Amazon Fine Food Reviews Analysis

Data Source: https://www.kaggle.com/snap/amazon-fine-food-reviews (https://www.kaggle.com/snap/amazon-fine-food-reviews)

EDA: https://nycdatascience.com/blog/student-works/amazon-fine-foods-visualization/ (https://nycdatascience.com/blog/student-works/amazon-fine-foods-visualization/)

The Amazon Fine Food Reviews dataset consists of reviews of fine foods from Amazon.

Number of reviews: 568,454
Number of users: 256,059
Number of products: 74,258
Timespan: Oct 1999 - Oct 2012
Number of Attributes/Columns in data: 10

Attribute Information:

1. Id
2. ProductId - unique identifier for the product
3. UserId - unqiue identifier for the user
4. ProfileName
5. HelpfulnessNumerator - number of users who found the review helpful
6. HelpfulnessDenominator - number of users who indicated whether they found the review helpful or not
7. Score - rating between 1 and 5
8. Time - timestamp for the review
9. Summary - brief summary of the review
10. Text - text of the review

Objective:

We want to train a model such that it is able to classify the incoming data point which is a reveiw text into positive review and negative review .For this task we will take in consideration of the review text and will work on it using different vectorizers like Bag of words,tfidf,and word to vector to generate features that can be feeded to our model for making predictions

[Q] How to determine if a review is positive or negative?

[Ans] We could use Score/Rating. A rating of 4 or 5 can be cosnidered as a positive review. A rating of 1 or 2 can be considered as negative one. A review of rating 3 is considered nuetral and such reviews are ignored from our analysis. This is an approximate and proxy way of determining the polarity (positivity/negativity) of a review.

[1]. Reading Data

[1.1] Loading the data

The dataset is available in two forms

1. .csv file
2. SQLite Database

In order to load the data, We have used the SQLITE dataset as it is easier to query the data and visualise the data efficiently.

Here as we only want to get the global sentiment of the recommendations (positive or negative), we will purposefully ignore all Scores equal to 3. If the score is above 3, then the recommendation wil be set to "positive". Otherwise, it will be set to "negative".

In [0]:

```
%matplotlib inline
import warnings
warnings.filterwarnings("ignore")


import sqlite3
import pandas as pd
import numpy as np
import nltk
import string
import matplotlib.pyplot as plt
import seaborn as sns

from nltk.stem.porter import PorterStemmer
import re
import string
from nltk.corpus import stopwords
from nltk.stem import PorterStemmer
from nltk.stem.wordnet import WordNetLemmatizer

import pickle

from tqdm import tqdm
import os
```

In [4]:

```
from google.colab import drive
drive.mount('/content/gdrive')
```

```
Go to this URL in a browser: https://accounts.google.com/o/oauth2/auth?client_id=947318989803-6bn6qk8qdgf4n4g3p
fee6491hc0brc4i.apps.googleusercontent.com&redirect_uri=urn%3Aietf%3Awg%3Aoauth%3A2.0%3Aoob&scope=email%20http
s%3A%2F%2Fwww.googleapis.com%2Fauth%2Fdocs.test%20https%3A%2F%2Fwww.googleapis.com%2Fauth%2Fdrive%20https%3A%2
F%2Fwww.googleapis.com%2Fauth%2Fdrive.photos.readonly%20https%3A%2F%2Fwww.googleapis.com%2Fauth%2Fpeopleapi.rea
donly&response_type=code (https://accounts.google.com/o/oauth2/auth?client_id=947318989803-6bn6qk8qdgf4n4g3pfee
6491hc0brc4i.apps.googleusercontent.com&redirect_uri=urn%3Aietf%3Awg%3Aoauth%3A2.0%3Aoob&scope=email%20https%3
A%2F%2Fwww.googleapis.com%2Fauth%2Fdocs.test%20https%3A%2F%2Fwww.googleapis.com%2Fauth%2Fdrive%20https%3A%2F%2F
www.googleapis.com%2Fauth%2Fdrive.photos.readonly%20https%3A%2F%2Fwww.googleapis.com%2Fauth%2Fpeopleapi.readonl
y&response_type=code)

Enter your authorization code:
··········
Mounted at /content/gdrive
```

In [5]:

```
# using SQLite Table to read data.
con = sqlite3.connect('gdrive/My Drive/database.sqlite')
filtered_data = pd.read_sql_query(""" SELECT * FROM Reviews WHERE Score != 3""", con)
# Give reviews with Score>3 a positive rating(1), and reviews with a score<3 a negative rating(0).
def partition(x):
    if x < 3:
        return 0
    return 1
#changing reviews with score less than 3 to be positive and vice-versa
actualScore = filtered_data['Score']
positiveNegative = actualScore.map(partition)
filtered_data['Score'] = positiveNegative
print("Number of data points in our data", filtered_data.shape)
filtered_data.head(3)
```

```
Number of data points in our data (525814, 10)
```

Out[5]:

	Id	ProductId	UserId	ProfileName	HelpfulnessNumerator	HelpfulnessDenominator	Score	Time	Summary	
0	1	B001E4KFG0	A3SGXH7AUHU8GW	delmartian	1	1	1	1303862400	Good Quality Dog Food	I sev c
1	2	B00813GRG4	A1D87F6ZCVE5NK	dll pa	0	0	0	1346976000	Not as Advertised	P a labe Pe
2	3	B000LQOCH0	ABXLMWJIXXAIN	Natalia Corres "Natalia Corres"	1	1	1	1219017600	"Delight" says it all	Th cont th arc

In [0]:
```
display = pd.read_sql_query("""
SELECT UserId, ProductId, ProfileName, Time, Score, Text, COUNT(*)
FROM Reviews
GROUP BY UserId
HAVING COUNT(*)>1
""", con)
```

In [7]:
```
print(display.shape)
display.head()
```

```
(80668, 7)
```

Out[7]:

	UserId	ProductId	ProfileName	Time	Score	Text	COUNT(*)
0	#oc-R115TNMSPFT9I7	B007Y59HVM	Breyton	1331510400	2	Overall its just OK when considering the price...	2
1	#oc-R11D9D7SHXIJB9	B005HG9ET0	Louis E. Emory "hoppy"	1342396800	5	My wife has recurring extreme muscle spasms, u...	3
2	#oc-R11DNU2NBKQ23Z	B007Y59HVM	Kim Cieszykowski	1348531200	1	This coffee is horrible and unfortunately not ...	2
3	#oc-R11O5J5ZVQE25C	B005HG9ET0	Penguin Chick	1346889600	5	This will be the bottle that you grab from the...	3
4	#oc-R12KPBODL2B5ZD	B007OSBE1U	Christopher P. Presta	1348617600	1	I didnt like this coffee. Instead of telling y...	2

In [8]:
```
display[display['UserId']=='AZY10LLTJ71NX']
```

Out[8]:

	UserId	ProductId	ProfileName	Time	Score	Text	COUNT(*)
80638	AZY10LLTJ71NX	B006P7E5ZI	undertheshrine "undertheshrine"	1334707200	5	I was recommended to try green tea extract to ...	5

In [9]:
```
display['COUNT(*)'].sum()
```

Out[9]:
```
393063
```

[2] Exploratory Data Analysis

[2.1] Data Cleaning: Deduplication

It is observed (as shown in the table below) that the reviews data had many duplicate entries. Hence it was necessary to remove duplicates in order to get unbiased results for the analysis of the data. Following is an example:

In [10]:
```
display= pd.read_sql_query("""
SELECT *
FROM Reviews
WHERE Score != 3 AND UserId="AR5J8UI46CURR"
ORDER BY ProductID
""", con)
display.head()
```

Out[10]:

	Id	ProductId	UserId	ProfileName	HelpfulnessNumerator	HelpfulnessDenominator	Score	Time	Summary
0	78445	B000HDL1RQ	AR5J8UI46CURR	Geetha Krishnan	2	2	5	1199577600	LOACKER QUADRATINI VANILLA WAFERS
1	138317	B000HDOPYC	AR5J8UI46CURR	Geetha Krishnan	2	2	5	1199577600	LOACKER QUADRATINI VANILLA WAFERS
2	138277	B000HDOPYM	AR5J8UI46CURR	Geetha Krishnan	2	2	5	1199577600	LOACKER QUADRATINI VANILLA WAFERS
3	73791	B000HDOPZG	AR5J8UI46CURR	Geetha Krishnan	2	2	5	1199577600	LOACKER QUADRATINI VANILLA WAFERS
4	155049	B000PAQ75C	AR5J8UI46CURR	Geetha Krishnan	2	2	5	1199577600	LOACKER QUADRATINI VANILLA WAFERS

As it can be seen above that same user has multiple reviews with same values for HelpfulnessNumerator, HelpfulnessDenominator, Score,

Time, Summary and Text and on doing analysis it was found that

ProductId=B000HDOPZG was Loacker Quadratini Vanilla Wafer Cookies, 8.82-Ounce Packages (Pack of 8)

ProductId=B000HDL1RQ was Loacker Quadratini Lemon Wafer Cookies, 8.82-Ounce Packages (Pack of 8) and so on

It was inferred after analysis that reviews with same parameters other than ProductId belonged to the same product just having different flavour or quantity. Hence in order to reduce redundancy it was decided to eliminate the rows having same parameters.

The method used for the same was that we first sort the data according to ProductId and then just keep the first similar product review and delelte the others. for eg. in the above just the review for ProductId=B000HDL1RQ remains. This method ensures that there is only one representative for each product and deduplication without sorting would lead to possibility of different representatives still existing for the same product.

In [0]:
```
#Sorting data according to ProductId in ascending order
sorted_data=filtered_data.sort_values('ProductId', axis=0, ascending=True, inplace=False, kind='quicksort',
```

In [12]:
```
#Deduplication of entries
final=sorted_data.drop_duplicates(subset={"UserId","ProfileName","Time","Text"}, keep='first', inplace=False
final.shape
```

Out[12]: (364173, 10)

In [13]:
```
#Checking to see how much % of data still remains
(final['Id'].size*1.0)/(filtered_data['Id'].size*1.0)*100
```

Out[13]: 69.25890143662969

Observation:- It was also seen that in two rows given below the value of HelpfulnessNumerator is greater than HelpfulnessDenominator which is not practically possible hence these two rows too are removed from calcualtions

In [14]:
```
display= pd.read_sql_query("""
SELECT *
FROM Reviews
WHERE Score != 3 AND Id=44737 OR Id=64422
ORDER BY ProductID
""", con)

display.head()
```

Out[14]:

	Id	ProductId	UserId	ProfileName	HelpfulnessNumerator	HelpfulnessDenominator	Score	Time	Summary	
0	64422	B000MIDROQ	A161DK06JJMCYF	J. E. Stephens "Jeanne"	3	1	5	1224892800	Bought This for My Son at College	sp I
1	44737	B001EQ55RW	A2V0I904FH7ABY	Ram	3	2	4	1212883200	Pure cocoa taste with crunchy almonds inside	a fi

In [0]:
```
final=final[final.HelpfulnessNumerator<=final.HelpfulnessDenominator]
```

In [16]:
```
#Before starting the next phase of preprocessing lets see the number of entries left
print(final.shape)

#How many positive and negative reviews are present in our dataset?
final['Score'].value_counts()
```

```
(364171, 10)
```

Out[16]:
```
1    307061
0     57110
Name: Score, dtype: int64
```

In [17]:
```
final = final.sample(100000)
final = final.sort_values('Time',ascending = True)

#considering the 50k datapoints
final.head(20)
```

Out[17]:

	Id	ProductId	UserId	ProfileName	HelpfulnessNumerator	HelpfulnessDenominator	Score	Tim
138683	150501	0006641040	AJ46FKXOVC7NR	Nicholas A Mesiano	2	2	1	9408096
346041	374343	B00004CI84	A1B2IZU1JLZA6	Wes	19	23	0	9482400
346141	374450	B00004CI84	ACJR7EQF9S6FP	Jeremy Robertson	2	3	1	9515232
121041	131217	B00004RAMX	A5NQLNC6QPGSI	Kim Nason	7	8	1	9650016
138001	149770	B00004S1C5	A1KXONFPU2XQ5K	Stephanie Manley	8	8	1	9657792
346102	374408	B00004CI84	A1GB1Q193DNFGR	Bruce Lee Pullen	5	5	1	9705312

	Id	ProductId	UserId	ProfileName	HelpfulnessNumerator	HelpfulnessDenominator	Score	Tim
138000	149768	B00004S1C5	A7P76IGRZZBFJ	E. Thompson "Soooooper Genius"	18	18	1	9759744
346054	374358	B00004CI84	A1HWMNSQF14MP8	will@socialaw.com	1	2	1	9781344
138682	150500	0006641040	A1IJKK6Q1GTEAY	A Customer	2	2	1	10093248
346032	374334	B00004CI84	A2HIZRVOKXKZ52	KAY N. FOWLER	0	0	1	10127808
443662	479723	B00005U2FA	A3TO9GEQEGKFDC	N. Smith "emerald999"	35	35	1	10202112
443669	479730	B00005U2FA	A7BP01VQO33U	Caleb	11	11	1	10221120
346053	374357	B00004CI84	A31RM5QU797HPJ	Drez	1	2	1	10245312
138707	150525	0006641040	A2QID6VCFTY51R	Rick	1	2	1	10254816

	Id	ProductId	UserId	ProfileName	HelpfulnessNumerator	HelpfulnessDenominator	Score	Tim
443667	479728	B00005U2FA	AR5RRP9N2UXDJ	Boraxo "Boraxo"	21	23	1	10291968
346027	374329	B00004CI84	A1JZV9MCT6KOX4	C. Eallonardo "Kali's Copilot"	0	0	1	10379232
226060	245108	B001O8NLV2	A356HBGSVZ5NRH	B.P. "tilley_traveler"	14	14	1	10380096
346040	374342	B00004CI84	A10L8O1ZMUIMR2	G. Kleinschmidt	61	79	0	10409472
333923	361310	B00005IX96	A3DPP97CNG990R	"websurpher"	12	12	1	10460448
333932	361319	B00005IX96	AGUF1WPEG4GSM	"lchang44"	5	8	0	10553760

[3] Preprocessing

[3.1]. Preprocessing Review Text

Now that we have finished deduplication our data requires some preprocessing before we go on further with analysis and making the prediction model.

Hence in the Preprocessing phase we do the following in the order below:-

1. Begin by removing the html tags
2. Remove any punctuations or limited set of special characters like , or . or # etc.
3. Check if the word is made up of english letters and is not alpha-numeric
4. Check to see if the length of the word is greater than 2 (as it was researched that there is no adjective in 2-letters)
5. Convert the word to lowercase
6. Remove Stopwords
7. Finally Snowball Stemming the word (it was obsereved to be better than Porter Stemming)

After which we collect the words used to describe positive and negative reviews

In [0]:

```
# https://stackoverflow.com/a/47091490/4084039
import re

def decontracted(phrase):
    # specific
    phrase = re.sub(r"won't", "will not", phrase)
    phrase = re.sub(r"can\'t", "can not", phrase)

    # general
    phrase = re.sub(r"n\'t", " not", phrase)
    phrase = re.sub(r"\'re", " are", phrase)
    phrase = re.sub(r"\'s", " is", phrase)
    phrase = re.sub(r"\'d", " would", phrase)
    phrase = re.sub(r"\'ll", " will", phrase)
    phrase = re.sub(r"\'t", " not", phrase)
    phrase = re.sub(r"\'ve", " have", phrase)
    phrase = re.sub(r"\'m", " am", phrase)
    return phrase
```

In [0]:
```
# Combining all the above statements
from tqdm import tqdm
from bs4 import BeautifulSoup
preprocessed_reviews = []
# tqdm is for printing the status bar
for sentance in (final['Text'].values):
    sentance = re.sub(r"http\S+", "", sentance)
    sentance = BeautifulSoup(sentance, 'lxml').get_text()
    sentance = decontracted(sentance)
    sentance = re.sub("\S*\d\S*", "", sentance).strip()
    sentance = re.sub('[^A-Za-z]+', ' ', sentance)
    # https://gist.github.com/sebleier/554280
    #sentance = ' '.join(e.lower() for e in sentance.split() if e.lower() not in stopwords)
    preprocessed_reviews.append(sentance.strip())
```

In [20]:
```
preprocessed_reviews[11]
```

Out[20]:
```
'I am never dissapointed with the great gadgets this company comes out with My brother picked up the new Concer
to for me and it is absolutely awesome My wife likes whites and I like reds so the stoppers really come in hand
y Also I love the new clicking sound it makes when the vacuum is at the correct level Neat design great looking
gift the absolute best invention for saving wines'
```

[3.2] Preparing the data for input to the model

We want to input the data in the format of padded vectors which comprises of ranks of words,it is a manual implementation of text tokenizer.So the methodology to be followed is:

- Counting the number of times a particular word appears in the training corpus.
- Giving the word with most number of occurence rank 1 and so on
- Sorting the list to get all the ranks in the corpus

In [0]:
```
#splitting the data
from sklearn.model_selection import train_test_split
X_train,X_test,Y_train,Y_test = train_test_split(preprocessed_reviews,final['Score'],test_size = 0.2,random_
```

In [22]:

```
from collections import defaultdict
word_dict = defaultdict(int)#dictionary containing the count of words in the reviews


# we will split every review and then use a dictionary to count the number of times a word appears in the tr
for review in X_train:
  for word in review.split():
    word_dict[word] += 1

print('number of unique words in the corpus are:',len(word_dict.keys()))
print('\n')

print('THe corpus with count of each words and number of times they occur are:',word_dict)

```

```
number of unique words in the corpus are: 71697


THe corpus with count of each words and number of times they occur are: defaultdict(<class 'int'>, {'I': 222
655, 'can': 24065, 'remember': 825, 'seeing': 285, 'the': 221973, 'show': 361, 'when': 15226, 'it': 120304,
'aired': 2, 'on': 36962, 'television': 15, 'years': 5303, 'ago': 2045, 'was': 43720, 'a': 160004, 'child': 5
44, 'My': 12058, 'sister': 397, 'later': 1065, 'bought': 6717, 'me': 16896, 'LP': 1, 'which': 10069, 'have':
59883, 'to': 137188, 'this': 71489, 'day': 6072, 'am': 19891, 'thirty': 62, 'something': 4914, 'used': 7814,
'series': 45, 'of': 106385, 'books': 99, 'songs': 6, 'did': 9760, 'my': 48171, 'student': 105, 'teaching': 1
7, 'for': 72283, 'preschoolers': 3, 'turned': 795, 'whole': 3744, 'school': 472, 'now': 7423, 'purchasing':
853, 'CD': 19, 'along': 1168, 'with': 47757, 'children': 688, 'The': 30580, 'tradition': 94, 'lives': 223,
'myself': 1819, 'always': 4897, 'enjoyed': 1465, 'movie': 283, 'is': 143444, 'very': 20613, 'funny': 246, 'a
nd': 173961, 'entertaining': 44, 'so': 29029, 'not': 78621, 'hesitate': 166, 'pick': 826, 'up': 13660, 'clam
shell': 2, 'edition': 37, 'guess': 1081, 'marketing': 145, 'plan': 682, 'make': 10493, 'more': 17606, 'famil
ies': 60, 'or': 24697, 'but': 43033, 'they': 29596, 'eliminated': 50, 'all': 19472, 'strong': 3570, 'profani
ty': 1, 'elements': 34, 'that': 57438, 'are': 48905, 'usually': 2607, 'edited': 10, 'in': 74139, 'version':
1464, 'YOU': 397, 'HAVE': 270, 'BEEN': 49, 'WARNED': 9, 'If': 8073, 'you': 47634, 'want': 5318, 'uncut': 6,
'AVOID': 17, 'THE': 1339, 'CLAMSHELL': 1, 'EDITION': 1, 'What': 1869, 'happens': 173, 'say': 4617, 'his': 34
85, 'name': 1021, 'three': 2142, 'times': 2150, 'Michael': 36, 'Keaten': 1, 'stars': 1842, 'comedy': 6, 'abo
```

In [23]:

```
'''We now want to get a training corpus with each if the words with their respective ranks i.e if a word occ
  Number of times in the corpus it will have a rank 1 and subsequently'''


#data frame for word and their frequencies
table = pd.DataFrame.from_dict(word_dict,orient = 'index', columns = ['Frequency'])
#sorting for the frequencies
table = table.sort_values('Frequency',ascending = False)
print(table.head(20))#top 20 words which are repeated most number of times are


top_words = list(table.index)
#top_words = top_words[:10000]
print('Number of words are :',len(top_words))



#we will create a dictionary to find the rank of the word appearing in the corpus
rank_dict = dict()
rank = 1
for i in top_words:
  rank_dict[i] = rank
  rank = rank + 1

print(rank_dict)
vocab_size = len(rank_dict.keys())
print('Number of unique words in the rank dictionary are ',vocab_size)

```

```
      Frequency
I        222655
the      221973
and      173961
a        160004
is       143444
to       137188
it       120304
of       106385
not       78621
in        74139
for       72283
this      71489
```

```
have      59883
that      57438
are       48905
my        48171
with      47757
you       47634
```

In [0]:

```
#now we want to create the data set for test and train
#after getting our word and rank dictionary ,we now want training and test data set


x_train = []#larger vector which will contain all the encoded reviews for traininfg data
x_test = []#larger vector which will contain all the encoded reveiws for test data

#X_train
for rev in X_train:
    row = []#for each review vector
    for word in rev.split():
        if word in rank_dict.keys():
        row.append(rank_dict[word])
    x_train.append(row)

#X_test
#(as to avoiding the data leakage we will get the test word vectors with the help of training data)
for rev in X_test:
    row = []
    for word in rev.split():
        if word in rank_dict.keys():
        row.append(rank_dict[word])
    x_test.append(row)

```

In [26]:

```
print(x_train[1])
print(len(x_train))

```

```
[1, 438, 167, 503, 12, 1827, 7, 5, 41, 2024, 3, 6187, 26, 1, 91, 9, 2702, 6, 806, 62, 2, 37675, 6798, 1, 666,
7, 19, 4, 2956, 924, 6, 84, 2, 1827, 51, 11, 5139, 31, 166, 20, 25, 13, 5764, 47, 227, 43427, 3, 7156, 14, 15,
322, 14077, 10, 2, 11312, 504, 1433, 1892, 5874, 15439, 104, 18, 152, 2, 18396, 504, 10746, 542, 43488, 41571]
80000
20000
```

WE will use three different architectures for model implementation

- Model with 2 hidden layers
- Model with 3 hidden layers
- Model with 5 hidden layers

In Each Architecture We will implement using Adam optimizer:

- 1 LSTM + Adam
- 2 LSTM + Adam
- 2 CNN + 1 LSTM + Adam

In [0]:

```
from keras.models import Sequential
from keras.preprocessing import sequence
from keras.initializers import he_normal
from keras.layers import Dense
from keras.layers.embeddings import Embedding
from keras.regularizers import L1L2
from keras.layers import BatchNormalization
from keras.layers import Dropout
from keras.layers import LSTM
from keras.layers import Flatten
```

In [29]:

```
#using the padding for each of the reviews
max_review_length = 400


X_train = sequence.pad_sequences(x_train,maxlen = max_review_length)
X_test = sequence.pad_sequences(x_test,maxlen = max_review_length)


print(X_train.shape)
print(X_train[1])
```

```
(80000, 400)
[    0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     1   438   167   503    12  1827
     7     5    41  2024     3  6187    26     1    91     9  2702     6
   806    62     2 37675  6798     1   666     7    19     4  2956   924
```

```
    6    84     2  1827    51    11  5139    31   166    20    25    13
 5764    47   227 43427     3  7156    14    15   322 14077    10     2
11312   504  1433  1892  5874 15439   104    18   152     2 18396   504
10746   542 43488 41571]
```

In [0]:
```
#model settings

batch_size = 200 #number of data points as input to the model in each iteration
#number of times whole data will pass through the model
nb_epochs = 10
#length of the embedding vector
embedd_vector = 32
```

In [0]:
```
import warnings
warnings.filterwarnings('ignore')
```

Model 1: 1 LSTM(100) + 2 DROPOUT + 1 BATCHNORMALIZATION + ADAM OPTIMIZER

In [32]:
```
model = Sequential()
model.add(Embedding(vocab_size,embedd_vector,input_length = max_review_length))
model.add(BatchNormalization())#adding the batchnormalization layer
model.add(Dropout(0.3))#adding a dropout layer before the LSTM model
model.add(LSTM(100))
model.add(Dropout(0.3))#adding a dropout layer before the output layer
model.add(Dense(1,activation = 'sigmoid'))
model.compile(loss = 'binary_crossentropy', optimizer = 'adam', metrics = ['accuracy'])
print(model.summary())
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:66: The n
ame tf.get_default_graph is deprecated. Please use tf.compat.v1.get_default_graph instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:541: The
name tf.placeholder is deprecated. Please use tf.compat.v1.placeholder instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:4432: The
name tf.random_uniform is deprecated. Please use tf.random.uniform instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:148: The
name tf.placeholder_with_default is deprecated. Please use tf.compat.v1.placeholder_with_default instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:3733: cal
ling dropout (from tensorflow.python.ops.nn_ops) with keep_prob is deprecated and will be removed in a futur
e version.
Instructions for updating:
Please use `rate` instead of `keep_prob`. Rate should be set to `rate = 1 - keep_prob`.
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/optimizers.py:793: The name tf.train.Op
timizer is deprecated. Please use tf.compat.v1.train.Optimizer instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:3657: The
name tf.log is deprecated. Please use tf.math.log instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensorflow_core/python/ops/nn_impl.py:183: wh
ere (from tensorflow.python.ops.array_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.where in 2.0, which has the same broadcast rule as np.where
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
embedding_1 (Embedding)      (None, 400, 32)           2294304
```

```
_________________________________________________________________
batch_normalization_1 (Batch (None, 400, 32)           128
_________________________________________________________________
dropout_1 (Dropout)          (None, 400, 32)           0
_________________________________________________________________
lstm_1 (LSTM)                (None, 100)               53200
_________________________________________________________________
dropout_2 (Dropout)          (None, 100)               0
_________________________________________________________________
dense_1 (Dense)              (None, 1)                 101
=================================================================
Total params: 2,347,733
Trainable params: 2,347,669
Non-trainable params: 64
_________________________________________________________________
None
```

In [33]:
```
history = model.fit(X_train,Y_train,batch_size = batch_size,epochs = nb_epochs,verbose = 1,validation_data =
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:1033: The
name tf.assign_add is deprecated. Please use tf.compat.v1.assign_add instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:1020: The
name tf.assign is deprecated. Please use tf.compat.v1.assign instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:3005: The
name tf.Session is deprecated. Please use tf.compat.v1.Session instead.

Train on 80000 samples, validate on 20000 samples
Epoch 1/10
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:190: The
name tf.get_default_session is deprecated. Please use tf.compat.v1.get_default_session instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:197: The
name tf.ConfigProto is deprecated. Please use tf.compat.v1.ConfigProto instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:207: The
name tf.global_variables is deprecated. Please use tf.compat.v1.global_variables instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:216: The
name tf.is_variable_initialized is deprecated. Please use tf.compat.v1.is_variable_initialized instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:223: The
name tf.variables_initializer is deprecated. Please use tf.compat.v1.variables_initializer instead.

80000/80000 [==============================] - 302s 4ms/step - loss: 0.2949 - acc: 0.8818 - val_loss: 0.2988
- val_acc: 0.8935
Epoch 2/10
80000/80000 [==============================] - 297s 4ms/step - loss: 0.1614 - acc: 0.9386 - val_loss: 0.1931
- val_acc: 0.9239
Epoch 3/10
80000/80000 [==============================] - 297s 4ms/step - loss: 0.1124 - acc: 0.9584 - val_loss: 0.2540
- val_acc: 0.9183
Epoch 4/10
80000/80000 [==============================] - 297s 4ms/step - loss: 0.0817 - acc: 0.9708 - val_loss: 0.2517
- val_acc: 0.9220
Epoch 5/10
80000/80000 [==============================] - 298s 4ms/step - loss: 0.0589 - acc: 0.9793 - val_loss: 0.2759
```

```
- val_acc: 0.9219
Epoch 6/10
80000/80000 [==============================] - 296s 4ms/step - loss: 0.0462 - acc: 0.9843 - val_loss: 0.3062
- val_acc: 0.9220
Epoch 7/10
80000/80000 [==============================] - 297s 4ms/step - loss: 0.0350 - acc: 0.9881 - val_loss: 0.3653
- val_acc: 0.9207
Epoch 8/10
80000/80000 [==============================] - 296s 4ms/step - loss: 0.0303 - acc: 0.9899 - val_loss: 0.3744
- val_acc: 0.9198
Epoch 9/10
80000/80000 [==============================] - 296s 4ms/step - loss: 0.0268 - acc: 0.9908 - val_loss: 0.3793
- val_acc: 0.9200
Epoch 10/10
80000/80000 [==============================] - 297s 4ms/step - loss: 0.0214 - acc: 0.9929 - val_loss: 0.3829
- val_acc: 0.9203
```

In [34]:

```
score = model.evaluate(X_test,Y_test)
print('loss on testd data is :',score[0])
print('Accuracy on test data is ',score[1])
```

```
20000/20000 [==============================] - 158s 8ms/step
loss on testd data is : 0.38287709151050076
Accuracy on test data is  0.92025
```

In [0]:

```
import pickle

def savetofile(obj,filename):
  pickle.dump(obj,open(filename+".p",'wb'))


def openfromfile(filename):
  temp = pickle.load(open(filename+".p",'rb'))
  return temp

history_1 = savetofile(history,'history_1')
model1 = savetofile(model,'model1')
```

In [0]:

```
# Model 2
```

MODEL 2 : lstm(100 cells) + lstm(50 cells)+ Sigmoid + Adam Optimizer + dropout + BatchNormalization

In [38]:

```
from keras.initializers import glorot_normal

model = Sequential()
model.add(Embedding(vocab_size,embedd_vector,input_length = max_review_length))
model.add(BatchNormalization())#adding the batchnormalization layer
model.add(Dropout(0.3))#setting the dropout rate to 3 which means 30 percent of the neurons will be consider
model.add(LSTM(100,return_sequences=True))
#model.add(BatchNormalization())
model.add(Dropout(0.3))
model.add(LSTM(50))
model.add(Dropout(0.3))
model.add(Dense(1,activation = 'sigmoid'))#adding the output layer
print(model.summary())
```

```
Model: "sequential_3"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
embedding_3 (Embedding)      (None, 400, 32)           2294304
_________________________________________________________________
batch_normalization_3 (Batch (None, 400, 32)           128
_________________________________________________________________
dropout_6 (Dropout)          (None, 400, 32)           0
_________________________________________________________________
lstm_4 (LSTM)                (None, 400, 100)          53200
_________________________________________________________________
dropout_7 (Dropout)          (None, 400, 100)          0
_________________________________________________________________
lstm_5 (LSTM)                (None, 50)                30200
_________________________________________________________________
dropout_8 (Dropout)          (None, 50)                0
_________________________________________________________________
dense_3 (Dense)              (None, 1)                 51
=================================================================
Total params: 2,377,883
Trainable params: 2,377,819
Non-trainable params: 64
```

```
_________________________________________________________________
None
```

In [39]:

```
model.compile(loss = 'binary_crossentropy',optimizer = 'adam',metrics = ['accuracy'])
history = model.fit(X_train,Y_train,batch_size = batch_size ,epochs = nb_epochs ,verbose = 1,validation_data
```

```
Train on 80000 samples, validate on 20000 samples
Epoch 1/10
80000/80000 [==============================] - 603s 8ms/step - loss: 0.2760 - acc: 0.8897 - val_loss: 0.2489 -
val_acc: 0.9133
Epoch 2/10
80000/80000 [==============================] - 596s 7ms/step - loss: 0.1543 - acc: 0.9419 - val_loss: 0.1936 -
val_acc: 0.9273
Epoch 3/10
80000/80000 [==============================] - 600s 7ms/step - loss: 0.1071 - acc: 0.9606 - val_loss: 0.2108 -
val_acc: 0.9269
Epoch 4/10
80000/80000 [==============================] - 603s 8ms/step - loss: 0.0742 - acc: 0.9743 - val_loss: 0.2389 -
val_acc: 0.9272
Epoch 5/10
80000/80000 [==============================] - 598s 7ms/step - loss: 0.0531 - acc: 0.9817 - val_loss: 0.2871 -
val_acc: 0.9251
Epoch 6/10
80000/80000 [==============================] - 587s 7ms/step - loss: 0.0408 - acc: 0.9864 - val_loss: 0.2914 -
val_acc: 0.9258
Epoch 7/10
80000/80000 [==============================] - 592s 7ms/step - loss: 0.0316 - acc: 0.9898 - val_loss: 0.3008 -
val_acc: 0.9257
Epoch 8/10
80000/80000 [==============================] - 592s 7ms/step - loss: 0.0275 - acc: 0.9910 - val_loss: 0.3399 -
val_acc: 0.9244
Epoch 9/10
80000/80000 [==============================] - 587s 7ms/step - loss: 0.0229 - acc: 0.9925 - val_loss: 0.3667 -
val_acc: 0.9231
Epoch 10/10
80000/80000 [==============================] - 592s 7ms/step - loss: 0.0198 - acc: 0.9933 - val_loss: 0.3902 -
val_acc: 0.9219
```

In [40]:
```
score  = model.evaluate(X_test,Y_test)
print('Loss on test data is',score[0])
print('Accuracy on test data is ',score[1])
```

```
20000/20000 [==============================] - 304s 15ms/step
Loss on test data is 0.3902494033191353
Accuracy on test data is  0.92185
```

In [0]:
```
history_2 = savetofile(history,'history_2')
model_2 = savetofile(model,'model_2')
```

In [0]:
```
import warnings
warnings.filterwarnings('ignore')
```

MODEL 3: 2 Convolutional layer + Maxpooling + LSTM(80) + BatchNormaliztion + Dropout + Adamoptimizer

In [43]:

```
#using a CNN and RNN model combined for sequence classification
from keras.layers.convolutional import Conv1D
from keras.layers.convolutional import MaxPooling1D

model = Sequential()
model.add(Embedding(vocab_size,embedd_vector,input_length = max_review_length))
model.add(LSTM(80,return_sequences =True))
model.add(Dropout(0.5))
model.add(Conv1D(filters = 128,kernel_size = 5,padding = 'same',activation = 'relu',kernel_initializer = he_
model.add(MaxPooling1D(5,5))
#model.add(BatchNormalization())
model.add(Dropout(0.4))
model.add(Conv1D(filters = 128,kernel_size = 5,padding = 'same',activation = 'relu',kernel_initializer = he_
model.add(MaxPooling1D(5,5))
#model.add(BatchNormalization())
model.add(Dropout(0.4))
model.add(Flatten())
model.add(Dense(128,activation = 'relu',kernel_initializer = he_normal(seed = None)))
model.add(Dropout(0.4))
model.add(Dense(1,activation = 'sigmoid'))

print(model.summary())
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:4479: The
name tf.truncated_normal is deprecated. Please use tf.random.truncated_normal instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:4267: The
name tf.nn.max_pool is deprecated. Please use tf.nn.max_pool2d instead.

Model: "sequential_4"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
embedding_4 (Embedding)      (None, 400, 32)           2294304
_________________________________________________________________
lstm_6 (LSTM)                (None, 400, 80)           36160
_________________________________________________________________
dropout_9 (Dropout)          (None, 400, 80)           0
_________________________________________________________________
conv1d_1 (Conv1D)            (None, 400, 128)          51328
_________________________________________________________________
```

```
max_pooling1d_1 (MaxPooling1 (None, 80, 128)           0
_________________________________________________________________
dropout_10 (Dropout)         (None, 80, 128)           0
_________________________________________________________________
conv1d_2 (Conv1D)            (None, 80, 128)           82048
_________________________________________________________________
max_pooling1d_2 (MaxPooling1 (None, 16, 128)           0
_________________________________________________________________
dropout_11 (Dropout)         (None, 16, 128)           0
_________________________________________________________________
flatten_1 (Flatten)          (None, 2048)              0
_________________________________________________________________
dense_4 (Dense)              (None, 128)               262272
_________________________________________________________________
dropout_12 (Dropout)         (None, 128)               0
_________________________________________________________________
dense_5 (Dense)              (None, 1)                 129
=================================================================
Total params: 2,726,241
Trainable params: 2,726,241
Non-trainable params: 0
_________________________________________________________________
None
```

In [44]:
```
model.compile(loss = 'binary_crossentropy',optimizer = 'adam',metrics = ['accuracy'])

history = model.fit(X_train,Y_train,batch_size = batch_size,epochs = nb_epochs,validation_data = [X_test,Y_t
```

```
Train on 80000 samples, validate on 20000 samples
Epoch 1/10
80000/80000 [==============================] - 316s 4ms/step - loss: 0.2710 - acc: 0.8918 - val_loss: 0.2000 -
val_acc: 0.9247
Epoch 2/10
80000/80000 [==============================] - 311s 4ms/step - loss: 0.1418 - acc: 0.9475 - val_loss: 0.1809 -
val_acc: 0.9295
Epoch 3/10
80000/80000 [==============================] - 311s 4ms/step - loss: 0.0937 - acc: 0.9660 - val_loss: 0.2105 -
val_acc: 0.9245
Epoch 4/10
80000/80000 [==============================] - 312s 4ms/step - loss: 0.0653 - acc: 0.9769 - val_loss: 0.2405 -
val_acc: 0.9179
Epoch 5/10
80000/80000 [==============================] - 311s 4ms/step - loss: 0.0467 - acc: 0.9837 - val_loss: 0.2782 -
val_acc: 0.9213
Epoch 6/10
80000/80000 [==============================] - 312s 4ms/step - loss: 0.0352 - acc: 0.9877 - val_loss: 0.3719 -
val_acc: 0.9188
Epoch 7/10
80000/80000 [==============================] - 313s 4ms/step - loss: 0.0275 - acc: 0.9907 - val_loss: 0.3611 -
val_acc: 0.9179
Epoch 8/10
80000/80000 [==============================] - 314s 4ms/step - loss: 0.0222 - acc: 0.9924 - val_loss: 0.4139 -
val_acc: 0.9159
Epoch 9/10
80000/80000 [==============================] - 311s 4ms/step - loss: 0.0200 - acc: 0.9935 - val_loss: 0.4202 -
val_acc: 0.9144
Epoch 10/10
80000/80000 [==============================] - 311s 4ms/step - loss: 0.0166 - acc: 0.9946 - val_loss: 0.5074 -
val_acc: 0.9171
```

In [45]:
```
score = model.evaluate(X_test,Y_test)
print('loss on test data is:',score[0])
print('Accuracy on test data is',score[1])

history_3 = savetofile(history,'history_3')
```

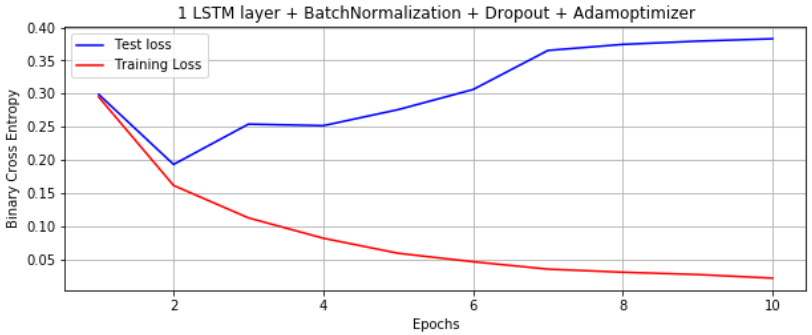
```
20000/20000 [==============================] - 155s 8ms/step
loss on test data is: 0.507415438480489
Accuracy on test data is 0.9171
```

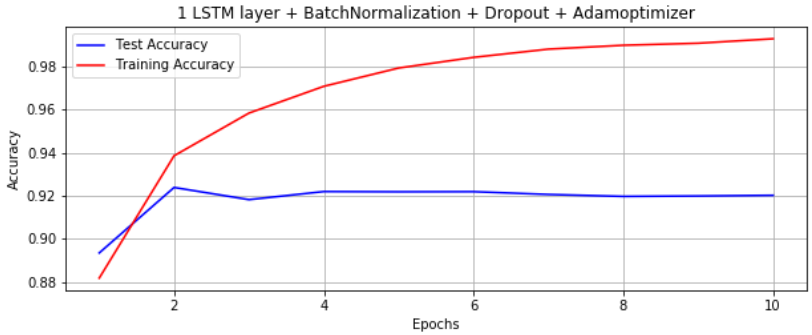
PLOTS

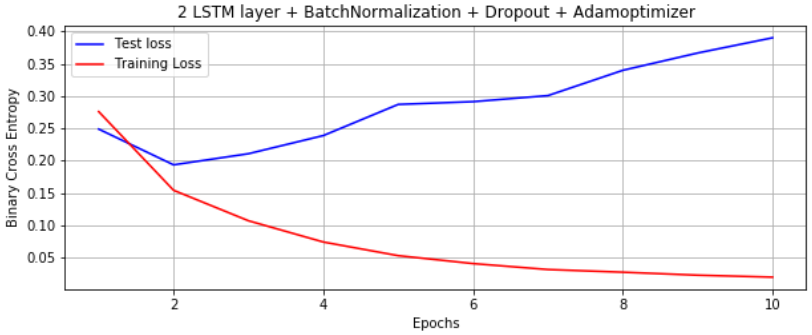
In [0]:

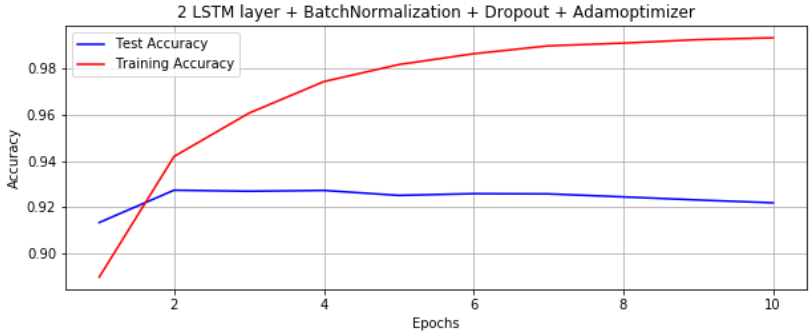
```
def diff_ops(model_h,text):

  x = list(range(1,(nb_epochs)+1))#definig the bin size on the x axis as we want to plot for each of the epo
  plt.figure(figsize = (22,8))
  #plt.grid()


    #this plots the loss vs epochs for each model
  plt.subplot(2,2,1)
  plt.grid()
  plt.plot(x,model_h.history['val_loss'],'b',label = 'Test loss')#test loss
  plt.plot(x,model_h.history['loss'],'r',label = 'Training Loss')#train loss
  plt.xlabel('Epochs')
  plt.ylabel('Binary Cross Entropy')
  plt.title(text)
  plt.legend(loc = 'best')

#================================================================================
    #this plots the test and train accuracy for each model
  plt.subplot(2,2,2)
  plt.grid()
  plt.plot(x,model_h.history['val_acc'],'b',label = 'Test Accuracy')#test accuracy
  plt.plot(x,model_h.history['acc'],'r',label = 'Training Accuracy')#training accuracy
  plt.xlabel('Epochs')
  plt.ylabel('Accuracy')
  plt.title(text)
  plt.legend(loc = 'best')
  plt.show()



```

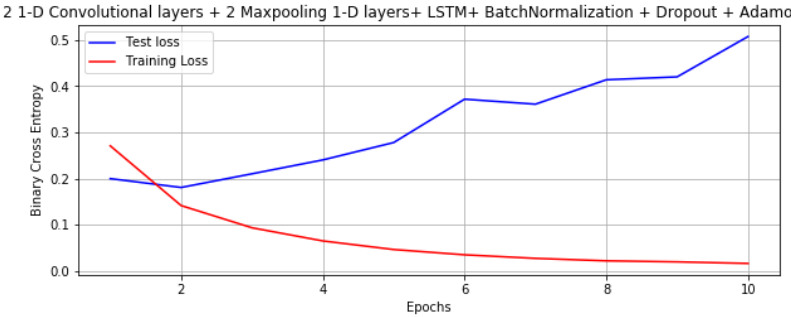
In [47]:
```
text = '1 LSTM layer + BatchNormalization + Dropout + Adamoptimizer'
diff_ops(openfromfile('history_1'),text)

text = '2 LSTM layer + BatchNormalization + Dropout + Adamoptimizer'
diff_ops(openfromfile('history_2'),text)

text = '2 1-D Convolutional layers + 2 Maxpooling 1-D layers+ LSTM+ BatchNormalization + Dropout + Adamoptim
diff_ops(openfromfile('history_3'),text)

```

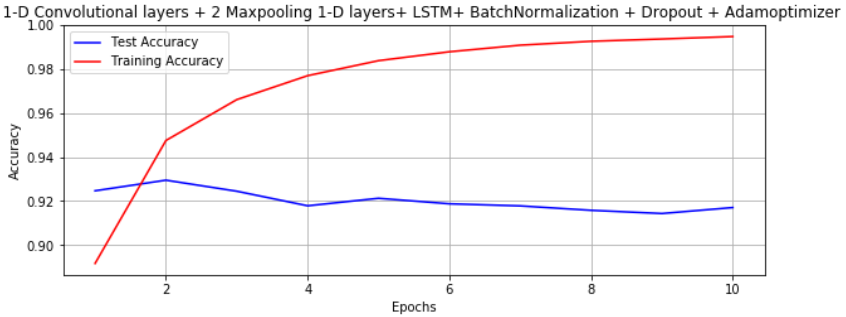












Conclusions

In [48]:

```
from prettytable import PrettyTable

history1 = openfromfile('history_1')#model 1
history2 = openfromfile('history_2')#model 2
history3 = openfromfile('history_3')#model 3

table_arch1 = PrettyTable()
models = ['1 LSTM + BatchNormalization + Dropout + AdamOptimizer','2 LSTM + BatchNormalization + Dropout + A
          '1 LSTM + 2 1D Convolutional Layers + 2 Maxpooling layers + BatchNormalization + Dropout + AdamOpt
tr_loss = [history1.history['loss'][nb_epochs-1],history2.history['loss'][nb_epochs-1],history3.history['los
tr_acc = [history1.history['acc'][nb_epochs-1],history2.history['acc'][nb_epochs-1],history3.history['acc'][
te_loss = [history1.history['val_loss'][nb_epochs-1],history2.history['val_loss'][nb_epochs-1],history3.hist
te_acc = [history1.history['val_acc'][nb_epochs-1],history2.history['val_acc'][nb_epochs-1],history3.history

table_arch1.add_column('Model',models)
table_arch1.add_column('trainig loss',tr_loss)
table_arch1.add_column('Training Accuracy(%)',tr_acc)
table_arch1.add_column('Test loss',te_loss)
table_arch1.add_column('Test_Accuracy(%)',te_acc)
print('\t\t\t\t\t\t\t\t 3 Different Models')
print(table_arch1)
print('\n\n\n')
```

```
                                                                3 Different Models
+-----------------------------------------------------------------------------------------------------------------+-
--------------------+---------------------+--------------------+--------------------+
|                                                    Model                                                        |
trainig loss      | Training Accuracy(%) |     Test loss      |  Test_Accuracy(%)  |
+-----------------------------------------------------------------------------------------------------------------+-
--------------------+---------------------+--------------------+--------------------+
|                          1 LSTM + BatchNormalization + Dropout + AdamOptimizer                                  |
0.02137223101221025  |  0.9928750067949295  | 0.3828770938515663 | 0.9202500039339065 |
|                          2 LSTM + BatchNormalization + Dropout + AdamOptimizer                                  |
0.019836417277983857 |  0.9932750064134598  | 0.3902494059503078 | 0.9218500053882599 |
| 1 LSTM + 2 1D Convolutional Layers + 2 Maxpooling layers + BatchNormalization + Dropout + AdamOptimizer |
0.01658578688147827  |  0.9945750051736831  | 0.5074470834434033 | 0.9171000027656555 |
+-----------------------------------------------------------------------------------------------------------------+-
--------------------+---------------------+--------------------+--------------------+
```

We get the model with 2 lstm layers i.e 0.921 to perform slightly better than model with single lstm .Though it performs far better than CNN + RNN model .This tells us that better accuracy can be attained by hyperparameter tuning using gridsearch cv.We can also use a Bidirectional LSTM for much better accuracy.