LSTM

In [ ]:

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

```
Drive already mounted at /content/drive; to attempt to forcibly remount, call
drive.mount("/content/drive", force_remount=True).
```

In [ ]:

```
# To enable plotly plot in Google Colab
# https://stackoverflow.com/questions/47230817/plotly-notebook-mode-with-google-
colaboratory/47230966
def configure_plotly_browser_state():
    import IPython
    display(IPython.core.display.HTML('''
        <script src="/static/components/requirejs/require.js"></script>
        <script>
          requirejs.config({
            paths: {
              base: '/static/base',
              plotly: 'https://cdn.plot.ly/plotly-1.5.1.min.js?noext',
            },
          });
        </script>
        '''))

def enable_plotly_in_cell():
    import IPython
    from plotly.offline import init_notebook_mode
    display(IPython.core.display.HTML('''<script src="/static/components/requirejs/require.js"></s
cript>'''))
    init_notebook_mode(connected=False)
```

In [ ]:

```
#importing libraries
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
%matplotlib inline
import seaborn as sns

from plotly.offline import init_notebook_mode, iplot
import plotly.graph_objs as go
configure_plotly_browser_state()
init_notebook_mode(connected=False)

from sklearn.model_selection import train_test_split
from sklearn.preprocessing import LabelEncoder
import pickle

import tensorflow as tf
from tensorflow.keras.preprocessing.text import Tokenizer
from tensorflow.keras.preprocessing.sequence import pad_sequences
```

In [ ]:

```
! ls '/content/drive/My Drive/Applied AI/Datasets/New Donors/'
```

```
co_occurence_matrix.csv  PreProcessed.csv        train_data.csv
glove.6B.100d.txt  Preprocessed_inc_others.csv
glove_vectors    resources.csv
```

In [ ]:

```
data = pd.read_csv('/content/drive/My Drive/Applied AI/Datasets/New
Donors/Preprocessed_inc_others.csv')
data.head()
```

Out[ ]:

	Unnamed: 0	school_state	teacher_prefix	project_grade_category	teacher_number_of_previously_posted_projects	project_is_approved
0	0	ca	mrs	grades_prek_2	53	1
1	1	ut	ms	grades_3_5	4	1
2	2	ca	mrs	grades_prek_2	10	1
3	3	ga	mrs	grades_prek_2	2	1
4	4	wa	mrs	grades_3_5	2	1

In [ ]:

```
y = data['project_is_approved'].values
X = data.drop(['project_is_approved'], axis=1)
X.head(2)
```

Out[ ]:

	Unnamed: 0	school_state	teacher_prefix	project_grade_category	teacher_number_of_previously_posted_projects	clean_categories	cl
0	0	ca	mrs	grades_prek_2	53	math_science	
1	1	ut	ms	grades_3_5	4	specialneeds	

In [ ]:

```
y = y.reshape(-1,1)
print(y.shape)
```

```
(109248, 1)
```

Splitting the data

In [ ]:

```
data_train, data_val, label_train, label_val  = train_test_split(X, y, test_size=0.2, stratify=y, r
andom_state=42)
data_train, data_test, label_train, label_test = train_test_split(data_train, label_train, test_siz
e=0.2, stratify=label_train, random_state=42)
```

In [ ]:

```
print(data_train.shape)
print(data_val.shape)
print(data_test.shape)
print(label_train.shape)
print(label_val.shape)
print(label_test.shape)
```

```
(69918, 14)
(21850, 14)
(17480, 14)
(69918, 1)
(21850, 1)
(17480, 1)
```

In [ ]:

```
X_train = data_train
X_val = data_val
X_test = data_test
y_train = label_train
y_val = label_val
y_test = label_test
```

In [ ]:

```
print(X_train.shape)
print(X_val.shape)
print(X_test.shape)
print(y_train.shape)
print(y_val.shape)
print(y_test.shape)
```

```
(69918, 14)
(21850, 14)
(17480, 14)
(69918, 1)
(21850, 1)
(17480, 1)
```

1. Model -1

1. Vectorizing all features

1.1 School State -Categorical variable

In [ ]:

```
X_train['school_state'].nunique()
```

Out[ ]:

```
51
```

Note:

- School_state is a categorical features and i am embedding it using https://medium.com/@satnalikamayank12/on-learning-embeddings-for-categorical-data-using-keras-165ff2773fc9 and https://towardsdatascience.com/deep-embeddings-for-categorical-variables-cat2vec-b05c8ab63ac0

In [ ]:

```
lb_state = LabelEncoder()
lb_state.fit(X_train['school_state'])
X_train_Sstate = (lb_state.transform(X_train['school_state'])).reshape(-1,1)
X_val_Sstate = (lb_state.transform(X_val['school_state'])).reshape(-1,1)
X_test_Sstate = (lb_state.transform(X_test['school_state'])).reshape(-1,1)
```

In [ ]:

```
print((X_train_Sstate).shape)
print((X_val_Sstate).shape)
print((X_test_Sstate).shape)
```

```
(69918, 1)
(21850, 1)
(17480, 1)
```

In [ ]:

```
num_words_Sstate = X_train['school_state'].nunique() + 1
op_embedding_dim_Sstate = int(min(np.ceil(X_train['school_state'].nunique()/2), 50))

print(num_words_Sstate)
print(op_embedding_dim_Sstate)
```

```
52
26
```

1.2 Clean Categories

In [ ]:

```
print(X_train['clean_categories'].nunique())
```

```
51
```

In [ ]:

```
lb_cat = LabelEncoder()
lb_cat.fit(X_train['clean_categories'])
X_train_cat = (lb_cat.transform(X_train['clean_categories'])).reshape(-1,1)
X_val_cat = (lb_cat.transform(X_val['clean_categories'])).reshape(-1,1)
X_test_cat = (lb_cat.transform(X_test['clean_categories'])).reshape(-1,1)
```

In [ ]:

```
print((X_train_cat).shape)
print((X_val_cat).shape)
print((X_test_cat).shape)
```

```
(69918, 1)
(21850, 1)
(17480, 1)
```

In [ ]:

```
num_words_cat = X_train['clean_categories'].nunique() + 1
op_embedding_dim_cat = int(min(np.ceil(X_train['clean_categories'].nunique()/2), 50))

print(num_words_cat)
print(op_embedding_dim_cat)
```

```
52
26
```

1.3 Clean Sub categories

In [ ]:

```
print(X_train['clean_subcategories'].nunique())
```

```
392
```

In [ ]:

```
#https://stackoverflow.com/questions/21057621/sklearn-labelencoder-with-never-seen-before-values
lb_subcat = LabelEncoder()
lb_subcat.fit(X_train['clean_subcategories'])

#if there is any unseen values in val and test from train put it as <unknown> and add it to the la
bel encoder class as mentioned in the link above
X_val['clean_subcategories'] = X_val['clean_subcategories'].map(lambda x: '<unknown>' if x not in l
b_subcat.classes_ else x)
X_test['clean_subcategories'] = X_test['clean_subcategories'].map(lambda x: '<unknown>' if x not in
lb_subcat.classes_ else x )
lb_subcat.classes_ = np.append(lb_subcat.classes_, '<unknown>')

X_train_subcat = (lb_subcat.transform(X_train['clean_subcategories'])).reshape(-1,1)
X_val_subcat = (lb_subcat.transform(X_val['clean_subcategories'])).reshape(-1,1)
X_test_subcat = (lb_subcat.transform(X_test['clean_subcategories'])).reshape(-1,1)
```

```
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:6: SettingWithCopyWarning:


A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
```

In [ ]:

```
print(X_train_subcat.shape)
print(X_val_subcat.shape)
print(X_test_subcat.shape)
```

```
(69918, 1)
(21850, 1)
(17480, 1)
```

In [ ]:

```
num_words_subcat = X_train['clean_subcategories'].nunique() + 1        # vocab = no of unique catego
ry + 1
op_embedding_dim_subcat = int(min(np.ceil(X_train['clean_subcategories'].nunique()/2), 50))

print(num_words_subcat)
print(op_embedding_dim_subcat)
```

```
393
50
```

1.4 Project Grade Category

In [ ]:

```
print(X_train['project_grade_category'].nunique())
```

```
4
```

In [ ]:

```
lb_grade = LabelEncoder()
lb_grade.fit(X_train['project_grade_category'])
X_train_grade = (lb_grade.transform(X_train['project_grade_category'])).reshape(-1,1)
X_val_grade = (lb_grade.transform(X_val['project_grade_category'])).reshape(-1,1)
X_test_grade = (lb_grade.transform(X_test['project_grade_category'])).reshape(-1,1)
```

In [ ]:

```
print(X_train_grade.shape)
print(X_val_grade.shape)
print(X_test_grade.shape)
```

```
(69918, 1)
(21850, 1)
(17480, 1)
```

In [ ]:

```
num_words_grade = X_train['project_grade_category'].nunique() + 1
op_embedding_dim_grade = int(min(np.ceil(X_train['project_grade_category'].nunique()/2), 50))

print(num_words_grade)
print(op_embedding_dim_grade)
```

```
5
2
```

1.5 Teacher Prefix

In [ ]:

```
print(X_train['teacher_prefix'].nunique())
```

```
5
```

In [ ]:

```
lb_prefix = LabelEncoder()
lb_prefix.fit(X_train['teacher_prefix'])
X_train_prefix = (lb_prefix.transform(X_train['teacher_prefix'])).reshape(-1,1)
X_val_prefix = (lb_prefix.transform(X_val['teacher_prefix'])).reshape(-1,1)
X_test_prefix = (lb_prefix.transform(X_test['teacher_prefix'])).reshape(-1,1)
```

In [ ]:

```
print(X_train_prefix.shape)
print(X_val_prefix.shape)
print(X_test_prefix.shape)
```

```
(69918, 1)
(21850, 1)
(17480, 1)
```

In [ ]:

```
num_words_prefix = X_train['teacher_prefix'].nunique() + 1
op_embedding_dim_prefix = int(min(np.ceil(X_train['teacher_prefix'].nunique()/2), 50))

print(num_words_prefix)
print(op_embedding_dim_prefix)
```

```
6
3
```

1.6 Combined Text : Essay and Project title

1.6.1 Embedding using Glove

In [ ]:

```
combined_text_train = X_train['essay']+X_train['title']
combined_text_val = X_val['essay'] + X_val['title']
combined_text_test = X_test['essay'] + X_test['title']
combined_text_train.head()
```

Out[ ]:

```
16528    my pre kindergarten students risk students mos...
99416    my middle school students little no access cre...
47276    the students class love read using technology ...
75882    most students live poverty level they talented...
41540    in class i diverse group students different ba...
dtype: object
```

In [ ]:

```
#https://machinelearningmastery.com/use-word-embedding-layers-deep-learning-keras/
from keras.preprocessing.sequence import pad_sequences

docs_train = [i for i in combined_text_train]
docs_val = [i for i in combined_text_val]
docs_test = [i for i in combined_text_test]

#tokenizer fitting on training data
tokenizer_combined_text = Tokenizer(num_words=5000)
tokenizer_combined_text.fit_on_texts(docs_train)

#encode as per the tokenizer in docs_train
encoded_docs_train = tokenizer_combined_text.texts_to_sequences(docs_train)
encoded_docs_val = tokenizer_combined_text.texts_to_sequences(docs_val)
encoded_docs_test = tokenizer_combined_text.texts_to_sequences(docs_test)

#padding the encoded docs with maximum length
max_length_combined_text = 400
X_train_combined_text = pad_sequences(encoded_docs_train, maxlen=max_length_combined_text, padding=
'post', truncating='post')
X_val_combined_text = pad_sequences(encoded_docs_val, maxlen=max_length_combined_text, padding='pos
t', truncating='post')
X_test_combined_text = pad_sequences(encoded_docs_test, maxlen=max_length_combined_text,
padding='post', truncating='post')
```

In [ ]:

```
print(X_train_combined_text.shape)
print(X_val_combined_text.shape)
print(X_test_combined_text.shape)
```

```
(69918, 400)
(21850, 400)
(17480, 400)
```

In [ ]:

```
with open('/content/drive/My Drive/Applied AI/Datasets/New Donors/glove_vectors', 'rb') as f:
```

```
with open('/content/drive/My Drive/Applied AI/Datasets/New Donors/glove_vectors', 'rb') as f:
    model = pickle.load(f)
    glove_words = set(model.keys())
```

In [ ]:

```
#creating a embedding matrix
max_words_combined_text = 5000
op_embedding_dim_combined_text = 300                                        # dimension of every woı
in glove model

embedding_matrix = np.zeros(shape=(max_words_combined_text, op_embedding_dim_combined_text))       #
shape= (vocab_size_combined_text,300)

for word, i in tokenizer_combined_text.word_index.items():
    if i < max_words_combined_text:
      try:
        embedding_vector = model[word]

        if embedding_vector is not None:
            embedding_matrix[i] = embedding_vector

      except:
          print('The word is not in the glove model:', word)
```

```
The word is not in the glove model: hokki
The word is not in the glove model: nannanhelp
The word is not in the glove model: nannanwe
The word is not in the glove model: nannana
The word is not in the glove model: nannanflexible
The word is not in the glove model: nannanlet
The word is not in the glove model: nannantechnology
The word is not in the glove model: nannanthe
The word is not in the glove model: nannanlearning
The word is not in the glove model: nannanreading
The word is not in the glove model: nannanchromebooks
The word is not in the glove model: nannanbuilding
The word is not in the glove model: nannanmaking
The word is not in the glove model: nannanwiggle
The word is not in the glove model: nannanbooks
The word is not in the glove model: nannanmath
The word is not in the glove model: nannanstem
The word is not in the glove model: nannancreating
The word is not in the glove model: nannani
The word is not in the glove model: nannanclassroom
The word is not in the glove model: nannanhands
The word is not in the glove model: nannanipads
The word is not in the glove model: nannanwobble
The word is not in the glove model: nannangetting
The word is not in the glove model: nannansupplies
The word is not in the glove model: nannanour
The word is not in the glove model: ozobots
The word is not in the glove model: nannanread
The word is not in the glove model: nannanscience
The word is not in the glove model: nannanipad
The word is not in the glove model: nannannew
The word is not in the glove model: nannanbringing
The word is not in the glove model: nannanit
The word is not in the glove model: nannanmoving
The word is not in the glove model: nannanget
The word is not in the glove model: nannanlistening
The word is not in the glove model: nannanart
The word is not in the glove model: nannanactive
The word is not in the glove model: nannanan
The word is not in the glove model: nannantech
The word is not in the glove model: nannanengaging
The word is not in the glove model: nannanhealthy
The word is not in the glove model: nannancan
The word is not in the glove model: nannanstudents
The word is not in the glove model: nannankeep
The word is not in the glove model: nannanmake
The word is not in the glove model: storyworks
The word is not in the glove model: nannanteaching
The word is not in the glove model: nannanmy
The word is not in the glove model: nannansensory
The word is not in the glove model: nannanready
The word is not in the glove model: nannankeeping
The word is not in the glove model: nannankindergarten
The word is not in the glove model: fitbits
The word is not in the glove model: nannanlisten
The word is not in the glove model: ozobot
The word is not in the glove model: gonoodle
The word is not in the glove model: nannan21st
The word is not in the glove model: nannanfirst
The word is not in the glove model: nannanusing
The word is not in the glove model: nannanalternative
The word is not in the glove model: nannanlittle
The word is not in the glove model: nannaninteractive
The word is not in the glove model: nannanexploring
The word is not in the glove model: nannanfun
The word is not in the glove model: nannanstudent
The word is not in the glove model: nannanheadphones
The word is not in the glove model: nannanfull
The word is not in the glove model: nannangrowing
The word is not in the glove model: nannanwhat
The word is not in the glove model: nannantablets
The word is not in the glove model: nannanall
The word is not in the glove model: nannancreative
The word is not in the glove model: nannansuper
The word is not in the glove model: nannanmore
The word is not in the glove model: nannanbook
The word is not in the glove model: nannanempowering
The word is not in the glove model: nannantime
The word is not in the glove model: nannanmrs
The word is not in the glove model: nannanspecial
The word is not in the glove model: nannanchrome
The word is not in the glove model: nannanchromebook
The word is not in the glove model: nannansteam
The word is not in the glove model: nannancomfy
The word is not in the glove model: nannanliteracy
The word is not in the glove model: nannantake
The word is not in the glove model: nannanfuture
The word is not in the glove model: nannanplease
The word is not in the glove model: nannanmusic
The word is not in the glove model: nannanwriting
The word is not in the glove model: nannancolor
The word is not in the glove model: nannanbring
The word is not in the glove model: nannanstand
The word is not in the glove model: nannanschool
The word is not in the glove model: nannancoding
The word is not in the glove model: nannanon
The word is not in the glove model: nannanyou
```

Note:

- These are the words that are not in glove model.

In [ ]:

```
print(embedding_matrix.shape)
```

```
(5000, 300)
```

1.7 Price

1.7.1 Price Unstandardised

In [ ]:

```
X_train_price_unstandardized = X_train['price'].values.reshape(-1,1)
X_val_price_unstandardized = X_val['price'].values.reshape(-1,1)
X_test_price_unstandardized = X_test['price'].values.reshape(-1,1)
```

In [ ]:

```
print(X_train_price_unstandardized.shape)
print(X_val_price_unstandardized.shape)
print(X_test_price_unstandardized.shape)
```

```
(69918, 1)
(21850, 1)
(17480, 1)
```

1.7.2 Price Standardized

In [ ]:

```
from sklearn.preprocessing import StandardScaler
sc_price = StandardScaler()
X_train_price = sc_price.fit_transform(X_train['price'].values.reshape(-1,1))
X_val_price = sc_price.transform(X_val['price'].values.reshape(-1,1))
X_test_price = sc_price.transform(X_test['price'].values.reshape(-1,1))
```

In [ ]:

```
print(X_train_price.shape)
print(X_val_price.shape)
print(X_test_price.shape)
```

```
(69918, 1)
(21850, 1)
(17480, 1)
```

1.8 Previously posted Projects

1.8.1 Unstandardized

In [ ]:

```
X_train_previous_unstandardized = X_train['teacher_number_of_previously_posted_projects'].values.r
eshape(-1,1)
X_val_previous_unstandardized =
X_val['teacher_number_of_previously_posted_projects'].values.reshape(-1,1)
X_test_previous_unstandardized =
X_test['teacher_number_of_previously_posted_projects'].values.reshape(-1,1)
```

In [ ]:

```
print(X_train_previous_unstandardized.shape)
print(X_val_previous_unstandardized.shape)
print(X_test_previous_unstandardized.shape)
```

```
(69918, 1)
(21850, 1)
(17480, 1)
```

1.8.2 Standardized

In [ ]:

```
from sklearn.preprocessing import StandardScaler
sc_previous = StandardScaler()
X_train_previous =
sc_previous.fit_transform(X_train['teacher_number_of_previously_posted_projects'].values.reshape(-
1,1))
X_val_previous =
sc_previous.transform(X_val['teacher_number_of_previously_posted_projects'].values.reshape(-1,1))
X_test_previous =
sc_previous.transform(X_test['teacher_number_of_previously_posted_projects'].values.reshape(-1,1))
```

In [ ]:

```
print(X_train_previous.shape)
print(X_val_previous.shape)
print(X_test_previous.shape)
```

```
(69918, 1)
(21850, 1)
(17480, 1)
```

1.9 Quantity

In [ ]:

```
X_train_quantity_unstandardized = X_train['quantity'].values.reshape(-1,1)
X_val_quantity_unstandardized = X_val['quantity'].values.reshape(-1,1)
X_test_quantity_unstandardized = X_test['quantity'].values.reshape(-1,1)
```

In [ ]:

```
print(X_train_quantity_unstandardized.shape)
print(X_val_quantity_unstandardized.shape)
print(X_test_quantity_unstandardized.shape)
```

```
(69918, 1)
(21850, 1)
(17480, 1)
```

1.9.2 Quantity standardized

In [ ]:

```
sc_quantity = StandardScaler()
X_train_quantity = sc_quantity.fit_transform(X_train['quantity'].values.reshape(-1,1))
X_val_quantity = sc_quantity.transform(X_val['quantity'].values.reshape(-1,1))
X_test_quantity = sc_quantity.transform(X_test['quantity'].values.reshape(-1,1))
```

In [ ]:

```
print(X_train_quantity.shape)
print(X_val_quantity.shape)
print(X_test_quantity.shape)
```

```
(69918, 1)
(21850, 1)
(17480, 1)
```

1.10 Taking only 10k points

In [ ]:

```
X_train_Sstate[0:10000].shape
```

Out[ ]:

```
(10000, 1)
```

In [ ]:

```
X_train_combined_text = X_train_combined_text[0:10000]
X_train_Sstate = X_train_Sstate[0:10000]
X_train_cat = X_train_cat[0:10000]
X_train_subcat = X_train_subcat[0:10000]
```

```
X_train_grade = X_train_grade[0:10000]
X_train_prefix = X_train_prefix[0:10000]
X_train_price = X_train_price[0:10000]
X_train_previous = X_train_previous[0:10000]
X_train_quantity = X_train_quantity[0:10000]
```

In [ ]:

```
#as per the task in order to use categorical cross entropy as a loss
from tensorflow.keras.utils import to_categorical
y_train = to_categorical(y_train, 2)
y_val = to_categorical(y_val, 2)

print(y_train.shape)
```

```
(69918, 2)
```

In [ ]:

```
y_train = y_train[0:10000]
print(y_train.shape)
```

```
(10000, 2)
```

In [ ]:

```
print(X_train_Sstate.shape)
print(X_train_cat.shape)
print(X_train_subcat.shape)
print(X_train_grade.shape)
print(X_train_prefix.shape)
print(X_train_price.shape)
print(X_train_previous.shape)
print(X_train_quantity.shape)
print(X_train_combined_text.shape)

print('='*50)
print(X_val_Sstate.shape)
print(X_val_cat.shape)
print(X_val_subcat.shape)
print(X_val_grade.shape)
print(X_val_prefix.shape)
print(X_val_price.shape)
print(X_val_previous.shape)
print(X_val_quantity.shape)
print(X_val_combined_text.shape)

print('='*50)
print(X_test_Sstate.shape)
print(X_test_cat.shape)
print(X_test_subcat.shape)
print(X_test_grade.shape)
print(X_test_prefix.shape)
print(X_test_price.shape)
print(X_test_previous.shape)
print(X_test_quantity.shape)
print(X_test_combined_text.shape)
```

```
(10000, 1)
(10000, 1)
(10000, 1)
(10000, 1)
(10000, 1)
(10000, 1)
(10000, 1)
(10000, 1)
(10000, 400)
==================================================
(21850, 1)
(21850, 1)
(21850, 1)
(21850, 1)
```

```
(21850, 1)
(21850, 1)
(21850, 1)
(21850, 1)
(21850, 400)
==================================================
(17480, 1)
(17480, 1)
(17480, 1)
(17480, 1)
(17480, 1)
(17480, 1)
(17480, 1)
(17480, 1)
(17480, 400)
```

2. Building Model-1

2.1 Concatenate numerical features

In [ ]:

```
#concatenate all numerical features
num_features_train = np.concatenate((X_train_price, X_train_previous, X_train_quantity), axis=1)
num_features_val = np.concatenate((X_val_price, X_val_previous, X_val_quantity), axis=1)
```

In [ ]:

```
num_features_train.shape
```

Out[ ]:

```
(10000, 3)
```

In [ ]:

```
num_features_train[0]
```

Out[ ]:

```
array([ 4.16454846, -0.40445317, -0.30566232])
```

Note:

- Embedding layer:

1. input_dim = max words we used --> 5000
2. output_dim = dimension of each word (after glove ,its 300)
3. input_length = size of each input_sentence -->(here 400 after truncating)

In [ ]:

```
#https://www.tensorflow.org/guide/keras/functional

# 1.combined text
#input_combined_text = Input(shape=(len(X_train_combined_text_embed[0]),), name='combined_text')
input_combined_text = tf.keras.Input(shape=(X_train_combined_text.shape[1]), name='combined_text')
embedding_layer_combined_text = tf.keras.layers.Embedding(max_words_combined_text,
#5000 number of words in vocabulary
                                                          op_embedding_dim_combined_text,
#300 dim of glove model
                                                          input_length=X_train_combined_text.shape
,  #400 max sequence length
                                                          weights=[embedding_matrix], trainable=Fal
,
                                                          name = 'embed_text')(input_combined_text)
lstm_combined_text = tf.keras.layers.LSTM(5, return_sequences=True)(embedding_layer_combined_text)
```

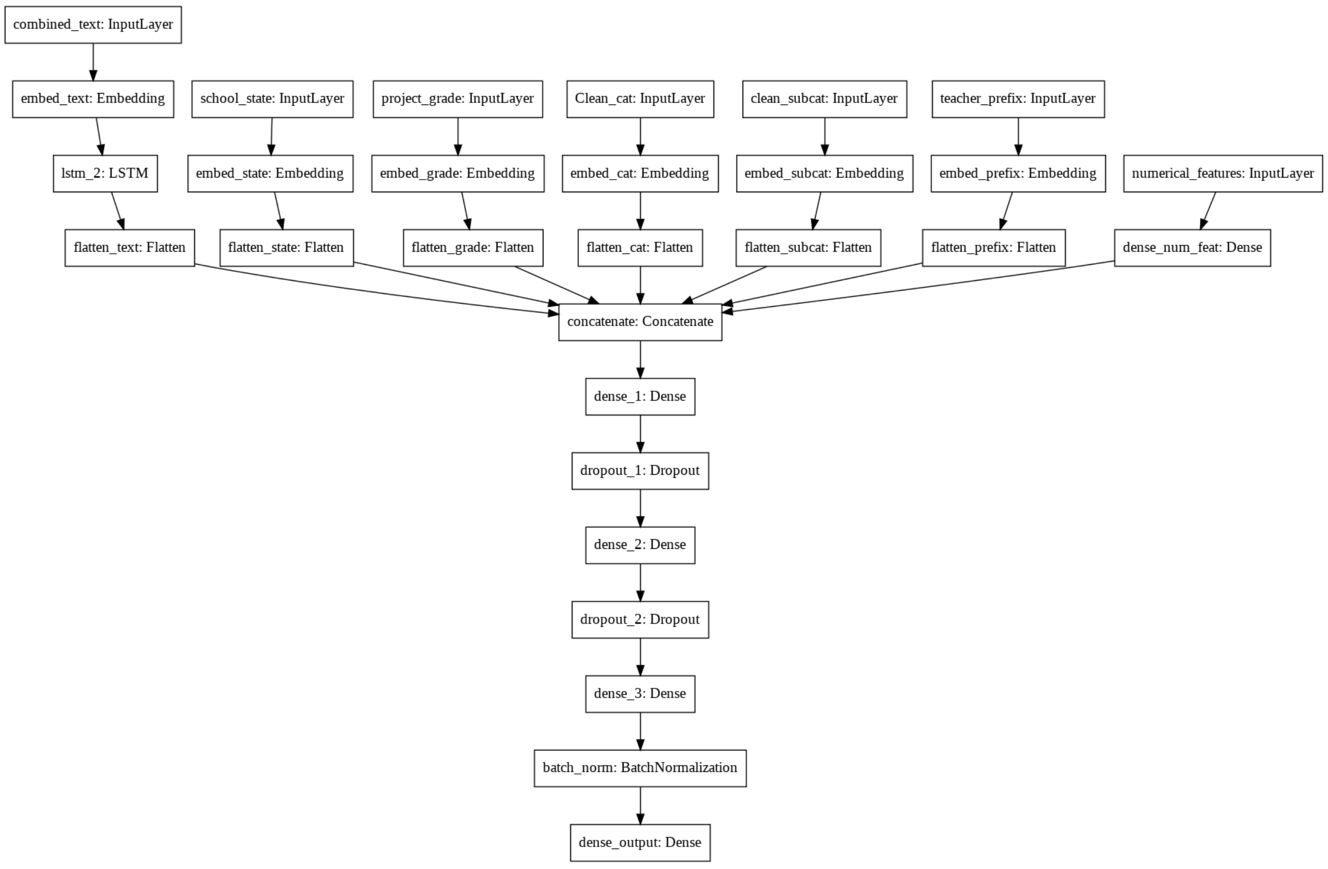
```
flatten_combined_text = tf.keras.layers.Flatten(name='flatten_text')(lstm_combined_text)

# 2.School state
input_Sstate = tf.keras.Input(shape=(X_train_Sstate.shape[1]), name='school_state')
embedding_layer_Sstate = tf.keras.layers.Embedding(input_dim=num_words_Sstate,
# 51 unique states +1
                                                    output_dim=op_embedding_dim_Sstate,
# 26
                                                    input_length=X_train_Sstate.shape[1],
# 1
                                                    name = 'embed_state')(input_Sstate)
flatten_Sstate = tf.keras.layers.Flatten(name='flatten_state')(embedding_layer_Sstate)

# 3.Project grade
input_grade = tf.keras.Input(shape=(X_train_grade.shape[1]), name='project_grade')
embedding_layer_grade = tf.keras.layers.Embedding(input_dim=num_words_grade,
# 4 grades +1
                                                   output_dim=op_embedding_dim_grade,
# 2
                                                   input_length=X_train_grade.shape[1],
# 1
                                                   name = 'embed_grade')(input_grade)
flatten_grade = tf.keras.layers.Flatten(name='flatten_grade')(embedding_layer_grade)

# 4.Categories
input_cat = tf.keras.Input(shape=(X_train_cat.shape[1]), name='Clean_cat')
embedding_layer_cat = tf.keras.layers.Embedding(input_dim=num_words_cat,
# 51 category +1
                                                 output_dim=op_embedding_dim_cat,
# 26
                                                 input_length=X_train_cat.shape[1],
# 1
                                                 name='embed_cat')(input_cat)
flatten_cat = tf.keras.layers.Flatten(name='flatten_cat')(embedding_layer_cat)

# 5.Sub categories
input_subcat = tf.keras.Input(shape=(X_train_subcat.shape[1]), name='clean_subcat')
embedding_layer_subcat = tf.keras.layers.Embedding(input_dim=num_words_subcat,
# 392 subcat +1
                                                    output_dim=op_embedding_dim_subcat,
# 50
                                                    input_length=X_train_subcat.shape[1],
# 1
                                                    name='embed_subcat')(input_subcat)
flatten_subcat = tf.keras.layers.Flatten(name='flatten_subcat')(embedding_layer_subcat)

# 6.Teacher prefix
input_prefix = tf.keras.Input(shape=(X_train_prefix.shape[1]), name='teacher_prefix')
embedding_layer_prefix = tf.keras.layers.Embedding(input_dim=num_words_prefix,
# 5 prefix + 1
                                                    output_dim=op_embedding_dim_prefix,
# 3
                                                    input_length=X_train_prefix.shape[1],
# 1
                                                    name='embed_prefix')(input_prefix)
flatten_prefix = tf.keras.layers.Flatten(name='flatten_prefix')(embedding_layer_prefix)

# 7.Numerical features
input_num_feat = tf.keras.Input(shape=(num_features_train.shape[1],), name='numerical_features')
# 3 for each numerical feature after concat
dense_num_feat = tf.keras.layers.Dense(1, activation='relu', name='dense_num_feat')(input_num_feat)

#Concatenate and flatten
concat_layers = tf.keras.layers.concatenate([flatten_combined_text, flatten_Sstate, flatten_grade,
flatten_cat,
                                              flatten_subcat, flatten_prefix, dense_num_feat],
name='concatenate')

#Dense layer
x = tf.keras.layers.Dense(128, activation='relu', name='dense_1')(concat_layers)
x = tf.keras.layers.Dropout(0.5, name='dropout_1')(x)
x = tf.keras.layers.Dense(128, activation='relu', name='dense_2')(x)
x = tf.keras.layers.Dropout(0.4, name='dropout_2')(x)
x = tf.keras.layers.Dense(32, activation='relu', name='dense_3')(x)
x = tf.keras.layers.BatchNormalization(name='batch_norm')(x)

#output
```

```
output = tf.keras.layers.Dense(2, activation='softmax', name='dense_output')(x)

inputs = [input_combined_text, input_Sstate, input_grade, input_cat, input_subcat, input_prefix, in
put_num_feat]
model_1 = tf.keras.Model(inputs=inputs, outputs=output, name='model-1')
```

In [ ]:

```
tf.keras.utils.plot_model(model_1, 'model_1.png', show_shapes=False)
```

Out[ ]:



In [ ]:

```
model_1.summary()
```

```
Model: "model-1"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
combined_text (InputLayer)      [(None, 400)]        0
__________________________________________________________________________________________________
embed_text (Embedding)          (None, 400, 300)     1500000     combined_text[0][0]
__________________________________________________________________________________________________
school_state (InputLayer)       [(None, 1)]          0
__________________________________________________________________________________________________
project_grade (InputLayer)      [(None, 1)]          0
__________________________________________________________________________________________________
Clean_cat (InputLayer)          [(None, 1)]          0
__________________________________________________________________________________________________
clean_subcat (InputLayer)       [(None, 1)]          0
__________________________________________________________________________________________________
teacher_prefix (InputLayer)     [(None, 1)]          0
__________________________________________________________________________________________________
lstm_6 (LSTM)                   (None, 400, 5)       6120        embed_text[0][0]
__________________________________________________________________________________________________
embed_state (Embedding)         (None, 1, 26)        1352        school_state[0][0]
__________________________________________________________________________________________________
embed_grade (Embedding)         (None, 1, 2)         10          project_grade[0][0]
__________________________________________________________________________________________________
embed_cat (Embedding)           (None, 1, 26)        1352        Clean_cat[0][0]
```

```
________________________________________________________________________________________________
embed_subcat (Embedding)        (None, 1, 50)        19650       clean_subcat[0][0]
________________________________________________________________________________________________
embed_prefix (Embedding)        (None, 1, 3)         18          teacher_prefix[0][0]
________________________________________________________________________________________________
numerical_features (InputLayer) [(None, 3)]          0
________________________________________________________________________________________________
flatten_text (Flatten)          (None, 2000)         0           lstm_6[0][0]
________________________________________________________________________________________________
flatten_state (Flatten)         (None, 26)           0           embed_state[0][0]
________________________________________________________________________________________________
flatten_grade (Flatten)         (None, 2)            0           embed_grade[0][0]
________________________________________________________________________________________________
flatten_cat (Flatten)           (None, 26)           0           embed_cat[0][0]
________________________________________________________________________________________________
flatten_subcat (Flatten)        (None, 50)           0           embed_subcat[0][0]
________________________________________________________________________________________________
flatten_prefix (Flatten)        (None, 3)            0           embed_prefix[0][0]
________________________________________________________________________________________________
dense_num_feat (Dense)          (None, 1)            4           numerical_features[0][0]
________________________________________________________________________________________________
concatenate (Concatenate)       (None, 2108)         0           flatten_text[0][0]
                                                                 flatten_state[0][0]
                                                                 flatten_grade[0][0]
                                                                 flatten_cat[0][0]
                                                                 flatten_subcat[0][0]
                                                                 flatten_prefix[0][0]
                                                                 dense_num_feat[0][0]
________________________________________________________________________________________________
dense_1 (Dense)                 (None, 128)          269952      concatenate[0][0]
________________________________________________________________________________________________
dropout_1 (Dropout)             (None, 128)          0           dense_1[0][0]
________________________________________________________________________________________________
dense_2 (Dense)                 (None, 128)          16512       dropout_1[0][0]
________________________________________________________________________________________________
dropout_2 (Dropout)             (None, 128)          0           dense_2[0][0]
________________________________________________________________________________________________
dense_3 (Dense)                 (None, 32)           4128        dropout_2[0][0]
________________________________________________________________________________________________
batch_norm (BatchNormalization) (None, 32)           128         dense_3[0][0]
________________________________________________________________________________________________
dense_output (Dense)            (None, 2)            66          batch_norm[0][0]
================================================================================================
Total params: 1,819,292
Trainable params: 319,228
Non-trainable params: 1,500,064
________________________________________________________________________________________________
```

2.1 Callbacks

In [ ]:

```
#https://colab.research.google.com/github/tensorflow/tensorboard/blob/master/docs/tensorboard_in_no
oks.ipynb
from tensorflow.keras.callbacks import TensorBoard

tb_path = '/content/drive/My Drive/Applied AI/Assignment/Assign 16-
LSTM/callbacks/tensorboard_model_1/'
tb = TensorBoard(log_dir=tb_path, histogram_freq=2, write_graph=True)
```

In [ ]:

```
#https://medium.com/@mukesh.kumar43585/model-checkpoint-google-colab-and-drive-as-persistent-stora
ge-for-long-training-runs-e35ffa0c33d9
from tensorflow.keras.callbacks import ModelCheckpoint
checkpoint_path = '/content/drive/My Drive/Applied AI/Assignment/Assign 16-
LSTM/callbacks/checkpoint_model_1/weights.{epoch:02d}-{val_loss:.2f}.hdf5'
checkpoint = ModelCheckpoint(checkpoint_path, monitor='val_auroc', verbose=1, save_best_only=True,
mode='max')
```

In [ ]:

```
#Early stopping
```

```
from tensorflow.keras.callbacks import EarlyStopping
early_stopping = EarlyStopping(monitor='val_loss', patience=10, verbose=2, mode='min', restore_best
_weights=True)
```

In [ ]:

```
#Reduce learning rate
from tensorflow.keras.callbacks import ReduceLROnPlateau
reduce_lr = ReduceLROnPlateau(monitor='val_auroc', factor=0.1)
```

In [ ]:

```
#https://github.com/taomanwai/tensorboardcolab
# https://medium.com/@mukesh.kumar43585/model-checkpoint-google-colab-and-drive-as-persistent-stor
age-for-long-training-runs-e35ffa0c33d9

callbacks_list = [tb, checkpoint, early_stopping, reduce_lr]
```

2.2 Metrics

In [ ]:

```
#https://stackoverflow.com/questions/41032551/how-to-compute-receiving-operating-characteristic-ro
c-and-auc-in-keras
import tensorflow as tf
from sklearn.metrics import roc_auc_score
def auc1(y_true, y_pred):                          #if there is only one class in y_true return roc scc
re as 0.5
    if len(np.unique(y_true[:,1])) == 1:
        return 0.5
    else:
        return roc_auc_score(y_true, y_pred)

def auroc(y_true, y_pred):
    return tf.py_function(auc1, (y_true, y_pred), tf.double)
```

2.3 Model Compile

In [ ]:

```
#compile
model_1.compile(optimizer='adam', loss='categorical_crossentropy', metrics=[auroc])
```

In [ ]:

```
batch_size = 128
epochs = 50
```

In [ ]:

```
train_data_1 = [X_train_combined_text, X_train_Sstate, X_train_grade, X_train_cat, X_train_subcat,
X_train_prefix, num_features_train]
val_data_1 = [X_val_combined_text, X_val_Sstate, X_val_grade, X_val_cat, X_val_subcat, X_val_prefix
, num_features_val]
```

2.4 Model fit

In [ ]:

```
history_1 = model_1.fit(train_data_1, y_train, callbacks=callbacks_list,
validation_data=(val_data_1, y_val), verbose=2, batch_size=batch_size, epochs=epochs)
```

```
Epoch 1/50
WARNING:tensorflow:Method (on_train_batch_end) is slow compared to the batch update (0.115452). Ch
eck your callbacks.
```

```
Epoch 00001: val_auroc improved from -inf to 0.60588, saving model to /content/drive/My
Drive/Applied AI/Assignment/Assign 16- LSTM/callbacks/checkpoint_model_1/weights.01-0.51.hdf5
79/79 - 7s - loss: 0.7053 - auroc: 0.5038 - val_loss: 0.5116 - val_auroc: 0.6059 - lr: 0.0010
Epoch 2/50

Epoch 00002: val_auroc improved from 0.60588 to 0.62823, saving model to /content/drive/My
Drive/Applied AI/Assignment/Assign 16- LSTM/callbacks/checkpoint_model_1/weights.02-0.43.hdf5
79/79 - 7s - loss: 0.4919 - auroc: 0.5284 - val_loss: 0.4276 - val_auroc: 0.6282 - lr: 0.0010
Epoch 3/50

Epoch 00003: val_auroc improved from 0.62823 to 0.65817, saving model to /content/drive/My
Drive/Applied AI/Assignment/Assign 16- LSTM/callbacks/checkpoint_model_1/weights.03-0.42.hdf5
79/79 - 7s - loss: 0.4400 - auroc: 0.5640 - val_loss: 0.4203 - val_auroc: 0.6582 - lr: 0.0010
Epoch 4/50

Epoch 00004: val_auroc improved from 0.65817 to 0.67422, saving model to /content/drive/My
Drive/Applied AI/Assignment/Assign 16- LSTM/callbacks/checkpoint_model_1/weights.04-0.41.hdf5
79/79 - 7s - loss: 0.4217 - auroc: 0.6181 - val_loss: 0.4081 - val_auroc: 0.6742 - lr: 0.0010
Epoch 5/50

Epoch 00005: val_auroc improved from 0.67422 to 0.69735, saving model to /content/drive/My
Drive/Applied AI/Assignment/Assign 16- LSTM/callbacks/checkpoint_model_1/weights.05-0.42.hdf5
79/79 - 7s - loss: 0.4050 - auroc: 0.6798 - val_loss: 0.4162 - val_auroc: 0.6974 - lr: 0.0010
Epoch 6/50

Epoch 00006: val_auroc improved from 0.69735 to 0.70812, saving model to /content/drive/My
Drive/Applied AI/Assignment/Assign 16- LSTM/callbacks/checkpoint_model_1/weights.06-0.40.hdf5
79/79 - 7s - loss: 0.3908 - auroc: 0.7107 - val_loss: 0.3956 - val_auroc: 0.7081 - lr: 0.0010
Epoch 7/50

Epoch 00007: val_auroc improved from 0.70812 to 0.71295, saving model to /content/drive/My
Drive/Applied AI/Assignment/Assign 16- LSTM/callbacks/checkpoint_model_1/weights.07-0.40.hdf5
79/79 - 7s - loss: 0.3814 - auroc: 0.7348 - val_loss: 0.4044 - val_auroc: 0.7130 - lr: 0.0010
Epoch 8/50

Epoch 00008: val_auroc did not improve from 0.71295
79/79 - 7s - loss: 0.3680 - auroc: 0.7640 - val_loss: 0.4127 - val_auroc: 0.7067 - lr: 0.0010
Epoch 9/50

Epoch 00009: val_auroc did not improve from 0.71295
79/79 - 7s - loss: 0.3522 - auroc: 0.7858 - val_loss: 0.4173 - val_auroc: 0.7106 - lr: 0.0010
Epoch 10/50

Epoch 00010: val_auroc did not improve from 0.71295
79/79 - 7s - loss: 0.3354 - auroc: 0.8143 - val_loss: 0.4228 - val_auroc: 0.7087 - lr: 0.0010
Epoch 11/50

Epoch 00011: val_auroc did not improve from 0.71295
79/79 - 7s - loss: 0.3110 - auroc: 0.8474 - val_loss: 0.4048 - val_auroc: 0.7007 - lr: 0.0010
Epoch 12/50

Epoch 00012: val_auroc did not improve from 0.71295
79/79 - 7s - loss: 0.2727 - auroc: 0.8878 - val_loss: 0.4385 - val_auroc: 0.6991 - lr: 1.0000e-04
Epoch 13/50

Epoch 00013: val_auroc did not improve from 0.71295
79/79 - 7s - loss: 0.2544 - auroc: 0.8998 - val_loss: 0.4467 - val_auroc: 0.6966 - lr: 1.0000e-04
Epoch 14/50

Epoch 00014: val_auroc did not improve from 0.71295
79/79 - 7s - loss: 0.2448 - auroc: 0.9132 - val_loss: 0.4587 - val_auroc: 0.6927 - lr: 1.0000e-04
Epoch 15/50

Epoch 00015: val_auroc did not improve from 0.71295
79/79 - 7s - loss: 0.2338 - auroc: 0.9161 - val_loss: 0.4668 - val_auroc: 0.6916 - lr: 1.0000e-04
Epoch 16/50

Epoch 00016: val_auroc did not improve from 0.71295
Restoring model weights from the end of the best epoch.
79/79 - 7s - loss: 0.2230 - auroc: 0.9223 - val_loss: 0.4811 - val_auroc: 0.6865 - lr: 1.0000e-04
Epoch 00016: early stopping
```

In [ ]:

```
y_pred_1 = model_1.predict(val_data_1)
```

```
y_pred_1 = model_1.predict(val_data_1)
print('AUC score:', roc_auc_score(y_val, y_pred_1))
```

```
AUC score: 0.7071735251007647
```

2.1.6 Tensorboard images

In [ ]:

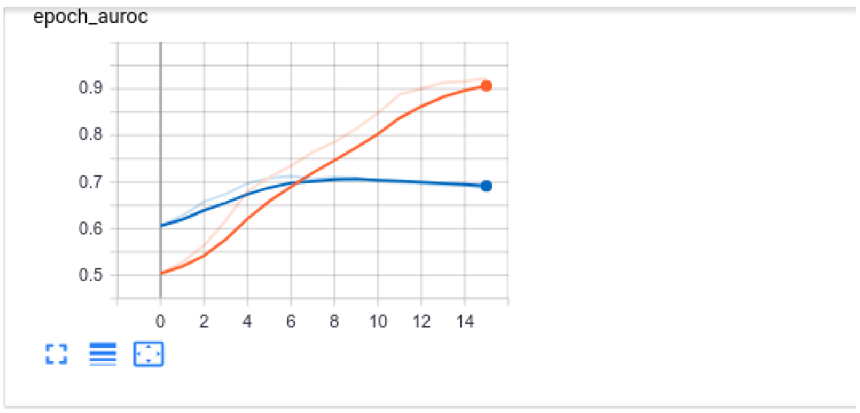
```
# Load the TensorBoard notebook extension
%load_ext tensorboard

%tensorboard --logdir '/content/drive/My Drive/Applied AI/Assignment/Assign 16-
LSTM/callbacks/tensorboard_model_1/'
```

```
The tensorboard extension is already loaded. To reload it, use:
  %reload_ext tensorboard
```

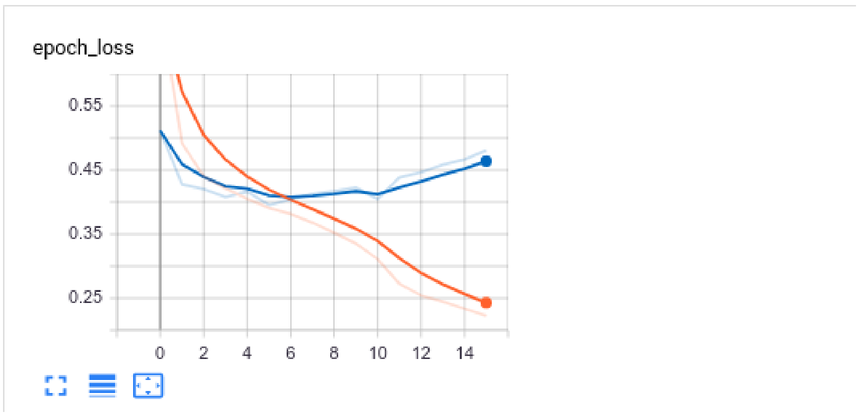
In [ ]:

```
from IPython.display import Image
Image('/content/drive/My Drive/Applied AI/Assignment /*Assign 16- LSTM /model_1_lstm.png')
```

Out[ ]:



epoch_loss



3.Model -2:

- Taking tfidf of essay and remove low idf and high idf words

In [ ]:

```
data.head()
```

Out[ ]:

	Unnamed: 0	school_state	teacher_prefix	project_grade_category	teacher_number_of_previously_posted_projects	project_is_approved
0	0	ca	mrs	grades_prek_2	53	1
1	1	ut	ms	grades_3_5	4	1
2	2	ca	mrs	grades_prek_2	10	1
3	3	ga	mrs	grades_prek_2	2	1
4	4	wa	mrs	grades_3_5	2	1

3.1Tfidf Vectorizer

In [ ]:

```
from sklearn.feature_extraction.text import TfidfVectorizer
vec = TfidfVectorizer()
vec.fit(X_train['essay'].values)
train_essay_tfidf = vec.transform(X_train['essay'].values)
val_essay_tfidf = vec.transform(X_val['essay'].values)
test_essay_tfidf = vec.transform(X_test['essay'].values)
```

In [ ]:

```
idf_words = dict(zip(vec.get_feature_names(), vec.idf_))
```

In [ ]:

```
print(len(idf_words))
```

```
47343
```

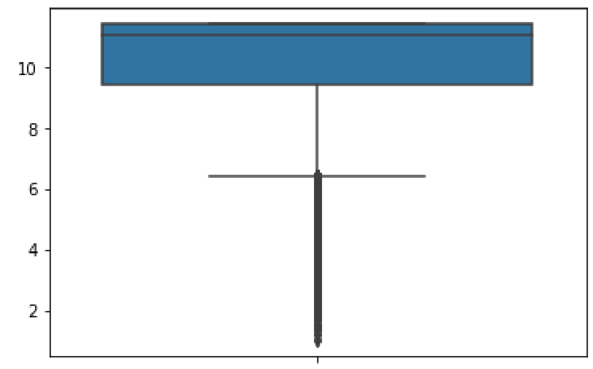
3.2 Boxplot in idf values

In [ ]:

```
idf = []
for k,v in idf_words.items():
    idf.append(v)
```

In [ ]:

```
import seaborn as sns
sns.boxplot(y=idf)
plt.show()
```



Note:

- We can see that mean of the idf values lies around 10.5 and anything less than 3 is not useful because they are rare words and also anything over 10.5 also not useful because they are frequent words. From this plot we can set a threshold like idf less than 3 and idf values more than 10.5 will not be useful

3.3 Percentiles

In [ ]:

```
#for every 10th percentile
for i in range(0,100, 10):
    print(f'the {i}th percentile of idf :', np.percentile(idf, i))
```

```
the 0th percentile of idf : 1.0075658420924976
the 10th percentile of idf : 7.445562506855311
the 20th percentile of idf : 8.896996170146164
the 30th percentile of idf : 9.8525076151736
the 40th percentile of idf : 10.545654795733544
the 50th percentile of idf : 11.056480419499536
the 60th percentile of idf : 11.056480419499536
the 70th percentile of idf : 11.4619455276077
the 80th percentile of idf : 11.4619455276077
the 90th percentile of idf : 11.4619455276077
```

In [ ]:

```
#for 1 - 10 th percentile
for i in range(0,11):
    print(f'the {i}th percentile of idf :', np.percentile(idf, i))
```

```
the 0th percentile of idf : 1.0075658420924976
the 1th percentile of idf : 4.04992596902919
the 2th percentile of idf : 4.887567280339473
the 3th percentile of idf : 5.403991239230884
the 4th percentile of idf : 5.79379023059465
the 5th percentile of idf : 6.176460428826842
the 6th percentile of idf : 6.497425502976704
the 7th percentile of idf : 6.770597645378556
the 8th percentile of idf : 7.013429151664985
the 9th percentile of idf : 7.235111782339519
the 10th percentile of idf : 7.445562506855311
```

Note:

- We can see that around 90% of words has idf values less than 11.4 and and 4% of words has idf values less than 4.04

In [ ]:

```
# we further look into 10-20% to get the lower idf value
for i in range(90,101):
    print(f'the {i}th percentile of idf :', np.percentile(idf, i))
```

```
the 90th percentile of idf : 11.4619455276077
the 91th percentile of idf : 11.4619455276077
the 92th percentile of idf : 11.4619455276077
the 93th percentile of idf : 11.4619455276077
the 94th percentile of idf : 11.4619455276077
the 95th percentile of idf : 11.4619455276077
the 96th percentile of idf : 11.4619455276077
the 97th percentile of idf : 11.4619455276077
the 98th percentile of idf : 11.4619455276077
the 99th percentile of idf : 11.4619455276077
the 100th percentile of idf : 11.4619455276077
```

Summary:

- We could remove words whose idf values less than 4.04 and more than 11

In [ ]:

```
final_idf = {}
for word, idf_value in idf_words.items():
    if float(idf_value)>4.04 and float(idf_value)<11:
        final_idf[word] = idf_value
```

In [ ]:

```
print(len(idf_words))
print(len(final_idf))
```

```
47343
23096
```

In [ ]:

```
final_words = []
for k,v in final_idf.items():
    final_words.append(k)
```

In [ ]:

```
len(final_words)
```

Out[ ]:

```
23096
```

Note:

- We got 23096 words from 47343 words by removing the idf values less than 4.04 and greater than 11

3.4 Applying tokenizer on final_words

In [ ]:

```
from tensorflow.keras.preprocessing.text import Tokenizer
tokenizer = Tokenizer()
tokenizer.fit_on_texts(final_words)
token_essay_train = tokenizer.texts_to_sequences(X_train['essay'].values)
token_essay_val = tokenizer.texts_to_sequences(X_val['essay'].values)
```

In [ ]:

```
#finding the maximum length of after tokenization
max(len(i) for i in token_essay_train)
max(len(i) for i in token_essay_train)
```

Out[ ]:

```
183
```

In [ ]:

```
max_length = 200
X_train_essay = pad_sequences(token_essay_train, maxlen=max_length, padding='post')
X_val_essay = pad_sequences(token_essay_val, maxlen=max_length, padding='post')
```

In [ ]:

```
print(X_train_essay.shape)
print(X_val_essay.shape)
```

```
(69918, 200)
(21850, 200)
```

In [ ]:

```
X_train_essay = X_train_essay[0:10000]
print(X_train_essay.shape)
```

```
(10000, 200)
```

3.5 Embedding matrix

In [ ]:

```
with open('/content/drive/My Drive/Applied AI/Datasets/New Donors/glove_vectors', 'rb') as f:
    glove_model = pickle.load(f)
    glove_words = set(model.keys())
```

In [ ]:

```
max_words = len(tokenizer.word_index.items())
print(max_words)
```

```
23096
```

In [ ]:

```
embedding_matrix_1 = np.zeros((max_words+1, 300))

for word, i in tokenizer.word_index.items():
    if word in glove_words:
       embedding_vector = glove_model[word]
       embedding_matrix_1[i] = embedding_vector
```

In [ ]:

```
embedding_matrix_1
```

Out[ ]:

```
array([[ 0.        ,  0.        ,  0.        , ...,  0.        ,  0.        ,
         0.        ],
       [ 0.38311   ,  0.58955   , -0.42684   , ...,  0.34844   ,  0.28596   ,
        -0.17433   ],
       [ 0.12829   ,  0.28556   , -0.50288   , ...,  0.078814  , -0.0054958,
        -0.23956   ],
       ...,
       [-0.33634   ,  0.3764    ,  1.0234    , ...,  0.39171   ,  0.15036   ,
        -0.42412   ],
       [ 0.12231   ,  0.13381   ,  0.60253   , ..., -0.37781   , -0.23027   ,
         0.060408 ],
       [ 0.73415  , -0.5235   , -0.20538  , ..., -0.19308  ,  0.46632  ,
        -0.47861  ]])
```

3.6 Model Architecture

In [ ]:

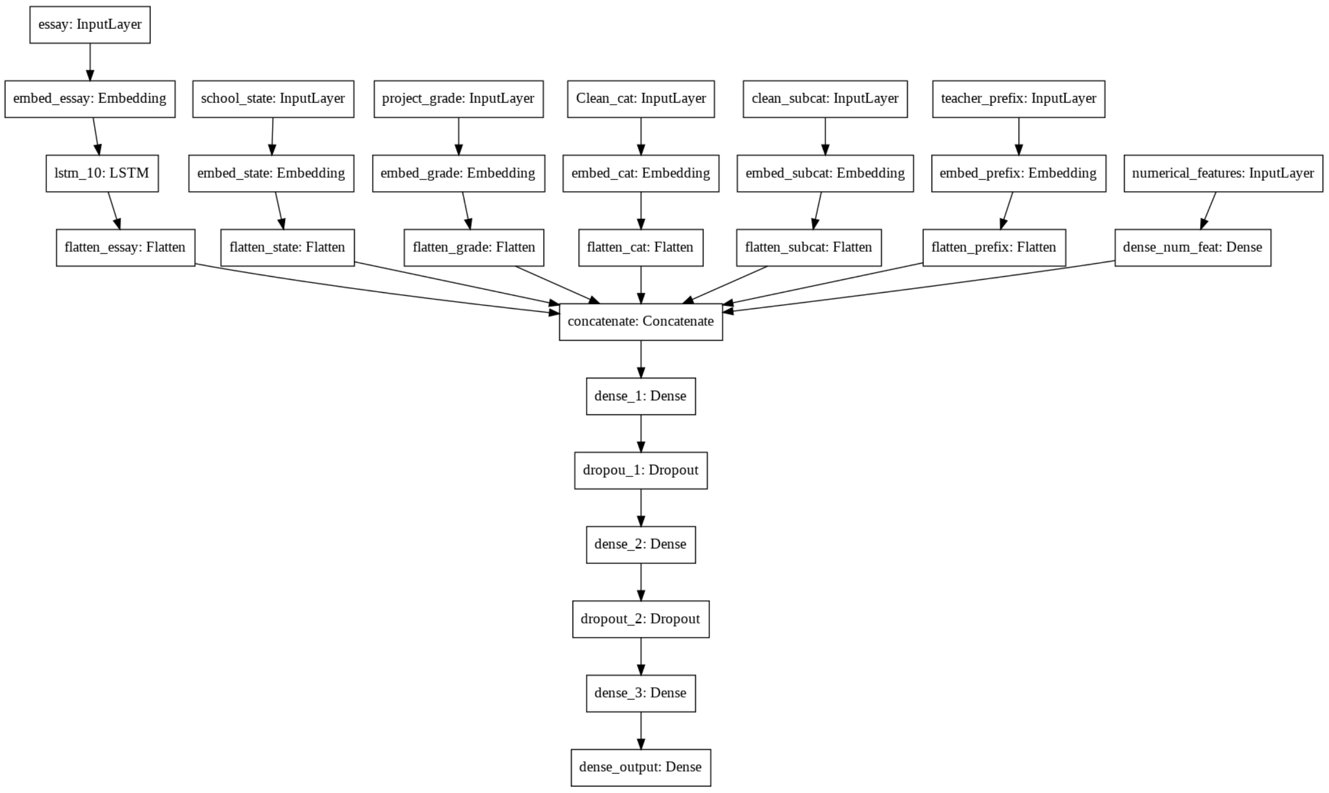
```
#https://www.tensorflow.org/guide/keras/functional

# 1.combined text
#input_combined_text = Input(shape=(len(X_train_combined_text_embed[0]),), name='combined_text')
input_essay = tf.keras.Input(shape=(X_train_essay.shape[1]), name='essay')
embedding_layer_essay = tf.keras.layers.Embedding(max_words+1,                                 #
number of words in vocabulary
                                                  300,                                       #3(
im of glove model
                                                  input_length=X_train_essay.shape[1],        #2(
max sequence length
                                                  weights=[embedding_matrix_1], trainable=False,
                                                  name = 'embed_essay')(input_essay)
lstm_essay = tf.keras.layers.LSTM(5, return_sequences=True)(embedding_layer_essay)
flatten_essay = tf.keras.layers.Flatten(name='flatten_essay')(lstm_essay)

# 2.School state
input_Sstate = tf.keras.Input(shape=(X_train_Sstate.shape[1]), name='school_state')
embedding_layer_Sstate = tf.keras.layers.Embedding(input_dim=num_words_Sstate,
# 51 unique states +1
                                                   output_dim=op_embedding_dim_Sstate,
# 26
                                                   input_length=X_train_Sstate.shape[1],
# 1
                                                   name = 'embed_state')(input_Sstate)
flatten_Sstate = tf.keras.layers.Flatten(name='flatten_state')(embedding_layer_Sstate)

# 3.Project grade
input_grade = tf.keras.Input(shape=(X_train_grade.shape[1]), name='project_grade')
embedding_layer_grade = tf.keras.layers.Embedding(input_dim=num_words_grade,
# 4 grades +1
                                                  output_dim=op_embedding_dim_grade,
# 2
                                                  input_length=X_train_grade.shape[1],
# 1
                                                  name = 'embed_grade')(input_grade)
flatten_grade = tf.keras.layers.Flatten(name='flatten_grade')(embedding_layer_grade)

# 4.Categories
input_cat = tf.keras.Input(shape=(X_train_cat.shape[1]), name='Clean_cat')
embedding_layer_cat = tf.keras.layers.Embedding(input_dim=num_words_cat,
# 51 category +1
                                                output_dim=op_embedding_dim_cat,
# 26
                                                input_length=X_train_cat.shape[1],
# 1
                                                name='embed_cat')(input_cat)
flatten_cat = tf.keras.layers.Flatten(name='flatten_cat')(embedding_layer_cat)

# 5.Sub categories
input_subcat = tf.keras.Input(shape=(X_train_subcat.shape[1]), name='clean_subcat')
embedding_layer_subcat = tf.keras.layers.Embedding(input_dim=num_words_subcat,
# 392 subcat +1
                                                   output_dim=op_embedding_dim_subcat,
# 50
                                                   input_length=X_train_subcat.shape[1],
# 1
                                                   name='embed_subcat')(input_subcat)
flatten_subcat = tf.keras.layers.Flatten(name='flatten_subcat')(embedding_layer_subcat)

# 6.Teacher prefix
input_prefix = tf.keras.Input(shape=(X_train_prefix.shape[1]), name='teacher_prefix')
embedding_layer_prefix = tf.keras.layers.Embedding(input_dim=num_words_prefix,
# 5 prefix + 1
                                                   output_dim=op_embedding_dim_prefix,
# 3
```

```
                                                              input_length=x_train_prefix.shape[1],
# 1
                                                              name='embed_prefix')(input_prefix)
flatten_prefix = tf.keras.layers.Flatten(name='flatten_prefix')(embedding_layer_prefix)

# 7.Numerical features
input_num_feat = tf.keras.Input(shape=(3,), name='numerical_features')  # 3 for each numerical feat
ure after concat
dense_num_feat = tf.keras.layers.Dense(1, activation='relu', name='dense_num_feat')(input_num_feat)

#Concatenate and flatten
concat_layers = tf.keras.layers.concatenate([flatten_essay, flatten_Sstate, flatten_grade, flatten_
cat, flatten_subcat, flatten_prefix, dense_num_feat], name='concatenate')

#Dense layer
x = tf.keras.layers.Dense(256, activation='relu', name='dense_1')(concat_layers)
x = tf.keras.layers.Dropout(0.5, name='dropou_1')(x)
x = tf.keras.layers.Dense(128, activation='relu', name='dense_2')(x)
x = tf.keras.layers.Dropout(0.4, name='dropout_2')(x)
x = tf.keras.layers.Dense(64, activation='relu', name='dense_3')(x)

#output
output = tf.keras.layers.Dense(2, activation='softmax', name='dense_output')(x)

inputs = [input_essay, input_Sstate, input_grade, input_cat, input_subcat, input_prefix, input_num_
feat]
model_2 = tf.keras.Model(inputs=inputs, outputs=output, name='model-1')
```

In [ ]:

```
tf.keras.utils.plot_model(model_2, 'model_2.png', show_shapes=False)
```

Out[ ]:



In [ ]:

```
model_2.summary()
```

```
Model: "model-1"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
essay (InputLayer)              [(None, 200)]        0

__________________________________________________________________________________________________
embed_essay (Embedding)         (None, 200, 300)     6929100     essay[0][0]
embed_essay (Embedding)         (None, 200, 300)     6929100     essay[0][0]
__________________________________________________________________________________________________
school_state (InputLayer)       [(None, 1)]          0
__________________________________________________________________________________________________
project_grade (InputLayer)      [(None, 1)]          0
__________________________________________________________________________________________________
Clean_cat (InputLayer)          [(None, 1)]          0
__________________________________________________________________________________________________
clean_subcat (InputLayer)       [(None, 1)]          0
__________________________________________________________________________________________________
teacher_prefix (InputLayer)     [(None, 1)]          0
__________________________________________________________________________________________________
lstm_10 (LSTM)                  (None, 200, 5)       6120        embed_essay[0][0]
__________________________________________________________________________________________________
embed_state (Embedding)         (None, 1, 26)        1352        school_state[0][0]
__________________________________________________________________________________________________
embed_grade (Embedding)         (None, 1, 2)         10          project_grade[0][0]
__________________________________________________________________________________________________
embed_cat (Embedding)           (None, 1, 26)        1352        Clean_cat[0][0]
__________________________________________________________________________________________________
embed_subcat (Embedding)        (None, 1, 50)        19650       clean_subcat[0][0]
__________________________________________________________________________________________________
embed_prefix (Embedding)        (None, 1, 3)         18          teacher_prefix[0][0]
__________________________________________________________________________________________________
numerical_features (InputLayer) [(None, 3)]          0
__________________________________________________________________________________________________
flatten_essay (Flatten)         (None, 1000)         0           lstm_10[0][0]
__________________________________________________________________________________________________
flatten_state (Flatten)         (None, 26)           0           embed_state[0][0]
__________________________________________________________________________________________________
flatten_grade (Flatten)         (None, 2)            0           embed_grade[0][0]
__________________________________________________________________________________________________
flatten_cat (Flatten)           (None, 26)           0           embed_cat[0][0]
__________________________________________________________________________________________________
flatten_subcat (Flatten)        (None, 50)           0           embed_subcat[0][0]
__________________________________________________________________________________________________
flatten_prefix (Flatten)        (None, 3)            0           embed_prefix[0][0]
__________________________________________________________________________________________________
dense_num_feat (Dense)          (None, 1)            4           numerical_features[0][0]
__________________________________________________________________________________________________
concatenate (Concatenate)       (None, 1108)         0           flatten_essay[0][0]
                                                                 flatten_state[0][0]
                                                                 flatten_grade[0][0]
                                                                 flatten_cat[0][0]
                                                                 flatten_subcat[0][0]
                                                                 flatten_prefix[0][0]
                                                                 dense_num_feat[0][0]
__________________________________________________________________________________________________
dense_1 (Dense)                 (None, 256)          283904      concatenate[0][0]
__________________________________________________________________________________________________
dropou_1 (Dropout)              (None, 256)          0           dense_1[0][0]
__________________________________________________________________________________________________
dense_2 (Dense)                 (None, 128)          32896       dropou_1[0][0]
__________________________________________________________________________________________________
dropout_2 (Dropout)             (None, 128)          0           dense_2[0][0]
__________________________________________________________________________________________________
dense_3 (Dense)                 (None, 64)           8256        dropout_2[0][0]
__________________________________________________________________________________________________
dense_output (Dense)            (None, 2)            130         dense_3[0][0]
==================================================================================================
Total params: 7,282,792
Trainable params: 353,692
Non-trainable params: 6,929,100
__________________________________________________________________________________________________
```

3.7 Callbacks

In [ ]:

```
#https://colab.research.google.com/github/tensorflow/tensorboard/blob/master/docs/tensorboard_in_no
oks.ipynb
from tensorflow.keras.callbacks import TensorBoard

tb_path = '/content/drive/My Drive/Applied AI/Assignment/Assign 16-
LSTM/callbacks/tensorboard_model_2/'
```

```
tb = TensorBoard(log_dir=tb_path, histogram_freq=2, write_graph=True)
```

In [ ]:

```
#https://medium.com/@mukesh.kumar43585/model-checkpoint-google-colab-and-drive-as-persistent-stora
ge-for-long-training-runs-e35ffa0c33d9
from tensorflow.keras.callbacks import ModelCheckpoint
checkpoint_path = '/content/drive/My Drive/Applied AI/Assignment/Assign 16-
LSTM/callbacks/checkpoint_model_2/ weights.{epoch:02d}-{val_loss:.2f}.hdf5'
checkpoint = ModelCheckpoint(checkpoint_path, monitor='val_auroc', verbose=1, save_best_only=True,
mode='max')
```

In [ ]:

```
#Early stopping
from tensorflow.keras.callbacks import EarlyStopping
early_stopping = EarlyStopping(monitor='val_loss', patience=10, verbose=2, mode='min', restore_best
_weights=True)
```

In [ ]:

```
#Reduce learning rate
from tensorflow.keras.callbacks import ReduceLROnPlateau
reduce_lr = ReduceLROnPlateau(monitor='val_auroc', factor=0.1)
```

In [ ]:

```
#https://github.com/taomanwai/tensorboardcolab
# https://medium.com/@mukesh.kumar43585/model-checkpoint-google-colab-and-drive-as-persistent-stor
age-for-long-training-runs-e35ffa0c33d9

callbacks_list = [tb, checkpoint, early_stopping, reduce_lr]
```

3.8 Custom Metrics- AUC ROC

In [ ]:

```
#https://stackoverflow.com/questions/41032551/how-to-compute-receiving-operating-characteristic-ro
c-and-auc-in-keras
import tensorflow as tf
from sklearn.metrics import roc_auc_score
def auc1(y_true, y_pred):                    #if there is only one class in y_true return roc sco
re as 0.5
    if len(np.unique(y_true[:,1])) == 1:
        return 0.5
    else:
        return roc_auc_score(y_true, y_pred)

def auroc(y_true, y_pred):
    return tf.py_function(auc1, (y_true, y_pred), tf.double)
```

3.9 Model compile

In [ ]:

```
#compile
model_2.compile(optimizer='adam', loss='categorical_crossentropy', metrics=[auroc])
```

In [ ]:

```
batch_size = 128
epochs = 50
```

In [ ]:

```
train_data_2 = [X_train_essay, X_train_Sstate, X_train_grade, X_train_cat, X_train_subcat, X_train_
prefix, num_features_train]
```

```
prefix, num_features_train]
val_data_2 = [X_val_essay, X_val_Sstate, X_val_grade, X_val_cat, X_val_subcat, X_val_prefix, num_fe
atures_val]
```

3.10 Model Fit

In [ ]:

```
history_2 = model_2.fit(train_data_2, y_train, callbacks=callbacks_list,
validation_data=(val_data_2, y_val), verbose=2, batch_size=batch_size, epochs=epochs)
```

```
Epoch 1/50
WARNING:tensorflow:Method (on_train_batch_end) is slow compared to the batch update (0.107818). Ch
eck your callbacks.

Epoch 00001: val_auroc did not improve from 0.66929
79/79 - 5s - loss: 0.4464 - auroc: 0.5710 - val_loss: 0.4057 - val_auroc: 0.6604 - lr: 0.0010
Epoch 2/50

Epoch 00002: val_auroc improved from 0.66929 to 0.67450, saving model to /content/drive/My
Drive/Applied AI/Assignment/Assign 16- LSTM/callbacks/checkpoint_model_2/ weights.02-0.40.hdf5
79/79 - 4s - loss: 0.4086 - auroc: 0.6693 - val_loss: 0.4015 - val_auroc: 0.6745 - lr: 0.0010
Epoch 3/50

Epoch 00003: val_auroc improved from 0.67450 to 0.67648, saving model to /content/drive/My
Drive/Applied AI/Assignment/Assign 16- LSTM/callbacks/checkpoint_model_2/ weights.03-0.40.hdf5
79/79 - 5s - loss: 0.3922 - auroc: 0.7246 - val_loss: 0.4019 - val_auroc: 0.6765 - lr: 0.0010
Epoch 4/50

Epoch 00004: val_auroc did not improve from 0.67648
79/79 - 4s - loss: 0.3744 - auroc: 0.7557 - val_loss: 0.4061 - val_auroc: 0.6740 - lr: 0.0010
Epoch 5/50

Epoch 00005: val_auroc did not improve from 0.67648
79/79 - 5s - loss: 0.3539 - auroc: 0.7962 - val_loss: 0.4276 - val_auroc: 0.6612 - lr: 0.0010
Epoch 6/50

Epoch 00006: val_auroc did not improve from 0.67648
79/79 - 4s - loss: 0.3294 - auroc: 0.8317 - val_loss: 0.4395 - val_auroc: 0.6604 - lr: 0.0010
Epoch 7/50

Epoch 00007: val_auroc did not improve from 0.67648
79/79 - 5s - loss: 0.3020 - auroc: 0.8648 - val_loss: 0.4588 - val_auroc: 0.6466 - lr: 0.0010
Epoch 8/50

Epoch 00008: val_auroc did not improve from 0.67648
79/79 - 4s - loss: 0.2702 - auroc: 0.8984 - val_loss: 0.5149 - val_auroc: 0.6339 - lr: 0.0010
Epoch 9/50

Epoch 00009: val_auroc did not improve from 0.67648
79/79 - 5s - loss: 0.2363 - auroc: 0.9221 - val_loss: 0.5459 - val_auroc: 0.6264 - lr: 0.0010
Epoch 10/50

Epoch 00010: val_auroc did not improve from 0.67648
79/79 - 4s - loss: 0.2012 - auroc: 0.9445 - val_loss: 0.5939 - val_auroc: 0.6279 - lr: 0.0010
Epoch 11/50

Epoch 00011: val_auroc did not improve from 0.67648
79/79 - 5s - loss: 0.1759 - auroc: 0.9603 - val_loss: 0.6297 - val_auroc: 0.6240 - lr: 0.0010
Epoch 12/50

Epoch 00012: val_auroc did not improve from 0.67648
Restoring model weights from the end of the best epoch.
79/79 - 4s - loss: 0.1487 - auroc: 0.9715 - val_loss: 0.7417 - val_auroc: 0.6173 - lr: 0.0010
Epoch 00012: early stopping
```

In [ ]:

```
y_pred_2 = model_2.predict(val_data_2)
print('The AUC score :', roc_auc_score(y_val, y_pred_2))
```

```
The AUC score : 0.6746252046238501
```

3.11 Tensorboard Images - model 2

In [ ]:

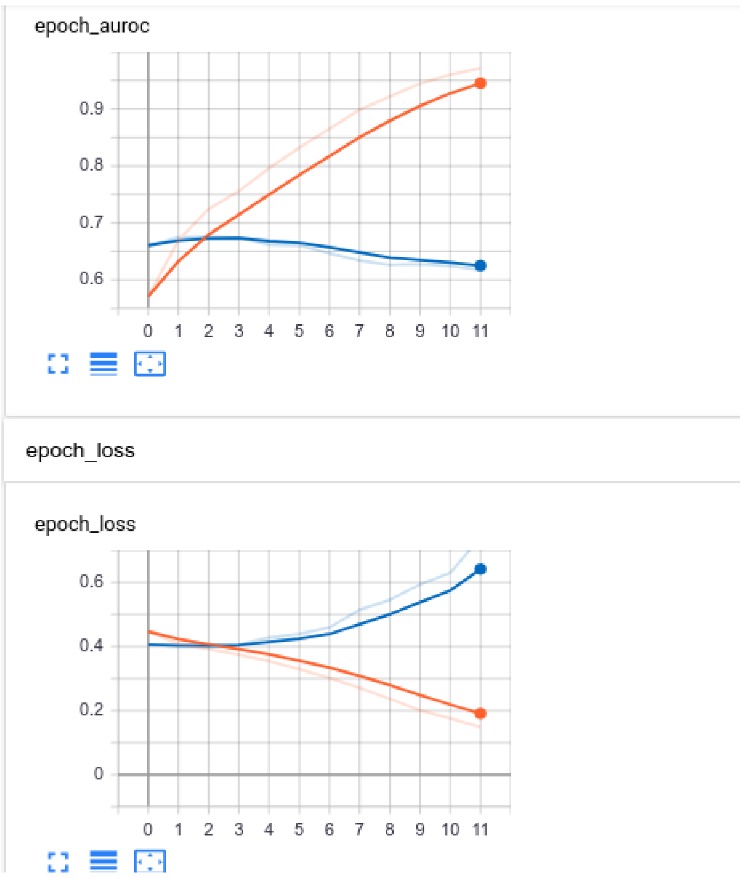
```
# Load the TensorBoard notebook extension
%load_ext tensorboard

%tensorboard --logdir '/content/drive/My Drive/Applied AI/Assignment/Assign 16-
LSTM/callbacks/tensorboard_model_2/'
```

```
The tensorboard extension is already loaded. To reload it, use:
  %reload_ext tensorboard
```

In [ ]:

```
from IPython.display import Image
Image('/content/drive/My Drive/Applied AI/Assignment /*Assign 16- LSTM /model_2_lstm.png')
```

Out[ ]:



4. Model-3:

In [ ]:

```
data.head()
```

Out[ ]:

	Unnamed: 0	school_state	teacher_prefix	project_grade_category	teacher_number_of_previously_posted_projects	project_is_approved
0	0	ca	mrs	grades_prek_2	53	1

	Unnamed: 0	school_state	teacher_prefix	project_grade_category	teacher_number_of_previously_posted_projects	project_is_approved
1	1	ut	ms	grades_3_5	4	1
2	2	ca	mrs	grades_prek_2	10	1
3	3	ga	mrs	grades_prek_2	2	1
4	4	wa	mrs	grades_3_5	2	1

4.1 School State

In [ ]:

```
from sklearn.feature_extraction.text import CountVectorizer
count_state = CountVectorizer()
count_state.fit(X_train['school_state'])
X_train_Sstate_3 = count_state.transform(X_train['school_state'])
X_val_Sstate_3 = count_state.transform(X_val['school_state'])
X_test_Sstate_3 = count_state.transform(X_test['school_state'])
```

In [ ]:

```
print(X_train_Sstate_3.shape)
print(X_val_Sstate_3.shape)
print(X_test_Sstate_3.shape)
```

```
(69918, 51)
(21850, 51)
(17480, 51)
```

4.2 Clean Category

In [ ]:

```
from sklearn.feature_extraction.text import CountVectorizer
count_cat = CountVectorizer()
count_cat.fit(X_train['clean_categories'])
X_train_cat_3 = count_cat.transform(X_train['clean_categories'])
X_val_cat_3 = count_cat.transform(X_val['clean_categories'])
X_test_cat_3 = count_cat.transform(X_test['clean_categories'])
```

In [ ]:

```
print(X_train_cat_3.shape)
print(X_val_cat_3.shape)
print(X_test_cat_3.shape)
```

```
(69918, 9)
(21850, 9)
(17480, 9)
```

4.3 Clean Subcategory

In [ ]:

```
count_subcat = CountVectorizer()
count_subcat.fit(X_train['clean_subcategories'])
X_train_subcat_3 = count_subcat.transform(X_train['clean_subcategories'])
X_val_subcat_3 = count_subcat.transform(X_val['clean_subcategories'])
X_test_subcat_3 = count_subcat.transform(X_test['clean_subcategories'])
```

In [ ]:

```
print(X_train_subcat_3.shape)
print(X_val_subcat_3.shape)
print(X_test_subcat_3.shape)
```

```
(69918, 30)
(21850, 30)
(17480, 30)
```

4.4 Project grade

In [ ]:

```
count_grade = CountVectorizer()
count_grade.fit(X_train['project_grade_category'])
X_train_grade_3 = count_grade.transform(X_train['project_grade_category'])
X_val_grade_3 = count_grade.transform(X_val['project_grade_category'])
X_test_grade_3 = count_grade.transform(X_test['project_grade_category'])
```

In [ ]:

```
print(X_train_grade_3.shape)
print(X_val_grade_3.shape)
print(X_test_grade_3.shape)
```

```
(69918, 4)
(21850, 4)
(17480, 4)
```

4.5 Teacher Prefix

In [ ]:

```
count_prefix = CountVectorizer()
count_prefix.fit(X_train['teacher_prefix'])
X_train_prefix_3 = count_prefix.transform(X_train['teacher_prefix'])
X_val_prefix_3 = count_prefix.transform(X_val['teacher_prefix'])
X_test_prefix_3 = count_prefix.transform(X_test['teacher_prefix'])
```

In [ ]:

```
print(X_train_prefix_3.shape)
print(X_val_prefix_3.shape)
print(X_test_prefix_3.shape)
```

```
(69918, 5)
(21850, 5)
(17480, 5)
```

4.6 Concatenate all categorical variabels

In [ ]:

```
from scipy.sparse import hstack
categorical_train = hstack([X_train_Sstate_3, X_train_cat_3, X_train_subcat_3, X_train_grade_3, X_t
rain_prefix_3]).todense()
categorical_val = hstack([X_val_Sstate_3, X_val_cat_3, X_val_subcat_3, X_val_grade_3, X_val_prefix_
3]).todense()
categorical_test = hstack([X_test_Sstate_3, X_test_cat_3, X_test_subcat_3, X_test_grade_3, X_test_p
refix_3]).todense()
```

In [ ]:

```
print(categorical_train.shape)
print(categorical_val.shape)
print(categorical_test.shape)
```

```
(69918, 99)
(21850, 99)
(17480, 99)
```

In [ ]:

```
categorical_train = categorical_train[0:10000]
print(categorical_train.shape)
```

```
(10000, 99)
```

4.7 concatenate numerical values

In [ ]:

```
#concatenate all numerical features
num_features_train = np.concatenate((X_train_price, X_train_previous, X_train_quantity), axis=1)
num_features_val = np.concatenate((X_val_price, X_val_previous, X_val_quantity), axis=1)
```

4.8 Concatenate both cat and num variables

In [ ]:

```
X_train_3 = np.hstack((categorical_train, num_features_train))
X_val_3 = np.hstack((categorical_val, num_features_val))
```

In [ ]:

```
print(X_train_3.shape)
print(X_val_3.shape)
```

```
(10000, 102)
(21850, 102)
```

Note:

- For Conv1D we need input dimension of (batch_size, steps, input_dim) . Here we have batch size can be considered as a 10000, steps is 102 and we need input_dim of 1 bcoz conv1D goes only in one dimension

In [ ]:

```
X_train_3 = np.expand_dims(X_train_3, axis=2)
X_val_3 = np.expand_dims(X_val_3, axis=2)

print(X_train_3.shape)
print(X_val_3.shape)
```

```
(10000, 102, 1)
(21850, 102, 1)
```

(21636, 102, 1)

4.9 Architecture

In [ ]:

```
from tensorflow.keras.regularizers import l2
```

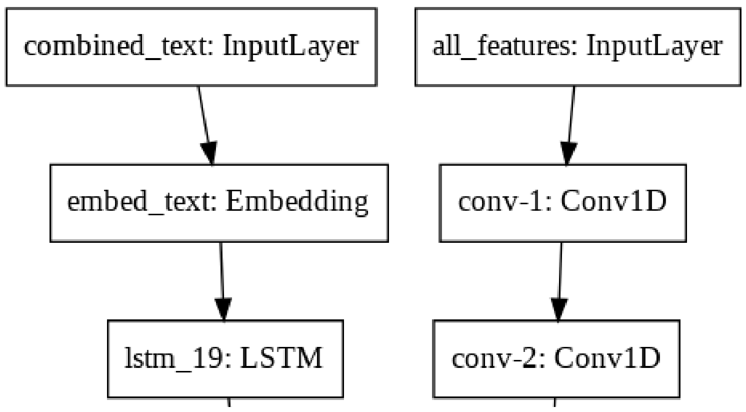
In [ ]:

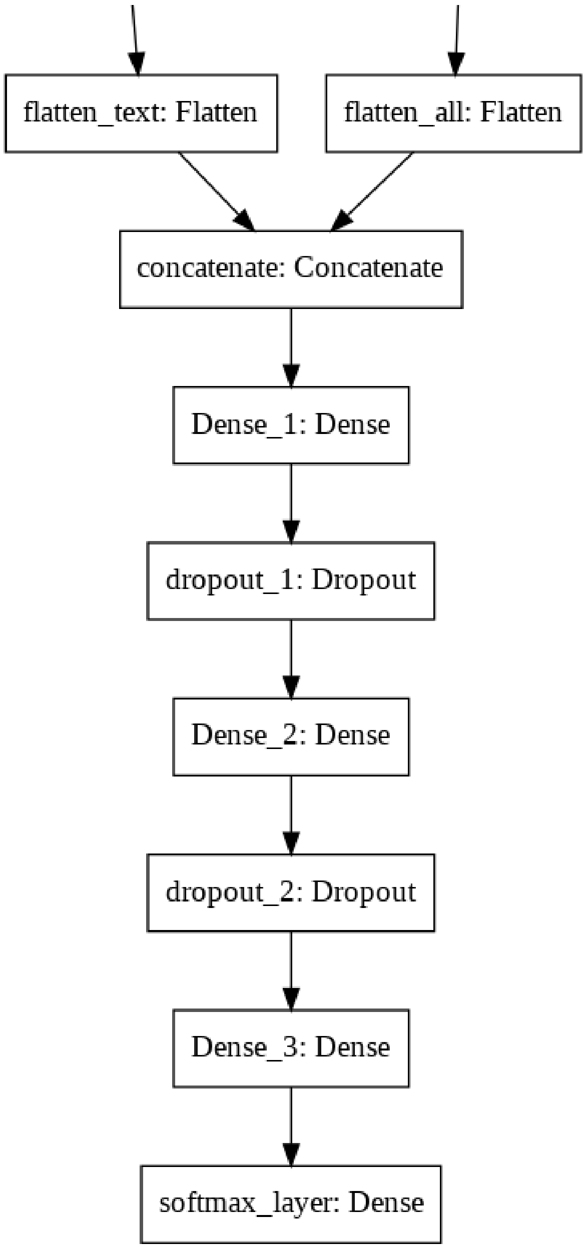
```
#https://www.tensorflow.org/guide/keras/functional

# 1.combined text
#input_combined_text = Input(shape=(len(X_train_combined_text_embed[0]),), name='combined_text')
input_combined_text = tf.keras.Input(shape=(X_train_combined_text.shape[1]), name='combined_text')
embedding_layer_combined_text = tf.keras.layers.Embedding(max_words_combined_text,
#5000 number of words in vocabulary
                                                           op_embedding_dim_combined_text,
#300 dim of glove model
                                                           input_length=X_train_combined_text.shape
,  #400 max sequence length
                                                           weights=[embedding_matrix], trainable=Fal
,
                                                           name = 'embed_text')(input_combined_text)
lstm_combined_text = tf.keras.layers.LSTM(5, return_sequences=True)(embedding_layer_combined_text)
flatten_combined_text = tf.keras.layers.Flatten(name='flatten_text')(lstm_combined_text)

#Conv1D
input_conv = tf.keras.Input(shape=(102,1), name='all_features')
x = tf.keras.layers.Conv1D(filters=128, kernel_size=3, activation='relu', kernel_initializer='he_no
rmal', name='conv-1')(input_conv)
x = tf.keras.layers.Conv1D(filters=128, kernel_size=3, activation='relu', kernel_initializer='he_no
rmal', name='conv-2')(x)
flatten_all = tf.keras.layers.Flatten(name='flatten_all')(x)

#concatenate
concatenate = tf.keras.layers.concatenate([flatten_combined_text, flatten_all], name='concatenate')

#Dense
x = tf.keras.layers.Dense(16, activation='relu', name='Dense_1', kernel_regularizer=l2(0.001))(conc
atenate)
x = tf.keras.layers.Dropout(0.5, name='dropout_1')(x)
x = tf.keras.layers.Dense(8, activation='relu', name='Dense_2', kernel_regularizer=l2(0.001))(x)
x = tf.keras.layers.Dropout(0.3, name='dropout_2')(x)
x = tf.keras.layers.Dense(4, activation='relu', name='Dense_3', kernel_regularizer=l2(0.001))(x)

#output
output = tf.keras.layers.Dense(2, activation='softmax',name='softmax_layer')(x)

#model_3
model_3 = tf.keras.models.Model(inputs=[input_combined_text, input_conv], outputs=[output])
```

In [ ]:

```
tf.keras.utils.plot_model(model_3, 'model_3.png', show_shapes=False)
```

Out[ ]:





In [ ]:

```
model_3.summary()
```

```
Model: "model_7"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
combined_text (InputLayer)      [(None, 400)]        0
__________________________________________________________________________________________________
all_features (InputLayer)       [(None, 102, 1)]     0
__________________________________________________________________________________________________
embed_text (Embedding)          (None, 400, 300)     1500000     combined_text[0][0]
__________________________________________________________________________________________________
conv-1 (Conv1D)                 (None, 100, 128)     512         all_features[0][0]
__________________________________________________________________________________________________
lstm_19 (LSTM)                  (None, 400, 5)       6120        embed_text[0][0]
__________________________________________________________________________________________________
conv-2 (Conv1D)                 (None, 98, 128)      49280       conv-1[0][0]
__________________________________________________________________________________________________
flatten_text (Flatten)          (None, 2000)         0           lstm_19[0][0]
__________________________________________________________________________________________________
flatten_all (Flatten)           (None, 12544)        0           conv-2[0][0]
__________________________________________________________________________________________________
concatenate (Concatenate)       (None, 14544)        0           flatten_text[0][0]
                                                                 flatten_all[0][0]
__________________________________________________________________________________________________
Dense_1 (Dense)                 (None, 16)           232720      concatenate[0][0]
```

```
________________________________________________________________________________________________________
dropout_1 (Dropout)              (None, 16)           0            Dense_1[0][0]
________________________________________________________________________________________________________
Dense_2 (Dense)                  (None, 8)            136          dropout_1[0][0]
________________________________________________________________________________________________________
dropout_2 (Dropout)              (None, 8)            0            Dense_2[0][0]
________________________________________________________________________________________________________
Dense_3 (Dense)                  (None, 4)            36           dropout_2[0][0]
________________________________________________________________________________________________________
softmax_layer (Dense)            (None, 2)            10           Dense_3[0][0]
========================================================================================================
Total params: 1,788,814
Trainable params: 288,814
Non-trainable params: 1,500,000
________________________________________________________________________________________________________
```

4.10 Callbacks

In [ ]:

```
#https://colab.research.google.com/github/tensorflow/tensorboard/blob/master/docs/tensorboard_in_nc
oks.ipynb
from tensorflow.keras.callbacks import TensorBoard

# Load the TensorBoard notebook extension
%load_ext tensorboard

tb_path = '/content/drive/My Drive/Applied AI/Assignment /Assign 16- LSTM
/callbacks/tensorboard_model_3/'
tb = TensorBoard(log_dir=tb_path, histogram_freq=2, write_graph=True)
```

```
The tensorboard extension is already loaded. To reload it, use:
  %reload_ext tensorboard
```

In [ ]:

```
#https://medium.com/@mukesh.kumar43585/model-checkpoint-google-colab-and-drive-as-persistent-stora
ge-for-long-training-runs-e35ffa0c33d9
from tensorflow.keras.callbacks import ModelCheckpoint
checkpoint_path = '/content/drive/My Drive/Applied AI/Assignment /Assign 16- LSTM
/callbacks/callbacks/checkpoint_model_3/weights.{epoch:02d}-{val_loss:.2f}.hdf5'
checkpoint = ModelCheckpoint(checkpoint_path, monitor='val_loss', verbose=1, save_best_only=True, m
ode='min')
```

In [ ]:

```
#Early stopping
from tensorflow.keras.callbacks import EarlyStopping
early_stopping = EarlyStopping(monitor='val_loss', patience=10, verbose=2, mode='min', restore_best
_weights=True)
```

In [ ]:

```
#Reduce learning rate
from tensorflow.keras.callbacks import ReduceLROnPlateau
reduce_lr = ReduceLROnPlateau(monitor='val_auroc', factor=0.1)
```

In [ ]:

```
#https://github.com/taomanwai/tensorboardcolab
# https://medium.com/@mukesh.kumar43585/model-checkpoint-google-colab-and-drive-as-persistent-stor
age-for-long-training-runs-e35ffa0c33d9

callbacks_list = [tb, checkpoint, early_stopping, reduce_lr]
```

4.11 Custom Metrics - ROC AUC

In [ ]:

```
#https://stackoverflow.com/questions/41032551/how-to-compute-receiving-operating-characteristic-ro
c-and-auc-in-keras
import tensorflow as tf
from sklearn.metrics import roc_auc_score
def auc1(y_true, y_pred):                    #if there is only one class in y_true return roc sco
re as 0.5
    if len(np.unique(y_true[:,1])) == 1:
        return 0.5
    else:
        return roc_auc_score(y_true, y_pred)

def auroc(y_true, y_pred):
    return tf.py_function(auc1, (y_true, y_pred), tf.double)
```

4.12 Model Compile

In [ ]:

```
#compile
model_3.compile(optimizer='adam', loss='categorical_crossentropy', metrics=[auroc])
```

In [ ]:

```
batch_size = 128
epochs = 50
```

In [ ]:

```
print(X_train_combined_text.shape)
print(X_train_3.shape)
```

```
(10000, 400)
(10000, 102, 1)
```

In [ ]:

```
train_data_3 = [X_train_combined_text, X_train_3]
val_data_3 = [X_val_combined_text, X_val_3]
```

4.13 Model Fit

In [ ]:

```
history_3 = model_3.fit(train_data_3, y_train, callbacks=callbacks_list,
validation_data=(val_data_3, y_val), verbose=2, epochs=epochs, batch_size=batch_size)
```

```
Epoch 1/50
WARNING:tensorflow:Method (on_train_batch_end) is slow compared to the batch update (0.127531). Ch
eck your callbacks.

Epoch 00001: val_loss improved from inf to 0.48379, saving model to /content/drive/My
Drive/Applied AI/Assignment /Assign 16- LSTM /callbacks/callbacks/checkpoint_model_3/weights.01-0.
48.hdf5
79/79 - 7s - loss: 0.5260 - auroc: 0.5313 - val_loss: 0.4838 - val_auroc: 0.6252 - lr: 0.0010
Epoch 2/50

Epoch 00002: val_loss improved from 0.48379 to 0.43267, saving model to /content/drive/My
Drive/Applied AI/Assignment /Assign 16- LSTM /callbacks/callbacks/checkpoint_model_3/weights.02-0.
43.hdf5
79/79 - 6s - loss: 0.4683 - auroc: 0.5998 - val_loss: 0.4327 - val_auroc: 0.6872 - lr: 0.0010
Epoch 3/50

Epoch 00003: val_loss improved from 0.43267 to 0.43170, saving model to /content/drive/My
Drive/Applied AI/Assignment /Assign 16- LSTM /callbacks/callbacks/checkpoint_model_3/weights.03-0.
43.hdf5
79/79 - 7s - loss: 0.4430 - auroc: 0.6565 - val_loss: 0.4317 - val_auroc: 0.7141 - lr: 0.0010
Epoch 4/50
Epoch 00004: val_loss improved from 0.43170 to 0.41753, saving model to /content/drive/My
Drive/Applied AI/Assignment /Assign 16- LSTM /callbacks/callbacks/checkpoint_model_3/weights.04-0.
42.hdf5
79/79 - 6s - loss: 0.4262 - auroc: 0.6969 - val_loss: 0.4175 - val_auroc: 0.7192 - lr: 0.0010
Epoch 5/50

Epoch 00005: val_loss did not improve from 0.41753
79/79 - 7s - loss: 0.4177 - auroc: 0.7177 - val_loss: 0.4238 - val_auroc: 0.7236 - lr: 0.0010
Epoch 6/50

Epoch 00006: val_loss did not improve from 0.41753
79/79 - 6s - loss: 0.4098 - auroc: 0.7390 - val_loss: 0.4184 - val_auroc: 0.7236 - lr: 0.0010
Epoch 7/50

Epoch 00007: val_loss improved from 0.41753 to 0.41573, saving model to /content/drive/My
Drive/Applied AI/Assignment /Assign 16- LSTM /callbacks/callbacks/checkpoint_model_3/weights.07-0.
42.hdf5
79/79 - 7s - loss: 0.3992 - auroc: 0.7570 - val_loss: 0.4157 - val_auroc: 0.7229 - lr: 0.0010
Epoch 8/50

Epoch 00008: val_loss improved from 0.41573 to 0.40461, saving model to /content/drive/My
Drive/Applied AI/Assignment /Assign 16- LSTM /callbacks/callbacks/checkpoint_model_3/weights.08-0.
40.hdf5
79/79 - 6s - loss: 0.3990 - auroc: 0.7577 - val_loss: 0.4046 - val_auroc: 0.7286 - lr: 0.0010
Epoch 9/50

Epoch 00009: val_loss did not improve from 0.40461
79/79 - 7s - loss: 0.3894 - auroc: 0.7826 - val_loss: 0.4106 - val_auroc: 0.7251 - lr: 0.0010
Epoch 10/50

Epoch 00010: val_loss did not improve from 0.40461
79/79 - 6s - loss: 0.3860 - auroc: 0.7905 - val_loss: 0.4112 - val_auroc: 0.7209 - lr: 0.0010
Epoch 11/50

Epoch 00011: val_loss did not improve from 0.40461
79/79 - 7s - loss: 0.3779 - auroc: 0.8062 - val_loss: 0.4130 - val_auroc: 0.7132 - lr: 0.0010
Epoch 12/50

Epoch 00012: val_loss did not improve from 0.40461
79/79 - 6s - loss: 0.3668 - auroc: 0.8214 - val_loss: 0.4124 - val_auroc: 0.7186 - lr: 1.0000e-04
Epoch 13/50

Epoch 00013: val_loss did not improve from 0.40461
79/79 - 6s - loss: 0.3619 - auroc: 0.8324 - val_loss: 0.4128 - val_auroc: 0.7194 - lr: 1.0000e-04
Epoch 14/50

Epoch 00014: val_loss did not improve from 0.40461
79/79 - 6s - loss: 0.3564 - auroc: 0.8410 - val_loss: 0.4138 - val_auroc: 0.7189 - lr: 1.0000e-04
Epoch 15/50

Epoch 00015: val_loss did not improve from 0.40461
79/79 - 7s - loss: 0.3579 - auroc: 0.8339 - val_loss: 0.4145 - val_auroc: 0.7193 - lr: 1.0000e-04
Epoch 16/50

Epoch 00016: val_loss did not improve from 0.40461
79/79 - 6s - loss: 0.3552 - auroc: 0.8398 - val_loss: 0.4148 - val_auroc: 0.7185 - lr: 1.0000e-04
Epoch 17/50

Epoch 00017: val_loss did not improve from 0.40461
79/79 - 7s - loss: 0.3542 - auroc: 0.8426 - val_loss: 0.4157 - val_auroc: 0.7187 - lr: 1.0000e-04
Epoch 18/50

Epoch 00018: val_loss did not improve from 0.40461
Restoring model weights from the end of the best epoch.
79/79 - 7s - loss: 0.3508 - auroc: 0.8459 - val_loss: 0.4164 - val_auroc: 0.7182 - lr: 1.0000e-04
Epoch 00018: early stopping
```

In [ ]:

```
y_pred_3 = model_3.predict(val_data_3)
print('AUC score:', roc_auc_score(y_val, y_pred_3))
```

```
AUC score: 0.7267076236087175
```

4.14 Tensorboard Images

In [ ]:

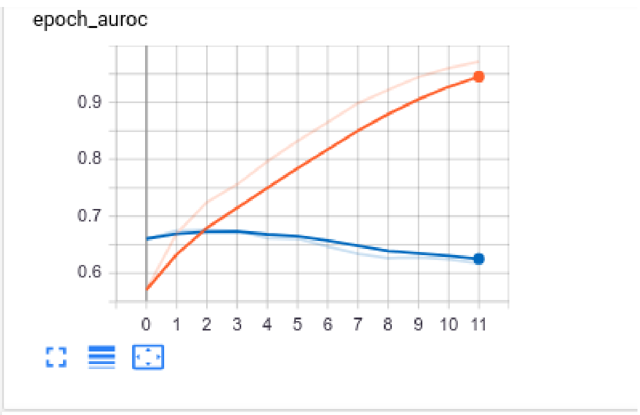
```
%tensorboard --logdir '/content/drive/My Drive/Applied AI/Assignment/Assign 16-
LSTM/callbacks/tensorboard_model_3/'
```

```
Reusing TensorBoard on port 6007 (pid 3676), started 0:54:04 ago. (Use '!kill 3676' to kill it.)
```

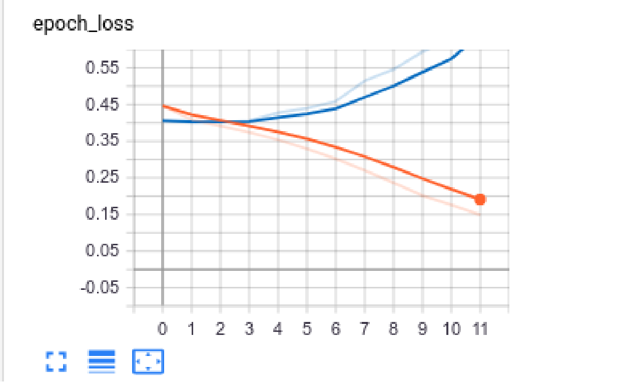
In [ ]:

```
Image('/content/drive/My Drive/Applied AI/Assignment /*Assign 16- LSTM /model_3_lstm.png')
```

Out[ ]:



epoch_loss



Summary:

- Even after tried so many parameters chanages and many epochs i get the best auc score of 0.72

In [ ]:

```
from prettytable import PrettyTable

x_pretty_table = PrettyTable()
x_pretty_table.field_names = ["Model", "AUC Score"]

x_pretty_table.add_row(["Model1","0.702"])
x_pretty_table.add_row(["Model2","0.67"])
x_pretty_table.add_row(["Model3","0.729"])


print(x_pretty_table)
```

```
+--------+-----------+
| Model  | AUC Score |
+--------+-----------+
| Model1 |   0.702   |
| Model2 |    0.67   |
| Model3 |   0.729   |
+--------+-----------+
```

That's the end of the code