AI and Deep Learning

Being familiar with ML programming

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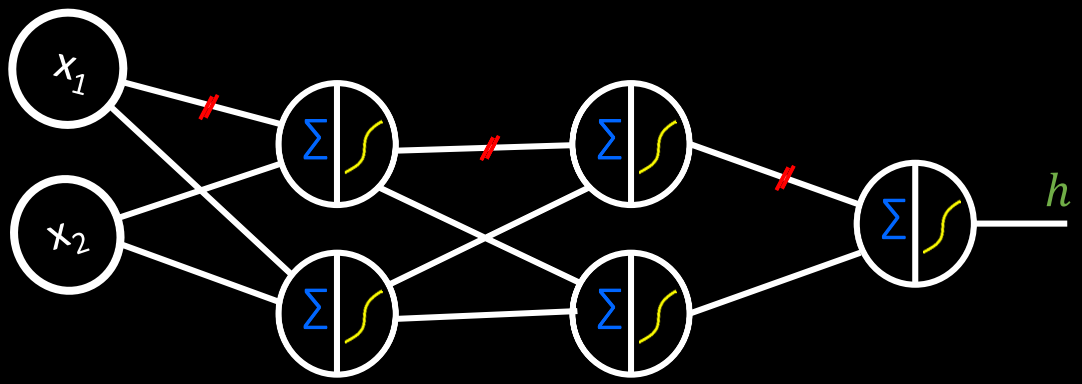
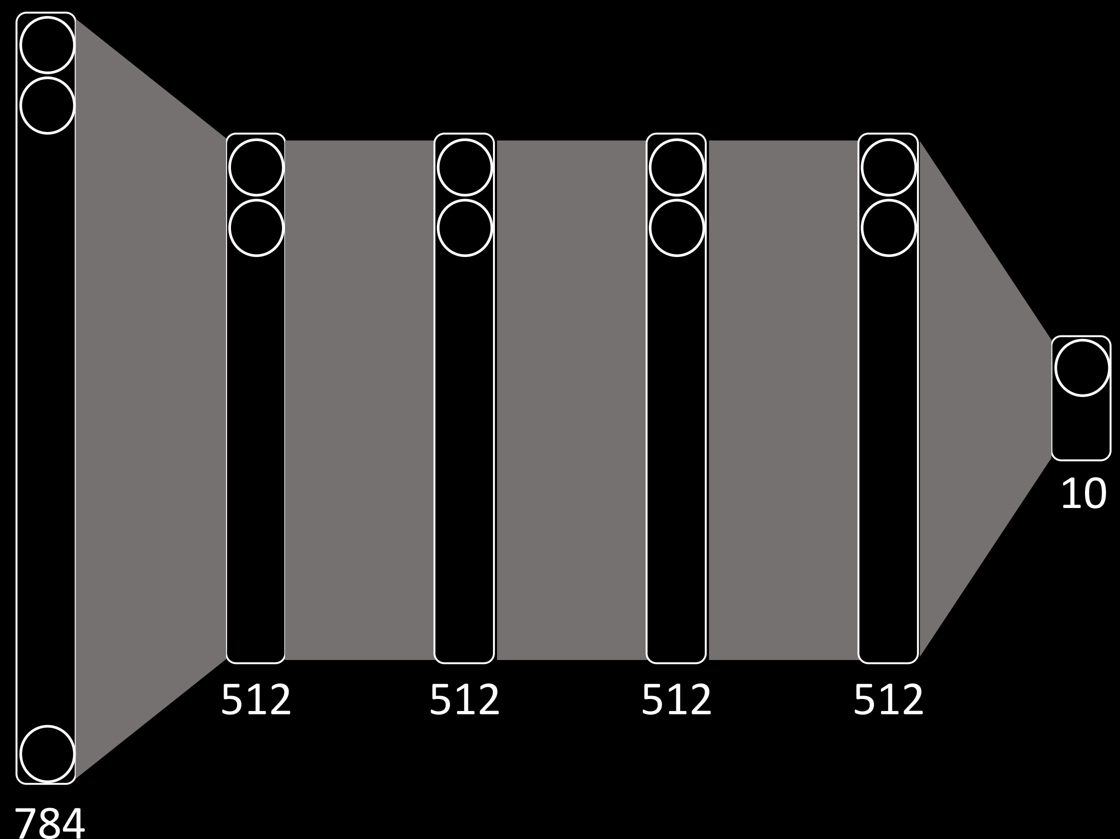
```
w = tf.Variable(tf.random_normal([1,1]))
w = tf.Variable(tf.random_normal([2,1]))
w = tf.Variable(tf.random_normal([2,4]))
```

A neuron having 1 input
A neuron having 2 inputs
Four neurons where each one has 2 inputs



w = tf.Variable(tf.random_normal([?, ?]))



w = tf.Variable(tf.random_normal([?, ?]))

Matrix Notification

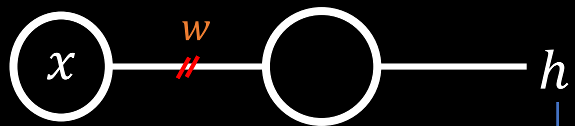
- Input data
- Weights (in synapses)
- Answer(s) by a neuron (hypothesis)
- Error/Loss E

(1)1-1/L

```
#----- training data
x_data = [[1]]
y_data = [[1]]

#----- a neuron
w = tf.Variable(tf.random_normal([1,1]))
hypo = w * x_data

#----- learning
cost = (hypo - y_data) ** 2
```



[1]

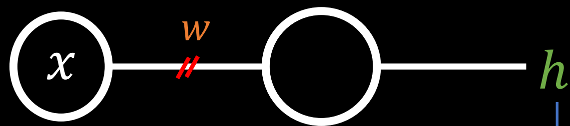
[1]

$$E = (w \cdot x - y)^2$$

$(1)\ (w)$ $\quad (1 \cdot w) \quad (1 \cdot w - 1)^2 \longrightarrow E(cost)$ (1 value)

1 input data $\longrightarrow$ 1 answer by the neuron

(3)1-1/L



$[1, 2, 3]$

$[1, 2, 3]$

$$E = (w \cdot x - y)^2$$

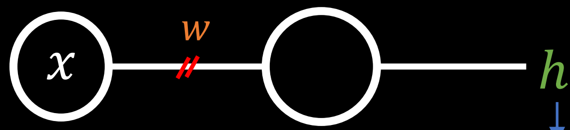
```
#----- training data
x_data = [[1], [2], [3]]
y_data = [[1], [2], [3]]

#----- a neuron
w = tf.Variable(tf.random_normal([1,1]))
hypo = w * x_data

#----- learning
cost = tf.reduce_mean((hypo - y_data) ** 2)
```

$\rightarrow$ (1) (w) $(1 \cdot w)$ $(1 \cdot w - 1)^2$

(3)1-1/L



$[1, 2, 3]$

$[1, 2, 3]$

$$E = (w \cdot x - y)^2$$

```
#----- training data
x_data = [[1], [2], [3]]
y_data = [[1], [2], [3]]

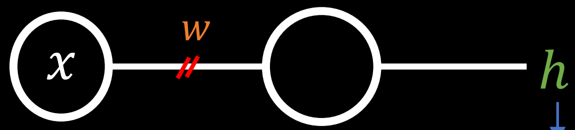
#----- a neuron
w = tf.Variable(tf.random_normal([1,1]))
hypo = w * x_data

#----- learning
cost = tf.reduce_mean((hypo - y_data) ** 2)
```

$\rightarrow$ $(1)\ (w)$ $\quad (1 \cdot w) \quad (1 \cdot w - 1)^2 +$

$\rightarrow$ $(2)\ (w)$ $\quad (2 \cdot w) \quad (2 \cdot w - 2)^2$

(3)1-1/L



$[1, 2, 3]$

$[1, 2, 3]$

$$E = (w \cdot x - y)^2$$

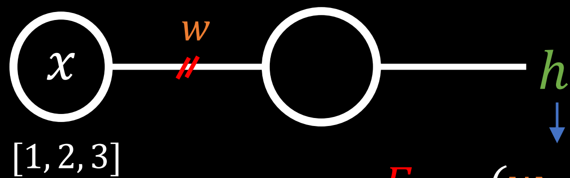
```
#----- training data
x_data = [[1], [2], [3]]
y_data = [[1], [2], [3]]

#----- a neuron
w = tf.Variable(tf.random_normal([1,1]))
hypo = w * x_data

#----- learning
cost = tf.reduce_mean((hypo - y_data) ** 2)
```

$\rightarrow$ (1) (w)	$(1 \cdot w)$	$(1 \cdot w - 1)^2 +$
$\rightarrow$ (2) (w)	$(2 \cdot w)$	$(2 \cdot w - 2)^2 +$
$\rightarrow$ (3) (w)	$(3 \cdot w)$	$(3 \cdot w - 3)^2$

(3)1-1/L




```
#----- training data
x_data = [[1], [2], [3]]
y_data = [[1], [2], [3]]

#----- a neuron
w = tf.Variable(tf.random_normal([1,1]))
hypo = w * x_data

#----- learning
cost = tf.reduce_mean((hypo - y_data) ** 2)
```

$[1, 2, 3]$

$$E = (w \cdot x - y)^2$$

$\rightarrow$ (1) (w) $\quad (1 \cdot w) \quad (1 \cdot w - 1)^2 +$

$\rightarrow$ (2) (w) $\quad (2 \cdot w) \quad (2 \cdot w - 2)^2 +$

$\rightarrow$ (3) (w) $\quad (3 \cdot w) \quad (3 \cdot w - 3)^2$

3 input data $\longrightarrow$ 3 answers by the neuron (h)

$$E = \sum_{i=1}^{3} (w x_i - y_i)^2$$

Number of input data
Number of answer/hypothesis
of a neuron(network)

(3)1-1/L

[1, 2, 3]

$$cost(E) = (w \cdot x - y)^2 \quad [1,2,3]$$

```
#----- training data
x_data = [[1], [2], [3]]
y_data = [[1], [2], [3]]

#----- a neuron
w = tf.Variable(tf.random_normal([1,1]))
hypo = w * x_data

#----- learning
cost = tf.reduce_mean((hypo - y_data) ** 2)
```

$\rightarrow$ (1) (w) $\quad (1 \cdot w) \quad (1 \cdot w - 1)^2 +$

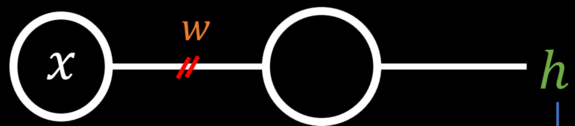
$\rightarrow$ (2) (w) $\quad (2 \cdot w) \quad (2 \cdot w - 2)^2 +$

$\rightarrow$ (3) (w) $\quad (3 \cdot w) \quad (3 \cdot w - 3)^2$

$$\left.\begin{matrix}(1 \cdot w - 1)^2 + \\ (2 \cdot w - 2)^2 + \\ (3 \cdot w - 3)^2\end{matrix}\right\} \frac{1}{3}\sum \longrightarrow E \text{ (1 value)}$$

$$E = \sum_{i=1}^{3} (w x_i - y_i)^2$$

(3)1-1/L



$[1, 2, 3]$

$[1, 2, 3]$

$$E = (w \cdot x - y)^2$$

```
#----- training data
x_data = [[1], [2], [3]]
y_data = [[1], [2], [3]]

#----- a neuron
w = tf.Variable(tf.random_normal([1,1]))
hypo = w * x_data

#----- learning
cost = tf.reduce_mean((hypo - y_data) ** 2)
```

$\rightarrow$ $(1)\ (w)$ $\quad (1 \cdot w) \quad (1 \cdot w - 1)^2 +$

$\rightarrow$ $(2)\ (w)$ $\quad (2 \cdot w) \quad (2 \cdot w - 2)^2 +$

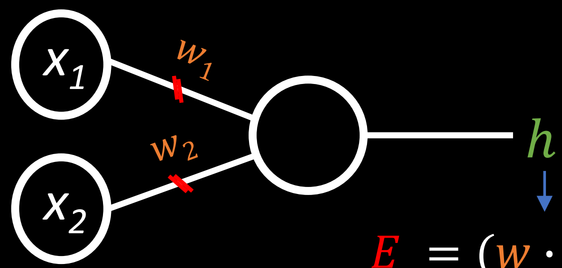
$\rightarrow$ $(3)\ (w)$ $\quad (3 \cdot w) \quad (3 \cdot w - 3)^2$

$$\left.\begin{matrix}(1 \cdot w - 1)^2 + \\ (2 \cdot w - 2)^2 + \\ (3 \cdot w - 3)^2\end{matrix}\right\} \frac{1}{3}\sum \longrightarrow E \text{ (1 value)}$$

$$\downarrow \begin{pmatrix}1\\2\\3\end{pmatrix}(w) \qquad \downarrow \underbrace{\begin{pmatrix}1 \cdot w\\2 \cdot w\\3 \cdot w\end{pmatrix}}_{h}$$

more data, increases downward
the same number of hypothesis
but E is a single value.

(1)2-1/L



$[[1, 1]]$

$[[1]]$

$$E = (w \cdot x - y)^2$$

```
#----- training data
x_data = [[1., 1]]
y_data = [[1.]]

#----- a neuron
w = tf.Variable(tf.random_normal([2, 1]))
hypo = tf.matmul(x_data, w)

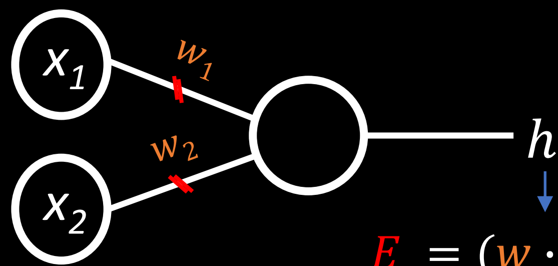
#----- learning
cost = tf.reduce_mean((hypo - y_data) ** 2)
```

$(1, 1)\ (w_1, w_2)$ $\quad (1 \cdot w_1 + 1 \cdot w_2)$ $\quad ((1 \cdot w_1 + 1 \cdot w_2) - 1)^2$

$(1, 1) \begin{pmatrix} w_1 \\ w_2 \end{pmatrix}$ $\quad (1 \cdot w_1 + 1 \cdot w_2)$

if we add more input, weight will also increase.

(3)2-1/L



[[1, 1], [2,2], [3,3]]

[[1], [2], [3]]

$$E = (w \cdot x - y)^2$$

```
#----- training data
x_data = [[1., 1], [2, 2], [3, 3]]
y_data = [[1.], [2], [3]]

#----- a neuron
w = tf.Variable(tf.random_normal([2, 1]))
hypo = tf.matmul(x_data, w)

#----- learning
cost = tf.reduce_mean((hypo - y_data) ** 2)
```

$\rightarrow$ $(1,1)\ (w_1, w_2)$ $\quad (1 \cdot w_1 + 1 \cdot w_2)$ $\quad ((1 \cdot w_1 + 1 \cdot w_2) - 1)^2$

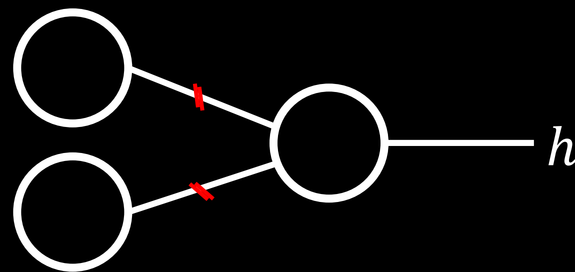
$\rightarrow$ $(2,2)\ (w_1, w_2)$ $\quad (2 \cdot w_1 + 2 \cdot w_2)$ $\quad ((2 \cdot w_1 + 2 \cdot w_2) - 2)^2$

$\rightarrow$ $(3,3)\ (w_1, w_2)$ $\quad (3 \cdot w_1 + 3 \cdot w_2)$ $\quad ((3 \cdot w_1 + 3 \cdot w_2) - 3)^2$

$$\left.\begin{matrix} ((1 \cdot w_1 + 1 \cdot w_2) - 1)^2 \\ ((2 \cdot w_1 + 2 \cdot w_2) - 2)^2 \\ ((3 \cdot w_1 + 3 \cdot w_2) - 3)^2 \end{matrix}\right\} \frac{1}{3}\sum \longrightarrow E$$

$$\begin{pmatrix} 1, 1 \\ 2, 2 \\ 3, 3 \end{pmatrix} \begin{pmatrix} w_1 \\ w_2 \end{pmatrix} \qquad \begin{pmatrix} 1 \cdot w_1 + 1 \cdot w_2 \\ 2 \cdot w_1 + 2 \cdot w_2 \\ 3 \cdot w_1 + 3 \cdot w_2 \end{pmatrix}$$

More input data, more row in the matrix,
the same number of hypothesis
however, E is a single value.

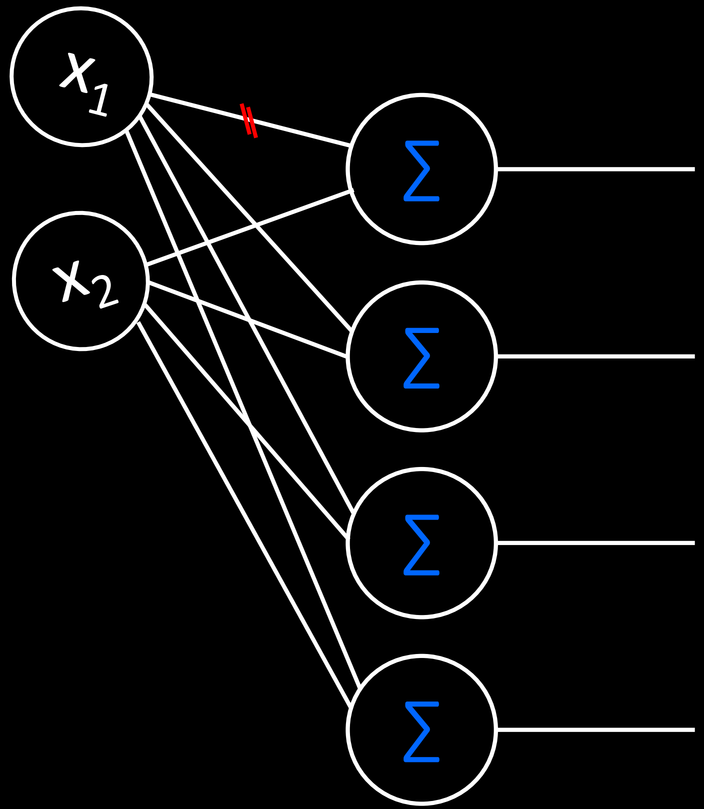


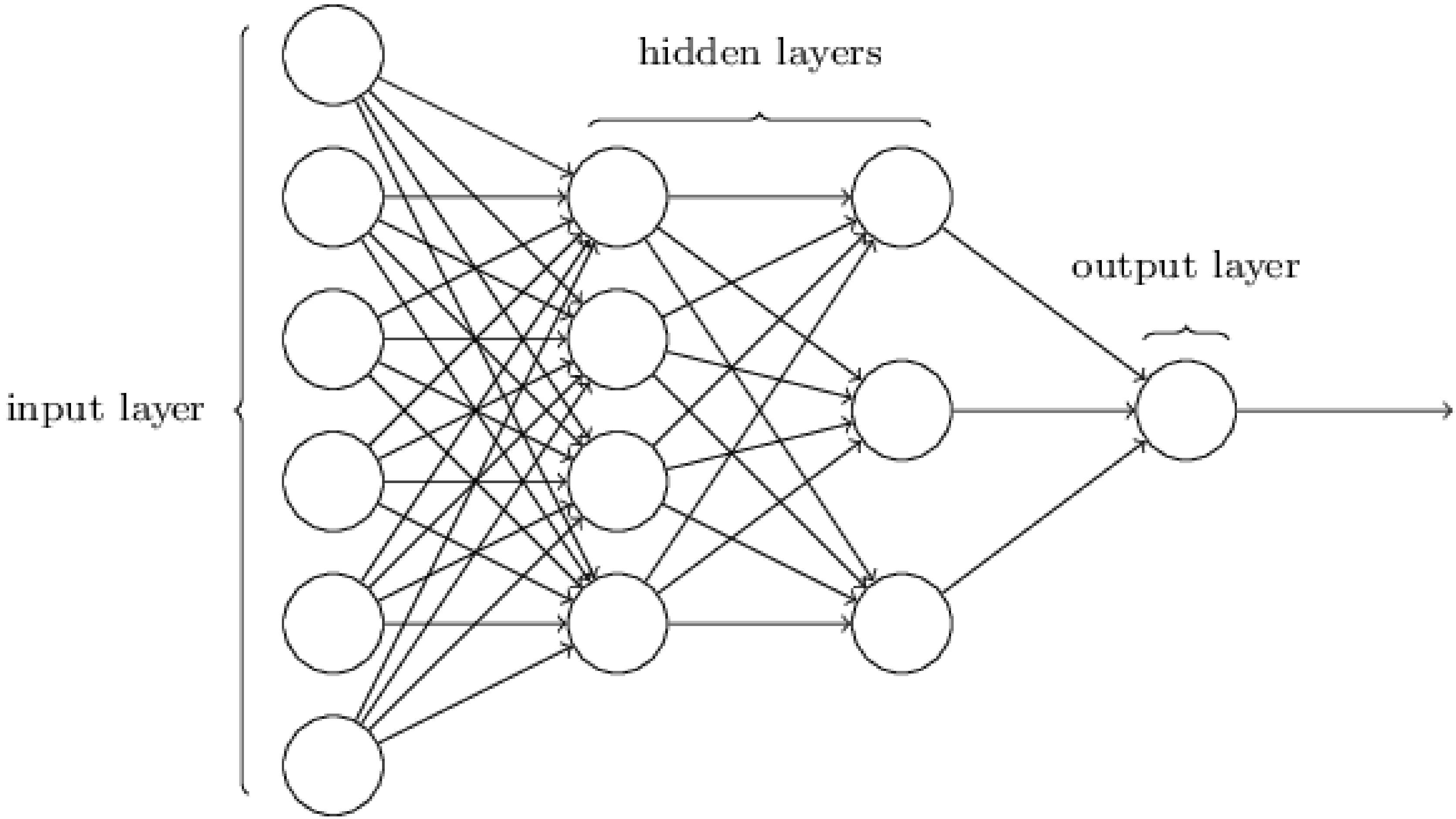
$$\begin{pmatrix} w_1 \\ w_2 \end{pmatrix}$$

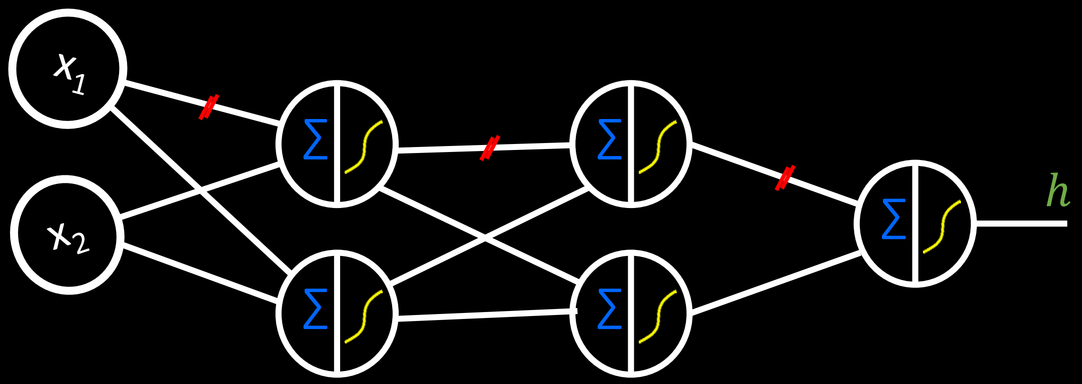
Draw a neuron for the below operation.

$$\begin{pmatrix} 1, 1 \\ 2, 2 \\ 3, 3 \end{pmatrix} \begin{pmatrix} w_1 \\ w_2 \end{pmatrix}$$

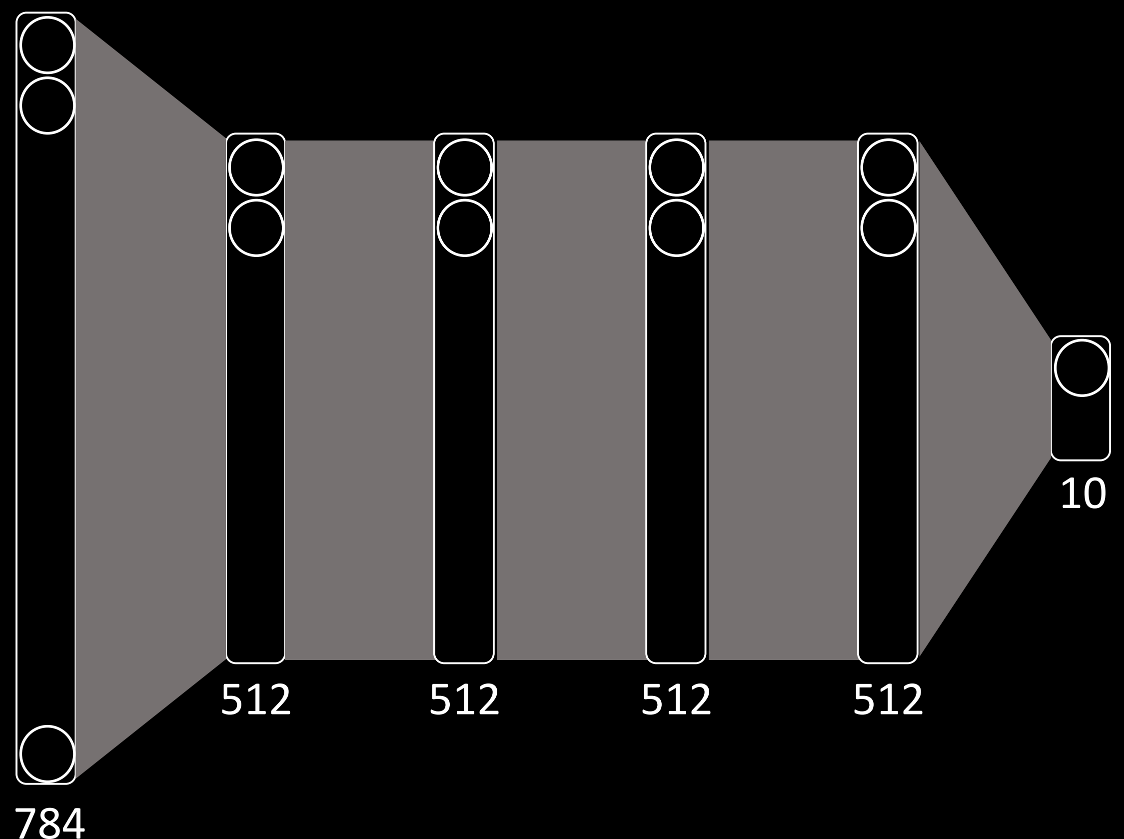
Add 1 more data.
Add 1 more input.
Add 1 more neuron.


x_1
x_2
Σ
Σ
Σ
Σ


hidden layers
output layer
input layer



x_1
x_2
h

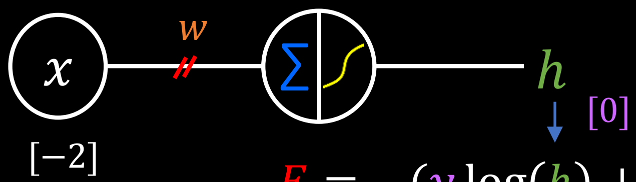

784
512
512
512
512
10

(1)1-1/C

```
#----- training data
x_data = [[-2.]]
y_data = [[0.]]

#------- a neuron
w = tf.Variable(tf.random_normal([1,1]))
hypo = tf.sigmoid(x_data * w)

#----- learning
cost = -tf.reduce_mean(y_data * tf.log(hypo) +
      tf.subtract(1., y_data) * tf.log(tf.subtract(1., hypo)))
```



$$E = -(y\log(h) + (1-y)\log(1-h))$$

$(-2)\ (w)$

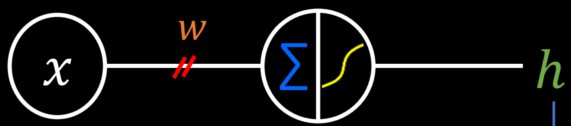
$sigmoid(-2 \cdot w) \rightarrow h \quad E$

(4)1-1/C

```
#----- training data
x_data = [[-2.], [-1], [1], [2]]
y_data = [[0.], [0], [1], [1]]

#------- a neuron
w = tf.Variable(tf.random_normal([1,1]))
hypo = tf.sigmoid(x_data * w)

#----- learning
cost = -tf.reduce_mean(y_data * tf.log(hypo) +
      tf.subtract(1., y_data) * tf.log(tf.subtract(1., hypo)))
```



$[-2., -1, 1, 2]$ $\quad$ $[0., 0, 1, 1]$

$$E = -(y \log(h) + (1 - y)\log(1 - h))$$

$\rightarrow (-2)\,(w)$ $\qquad$ $sigmoid(-2 \cdot w) \rightarrow h$ $\quad : E_1$

(4)1-1/C

```
#----- training data
x_data = [[-2.], [-1], [1], [2]]
y_data = [[0.], [0], [1], [1]]

#------- a neuron
w = tf.Variable(tf.random_normal([1,1]))
hypo = tf.sigmoid(x_data * w)

#----- learning
cost = -tf.reduce_mean(y_data * tf.log(hypo) +
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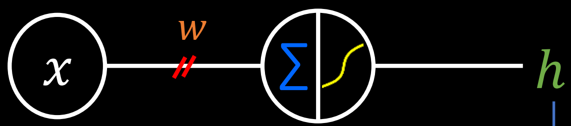
```



$[-2., -1, 1, 2]$

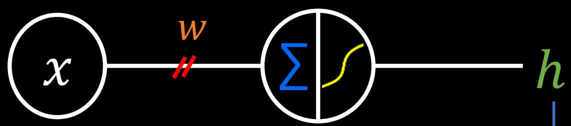
$[0., 0, 1, 1]$

$$E = -(y \log(h) + (1 - y)\log(1 - h))$$

$\rightarrow$ $(-2)\ (w)$ $\quad$ $sigmoid(-2 \cdot w) \rightarrow h$ $\quad$: E_1

$\rightarrow$ $(-1)\ (w)$ $\quad$ $sigmoid(-1 \cdot w) \rightarrow h$ $\quad$: E_2

(4)1-1/C



$[-2., -1, 1, 2]$

$[0., 0, 1, 1]$

$$E = -(y\log(h) + (1-y)\log(1-h))$$

```
#----- training data
x_data = [[-2.], [-1], [1], [2]]
y_data = [[0.], [0], [1], [1]]

#------- a neuron
w = tf.Variable(tf.random_normal([1,1]))
hypo = tf.sigmoid(x_data * w)

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```

$\rightarrow (-2)\ (w)$ $\quad sigmoid(-2 \cdot w) \rightarrow h \quad : E_1$

$\rightarrow (-1)\ (w)$ $\quad sigmoid(-1 \cdot w) \rightarrow h \quad : E_2$

$\rightarrow (1)\ (w)$ $\quad sigmoid(1 \cdot w) \rightarrow h \quad : E_3$

(4)1-1/C

```
#----- training data
x_data = [[-2.], [-1], [1], [2]]
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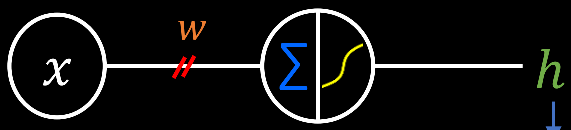


$[0., 0, 1, 1]$

$[-2., -1, 1, 2]$

$$E = -(y\log(h) + (1-y)\log(1-h))$$

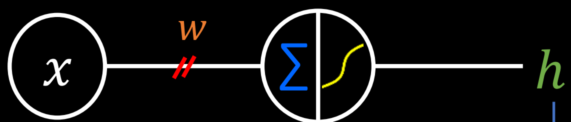
$\rightarrow \ (-2)\,(w) \qquad sigmoid(-2 \cdot w) \rightarrow h \quad : E_1$

$\rightarrow \ (-1)\,(w) \qquad sigmoid(-1 \cdot w) \rightarrow h \quad : E_2$

$\rightarrow \ (1)\,(w) \qquad sigmoid(1 \cdot w) \rightarrow h \quad : E_3$

$\rightarrow \ (2)\,(w) \qquad sigmoid(2 \cdot w) \rightarrow h \quad : E_4$

(4)1-1/C



$[-2., -1, 1, 2]$

$[0., 0, 1, 1]$

$$E = -(y\log(h) + (1-y)\log(1-h))$$

```
#----- training data
x_data = [[-2.], [-1], [1], [2]]
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#------- a neuron
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```

$\rightarrow (-2)\,(w)$ $\quad sigmoid(-2 \cdot w) \rightarrow h \quad : E_1$

$\rightarrow (-1)\,(w)$ $\quad sigmoid(-1 \cdot w) \rightarrow h \quad : E_2$

$\rightarrow (1)\,(w)$ $\quad sigmoid(1 \cdot w) \rightarrow h \quad : E_3$

$\rightarrow (2)\,(w)$ $\quad sigmoid(2 \cdot w) \rightarrow h \quad : E_4$

$$\left.\begin{matrix} E_1 \\ E_2 \\ E_3 \\ E_4 \end{matrix}\right\} \frac{1}{4}\sum \rightarrow E$$ (1 value)

```
#----- training data
x_data = [[-2.], [-1], [1], [2]]
y_data = [[0.], [0], [1], [1]]

#------- a neuron
w = tf.Variable(tf.random_normal([1,1]))
hypo = tf.sigmoid(x_data * w)

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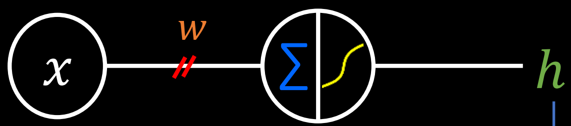
```

(4)1-1/C



$[-2., -1, 1, 2]$

$[0., 0, 1, 1]$

$$E = -(y\log(h) + (1-y)\log(1-h))$$

$\rightarrow (-2)\,(w)$ $\quad sigmoid(-2\cdot w) \rightarrow h \quad : E_1$

$\rightarrow (-1)\,(w)$ $\quad sigmoid(-1\cdot w) \rightarrow h \quad : E_2$

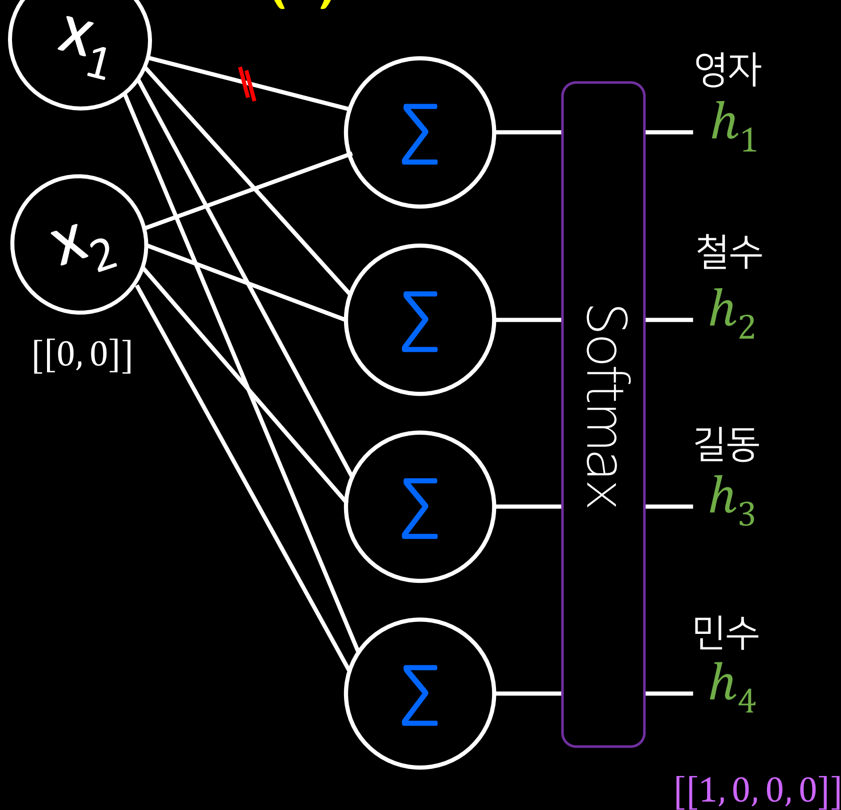
$\rightarrow (1)\,(w)$ $\quad sigmoid(1\cdot w) \rightarrow h \quad : E_3$

$\rightarrow (2)\,(w)$ $\quad sigmoid(2\cdot w) \rightarrow h \quad : E_4$

$\left.\begin{matrix} E_1 \\ E_2 \\ E_3 \\ E_4 \end{matrix}\right\} \frac{1}{4}\sum \rightarrow E$ (1 value)

$$\begin{pmatrix} -2 \\ -1 \\ 1 \\ 2 \end{pmatrix}(w) \qquad \begin{pmatrix} sigmoid(-2\cdot w) \\ sigmoid(-1\cdot w) \\ sigmoid(1\cdot w) \\ sigmoid(2\cdot w) \end{pmatrix}$$

(1)2-4/C




```
#----- training data
x_data = [[0., 0]]
y_data = [[1,0,0,0]]

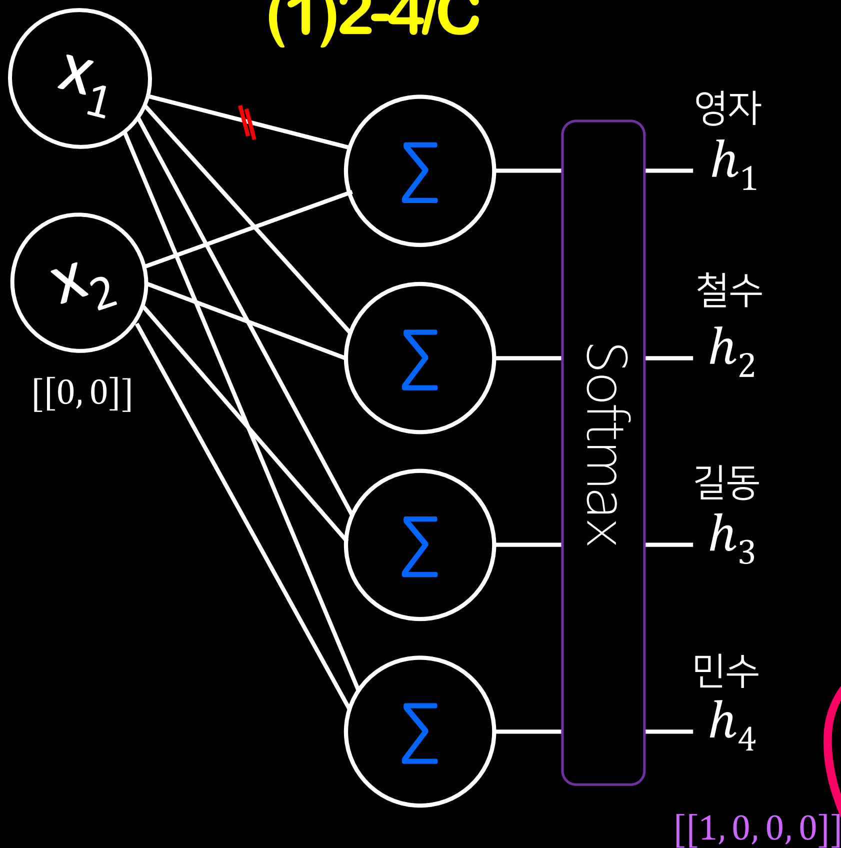
#------- 2 inputs 4 neurons
W = tf.Variable(tf.random_normal([2, 4]))
output = tf.matmul(x_data, W)  # logit (?, 4)

#----- learning
cost = tf.reduce_mean(tf.nn.softmax_cross_
entropy_with_logits(logits=logits, labels=y_data))
```

$$\left((0,0) \begin{pmatrix} w_{11}, w_{21}, w_{31}, w_{41} \\ w_{12}, w_{22}, w_{31}, w_{41} \end{pmatrix} \right)$$

if we add 1 more neuron,
then, 1 more column in weight matrix.

(1)2-4/C




```
#----- training data
x_data = [[0., 0], [0, 1], [1, 0], [1, 1]]
y_data = [[1,0,0,0], [0,1,0,0], [0,0,1,0], [0,0,0,1]]

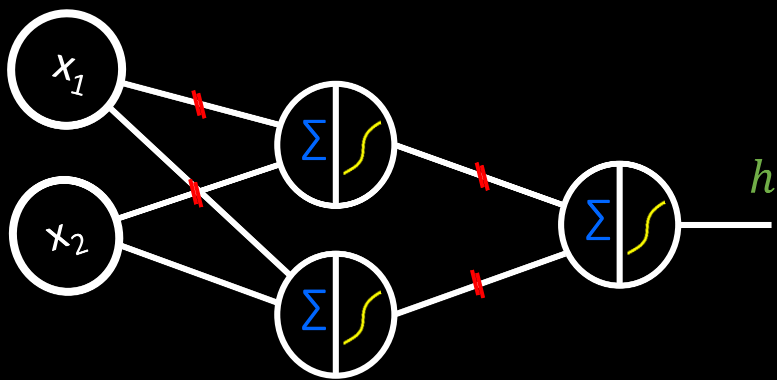
#------- 2 inputs 4 neurons
W = tf.Variable(tf.random_normal([2, 4]))
output = tf.matmul(x_data, W)  # logit (?, 4)

#----- learning
cost = tf.reduce_mean(tf.nn.softmax_cross_
entropy_with_logits(logits=logits, labels=y_data))
```

$$\left(\begin{pmatrix} 0, 0 \\ 0, 1 \\ 1, 0 \\ 1, 1 \end{pmatrix} \begin{pmatrix} w_{11}, w_{21}, w_{31}, w_{41} \\ w_{12}, w_{22}, w_{31}, w_{41} \end{pmatrix} \right)$$

Add 3 more data instances.

(4)2-2-1/C



$$\begin{pmatrix} 0,0 \\ 0,1 \\ 1,0 \\ 1,1 \end{pmatrix} \quad \begin{pmatrix} w_{11}^1, w_{21}^1 \\ w_{12}^1, w_{22}^1 \end{pmatrix} \quad \begin{pmatrix} w_1^2 \\ w_1^2 \end{pmatrix} \longrightarrow h$$

$$(4 \times 2) \quad (2 \times 2) \quad (2 \times 1) \quad (4 \times 1)$$

```
#----- training data
x_data = [[0., 0], [0, 1], [1, 0], [1, 1]]
y_data = [[0], [1], [1], [0]]

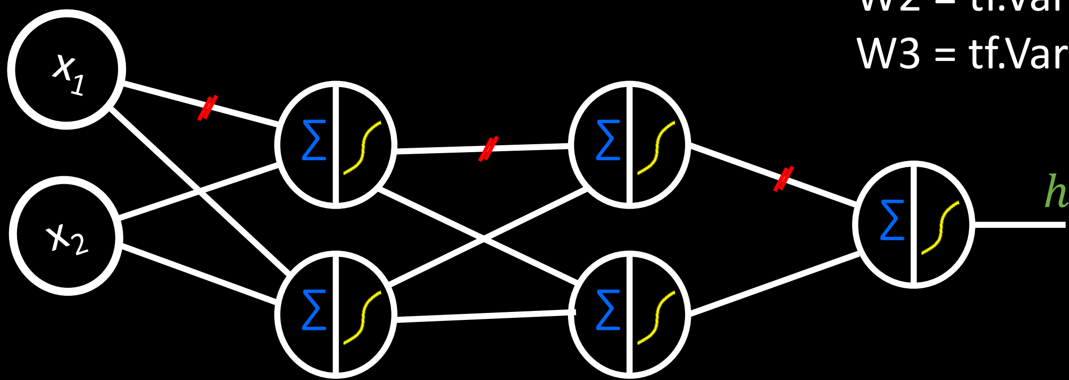
#------- 2 neurons + 1 neuron
W1 = tf.Variable(tf.random_normal([2, 2]))
b1 = tf.Variable(tf.random_normal([2]))
output1 = tf.sigmoid(tf.matmul(x_data, W1) + b1)

W2 = tf.Variable(tf.random_normal([2, 1]))
b2 = tf.Variable(tf.random_normal([1]))
hypo = tf.sigmoid(tf.matmul(output1, W2) + b2)

#----- learning
cost = -tf.reduce_mean(y_data * tf.log(hypo) +
        tf.subtract(1., y_data) * tf.log(tf.subtract(1., hypo)))
```

(4)2-2-2-1/C

```
x_data = [[0., 0], [0, 1], [1, 0], [1, 1]]
y_data = [[0], [1], [1], [0]]
W1 = tf.Variable(tf.random_normal([2, 2]))
W2 = tf.Variable(tf.random_normal([2, 2]))
W3 = tf.Variable(tf.random_normal([2, 1]))
```



$$\begin{pmatrix} 0,0 \\ 0,1 \\ 1,0 \\ 1,1 \end{pmatrix} \quad \begin{pmatrix} w_{11}^1, w_{21}^1 \\ w_{12}^1, w_{22}^1 \end{pmatrix} \quad \begin{pmatrix} w_{11}^2, w_{21}^2 \\ w_{12}^2, w_{22}^2 \end{pmatrix} \quad \begin{pmatrix} w_1^3 \\ w_1^3 \end{pmatrix} \longrightarrow h$$

$$(4 \times 2) \quad (2 \times 2) \quad (2 \times 2) \quad (2 \times 1) \quad (4 \times 1)$$

(n)784-10/C

(n)784-256-256-10/C

(n)784-512-512-512-512-10/C