** Charts and Tensorboard plots are visible in the pdf version submitted ** Assignment 5 - RNN, LSTM and GRU models

In [ ]:

In [256]:

```
from sklearn. ensemble import VotingClassifier
```

In [162]:

```
import os
```

In [ ]:

In [ ]:

In [65]:

```
import keras
from keras.optimizers import SGD
```

In [66]:

```
import re
from keras.models import Sequential, load_model
from keras.layers import Dense, LSTM, Embedding, Dropout
from keras.preprocessing.text import Tokenizer
from keras.preprocessing.sequence import pad_sequences
```

In [ ]:

In [67]:

```
import tensorflow as tf
from tensorflow.keras import layers
```

In [68]:

```
import datetime
```

In [69]:

```
from sklearn.model_selection import train_test_split
```

In [ ]:

In [70]:
```
from keras import optimizers
```

In [71]:
```
import numpy as np
```

In [ ]:

In [ ]:

In [ ]:

In [ ]:

Task 1 - Load and preprocess the data

In [72]:
```
import pandas as pd

# Read train data
df = pd.read_csv('data/sst_train.txt', sep='\t', header=None, names=['truth', 'text'])
```

In [ ]:

In [73]:
```
# Read dev data
dev = pd.read_csv('data/sst_dev.txt', sep='\t', header=None, names=['truth', 'text'])
```

In [ ]:

In [74]:
```
# Read test data
test = pd.read_csv('data/sst_test.txt', sep='\t', header=None, names=['truth', 'text'])
```

In [ ]:

In [ ]:

In [75]:
```
df['truth'] = df['truth'].str.replace('__label__', '')
```

In [ ]:

In [76]:
```
dev['truth'] = dev['truth'].str.replace('__label__', '')
```

In [ ]:

In [77]:
```
test['truth'] = test['truth'].str.replace('__label__', '')
```

In [ ]:

In [78]:
```
df['truth'] = df['truth'].astype(int).astype('category')
```

In [ ]:

In [79]:
```
dev['truth'] = dev['truth'].astype(int).astype('category')
```

In [ ]:

In [80]:
```
test['truth'] = test['truth'].astype(int).astype('category')
```

In [ ]:

In [81]:
```
dev.head()
```

Out[81]:
```
   truth                                               text
0      4    It 's a lovely film with lovely performances b...
1      3  No one goes unindicted here , which is probabl...
2      4     And if you 're not nearly moved to tears by a ...
3      5                          A warm , funny , engaging film .
4      5  Uses sharp humor and insight into human nature...
```

In [ ]:

In [82]:

```
test.head()
```

Out[82]:

	truth	text
0	3	Effective but too-tepid biopic
1	4	If you sometimes like to go to the movies to h...
2	5	Emerges as something rare , an issue movie tha...
3	3	The film provides some great insight into the ...
4	5	Offers that rare combination of entertainment ...

In [ ]:

In [ ]:

In [83]:

```
df.head()
```

Out[83]:

	truth	text
0	4	The Rock is destined to be the 21st Century 's...
1	5	The gorgeously elaborate continuation of `` Th...
2	4	Singer/composer Bryan Adams contributes a slew...
3	3	You 'd think by now America would have had eno...
4	4	Yet the act is still charming here .

In [ ]:

In [84]:

```
# count training samples
df.shape[0]
```

Out[84]:

```
8544
```

In [ ]:

In [ ]:

In [ ]:

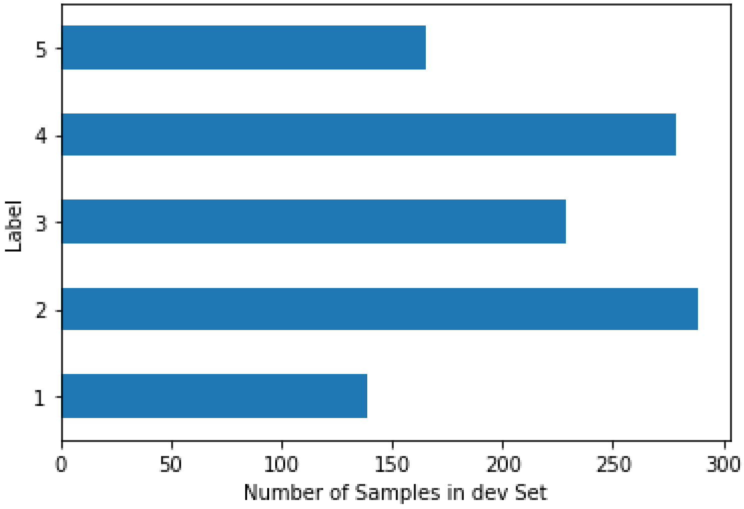
In [85]:

```
import matplotlib.pyplot as plt
```

Dev data Visualizations

In [86]:

```
ax = dev['truth'].value_counts(sort=False).plot(kind='barh')
ax.set_xlabel("Number of Samples in dev Set")
ax.set_ylabel("Label")
plt.show()
```



In [ ]:

In [87]:

```
data_dev = dev['text']
```

In [88]:

```
dev_X = list()
```

In [89]:
```
for i in range(len(dev)):
    integer_encoded = [ord(char) for char in data_dev[i]]
    dev_X.append(integer_encoded)
```

In [ ]:

In [90]:
```
dev_X_test = np.array(dev_X)
```

In [91]:
```
dev_X_test.shape
```

Out[91]:
```
(1101,)
```

In [92]:
```
dev_X_t = pad_sequences(dev_X_test, maxlen=267)
```

In [93]:
```
dev_X_t.shape
```

Out[93]:
```
(1101, 267)
```

In [ ]:

In [94]:
```
dev_y = pd.get_dummies(dev['truth']).values
```

In [95]:
```
dev_y
```

Out[95]:
```
array([[0, 0, 0, 1, 0],
       [0, 0, 1, 0, 0],
       [0, 0, 0, 1, 0],
       ...,
       [0, 1, 0, 0, 0],
       [0, 0, 1, 0, 0],
       [0, 1, 0, 0, 0]], dtype=uint8)
```

In [ ]:

In [ ]:

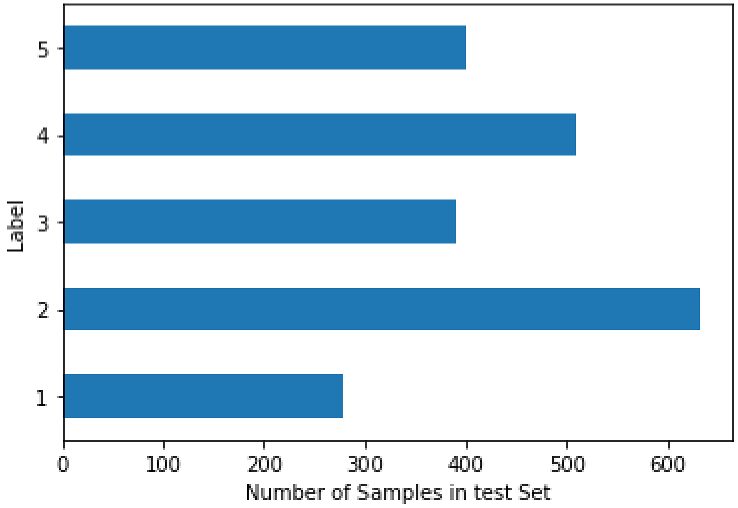
In [ ]:

In [ ]:

Test Data Visualizations

In [96]:

```
ax = test['truth'].value_counts(sort=False).plot(kind='barh')
ax.set_xlabel("Number of Samples in test Set")
ax.set_ylabel("Label")
plt.show()
```



In [ ]:

In [97]:

```
data_test = test['text']
```

In [98]:

```
test_X = list()
```

In [99]:

```
for i in range(len(test)):
    integer_encoded = [ord(char) for char in data_test[i]]
    test_X.append(integer_encoded)
```

In [100]:

```
test_X_2 = np.array(test_X)
```

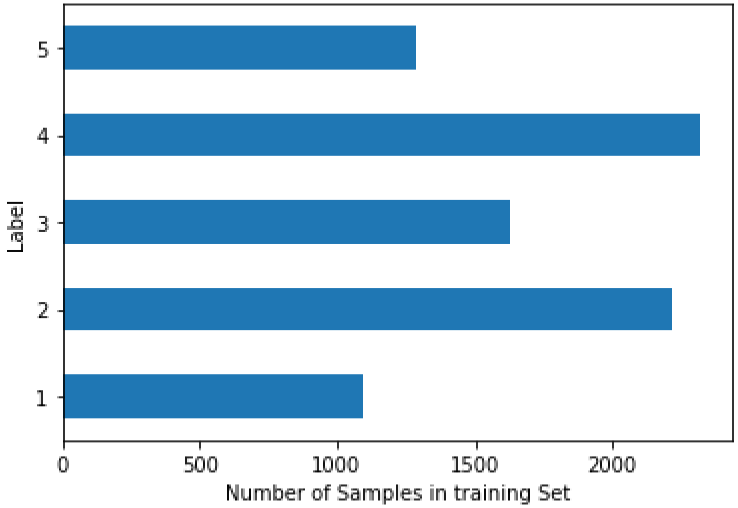
```
In [101]: test_X_2.shape

Out[101]: (2210,)

In [102]: test_X_t = pad_sequences(test_X_2, maxlen=267)

In [103]: test_X_t.shape

Out[103]: (2210, 267)

In [ ]:

In [104]: test_y = pd.get_dummies(test['truth']).values

In [105]: test_y

Out[105]: array([[0, 0, 1, 0, 0],
                 [0, 0, 0, 1, 0],
                 [0, 0, 0, 0, 1],
                 ...,
                 [0, 0, 0, 0, 1],
                 [0, 0, 0, 1, 0],
                 [1, 0, 0, 0, 0]], dtype=uint8)

In [ ]:

In [ ]:

In [ ]:

In [ ]:

In [ ]:

In [ ]:
```

In [ ]:

Training Data Visualizations

In [106]:

```


ax = df['truth'].value_counts(sort=False).plot(kind='barh')
ax.set_xlabel("Number of Samples in training Set")
ax.set_ylabel("Label")
plt.show()
```



In [277]:

```
y = df['truth'].values
```

In [278]:

```
y
```

Out[278]:

```
[4, 5, 4, 3, 4, ..., 1, 2, 4, 1, 2]
Length: 8544
Categories (5, int64): [1, 2, 3, 4, 5]
```

In [ ]:

```
In [109]: y_train = np.array(y)
```

```
In [276]: y_train
```

```
Out[276]: array([[0, 0, 0, 1, 0],
                 [0, 0, 1, 0, 0],
                 [0, 1, 0, 0, 0],
                 ...,
                 [0, 0, 1, 0, 0],
                 [0, 0, 0, 1, 0],
                 [0, 0, 1, 0, 0]], dtype=uint8)
```

```
In [111]: y_train[0]
```

```
Out[111]: 4
```

```
In [112]: y_train.shape
```

```
Out[112]: (8544,)
```

```
In [ ]:
```

```
In [113]: y_t = pd.get_dummies(df['truth']).values
```

```
In [114]: y_t
```

```
Out[114]: array([[0, 0, 0, 1, 0],
                 [0, 0, 0, 0, 1],
                 [0, 0, 0, 1, 0],
                 ...,
                 [0, 0, 0, 1, 0],
                 [1, 0, 0, 0, 0],
                 [0, 1, 0, 0, 0]], dtype=uint8)
```

```
In [115]: len(y_t)
```

```
Out[115]: 8544
```

In [ ]:

In [ ]:

In [116]:

```
from numpy import argmax
# define input string
#data = 'hello world'
data = df['text']
print(data[0])
```

```
The Rock is destined to be the 21st Century 's new `` Conan '' and that he 's going to make a splas
h even greater than Arnold Schwarzenegger , Jean-Claud Van Damme or Steven Segal .
```

In [ ]:

In [ ]:

In [ ]:

In [ ]:

In [117]:

```
X = list()
```

In [118]:

```
#X.append(onehot_encoded)

#X.append(integer_encoded)
```

In [119]:

```
len(data)
```

Out[119]:

```
8544
```

In [ ]:

In [ ]:

In [120]:
```
for i in range(len(data)):
    integer_encoded = [ord(char) for char in data[i]]
    X.append(integer_encoded)
```

In [ ]:

In [ ]:

In [121]:
```
len(X[1])
```

Out[121]:
```
226
```

In [ ]:

In [ ]:

In [ ]:
```
X
```

In [ ]:

In [ ]:

In [ ]:

In [123]:
```
#X = np.array(onehot_encoded)
```

In [124]:
```
X_train = np.array(X)
```

In [ ]:

In [ ]:
```
X_train
```

In [126]:

```
X_train.shape
```

Out[126]:

```
(8544,)
```

In [ ]:

In [ ]:

In [ ]:

In [127]:

```
# invert encoding
#inverted = int_to_char[argmax(onehot_encoded[0])]
#print(inverted)
```

In [ ]:

In [128]:

```
X_train.shape
```

Out[128]:

```
(8544,)
```

In [129]:

```
X_t = pad_sequences(X_train)
```

In [ ]:

In [ ]:

In [ ]:

In [130]:

```
X_train, X_test, y_train, y_test = train_test_split(X_t, y_t, test_size=0.2, random_state=0)
```

In [ ]:

In [ ]:

Create vanilla RNN model

In [287]:

```
model_rnn = tf.keras.Sequential()
model_rnn.add(layers.Embedding(5000, 256, input_length=X_train.shape[1]))
```

In [288]:

```
#model_rnn.add(layers.Dropout(0.3))
```

In [289]:

```
model_rnn.add(layers.SimpleRNN(256))
model_rnn.add(layers.Dense(5, activation='softmax'))
```

In [290]:

```
model_rnn.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['accuracy'])
model_rnn.summary()
```

```
Model: "sequential_7"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
embedding_6 (Embedding)      (None, 267, 256)          1280000
_________________________________________________________________
simple_rnn_7 (SimpleRNN)     (None, 256)               131328
_________________________________________________________________
dense_5 (Dense)              (None, 5)                 1285
=================================================================
Total params: 1,412,613
Trainable params: 1,412,613
Non-trainable params: 0
_________________________________________________________________
```

In [ ]:

In [291]:

```
batch_size = 32
epochs = 10
```

In [ ]:

In [292]:

```
# Clear any logs from previous runs
# !rm -rf ./logs/
```

In [ ]:

In [293]:
```
log_dir_1="logs_1/fit/" + datetime.datetime.now().strftime("%Y%m%d-%H%M%S")
```

In [294]:
```
tensorboard_callback = tf.keras.callbacks.TensorBoard(log_dir=log_dir_1, histogram_freq=1)
```

In [ ]:
```

```

In [ ]:
```

```

In [295]:
```
#model_rnn.fit(X_train, y_train, validation_data=(X_test, y_test), epochs=epochs, batch_size=batch_s


model_rnn.fit(X_train, y_train, validation_data=(X_test, y_test), epochs=epochs, batch_size=batch_si
```

```
Train on 6835 samples, validate on 1709 samples
Epoch 1/10
WARNING:tensorflow:Method (on_train_batch_end) is slow compared to the batch update (0.421986). Che
ck your callbacks.
6835/6835 - 29s - loss: 1.6206 - accuracy: 0.2506 - val_loss: 1.5783 - val_accuracy: 0.2709
Epoch 2/10
6835/6835 - 27s - loss: 1.6193 - accuracy: 0.2600 - val_loss: 1.5777 - val_accuracy: 0.2709
Epoch 3/10
6835/6835 - 27s - loss: 1.6368 - accuracy: 0.2506 - val_loss: 1.6156 - val_accuracy: 0.2657
Epoch 4/10
6835/6835 - 26s - loss: 1.5861 - accuracy: 0.2587 - val_loss: 1.5774 - val_accuracy: 0.2697
Epoch 5/10
6835/6835 - 26s - loss: 1.5891 - accuracy: 0.2648 - val_loss: 1.5862 - val_accuracy: 0.2697
Epoch 6/10
6835/6835 - 26s - loss: 1.5865 - accuracy: 0.2713 - val_loss: 1.5817 - val_accuracy: 0.2703
Epoch 7/10
6835/6835 - 26s - loss: 1.5854 - accuracy: 0.2679 - val_loss: 1.5842 - val_accuracy: 0.2709
Epoch 8/10
6835/6835 - 26s - loss: 1.5814 - accuracy: 0.2614 - val_loss: 1.5969 - val_accuracy: 0.2715
Epoch 9/10
6835/6835 - 26s - loss: 1.5902 - accuracy: 0.2680 - val_loss: 1.5852 - val_accuracy: 0.2738
Epoch 10/10
6835/6835 - 26s - loss: 1.5839 - accuracy: 0.2625 - val_loss: 1.5779 - val_accuracy: 0.2709
```

Out[295]:
```
<tensorflow.python.keras.callbacks.History at 0x7f15400fb410>
```

In [ ]:

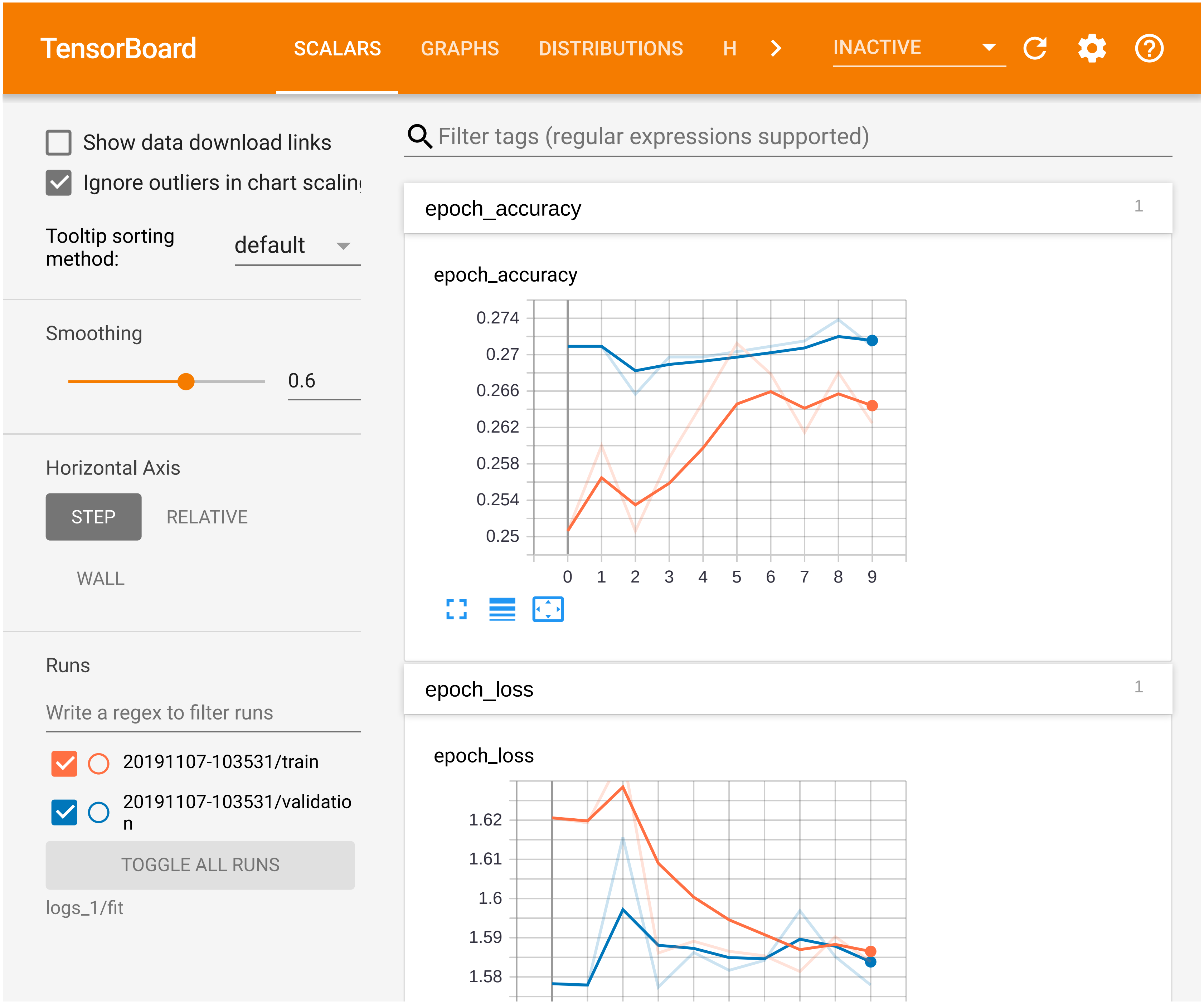
```

```

Tensorboard Visualizations

In [2]:

```
%load_ext tensorboard
```

```
In [169]: %tensorboard --logdir logs_1/fit
```



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☑ Ignore outliers in chart scalin

Tooltip sorting method: default

Smoothing 0.6

Horizontal Axis

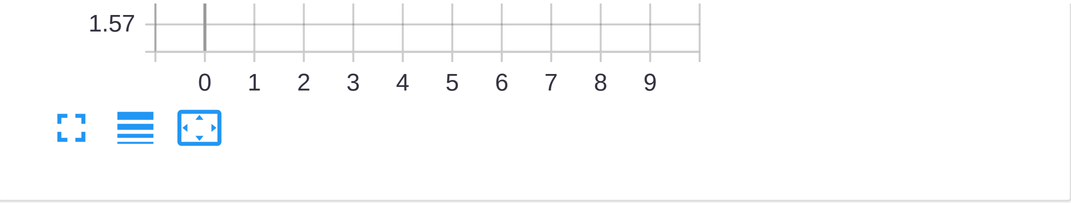
Runs

Write a regex to filter runs

☑ ○ 20191107-103531/train

☑ ○ 20191107-103531/validation

logs_1/fit



In [ ]:

In [ ]:

In [ ]:

Accuracy of vanilla rnn model on dev subset

In [ ]:

```
score, acc = model_rnn.evaluate(dev_X_t, dev_y)
```

In [343]:

```
acc
```

Out[343]:

```
0.26430517
```

Accuracy of vanilla rnn on dev subset = 26.43%

In [ ]:

In [ ]:

In [ ]:

In [ ]:

Create vanilla RNN model - 2

In [397]:

```
model_rnn_2 = tf.keras.Sequential()
model_rnn_2.add(layers.Embedding(5000, 256, input_length=X_train.shape[1]))

model_rnn_2.add(layers.SimpleRNN(256))
model_rnn_2.add(layers.Dense(5, activation='softmax'))



adam = tf.keras.optimizers.Adam(learning_rate=0.001, beta_1=0.9, beta_2=0.999, amsgrad=False)
#sgd = SGD(lr=0.01, decay=1e-6, momentum=0.9, nesterov=True)

model_rnn_2.compile(loss='categorical_crossentropy', optimizer=adam, metrics=['accuracy'])
#model_rnn.summary()

batch_size = 32
epochs = 20

log_dir_5="logs_5/fit/" + datetime.datetime.now().strftime("%Y%m%d-%H%M%S")
tensorboard_callback = tf.keras.callbacks.TensorBoard(log_dir=log_dir_5, histogram_freq=1)

model_rnn_2.fit(X_train, y_train, validation_data=(X_test, y_test), epochs=epochs, batch_size=batch_
```

```
Train on 6835 samples, validate on 1709 samples
Epoch 1/20
WARNING:tensorflow:Method (on_train_batch_end) is slow compared to the batch update (0.442880). Che
ck your callbacks.
6835/6835 - 28s - loss: 1.6073 - accuracy: 0.2534 - val_loss: 1.6004 - val_accuracy: 0.2703
Epoch 2/20
6835/6835 - 26s - loss: 1.5903 - accuracy: 0.2660 - val_loss: 1.5640 - val_accuracy: 0.2703
Epoch 3/20
6835/6835 - 26s - loss: 1.6017 - accuracy: 0.2614 - val_loss: 1.5946 - val_accuracy: 0.1861
Epoch 4/20
6835/6835 - 26s - loss: 1.5865 - accuracy: 0.2631 - val_loss: 1.6006 - val_accuracy: 0.1861
Epoch 5/20
6835/6835 - 26s - loss: 1.5823 - accuracy: 0.2718 - val_loss: 1.5997 - val_accuracy: 0.2709
Epoch 6/20
6835/6835 - 26s - loss: 1.5830 - accuracy: 0.2691 - val_loss: 1.5618 - val_accuracy: 0.2738
Epoch 7/20
6835/6835 - 27s - loss: 1.5866 - accuracy: 0.2658 - val_loss: 1.6199 - val_accuracy: 0.1270
Epoch 8/20
6835/6835 - 26s - loss: 1.5873 - accuracy: 0.2604 - val_loss: 1.6174 - val_accuracy: 0.2738
```

```
Epoch 9/20
6835/6835 - 26s - loss: 1.5778 - accuracy: 0.2642 - val_loss: 1.5705 - val_accuracy: 0.2750
Epoch 10/20
6835/6835 - 26s - loss: 1.5817 - accuracy: 0.2729 - val_loss: 1.5705 - val_accuracy: 0.2697
Epoch 11/20
6835/6835 - 26s - loss: 1.5857 - accuracy: 0.2645 - val_loss: 1.5676 - val_accuracy: 0.2762
Epoch 12/20
6835/6835 - 26s - loss: 1.5901 - accuracy: 0.2606 - val_loss: 1.5588 - val_accuracy: 0.2721
Epoch 13/20
6835/6835 - 26s - loss: 1.5801 - accuracy: 0.2603 - val_loss: 1.5693 - val_accuracy: 0.2721
Epoch 14/20
6835/6835 - 26s - loss: 1.5867 - accuracy: 0.2576 - val_loss: 1.5688 - val_accuracy: 0.2733
Epoch 15/20
6835/6835 - 26s - loss: 1.5741 - accuracy: 0.2768 - val_loss: 1.5646 - val_accuracy: 0.2709
Epoch 16/20
6835/6835 - 26s - loss: 1.5921 - accuracy: 0.2711 - val_loss: 1.5761 - val_accuracy: 0.2721
Epoch 17/20
6835/6835 - 26s - loss: 1.5828 - accuracy: 0.2636 - val_loss: 1.5698 - val_accuracy: 0.2709
Epoch 18/20
6835/6835 - 26s - loss: 1.5804 - accuracy: 0.2629 - val_loss: 1.5748 - val_accuracy: 0.2703
Epoch 19/20
6835/6835 - 26s - loss: 1.5795 - accuracy: 0.2686 - val_loss: 1.5655 - val_accuracy: 0.2733
Epoch 20/20
6835/6835 - 26s - loss: 1.5825 - accuracy: 0.2753 - val_loss: 1.5611 - val_accuracy: 0.2715
```

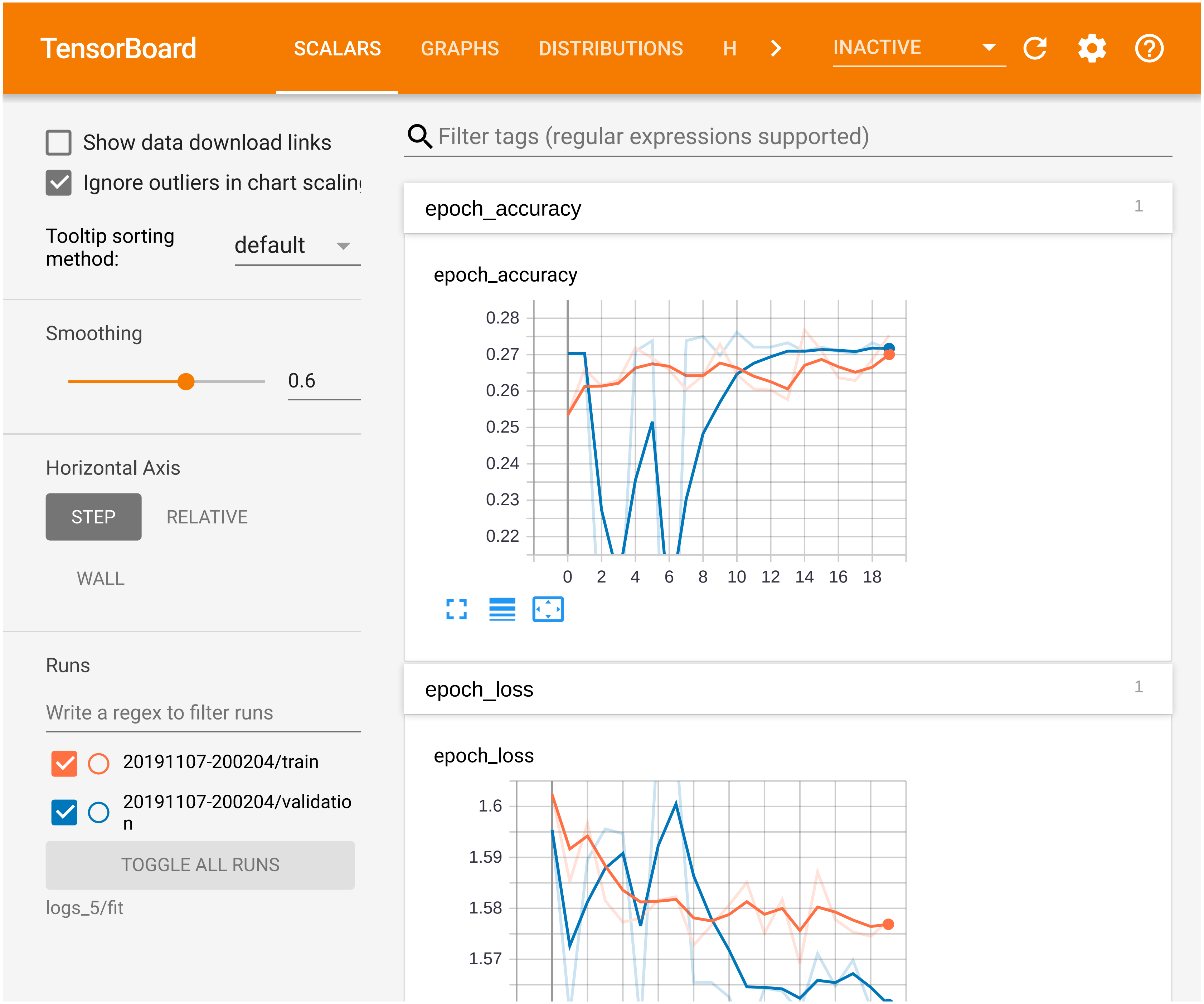
```
Out[397]: <tensorflow.python.keras.callbacks.History at 0x7f153a809210>
```

```
In [ ]:
```

```
In [ ]:
```

With learning_rate = 0.001

```
In [170]: %tensorboard --logdir logs_5/fit
```



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Tooltip sorting method: default

Smoothing

0.6

Horizontal Axis

STEP RELATIVE

WALL

Runs

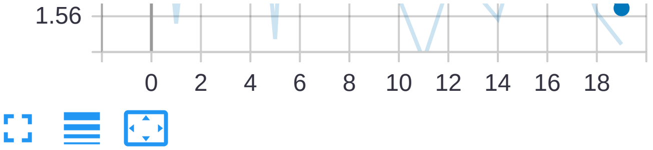
Write a regex to filter runs

☑ ○ 20191107-200204/train

☑ ○ 20191107-200204/validatio n

TOGGLE ALL RUNS

logs_5/fit



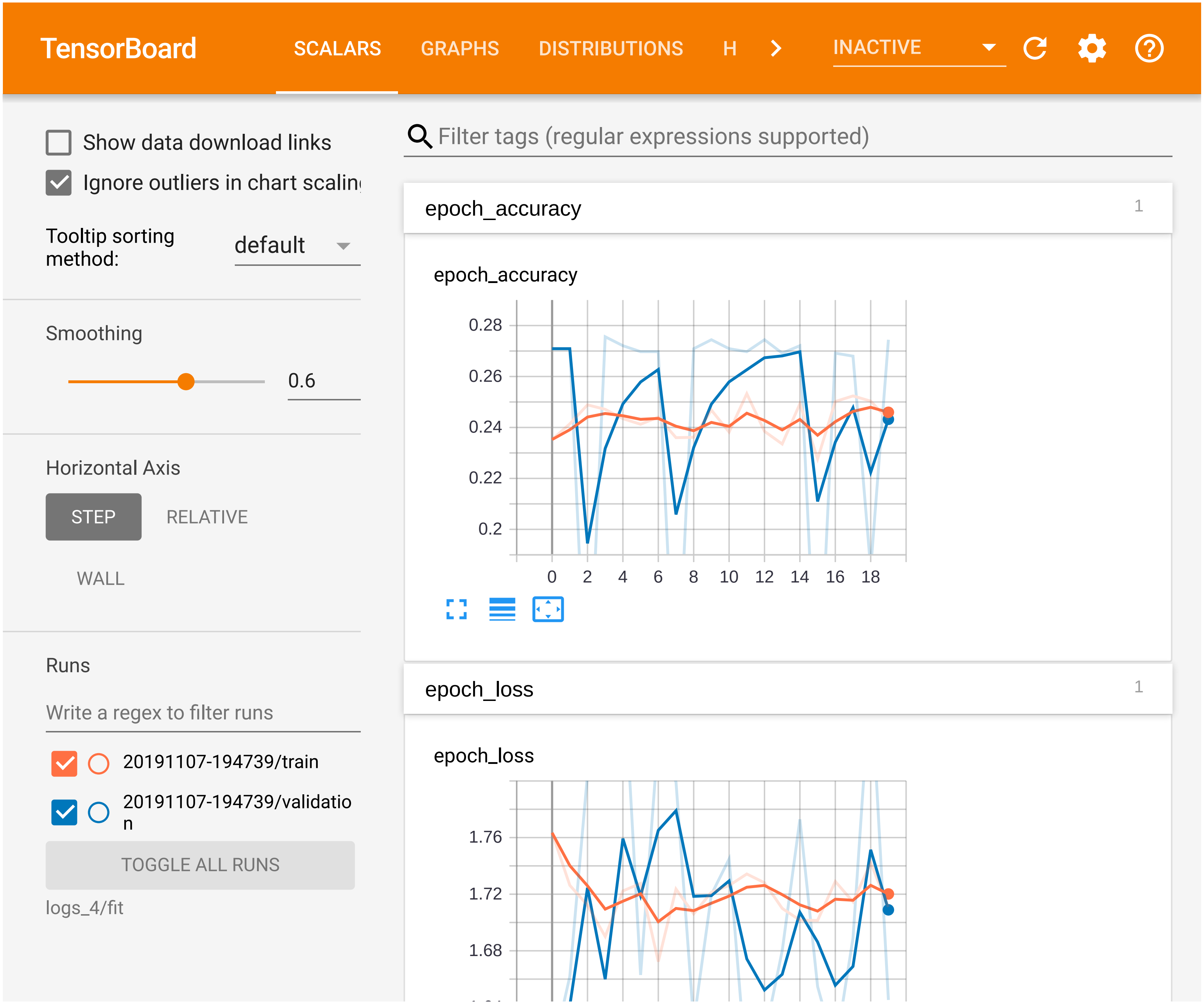
In [ ]:

In [ ]:

In [ ]:

With learning_rate = 0.01

```
In [171]: %tensorboard --logdir logs_4/fit
```



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☑ Ignore outliers in chart scalin

Tooltip sorting method: default

Smoothing 0.6

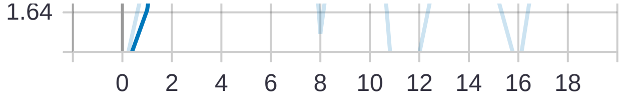
Horizontal Axis: STEP

Runs

☑ ○ 20191107-194739/train

☑ ○ 20191107-194739/validation

logs_4/fit



In [ ]:

Create vanilla RNN model - 3

In [251]:

```
model_rnn_3 = tf.keras.Sequential()
model_rnn_3.add(layers.Embedding(5000, 350, input_length=X_train.shape[1]))

model_rnn_3.add(layers.SimpleRNN(350))
model_rnn_3.add(layers.Dense(5, activation='softmax'))



adam = tf.keras.optimizers.Adam(learning_rate=0.001, beta_1=0.9, beta_2=0.999, amsgrad=False)
#sgd = SGD(lr=0.01, decay=1e-6, momentum=0.9, nesterov=True)

model_rnn_3.compile(loss='categorical_crossentropy', optimizer=adam, metrics=['accuracy'])
#model_rnn.summary()

batch_size = 32
epochs = 20

log_dir_19="logs_19/fit/" + datetime.datetime.now().strftime("%Y%m%d-%H%M%S")
tensorboard_callback = tf.keras.callbacks.TensorBoard(log_dir=log_dir_19, histogram_freq=1)

model_rnn_3.fit(X_train, y_train, validation_data=(X_test, y_test), epochs=epochs, batch_size=batch_
```

```
Train on 6835 samples, validate on 1709 samples
Epoch 1/20
WARNING:tensorflow:Method (on_train_batch_end) is slow compared to the batch update (0.440004). Che
ck your callbacks.
6835/6835 - 44s - loss: 1.6198 - accuracy: 0.2493 - val_loss: 1.5842 - val_accuracy: 0.2703
Epoch 2/20
6835/6835 - 41s - loss: 1.6034 - accuracy: 0.2559 - val_loss: 1.5649 - val_accuracy: 0.2709
Epoch 3/20
6835/6835 - 41s - loss: 1.5930 - accuracy: 0.2613 - val_loss: 1.6117 - val_accuracy: 0.1861
Epoch 4/20
6835/6835 - 41s - loss: 1.5893 - accuracy: 0.2673 - val_loss: 1.6076 - val_accuracy: 0.1732
Epoch 5/20
6835/6835 - 41s - loss: 1.5954 - accuracy: 0.2582 - val_loss: 1.5960 - val_accuracy: 0.1861
Epoch 6/20
6835/6835 - 41s - loss: 1.5898 - accuracy: 0.2614 - val_loss: 1.5620 - val_accuracy: 0.2727
Epoch 7/20
6835/6835 - 41s - loss: 1.5871 - accuracy: 0.2623 - val_loss: 1.5816 - val_accuracy: 0.2703
Epoch 8/20
6835/6835 - 41s - loss: 1.5912 - accuracy: 0.2667 - val_loss: 1.5778 - val_accuracy: 0.2709
Epoch 9/20
```

```
6835/6835 - 41s - loss: 1.5873 - accuracy: 0.2604 - val_loss: 1.5837 - val_accuracy: 0.2697
Epoch 10/20
6835/6835 - 41s - loss: 1.5902 - accuracy: 0.2632 - val_loss: 1.5902 - val_accuracy: 0.2715
Epoch 11/20
6835/6835 - 41s - loss: 1.5956 - accuracy: 0.2632 - val_loss: 1.5835 - val_accuracy: 0.2709
Epoch 12/20
6835/6835 - 41s - loss: 1.5853 - accuracy: 0.2647 - val_loss: 1.5678 - val_accuracy: 0.2709
Epoch 13/20
6835/6835 - 41s - loss: 1.5883 - accuracy: 0.2679 - val_loss: 1.5810 - val_accuracy: 0.2791
Epoch 14/20
6835/6835 - 41s - loss: 1.5834 - accuracy: 0.2562 - val_loss: 1.5687 - val_accuracy: 0.2850
Epoch 15/20
6835/6835 - 41s - loss: 1.5777 - accuracy: 0.2736 - val_loss: 1.5724 - val_accuracy: 0.2709
Epoch 16/20
6835/6835 - 41s - loss: 1.5853 - accuracy: 0.2657 - val_loss: 1.5850 - val_accuracy: 0.2159
Epoch 17/20
6835/6835 - 41s - loss: 1.5907 - accuracy: 0.2666 - val_loss: 1.5771 - val_accuracy: 0.2709
Epoch 18/20
6835/6835 - 41s - loss: 1.5803 - accuracy: 0.2657 - val_loss: 1.5687 - val_accuracy: 0.2861
Epoch 19/20
6835/6835 - 41s - loss: 1.5808 - accuracy: 0.2676 - val_loss: 1.6080 - val_accuracy: 0.1843
Epoch 20/20
6835/6835 - 41s - loss: 1.5847 - accuracy: 0.2672 - val_loss: 1.5827 - val_accuracy: 0.2499
```

```
Out[251]: <tensorflow.python.keras.callbacks.History at 0x7f3d457adad0>
```

```
In [262]: %tensorboard --logdir logs_19/fit
```

```
ERROR: Failed to launch TensorBoard (exited with 255).
Contents of stderr:
E1112 00:12:30.043277 140338601187136 program.py:226] TensorBoard could not bind to any port around
6006 (tried 10 times)
ERROR: TensorBoard could not bind to any port around 6006 (tried 10 times)
```

```
In [ ]:
```

Create vanilla RNN model - 4 - Double Layer size

In [194]:

```
model_rnn_4 = tf.keras.Sequential()
model_rnn_4.add(layers.Embedding(5000, 256, input_length=X_train.shape[1]))

model_rnn_4.add(layers.SimpleRNN(256, return_sequences=True))

model_rnn_4.add(layers.SimpleRNN(256))

model_rnn_4.add(layers.Dense(5, activation='softmax'))


adam = tf.keras.optimizers.Adam(learning_rate=0.001, beta_1=0.9, beta_2=0.999, amsgrad=False)
#sgd = SGD(lr=0.01, decay=1e-6, momentum=0.9, nesterov=True)

model_rnn_4.compile(loss='categorical_crossentropy', optimizer=adam, metrics=['accuracy'])
#model_rnn.summary()

batch_size = 32
epochs = 20

log_dir_14="logs_14/fit/" + datetime.datetime.now().strftime("%Y%m%d-%H%M%S")
tensorboard_callback = tf.keras.callbacks.TensorBoard(log_dir=log_dir_14, histogram_freq=1)

model_rnn_4.fit(X_train, y_train, validation_data=(X_test, y_test), epochs=epochs, batch_size=batch_
```

```
Train on 6835 samples, validate on 1709 samples
Epoch 1/20
WARNING:tensorflow:Method (on_train_batch_end) is slow compared to the batch update (0.918587). C
heck your callbacks.
6835/6835 - 53s - loss: 1.7610 - accuracy: 0.2136 - val_loss: 1.5712 - val_accuracy: 0.2657
Epoch 2/20
6835/6835 - 49s - loss: 1.6294 - accuracy: 0.2530 - val_loss: 1.5805 - val_accuracy: 0.2662
Epoch 3/20
6835/6835 - 49s - loss: 1.5864 - accuracy: 0.2591 - val_loss: 1.5716 - val_accuracy: 0.2662
Epoch 4/20
6835/6835 - 51s - loss: 1.5836 - accuracy: 0.2626 - val_loss: 1.5884 - val_accuracy: 0.2703
Epoch 5/20
6835/6835 - 50s - loss: 1.5904 - accuracy: 0.2634 - val_loss: 1.5725 - val_accuracy: 0.2662
Epoch 6/20
6835/6835 - 51s - loss: 1.5873 - accuracy: 0.2638 - val_loss: 1.5823 - val_accuracy: 0.2662
Epoch 7/20
```

```
6835/6835 - 49s - loss: 1.5872 - accuracy: 0.2617 - val_loss: 1.5919 - val_accuracy: 0.2703
Epoch 8/20
6835/6835 - 49s - loss: 1.5893 - accuracy: 0.2655 - val_loss: 1.5754 - val_accuracy: 0.2662
Epoch 9/20
6835/6835 - 49s - loss: 1.5906 - accuracy: 0.2616 - val_loss: 1.5897 - val_accuracy: 0.2662
Epoch 10/20
6835/6835 - 50s - loss: 1.5841 - accuracy: 0.2636 - val_loss: 1.5692 - val_accuracy: 0.2703
Epoch 11/20
6835/6835 - 49s - loss: 1.5837 - accuracy: 0.2597 - val_loss: 1.5797 - val_accuracy: 0.2662
Epoch 12/20
6835/6835 - 49s - loss: 1.5839 - accuracy: 0.2753 - val_loss: 1.5697 - val_accuracy: 0.2703
Epoch 13/20
6835/6835 - 49s - loss: 1.5925 - accuracy: 0.2676 - val_loss: 1.5914 - val_accuracy: 0.1861
Epoch 14/20
6835/6835 - 49s - loss: 1.5848 - accuracy: 0.2553 - val_loss: 1.5916 - val_accuracy: 0.2662
Epoch 15/20
6835/6835 - 49s - loss: 1.5901 - accuracy: 0.2688 - val_loss: 1.5811 - val_accuracy: 0.2703
Epoch 16/20
6835/6835 - 49s - loss: 1.5884 - accuracy: 0.2632 - val_loss: 1.6444 - val_accuracy: 0.2662
Epoch 17/20
6835/6835 - 50s - loss: 1.5871 - accuracy: 0.2641 - val_loss: 1.5696 - val_accuracy: 0.2703
Epoch 18/20
6835/6835 - 51s - loss: 1.5979 - accuracy: 0.2506 - val_loss: 1.5639 - val_accuracy: 0.2662
Epoch 19/20
6835/6835 - 51s - loss: 1.5939 - accuracy: 0.2528 - val_loss: 1.5707 - val_accuracy: 0.2703
Epoch 20/20
6835/6835 - 51s - loss: 1.5829 - accuracy: 0.2606 - val_loss: 1.5771 - val_accuracy: 0.2703
```

```
Out[194]: <tensorflow.python.keras.callbacks.History at 0x7f3db5fd2e50>
```

Doubling the layer of vanilla RNN does not improve validation accuracy

```
In [ ]:
```

```
In [ ]:
```

In [263]:
```
%tensorboard --logdir logs_14/fit
```

```
ERROR: Failed to launch TensorBoard (exited with 255).
Contents of stderr:
E1112 00:12:55.089560 140568162531136 program.py:226] TensorBoard could not bind to any port around
6006 (tried 10 times)
ERROR: TensorBoard could not bind to any port around 6006 (tried 10 times)
```

In [ ]:

In [ ]:

Create LSTM Model

In [298]:
```
# Clear any logs from previous runs
#!rm -rf ./logs/
```

In [219]:
```
log_dir_18="logs_18/fit/" + datetime.datetime.now().strftime("%Y%m%d-%H%M%S")
```

In [220]:
```
tensorboard_callback = tf.keras.callbacks.TensorBoard(log_dir=log_dir_18, histogram_freq=1)
```

In [ ]:

In [221]:
```
model_lstm = tf.keras.Sequential()
model_lstm.add(layers.Embedding(5000, 500, input_length=X_train.shape[1]))
```

In [222]:
```
model_lstm.add(layers.Dropout(0.5))
```

In [223]:
```
model_lstm.add(layers.LSTM(500, dropout=0.5, recurrent_dropout=0.5))
model_lstm.add(layers.Dense(5, activation='softmax'))
```

In [ ]:

In [224]:

```
model_lstm.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['accuracy'])
model_lstm.summary()
```

```
Model: "sequential_24"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
embedding_7 (Embedding)      (None, 267, 500)          2500000
_________________________________________________________________
dropout_4 (Dropout)          (None, 267, 500)          0
_________________________________________________________________
lstm_28 (LSTM)               (None, 500)               2002000
_________________________________________________________________
dense_13 (Dense)             (None, 5)                 2505
=================================================================
Total params: 4,504,505
Trainable params: 4,504,505
Non-trainable params: 0
_________________________________________________________________
```

In [ ]:

In [ ]:

In [225]:

```
batch_size = 32
epochs = 15
```

In [226]:

```
model_lstm.fit(X_train, y_train, validation_data=(X_test, y_test), epochs=epochs, batch_size=batch_s
```

```
Train on 6835 samples, validate on 1709 samples
Epoch 1/15
6835/6835 - 276s - loss: 1.5758 - accuracy: 0.2742 - val_loss: 1.5610 - val_accuracy: 0.2756
Epoch 2/15
6835/6835 - 272s - loss: 1.5708 - accuracy: 0.2683 - val_loss: 1.5681 - val_accuracy: 0.2756
Epoch 3/15
6835/6835 - 277s - loss: 1.5636 - accuracy: 0.2907 - val_loss: 1.5733 - val_accuracy: 0.2733
Epoch 4/15
6835/6835 - 272s - loss: 1.5649 - accuracy: 0.2803 - val_loss: 1.5561 - val_accuracy: 0.2779
Epoch 5/15
6835/6835 - 271s - loss: 1.5614 - accuracy: 0.2806 - val_loss: 1.5636 - val_accuracy: 0.2750
Epoch 6/15
6835/6835 - 270s - loss: 1.5574 - accuracy: 0.2907 - val_loss: 1.5569 - val_accuracy: 0.2902
Epoch 7/15
6835/6835 - 271s - loss: 1.5593 - accuracy: 0.2910 - val_loss: 1.5576 - val_accuracy: 0.2762
Epoch 8/15
6835/6835 - 271s - loss: 1.5548 - accuracy: 0.2926 - val_loss: 1.5567 - val_accuracy: 0.2844
Epoch 9/15
6835/6835 - 272s - loss: 1.5549 - accuracy: 0.2854 - val_loss: 1.5529 - val_accuracy: 0.2978
Epoch 10/15
6835/6835 - 272s - loss: 1.5553 - accuracy: 0.2970 - val_loss: 1.5558 - val_accuracy: 0.2978
Epoch 11/15
6835/6835 - 271s - loss: 1.5503 - accuracy: 0.2977 - val_loss: 1.5567 - val_accuracy: 0.2867
Epoch 12/15
6835/6835 - 271s - loss: 1.5450 - accuracy: 0.2945 - val_loss: 1.5562 - val_accuracy: 0.2774
Epoch 13/15
6835/6835 - 271s - loss: 1.5451 - accuracy: 0.3001 - val_loss: 1.5622 - val_accuracy: 0.2756
Epoch 14/15
6835/6835 - 271s - loss: 1.5409 - accuracy: 0.3050 - val_loss: 1.5561 - val_accuracy: 0.3037
Epoch 15/15
6835/6835 - 274s - loss: 1.5380 - accuracy: 0.3078 - val_loss: 1.5553 - val_accuracy: 0.2908
```

Out[226]:

```
<tensorflow.python.keras.callbacks.History at 0x7f3dbda0a610>
```

In [264]:

```
%tensorboard --logdir logs_18/fit
```

```
ERROR: Failed to launch TensorBoard (exited with 255).
Contents of stderr:
E1112 00:13:29.759110 140098707699520 program.py:226] TensorBoard could not bind to any port around
6006 (tried 10 times)
ERROR: TensorBoard could not bind to any port around 6006 (tried 10 times)
```

In [228]:

```
loss, acc = model_lstm.evaluate(test_X_t, test_y, verbose=2)
print("Test set Accuracy: {:5.2f}%".format(100*acc))
```

```
2210/1 - 29s - loss: 1.5446 - accuracy: 0.2588
Test set Accuracy: 25.88%
```

In [ ]:

In [ ]:

In [ ]:

In [218]:

```
loss, acc = model_lstm.evaluate(test_X_t, test_y, verbose=2)
print("Test set Accuracy: {:5.2f}%".format(100*acc))
```

```
2210/1 - 9s - loss: 1.5518 - accuracy: 0.2683
Test set Accuracy: 26.83%
```

In [ ]:

In [265]:

```
%tensorboard --logdir logs_17/fit
```

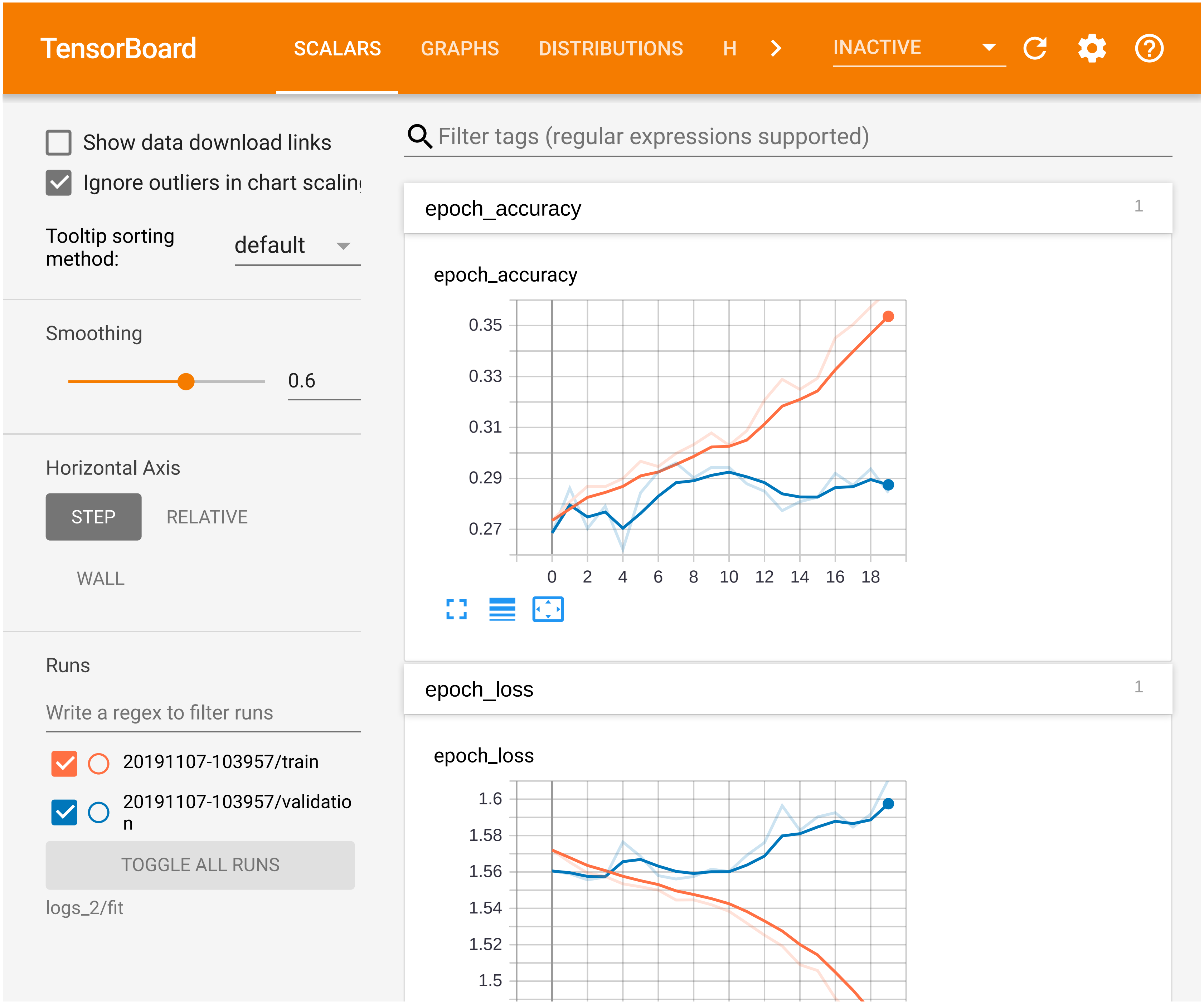
```
ERROR: Failed to launch TensorBoard (exited with 255).
Contents of stderr:
E1112 00:13:54.057028 139840611579712 program.py:226] TensorBoard could not bind to any port around
6006 (tried 10 times)
ERROR: TensorBoard could not bind to any port around 6006 (tried 10 times)
```

In [ ]:

```
In [ ]:
```

LSTM Tensorboard Visualizations

```
In [173]: %tensorboard --logdir logs_2/fit
```



☐ Show data download links

☑ Ignore outliers in chart scalin

Tooltip sorting method: default

Smoothing

0.6

Horizontal Axis

STEP RELATIVE WALL

Runs

Write a regex to filter runs

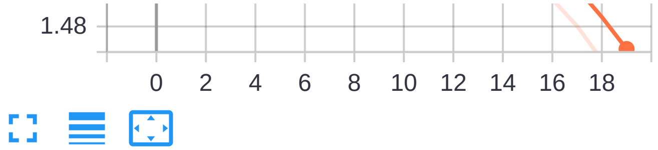
☑ ○ 20191107-103957/train

☑ ○ 20191107-103957/validation

TOGGLE ALL RUNS

logs_2/fit

Filter tags (regular expressions supported)



```
In [ ]:
```

Accuracy of LSTM model on dev subset

```
In [ ]: score, acc = model_lstm.evaluate(dev_X_t, dev_y)
```

```
In [345]: acc
```

```
Out[345]: 0.2770209
```

Accuracy of LSTM on dev subset = 27.70%

```
In [ ]:
```

```
In [ ]:
```

Create LSTM Model - 2

```
In [401]: log_dir_7="logs_7/fit/" + datetime.datetime.now().strftime("%Y%m%d-%H%M%S")

          tensorboard_callback = tf.keras.callbacks.TensorBoard(log_dir=log_dir_7, histogram_freq=1)
```

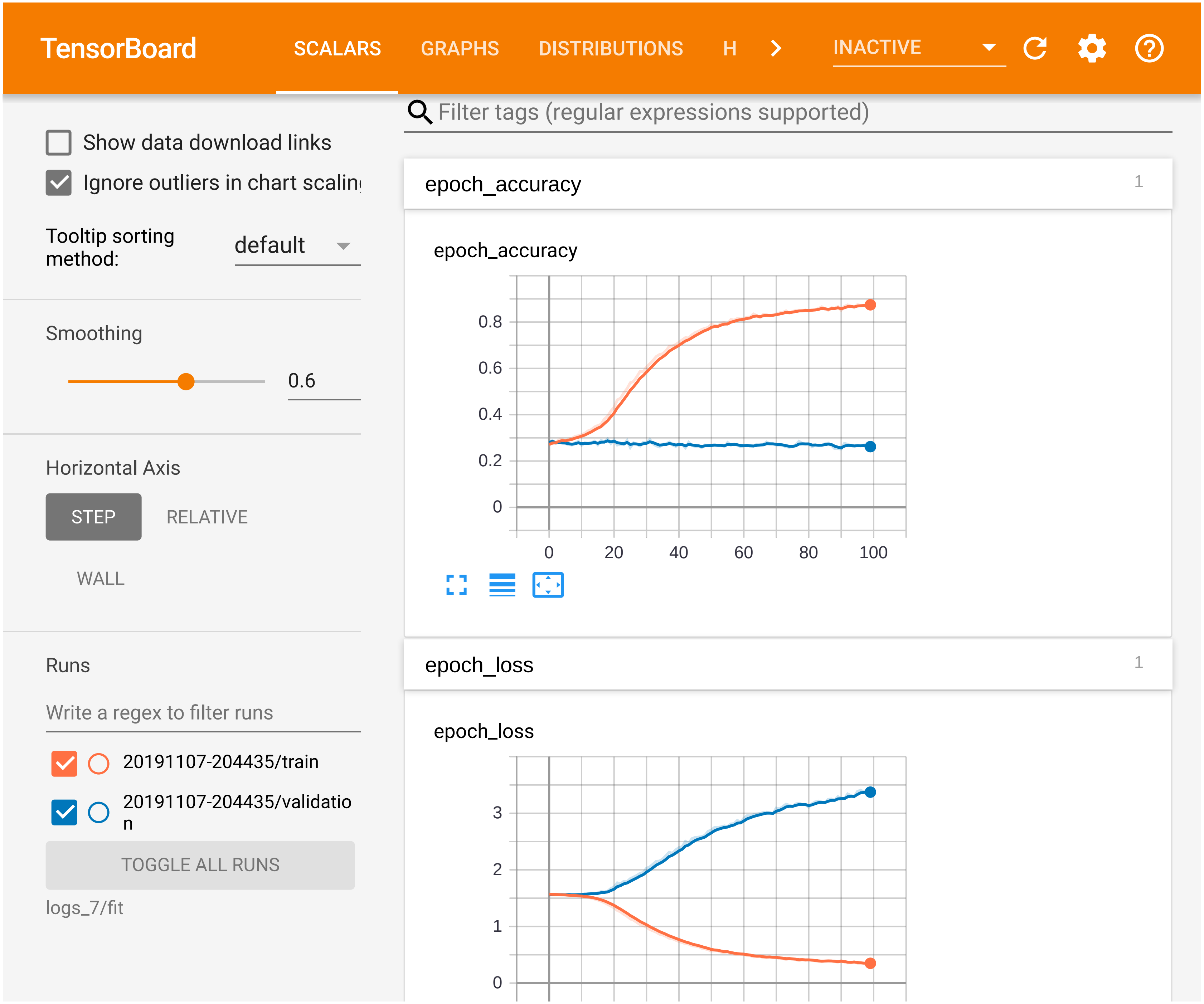
In [402]:

```
model_lstm_2 = tf.keras.Sequential()
model_lstm_2.add(layers.Embedding(5000, 256, input_length=X_train.shape[1]))



model_lstm_2.add(layers.Dropout(0.3))

model_lstm_2.add(layers.LSTM(256, dropout=0.3, recurrent_dropout=0.2))
model_lstm_2.add(layers.Dense(5, activation='softmax'))

adam = tf.keras.optimizers.Adam(learning_rate=0.001, beta_1=0.9, beta_2=0.999, amsgrad=False)

model_lstm_2.compile(loss='categorical_crossentropy', optimizer=adam, metrics=['accuracy'])
#model_lstm.summary()


batch_size = 16
epochs = 100

model_lstm_2.fit(X_train, y_train, validation_data=(X_test, y_test), epochs=epochs, batch_size=batch
```

```
Train on 6835 samples, validate on 1709 samples
Epoch 1/100
WARNING:tensorflow:Method (on_train_batch_end) is slow compared to the batch update (0.927149). C
heck your callbacks.
6835/6835 - 124s - loss: 1.5718 - accuracy: 0.2713 - val_loss: 1.5603 - val_accuracy: 0.2803
Epoch 2/100
6835/6835 - 119s - loss: 1.5649 - accuracy: 0.2809 - val_loss: 1.5618 - val_accuracy: 0.2879
Epoch 3/100
6835/6835 - 119s - loss: 1.5611 - accuracy: 0.2799 - val_loss: 1.5610 - val_accuracy: 0.2756
Epoch 4/100
6835/6835 - 119s - loss: 1.5587 - accuracy: 0.2909 - val_loss: 1.5599 - val_accuracy: 0.2815
Epoch 5/100
6835/6835 - 119s - loss: 1.5556 - accuracy: 0.2938 - val_loss: 1.5612 - val_accuracy: 0.2768
Epoch 6/100
6835/6835 - 120s - loss: 1.5554 - accuracy: 0.2857 - val_loss: 1.5584 - val_accuracy: 0.2756
Epoch 7/100
6835/6835 - 119s - loss: 1.5474 - accuracy: 0.2951 - val_loss: 1.5655 - val_accuracy: 0.2709
Epoch 8/100
6835/6835 - 119s - loss: 1.5454 - accuracy: 0.2973 - val_loss: 1.5561 - val_accuracy: 0.2692
Epoch 9/100
```

In [ ]:

In [174]:
```
%tensorboard --logdir logs_7/fit
```



□ Show data download links

☑ Ignore outliers in chart scalin

Tooltip sorting method: default

Smoothing 0.6

Horizontal Axis: STEP RELATIVE WALL

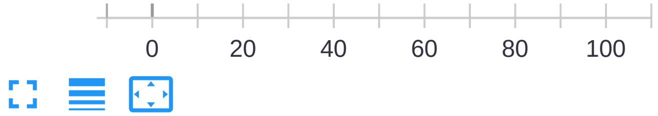
Runs

Write a regex to filter runs

☑ ○ 20191107-204435/train

☑ ○ 20191107-204435/validation

logs_7/fit



In [ ]:

Doubling LSTM

In [ ]:

In [196]:

```
model_lstm_3 = tf.keras.Sequential()
model_lstm_3.add(layers.Embedding(5000, 256, input_length=X_train.shape[1]))



model_lstm_3.add(layers.Dropout(0.3))

model_lstm_3.add(layers.LSTM(256, return_sequences=True, dropout=0.3, recurrent_dropout=0.2))


model_lstm_3.add(layers.LSTM(256, dropout=0.3, recurrent_dropout=0.2))

model_lstm_3.add(layers.Dense(5, activation='softmax'))

adam = tf.keras.optimizers.Adam(learning_rate=0.001, beta_1=0.9, beta_2=0.999, amsgrad=False)

model_lstm_3.compile(loss='categorical_crossentropy', optimizer=adam, metrics=['accuracy'])
#model_lstm.summary()


batch_size = 16
epochs = 10


log_dir_15="logs_15/fit/" + datetime.datetime.now().strftime("%Y%m%d-%H%M%S")

tensorboard_callback = tf.keras.callbacks.TensorBoard(log_dir=log_dir_15, histogram_freq=1)

model_lstm_3.fit(X_train, y_train, validation_data=(X_test, y_test), epochs=epochs, batch_size=batch
```

```
Train on 6835 samples, validate on 1709 samples
Epoch 1/10
WARNING:tensorflow:Method (on_train_batch_end) is slow compared to the batch update (1.967493). C
heck your callbacks.
6835/6835 - 247s - loss: 1.5763 - accuracy: 0.2598 - val_loss: 1.5657 - val_accuracy: 0.2668
Epoch 2/10
6835/6835 - 237s - loss: 1.5696 - accuracy: 0.2723 - val_loss: 1.5665 - val_accuracy: 0.2873
Epoch 3/10
6835/6835 - 237s - loss: 1.5683 - accuracy: 0.2783 - val_loss: 1.5698 - val_accuracy: 0.2715
Epoch 4/10
6835/6835 - 235s - loss: 1.5728 - accuracy: 0.2695 - val_loss: 1.5652 - val_accuracy: 0.2662
```

```
Epoch 5/10
6835/6835 - 235s - loss: 1.5691 - accuracy: 0.2699 - val_loss: 1.5630 - val_accuracy: 0.2697
Epoch 6/10
6835/6835 - 239s - loss: 1.5677 - accuracy: 0.2742 - val_loss: 1.5570 - val_accuracy: 0.2744
Epoch 7/10
6835/6835 - 236s - loss: 1.5667 - accuracy: 0.2740 - val_loss: 1.5583 - val_accuracy: 0.2727
Epoch 8/10
6835/6835 - 235s - loss: 1.5659 - accuracy: 0.2794 - val_loss: 1.5599 - val_accuracy: 0.2727
Epoch 9/10
6835/6835 - 235s - loss: 1.5654 - accuracy: 0.2780 - val_loss: 1.5584 - val_accuracy: 0.2733
Epoch 10/10
6835/6835 - 235s - loss: 1.5660 - accuracy: 0.2727 - val_loss: 1.5593 - val_accuracy: 0.2727
```

```
Out[196]: <tensorflow.python.keras.callbacks.History at 0x7f3f2c9c76d0>
```

```
In [ ]:
```

Doubling LSTM layer does not improve validation accuracy

```
In [ ]:
```

```
In [268]: %tensorboard --logdir logs_15/fit
```

```
ERROR: Failed to launch TensorBoard (exited with 255).
Contents of stderr:
E1112 00:15:39.989207 140272832292672 program.py:226] TensorBoard could not bind to any port around
6006 (tried 10 times)
ERROR: TensorBoard could not bind to any port around 6006 (tried 10 times)
```

```
In [ ]:
```

```
In [ ]:
```

```
In [ ]:
```

Create GRU model

In [ ]:

In [ ]:

In [238]:

```
model_gru = tf.keras.Sequential()
model_gru.add(layers.Embedding(5000, 256, input_length=X_train.shape[1]))
```

In [239]:

```
model_gru.add(layers.GRU(256))
model_gru.add(layers.Dense(5, activation='softmax'))
```

