da24c026

September 26, 2024

#DA24C026 - Assignment 6

Task 1

[4]:
```
pip install datasets
```

```
Collecting datasets
  Downloading datasets-3.0.1-py3-none-any.whl.metadata (20 kB)
Requirement already satisfied: filelock in /usr/local/lib/python3.10/dist-
packages (from datasets) (3.16.1)
Requirement already satisfied: numpy>=1.17 in /usr/local/lib/python3.10/dist-
packages (from datasets) (1.26.4)
Collecting pyarrow>=15.0.0 (from datasets)
  Downloading pyarrow-17.0.0-cp310-cp310-manylinux_2_28_x86_64.whl.metadata (3.3
kB)
Collecting dill<0.3.9,>=0.3.0 (from datasets)
  Downloading dill-0.3.8-py3-none-any.whl.metadata (10 kB)
Requirement already satisfied: pandas in /usr/local/lib/python3.10/dist-packages
(from datasets) (2.1.4)
Requirement already satisfied: requests>=2.32.2 in
/usr/local/lib/python3.10/dist-packages (from datasets) (2.32.3)
Requirement already satisfied: tqdm>=4.66.3 in /usr/local/lib/python3.10/dist-
packages (from datasets) (4.66.5)
Collecting xxhash (from datasets)
  Downloading
xxhash-3.5.0-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata
(12 kB)
Collecting multiprocess (from datasets)
  Downloading multiprocess-0.70.16-py310-none-any.whl.metadata (7.2 kB)
Requirement already satisfied: fsspec<=2024.6.1,>=2023.1.0 in
/usr/local/lib/python3.10/dist-packages (from
fsspec[http]<=2024.6.1,>=2023.1.0->datasets) (2024.6.1)
Requirement already satisfied: aiohttp in /usr/local/lib/python3.10/dist-
packages (from datasets) (3.10.5)
Requirement already satisfied: huggingface-hub>=0.22.0 in
/usr/local/lib/python3.10/dist-packages (from datasets) (0.24.7)
Requirement already satisfied: packaging in /usr/local/lib/python3.10/dist-
packages (from datasets) (24.1)
Requirement already satisfied: pyyaml>=5.1 in /usr/local/lib/python3.10/dist-
```

```
packages (from datasets) (6.0.2)
Requirement already satisfied: aiohappyeyeballs>=2.3.0 in
/usr/local/lib/python3.10/dist-packages (from aiohttp->datasets) (2.4.0)
Requirement already satisfied: aiosignal>=1.1.2 in
/usr/local/lib/python3.10/dist-packages (from aiohttp->datasets) (1.3.1)
Requirement already satisfied: attrs>=17.3.0 in /usr/local/lib/python3.10/dist-
packages (from aiohttp->datasets) (24.2.0)
Requirement already satisfied: frozenlist>=1.1.1 in
/usr/local/lib/python3.10/dist-packages (from aiohttp->datasets) (1.4.1)
Requirement already satisfied: multidict<7.0,>=4.5 in
/usr/local/lib/python3.10/dist-packages (from aiohttp->datasets) (6.1.0)
Requirement already satisfied: yarl<2.0,>=1.0 in /usr/local/lib/python3.10/dist-
packages (from aiohttp->datasets) (1.11.1)
Requirement already satisfied: async-timeout<5.0,>=4.0 in
/usr/local/lib/python3.10/dist-packages (from aiohttp->datasets) (4.0.3)
Requirement already satisfied: typing-extensions>=3.7.4.3 in
/usr/local/lib/python3.10/dist-packages (from huggingface-hub>=0.22.0->datasets)
(4.12.2)
Requirement already satisfied: charset-normalizer<4,>=2 in
/usr/local/lib/python3.10/dist-packages (from requests>=2.32.2->datasets)
(3.3.2)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.10/dist-
packages (from requests>=2.32.2->datasets) (3.10)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/usr/local/lib/python3.10/dist-packages (from requests>=2.32.2->datasets)
(2.2.3)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.10/dist-packages (from requests>=2.32.2->datasets)
(2024.8.30)
Requirement already satisfied: python-dateutil>=2.8.2 in
/usr/local/lib/python3.10/dist-packages (from pandas->datasets) (2.8.2)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.10/dist-
packages (from pandas->datasets) (2024.2)
Requirement already satisfied: tzdata>=2022.1 in /usr/local/lib/python3.10/dist-
packages (from pandas->datasets) (2024.1)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.10/dist-
packages (from python-dateutil>=2.8.2->pandas->datasets) (1.16.0)
Downloading datasets-3.0.1-py3-none-any.whl (471 kB)
                         471.6/471.6 kB
9.9 MB/s eta 0:00:00
Downloading dill-0.3.8-py3-none-any.whl (116 kB)
                         116.3/116.3 kB
7.9 MB/s eta 0:00:00
Downloading pyarrow-17.0.0-cp310-cp310-manylinux_2_28_x86_64.whl (39.9 MB)
                         39.9/39.9 MB
17.7 MB/s eta 0:00:00
Downloading multiprocess-0.70.16-py310-none-any.whl (134 kB)
                         134.8/134.8 kB
```

```
9.2 MB/s eta 0:00:00
Downloading
xxhash-3.5.0-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (194 kB)
                           194.1/194.1 kB
12.5 MB/s eta 0:00:00
Installing collected packages: xxhash, pyarrow, dill, multiprocess,
datasets
  Attempting uninstall: pyarrow
    Found existing installation: pyarrow 14.0.2
    Uninstalling pyarrow-14.0.2:
      Successfully uninstalled pyarrow-14.0.2
ERROR: pip's dependency resolver does not currently take into account all
the packages that are installed. This behaviour is the source of the following
dependency conflicts.
cudf-cu12 24.4.1 requires pyarrow<15.0.0a0,>=14.0.1, but you have pyarrow 17.0.0
which is incompatible.

Successfully installed datasets-3.0.1 dill-0.3.8 multiprocess-0.70.16
pyarrow-17.0.0 xxhash-3.5.0
```

[50]:
```
import os
import numpy as np
import pandas as pd
from matplotlib import pyplot as plt
from sklearn.preprocessing import LabelEncoder
from sklearn.decomposition import TruncatedSVD
from sklearn.model_selection import train_test_split, GridSearchCV
from sklearn.feature_extraction.text import CountVectorizer, TfidfTransformer
from sklearn.discriminant_analysis import LinearDiscriminantAnalysis as LDA
from sklearn.discriminant_analysis import QuadraticDiscriminantAnalysis as QDA
from sklearn.pipeline import Pipeline
from sklearn.metrics import classification_report
from sklearn.naive_bayes import MultinomialNB
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.metrics import confusion_matrix, ConfusionMatrixDisplay
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.metrics import ConfusionMatrixDisplay, accuracy_score, f1_score,␣
 ↪classification_report
```

[2]:
```
from datasets import load_dataset
dataset = load_dataset("qanastek/MASSIVE", split='train')
print(dataset)
```

```
/usr/local/lib/python3.10/dist-packages/huggingface_hub/utils/_token.py:89:
UserWarning:
The secret `HF_TOKEN` does not exist in your Colab secrets.
```

```
To authenticate with the Hugging Face Hub, create a token in your settings tab
(https://huggingface.co/settings/tokens), set it as secret in your Google Colab
and restart your session.
You will be able to reuse this secret in all of your notebooks.
Please note that authentication is recommended but still optional to access
public models or datasets.
  warnings.warn(

MASSIVE.py:   0%|          | 0.00/32.3k [00:00<?, ?B/s]

README.md:   0%|          | 0.00/34.1k [00:00<?, ?B/s]

The repository for qanastek/MASSIVE contains custom code which must be executed
to correctly load the dataset. You can inspect the repository content at
https://hf.co/datasets/qanastek/MASSIVE.
You can avoid this prompt in future by passing the argument
`trust_remote_code=True`.

Do you wish to run the custom code? [y/N] y

Downloading data:   0%|          | 0.00/39.5M [00:00<?, ?B/s]

Generating train split: 0 examples [00:00, ? examples/s]

Generating validation split: 0 examples [00:00, ? examples/s]

Generating test split: 0 examples [00:00, ? examples/s]

Dataset({
    features: ['id', 'locale', 'partition', 'scenario', 'intent', 'utt',
'annot_utt', 'tokens', 'ner_tags', 'worker_id', 'slot_method', 'judgments'],
    num_rows: 587214
})
```

