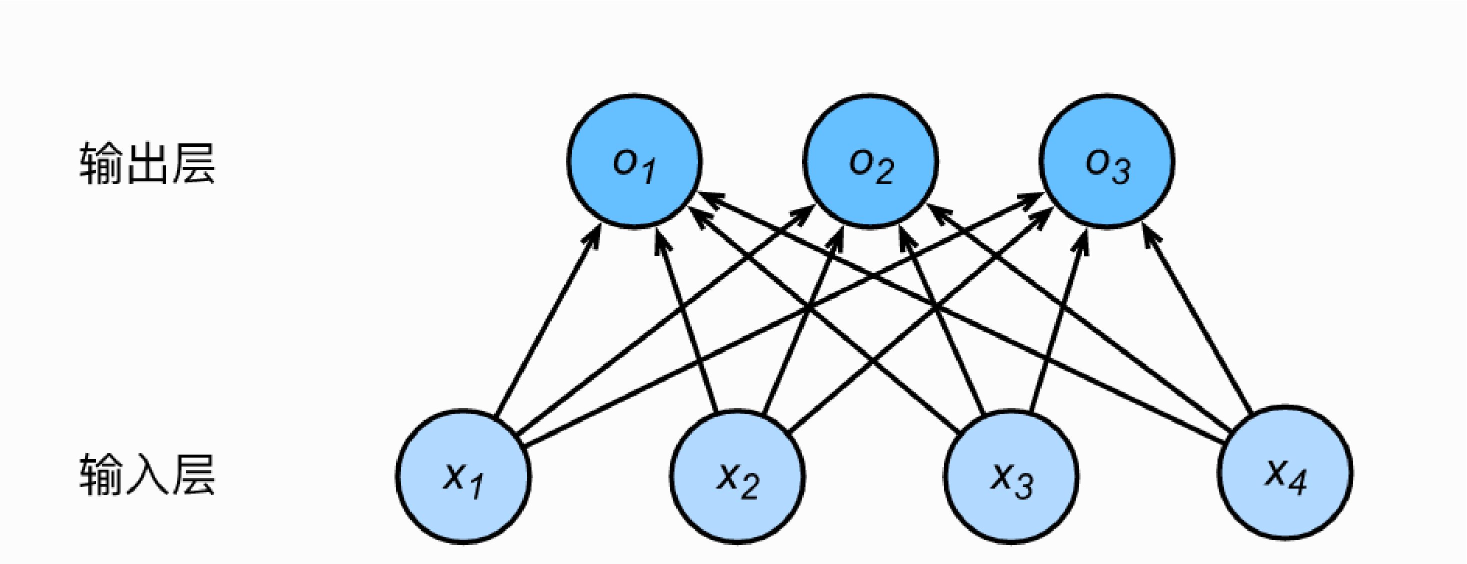




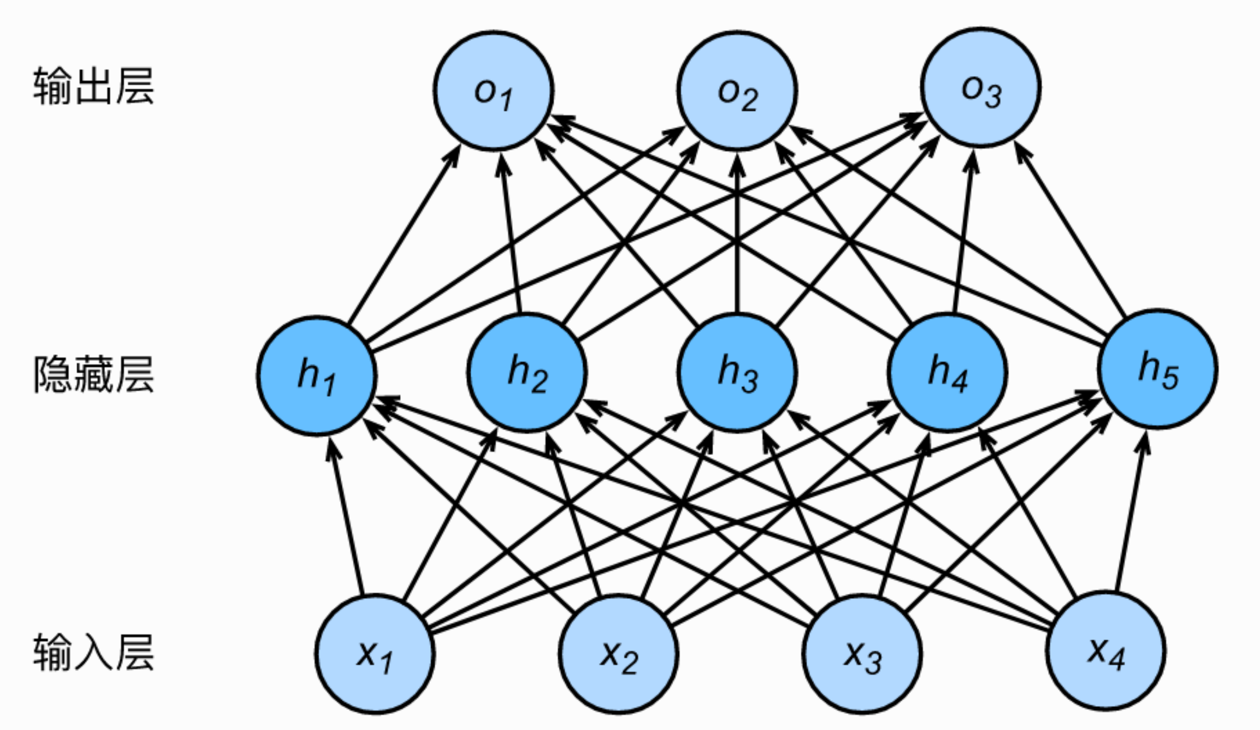
Activation Function

Logistic (a.k.a Soft step)		$f(x) = \frac{1}{1+e^{-x}}$	$f'(x) = f(x)(1-f(x))$
TanH		$f(x) = \tanh(x) = \frac{2}{1+e^{-2x}} - 1$	$f'(x) = 1 - f(x)^2$
ArcTan		$f(x) = \tan^{-1}(x)$	$f'(x) = \frac{1}{x^2+1}$
Rectified Linear Unit (ReLU)[7]		$f(x) = \begin{cases} 0 & \text{for } x < 0 \\ x & \text{for } x \geq 0 \end{cases}$	$f'(x) = \begin{cases} 0 & \text{for } x < 0 \\ 1 & \text{for } x \geq 0 \end{cases}$
Parameteric Rectified Linear Unit (PReLU)[8]		$f(x) = \begin{cases} \alpha x & \text{for } x < 0 \\ x & \text{for } x \geq 0 \end{cases}$	$f'(x) = \begin{cases} \alpha & \text{for } x < 0 \\ 1 & \text{for } x \geq 0 \end{cases}$