In [240]:

```
model_gru.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['accuracy'])
model_gru.summary()
```

```
Model: "sequential_25"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
embedding_8 (Embedding)      (None, 267, 256)          1280000
_________________________________________________________________
gru_2 (GRU)                  (None, 256)               394752
_________________________________________________________________
dense_14 (Dense)             (None, 5)                 1285
=================================================================
Total params: 1,676,037
Trainable params: 1,676,037
Non-trainable params: 0
_________________________________________________________________
```

In [241]:

```
batch_size = 32
epochs = 20
```

In [ ]:

In [242]:

```
# Clear any logs from previous runs
#!rm -rf ./logs/
```

In [243]:

```
log_dir_3="logs_3/fit/" + datetime.datetime.now().strftime("%Y%m%d-%H%M%S")
```

In [244]:

```
tensorboard_callback = tf.keras.callbacks.TensorBoard(log_dir=log_dir_3, histogram_freq=1)
```

In [ ]:

In [ ]:

In [245]:

```
model_gru.fit(X_train, y_train, validation_data=(X_test, y_test), epochs=epochs, batch_size=batch_si
```

```
Train on 6835 samples, validate on 1709 samples
Epoch 1/20
WARNING:tensorflow:Method (on_train_batch_end) is slow compared to the batch update (0.882006). Che
ck your callbacks.
6835/6835 - 72s - loss: 1.5719 - accuracy: 0.2692 - val_loss: 1.5626 - val_accuracy: 0.2779
Epoch 2/20
6835/6835 - 68s - loss: 1.5653 - accuracy: 0.2742 - val_loss: 1.5680 - val_accuracy: 0.2727
Epoch 3/20
6835/6835 - 69s - loss: 1.5596 - accuracy: 0.2830 - val_loss: 1.5621 - val_accuracy: 0.2686
Epoch 4/20
6835/6835 - 69s - loss: 1.5551 - accuracy: 0.2939 - val_loss: 1.5637 - val_accuracy: 0.2744
Epoch 5/20
6835/6835 - 68s - loss: 1.5519 - accuracy: 0.2951 - val_loss: 1.5624 - val_accuracy: 0.2774
Epoch 6/20
6835/6835 - 68s - loss: 1.5481 - accuracy: 0.2985 - val_loss: 1.5650 - val_accuracy: 0.2762
Epoch 7/20
6835/6835 - 68s - loss: 1.5442 - accuracy: 0.3023 - val_loss: 1.5559 - val_accuracy: 0.2873
Epoch 8/20
6835/6835 - 68s - loss: 1.5398 - accuracy: 0.2999 - val_loss: 1.5626 - val_accuracy: 0.2978
Epoch 9/20
6835/6835 - 70s - loss: 1.5340 - accuracy: 0.3138 - val_loss: 1.5642 - val_accuracy: 0.2896
Epoch 10/20
6835/6835 - 68s - loss: 1.5210 - accuracy: 0.3108 - val_loss: 1.5613 - val_accuracy: 0.2972
Epoch 11/20
6835/6835 - 68s - loss: 1.5047 - accuracy: 0.3230 - val_loss: 1.5706 - val_accuracy: 0.2733
Epoch 12/20
6835/6835 - 68s - loss: 1.4695 - accuracy: 0.3501 - val_loss: 1.5598 - val_accuracy: 0.2949
Epoch 13/20
6835/6835 - 68s - loss: 1.4112 - accuracy: 0.3914 - val_loss: 1.5836 - val_accuracy: 0.2955
Epoch 14/20
6835/6835 - 68s - loss: 1.3208 - accuracy: 0.4388 - val_loss: 1.6476 - val_accuracy: 0.2815
Epoch 15/20
6835/6835 - 68s - loss: 1.1865 - accuracy: 0.4976 - val_loss: 1.7373 - val_accuracy: 0.2785
Epoch 16/20
6835/6835 - 68s - loss: 1.0149 - accuracy: 0.5890 - val_loss: 1.8808 - val_accuracy: 0.2955
Epoch 17/20
6835/6835 - 68s - loss: 0.8169 - accuracy: 0.6825 - val_loss: 2.0533 - val_accuracy: 0.3084
Epoch 18/20
6835/6835 - 68s - loss: 0.6009 - accuracy: 0.7760 - val_loss: 2.4067 - val_accuracy: 0.2850
Epoch 19/20
```

```
6835/6835 - 68s - loss: 0.4321 - accuracy: 0.8505 - val_loss: 2.6931 - val_accuracy: 0.2943
Epoch 20/20
6835/6835 - 69s - loss: 0.3065 - accuracy: 0.9002 - val_loss: 3.0015 - val_accuracy: 0.2932
```

Out[245]:

```
<tensorflow.python.keras.callbacks.History at 0x7f3d54e10250>
```

In [ ]:

GRU Tensorboard Visualizations

In [ ]:

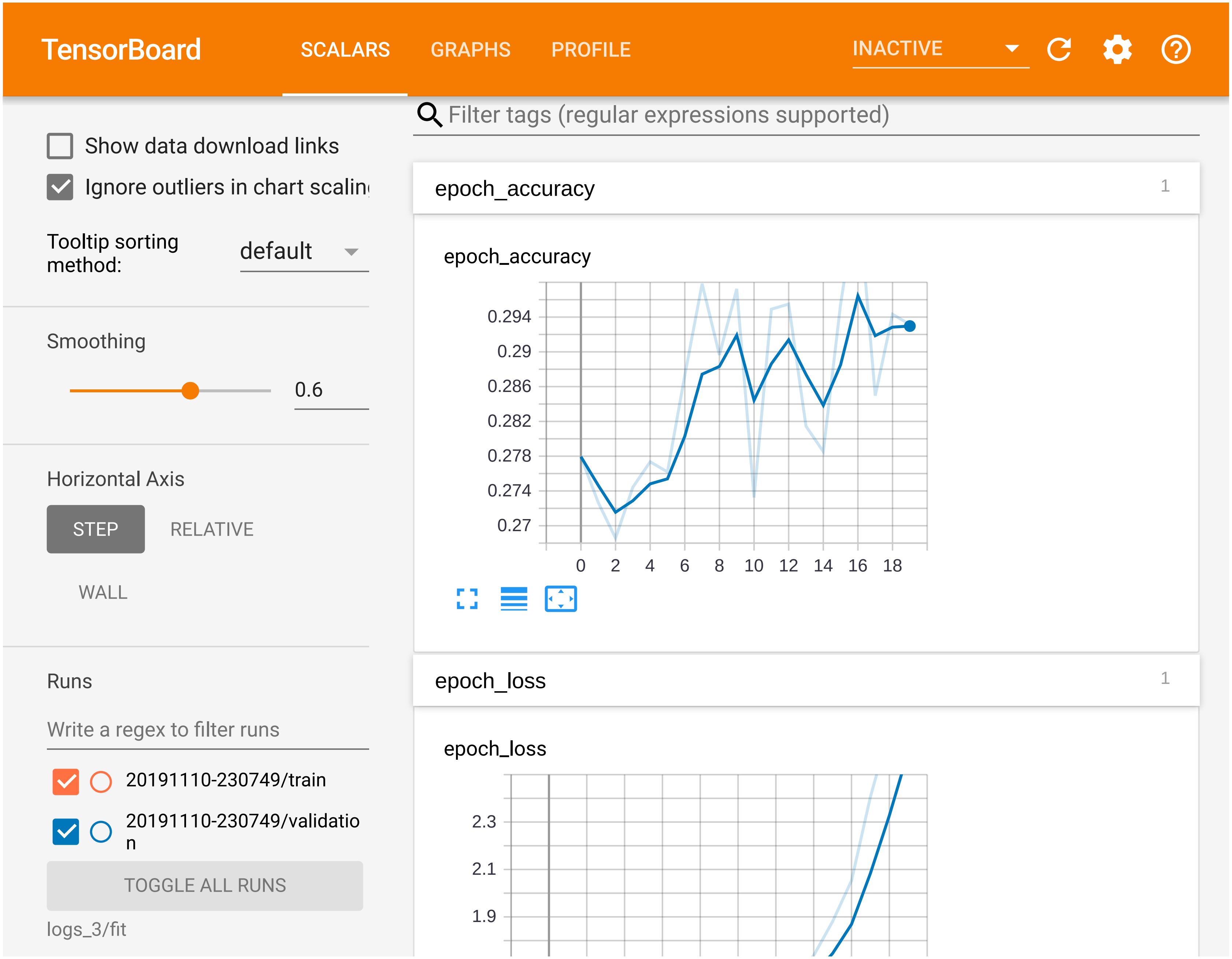
In [269]:

```
%load_ext tensorboard
```

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

In [270]:
```
%tensorboard --logdir logs_3/fit
```

```
Reusing TensorBoard on port 6015 (pid 20542), started 2 days, 15:33:50 ago. (Use '!kill 20542' to k
ill it.)
```



☐ Show data download links

☑ Ignore outliers in chart scalin

Tooltip sorting method: default

Smoothing 0.6

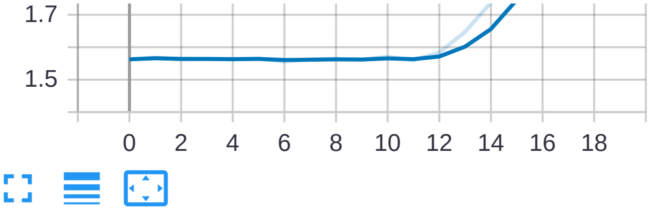
Horizontal Axis: STEP

Runs

☑ ○ 20191110-230749/train

☑ ○ 20191110-230749/validation

logs_3/fit



In [ ]:

In [ ]:

Accuracy of GRU model on dev subset

In [ ]:

```
score, acc = model_gru.evaluate(dev_X_t, dev_y)
```

In [347]:

```
acc
```

Out[347]:

```
0.25613078
```

Accuracy of GRU model on dev subset = 25.61%

In [ ]:

Create GRU model - 2

In [418]:

```
model_gru_2 = tf.keras.Sequential()
model_gru_2.add(layers.Embedding(5000, 256, input_length=X_train.shape[1]))


model_gru_2.add(layers.Dropout(0.3))

model_gru_2.add(layers.GRU(256))


model_gru_2.add(layers.Dropout(0.3))




model_gru_2.add(layers.Dense(5, activation='softmax'))

model_gru_2.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['accuracy'])
model_gru_2.summary()

batch_size = 32
epochs = 10


log_dir_9="logs_9/fit/" + datetime.datetime.now().strftime("%Y%m%d-%H%M%S")
tensorboard_callback = tf.keras.callbacks.TensorBoard(log_dir=log_dir_9, histogram_freq=1)


model_gru_2.fit(X_train, y_train, validation_data=(X_test, y_test), epochs=epochs, batch_size=batch_
```

```
Model: "sequential_27"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
embedding_26 (Embedding)     (None, 267, 256)          1280000   
_________________________________________________________________
dropout_5 (Dropout)          (None, 267, 256)          0         
_________________________________________________________________
gru_4 (GRU)                  (None, 256)               394752    
_________________________________________________________________
dropout_6 (Dropout)          (None, 256)               0         
```

```
_________________________________________________________________
dense_25 (Dense)             (None, 5)                 1285      
=================================================================
Total params: 1,676,037
Trainable params: 1,676,037
Non-trainable params: 0
_________________________________________________________________
Train on 6835 samples, validate on 1709 samples
Epoch 1/10
WARNING:tensorflow:Method (on_train_batch_end) is slow compared to the batch update (0.891410). Che
ck your callbacks.
6835/6835 - 74s - loss: 1.5734 - accuracy: 0.2658 - val_loss: 1.5675 - val_accuracy: 0.2744
Epoch 2/10
6835/6835 - 70s - loss: 1.5670 - accuracy: 0.2759 - val_loss: 1.5578 - val_accuracy: 0.2703
Epoch 3/10
6835/6835 - 70s - loss: 1.5620 - accuracy: 0.2811 - val_loss: 1.5564 - val_accuracy: 0.2896
Epoch 4/10
6835/6835 - 69s - loss: 1.5583 - accuracy: 0.2878 - val_loss: 1.5621 - val_accuracy: 0.2826
Epoch 5/10
6835/6835 - 70s - loss: 1.5564 - accuracy: 0.2876 - val_loss: 1.5599 - val_accuracy: 0.2844
Epoch 6/10
6835/6835 - 70s - loss: 1.5531 - accuracy: 0.2887 - val_loss: 1.5581 - val_accuracy: 0.2861
Epoch 7/10
6835/6835 - 70s - loss: 1.5491 - accuracy: 0.3031 - val_loss: 1.5573 - val_accuracy: 0.2756
Epoch 8/10
6835/6835 - 70s - loss: 1.5436 - accuracy: 0.3045 - val_loss: 1.5545 - val_accuracy: 0.2891
Epoch 9/10
6835/6835 - 70s - loss: 1.5370 - accuracy: 0.3058 - val_loss: 1.5649 - val_accuracy: 0.2779
Epoch 10/10
6835/6835 - 70s - loss: 1.5311 - accuracy: 0.3154 - val_loss: 1.5549 - val_accuracy: 0.2932
```

```
Out[418]: <tensorflow.python.keras.callbacks.History at 0x7f1389b57410>
```

```
In [271]: %tensorboard --logdir logs_9/fit
```

```
ERROR: Failed to launch TensorBoard (exited with 255).
Contents of stderr:
E1112 00:16:19.276887 140082655811392 program.py:226] TensorBoard could not bind to any port around
6006 (tried 10 times)
ERROR: TensorBoard could not bind to any port around 6006 (tried 10 times)
```

In [ ]:

In [ ]:

Doubling GRU layer model

In [ ]:

In [198]:

```
model_gru_3 = tf.keras.Sequential()
model_gru_3.add(layers.Embedding(5000, 256, input_length=X_train.shape[1]))


model_gru_3.add(layers.Dropout(0.3))

model_gru_3.add(layers.GRU(256, return_sequences=True))

model_gru_3.add(layers.GRU(256))


model_gru_3.add(layers.Dropout(0.3))



model_gru_3.add(layers.Dense(5, activation='softmax'))

model_gru_3.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['accuracy'])
#model_gru_3.summary()

batch_size = 32
epochs = 10


log_dir_16="logs_16/fit/" + datetime.datetime.now().strftime("%Y%m%d-%H%M%S")
tensorboard_callback = tf.keras.callbacks.TensorBoard(log_dir=log_dir_16, histogram_freq=1)


#model_gru_3.fit(X_train, y_train, validation_data=(X_test, y_test), epochs=epochs, batch_size=batch

model_gru_3.fit(X_t, y_t, validation_data=(dev_X_t, dev_y), epochs=epochs, batch_size=batch_size, ve
```

```
Train on 8544 samples, validate on 1101 samples
Epoch 1/10
WARNING:tensorflow:Method (on_train_batch_end) is slow compared to the batch update (1.201706). C
heck your callbacks.
8544/8544 - 160s - loss: 1.5742 - accuracy: 0.2697 - val_loss: 1.5765 - val_accuracy: 0.2543
Epoch 2/10
8544/8544 - 152s - loss: 1.5666 - accuracy: 0.2796 - val_loss: 1.5808 - val_accuracy: 0.2498
```

```
Epoch 3/10
8544/8544 - 152s - loss: 1.5653 - accuracy: 0.2773 - val_loss: 1.5706 - val_accuracy: 0.2625
Epoch 4/10
8544/8544 - 152s - loss: 1.5623 - accuracy: 0.2811 - val_loss: 1.5721 - val_accuracy: 0.2725
Epoch 5/10
8544/8544 - 152s - loss: 1.5599 - accuracy: 0.2786 - val_loss: 1.5771 - val_accuracy: 0.2480
Epoch 6/10
8544/8544 - 152s - loss: 1.5571 - accuracy: 0.2933 - val_loss: 1.5853 - val_accuracy: 0.2543
Epoch 7/10
8544/8544 - 152s - loss: 1.5530 - accuracy: 0.2921 - val_loss: 1.5823 - val_accuracy: 0.2707
Epoch 8/10
8544/8544 - 152s - loss: 1.5515 - accuracy: 0.2949 - val_loss: 1.5787 - val_accuracy: 0.2834
Epoch 9/10
8544/8544 - 152s - loss: 1.5456 - accuracy: 0.2990 - val_loss: 1.5703 - val_accuracy: 0.2570
Epoch 10/10
8544/8544 - 153s - loss: 1.5422 - accuracy: 0.2989 - val_loss: 1.5719 - val_accuracy: 0.2725
```

```
Out[198]: <tensorflow.python.keras.callbacks.History at 0x7f3dbd302090>
```

Doubling GRU model layer does not improve validation accuracy

```
In [ ]:
```

```
In [199]: %tensorboard --logdir logs_16/fit
```

```
ERROR: Failed to launch TensorBoard (exited with 255).
Contents of stderr:
E1110 00:51:09.285538 139798023501632 program.py:226] TensorBoard could not bind to any port around
6006 (tried 10 times)
ERROR: TensorBoard could not bind to any port around 6006 (tried 10 times)
```

```
In [ ]:
```

```
In [ ]:
```

Overfitting - with dropout=0.3

In [177]:

```
%tensorboard --logdir logs_8/fit
```

```
ERROR: Failed to launch TensorBoard (exited with 255).
Contents of stderr:
E1109 08:42:37.262158 140054096025408 program.py:226] TensorBoard could not bind to any port around
6006 (tried 10 times)
ERROR: TensorBoard could not bind to any port around 6006 (tried 10 times)
```

In [ ]:

In [ ]:

In [134]:

```
X_train.shape
```

Out[134]:

```
(6835, 267)
```

In [ ]:

BiDIRECTIONAL RNN

In [ ]:

In [158]:

```
model_bid = tf.keras.Sequential()

model_bid.add(layers.Embedding(5000, 10, input_length=X_train.shape[1]))


model_bid.add(layers.Bidirectional(layers.LSTM(10, return_sequences=True)))

#model_bid.add(layers.Bidirectional(layers.LSTM(10, return_sequences=True), input_shape=(6835, 267))



model_bid.add(layers.Bidirectional(layers.LSTM(10)))
model_bid.add(layers.Dense(5))
model_bid.add(layers.Activation('softmax'))
model_bid.compile(loss='categorical_crossentropy', optimizer='rmsprop', metrics=['accuracy'])

model_bid.summary()
```

```
Model: "sequential_19"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
embedding_2 (Embedding)      (None, 267, 10)           50000     
_________________________________________________________________
bidirectional_17 (Bidirectio (None, 267, 20)           1680      
_________________________________________________________________
bidirectional_18 (Bidirectio (None, 20)                2480      
_________________________________________________________________
dense_8 (Dense)              (None, 5)                 105       
_________________________________________________________________
activation_7 (Activation)    (None, 5)                 0         
=================================================================
Total params: 54,265
Trainable params: 54,265
Non-trainable params: 0
_________________________________________________________________
```

In [ ]:

In [166]:

```
batch_size = 32
epochs = 10


log_dir_13="logs_13/fit/" + datetime.datetime.now().strftime("%Y%m%d-%H%M%S")
tensorboard_callback = tf.keras.callbacks.TensorBoard(log_dir=log_dir_13, histogram_freq=1)

# define checkpoint
checkpoint_path = "training_2/cp.ckpt"
checkpoint_dir = os.path.dirname(checkpoint_path)

# Create a callback that saves the model's weights
cp_callback = tf.keras.callbacks.ModelCheckpoint(filepath=checkpoint_path, monitor='accuracy', save_


model_bid.fit(X_train, y_train, validation_data=(X_test, y_test), epochs=epochs, batch_size=batch_si
```

```
Train on 6835 samples, validate on 1709 samples
Epoch 1/10
WARNING:tensorflow:Method (on_train_batch_end) is slow compared to the batch update (3.036925). C
heck your callbacks.

Epoch 00001: accuracy improved from -inf to 0.32963, saving model to training_2/cp.ckpt
6835/6835 - 46s - loss: 1.5152 - accuracy: 0.3296 - val_loss: 1.5677 - val_accuracy: 0.2867
Epoch 2/10

Epoch 00002: accuracy did not improve from 0.32963
6835/6835 - 38s - loss: 1.5167 - accuracy: 0.3251 - val_loss: 1.5604 - val_accuracy: 0.2937
Epoch 3/10

Epoch 00003: accuracy did not improve from 0.32963
6835/6835 - 38s - loss: 1.5152 - accuracy: 0.3293 - val_loss: 1.5642 - val_accuracy: 0.2932
Epoch 4/10

Epoch 00004: accuracy improved from 0.32963 to 0.33021, saving model to training_2/cp.ckpt
6835/6835 - 38s - loss: 1.5127 - accuracy: 0.3302 - val_loss: 1.5741 - val_accuracy: 0.2733
Epoch 5/10

Epoch 00005: accuracy improved from 0.33021 to 0.33270, saving model to training_2/cp.ckpt
6835/6835 - 38s - loss: 1.5113 - accuracy: 0.3327 - val_loss: 1.5642 - val_accuracy: 0.2803
```

```
Epoch 6/10

Epoch 00006: accuracy improved from 0.33270 to 0.33899, saving model to training_2/cp.ckpt
6835/6835 - 38s - loss: 1.5082 - accuracy: 0.3390 - val_loss: 1.5851 - val_accuracy: 0.2744
Epoch 7/10

Epoch 00007: accuracy did not improve from 0.33899
6835/6835 - 38s - loss: 1.5074 - accuracy: 0.3386 - val_loss: 1.5648 - val_accuracy: 0.2844
Epoch 8/10

Epoch 00008: accuracy did not improve from 0.33899
6835/6835 - 38s - loss: 1.5098 - accuracy: 0.3302 - val_loss: 1.5804 - val_accuracy: 0.2885
Epoch 9/10

Epoch 00009: accuracy did not improve from 0.33899
6835/6835 - 38s - loss: 1.5092 - accuracy: 0.3333 - val_loss: 1.5714 - val_accuracy: 0.2744
Epoch 10/10

Epoch 00010: accuracy did not improve from 0.33899
6835/6835 - 38s - loss: 1.5120 - accuracy: 0.3260 - val_loss: 1.5682 - val_accuracy: 0.2750
```

Out[166]:

```
<tensorflow.python.keras.callbacks.History at 0x7f3eef9b9910>
```

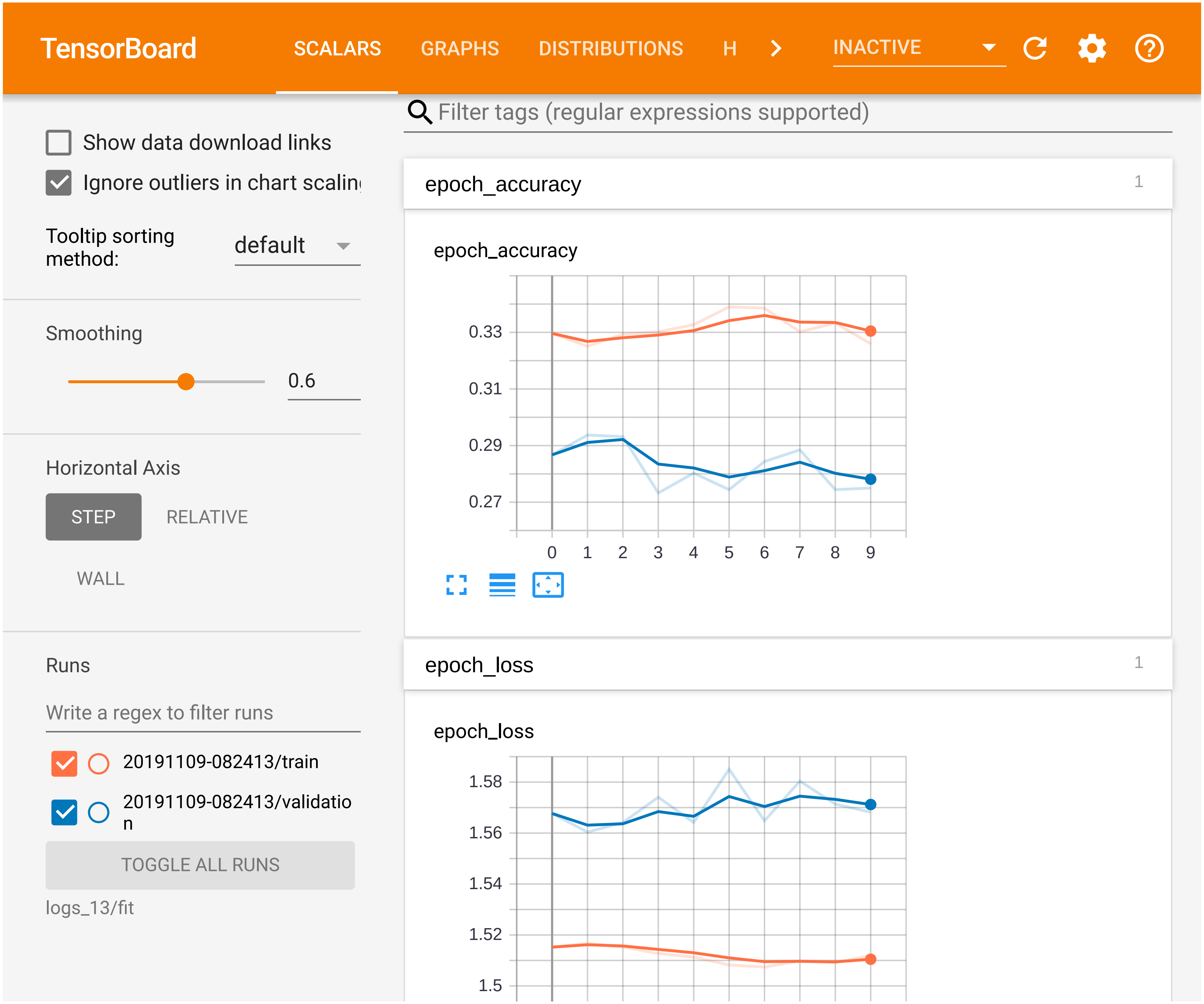
In [ ]:

In [167]:

```
# Loads the weights
model_bid.load_weights(checkpoint_path)

loss, acc = model_bid.evaluate(test_X_t, test_y, verbose=2)
print("Test set Accuracy: {:5.2f}%".format(100*acc))
```

```
2210/1 - 2s - loss: 1.7128 - accuracy: 0.2986
Test set Accuracy: 29.86%
```

In [168]:
```
%tensorboard --logdir logs_13/fit
```



□ Show data download links

☑ Ignore outliers in chart scalin

Tooltip sorting method: default

Smoothing 0.6

Horizontal Axis

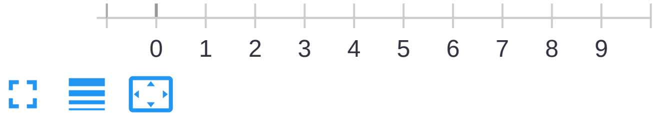
Runs

Write a regex to filter runs

☑ ○ 20191109-082413/train

☑ ○ 20191109-082413/validation

logs_13/fit



In [ ]:

```
```

In [ ]:

```
```

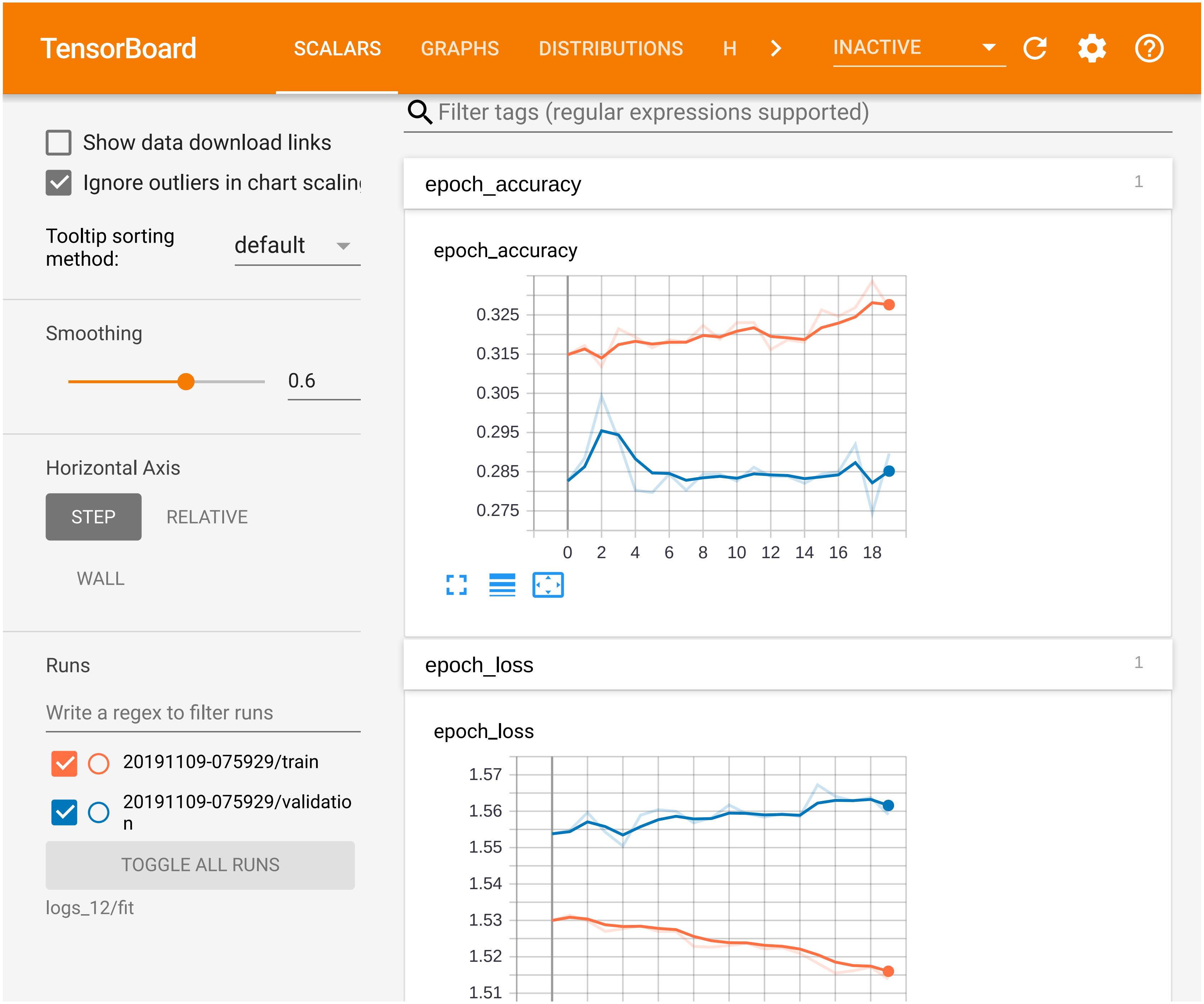
evaluation on test data

In [ ]:

```
# Loads the weights
model_bid.load_weights(checkpoint_path)

loss, acc = model_bid.evaluate(test_X_t, test_y, verbose=2)
print("Test set Accuracy: {:5.2f}%".format(100*acc))
```

Test set Accuracy: 29.86% - Using Bidirectional LSTM

In [165]:
```
%tensorboard --logdir logs_12/fit
```



TensorBoard SCALARS GRAPHS DISTRIBUTIONS H > INACTIVE

Filter tags (regular expressions supported)

□ Show data download links

☑ Ignore outliers in chart scalin

Tooltip sorting method: default

Smoothing 0.6

Horizontal Axis

STEP RELATIVE WALL

Runs

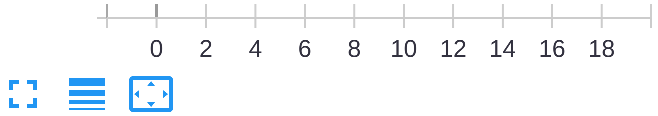
Write a regex to filter runs

☑ ○ 20191109-075929/train

☑ ○ 20191109-075929/validation

TOGGLE ALL RUNS

logs_12/fit

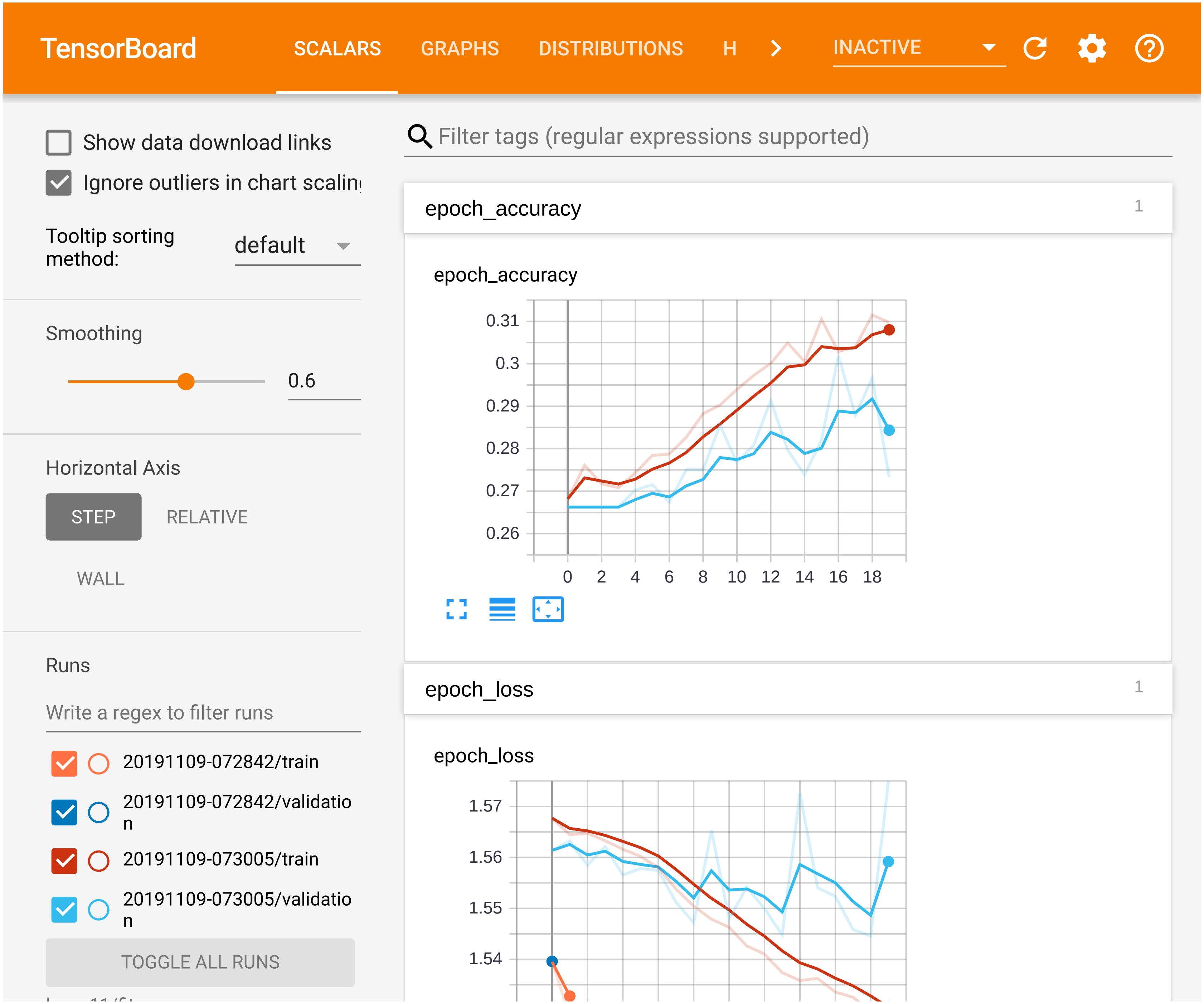


In [ ]:

In [ ]:

Bidirectional LSTM with 20 epochs

```
In [160]: %tensorboard --logdir logs_11/fit
```



☐ Show data download links

☑ Ignore outliers in chart scalin

Tooltip sorting method: default

Smoothing 0.6

Horizontal Axis

STEP RELATIVE WALL

Runs

Write a regex to filter runs

☑ ○ 20191109-072842/train

☑ ○ 20191109-072842/validation

☑ ○ 20191109-073005/train

☑ ○ 20191109-073005/validation

TOGGLE ALL RUNS

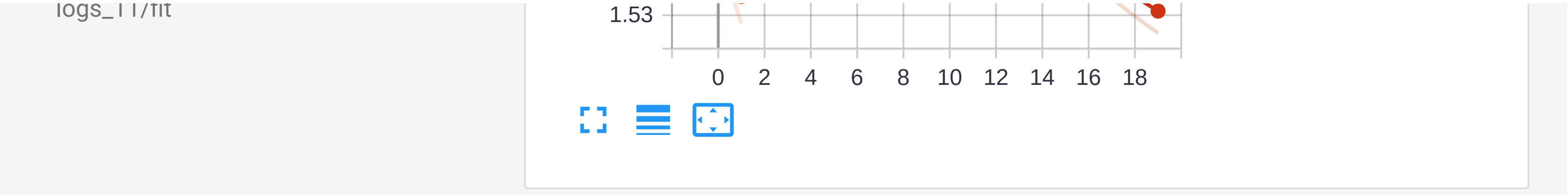
Filter tags (regular expressions supported)

epoch_accuracy 1

epoch_accuracy

epoch_loss 1

epoch_loss



In [ ]:

In [ ]:

Bidirectional - with 10 epochs

In [178]:
```
%tensorboard --logdir logs_10/fit
```

```
ERROR: Failed to launch TensorBoard (exited with 255).
Contents of stderr:
E1109 08:42:54.047511 140117797828416 program.py:226] TensorBoard could not bind to any port around
6006 (tried 10 times)
ERROR: TensorBoard could not bind to any port around 6006 (tried 10 times)
```

In [ ]:

In [ ]:

Task 4 - Evaluate best model on test data

In [ ]:

In [ ]:
```
score, acc = model_lstm.evaluate(test_X_t, test_y)
```

In [358]:
```
acc
```

Out[358]:
```
0.28597286
```

Accuracy of the best model on test data = 28.60%

Accuracy of the best model on test data = 2[illegible]%

In [ ]:

```

```

In [ ]:

```

```

In [359]:

```
score, acc = model_gru.evaluate(test_X_t, test_y)
```

```
===================================================================================================
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```

In [ ]:

```

```

In [360]:

```
score, acc = model_rnn.evaluate(test_X_t, test_y)
```

```
=================================================================================================
=================================================================================================
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=================================================================================================
```

In [ ]:

In [ ]:

In [232]:

```
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn import metrics
```

In [ ]:

Evaluation of best LSTM model on the test set

In [229]:

```
predictions_lstm = np.argmax(model_lstm.predict(test_X_t), axis=1)
```

In [230]:
```
predictions_lstm
```

Out[230]:
```
array([1, 3, 1, ..., 3, 3, 1])
```

In [379]:
```
predictions_lstm[-10:]
```

Out[379]:
```
array([1, 1, 1, 1, 3, 3, 4, 4, 1, 1])
```

In [368]:
```
len(test_y)
```

Out[368]:
```
2210
```

In [233]:
```
cm_lstm = metrics.confusion_matrix(test['truth'].values, predictions_lstm)
print(cm_lstm)
```

```
[[  0   0   0   0   0   0]
 [  1  93   6 173   6   0]
 [  0 177  14 432  10   0]
 [  0 114  11 259   5   0]
 [  0 117   6 374  13   0]
 [  2  81   5 302   9   0]]
```

In [ ]:
```

```

In [ ]:
```

```

In [234]:
```
from sklearn.metrics import classification_report
```

```
In [235]: print(classification_report(test['truth'].values, predictions_lstm))
```

```
              precision    recall  f1-score   support

           0       0.00      0.00      0.00         0
           1       0.16      0.33      0.22       279
           2       0.33      0.02      0.04       633
           3       0.17      0.67      0.27       389
           4       0.30      0.03      0.05       510
           5       0.00      0.00      0.00       399

    accuracy                           0.17      2210
   macro avg       0.16      0.17      0.10      2210
weighted avg       0.22      0.17      0.10      2210



/home/demolakstate/anaconda3/envs/nlp/lib/python3.7/site-packages/sklearn/metrics/classification.p
y:1437: UndefinedMetricWarning: Precision and F-score are ill-defined and being set to 0.0 in label
s with no predicted samples.
  'precision', 'predicted', average, warn_for)
/home/demolakstate/anaconda3/envs/nlp/lib/python3.7/site-packages/sklearn/metrics/classification.p
y:1439: UndefinedMetricWarning: Recall and F-score are ill-defined and being set to 0.0 in labels w
ith no true samples.
  'recall', 'true', average, warn_for)
```

```
In [ ]:
```

Evaluation of best GRU model on the test set

In [249]:

```
predictions_gru = np.argmax(model_gru.predict(test_X_t), axis=1)

predictions_gru

cm_gru = metrics.confusion_matrix(test['truth'].values, predictions_gru)
print(cm_gru)

print(classification_report(test['truth'].values, predictions_gru))
```

```
[[  0   0   0   0   0   0]
 [ 37  88  53  76  25   0]
 [ 79 198 126 181  49   0]
 [ 38  88  87 142  34   0]
 [ 38  87  89 205  91   0]
 [ 20  45  55 183  96   0]]
              precision    recall  f1-score   support

           0       0.00      0.00      0.00         0
           1       0.17      0.32      0.22       279
           2       0.31      0.20      0.24       633
           3       0.18      0.37      0.24       389
           4       0.31      0.18      0.23       510
           5       0.00      0.00      0.00       399

    accuracy                           0.20      2210
   macro avg       0.16      0.18      0.16      2210
weighted avg       0.21      0.20      0.19      2210


/home/demolakstate/anaconda3/envs/nlp/lib/python3.7/site-packages/sklearn/metrics/classification.p
y:1437: UndefinedMetricWarning: Precision and F-score are ill-defined and being set to 0.0 in label
s with no predicted samples.
  'precision', 'predicted', average, warn_for)
/home/demolakstate/anaconda3/envs/nlp/lib/python3.7/site-packages/sklearn/metrics/classification.p
y:1439: UndefinedMetricWarning: Recall and F-score are ill-defined and being set to 0.0 in labels w
ith no true samples.
  'recall', 'true', average, warn_for)
```

In [ ]:

Evaluation of best RNN model on the test set

In [255]:
```
predictions_rnn = np.argmax(model_rnn_3.predict(test_X_t), axis=1)

predictions_rnn

cm_rnn = metrics.confusion_matrix(test['truth'].values, predictions_rnn)
print(cm_rnn)

print(classification_report(test['truth'].values, predictions_rnn))
```

```
[[  9   2 184  84   0]
 [ 12   6 431 184   0]
 [ 17   7 268  97   0]
 [  6   3 349 152   0]
 [  0   4 282 113   0]]
              precision    recall  f1-score   support

           1       0.20      0.03      0.06       279
           2       0.27      0.01      0.02       633
           3       0.18      0.69      0.28       389
           4       0.24      0.30      0.27       510
           5       0.00      0.00      0.00       399

    accuracy                           0.20      2210
   macro avg       0.18      0.21      0.12      2210
weighted avg       0.19      0.20      0.12      2210


/home/demolakstate/anaconda3/envs/nlp/lib/python3.7/site-packages/sklearn/metrics/classification.p
y:1437: UndefinedMetricWarning: Precision and F-score are ill-defined and being set to 0.0 in label
s with no predicted samples.
  'precision', 'predicted', average, warn_for)
```

In [ ]:
```

```

Discussion of the different models performance

Bidirectional LSTM had the highest accuracy of 29.86% on the test data. This is followed by LSTM

and RNN both with 28.60% and finally GRU model of 27.69%. MODEL_RNN_3 did well in predicting sentences of label 3 - "Neutral" with an F-Score of 28%. The model did badly on all other classes, and most especially on label 5. MODEL_GRU did well on labels 3 and 1 with F-Score of 24% and 22% respectively, but badly on the others and especially on label 5. MODEL_LSTM did well on label 3, but badly on all others and especially label 5. In conclusion, all the experiemented model architectures were able to do a good job in classifying sentence sentiments that are "Neutral". They all struggled with "Strongly Positive" sentiments.

In [ ]:

In [ ]:

Task 4 - Text Generation Language Model

In [ ]:

In [ ]:

In [183]:

```
from keras.callbacks import ModelCheckpoint
from keras.utils import np_utils
```

In [ ]:

In [ ]:

In [184]:

```
raw_text = df['text'].str.lower()
```

In [185]:
```
raw_text
```

Out[185]:
```
0       the rock is destined to be the 21st century 's...
1       the gorgeously elaborate continuation of `` th...
2       singer/composer bryan adams contributes a slew...
3       you 'd think by now america would have had eno...
4                    yet the act is still charming here .
                              ...
8539                                      a real snooze .
8540                                       no surprises .
8541    we 've seen the hippie-turned-yuppie plot befo...
8542    her fans walked out muttering words like `` ho...
8543                                  in this case zero .
Name: text, Length: 8544, dtype: object
```

In [186]:
```
# create mapping of unique chars to integers
chars = sorted(list(set(raw_text)))

char_to_int = dict((c, i) for i, c in enumerate(chars))
```

In [187]:
```
# summarize the loaded data
n_chars = len(raw_text)
n_vocab = len(chars)

print("Total Characters: ", n_chars)
print("Total Vocab: ", n_vocab)
```

```
Total Characters:  8544
Total Vocab:  8534
```

In [188]:

```
# prepare the dataset of input to output pairs encoded as integers
seq_length = 100
dataX = []
dataY = []
for i in range(0, n_chars - seq_length, 1):
    seq_in = raw_text[i:i + seq_length]
    seq_out = raw_text[i + seq_length]
    dataX.append([char_to_int[char] for char in seq_in])
    dataY.append(char_to_int[seq_out])


n_patterns = len(dataX)
print("Total Patterns: ", n_patterns)
```

```
Total Patterns:  8444
```

In [189]:

```
# reshape X to be [samples, time steps, features]
X = np.reshape(dataX, (n_patterns, seq_length, 1))

# normalize
X = X / float(n_vocab)
# one hot encode the output variable
y = np_utils.to_categorical(dataY)
```

In [ ]:

In [190]:

```
# define the LSTM model
model = Sequential()
model.add(LSTM(256, input_shape=(X.shape[1], X.shape[2]), return_sequences=True))
model.add(Dropout(0.2))
model.add(LSTM(256))
model.add(Dropout(0.2))
model.add(Dense(y.shape[1], activation='softmax'))
model.compile(loss='categorical_crossentropy', optimizer='adam')
```

In [ ]:

In [436]:

```
# define the checkpoint
filepath="Weights-LSTM-improvement-{epoch:02d}-{loss:.4f}-bigger.hdfs"
checkpoint = ModelCheckpoint(filepath, monitor='loss', verbose=1, save_best_only=True, mode='min')

callbacks_list = [checkpoint]

# fit the model

model.fit(X, y, epochs=80, batch_size=64, callbacks=callbacks_list)
```

```
8444/8444 [==============================] - 52s 6ms/step - loss: 9.0822

Epoch 00002: loss did not improve from 9.06460
Epoch 3/80
8444/8444 [==============================] - 52s 6ms/step - loss: 9.0538

Epoch 00003: loss improved from 9.06460 to 9.05378, saving model to Weights-LSTM-improvement-03-
9.0538-bigger.hdfs
Epoch 4/80
8444/8444 [==============================] - 52s 6ms/step - loss: 9.0529

Epoch 00004: loss improved from 9.05378 to 9.05290, saving model to Weights-LSTM-improvement-04-
9.0529-bigger.hdfs
Epoch 5/80
8444/8444 [==============================] - 52s 6ms/step - loss: 9.0522

Epoch 00005: loss improved from 9.05290 to 9.05219, saving model to Weights-LSTM-improvement-05-
9.0522-bigger.hdfs
Epoch 6/80
8444/8444 [==============================] - 52s 6ms/step - loss: 9.0516
```

In [ ]:

In [438]:

```
# Load Larger LSTM network and generate text

import sys

int_to_char = dict((i, c) for i, c in enumerate(chars))
# summarize the loaded data
n_chars = len(raw_text)
n_vocab = len(chars)
print("Total Characters: ", n_chars)
print("Total Vocab: ", n_vocab)

# prepare the dataset of input to output pairs encoded as integers
seq_length = 100
dataX = []
dataY = []

for i in range(0, n_chars - seq_length, 1):
    seq_in = raw_text[i:i + seq_length]
    seq_out = raw_text[i + seq_length]
    dataX.append([char_to_int[char] for char in seq_in])
    dataY.append(char_to_int[seq_out])

n_patterns = len(dataX)
print("Total Patterns: ", n_patterns)
# reshape X to be [samples, time steps, features]
X = np.reshape(dataX, (n_patterns, seq_length, 1))

# normalize

X = X / float(n_vocab)
# one hot encode the output variable
y = np_utils.to_categorical(dataY)

# define the LSTM model
model = Sequential()
model.add(LSTM(256, input_shape=(X.shape[1], X.shape[2]), return_sequences=True))
model.add(Dropout(0.2))
model.add(LSTM(256))
model.add(Dropout(0.2))
model.add(Dense(y.shape[1], activation='softmax'))

# Load the network weights
```

```
filename = "Weights-LSTM-improvement-80-9.0447-bigger.hdfs"
#filename = "Weights-LSTM-improvement-44-1.3592-bigger.hdfs"
model.load_weights(filename)

model.compile(loss='categorical_crossentropy', optimizer='adam')

# pick a random seed

start = np.random.randint(0, len(dataX)-1)
pattern = dataX[start]
print("Seed:")
print("\"", ''.join([int_to_char[value] for value in pattern]), "\"")
# generate characters
for i in range(700):
    x = np.reshape(pattern, (1, len(pattern), 1))
    x = x / float(n_vocab)
    prediction = model.predict(x, verbose=0)
    index = np.argmax(prediction)
    result = int_to_char[index]
    seq_in = [int_to_char[value] for value in pattern]
    sys.stdout.write(result)
    pattern.append(index)
    pattern = pattern[1:len(pattern)]

print("\nDone")
```

```
Total Characters:  8544
Total Vocab:  8534
Total Patterns:  8444
Seed:
" a generic family comedy unlikely to be appreciated by anyone outside the under-10 set .kung pow
seems like some futile concoction that was developed hastily after oedekerk and his fellow moviem
akers got through crashing a college keg party .kurys seems intimidated by both her subject matte
r and the period trappings of this debut venture into the heritage business .the film virtually c
hokes on its own self-consciousness .a manipulative feminist empowerment tale thinly posing as a 
serious drama about spousal abuse .everything in maid in manhattan is exceedingly pleasant , desi
gned not to offend .it goes down easy , leaving virtually no aftertaste .a profoundly stupid affa
ir , populating its hackneyed and meanspirited storyline with cardboard characters and performers
who value cash above credibility .... pays tribute to heroes the way julia roberts hands out awar
ds -- with phony humility barely camouflaging grotesque narcissism .time stands still in more way
s that one in clockstoppers , a sci-fi thriller as lazy as it is interminable .as a director , ea
stwood is off his game -- there 's no real sense of suspense , and none of the plot ` surprises '
are really surprising .eccentric enough to stave off doldrums , caruso 's self-conscious debut is
```

```
also eminently forgettable .to work , love stories require the full emotional involvement and sup
port of a viewer .that is made almost impossible by events that set the plot in motion .although
```

In [ ]:

In [ ]:

In [ ]:

100 epochs

In [ ]:

In [57]:
```python
# define the checkpoint
filepath="Weights-LSTM-improvement-{epoch:02d}-{loss:.4f}-bigger.hdfs"
checkpoint = ModelCheckpoint(filepath, monitor='loss', verbose=1, save_best_only=True, mode='min')

callbacks_list = [checkpoint]

# fit the model

model.fit(X, y, epochs=100, batch_size=64, callbacks=callbacks_list)
```

```
Epoch 00093: loss improved from 0.01940 to 0.01827, saving model to Weights-LSTM-improvement-93-
0.0183-bigger.hdfs
Epoch 94/100

8444/8444 [==============================] - 52s 6ms/step - loss: 0.0185

Epoch 00094: loss did not improve from 0.01827
Epoch 95/100
8444/8444 [==============================] - 52s 6ms/step - loss: 0.0175

Epoch 00095: loss improved from 0.01827 to 0.01750, saving model to Weights-LSTM-improvement-95-
0.0175-bigger.hdfs
Epoch 96/100
8444/8444 [==============================] - 52s 6ms/step - loss: 0.0165

Epoch 00096: loss improved from 0.01750 to 0.01653, saving model to Weights-LSTM-improvement-96-
0.0165-bigger.hdfs
Epoch 97/100
8444/8444 [==============================] - 52s 6ms/step - loss: 0.0152

Epoch 00097: loss improved from 0.01653 to 0.01520, saving model to Weights-LSTM-improvement-97-
```

In [ ]:

In [60]:

```
# Load Larger LSTM network and generate text

import sys

int_to_char = dict((i, c) for i, c in enumerate(chars))
# summarize the loaded data
n_chars = len(raw_text)
n_vocab = len(chars)
print("Total Characters: ", n_chars)
print("Total Vocab: ", n_vocab)

# prepare the dataset of input to output pairs encoded as integers
seq_length = 100
dataX = []
dataY = []

for i in range(0, n_chars - seq_length, 1):
    seq_in = raw_text[i:i + seq_length]
    seq_out = raw_text[i + seq_length]
    dataX.append([char_to_int[char] for char in seq_in])
    dataY.append(char_to_int[seq_out])

n_patterns = len(dataX)
print("Total Patterns: ", n_patterns)
# reshape X to be [samples, time steps, features]
X = np.reshape(dataX, (n_patterns, seq_length, 1))

# normalize

X = X / float(n_vocab)
# one hot encode the output variable
y = np_utils.to_categorical(dataY)

# define the LSTM model
model = Sequential()
model.add(LSTM(256, input_shape=(X.shape[1], X.shape[2]), return_sequences=True))
model.add(Dropout(0.2))
model.add(LSTM(256))
model.add(Dropout(0.2))
model.add(Dense(y.shape[1], activation='softmax'))

# Load the network weights
```

```
filename = "Weights-LSTM-improvement-80-9.0447-bigger.hdfs"
#filename = "Weights-LSTM-improvement-44-1.3592-bigger.hdfs"
model.load_weights(filename)

model.compile(loss='categorical_crossentropy', optimizer='adam')

# pick a random seed

start = np.random.randint(0, len(dataX)-1)
pattern = dataX[start]
print("Seed:")
print("\"", ''.join([int_to_char[value] for value in pattern]), "\"")
# generate characters
for i in range(70):
    x = np.reshape(pattern, (1, len(pattern), 1))
    x = x / float(n_vocab)
    prediction = model.predict(x, verbose=0)
    index = np.argmax(prediction)
    result = int_to_char[index]
    seq_in = [int_to_char[value] for value in pattern]
    sys.stdout.write(result)
    pattern.append(index)
    pattern = pattern[1:len(pattern)]

print("\nDone")
```

```
he line , to find a place among the studio 's animated classics .slow and ponderous , but rohmer
's drama builds to an intense indoor drama about compassion , sacrifice , and christian love in t
he face of political corruption .if you 're not totally weirded - out by the notion of cinema as
community-therapy spectacle , quitting hits home with disorienting force .austin powers for the m
ost part is extremely funny , the first part making up for any flaws that come later .while tatto
o borrows heavily from both seven and the silence of the lambs , it manages to maintain both a le
vel of sophisticated intrigue and human-scale characters that suck the audience in .cho continues
her exploration of the outer limits of raunch with considerable brio .elvira fans could hardly as
k for more .a canny , derivative , wildly gruesome portrait of a london sociopath who 's the scar
iest of sadists .the movie should be credited with remembering his victims .fast-paced and wonder
fully edited , the film is extremely thorough .a bracing , unblinking work that serves as a painf
ul elegy and sobering cautionary tale .hashiguchi uses the situation to evoke a japan bustling at
op an undercurrent of loneliness and isolation .as if trying to grab a lump of play-doh , the har
der that liman tries to squeeze his story , the more details slip out between his fingers .my big
fat greek wedding is not only the best date movie of the year , it 's also a -- dare i say it twi
ce -- delightfully charming -- and totally american , i might add -- slice of comedic bliss .few
films have captured the chaos of an urban conflagration with such fury , and audience members wil
l leave feeling as shaken as nesbitt 's cooper looks when the bullets stop flying .another love s
```

```
tory in 2002 's remarkable procession of sweeping pictures that have reinvigorated the romance ge
```

In [ ]:

In [ ]:

500 epochs

In [ ]:

In [61]:

```
# define the LSTM model
model_500 = Sequential()
model_500.add(LSTM(256, input_shape=(X.shape[1], X.shape[2]), return_sequences=True))
model_500.add(Dropout(0.2))
model_500.add(LSTM(256))
model_500.add(Dropout(0.2))
model_500.add(Dense(y.shape[1], activation='softmax'))
model_500.compile(loss='categorical_crossentropy', optimizer='adam')
```

In [ ]:

In [ ]:

In [62]:

```
# define the checkpoint
filepath="Weights-LSTM-improvement-{epoch:02d}-{loss:.4f}-bigger.hdfs"
checkpoint = ModelCheckpoint(filepath, monitor='loss', verbose=1, save_best_only=True, mode='min')

callbacks_list = [checkpoint]

# fit the model

model_500.fit(X, y, epochs=500, batch_size=64, callbacks=callbacks_list)
```

```
Epoch 00496: loss did not improve from 9.02926
Epoch 497/500
8444/8444 [==============================] - 51s 6ms/step - loss: 9.0445

Epoch 00497: loss did not improve from 9.02926
Epoch 498/500
8444/8444 [==============================] - 51s 6ms/step - loss: 9.0445

Epoch 00498: loss did not improve from 9.02926
Epoch 499/500
8444/8444 [==============================] - 51s 6ms/step - loss: 9.0445

Epoch 00499: loss did not improve from 9.02926
Epoch 500/500
8444/8444 [==============================] - 51s 6ms/step - loss: 9.0445

Epoch 00500: loss did not improve from 9.02926
```

Out[62]:

```
<keras.callbacks.callbacks.History at 0x7f3df1541e90>
```

In [ ]:

In [63]:

```
# Load Larger LSTM network and generate text

import sys

int_to_char = dict((i, c) for i, c in enumerate(chars))
# summarize the loaded data
n_chars = len(raw_text)
n_vocab = len(chars)
print("Total Characters: ", n_chars)
print("Total Vocab: ", n_vocab)

# prepare the dataset of input to output pairs encoded as integers
seq_length = 100
dataX = []
dataY = []

for i in range(0, n_chars - seq_length, 1):
    seq_in = raw_text[i:i + seq_length]
    seq_out = raw_text[i + seq_length]
    dataX.append([char_to_int[char] for char in seq_in])
    dataY.append(char_to_int[seq_out])

n_patterns = len(dataX)
print("Total Patterns: ", n_patterns)
# reshape X to be [samples, time steps, features]
X = np.reshape(dataX, (n_patterns, seq_length, 1))

# normalize

X = X / float(n_vocab)
# one hot encode the output variable
y = np_utils.to_categorical(dataY)

# define the LSTM model
model_500 = Sequential()
model_500.add(LSTM(256, input_shape=(X.shape[1], X.shape[2]), return_sequences=True))
model_500.add(Dropout(0.2))
model_500.add(LSTM(256))
model_500.add(Dropout(0.2))
model_500.add(Dense(y.shape[1], activation='softmax'))

# Load the network weights
```

```
filename = "Weights-LSTM-improvement-80-9.0447-bigger.hdfs"
#filename = "Weights-LSTM-improvement-44-1.3592-bigger.hdfs"
model_500.load_weights(filename)

model_500.compile(loss='categorical_crossentropy', optimizer='adam')

# pick a random seed

start = np.random.randint(0, len(dataX)-1)
pattern = dataX[start]
print("Seed:")
print("\"", ''.join([int_to_char[value] for value in pattern]), "\"")
# generate characters
for i in range(70):
    x = np.reshape(pattern, (1, len(pattern), 1))
    x = x / float(n_vocab)
    prediction = model_500.predict(x, verbose=0)
    index = np.argmax(prediction)
    result = int_to_char[index]
    seq_in = [int_to_char[value] for value in pattern]
    sys.stdout.write(result)
    pattern.append(index)
    pattern = pattern[1:len(pattern)]

print("\nDone")
```

```
of the worst movies of the year .one of the worst movies of the year .one of the worst movies of
the year .one of the worst movies of the year .one of the worst movies of the year .one of the wo
rst movies of the year .one of the worst movies of the year .one of the worst movies of the year
.one of the worst movies of the year .one of the worst movies of the year .one of the worst movie
s of the year .one of the worst movies of the year .one of the worst movies of the year .one of t
he worst movies of the year .one of the worst movies of the year .one of the worst movies of the
year .one of the worst movies of the year .one of the worst movies of the year .one of the worst
movies of the year .one of the worst movies of the year .one of the worst movies of the year .one
of the worst movies of the year .one of the worst movies of the year .one of the worst movies of
the year .one of the worst movies of the year .one of the worst movies of the year .one of the wo
rst movies of the year .one of the worst movies of the year .one of the worst movies of the year
.one of the worst movies of the year .one of the worst movies of the year .one of the worst movie
s of the year .one of the worst movies of the year .one of the worst movies of the year .one of t
he worst movies of the year .one of the worst movies of the year .one of the worst movies of the
year .one of the worst movies of the year .one of the worst movies of the year .one of the worst
movies of the year .one of the worst movies of the year .one of the worst movies of the year .one
of the worst movies of the year .one of the worst movies of the year .one of the worst movies of
the year .one of the worst movies of the year .one of the worst movies of the year .one of the wo
rst movies of the year .one of the worst movies of the year .
rst movies of the year .one of the worst movies of the year .
Done
```

In [ ]:

In [ ]:

In [ ]:

1000 epochs

In [ ]:

In [191]:

```
# define the LSTM model
model_1000 = Sequential()
model_1000.add(LSTM(256, input_shape=(X.shape[1], X.shape[2]), return_sequences=True))
model_1000.add(Dropout(0.2))
model_1000.add(LSTM(256))
model_1000.add(Dropout(0.2))
model_1000.add(Dense(y.shape[1], activation='softmax'))
model_1000.compile(loss='categorical_crossentropy', optimizer='adam')
```

In [ ]:

In [ ]:

In [192]:

```
# define the checkpoint
filepath="Weights-LSTM-improvement-{epoch:02d}-{loss:.4f}-bigger.hdfs"
checkpoint = ModelCheckpoint(filepath, monitor='loss', verbose=1, save_best_only=True, mode='min')

callbacks_list = [checkpoint]

# fit the model

model_1000.fit(X, y, epochs=1000, batch_size=64, callbacks=callbacks_list)
```

```
Epoch 00996: loss did not improve from 9.00526
Epoch 997/1000
8444/8444 [==============================] - 52s 6ms/step - loss: 9.0445

Epoch 00997: loss did not improve from 9.00526
Epoch 998/1000
8444/8444 [==============================] - 52s 6ms/step - loss: 9.0445

Epoch 00998: loss did not improve from 9.00526
Epoch 999/1000
8444/8444 [==============================] - 52s 6ms/step - loss: 9.0445

Epoch 00999: loss did not improve from 9.00526
Epoch 1000/1000
8444/8444 [==============================] - 52s 6ms/step - loss: 9.0445

Epoch 01000: loss did not improve from 9.00526
```

Out[192]:

```
<keras.callbacks.callbacks.History at 0x7f3f26f634d0>
```

In [ ]:

In [193]:

```
# Load Larger LSTM network and generate text

import sys

int_to_char = dict((i, c) for i, c in enumerate(chars))
# summarize the loaded data
n_chars = len(raw_text)
n_vocab = len(chars)
print("Total Characters: ", n_chars)
print("Total Vocab: ", n_vocab)

# prepare the dataset of input to output pairs encoded as integers
seq_length = 100
dataX = []
dataY = []

for i in range(0, n_chars - seq_length, 1):
    seq_in = raw_text[i:i + seq_length]
    seq_out = raw_text[i + seq_length]
    dataX.append([char_to_int[char] for char in seq_in])
    dataY.append(char_to_int[seq_out])

n_patterns = len(dataX)
print("Total Patterns: ", n_patterns)
# reshape X to be [samples, time steps, features]
X = np.reshape(dataX, (n_patterns, seq_length, 1))

# normalize

X = X / float(n_vocab)
# one hot encode the output variable
y = np_utils.to_categorical(dataY)

# define the LSTM model
model_1000 = Sequential()
model_1000.add(LSTM(256, input_shape=(X.shape[1], X.shape[2]), return_sequences=True))
model_1000.add(Dropout(0.2))
model_1000.add(LSTM(256))
model_1000.add(Dropout(0.2))
model_1000.add(Dense(y.shape[1], activation='softmax'))

# Load the network weights
```

```
filename = "Weights-LSTM-improvement-80-9.0447-bigger.hdfs"
#filename = "Weights-LSTM-improvement-44-1.3592-bigger.hdfs"
model_1000.load_weights(filename)

model_1000.compile(loss='categorical_crossentropy', optimizer='adam')

# pick a random seed

start = np.random.randint(0, len(dataX)-1)
pattern = dataX[start]
print("Seed:")
print("\"", ''.join([int_to_char[value] for value in pattern]), "\"")
# generate characters
for i in range(70):
    x = np.reshape(pattern, (1, len(pattern), 1))
    x = x / float(n_vocab)
    prediction = model_1000.predict(x, verbose=0)
    index = np.argmax(prediction)
    result = int_to_char[index]
    seq_in = [int_to_char[value] for value in pattern]
    sys.stdout.write(result)
    pattern.append(index)
    pattern = pattern[1:len(pattern)]

print("\nDone")
```

```
s a self-aware , often self-mocking , intelligence .the chateau is a risky venture that never qui
te goes where you expect and often surprises you with unexpected comedy .a very well-meaning movi
e , and it will stand in future years as an eloquent memorial to the world trade center tragedy .
there are n't many conclusive answers in the film , but there is an interesting story of pointed 
personalities , courage , tragedy and the little guys vs. the big guys .vividly demonstrates that
the director of such hollywood blockbusters as patriot games can still turn out a small , persona
l film with an emotional wallop .a four star performance from kevin kline who unfortunately works
with a two star script .dogtown & z-boys evokes the blithe rebel fantasy with the kind of insouci
ance embedded in the sexy demise of james dean .if you do n't flee , you might be seduced .if you
do n't laugh , flee .payne constructs a hilarious ode to middle america and middle age with this 
unlikely odyssey , featuring a pathetic , endearing hero who is all too human .koury frighteningl
y and honestly exposes one teenager 's uncomfortable class resentment and , in turn , his self-in
flicted retaliation .the santa clause 2 proves itself a more streamlined and thought out encounte
r than the original could ever have hoped to be .now as a former gong show addict , i 'll admit i
t , my only complaint is that we did n't get more re-creations of all those famous moments from t
he show .succeeds where its recent predecessor miserably fails because it demands that you suffer
the dreadfulness of war from both sides .the first bond movie in ages that is n't fake fun .this 
odd , poetic road movie , spiked by jolts of pop music , pretty much takes place in morton 's eve
r watchful gaze , and it 's a tribute to the actress , and to her inventive director , that the
```

```
r-watchful gaze -- and it 's a tribute to the actress , and to her inventive director , that the
journey is such a mesmerizing one .a film centering on a traditional indian wedding in contempora
```

In [ ]:

In [ ]:

Qualitative Discussion of the model

All the models did pretty well at the initial text character generation. The model trained with 100 epochs, unlike that of 500 epochs and 1000 epochs, did not make so much sense at the end of the first paragraph. All the models failed at the generation of the second paragraph.

In [ ]: