# Appendix-2: Logistic Regression

Logistic Regression is a binary classification algorithm that can be extended to multiclass classification by using one-vs-rest or softmax. It is a linear model that learns a weight vector and a bias term to map the input features to a probability score.

For our implementation, we used scikit-learn's LogisticRegression classifier with the default L2 regularization.

In [1]:
```
# import library dependencies
import numpy as np
from sklearn.linear_model import LogisticRegression
from sklearn.metrics import accuracy_score, precision_score, recall_score, f
from sklearn.model_selection import train_test_split
from sklearn.model_selection import learning_curve
import matplotlib.pyplot as plt
import joblib
```

## Import Data

In [2]:
```
ROOT_PATH='../'
```

In [3]:
```
# function to open pickle file
def unpickle(file):
    import pickle
    with open(file, 'rb') as fo:
        dict = pickle.load(fo, encoding='bytes')
    return dict
```

In [4]:
```
# store each pickle files in individual batches
batch1 = unpickle(ROOT_PATH+"cifar-10-batches-py/data_batch_1")
batch2 = unpickle(ROOT_PATH+"cifar-10-batches-py/data_batch_2")
batch3 = unpickle(ROOT_PATH+"cifar-10-batches-py/data_batch_3")
batch4 = unpickle(ROOT_PATH+"cifar-10-batches-py/data_batch_4")
batch5 = unpickle(ROOT_PATH+"cifar-10-batches-py/data_batch_5")
test_batch = unpickle(ROOT_PATH+"cifar-10-batches-py/test_batch")
```

In [5]:
```
# function to create labels and images from data
def load_data0(btch):
    labels = btch[b'labels']
    imgs = btch[b'data'].reshape((-1, 32, 32, 3))

    res = []
    for ii in range(imgs.shape[0]):
        img = imgs[ii].copy()
        img = np.fliplr(np.rot90(np.transpose(img.flatten().reshape(3,32,32)
        res.append(img)
    imgs = np.stack(res)
    return labels, imgs
```

In [6]:
```python
# function to load data into training and test set
def load_data():
    x_train_l = []
    y_train_l = []
    for ibatch in [batch1, batch2, batch3, batch4, batch5]:
        labels, imgs = load_data0(ibatch)
        x_train_l.append(imgs)
        y_train_l.extend(labels)
    x_train = np.vstack(x_train_l)
    y_train = np.vstack(y_train_l)

    x_test_l = []
    y_test_l = []
    labels, imgs = load_data0(test_batch)
    x_test_l.append(imgs)
    y_test_l.extend(labels)
    x_test = np.vstack(x_test_l)
    y_test = np.vstack(y_test_l)
    return (x_train, y_train), (x_test, y_test)
```

## Preprocess Data

In [7]:
```python
# create training and test set
(x_train, y_train), (x_test, y_test) = load_data()
```

In [8]:
```python
print('x_train shape:', x_train.shape)
print('y_train shape:', y_train.shape)
print('x_test shape:', x_test.shape)
print('y_test shape:', y_test.shape)
```

```
x_train shape: (50000, 32, 32, 3)
y_train shape: (50000, 1)
x_test shape: (10000, 32, 32, 3)
y_test shape: (10000, 1)
```

In [9]:
```python
print(x_train.shape[0], 'train samples (x)')
print(y_train.shape[0], 'train samples (y)')
```

```
50000 train samples (x)
50000 train samples (y)
```

In [10]:
```python
print(x_test.shape[0], 'test samples (x)')
print(y_test.shape[0], 'test samples (y)')
```

```
10000 test samples (x)
10000 test samples (y)
```

In [11]:
```python
# Flatten the images
X_train = x_train.reshape(x_train.shape[0], -1)
X_test = x_test.reshape(x_test.shape[0], -1)
```

In [12]:
```python
# Normalize the data
X_train = X_train.astype('float32') / 255
X_test = X_test.astype('float32') / 255
```

In [13]:
```
# Reshape y_train and y_test to 1d arrays
y_train = y_train.ravel()
y_test = y_test.ravel()
```

In [14]:
```
# Split the data into training and validation sets
X_train, X_val, y_train, y_val = train_test_split(X_train, y_train, test_siz
```

## Define model and train

In [15]:
```
# Define the model
lr = LogisticRegression(solver='saga', multi_class='multinomial', verbose=1,
```

In [16]:
```
# Train the model
lr.fit(X_train, y_train)
```

```
[Parallel(n_jobs=-1)]: Using backend ThreadingBackend with 8 concurrent work
ers.
Epoch 1, change: 1.00000000
Epoch 2, change: 0.31112364
Epoch 3, change: 0.17446972
Epoch 4, change: 0.13395590
Epoch 5, change: 0.10465156
Epoch 6, change: 0.08240297
Epoch 7, change: 0.07107364
Epoch 8, change: 0.06299022
Epoch 9, change: 0.05496485
Epoch 10, change: 0.04876496
Epoch 11, change: 0.04347889
Epoch 12, change: 0.03975073
Epoch 13, change: 0.03597004
Epoch 14, change: 0.03368282
Epoch 15, change: 0.03095332
Epoch 16, change: 0.02869766
Epoch 17, change: 0.02641392
Epoch 18, change: 0.02535186
Epoch 19, change: 0.02388932
Epoch 20, change: 0.02200129
Epoch 21, change: 0.02163129
Epoch 22, change: 0.02128161
Epoch 23, change: 0.02059028
Epoch 24, change: 0.01865203
Epoch 25, change: 0.01795270
Epoch 26, change: 0.01607023
Epoch 27, change: 0.01583829
Epoch 28, change: 0.01565392
Epoch 29, change: 0.01546345
Epoch 30, change: 0.01513787
Epoch 31, change: 0.01497226
Epoch 32, change: 0.01479146
Epoch 33, change: 0.01458597
Epoch 34, change: 0.01440972
Epoch 35, change: 0.01427177
Epoch 36, change: 0.01411566
Epoch 37, change: 0.01401397
```

```
Epoch 38, change: 0.01373388
Epoch 39, change: 0.01373598
Epoch 40, change: 0.01352168
Epoch 41, change: 0.01338393
Epoch 42, change: 0.01327477
Epoch 43, change: 0.01084361
Epoch 44, change: 0.00982642
Epoch 45, change: 0.00969253
Epoch 46, change: 0.00964628
Epoch 47, change: 0.00957087
Epoch 48, change: 0.00948417
Epoch 49, change: 0.00934124
Epoch 50, change: 0.00925452
Epoch 51, change: 0.00920188
Epoch 52, change: 0.00909640
Epoch 53, change: 0.00903079
Epoch 54, change: 0.00895362
Epoch 55, change: 0.00886839
Epoch 56, change: 0.00878574
Epoch 57, change: 0.00873875
Epoch 58, change: 0.00863774
Epoch 59, change: 0.00869238
Epoch 60, change: 0.00858687
Epoch 61, change: 0.00855210
Epoch 62, change: 0.00847020
Epoch 63, change: 0.00845270
Epoch 64, change: 0.00838347
Epoch 65, change: 0.00833689
Epoch 66, change: 0.00832005
Epoch 67, change: 0.00825901
Epoch 68, change: 0.00819180
Epoch 69, change: 0.00813890
Epoch 70, change: 0.00811382
Epoch 71, change: 0.00807347
Epoch 72, change: 0.00801967
Epoch 73, change: 0.00799779
Epoch 74, change: 0.00792955
Epoch 75, change: 0.00791504
Epoch 76, change: 0.00785810
Epoch 77, change: 0.00781890
Epoch 78, change: 0.00778453
Epoch 79, change: 0.00773823
Epoch 80, change: 0.00768907
Epoch 81, change: 0.00764233
Epoch 82, change: 0.00759667
Epoch 83, change: 0.00756469
Epoch 84, change: 0.00754886
Epoch 85, change: 0.00749367
Epoch 86, change: 0.00746561
Epoch 87, change: 0.00745094
Epoch 88, change: 0.00740415
Epoch 89, change: 0.00736822
Epoch 90, change: 0.00733791
Epoch 91, change: 0.00729506
Epoch 92, change: 0.00726959
Epoch 93, change: 0.00724233
Epoch 94, change: 0.00718576
```

```
Epoch 95, change: 0.00717703
Epoch 96, change: 0.00705124
Epoch 97, change: 0.00535775
Epoch 98, change: 0.00620047
Epoch 99, change: 0.00575072
Epoch 100, change: 0.00492825
Epoch 101, change: 0.00466867
Epoch 102, change: 0.00465837
Epoch 103, change: 0.00462734
Epoch 104, change: 0.00461888
Epoch 105, change: 0.00460546
Epoch 106, change: 0.00460275
Epoch 107, change: 0.00456668
Epoch 108, change: 0.00457150
Epoch 109, change: 0.00452120
Epoch 110, change: 0.00451159
Epoch 111, change: 0.00448301
Epoch 112, change: 0.00446376
Epoch 113, change: 0.00443487
Epoch 114, change: 0.00442269
Epoch 115, change: 0.00441022
Epoch 116, change: 0.00438745
Epoch 117, change: 0.00436103
Epoch 118, change: 0.00434608
Epoch 119, change: 0.00432291
Epoch 120, change: 0.00430955
Epoch 121, change: 0.00429212
Epoch 122, change: 0.00428452
Epoch 123, change: 0.00426431
Epoch 124, change: 0.00425937
Epoch 125, change: 0.00424089
Epoch 126, change: 0.00422770
Epoch 127, change: 0.00419753
Epoch 128, change: 0.00417554
Epoch 129, change: 0.00416087
Epoch 130, change: 0.00414606
Epoch 131, change: 0.00411834
Epoch 132, change: 0.00410878
Epoch 133, change: 0.00410271
Epoch 134, change: 0.00407760
Epoch 135, change: 0.00404989
Epoch 136, change: 0.00404991
Epoch 137, change: 0.00402752
Epoch 138, change: 0.00400432
Epoch 139, change: 0.00399800
Epoch 140, change: 0.00396836
Epoch 141, change: 0.00397393
Epoch 142, change: 0.00393468
Epoch 143, change: 0.00393113
Epoch 144, change: 0.00391113
Epoch 145, change: 0.00389295
Epoch 146, change: 0.00389738
Epoch 147, change: 0.00386684
Epoch 148, change: 0.00385265
Epoch 149, change: 0.00384862
Epoch 150, change: 0.00382350
Epoch 151, change: 0.00381218
```

```
Epoch 152, change: 0.00379862
Epoch 153, change: 0.00377759
Epoch 154, change: 0.00378375
Epoch 155, change: 0.00375129
Epoch 156, change: 0.00375033
Epoch 157, change: 0.00372565
Epoch 158, change: 0.00371537
Epoch 159, change: 0.00370011
Epoch 160, change: 0.00368239
Epoch 161, change: 0.00366976
Epoch 162, change: 0.00366379
Epoch 163, change: 0.00364228
Epoch 164, change: 0.00362096
Epoch 165, change: 0.00362078
Epoch 166, change: 0.00362110
Epoch 167, change: 0.00359346
Epoch 168, change: 0.00358320
Epoch 169, change: 0.00356692
Epoch 170, change: 0.00356411
Epoch 171, change: 0.00353869
Epoch 172, change: 0.00353537
Epoch 173, change: 0.00351795
Epoch 174, change: 0.00349730
Epoch 175, change: 0.00349140
Epoch 176, change: 0.00348865
Epoch 177, change: 0.00347272
Epoch 178, change: 0.00344886
Epoch 179, change: 0.00344399
Epoch 180, change: 0.00343319
Epoch 181, change: 0.00342618
Epoch 182, change: 0.00340448
Epoch 183, change: 0.00340712
Epoch 184, change: 0.00338400
Epoch 185, change: 0.00336853
Epoch 186, change: 0.00336046
Epoch 187, change: 0.00335725
Epoch 188, change: 0.00333493
Epoch 189, change: 0.00333823
Epoch 190, change: 0.00332182
Epoch 191, change: 0.00330513
Epoch 192, change: 0.00329214
Epoch 193, change: 0.00328733
Epoch 194, change: 0.00327466
Epoch 195, change: 0.00326756
Epoch 196, change: 0.00324804
Epoch 197, change: 0.00324450
Epoch 198, change: 0.00323318
Epoch 199, change: 0.00321265
Epoch 200, change: 0.00321289
Epoch 201, change: 0.00319917
Epoch 202, change: 0.00319759
Epoch 203, change: 0.00317904
Epoch 204, change: 0.00316619
Epoch 205, change: 0.00316073
Epoch 206, change: 0.00315321
Epoch 207, change: 0.00313662
Epoch 208, change: 0.00312802
```

```
Epoch 209, change: 0.00311834
Epoch 210, change: 0.00311291
Epoch 211, change: 0.00310606
Epoch 212, change: 0.00308611
Epoch 213, change: 0.00308659
Epoch 214, change: 0.00306932
Epoch 215, change: 0.00306716
Epoch 216, change: 0.00305489
Epoch 217, change: 0.00304344
Epoch 218, change: 0.00303197
Epoch 219, change: 0.00303247
Epoch 220, change: 0.00302720
Epoch 221, change: 0.00302247
Epoch 222, change: 0.00301566
Epoch 223, change: 0.00300775
Epoch 224, change: 0.00301121
Epoch 225, change: 0.00299277
Epoch 226, change: 0.00299339
Epoch 227, change: 0.00299182
Epoch 228, change: 0.00298343
Epoch 229, change: 0.00298234
Epoch 230, change: 0.00296846
Epoch 231, change: 0.00296750
Epoch 232, change: 0.00297102
Epoch 233, change: 0.00296175
Epoch 234, change: 0.00296209
Epoch 235, change: 0.00295101
Epoch 236, change: 0.00293814
Epoch 237, change: 0.00294865
Epoch 238, change: 0.00293578
Epoch 239, change: 0.00293766
Epoch 240, change: 0.00292690
Epoch 241, change: 0.00291075
Epoch 242, change: 0.00290674
Epoch 243, change: 0.00290138
Epoch 244, change: 0.00289413
Epoch 245, change: 0.00287969
Epoch 246, change: 0.00287256
Epoch 247, change: 0.00286673
Epoch 248, change: 0.00285579
Epoch 249, change: 0.00284928
Epoch 250, change: 0.00284070
Epoch 251, change: 0.00283307
Epoch 252, change: 0.00282159
Epoch 253, change: 0.00282031
Epoch 254, change: 0.00280657
Epoch 255, change: 0.00280155
Epoch 256, change: 0.00279448
Epoch 257, change: 0.00278758
Epoch 258, change: 0.00277935
Epoch 259, change: 0.00277420
Epoch 260, change: 0.00275748
Epoch 261, change: 0.00275552
Epoch 262, change: 0.00274883
Epoch 263, change: 0.00273772
Epoch 264, change: 0.00273119
Epoch 265, change: 0.00272985
```

```
Epoch 266, change: 0.00271279
Epoch 267, change: 0.00270759
Epoch 268, change: 0.00269595
Epoch 269, change: 0.00269727
Epoch 270, change: 0.00268597
Epoch 271, change: 0.00267582
Epoch 272, change: 0.00267322
Epoch 273, change: 0.00265920
Epoch 274, change: 0.00265300
Epoch 275, change: 0.00265128
Epoch 276, change: 0.00265039
Epoch 277, change: 0.00263338
Epoch 278, change: 0.00262368
Epoch 279, change: 0.00261972
Epoch 280, change: 0.00261417
Epoch 281, change: 0.00260349
Epoch 282, change: 0.00259404
Epoch 283, change: 0.00258989
Epoch 284, change: 0.00258671
Epoch 285, change: 0.00257762
Epoch 286, change: 0.00257144
Epoch 287, change: 0.00255908
Epoch 288, change: 0.00255388
Epoch 289, change: 0.00254498
Epoch 290, change: 0.00254688
Epoch 291, change: 0.00253508
Epoch 292, change: 0.00253363
Epoch 293, change: 0.00252212
Epoch 294, change: 0.00251260
Epoch 295, change: 0.00250960
Epoch 296, change: 0.00250028
Epoch 297, change: 0.00249664
Epoch 298, change: 0.00249363
Epoch 299, change: 0.00247968
Epoch 300, change: 0.00247410
Epoch 301, change: 0.00247454
Epoch 302, change: 0.00245911
Epoch 303, change: 0.00245824
Epoch 304, change: 0.00245009
Epoch 305, change: 0.00244622
Epoch 306, change: 0.00243742
Epoch 307, change: 0.00243192
Epoch 308, change: 0.00243095
Epoch 309, change: 0.00241612
Epoch 310, change: 0.00241648
Epoch 311, change: 0.00240809
Epoch 312, change: 0.00240041
Epoch 313, change: 0.00239995
Epoch 314, change: 0.00239938
Epoch 315, change: 0.00240401
Epoch 316, change: 0.00239655
Epoch 317, change: 0.00239763
Epoch 318, change: 0.00240084
Epoch 319, change: 0.00239959
Epoch 320, change: 0.00240306
Epoch 321, change: 0.00239647
Epoch 322, change: 0.00239649
```

```
Epoch 323, change: 0.00239840
Epoch 324, change: 0.00239263
Epoch 325, change: 0.00239571
Epoch 326, change: 0.00239088
Epoch 327, change: 0.00239209
Epoch 328, change: 0.00238614
Epoch 329, change: 0.00239612
Epoch 330, change: 0.00239518
Epoch 331, change: 0.00238822
Epoch 332, change: 0.00238740
Epoch 333, change: 0.00239265
Epoch 334, change: 0.00238695
Epoch 335, change: 0.00239166
Epoch 336, change: 0.00239591
Epoch 337, change: 0.00239093
Epoch 338, change: 0.00238712
Epoch 339, change: 0.00237112
Epoch 340, change: 0.00238027
Epoch 341, change: 0.00240292
Epoch 342, change: 0.00239605
Epoch 343, change: 0.00239930
Epoch 344, change: 0.00240023
Epoch 345, change: 0.00239359
Epoch 346, change: 0.00239700
Epoch 347, change: 0.00239776
Epoch 348, change: 0.00239107
Epoch 349, change: 0.00238407
Epoch 350, change: 0.00239163
Epoch 351, change: 0.00238624
Epoch 352, change: 0.00239050
Epoch 353, change: 0.00238446
Epoch 354, change: 0.00238628
Epoch 355, change: 0.00238517
Epoch 356, change: 0.00237968
Epoch 357, change: 0.00236870
Epoch 358, change: 0.00237131
Epoch 359, change: 0.00237415
Epoch 360, change: 0.00237323
Epoch 361, change: 0.00237136
Epoch 362, change: 0.00238742
Epoch 363, change: 0.00237525
Epoch 364, change: 0.00237183
Epoch 365, change: 0.00236979
Epoch 366, change: 0.00237607
Epoch 367, change: 0.00237213
Epoch 368, change: 0.00238169
Epoch 369, change: 0.00237275
Epoch 370, change: 0.00237446
Epoch 371, change: 0.00237473
Epoch 372, change: 0.00237662
Epoch 373, change: 0.00237774
Epoch 374, change: 0.00237725
Epoch 375, change: 0.00237908
Epoch 376, change: 0.00237704
Epoch 377, change: 0.00237470
Epoch 378, change: 0.00237397
Epoch 379, change: 0.00237163
```

```
Epoch 380, change: 0.00237745
Epoch 381, change: 0.00237517
Epoch 382, change: 0.00237545
Epoch 383, change: 0.00238008
Epoch 384, change: 0.00237000
Epoch 385, change: 0.00237512
Epoch 386, change: 0.00237266
Epoch 387, change: 0.00236870
Epoch 388, change: 0.00237936
Epoch 389, change: 0.00222678
Epoch 390, change: 0.00217650
Epoch 391, change: 0.00172520
Epoch 392, change: 0.00160622
Epoch 393, change: 0.00189626
Epoch 394, change: 0.00201284
Epoch 395, change: 0.00221536
Epoch 396, change: 0.00211227
Epoch 397, change: 0.00198514
Epoch 398, change: 0.00226736
Epoch 399, change: 0.00202234
Epoch 400, change: 0.00238240
Epoch 401, change: 0.00208670
Epoch 402, change: 0.00202490
Epoch 403, change: 0.00204573
Epoch 404, change: 0.00238281
Epoch 405, change: 0.00228283
Epoch 406, change: 0.00182684
Epoch 407, change: 0.00231843
Epoch 408, change: 0.00172930
Epoch 409, change: 0.00186291
Epoch 410, change: 0.00147470
Epoch 411, change: 0.00174597
Epoch 412, change: 0.00217184
Epoch 413, change: 0.00236824
Epoch 414, change: 0.00175077
Epoch 415, change: 0.00131492
Epoch 416, change: 0.00157649
Epoch 417, change: 0.00131087
Epoch 418, change: 0.00167438
Epoch 419, change: 0.00166562
Epoch 420, change: 0.00136874
Epoch 421, change: 0.00142823
Epoch 422, change: 0.00146169
Epoch 423, change: 0.00134029
Epoch 424, change: 0.00127628
Epoch 425, change: 0.00128050
Epoch 426, change: 0.00119431
Epoch 427, change: 0.00125811
Epoch 428, change: 0.00125162
Epoch 429, change: 0.00143894
Epoch 430, change: 0.00121691
Epoch 431, change: 0.00150610
Epoch 432, change: 0.00120916
Epoch 433, change: 0.00161309
Epoch 434, change: 0.00137820
Epoch 435, change: 0.00119570
Epoch 436, change: 0.00130914
```

```
Epoch 437, change: 0.00134212
Epoch 438, change: 0.00131807
Epoch 439, change: 0.00131349
Epoch 440, change: 0.00180832
Epoch 441, change: 0.00237167
Epoch 442, change: 0.00237644
Epoch 443, change: 0.00237883
Epoch 444, change: 0.00237366
Epoch 445, change: 0.00236748
Epoch 446, change: 0.00236945
Epoch 447, change: 0.00236474
Epoch 448, change: 0.00236432
Epoch 449, change: 0.00236277
Epoch 450, change: 0.00183380
Epoch 451, change: 0.00146719
Epoch 452, change: 0.00119511
Epoch 453, change: 0.00119434
Epoch 454, change: 0.00119386
Epoch 455, change: 0.00119315
Epoch 456, change: 0.00126528
Epoch 457, change: 0.00119428
Epoch 458, change: 0.00128678
Epoch 459, change: 0.00119341
Epoch 460, change: 0.00120014
Epoch 461, change: 0.00119374
Epoch 462, change: 0.00119409
Epoch 463, change: 0.00119297
Epoch 464, change: 0.00119400
Epoch 465, change: 0.00119347
Epoch 466, change: 0.00119466
Epoch 467, change: 0.00122705
Epoch 468, change: 0.00119341
Epoch 469, change: 0.00154775
Epoch 470, change: 0.00119240
Epoch 471, change: 0.00125598
Epoch 472, change: 0.00119210
Epoch 473, change: 0.00143872
Epoch 474, change: 0.00119225
Epoch 475, change: 0.00122610
Epoch 476, change: 0.00119246
Epoch 477, change: 0.00119255
Epoch 478, change: 0.00119431
Epoch 479, change: 0.00119378
Epoch 480, change: 0.00119395
Epoch 481, change: 0.00119178
Epoch 482, change: 0.00119363
Epoch 483, change: 0.00119404
Epoch 484, change: 0.00119214
Epoch 485, change: 0.00119226
Epoch 486, change: 0.00119086
Epoch 487, change: 0.00119481
Epoch 488, change: 0.00119401
Epoch 489, change: 0.00122390
Epoch 490, change: 0.00119228
Epoch 491, change: 0.00119255
Epoch 492, change: 0.00119371
Epoch 493, change: 0.00119112
```

```
Epoch 494, change: 0.00119190
Epoch 495, change: 0.00119217
Epoch 496, change: 0.00132591
Epoch 497, change: 0.00119128
Epoch 498, change: 0.00134031
Epoch 499, change: 0.00119476
Epoch 500, change: 0.00139087
Epoch 501, change: 0.00143314
Epoch 502, change: 0.00127166
Epoch 503, change: 0.00128441
Epoch 504, change: 0.00119309
Epoch 505, change: 0.00130530
Epoch 506, change: 0.00140873
Epoch 507, change: 0.00154390
Epoch 508, change: 0.00129209
Epoch 509, change: 0.00125857
Epoch 510, change: 0.00128727
Epoch 511, change: 0.00146484
Epoch 512, change: 0.00144715
Epoch 513, change: 0.00150014
Epoch 514, change: 0.00135295
Epoch 515, change: 0.00119341
Epoch 516, change: 0.00145061
Epoch 517, change: 0.00119237
Epoch 518, change: 0.00126799
Epoch 519, change: 0.00140673
Epoch 520, change: 0.00119249
Epoch 521, change: 0.00128651
Epoch 522, change: 0.00131331
Epoch 523, change: 0.00119235
Epoch 524, change: 0.00119426
Epoch 525, change: 0.00148332
Epoch 526, change: 0.00119262
Epoch 527, change: 0.00119214
Epoch 528, change: 0.00119241
Epoch 529, change: 0.00119131
Epoch 530, change: 0.00119223
Epoch 531, change: 0.00119152
Epoch 532, change: 0.00119212
Epoch 533, change: 0.00119197
Epoch 534, change: 0.00119110
Epoch 535, change: 0.00119164
Epoch 536, change: 0.00119134
Epoch 537, change: 0.00119453
Epoch 538, change: 0.00118896
Epoch 539, change: 0.00119143
Epoch 540, change: 0.00124383
Epoch 541, change: 0.00119126
Epoch 542, change: 0.00119099
Epoch 543, change: 0.00119328
Epoch 544, change: 0.00119152
Epoch 545, change: 0.00119215
Epoch 546, change: 0.00118962
Epoch 547, change: 0.00119132
Epoch 548, change: 0.00119129
Epoch 549, change: 0.00118992
Epoch 550, change: 0.0max_iter reached after 3547 seconds
```

```
/Users/shrivastavasatyam/miniconda3/lib/python3.10/site-packages/sklearn/linear_model/_sag.py:350: ConvergenceWarning: The max_iter was reached which means the coef_ did not converge
  warnings.warn(
[Parallel(n_jobs=-1)]: Done   1 out of   1 | elapsed: 59.1min finished
```

Out[16]:

```
LogisticRegression

LogisticRegression(max_iter=1000, multi_class='multinomial', n_jobs=-1,
                   solver='saga', verbose=1)
```

### Save and load model

In [17]:

```python
# Save the model to a file
joblib.dump(lr, 'logistic_regression_model_saga.sav')
```

Out[17]:

```
['logistic_regression_model_saga.sav']
```

In [18]:

```python
# Load the saved model from a file
loaded_model = joblib.load('logistic_regression_model_saga.sav')
```

### Evaluate the model

In [19]:

```python
# Evaluate the model
train_acc = accuracy_score(y_train, loaded_model.predict(X_train))
val_acc = accuracy_score(y_val, loaded_model.predict(X_val))
test_acc = accuracy_score(y_test, loaded_model.predict(X_test))

print(f"Train Accuracy: {train_acc:.4f}")
print(f"Val Accuracy: {val_acc:.4f}")
print(f"Test Accuracy: {test_acc:.4f}")
```

```
Train Accuracy: 0.5047
Val Accuracy: 0.3848
Test Accuracy: 0.3864
```

In [20]:

```python
# Calculate precision, recall, and F1 score on test set
test_pred = loaded_model.predict(X_test)
precision = precision_score(y_test, test_pred, average='weighted')
recall = recall_score(y_test, test_pred, average='weighted')
f1 = f1_score(y_test, test_pred, average='weighted')

print(f"Test Precision: {precision:.4f}")
print(f"Test Recall: {recall:.4f}")
print(f"Test F1 score: {f1:.4f}")
```

```
Test Precision: 0.3833
Test Recall: 0.3864
Test F1 score: 0.3843
```