Assignment : 14

1. You can work with preprocessed_data.csv for the assignment. You can get the data from - Data folder
2. Load the data in your notebook.
3. After step 2 you have to train 3 types of models as discussed below.
4. For all the model use 'auc' as a metric. check this and this for using auc as a metric
5. You are free to choose any number of layers/hiddden units but you have to use same type of architectures shown below.
6. You can use any one of the optimizers and choice of Learning rate and momentum.
7. For all the model's use TensorBoard and plot the Metric value and Loss with epoch. While submitting, take a screenshot of plots and include those images in a separate pad and write your observations about them.
8. Make sure that you are using GPU to train the given models.

You can use gdown modules to import dataset for the assignment.

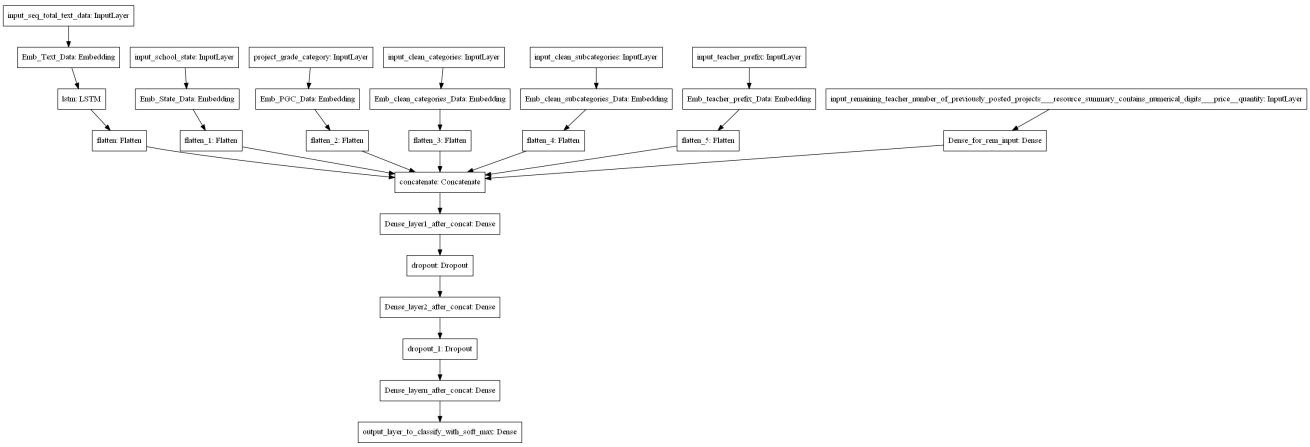
For importing any file from drive to Colab you can write the syntax as `!gdown --id file_id`.

You can run the below cell to import the required preprocessed data.csv file and glove vector.

```
!gdown --id 1GpATd_pM4mcnWWIs28-s1lgqdAg2Wdv-    # preprocessed_data.csv
!gdown --id 1pGd5tLwA30M7wkbJKdXHaae9tYVDICJ_    # glove_vectors
```

Model-1

Build and Train deep neural network as shown below



ref: https://i.imgur.com/w395Yk9.png

- **Input_seq_total_text_data** --- You have to give Total text data columns. After this use the Embedding layer to get word vectors. Use given predefined glove word vectors, don't train any word vectors. After this use LSTM and get the LSTM output and Flatten that output.
- **Input_school_state** --- Give 'school_state' column as input to embedding layer and Train the Keras Embedding layer.
- **Project_grade_category** --- Give 'project_grade_category' column as input to embedding layer and Train the Keras Embedding layer.
- **Input_clean_categories** --- Give 'input_clean_categories' column as input to embedding layer and Train the Keras Embedding layer.
- **Input_clean_subcategories** --- Give 'input_clean_subcategories' column as input to embedding layer and Train the Keras Embedding layer.
- **Input_clean_subcategories** --- Give 'input_teacher_prefix' column as input to embedding layer and Train the Keras Embedding layer.
- **Input_remaining_teacher_number_of_previously_posted_projects._resource_summary_contains_numerical_digits._price._qua** ---concatenate remaining columns and add a Dense layer after that.

Below is an example of embedding layer for a categorical columns. In below code all are dummy values, we gave only for referance.

Below is an example of embedding layer for a categorical columns. In below code all are dummy values, we gave only for referance.

```
# https://stats.stackexchange.com/questions/270546/how-does-keras-embedding-layer-work
input_layer = Input(shape=(n,))
embedding = Embedding(no_1, no_2, input_length=n)(input_layer)
flatten = Flatten()(embedding)
```

1. Go through this blog, if you have any doubt on using predefined Embedding values in Embedding layer - https://machinelearningmastery.com/use-word-embedding-layers-deep-learning-keras/

2. Please go through this link https://keras.io/getting-started/functional-api-guide/ and check the 'Multi-input and multi-output models' then you will get to know how to give multiple inputs.

Model-1

In [1]:
```
import os
import re
import pickle
import shutil

import numpy as np
import pandas as pd
from tqdm import tqdm

import seaborn as sns
from datetime import datetime
import matplotlib.pyplot as plt
from scipy.sparse import hstack

from sklearn.metrics import roc_auc_score
from sklearn.preprocessing import MinMaxScaler
from sklearn.model_selection import train_test_split
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.feature_extraction.text import CountVectorizer

import tensorflow
import tensorflow as tf
from tensorflow.keras import Model
from tensorflow.keras.layers import Input
from tensorflow.keras.layers import Dense
from tensorflow.keras.layers import LSTM
from tensorflow.keras.layers import Conv1D
from tensorflow.keras.layers import Dropout
from tensorflow.keras.layers import Flatten
from tensorflow.keras.layers import Embedding
from tensorflow.keras.layers import Concatenate
from tensorflow.keras.callbacks import TensorBoard
from tensorflow.keras.callbacks import EarlyStopping
from tensorflow.keras.callbacks import ModelCheckpoint
from tensorflow.keras.callbacks import ReduceLROnPlateau
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.utils import plot_model
from keras.utils.np_utils import to_categorical
from tensorflow.keras.utils import pad_sequences
# from tensorflow.keras.utils.np_utils import to_categorical
from tensorflow.keras.preprocessing.text import Tokenizer

import warnings
warnings.filterwarnings('ignore')

plt.style.use('fivethirtyeight')
plt.show()
```

In [2]:
```
!nvidia-smi
```

```
Mon Aug  1 11:40:06 2022
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 470.82.01    Driver Version: 470.82.01    CUDA Version: 11.7     |
|-------------------------------+----------------------+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|                               |                      |               MIG M. |
|===============================+======================+======================|
|   0  NVIDIA A10G         On   | 00000000:00:1E.0 Off |                    0 |
|  0%   26C    P8     9W / 300W |      0MiB / 22731MiB |      0%      Default |
|                               |                      |                  N/A |
+-------------------------------+----------------------+----------------------+

+-----------------------------------------------------------------------------+
| Processes:                                                                  |
|  GPU   GI   CI        PID   Type   Process name                  GPU Memory |
|        ID   ID                                                   Usage      |
|=============================================================================|
|  No running processes found                                                 |
+-----------------------------------------------------------------------------+
```

In [3]:
```
# Read the csv file

df = pd.read_csv('preprocessed_data.csv')
```

```
print(f'Shape : {df.shape}')
df.head(2)
```

```
Shape : (109248, 9)
```

Out[3]:

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

Since `preprocessed_data.csv` does not contain the **quantity** coulumn, we have to rergenerate the preprocessed data once agin.

In [4]:

```
train_df = pd.read_csv('train_data.csv')
print(f'Shape : {train_df.shape}')
train_df.head(2)
```

```
Shape : (109248, 17)
```

Out[4]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	project_submitted_datetime	project_grade_category
0	160221	p253737	c90749f5d961ff158d4b4d1e7dc665fc	Mrs.	IN	2016-12-05 13:43:57	Grades PreK-2
1	140945	p258326	897464ce9ddc600bced1151f324dd63a	Mr.	FL	2016-10-25 09:22:10	Grades 6-8

In [5]:

```
resources = pd.read_csv('resources.csv')
print(f'Shape : {resources.shape}')
resources.head(2)
```

```
Shape : (1541272, 4)
```

Out[5]:

	id	description	quantity	price
0	p233245	LC652 - Lakeshore Double-Space Mobile Drying Rack	1	149.00
1	p069063	Bouncy Bands for Desks (Blue support pipes)	3	14.95

In [6]:

```
quantity_price = resources.groupby('id').agg({'price':'sum', 'quantity':'sum'}).reset_index()
quantity_price.head(3)
```

Out[6]:

	id	price	quantity
0	p000001	459.56	7
1	p000002	515.89	21
2	p000003	298.97	4

In [7]:

```
df_project = pd.merge(train_df, quantity_price, on='id', how='left')
print(f'Shape : {df_project.shape}')
df_project.head(3)
```

```
Shape : (109248, 19)
```

Out[7]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	project_submitted_datetime	project_grade_category
0	160221	p253737	c90749f5d961ff158d4b4d1e7dc665fc	Mrs.	IN	2016-12-05 13:43:57	Grades PreK-2
1	140945	p258326	897464ce9ddc600bced1151f324dd63a	Mr.	FL	2016-10-25 09:22:10	Grades 6-8
2	21895	p182444	3465aaf82da834c0582ebd0ef8040ca0	Ms.	AZ	2016-08-31 12:03:56	Grades 6-8

Preprocessing Categorical Features

We need to remove the spaces, and special characters

- Remove additional spaces
- Remove dots : '.'
- Replace '-' with '_'
- Replace ' The ' with ''
- Replace '&' with '_'
- Replace ',' with '_'
- Convert all the characters to small case

In [8]:
```
# project_grade_category

df_project['project_grade_category'] = df_project['project_grade_category'].str.replace(' ','_')
df_project['project_grade_category'] = df_project['project_grade_category'].str.replace('-','_')
df_project['project_grade_category'] = df_project['project_grade_category'].str.lower()
df_project['project_grade_category'].value_counts()
```

Out[8]:
```
grades_prek_2    44225
grades_3_5       37137
grades_6_8       16923
grades_9_12      10963
Name: project_grade_category, dtype: int64
```

In [9]:
```
# project_subject_categories

df_project['clean_categories'] = df_project['project_subject_categories'].str.replace(' The ','')
df_project['clean_categories'] = df_project['clean_categories'].str.replace(' ','')
df_project['clean_categories'] = df_project['clean_categories'].str.replace('&','_')
df_project['clean_categories'] = df_project['clean_categories'].str.replace(',','_')
df_project['clean_categories'] = df_project['clean_categories'].str.lower()
df_project['clean_categories'].value_counts()
```

Out[9]:
```
literacy_language                        23655
math_science                             17072
literacy_language_math_science           14636
health_sports                            10177
music_arts                                5180
specialneeds                              4226
literacy_language_specialneeds            3961
appliedlearning                           3771
math_science_literacy_language            2289
appliedlearning_literacy_language         2191
history_civics                            1851
math_science_specialneeds                 1840
literacy_language_music_arts              1757
math_science_music_arts                   1642
appliedlearning_specialneeds              1467
history_civics_literacy_language          1421
health_sports_specialneeds                1391
warmth_care_hunger                        1309
math_science_appliedlearning              1220
appliedlearning_math_science              1052
literacy_language_history_civics           809
health_sports_literacy_language            803
appliedlearning_music_arts                 758
math_science_history_civics                652
literacy_language_appliedlearning          636
appliedlearning_health_sports              608
math_science_health_sports                 414
history_civics_math_science                322
history_civics_music_arts                  312
specialneeds_music_arts                    302
health_sports_math_science                 271
history_civics_specialneeds                252
health_sports_appliedlearning              192
appliedlearning_history_civics             178
health_sports_music_arts                   155
music_arts_specialneeds                    138
literacy_language_health_sports             72
health_sports_history_civics                43
specialneeds_health_sports                  42
history_civics_appliedlearning              42
health_sports_warmth_care_hunger            23
specialneeds_warmth_care_hunger             23
music_arts_health_sports                    19
music_arts_history_civics                   18
history_civics_health_sports                13
math_science_warmth_care_hunger             11
appliedlearning_warmth_care_hunger          10
music_arts_appliedlearning                  10
literacy_language_warmth_care_hunger         9
music_arts_warmth_care_hunger                2
history_civics_warmth_care_hunger            1
Name: clean_categories, dtype: int64
```

In [10]:
```
# teacher_prefix

df_project['teacher_prefix'].fillna('Mrs.', inplace = True)
df_project['teacher_prefix'] = df_project['teacher_prefix'].str.replace('.', '', regex = True)
df_project['teacher_prefix'] = df_project['teacher_prefix'].str.lower()
df_project['teacher_prefix'].value_counts()
```

Out[10]:
```
mrs        57272
ms         38955
mr         10648
teacher     2360
dr            13
Name: teacher_prefix, dtype: int64
```

In [11]:
```
# project_subject_subcategories

df_project['clean_subcategories'] = df_project['project_subject_subcategories'].str.replace(' The ','')
df_project['clean_subcategories'] = df_project['clean_subcategories'].str.replace(' ','')
df_project['clean_subcategories'] = df_project['clean_subcategories'].str.replace('&','_')
df_project['clean_subcategories'] = df_project['clean_subcategories'].str.replace(',','_')
df_project['clean_subcategories'] = df_project['clean_subcategories'].str.lower()
df_project['clean_subcategories'].value_counts()
```

Out[11]:
```
literacy                                 9486
literacy_mathematics                     8325
literature_writing_mathematics           5923
literacy_literature_writing              5571
mathematics                              5379
                                         ...
communityservice_financialliteracy          1
communityservice_music                      1
literature_writing_nutritioneducation       1
gym_fitness_warmth_care_hunger              1
history_geography_warmth_care_hunger        1
Name: clean_subcategories, Length: 401, dtype: int64
```

In [12]:
```
# school_state
```

In [12]:
```
df_project['school_state'] = df_project['school_state'].str.lower()
df_project['school_state'].unique()
```

Out[12]:
```
array(['in', 'fl', 'az', 'ky', 'tx', 'ct', 'ga', 'sc', 'nc', 'ca', 'ny',
       'ok', 'ma', 'nv', 'oh', 'pa', 'al', 'la', 'va', 'ar', 'wa', 'wv',
       'id', 'tn', 'ms', 'co', 'ut', 'il', 'mi', 'hi', 'ia', 'ri', 'nj',
       'mo', 'de', 'mn', 'me', 'wy', 'nd', 'or', 'ak', 'md', 'wi', 'sd',
       'ne', 'nm', 'dc', 'ks', 'mt', 'nh', 'vt'], dtype=object)
```

In [13]:
```
# https://gist.github.com/sebleier/554280

stopwords = ["i", "me", "my", "myself", "we", "our", "ours", "ourselves", "you", "your", "yours",
             "yourself", "yourselves", "he", "him", "his", "himself", "she", "her", "hers",
             "herself", "it", "its", "itself", "they", "them", "their", "theirs", "themselves",
             "what", "which", "who", "whom", "this", "that", "these", "those", "am", "is", "are",
             "was", "were", "be", "been", "being", "have", "has", "had", "having", "do", "does",
             "did", "doing", "a", "an", "the", "and", "but", "if", "or", "because", "as", "until",
             "while", "of", "at", "by", "for", "with", "about", "against", "between", "into",
             "through", "during", "before", "after", "above", "below", "to", "from", "up", "down",
             "in", "out", "on", "off", "over", "under", "again", "further", "then", "once", "here",
             "there", "when", "where", "why", "how", "all", "any", "both", "each", "few", "more",
             "most", "other", "some", "such", "no", "nor", "not", "only", "own", "same", "so", "than",
             "too", "very", "s", "t", "can", "will", "just", "don", "should", "now"]
```

In [14]:
```
# https://stackoverflow.com/a/47091490/4084039

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 [15]:
```
# https://gist.github.com/sebleier/554280
# Combining all the above stundents
def preprocess_text(text_data):

    preprocessed_text = []

    for sentance in tqdm(text_data):

        sent = decontracted(sentance)
        sent = sent.replace('\\r', ' ')
        sent = sent.replace('\\n', ' ')
        sent = sent.replace('\\"', ' ')
        sent = re.sub('[^A-Za-z0-9]+', ' ', sent)

        sent = ' '.join(e for e in sent.split() if e.lower() not in stopwords)

        preprocessed_text.append(sent.lower().strip())

    return preprocessed_text
```

In [16]:
```
df_project['essay'] = df_project['project_essay_1'].map(str) + \
                      df_project['project_essay_2'].map(str) + \
                      df_project['project_essay_3'].map(str) + \
                      df_project['project_essay_4'].map(str)

df_project['processed_essay'] = preprocess_text(df_project['essay'].values)
```

```
100%|██████████| 109248/109248 [00:48<00:00, 2259.67it/s]
```

In [17]:
```
print('9 : BEFORE Processing')
print('=' * 21)
print(df_project['essay'].values[9])
print('\nAFTER Processing')
print('=' *16)
print(df_project['processed_essay'].values[9])
```

```
9 : BEFORE Processing
======================
Over 95% of my students are on free or reduced lunch.  I have a few who are homeless, but despite that, they co
me to school with an eagerness to learn.  My students are inquisitive eager learners who  embrace the challenge
of not having great books and other resources  every day.  Many of them are not afforded the opportunity to eng
age with these big colorful pages of a book on a regular basis at home and they don't travel to the public libr
ary.  \r\nIt is my duty as a teacher to do all I can to provide each student an opportunity to succeed in every
aspect of life. \r\nReading is Fundamental! My students will read these books over and over again while boostin
g their comprehension skills. These books will be used for read alouds, partner reading and for Independent rea
ding. \r\nThey will engage in reading to build their \"Love for Reading\" by reading for pure enjoyment. They w
ill be introduced to some new authors as well as some old favorites. I want my students to be ready for the 21s
t Century and know the pleasure of holding a good hard back book in hand. There's nothing like a good book to r
ead!  \r\nMy students will soar in Reading, and more because of your consideration and generous funding contrib
ution. This will help build stamina and prepare for 3rd grade. Thank you so much for reading our proposal!nanna
n

AFTER Processing
================
95 students free reduced lunch homeless despite come school eagerness learn students inquisitive eager learners
embrace challenge great books resources every day many afforded opportunity engage big colorful pages book regu
lar basis home travel public library duty teacher provide student opportunity succeed every aspect life reading
fundamental students read books boosting comprehension skills books used read alouds partner reading independen
t reading engage reading build love reading reading pure enjoyment introduced new authors well old favorites wa
nt students ready 21st century know pleasure holding good hard back book hand nothing like good book read stude
nts soar reading consideration generous funding contribution help build stamina prepare 3rd grade thank much re
ading proposal nannan
```

In [18]:
```
df_project['clean_project_resource_summary'] = preprocess_text(df_project['project_resource_summary'].values)
```

```
100%|██████████| 109248/109248 [00:04<00:00, 21921.30it/s]
```

In [19]:
```
print('9 : BEFORE Processing')
print('=' * 21)
print(df_project['project_resource_summary'].values[9])
print('\nAFTER Processing')
print('=' *16)
print(df_project['clean_project_resource_summary'].values[9])
```

```
9 : BEFORE Processing
======================
My students need great books to use during Independent Reading, Read Alouds, Partner Reading and Author Studies
.

AFTER Processing
================
students need great books use independent reading read alouds partner reading author studies
```

In [20]:
```
def contains_numerical(data):

    if re.findall(r'\d', data):
        return 1

    return 0

df_project['resource_summary_contain_numerical'] = df_project['clean_project_resource_summary']. \
                                                    apply(contains_numerical)
```

In [21]:
```
preprocessed_columns = ['school_state', 'teacher_prefix', 'project_grade_category',
                        'clean_categories', 'clean_subcategories', 'processed_essay',
                        'teacher_number_of_previously_posted_projects', 'price', 'quantity',
                        'resource_summary_contain_numerical', 'project_is_approved']

final_df = df_project[preprocessed_columns]
print(f'Shape : {final_df.shape}')
final_df.head(2)
```

```
Shape : (109248, 11)
```

Out[21]:

	school_state	teacher_prefix	project_grade_category	clean_categories	clean_subcategories	processed_essay	teacher_num
0	in	mrs	grades_prek_2	literacy_language	esl_literacy	students english learners working english seco...	
1	fl	mr	grades_6_8	history_civics_health_sports	civics_government_teamsports	students arrive school eager learn polite gene...	

In [22]:
```
# Creating required directories

if os.path.exists('Processed_Data') and os.path.isdir('Model_Plots'):
    shutil.rmtree('Processed_Data')
    shutil.rmtree('Model_Plots')

os.mkdir('Processed_Data')
os.mkdir('Model_Plots')

if os.path.exists('modelCheck'):
    shutil.rmtree('modelCheck')
```

```
if os.path.isdir('logs'):
    shutil.rmtree('logs')
```

In [23]:
```
final_df.to_csv('Processed_Data/final_df.csv', index = False)
```

In [24]:
```
final_df = pd.read_csv('Processed_Data/final_df.csv')
```

In [25]:
```
Y = final_df['project_is_approved']
X = final_df.drop('project_is_approved', axis = 1)

print(f'Shape X : {X.shape}\nShape Y : {Y.shape}')
```

```
Shape X : (109248, 10)
Shape Y : (109248,)
```

In [26]:
```
# perform stratified train test split on the dataset

x_train, x_test, y_train, y_test = train_test_split(X, Y, test_size = 0.3,
                                                    stratify = Y, random_state = 40)
```

In [27]:
```
print(f'x_train shape : {x_train.shape}')
print(f'y_train shape : {y_train.shape}\n')
print(f'x_test shape  : {x_test.shape}')
print(f'y_test shape  : {y_test.shape}')
```

```
x_train shape : (76473, 10)
y_train shape : (76473,)

x_test shape  : (32775, 10)
y_test shape  : (32775,)
```

1.1 Text Vectorization

Since the data is already preprocessed, we can directly move to vectorization part

First we will vectorize the text data

For vectorization of text data in deep learning we use tokenizer, you can go through below references

https://www.kdnuggets.com/2020/03/tensorflow-keras-tokenization-text-data-prep.html

https://stackoverflow.com/questions/51956000/what-does-keras-tokenizer-method-exactly-do

After text vectorization you should get train_padded_docs and test_padded_docs

After getting the padded_docs you have to use predefined glove vectors to get 300 dim representation for each word we will be storing this data in form of an embedding matrix and will use it while defining our model.

Please go through following blog's 'Example of Using Pre-Trained GloVe Embedding' section to understand how to create embedding matrix https://machinelearningmastery.com/use-word-embedding-layers-deep-learning-keras/

In [28]:
```
with open('glove_vectors', 'rb') as f:
    glove = pickle.load(f)
```

In [29]:
```
%%time

# https://www.tensorflow.org/api_docs/python/tf/keras/preprocessing/text/Tokenizer

token = Tokenizer()

token.fit_on_texts(x_train['processed_essay'])

essay_train = token.texts_to_sequences(x_train['processed_essay'])
essay_test = token.texts_to_sequences(x_test['processed_essay'])

essay_train_padded = pad_sequences(essay_train, maxlen = 300)
essay_test_padded = pad_sequences(essay_test, maxlen = 300)

word_index = token.word_index
```

```
CPU times: user 13.6 s, sys: 66.8 ms, total: 13.7 s
Wall time: 13.7 s
```

In [30]:
```
num_words = len(word_index) + 1

embedding_matrix = np.zeros((num_words, 300))
embedding_matrix.shape
```

Out[30]:
```
(49000, 300)
```

In [31]:
```
# https://www.kaggle.com/code/shahules/basic-eda-cleaning-and-glove
```

```
# https://www.kaggle.com/code/shahules/basic-eda-cleaning-and-glove?scriptVersionId=26011146&cellId=72

for word, count in tqdm(word_index.items()):
    if glove.get(word) is not None:
        embedding_matrix[count] = glove.get(word)

len(embedding_matrix)
```

```
100%|██████████| 48999/48999 [00:00<00:00, 428457.93it/s]
```

Out[31]:
```
49000
```

1.2 Categorical feature Vectorization

For model 1 and model 2, we have to assign a unique number to each feature in a particular categorical column.

You can either use tokenizer,label encoder or ordinal encoder to perform the task

Label encoder gives an error for 'unseen values' (values present in test but not in train)

Handle unseen values with label encoder - https://stackoverflow.com/a/56876351

Ordinal encoder also gives error with unseen values but you can use modify handle_unknown parameter

Documentation of ordianl encoder https://scikit-learn.org/stable/modules/generated/sklearn.preprocessing.OrdinalEncoder.html

After categorical feature vectorization you will have column_train_data and column_test_data.

In [32]:
```
%%time
max_length = 1

token = Tokenizer()
token.fit_on_texts(x_train['school_state'])
school_state_train = token.texts_to_sequences(x_train['school_state'])
school_state_test = token.texts_to_sequences(x_test['school_state'])
school_state_train_padded = pad_sequences(school_state_train, maxlen = max_length)
school_state_test_padded = pad_sequences(school_state_test, maxlen = max_length)

school_state_lab = len(token.word_index) + 1

token = Tokenizer()
token.fit_on_texts(x_train['teacher_prefix'])
teacher_prefix_train = token.texts_to_sequences(x_train['teacher_prefix'])
teacher_prefix_test = token.texts_to_sequences(x_test['teacher_prefix'])
teacher_prefix_train_padded = pad_sequences(teacher_prefix_train, maxlen = max_length)
teacher_prefix_test_padded = pad_sequences(teacher_prefix_test, maxlen = max_length)

teacher_prefix_lab = len(token.word_index) + 1

token = Tokenizer()
token.fit_on_texts(x_train['project_grade_category'])
project_grade_category_train = token.texts_to_sequences(x_train['project_grade_category'])
project_grade_category_test = token.texts_to_sequences(x_test['project_grade_category'])
project_grade_category_train_padded = pad_sequences(project_grade_category_train, maxlen = max_length)
project_grade_category_test_padded = pad_sequences(project_grade_category_test, maxlen = max_length)

project_grade_category_lab = len(token.word_index) + 1

token = Tokenizer()
token.fit_on_texts(x_train['clean_categories'])
clean_categories_train = token.texts_to_sequences(x_train['clean_categories'])
clean_categories_test = token.texts_to_sequences(x_test['clean_categories'])
clean_categories_train_padded = pad_sequences(clean_categories_train, maxlen = max_length)
clean_categories_test_padded = pad_sequences(clean_categories_test, maxlen = max_length)

clean_categories_lab = len(token.word_index) + 1

token = Tokenizer()
token.fit_on_texts(x_train['clean_subcategories'])
clean_subcategories_train = token.texts_to_sequences(x_train['clean_subcategories'])
clean_subcategories_test = token.texts_to_sequences(x_test['clean_subcategories'])
clean_subcategories_train_padded = pad_sequences(clean_subcategories_train, maxlen = max_length)
clean_subcategories_test_padded = pad_sequences(clean_subcategories_test, maxlen = max_length)

clean_subcategories_lab = len(token.word_index) + 1
```

```
CPU times: user 8.13 s, sys: 23.3 ms, total: 8.15 s
Wall time: 8.15 s
```

1.3 Numerical feature Vectorization

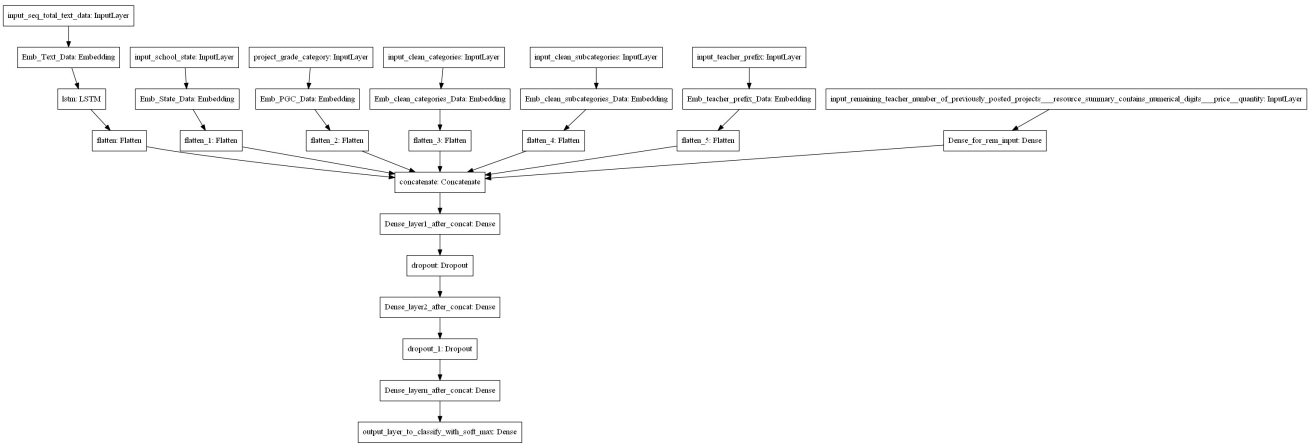
You have to standardise the numerical columns

Stack both the numerical features

After numerical feature vectorization you will have numerical_data_train and numerical_data_test

In [33]:
```
min_max = MinMaxScaler()
x_train['price'] = min_max.fit_transform(x_train[['price']])
x_test['price'] = min_max.transform(x_test[['price']])

min_max = MinMaxScaler()
x_train['quantity'] = min_max.fit_transform(x_train[['quantity']])
x_test['quantity'] = min_max.transform(x_test[['quantity']])

nums_colums  = ['price', 'quantity', 'resource_summary_contain_numerical']
x_train_nums = x_train[nums_colums]
x_test_nums = x_test[nums_colums]
```

1.4 Defining the model



As of now we have vectorized all our features now we will define our model.

As it is clear from above image that the given model has multiple input layers and hence we have to use functional API

Please go through - https://keras.io/guides/functional_api/

It is a good programming practise to define your complete model i.e all inputs , intermediate and output layers at one place.

While defining your model make sure that you use variable names while defining any length,dimension or size.

for ex.- you should write the code as `input_text = Input(shape=(pad_length,))` and not as `input_text = Input(shape=(300,))`

the embedding layer for text data should be non trainable

the embedding layer for categorical data should be trainable

https://stats.stackexchange.com/questions/270546/how-does-keras-embedding-layer-work

https://towardsdatascience.com/deep-embeddings-for-categorical-variables-cat2vec-b05c8ab63ac0

`print model.summary()` after you have defined the model

plot the model using `utils.plot_model` module and make sure that it is similar to the above image

In [34]:
```
# https://keras.io/api/layers/recurrent_layers/lstm/

tensorflow.keras.backend.clear_session()
tensorflow.random.set_seed(42)
OUT_DIM = 6

seq_input = Input(shape = (300,), name = 'Input_Text_Data')
embed_sqe_input = Embedding(input_dim = num_words, output_dim = 300, weights = [embedding_matrix],
                            trainable = False, name = 'Embed_Text_Data')(seq_input)
lstm_ = LSTM(128, activation = 'relu', return_sequences = True, name = 'LSTM')(embed_sqe_input)
flatten_seq = Flatten(name = 'Flat_LSTM')(lstm_)

school_input = Input(shape = (1,), name = 'School_State')
embed_school_input = Embedding(input_dim = school_state_lab, output_dim = OUT_DIM,
                               name = 'Embed_School_State')(school_input)
flatten_school = Flatten(name = 'Flat_School')(embed_school_input)

teacher_input = Input(shape = (1,), name = 'Teacher_Prefix')
embed_teacher_input = Embedding(input_dim = teacher_prefix_lab, output_dim = OUT_DIM,
                               name = 'Embed_Teacher_Prefix', trainable = True)(teacher_input)
flatten_teacher = Flatten(name = 'Flat_Teacher_Prefix')(embed_teacher_input)
```

```
grade_input = Input(shape = (1,), name = 'Project_Grade_Categ.')
embed_grade_input = Embedding(input_dim = project_grade_category_lab, output_dim =OUT_DIM,
                              name = 'Embed_Project_Grade_Categ.', trainable = True)(grade_input)
flatten_grade = Flatten(name = 'Flat_Project_Grade_Categ.')(embed_grade_input)

cat_input = Input(shape = (1,), name = 'Clean_Categ.')
embed_cat_input = Embedding(input_dim = clean_categories_lab, output_dim = OUT_DIM,
                            name = 'Embed_Clean_Categ.')(cat_input)
flatten_cat = Flatten(name = 'Flat_Clean_Categ.')(embed_cat_input)

clean_cat_input = Input(shape = (1,), name = 'Clean_Subcateg.')
embed_clean_cat_input = Embedding(input_dim = clean_subcategories_lab, output_dim = OUT_DIM,
                            name = 'Embed_Clean_Subcateg.', trainable = True)(clean_cat_input)
flatten_clean_cat = Flatten(name = 'Flat_Clean_Subcateg.')(embed_clean_cat_input)


numerical_input = Input(shape = (3,), name = 'Remaining_Numericals__Price_Quantity_ResourceSummmary')
dense_numerical = Dense(128, activation = 'relu' , kernel_initializer = 'he_normal',
                        name = 'Numericals__Price_Quantity_ResourceSummmary', trainable = True)(numerical_input)

concat_list = [flatten_seq, flatten_school, flatten_teacher, flatten_grade,
               flatten_cat, flatten_clean_cat, dense_numerical]
inp_list = [seq_input, school_input, teacher_input, grade_input, cat_input,
            clean_cat_input, numerical_input]

concat_1 = Concatenate(name = 'Concatenate')(concat_list)
dense_1 = Dense(256, activation = 'relu', name = 'Dense_Layer1_After_Concat.')(concat_1)

dropout_1 = Dropout(0.5, name = 'Dropout-1')(dense_1)
dense_2 = Dense(256, activation = 'relu', name = 'Dense_Layer2_After_Concat')(dropout_1)

dropout_2 = Dropout(0.5, name = 'Dropout-2')(dense_2)
dense_3 = Dense(8, activation = 'relu', name = 'Dense_Layer3_After_Concat')(dropout_2)

out_put_softmax = Dense(2, activation = 'sigmoid', name = 'Output_layer_to_classify_with_softmax')(dense_3)

model_1 = Model(inputs = inp_list, outputs = out_put_softmax, name = 'Model_1')

model_1.summary()
```

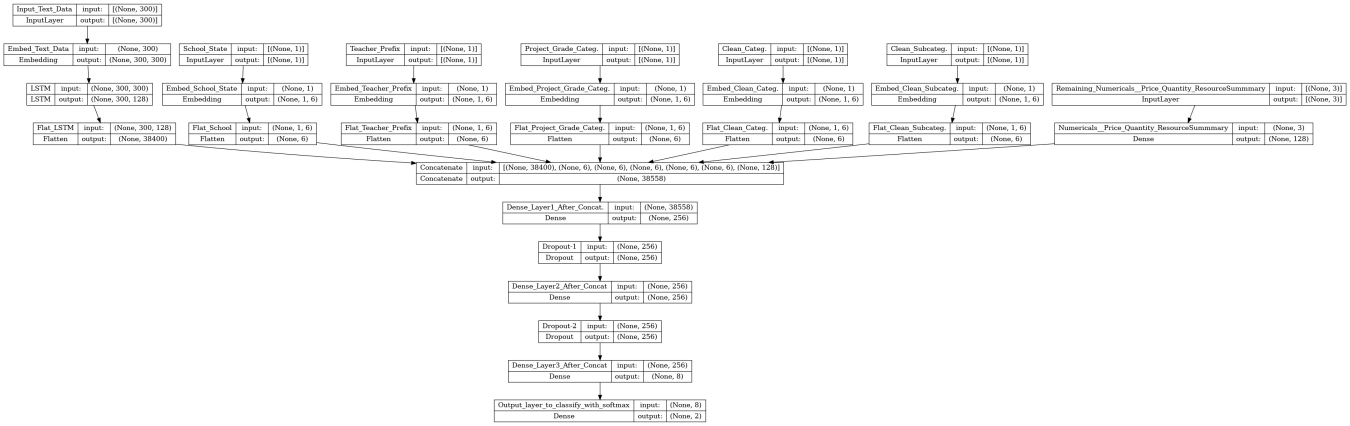
```
WARNING:tensorflow:Layer LSTM will not use cuDNN kernels since it doesn't meet the criteria. It will use a gene
ric GPU kernel as fallback when running on GPU.
Model: "Model_1"
```

Layer (type)	Output Shape	Param #	Connected to
Input_Text_Data (InputLayer)	[(None, 300)]	0	[]
Embed_Text_Data (Embedding)	(None, 300, 300)	14700000	['Input_Text_Data[0][0]']
School_State (InputLayer)	[(None, 1)]	0	[]
Teacher_Prefix (InputLayer)	[(None, 1)]	0	[]
Project_Grade_Categ. (InputLayer)	[(None, 1)]	0	[]
Clean_Categ. (InputLayer)	[(None, 1)]	0	[]
Clean_Subcateg. (InputLayer)	[(None, 1)]	0	[]
LSTM (LSTM)	(None, 300, 128)	219648	['Embed_Text_Data[0][0]']
Embed_School_State (Embedding)	(None, 1, 6)	312	['School_State[0][0]']
Embed_Teacher_Prefix (Embedding)	(None, 1, 6)	36	['Teacher_Prefix[0][0]']
Embed_Project_Grade_Categ. (Embedding)	(None, 1, 6)	60	['Project_Grade_Categ.[0][0]']
Embed_Clean_Categ. (Embedding)	(None, 1, 6)	96	['Clean_Categ.[0][0]']
Embed_Clean_Subcateg. (Embedding)	(None, 1, 6)	228	['Clean_Subcateg.[0][0]']
Remaining_Numericals__Price_Quantity_ResourceSummmary (InputLayer)	[(None, 3)]	0	[]
Flat_LSTM (Flatten)	(None, 38400)	0	['LSTM[0][0]']
Flat_School (Flatten)	(None, 6)	0	['Embed_School_State[0][0]']
Flat_Teacher_Prefix (Flatten)	(None, 6)	0	['Embed_Teacher_Prefix[0][0]']
Flat_Project_Grade_Categ. (Flatten)	(None, 6)	0	['Embed_Project_Grade_Categ.[0][0]']

```
Flat_Clean_Categ. (Flatten)    (None, 6)           0           ['Embed_Clean_Categ.[0][0]']

Flat_Clean_Subcateg. (Flatten)  (None, 6)          0           ['Embed_Clean_Subcateg.[0][0]']

Numericals__Price_Quantity_Res  (None, 128)        512         ['Remaining_Numericals__Price_Qua
ourceSummmary (Dense)                                          ntity_ResourceSummmary[0][0]']

Concatenate (Concatenate)      (None, 38558)       0           ['Flat_LSTM[0][0]',
                                                                'Flat_School[0][0]',
                                                                'Flat_Teacher_Prefix[0][0]',
                                                                'Flat_Project_Grade_Categ.[0][0]
                                                                ',
                                                                'Flat_Clean_Categ.[0][0]',
                                                                'Flat_Clean_Subcateg.[0][0]',
                                                                'Numericals__Price_Quantity_Reso
                                                                urceSummmary[0][0]']

Dense_Layer1_After_Concat. (De  (None, 256)         9871104     ['Concatenate[0][0]']
nse)

Dropout-1 (Dropout)            (None, 256)         0           ['Dense_Layer1_After_Concat.[0][0
                                                               ]']

Dense_Layer2_After_Concat (Den  (None, 256)         65792       ['Dropout-1[0][0]']
se)

Dropout-2 (Dropout)            (None, 256)         0           ['Dense_Layer2_After_Concat[0][0]
                                                               ']

Dense_Layer3_After_Concat (Den  (None, 8)           2056        ['Dropout-2[0][0]']
se)

Output_layer_to_classify_with_  (None, 2)           18          ['Dense_Layer3_After_Concat[0][0]
softmax (Dense)                                                ']

==================================================================================================
Total params: 24,859,862
Trainable params: 10,159,862
Non-trainable params: 14,700,000
__________________________________________________________________________________________________
```

In [35]:
```
plot_model(model_1, to_file = 'Model_Plots/model_1.png', show_shapes = True)
```

Out[35]:



In [36]:
```
# https://keras.io/api/callbacks/reduce_lr_on_plateau/
# https://keras.io/api/callbacks/early_stopping/
# https://keras.io/api/callbacks/tensorboard/
# https://keras.io/api/callbacks/model_checkpoint/

logdir = 'logs/model_1/' + datetime.now().strftime('%Y%m%d_%H%M%S')
tensorBoard = TensorBoard(log_dir = logdir, histogram_freq = 1)

filepath = 'modelCheck/model_1/epo_{epoch:02d}-accu_{val_auc:.4f}.hdf5'
model_checkP = ModelCheckpoint(filepath, monitor = 'val_auc', verbose = 1, save_best_only = True)

reduce_lr = ReduceLROnPlateau(monitor = 'val_auc', factor = 0.9, patience = 2, verbose = 1)

early_stop = EarlyStopping(monitor = 'val_auc', patience = 2, verbose = 1)

CallBacks = [tensorBoard, model_checkP, reduce_lr, early_stop]
```

1.5 Compiling and fititng your model

Define custom auc as metric , do not use tf.keras.metrics

https://stackoverflow.com/a/46844409 - custom AUC reference 1

https://www.kaggle.com/c/santander-customer-transaction-prediction/discussion/80807 - custom AUC reference 2

Compile and fit your model

In [37]:
```
y_train_cat = to_categorical(y_train, 2)
y_test_cat = to_categorical(y_test, 2)
```

In [38]:
```
train_list = [essay_train_padded, school_state_train_padded, teacher_prefix_train_padded,
              project_grade_category_train_padded,
              clean_categories_train_padded, clean_subcategories_train_padded, x_train_nums]

test_list = [essay_test_padded, school_state_test_padded, teacher_prefix_test_padded,
             project_grade_category_test_padded,
            clean_categories_test_padded, clean_subcategories_test_padded, x_test_nums]
```

In [39]:
```
# https://stackoverflow.com/a/69248506
def roc_score_(y_true, y_pred):
    return roc_auc_score(y_true, y_pred, average = 'micro')

def auc(y_true, y_pred):
    return tf.py_function(roc_score_, (y_true, y_pred), tf.double)
```

In [40]:
```
# https://keras.io/api/losses/probabilistic_losses/#categoricalcrossentropy-class
# https://keras.io/api/optimizers/adam/

optim = Adam(learning_rate = 0.001)
model_1.compile(optimizer = optim, metrics = [auc], loss = 'categorical_crossentropy')
```

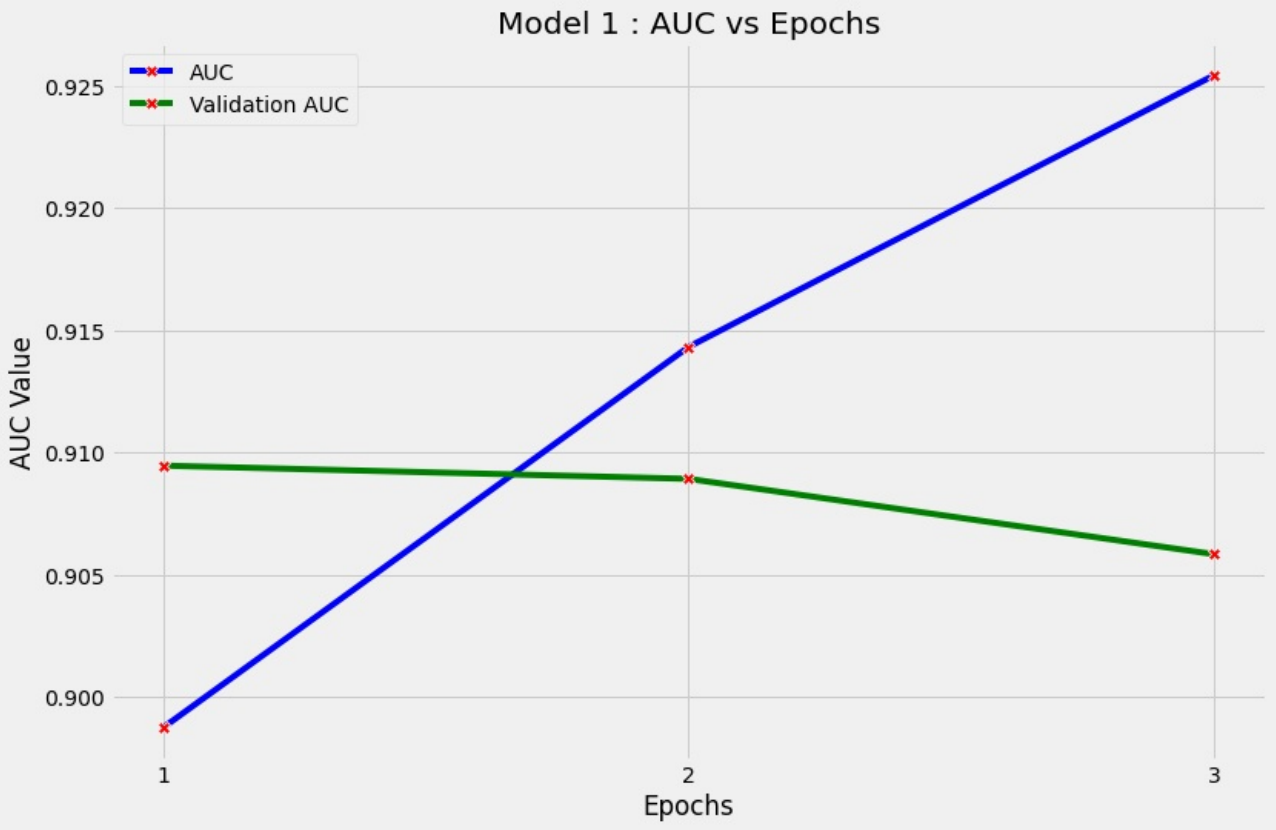
In [41]:
```
EPOCHS_1 = 5

Model1 = model_1.fit(train_list, y_train_cat, epochs = EPOCHS_1, batch_size = 128, verbose = 1,
            validation_data = (test_list, y_test_cat), callbacks = CallBacks)
```

```
Epoch 1/5
598/598 [==============================] - ETA: 0s - loss: 0.3945 - auc: 0.8988
Epoch 1: val_auc improved from inf to 0.90947, saving model to modelCheck/model_1/epo_01-accu_0.9095.hdf5
598/598 [==============================] - 240s 397ms/step - loss: 0.3945 - auc: 0.8988 - val_loss: 0.3838 - va
l_auc: 0.9095 - lr: 0.0010
Epoch 2/5
598/598 [==============================] - ETA: 0s - loss: 0.3864 - auc: 0.9143
Epoch 2: val_auc improved from 0.90947 to 0.90893, saving model to modelCheck/model_1/epo_02-accu_0.9089.hdf5
598/598 [==============================] - 238s 397ms/step - loss: 0.3864 - auc: 0.9143 - val_loss: 0.3766 - va
l_auc: 0.9089 - lr: 0.0010
Epoch 3/5
598/598 [==============================] - ETA: 0s - loss: 0.3422 - auc: 0.9254
Epoch 3: val_auc improved from 0.90893 to 0.90585, saving model to modelCheck/model_1/epo_03-accu_0.9058.hdf5
598/598 [==============================] - 237s 397ms/step - loss: 0.3422 - auc: 0.9254 - val_loss: 0.3773 - va
l_auc: 0.9058 - lr: 0.0010
Epoch 3: early stopping
```

In [42]:
```
model_1_auc = round(Model1.history['auc'][-1], 3)
model_1_val_acc = round(Model1.history['val_auc'][-1], 3)
model_1_loss = round(Model1.history['val_loss'][-1], 3)

print(f"AUC score of the Model-1\t\t: {model_1_auc}")
print(f"Validation accuracy of the Model-1\t: {model_1_val_acc}")
print(f"Validation loss of the Model-1\t\t: {model_1_loss}")
```

```
AUC score of the Model-1                : 0.925
Validation accuracy of the Model-1      : 0.906
Validation loss of the Model-1          : 0.377
```

In [43]:
```
# https://wellsr.com/python/seaborn-line-plot-data-visualization/
# https://seaborn.pydata.org/generated/seaborn.lineplot.html

epochs_ = list(range(1, len(Model1.history['auc']) + 1))
plt.figure(figsize = (12, 8))

sns.lineplot(y = 'auc', data = Model1.history , x = epochs_, label = 'AUC', color = 'b',
            marker = 'X', mfc = 'red', ms = 8)

sns.lineplot(y = 'val_auc', data = Model1.history , x = epochs_, label = 'Validation AUC',
            color = 'g', marker = 'X', mfc = 'red', ms = 8)

plt.title('Model 1 : AUC vs Epochs')
plt.xticks(epochs_) ; plt.xlabel('Epochs') ; plt.ylabel('AUC Value') ; plt.show()
```



In [44]:
```
model_1.save('Processed_Data/model_1.h5')
```

Model-2

Use the same model as above but for 'input_seq_total_text_data' give only some words in the sentance not all the words. Filter the words as below.

1. Fit TF-IDF vectorizer on the Train data

2. Get the idf value for each word we have in the train data. Please go through this

3. Do some analysis on the Idf values and based on those values choose the low and high threshold value. Because very
frequent words and very very rare words don't give much information.
Hint - A preferable IDF range is 2-11 for model 2.

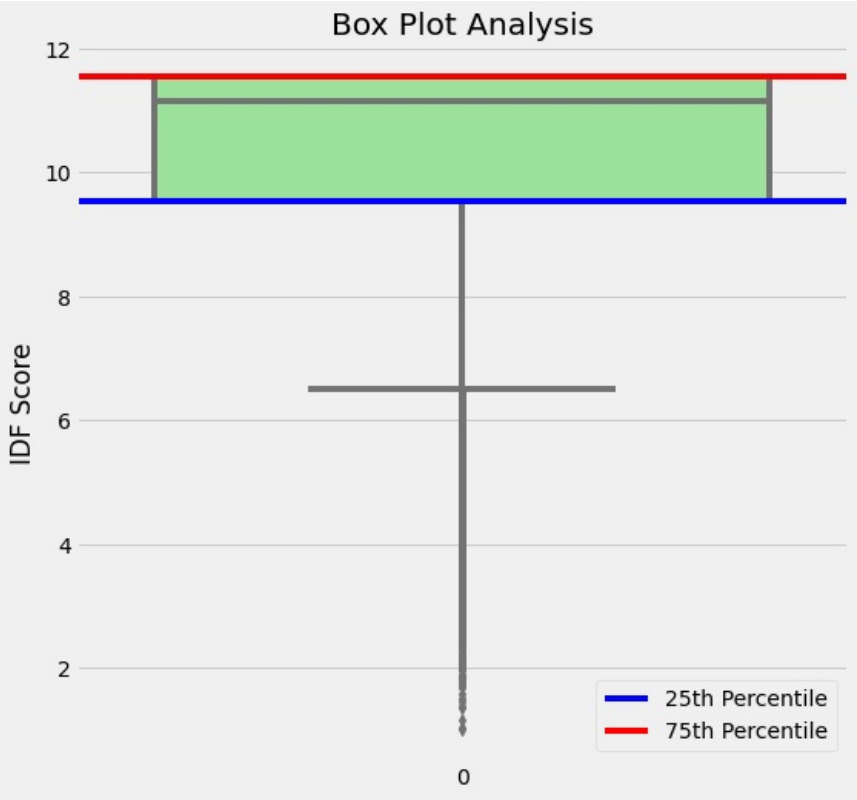
4.Remove the low idf value and high idf value words from the train and test data. You can go through each of the
sentence of train and test data and include only those features(words) which are present in the defined IDF range.
5. Perform tokenization on the modified text data same as you have done for previous model.
6. Create embedding matrix for model 2 and then use the rest of the features similar to previous model.
7. Define the model, compile and fit the model.

In [45]:
```
# https://scikit-learn.org/stable/modules/generated/sklearn.feature_extraction.text.TfidfVectorizer.html
# https://stackoverflow.com/a/23796566

vect = TfidfVectorizer()
tfidf = vect.fit_transform(x_train['processed_essay'])

words_ = vect.get_feature_names_out()
idf_values_ = vect.idf_
```

In [46]:
```
for i in range(0, 101, 10):
    print(f'{i:3} percentile value is {round(np.percentile(idf_values_ , i), 3):7}')
```

```
  0 percentile value is   1.008
 10 percentile value is   7.541
 20 percentile value is   8.987
 30 percentile value is   9.942
 40 percentile value is  10.635
 50 percentile value is  11.146
 60 percentile value is  11.146
 70 percentile value is  11.552
 80 percentile value is  11.552
 90 percentile value is  11.552
100 percentile value is  11.552
```

In [47]:
```
plt.figure(figsize=(8,8))
sns.boxplot(data = idf_values_, orient = 'v', color = 'lightgreen')
plt.title('Box Plot Analysis')
plt.axhline(round(np.percentile(idf_values_ , 25), 3), color = 'b', label = '25th Percentile')
plt.axhline(round(np.percentile(idf_values_ , 75), 3), color = 'r', label = '75th Percentile')
plt.legend(loc = 4)
plt.ylabel('IDF Score')
plt.show()

twnty5 = round(np.percentile(idf_values_ , 25), 3)
sventy5 = round(np.percentile(idf_values_ , 75), 3)

print(f'TF-IDF scores at 25th percentile : \u001b[34;1m{twnty5:6}\u001b[0m')
print(f'TF-IDF scores at 75th percentile : \u001b[31;1m{sventy5:6}')
```




```
TF-IDF scores at 25th percentile :  9.537
TF-IDF scores at 75th percentile : 11.552
```

- Hint - A preferable IDF range is 2-11 for model 2.
- Since most of the values lie in **11** range, we are choosing `idf` values inbetween **25th** and **75th** percentile

In [48]:
```
idf_sorted_words = []

for w, idf in zip(words_, idf_values_):
    if idf >= twnty5 and sventy5 >= idf:
        idf_sorted_words.append(w)

print(len(idf_sorted_words))
```

```
36460
```

In [49]:
```
def idf_processing(data, idf_words):

    idf_pro = []
    for row in tqdm(data):
        senten = []
        for word in row.split():
            if word in idf_words:
                senten.append(word)
        idf_pro.append(' '.join(senten))
```

```
    return idf_pro

x_train_idf_words = idf_processing(x_train['processed_essay'], set(idf_sorted_words))
x_test_idf_words = idf_processing(x_test['processed_essay'], set(idf_sorted_words))
```

```
100%|██████████| 76473/76473 [00:01<00:00, 63809.68it/s]
100%|██████████| 32775/32775 [00:00<00:00, 64338.34it/s]
```

In [50]:
```
# https://www.tensorflow.org/api_docs/python/tf/keras/preprocessing/text/Tokenizer
MAXLN = 800

token = Tokenizer()

token.fit_on_texts(x_train_idf_words)

idf_essay_train = token.texts_to_sequences(x_train_idf_words)
idf_essay_test = token.texts_to_sequences(x_test_idf_words)

idf_essay_train_padded = pad_sequences(idf_essay_train, maxlen = MAXLN)
idf_essay_test_padded = pad_sequences(idf_essay_test, maxlen = MAXLN)

word_index = token.word_index
```

In [51]:
```
num_words = len(word_index) + 1

embedding_matrix = np.zeros((num_words, 300))
embedding_matrix.shape
```

Out[51]:
```
(36461, 300)
```

In [52]:
```
# https://www.kaggle.com/code/shahules/basic-eda-cleaning-and-glove

for word, count in tqdm(word_index.items()):
    if glove.get(word) is not None:
        embedding_matrix[count] = glove.get(word)

embedding_matrix.shape
```

```
100%|██████████| 36460/36460 [00:00<00:00, 433629.81it/s]
```

Out[52]:
```
(36461, 300)
```

In [53]:
```
tensorflow.keras.backend.clear_session()
tensorflow.random.set_seed(56)

idf_seq_input = Input(shape = (800,), name = 'Input_Text_Data')
idf_embed_sqe_input = Embedding(input_dim = num_words, output_dim = 300, weights = [embedding_matrix],
                            trainable = False, name = 'IDF_Embed_Text_Data')(idf_seq_input)
idf_lstm_ = LSTM(128, activation = 'relu', return_sequences = True, name = 'LSTM')(idf_embed_sqe_input)
idf_flatten_seq = Flatten(name = 'Flat_LSTM')(idf_lstm_)


concat_list = [idf_flatten_seq, flatten_school, flatten_teacher, flatten_grade,
                    flatten_cat, flatten_clean_cat, dense_numerical]

inp_list = [idf_seq_input, school_input, teacher_input, grade_input, cat_input,
                    clean_cat_input, numerical_input]

concat_1 = Concatenate(name = 'Concatenate')(concat_list)
dense_1 = Dense(256, activation = 'relu', name = 'IDF_Dense_Layer1_After_Concat.')(concat_1)

dropout_1 = Dropout(0.5, name = 'Dropout-1')(dense_1)
dense_2 = Dense(256, activation = 'relu', name = 'IDF_Dense_Layer2_After_Concat')(dropout_1)

dropout_2 = Dropout(0.5, name = 'Dropout-2')(dense_2)
dense_3 = Dense(8, activation = 'relu', name = 'IDF_Dense_Layer3_After_Concat')(dropout_2)

out_put_softmax = Dense(2, activation = 'softmax', name = 'IDF_Output_layer_to_classify_with_softmax')(dense_3)

model_2 = Model(inputs = inp_list, outputs = out_put_softmax, name = 'Model_2')

model_2.summary()
```

```
WARNING:tensorflow:Layer LSTM will not use cuDNN kernels since it doesn't meet the criteria. It will use a gene
ric GPU kernel as fallback when running on GPU.
Model: "Model_2"
```

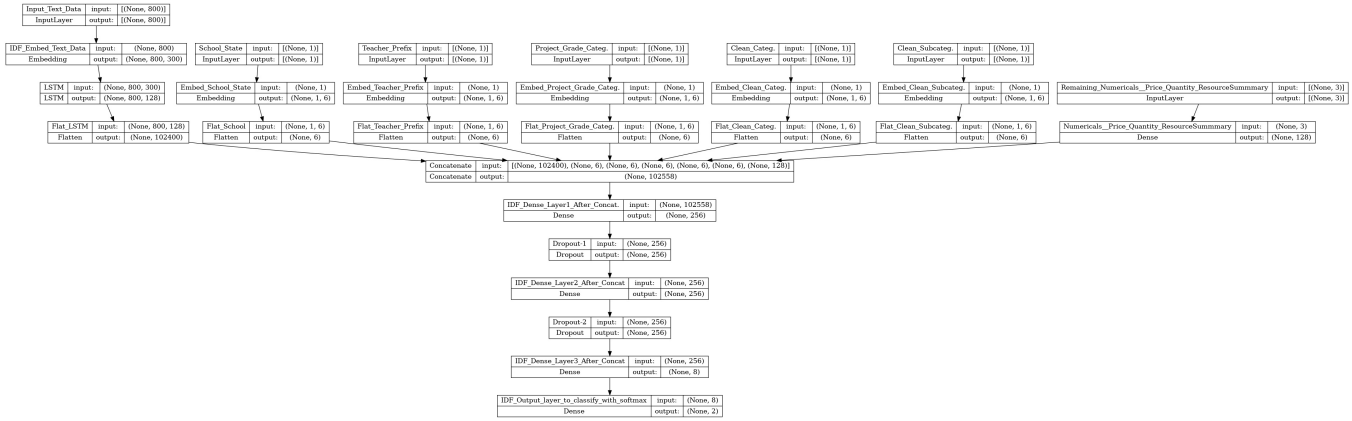
Layer (type)	Output Shape	Param #	Connected to
Input_Text_Data (InputLayer)	[(None, 800)]	0	[]
IDF_Embed_Text_Data (Embedding)	(None, 800, 300)	10938300	['Input_Text_Data[0][0]']
School_State (InputLayer)	[(None, 1)]	0	[]
Teacher_Prefix (InputLayer)	[(None, 1)]	0	[]

```
Project_Grade_Categ. (InputLay  [(None, 1)]         0           []
er)

Clean_Categ. (InputLayer)       [(None, 1)]         0           []

Clean_Subcateg. (InputLayer)    [(None, 1)]         0           []

LSTM (LSTM)                     (None, 800, 128)    219648      ['IDF_Embed_Text_Data[0][0]']

Embed_School_State (Embedding)  (None, 1, 6)        312         ['School_State[0][0]']

Embed_Teacher_Prefix (Embeddin  (None, 1, 6)        36          ['Teacher_Prefix[0][0]']
g)

Embed_Project_Grade_Categ. (Em  (None, 1, 6)        60          ['Project_Grade_Categ.[0][0]']
bedding)

Embed_Clean_Categ. (Embedding)  (None, 1, 6)        96          ['Clean_Categ.[0][0]']

Embed_Clean_Subcateg. (Embeddi  (None, 1, 6)        228         ['Clean_Subcateg.[0][0]']
ng)

Remaining_Numericals__Price_Qu  [(None, 3)]         0           []
antity_ResourceSummmary (Input
Layer)

Flat_LSTM (Flatten)             (None, 102400)      0           ['LSTM[0][0]']

Flat_School (Flatten)           (None, 6)           0           ['Embed_School_State[0][0]']

Flat_Teacher_Prefix (Flatten)   (None, 6)           0           ['Embed_Teacher_Prefix[0][0]']

Flat_Project_Grade_Categ. (Fla  (None, 6)           0           ['Embed_Project_Grade_Categ.[0][0
tten)                                                           ]']

Flat_Clean_Categ. (Flatten)     (None, 6)           0           ['Embed_Clean_Categ.[0][0]']

Flat_Clean_Subcateg. (Flatten)  (None, 6)           0           ['Embed_Clean_Subcateg.[0][0]']

Numericals__Price_Quantity_Res  (None, 128)         512         ['Remaining_Numericals__Price_Qua
ourceSummmary (Dense)                                           ntity_ResourceSummmary[0][0]']

Concatenate (Concatenate)       (None, 102558)      0           ['Flat_LSTM[0][0]',
                                                                 'Flat_School[0][0]',
                                                                 'Flat_Teacher_Prefix[0][0]',
                                                                 'Flat_Project_Grade_Categ.[0][0]
                                                                ',
                                                                 'Flat_Clean_Categ.[0][0]',
                                                                 'Flat_Clean_Subcateg.[0][0]',
                                                                 'Numericals__Price_Quantity_Reso
                                                                urceSummmary[0][0]']

IDF_Dense_Layer1_After_Concat.  (None, 256)         26255104    ['Concatenate[0][0]']
 (Dense)

Dropout-1 (Dropout)             (None, 256)         0           ['IDF_Dense_Layer1_After_Concat.[
                                                                0][0]']

IDF_Dense_Layer2_After_Concat   (None, 256)         65792       ['Dropout-1[0][0]']
(Dense)

Dropout-2 (Dropout)             (None, 256)         0           ['IDF_Dense_Layer2_After_Concat[0
                                                                ][0]']

IDF_Dense_Layer3_After_Concat   (None, 8)           2056        ['Dropout-2[0][0]']
(Dense)

IDF_Output_layer_to_classify_w  (None, 2)           18          ['IDF_Dense_Layer3_After_Concat[0
ith_softmax (Dense)                                             ][0]']

==================================================================================================
Total params: 37,482,162
Trainable params: 26,543,862
Non-trainable params: 10,938,300
__________________________________________________________________________________________________
```

In [54]:

```
plot_model(model_2, to_file = 'Model_Plots/model_2.png', show_shapes = True)
```

Out[54]:



In [55]:
```
# https://keras.io/api/callbacks/reduce_lr_on_plateau/
# https://keras.io/api/callbacks/early_stopping/
# https://keras.io/api/callbacks/tensorboard/
# https://keras.io/api/callbacks/model_checkpoint/

logdir = 'logs/model_2/' + datetime.now().strftime('%Y%m%d_%H%M%S')
tensorBoard = TensorBoard(log_dir = logdir, histogram_freq = 1)

filepath = 'modelCheck/model_2/epo_{epoch:02d}-accu_{val_auc:.4f}.hdf5'
model_checkP = ModelCheckpoint(filepath, monitor = 'val_auc', verbose = 1, save_best_only = True)

CallBacks = [tensorBoard, model_checkP, reduce_lr, early_stop]
```

In [56]:
```
train_list = [idf_essay_train_padded, school_state_train_padded, teacher_prefix_train_padded,
              project_grade_category_train_padded,
              clean_categories_train_padded, clean_subcategories_train_padded, x_train_nums]

test_list = [idf_essay_test_padded, school_state_test_padded, teacher_prefix_test_padded,
             project_grade_category_test_padded,
            clean_categories_test_padded, clean_subcategories_test_padded, x_test_nums]
```

In [57]:
```
# https://keras.io/api/losses/probabilistic_losses/#categoricalcrossentropy-class
# https://keras.io/api/optimizers/adam/

optim = Adam(learning_rate = 0.001)
model_2.compile(optimizer = optim, metrics = [auc], loss = 'categorical_crossentropy')
```

In [58]:
```
EPOCHS_2 = 4

Model2 = model_2.fit(train_list, y_train_cat, epochs = EPOCHS_2, batch_size = 128, verbose = 1,
            validation_data = (test_list, y_test_cat), callbacks = CallBacks)
```

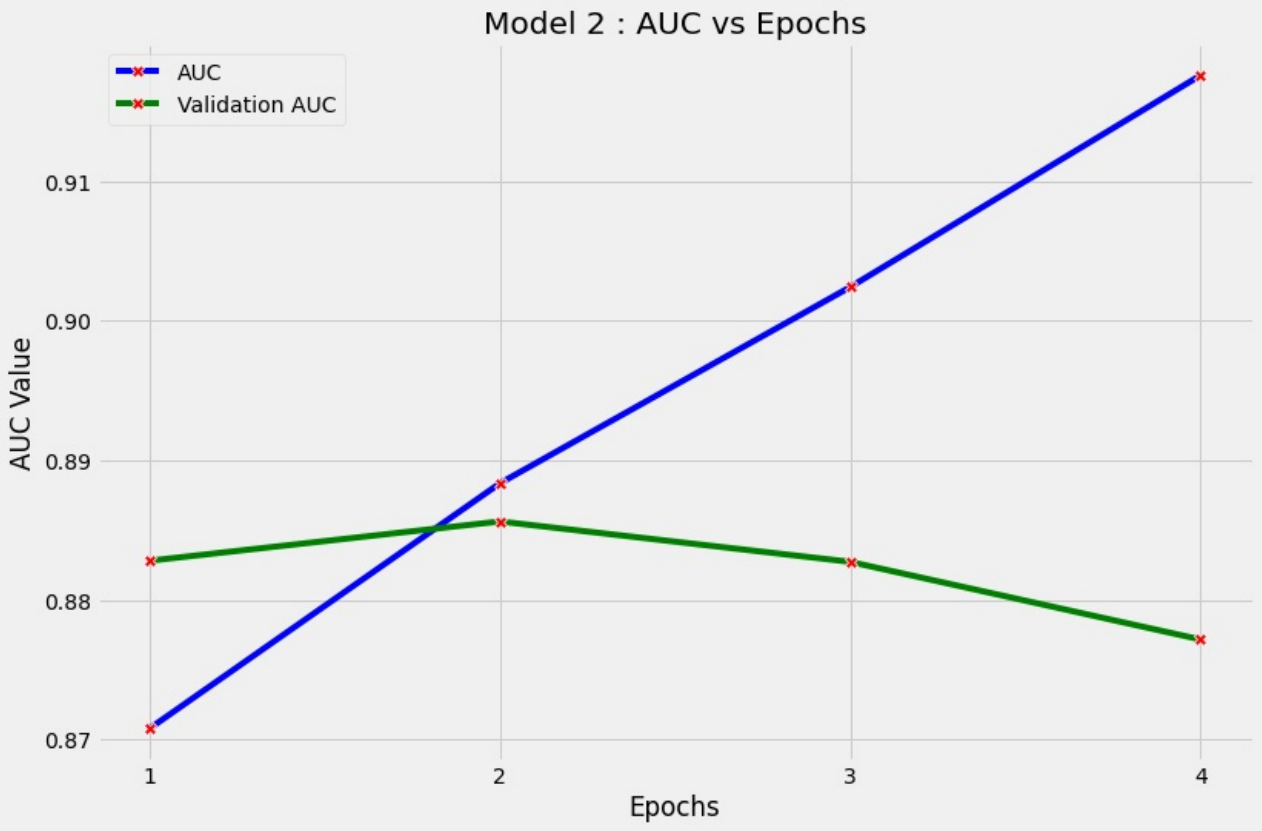
```
Epoch 1/4
598/598 [==============================] - ETA: 0s - loss: 0.4243 - auc: 0.8708
Epoch 1: val_auc improved from inf to 0.88282, saving model to modelCheck/model_2/epo_01-accu_0.8828.hdf5
598/598 [==============================] - 619s 1s/step - loss: 0.4243 - auc: 0.8708 - val_loss: 0.4106 - val_a
uc: 0.8828 - lr: 0.0010
Epoch 2/4
598/598 [==============================] - ETA: 0s - loss: 0.4066 - auc: 0.8884
Epoch 2: val_auc did not improve from 0.88282
598/598 [==============================] - 617s 1s/step - loss: 0.4066 - auc: 0.8884 - val_loss: 0.4103 - val_a
uc: 0.8856 - lr: 0.0010
Epoch 3/4
598/598 [==============================] - ETA: 0s - loss: 0.3885 - auc: 0.9024
Epoch 3: val_auc improved from 0.88282 to 0.88274, saving model to modelCheck/model_2/epo_03-accu_0.8827.hdf5

Epoch 3: ReduceLROnPlateau reducing learning rate to 0.0009900000427477062.
598/598 [==============================] - 616s 1s/step - loss: 0.3885 - auc: 0.9024 - val_loss: 0.4184 - val_a
uc: 0.8827 - lr: 0.0010
Epoch 4/4
598/598 [==============================] - ETA: 0s - loss: 0.3600 - auc: 0.9176
Epoch 4: val_auc improved from 0.88274 to 0.87718, saving model to modelCheck/model_2/epo_04-accu_0.8772.hdf5
598/598 [==============================] - 616s 1s/step - loss: 0.3600 - auc: 0.9176 - val_loss: 0.4468 - val_a
uc: 0.8772 - lr: 9.0000e-04
Epoch 4: early stopping
```

In [59]:
```
model_2_auc = round(Model2.history['auc'][-1], 3)
model_2_val_acc = round(Model2.history['val_auc'][-1], 3)
model_2_loss = round(Model2.history['val_loss'][-1], 3)

print(f"AUC score of the Model-2\t\t: {model_2_auc}")
print(f"Validation accuracy of the Model-2\t: {model_2_val_acc}")
print(f"Validation loss of the Model-2\t\t: {model_2_loss}")
```

```
AUC score of the Model-2                : 0.918
Validation accuracy of the Model-2      : 0.877
Validation loss of the Model-2          : 0.447
```

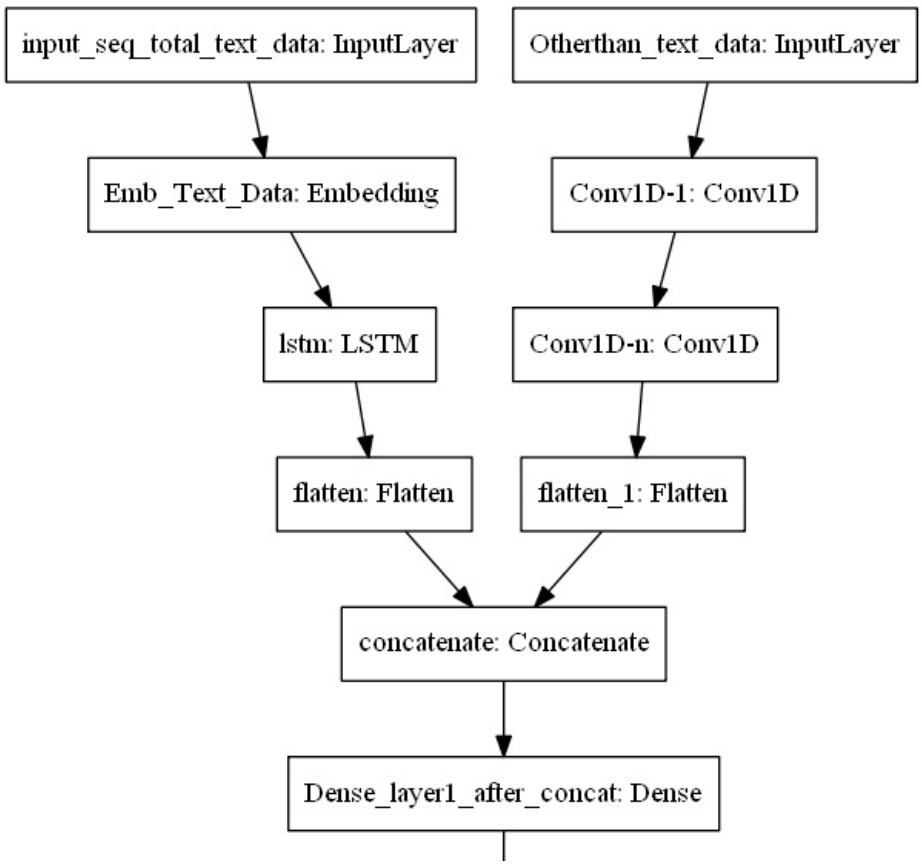
In [60]:
```
# https://wellsr.com/python/seaborn-line-plot-data-visualization/
# https://seaborn.pydata.org/generated/seaborn.lineplot.html
```

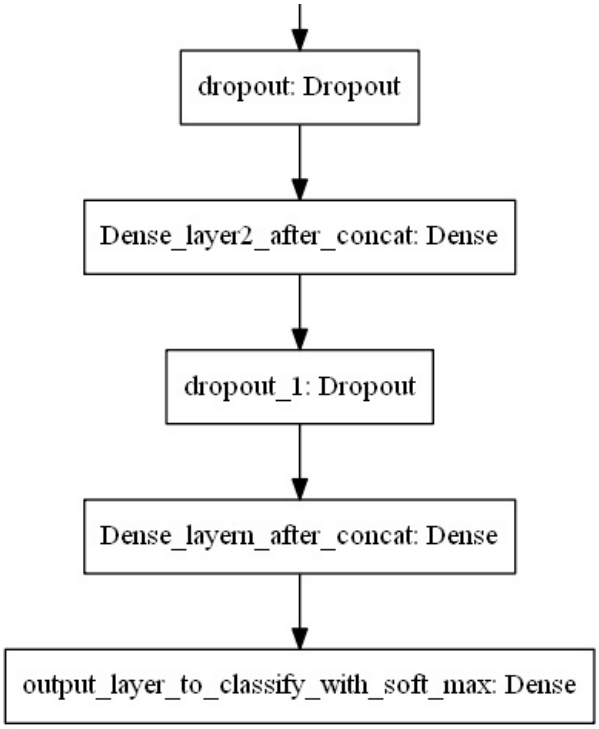
```
epochs_ = list(range(1, len(Model2.history['auc']) + 1))
plt.figure(figsize = (12, 8))

sns.lineplot(y = 'auc', data = Model2.history , x = epochs_, label = 'AUC', color = 'b',
             marker = 'X', mfc = 'red', ms = 8)

sns.lineplot(y = 'val_auc', data = Model2.history , x = epochs_, label = 'Validation AUC',
             color = 'g', marker = 'X', mfc = 'red', ms = 8)

plt.title('Model 2 : AUC vs Epochs')
plt.xticks(epochs_) ; plt.xlabel('Epochs') ; plt.ylabel('AUC Value') ; plt.show()
```



In [61]:
```
model_2.save('Processed_Data/model_2.h5')
```

Model-3





ref: https://i.imgur.com/fkQ8nGo.png

In this model you can use the text vectorized data from model1

For other than text data consider the following steps

You have to perform one hot encoding of categorical features. You can use `onehotencoder()` or `countvectorizer()` for the same.

Stack up standardised numerical features and all the one hot encoded categorical features

The input to conv1d layer is 3d, you can convert your 2d data to 3d using `np.newaxis`

Note - deep learning models won't work with sparse features, you have to convert them to dense features before fitting in the model.

In [62]:
```
def vectorizer_(ColumnN):

    vector = CountVectorizer()
    return vector.fit_transform(x_train[ColumnN]), vector.transform(x_test[ColumnN])

cV_school_state_tr, cV_school_state_te = vectorizer_('school_state')
cV_teacher_prefix_tr, cV_teacher_prefix_te = vectorizer_('teacher_prefix')
cV_proj_gr_cat_tr, cV_proj_gr_cat_te = vectorizer_('project_grade_category')
cV_clean_cat_tr, cV_clean_cat_te = vectorizer_('clean_categories')
cV_clean_subcat_tr, cV_clean_subcat_te = vectorizer_('clean_subcategories')


stack_train = hstack((cV_school_state_tr, cV_teacher_prefix_tr, cV_proj_gr_cat_tr,
                      cV_clean_cat_tr, cV_clean_subcat_tr))

stack_test = hstack((cV_school_state_te, cV_teacher_prefix_te, cV_proj_gr_cat_te,
                      cV_clean_cat_te, cV_clean_subcat_te))

print(f'Shape of train stack (only Cat. variables): {stack_train.shape}')
print(f'Shape of test stack  (only Cat. variables): {stack_test.shape}')
```

```
Shape of train stack (only Cat. variables): (76473, 498)
Shape of test stack  (only Cat. variables): (32775, 498)
```

In [63]:
```
stack_train = hstack((cV_school_state_tr, cV_teacher_prefix_tr, cV_proj_gr_cat_tr,
                      cV_clean_cat_tr, cV_clean_subcat_tr,
                      np.array(x_train['price']).reshape(-1, 1),
                      np.array(x_train['quantity']).reshape(-1, 1),
                      np.array(x_train['resource_summary_contain_numerical']).reshape(-1, 1)))

stack_test = hstack((cV_school_state_te, cV_teacher_prefix_te, cV_proj_gr_cat_te,
                      cV_clean_cat_te, cV_clean_subcat_te,
                      np.array(x_test['price']).reshape(-1, 1),
                      np.array(x_test['quantity']).reshape(-1, 1),
                      np.array(x_test['resource_summary_contain_numerical']).reshape(-1, 1)))

print(f'Shape of train stack (Cat. + num. variables) : {stack_train.shape}')
print(f'Shape of test stack  (Cat. + num. variables) : {stack_test.shape}')
```

```
Shape of train stack (Cat. + num. variables) : (76473, 501)
Shape of test stack  (Cat. + num. variables) : (32775, 501)
```

In [64]:
```
stack_train = np.expand_dims(stack_train.todense(), axis=2)
```

```
stack_test = np.expand_dims(stack_test.todense(), axis=2)

print('Converting 2D vector space to 3D vector space')
print('-' * 45)
print(f'Shape of train stack (Cat. + num. variables) : {stack_train.shape}')
print(f'Shape of test stack  (Cat. + num. variables) : {stack_test.shape}')
```

```
Converting 2D vector space to 3D vector space
---------------------------------------------
Shape of train stack (Cat. + num. variables) : (76473, 501, 1)
Shape of test stack  (Cat. + num. variables) : (32775, 501, 1)
```

In [65]:
```
# https://www.tensorflow.org/api_docs/python/tf/keras/preprocessing/text/Tokenizer

token = Tokenizer()

token.fit_on_texts(x_train['processed_essay'])

essay_train = token.texts_to_sequences(x_train['processed_essay'])
essay_test = token.texts_to_sequences(x_test['processed_essay'])

essay_train_padded = pad_sequences(essay_train, maxlen = 300)
essay_test_padded = pad_sequences(essay_test, maxlen = 300)

word_index = token.word_index
```

In [66]:
```
num_words = len(word_index) + 1

embedding_matrix = np.zeros((num_words, 300))
embedding_matrix.shape
```

Out[66]:
```
(49000, 300)
```

In [67]:
```
for word, count in tqdm(word_index.items()):

    if glove.get(word) is not None:
        embedding_matrix[count] = glove.get(word)

len(embedding_matrix)
```

```
100%|██████████| 48999/48999 [00:00<00:00, 427560.32it/s]
```

Out[67]:
```
49000
```

In [68]:
```
tensorflow.keras.backend.clear_session()
tensorflow.random.set_seed(42)

seq_input = Input(shape = (300,), name = 'Input_Seq_Text_Data')
embed_sqe_input = Embedding(input_dim = num_words, output_dim = 300, weights = [embedding_matrix],
                            trainable = False, name = 'Emb_Text_Data')(seq_input)
lstm_ = LSTM(128, activation = 'relu', return_sequences = True, name = 'LSTM')(embed_sqe_input)
flatten_seq = Flatten(name = 'Flat_LSTM')(lstm_)


non_seq_inp = Input(shape = (stack_train.shape[1], 1), name = 'Otherthan_Text_Data')
x = Conv1D(filters = 64, kernel_size = 2, activation = 'relu', name = 'Conv_1')(non_seq_inp)
x = Conv1D(filters = 32, kernel_size = 2, activation = 'relu', name = 'Conv_2')(x)
# x = Conv1D(filters = 64, kernel_size = 4, activation = 'relu', name = 'Conv_3')(x)
flatten_conv = Flatten(name = 'Flat_NONs')(x)

concat_layer = Concatenate(name = 'Concatenate')([flatten_seq, flatten_conv])

x = Dense(256, activation ='relu', name = 'Dense_layer1_after_concat')(concat_layer)
x = Dropout(0.5, name = 'Dropout1_after_concat')(x)
x = Dense(64, activation ='relu', name = 'Dense_layer2_after_concat')(x)
x = Dropout(0.5, name = 'Dropout2_after_concat')(x)
x = Dense(16, activation ='relu', name = 'Dense_layer3_after_concat')(x)

out_put_l = Dense(2, activation = 'softmax', name = 'output_layer_to_softmax')(x)

model_3 = Model(inputs=[seq_input, non_seq_inp], outputs = out_put_l, name = 'Model_3')

model_3.summary()
```

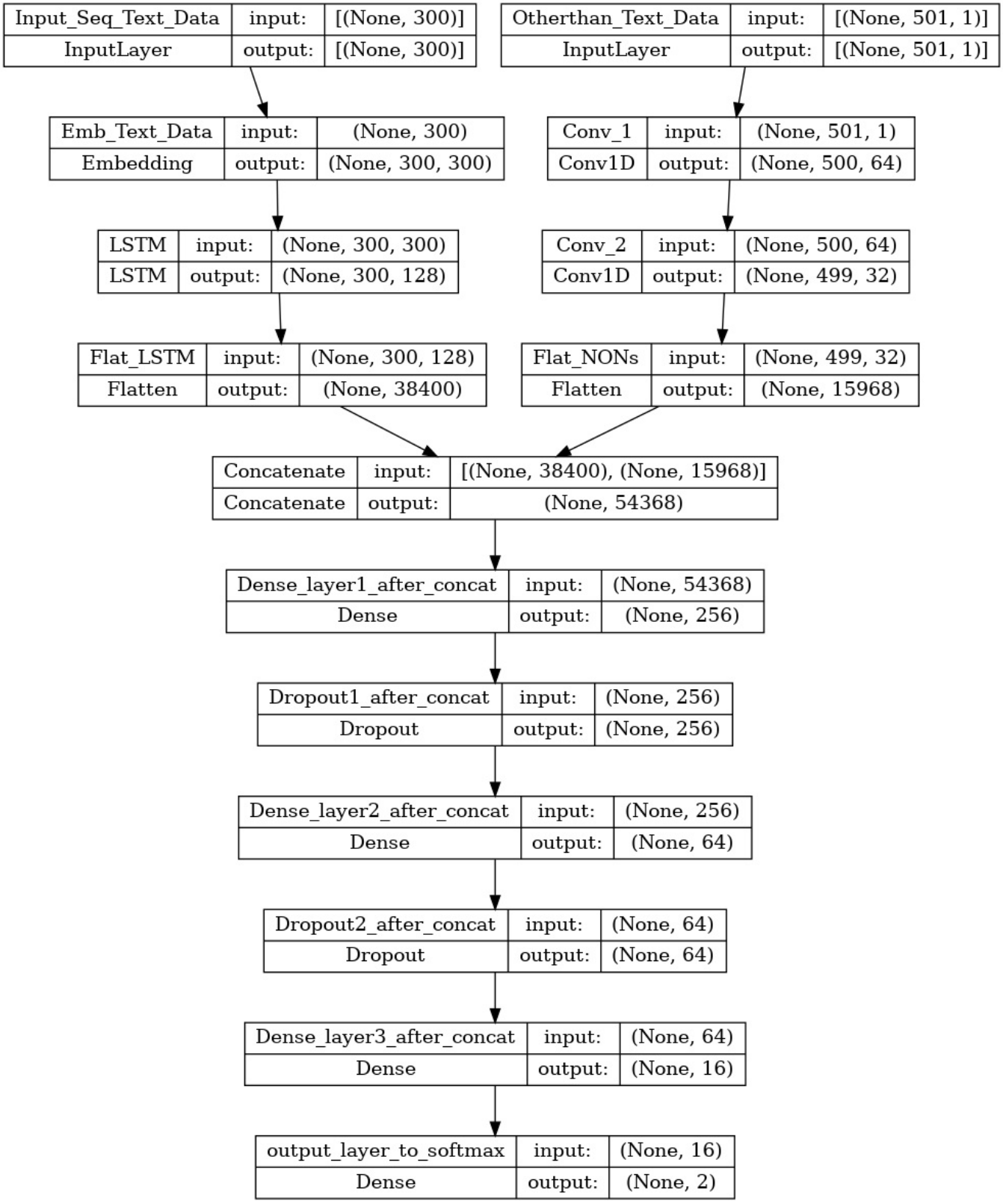
```
WARNING:tensorflow:Layer LSTM will not use cuDNN kernels since it doesn't meet the criteria. It will use a gene
ric GPU kernel as fallback when running on GPU.
Model: "Model_3"
```

Layer (type)	Output Shape	Param #	Connected to
Input_Seq_Text_Data (InputLaye r)	[(None, 300)]	0	[]
Otherthan_Text_Data (InputLaye r)	[(None, 501, 1)]	0	[]
Emb_Text_Data (Embedding)	(None, 300, 300)	14700000	['Input_Seq_Text_Data[0][0]']
Conv_1 (Conv1D)	(None, 500, 64)	192	['Otherthan_Text_Data[0][0]']
LSTM (LSTM)	(None, 300, 128)	219648	['Emb_Text_Data[0][0]']
Conv_2 (Conv1D)	(None, 499, 32)	4128	['Conv_1[0][0]']
Flat_LSTM (Flatten)	(None, 38400)	0	['LSTM[0][0]']
Flat_NONs (Flatten)	(None, 15968)	0	['Conv_2[0][0]']
Concatenate (Concatenate)	(None, 54368)	0	['Flat_LSTM[0][0]', 'Flat_NONs[0][0]']
Dense_layer1_after_concat (Den se)	(None, 256)	13918464	['Concatenate[0][0]']
Dropout1_after_concat (Dropout)	(None, 256)	0	['Dense_layer1_after_concat[0][0] ']
Dense_layer2_after_concat (Den se)	(None, 64)	16448	['Dropout1_after_concat[0][0]']
Dropout2_after_concat (Dropout)	(None, 64)	0	['Dense_layer2_after_concat[0][0] ']
Dense_layer3_after_concat (Den se)	(None, 16)	1040	['Dropout2_after_concat[0][0]']
output_layer_to_softmax (Dense)	(None, 2)	34	['Dense_layer3_after_concat[0][0] ']

```
Total params: 28,859,954
Trainable params: 14,159,954
Non-trainable params: 14,700,000
```

In [69]:
```
plot_model(model_3, to_file = 'Model_Plots/model_3.png', show_shapes = True)
```

Out[69]:



In [70]:
```
logdir = 'logs/model_3/' + datetime.now().strftime('%Y%m%d_%H%M%S')
tensorBoard = TensorBoard(log_dir = logdir, histogram_freq = 1)

filepath = 'modelCheck/model_3/epo_{epoch:02d}-accu_{val_auc:.4f}.hdf5'
model_checkP = ModelCheckpoint(filepath, monitor = 'val_auc', verbose = 1, save_best_only = True)

CallBacks = [tensorBoard, model_checkP, reduce_lr, early_stop]
```

In [71]:
```
# https://keras.io/api/losses/probabilistic_losses/#categoricalcrossentropy-class
# https://keras.io/api/optimizers/adam/

optim = Adam(learning_rate = 0.001)
model_3.compile(optimizer = optim, loss = 'categorical_crossentropy', metrics = [auc])
```

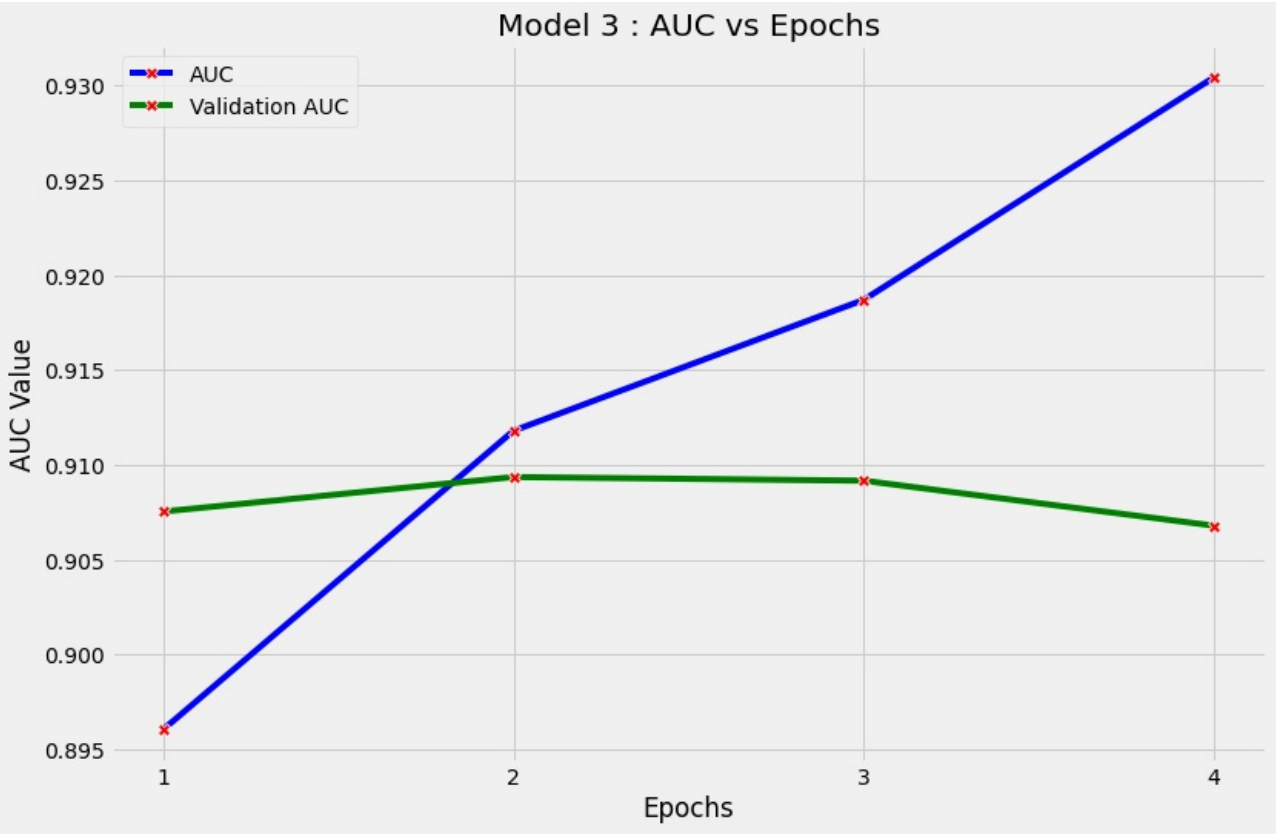
In [72]:
```
EPOCHS_3 = 5

Model3 = model_3.fit([essay_train_padded, stack_train], y_train_cat, epochs = EPOCHS_3,
                     validation_data = ([essay_test_padded, stack_test], y_test_cat),
                     batch_size = 128, verbose = 1, callbacks = CallBacks)
```

```
Epoch 1/5
598/598 [==============================] - ETA: 0s - loss: 0.4081 - auc: 0.8960
Epoch 1: val_auc improved from inf to 0.90753, saving model to modelCheck/model_3/epo_01-accu_0.9075.hdf5
598/598 [==============================] - 238s 393ms/step - loss: 0.4081 - auc: 0.8960 - val_loss: 0.3917 - va
l_auc: 0.9075 - lr: 0.0010
Epoch 2/5
598/598 [==============================] - ETA: 0s - loss: 0.3777 - auc: 0.9118
Epoch 2: val_auc did not improve from 0.90753
598/598 [==============================] - 234s 392ms/step - loss: 0.3777 - auc: 0.9118 - val_loss: 0.3991 - va
l_auc: 0.9094 - lr: 0.0010
Epoch 3/5
598/598 [==============================] - ETA: 0s - loss: 0.3640 - auc: 0.9187
Epoch 3: val_auc did not improve from 0.90753

Epoch 3: ReduceLROnPlateau reducing learning rate to 0.0009900000427477062.
598/598 [==============================] - 234s 392ms/step - loss: 0.3640 - auc: 0.9187 - val_loss: 0.3882 - va
l_auc: 0.9092 - lr: 0.0010
Epoch 4/5
598/598 [==============================] - ETA: 0s - loss: 0.3376 - auc: 0.9304
Epoch 4: val_auc improved from 0.90753 to 0.90679, saving model to modelCheck/model_3/epo_04-accu_0.9068.hdf5
598/598 [==============================] - 235s 393ms/step - loss: 0.3376 - auc: 0.9304 - val_loss: 0.3908 - va
l_auc: 0.9068 - lr: 9.0000e-04
Epoch 4: early stopping
```

In [73]:
```
model_3_auc = round(Model3.history['auc'][-1], 3)
model_3_val_acc = round(Model3.history['val_auc'][-1], 3)
model_3_loss = round(Model3.history['val_loss'][-1], 3)

print(f"AUC score of the Model-3\t\t: {model_3_auc}")
print(f"Validation accuracy of the Model-3\t: {model_3_val_acc}")
print(f"Validation loss of the Model-3\t\t: {model_3_loss}")
```

```
AUC score of the Model-3                : 0.93
Validation accuracy of the Model-3      : 0.907
Validation loss of the Model-3          : 0.391
```

In [74]:
```
# https://wellsr.com/python/seaborn-line-plot-data-visualization/
# https://seaborn.pydata.org/generated/seaborn.lineplot.html

epochs_ = list(range(1, len(Model3.history['auc']) + 1))
plt.figure(figsize = (12, 8))

sns.lineplot(y = 'auc', data = Model3.history , x = epochs_, label = 'AUC', color = 'b',
             marker = 'X', mfc = 'red', ms = 8)

sns.lineplot(y = 'val_auc', data = Model3.history , x = epochs_, label = 'Validation AUC',
             color = 'g', marker = 'X', mfc = 'red', ms = 8)

plt.title('Model 3 : AUC vs Epochs')
plt.xticks(epochs_) ; plt.xlabel('Epochs') ; plt.ylabel('AUC Value') ; plt.show()
```



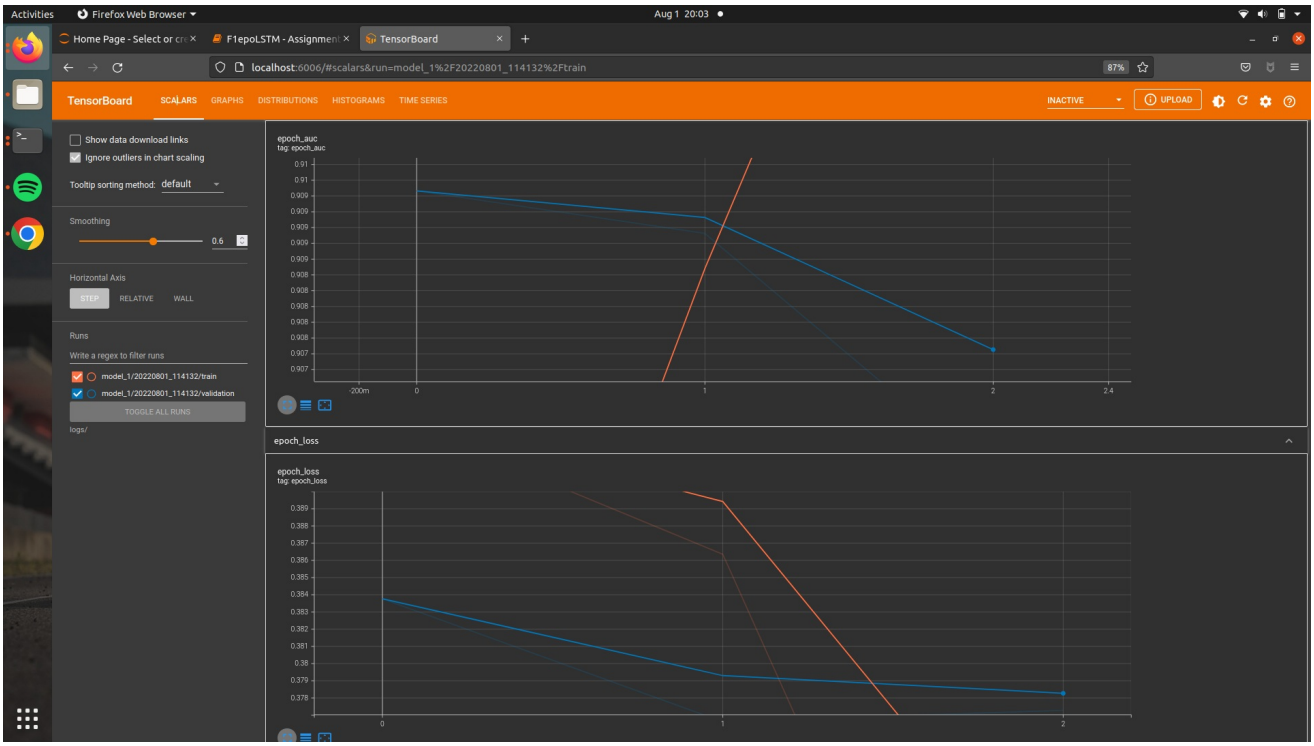
In [75]:
```
model_3.save('Processed_Data/model_3.h5')
```

Model Comparission Table

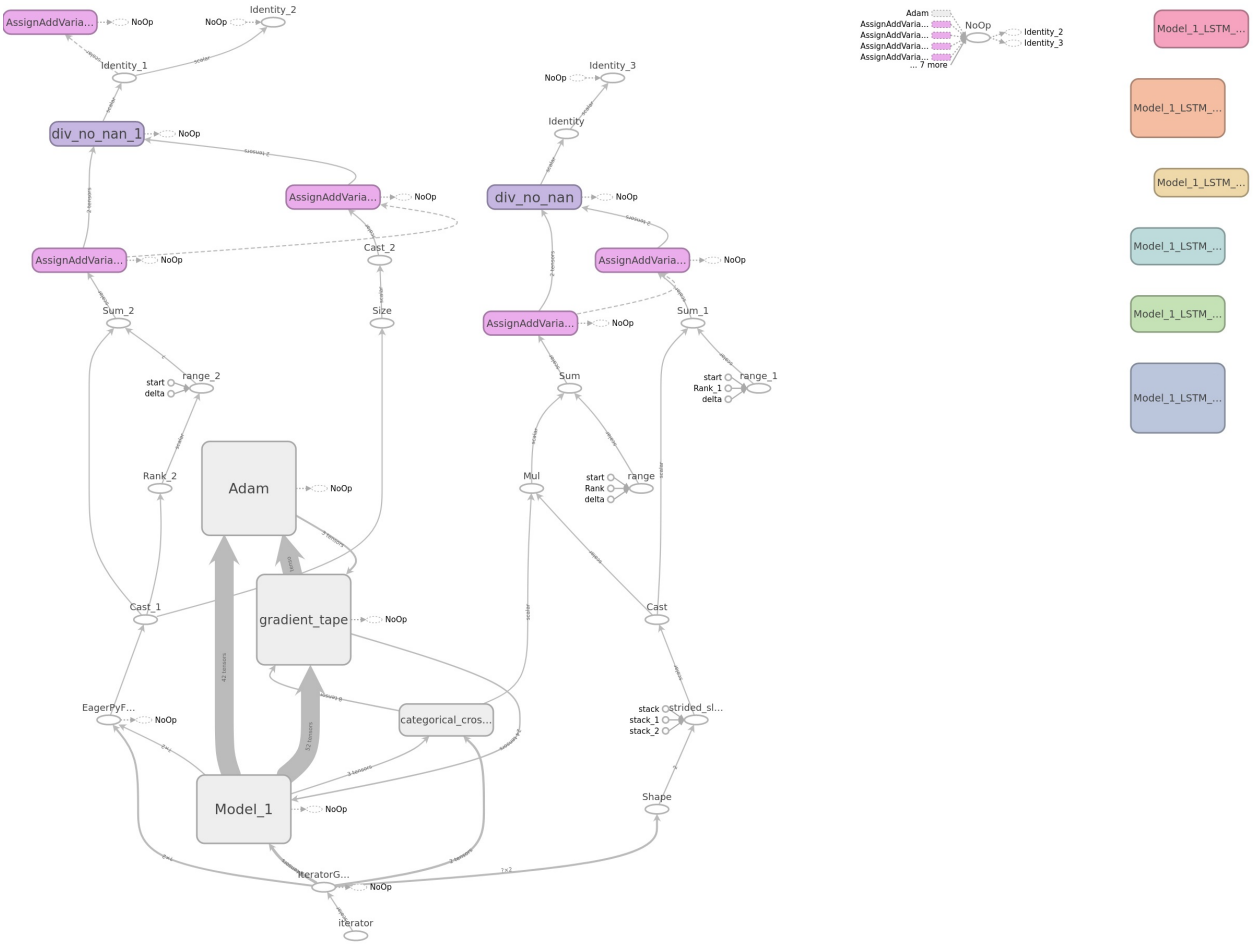
In [76]:
```
from prettytable import PrettyTable

p_table = PrettyTable()

p_table.field_names = ['Model No', 'Epochs', 'AUC Score', 'Validation AUC Score', 'Val. AUC Loss']
p_table.add_row(['Model 1', 3, model_1_auc, model_1_val_acc, model_1_loss])
p_table.add_row(['Model 2', 4, model_2_auc, model_2_val_acc, model_2_loss])
p_table.add_row(['Model 3', 4, model_3_auc, model_3_val_acc, model_3_loss])

print(p_table)
```

```
+----------+--------+-----------+----------------------+---------------+
| Model No | Epochs | AUC Score | Validation AUC Score | Val. AUC Loss |
+----------+--------+-----------+----------------------+---------------+
| Model 1  |   3    |   0.925   |        0.906         |     0.377     |
| Model 2  |   4    |   0.918   |        0.877         |     0.447     |
| Model 3  |   4    |    0.93   |        0.907         |     0.391     |
+----------+--------+-----------+----------------------+---------------+
```

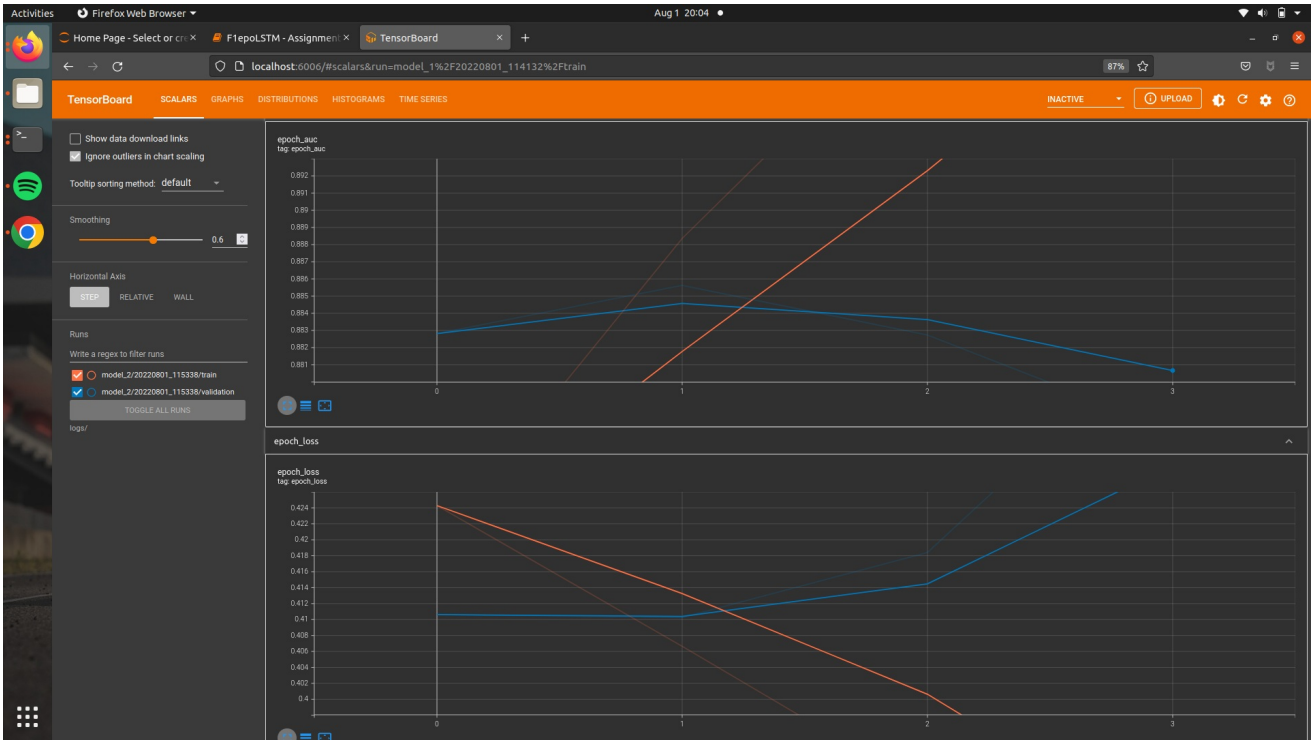
Model 1



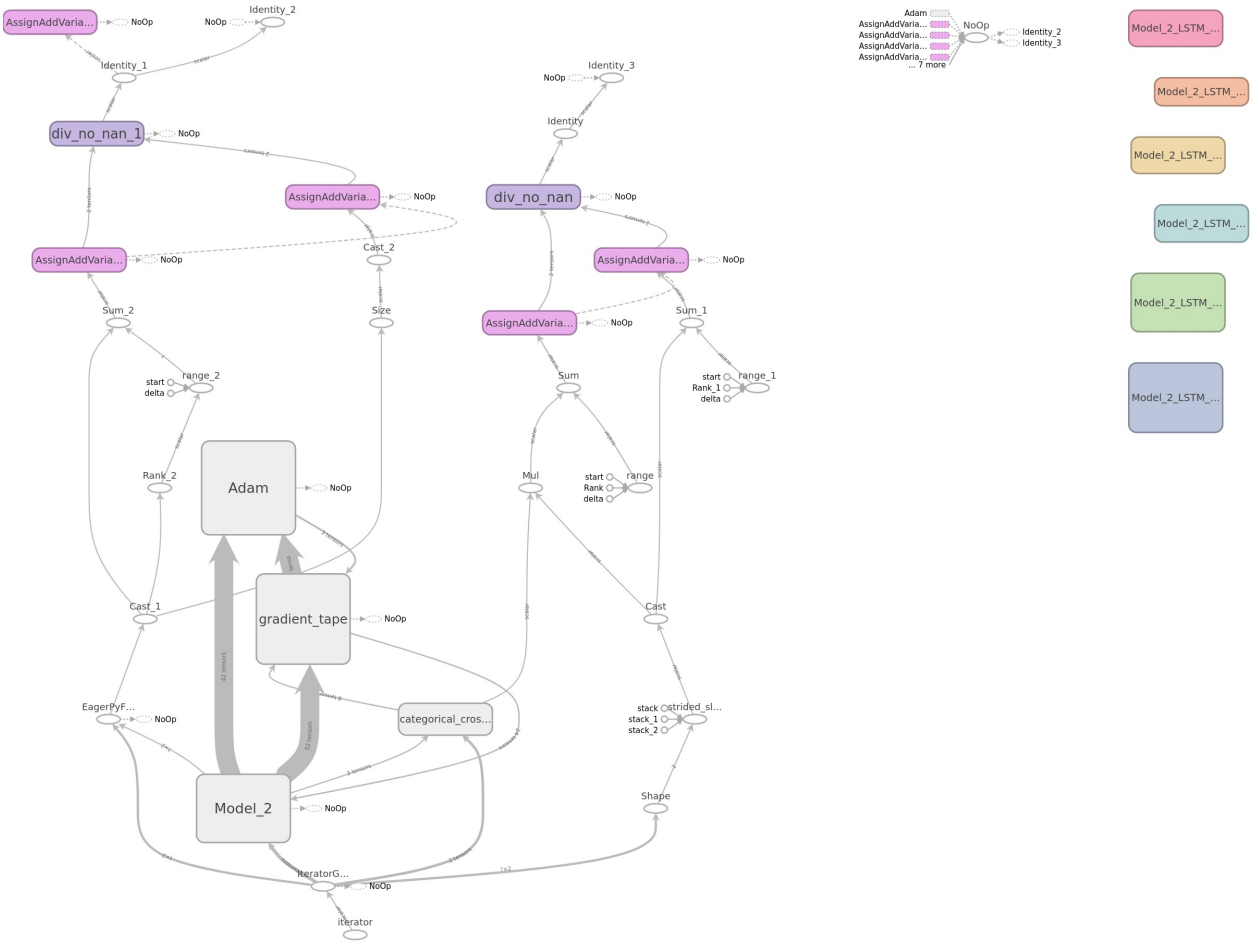
Graph



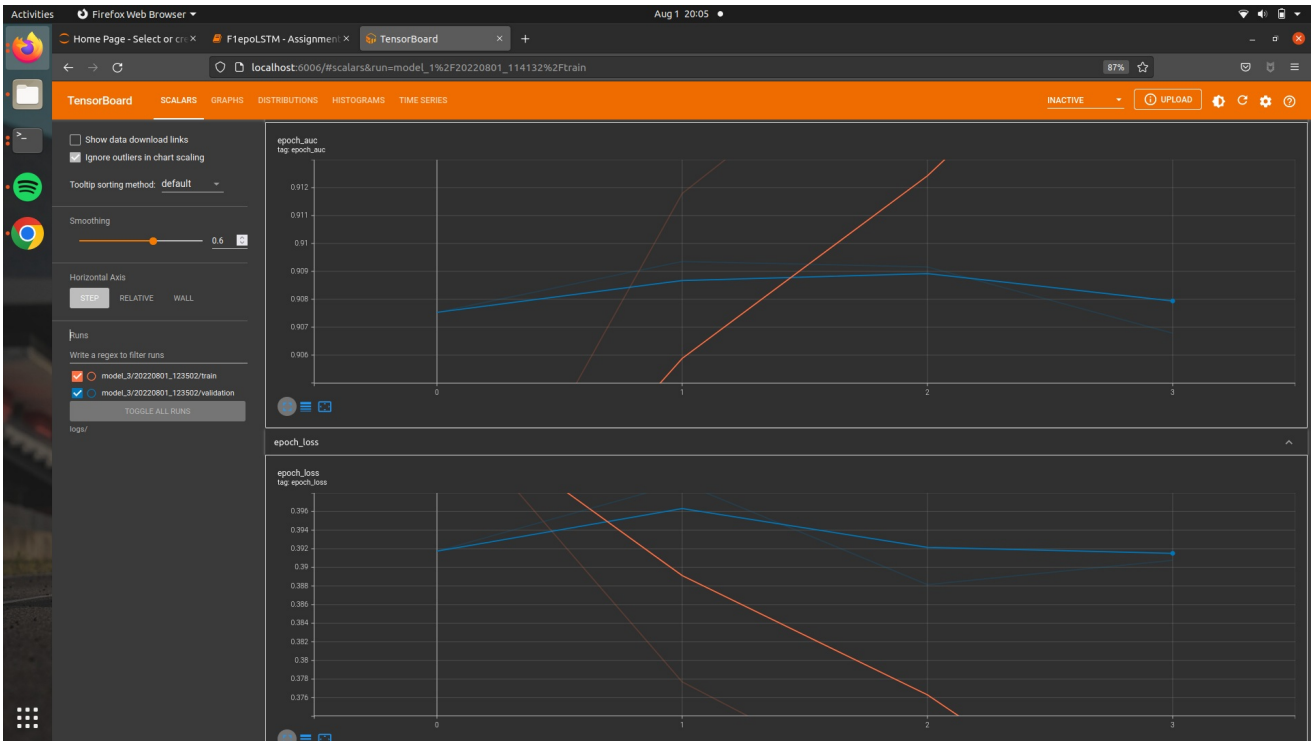
Model 2



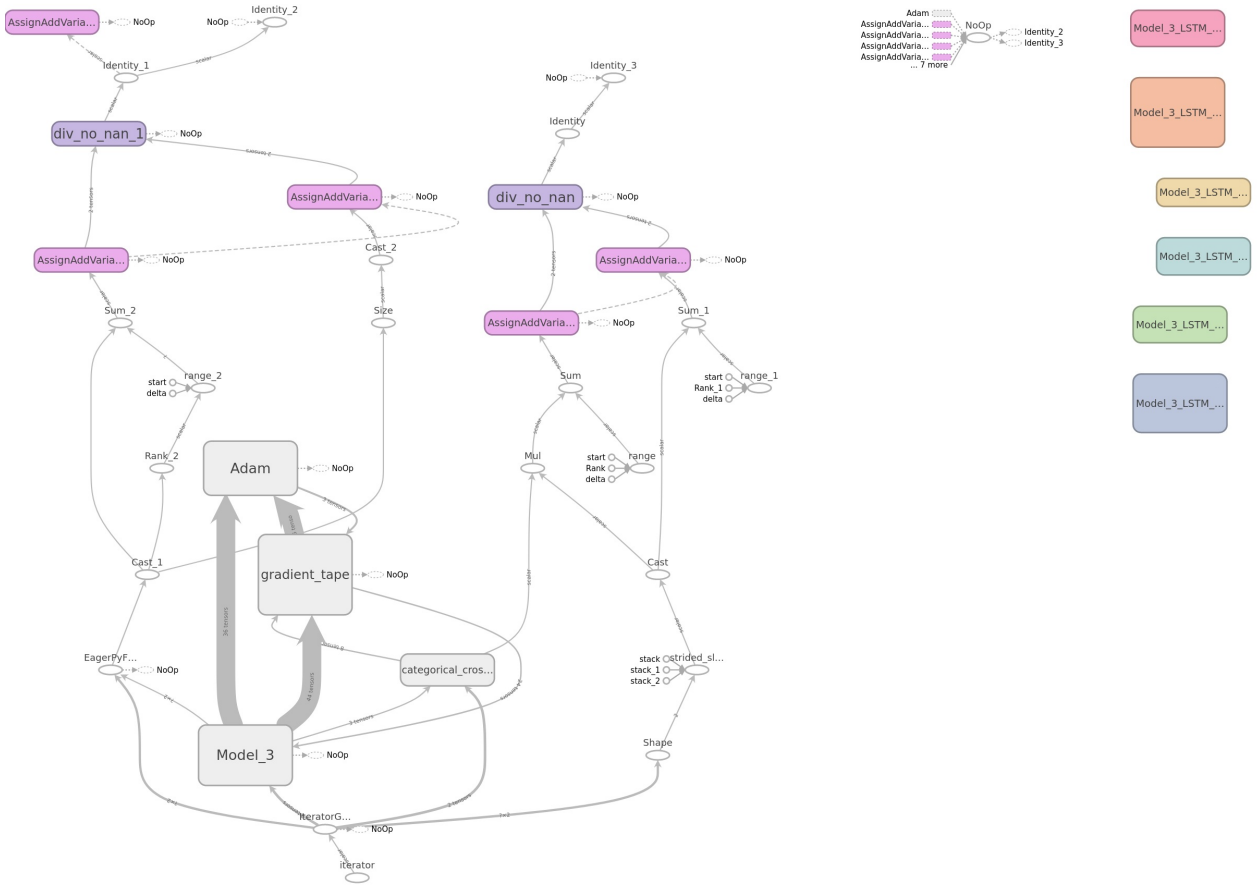
Graph



Model 3



Graph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NoOp
Identity_2
Identity_1
div_no_nan_1
AssignAddVaria...
Cast_2
Sum_2
Size
range_2
start
delta
Rank_2
Adam
gradient_tape
Cast_1
EagerPyF...
categorical_cros...
Model_3
IteratorG...
iterator
Identity_3
Identity
div_no_nan
Sum_1
Sum
range_1
Rank_1
Mul
range
Cast
stack
stack_1
stack_2
strided_sl...
Shape
Adam
... 7 more
Identity_3
Model_3_LSTM_...