

# Support Vector Machine (SVM)

May 2, 2024

## 1 Support Vector Machine

### 1.1 Initialization

Connect to Google Drive:

```
[ ]: # from google.colab import drive
      # drive.mount('/content/drive')

      # %cd '/content/drive/MyDrive/GitHub/emotion-dectection-from-text'
```

Preparing necessary packages (may need to add more):

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

      from sklearn.svm import SVC
      from sklearn.model_selection import GridSearchCV, cross_val_score
      from sklearn.metrics import accuracy_score
      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_bow
      X_test = X_test_bow
```

## 1.2 Basic training

We define and train a model with simple hyperparameter in which kernel is linear,  $C = 1.0$ , etc:

```
[ ]: svm_model = SVC(kernel='linear')
     svm_model.fit(X_train, y_train)
```

```
[ ]: SVC(kernel='linear')
```

Evaluate model using preset function:

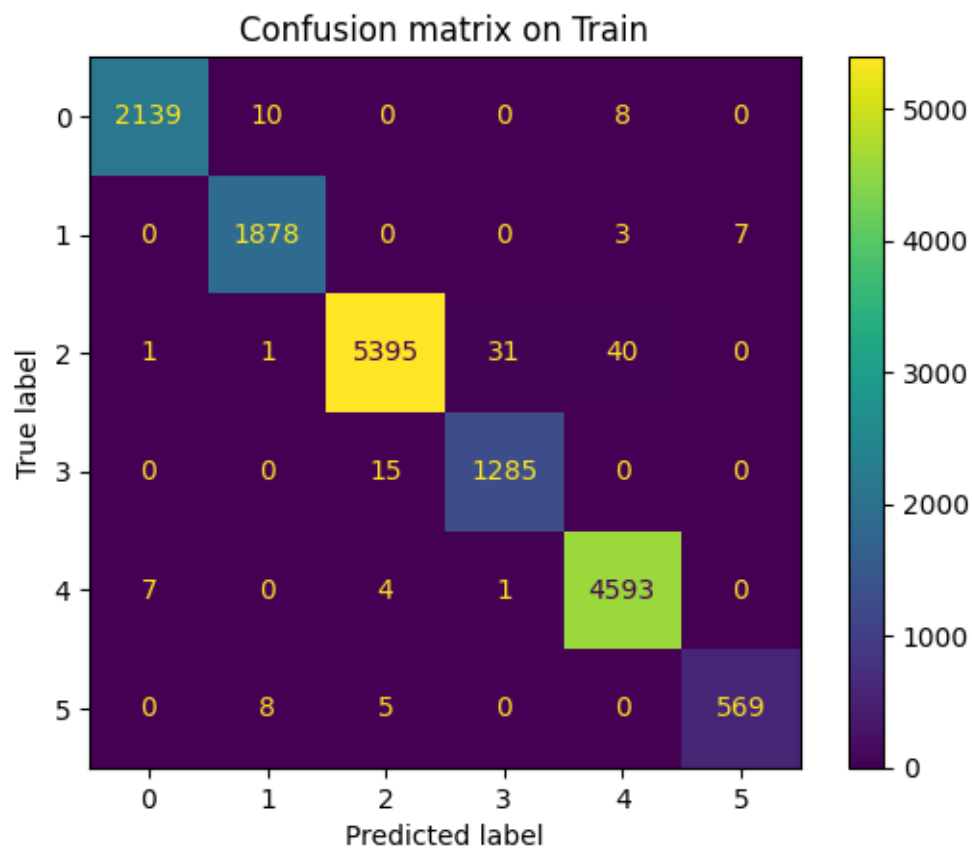
```
[ ]: evaluate_model(svm_model, X_train, X_test, y_train, y_test,
                  ↪include_training=True)
```

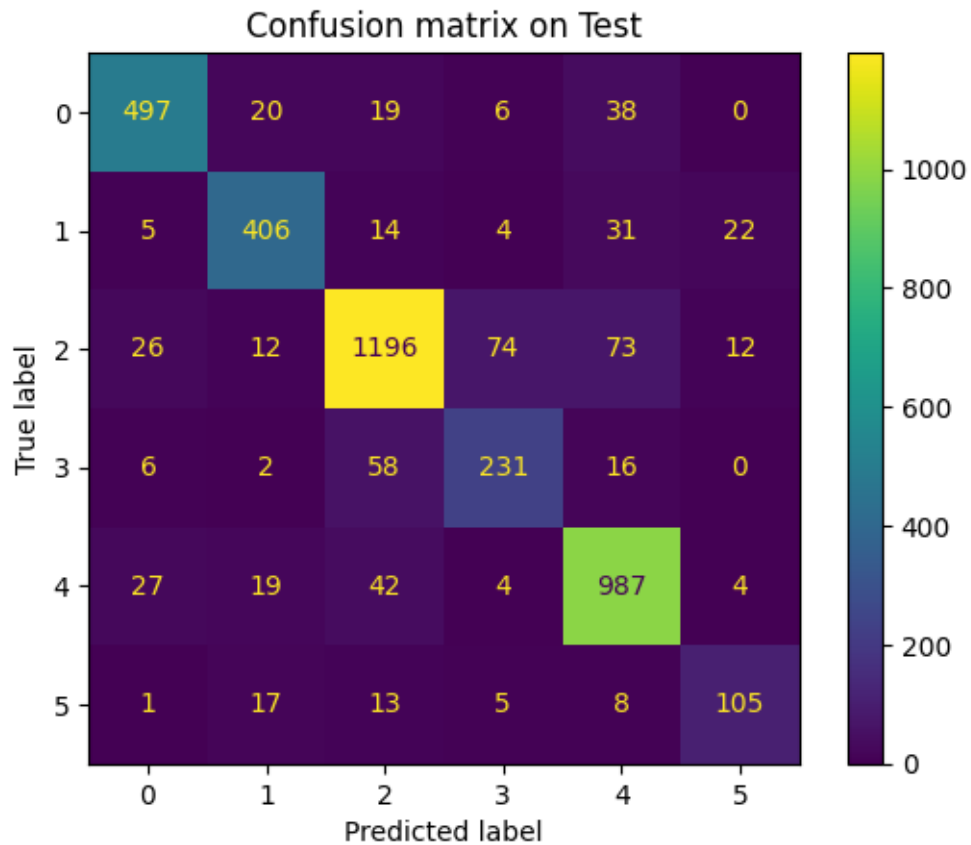
Score of on train are:

- Accuracy score: 0.99
- Micro F1 score: 0.99
- Macro F1 score: 0.99

Score of on test are:

- Accuracy score: 0.86
- Micro F1 score: 0.86
- Macro F1 score: 0.82

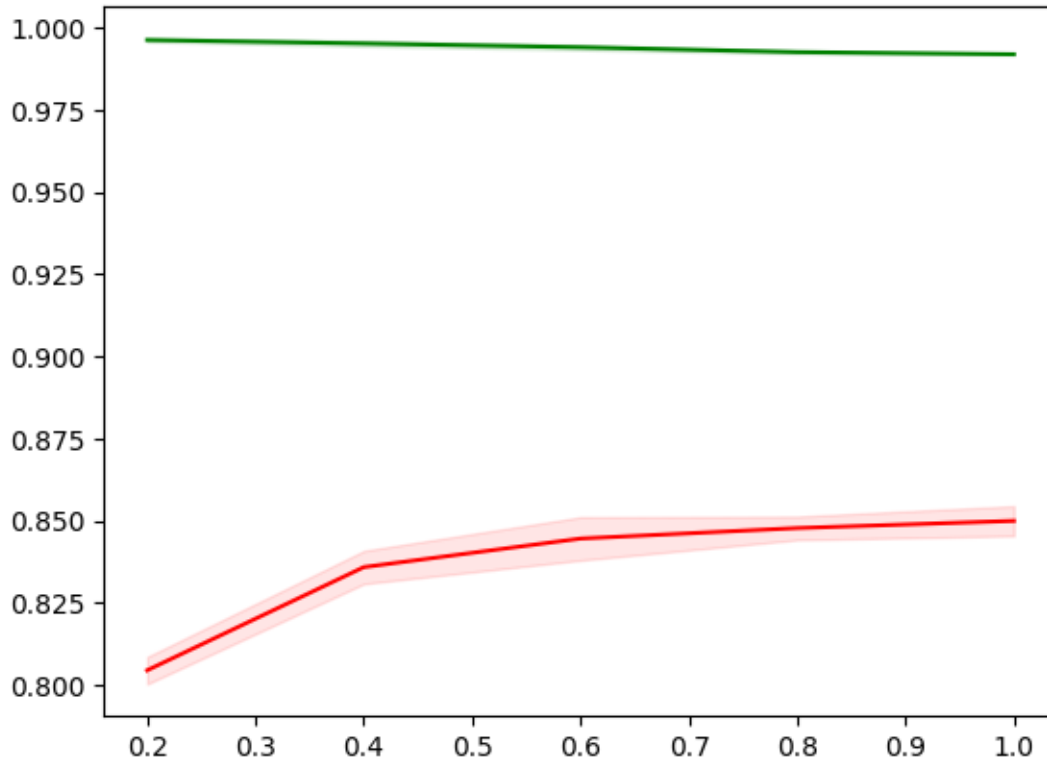




This model gives a pretty good score but it seems to be overfitting.

Draw learning curve using preset function:

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



**Review:** SVM can result a better result if we do some hyperparameter tuning to resolve the overfitting

### 1.3 Model selection

This section will be separated in 4 parts for 4 kernels instead of using GridSearchCV in order to get the better result

#### 1.3.1 Linear function kernel

Formula:

$$k(x, z) = x^T z$$

First, we search in a big range 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
```

```

svm_model = SVC(kernel='linear', C=c)
svm_model.fit(X_train, y_train)

# Calculate score of cross validation
train_score = accuracy_score(y_train, svm_model.predict(X_train))
cv_score = np.mean(cross_val_score(svm_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)

```

```

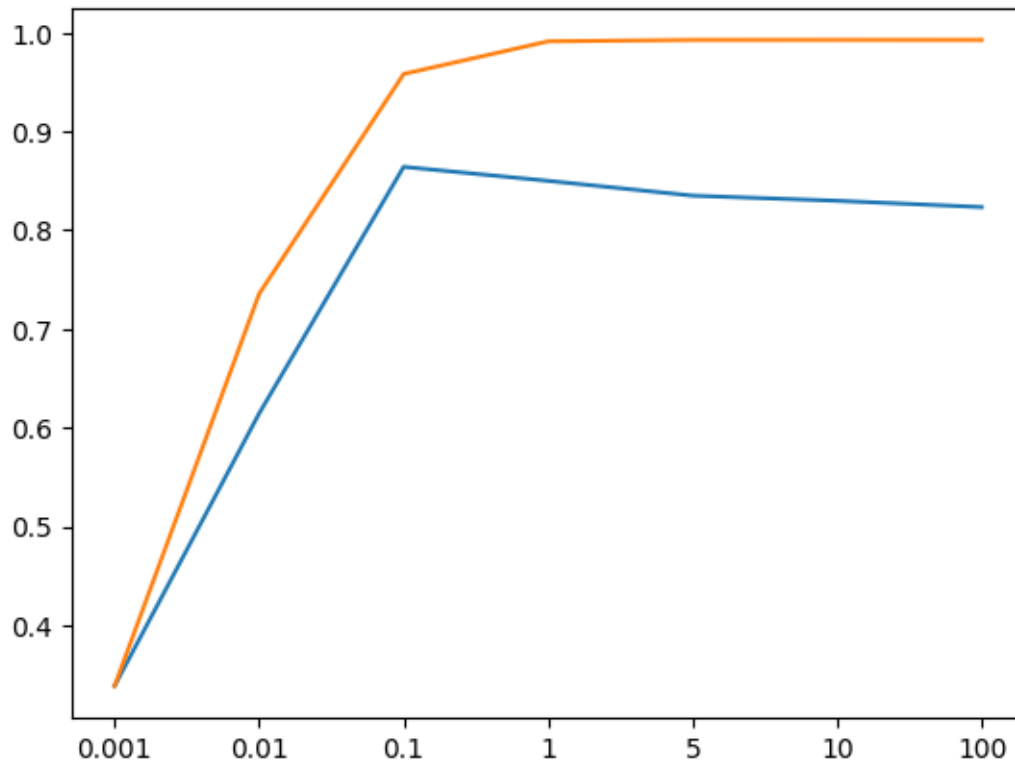
[0.001, 0.01, 0.1, 1, 5, 10, 100]
[0.3386875, 0.7355, 0.958125, 0.9911875, 0.9925625, 0.992625, 0.9925625]
[0.33868750000000001, 0.6144375, 0.8641249999999999, 0.8499375, 0.8349375,
0.82975, 0.8233749999999999]

```

```

[ ]: [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')]

```



From the result of above section, we can see the good value of  $C$  is near the value 0.1.

Scope to  $C = 0.1$ :

```
[ ]: C_list = [0.025, 0.05, 0.075, 0.1, 0.25, 0.5, 0.75]

# 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
    svm_model = SVC(kernel='linear', C=c)
    svm_model.fit(X_train, y_train)

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

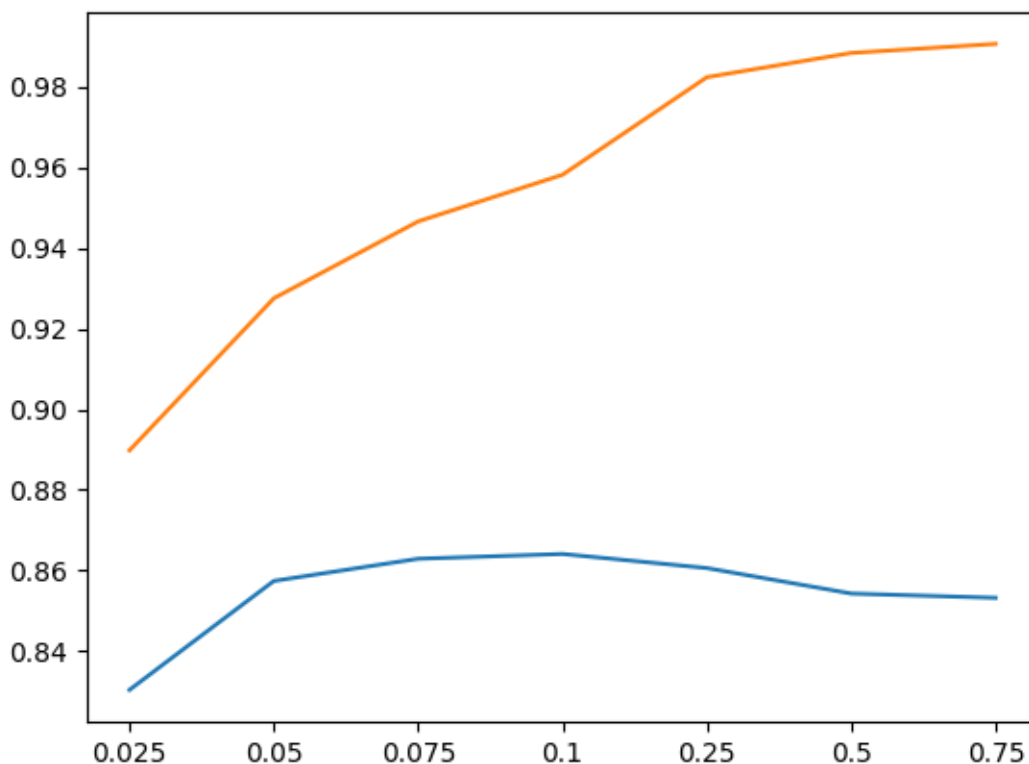
    trs_list.append(train_score)
    cvs_list.append(cv_score)
```

```
[ ]: # 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)

[0.025, 0.05, 0.075, 0.1, 0.25, 0.5, 0.75]
[0.8898125, 0.9275, 0.9465625, 0.958125, 0.9823125, 0.9883125, 0.9905625]
[0.8304375, 0.8574375, 0.8629374999999999, 0.8641249999999999, 0.860625,
0.8543125, 0.8532499999999998]

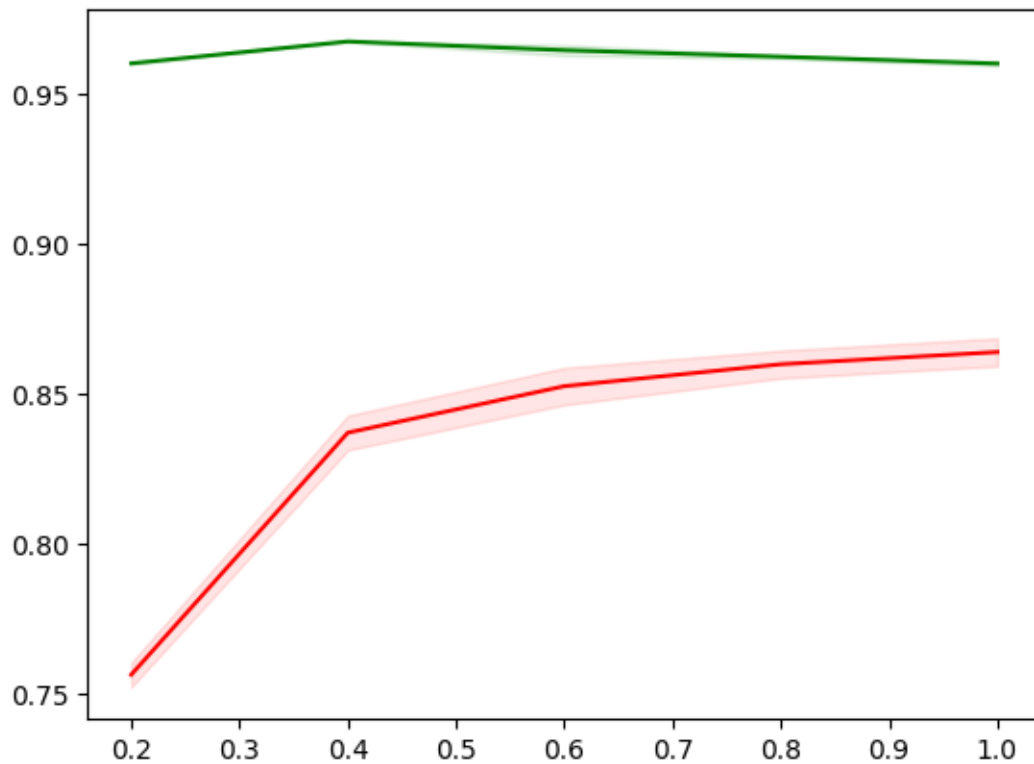
[ ]: [Text(0, 0, '0.025'),
      Text(1, 0, '0.05'),
      Text(2, 0, '0.075'),
      Text(3, 0, '0.1'),
      Text(4, 0, '0.25'),
      Text(5, 0, '0.5'),
      Text(6, 0, '0.75')]
```



As the result, we can claim that  $C = 0.1$  give a model with good accuracy and avoid overfitting. We will test the model again in test set.

```
[ ]: best_svm_linear_model = SVC(kernel='linear', C=0.1)
```

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



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

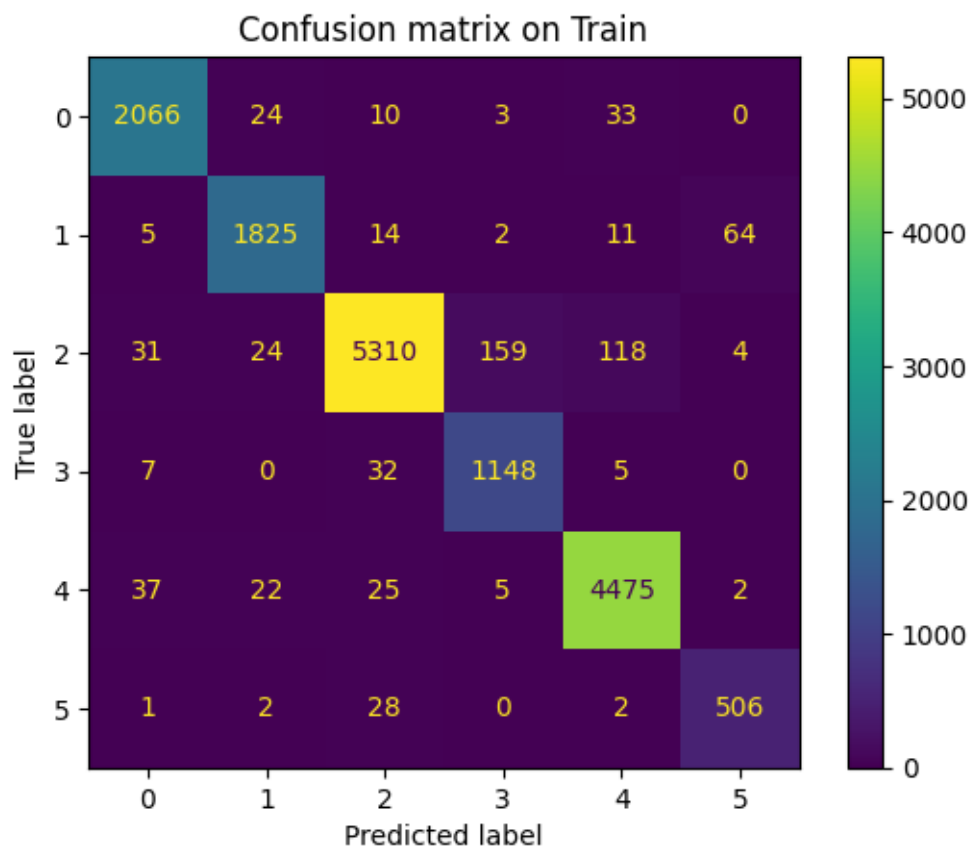
Score of on train are:

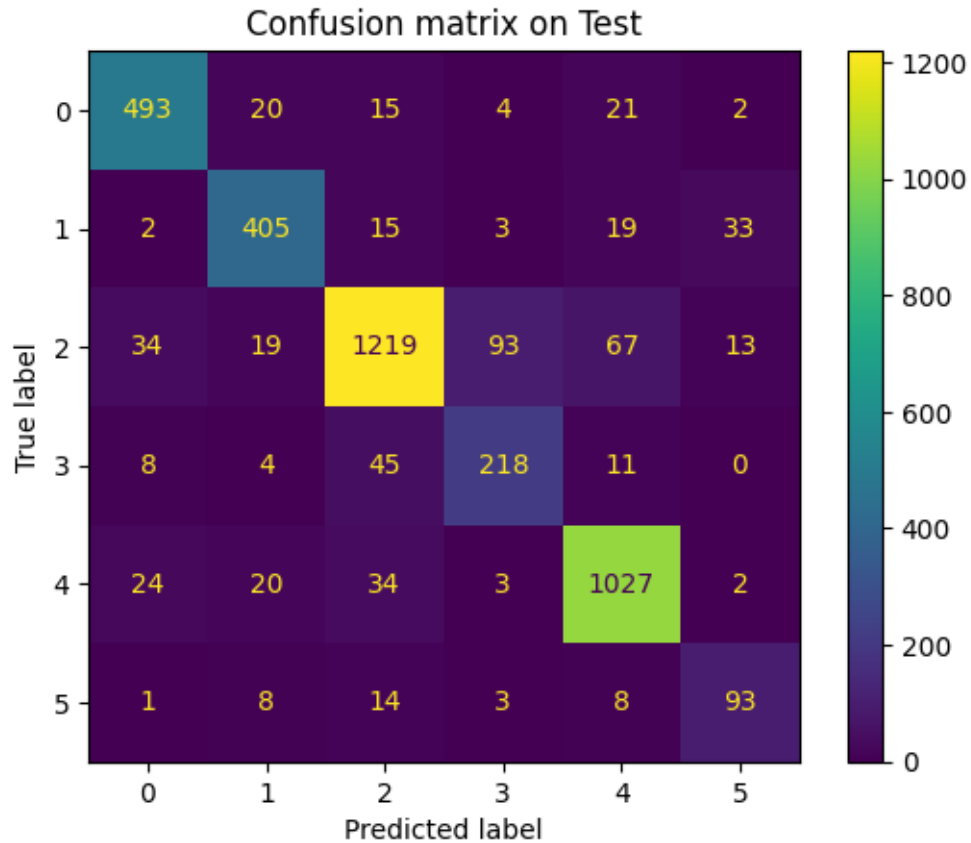
- Accuracy score: 0.96
- Micro F1 score: 0.96
- Macro F1 score: 0.95

Score of on test are:

- Accuracy score: 0.86
- Micro F1 score: 0.86
- Macro F1 score: 0.82







### 1.3.2 Radial basis function kernel

Formula:

$$k(x, z) = e^{-\gamma \|x - z\|_2^2}$$

First, we using grid search in a big domain.

```
[ ]: dict_param = {
    'C' : np.asarray([0.01, 0.1, 1, 10.0, 100]),
    'gamma': np.logspace(-3, 2, 6)
}

grid_search = GridSearchCV(SVC(kernel='rbf'), dict_param, cv = 5, n_jobs=8)
grid_search.fit(X_train, y_train)

[ ]: GridSearchCV(cv=5, estimator=SVC(), n_jobs=8,
    param_grid={'C': array([1.e-02, 1.e-01, 1.e+00, 1.e+01, 1.e+02]),
    'gamma': array([1.e-03, 1.e-02, 1.e-01, 1.e+00, 1.e+01,
    1.e+02])})
```

```
[ ]: print('Best score: ', grid_search.best_score_, '\n')

print('Bad hyperparameter:')
df = pd.DataFrame(
    dict(
        C = [val['C'] for val in grid_search.cv_results_['params']],
        gamma = [val['gamma'] for val in grid_search.cv_results_['params']],
        score = grid_search.cv_results_['mean_test_score']
    )
)
df = df[df['score'] < 0.8]
for param in dict_param:
    for value in dict_param[param]:
        if len(df[df[param] == value]) == 30 // len(dict_param[param]):
            print(param, value)
```

Best score: 0.862125

Bad hyperparameter:

C 0.01  
C 0.1  
C 1.0  
gamma 0.1  
gamma 1.0  
gamma 10.0  
gamma 100.0

We filter all the parameters that appear in all the bad models (validation accuracy < 0.8) \* C = 0.01  
\* C = 0.1 \* C = 1 \*  $\gamma = 100.0$  \*  $\gamma = 10.0$  \*  $\gamma = 1.0$

So that we can shrink the range of parameters

We repeat the algorithm again and again until there is no bad parameter to receive the best model

```
[ ]: dict_param = {
    'C' : np.linspace(25, 100, 10),
    'gamma': np.logspace(-3, -2, 10)
}

grid_search = GridSearchCV(SVC(kernel='rbf'), dict_param, cv = 5, n_jobs=8)
grid_search.fit(X_train, y_train)
```

```
[ ]: GridSearchCV(cv=5, estimator=SVC(), n_jobs=8,
    param_grid={'C': array([ 25.          ,  33.33333333,  41.66666667,
50.          ,
58.33333333,  66.66666667,  75.          ,  83.33333333,
91.66666667, 100.          ]),
    'gamma': array([0.001          , 0.00129155, 0.0016681 ,
0.00215443, 0.00278256,
```

```
0.00359381, 0.00464159, 0.00599484, 0.00774264, 0.01 ]))
```

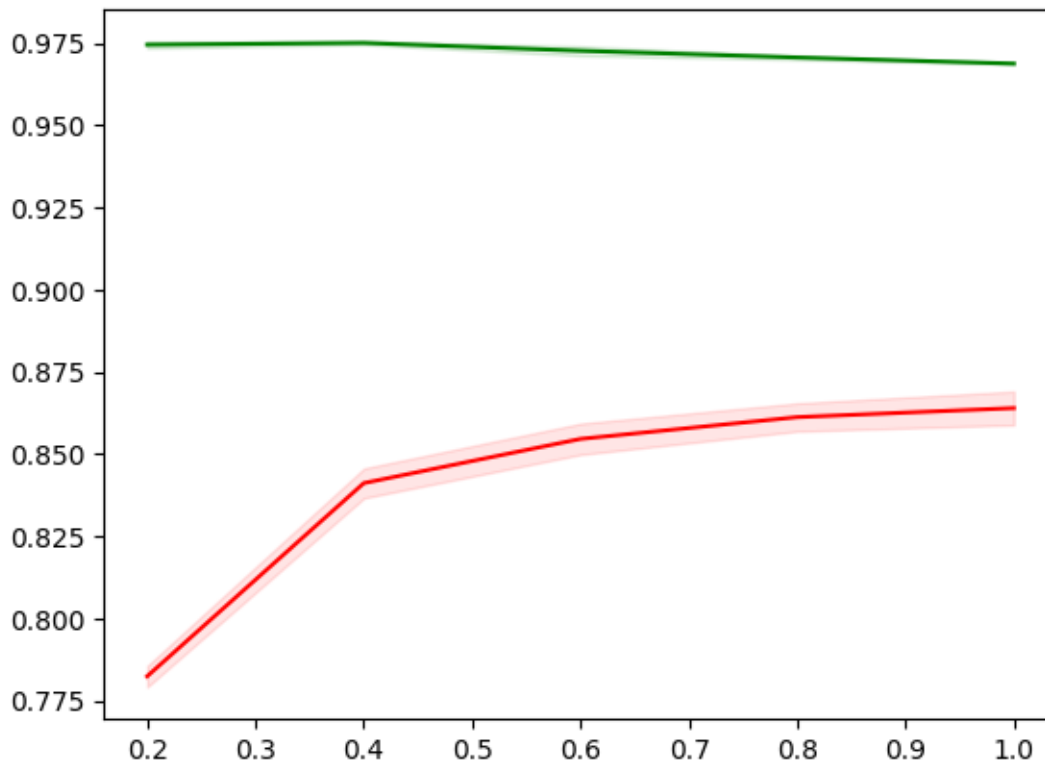
```
[ ]: df = pd.DataFrame(  
    dict(  
        C = [val['C'] for val in grid_search.cv_results_['params']],  
        gamma = [val['gamma'] for val in grid_search.cv_results_['params']],  
        score = grid_search.cv_results_['mean_test_score']  
    )  
)  
print(df[df['score'] == min(df['score'])])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

```
      C      gamma      score  
98  100.0  0.007743  0.845313
```

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

```
SVC(C=50.0, gamma=0.001291549665014884) 0.8639375000000001
```

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



```
[ ]: best_svm_rbf_model.fit(X_train, y_train)
```

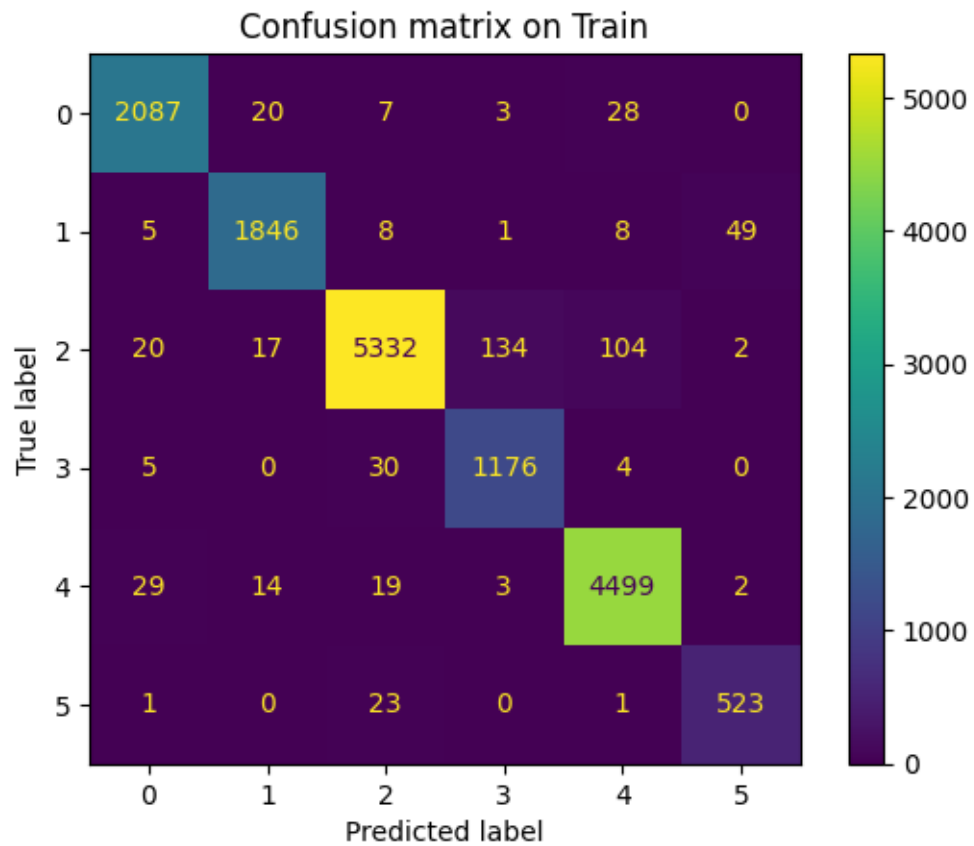
```
evaluate_model(best_svm_rbf_model, X_train, X_test, y_train, y_test, □  
↪include_training=True)
```

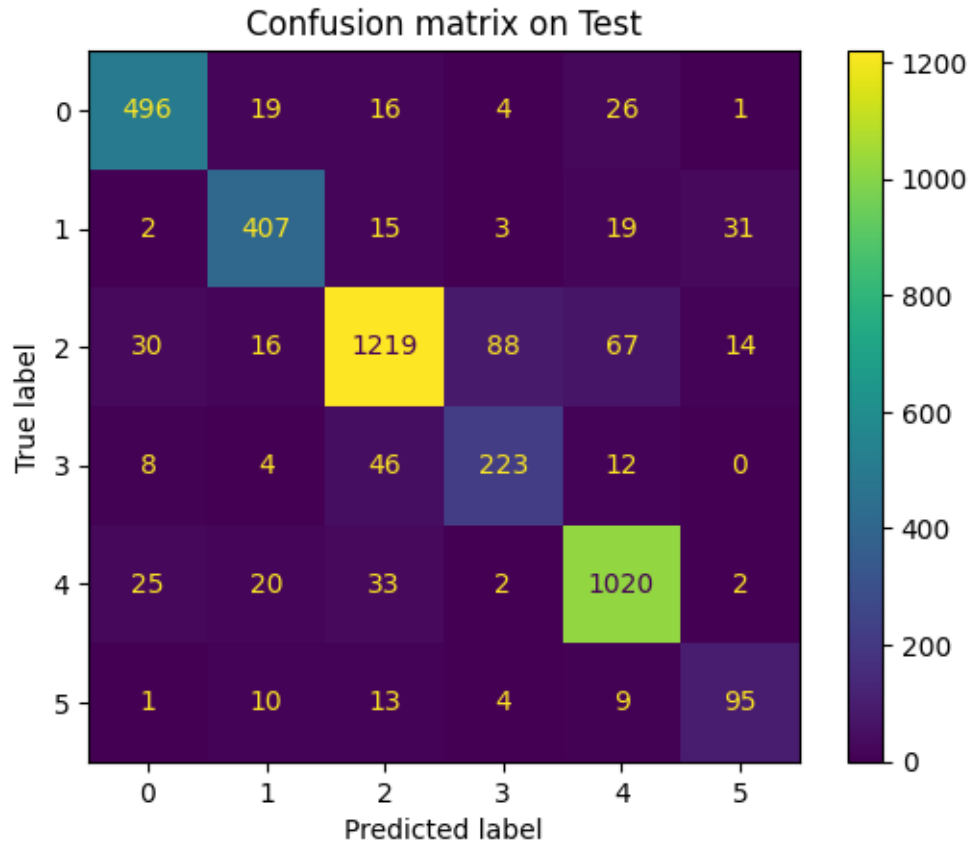
Score of on train are:

- Accuracy score: 0.97
- Micro F1 score: 0.97
- Macro F1 score: 0.96

Score of on test are:

- Accuracy score: 0.86
- Micro F1 score: 0.86
- Macro F1 score: 0.82





### 1.3.3 Sigmoid function kernel

Formula:

$$k(x, z) = \tanh(\gamma x^T z + r)$$

We use the same method in the above section to tuning this kernel

```
[ ]: dict_param = {
    'C' : np.asarray([0.001, 0.01, 0.1, 1, 10.0, 100]),
    'gamma': np.asarray([0.001, 0.01, 0.1, 1, 10.0, 100]),
    'coef0': np.asarray([0.001, 0.01, 0.1, 1, 10.0, 100])
}

grid_search = GridSearchCV(SVC(kernel='sigmoid'), dict_param, cv = 5, n_jobs=8)
grid_search.fit(X_train, y_train)

[ ]: GridSearchCV(cv=5, estimator=SVC(kernel='sigmoid'), n_jobs=8,
    param_grid={'C': array([1.e-03, 1.e-02, 1.e-01, 1.e+00, 1.e+01,
    1.e+02]),
    'coef0': array([1.e-03, 1.e-02, 1.e-01, 1.e+00, 1.e+01,
```

```
1.e+02]],
                                'gamma': array([1.e-03, 1.e-02, 1.e-01, 1.e+00, 1.e+01,
1.e+02]))})
```

```
[ ]: print('Best score: ', grid_search.best_score_, '\n')

print('Bad hyperparameter:')
df = pd.DataFrame(
    dict(
        C = [val['C'] for val in grid_search.cv_results_['params']],
        gamma = [val['gamma'] for val in grid_search.cv_results_['params']],
        coef0 = [val['coef0'] for val in grid_search.cv_results_['params']],
        score = grid_search.cv_results_['mean_test_score']
    )
)
df = df[df['score'] < 0.8]

for param in dict_param:
    for value in dict_param[param]:
        if len(df[df[param] == value]) == 6 * 6:
            print(param, value)
```

Best score: 0.8641249999999999

Bad hyperparameter:

C 0.001  
C 0.01  
C 0.1  
gamma 1.0  
gamma 10.0  
gamma 100.0  
coef0 10.0  
coef0 100.0

```
[ ]: dict_param = {
    'C' : np.linspace(1, 100, 5),
    'gamma': np.linspace(0.001, 0.01, 5),
    'coef0': np.linspace(0.001, 1, 5)
}

grid_search = GridSearchCV(SVC(kernel='sigmoid'), dict_param, cv = 5, n_jobs=8)
grid_search.fit(X_train, y_train)
```

```
[ ]: GridSearchCV(cv=5, estimator=SVC(kernel='sigmoid'), n_jobs=8,
                param_grid={'C': array([ 1. , 25.75, 50.5 , 75.25, 100. ]),
                            'coef0': array([0.001 , 0.25075, 0.5005 , 0.75025, 1.
]),
                            'gamma': array([0.001 , 0.00325, 0.0055 , 0.00775,
```

```
0.01 ]))
```

```
[ ]: df = pd.DataFrame(  
    dict(  
        C = [val['C'] for val in grid_search.cv_results_['params']],  
        gamma = [val['gamma'] for val in grid_search.cv_results_['params']],  
        coef0 = [val['coef0'] for val in grid_search.cv_results_['params']],  
        score = grid_search.cv_results_['mean_test_score']  
    )  
)  
df = df[df['score'] < 0.8]  
print(len(df))  
for param in dict_param:  
    for value in dict_param[param]:  
        if len(df[df[param] == value]) >= 150 // len(dict_param[param]):  
            print(param, value)
```

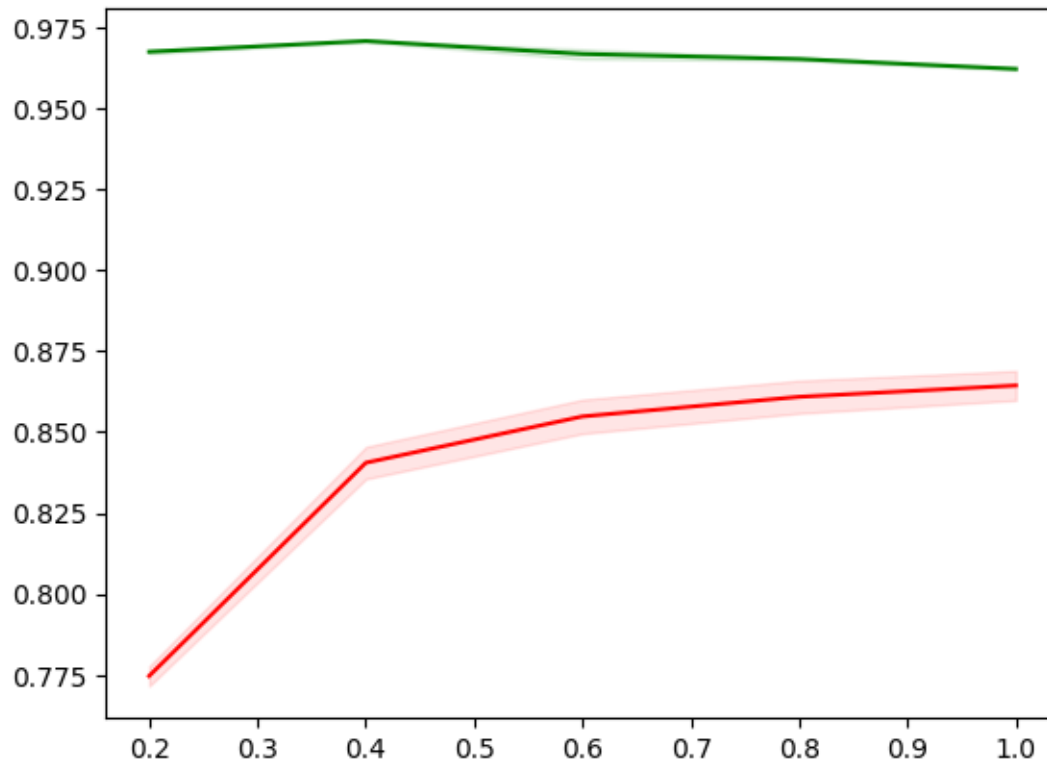
27

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

```
SVC(C=50.5, coef0=1.0, gamma=0.0055000000000000005, kernel='sigmoid')  
0.8643749999999999
```

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





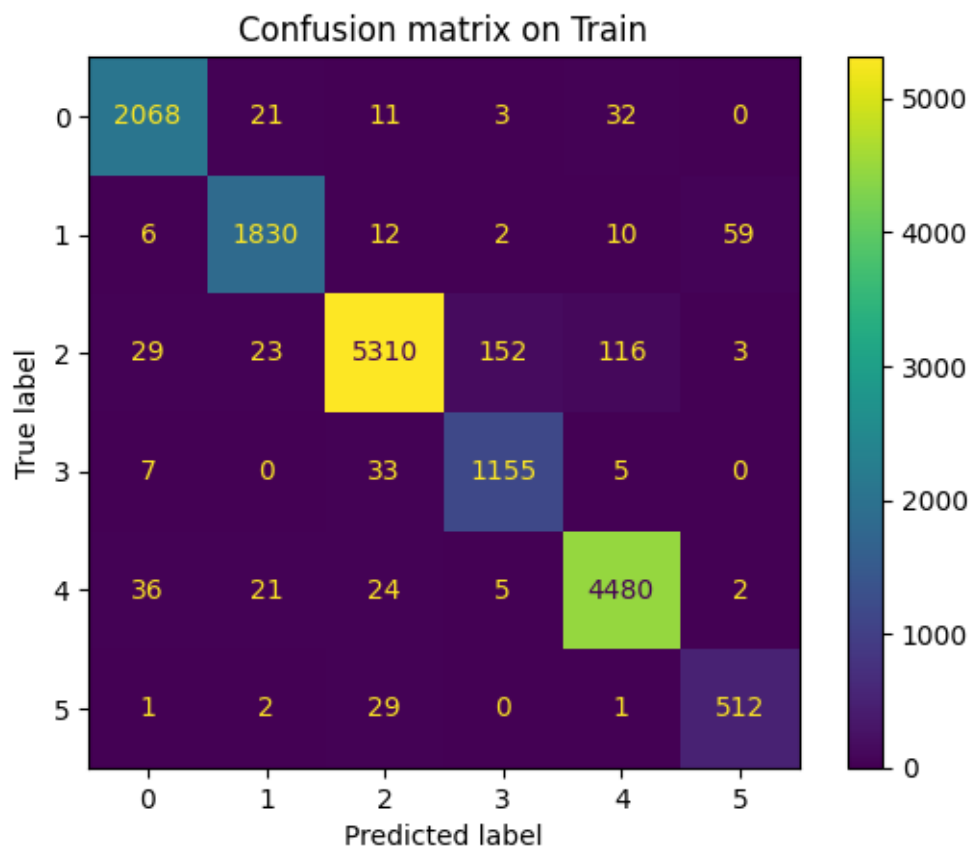
```
[ ]: best_svm_sig_model.fit(X_train, y_train)
      evaluate_model(best_svm_sig_model, X_train, X_test, y_train, y_test,
                    ↪ include_training=True)
```

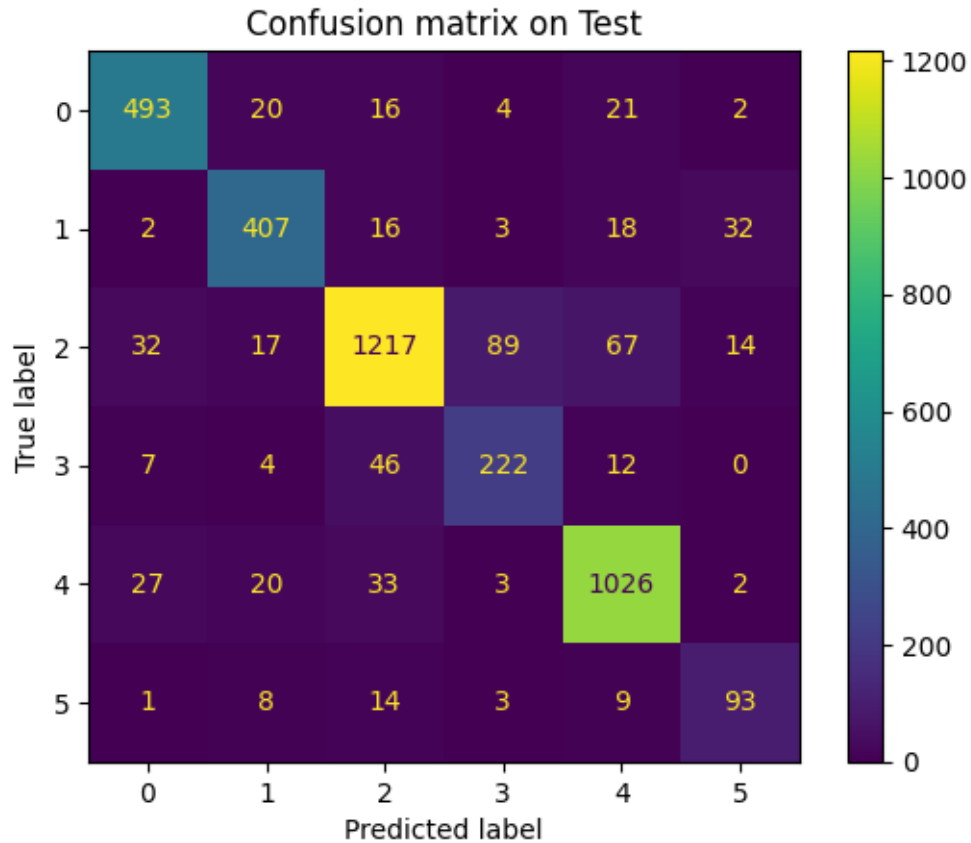
Score of on train are:

- Accuracy score: 0.96
- Micro F1 score: 0.96
- Macro F1 score: 0.95

Score of on test are:

- Accuracy score: 0.86
- Micro F1 score: 0.86
- Macro F1 score: 0.82





### 1.3.4 Polynomial function kernel

Formula:

$$k(x, z) = (r + \gamma x^T z)^d$$

```
[ ]: dict_param = {
    'C' : np.asarray([0.001, 0.01, 0.1, 1, 10.0, 100]),
    'gamma': np.asarray([0.001, 0.01, 0.1, 1]),
    'coef0': np.asarray([0.001, 0.01, 0.1, 1]),
    'degree': np.asarray([2, 3, 4])
}

grid_search = GridSearchCV(SVC(kernel='poly'), dict_param, cv = 5, n_jobs=8)
grid_search.fit(X_train, y_train)
```

```
[ ]: GridSearchCV(cv=5, estimator=SVC(kernel='poly'), n_jobs=8,
    param_grid={'C': array([1.e-03, 1.e-02, 1.e-01, 1.e+00, 1.e+01,
    1.e+02]),
    'coef0': array([0.001, 0.01 , 0.1 , 1.   ]),
    'degree': array([2, 3, 4]),
```

```
'gamma': array([0.001, 0.01 , 0.1 , 1. ]))
```

```
[ ]: print('Best score: ', grid_search.best_score_, '\n')

print('Bad hyperparameter:')
df = pd.DataFrame(
    dict(
        C = [val['C'] for val in grid_search.cv_results_['params']],
        gamma = [val['gamma'] for val in grid_search.cv_results_['params']],
        coef0 = [val['coef0'] for val in grid_search.cv_results_['params']],
        degree = [val['degree'] for val in grid_search.cv_results_['params']],
        score = grid_search.cv_results_['mean_test_score']
    )
)
df = df[df['score'] < 0.85]

for param in dict_param:
    for value in dict_param[param]:
        if len(df[df[param] == value]) == 288 // len(dict_param[param]):
            print(param, value)
```

Best score: 0.8619999999999999

Bad hyperparameter:

C 0.001

C 0.01

C 0.1

gamma 1.0

coef0 0.001

coef0 0.01

```
[ ]: dict_param = {
    'C' : np.linspace(10, 100, 4),
    'gamma': np.linspace(0.001, 0.004, 4),
    'coef0': np.linspace(0.7, 1, 4),
    'degree': np.asarray([2, 3, 4])
}

grid_search = GridSearchCV(SVC(kernel='poly'), dict_param, cv = 5, n_jobs=8)
grid_search.fit(X_train, y_train)
```

```
[ ]: GridSearchCV(cv=5, estimator=SVC(kernel='poly'), n_jobs=8,
    param_grid={'C': array([ 10., 40., 70., 100.]),
        'coef0': array([0.7, 0.8, 0.9, 1. ]),
        'degree': array([2, 3, 4]),
        'gamma': array([0.001, 0.002, 0.003, 0.004])})
```

```
[ ]: print('Best score: ', grid_search.best_score_, '\n')

print('Bad hyperparameter:')
df = pd.DataFrame(
    dict(
        C = [val['C'] for val in grid_search.cv_results_['params']],
        gamma = [val['gamma'] for val in grid_search.cv_results_['params']],
        coef0 = [val['coef0'] for val in grid_search.cv_results_['params']],
        degree = [val['degree'] for val in grid_search.cv_results_['params']],
        score = grid_search.cv_results_['mean_test_score']
    )
)
df = df[df['score'] < 0.85]

for param in dict_param:
    for value in dict_param[param]:
        if len(df[df[param] == value]) == 192 // len(dict_param[param]):
            print(param, value)
```

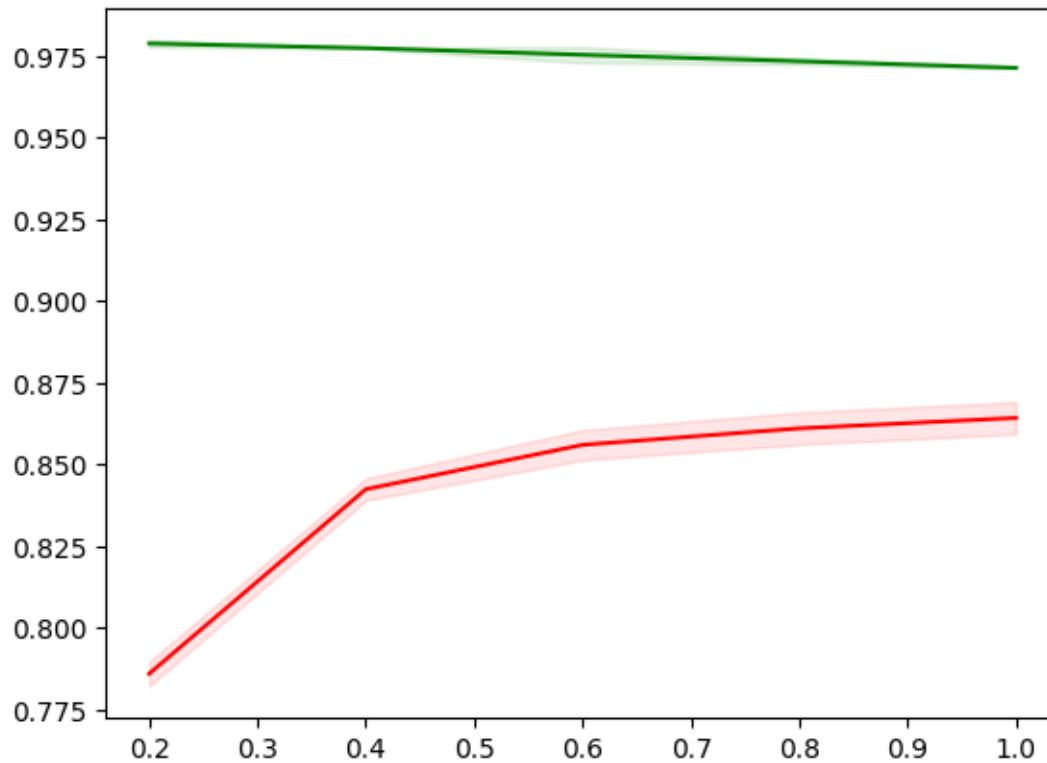
Best score: 0.8641874999999999

Bad hyperparameter:

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

SVC(C=100.0, coef0=0.7, degree=2, gamma=0.001, kernel='poly') 0.8641874999999999

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



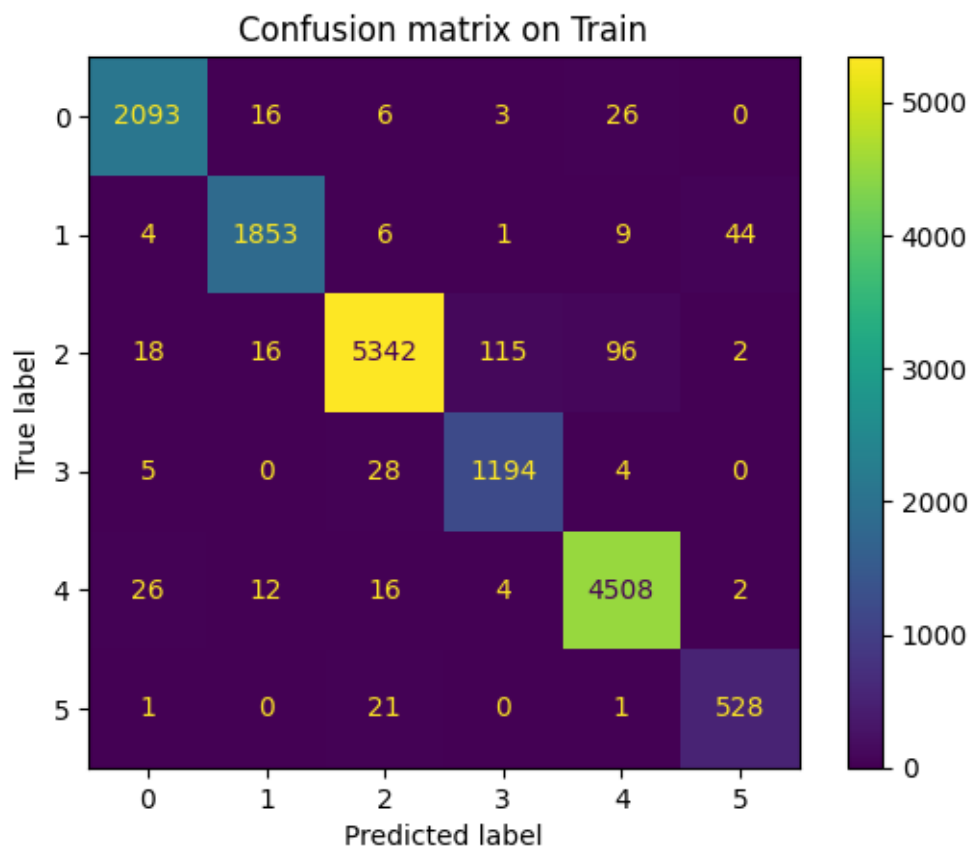
```
[ ]: best_svm_poly_model.fit(X_train, y_train)
      evaluate_model(best_svm_poly_model, X_train, X_test, y_train, y_test,
                    ↪ include_training=True)
```

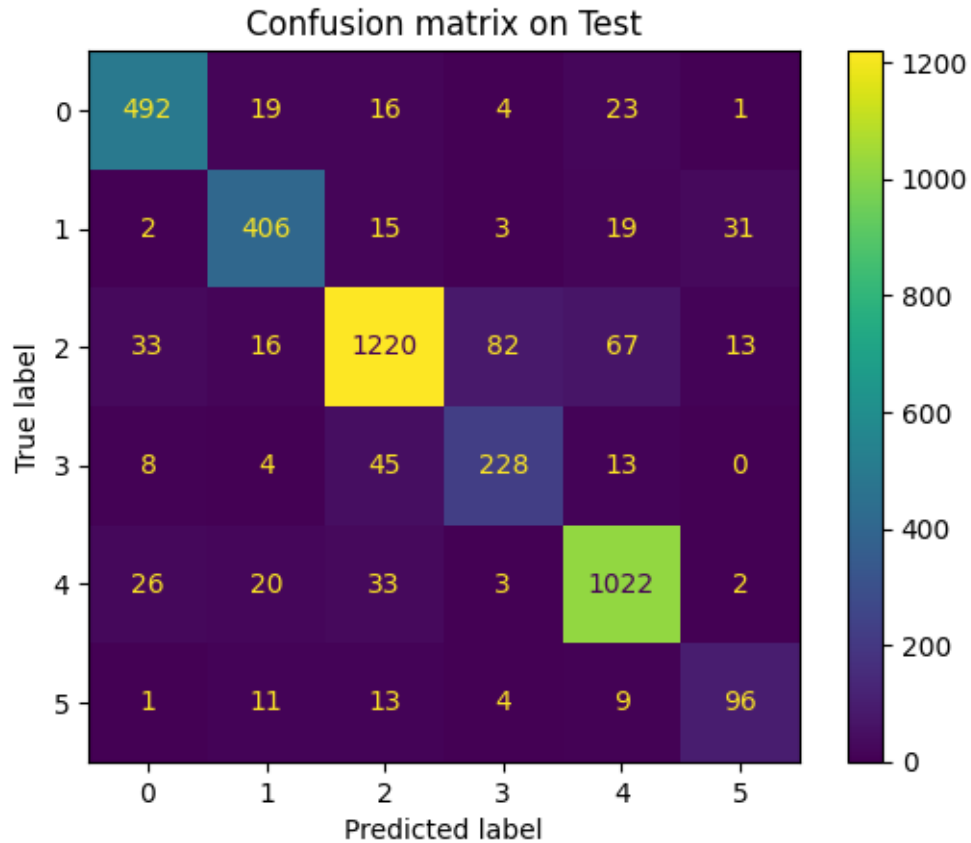
Score of on train are:

- Accuracy score: 0.97
- Micro F1 score: 0.97
- Macro F1 score: 0.96

Score of on test are:

- Accuracy score: 0.87
- Micro F1 score: 0.87
- Macro F1 score: 0.82





## 1.4 Export model

All the kernels have almost the same result.

Although polynomial kernel has 1% accuracy than the other models, I will choose linear kernel to be the best one because of its simplicity and interpretability.

```
[ ]: best_svm_model = best_svm_linear_model

directory = "data/models/svm/"

dump(best_svm_model, directory + "best_svm_bow_model.joblib")
```

```
[ ]: ['data/models/svm/best_svm_bow_model.joblib']
```