Softmax Regression - tfidf

May 12, 2024

[ ]:
```
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import pandas as pd
import warnings
warnings.filterwarnings('ignore')

from sklearn.linear_model import LogisticRegression
from sklearn.model_selection import GridSearchCV, cross_val_score
from sklearn.metrics import accuracy_score
from sklearn.preprocessing import StandardScaler
from joblib import dump, load

from preset_function import evaluate_model, draw_learning_curve,␣
 ↪load_processed_data

X_train_bow, X_test_bow, X_train_tfidf, X_test_tfidf, \
    X_train_bow_L1, X_test_bow_L1, X_train_tfidf_L1, X_test_tfidf_L1 =␣
 ↪load_processed_data('input')

y_train, y_test = load_processed_data('output')

%matplotlib inline
```

Select dataset:

[ ]:
```
X_train = X_train_tfidf
X_test = X_test_tfidf
```

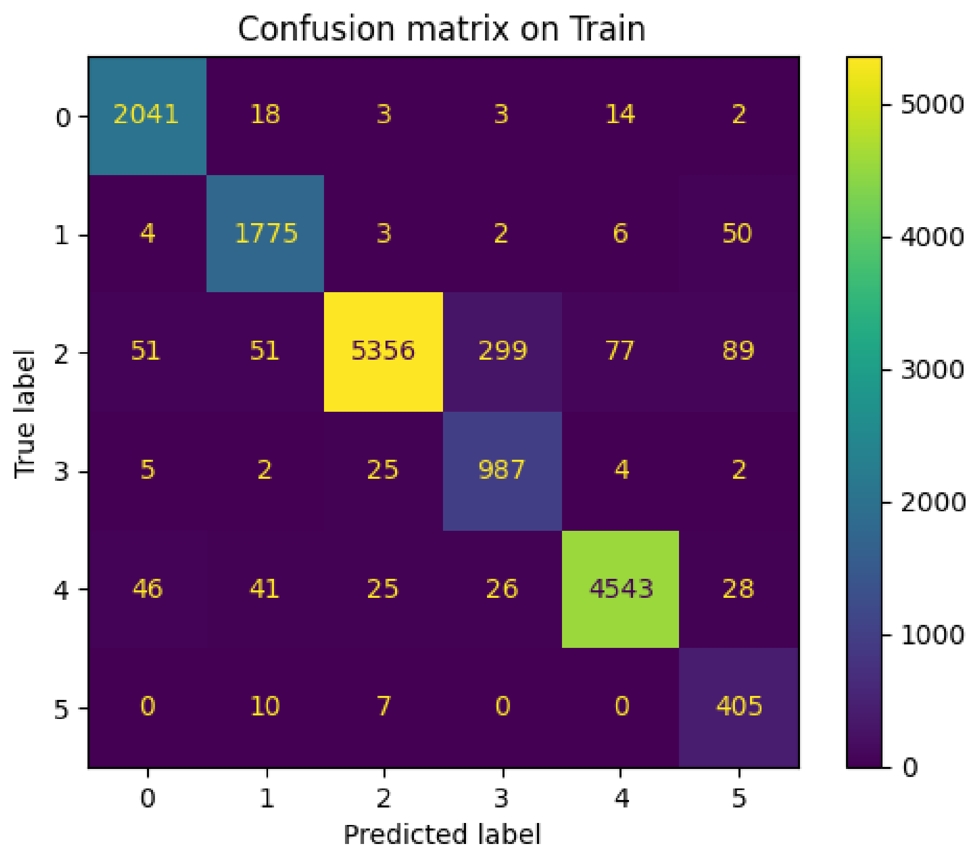
1 Basic training

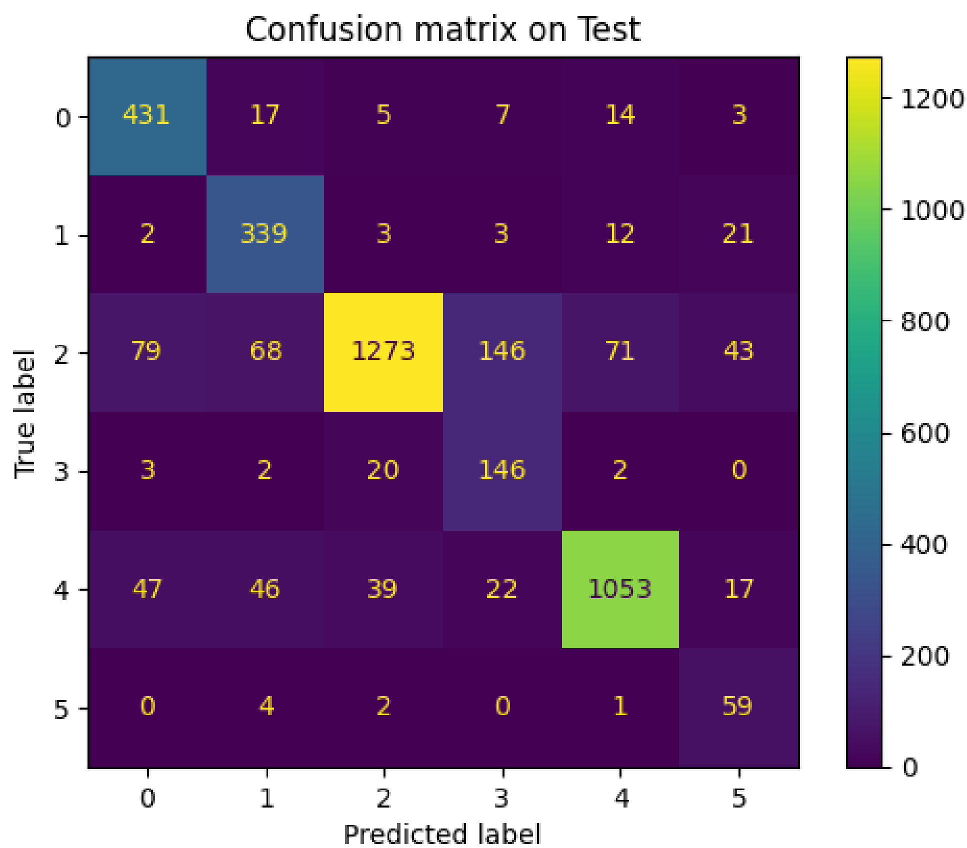
[ ]:
```
softmax_model = LogisticRegression(multi_class='multinomial')
softmax_model.fit(X_train, y_train)
```

[ ]:
```
LogisticRegression(multi_class='multinomial')
```

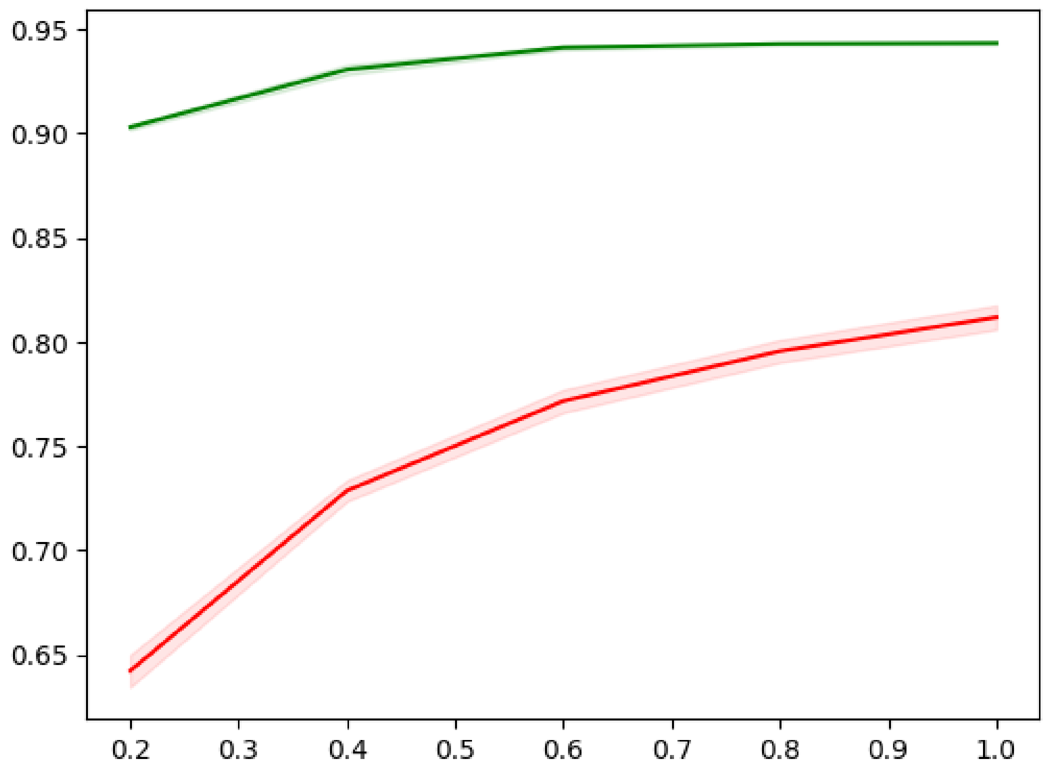
```
[ ]: evaluate_model(softmax_model, X_train, X_test, y_train, y_test,
         include_training=True)
```

```
Score of on train are:
        - Accuracy score: 0.9442
        - Micro F1 score: 0.9442
        - Macro F1 score: 0.9143
Score of on test are:
        - Accuracy score: 0.8253
        - Micro F1 score: 0.8253
        - Macro F1 score: 0.7504
```





[ ]:
```
draw_learning_curve(softmax_model, X_train, y_train)
```



2 Multiple tuning

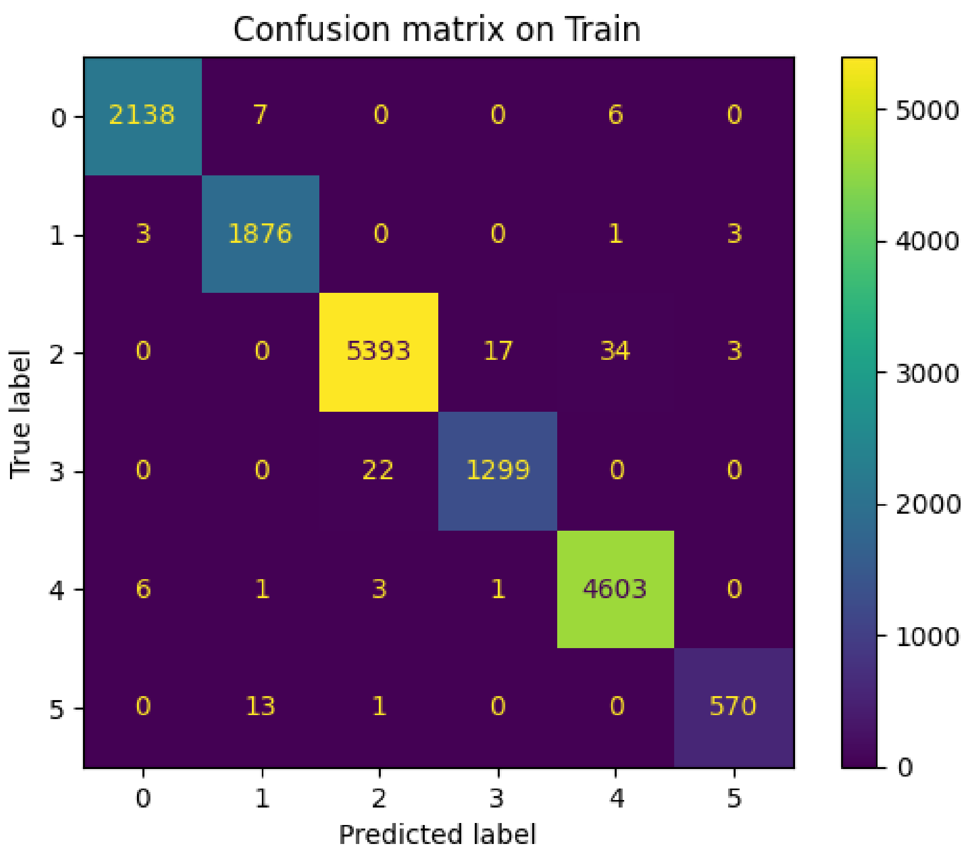
2.1 No regularization

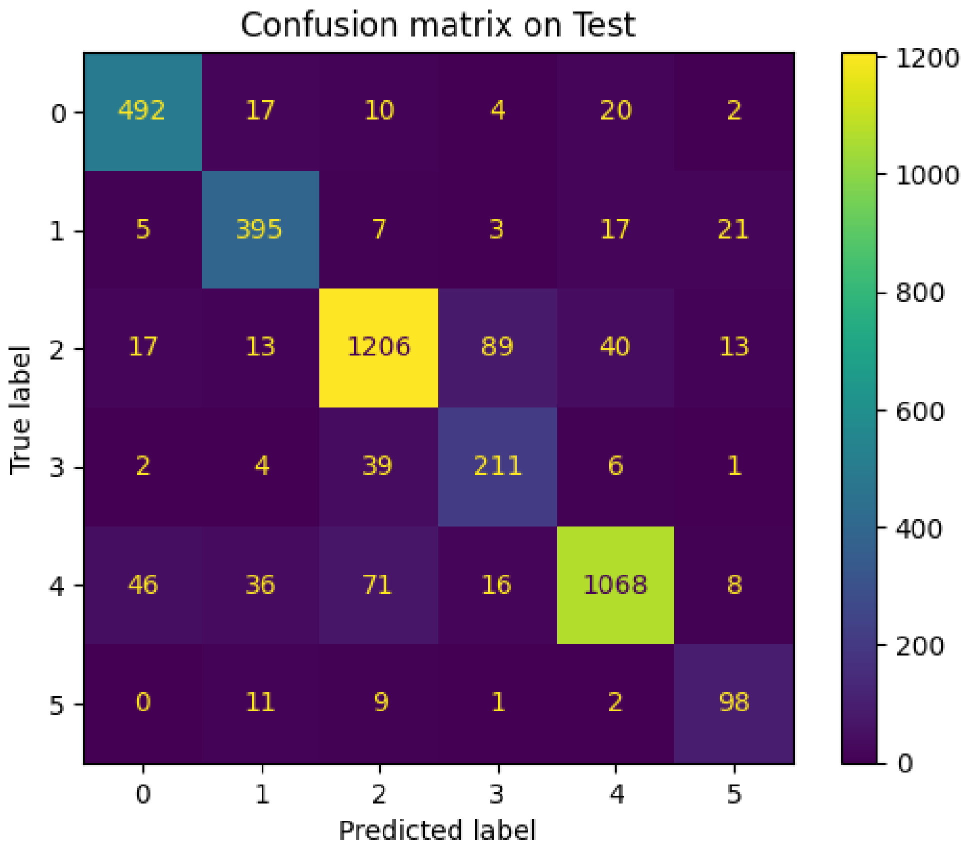
[ ]:
```
softmax_model = LogisticRegression(penalty=None, solver='lbfgs',␣
↪multi_class='multinomial')
softmax_model.fit(X_train, y_train)
```

[ ]:
```
LogisticRegression(multi_class='multinomial', penalty=None)
```

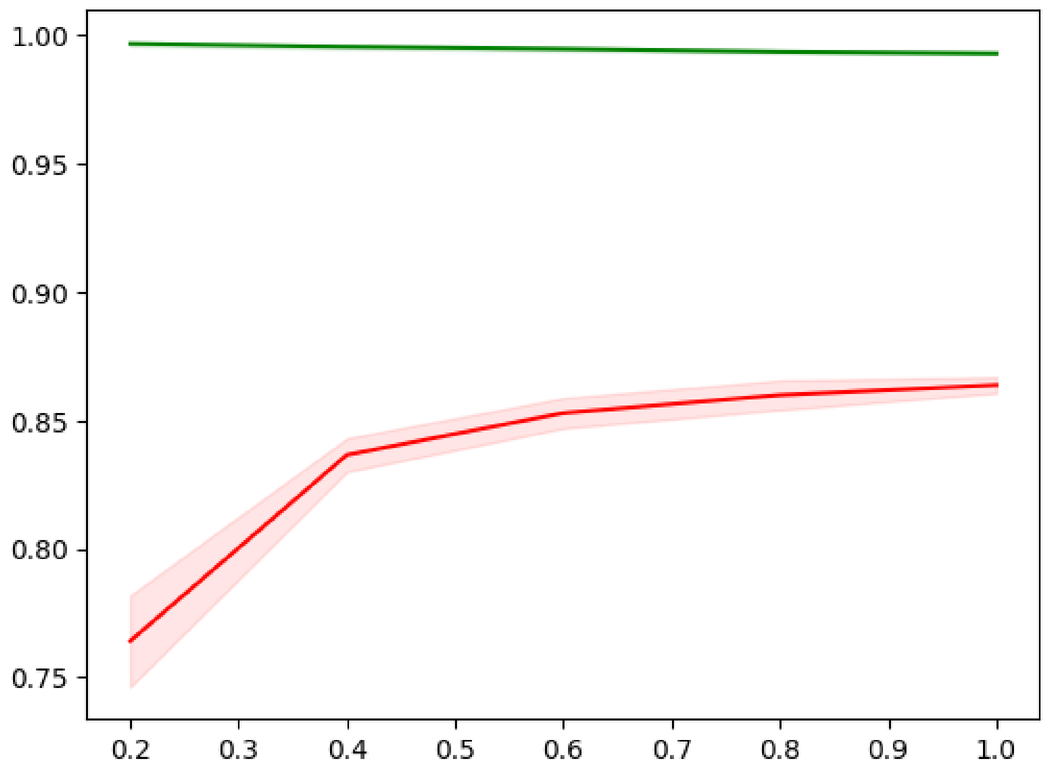
[ ]:
```
evaluate_model(softmax_model, X_train, X_test, y_train, y_test,␣
↪include_training=True)
```

```
Score of on train are:
        - Accuracy score: 0.9924
        - Micro F1 score: 0.9924
        - Macro F1 score: 0.9903
Score of on test are:
        - Accuracy score: 0.8675
        - Micro F1 score: 0.8675
        - Macro F1 score: 0.8305
```


Confusion matrix on Train
True label
Predicted label
0
1
2
3
4
5
2138
7
6
1876
1
3
5393
17
34
22
1299
4603
13
570
5000
4000
3000
2000
1000
0



[ ]:
```
draw_learning_curve(softmax_model, X_train, y_train)
```



2.2 L1 regularization

First, we try to plot the validation score through a list of C from 0.001 to 100

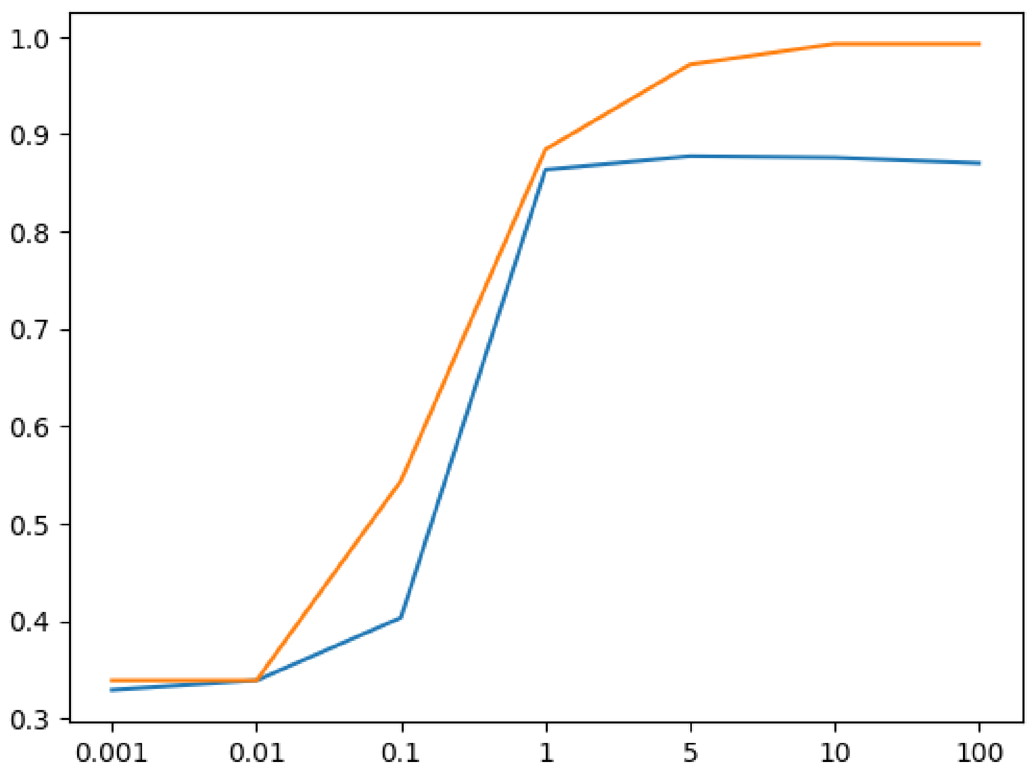
[ ]:
```
C_list = [0.001, 0.01, 0.1, 1, 5, 10, 100]

# Define a list in order to store accuracy points
cvs_list = list()
trs_list = list()

for c in C_list:
    # Define model for each C
    softmax_model = LogisticRegression(C=c, penalty='l1', solver='saga',␣
 ↪multi_class='multinomial')
    softmax_model.fit(X_train, y_train)

    # Calculate score of cross validation
    train_score = accuracy_score(y_train, softmax_model.predict(X_train))
    cv_score = np.mean(cross_val_score(softmax_model, X_train, y_train, cv=5,␣
 ↪n_jobs=8))

    trs_list.append(train_score)
```

```
    cvs_list.append(cv_score)
```

[ ]:
```
# Print the result
print(C_list)
print(trs_list)
print(cvs_list)

# Draw the plot
fig = sns.lineplot(x=list(range(len(C_list))), y=cvs_list)
fig = sns.lineplot(x=list(range(len(C_list))), y=trs_list)
fig.set_xticks(range(len(C_list)))
fig.set_xticklabels(C_list)
```

```
[0.001, 0.01, 0.1, 1, 5, 10, 100]
[0.3386875, 0.3386875, 0.5438125, 0.88425, 0.971375, 0.992625, 0.992625]
[0.329, 0.3386875000000001, 0.4031874999999999, 0.8634375000000001,
0.8772500000000001, 0.875875, 0.870125]
```

[ ]:
```
[Text(0, 0, '0.001'),
 Text(1, 0, '0.01'),
 Text(2, 0, '0.1'),
 Text(3, 0, '1'),
 Text(4, 0, '5'),
 Text(5, 0, '10'),
 Text(6, 0, '100')]
```



We can see the good value of C is near $C = 5$, then we scope to $C = 5$:

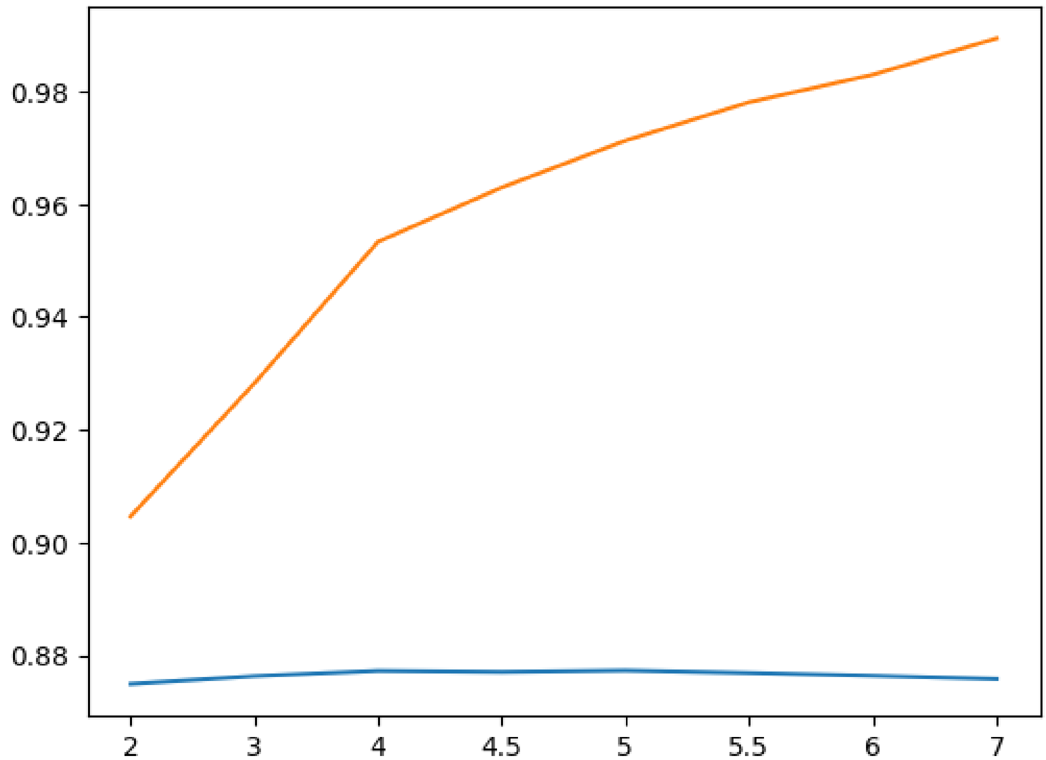
[ ]:
```
C_list = [2, 3, 4, 4.5, 5, 5.5, 6, 7]

# Define a list in order to store accuracy points
cvs_list = list()
trs_list = list()

for c in C_list:
    # Define model for each C
    softmax_model = LogisticRegression(C=c, penalty='l1', solver='saga',␣
 ↪multi_class='multinomial')
    softmax_model.fit(X_train, y_train)

    # Calculate score of cross validation
    train_score = accuracy_score(y_train, softmax_model.predict(X_train))
    cv_score = np.mean(cross_val_score(softmax_model, X_train, y_train, cv=5,␣
 ↪n_jobs=8))

    trs_list.append(train_score)
    cvs_list.append(cv_score)
```

[ ]:
```
# Print the result
print(C_list)
print(trs_list)
print(cvs_list)

# Draw the plot
fig = sns.lineplot(x=list(range(len(C_list))), y=cvs_list)
fig = sns.lineplot(x=list(range(len(C_list))), y=trs_list)
fig.set_xticks(range(len(C_list)))
fig.set_xticklabels(C_list)
```

```
[2, 3, 4, 4.5, 5, 5.5, 6, 7]
[0.904625, 0.9281875, 0.9533125, 0.9629375, 0.97125, 0.9780625, 0.9829375,
0.989375]
[0.8749375, 0.8763124999999998, 0.8772499999999999, 0.8770625000000001,
0.8773125, 0.8768750000000001, 0.8763750000000001, 0.8758125]
```

[ ]:
```
[Text(0, 0, '2'),
 Text(1, 0, '3'),
 Text(2, 0, '4'),
 Text(3, 0, '4.5'),
 Text(4, 0, '5'),
 Text(5, 0, '5.5'),
```

```
 Text(6, 0, '6'),
 Text(7, 0, '7')]
```

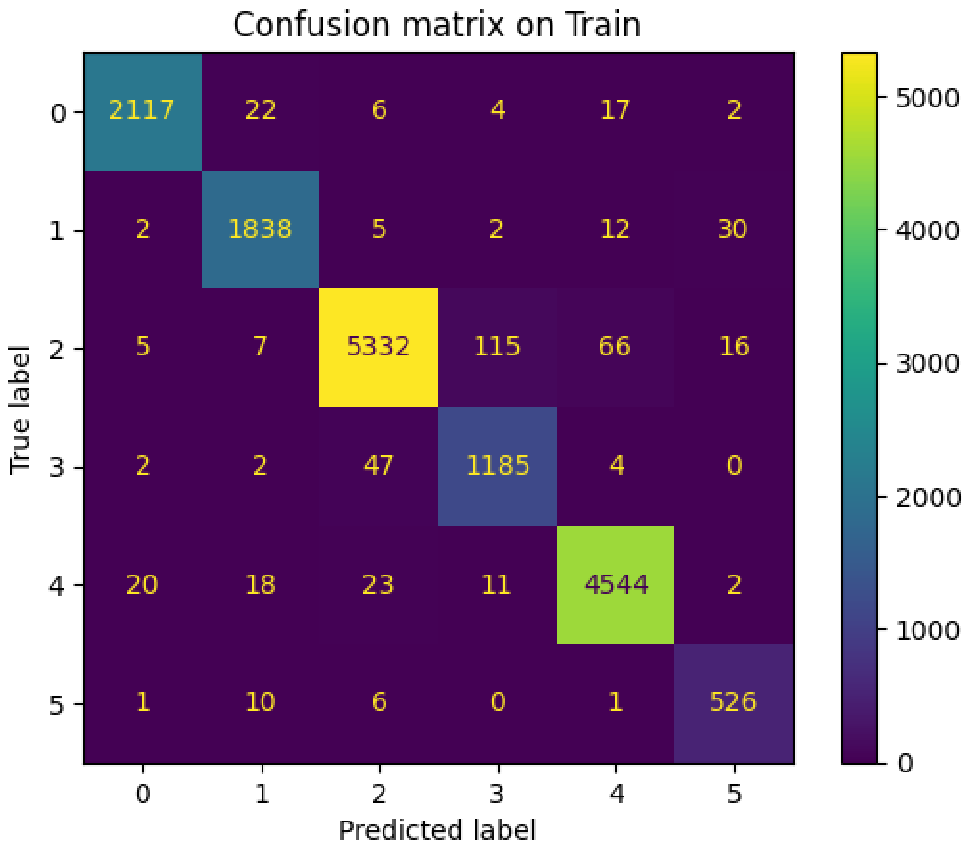


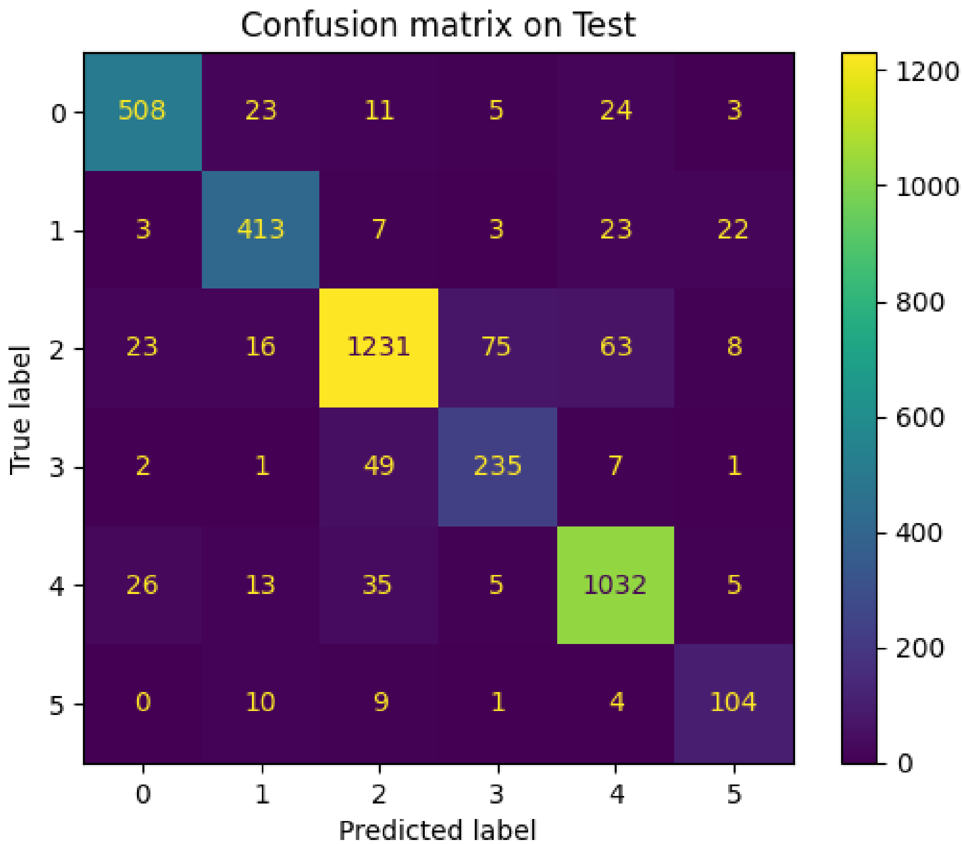
We choose $C = 5$ to be the best model.

```
[ ]: best_l1_softmax_model = LogisticRegression(C=5, penalty='l1', solver='saga',␣
      ↪multi_class='multinomial')
```

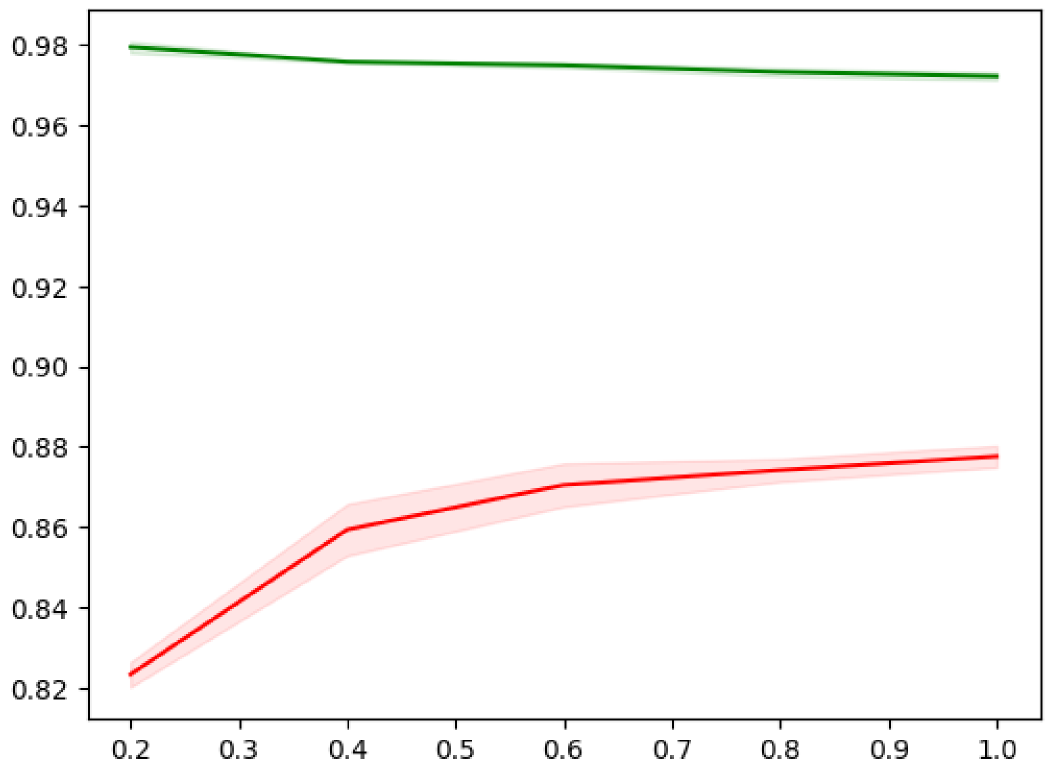
```
[ ]: best_l1_softmax_model.fit(X_train, y_train)
     evaluate_model(best_l1_softmax_model, X_train, X_test, y_train, y_test,␣
      ↪include_training=True)
```

```
Score of on train are:
        - Accuracy score: 0.9714
        - Micro F1 score: 0.9714
        - Macro F1 score: 0.9621
Score of on test are:
        - Accuracy score: 0.8808
        - Micro F1 score: 0.8808
        - Macro F1 score: 0.8493
```


Confusion matrix on Train
True label
Predicted label
0
1
2
3
4
5
2117
22
6
4
17
2
1838
5
12
30
7
5332
115
66
16
47
1185
0
20
18
23
11
4544
1
10
526
5000
4000
3000
2000
1000




```
[ ]: draw_learning_curve(best_l1_softmax_model, X_train, y_train)
```



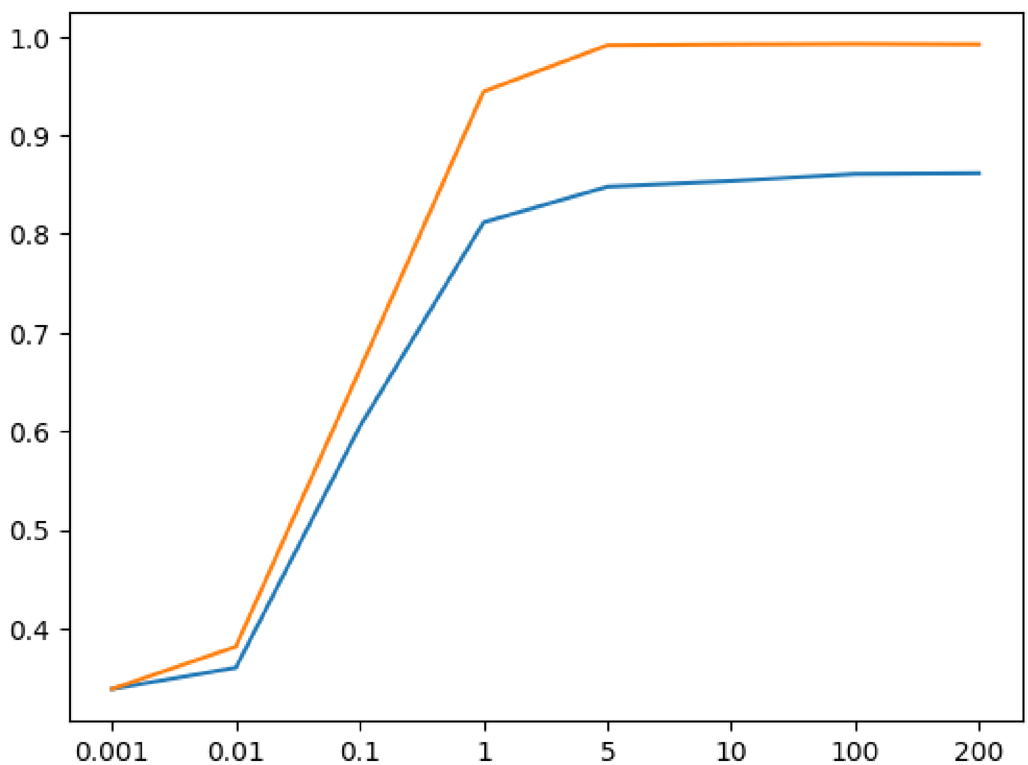
2.3 L2 regularization

[ ]:
```
C_list = [0.001, 0.01, 0.1, 1, 5, 10, 100, 200]

# Define a list in order to store accuracy points
cvs_list = list()
trs_list = list()

for c in C_list:
    # Define model for each C
    softmax_model = LogisticRegression(C=c, penalty='l2', solver='lbfgs',␣
 ↪multi_class='multinomial')
    softmax_model.fit(X_train, y_train)

    # Calculate score of cross validation
    train_score = accuracy_score(y_train, softmax_model.predict(X_train))
    cv_score = np.mean(cross_val_score(softmax_model, X_train, y_train, cv=5,␣
 ↪n_jobs=8))

    trs_list.append(train_score)
    cvs_list.append(cv_score)
```

[ ]:
```
# Print the result
print(C_list)
print(trs_list)
print(cvs_list)

# Draw the plot
fig = sns.lineplot(x=list(range(len(C_list))), y=cvs_list)
fig = sns.lineplot(x=list(range(len(C_list))), y=trs_list)
fig.set_xticks(range(len(C_list)))
fig.set_xticklabels(C_list)
```

```
[0.001, 0.01, 0.1, 1, 5, 10, 100, 200]
[0.3386875, 0.381625, 0.6619375, 0.9441875, 0.99125, 0.9920625, 0.992625,
0.9921875]
[0.3386875000000001, 0.36025, 0.6044375, 0.811625, 0.8478125000000001, 0.8535,
0.86075, 0.8615]
```

[ ]:
```
[Text(0, 0, '0.001'),
 Text(1, 0, '0.01'),
 Text(2, 0, '0.1'),
 Text(3, 0, '1'),
 Text(4, 0, '5'),
 Text(5, 0, '10'),
 Text(6, 0, '100'),
 Text(7, 0, '200')]
```



We can see the good value of C is near $C = 100$, then we scope to $C = 100$:

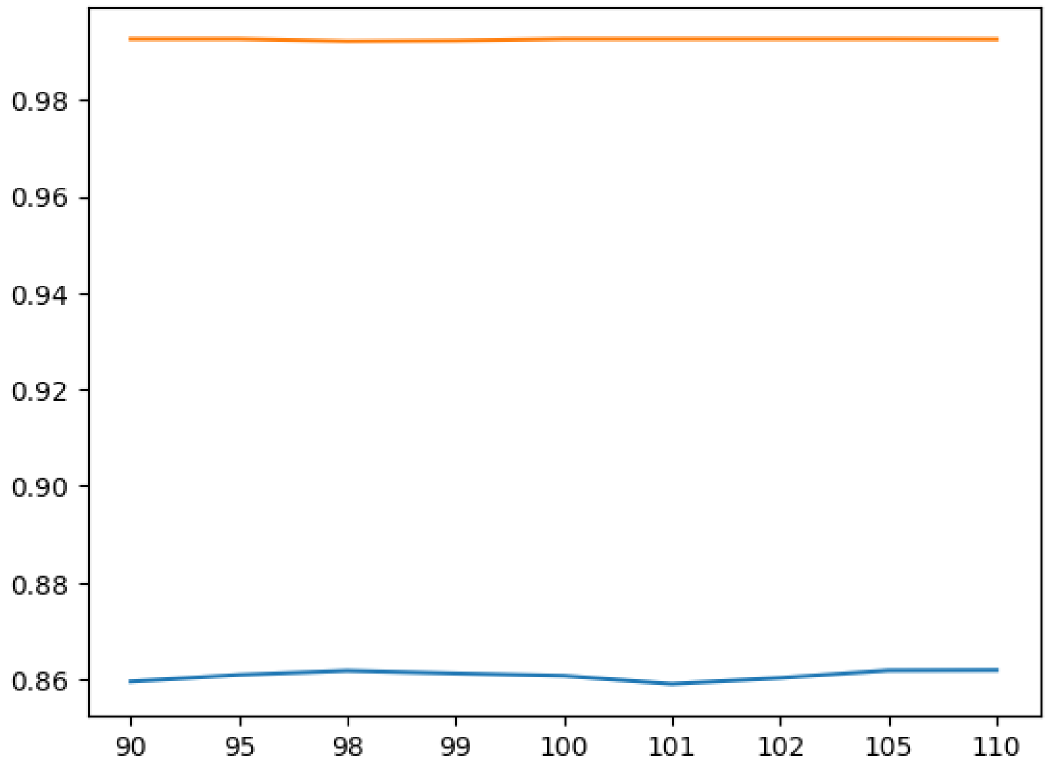
[ ]:
```
C_list = [90, 95, 98, 99, 100, 101, 102, 105, 110]

# Define a list in order to store accuracy points
cvs_list = list()
trs_list = list()

for c in C_list:
    # Define model for each C
    softmax_model = LogisticRegression(C=c, penalty='l2', solver='lbfgs',␣
 ↪multi_class='multinomial')
    softmax_model.fit(X_train, y_train)

    # Calculate score of cross validation
    train_score = accuracy_score(y_train, softmax_model.predict(X_train))
    cv_score = np.mean(cross_val_score(softmax_model, X_train, y_train, cv=5,␣
 ↪n_jobs=8))

    trs_list.append(train_score)
    cvs_list.append(cv_score)
```

[ ]:
```
# Print the result
print(C_list)
print(trs_list)
print(cvs_list)

# Draw the plot
fig = sns.lineplot(x=list(range(len(C_list))), y=cvs_list)
fig = sns.lineplot(x=list(range(len(C_list))), y=trs_list)
fig.set_xticks(range(len(C_list)))
fig.set_xticklabels(C_list)
```

```
[90, 95, 98, 99, 100, 101, 102, 105, 110]
[0.992625, 0.992625, 0.992125, 0.99225, 0.992625, 0.992625, 0.992625, 0.992625,
0.9925625]
[0.8595624999999998, 0.8609375, 0.8618124999999999, 0.8612499999999998, 0.86075,
0.8590625, 0.8603124999999998, 0.8618750000000001, 0.8619375]
```

[ ]:
```
[Text(0, 0, '90'),
 Text(1, 0, '95'),
 Text(2, 0, '98'),
 Text(3, 0, '99'),
 Text(4, 0, '100'),
 Text(5, 0, '101'),
```

```
 Text(6, 0, '102'),
 Text(7, 0, '105'),
 Text(8, 0, '110')]
```

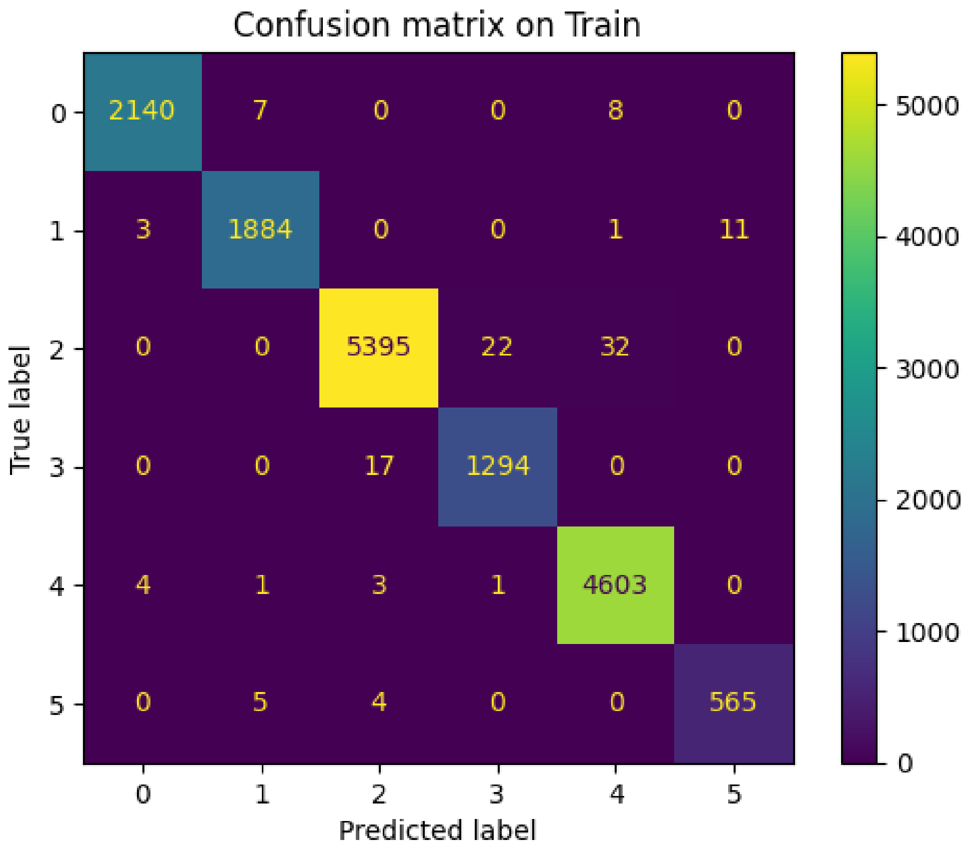


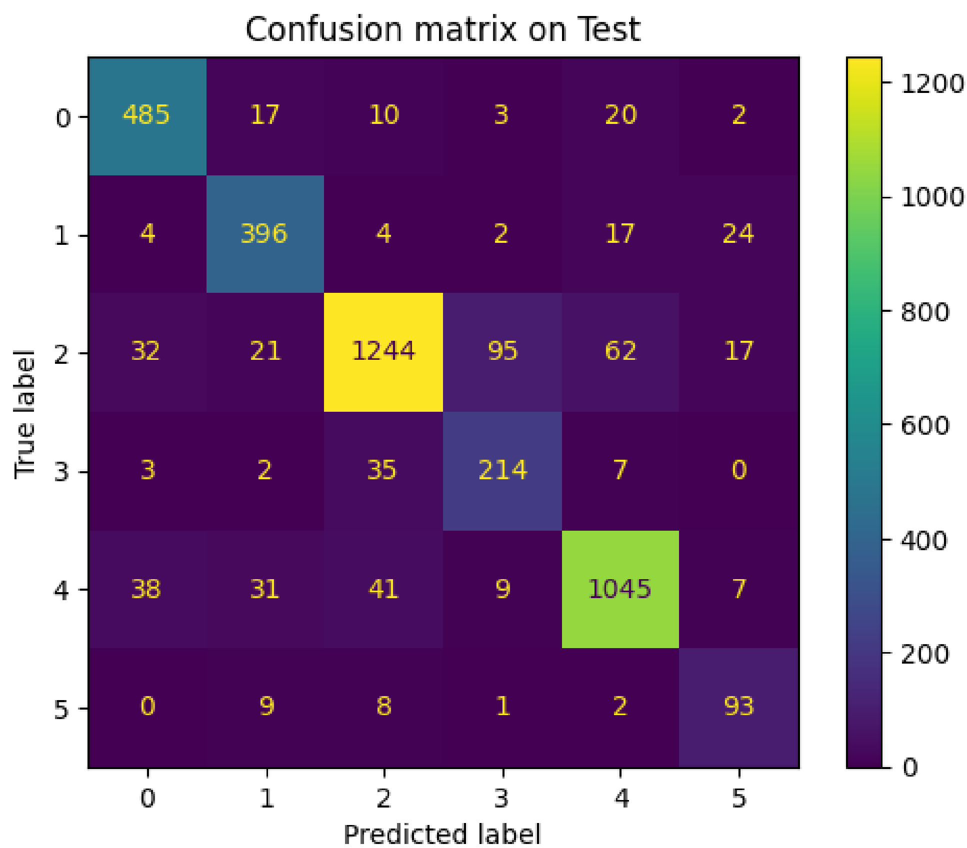
We choose $C = 110$ to be the best model.

```
[ ]: best_l2_softmax_model = LogisticRegression(C=110, penalty='l2', solver='lbfgs',
      multi_class='multinomial')
```

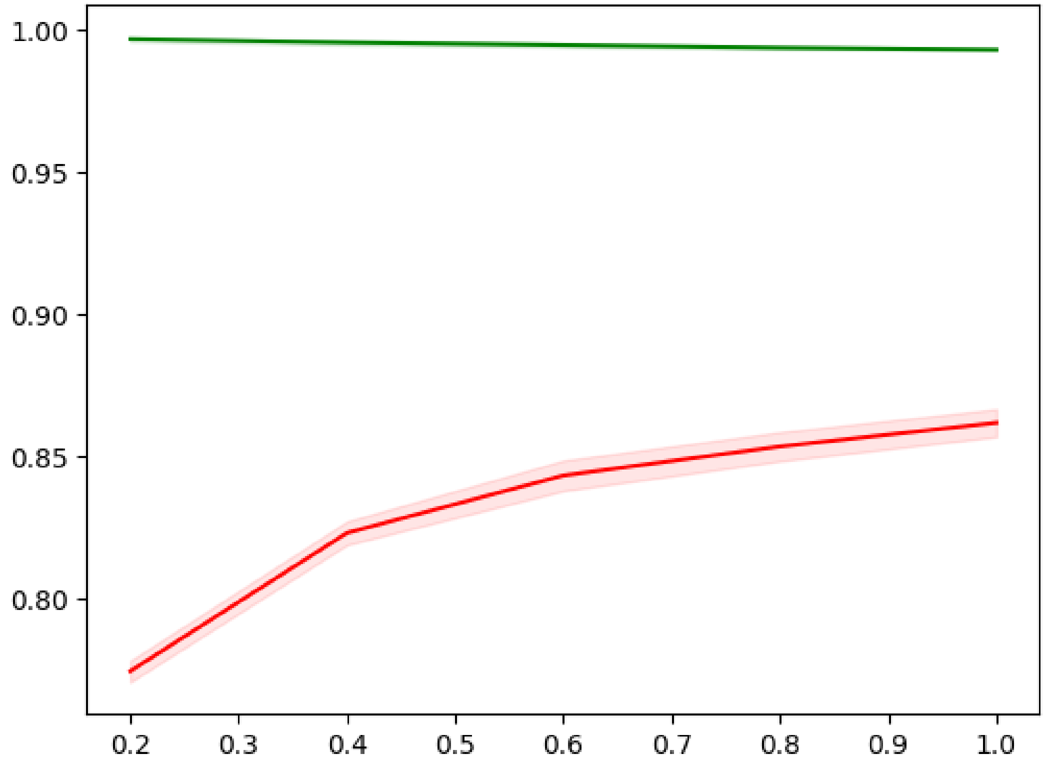
```
[ ]: best_l2_softmax_model.fit(X_train, y_train)
     evaluate_model(best_l2_softmax_model, X_train, X_test, y_train, y_test,
      include_training=True)
```

```
Score of on train are:
        - Accuracy score: 0.9926
        - Micro F1 score: 0.9926
        - Macro F1 score: 0.9904
Score of on test are:
        - Accuracy score: 0.8692
        - Micro F1 score: 0.8692
        - Macro F1 score: 0.8304
```


Confusion matrix on Train
True label
Predicted label
0
1
2
3
4
5
2140 7 0 0 8 0
3 1884 0 0 1 11
0 0 5395 22 32 0
0 0 17 1294 0 0
4 1 3 1 4603 0
0 5 4 0 0 565
5000
4000
3000
2000
1000
0



[ ]:
```
draw_learning_curve(best_l2_softmax_model, X_train, y_train)
```



2.4 Elastic regularization

[ ]:
```
dict_param = {
    'C' : [0.001, 0.01, 0.1, 1, 5, 10, 100],
    'l1_ratio' : np.linspace(0.1, 0.9, 5)
}

softmax_model = LogisticRegression(penalty='elasticnet', solver='saga',␣
 ↪multi_class='multinomial')
grid_search = GridSearchCV(softmax_model, dict_param, scoring='accuracy', cv=5,␣
 ↪n_jobs=-1)
grid_search.fit(X_train, y_train)
```

[ ]:
```
GridSearchCV(cv=5,
             estimator=LogisticRegression(multi_class='multinomial',
                                          penalty='elasticnet', solver='saga'),
             n_jobs=-1,
             param_grid={'C': [0.001, 0.01, 0.1, 1, 5, 10, 100],
                         'l1_ratio': array([0.1, 0.3, 0.5, 0.7, 0.9])},
             scoring='accuracy')
```

[ ]:
```
df = pd.DataFrame(
  dict(
    C = [val['C'] for val in grid_search.cv_results_['params']],
    l1_ratio = [val['l1_ratio'] for val in grid_search.cv_results_['params']],
    score = grid_search.cv_results_['mean_test_score']
  )
)
df = df[df['score'] < 0.8]
print("Bad hyperparameter:")
for param in dict_param:
  for value in dict_param[param]:
    if len(df[df[param] == value]) == 35 // len(dict_param[param]):
      print(param, value)
```

```
Bad hyperparameter:
C 0.001
C 0.01
C 0.1
```

[ ]:
```
dict_param = {
    'C' : np.logspace(0, 2, 5),
    'l1_ratio' : np.linspace(0.1, 0.9, 5)
}

softmax_model = LogisticRegression(penalty='elasticnet', solver='saga',␣
 ↪multi_class='multinomial')
grid_search = GridSearchCV(softmax_model, dict_param, scoring='accuracy', cv=5,␣
 ↪n_jobs=-1)
grid_search.fit(X_train, y_train)
```

[ ]:
```
GridSearchCV(cv=5,
             estimator=LogisticRegression(multi_class='multinomial',
                                          penalty='elasticnet', solver='saga'),
             n_jobs=-1,
             param_grid={'C': array([  1.        ,   3.16227766,  10.        ,
31.6227766 ,
       100.        ]),
                         'l1_ratio': array([0.1, 0.3, 0.5, 0.7, 0.9])},
             scoring='accuracy')
```

[ ]:
```
df = pd.DataFrame(
  dict(
    C = [val['C'] for val in grid_search.cv_results_['params']],
    l1_ratio = [val['l1_ratio'] for val in grid_search.cv_results_['params']],
    score = grid_search.cv_results_['mean_test_score']
  )
)
print(df)
```

```
            C  l1_ratio     score
0    1.000000       0.1  0.821063
1    1.000000       0.3  0.831812
2    1.000000       0.5  0.839813
3    1.000000       0.7  0.848938
4    1.000000       0.9  0.861063
5    3.162278       0.1  0.849187
6    3.162278       0.3  0.859062
7    3.162278       0.5  0.866500
8    3.162278       0.7  0.871562
9    3.162278       0.9  0.876250
10  10.000000       0.1  0.857062
11  10.000000       0.3  0.864437
12  10.000000       0.5  0.869438
13  10.000000       0.7  0.872188
14  10.000000       0.9  0.875313
15  31.622777       0.1  0.858938
16  31.622777       0.3  0.864375
17  31.622777       0.5  0.867563
18  31.622777       0.7  0.869813
19  31.622777       0.9  0.872750
20 100.000000       0.1  0.860750
21 100.000000       0.3  0.862750
22 100.000000       0.5  0.865313
23 100.000000       0.7  0.867750
24 100.000000       0.9  0.868375
```

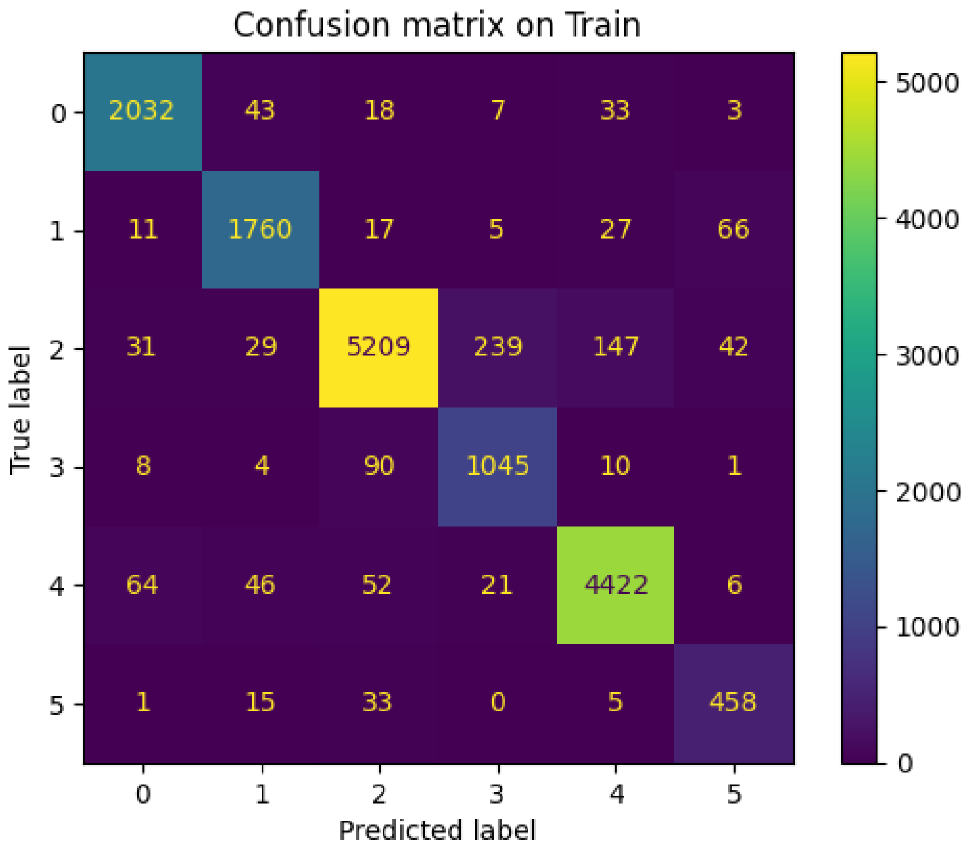
[ ]:
```
print(grid_search.best_estimator_, grid_search.best_score_)
```

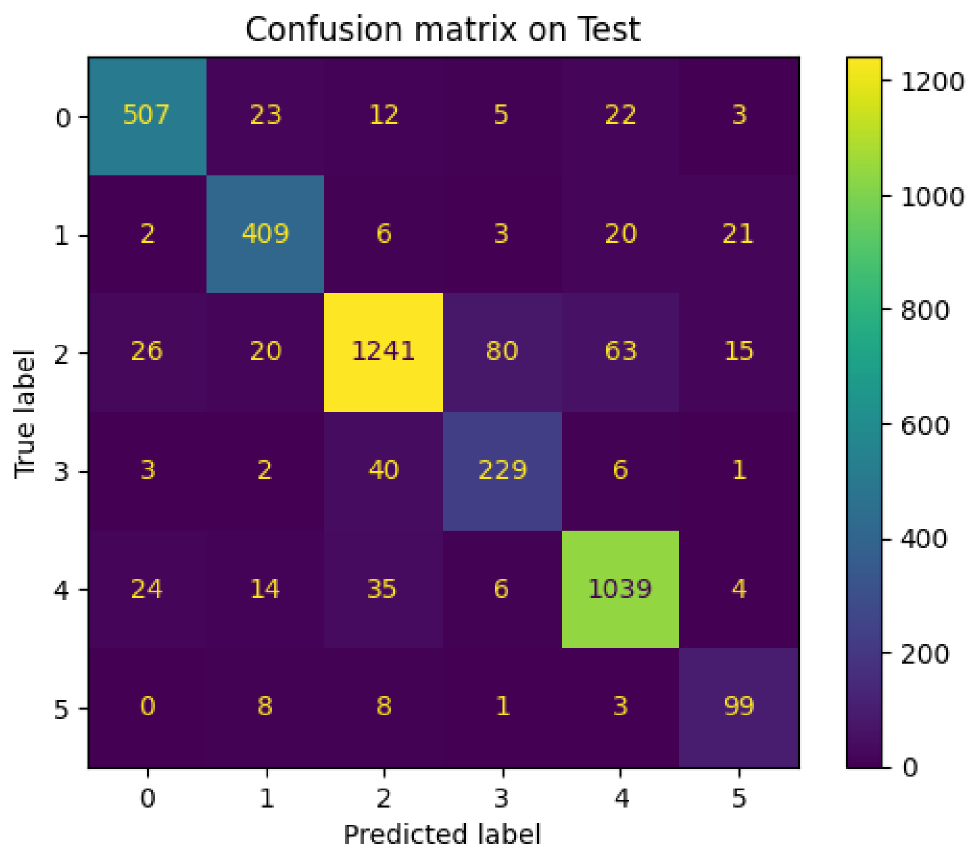
```
LogisticRegression(C=3.1622776601683795, l1_ratio=0.9,
                   multi_class='multinomial', penalty='elasticnet',
                   solver='saga') 0.87625
```

[ ]:
```
best_en_softmax_model = LogisticRegression(C=3.1622776601683795, l1_ratio=0.9,
                    multi_class='multinomial', penalty='elasticnet',
                    solver='saga')
```

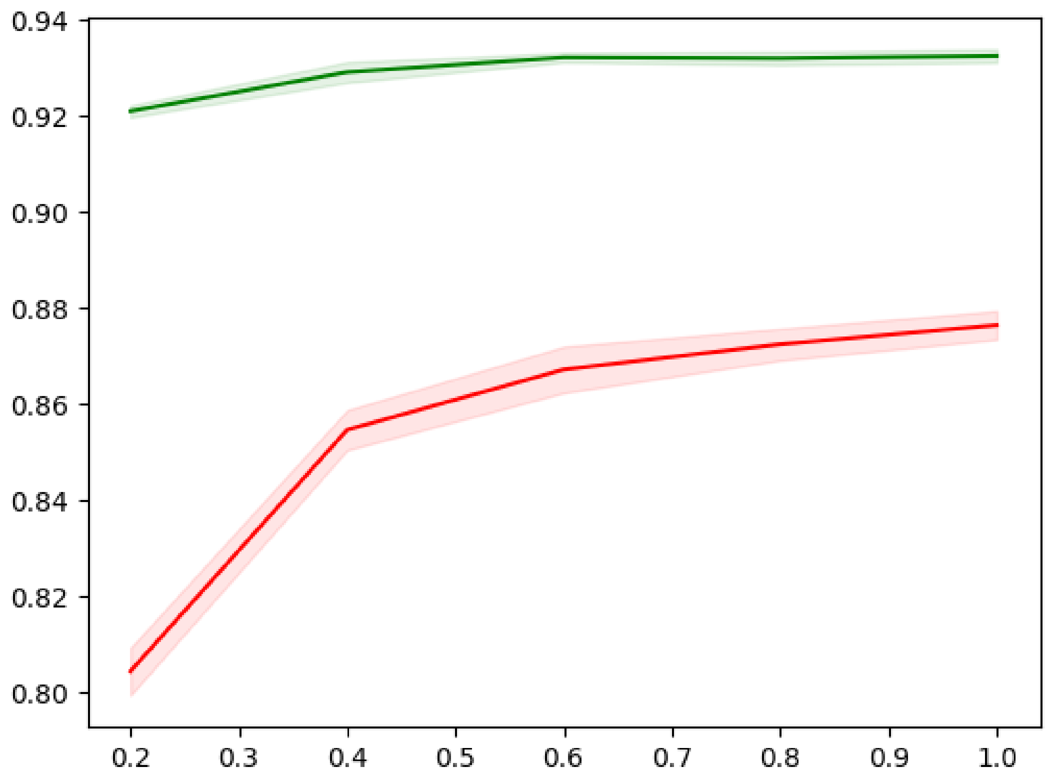
[ ]:
```
best_en_softmax_model.fit(X_train, y_train)
evaluate_model(best_en_softmax_model, X_train, X_test, y_train, y_test,␣
 ↪include_training=True)
```

```
Score of on train are:
        - Accuracy score: 0.9329
        - Micro F1 score: 0.9329
        - Macro F1 score: 0.9098
Score of on test are:
        - Accuracy score: 0.8810
        - Micro F1 score: 0.8810
        - Macro F1 score: 0.8473
```


Confusion matrix on Train
True label
Predicted label
0
1
2
3
4
5
2032
43
18
7
33
3
11
1760
17
5
27
66
31
29
5209
239
147
42
8
4
90
1045
10
1
64
46
52
21
4422
6
1
15
33
0
5
458
5000
4000
3000
2000
1000
0



[ ]:
```
draw_learning_curve(best_en_softmax_model, X_train, y_train)
```



3 Conclusion

There are a few difference among the accuracy of these 3 regularization. However, Elastic-net regularization gives the best performance then I will choose it to be the best model in this notebook.

[ ]:
```
best_softmax_model = best_en_softmax_model
```

[ ]:
```
directory = "data/models/softmax/"

dump(best_softmax_model, directory + "best_softmax_tfidf_model.joblib")
```

[ ]:
```
['data/models/softmax/best_softmax_tfidf_model.joblib']
```