

hw1-233171152229169167233155175-q1

March 8, 2025

```
[85]: import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
```

0.1 1. Load data

1. Load provided Iris.csv file.
2. Change the Species columns to numeric label 0, 1, 2 and output a numpy.ndarray in shape (num_data, 1).
3. Convert SepalLengthCm, SepalWidthCm column into numpy.ndarray in shape (num_data, 2).

1.1 Load provided Iris.csv file. Show the first 10 lines (1 points.)

```
[86]: #####
# Write your code here #
df = pd.read_csv('Iris.csv')
df.head(10)
#####
```

```
[86]:
```

	Id	SepalLengthCm	SepalWidthCm	PetalLengthCm	PetalWidthCm	Species
0	1	5.1	3.5	1.4	0.2	Iris-setosa
1	2	4.9	3.0	1.4	0.2	Iris-setosa
2	3	4.7	3.2	1.3	0.2	Iris-setosa
3	4	4.6	3.1	1.5	0.2	Iris-setosa
4	5	5.0	3.6	1.4	0.2	Iris-setosa
5	6	5.4	3.9	1.7	0.4	Iris-setosa
6	7	4.6	3.4	1.4	0.3	Iris-setosa
7	8	5.0	3.4	1.5	0.2	Iris-setosa
8	9	4.4	2.9	1.4	0.2	Iris-setosa
9	10	4.9	3.1	1.5	0.1	Iris-setosa

1.2 Change the Species columns to numeric label 0, 1, 2 and output a numpy.ndarray in shape (num_data, 1). Show data every 10 lines. (2 points)

```
[87]: #####
# Write your code here #
```

```
df['Species_label'] = df['Species'].map({'Iris-setosa':0,'Iris-versicolor':
    ↪1,'Iris-virginica':2})
species_labels = df['Species_label'].values.reshape(-1,1)
df.iloc[:10]
#####
```

```
[87]:
```

	Id	SepalLengthCm	SepalWidthCm	PetalLengthCm	PetalWidthCm	\
0	1	5.1	3.5	1.4	0.2	
10	11	5.4	3.7	1.5	0.2	
20	21	5.4	3.4	1.7	0.2	
30	31	4.8	3.1	1.6	0.2	
40	41	5.0	3.5	1.3	0.3	
50	51	7.0	3.2	4.7	1.4	
60	61	5.0	2.0	3.5	1.0	
70	71	5.9	3.2	4.8	1.8	
80	81	5.5	2.4	3.8	1.1	
90	91	5.5	2.6	4.4	1.2	
100	101	6.3	3.3	6.0	2.5	
110	111	6.5	3.2	5.1	2.0	
120	121	6.9	3.2	5.7	2.3	
130	131	7.4	2.8	6.1	1.9	
140	141	6.7	3.1	5.6	2.4	

	Species	Species_label
0	Iris-setosa	0
10	Iris-setosa	0
20	Iris-setosa	0
30	Iris-setosa	0
40	Iris-setosa	0
50	Iris-versicolor	1
60	Iris-versicolor	1
70	Iris-versicolor	1
80	Iris-versicolor	1
90	Iris-versicolor	1
100	Iris-virginica	2
110	Iris-virginica	2
120	Iris-virginica	2
130	Iris-virginica	2
140	Iris-virginica	2

1.3 Convert `SepalLengthCm` and `SepalWidthCm` columns to ndarray in shape `[num_data, 2]`. Convert numeric label column to ndarray in shape `[num_data, 1]`. Print these two ndarray (1 point).

```
[88]: #####
# Write your code here #
sepal_data = df[['SepalLengthCm','SepalWidthCm']].values
species_labels = df['Species_label'].values.reshape(-1,1)
```

```
print(sepal_data)
print(species_labels)
#####
```

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[[5.1 3.5]
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```

0.2 2. Softmax, Cost, and Derivative Functions

2.1 Develop softmax function and try to output softmax function output of this example (3 points).

Softmax function

$$\hat{y}_c = \frac{\exp(z_c)}{\sum_{j=1}^C \exp(z_j)}, \text{ where } c \text{ is class index and } C \text{ is the number of classes.}$$

```
[89]: def softmax(z):
    """
    Calculating softmax function.
    Args:
        z: (numpy.ndarray in shape [num_data, num_classes]) logit
    Returns:
        pred: (numpy.ndarray in shape [num_data, num_classes]) predict value
    """
    #####
    # Write your code here #
    z_exp = np.exp(z-np.max(z,axis=1,keepdims=True))
    pred = z_exp/np.sum(z_exp,axis=1,keepdims=True)
    #####

    return pred

test_z = np.array([[1, 1, 1],
                   [1, 3, 5],
                   [-1, 0, 1]])

softmax(test_z)
```

```
[89]: array([[0.33333333, 0.33333333, 0.33333333],
             [0.01587624, 0.11731043, 0.86681333],
             [0.09003057, 0.24472847, 0.66524096]])
```

2.2 Develop cost function of multi-class logistic regression and try to output cost function output of this example (3 points). Cost function

$$\mathcal{L} = -\frac{1}{N} \sum_{i=1}^N \sum_{c=1}^C y_{ic} \log(\hat{y}_{ic}), \text{ where } N \text{ is the number of data}$$

(Hint: convert label ndarray to the same shape of predicted ndarray, e.g.

$$\begin{bmatrix} 0 \\ 1 \\ 2 \\ 1 \\ 0 \end{bmatrix} \Rightarrow \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

```
[90]: def cost_function(pred, label):
        """
        Calculating cost function.
        Args:
            pred: (numpy.ndarray in shape [num_data, num_classes]) predict value_
        ↪after softmax
        Returns:
            loss: (numpy.ndarray)
        """
        #####
        # Write your code here #
        num_data = pred.shape[0]
        num_classes = pred.shape[1]
        y_one_hot = np.zeros((num_data, num_classes))
        y_one_hot[np.arange(num_data), label.flatten()] = 1

        loss = float(-np.sum(y_one_hot*np.log(pred))/num_data)
        #####
        return loss

test_pred = np.array([[0.1, 0.2, 0.7],
                      [0.2, 0.6, 0.2],
                      [0.2, 0.1, 0.7]])
test_label = np.array([[2], [1], [0]])
cost_function(test_pred, test_label)
```

```
[90]: 0.8256461600462744
```

2.3 Develop gradient calculation of multi-class logistic regression and try to output gradient of given example. You're required to derive the derivatives $\frac{\partial \mathcal{L}}{\partial \mathbf{w}}$ by yourself and write it in your writing

problems. Assume all $x_0 = 1$, predicted values should be $\hat{y}_i = \text{Softmax}(\mathbf{x}_i^T \mathbf{w})$ (3 points for coding, 3 points for mathematical derivation).

```
[91]: def get_gradient(X, y, y_pred):
    """
    Calculate gradient for gradient descent.
    Args:
        X: (numpy.ndarray in shape [num_data, 3])
        y: (numpy.ndarray in shape [num_data, 1])
        y_pred: (numpy.ndarray in shape [num_data, num_classes])
    Return:
        gradient: (numpy.ndarray in [3, 3]) gradient of w
    """
    #####
    # Write your code here #
    num_data = X.shape[0]
    num_classes = y_pred.shape[1]

    y_one_hot = np.zeros((num_data, num_classes))
    y_one_hot[np.arange(num_data), y.flatten()] = 1

    error = y_pred - y_one_hot
    gradient = np.dot(X.T, error) / num_data
    #####
    return gradient

test_X = np.array([[1, 1, 2],
                   [1, 2, 3],
                   [1, 3, 4],
                   [1, 4, 5]])
test_y = np.array([[0], [1], [1], [2]])
test_y_pred = np.array([[0.1, 0.2, 0.7],
                        [0.2, 0.4, 0.4],
                        [0.2, 0.3, 0.5],
                        [0.3, 0.4, 0.3]])
get_gradient(test_X, test_y, test_y_pred)
```

```
[91]: array([[ -0.05 , -0.175,  0.225],
             [ 0.325, -0.375,  0.05 ],
             [ 0.275, -0.55 ,  0.275]])
```

0.3 3. Gradient Descent

3.1 Convert data according to assumption of $x_0 = 1$. (1 point)

```
[92]: #####
    # Write your code here #
    df = pd.read_csv('Iris.csv')
```

```

X = df[['SepalLengthCm', 'SepalWidthCm']].values
X_with_bias = np.c_[np.ones(X.shape[0]), X]
print(X_with_bias)
#####

```

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[1.  6.  3. ]
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[1.  6.5 3. ]
[1.  6.2 3.4]
[1.  5.9 3. ]]

```

3.2 Initialize value of w and start up gradient descent. Record cost function value iteration by iteration. (3 points)

```

[93]: def gradient_descent(X, y, lr, epoch):
    np.random.seed(42) # set random seed to control initialized value
    w = np.random.rand(3, 3)

    #####
    # Write your code here #
    num_samples = X.shape[0]
    cost_record = []

    for i in range(epoch):
        z = np.dot(X,w)
        y_hat = softmax(z)
        y_one_hot = np.zeros((num_samples,len(np.unique(y))))
        y_one_hot[np.arange(num_samples),y.flatten()]=1
        gradient = np.dot(X.T,(y_hat-y_one_hot))/num_samples
        w-=lr*gradient
        cost=-np.sum(y_one_hot*np.log(y_hat))/num_samples
        cost_record.append(cost)
        print(f"[Epoch {i+1}] Cost funtion = {cost:.4f}")
    #####

    return w

epoch = 10000
lr = 0.1
cost_record = []
data = pd.read_csv('Iris.csv')

data['Species_label'] = data['Species'].map({'Iris-setosa': 0,
↪ 'Iris-versicolor': 1, 'Iris-virginica': 2})
X = data[['SepalLengthCm', 'SepalWidthCm']].values
y = data['Species_label'].values

```

```
X = np.c_[np.ones(X.shape[0]), X]
w = gradient_descent(X, y, lr, epoch)
```

```
[Epoch 1] Cost funtion = 1.4265
[Epoch 2] Cost funtion = 1.3192
[Epoch 3] Cost funtion = 1.2950
[Epoch 4] Cost funtion = 1.2800
[Epoch 5] Cost funtion = 1.2671
[Epoch 6] Cost funtion = 1.2550
[Epoch 7] Cost funtion = 1.2433
[Epoch 8] Cost funtion = 1.2318
[Epoch 9] Cost funtion = 1.2205
[Epoch 10] Cost funtion = 1.2095
[Epoch 11] Cost funtion = 1.1987
[Epoch 12] Cost funtion = 1.1881
[Epoch 13] Cost funtion = 1.1777
[Epoch 14] Cost funtion = 1.1675
[Epoch 15] Cost funtion = 1.1575
[Epoch 16] Cost funtion = 1.1476
[Epoch 17] Cost funtion = 1.1380
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[Epoch 19] Cost funtion = 1.1194
[Epoch 20] Cost funtion = 1.1103
[Epoch 21] Cost funtion = 1.1015
[Epoch 22] Cost funtion = 1.0928
[Epoch 23] Cost funtion = 1.0843
[Epoch 24] Cost funtion = 1.0760
[Epoch 25] Cost funtion = 1.0678
[Epoch 26] Cost funtion = 1.0598
[Epoch 27] Cost funtion = 1.0520
[Epoch 28] Cost funtion = 1.0444
[Epoch 29] Cost funtion = 1.0369
[Epoch 30] Cost funtion = 1.0295
[Epoch 31] Cost funtion = 1.0223
[Epoch 32] Cost funtion = 1.0153
[Epoch 33] Cost funtion = 1.0084
[Epoch 34] Cost funtion = 1.0017
[Epoch 35] Cost funtion = 0.9951
[Epoch 36] Cost funtion = 0.9886
[Epoch 37] Cost funtion = 0.9823
[Epoch 38] Cost funtion = 0.9761
[Epoch 39] Cost funtion = 0.9700
[Epoch 40] Cost funtion = 0.9641
[Epoch 41] Cost funtion = 0.9582
[Epoch 42] Cost funtion = 0.9525
[Epoch 43] Cost funtion = 0.9470
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[Epoch 44] Cost function = 0.9415
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[Epoch 67] Cost function = 0.8415
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```

3.3 Plot cost function v.s. epoch curve. (1 point)

```
[94]: #####
# Write your code here #
def gradient_descent(X, y, lr, epoch):
    np.random.seed(42) # set random seed to control initialized value
    w = np.random.rand(3, 3)

    #####
    # Write your code here #
    num_samples = X.shape[0]
    cost_record = []

    for i in range(epoch):
        z = np.dot(X,w)
        y_hat = softmax(z)
        y_one_hot = np.zeros((num_samples, len(np.unique(y))))
        y_one_hot[np.arange(num_samples), y.flatten()]=1
        gradient = np.dot(X.T, (y_hat-y_one_hot))/num_samples
        w=-lr*gradient
        cost=-np.sum(y_one_hot*np.log(y_hat))/num_samples
        cost_record.append(cost)

    #####

    return w, cost_record
```



```

epoch = 10000
lr = 0.1
cost_record = []
data = pd.read_csv('Iris.csv')

data['Species_label'] = data['Species'].map({'Iris-setosa': 0, 'Iris-versicolor': 1, 'Iris-virginica': 2})
X = data[['SepalLengthCm', 'SepalWidthCm']].values
y = data['Species_label'].values

X = np.c_[np.ones(X.shape[0]), X]
w, cost_record = gradient_descent(X, y, lr, epoch)

plt.plot(cost_record, color='b', linestyle='--')
plt.xlabel('Epoch')
plt.ylabel('Cost Function')

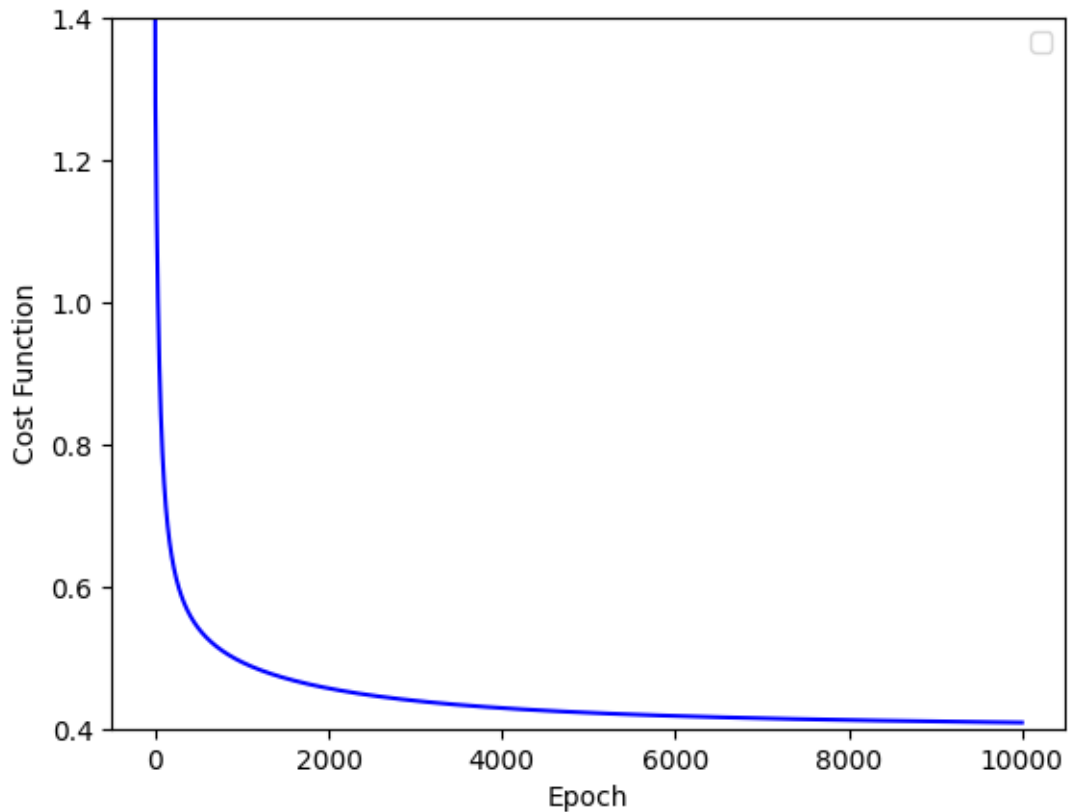
plt.ylim(0.4, 1.4)
plt.xticks(np.arange(0, epoch + 1, 2000))

plt.legend()
plt.show()
#####

```

C:\Users\Lenovo\AppData\Local\Temp\ipykernel_32976\825418177.py:45: UserWarning: No artists with labels found to put in legend. Note that artists whose label start with an underscore are ignored when legend() is called with no argument.

```
plt.legend()
```



0.4 4. Plot result

4.1 Plot scatters using ground-truth label. (2 points)

```
[95]: #####
# Write your code here #
data = pd.read_csv('Iris.csv')
data['Species_label'] = data['Species'].map({'Iris-setosa': 0,
↪ 'Iris-versicolor': 1, 'Iris-virginica': 2})

sepal_length = data['SepalLengthCm'].values
sepal_width = data['SepalWidthCm'].values
species_labels = data['Species_label'].values

colors = ['red', 'green', 'blue'] # Red for setosa, Green for versicolor, Blue
↪ for virginica
species_names = ['Iris-setosa', 'Iris-versicolor', 'Iris-virginica']

plt.figure(figsize=(8, 6))
for i in range(3):
    plt.scatter(
```

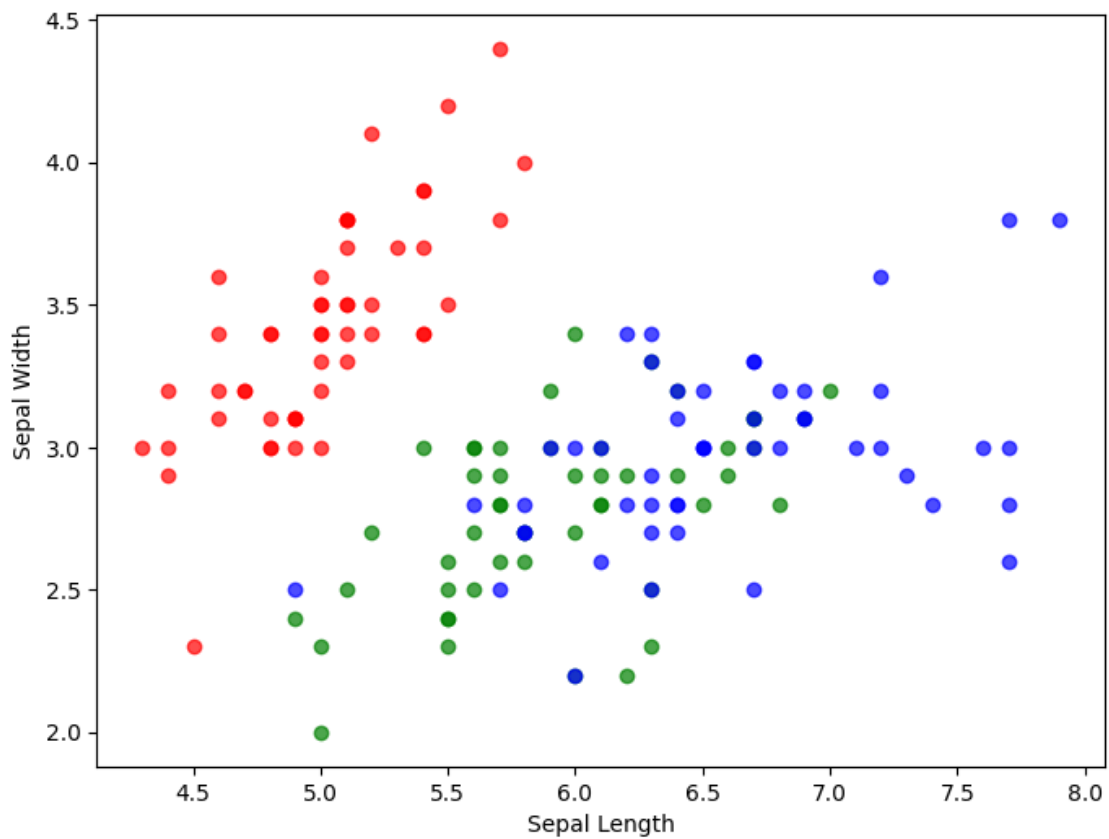
```

        sepal_length[species_labels == i],
        sepal_width[species_labels == i],
        color=colors[i],
        label=species_names[i],
        alpha=0.7
    )

plt.xlabel('Sepal Length')
plt.ylabel('Sepal Width')

plt.show()
#####

```



4.1 Plot scatters using predicted label. (2 points)

```

[96]: #####
      # Write your code here #
      data = pd.read_csv('Iris.csv')

```

```

data['Species_label'] = data['Species'].map({'Iris-setosa': 0,
↳ 'Iris-versicolor': 1, 'Iris-virginica': 2})

sepal_length = data['SepalLengthCm'].values
sepal_width = data['SepalWidthCm'].values
species_labels = data['Species_label'].values
colors = ['red', 'green', 'blue'] # Red for setosa, Green for versicolor, Blue
↳ for virginica
species_names = ['Iris-setosa', 'Iris-versicolor', 'Iris-virginica']
X = np.c_[np.ones(data.shape[0]), data[['SepalLengthCm', 'SepalWidthCm']]].
↳ values]
def softmax(z):
    z_exp = np.exp(z - np.max(z, axis=1, keepdims=True))
    return z_exp / np.sum(z_exp, axis=1, keepdims=True)
def gradient_descent(X, y, lr, epoch):
    np.random.seed(42) # set random seed to control initialized value
    w = np.random.rand(3, 3)

    #####
    # Write your code here #
    num_samples = X.shape[0]
    cost_record = []

    for i in range(epoch):
        z = np.dot(X,w)
        y_hat = softmax(z)
        y_one_hot = np.zeros((num_samples, len(np.unique(y))))
        y_one_hot[np.arange(num_samples), y.flatten()]=1
        gradient = np.dot(X.T, (y_hat-y_one_hot))/num_samples
        w=-lr*gradient
        cost=-np.sum(y_one_hot*np.log(y_hat))/num_samples
        cost_record.append(cost)

    #####

    return w
w=gradient_descent(X, y, lr, epoch)
z=np.dot(X,w)
y_pred=softmax(z)
predicted_labels = np.argmax(y_pred, axis=1)

plt.figure(figsize=(8, 6))
for i in range(3):
    plt.scatter(
        sepal_length[predicted_labels==i],
        sepal_width[predicted_labels==i],
        color=colors[i],

```

```

        label=species_names[i],
        alpha=0.7)
plt.xlabel('Sepal Length')
plt.ylabel('Sepal Width')
plt.legend()
plt.show()
#####

```

