ShritejShrikant_file2_hw2

September 10, 2023

0.1 Install/Import *Libraries*

[3]:

```

```

```
                                        100.3/100.3

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```

[43]:

```
# Import necessary libraries
import pandas as pd
from pathlib import Path

# Import the joblib library for saving and loading models
import joblib

# Import scikit-learn classes for building models
from sklearn.linear_model import LogisticRegression
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.model_selection import *
from sklearn.metrics import classification_report
from sklearn.pipeline import Pipeline
from sklearn.compose import ColumnTransformer
from sklearn.base import TransformerMixin, BaseEstimator

from skopt.space import Real, Categorical, Integer
from sklearn.metrics import precision_recall_curve, auc, make_scorer,␣
  ↪cohen_kappa_score, balanced_accuracy_score, confusion_matrix
from skopt import BayesSearchCV
from skopt.space import Real, Categorical, Integer

import spacy

# Import the scipy library for working with sparse matrices
from scipy.sparse import csr_matrix
```

[5]:

```
import sys
if 'google.colab' in str(get_ipython()):
    from google.colab import drive
    drive.mount('/content/drive')

    !pip install -U nltk -qq
    !pip install -U spacy -qq
    !python -m spacy download en_core_web_sm -qq
    !pip install -U scikit-optimize -qq

    basepath = '/content/drive/MyDrive/NLP/'
    sys.path.append('/content/drive/MyDrive/NLP/custom-functions')
else:
    basepath = '/home/harpreet/Insync/google_drive_shaannoor/data'
    sys.path.append(
        '/home/harpreet/Insync/google_drive_shaannoor/data/custom-functions')
```

```
Mounted at /content/drive
2023-09-10 17:50:56.766502: W
tensorflow/compiler/tf2tensorrt/utils/py_utils.cc:38] TF-TRT Warning: Could not
find TensorRT
                           12.8/12.8 MB
103.9 MB/s eta 0:00:00
 Download and installation successful
You can now load the package via spacy.load('en_core_web_sm')
```

[6]:
```
sys.path
```

[6]:
```
['/content',
 '/env/python',
 '/usr/lib/python310.zip',
 '/usr/lib/python3.10',
 '/usr/lib/python3.10/lib-dynload',
 '',
 '/usr/local/lib/python3.10/dist-packages',
 '/usr/lib/python3/dist-packages',
 '/usr/local/lib/python3.10/dist-packages/IPython/extensions',
 '/root/.ipython',
 '/content/drive/MyDrive/NLP/custom-functions']
```

[7]:
```
base_folder = Path(basepath)
data_folder = base_folder/'datasets/spam'
model_folder = base_folder/'models/spam'
custom_functions = base_folder/'custom-functions'
```

[8]:
```
import custom_preprocessor_mod as cp
from featurizer import ManualFeatures
from plot_learning_curve import plot_learning_curve
```

0.2 Load Dataset

Downloaded the dataset from here : https://www.kaggle.com/datasets/uciml/sms-spam-collection-dataset

[9]:
```
data = pd.read_csv(data_folder/'spam.csv', encoding='latin-1')
data.head()
```

[9]:
```
     v1                                                 v2 Unnamed: 2  \
0   ham  Go until jurong point, crazy.. Available only …        NaN
1   ham                      Ok lar… Joking wif u oni…        NaN
2  spam  Free entry in 2 a wkly comp to win FA Cup fina…        NaN
3   ham  U dun say so early hor… U c already then say…        NaN
4   ham  Nah I don't think he goes to usf, he lives aro…        NaN

  Unnamed: 3 Unnamed: 4
0        NaN        NaN
1        NaN        NaN
2        NaN        NaN
3        NaN        NaN
4        NaN        NaN
```

[10]:
```
data.shape
```

[10]:
```
(5572, 5)
```

[11]:
```
data.isnull().sum()
```

[11]:
```
v1               0
v2               0
Unnamed: 2    5522
Unnamed: 3    5560
Unnamed: 4    5566
dtype: int64
```

[12]:
```
data['v1'].value_counts()
```

[12]:
```
ham     4825
spam     747
Name: v1, dtype: int64
```

[13]:
```
data.drop(columns=['Unnamed: 2', 'Unnamed: 3', 'Unnamed: 4'], inplace=True)
data.rename(columns={'v1': 'label', 'v2': 'text'}, inplace=True)
data.head()
```

[13]:
```
  label                                               text
0   ham  Go until jurong point, crazy.. Available only …
1   ham                      Ok lar… Joking wif u oni…
```

```
2  spam  Free entry in 2 a wkly comp to win FA Cup fina…
3   ham  U dun say so early hor… U c already then say…
4   ham  Nah I don't think he goes to usf, he lives aro…
```

[14]:
```
data['label'].value_counts(normalize=True)*100
```

[14]:
```
ham     86.593683
spam    13.406317
Name: label, dtype: float64
```

[14]:
```

```

[15]:
```
# prompt: convert above labels: 0 for 'ham' & 1 'spam for above dataset

data['label'].replace(['ham', 'spam'], [0, 1], inplace=True)
data['label'].value_counts(normalize=True)*100
```

[15]:
```
0    86.593683
1    13.406317
Name: label, dtype: float64
```

[16]:
```
print(data.shape)

print(data['label'].value_counts())

x = data['text']
y = data['label']

x_train, x_test, y_train, y_test = train_test_split(x, y, test_size=0.2,␣
 ↪random_state=21, stratify=y, shuffle=True)


print(x_train.shape, x_test.shape, y_train.shape, y_test.shape)

print(y_train.value_counts())
print(y_test.value_counts())
```

```
(5572, 2)
0    4825
1     747
Name: label, dtype: int64
(4457,) (1115,) (4457,) (1115,)
0    3859
1     598
Name: label, dtype: int64
0    966
1    149
```

```
Name: label, dtype: int64
```

[17]:
```python
xtrain = x_train.values
ytrain = y_train.values

xtest = x_test.values
ytest = y_test.values


print(xtrain.shape, ytrain.shape)
```

```
(4457,) (4457,)
```

[17]:
```python

```

0.3 Spacy

[18]:
```python
# Spacy Tokenizer
# Loading the 'en_core_web_sm' language model from the spaCy library
nlp = spacy.load('en_core_web_sm')


disabled = nlp.select_pipes(
    disable=['tok2vec', 'tagger', 'parser', 'attribute_ruler', 'lemmatizer',␣
 ↪'ner'])


def spacy_tokenizer(data):
    doc = nlp(data)
    return [token.text for token in doc]


cpp = cp.SpacyPreprocessor(
    model='en_core_web_sm')



def spacy_preprocessor(text):
    filtered_text = cpp.transform([text])
    return " ".join(filtered_text)
```

[19]:
```python
# save this to a file
X_train_cleaned = cpp.transform(xtrain)
file_X_train_cleaned_sparse_embed = data_folder / \
    'x_train_cleaned_sparse_embed_full.pkl'
joblib.dump(X_train_cleaned, file_X_train_cleaned_sparse_embed)
```

```
/content/drive/MyDrive/NLP/custom-functions/custom_preprocessor_mod.py:90:
MarkupResemblesLocatorWarning: The input looks more like a filename than markup.
You may want to open this file and pass the filehandle into Beautiful Soup.
  soup = BeautifulSoup(text, "html.parser")
```

[19]:
```
['/content/drive/MyDrive/NLP/datasets/spam/x_train_cleaned_sparse_embed_full.pkl
']
```

[20]:
```
X_test_cleaned = cpp.transform(xtest)
# save  this to a file
file_X_test_cleaned_sparse_embed = data_folder /␣
 ↪'x_test_cleaned_sparse_embed_full.pkl'
joblib.dump(X_test_cleaned, file_X_test_cleaned_sparse_embed)
```

[20]:
```
['/content/drive/MyDrive/NLP/datasets/spam/x_test_cleaned_sparse_embed_full.pkl'
]
```

0.4 Defining Class Weights for Imbalanced data to train Classifier

[21]:
```
w = {}

w[1] = int(y_train.value_counts()[0]/ytrain.shape[0]*100)

w[0] = 100 - w[1]

print(w)
```

```
{1: 86, 0: 14}
```

0.5 Final Pipeline (Pipeline 3): Combine Manual Features and TfID vectors

[ ]:
```

```

[22]:
```
featurizer = ManualFeatures(spacy_model='en_core_web_sm')
```

[23]:
```
X_train_features, feature_names = featurizer.fit_transform(xtrain)
```

```
/content/drive/MyDrive/NLP/custom-functions/custom_preprocessor_mod.py:90:
MarkupResemblesLocatorWarning: The input looks more like a filename than markup.
You may want to open this file and pass the filehandle into Beautiful Soup.
  soup = BeautifulSoup(text, "html.parser")
```

[24]:
```
print(X_train_features.shape)
X_train_features[0:3]
```

```
(4457, 11)
```

```
[24]: array([[13.        , 58.        , 46.        ,  3.28571429,  0.        ,
          0.        ,  0.        ,  4.        ,  1.        ,  3.        ,
          0.        ],
        [13.        , 51.        , 39.        ,  2.78571429,  0.        ,
          0.        ,  0.        ,  1.        ,  3.        ,  3.        ,
          0.        ],
        [10.        , 53.        , 44.        ,  4.        ,  0.        ,
          0.        ,  0.        ,  3.        ,  0.        ,  1.        ,
          1.        ]])
```

```
[25]: X_train_cleaned_sparse_embed = joblib.load(file_X_train_cleaned_sparse_embed)

X_train_final = pd.concat((pd.DataFrame(X_train_cleaned_sparse_embed,␣
 ↪columns=['cleaned_text']),
                            pd.DataFrame(X_train_features,␣
 ↪columns=feature_names)), axis=1)

X_train_final.head()
```

```
[25]:                          cleaned_text  count_words  count_characters  \
0   sen tell go join uncle finance cbe         13.0              58.0
1             reach home n bathe liao u         13.0              51.0
2  hello site download song urgent pls         10.0              53.0
3                       hi:)ct employee          5.0              28.0
4                aight pick open tonight         10.0              49.0

   count_characters_no_space  avg_word_length  count_digits  count_numbers  \
0                       46.0         3.285714           0.0            0.0
1                       39.0         2.785714           0.0            0.0
2                       44.0         4.000000           0.0            0.0
3                       24.0         4.000000           0.0            0.0
4                       40.0         3.636364           0.0            0.0

   noun_count  aux_count  verb_count  adj_count  ner
0         0.0        4.0         1.0        3.0  0.0
1         0.0        1.0         3.0        3.0  0.0
2         0.0        3.0         0.0        1.0  1.0
3         0.0        1.0         1.0        1.0  0.0
4         1.0        2.0         1.0        2.0  0.0
```

```
[26]: class SparseTransformer(TransformerMixin, BaseEstimator):
    def __init__(self):
        pass

    def fit(self, X, y=None):
        return self
    def transform(self, X, y=None):
        return csr_matrix(X)


sparse_features = Pipeline([('sparse', SparseTransformer()), ])
vectorizer = Pipeline([('tfidf', TfidfVectorizer(max_features=5)), ])

combined_features = ColumnTransformer(
    transformers=[
        ('tfidf', vectorizer, 'cleaned_text'),
    ], remainder=sparse_features
)
```

0.5.1 Create Final Pipeline

[27]:
```
classifier_3 = Pipeline([('combined_features',  combined_features),
                         ('classifier', LogisticRegression(max_iter=10000,␣
 ↪random_state=21, class_weight=w)),
                         ])
```

[53]:
```
# We are exploring a small combination of parameters
# If the search space is very large then we should use RandomSerachCV or some␣
 ↪other methods

param_bayes_classifier_3 = {'combined_features__tfidf__tfidf__max_features':␣
 ↪Integer(500, 10000),
                           #'combined_features__tfidf__tfidf__ngram_range':␣
 ↪Categorical([(1, 1), (1, 2), (1, 3)]),
                           'combined_features__tfidf__tfidf__max_df': Real(0.2,␣
 ↪0.8),
                           'combined_features__tfidf__tfidf__min_df': Real(0.
 ↪01, 0.05, prior='log-uniform'),
                           'classifier__solver': Categorical(['liblinear',␣
 ↪'saga', 'newton-cg', 'lbfgs']),

                           'classifier__C': Real(0.001, 1000,␣
 ↪prior='log-uniform')
                           }
```

[54]:
```
# Define a custom scoring function for PR AUC
def custom_pr_auc_scorer(y, y_proba):
    #y_proba = estimator.predict_proba(X)[:, 1]  # Probability of positive class
    precision, recall, _ = precision_recall_curve(y, y_proba)
    pr_auc = auc(recall, precision)
    return pr_auc
```

```
# Define a custom scoring function for Cohen's Kappa
def custom_kappa_scorer(y, y_pred):
    kappa = cohen_kappa_score(y, y_pred)
    return kappa


# Use cross-validation with the custom scoring function
pr_auc_scorer = make_scorer(custom_pr_auc_scorer, greater_is_better=True)  #␣
 ↪Set greater_is_better=True for higher PR AUC scores


# Use cross-validation with the custom scoring function
kappa_scorer = make_scorer(custom_kappa_scorer)
```

0.5.2 Perform Bayesian Optimization

[55]:
```
# Perform Bayesian optimization
optimizer3 = BayesSearchCV(estimator=classifier_3, search_spaces=␣
 ↪param_bayes_classifier_3, n_iter=66, cv=5, n_jobs = -1, verbose = 1
                          , scoring=pr_auc_scorer
                           )


# Fit the model to the data
optimizer3.fit(X_train_final, ytrain)

# Print the best hyperparameters aand corresponding score
print("Best score:", optimizer3.best_score_)
print("Best hyperparameters:", optimizer3.best_params_)
```

```
Fitting 5 folds for each of 1 candidates, totalling 5 fits
Fitting 5 folds for each of 1 candidates, totalling 5 fits
Fitting 5 folds for each of 1 candidates, totalling 5 fits
Fitting 5 folds for each of 1 candidates, totalling 5 fits
Fitting 5 folds for each of 1 candidates, totalling 5 fits
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Fitting 5 folds for each of 1 candidates, totalling 5 fits
Fitting 5 folds for each of 1 candidates, totalling 5 fits
Fitting 5 folds for each of 1 candidates, totalling 5 fits
Fitting 5 folds for each of 1 candidates, totalling 5 fits
Fitting 5 folds for each of 1 candidates, totalling 5 fits
Fitting 5 folds for each of 1 candidates, totalling 5 fits
Fitting 5 folds for each of 1 candidates, totalling 5 fits
Best score: 0.931513850007699
Best hyperparameters: OrderedDict([('classifier__C', 0.17159080752918784),
('classifier__solver', 'newton-cg'), ('combined_features__tfidf__tfidf__max_df',
0.8), ('combined_features__tfidf__tfidf__max_features', 10000),
('combined_features__tfidf__tfidf__min_df', 0.01)])
```

[56]:
```
print("Best cross-validation score: {:.2f}".format(optimizer3.best_score_))
print("\nBest parameters: ", optimizer3.best_params_)
print("\nBest estimator: ", optimizer3.best_estimator_)
```

```
Best cross-validation score: 0.93

Best parameters:  OrderedDict([('classifier__C', 0.17159080752918784),
('classifier__solver', 'newton-cg'), ('combined_features__tfidf__tfidf__max_df',
0.8), ('combined_features__tfidf__tfidf__max_features', 10000),
('combined_features__tfidf__tfidf__min_df', 0.01)])

Best estimator:  Pipeline(steps=[('combined_features',
                 ColumnTransformer(remainder=Pipeline(steps=[('sparse',
SparseTransformer())]),
                                   transformers=[('tfidf',
                                                  Pipeline(steps=[('tfidf',
TfidfVectorizer(max_df=0.8,
   max_features=10000,
   min_df=0.01))]),
                                                  'cleaned_text')])),
                ('classifier',
                 LogisticRegression(C=0.17159080752918784,
                                    class_weight={0: 14, 1: 86}, max_iter=10000,
                                    random_state=21, solver='newton-cg'))])
```

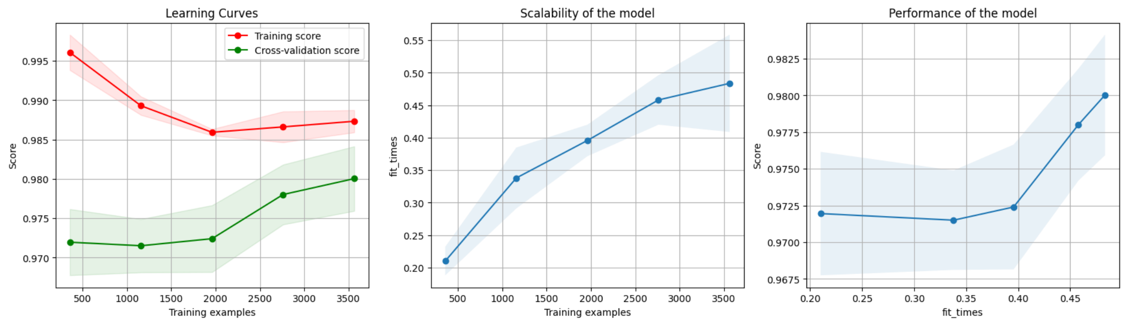
0.5.3 Save & Load Model

[57]:
```
file_best_estimator_pipeline3 = model_folder / \
    'logistic_final.pkl'
file_complete_bayes_pipeline3= model_folder / \
    'logistic_final_complete_bayes_full.pkl'

joblib.dump(optimizer3.best_estimator_, file_best_estimator_pipeline3)
joblib.dump(optimizer3, file_complete_bayes_pipeline3)



# load the saved model
best_estimator_pipeline3_round1 = joblib.load(
    file_best_estimator_pipeline3)
complete_bayes_pipeline3_round1 = joblib.load(
    file_complete_bayes_pipeline3)
```

0.5.4 Plot Learning Curve

[58]:
```
# plot learning curces
plot_learning_curve(best_estimator_pipeline3_round1, 'Learning Curves',
                    X_train_final, ytrain, n_jobs=-1)
```

[58]:
```
<module 'matplotlib.pyplot' from '/usr/local/lib/python3.10/dist-
packages/matplotlib/pyplot.py'>
```



[59]:
```
# let's check the train scores
print(best_estimator_pipeline3_round1.score(X_train_final, y_train))

# let's check the cross validation score
print(complete_bayes_pipeline3_round1.best_score_)
```

```
0.9847431007404084
0.931513850007699
```

[60]:
```
X_train_final.shape
```

[60]:
```
(4457, 12)
```

[60]:
```

```

0.5.5 Evaluate on Test

[61]:
```
# Final Pipeline
def final_pipeline(text):
    cleaned_text = cpp.transform(text)
    # cleaned_text = joblib.load(file_X_test_cleaned_sparse_embed)
    X_features, feature_names = featurizer.fit_transform(text)
    X_final = pd.concat((pd.DataFrame(cleaned_text, columns=['cleaned_text']),
                              pd.DataFrame(X_features, columns=feature_names)),␣
↪axis=1)
    best_estimator_pipeline3_round1 = joblib.load(
        file_best_estimator_pipeline3)
    predictions = best_estimator_pipeline3_round1.predict(X_final)
    return predictions
```

[62]:
```
# predicted values for Test data set
y_test_pred = final_pipeline(xtest)
```

```
/content/drive/MyDrive/NLP/custom-functions/custom_preprocessor_mod.py:90:
MarkupResemblesLocatorWarning: The input looks more like a filename than markup.
You may want to open this file and pass the filehandle into Beautiful Soup.
  soup = BeautifulSoup(text, "html.parser")
```

[62]:
```

```

[63]:
```
print('\nTest set classification report:\n\n',
      classification_report(y_test, y_test_pred))
```

```

Test set classification report:

               precision    recall  f1-score   support

           0       0.99      0.98      0.98       966
           1       0.87      0.93      0.90       149

    accuracy                           0.97      1115
   macro avg       0.93      0.96      0.94      1115
weighted avg       0.97      0.97      0.97      1115
```

[64]:
```
# prompt: plot confusion matrix

print(confusion_matrix(ytest, y_test_pred))
```

```
[[945  21]
 [ 10 139]]
```

[65]:
```
print(custom_pr_auc_scorer(ytest, y_test_pred))
```

```
0.9053022579528697
```

[66]:
```
print(balanced_accuracy_score(ytest, y_test_pred))
```

```
0.9555733878027429
```

0.5.6 Final Score on the Chosen Metric

Precision Recall AUC - 0.9019822478991

```
[ ]:
```