

logistic-assignment1

March 8, 2025

```
[1]: 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.)

```
[2]: df = pd.read_csv('D:\MG\ CUHKSZ\~ \DDA3020\Assignments\A1\Iris.csv')

print("1.1 First 10 lines of Iris.csv:")
print(df.head(10))
```

1.1 First 10 lines of Iris.csv:

	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: SyntaxWarning: invalid escape sequence '\M'
```

```
<>:1: SyntaxWarning: invalid escape sequence '\M'
```

```
C:\Users\19927\AppData\Local\Temp\ipykernel_3732\3170916924.py:1: SyntaxWarning:
invalid escape sequence '\M'
```

```
df = pd.read_csv('D:\MG\ CUHKSZ\~ \DDA3020\Assignments\A1\Iris.csv')
```

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)

```
[3]: species_map = {'Iris-setosa': 0, 'Iris-versicolor': 1, 'Iris-virginica': 2}
df['Species_label'] = df['Species'].map(species_map)
print("\n1.2 Species mapped to numeric labels (every 10th line):")
print(df.iloc[::10][['Id', 'SepalLengthCm', 'SepalWidthCm', 'PetalLengthCm', 'PetalWidthCm', 'Species', 'Species_label']])
```

1.2 Species mapped to numeric labels (every 10th line):

	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).

```
[4]: X = df[['SepalLengthCm', 'SepalWidthCm']].values # Shape: (150, 2)
y = df['Species_label'].values.reshape(-1, 1) # Shape: (150, 1)
print("\n1.3 Features X (SepalLengthCm, SepalWidthCm):")
```

```
print(X)
print("Labels y:")
print(y)
```

1.3 Features X (SepalLengthCm, SepalWidthCm):

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[5.1 3.5]
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Labels y :

[illegible]

[illegible]

[illegible]


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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

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

```
[5]: 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
    """
    z_max = np.max(z, axis=1, keepdims=True) # For numerical stability
    exp_z = np.exp(z - z_max)
    sum_exp_z = np.sum(exp_z, axis=1, keepdims=True)
    pred = exp_z / sum_exp_z

    return pred

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

```
softmax(test_z)
```

```
[5]: 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.

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

```
[6]: 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)
    """
    N = pred.shape[0]
    y_onehot = np.zeros_like(pred)
    y_onehot[np.arange(N), label.flatten()] = 1
    loss = -np.sum(y_onehot * np.log(pred + 1e-8)) / N # Add epsilon to avoid_
    ↪log(0)
    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)
```

```
[6]: 0.825646133062148
```

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).

```
[7]: 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
    """
    N = X.shape[0]
    y_onehot = np.zeros_like(y_pred)
    y_onehot[np.arange(N), y.flatten()] = 1
    gradient = (1 / N) * X.T @ (y_pred - y_onehot)
    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)
```

```
[7]: 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)

```
[8]: X_with_bias = np.hstack([np.ones((X.shape[0], 1)), X]) # Shape: (150, 3)
print("\n3.1 X with bias term:")
print(X_with_bias)
```

3.1 X with bias term:

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[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)

```
[9]: def gradient_descent(X, y, lr, epoch):
    np.random.seed(42) # Set random seed for reproducibility
    w = np.random.rand(3, 3) # Initialize weights (3 features, 3 classes)
    cost_record = [] # To store cost values

    for i in range(epoch):
        z = X @ w # Compute logits
        y_pred = softmax(z) # Compute predictions
        cost = cost_function(y_pred, y) # Compute cost
        cost_record.append(cost)
        gradient = get_gradient(X, y, y_pred) # Compute gradient
        w = w - lr * gradient # Update weights
        print(f"[Epoch {i+1}] Cost function = {cost:.4f}")

    return w, cost_record

# Parameters
epoch = 10000
lr = 0.1
X = X_with_bias
w, cost_record = gradient_descent(X, y, lr, epoch)
```

```
[Epoch 1] Cost function = 1.4265
[Epoch 2] Cost function = 1.3192
[Epoch 3] Cost function = 1.2950
[Epoch 4] Cost function = 1.2800
[Epoch 5] Cost function = 1.2671
[Epoch 6] Cost function = 1.2550
[Epoch 7] Cost function = 1.2433
[Epoch 8] Cost function = 1.2318
[Epoch 9] Cost function = 1.2205
[Epoch 10] Cost function = 1.2095
[Epoch 11] Cost function = 1.1987
[Epoch 12] Cost function = 1.1881
[Epoch 13] Cost function = 1.1777
[Epoch 14] Cost function = 1.1675
[Epoch 15] Cost function = 1.1575
[Epoch 16] Cost function = 1.1476
[Epoch 17] Cost function = 1.1380
[Epoch 18] Cost function = 1.1286
[Epoch 19] Cost function = 1.1194
[Epoch 20] Cost function = 1.1103
```

[Epoch 21] Cost function = 1.1015
[Epoch 22] Cost function = 1.0928
[Epoch 23] Cost function = 1.0843
[Epoch 24] Cost function = 1.0760
[Epoch 25] Cost function = 1.0678
[Epoch 26] Cost function = 1.0598
[Epoch 27] Cost function = 1.0520
[Epoch 28] Cost function = 1.0444
[Epoch 29] Cost function = 1.0369
[Epoch 30] Cost function = 1.0295
[Epoch 31] Cost function = 1.0223
[Epoch 32] Cost function = 1.0153
[Epoch 33] Cost function = 1.0084
[Epoch 34] Cost function = 1.0017
[Epoch 35] Cost function = 0.9951
[Epoch 36] Cost function = 0.9886
[Epoch 37] Cost function = 0.9823
[Epoch 38] Cost function = 0.9761
[Epoch 39] Cost function = 0.9700
[Epoch 40] Cost function = 0.9641
[Epoch 41] Cost function = 0.9582
[Epoch 42] Cost function = 0.9525
[Epoch 43] Cost function = 0.9470
[Epoch 44] Cost function = 0.9415
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[Epoch 58] Cost function = 0.8754
[Epoch 59] Cost function = 0.8714
[Epoch 60] Cost function = 0.8674
[Epoch 61] Cost function = 0.8635
[Epoch 62] Cost function = 0.8597
[Epoch 63] Cost function = 0.8559
[Epoch 64] Cost function = 0.8522
[Epoch 65] Cost function = 0.8486
[Epoch 66] Cost function = 0.8450
[Epoch 67] Cost function = 0.8415
[Epoch 68] Cost function = 0.8381

[Epoch 69] Cost function = 0.8348
[Epoch 70] Cost function = 0.8314
[Epoch 71] Cost function = 0.8282
[Epoch 72] Cost function = 0.8250
[Epoch 73] Cost function = 0.8219
[Epoch 74] Cost function = 0.8188
[Epoch 75] Cost function = 0.8158
[Epoch 76] Cost function = 0.8128
[Epoch 77] Cost function = 0.8098
[Epoch 78] Cost function = 0.8070
[Epoch 79] Cost function = 0.8041
[Epoch 80] Cost function = 0.8014
[Epoch 81] Cost function = 0.7986
[Epoch 82] Cost function = 0.7959
[Epoch 83] Cost function = 0.7933
[Epoch 84] Cost function = 0.7907
[Epoch 85] Cost function = 0.7881
[Epoch 86] Cost function = 0.7856
[Epoch 87] Cost function = 0.7831
[Epoch 88] Cost function = 0.7807
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[Epoch 95] Cost function = 0.7646
[Epoch 96] Cost function = 0.7624
[Epoch 97] Cost function = 0.7603
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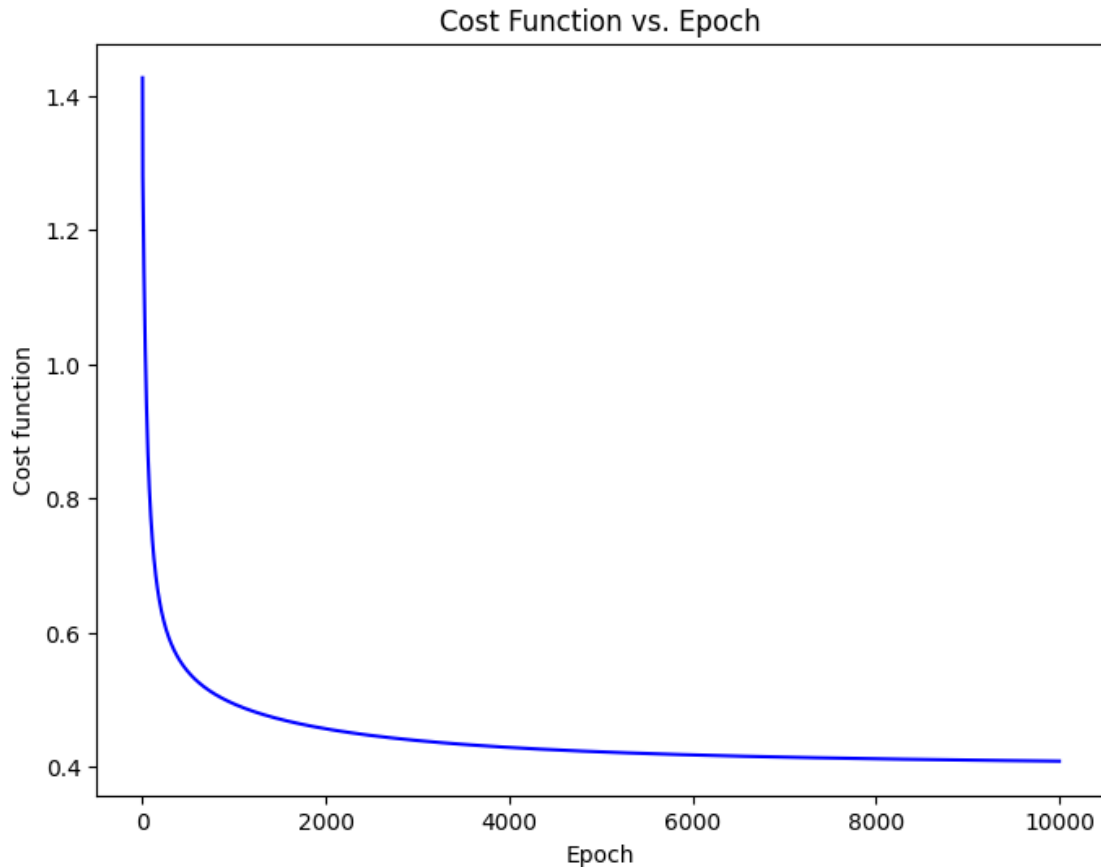
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[Epoch 9999] Cost function = 0.4085
[Epoch 10000] Cost function = 0.4085
```

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

```
[10]: plt.figure(figsize=(8, 6))
plt.plot(range(1, epoch + 1), cost_record, color='blue') # Plot cost vs. epoch
plt.xlabel('Epoch')
plt.ylabel('Cost function')
plt.title('Cost Function vs. Epoch')
plt.show()
```



0.4 4. Plot result

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

```
[ ]: # Compute logits
z = X_with_bias @ w

# Compute predicted probabilities using softmax
y_pred = softmax(z)

# Get predicted labels
predicted_labels = np.argmax(y_pred, axis=1)
```

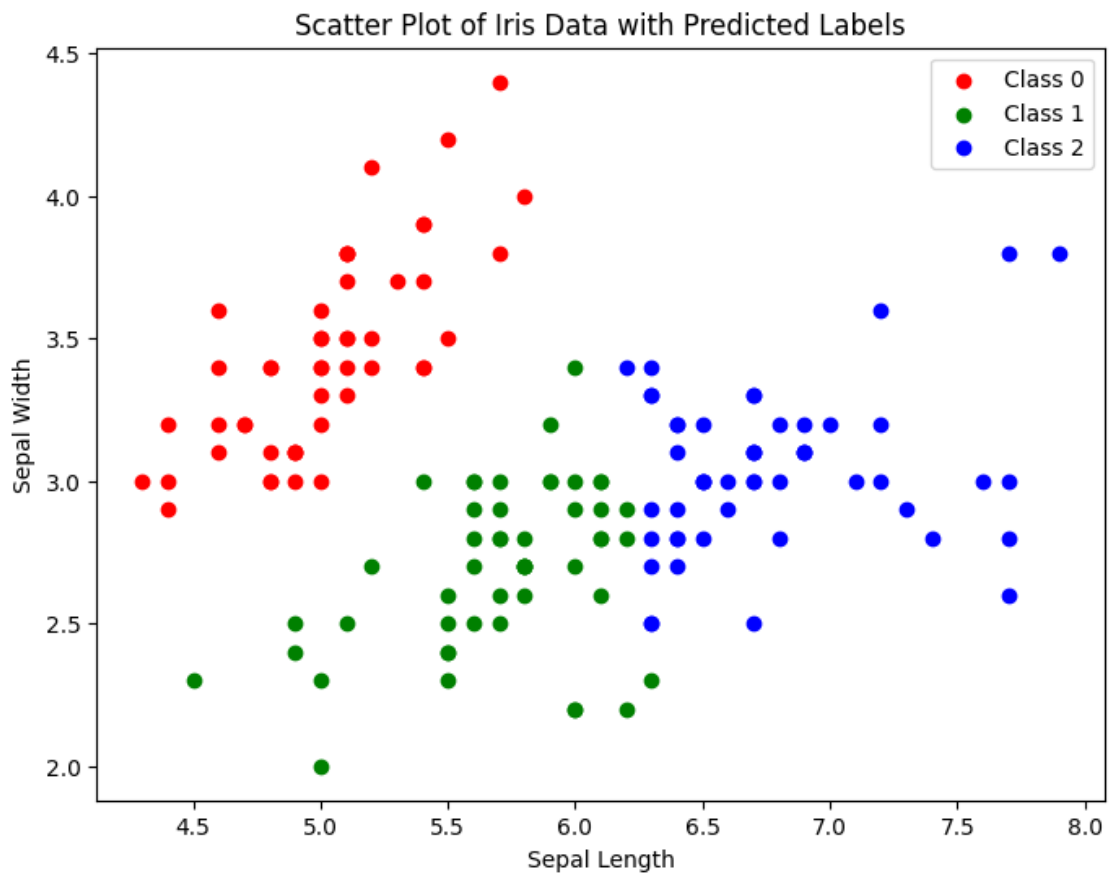


```

# Create scatter plot
plt.figure(figsize=(8, 6))
colors = {0: 'red', 1: 'green', 2: 'blue'} # Color mapping for each class
for class_label in np.unique(predicted_labels):
    mask = predicted_labels == class_label
    plt.scatter(df['SepalLengthCm'][mask], df['SepalWidthCm'][mask],
                c=colors[class_label], label=f'Class {class_label}')

# Add labels and title
plt.xlabel('Sepal Length')
plt.ylabel('Sepal Width')
plt.title('Scatter Plot of Iris Data with Predicted Labels')
plt.legend()
plt.show()

```



4.2 Plot scatters using predicted label. (2 points)

```
[14]: z = X_with_bias @ w
y_pred = softmax(z)
predicted_labels = np.argmax(y_pred, axis=1)

plt.figure(figsize=(8, 6))
colors = {0: 'red', 1: 'green', 2: 'blue'}
for class_label in np.unique(predicted_labels):
    mask = predicted_labels == class_label
    plt.scatter(df['SepalLengthCm'][mask], df['SepalWidthCm'][mask],
                c=colors[class_label], label=f'Class {class_label}')
plt.xlabel('Sepal Length')
plt.ylabel('Sepal Width')
plt.title('Scatter Plot of Iris Data with Predicted Labels')
plt.legend()
plt.show()
```