[3]:
```
df=pd.DataFrame(dataset)
```

[4]:
```
df.head()
```

[4]:

	id	locale	partition	scenario	intent	utt	\
0	1	mn-MN	train	9	55		
1	2	mn-MN	train	9	55		
2	4	mn-MN	train	14	7		
3	5	mn-MN	train	14	7		
4	6	mn-MN	train	14	7	olly	

```
                                                annot_utt  \
0  [date :     ] [time :      ]      …
1  [time :               ]
2
3
4             olly [time :        ]

                                                tokens                ner_tags  \
0      [    ,    ,    ,    ,       ]       [7, 60, 16, 0, 0]
1  [    ,    ,    ,    ,     ,    ]  [60, 16, 16, 16, 0, 0]
2                                  [  ,     ]                  [0, 0]
3                                    [  ]                       [0]
4              [olly,    ,    ,   ,    ]       [0, 60, 16, 0, 0]

  worker_id                                          slot_method  \
0        16  {'slot': ['time', 'date'], 'method': ['transla…
1        16      {'slot': ['time'], 'method': ['translation']}
2        16                          {'slot': [], 'method': []}
3         2                          {'slot': [], 'method': []}
4        16      {'slot': ['time'], 'method': ['translation']}

                                          judgments
0  {'worker_id': ['5', '4', '2'], 'intent_score':…
1  {'worker_id': ['4', '5', '2'], 'intent_score':…
2  {'worker_id': ['10', '2', '4'], 'intent_score'…
3  {'worker_id': ['4', '26', '43'], 'intent_score…
4  {'worker_id': ['16', '5', '43'], 'intent_score…
```

Retaining data with just 27 required languages.

[12]:
```
locales=['af-ZA', 'da-DK', 'de-DE', 'en-US', 'es-ES', 'fr-FR', 'fi-FI',␣
 ↪'hu-HU', 'is-IS', 'it-IT', 'jv-ID', 'lv-LV', 'ms-MY', 'nb-NO', 'nl-NL',␣
 ↪'pl-PL', 'pt-PT',
'ro-RO', 'ru-RU', 'sl-SL', 'sv-SE', 'sq-AL', 'sw-KE', 'tl-PH', 'tr-TR',␣
 ↪'vi-VN', 'cy-GB' ]

df_tarin = df.loc[(df['locale'].isin(locales))]
df_train = df_tarin[['locale','utt','tokens']]
```

[13]:
```
df_train.head()
```

[13]:
```
       locale                                        utt  \
11514  af-ZA    maak my wakker nege-uur v. m. op vrydag
11515  af-ZA      stel 'n alarm vir twee ure van nou af
11516  af-ZA                              janneman stilte
11517  af-ZA                                        stop
```

```
11518  af-ZA  janneman onderbreek dit vir tien sekondes

                                                    tokens
11514  [maak, my, wakker, nege-uur, v., m., op, vrydag]
11515   [stel, 'n, alarm, vir, twee, ure, van, nou, af]
11516                                [janneman, stilte]
11517                                             [stop]
11518  [janneman, onderbreek, dit, vir, tien, sekondes]
```

[7]:
```
pip install unidecode
```

```
Collecting unidecode
  Downloading Unidecode-1.3.8-py3-none-any.whl.metadata (13 kB)
Downloading Unidecode-1.3.8-py3-none-any.whl (235 kB)
                         235.5/235.5 kB
5.3 MB/s eta 0:00:00
Installing collected packages: unidecode
Successfully installed unidecode-1.3.8
```

Creating files for 27 languages each

[15]:
```
import unidecode
for loc in locales:
     utters = df_train[df_train['loc'] == loc]['utt']
     utters = utters.apply(lambda x: unidecode.unidecode(x))
     with open(f"{loc}.txt", "w", encoding="utf-8") as file:
         file.write("\n".join(utters))
```

Task 2

Creating test and validation sets

[9]:
```
dataset_test = load_dataset("qanastek/MASSIVE", split='test',␣
 ↪trust_remote_code=True)
df_test=pd.DataFrame(dataset_test)
```

