(2)

In [ ]:

```
import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
import seaborn as sns
from sklearn.feature_extraction.text import TfidfVectorizer
from nltk.tokenize import TweetTokenizer
from nltk.corpus import stopwords
from sklearn.naive_bayes import MultinomialNB
from sklearn.metrics import confusion_matrix
from sklearn.metrics import classification_report
from sklearn.ensemble import RandomForestClassifier
from xgboost import XGBClassifier
from sklearn import svm
from imblearn.over_sampling import RandomOverSampler
from imblearn.under_sampling import NearMiss
from imblearn.over_sampling import SMOTE
from imblearn.combine import SMOTETomek
from vaderSentiment.vaderSentiment import SentimentIntensityAnalyzer
from scipy.sparse import hstack
import nltk
from sklearn.tree import DecisionTreeClassifier
from sklearn.linear_model import LogisticRegression
from nltk.stem import WordNetLemmatizer
import gensim
import re
import pyLDAvis
import pyLDAvis.gensim_models as gensimvis
from gensim.models import CoherenceModel
from nltk import pos_tag
from gensim.models import LdaModel
from operator import itemgetter
import nlpaug.augmenter.word as naw
from tensorflow.keras.layers import Embedding,LSTM, Dense, Bidirectional, GRU
from tensorflow.keras.preprocessing.sequence import pad_sequences
from tensorflow.keras.models import Sequential
from tensorflow.keras.preprocessing.text import one_hot
from tensorflow.keras import utils
```

```
C:\Users\عبد العزيز\AppData\Roaming\Python\Python37\site-packages\tensorflow\py
thon\framework\dtypes.py:585: DeprecationWarning: `np.object` is a deprecated
alias for the builtin `object`. To silence this warning, use `object` by itsel
f. Doing this will not modify any behavior and is safe.
Deprecated in NumPy 1.20; for more details and guidance: https://numpy.org/dev
docs/release/1.20.0-notes.html#deprecations
  np.object,
C:\Users\عبد العزيز\AppData\Roaming\Python\Python37\site-packages\tensorflow\py
thon\framework\dtypes.py:627: DeprecationWarning: `np.object` is a deprecated
alias for the builtin `object`. To silence this warning, use `object` by itsel
f. Doing this will not modify any behavior and is safe.
Deprecated in NumPy 1.20; for more details and guidance: https://numpy.org/dev
docs/release/1.20.0-notes.html#deprecations
  np.object,
C:\Users\عبد العزيز\AppData\Roaming\Python\Python37\site-packages\tensorflow\py
thon\framework\dtypes.py:637: DeprecationWarning: `np.bool` is a deprecated al
ias for the builtin `bool`. To silence this warning, use `bool` by itself. Doi
ng this will not modify any behavior and is safe. If you specifically wanted t
```

```
he numpy scalar type, use `np.bool_` here.
Deprecated in NumPy 1.20; for more details and guidance: https://numpy.org/dev
docs/release/1.20.0-notes.html#deprecations
  np.bool,
C:\Users\عبد العزيز\AppData\Roaming\Python\Python37\site-packages\tensorflow\py
thon\framework\tensor_util.py:176: DeprecationWarning: `np.object` is a deprec
ated alias for the builtin `object`. To silence this warning, use `object` by
itself. Doing this will not modify any behavior and is safe.
Deprecated in NumPy 1.20; for more details and guidance: https://numpy.org/dev
docs/release/1.20.0-notes.html#deprecations
  np.object: SlowAppendObjectArrayToTensorProto,
C:\Users\عبد العزيز\AppData\Roaming\Python\Python37\site-packages\tensorflow\py
thon\framework\tensor_util.py:177: DeprecationWarning: `np.bool` is a deprecat
ed alias for the builtin `bool`. To silence this warning, use `bool` by itsel
f. Doing this will not modify any behavior and is safe. If you specifically wa
nted the numpy scalar type, use `np.bool_` here.
Deprecated in NumPy 1.20; for more details and guidance: https://numpy.org/dev
docs/release/1.20.0-notes.html#deprecations
  np.bool: SlowAppendBoolArrayToTensorProto,
C:\Users\عبد العزيز\AppData\Roaming\Python\Python37\site-packages\tensorflow\py
thon\ops\numpy_ops\np_random.py:110: DeprecationWarning: `np.int` is a depreca
ted alias for the builtin `int`. To silence this warning, use `int` by itself.
Doing this will not modify any behavior and is safe. When replacing `np.int`,
you may wish to use e.g. `np.int64` or `np.int32` to specify the precision. If
you wish to review your current use, check the release note link for additiona
l information.
Deprecated in NumPy 1.20; for more details and guidance: https://numpy.org/dev
docs/release/1.20.0-notes.html#deprecations
  def randint(low, high=None, size=None, dtype=onp.int):  # pylint: disable=mi
```

data preprocessing

In [ ]:
```
df = pd.read_csv('train_data.csv')
df.sample(10)
```

Out[ ]:

	name	brand	categories	primaryCategories	reviews.date	revie
3720	Fire Tablet, 7 Display, Wi-Fi, 16 GB - Include...	Amazon	Fire Tablets,Computers/Tablets & Networking,Ta...	Electronics	2016-06-24T00:00:00.000Z	G gif g
1489	Fire HD 8 Tablet with Alexa, 8" HD Display, 32...	Amazon	Tablets,Fire Tablets,Computers & Tablets,All T...	Electronics	2017-03-03T00:00:00.000Z	I was st my
2697	Fire Kids Edition Tablet, 7 Display, Wi-Fi, 16...	Amazon	Fire Tablets,Tablets,All Tablets,Amazon Tablet...	Electronics	2017-01-06T00:00:00.000Z	C todd to c to d

	name	brand	categories	primaryCategories	reviews.date	revie
521	Amazon Echo Show Alexa-enabled Bluetooth Speak...	Amazon	Amazon Echo,Virtual Assistant Speakers,Electro...	Electronics,Hardware	2017-12-10T00:00:00.000Z	Go t du h
317	All-New Fire HD 8 Tablet, 8" HD Display, Wi-Fi...	Amazon	Electronics,iPad & Tablets,All Tablets,Fire Ta...	Electronics	2017-01-08T00:00:00.000Z	Pu thi nep love
2924	Amazon Echo Show Alexa-enabled Bluetooth Speak...	Amazon	Amazon Echo,Virtual Assistant Speakers,Electro...	Electronics,Hardware	2017-12-15T00:00:00.000Z	I v or my w
2185	Fire Kids Edition Tablet, 7 Display, Wi-Fi, 16...	Amazon	Fire Tablets,Tablets,All Tablets,Amazon Tablet...	Electronics	2017-02-20T00:00:00.000Z	tab user and y
795	Amazon Tap - Alexa-Enabled Portable Bluetooth ...	Amazon	Amazon Echo,Home Theater & Audio,MP3 MP4 Playe...	Electronics	2017-02-08T00:00:00.000Z	Wor v ech real
1091	Fire Tablet with Alexa, 7" Display, 16 GB, Mag...	Amazon	Tablets,Fire Tablets,Electronics,iPad & Tablet...	Electronics	2016-06-18T00:00:00.000Z	Nic table Dc
2619	All-New Fire HD 8 Tablet, 8" HD Display	Amazon	Electronics,iPad & Tablets,All Tablets,Fire Ta...	Electronics	2016-11-18T00:00:00.000Z	porta it.

In [ ]:
```
df_test = pd.read_csv('test_data_hidden.csv')
df_test.sample()
```

Out[ ]:

	name	brand	categories	primaryCategories	reviews.date	reviews
207	Fire Tablet, 7	Amazon	Fire Tablets,Computers/Tablets	Electronics	2016-06-24T00:00:00.000Z	Bough to

	name	brand	categories	primaryCategories	reviews.date	reviews
	Display, Wi-Fi, 16 GB -		& Networking,Ta...			aroun Internet

In [ ]:
```
df_test.describe()
```

Out[ ]:

	name	brand	categories	primaryCategories	reviews.date	reviews.text
count	1000	1000	1000	1000	1000	1000
unique	23	1	23	4	366	979
top	Amazon Echo Show Alexa-enabled Bluetooth Speak...	Amazon	Electronics,iPad & Tablets,All Tablets,Fire Ta...	Electronics	2017-01-23T00:00:00.000Z	I bought the white version and have it in the ...
freq	169	1000	169	676	26	2

In [ ]:
```
df_test.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1000 entries, 0 to 999
Data columns (total 8 columns):
 #   Column             Non-Null Count  Dtype 
---  ------             --------------  ----- 
 0   name               1000 non-null   object
 1   brand              1000 non-null   object
 2   categories         1000 non-null   object
 3   primaryCategories  1000 non-null   object
 4   reviews.date       1000 non-null   object
 5   reviews.text       1000 non-null   object
 6   reviews.title      997 non-null    object
 7   sentiment          1000 non-null   object
dtypes: object(8)
memory usage: 62.6+ KB
```

In [ ]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 4000 entries, 0 to 3999
Data columns (total 8 columns):
 #   Column             Non-Null Count  Dtype 
---  ------             --------------  ----- 
 0   name               4000 non-null   object
 1   brand              4000 non-null   object
 2   categories         4000 non-null   object
 3   primaryCategories  4000 non-null   object
 4   reviews.date       4000 non-null   object
 5   reviews.text       4000 non-null   object
 6   reviews.title      3990 non-null   object
```

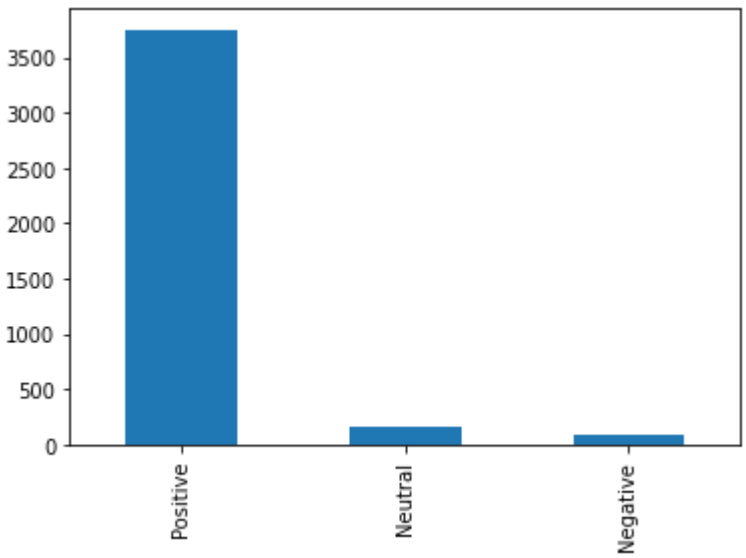
```
 7   sentiment          4000 non-null   object
dtypes: object(8)
```

In [ ]:
```
df.describe()
```

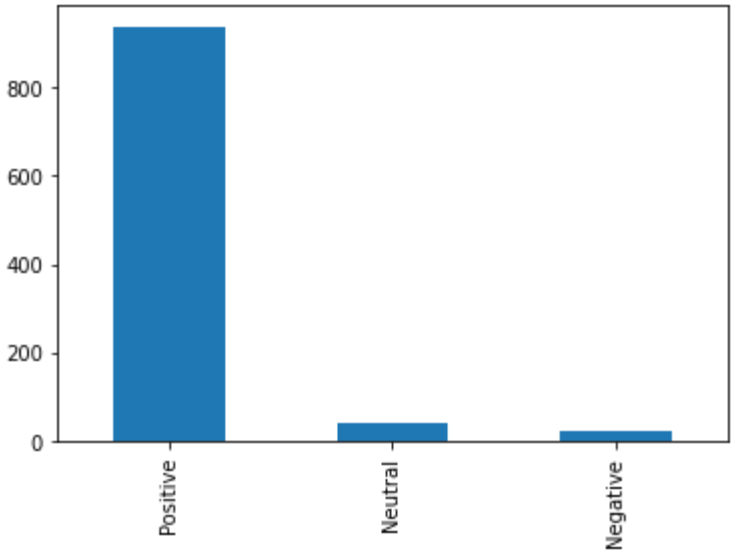
Out[ ]:

	name	brand	categories	primaryCategories	reviews.date	reviews.text
count	4000	4000	4000	4000	4000	4000
unique	23	1	23	4	638	3598
top	Amazon Echo Show Alexa-enabled Bluetooth Speak...	Amazon	Electronics,iPad & Tablets,All Tablets,Fire Ta...	Electronics	2017-01-23T00:00:00.000Z	I bought this kindle for my 11yr old granddaug...
freq	676	4000	628	2600	99	4

In [ ]:
```
df['sentiment'].value_counts().plot(kind = 'bar')
plt.show()
```



In [ ]:
```
df_test['sentiment'].value_counts().plot(kind = 'bar')
plt.show()
```



In [ ]:
```
df[df.duplicated()].count()
```

Out[ ]:
```
name                 58
brand                58
categories           58
primaryCategories    58
reviews.date         58
reviews.text         58
reviews.title        58
sentiment            58
dtype: int64
```

In [ ]:
```
df_test[df_test.duplicated()].count()
```

Out[ ]:
```
name                 3
brand                3
categories           3
primaryCategories    3
reviews.date         3
reviews.text         3
reviews.title        3
sentiment            3
dtype: int64
```

In [ ]:
```
df_test.drop_duplicates(inplace = True)
df_test.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 997 entries, 0 to 999
Data columns (total 8 columns):
 #   Column              Non-Null Count  Dtype
---  ------              --------------  -----
 0   name                997 non-null    object
 1   brand               997 non-null    object
 2   categories          997 non-null    object
 3   primaryCategories   997 non-null    object
 4   reviews.date        997 non-null    object
 5   reviews.text        997 non-null    object
```

```
 6   reviews.title      994 non-null    object
 7   sentiment          997 non-null    object
dtypes: object(8)
```

In [ ]:
```
df.drop_duplicates(inplace = True)
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 3942 entries, 0 to 3999
Data columns (total 8 columns):
 #   Column             Non-Null Count  Dtype
---  ------             --------------  -----
 0   name               3942 non-null   object
 1   brand              3942 non-null   object
 2   categories         3942 non-null   object
 3   primaryCategories  3942 non-null   object
 4   reviews.date       3942 non-null   object
 5   reviews.text       3942 non-null   object
 6   reviews.title      3932 non-null   object
 7   sentiment          3942 non-null   object
dtypes: object(8)
memory usage: 277.2+ KB
```

In [ ]:
```
df['brand'].value_counts()
```

Out[ ]:
```
Amazon    3942
Name: brand, dtype: int64
```

In [ ]:
```
df['categories'].value_counts()
```

Out[ ]:
```
Electronics,iPad & Tablets,All Tablets,Fire Tablets,Tablets,Computers & Tablet
s
628
Computers,Amazon Echo,Virtual Assistant Speakers,Audio & Video Components,Elec
tronics Features,Computer Accessories,Home & Tools,See more Amazon Echo Show S
mart Assistant - White,Smart Home Automation,Electronics,TVs Entertainment,Spe
akers,Smart Hub & Kits,Digital Device 3,Consumer Electronics,Wireless Speaker
s,Home Improvement,Amazon Home,Amazon,Computer Speakers,Voice-Enabled Smart As
sistants
514
Amazon Echo,Smart Home,Networking,Home & Tools,Home Improvement,Smart Home Aut
omation,Voice Assistants,Amazon Home,Amazon,Smart Hub & Kits,Digital Device 3
483
Computers,Fire Tablets,Electronics Features,Computer Accessories,Tablets,Top R
ated,Amazon Tablets,Electronics,Kids' Tablets,iPad & Tablets,Cases & Bags,Elec
tronics, Tech Toys, Movies, Music,Computers & Tablets
446
Computers/Tablets & Networking,Tablets & eBook Readers,Computers & Tablets,Tab
lets,All Tablets
340
Fire Tablets,Computers/Tablets & Networking,Tablets,All Tablets,Amazon Tablet
s,Frys,Computers & Tablets,Tablets & eBook Readers
294
Fire Tablets,Tablets,All Tablets,Amazon Tablets,Computers & Tablets
231
Amazon Echo,Home Theater & Audio,MP3 MP4 Player Accessories,Electronics,Portab
```

```
le Audio,Compact Radios Stereos,Smart Hubs & Wireless Routers,Featured Brands,
Smart Home & Connected Living,Home Security,Kindle Store,Electronic Component
s,Home Automation,Mobile Bluetooth Speakers,Home, Garage & Office,Amazon Tap,H
ome,Mobile Speakers,TVs & Electronics,Portable Bluetooth Speakers,Bluetooth &
Wireless Speakers,Electronics Features,Frys,Speakers,Mobile,Digital Device 3,S
mart Home,Home Improvement,Electronics, Tech Toys, Movies, Music,Smart Home &
Home Automation Devices,Smart Hubs,MP3 Player Accessories,Home Safety & Securi
ty,Voice Assistants,Amazon Home,Alarms & Sensors,Portable Audio & Electronics,
Amazon Devices,Audio,Bluetooth Speakers,MP3 Accessories,All Bluetooth & Wirele
ss Speakers    177
Amazon Echo,Virtual Assistant Speakers,Electronics Features,Home & Tools,Smart
Home Automation,TVs Entertainment,Speakers,Smart Hub & Kits,Digital Device 3,W
ireless Speakers,Smart Home,Home Improvement,Voice Assistants,Amazon Home,Amaz
on
162
Office,eBook Readers,Electronics Features,Walmart for Business,Tablets,Electro
nics,Amazon Ereaders,Office Electronics,iPad & Tablets,Kindle E-readers,All Ta
blets,Amazon Book Reader,Computers & Tablets
122
eBook Readers,Fire Tablets,Electronics Features,Tablets,Amazon Tablets,College
Ipads & Tablets,Electronics,Electronics Deals,College Electronics,Featured Bra
nds,All Tablets,Computers & Tablets,Back To College,Amazon Devices,Tablets & E
-Readers
82
Tablets,Fire Tablets,Electronics,iPad & Tablets,Android Tablets,Computers & Ta
blets,All Tablets
80
Computers,Electronics Features,Tablets,Electronics,iPad & Tablets,Kindle E-rea
ders,iPad Accessories,Used:Tablets,E-Readers,E-Readers & Accessories,Computers
/Tablets & Networking,Used:Computers Accessories,iPads Tablets,All Tablets,Tab
lets & E-readers,Computers & Tablets,Amazon,Tablets & eBook Readers
76
eBook Readers,Electronics Features,Walmart for Business,Tablets,See more Amazo
n Kindle Voyage (Wi-Fi),Electronics,Office Electronics,iPad & Tablets,Kindle E
-readers,E-Readers & Accessories,All Tablets,See more Amazon Kindle Voyage 4G
B, Wi-Fi  3G (Unlocked...,Computers & Tablets
65
Fire Tablets,Tablets,Computers/Tablets & Networking,Other Computers & Networki
ng,Computers & Tablets,All Tablets
45
Tablets,Fire Tablets,Computers & Tablets,All Tablets
43
Fire Tablets,Tablets,All Tablets,Amazon Tablets
35
Tablets,Fire Tablets,Electronics,Computers,Computer Components,Hard Drives & S
torage,Computers & Tablets,All Tablets
35
Kindle E-readers,Electronics Features,Computers & Tablets,E-Readers & Accessor
ies,E-Readers,eBook Readers
26
Computers & Accessories,Tablet & E-Reader Accessories,Amazon Devices & Accesso
ries,Electronics,Power Adapters & Cables,Computers Features,Cell Phone Accesso
ries,Cell Phone Batteries & Power,Digital Device Accessory,Tablet Accessories,
Featured Brands,Kindle Fire (2nd Generation) Accessories,Kindle Store,Power Ad
apters Cables,Electrical,Home,Tablets & E-Readers,Chargers Adapters,Chargers &
Adapters,Electronics Features,Fire Tablet Accessories,Amazon Book Reader Acces
sory,Cell Phones,Amazon Device Accessories,Home Improvement,Fire (5th Generati
on) Accessories,Amazon Devices,Cables & Chargers
20
```

```
Computers & Tablets,E-Readers & Accessories,eBook Readers,Kindle E-readers
19
eBook Readers,E-Readers & Accessories,Amazon Book Reader,Computers & Tablets,A
mazon Ereaders,Kindle E-readers,E-Readers
17
Amazon SMP,TV, Video & Home Audio,Electronics,Electronics Deals,TVs Entertainm
ent,Digital Device 4,Tvs & Home Theater,Featured Brands,Video Devices & TV Tun
ers,Consumer Electronics,TV & Video,Internet & Media Streamers,Streaming Media
Players,Fire TV,Streaming Devices,Amazon Devices,Amazon,See more Amazon Fire T
V with Alexa Voice Remote Digital...
2
```

In [ ]:
```
df['primaryCategories'].value_counts()
```

Out[ ]:
```
Electronics                    2562
Electronics,Hardware           1159
Office Supplies,Electronics     204
Electronics,Media                17
Name: primaryCategories, dtype: int64
```

In [ ]:
```
df['reviews.date']
```

Out[ ]:
```
0       2016-12-26T00:00:00.000Z
1       2018-01-17T00:00:00.000Z
2       2017-12-20T00:00:00.000Z
3       2017-08-04T00:00:00.000Z
4       2017-01-23T00:00:00.000Z
                  ...
3995    2017-12-08T00:00:00.000Z
3996    2017-03-31T00:00:00.000Z
3997    2017-01-19T00:00:00.000Z
3998    2016-05-27T00:00:00.000Z
3999    2016-12-30T00:00:00.000Z
Name: reviews.date, Length: 3942, dtype: object
```

In [ ]:
```
df['reviews.title']
```

Out[ ]:
```
0                                Powerful tablet
1                     Amazon Echo Plus AWESOME
2                                      Average
3                                  Greatttttt
4                                Very durable!
                           ...
3995                                   Fun toy
3996                             Great Product
3997                     Great "dumb" speaker
3998    A great 7 inch tablet at a great price
3999                          Gets the job done
Name: reviews.title, Length: 3942, dtype: object
```

In [ ]:
```
#based on the above i see that some columns will not be needed
df_updated = df[['reviews.text', 'sentiment']].copy()
df_test_updated = df_test[['reviews.text', 'sentiment']].copy()
```

In [ ]:
```
df_updated.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 3942 entries, 0 to 3999
Data columns (total 2 columns):
 #   Column        Non-Null Count  Dtype 
---  ------        --------------  ----- 
 0   reviews.text  3942 non-null   object
 1   sentiment     3942 non-null   object
dtypes: object(2)
memory usage: 92.4+ KB
```

In [ ]:
```
df_test_updated.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 997 entries, 0 to 999
Data columns (total 2 columns):
 #   Column        Non-Null Count  Dtype 
---  ------        --------------  ----- 
 0   reviews.text  997 non-null    object
 1   sentiment     997 non-null    object
dtypes: object(2)
memory usage: 23.4+ KB
```

In [ ]:
```
df_updated.sample(10)
```

Out[ ]:

	reviews.text	sentiment
2274	I got this for my daughter's for Christmas thi...	Positive
2936	Love it Love it Love it!!!!!!!!!!!!!!!!!!!!!!!...	Positive
2489	Great beginner tablet for kids I would recomme...	Neutral
187	This device is a good if you are looking for a...	Neutral
290	It is amazing that you can get this much tech ...	Positive
3012	For the price guy cannot beat it great for wat...	Positive
2347	This is my first Amazon Echo and it was a grea...	Positive
113	Excellent value for my 3 yr old, everything yo...	Positive
3169	I originally purchased a Kindle paperwhite but...	Positive
486	still learning new things about my tablet. ver...	Positive

In [ ]:
```
df_updated['reviews.text'] = df_updated['reviews.text'].apply(str.lower)
df_updated['reviews.text'] = df_updated['reviews.text'].str.replace(r'[^a-zA-Z
df_updated.sample(10)
```

Out[ ]:

	reviews.text	sentiment
3706	love it it s a lot of fun great speakers t...	Positive
3338	for its price this a great little tablet it ...	Positive

	reviews.text	sentiment
77	both love this tablet and the numerous educati...	Positive
2745	my daughter loves her new tablet plenty of ga...	Positive
2506	i have two of these for my kids ages and ...	Positive
171	the tablet was a good gift for christmas i bo...	Positive
3934	after owning the kids samsung this seems conf...	Negative
1862	got this for the kids for xmas was the best ...	Positive
1444	kind of hard adding smart items but when you d...	Positive

In [ ]:
```
df_test_updated['reviews.text'] = df_test_updated['reviews.text'].apply(str.l
df_test_updated['reviews.text'] = df_test_updated['reviews.text'].str.replace
df_test_updated.sample(10)
```

Out[ ]:

	reviews.text	sentiment
240	very happy and satisfiedeasier to handle fast...	Positive
650	very happy with amazon not hesitating to integ...	Positive
587	great notepad huge screen and easily download...	Positive
920	we have always been nexus tablet desciples an...	Positive
421	this is the main reason why i went with amazon...	Positive
857	love the amazon alexa products i have show ...	Positive
293	the original electronic book bought it for my...	Positive
872	they are both responsive to each other and it ...	Positive
880	love this tablet it does everything i need it...	Positive
386	we already had a tablet for our son and it was...	Positive

In [ ]:
```
df_updated.columns = ['text', 'sentiment']
df_test_updated.columns = ['text', 'sentiment']
```

In [ ]:
```
tweet_tokenizer = TweetTokenizer()

df_updated['text'] = [tweet_tokenizer.tokenize(text) for text in df_updated['
df_updated.sample(10)
```

Out[ ]:

	text	sentiment
2775	[it, would, not, load, my, books, proper, took...	Negative
2253	[i, bought, this, tablet, for, my, kids, to, w...	Positive
6	[my, year, old, daughter, saved, up, to, by, t...	Neutral

	text	sentiment
1612	[i, love, the, fact, that, i, can, just, use, ...	Positive
292	[good, product, for, a, young, child, to, play...	Positive
1728	[everything, was, as, i, expected, and, order,...	Positive
3044	[purchased, for, my, year, old, mother, as, a,...	Positive
2030	[not, only, does, it, round, out, my, collecti...	Positive
2553	[great, tablet, for, reading, and, game, play,...	Positive

In [ ]:
```
df_test_updated['text'] = [tweet_tokenizer.tokenize(text) for text in df_test_
df_updated.sample(10)
```

Out[ ]:

	text	sentiment
2961	[i, had, trouble, linking, to, my, joule, cook...	Positive
659	[i, bought, my, kindle, about, months, ago, an...	Positive
2920	[i, have, had, every, kindle, since, the, firs...	Positive
3498	[i, love, alexa, has, a, pretty, good, speaker...	Positive
106	[my, year, old, loves, it, good, control, opti...	Positive
2364	[always, a, big, fan, of, kindle, this, is, my...	Positive
3951	[i, purchased, it, so, the, weather, and, info...	Positive
334	[this, tablet, works, great, and, my, daughter...	Positive
3348	[it, was, ok, you, need, internet, the, sdmini...	Neutral
3652	[you, will, not, find, another, tablet, like, ...	Positive

In [ ]:
```
lem = WordNetLemmatizer()

df_updated['lemmatize_text'] = [[lem.lemmatize(word) for word in text ] for te
df_updated.sample(10)
```

Out[ ]:

	text	sentiment	lemmatize_text
3703	[great, to, talk, and, see, family, at, anytim...	Positive	[great, to, talk, and, see, family, at, anytim...
2980	[have, been, using, my, kindle, app, on, my, i...	Positive	[have, been, using, my, kindle, app, on, my, i...
2342	[my, year, old, daughter, loves, this, tablet,...	Positive	[my, year, old, daughter, love, this, tablet, ...
684	[i, bought, of, these, to, use, in, a, school,...	Positive	[i, bought, of, these, to, use, in, a, school,...
1028	[this, is, my, first, fire, kindle, i, love, i...	Positive	[this, is, my, first, fire, kindle, i, love, i...
1147	[it, needs, the, internet, to, connect, to, yo...	Positive	[it, need, the, internet, to, connect, to, you...
1696	[i, love, my, kindle, it, fast, great, pict, q...	Positive	[i, love, my, kindle, it, fast, great, pict, q...
2951	[video, quality, is, very, good, works, well, ...	Positive	[video, quality, is, very, good, work, well, w...

	text	sentiment	lemmatize_text
2964	[love, this, product, super, easy, to, use, an...	Positive	[love, this, product, super, easy, to, use, an...

In [ ]:
```
df_test_updated['lemmatize_text'] = [[lem.lemmatize(word) for word in text ] 
df_test_updated.sample(10)
```

Out[ ]:

	text	sentiment	lemmatize_text
607	[i, bought, of, these, for, gifts, i, love, my...	Positive	[i, bought, of, these, for, gift, i, love, my,...
628	[i, bought, two, of, these, for, my, granddaug...	Positive	[i, bought, two, of, these, for, my, granddaug...
406	[bought, it, for, my, son, wife, they, love, i...	Positive	[bought, it, for, my, son, wife, they, love, i...
475	[i, love, my, amazon, fire, hd, it, s, not, to...	Positive	[i, love, my, amazon, fire, hd, it, s, not, to...
583	[i, had, an, alexa, but, thought, the, show, w...	Positive	[i, had, an, alexa, but, thought, the, show, w...
169	[my, nd, fire, great, picture, quality, easy, ...	Positive	[my, nd, fire, great, picture, quality, easy, ...
775	[this, is, a, great, tablet, for, the, price, ...	Positive	[this, is, a, great, tablet, for, the, price, ...
581	[overall, it, is, a, good, tablet, but, i, am,...	Neutral	[overall, it, is, a, good, tablet, but, i, am,...
399	[the, amazon, fire, hd, is, one, of, the, best...	Positive	[the, amazon, fire, hd, is, one, of, the, best...
553	[the, display, is, not, as, sharp, and, vivid,...	Neutral	[the, display, is, not, a, sharp, and, vivid, ...

In [ ]:
```
stop_words = stopwords.words('english')

df_updated['lemmatize_text'] = [[word for word in text if word not in stop_wo
df_updated.sample(10)
```

Out[ ]:

	text	sentiment	lemmatize_text
1705	[i, am, very, satisfied, with, my, purchase, m...	Positive	[satisfied, purchase, girlfriend, happy]
1379	[bought, it, for, my, son, he, likes, it, very...	Positive	[bought, son, like, good, alternate, expensive...
1200	[this, is, an, amazing, product, for, reading,...	Positive	[amazing, product, reading, book, watching, mo...
3326	[it, is, a, very, good, e, reader, battery, la...	Positive	[good, e, reader, battery, last, week]
888	[my, wife, and, kids, love, it, easy, to, use,...	Positive	[wife, kid, love, easy, use, great, price]
2892	[got, for, my, parents, as, a, gift, simple, t...	Positive	[got, parent, gift, simple, use, like, got, sa...
1681	[i, have, multiple, echo, devices, so, purchas...	Positive	[multiple, echo, device, purchasing, another, ...
3601	[bought, this, for, my, mom, who, is, in, her,...	Positive	[bought, mom, perfect, easy, use, older, gener...

	text	sentiment	lemmatize_text
3443	[she, has, dropped, it, a, few, times, and, th...	Positive	[ha, dropped, time, case, great]

In [ ]:
```
df_test_updated['lemmatize_text'] = [[word for word in text if word not in sto
df_test_updated.sample(10)
```

Out[ ]:

	text	sentiment	lemmatize_text
594	[always, a, good, price, and, good, for, what,...	Positive	[always, good, price, good, meant]
639	[bought, this, for, my, daughter, to, use, in,...	Positive	[bought, daughter, use, school, love, product,...
530	[i, have, both, the, kindle, voyage, and, the,...	Positive	[kindle, voyage, low, end, kindle, fire, fire,...
518	[this, device, meets, the, needs, of, my, gran...	Positive	[device, meet, need, grandson, read, play, gam...
925	[this, is, a, great, tablet, for, my, teen, sh...	Positive	[great, tablet, teen, love, price, beat]
376	[once, the, games, are, downloaded, it, was, g...	Positive	[game, downloaded, wa, great, long, road, trip]
517	[the, new, tablet, is, great, nice, upgrades, ...	Positive	[new, tablet, great, nice, upgrade, love, easy...
62	[the, family, and, i, love, alexa, view, and, ...	Positive	[family, love, alexa, view, got, hooked, every...
684	[great, choice, battery, life, outstanding, ma...	Positive	[great, choice, battery, life, outstanding, ma...
528	[great, product, loving, alexa, was, so, happy...	Positive	[great, product, loving, alexa, wa, happy, kno...

In [ ]:
```
df_updated['updated_text'] = [' '.join(text) for text in df_updated['lemmatize
df_updated['text'] = [' '.join(text) for text in df_updated['text']]
df_updated.sample(10)
```

Out[ ]:

	text	sentiment	lemmatize_text	updated_text
1421	i haven t used any other kindle before but thi...	Positive	[used, kindle, kindle, wa, made, job, doe, pro...	used kindle kindle wa made job doe properly sl...
2946	it s so fantastic to just ask a device to turn...	Positive	[fantastic, ask, device, turn, light, play, mu...	fantastic ask device turn light play music con...
2244	download can be slow at times overall good pro...	Positive	[download, slow, time, overall, good, product]	download slow time overall good product
3690	this was bought for a gift but it looks nice j...	Positive	[wa, bought, gift, look, nice, wa, expected]	wa bought gift look nice wa expected
3456	i debated buying the new kindle oasis since i ...	Positive	[debated, buying, new, kindle, oasis, since, o...	debated buying new kindle oasis since owned ev...

	text	sentiment	lemmatize_text	updated_text
33	this is a great tablet for basic needs interne...	Positive	[great, tablet, basic, need, internet, video, ...	great tablet basic need internet video streami...
1946	decent little tablet if you are not a game pla...	Neutral	[decent, little, tablet, game, player, tablet,...	decent little tablet game player tablet shuts ...
622	the amazon fire is an inexpensive wifi device ...	Positive	[amazon, fire, inexpensive, wifi, device, use,...	amazon fire inexpensive wifi device use answer...
3639	my son uses this tablet for movies and music a...	Positive	[son, us, tablet, movie, music, surf, internet...	son us tablet movie music surf internet money ...

In [ ]:
```
df_test_updated['updated_text'] = [' '.join(text) for text in df_test_updated
df_test_updated['text'] = [' '.join(text) for text in df_test_updated['text']]
df_test_updated.sample(10)
```

Out[ ]:

	text	sentiment	lemmatize_text	updated_text
704	i have an old kindle touch the last one that s...	Positive	[old, kindle, touch, last, one, still, text, v...	old kindle touch last one still text voice lon...
212	can not tell you the price of merchandise when...	Positive	[tell, price, merchandise, asked]	tell price merchandise asked
564	had the echo plus over a week and this thing i...	Positive	[echo, plus, week, thing, amazing, great, soun...	echo plus week thing amazing great sound easy ...
292	i love my smart portable speaker it has games ...	Positive	[love, smart, portable, speaker, ha, game, wea...	love smart portable speaker ha game weather ne...
89	biting as a gift my only concern was the size ...	Positive	[biting, gift, concern, wa, size, amazon, inte...	biting gift concern wa size amazon interface w...
23	this is a great tablet for the price i have on...	Positive	[great, tablet, price, one, purchased, year, a...	great tablet price one purchased year ago use ...
783	i bought this as a backup i am currently using...	Positive	[bought, backup, currently, using, headphone]	bought backup currently using headphone
410	great sound and amazing options love this grea...	Positive	[great, sound, amazing, option, love, great, r...	great sound amazing option love great replacem...
956	i got the first version for my sister and she ...	Positive	[got, first, version, sister, able, put, year,...	got first version sister able put year got one...
977	perfect size for reading watching movies and c...	Positive	[perfect, size, reading, watching, movie, carr...	perfect size reading watching movie carrying p...

In [ ]:
```
df_updated['review_length'] = [len(review) for review in df_updated['updated_t
df_updated.sample(10)
```

Out[ ]:

	text	sentiment	lemmatize_text	updated_text	review_length
3324	my kids like it very much the price is low the...	Positive	[kid, like, much, price, low, tablet, light, w...	kid like much price low tablet light weighted	45

	text	sentiment	lemmatize_text	updated_text	review_length
3732	this is my th amazon alexa product i used to h...	Positive	[th, amazon, alexa, product, used, alexa, echo...	th amazon alexa product used alexa echo moved ...	168
1213	great for keeping around the house and doing b...	Positive	[great, keeping, around, house, basic, interne...	great keeping around house basic internet func...	207
1169	we purchased the echo show for christmas this ...	Positive	[purchased, echo, show, christmas, year, love,...	purchased echo show christmas year love much k...	85
2601	we struggled with a surprise christmas gift th...	Positive	[struggled, surprise, christmas, gift, year, s...	struggled surprise christmas gift year store s...	70
2468	i love this product would really recommend to ...	Positive	[love, product, would, really, recommend, one]	love product would really recommend one	39
3666	my niece loves this tablet she will not put it...	Positive	[niece, love, tablet, put]	niece love tablet put	21
191	love how user friendly the kindle fire is for ...	Positive	[love, user, friendly, kindle, fire, age]	love user friendly kindle fire age	34
1505	i live in a small apartment and this fan kept ...	Positive	[live, small, apartment, fan, kept, whole, pla...	live small apartment fan kept whole place cool	46
	i control all my smart		[control, smart, home,	control smart home	

In [ ]:
```
df_test_updated['review_length'] = [len(review) for review in df_test_updated
df_test_updated.sample(10)
```

Out[ ]:

	text	sentiment	lemmatize_text	updated_text	review_length
659	it great just a little small then what i would...	Positive	[great, little, small, would, like]	great little small would like	29
817	perfect start for smart home works perfect wit...	Positive	[perfect, start, smart, home, work, perfect, e...	perfect start smart home work perfect echo	42
833	we own an ipad samsug tablets and we have both...	Positive	[ipad, samsug, tablet, love, fire, wave, better]	ipad samsug tablet love fire wave better	40
187	great product i m at the beginning stages of h...	Positive	[great, product, beginning, stage, smart, home...	great product beginning stage smart home wa pe...	60
181	this replaced my old kindle fire i have not ye...	Positive	[replaced, old, kindle, fire, yet, explored, f...	replaced old kindle fire yet explored feature ...	98

	text	sentiment	lemmatize_text	updated_text	review_length
873	great overall would be nice to have parental c...	Positive	[great, overall, would, nice, parental, contro...	great overall would nice parental control though	48
254	this is the hub dollar my smart devices and it...	Positive	[hub, dollar, smart, device, worksthis, hub, d...	hub dollar smart device worksthis hub dollar s...	62
25	i decided to buy this instead of a traditional...	Positive	[decided, buy, instead, traditional, kindle, r...	decided buy instead traditional kindle regret ...	143
220	i m in love with alexa love her fir music quic...	Positive	[love, alexa, love, fir, music, quick, weather...	love alexa love fir music quick weather update...	131
	love the echo show		[love, echo, show,	love echo show allows	

In [ ]:
```
df_updated['sentiment'] = df_updated['sentiment'].map({'Negative': 0, 'Neutral
df_updated.sample(10)
```

Out[ ]:

	text	sentiment	lemmatize_text	updated_text	review_length
1304	bought for my yr old grandson and he loves it ...	2	[bought, yr, old, grandson, love, ha, lot, lea...	bought yr old grandson love ha lot learning nu...	65
291	easy to use purchased for my nephew he s he lo...	2	[easy, use, purchased, nephew, love]	easy use purchased nephew love	30
3712	i bought this because i recently signed up for...	2	[bought, recently, signed, amazon, prime, want...	bought recently signed amazon prime wanted tak...	79
3049	my grandkids love it they use it at home and w...	2	[grandkids, love, use, home, travel]	grandkids love use home travel	30
3680	my daughter loves her tablet i love free time ...	2	[daughter, love, tablet, love, free, time, lov...	daughter love tablet love free time love case ...	77
2622	my wife loves the tablet she s only using it f...	2	[wife, love, tablet, using, internet, far, ha,...	wife love tablet using internet far ha worked ...	56
2569	my wife loves it replaces a kindle from like	2	[wife, love, replaces, kindle, like]	wife love replaces kindle like	30
1468	gets use everyday by my girlfriend who i bough...	2	[get, use, everyday, girlfriend, bought, compl...	get use everyday girlfriend bought complaint a...	77
622	the amazon fire is an inexpensive wifi device ...	2	[amazon, fire, inexpensive, wifi, device, use,...	amazon fire inexpensive wifi device use answer...	108

	text	sentiment	lemmatize_text	updated_text	review_length
	i like the display		[like, display, news,	like display news	

In [ ]:
```
df_test_updated['sentiment'] = df_test_updated['sentiment'].map({'Negative': (
df_test_updated.sample(10)
```

Out[ ]:

	text	sentiment	lemmatize_text	updated_text	review_length
470	super easy to setup for the kids to use parent...	2	[super, easy, setup, kid, use, parental, contr...	super easy setup kid use parental control bonus	47
114	we were interested in the echo line of product...	2	[interested, echo, line, product, purchased, v...	interested echo line product purchased vivint ...	156
328	great tablet for web access and works well gam...	2	[great, tablet, web, access, work, well, gamin...	great tablet web access work well gaming reaso...	79
163	easy to use and elegant in design perfect gift...	2	[easy, use, elegant, design, perfect, gift, kid]	easy use elegant design perfect gift kid	40
565	the kindle fire hd has a larger screen vs and ...	2	[kindle, fire, hd, ha, larger, screen, v, imag...	kindle fire hd ha larger screen v image crispe...	61
938	my daughter absolutely love her tablet and i l...	2	[daughter, absolutely, love, tablet, love, kid...	daughter absolutely love tablet love kid friendly	49
726	i thought it would be as big as small paper bu...	1	[thought, would, big, small, paper, turn, like...	thought would big small paper turn like palm t...	134
428	gift for my grandpa so he can do internet sear...	2	[gift, grandpa, internet, search, chair, play,...	gift grandpa internet search chair play game l...	73
600	i love my echo show i wish you could watch mov...	2	[love, echo, show, wish, could, watch, movie, ...	love echo show wish could watch movie tc show ...	69
243	i bought this tablet for my year old grand dau...	2	[bought, tablet, year, old, grand, daughter, l...	bought tablet year old grand daughter love set...	243

In [ ]:
```
X_train = df_updated[['updated_text']]
y_train = df_updated['sentiment']
X_test = df_test_updated[['updated_text']]
y_test = df_test_updated['sentiment']
```

In [ ]:
```
text_vect = TfidfVectorizer()
text_vect.fit(X_train['updated_text'])
X_train_transform = text_vect.transform(X_train['updated_text'])
X_test_transform = text_vect.transform(X_test['updated_text'])
```

- apply ML algorithms without handling class imbalance

In [ ]:
```
def model_training(model, X_train = X_train_transform, y_train = y_train, X_te
    model.fit(X_train, y_train)
    return model.predict(X_test)
```

In [ ]:
```
def model_score(y_pred):
    return [confusion_matrix(y_test, y_pred), classification_report(y_test, y_
```

In [ ]:
```
def test(X_train = X_train_transform, y_train = y_train, X_test = X_test_trans
    result = []
    if nb_test:
      result.append(model_score(model_training(MultinomialNB(**nb_params),X_t

    result.append(model_score(model_training(RandomForestClassifier(**rf_para
    result.append(model_score(model_training(XGBClassifier(**XGB_params),X_tra
    result.append(model_score(model_training(svm.SVC(**svc_params),X_train,y_t
    result.append(model_score(model_training(DecisionTreeClassifier(**dt_para
    result.append(model_score(model_training(LogisticRegression(**lr),X_train,
    return result
```

In [ ]:

```
nb_params = {
    'class_prior': [0.9 , 0.70, 0.14]
}

rf_params = {
    'max_depth':20,
     'n_estimators': 500,
     'class_weight': 'balanced'
}
XGB_params = {
    'objective': 'multi:softmax',
    'max_depth': 30,
    'learning_rate': 0.01,
    'verbosity': 0,
    'n_estimators': 1000,
    'early_stopping_round':10,
    'num_class':3,
}

svc_params = {
    'class_weight': 'balanced'
}
dt_params = {

}

lr = {
    'solver':'lbfgs',
    'max_iter':50000,
    'multi_class':'ovr'
}
result = test()
```

```
C:\Users\عبد العزيز\AppData\Roaming\Python\Python37\site-packages\xgboost\sklea
rn.py:1146: UserWarning: The use of label encoder in XGBClassifier is deprecat
ed and will be removed in a future release. To remove this warning, do the fol
lowing: 1) Pass option use_label_encoder=False when constructing XGBClassifier
object; and 2) Encode your labels (y) as integers starting with 0, i.e. 0, 1,
2, ..., [num_class - 1].
  warnings.warn(label_encoder_deprecation_msg, UserWarning)
C:\Users\عبد العزيز\AppData\Roaming\Python\Python37\site-packages\sklearn\metri
cs\_classification.py:1248: UndefinedMetricWarning: Precision and F-score are
ill-defined and being set to 0.0 in labels with no predicted samples. Use `zer
o_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
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o_division` parameter to control this behavior.
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ill-defined and being set to 0.0 in labels with no predicted samples. Use `zer
o_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```

In [ ]:

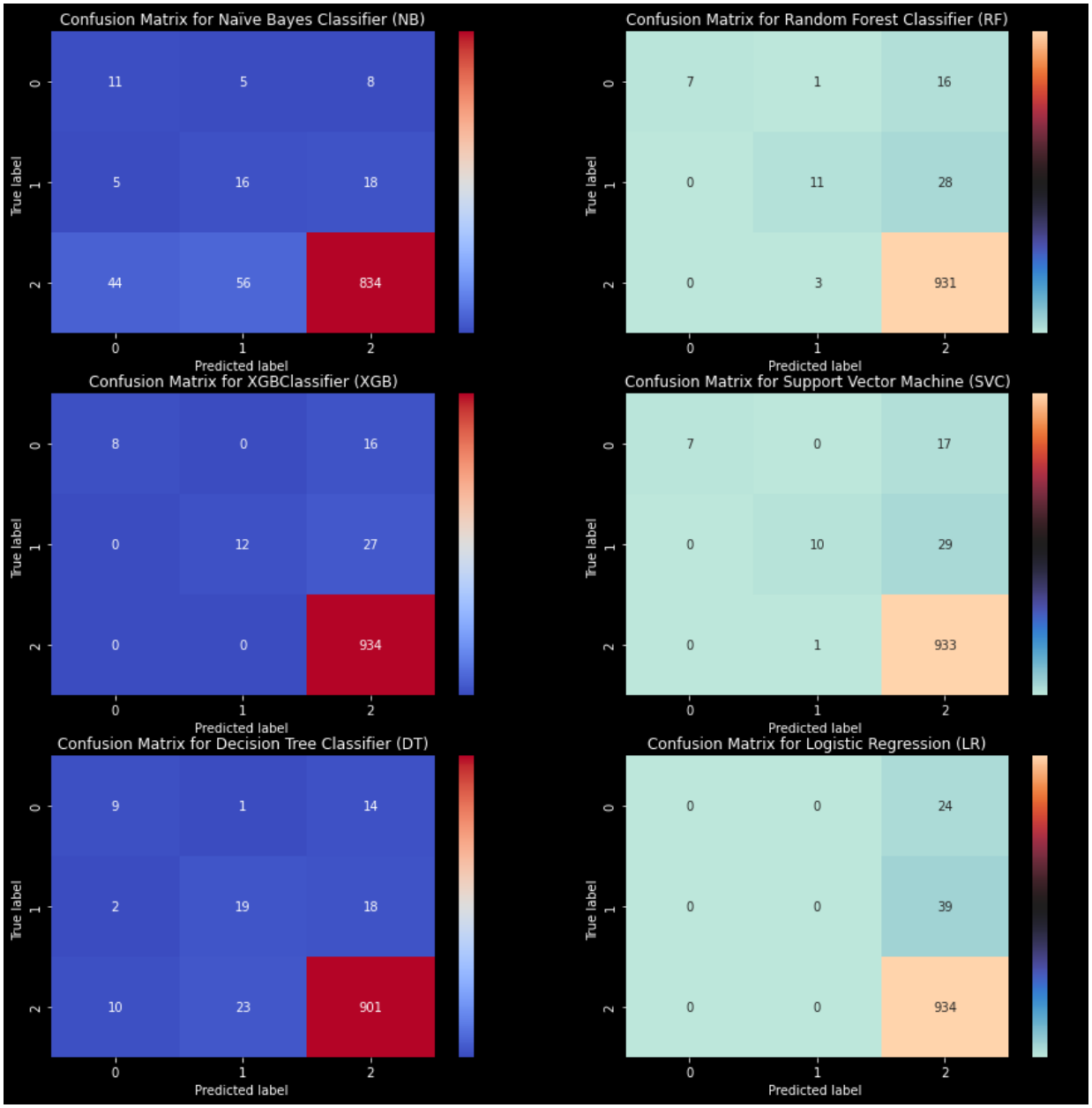
```
def plot_result():
  evaluation_results = pd.DataFrame(np.zeros((6,4)), columns=['Accuracy', 'Mac
  evaluation_results.index=index
  for i in range(len(result)):
    if(len(result) !=5 ):
      evaluation_results.iloc[i]['Accuracy'] = result[i][1]['accuracy']
      evaluation_results.iloc[i]['Macro AVG F1-score'] = result[i][1]['macro a
      evaluation_results.iloc[i]['Macro AVG Precision'] = result[i][1]['macro
      evaluation_results.iloc[i]['Macro AVG Recall'] = result[i][1]['macro avg
    else:
      evaluation_results.iloc[i+1]['Accuracy'] = result[i][1]['accuracy']
      evaluation_results.iloc[i+1]['Macro AVG F1-score'] = result[i][1]['macro
      evaluation_results.iloc[i+1]['Macro AVG Precision'] = result[i][1]['maci
      evaluation_results.iloc[i+1]['Macro AVG Recall'] = result[i][1]['macro a
  with plt.style.context('dark_background'):
    plt.figure(figsize=(13.42,7))
    f = sns.heatmap(evaluation_results, cmap='YlGnBu', annot=True, fmt='.3f')
    f.set_title("Model score" , color = "white")
    plt.xlabel("Score " , color = "white")
    plt.ylabel("Models " , color = "white")

index = ['Naïve Bayes Classifier (NB)','Random Forest Classifier (RF)','XGBCla
         'Support Vector Machine (SVC)','Decision Tree Classifier (DT)','Logis
plot_result()
```

In [ ]:

```
def plot_matrix():
  colors = ['coolwarm', 'icefire']
  size  = len(result)//2
  with plt.style.context('dark_background'):
    fig, axs = plt.subplots(size, 2,figsize=(15,15))
  count = 0
  for i in range(size):
    for j in range(2):
          f = sns.heatmap(result[count][0],cmap= colors[j], annot=True, fmt='
          axs[i][j].set_title('Confusion Matrix for {}'.format(index[count]) 
          axs[i][j].set_xlabel("Predicted label " , color = "white")
          axs[i][j].set_ylabel("True label " , color = "white")
          count+=1
          if(count >len(result)):
            break
  plt.show()
  if(size == 2):
    with plt.style.context('dark_background'):
          plt.figure(figsize=(15/2,15/2))
          f = sns.heatmap(result[4][0],cmap = 'coolwarm', annot=True, fmt='d'
          f.set_title('Confusion Matrix for {}'.format(index[5]) , color = "wh
          plt.xlabel("Predicted label " , color = "white")
          plt.ylabel("True label " , color = "white")
          plt.show()

plot_matrix()
```



- feature eng add sentiment score

In [ ]:

```
analyzer = SentimentIntensityAnalyzer()
df_updated['score']= [analyzer.polarity_scores(text)['compound'] for text in c
df_test_updated['score']= [analyzer.polarity_scores(text)['compound'] for text

X_train = df_updated[['updated_text', 'score']]
y_train = df_updated['sentiment']
X_test = df_test_updated[['updated_text', 'score']]
y_test = df_test_updated['sentiment']
```

In [ ]:
```
text_vect = TfidfVectorizer()
text_vect.fit(X_train['updated_text'])
X_train_transform = text_vect.transform(X_train['updated_text'])
X_test_transform = text_vect.transform(X_test['updated_text'])

X_train_transform_sent_score = hstack([X_train_transform, X_train['score'].va
X_test_transform_sent_score = hstack([X_test_transform, X_test['score'].values
```

In [ ]:
```
result = test(X_train_transform_sent_score,y_train ,X_test_transform_sent_sco
```

```
C:\Users\عبد العزيز\AppData\Roaming\Python\Python37\site-packages\xgboost\sklea
rn.py:1146: UserWarning: The use of label encoder in XGBClassifier is deprecat
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lowing: 1) Pass option use_label_encoder=False when constructing XGBClassifier
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ill-defined and being set to 0.0 in labels with no predicted samples. Use `zer
o_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```
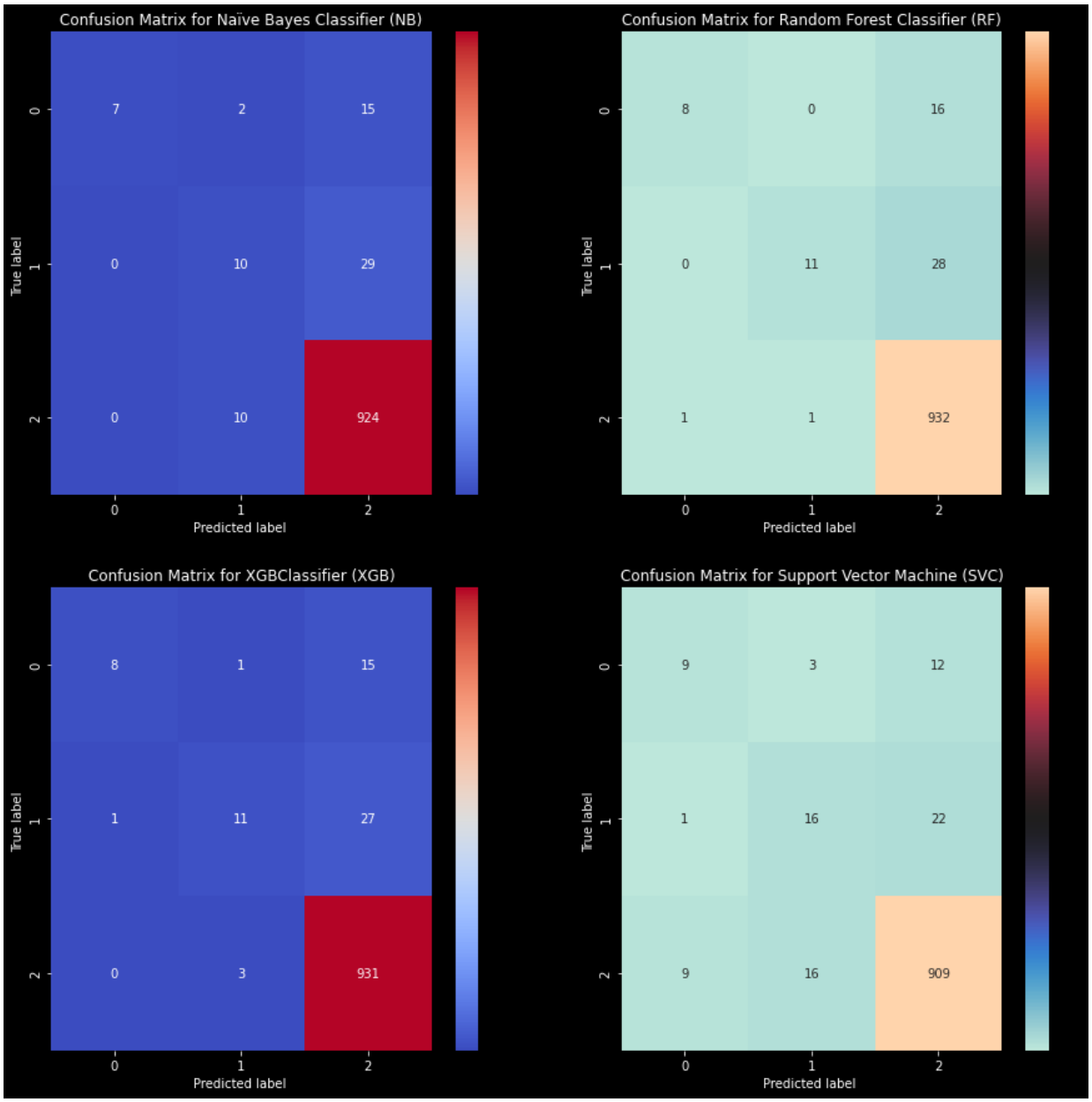

In [ ]:
```
plot_result()
```

In [ ]:
```
plot_matrix()
```



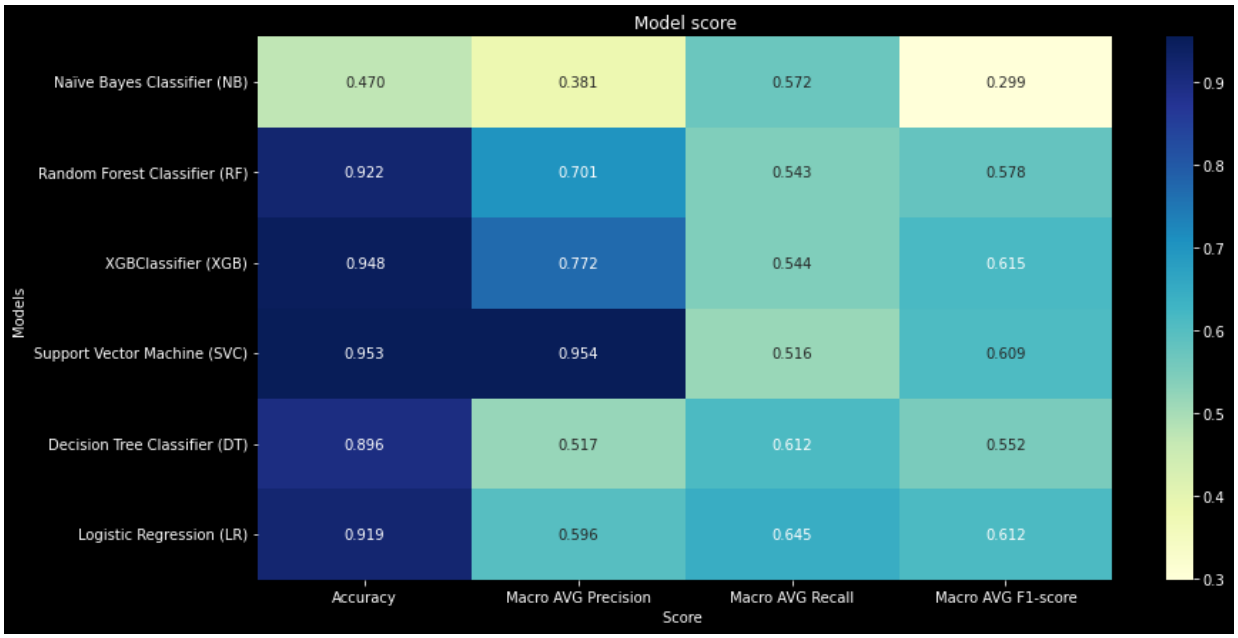
- Apply oversampling

In [ ]:
```
ros = RandomOverSampler(random_state=1)

X_res, y_res = ros.fit_resample(X_train_transform, y_train)
```

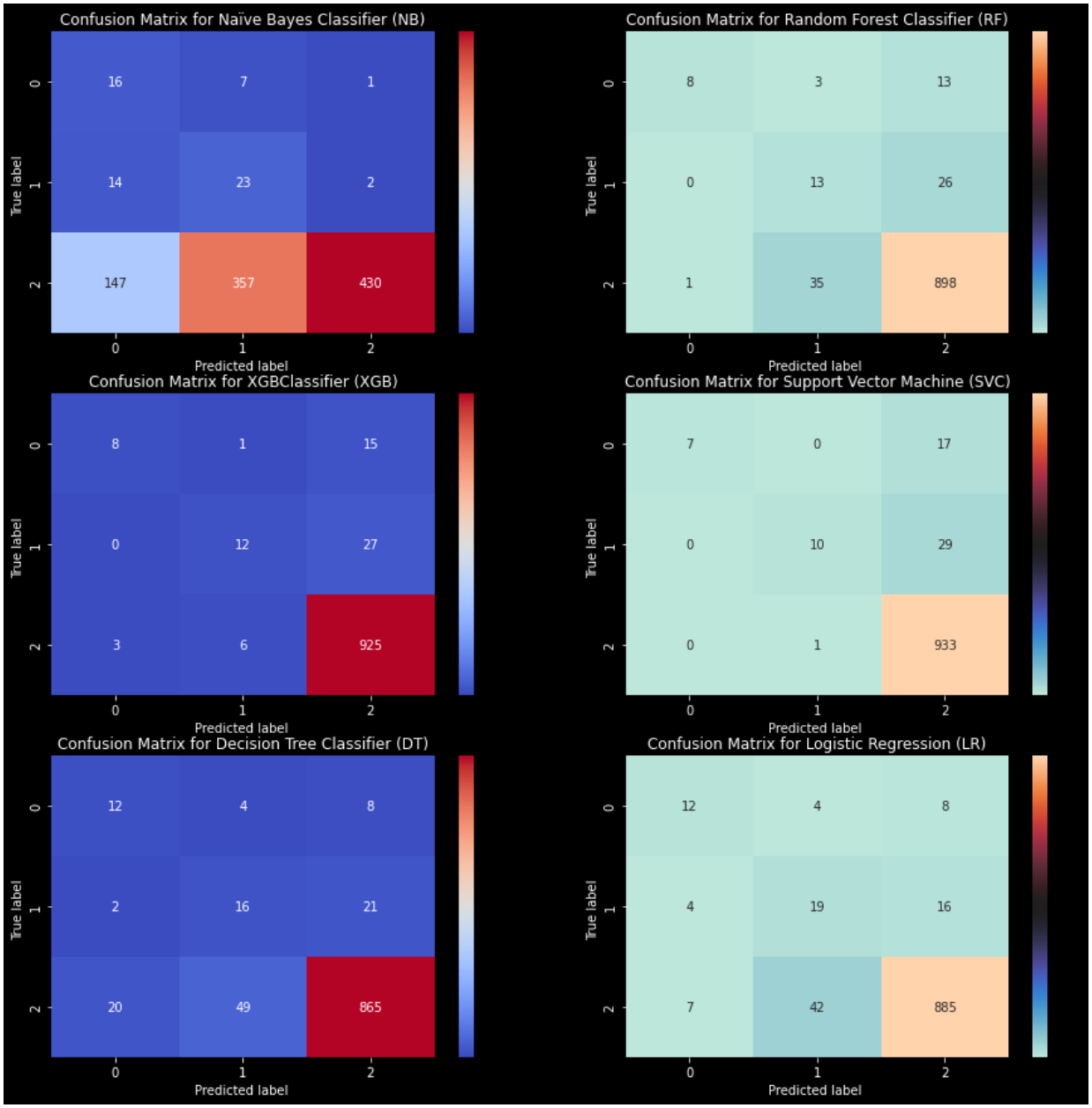
In [ ]:
```
result = test(X_res,y_res,X_test_transform)
```

```
C:\Users\عبد العزيز\AppData\Roaming\Python\Python37\site-packages\xgboost\sklea
rn.py:1146: UserWarning: The use of label encoder in XGBClassifier is deprecat
ed and will be removed in a future release. To remove this warning, do the fol
lowing: 1) Pass option use_label_encoder=False when constructing XGBClassifier
object; and 2) Encode your labels (y) as integers starting with 0, i.e. 0, 1,
2, ..., [num_class - 1].
  warnings.warn(label_encoder_deprecation_msg, UserWarning)
```

In [ ]:
```
plot_result()
```



In [ ]:
```
plot_matrix()
```



In [ ]:
```
text_vect = TfidfVectorizer()
text_vect.fit(X_train['updated_text'])
X_train_transform = text_vect.transform(X_train['updated_text'])
X_test_transform = text_vect.transform(X_test['updated_text'])
```

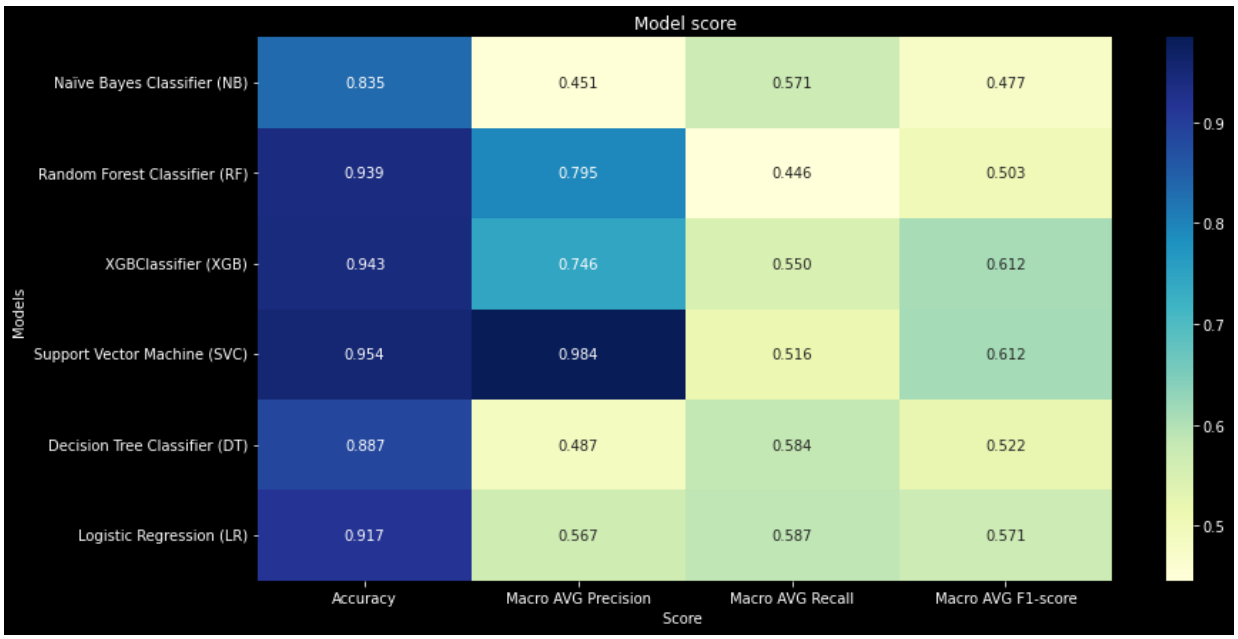
In [ ]:
```
oversample = SMOTE()
X_train_transform_smote, y_train_smote = oversample.fit_resample(X_train_trans

X_train_transform_smote.shape,y_train_smote.shape
```

Out[ ]: ((11082, 4131), (11082,))

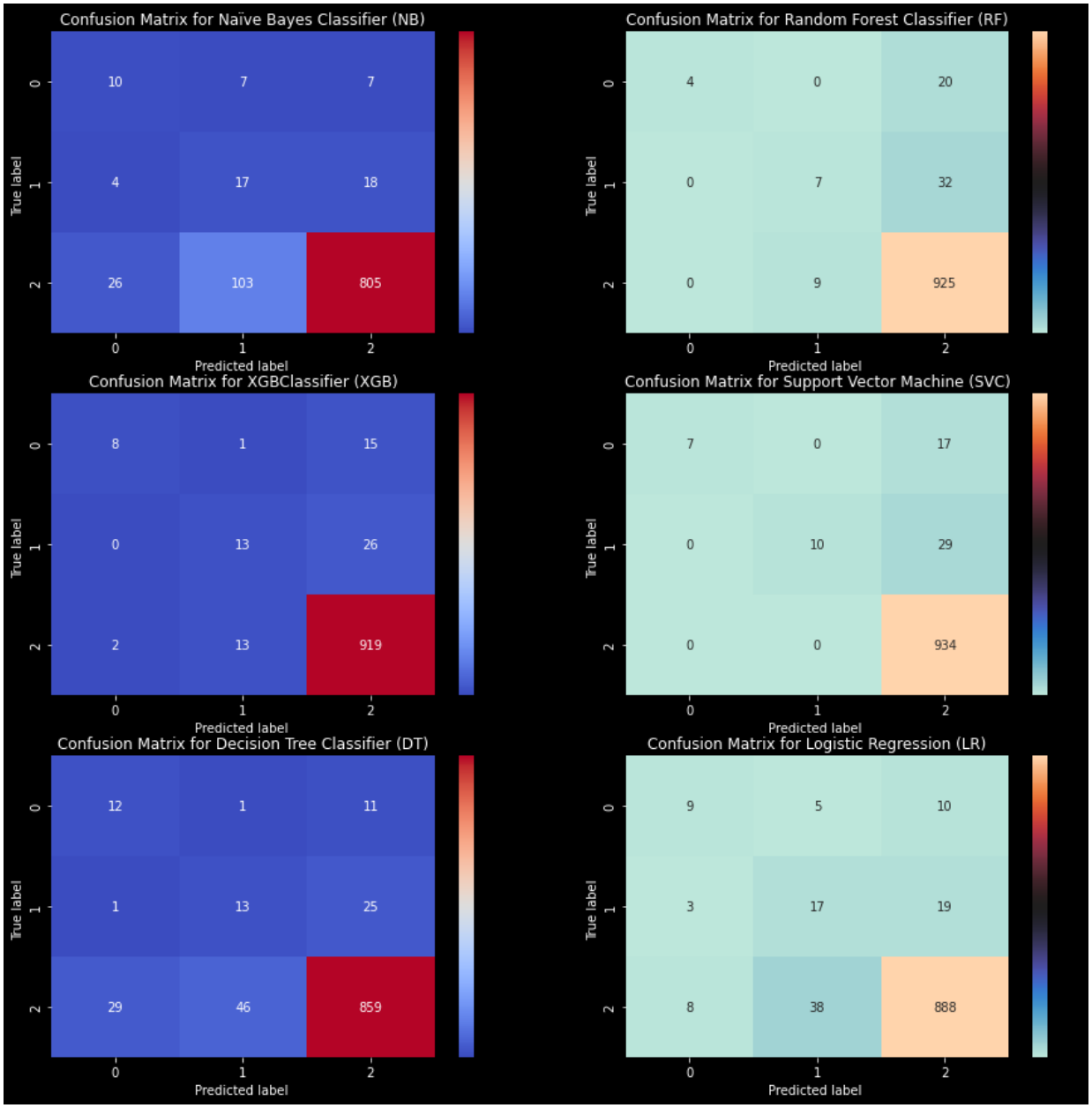
In [ ]:
```
nb_params = {
    'class_prior':[0.09,0.1,0.09]
}

dt_params = {
}

result = test(X_train_transform_smote, y_train_smote, X_test_transform)
```

```
C:\Users\عبد العزيز\AppData\Roaming\Python\Python37\site-packages\xgboost\sklearn.py:1146: UserWarning: The use of label encoder in XGBClassifier is deprecated and will be removed in a future release. To remove this warning, do the following: 1) Pass option use_label_encoder=False when constructing XGBClassifier object; and 2) Encode your labels (y) as integers starting with 0, i.e. 0, 1, 2, ..., [num_class - 1].
  warnings.warn(label_encoder_deprecation_msg, UserWarning)
```

In [ ]:
```
plot_result()
```



In [ ]:
```
plot_matrix()
```



- apply text augmentation

In [ ]:
```
X_train = df_updated[['updated_text']]
y_train = df_updated['sentiment']
X_test = df_test_updated[['updated_text']]
y_test = df_test_updated['sentiment']
```

In [ ]:
```
aug_w2v = naw.ContextualWordEmbsAug(model_path='bert-base-uncased', action="i
```

In [ ]:
```
def augment_text(train,samples=1000,target = 0):
    df_n=train[train['sentiment'] == target].reset_index(drop=True)
    new_text = []
    for i in np.random.randint(0,len(df_n),samples):
        text = df_n.iloc[i]['text']
        augmented_text = aug_w2v.augment(text)
        new_text.append(augmented_text)
    new=pd.DataFrame({'text':new_text,'sentiment':target})
    train = train.append(new).reset_index(drop=True)
    return train
```

In [ ]:
```
df_test = df_updated[['text', 'sentiment']].copy()
df_test.sample()
```

Out[ ]:

	text	sentiment
3932	bought this for my teenage daughter and it wor...	2

In [ ]:
```
df_test = augment_text(df_test,samples=1000 ,target = 1)
df_test = augment_text(df_test,samples=1000 ,target = 0)
```

In [ ]:
```
df_test['aug_text'] = [tweet_tokenizer.tokenize(text) for text in df_test['tex
df_test['aug_text'] = [[lem.lemmatize(word) for word in text ] for text in df_
df_test['aug_text'] = [[word for word in text if word not in stop_words] for t
df_test.sample(10)
```

Out[ ]:

	text	sentiment	aug_text
5418	with this solution does not give great easy an...	0	[solution, doe, give, great, easy, answer, use...
581	i bought a year ago for our oldest kid came ba...	2	[bought, year, ago, oldest, kid, came, back, y...
4627	... i wish it never has included some more of ...	1	[..., wish, never, ha, included, apps, play, s...
1435	kind of hard adding smart items but when you d...	2	[kind, hard, adding, smart, item, nice, talk, ...
3923	the kindle fire is a wonderful small device to...	2	[kindle, fire, wonderful, small, device, use, ...
18	got this model only because of the sale price ...	2	[got, model, sale, price, built, hub, control,...
4739	unfortunately we only bought this because we t...	1	[unfortunately, bought, thought, would, great,...
3905	i have been transforming my house to a smart h...	2	[transforming, house, smart, home, far, thus, ...
2758	i m disappointed sometimes gives doesn t under...	1	[disappointed, sometimes, give, understand]

	text	sentiment	aug_text

In [ ]:
```
df_test['updated_text'] = [' '.join(text) for text in df_test['aug_text']]
df_test.sample(10)
```

Out[ ]:

	text	sentiment	aug_text	updated_text
3824	its pretty good for the price my only concern ...	2	[pretty, good, price, concern, quality, pictur...	pretty good price concern quality picture hd o...
4242	wish it was just easier to also understand set...	1	[wish, wa, easier, also, understand, set, chil...	wish wa easier also understand set child accid...
3421	these kindle fire tablets simply can t be beat...	2	[kindle, fire, tablet, simply, beat, term, val...	kindle fire tablet simply beat term value bang...
3288	my kids like it very much the price is low the...	2	[kid, like, much, price, low, tablet, light, w...	kid like much price low tablet light weighted
125	this item work just as i expected it to great ...	2	[item, work, expected, great, product]	item work expected great product
3580	great tablet so affordable and an awesome service	2	[great, tablet, affordable, awesome, service]	great tablet affordable awesome service
1101	bought this mostly as a backup and to read a f...	0	[bought, mostly, backup, read, book, since, la...	bought mostly backup read book since larger ce...
1861	between this product and siri alexais much mor...	2	[product, siri, alexais, much, useful, reliabl...	product siri alexais much useful reliable cont...
30	we are new to connected home equipment i got t...	2	[new, connected, home, equipment, got, wife, k...	new connected home equipment got wife kitchen ...
485	use it in bathroom to listen to my amazon musi...	2	[use, bathroom, listen, amazon, music, alexa, ...	use bathroom listen amazon music alexa control...

In [ ]:
```
vect_aug = TfidfVectorizer()
vect_aug.fit(df_test['updated_text'])
```

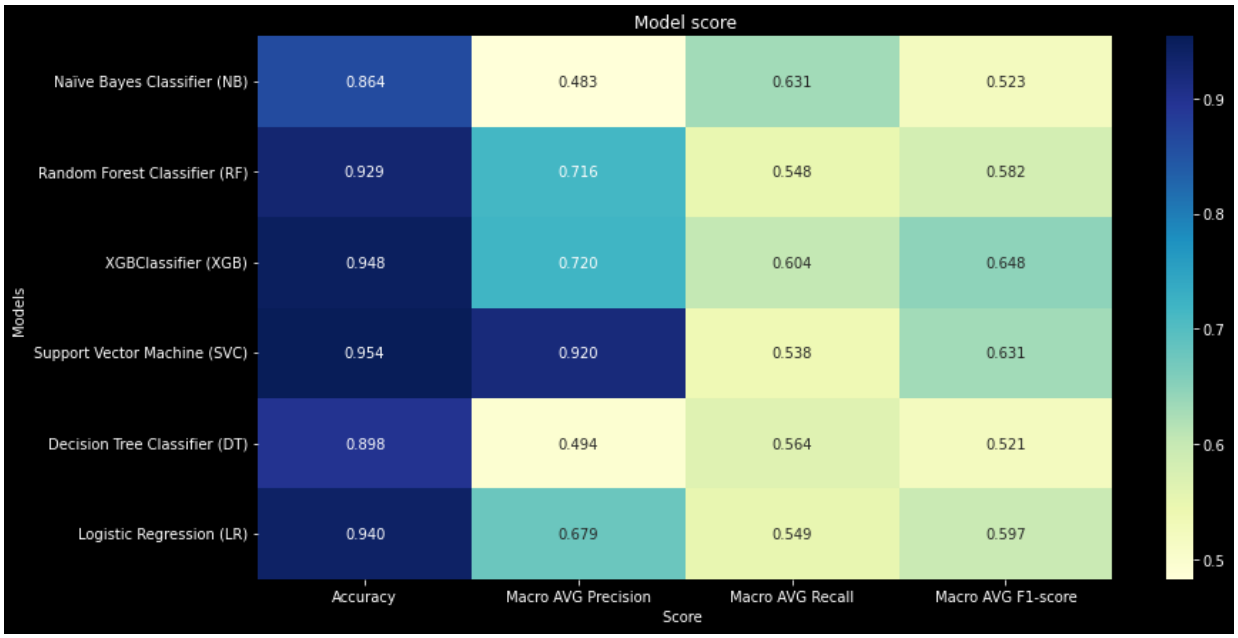
Out[ ]:
```
TfidfVectorizer()
```

In [ ]:
```
X_train_aug = df_test['updated_text']
y_train_aug = df_test['sentiment']
X_train_transform_aug = vect_aug.transform(X_train_aug)
X_test_transform_aug = vect_aug.transform(X_test['updated_text'])
```

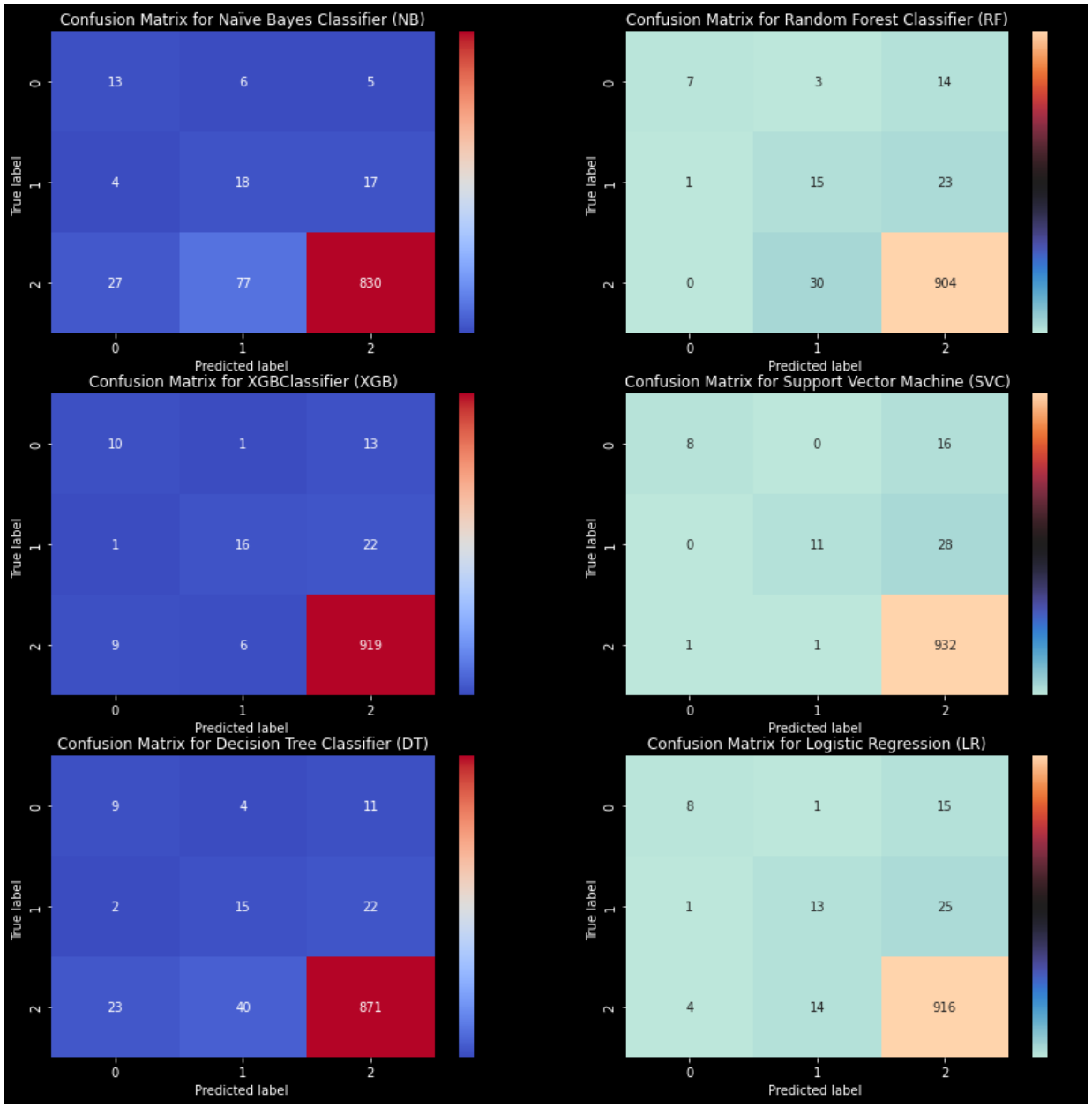
In [ ]:
```
rf_params = {
    'max_depth':20,
     'n_estimators': 500,
     'class_weight': 'balanced'
}

nb_params = {
    'class_prior': [0.3,0.315,0.2]
}


result = test(X_train_transform_aug,y_train_aug ,X_test_transform_aug)
```

```
C:\Users\عبد العزيز\AppData\Roaming\Python\Python37\site-packages\xgboost\sklearn.py:1146: UserWarning: The use of label encoder in XGBClassifier is deprecated and will be removed in a future release. To remove this warning, do the following: 1) Pass option use_label_encoder=False when constructing XGBClassifier object; and 2) Encode your labels (y) as integers starting with 0, i.e. 0, 1, 2, ..., [num_class - 1].
  warnings.warn(label_encoder_deprecation_msg, UserWarning)
```

In [ ]:
```
plot_result()
```



In [ ]:
```
plot_matrix()
```



In [ ]:

```
df_test['score']= [analyzer.polarity_scores(text)['compound'] for text in df_t
X_test['score'] = [analyzer.polarity_scores(text)['compound'] for text in X_te
df_test[df_test['sentiment'] == 0].sample(10)
```

```
C:\Users\عبد العزيز\AppData\Roaming\Python\Python37\site-packages\ipykernel_lau
ncher.py:2: 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/st
able/user_guide/indexing.html#returning-a-view-versus-a-copy
```

Out[ ]:

	text	sentiment	aug_text	updated_text	score
5492	in this area is just a little regular fire tab...	0	[area, little, regular, fire, tablet, ha, prot...	area little regular fire tablet ha protective ...	0.0717

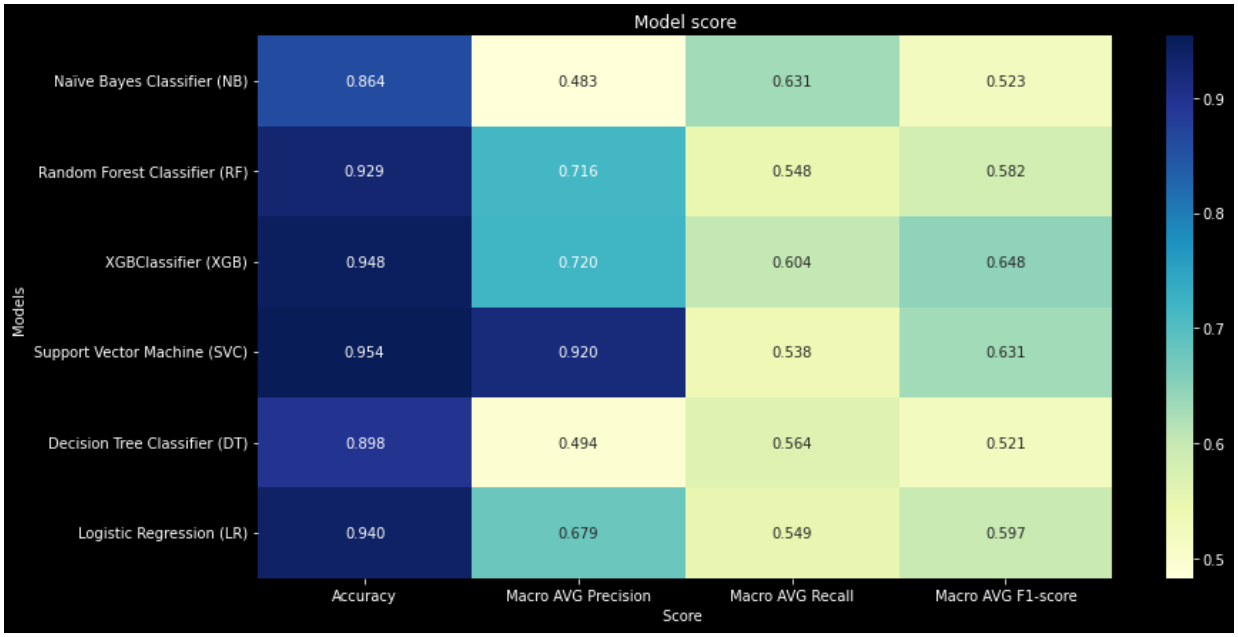
	text	sentiment	aug_text	updated_text	score
5207	perhaps she could really perform some tasks la...	0	[perhaps, could, really, perform, task, later,...	perhaps could really perform task later involv...	0.0000
5561	she could sometimes perform some tasks but the...	0	[could, sometimes, perform, task, thing, know,...	could sometimes perform task thing know agriva...	0.0000
5832	hi i ordered this for my daughter who has an e...	0	[hi, ordered, daughter, ha, extensive, liking,...	hi ordered daughter ha extensive liking tablet...	0.9641
5179	super slow although not of decent beta quality...	0	[super, slow, although, decent, beta, quality,...	super slow although decent beta quality would ...	0.8519
5724	just okay product it was purchased for my form...	0	[okay, product, wa, purchased, former, girlfri...	okay product wa purchased former girlfriend da...	-0.3851
5101	although my late first home tablet was a kindl...	0	[although, late, first, home, tablet, wa, kind...	although late first home tablet wa kindle wa a...	-0.2023
5546	i have to say it never was a little too confus...	0	[say, never, wa, little, confusing, frustratin...	say never wa little confusing frustrating wa g...	0.0586
5278	application purchased on this device already a...	0	[application, purchased, device, already, laun...	application purchased device already launch pa...	-0.3412

In [ ]:
```
X_train_transform_aug_score = hstack([X_train_transform_aug, df_test['score']
X_test_transform_score = hstack([X_test_transform_aug, X_test['score'].values
```

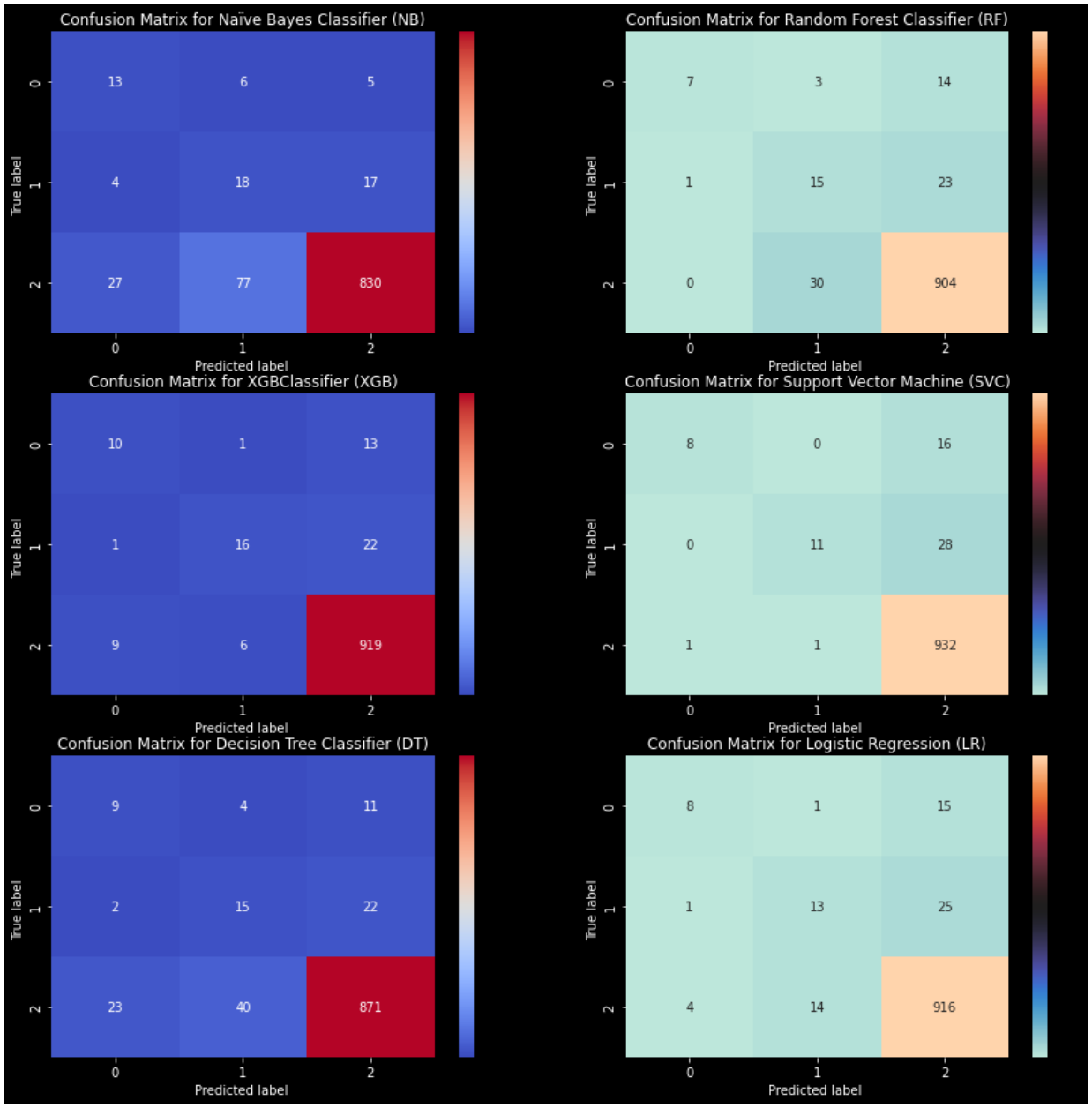
In [ ]:
```
svc_params = {
    'class_weight': 'balanced'
}
dt_params = {
    'class_weight': 'balanced'
}
resutl = test( X_train_transform_aug_score, y_train_aug, X_test_transform_sco
```

```
C:\Users\عبد العزيز\AppData\Roaming\Python\Python37\site-packages\xgboost\sklea
rn.py:1146: UserWarning: The use of label encoder in XGBClassifier is deprecat
ed and will be removed in a future release. To remove this warning, do the fol
lowing: 1) Pass option use_label_encoder=False when constructing XGBClassifier
object; and 2) Encode your labels (y) as integers starting with 0, i.e. 0, 1,
2, ..., [num_class - 1].
  warnings.warn(label_encoder_deprecation_msg, UserWarning)
```

In [ ]:
```
plot_result()
```



In [ ]:
```
plot_matrix()
```



- Apply under sampling after text aug

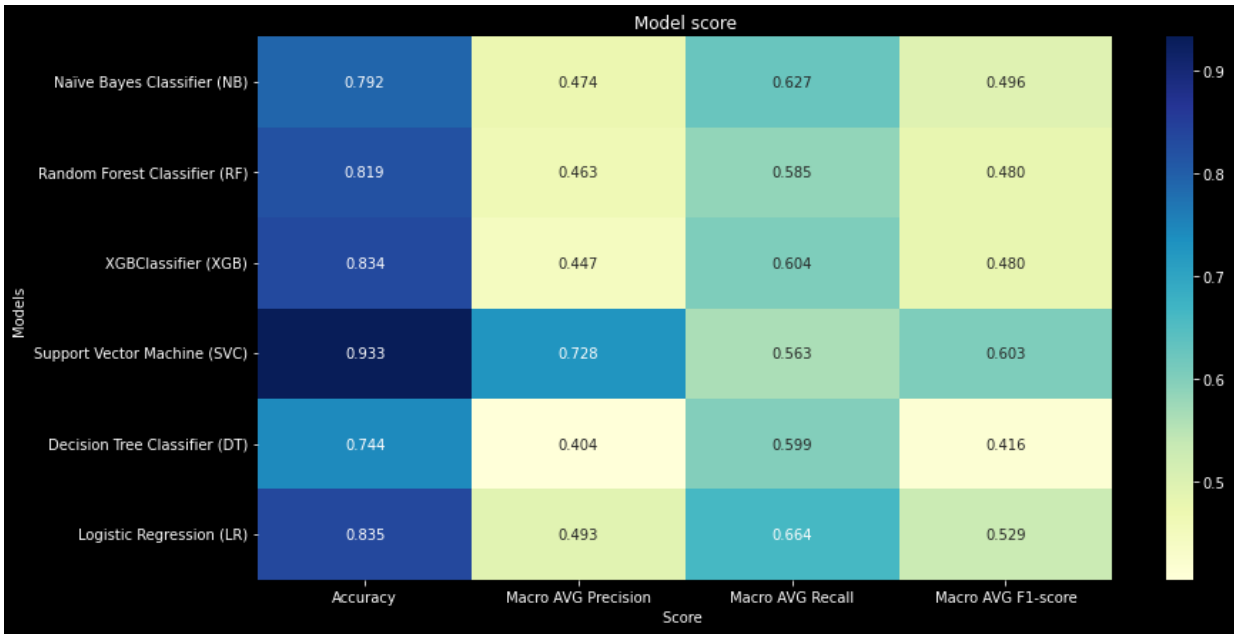
In [ ]:
```
undersample = NearMiss()
X_train_transform_near_miss, y_train_near_miss = undersample.fit_resample(X_t

X_train_transform_near_miss.shape,y_train_near_miss.shape
```

Out[ ]:
```
((3270, 4705), (3270,))
```

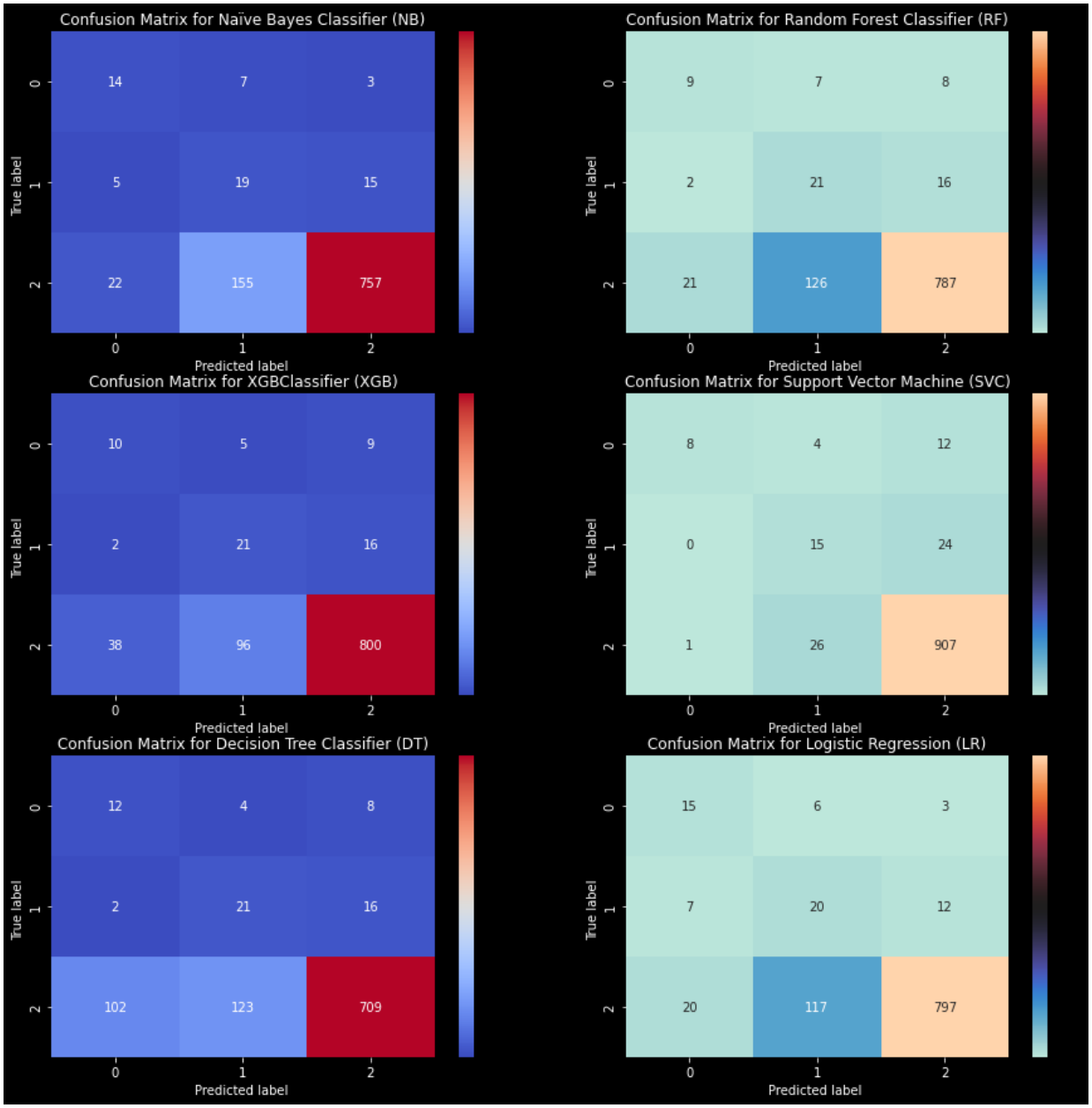
In [ ]:
```
rf_params = {
    'max_depth':20,
     'n_estimators': 500,
     'class_weight': 'balanced'
}

nb_params = {
    'class_prior':[0.09,0.1,0.09]
}

dt_params = {
}

result = test(X_train_transform_near_miss, y_train_near_miss, X_test_transforr
```

```
C:\Users\عبدالعزيز\AppData\Roaming\Python\Python37\site-packages\xgboost\sklea
rn.py:1146: UserWarning: The use of label encoder in XGBClassifier is deprecat
ed and will be removed in a future release. To remove this warning, do the fol
lowing: 1) Pass option use_label_encoder=False when constructing XGBClassifier
object; and 2) Encode your labels (y) as integers starting with 0, i.e. 0, 1,
2, ..., [num_class - 1].
  warnings.warn(label_encoder_deprecation_msg, UserWarning)
```

In [ ]:
```
plot_result()
```



In [ ]:
```
plot_matrix()
```



In [ ]:
```
combinesample = SMOTETomek()
X_train_transform_smote_tomek, y_train_smote_tomek = combinesample.fit_resampl

X_train_transform_smote_tomek.shape,y_train_smote_tomek.shape
```

Out[ ]:
```
((11082, 4705), (11082,))
```

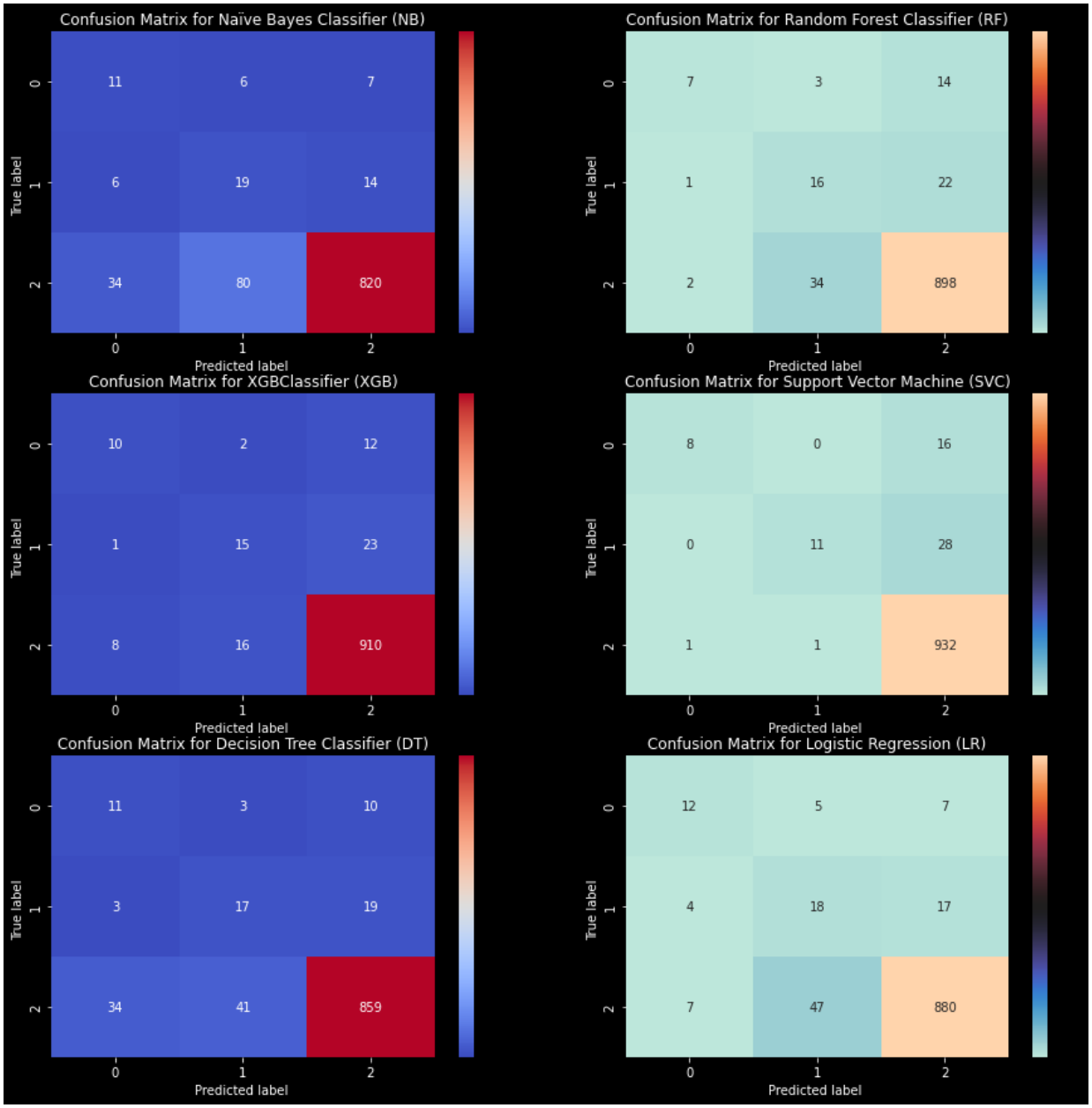
In [ ]:
```
nb_params = {
}

result = test(X_train_transform_smote_tomek, y_train_smote_tomek, X_test_trans
```

```
C:\Users\عبد العزيز\AppData\Roaming\Python\Python37\site-packages\xgboost\sklea
rn.py:1146: UserWarning: The use of label encoder in XGBClassifier is deprecat
ed and will be removed in a future release. To remove this warning, do the fol
lowing: 1) Pass option use_label_encoder=False when constructing XGBClassifier
object; and 2) Encode your labels (y) as integers starting with 0, i.e. 0, 1,
```

```
2, ..., [num_class - 1].
  warnings.warn(label encoder deprecation msg, UserWarning)
```

In [ ]:
```
plot_result()
```

In [ ]:
```
plot_matrix()
```



- LSTM and GRU

In [ ]:
```
y_train = utils.to_categorical(y_train)
y_test = utils.to_categorical(y_test)
y_train.shape
```

Out[ ]:
```
(3942, 3)
```

In [ ]:
```
voc_size=10000
dim = 90
onehot_train=[one_hot(words,voc_size) for words in X_train['updated_text']]
print(onehot_train[:3])

sent_length=df_updated['review_length'].max()
embedded_docs=pad_sequences(onehot_train,padding='pre',maxlen=sent_length)
print(embedded_docs[:3])

onehot_test = [one_hot(words,voc_size) for words in X_test['updated_text']]
embedded_docs_test =pad_sequences(onehot_test,padding='pre',maxlen=sent_lengt
print(embedded_docs[:3])
```

```
[[7513, 7547, 7408, 1771, 8486, 5752, 8532, 5398, 1136, 7241, 3058, 1886, 707
1, 2905, 9935, 6282, 2800, 6282, 2322, 3097, 7418, 7059, 5833, 3793, 6251, 330
5, 4733, 7198, 7557, 6282, 3737, 571, 3801, 541, 5833, 332, 2577, 2761, 1771,
7418, 404], [7513, 9769, 6282, 2429, 4729, 9769, 2067, 4729, 634, 7631, 1934,
2128, 8417, 706, 5390, 1490, 1775, 4126, 8213, 6665, 3981, 6515, 9655, 4775, 3
280, 6515, 7238, 2177, 1400, 7584, 2073, 2868, 1018, 1756, 43, 3890, 9655, 516
5, 1177, 9399, 1958, 6515, 5900, 8944, 3116, 4599, 7126, 8944, 1466, 3116, 161
4, 9406, 8413, 6515, 5165, 2314, 6560, 5936, 388, 3737, 1098], [6607, 6515, 92
87, 131, 330, 3188, 4667, 5630, 8189]]
[[   0    0    0 ... 1771 7418  404]
 [   0    0    0 ...  388 3737 1098]
 [   0    0    0 ... 4667 5630 8189]]
[[   0    0    0 ... 1771 7418  404]
 [   0    0    0 ...  388 3737 1098]
 [   0    0    0 ... 4667 5630 8189]]
```

In [ ]:
```
def lstm_test():
  model = Sequential()
  model.add(Embedding(voc_size, dim, input_length= sent_length))
  model.add(LSTM(150))
  model.add(Dense(64,activation='relu'))
  model.add(Dense(3,activation='softmax'))
  model.compile(loss='categorical_crossentropy',optimizer='adam',metrics=['ac
  model.summary()
  return model
```

In [ ]:
```
model = lstm_test()
X_train_final = np.array(embedded_docs)
X_test_final = np.array(embedded_docs_test)
history = model.fit(X_train_final, y_train, validation_data = (X_test_final, y
```

```
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
embedding_1 (Embedding)      (None, 4758, 90)          900000
_________________________________________________________________
lstm_1 (LSTM)                (None, 150)               144600
_________________________________________________________________
dense_2 (Dense)              (None, 64)                9664
_________________________________________________________________
dense_3 (Dense)              (None, 3)                 195
```

```
=================================================================
Total params: 1,054,459
Trainable params: 1,054,459
Non-trainable params: 0
_________________________________________________________________
Epoch 1/3
62/62 [==============================] - 43s 542ms/step - loss: 0.3607 - accur
acy: 0.9267 - val_loss: 0.2753 - val_accuracy: 0.9368
Epoch 2/3
62/62 [==============================] - 33s 533ms/step - loss: 0.2612 - accur
acy: 0.9371 - val_loss: 0.2452 - val_accuracy: 0.9378
Epoch 3/3
62/62 [==============================] - 34s 543ms/step - loss: 0.1658 - accur
```

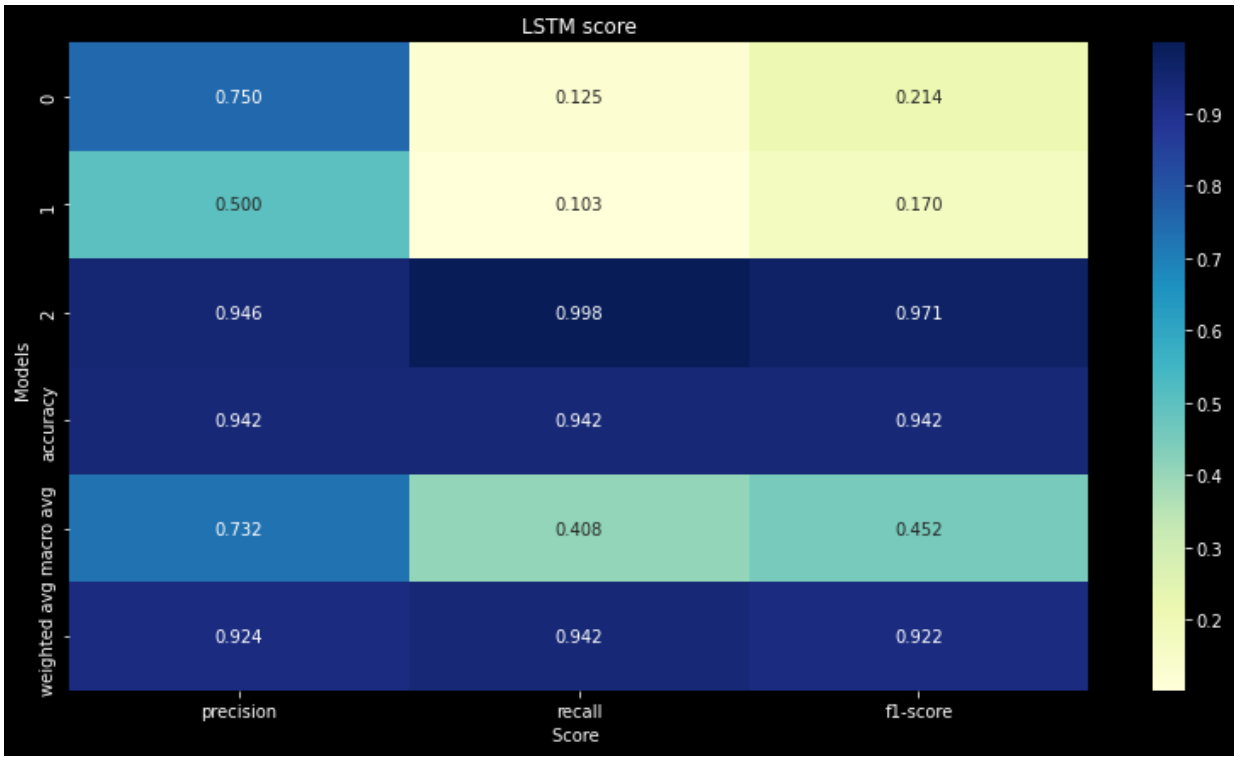
In [ ]:

```
def model_matrix():
    with plt.style.context('dark_background'):
        cm = confusion_matrix(y_test_result, y_pred)
        f = sns.heatmap(cm, annot=True, fmt='d')
        f.set_title("confusion_matrix" , color = "white")
        plt.xlabel("Predicted label " , color = "white")
        plt.ylabel("True label " , color = "white")
        plt.show()

def model_class_report(name):
    target_names = [str(i) for i in range(0,3)]
    class_report = pd.DataFrame(classification_report(y_test_result, y_pred, t
    with plt.style.context('dark_background'):
      plt.figure(figsize=(13.42,7))
      f = sns.heatmap(class_report.iloc[:-1, :].T, cmap='YlGnBu', annot=True,
      f.set_title('{} score'.format(name) , color = "white")
      plt.xlabel("Score " , color = "white")
      plt.ylabel("Models " , color = "white")

def model_accuracy_report():
    with plt.style.context('dark_background'):
        plt.plot(history.history['accuracy'])
        plt.plot(history.history['val_accuracy'])
        plt.title('model accuracy')
        plt.ylabel('accuracy')
        plt.xlabel('epoch')
        plt.legend(['train', 'test'], loc='upper left')
        plt.show()
def model_loss_report():
    with plt.style.context('dark_background'):
      plt.plot(history.history['loss'])
      plt.plot(history.history['val_loss'])
      plt.title('model loss')
      plt.ylabel('loss')
      plt.xlabel('epoch')
      plt.legend(['train', 'test'], loc='upper left')
      plt.show()
```

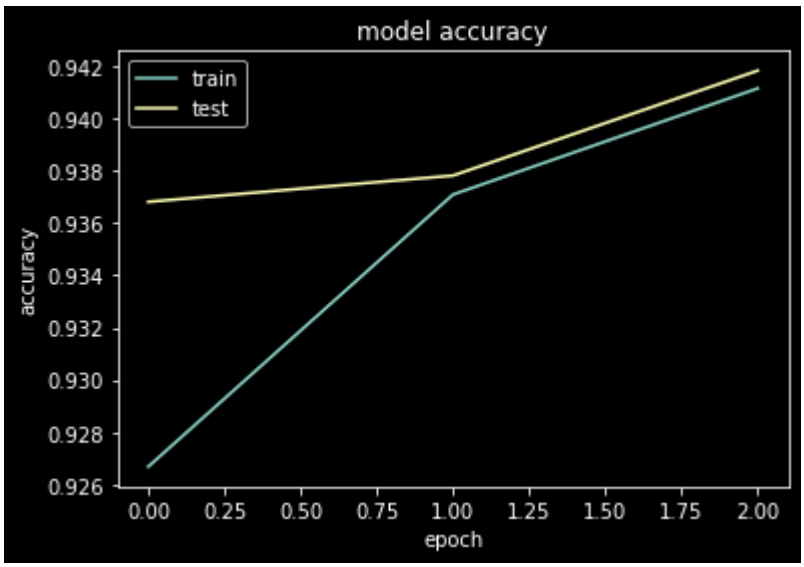
In [ ]:

```
Y_pred = model.predict(X_test_final)
y_pred = np.argmax(Y_pred, axis=1)
y_test_result = np.argmax(y_test, axis=1)
```

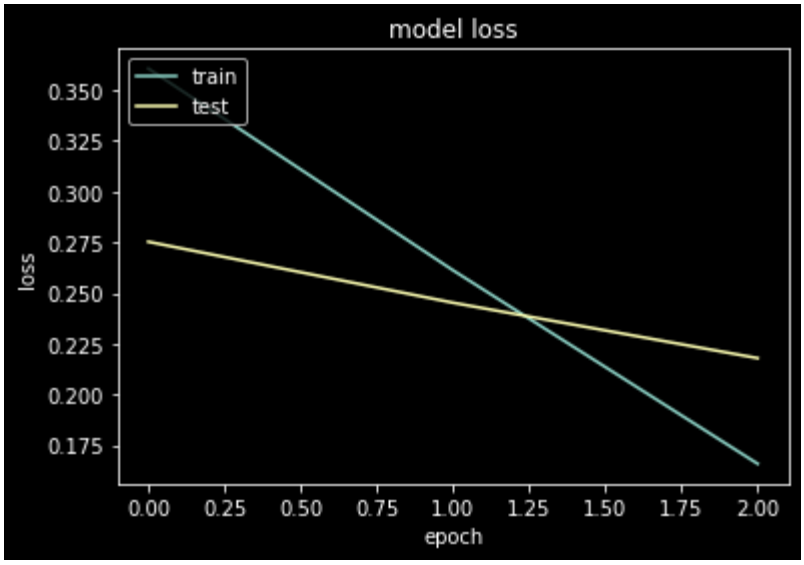
In [ ]:
```
model_class_report('LSTM')
```



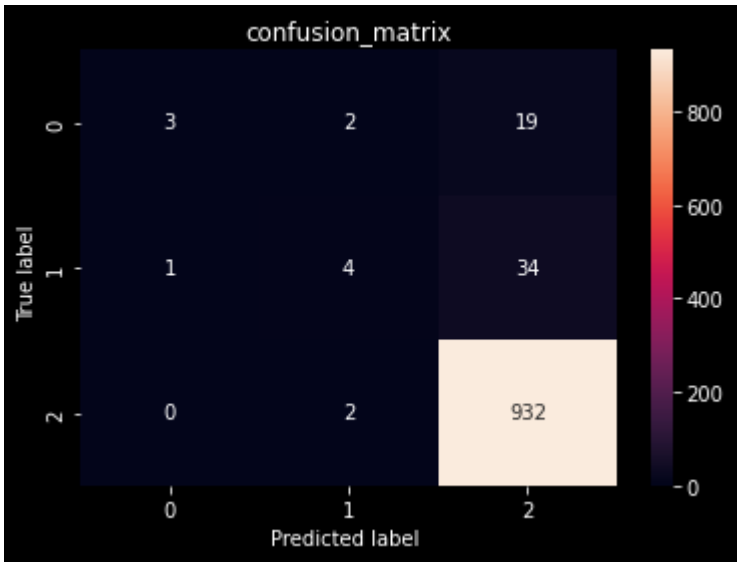
In [ ]:
```
model_accuracy_report()
```



In [ ]:
```
model_loss_report()
```



In [ ]:
```
model_matrix()
```



In [ ]:
```
def GRU_test():
  model = Sequential()
  model.add(Embedding(voc_size, dim, input_length= sent_length))
  model.add(GRU(150))
  model.add(Dense(64,activation='relu'))
  model.add(Dense(3,activation='softmax'))
  model.compile(loss='categorical_crossentropy',optimizer='adam',metrics=['ac
  model.summary()
  return model
```

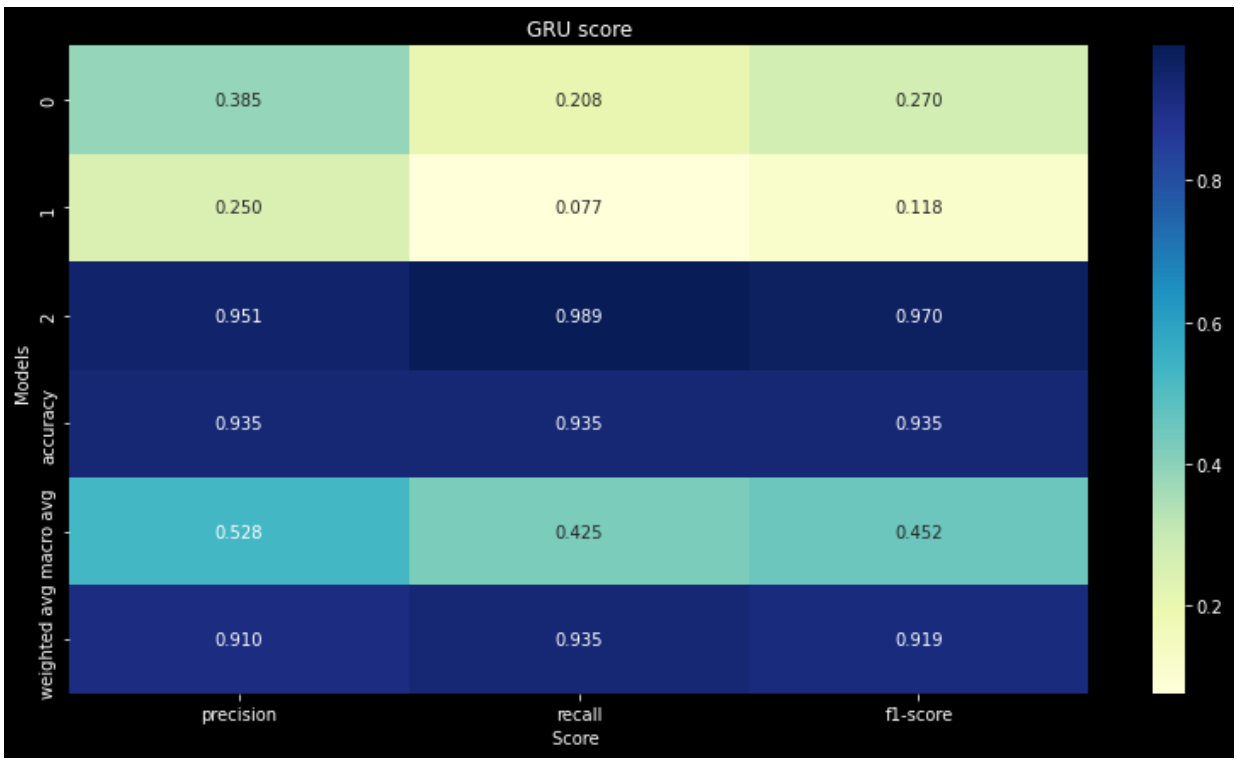
In [ ]:
```
model = GRU_test()
history = model.fit(X_train_final, y_train, validation_data = (X_test_final, y
```

```
Model: "sequential_2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
```

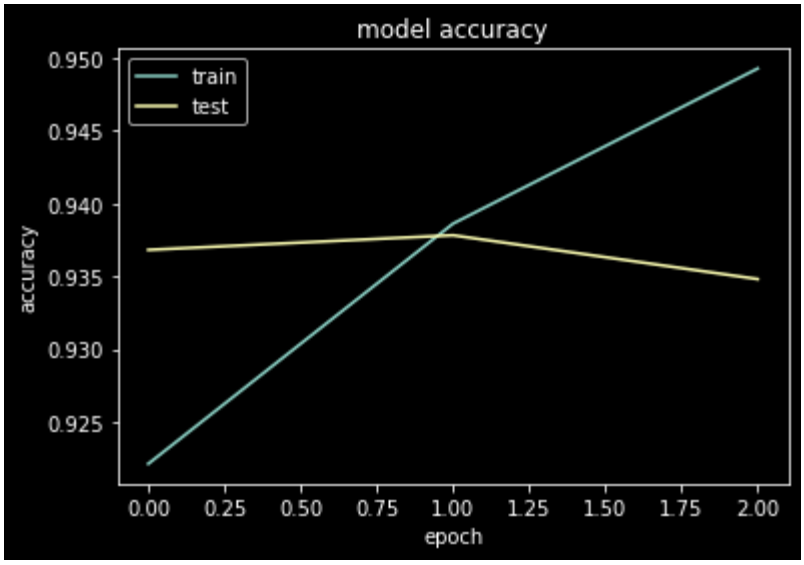
```
embedding_2 (Embedding)      (None, 4758, 90)          900000
_________________________________________________________________
gru (GRU)                    (None, 150)               108900
_________________________________________________________________
dense_4 (Dense)              (None, 64)                9664
_________________________________________________________________
dense_5 (Dense)              (None, 3)                 195
=================================================================
Total params: 1,018,759
Trainable params: 1,018,759
Non-trainable params: 0
_________________________________________________________________
Epoch 1/3
62/62 [==============================] - 37s 581ms/step - loss: 0.3902 - accur
acy: 0.9221 - val_loss: 0.2447 - val_accuracy: 0.9368
Epoch 2/3
62/62 [==============================] - 36s 580ms/step - loss: 0.1984 - accur
acy: 0.9386 - val_loss: 0.2312 - val_accuracy: 0.9378
Epoch 3/3
62/62 [==============================] - 37s 599ms/step - loss: 0.1328 - accur
```

In [ ]:
```
Y_pred = model.predict(X_test_final)
y_pred = np.argmax(Y_pred, axis=1)
y_test_result = np.argmax(y_test, axis=1)
```

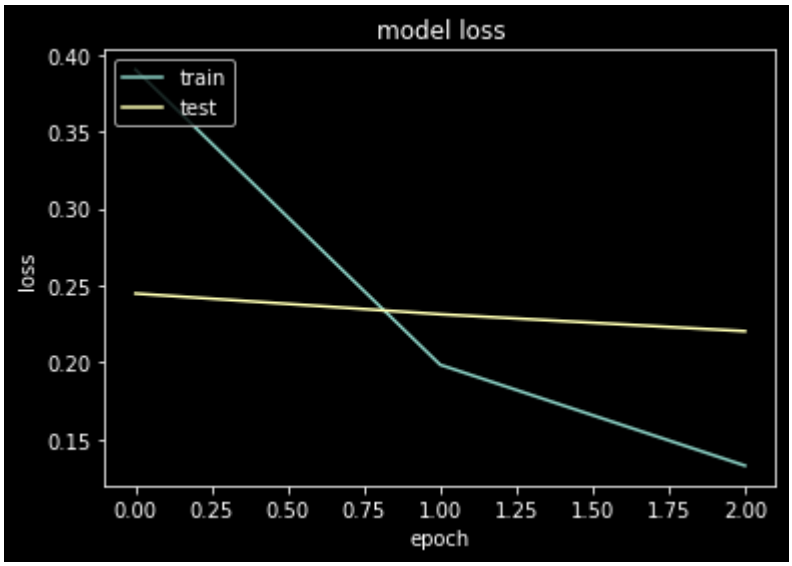
In [ ]:
```
model_class_report('GRU')
```



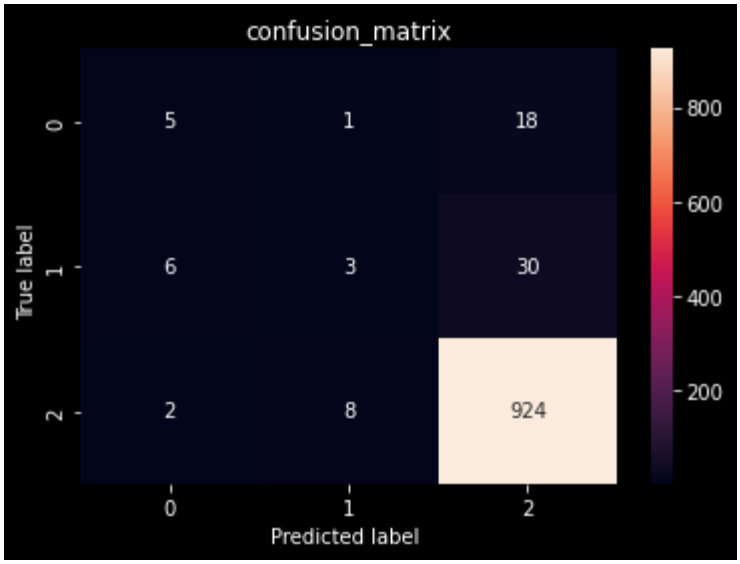
In [ ]:
```
model_accuracy_report()
```



In [ ]:
```
model_loss_report()
```



In [ ]:
```
model_matrix()
```



In [ ]:
```
y_train_aug = utils.to_categorical(y_train_aug)
y_train.shape
```

Out[ ]:
```
(3942, 3)
```

In [ ]:
```
onehot_train=[one_hot(words,voc_size) for words in X_train_aug]

sent_length=df_updated['review_length'].max()
embedded_docs=pad_sequences(onehot_train,padding='pre',maxlen=sent_length)

onehot_test = [one_hot(words,voc_size) for words in X_test['updated_text']]
embedded_docs_test =pad_sequences(onehot_test,padding='pre',maxlen=sent_lengt
```

In [ ]:
```
X_train_final = np.array(embedded_docs)
X_test_final = np.array(embedded_docs_test)
```

In [ ]:
```
model = lstm_test()
```

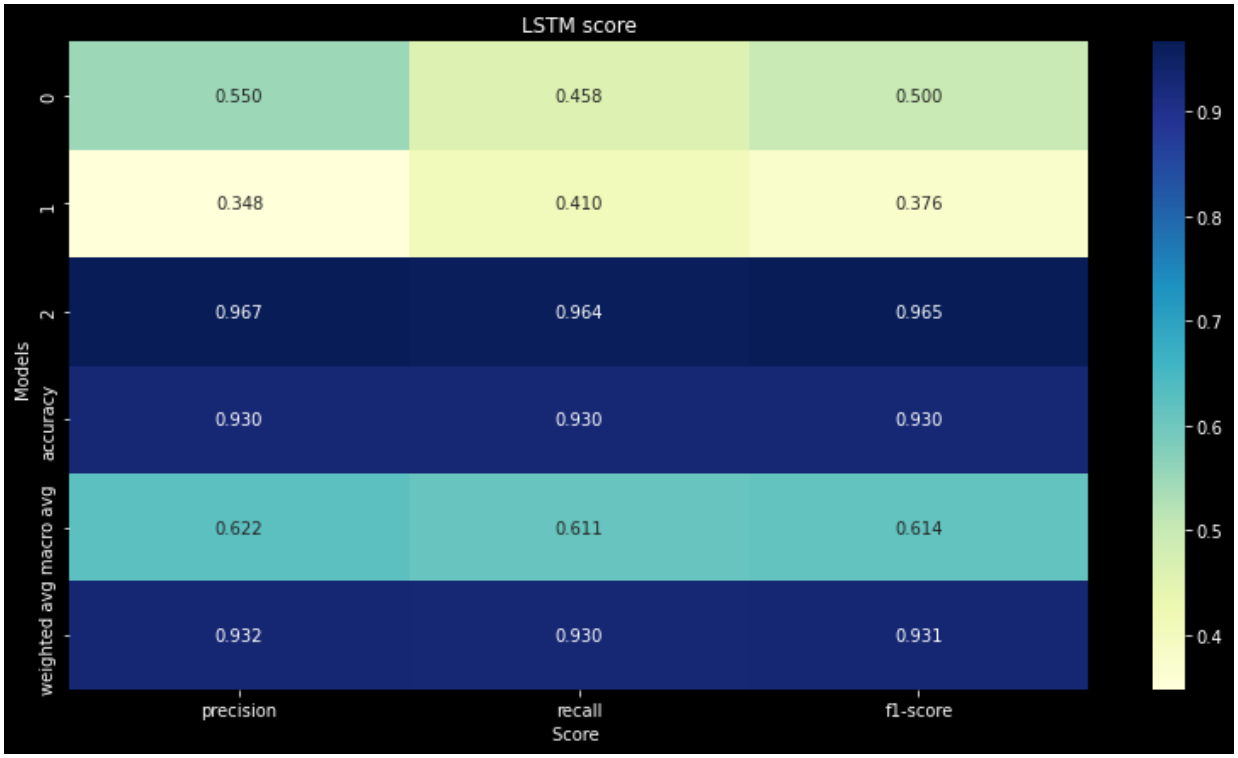
```
Model: "sequential_3"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
embedding_3 (Embedding)      (None, 4758, 90)          900000
_________________________________________________________________
lstm_2 (LSTM)                (None, 150)               144600
_________________________________________________________________
dense_6 (Dense)              (None, 64)                9664
_________________________________________________________________
dense_7 (Dense)              (None, 3)                 195
=================================================================
Total params: 1,054,459
Trainable params: 1,054,459
Non-trainable params: 0
_________________________________________________________________
```

In [ ]:
```
history = model.fit(X_train_final, y_train_aug, validation_data = (X_test_fina
```

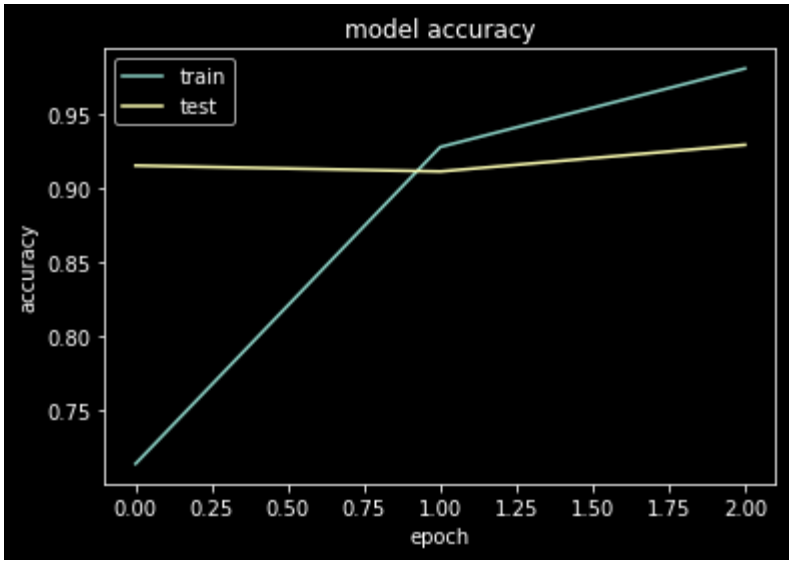
```
Epoch 1/3
93/93 [==============================] - 51s 523ms/step - loss: 0.6662 - accur
acy: 0.7137 - val_loss: 0.2445 - val_accuracy: 0.9157
Epoch 2/3
93/93 [==============================] - 50s 541ms/step - loss: 0.1964 - accur
acy: 0.9283 - val_loss: 0.2827 - val_accuracy: 0.9117
Epoch 3/3
93/93 [==============================] - 53s 571ms/step - loss: 0.0604 - accur
acy: 0.9815 - val_loss: 0.2767 - val_accuracy: 0.9298
```

In [ ]:
```
Y_pred = model.predict(X_test_final)
y_pred = np.argmax(Y_pred, axis=1)
y_test_result = np.argmax(y_test, axis=1)
```

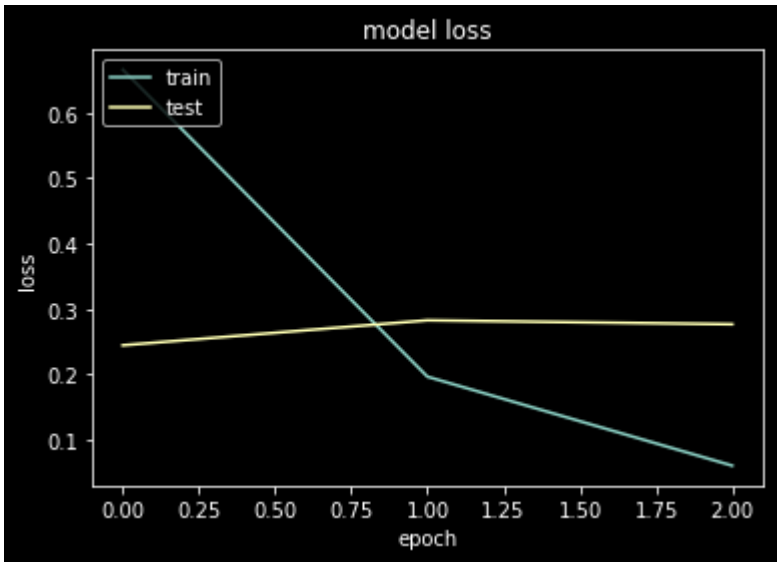
In [ ]:
```
model_class_report('LSTM')
```



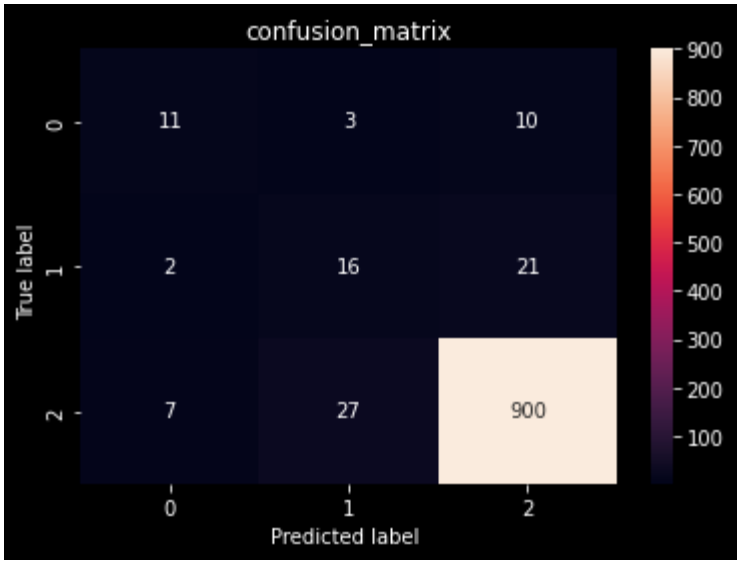
In [ ]:
```
model_accuracy_report()
```



In [ ]:
```
model_loss_report()
```



In [ ]:
```
model_matrix()
```

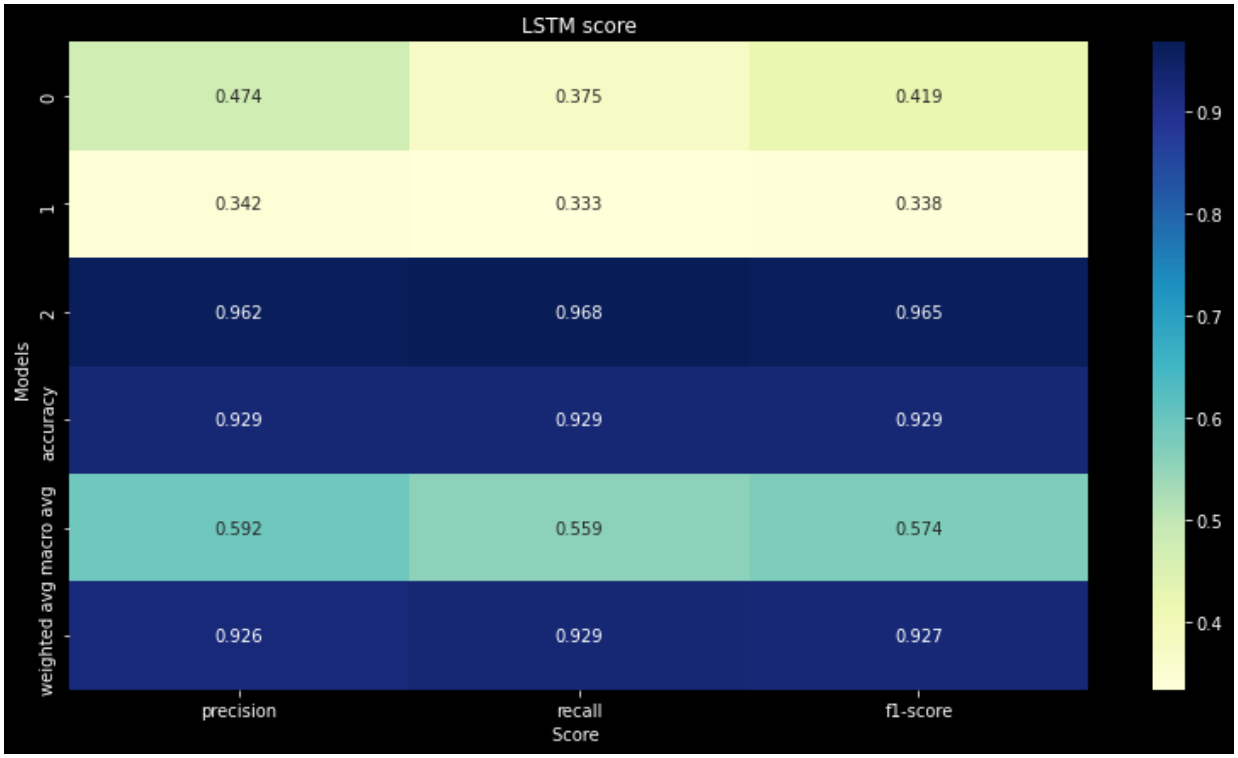


In [ ]:
```
model = GRU_test()
history = model.fit(X_train_final, y_train_aug, validation_data = (X_test_fina
```

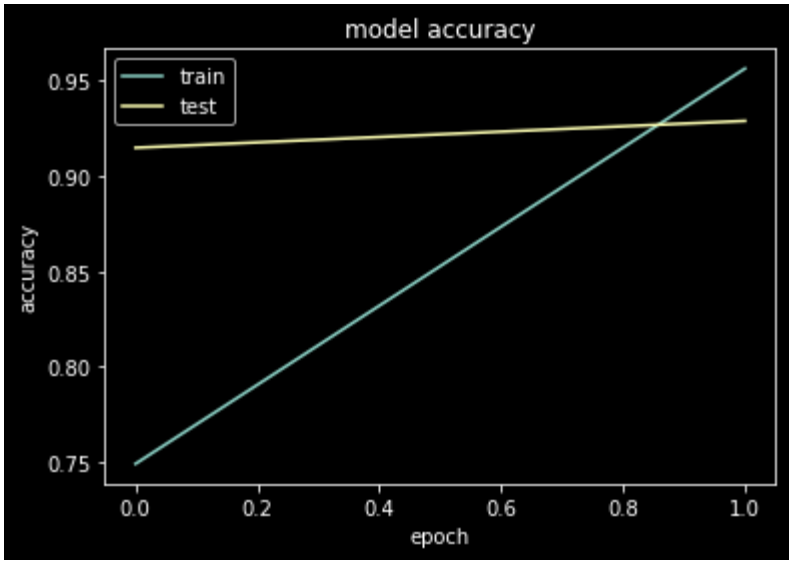
```
Model: "sequential_4"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
embedding_4 (Embedding)      (None, 4758, 90)          900000
_________________________________________________________________
gru_1 (GRU)                  (None, 150)               108900
_________________________________________________________________
dense_8 (Dense)              (None, 64)                9664
_________________________________________________________________
dense_9 (Dense)              (None, 3)                 195
=================================================================
Total params: 1,018,759
Trainable params: 1,018,759
Non-trainable params: 0
_________________________________________________________________
Epoch 1/2
93/93 [==============================] - 57s 599ms/step - loss: 0.6039 - accur
acy: 0.7492 - val_loss: 0.2358 - val_accuracy: 0.9147
Epoch 2/2
93/93 [==============================] - 59s 634ms/step - loss: 0.1197 - accur
acy: 0.9562 - val_loss: 0.2847 - val_accuracy: 0.9288
```

In [ ]:
```
Y_pred = model.predict(X_test_final)
y_pred = np.argmax(Y_pred, axis=1)
y_test_result = np.argmax(y_test, axis=1)
```

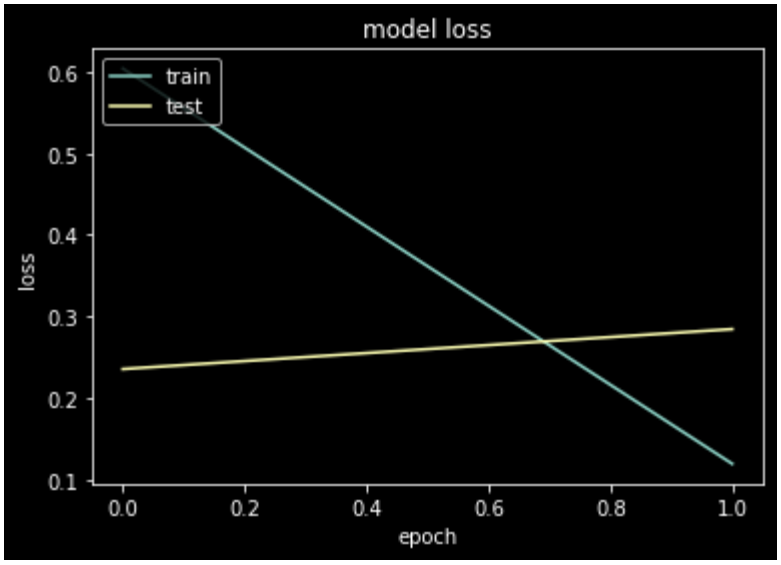
In [ ]:
```
model_class_report('LSTM')
```



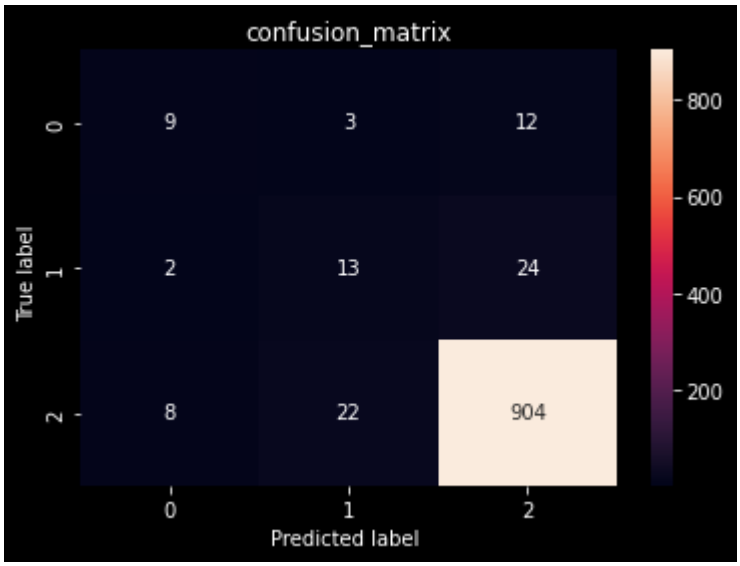
In [ ]:
```
model_accuracy_report()
```



In [ ]:
```
model_loss_report()
```



In [ ]:
```
model_matrix()
```



- Topic Modeling

In [ ]:
```
review_df1 = pd.read_csv('train_data.csv')
review_df2 =  pd.read_csv('test_data.csv')
review_df3 =  pd.read_csv('test_data_hidden.csv')
merge = pd.concat([review_df1,review_df2,review_df3])
reviews_df = merge[['reviews.text']].copy()
reviews_df.sample(10)
```

Out[ ]:

	reviews.text
3010	This tablet was an upgrade from the Nabi Jr fo...
2187	We bought one for my wife and my mother-in-law...
946	I purchased two of these for my kids, ages 12 ...
756	For the price, you should be able to use as a ...

	reviews.text
2519	Great tablet for the price. Add to that expand...
333	This tablet is so great for school children to...
3240	I purchased the Amazon - Fire Kids Edition - 7...
1691	Purchased this for 6 year old boy and couldn't...
700	I like this smart machine and will recommend t...

In [ ]:
```
reviews_df['review_length'] = [len(review) for review in reviews_df['reviews.t
reviews_df.sample(10)
```

Out[ ]:

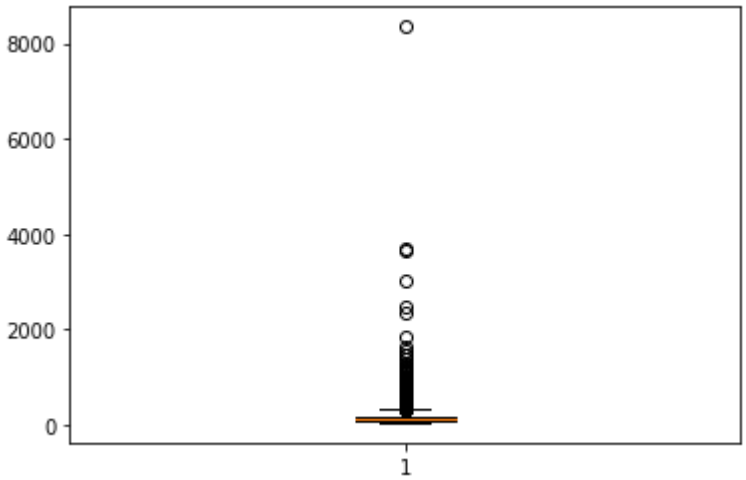
	reviews.text	review_length
636	Grandson is enjoying the new games on it. It's...	73
660	My granddaughter loves this system. It is easy...	98
3301	Does what it is advertise for and more. Had fu...	119
2705	This is great. The entire family is using it. ...	159
1155	I purchased this for my husbandHe had been wai...	107
1128	This little sorcerer's box displays magical pi...	78
901	Got this tablet for my mother and liked it so ...	122
1349	Never owned a tablet before, but am loving it ...	53
2030	Not only does it round out my collection of Al...	193
3568	I have grown very accustomed to having Alexa a...	681

In [ ]:
```
reviews_df[reviews_df.duplicated()].count()
reviews_df.drop_duplicates(inplace = True)
reviews_df.sample(10)
```

Out[ ]:

	reviews.text	review_length
3342	I've wanted a kindle for a while and decided t...	101
2055	Bought it for my wife she loves it and I would...	70
2611	This product was easy to set up and to use. Wo...	97
2651	Great price - great shipping - great item! Per...	88
240	When I tried to hook it up it wouldn't recogni...	172
2183	Easy and age appropriate. Can set timers for t...	137
880	Love this tablet. It does everything I need it...	280
1167	Really affordable present for a kid.. Or just ...	57
734	This was the first tablet we purchased for our...	64

In [ ]:
```
plt.boxplot(reviews_df.review_length)
plt.show()
```



In [ ]:
```
reviews_df.columns= ['review' , 'review_length']
reviews_df.sample(10)
```

Out[ ]:

	review	review_length
408	The touch screen adds a new dimension to the E...	238
1203	I like the unit but battery seems to run down ...	112
788	MY DAUTHER LOVES THIS TABLET, IS EXCELLENT FOR...	69
2812	I bought two of these for Christmas for my 3 a...	543
1984	Love this product easy to use and it does so m...	52
398	Very sturdy for little people who might drop i...	60
828	The show is our new best friend. We watch show...	136
1591	Worked as advertised - easy to set up and link...	59
3940	It has been a lot of fun using in our kitchen....	100
2523	This is a perfect upgrade to my kitchen Amazon...	771

In [ ]:
```
reviews_df.review = reviews_df.review.apply(str.lower)
reviews_df.review = reviews_df.review.str.replace(r'[^a-zA-Z\s]', ' ',regex=T
reviews_df.review = reviews_df.review.str.replace(r'\s{2,}', ' ',regex=True)
```

In [ ]:
```
reviews= reviews_df.review.to_list()
reviews[0],len(reviews)
```

Out[ ]:
```
('purchased on black fridaypros great price even off sale very powerful and fa
st with quad core processors amazing soundwell builtcons amazon ads amazon nee
d this to subsidize the tablet and will remove the adds if you pay them inabil
ity to access other apps except the ones from amazon there is a way which i wa
```

```
s able to accomplish to add the google play storenet this is a great tablet fo
r the money',
 4385)
```

In [ ]:
```
tweet_tokenizer = TweetTokenizer()
review_tokens = [tweet_tokenizer.tokenize(text) for text in reviews]
review_tokens[:2]
len(review_tokens)
```

Out[ ]:
```
4385
```

In [ ]:
```
reviews_with_one_word = [i for i in review_tokens if len(i) == 1]

for i in reviews_with_one_word:
    review_tokens.remove(i)
```

In [ ]:
```
review_pos  = [pos_tag(text) for text in review_tokens]
review_pos[:3]
```

Out[ ]:
```
[[('purchased', 'VBN'),
  ('on', 'IN'),
  ('black', 'JJ'),
  ('fridaypros', 'JJ'),
  ('great', 'JJ'),
  ('price', 'NN'),
  ('even', 'RB'),
  ('off', 'IN'),
  ('sale', 'NN'),
  ('very', 'RB'),
  ('powerful', 'JJ'),
  ('and', 'CC'),
  ('fast', 'JJ'),
  ('with', 'IN'),
  ('quad', 'NN'),
  ('core', 'NN'),
  ('processors', 'NNS'),
  ('amazing', 'VBG'),
  ('soundwell', 'NN'),
  ('builtcons', 'NNS'),
  ('amazon', 'VBP'),
  ('ads', 'NNS'),
  ('amazon', 'RB'),
  ('need', 'VBP'),
  ('this', 'DT'),
  ('to', 'TO'),
  ('subsidize', 'VB'),
  ('the', 'DT'),
  ('tablet', 'NN'),
  ('and', 'CC'),
  ('will', 'MD'),
  ('remove', 'VB'),
  ('the', 'DT'),
  ('adds', 'VBZ'),
  ('if', 'IN'),
  ('you', 'PRP'),
```

```
 ('pay', 'VBP'),
 ('them', 'PRP'),
 ('inability', 'NN'),
 ('to', 'TO'),
 ('access', 'NN'),
 ('other', 'JJ'),
 ('apps', 'NN'),
 ('except', 'IN'),
 ('the', 'DT'),
 ('ones', 'NNS'),
 ('from', 'IN'),
 ('amazon', 'NN'),
 ('there', 'EX'),
 ('is', 'VBZ'),
 ('a', 'DT'),
 ('way', 'NN'),
 ('which', 'WDT'),
 ('i', 'NN'),
 ('was', 'VBD'),
 ('able', 'JJ'),
 ('to', 'TO'),
 ('accomplish', 'VB'),
 ('to', 'TO'),
 ('add', 'VB'),
 ('the', 'DT'),
 ('google', 'NN'),
 ('play', 'NN'),
 ('storenet', 'NN'),
 ('this', 'DT'),
 ('is', 'VBZ'),
 ('a', 'DT'),
 ('great', 'JJ'),
 ('tablet', 'NN'),
 ('for', 'IN'),
 ('the', 'DT'),
 ('money', 'NN')],
[('i', 'NNS'),
 ('purchased', 'VBD'),
 ('two', 'CD'),
 ('amazon', 'NN'),
 ('in', 'IN'),
 ('echo', 'JJ'),
 ('plus', 'CC'),
 ('and', 'CC'),
 ('two', 'CD'),
 ('dots', 'NNS'),
 ('plus', 'CC'),
 ('four', 'CD'),
 ('fire', 'NN'),
 ('sticks', 'NNS'),
 ('and', 'CC'),
 ('the', 'DT'),
 ('hub', 'NN'),
 ('philips', 'VBZ'),
 ('hue', 'NN'),
 ('for', 'IN'),
 ('lamp', 'NN'),
 ('for', 'IN'),
 ('the', 'DT'),
```

```
('family', 'NN'),
('at', 'IN'),
('christmas', 'NN'),
('i', 'NN'),
('m', 'VBP'),
('so', 'RB'),
('happy', 'JJ'),
('with', 'IN'),
('these', 'DT'),
('purchases', 'NNS'),
('and', 'CC'),
('learning', 'VBG'),
('so', 'RB'),
('much', 'JJ'),
('with', 'IN'),
('alexa', 'IN'),
('you', 'PRP'),
('can', 'MD'),
('start', 'VB'),
('your', 'PRP$'),
('daily', 'JJ'),
('routine', 'NN'),
('with', 'IN'),
('alexa', 'JJ'),
('and', 'CC'),
('program', 'NN'),
('it', 'PRP'),
('to', 'TO'),
('whatever', 'VB'),
('you', 'PRP'),
('would', 'MD'),
('like', 'VB'),
('to', 'TO'),
('include', 'VB'),
('news', 'NN'),
('weather', 'NN'),
('music', 'NN'),
('horoscope', 'NN'),
('also', 'RB'),
('you', 'PRP'),
('can', 'MD'),
('start', 'VB'),
('your', 'PRP$'),
('day', 'NN'),
('off', 'IN'),
('with', 'IN'),
('a', 'DT'),
('compliment', 'NN'),
('and', 'CC'),
('i', 'NN'),
('think', 'VBP'),
('is', 'VBZ'),
('very', 'RB'),
('important', 'JJ'),
('alexa', 'NN'),
('gave', 'VBD'),
('me', 'PRP'),
('the', 'DT'),
('best', 'JJS'),
```

```
 ('chili', 'NN'),
 ('recipe', 'NN'),
 ('i', 'NN'),
 ('mean', 'VBP'),
 ('the', 'DT'),
 ('best', 'JJS'),
 ('it', 'PRP'),
 ('s', 'VBZ'),
 ('called', 'VBN'),
 ('chili', 'NN'),
 ('i', 'NN'),
 ('i', 'VBP'),
 ('want', 'VBP'),
 ('my', 'PRP$'),
 ('husband', 'NN'),
 ('to', 'TO'),
 ('use', 'VB'),
 ('alexa', 'NN'),
 ('to', 'TO'),
 ('stay', 'VB'),
 ('organized', 'VBN'),
 ('for', 'IN'),
 ('business', 'NN'),
 ('dates', 'NNS'),
 ('and', 'CC'),
 ('reminders', 'NNS'),
 ('this', 'DT'),
 ('is', 'VBZ'),
 ('the', 'DT'),
 ('way', 'NN'),
 ('to', 'TO'),
 ('go', 'VB')],
[('just', 'RB'),
 ('an', 'DT'),
 ('average', 'JJ'),
 ('alexa', 'JJ'),
 ('option', 'NN'),
 ('does', 'VBZ'),
 ('show', 'VB'),
 ('a', 'DT'),
 ('few', 'JJ'),
 ('things', 'NNS'),
 ('on', 'IN'),
 ('screen', 'NN'),
 ('but', 'CC'),
 ('still', 'RB'),
```

In [ ]:

```
nouns = []
for text in review_pos:
    temp = []
    for noun in text:
        if re.match('N[NP].*', noun[1]):
            temp.append(noun)
    nouns.append(temp)
nouns[:3]
```

Out[ ]:

```
[[('price', 'NN'),
 ('sale', 'NN'),
```

```
 ('quad', 'NN'),
 ('core', 'NN'),
 ('processors', 'NNS'),
 ('soundwell', 'NN'),
 ('builtcons', 'NNS'),
 ('ads', 'NNS'),
 ('tablet', 'NN'),
 ('inability', 'NN'),
 ('access', 'NN'),
 ('apps', 'NN'),
 ('ones', 'NNS'),
 ('amazon', 'NN'),
 ('way', 'NN'),
 ('i', 'NN'),
 ('google', 'NN'),
 ('play', 'NN'),
 ('storenet', 'NN'),
 ('tablet', 'NN'),
 ('money', 'NN')],
[('i', 'NNS'),
 ('amazon', 'NN'),
 ('dots', 'NNS'),
 ('fire', 'NN'),
 ('sticks', 'NNS'),
 ('hub', 'NN'),
 ('hue', 'NN'),
 ('lamp', 'NN'),
 ('family', 'NN'),
 ('christmas', 'NN'),
 ('i', 'NN'),
 ('purchases', 'NNS'),
 ('routine', 'NN'),
 ('program', 'NN'),
 ('news', 'NN'),
 ('weather', 'NN'),
 ('music', 'NN'),
 ('horoscope', 'NN'),
 ('day', 'NN'),
 ('compliment', 'NN'),
 ('i', 'NN'),
 ('alexa', 'NN'),
 ('chili', 'NN'),
 ('recipe', 'NN'),
 ('i', 'NN'),
 ('chili', 'NN'),
 ('i', 'NN'),
 ('husband', 'NN'),
 ('alexa', 'NN'),
 ('business', 'NN'),
 ('dates', 'NNS'),
 ('reminders', 'NNS'),
 ('way', 'NN')],
[('option', 'NN'), ('things', 'NNS'), ('screen', 'NN')]]
```

In [ ]:
```
lem = WordNetLemmatizer()
root_tokens = []
for words in nouns:
    temp = []
    for token in words:
        temp.append(lem.lemmatize(token[0]))
    root_tokens.append(temp)

root_tokens[:3]
```

Out[ ]:
```
[['price',
  'sale',
  'quad',
  'core',
  'processor',
  'soundwell',
  'builtcons',
  'ad',
  'tablet',
  'inability',
  'access',
  'apps',
  'one',
  'amazon',
  'way',
  'i',
  'google',
  'play',
  'storenet',
  'tablet',
  'money'],
 ['i',
  'amazon',
  'dot',
  'fire',
  'stick',
  'hub',
  'hue',
  'lamp',
  'family',
  'christmas',
  'i',
  'purchase',
  'routine',
  'program',
  'news',
  'weather',
  'music',
  'horoscope',
  'day',
  'compliment',
  'i',
  'alexa',
  'chili',
  'recipe',
  'i',
  'chili',
```

```
 'i',
 'husband',
 'alexa',
 'business',
 'date',
 'reminder',
 'way'],
```

In [ ]:
```
stop_words = stopwords.words('english')
clean_data = []
for noun in nouns:
    temp =[]
    for token in noun:
        if token[0] not in stop_words and len(token[0]) >=4 and token[0].isal
            temp.append(token[0])
    if len(temp) != 0:
        clean_data.append(temp)
```

In [ ]:
```
id2word = gensim.corpora.Dictionary(clean_data)


corpus = [id2word.doc2bow(text) for text in clean_data]


corpus[:2]
```

Out[ ]:
```
[[(0, 1),
  (1, 1),
  (2, 1),
  (3, 1),
  (4, 1),
  (5, 1),
  (6, 1),
  (7, 1),
  (8, 1),
  (9, 1),
  (10, 1),
  (11, 1),
  (12, 1),
  (13, 1),
  (14, 1),
  (15, 1),
  (16, 2)],
 [(1, 1),
  (17, 2),
  (18, 1),
  (19, 2),
  (20, 1),
  (21, 1),
  (22, 1),
  (23, 1),
  (24, 1),
  (25, 1),
  (26, 1),
  (27, 1),
  (28, 1),
```

```
 (29, 1),
 (30, 1),
 (31, 1),
 (32, 1),
 (33, 1),
 (34, 1),
 (35, 1),
 (36, 1),
```

In [ ]:
```
def calculate_topic_cv(topic_range):
  cv_score =[]
  topic_num = []
  for i in range(2,topic_range):
    topic_num.append(i)
    ldamodel = LdaModel(corpus = corpus, num_topics= i, id2word= id2word, pass
    cv_score.append(CoherenceModel(model=ldamodel,texts=clean_data, dictionary
    print('topic {i}: {cv}'.format(i = i, cv = cv_score[i-2]))
  return topic_num,cv_score
```

In [ ]:
```
topic_num,cv_score = calculate_topic_cv(8)
```

```
topic 2: 0.46098026716617463
topic 3: 0.4708944024094386
topic 4: 0.4767619513321677
topic 5: 0.46999349507571325
topic 6: 0.45451908995456086
topic 7: 0.4470742902762419
```

In [ ]:
```
topic_num,cv_score
```

Out[ ]:
```
([2, 3, 4, 5, 6, 7],
 [0.46098026716617463,
  0.4708944024094386,
  0.4767619513321677,
  0.46999349507571325,
  0.45451908995456086,
  0.44707429027624191])
```

In [ ]:
```
num_of_topics = 4

lda = LdaModel(corpus = corpus, num_topics= num_of_topics, id2word= id2word, p


print('LDA model')
for idx in range(num_of_topics):
    print('Topic #%s:'%idx , lda.print_topic(idx,12))
```

```
LDA model
Topic #0: 0.043*"alexa" + 0.037*"device" + 0.036*"music" + 0.024*"home" + 0.02
3*"things" + 0.023*"amazon" + 0.021*"sound" + 0.019*"house" + 0.018*"speaker"
+ 0.018*"lights" + 0.017*"echo" + 0.016*"family"
Topic #1: 0.054*"kindle" + 0.038*"books" + 0.026*"screen" + 0.021*"reader" +
0.020*"fire" + 0.018*"size" + 0.014*"battery" + 0.014*"case" + 0.013*"page" +
0.013*"paperwhite" + 0.012*"book" + 0.011*"model"
Topic #2: 0.055*"product" + 0.042*"echo" + 0.038*"show" + 0.019*"video" + 0.01
```

```
7*"music" + 0.016*"works" + 0.014*"screen" + 0.013*"amazon" + 0.010*"husband"
+ 0.010*"time" + 0.009*"family" + 0.009*"alarm"
Topic #3: 0.110*"tablet" + 0.038*"price" + 0.036*"kids" + 0.029*"games" + 0.02
8*"gift" + 0.027*"year" + 0.026*"fire" + 0.019*"apps" + 0.018*"daughter" + 0.0
```

In [ ]:
```
coherence_lda_model = CoherenceModel(model= lda,texts= clean_data, dictionary=


print('coherence score: ', coherence_lda_model.get_coherence())
```

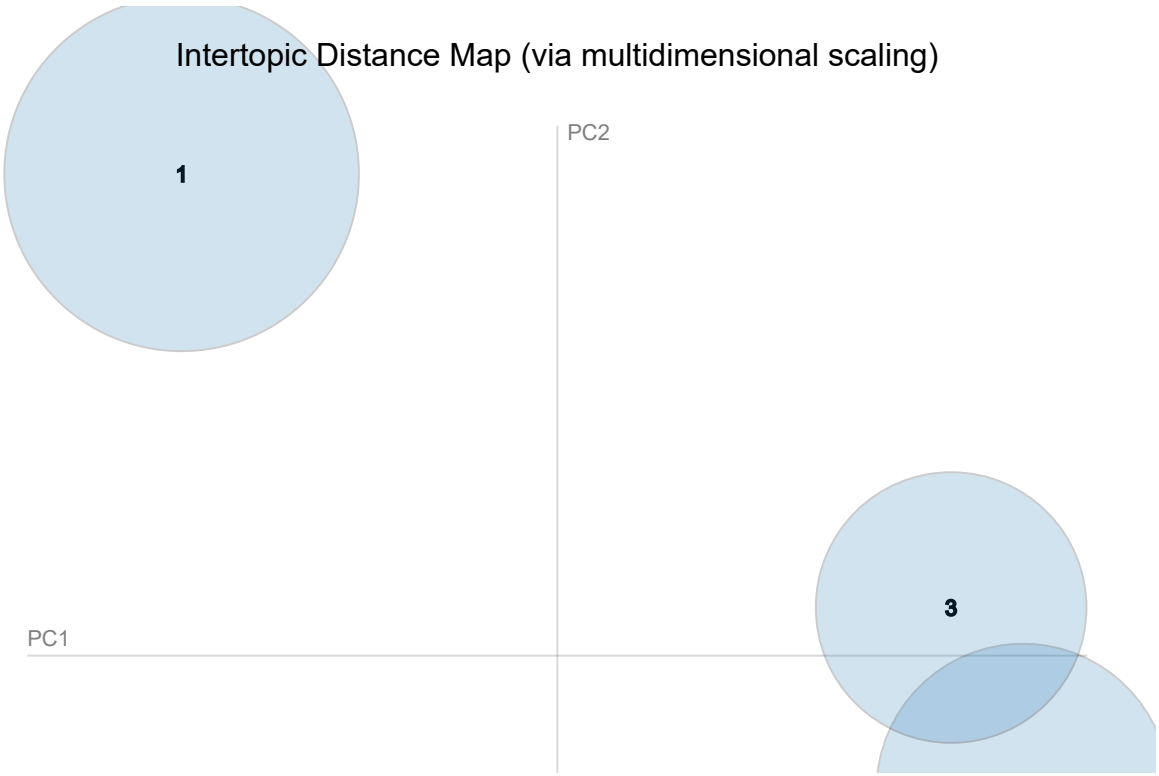
```
coherence score:  0.4767619513321677
```

In [ ]:
```
pyLDAvis.enable_notebook()
vis = gensimvis.prepare(lda, corpus, id2word)

pyLDAvis.save_html(vis, 'lda4.html')
vis
```

```
D:\visualstudio\shared\Python37_64\lib\site-packages\pyLDAvis\_prepare.py:247:
FutureWarning: In a future version of pandas all arguments of DataFrame.drop e
xcept for the argument 'labels' will be keyword-only
  by='saliency', ascending=False).head(R).drop('saliency', 1)
```

Out[ ]:

Selected Topic: 0 Previous Topic Next Topic Clear Topic



In [ ]:
```
lda_topics= lda.show_topics(formatted=False)

topics_only = []
for topic in lda_topics:
    temp_str  = ''
    for sub_topic in topic[1]:
        temp.append(sub_topic[0])
        temp_str += sub_topic[0] + ', '
    topics_only.append([topic[0] ,temp_str])

topics_only
```

Out[ ]:
```
[[0,
  'alexa, device, music, home, things, amazon, sound, house, speaker, lights,
'],
 [1,
  'kindle, books, screen, reader, fire, size, battery, case, page, paperwhite,
'],
 [2,
  'product, echo, show, video, music, works, screen, amazon, husband, time,
'],
 [3,
  'tablet, price, kids, games, gift, year, fire, apps, daughter, tablets, ']]
```

In [ ]:
```
topics_df = pd.DataFrame(topics_only, columns = ['Topic Number','Topic top wo
topics_df['Topic name'] = ['alexa', 'kindle', 'sound quality of a product may
```

In [ ]:
```
final_review = pd.DataFrame([', '.join(sent) for sent in clean_data], columns
```

In [ ]:
```
topic_number = []
for sent in lda[corpus]:
  temp = []
  other = []
  for topic_num in sent:
    if topic_num[1] >= 0.35:
      temp.append(topic_num[0])
  if(len(temp) >= 1):
    topic_number.append(temp)
  else:
    topic_number.append([max(sent,key=itemgetter(1))[0]])
```

In [ ]:
```
final_review['Topic Number'] = [', '.join(map(str,number)) for number in topic
final_review.sample(10)
```

Out[ ]:

	Review keywords	Topic Number
3144	devices, drop, video, chat, feature	2
3618	daughter, tablet, mickey, clubhouse	0, 3
972	kids, case, daughter, thing, sound, louder	2, 3
1023	couple, gifts, cute, voice, room	1

	Review keywords	Topic Number
3308	sound, google, home, echo	0
74	home, help, room	0
1612	purchase, girlfriend	2
570	child, tablet, rate, child, rides, days, cost,...	1, 3
2076	technology, everyone, life	2

In [ ]:

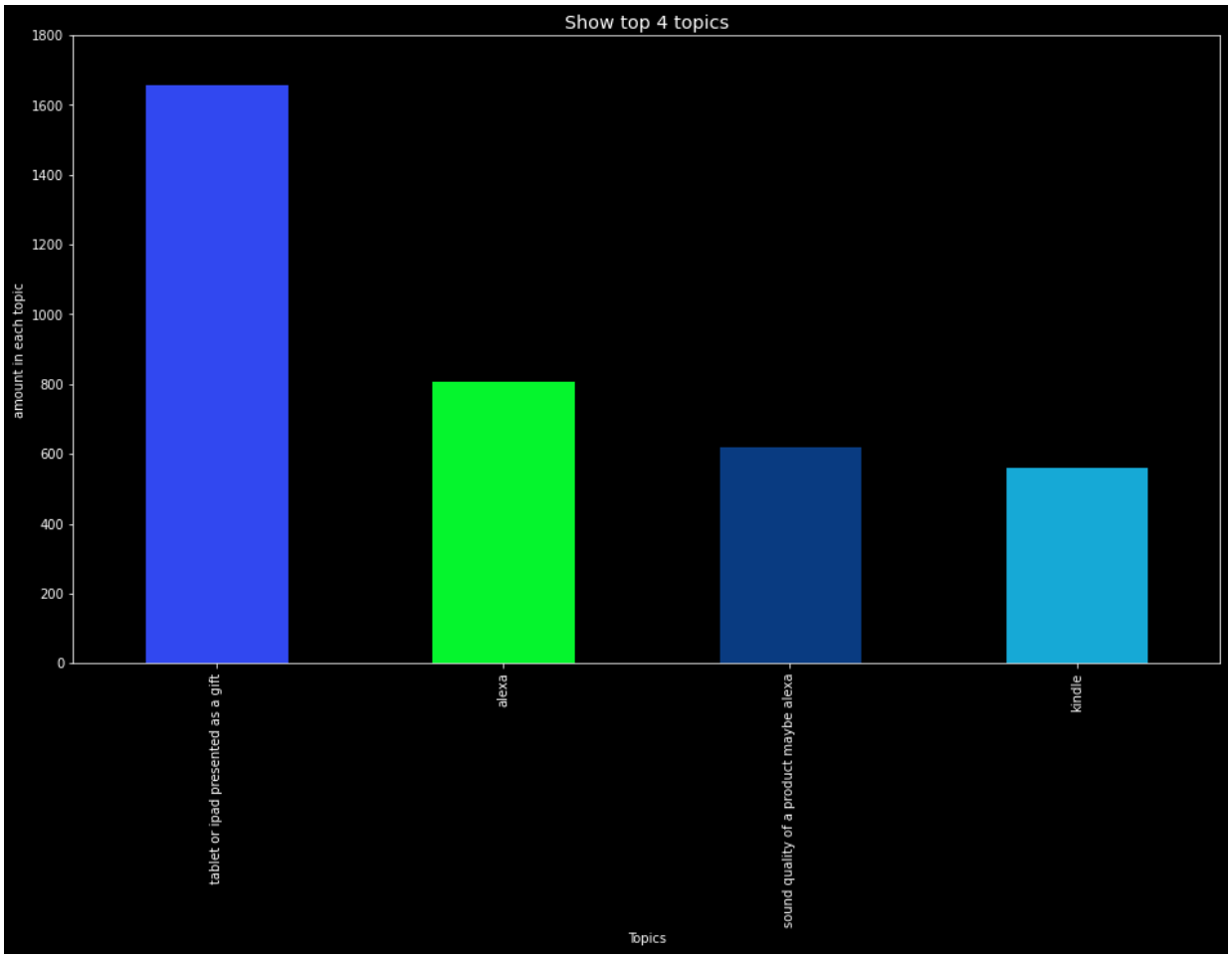
```
topic_names = []
for topic_num in topic_number:
    temp = []
    for i in topic_num:
        temp.append(topics_df.iloc[i]['Topic name'])
    topic_names.append(', '.join(temp))
final_review['Topic name'] = topic_names

final_review.sample(10)
```

Out[ ]:

	Review keywords	Topic Number	Topic name
109	tablets, wonders, needs, tablet, browsing, gam...	3	tablet or ipad presented as a gift
2768	tablet, ones, feature, everything, kind, apps	3	tablet or ipad presented as a gift
3283	blocks, nothing, amazon, block, kindle	1	kindle
68	tablet, good, games, netflix	3	tablet or ipad presented as a gift
518	bluetooth, speakers, quality, questions	0	alexa
3094	reading, kindles, light, light, size, wise, pa...	1	kindle
2613	product, picture, voice, control	0, 2	alexa, sound quality of a product maybe alexa
863	games, jeopardy, family, edition, kids, jokes	0, 3	alexa, tablet or ipad presented as a gift
673	tablets, youtube, reading	3	tablet or ipad presented as a gift
1636	accessory, alexis, system	3	tablet or ipad presented as a gift

In [ ]:

```
colors=['#3148F0','#05F52D',
        '#093B81', '#16A9D6',
        '#16A9D6', '#DAC83C', '#DAC83C', '#EF4B9D', '#EF4B9D', '#D72E5B', '#D

final_review['Topic name'].value_counts()[:4]

with plt.style.context('dark_background'):
    plt.grid(color='w', linestyle='solid')
    plt.ticklabel_format(useOffset = False,style='plain')
    plt.style.use('classic')
    final_review['Topic name'].value_counts()[:4].plot(
        kind ='bar',figsize=(16,9), xlabel= 'Topics',
        ylabel= 'amount in each topic', color= colors,title='Show top 4 topics
    plt.show()
```



In [ ]: