Logistic regression for a binary classification with a non-linear classification boundary - 20145822 김영현

Training Code

```
import numpy as np
import matplotlib.pyplot as plt
import math

# data input
data    = np.genfromtxt("/content/drive/My Drive/Colab Notebooks/data06/data-nonlinear.txt", delimiter=',')

pointX  = data[:, 0]
pointY  = data[:, 1]
label   = data[:, 2]

pointX0 = pointX[label == 0]
pointY0 = pointY[label == 0]

pointX1 = pointX[label == 1]
pointY1 = pointY[label == 1]

# function definition
# calculate f_k value
def func_k_calc(x, y, x_exp, y_exp):
  return (x ** x_exp) * (y ** y_exp)
# calculate g function value
def func_calc(theta_list, x, y, dim_list):
  func_val = 0
  for i in range(len(theta_list)):
```

```
    func_val += theta_list[i] * func_k_calc(x, y, dim_list[i][0], dim_list[i][1])
  return func_val
# calculate z values
def z_calc(theta_list, pointX, pointY, dim_list):
  z = []
  for i in range(len(pointX)):
    z_iteration = func_calc(theta_list, pointX[i], pointY[i], dim_list)
    z.append(z_iteration)
  return z
# calculate sigmoid values
def calc_sigmoid(z):
  sigmoid = []
  for i in range(len(z)):
    sigmoid.append(1/(1+math.exp(-z[i])))
  return sigmoid
# calculate objective function value
def ob_func(label, sigmoid):
  sum = 0
  for i in range(len(label)):
    oprd_left = (-1*label[i]) * math.log(sigmoid[i])
    oprd_right = (1-label[i]) * math.log(1-sigmoid[i])
    sum += oprd_left - oprd_right
  return sum/len(label)
# calculate next theta value
def theta_desc(theta_list, alpha, pointX, pointY, label, sigmoid, dim_list):
  sum = [0, 0, 0, 0, 0, 0]
  for i in range(len(sigmoid)):
    for j in range(len(theta_list)):
      sum[j] += (sigmoid[i] - label[i]) * func_k_calc(pointX[i], pointY[i], dim_list[j][0], dim_list[j][1])

  for i in range(len(theta_list)):
    sum[i] = sum[i] / len(sigmoid) * alpha
    theta_list[i] = theta_list[i] - sum[i]

  return theta_list

# initialize g(x, y, theta) function
theta_list = [1, 1, 1, 1, 1, 1]
```

```
theta_list = [1,1,1,1,1,1]
dim_list = [[0,0],
            [1,0],
            [0,1],
            [2,0],
            [1,1],
            [0,2]]
# variable initialization
alpha = 0.001
iteration = 0
# variable list for store iteration data
ob_func_list = []
theta_desc_list = []
accuracy_list = []
# iteration
while True:
  # calculate each value for this iteration
  z_list = z_calc(theta_list, pointX, pointY, dim_list)
  sigmoid_list = calc_sigmoid(z_list)
  ob_func_val = ob_func(label, sigmoid_list)
  # store predictions
  predictions = []
  p_count = 0
  for i in z_list:
    if i < 0:
      predictions.append(0)
    else:
      predictions.append(1)
  # calculate accuracy
  acc_hit = 0
  for i in range(len(label)):
    if label[i] == predictions[i]:
      acc_hit += 1
  accuracy_list.append(acc_hit/len(label) * 100)
  # store each value
  theta_desc_list.append(theta_list)
  ob_func_list.append(ob_func_val)
  # escape rule
```

```
  if iteration > 0:
    if abs(ob_func_list[iteration] - ob_func_list[iteration-1]) < 0.00000001:
      break
  # update next theta values & iteration value
  theta_list = theta_desc(theta_list, alpha, pointX, pointY, label, sigmoid_list, dim_list)
  iteration += 1

print("Training finished with")
print("iteration : ", iteration)
print("training error : ", ob_func_list[-1])
print("theta : ", theta_desc_list[-1])
print("final accuracy : ", accuracy_list[-1])

iterations = [i for i in range(iteration+1)]
```

```
Training finished with
iteration :  1421848
training error :  0.3538469246412979
theta :  [4.240730905637933, 2.522055652945009, 3.301065516913026, -9.847801209401586, -5.746735424916975, -9.528838799692313]
final accuracy :  85.59322033898306
```

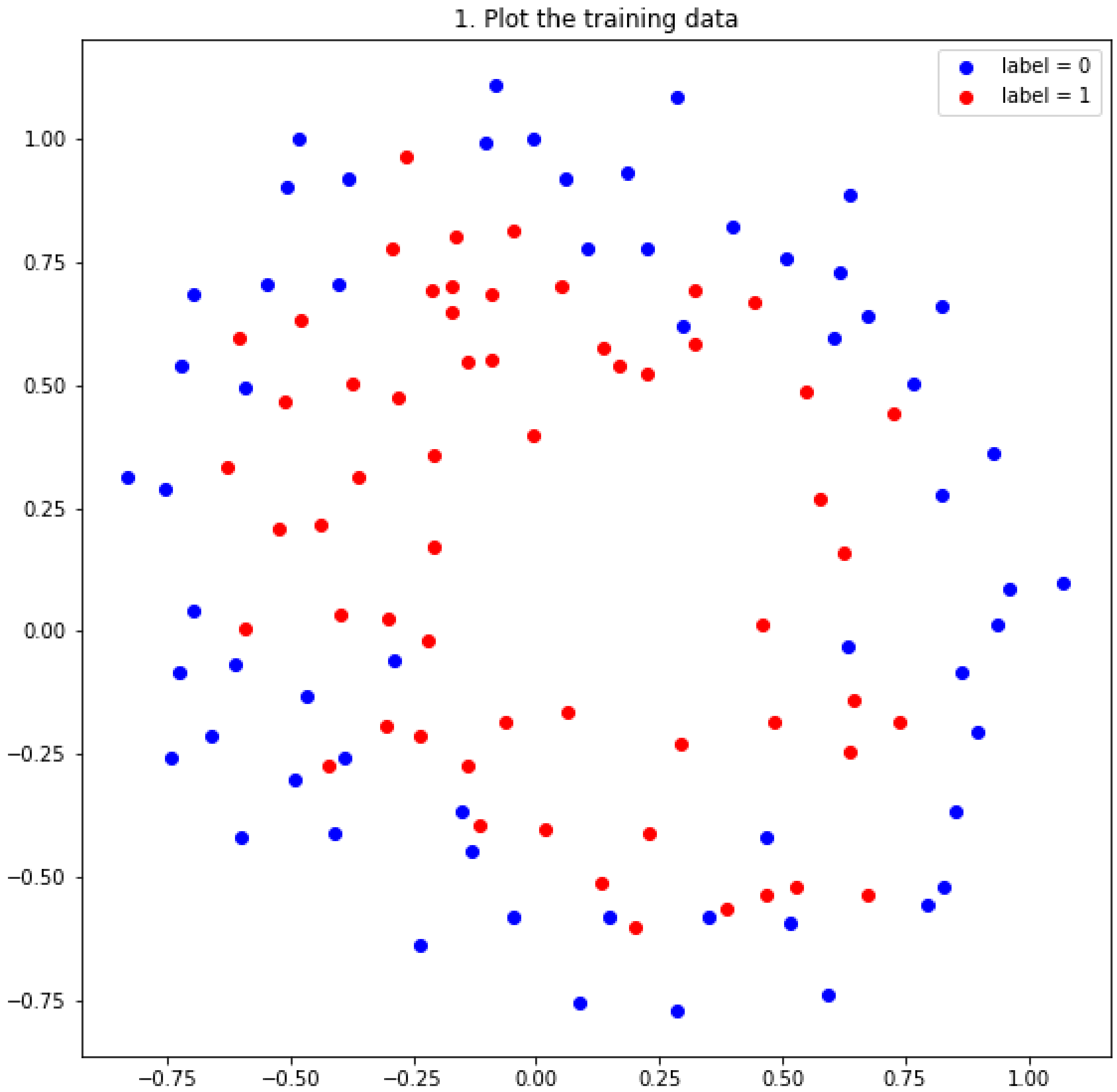
Submission

---

1. Plot the training data

```
import numpy as np
import matplotlib.pyplot as plt
import math
# 1. Plot the training data
plt.figure(figsize=(8,8))
plt.title("1. Plot the training data")
plt.scatter(pointX0, pointY0, c='b', label='label = 0')
plt.scatter(pointX1, pointY1, c='r', label='label = 1')
plt.tight_layout()
```

```
plt.tight_layout()
plt.gca().set_aspect('equal', adjustable='box')
plt.legend()
plt.show()
```

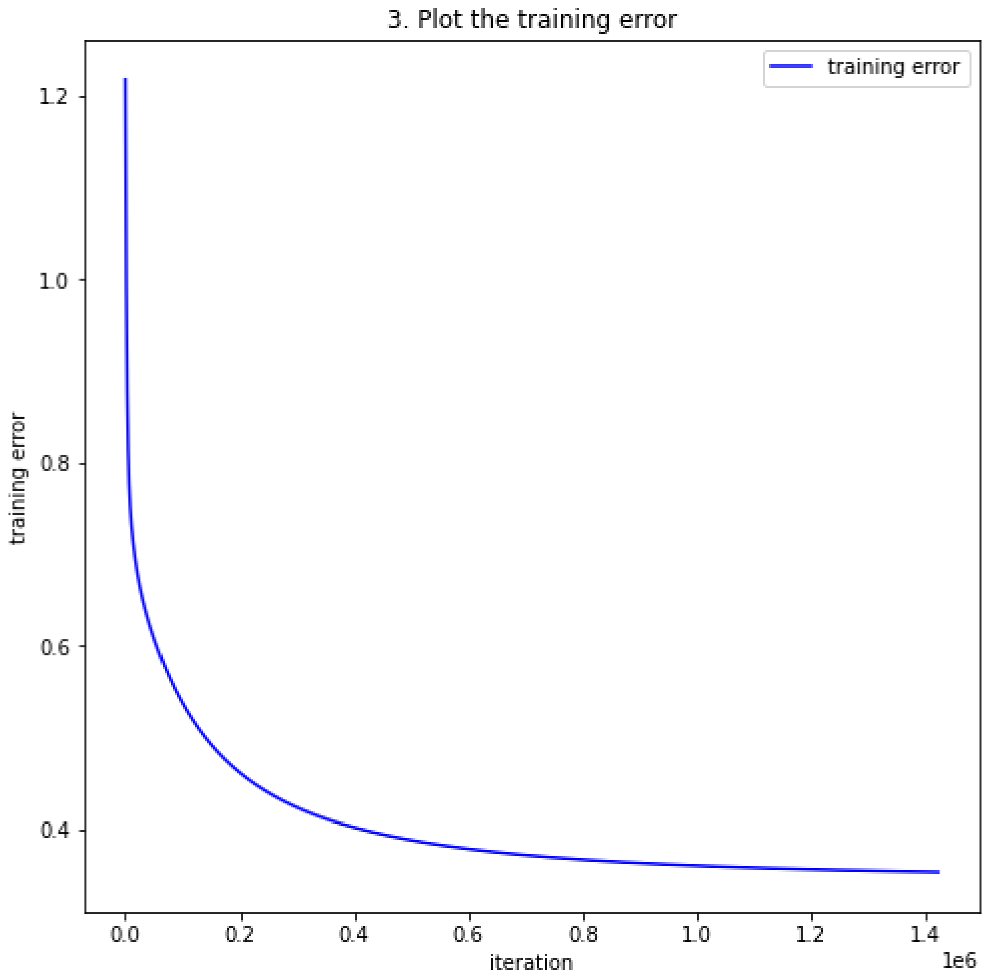


2. Write down the high dimensional function $g(x, y, \theta)$

- $g(x, y, \theta) = \theta_0 f_0(x, y) + \theta_1 f_1(x, y) + \theta_2 f_2(x, y) + \theta_3 f_3(x, y) + \theta_4 f_4(x, y) + \theta_5 f_5(x, y)$ with each function
  - $f_0(x, y) = 1$
  - $f_1(x, y) = x$
  - $f_2(x, y) = y$
  - $f_3(x, y) = x^2$
  - $f_4(x, y) = xy$
  - $f_5(x, y) = y^2$
- same as, $g(x, y, \theta) = \theta_0 + \theta_1 x + \theta_2 y + \theta_3 x^2 + \theta_4 xy + \theta_5 y^2$
- The initial value of all θ was set to 1.

3. Plot the training error

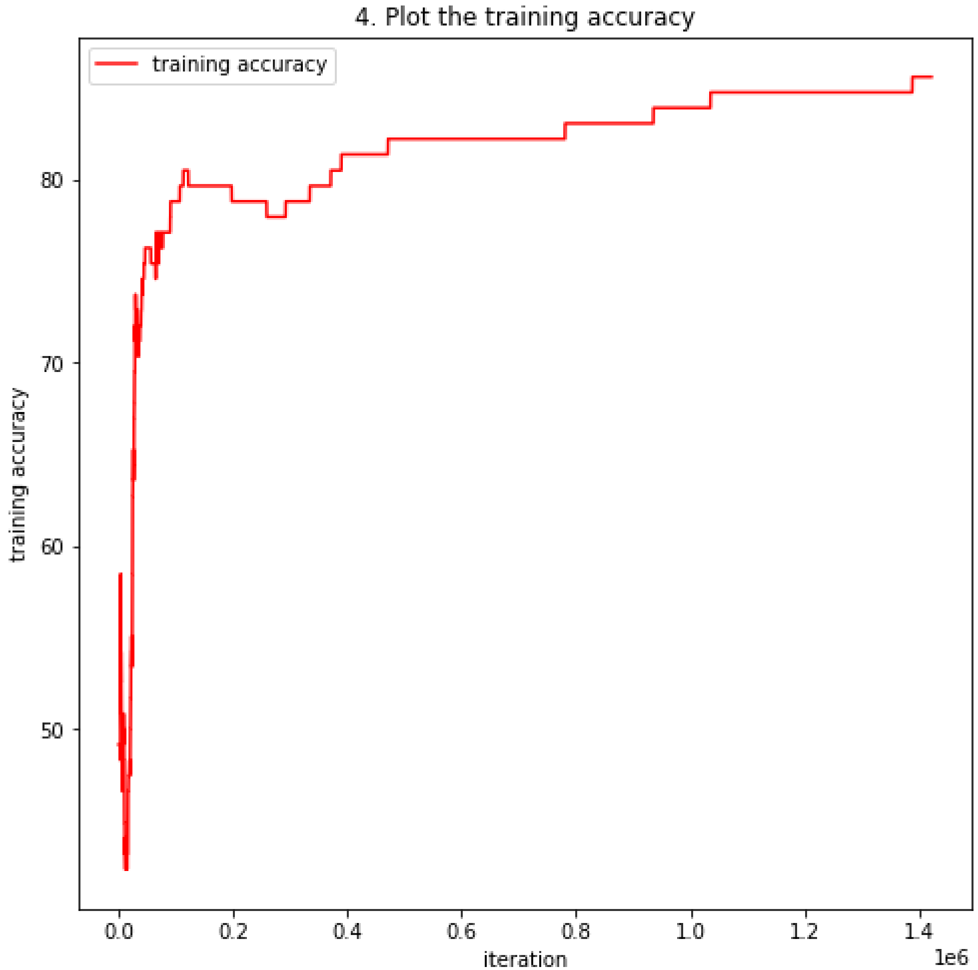
```
import numpy as np
import matplotlib.pyplot as plt
import math
# 3. Plot the training error
plt.figure(figsize=(8,8))
plt.title("3. Plot the training error")
plt.xlabel('iteration')
plt.ylabel('training error')
plt.plot(iterations, ob_func_list, c='b', label='training error')
plt.legend()
plt.show()
```



4. Plot the training accuracy

```
import numpy as np
import matplotlib.pyplot as plt
import math
# 4. Plot the training accuracy
plt.figure(figsize=(8,8))
```

```
plt.title("4. Plot the training accuracy")
plt.xlabel('iteration')
plt.ylabel('training accuracy')
plt.plot(iterations, accuracy_list, c='r', label='training accuracy')
plt.legend()
plt.show()
```



5. Write down the final training accuracy

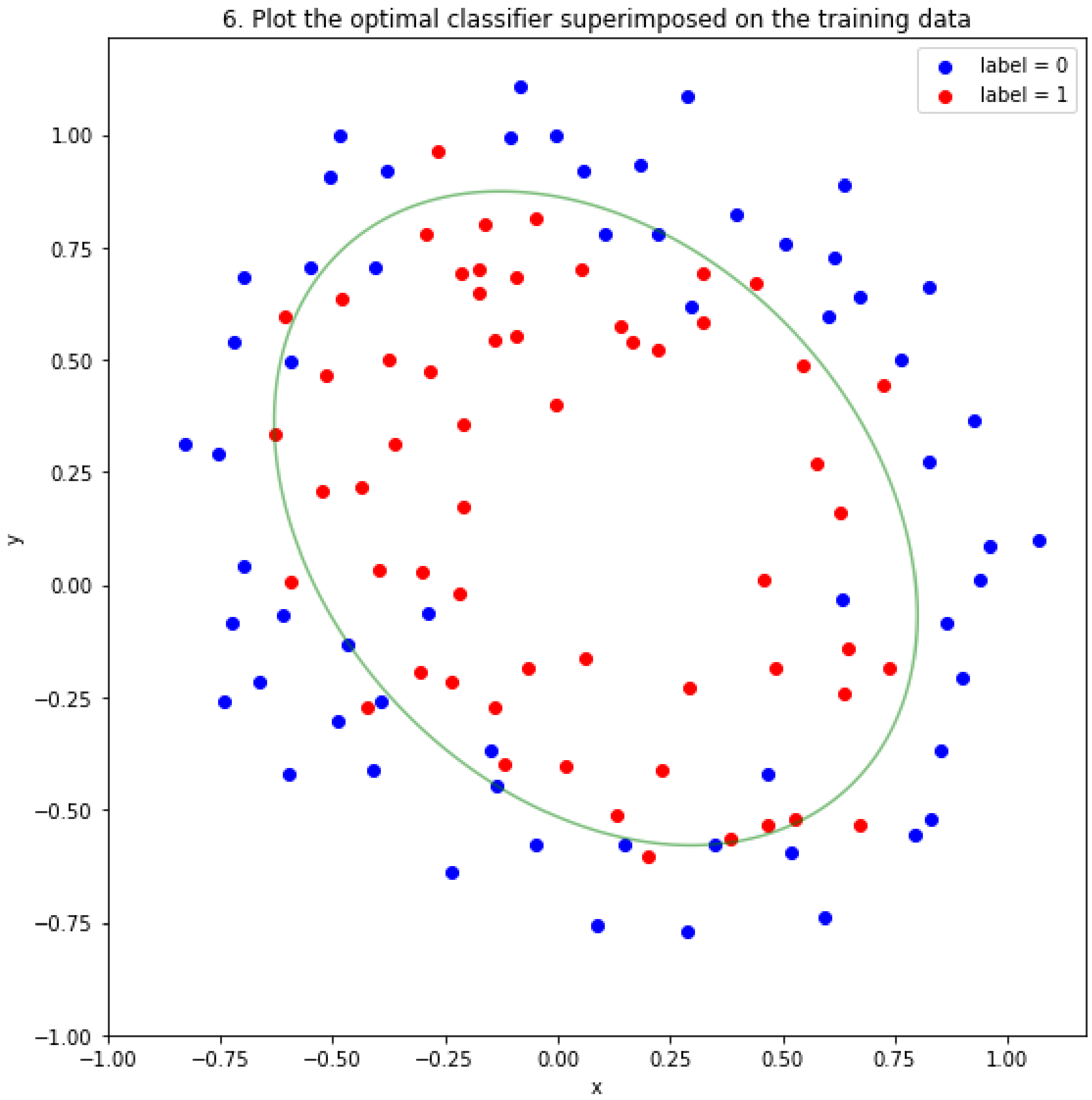
```
print("5. Write down the final training accuracy")
print("Final Training Accuracy : ", accuracy_list[-1], "%")
```

```
5. Write down the final training accuracy
Final Training Accuracy :  85.59322033898306 %
```

6. Plot the optimal classifier superimposed on the training data

```
import numpy as np
import matplotlib.pyplot as plt
import math

val = np.arange(-1, 1, 0.01)
X, Y = np.meshgrid(val, val)
Z = func_calc(theta_list, X, Y, dim_list)
# 6. Plot the optimal classifier superimposed on the training data
plt.figure(figsize=(8,8))
plt.title("6. Plot the optimal classifier superimposed on the training data")
plt.xlabel('x')
plt.ylabel('y')
plt.scatter(pointX0, pointY0, c='b', label='label = 0')
plt.scatter(pointX1, pointY1, c='r', label='label = 1')
plt.contour(X, Y, Z, 0, alpha=.5, colors='g')
plt.tight_layout()
plt.gca().set_aspect('equal', adjustable='box')
plt.legend()
plt.show()
```



6. Plot the optimal classifier superimposed on the training data
label = 0
label = 1
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
y
−1.00
−0.75
−0.50
−0.25
0.00
0.25
0.50
0.75
1.00
x