[10]:
```
df_test=df_test.loc[(df_test['locale'].isin(locales))]
```

[11]:
```
df_test=df_test[['locale','utt','tokens']]
```

[18]:
```
dataset_test = load_dataset("qanastek/MASSIVE", split='validation',␣
 ↪trust_remote_code=True)
df_val=pd.DataFrame(dataset_test)

df_val=df_val.loc[(df_val['locale'].isin(locales))]
df_val=df_val[['locale','utt','tokens']]
```

[19]:
```
y_train=df_tarin['locale']
x_train=df_tarin.drop('locale', axis= 1)
y_test=df_test['locale']
x_test=df_test.drop('locale', axis= 1)
y_val=df_val['locale']
x_val=df_val.drop('locale', axis= 1)
```

Conversion of text data to vectors

[20]:
```
vectorizer = TfidfVectorizer()
x_vect = vectorizer.fit_transform(x_train['utt'])
```

[21]:
```
x_test_vect= vectorizer.transform(x_test['utt'])
x_val_vect=  vectorizer.transform(x_val['utt'])
```

Multinomial Naive Bayes Training

[22]:
```
clf = MultinomialNB()
clf.fit(x_vect, y_train)
```

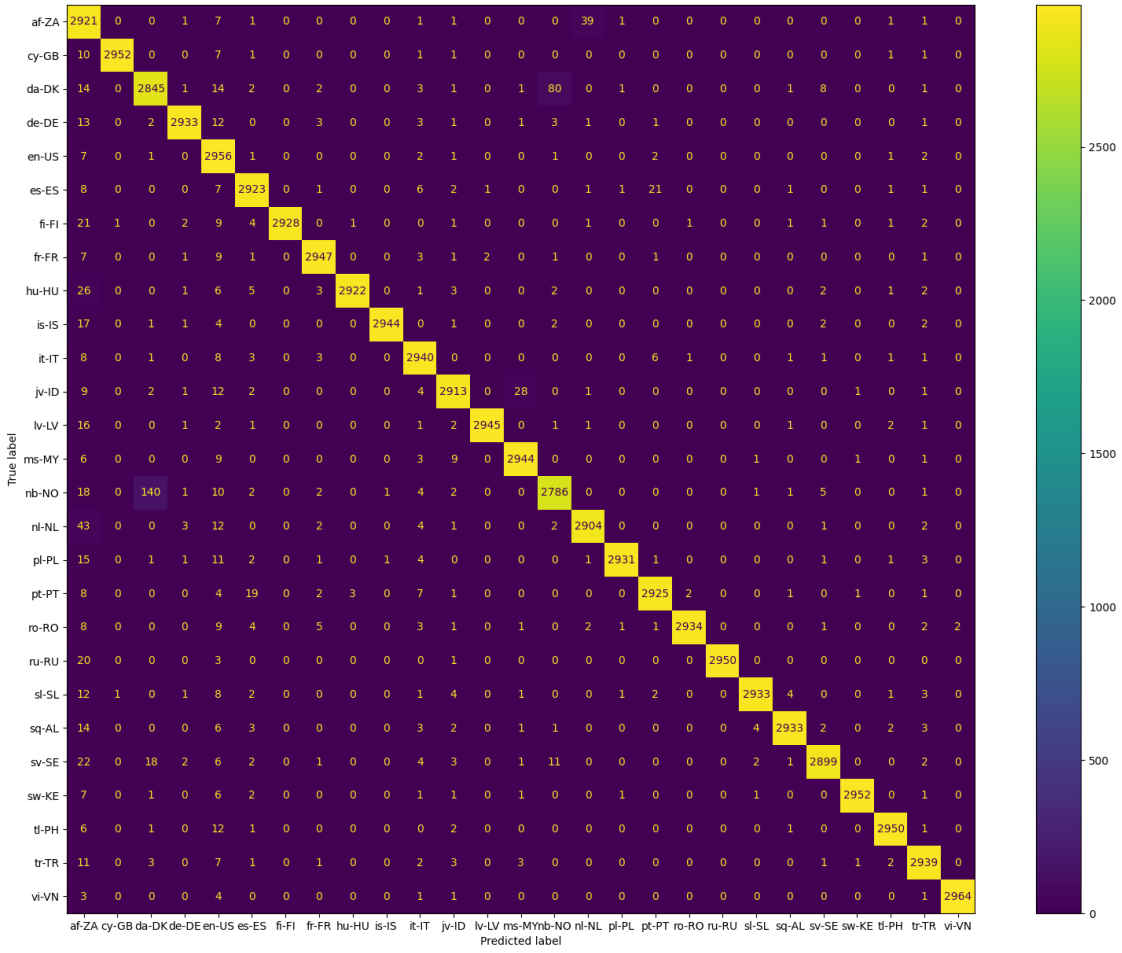
[22]:
```
MultinomialNB()
```

[23]:
```
y_hat=clf.predict(x_test_vect)
```

[24]:
```
matrix = confusion_matrix(y_test, y_hat)
```

[30]:
```
disp = ConfusionMatrixDisplay(confusion_matrix=matrix, display_labels=clf.
 ↪classes_)
fig, ax = plt.subplots(figsize=(20, 15))
disp.plot(ax=ax, cmap=plt.cm.viridis)
```

[30]:
```
<sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at
0x7d5cc3e46f80>
```



[33]:
```
print(accuracy_score(y_hat, y_test))
```

```
0.98399711076241
```

Cross Validating for different hyperparameters

[36]:
```
best_alpha = None
best_val_accuracy = 0
best_classifier = None

alpha_vals=[0,1,2,3,4,5,6,7,8,9,10]
for alpha in alpha_vals:

    nb_classifier = MultinomialNB(alpha=alpha)
    nb_classifier.fit(x_vect, y_train)

    # Evaluate on the validation set
    y_val_pred = nb_classifier.predict(x_val_vect)
```

```
    val_accuracy = accuracy_score(y_val, y_val_pred)

    print(f"Validation Accuracy for alpha={alpha}: {val_accuracy}")

    # Keep track of the best alpha and corresponding model
    if val_accuracy > best_val_accuracy:
        best_val_accuracy = val_accuracy
        best_alpha = alpha
        best_classifier = nb_classifier

print(f"\nBest alpha found: {best_alpha} with validation accuracy:␣
 ↪{best_val_accuracy}")
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/naive_bayes.py:890:
RuntimeWarning: divide by zero encountered in log
  self.feature_log_prob_ = np.log(smoothed_fc) - np.log(
```

```
Validation Accuracy for alpha=0: 0.9428139403545208
Validation Accuracy for alpha=1: 0.9842050609389518
Validation Accuracy for alpha=2: 0.9832030751853673
Validation Accuracy for alpha=3: 0.9823103969685376
Validation Accuracy for alpha=4: 0.981745641361972
Validation Accuracy for alpha=5: 0.9811626678326137
Validation Accuracy for alpha=6: 0.9805432584576707
Validation Accuracy for alpha=7: 0.9800695924650671
Validation Accuracy for alpha=8: 0.9795594906268787
Validation Accuracy for alpha=9: 0.9794137472445392
Validation Accuracy for alpha=10: 0.9790493887886903

Best alpha found: 1 with validation accuracy: 0.9842050609389518
```

Testing through best classifier

[39]:
```
y_test_pred = nb_classifier.predict(x_test_vect)
test_accuracy = accuracy_score(y_test, y_test_pred)
```

[40]:
```
print(test_accuracy)
```

```
0.9785797902812026
```

Reporting performance metrics on validation and test sets

[42]:
```
print("Validation Set Performance:")
print(classification_report(y_val, y_val_pred, target_names=locales))
print("Test Set Performance:")
print(classification_report(y_test, y_test_pred, target_names=locales))
conf_matrix = confusion_matrix(y_test, y_test_pred, labels=locales)
print(f"Validation Accuracy: {val_accuracy}")
print(f"Test Accuracy: {test_accuracy}")
```

Validation Set Performance:

	precision	recall	f1-score	support
af-ZA	0.90	0.97	0.93	2033
da-DK	1.00	0.99	0.99	2033
de-DE	0.93	0.95	0.94	2033
en-US	0.99	0.98	0.98	2033
es-ES	0.94	0.99	0.96	2033
fr-FR	0.97	0.97	0.97	2033
fi-FI	1.00	0.98	0.99	2033
hu-HU	0.98	0.99	0.98	2033
is-IS	1.00	0.97	0.99	2033
it-IT	1.00	0.99	0.99	2033
jv-ID	0.98	0.99	0.98	2033
lv-LV	0.98	0.98	0.98	2033
ms-MY	1.00	0.99	0.99	2033
nb-NO	0.98	0.99	0.98	2033
nl-NL	0.96	0.92	0.94	2033
pl-PL	0.97	0.96	0.97	2033
pt-PT	0.98	0.98	0.98	2033
ro-RO	0.97	0.98	0.98	2033
ru-RU	0.99	0.98	0.98	2033
sl-SL	1.00	0.99	1.00	2033
sv-SE	1.00	0.99	0.99	2033
sq-AL	0.99	0.99	0.99	2033
sw-KE	0.96	0.98	0.97	2033
tl-PH	1.00	0.99	0.99	2033
tr-TR	0.99	0.99	0.99	2033
vi-VN	1.00	0.98	0.99	2033
cy-GB	1.00	1.00	1.00	2033
accuracy			0.98	54891
macro avg	0.98	0.98	0.98	54891
weighted avg	0.98	0.98	0.98	54891

Test Set Performance:

	precision	recall	f1-score	support
af-ZA	0.88	0.98	0.93	2974
da-DK	1.00	0.99	0.99	2974
de-DE	0.93	0.95	0.94	2974
en-US	0.99	0.98	0.99	2974
es-ES	0.92	0.99	0.96	2974
fr-FR	0.97	0.98	0.97	2974
fi-FI	1.00	0.98	0.99	2974
hu-HU	0.98	0.99	0.99	2974
is-IS	1.00	0.97	0.98	2974
it-IT	1.00	0.99	0.99	2974

```
          jv-ID       0.97      0.99      0.98      2974
          lv-LV       0.98      0.97      0.98      2974
          ms-MY       1.00      0.99      0.99      2974
          nb-NO       0.98      0.99      0.99      2974
          nl-NL       0.95      0.92      0.93      2974
          pl-PL       0.98      0.97      0.97      2974
          pt-PT       1.00      0.98      0.99      2974
          ro-RO       0.98      0.98      0.98      2974
          ru-RU       1.00      0.98      0.99      2974
          sl-SL       1.00      0.99      1.00      2974
          sv-SE       0.99      0.98      0.99      2974
          sq-AL       0.99      0.98      0.99      2974
          sw-KE       0.99      0.97      0.98      2974
          tl-PH       1.00      0.99      0.99      2974
          tr-TR       0.99      0.99      0.99      2974
          vi-VN       0.98      0.98      0.98      2974
          cy-GB       1.00      1.00      1.00      2974

       accuracy                           0.98     80298
      macro avg       0.98      0.98      0.98     80298
   weighted avg       0.98      0.98      0.98     80298

Validation Accuracy: 0.9790493887886903
Test Accuracy: 0.9785797902812026
```

Task 3

Mapping languages to continents

[43]:
```
locale_continent = {'af-ZA': 'Africa', 'da-DK': 'Europe', 'de-DE': 'Europe',␣
 ↪'en-US': 'North America',
   'es-ES': 'Europe', 'fr-FR': 'Europe', 'fi-FI': 'Europe', 'hu-HU': 'Europe',␣
 ↪'is-IS': 'Europe',
   'it-IT': 'Europe', 'jv-ID': 'Asia', 'lv-LV': 'Europe', 'ms-MY': 'Asia',␣
 ↪'nb-NO': 'Europe',
   'nl-NL': 'Europe', 'pl-PL': 'Europe', 'pt-PT': 'Europe', 'ro-RO': 'Europe',␣
 ↪'ru-RU': 'Europe',
   'sl-SL': 'Europe', 'sv-SE': 'Europe', 'sq-AL': 'Europe', 'sw-KE': 'Africa',␣
 ↪'tl-PH': 'Asia',
   'tr-TR': 'Asia', 'vi-VN': 'Asia', 'cy-GB': 'Europe'}


df_train['continent'] = df_train['locale'].map(locale_continent)
df_val['continent'] = df_val['locale'].map(locale_continent)
df_test['continent'] = df_test['locale'].map(locale_continent)
```

```
<ipython-input-43-457c7fb0a19f>:9: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
```

```
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  df_train['continent'] = df_train['locale'].map(locale_to_continent)
```

Conversion of text to vectors

[46]:
```
label_encoder = LabelEncoder()
vectorizer = TfidfVectorizer(max_features=10000)
X_train = vectorizer.fit_transform(df_train['utt'])
y_train = label_encoder.fit_transform(df_train['continent'])
y_val = label_encoder.transform(df_val['continent'])
X_val = vectorizer.transform(df_val['utt'])
X_test = vectorizer.transform(df_test['utt'])
y_test = df_test['continent']
```

[51]:
```
class RDA:
    def __init__(self, lambda_):
        self.lambda_ = lambda_
        self.lda = LDA()
        self.qda = QDA()

    def fit(self, X, y):
        self.lda.fit(X, y)
        self.qda.fit(X, y)

    def predict(self, X):
        lda_prob = self.lda.predict_prob(X)
        qda_prob = self.qda.predict_prob(X)

        prob = (1 - self.lambda_) * lda_prob + self.lambda_ * qda_prob
        return np.argmax(prob, axis=1)

    def predict_prob(self, X):
        lda_probab = self.lda.predict_prob(X)
        qda_probab = self.qda.predict_prob(X)
        return (1 - self.lambda_param) * lda_probab + self.lambda_ * qda_probab
```

[52]:
```
svd = TruncatedSVD(n_components=500)  # Number of components to keep which in␣
 ↪this case is chosen to be 500

X_train_svd = svd.fit_transform(X_train)
X_val_svd = svd.transform(X_val)

for lambda_ in [0.0, 0.25, 0.5, 0.75, 1.0]:
    print(f"\nTraining RDA model with lambda={lambda_}")
```

```
    rda_model = RDA(lambda_=lambda_)

    rda_model.fit(X_train_svd, y_train)

    y_val_pred = rda_model.predict(X_val_svd)
    val_accuracy = accuracy_score(y_val, y_val_pred)


    print(f"Validation Accuracy: {val_accuracy}")
    print(classification_report(y_val, y_val_pred,␣
↪target_names=df_val['continent'].unique()))
```

```
Training RDA model with lambda=0.0
Validation Accuracy: 0.9413565065311253
               precision    recall  f1-score   support

       Africa       0.97      0.80      0.87      4066
       Europe       1.00      0.82      0.90     10165
         Asia       0.93      1.00      0.96     38627
North America       0.96      0.82      0.88      2033

     accuracy                           0.94     54891
    macro avg       0.96      0.86      0.90     54891
 weighted avg       0.94      0.94      0.94     54891


Training RDA model with lambda=0.25
Validation Accuracy: 0.9445264250970105
               precision    recall  f1-score   support

       Africa       0.97      0.81      0.88      4066
       Europe       1.00      0.83      0.91     10165
         Asia       0.93      1.00      0.96     38627
North America       0.96      0.82      0.89      2033

     accuracy                           0.94     54891
    macro avg       0.96      0.86      0.91     54891
 weighted avg       0.95      0.94      0.94     54891


Training RDA model with lambda=0.5
Validation Accuracy: 0.9452551420087082
               precision    recall  f1-score   support

       Africa       0.87      0.97      0.91      4066
       Europe       0.93      0.98      0.95     10165
```

```
         Asia       1.00      0.93      0.96     38627
North America       0.56      0.99      0.71      2033

     accuracy                           0.95     54891
    macro avg       0.84      0.97      0.89     54891
 weighted avg       0.96      0.95      0.95     54891


Training RDA model with lambda=0.75
Validation Accuracy: 0.9450365269351988
               precision    recall  f1-score   support

       Africa       0.87      0.97      0.91      4066
       Europe       0.93      0.98      0.95     10165
         Asia       1.00      0.93      0.96     38627
North America       0.56      0.99      0.71      2033

     accuracy                           0.95     54891
    macro avg       0.84      0.97      0.89     54891
 weighted avg       0.96      0.95      0.95     54891


Training RDA model with lambda=1.0
Validation Accuracy: 0.9450183090124064
               precision    recall  f1-score   support

       Africa       0.87      0.97      0.91      4066
       Europe       0.93      0.98      0.95     10165
         Asia       1.00      0.93      0.96     38627
North America       0.56      0.99      0.71      2033

     accuracy                           0.95     54891
    macro avg       0.84      0.97      0.89     54891
 weighted avg       0.96      0.95      0.95     54891
```

[ ]: