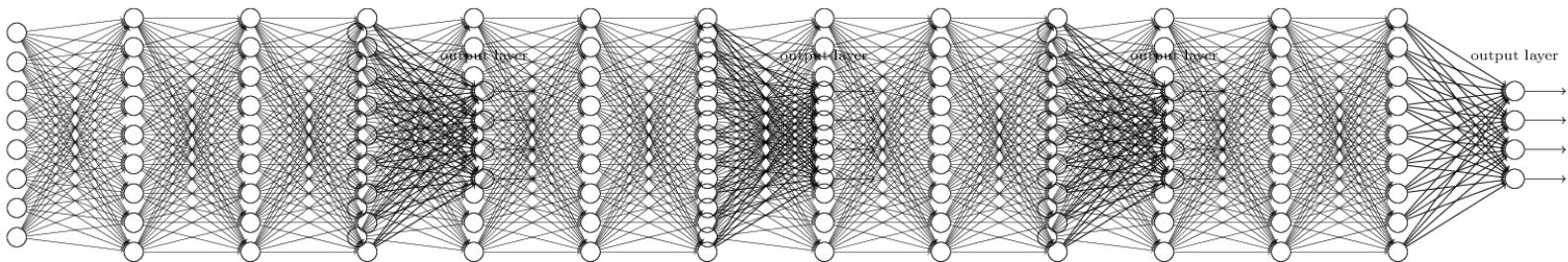


NN Backpropagation

Lecture 09

Back propagation : How to train?



Gradient descent algorithm

$$cost(W) = \frac{1}{2m} \sum_{i=1}^m (Wx^{(i)} - y^{(i)})^2$$

learning_rate

$$W := W - \alpha \frac{\partial}{\partial W} cost(W)$$

$$W := W - \alpha \frac{1}{m} \sum_{i=1}^m (Wx^{(i)} - y^{(i)})x^{(i)}$$

Gradient descent algorithm : Tensorflow

$$cost(W) = \frac{1}{2m} \sum_{i=1}^m (Wx^{(i)} - y^{(i)})^2$$

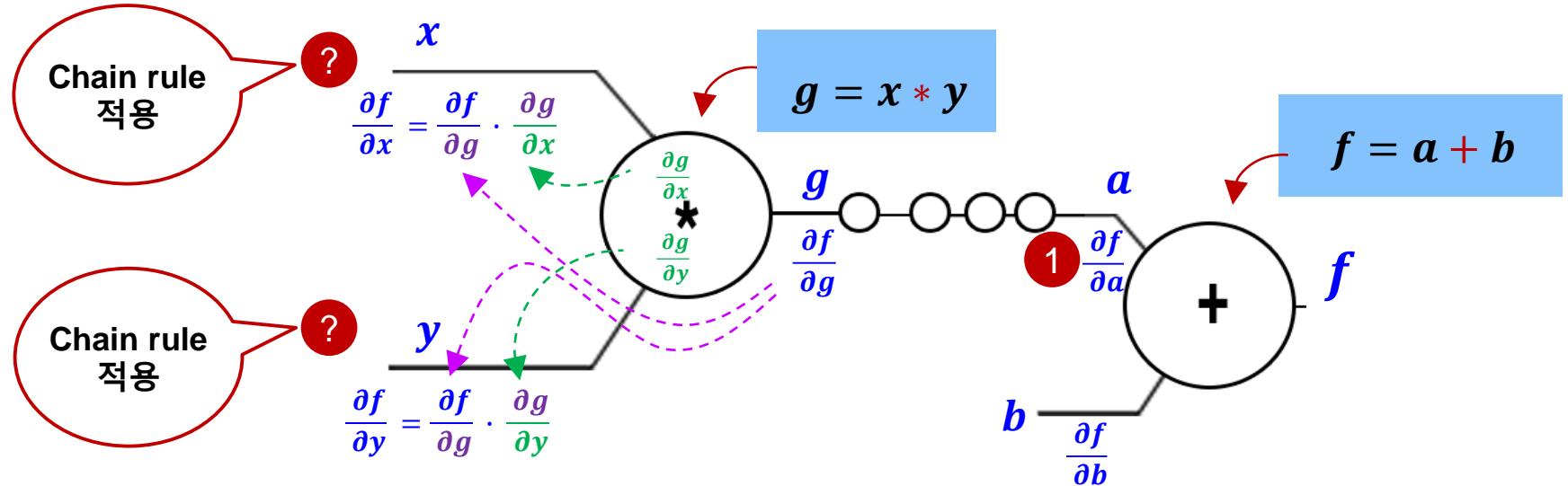
$$W := W - \alpha \frac{\partial}{\partial W} cost(W)$$

learning_rate
↓



```
train = tf.train.GradientDescentOptimizer(learning_rate=0.1).minimize(cost)
```

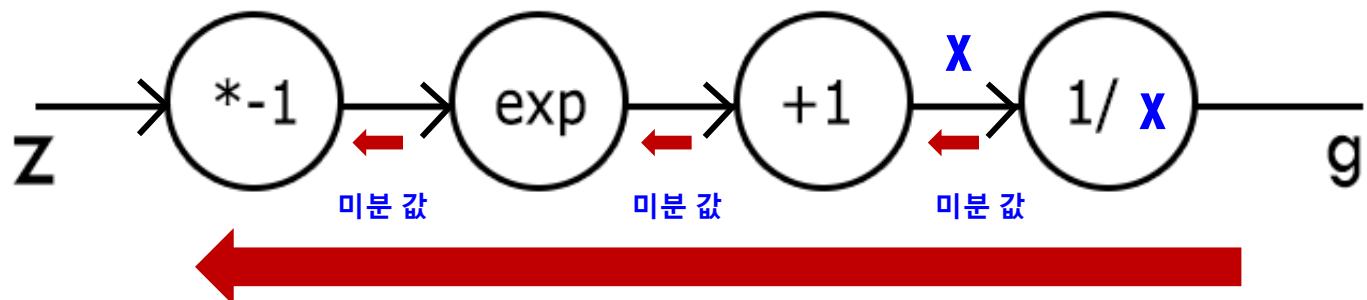
Back propagation (chain rule)



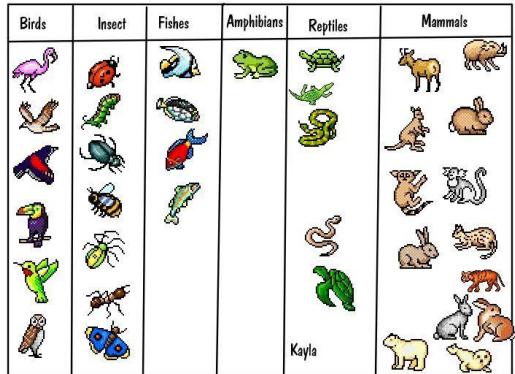
Back propagation (chain rule) : Sigmoid

$$g(z) = \frac{1}{1 + e^{-z}} \quad \rightarrow \quad ? \frac{\partial g}{\partial z}$$

A blue arrow points from the variable x to the term $1 + e^{-z}$ in the denominator of the sigmoid function.



Animal classification



x_data

1	0	0	1	0	0	0	1	1	0	0	4	1	0	1	0	1	0	0	3
0	0	1	0	0	1	1	1	1	0	0	1	0	1	0	0	1	0	0	0
1	0	0	1	0	0	1	1	1	1	0	0	4	0	0	0	1	0	0	1
1	0	0	1	0	0	1	1	1	1	0	0	4	1	0	0	1	0	0	0
1	0	0	1	0	0	0	1	1	1	0	0	4	1	0	0	1	0	0	0
1	0	0	1	0	0	0	0	1	1	1	0	0	4	1	1	1	1	0	0
0	0	1	0	0	1	0	1	1	1	0	0	1	0	1	1	0	1	0	3
0	0	1	0	0	1	1	1	1	1	0	0	1	0	1	0	0	1	0	3
1	0	0	1	0	0	0	1	1	1	1	0	0	4	0	0	1	0	0	0
1	0	0	1	0	0	0	1	1	1	1	0	0	4	1	0	0	1	0	0
0	1	1	0	1	0	0	0	1	1	1	0	0	2	1	1	0	0	1	1
0	0	1	0	0	0	1	1	1	1	0	0	1	0	1	0	0	0	1	3
0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	6
0	0	1	0	0	0	1	1	0	0	0	0	4	0	0	0	0	0	0	6
0	0	1	0	0	0	1	1	0	0	0	0	6	0	0	0	0	0	0	6
0	1	1	0	1	0	1	0	1	0	0	0	2	1	0	0	0	0	1	1
1	0	0	1	0	0	0	1	1	1	1	0	0	4	1	0	0	1	0	0

y_data
0~6

Predicting animal type based on various features

```
xy = np.loadtxt('g:\data-04-zoo.csv', delimiter=',', dtype=np.float32)
x_data = xy[:, 0:-1]
y_data = xy[:, [-1]]
```

```

import tensorflow as tf
import numpy as np
tf.set_random_seed(777) # for reproducibility

# Predicting animal type based on various features
xy = np.loadtxt('g:\data-04-zoo.csv', delimiter=',', dtype=np.float32)
x_data = xy[:, 0:-1] # column : 16
N = x_data.shape[0] # [0]column의 row 개수 101 0] 출력됨 → N 은 101 0/].
y_data = xy[:, [-1]] # column : 1

# y_data has labels from 0 ~ 6
print("v has one of the following values")
print(np.unique(y_data)) # [0. 1. 2. 3. 4. 5. 6.] 출력됨

# X_data.shape = (101, 16) => 101 samples, 16 features
# v data.shape = (101, 1) => 101 samples, 1 label
print("Shape of X data: ", x_data.shape) # (101, 16) 출력됨
print("Shape of y data: ", y_data.shape) # (101, 1) 출력됨

nb_classes = 7 # 0 ~ 6

x = tf.placeholder(tf.float32, [None, 16])
y = tf.placeholder(tf.int32, [None, 1]) # 0 ~ 6

target1 = tf.one_hot(y, nb_classes) # one hot : ex) [[[1. 0. 0. 0. 0. 0. 0.]] [... 이럴게 one hot 형태로 101개 출력
target2= tf.reshape(target1, [-1, nb_classes])
target3 = tf.cast(target2, tf.float32)

W = tf.Variable(tf.random_normal([16, nb_classes]), name='weight')
b = tf.Variable(tf.random_normal([nb_classes]), name='bias')

```

Backpropagation (Without using the gradient descent algorithm)

S def sigma(x):
 # sigmoid function
 # $\sigma(x) = 1 / (1 + \exp(-x))$
 return 1. / (1. + tf.exp(-x))

sp def sigma_prime(x):
 # derivative of the sigmoid function
 # $\sigma'(x) = \sigma(x) * (1 - \sigma(x))$

$$g(z) = \frac{1}{1 + e^{-z}}$$

$$\frac{\partial g}{\partial z}$$

Backpropagation

(Without using the gradient descent algorithm)

Forward propagation

layer_1 = tf.matmul(X, W) + b
 y_pred = sigma(layer_1) # $g(z)$, sigmoid 출력

S # Loss Function (end of forward propagation), target3 : one-hot (True value Y) , y_pred: sigmoid
 loss_i = - target3 * tf.log(y_pred) - (1. - target3) * tf.log(1. - y_pred)
 loss = tf.reduce_sum(loss_i)

Dimension Check
 assert y_pred.shape.as_list() == target3.shape.as_list() # assert 는 == 0이 아닙니다 error 처리

Back prop (chain rule)

How to derive? please read "Neural Net Backprop in one slide!"

```

sp
d_loss = (y_pred - target3) / (y_pred * (1. - y_pred) + 1e-7)
d_sigma = sigma_prime(layer_1)
d_layer = d_loss * d_sigma
d_b = d_layer # backpropagation 의 b 값 계산
d_W = tf.matmul(tf.transpose(x), d_layer) # transpose(x)는 x를 전치함
                                         # backpropagation 의 W 값 계산

```

Updating network using gradients (backpropagation 의 b, W 값 할당)

```

learning_rate = 0.01
train_step = [
    tf.assign(W, W - learning_rate * d_W), # W를 W - learning_rate * d_W으로 할당한다.
    tf.assign(b, b - learning_rate * tf.reduce_sum(d_b)), # b를 b - learning_rate * tf.reduce_sum(d_b)으로 할당한다.
]

```

Prediction and Accuracy

```

prediction = tf.argmax(y_pred, 1)
acct_mat = tf.equal(tf.argmax(y_pred, 1), tf.argmax(target3, 1))
acct_res = tf.reduce_mean(tf.cast(acct_mat, tf.float32))

```

Backpropagation

(Without using the gradient descent algorithm)

```
# Launch graph
with tf.Session() as sess:
    sess.run(tf.global_variables_initializer())
```

```
for step in range(500):
    # Back prop (chain rule)를 적용한 W, b를 할당하기 위해선
    sess.run(train_step, feed_dict={X: x_data, y: y_data})

    if step % 10 == 0:
        # Within 300 steps, you should see an accuracy of 100%
        step_loss, acc = sess.run([loss, acc], feed_dict={X: x_data, y: y_data})
        print("Step: {:5}\t Loss: {:.10f}\t Acc: {:.2%}" .format(step, step_loss, acc))
```

```
# Let's see if we can predict
pred = sess.run(prediction, feed_dict={X: x_data})
line = 0
for p, y in zip(pred, y_data):
    line += 1
    msg = "[{}]\t Prediction: {:d}\t True y: {:d}"
    print("Line :" ,line, "--> ",msg.format(p == int(y[0]), p, int(y[0])))
```

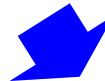
Backpropagation

(Without using the gradient descent algorithm)

```
# Predicting animal type based on various features
xy = np.loadtxt('g:\\data-04-zoo.csv', delimiter=',', dtype=np.float32)
x_data = xy[:, 0:-1] # column : 16
N = x_data.shape[0] # [0]열의 행의 개수 101 이 출력됨 → N 은 101 이다.
Y_data = xy[:, [-1]] # column : 1

# y_data has labels from 0 ~ 6
Print("y has one of the following values ")
Print(np.unique(y_data)) # [0. 1. 2. 3. 4. 5. 6.] 출력됨

# X_data.shape = (101, 16) => 101 samples, 16 features
# y_data.shape = (101, 1)  => 101 samples, 1 label
print("Shape of X data: ", x_data.shape) # (101, 16) 출력됨
print("Shape of y data: ", y_data.shape) # (101, 1) 출력됨
```



```
y has one of the following values
[0. 1. 2. 3. 4. 5. 6.]
Shape of X data: (101, 16)
Shape of y data: (101, 1)
```

```
target1 = tf.one_hot(y, nb_classes) # ex) [[[1. 0. 0. 0. 0. 0. 0. 0.]] [[..이렇게 one hot 형태로 101개 출력  
target2 = tf.reshape(target1, [-1, nb_classes])  
target3 = tf.cast(target2, tf.float32)
```

ex09_1 (propagation).ipynb

(Notes)

```
# Launch graph
with tf.Session() as sess:
    sess.run(tf.global_variables_initializer())
    print("target1 :",sess.run(target1, feed_dict={X: x_data, y: y_data}))
    print("target2 :",sess.run(target2, feed_dict={X: x_data, y: y_data}))
    print("target3 :",sess.run(target3, feed_dict={X: x_data, y: y_data}))
```

추가해서
확인 !!

```
target1 = tf.one_hot(y, nb_classes)

target1 : [[[1. 0. 0. 0. 0. 0. 0. 0.]]]
          [[1. 0. 0. 0. 0. 0. 0. 0.]]
          [[0. 0. 0. 1. 0. 0. 0. 0.]]
          [[1. 0. 0. 0. 0. 0. 0. 0.]]
          [[1. 0. 0. 0. 0. 0. 0. 0.]]
          [[1. 0. 0. 0. 0. 0. 0. 0.]]
```

```
target2 = tf.reshape(target1, [-1, nb_classes])
```



```
target2 : [[1. 0. 0. 0. 0. 0. 0. 0.]  
          [1. 0. 0. 0. 0. 0. 0. 0.]  
          [0. 0. 0. 1. 0. 0. 0. 0.]  
          [1. 0. 0. 0. 0. 0. 0. 0.]  
          [1. 0. 0. 0. 0. 0. 0. 0.]  
          [1. 0. 0. 0. 0. 0. 0. 0.]  
          [1. 0. 0. 0. 0. 0. 0. 0.]  
          [0. 0. 0. 1. 0. 0. 0. 0.]]
```

```
target3 = tf.cast(target2, tf.float32)

target3 : [[1. 0. 0. 0. 0. 0. 0. 0.]
           [1. 0. 0. 0. 0. 0. 0. 0.]
           [0. 0. 0. 1. 0. 0. 0. 0.]
           [1. 0. 0. 0. 0. 0. 0. 0.]
           [1. 0. 0. 0. 0. 0. 0. 0.]
           [1. 0. 0. 0. 0. 0. 0. 0.]
           [1. 0. 0. 0. 0. 0. 0. 0.]]
```

ex09_1 (propagation).ipynb

(Notes)

```
target1 = tf.one_hot(y, nb_classes) # ex) [[1. 0. 0. 0. 0. 0. 0.]] 이렇게 one hot 형태로 101개 출력
target2 = tf.reshape(target1, [-1, nb_classes])
target3 = tf.cast(target2, tf.float32)
```

```
# Forward propagation
layer_1 = tf.matmul(X, W) + b
y_pred = sigma(layer_1) # Layer_1 각 행에서 표준편차

# Loss Function (end of forward propagation)
loss_i = - target3 * tf.log(y_pred) - (1. - target3) * tf.log(1. - y_pred)
loss = tf.reduce_sum(loss_i)
```

```
# Dimension Check
assert y_pred.shape.as_list() == target3.shape.as_list()
```

```
# Prediction and Accuracy
prediction = tf.argmax(y_pred, 1)
acct_mat = tf.equal(tf.argmax(y_pred, 1), tf.argmax(target3, 1))
acct_res = tf.reduce_mean(tf.cast(acct_mat, tf.float32))
```

```
# Launch graph
with tf.Session() as sess:
    sess.run(tf.global_variables_initializer())
```

```
print("• layer_1 \n", sess.run(layer_1, feed_dict={X: x_data, y: y_data}))
print("• y_pred \n", sess.run(y_pred, feed_dict={X: x_data, y: y_data}))
```

- layer_1


```
[-1.03140700e+00 -7.79828429e-02  3.71772528e+00  6.74435520e+00
       -8.10283566e+00 -1.14475656e+00  8.27225494e+00]
      [-3.32648945e+00  6.78884089e-01  3.46578169e+00  7.85745239e+00
       -8.47612953e+00 -3.18839216e+00  9.72614765e+00]
      [ 2.57165432e+00  3.03211141e+00  4.04691076e+00  3.67466688e+00
       -7.77052164e-01 -4.31904793e-02  3.20639515e+00]
```
- .
- .
- .
- y_pred


```
[2.62811422e-01 4.80514139e-01 9.76286829e-01 9.98823822e-01
       3.02588043e-04 2.41448119e-01 9.99744594e-01]
      [3.46735418e-02 6.63489640e-01 9.69698310e-01 9.99613345e-01
       2.08340265e-04 3.96048911e-02 9.99940276e-01]
      [9.29014921e-01 9.54003930e-01 9.82823849e-01 9.75269258e-01
       3.14955562e-01 4.89204049e-01 9.61074293e-01]
```
- .
- .
- .

추가해서
확인 !!



```
target1 = tf.one_hot(y, nb_classes) # ex) [[1. 0. 0. 0. 0. 0. 0.]] 이렇게 one hot 형태로 101개 출력
target2 = tf.reshape(target1, [-1, nb_classes])
target3 = tf.cast(target2, tf.float32)
```

ex09_1 (propagation).ipynb

(Notes)

```
# Forward propagation
layer_1 = tf.matmul(X, W) + b
y_pred = sigma(layer_1) # Layer_1 각 행에서 표준편차
```

$$C(H(x), y) = -y \log(H(x)) - (1-y) \log(1-H(x))$$

```
# Loss Function (end of forward propagation)
loss_i = - target3 * tf.log(y_pred) - (1. - target3) * tf.log(1. - y_pred)
loss = tf.reduce_sum(loss_i)
```

```
# Dimension Check
assert y_pred.shape.as_list() == target3.shape.as_list()
```

```
# Prediction and Accuracy
prediction = tf.argmax(y_pred, 1)
acct_mat = tf.equal(tf.argmax(y_pred, 1), tf.argmax(target3, 1))
acct_res = tf.reduce_mean(tf.cast(acct_mat, tf.float32))
```

```
# Launch graph
with tf.Session() as sess:
    sess.run(tf.global_variables_initializer())
```

```
for step in range(500):
    sess.run(train_step, feed_dict={X: x_data, y: y_data})

    if step % 10 == 0:
        # Within 300 steps, you should see an accuracy of 100%
        step_loss, acc = sess.run([loss, acct_res], feed_dict={X: x_data, y: y_data})
        print("Step: {:5}\t Loss: {:.10f}\t Acc: {:.2%}" .format(step, step_loss, acc))
```

Step: 0	Loss: 560.45282	Acc: 36.63%
Step: 10	Loss: 120.88565	Acc: 81.19%
Step: 20	Loss: 86.91508	Acc: 83.17%
Step: 30	Loss: 71.21052	Acc: 89.11%
Step: 40	Loss: 61.65193	Acc: 89.11%
Step: 50	Loss: 54.69436	Acc: 93.07%
.	.	.
Step: 450	Loss: 12.54190	Acc: 100.00%
Step: 460	Loss: 12.33679	Acc: 100.00%
Step: 470	Loss: 12.13882	Acc: 100.00%
Step: 480	Loss: 11.94763	Acc: 100.00%
Step: 490	Loss: 11.76283	Acc: 100.00%



```
target1 = tf.one_hot(y, nb_classes) # ex) [[1. 0. 0. 0. 0. 0. 0.]] 이렇게 one hot 형태로 101개 출력
target2 = tf.reshape(target1, [-1, nb_classes])
target3 = tf.cast(target2, tf.float32)
```

ex09_1 (propagation).ipynb

(Notes)

```
# Forward propagation
layer_1 = tf.matmul(X, W) + b
y_pred = sigma(layer_1) # Layer_1 각 행에서 표준편차
```

```
# Loss Function (end of forward propagation)
loss_i = - target3 * tf.log(y_pred) - (1. - target3) * tf.log(1. - y_pred)
loss = tf.reduce_sum(loss_i)
```

```
# Dimension Check
assert y_pred.shape.as_list() == target3.shape.as_list()
```

```
# Prediction and Accuracy
prediction = tf.argmax(y_pred, 1)
```

```
acct_mat = tf.equal(tf.argmax(y_pred, 1), tf.argmax(target3, 1))
acct_res = tf.reduce_mean(tf.cast(acct_mat, tf.float32))
```

```
# Launch graph
with tf.Session() as sess:
    sess.run(tf.global_variables_initializer())
```

```
for step in range(500):
    sess.run(train_step, feed_dict={X: x_data, y: y_data})
```

```
if step % 10 == 0:
    # Within 300 steps, you should see an accuracy of 100%
    step_loss, acc = sess.run([loss, acct_res], feed_dict={X: x_data, y: y_data})
    print("Step: {:5}\t Loss: {:.10.5f}\t Acc: {:.2%}" .format(step, step_loss, acc))
```

Step: 0	Loss: 560.45282	Acc: 36.63%
Step: 10	Loss: 120.88565	Acc: 81.19%
Step: 20	Loss: 86.91508	Acc: 83.17%
Step: 30	Loss: 71.21052	Acc: 89.11%
Step: 40	Loss: 61.65193	Acc: 89.11%
Step: 50	Loss: 54.69436	Acc: 93.07%
.	.	.
Step: 450	Loss: 12.54190	Acc: 100.00%
Step: 460	Loss: 12.33679	Acc: 100.00%
Step: 470	Loss: 12.13882	Acc: 100.00%
Step: 480	Loss: 11.94763	Acc: 100.00%
Step: 490	Loss: 11.76283	Acc: 100.00%



Accuracy values from Step 0 to Step 500.

```
# Prediction and Accuracy
prediction = tf.argmax(y_pred, 1) # 예측한 y_pred에서 제일 큰 값이 있는 열 위치
```

```
# Launch graph
with tf.Session() as sess:
    sess.run(tf.global_variables_initializer())

    for step in range(500):
        sess.run(train_step, feed_dict={X: x_data, y: y_data})

        if step % 10 == 0:
            # Within 300 steps, you should see an accuracy of 100%
            step_loss, acc = sess.run([loss, acct_res], feed_dict={X: x_data, y: y_data})
            print("Step: {:5}\t Loss: {:.10f}\t Acc: {:.2%}" .format(step, step_loss, acc))

# Let's see if we can predict
    # 예측한 y_pred에서 제일 큰 값이 있는 열 위치
pred = sess.run(prediction, feed_dict={X: x_data})
line = 0
for p, y in zip(pred, y_data):
    line += 1
    msg = "[{}]\t Prediction: {:d}\t True y: {:d} "
    print("Line : " ,line, "-->",msg.format(p == int(y[0]), p, int(y[0])))
    # p == int(y[0]) : 예측한 y_pred에서 제일 큰 값이 있는 열 위치와 True value (y[0]) 이 같은 값인지 비교하여 같으면 True 출력
    # p : 예측한 y pred에서 제일 큰 값이 있는 열 위치 출력
    # int(y[0]) : True value (y[0]) 출력
```

ex09_1 (propagation).ipynb

(Notes)

```
Line : 1 --> [True] Prediction: 0 True y: 0
Line : 2 --> [True] Prediction: 0 True y: 0
Line : 3 --> [True] Prediction: 3 True y: 3
Line : 4 --> [True] Prediction: 0 True y: 0
Line : 5 --> [True] Prediction: 0 True y: 0
Line : 6 --> [True] Prediction: 0 True y: 0
Line : 7 --> [True] Prediction: 0 True y: 0
.
.
.
Line : 97 --> [True] Prediction: 0 True y: 0
Line : 98 --> [True] Prediction: 5 True y: 5
Line : 99 --> [True] Prediction: 0 True y: 0
Line : 100 --> [True] Prediction: 6 True y: 6
Line : 101 --> [True] Prediction: 1 True y: 1
```