One-layer Fully Connected Network

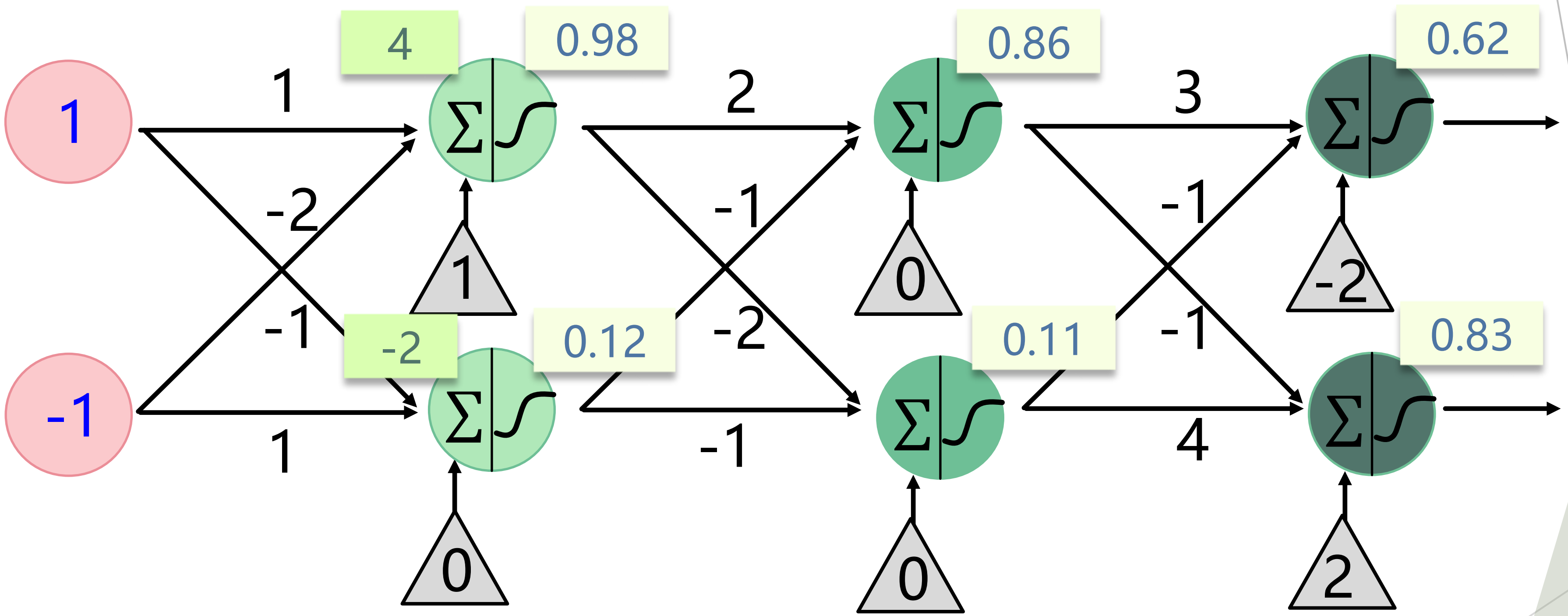


Two-layer Fully Connected Network



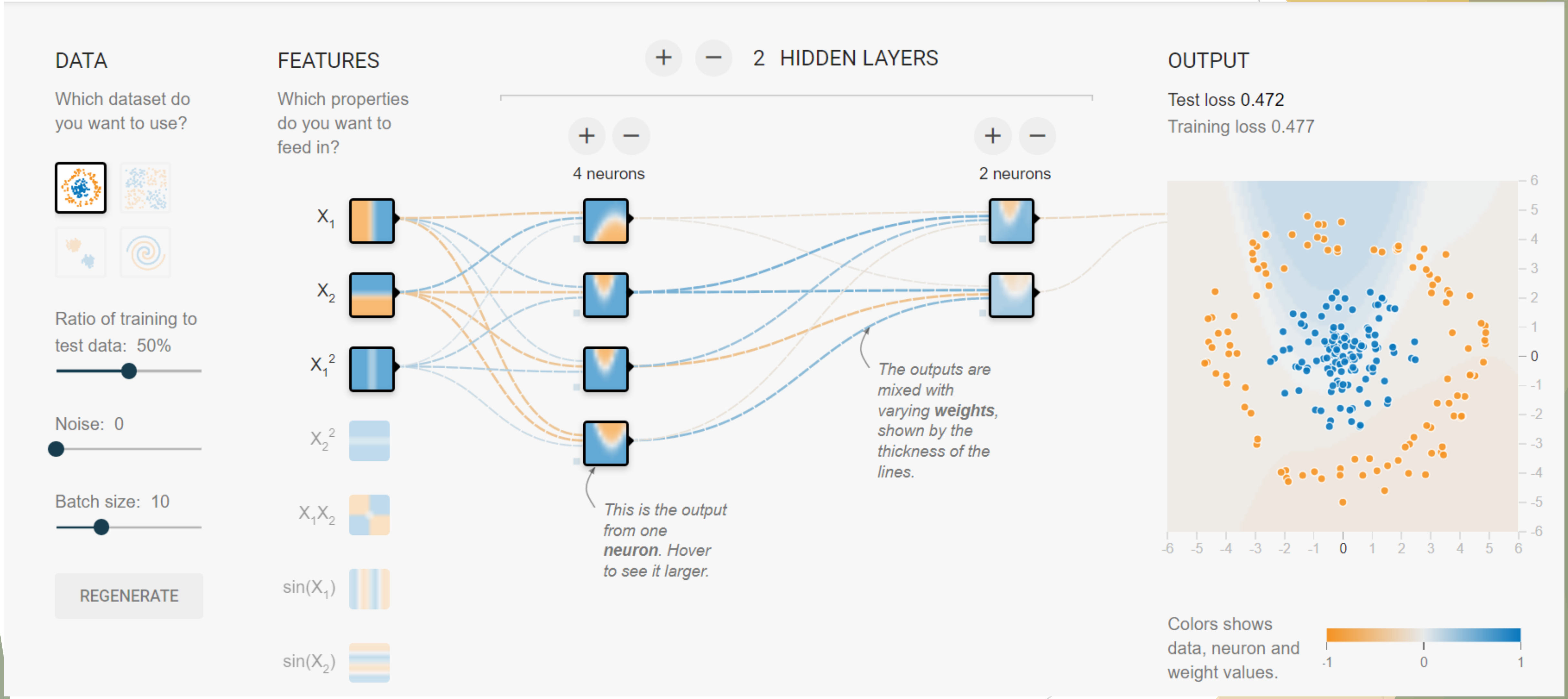
$$\begin{aligned} \boldsymbol{H} &= \phi(\boldsymbol{X}\boldsymbol{W}_h + \boldsymbol{b}_h), \\ \boldsymbol{O} &= \boldsymbol{H}\boldsymbol{W}_o + \boldsymbol{b}_o, \end{aligned}$$

Example:



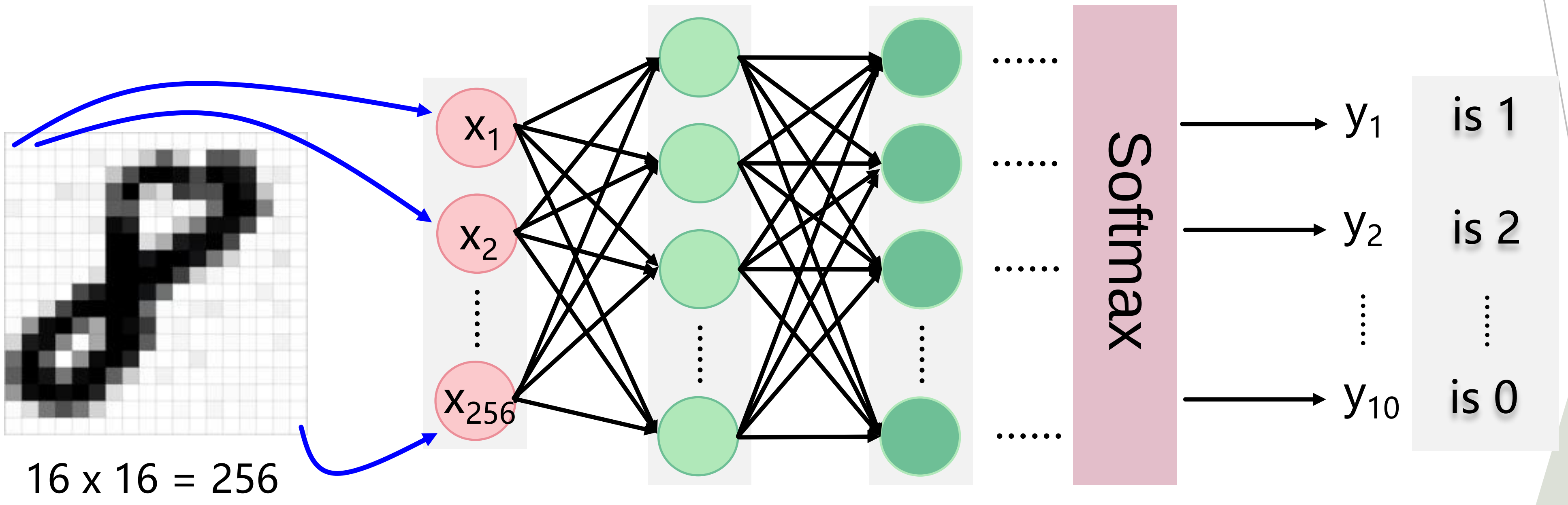
函数：$f\left(\begin{bmatrix}1\\-1\end{bmatrix}\right)=\begin{bmatrix}0.62\\0.83\end{bmatrix}$

Two-layer Fully Connected Network

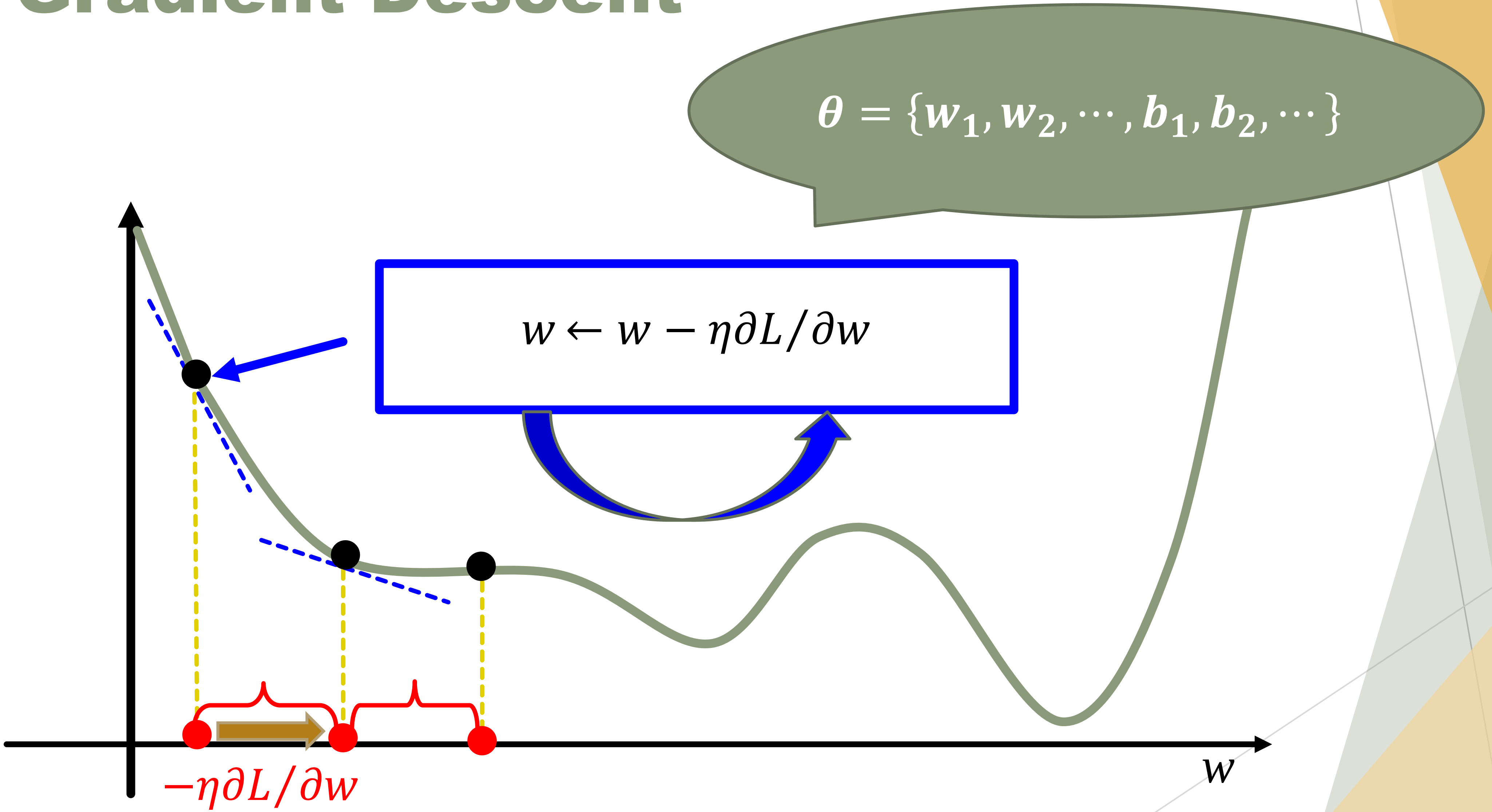


https://playground.tensorflow.org/

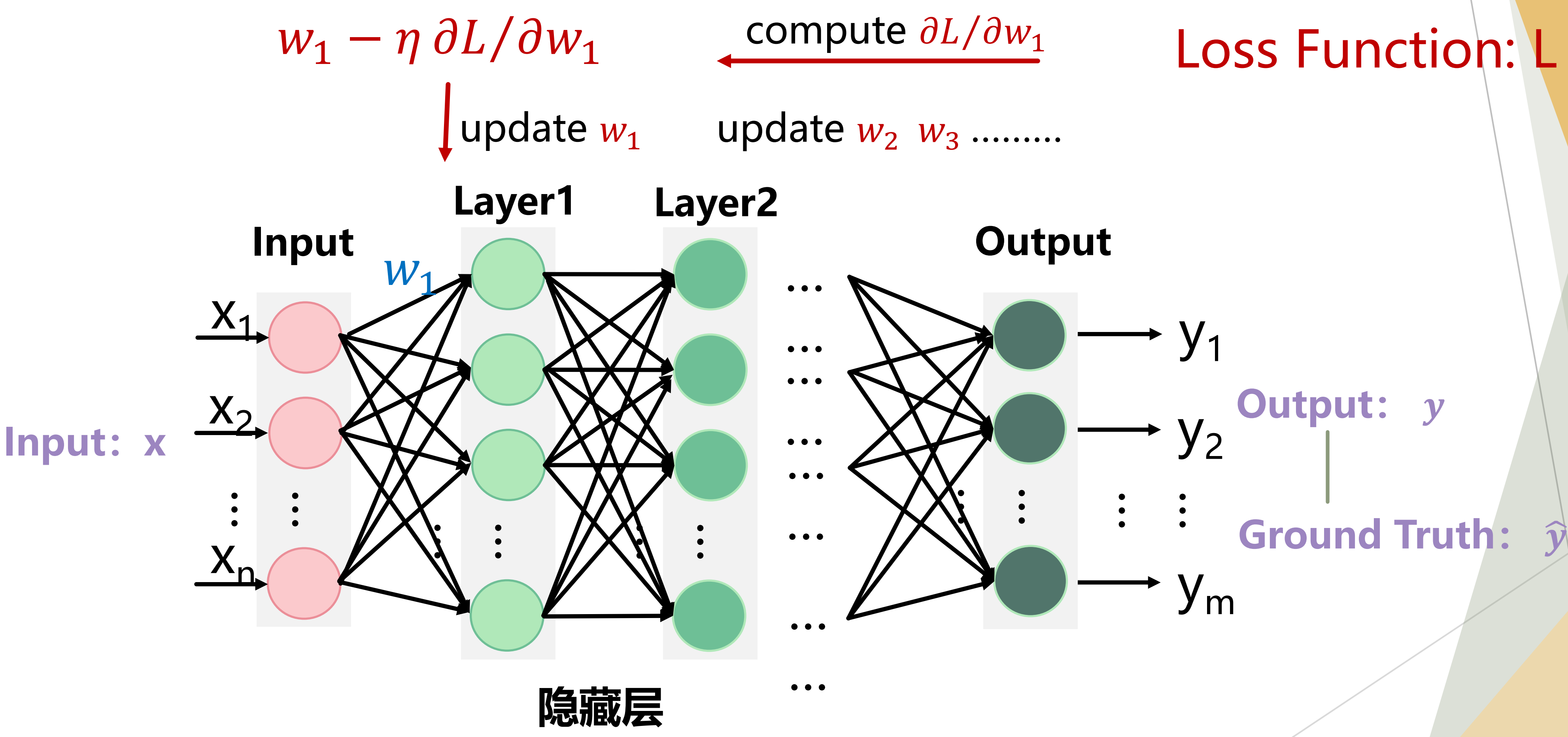
Loss Function



Gradient Descent

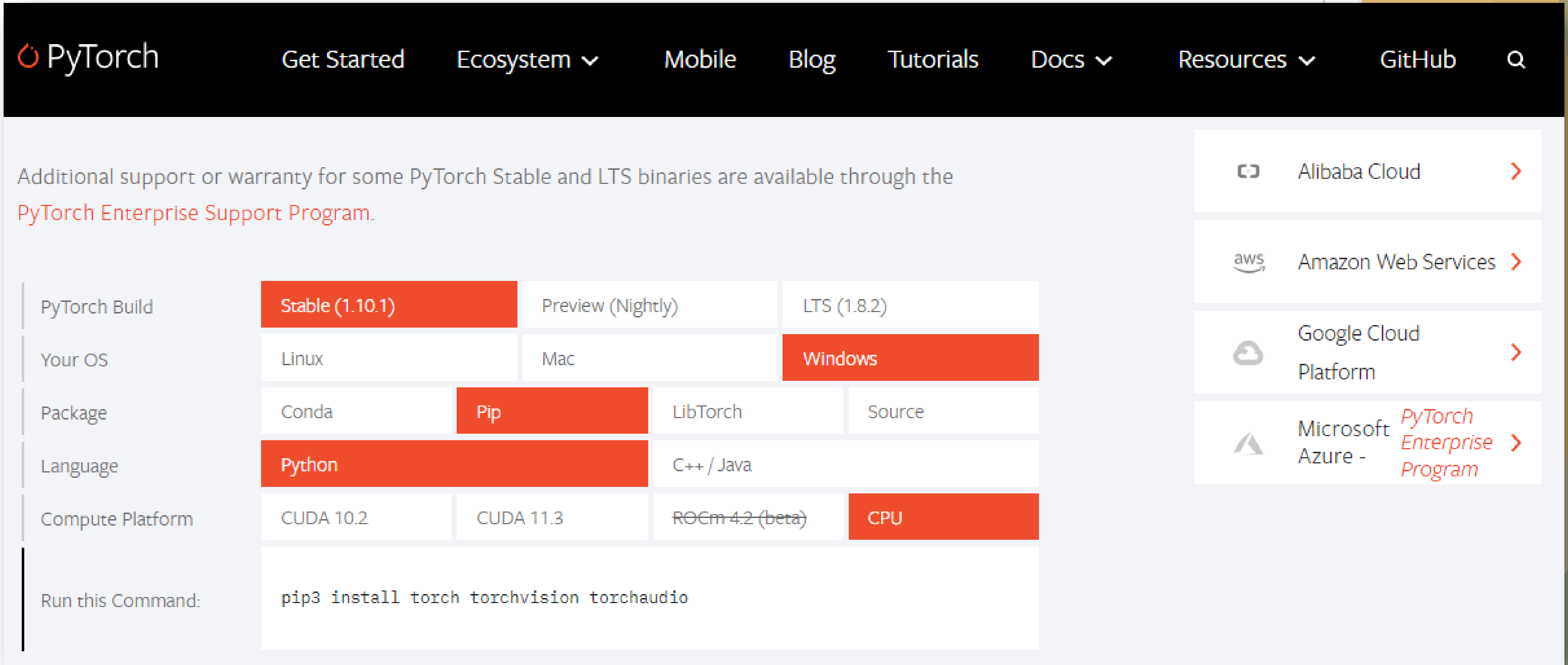


Backpropagation



PyTorch

https://pytorch.org/



PyTorch

https://pytorch.org/

Computational Graphs

Numpy

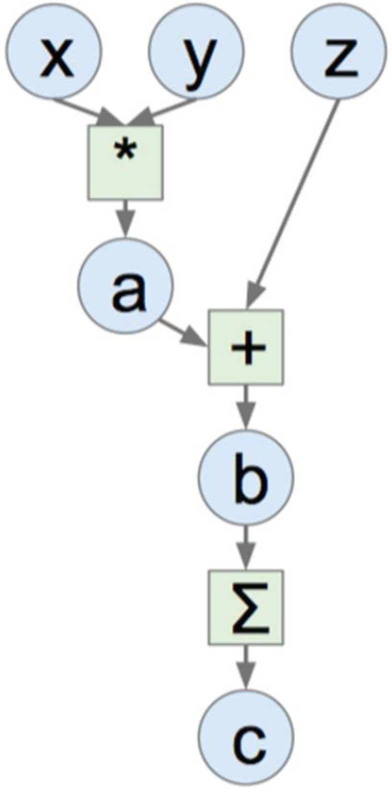
```python
import numpy as np
np.random.seed(0)

N, D = 3, 4

x = np.random.randn(N, D)
y = np.random.randn(N, D)
z = np.random.randn(N, D)

a = x * y
b = a + z
c = np.sum(b)

grad_c = 1.0
grad_b = grad_c * np.ones((N, D))
grad_a = grad_b.copy()
grad_z = grad_b.copy()
grad_x = grad_a * y
grad_y = grad_a * x
```



PyTorch

```python
import torch

N, D = 3, 4
x = torch.randn(N, D, requires_grad=True)
y = torch.randn(N, D)
z = torch.randn(N, D)

a = x * y
b = a + z
c = torch.sum(b)

c.backward()
print(x.grad)
```

PyTorch handles gradients for us!

PyTorch_Tensor.ipynb

Build Fully Connected Layer by PyTorch

class `torch.nn.Linear`(*in_features, out_features, bias=True*) [source]

Applies a linear transformation to the incoming data: $y = xA^T + b$

Parameters:

- **in_features** – size of each input sample
- **out_features** – size of each output sample
- **bias** – If set to False, the layer will not learn an additive bias. Default: `True`

Shape:

- Input: $(N, *, in\_features)$ where $*$ means any number of additional dimensions
- Output: $(N, *, out\_features)$ where all but the last dimension are the same shape as the input.

Variables:

- **weight** – the learnable weights of the module of shape *(out_features x in_features)*
- **bias** – the learnable bias of the module of shape *(out_features)*

Build Fully Connected Layer by PyTorch

```
import torch.nn as nn
input = torch.randn(10,100) # (BatchSize, length)
fc1 = nn.Linear(100, 200)
output_fc1 = fc1(input)

print("Size of Input is", input.shape)
print("Size of fc1 Output is", output_fc1.shape)

params = list(fc1.parameters())
print("Parameter Number of fc1 is %d " % len(params))

for name, parameters in fc1.named_parameters():
    print(name, ':', parameters.size())
```

```
Size of Input is torch.Size([10, 100])
Size of fc1 Output is torch.Size([10, 200])
The Number of fc1 is 2
weight : torch.Size([200, 100])
bias : torch.Size([200])
```

Build Fully Connected Layer by PyTorch

```
import torch.nn as nn
input = torch.randn(10,100) # (BatchSize, length)
fc1 = nn.Linear(100, 200, bias=False)
output_fc1 = fc1(input)

print("Size of Input is", input.shape)
print("Size of fc1 Output is", output_fc1.shape)

params = list(fc1.parameters())
print("Parameter Number of fc1 is %d " % len(params))

for name, parameters in fc1.named_parameters():
    print(name, ':', parameters.size())
```

```
Size of Input is torch.Size([10, 100])
Size of fc1 Output is torch.Size([10, 200])
The Number of fc1 is 1
weight : torch.Size([200, 100])
```

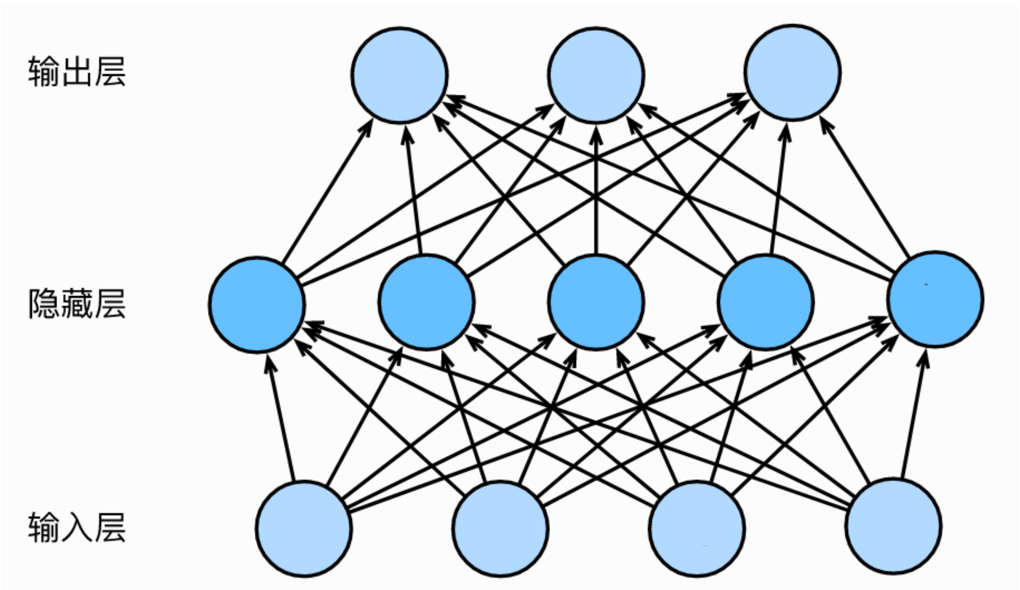
Regression (From Numpy to PyTorch)

$$h = XW_1$$

$$h_{\text{relu}} = \max(0, h)$$

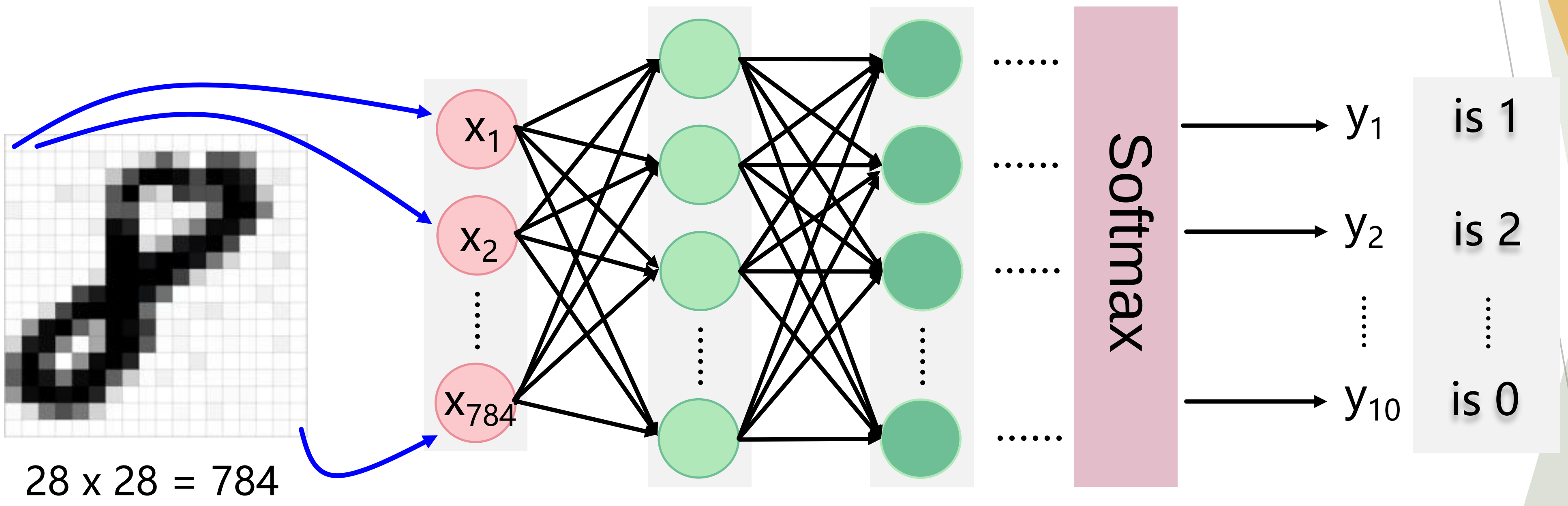
$$Y_{\text{pred}} = h_{\text{relu}} W_2$$

$$f = ||Y - Y_{\text{pred}}||_F^2$$



From_Numpy_To_PyTorch.ipynb

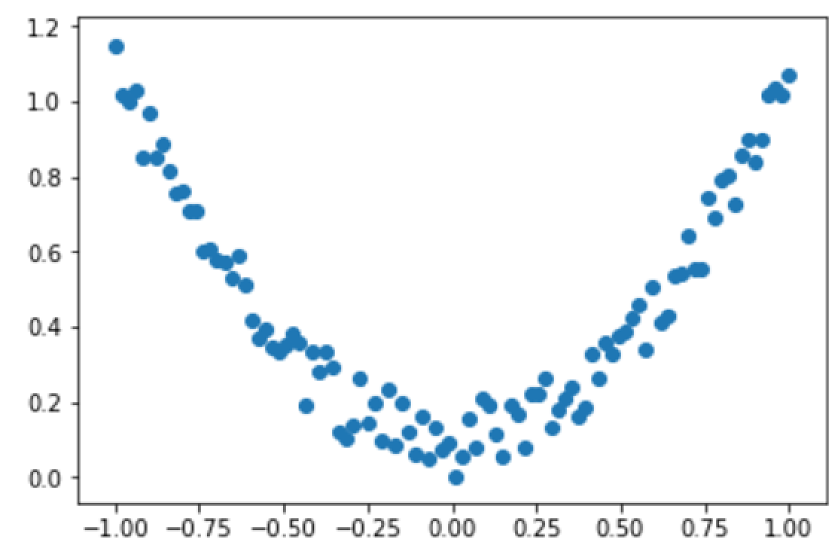
MNIST Classification



MNIST_FC.ipynb

Homework

Homework.ipynb or Homework.py




```
torch.manual_seed(1)    # reproducible

x = torch.unsqueeze(torch.linspace(-1, 1, 100), dim=1)
y = x.pow(2) + 0.2*torch.rand(x.size())
```

```python
class Net(torch.nn.Module):
    def __init__(self, n_feature, n_hidden, n_output):
        super(Net, self).__init__()


    def forward(self, x):

        return x
```

```python
net = Net(n_feature=1, n_hidden=20, n_output=1)     # define the network
print(net)  # net architecture
```

Questions?