In [0]:

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

```
Go to this URL in a browser: https://acco
unts.google.com/o/oauth2/auth?client_id=9
47318989803-6bn6qk8qdgf4n4g3pfee6491hc0br
c4i.apps.googleusercontent.com&redirect_u
ri=urn%3aietf%3awg%3aoauth%3a2.0%3aoob&re
sponse_type=code&scope=email%20https%3a%2
f%2fwww.googleapis.com%2fauth%2fdocs.tes
t%20https%3a%2f%2fwww.googleapis.com%2fau
th%2fdrive%20https%3a%2f%2fwww.googleapi
s.com%2fauth%2fdrive.photos.readonly%20ht
tps%3a%2f%2fwww.googleapis.com%2fauth%2fp
eopleapi.readonly

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

In [0]:

```
%cd /content/drive/My Drive
```

```
/content/drive/My Drive
```

In [0]:

```
# Importing Libraries
```

In [0]:

```
import pandas as pd
import numpy as np
```

In [0]:

```
# Activities are the class labels
# It is a 6 class classification
ACTIVITIES = {
    0: 'WALKING',
    1: 'WALKING_UPSTAIRS',
    2: 'WALKING_DOWNSTAIRS',
    3: 'SITTING',
    4: 'STANDING',
    5: 'LAYING',
}

# Utility function to print the confusion matrix
def confusion_matrix(Y_true, Y_pred):
    Y_true = pd.Series([ACTIVITIES[y] for y in np.argmax(Y_true, axis=1)])
    Y_pred = pd.Series([ACTIVITIES[y] for y in np.argmax(Y_pred, axis=1)])

    return pd.crosstab(Y_true, Y_pred, rownames=['True'], colnames=['Pred'])
```

Data

In [0]:

```
# Data directory
DATADIR = 'UCI_HAR_Dataset'
```

In [0]:

```
# Raw data signals
# Signals are from Accelerometer and Gyroscope
# The signals are in x,y,z directions
# Sensor signals are filtered to have only body acceleration
# excluding the acceleration due to gravity
# Triaxial acceleration from the accelerometer is total acceleration
SIGNALS = [
    "body_acc_x",
    "body_acc_y",
    "body_acc_z",
    "body_gyro_x",
    "body_gyro_y",
    "body_gyro_z",
    "total_acc_x",
    "total_acc_y",
    "total_acc_z"
]
```

In [0]:

```
# Utility function to read the data from csv fi
le
def _read_csv(filename):
    return pd.read_csv(filename, delim_whitespa
ce=True, header=None)

# Utility function to load the load
def load_signals(subset):
    signals_data = []

    for signal in SIGNALS:
        filename = f'UCI_HAR_Dataset/{subset}/I
nertial Signals/{signal}_{subset}.txt'
        signals_data.append(
            _read_csv(filename).as_matrix()
        )

    # Transpose is used to change the dimension
ality of the output,
    # aggregating the signals by combination of
sample/timestep.
    # Resultant shape is (7352 train/2947 test
 samples, 128 timesteps, 9 signals)
    return np.transpose(signals_data, (1, 2, 0
))
```

In [0]:

```python
def load_y(subset):
    """
    The objective that we are trying to predict is a integer, from 1 to 6,
    that represents a human activity. We return a binary representation of
    every sample objective as a 6 bits vector using One Hot Encoding
    (https://pandas.pydata.org/pandas-docs/stable/generated/pandas.get_dummies.html)
    """
    filename = f'UCI_HAR_Dataset/{subset}/y_{subset}.txt'
    y = _read_csv(filename)[0]

    return pd.get_dummies(y).as_matrix()
```

In [0]:

```python
def load_data():
    """
    Obtain the dataset from multiple files.
    Returns: X_train, X_test, y_train, y_test
    """
    X_train, X_test = load_signals('train'), load_signals('test')
    y_train, y_test = load_y('train'), load_y('test')

    return X_train, X_test, y_train, y_test
```

In [0]:

```python
# Importing tensorflow
np.random.seed(42)
import tensorflow as tf
tf.set_random_seed(42)
```

```
The default version of TensorFlow in Colab
will soon switch to TensorFlow 2.x.
```

We recommend you upgrade now or ensure your notebook will continue to use TensorFlow 1.x via the `%tensorflow_version 1.x` magic: more info.

In [0]:

```
# Configuring a session
session_conf = tf.ConfigProto(
    intra_op_parallelism_threads=1,
    inter_op_parallelism_threads=1
)
```

In [0]:

```
# Import Keras
from keras import backend as K
sess = tf.Session(graph=tf.get_default_graph(),
config=session_conf)
K.set_session(sess)
```

```
Using TensorFlow backend.
```

In [0]:

```
# Importing libraries
from keras.models import Sequential
from keras.layers import LSTM
from keras.layers.core import Dense, Dropout
```

In [0]:

```
# Initializing parameters
epochs = 30
batch_size = 16
n_hidden = 32
```

In [0]:

```
# Utility function to count the number of class
es
def _count_classes(y):
    return len(set([tuple(category) for categor
y in y]))
```

In [0]:

```
# Loading the train and test data
X_train, X_test, Y_train, Y_test = load_data()
```

```
/usr/local/lib/python3.6/dist-packages/ip
ykernel_launcher.py:11: FutureWarning: Me
thod .as_matrix will be removed in a futu
re version. Use .values instead.
  # This is added back by InteractiveShel
lApp.init_path()
/usr/local/lib/python3.6/dist-packages/ip
ykernel_launcher.py:12: FutureWarning: Me
thod .as_matrix will be removed in a futu
re version. Use .values instead.
  if sys.path[0] == '':
```

In [0]:

```
timesteps = len(X_train[0])
input_dim = len(X_train[0][0])
n_classes = _count_classes(Y_train)

print(timesteps)
print(input_dim)
print(len(X_train))
```

```
128
9
7352
```

- Defining the Architecture of LSTM

1- Layer LSTM

In [0]:

```
# Initiliazing the sequential model
model = Sequential()
```

```
# Configuring the parameters
model.add(LSTM(n_hidden, input_shape=(timesteps
, input_dim)))
# Adding a dropout layer
model.add(Dropout(0.5))
# Adding a dense output layer with sigmoid acti
vation
model.add(Dense(n_classes, activation='sigmoid'
))
model.summary()
```

```
WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:541: The name tf.placeho
lder is deprecated. Please use tf.compat.
v1.placeholder instead.

WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:4432: The name tf.random
_uniform is deprecated. Please use tf.ran
dom.uniform instead.

WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:148: The name tf.placeho
lder_with_default is deprecated. Please u
se tf.compat.v1.placeholder_with_default
instead.

WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:3733: calling dropout (f
rom tensorflow.python.ops.nn_ops) with ke
ep_prob is deprecated and will be removed
in a future version.
```

```
Instructions for updating:
Please use `rate` instead of `keep_prob`.
Rate should be set to `rate = 1 - keep_pr
ob`.
Model: "sequential_1"
_________________________________________
________________________
Layer (type)                 Output Shape
Param #
=========================================
========================
lstm_1 (LSTM)                (None, 32)
5376
_________________________________________
________________________
dropout_1 (Dropout)          (None, 32)
0
_________________________________________
________________________
dense_1 (Dense)              (None, 6)
198
=========================================
========================
Total params: 5,574
Trainable params: 5,574
Non-trainable params: 0
_________________________________________
________________________
```

In [0]:

```python
# Compiling the model
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

```
WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/optimizers.p
```

```
y:793: The name tf.train.Optimizer is dep
recated. Please use tf.compat.v1.train.Op
timizer instead.

WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:3576: The name tf.log is
deprecated. Please use tf.math.log instea
d.
```

In [0]:

```
# Training the model
model.fit(X_train,
          Y_train,
          batch_size=batch_size,
          validation_data=(X_test, Y_test),
          epochs=epochs)
```

```
WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/tensorflow_core/pyt
hon/ops/math_grad.py:1424: where (from te
nsorflow.python.ops.array_ops) is depreca
ted and will be removed in a future versi
on.
Instructions for updating:
Use tf.where in 2.0, which has the same b
roadcast rule as np.where
WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:1033: The name tf.assign
_add is deprecated. Please use tf.compat.
v1.assign_add instead.

WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:1020: The name tf.assign
```

```
is deprecated. Please use tf.compat.v1.as
sign instead.

Train on 7352 samples, validate on 2947 s
amples
Epoch 1/30
WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:190: The name tf.get_def
ault_session is deprecated. Please use t
f.compat.v1.get_default_session instead.

WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:207: The name tf.global_
variables is deprecated. Please use tf.co
mpat.v1.global_variables instead.

WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:216: The name tf.is_vari
able_initialized is deprecated. Please us
e tf.compat.v1.is_variable_initialized in
stead.

WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:223: The name tf.variabl
es_initializer is deprecated. Please use
tf.compat.v1.variables_initializer instea
d.

7352/7352 [==============================
=] - 29s 4ms/step - loss: 1.3389 - acc:
0.4314 - val_loss: 1.1651 - val_acc: 0.47
47
```

```
Epoch 2/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.9892 - acc:
0.5755 - val_loss: 0.9336 - val_acc: 0.61
08
Epoch 3/30
7352/7352 [=============================
=] - 28s 4ms/step - loss: 0.8011 - acc:
0.6517 - val_loss: 0.7875 - val_acc: 0.61
21
Epoch 4/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.6928 - acc:
0.6710 - val_loss: 0.7502 - val_acc: 0.59
48
Epoch 5/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.6376 - acc:
0.6949 - val_loss: 0.7110 - val_acc: 0.66
68
Epoch 6/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.6068 - acc:
0.7119 - val_loss: 0.6957 - val_acc: 0.71
39
Epoch 7/30
7352/7352 [=============================
=] - 28s 4ms/step - loss: 0.5871 - acc:
0.7489 - val_loss: 0.6852 - val_acc: 0.72
79
Epoch 8/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.5303 - acc:
0.7745 - val_loss: 0.6408 - val_acc: 0.72
34
Epoch 9/30
```

```
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.4951 - acc:
0.7961 - val_loss: 0.5960 - val_acc: 0.75
57
Epoch 10/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.4515 - acc:
0.8093 - val_loss: 0.5572 - val_acc: 0.76
99
Epoch 11/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.4135 - acc:
0.8353 - val_loss: 0.5492 - val_acc: 0.84
63
Epoch 12/30
7352/7352 [=============================
=] - 28s 4ms/step - loss: 0.3802 - acc:
0.8731 - val_loss: 0.4911 - val_acc: 0.86
66
Epoch 13/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.4168 - acc:
0.8792 - val_loss: 0.5795 - val_acc: 0.85
37
Epoch 14/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.3700 - acc:
0.8988 - val_loss: 0.4918 - val_acc: 0.88
06
Epoch 15/30
7352/7352 [=============================
=] - 28s 4ms/step - loss: 0.2926 - acc:
0.9165 - val_loss: 0.5425 - val_acc: 0.85
04
Epoch 16/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.2880 - acc:
0.9168 - val_loss: 0.5183 - val_acc: 0.86
39
Epoch 17/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.2306 - acc:
0.9294 - val_loss: 0.4404 - val_acc: 0.89
11
Epoch 18/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.2707 - acc:
0.9289 - val_loss: 0.4641 - val_acc: 0.88
36
Epoch 19/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.2782 - acc:
0.9195 - val_loss: 0.4516 - val_acc: 0.89
75
Epoch 20/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.2496 - acc:
0.9272 - val_loss: 0.6715 - val_acc: 0.86
60
Epoch 21/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.2450 - acc:
0.9316 - val_loss: 0.7771 - val_acc: 0.83
85
Epoch 22/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.2659 - acc:
0.9324 - val_loss: 0.5177 - val_acc: 0.87
99
Epoch 23/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.2160 - acc:
```

```
0.9331 - val_loss: 0.7904 - val_acc: 0.83
88
Epoch 24/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.2229 - acc:
0.9339 - val_loss: 0.5659 - val_acc: 0.88
94
Epoch 25/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.2063 - acc:
0.9361 - val_loss: 0.4861 - val_acc: 0.88
50
Epoch 26/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.1836 - acc:
0.9400 - val_loss: 0.5115 - val_acc: 0.89
31
Epoch 27/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.1795 - acc:
0.9459 - val_loss: 0.4421 - val_acc: 0.90
87
Epoch 28/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.1620 - acc:
0.9455 - val_loss: 0.4468 - val_acc: 0.90
40
Epoch 29/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.1745 - acc:
0.9461 - val_loss: 0.5308 - val_acc: 0.90
26
Epoch 30/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.1664 - acc:
0.9459 - val_loss: 0.5550 - val_acc: 0.89
```

```
07
```

Out[0]:

```
<keras.callbacks.History at 0x7ff68e349f2
8>
```

In [0]:

```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_
test)))
```

```
Pred                LAYING  SITTING  ...
WALKING_DOWNSTAIRS  WALKING_UPSTAIRS
True                                 ...
LAYING                 510        0  ...
0                 27
SITTING                  1      374  ...
1                 17
STANDING                 0       73  ...
0                 17
WALKING                  0        0  ...
27                 41
WALKING_DOWNSTAIRS       0        0  ...
414                  6
WALKING_UPSTAIRS         0        0  ...
12                458

[6 rows x 6 columns]
```

In [0]:

```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [=============================
=] - 1s 302us/step
```

In [0]:

```
score
```

Out[0]:

```
[0.5549750696317388, 0.8907363420427553]
```

- With a simple 2 layer architecture we got 89.07% accuracy and a loss of 0.55
- We can further imporve the performace with Hyperparameter tuning

Model- 1(LSTM Units=32,dropout=0.5)

In [0]:

```
# Initiliazing the sequential model
model = Sequential()
# Configuring the parameters
model.add(LSTM(32, input_shape=(timesteps, input_dim)))
# Adding a dropout layer
model.add(Dropout(0.5))
# Adding a dense output layer with sigmoid activation
model.add(Dense(n_classes, activation='sigmoid'))
model.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
lstm_2 (LSTM)                (None, 32)                5376      
_________________________________________________________________
dropout_2 (Dropout)          (None, 32)
```

```
0
_________________________________________
________________________
dense_2 (Dense)              (None, 6)
198
=========================================
========================
Total params: 5,574
Trainable params: 5,574
Non-trainable params: 0
_________________________________________
________________________
```

In [0]:

```
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

In [0]:

```
# Training the model
model.fit(X_train,
          Y_train,
          batch_size=batch_size,
          validation_data=(X_test, Y_test),
          epochs=epochs)
```

```
Train on 7352 samples, validate on 2947 s
amples
Epoch 1/30
7352/7352 [==============================
=] - 28s 4ms/step - loss: 1.3445 - acc:
0.4415 - val_loss: 1.2233 - val_acc: 0.45
81
Epoch 2/30
7352/7352 [==============================
=] - 28s 4ms/step - loss: 1.1281 - acc:
0.5061 - val_loss: 1.1085 - val_acc: 0.56
```

```
33
Epoch 3/30
7352/7352 [=============================
=] - 28s 4ms/step - loss: 0.8849 - acc:
0.6329 - val_loss: 0.9060 - val_acc: 0.64
27
Epoch 4/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.7139 - acc:
0.7004 - val_loss: 0.7249 - val_acc: 0.70
55
Epoch 5/30
7352/7352 [=============================
=] - 28s 4ms/step - loss: 0.7125 - acc:
0.7100 - val_loss: 0.6530 - val_acc: 0.72
14
Epoch 6/30
7352/7352 [=============================
=] - 28s 4ms/step - loss: 0.5608 - acc:
0.7801 - val_loss: 0.5915 - val_acc: 0.79
61
Epoch 7/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.4779 - acc:
0.8319 - val_loss: 0.5202 - val_acc: 0.81
78
Epoch 8/30
7352/7352 [=============================
=] - 28s 4ms/step - loss: 0.3850 - acc:
0.8814 - val_loss: 0.4463 - val_acc: 0.84
87
Epoch 9/30
7352/7352 [=============================
=] - 28s 4ms/step - loss: 0.3342 - acc:
0.9025 - val_loss: 0.3651 - val_acc: 0.87
89
```

```
Epoch 10/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.2787 - acc:
0.9176 - val_loss: 0.4139 - val_acc: 0.86
87
Epoch 11/30
7352/7352 [=============================
=] - 28s 4ms/step - loss: 0.2551 - acc:
0.9200 - val_loss: 0.4822 - val_acc: 0.88
43
Epoch 12/30
7352/7352 [=============================
=] - 28s 4ms/step - loss: 0.2616 - acc:
0.9197 - val_loss: 0.4221 - val_acc: 0.87
14
Epoch 13/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.2157 - acc:
0.9306 - val_loss: 0.3199 - val_acc: 0.89
72
Epoch 14/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.2274 - acc:
0.9293 - val_loss: 0.3058 - val_acc: 0.90
91
Epoch 15/30
7352/7352 [=============================
=] - 28s 4ms/step - loss: 0.2027 - acc:
0.9339 - val_loss: 0.6295 - val_acc: 0.85
71
Epoch 16/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.2103 - acc:
0.9270 - val_loss: 0.4500 - val_acc: 0.89
72
Epoch 17/30
```

```
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.1874 - acc:
0.9339 - val_loss: 0.3324 - val_acc: 0.91
11
Epoch 18/30
7352/7352 [=============================
=] - 28s 4ms/step - loss: 0.1798 - acc:
0.9395 - val_loss: 0.2693 - val_acc: 0.90
97
Epoch 19/30
7352/7352 [=============================
=] - 28s 4ms/step - loss: 0.1777 - acc:
0.9376 - val_loss: 0.4728 - val_acc: 0.87
82
Epoch 20/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.1765 - acc:
0.9426 - val_loss: 0.4028 - val_acc: 0.88
80
Epoch 21/30
7352/7352 [=============================
=] - 28s 4ms/step - loss: 0.1755 - acc:
0.9421 - val_loss: 0.3165 - val_acc: 0.90
33
Epoch 22/30
7352/7352 [=============================
=] - 28s 4ms/step - loss: 0.1525 - acc:
0.9445 - val_loss: 0.3718 - val_acc: 0.90
80
Epoch 23/30
7352/7352 [=============================
=] - 28s 4ms/step - loss: 0.1624 - acc:
0.9449 - val_loss: 0.4211 - val_acc: 0.89
85
Epoch 24/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.1685 - acc:
0.9448 - val_loss: 0.5135 - val_acc: 0.90
06
Epoch 25/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.1947 - acc:
0.9431 - val_loss: 0.4896 - val_acc: 0.90
06
Epoch 26/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.1591 - acc:
0.9441 - val_loss: 0.4589 - val_acc: 0.90
19
Epoch 27/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.1754 - acc:
0.9461 - val_loss: 0.4298 - val_acc: 0.90
43
Epoch 28/30
7352/7352 [=============================
=] - 28s 4ms/step - loss: 0.1513 - acc:
0.9450 - val_loss: 0.3748 - val_acc: 0.91
35
Epoch 29/30
7352/7352 [=============================
=] - 27s 4ms/step - loss: 0.1591 - acc:
0.9450 - val_loss: 0.2734 - val_acc: 0.91
28
Epoch 30/30
7352/7352 [=============================
=] - 28s 4ms/step - loss: 0.1612 - acc:
0.9445 - val_loss: 0.3298 - val_acc: 0.90
87
```

Out[0]:

```
<keras.callbacks.History at 0x7ff68497d
748>
```

In [0]:

```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_
test)))
```

```
Pred                    LAYING  SITTING  ...  
WALKING_DOWNSTAIRS  WALKING_UPSTAIRS
True                                     ...  
LAYING                     510        0  ...  
0                 27
SITTING                      0      417  ...  
0                  1
STANDING                     0      108  ...  
0                  0
WALKING                      0        1  ...  
21                  5
WALKING_DOWNSTAIRS           0        0  ...  
408                  9
WALKING_UPSTAIRS             0        0  ...  
2                450

[6 rows x 6 columns]
```

In [0]:

```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================
=] - 1s 320us/step
```

In [0]:

```
score
```

Out[0]:

```
[0.32979796789985005, 0.9087207329487614]
```

Model-2:LSTM units

48,dropout=0.5

In [0]:

```
# Initiliazing the sequential model
model = Sequential()
# Configuring the parameters
model.add(LSTM(48, input_shape=(timesteps, input_dim)))
# Adding a dropout layer
model.add(Dropout(0.5))
# Adding a dense output layer with sigmoid activation
model.add(Dense(n_classes, activation='sigmoid'))
model.summary()
```

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

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

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


WARNING:tensorflow:From /usr/local/lib/py
```

```
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:3733: calling dropout (f
rom tensorflow.python.ops.nn_ops) with ke
ep_prob is deprecated and will be removed
in a future version.
Instructions for updating:
Please use `rate` instead of `keep_prob`.
Rate should be set to `rate = 1 - keep_pr
ob`.
Model: "sequential_1"
_________________________________________
________________________
Layer (type)                 Output Shape
Param #
=========================================
========================
lstm_1 (LSTM)                (None, 48)
11136
_________________________________________
________________________
dropout_1 (Dropout)          (None, 48)
0
_________________________________________
________________________
dense_1 (Dense)              (None, 6)
294
=========================================
========================
Total params: 11,430
Trainable params: 11,430
Non-trainable params: 0
_________________________________________
________________________
```

In [0]:

```
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

```
WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/optimizers.p
y:793: The name tf.train.Optimizer is dep
recated. Please use tf.compat.v1.train.Op
timizer instead.

WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:3576: The name tf.log is
deprecated. Please use tf.math.log instea
d.
```

In [0]:

```
# Training the model
model.fit(X_train,
          Y_train,
          batch_size=batch_size,
          validation_data=(X_test, Y_test),
          epochs=epochs)
```

```
WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/tensorflow_core/pyt
hon/ops/math_grad.py:1424: where (from te
nsorflow.python.ops.array_ops) is depreca
ted and will be removed in a future versi
on.
Instructions for updating:
Use tf.where in 2.0, which has the same b
roadcast rule as np.where
WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:1033: The name tf.assign
_add is deprecated. Please use tf.compat.
```

```
v1.assign_add instead.

WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:1020: The name tf.assign
is deprecated. Please use tf.compat.v1.as
sign instead.

Train on 7352 samples, validate on 2947 s
amples
Epoch 1/30
WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:190: The name tf.get_def
ault_session is deprecated. Please use t
f.compat.v1.get_default_session instead.

WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:207: The name tf.global_
variables is deprecated. Please use tf.co
mpat.v1.global_variables instead.

WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:216: The name tf.is_vari
able_initialized is deprecated. Please us
e tf.compat.v1.is_variable_initialized in
stead.

WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:223: The name tf.variabl
es_initializer is deprecated. Please use
tf.compat.v1.variables_initializer instea
d.
```

```
7352/7352 [=============================
=] - 86s 12ms/step - loss: 1.2732 - acc:
0.4558 - val_loss: 1.1303 - val_acc: 0.46
11
Epoch 2/30
7352/7352 [=============================
=] - 82s 11ms/step - loss: 1.0337 - acc:
0.5359 - val_loss: 0.8911 - val_acc: 0.64
37
Epoch 3/30
7352/7352 [=============================
=] - 83s 11ms/step - loss: 0.8027 - acc:
0.6431 - val_loss: 0.8240 - val_acc: 0.66
17
Epoch 4/30
7352/7352 [=============================
=] - 83s 11ms/step - loss: 0.6917 - acc:
0.7274 - val_loss: 0.5926 - val_acc: 0.76
79
Epoch 5/30
7352/7352 [=============================
=] - 83s 11ms/step - loss: 0.5369 - acc:
0.8041 - val_loss: 0.5703 - val_acc: 0.79
13
Epoch 6/30
7352/7352 [=============================
=] - 83s 11ms/step - loss: 0.4457 - acc:
0.8521 - val_loss: 0.5444 - val_acc: 0.80
05
Epoch 7/30
7352/7352 [=============================
=] - 83s 11ms/step - loss: 0.3567 - acc:
0.8871 - val_loss: 0.3817 - val_acc: 0.86
83
Epoch 8/30
```

```
7352/7352 [=============================
=] - 83s 11ms/step - loss: 0.2710 - acc:
0.9172 - val_loss: 0.3285 - val_acc: 0.88
53
Epoch 9/30
7352/7352 [=============================
=] - 82s 11ms/step - loss: 0.2320 - acc:
0.9212 - val_loss: 0.4021 - val_acc: 0.87
38
Epoch 10/30
7352/7352 [=============================
=] - 82s 11ms/step - loss: 0.2300 - acc:
0.9268 - val_loss: 0.2447 - val_acc: 0.90
26
Epoch 11/30
7352/7352 [=============================
=] - 83s 11ms/step - loss: 0.2201 - acc:
0.9253 - val_loss: 0.3741 - val_acc: 0.88
12
Epoch 12/30
7352/7352 [=============================
=] - 83s 11ms/step - loss: 0.1981 - acc:
0.9339 - val_loss: 0.4054 - val_acc: 0.88
63
Epoch 13/30
7352/7352 [=============================
=] - 83s 11ms/step - loss: 0.2283 - acc:
0.9342 - val_loss: 0.3508 - val_acc: 0.89
51
Epoch 14/30
7352/7352 [=============================
=] - 83s 11ms/step - loss: 0.2011 - acc:
0.9335 - val_loss: 0.3284 - val_acc: 0.89
31
Epoch 15/30
7352/7352 [=============================
=] - 83s 11ms/step - loss: 0.1705 - acc:
0.9374 - val_loss: 0.3599 - val_acc: 0.88
80
Epoch 16/30
7352/7352 [==============================
=] - 83s 11ms/step - loss: 0.1637 - acc:
0.9416 - val_loss: 0.2643 - val_acc: 0.90
94
Epoch 17/30
7352/7352 [==============================
=] - 83s 11ms/step - loss: 0.1894 - acc:
0.9355 - val_loss: 0.4051 - val_acc: 0.88
43
Epoch 18/30
7352/7352 [==============================
=] - 82s 11ms/step - loss: 0.1852 - acc:
0.9396 - val_loss: 0.3345 - val_acc: 0.90
40
Epoch 19/30
7352/7352 [==============================
=] - 83s 11ms/step - loss: 0.1577 - acc:
0.9425 - val_loss: 0.2728 - val_acc: 0.91
01
Epoch 20/30
7352/7352 [==============================
=] - 84s 11ms/step - loss: 0.1453 - acc:
0.9459 - val_loss: 0.2903 - val_acc: 0.90
46
Epoch 21/30
7352/7352 [==============================
=] - 83s 11ms/step - loss: 0.1725 - acc:
0.9444 - val_loss: 0.2764 - val_acc: 0.91
25
Epoch 22/30
7352/7352 [==============================
=] - 83s 11ms/step - loss: 0.1561 - acc:
```

```
0.9465 - val_loss: 0.3596 - val_acc: 0.87
82
Epoch 23/30
7352/7352 [=============================
=] - 84s 11ms/step - loss: 0.1524 - acc:
0.9460 - val_loss: 0.3936 - val_acc: 0.88
60
Epoch 24/30
7352/7352 [=============================
=] - 84s 11ms/step - loss: 0.1448 - acc:
0.9482 - val_loss: 0.2243 - val_acc: 0.91
99
Epoch 25/30
7352/7352 [=============================
=] - 83s 11ms/step - loss: 0.1292 - acc:
0.9528 - val_loss: 0.3412 - val_acc: 0.90
87
Epoch 26/30
7352/7352 [=============================
=] - 83s 11ms/step - loss: 0.1636 - acc:
0.9479 - val_loss: 0.2334 - val_acc: 0.92
16
Epoch 27/30
7352/7352 [=============================
=] - 82s 11ms/step - loss: 0.1328 - acc:
0.9538 - val_loss: 0.3467 - val_acc: 0.91
55
Epoch 28/30
7352/7352 [=============================
=] - 83s 11ms/step - loss: 0.1347 - acc:
0.9513 - val_loss: 0.5424 - val_acc: 0.89
99
Epoch 29/30
7352/7352 [=============================
=] - 82s 11ms/step - loss: 0.1484 - acc:
0.9489 - val_loss: 0.3533 - val_acc: 0.90
```

```
19
Epoch 30/30
7352/7352 [==============================
=] - 83s 11ms/step - loss: 0.1520 - acc:
0.9475 - val_loss: 0.2968 - val_acc: 0.91
75
```

Out[0]:

```
<keras.callbacks.History at 0x7fa186a96f2
8>
```

In [0]:

```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_
test)))
```

```
Pred                LAYING  SITTING  ...
WALKING_DOWNSTAIRS  WALKING_UPSTAIRS
True                                 ...
LAYING                 510        0  ...
0                 27
SITTING                  1      400  ...
0                  0
STANDING                 0       88  ...
0                  0
WALKING                  0        0  ...
10                 10
WALKING_DOWNSTAIRS       0        0  ...
410                  9
WALKING_UPSTAIRS         0        0  ...
4                465

[6 rows x 6 columns]
```

In [0]:

```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================
=] - 6s 2ms/step
```

In [0]:

```
score
```

Out[0]:

```
[0.2968081940932087, 0.9175432643366135]
```

LSTM units 64,dropout=0.25

In [0]:

```
# Initiliazing the sequential model
model = Sequential()
# Configuring the parameters
model.add(LSTM(64, input_shape=(timesteps, inpu
t_dim)))
# Adding a dropout layer
model.add(Dropout(0.25))
# Adding a dense output layer with sigmoid acti
vation
model.add(Dense(n_classes, activation='sigmoid'
))
model.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
_________________________
Layer (type)                 Output Shape
Param #
=================================================================
========================
lstm_2 (LSTM)                (None, 64)
18944
_________________________________________________________________
_________________________
dropout_2 (Dropout)          (None, 64)

0
```

```
_________________________________________
________________________
dense_2 (Dense)              (None, 6)
390
=========================================
========================
Total params: 19,334
Trainable params: 19,334
Non-trainable params: 0
_________________________________________
________________________
```

In [0]:

```python
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

In [0]:

```python
# Training the model
model.fit(X_train,
          Y_train,
          batch_size=batch_size,
          validation_data=(X_test, Y_test),
          epochs=epochs)
```

```
Train on 7352 samples, validate on 2947 s
amples
Epoch 1/30
7352/7352 [=============================
=] - 85s 12ms/step - loss: 1.2476 - acc:
0.4400 - val_loss: 1.1749 - val_acc: 0.45
88
Epoch 2/30
7352/7352 [=============================
=] - 85s 12ms/step - loss: 0.9634 - acc:
0.5739 - val_loss: 0.8059 - val_acc: 0.69
12
```

```
Epoch 3/30
7352/7352 [=============================
=] - 84s 11ms/step - loss: 0.6816 - acc:
0.7278 - val_loss: 0.6412 - val_acc: 0.80
01
Epoch 4/30
7352/7352 [=============================
=] - 85s 12ms/step - loss: 0.4905 - acc:
0.8364 - val_loss: 0.5425 - val_acc: 0.82
90
Epoch 5/30
7352/7352 [=============================
=] - 84s 11ms/step - loss: 0.4151 - acc:
0.8562 - val_loss: 0.4200 - val_acc: 0.84
97
Epoch 6/30
7352/7352 [=============================
=] - 84s 11ms/step - loss: 0.2822 - acc:
0.9053 - val_loss: 0.3974 - val_acc: 0.87
24
Epoch 7/30
7352/7352 [=============================
=] - 83s 11ms/step - loss: 0.2325 - acc:
0.9208 - val_loss: 0.3152 - val_acc: 0.88
43
Epoch 8/30
7352/7352 [=============================
=] - 84s 11ms/step - loss: 0.2086 - acc:
0.9282 - val_loss: 0.3597 - val_acc: 0.87
65
Epoch 9/30
7352/7352 [=============================
=] - 84s 11ms/step - loss: 0.1750 - acc:
0.9346 - val_loss: 0.2888 - val_acc: 0.90
30
Epoch 10/30
```

```
7352/7352 [=============================
=] - 84s 11ms/step - loss: 0.1876 - acc:
0.9342 - val_loss: 0.3309 - val_acc: 0.90
13
Epoch 11/30
7352/7352 [=============================
=] - 84s 11ms/step - loss: 0.1740 - acc:
0.9372 - val_loss: 0.2955 - val_acc: 0.90
23
Epoch 12/30
7352/7352 [=============================
=] - 84s 11ms/step - loss: 0.1586 - acc:
0.9449 - val_loss: 0.3282 - val_acc: 0.90
26
Epoch 13/30
7352/7352 [=============================
=] - 84s 11ms/step - loss: 0.1722 - acc:
0.9433 - val_loss: 0.2853 - val_acc: 0.91
69
Epoch 14/30
7352/7352 [=============================
=] - 84s 11ms/step - loss: 0.1490 - acc:
0.9460 - val_loss: 0.2948 - val_acc: 0.90
46
Epoch 15/30
7352/7352 [=============================
=] - 84s 11ms/step - loss: 0.1496 - acc:
0.9460 - val_loss: 0.2728 - val_acc: 0.91
75
Epoch 16/30
7352/7352 [=============================
=] - 84s 11ms/step - loss: 0.1489 - acc:
0.9455 - val_loss: 0.2801 - val_acc: 0.91
48
Epoch 17/30
7352/7352 [=============================
=] - 85s 11ms/step - loss: 0.1406 - acc:
0.9486 - val_loss: 0.2688 - val_acc: 0.91
01
Epoch 18/30
7352/7352 [==============================
=] - 85s 12ms/step - loss: 0.1365 - acc:
0.9513 - val_loss: 0.2539 - val_acc: 0.91
18
Epoch 19/30
7352/7352 [==============================
=] - 85s 12ms/step - loss: 0.1390 - acc:
0.9514 - val_loss: 0.2786 - val_acc: 0.90
97
Epoch 20/30
7352/7352 [==============================
=] - 84s 11ms/step - loss: 0.1405 - acc:
0.9518 - val_loss: 0.3397 - val_acc: 0.91
14
Epoch 21/30
7352/7352 [==============================
=] - 83s 11ms/step - loss: 0.1411 - acc:
0.9514 - val_loss: 0.3761 - val_acc: 0.90
19
Epoch 22/30
7352/7352 [==============================
=] - 84s 11ms/step - loss: 0.1336 - acc:
0.9501 - val_loss: 0.3187 - val_acc: 0.90
50
Epoch 23/30
7352/7352 [==============================
=] - 84s 11ms/step - loss: 0.1391 - acc:
0.9497 - val_loss: 0.2953 - val_acc: 0.91
62
Epoch 24/30
7352/7352 [==============================
=] - 84s 11ms/step - loss: 0.1342 - acc:
```

```
0.9533 - val_loss: 0.3452 - val_acc: 0.91
31
Epoch 25/30
7352/7352 [=============================
=] - 84s 11ms/step - loss: 0.1310 - acc:
0.9487 - val_loss: 0.3872 - val_acc: 0.91
65
Epoch 26/30
7352/7352 [=============================
=] - 84s 11ms/step - loss: 0.1297 - acc:
0.9543 - val_loss: 0.4000 - val_acc: 0.91
48
Epoch 27/30
7352/7352 [=============================
=] - 84s 11ms/step - loss: 0.1464 - acc:
0.9461 - val_loss: 0.3745 - val_acc: 0.90
50
Epoch 28/30
7352/7352 [=============================
=] - 83s 11ms/step - loss: 0.1316 - acc:
0.9529 - val_loss: 0.3626 - val_acc: 0.91
58
Epoch 29/30
7352/7352 [=============================
=] - 84s 11ms/step - loss: 0.1414 - acc:
0.9506 - val_loss: 0.5936 - val_acc: 0.89
35
Epoch 30/30
7352/7352 [=============================
=] - 84s 11ms/step - loss: 0.1341 - acc:
0.9475 - val_loss: 0.4333 - val_acc: 0.89
72
```

Out[0]:

```
<keras.callbacks.History at 0x7fa12f088
fd0>
```

In [0]:

```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                    LAYING  SITTING  ...
WALKING_DOWNSTAIRS  WALKING_UPSTAIRS
True                                     ...
LAYING                     511        0  ...
0                 26
SITTING                      2      377  ...
1                  1
STANDING                     0       83  ...
0                  0
WALKING                      0        0  ...
2                 19
WALKING_DOWNSTAIRS           0        0  ...
391                 5
WALKING_UPSTAIRS             0        0  ...
0                441

[6 rows x 6 columns]
```

In [0]:

```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================
=] - 6s 2ms/step
```

In [0]:

```
score
```

Out[0]:

```
[0.4332898249001449, 0.8971835765184933]
```

(64 layers,dropout=0.5)

In [0]:

```
# Initiliazing the sequential model
model = Sequential()
# Configuring the parameters
model.add(LSTM(64, input_shape=(timesteps, inpu
t_dim)))
# Adding a dropout layer
model.add(Dropout(0.5))
# Adding a dense output layer with sigmoid acti
vation
model.add(Dense(n_classes, activation='sigmoid'
))
model.summary()
```

```
Model: "sequential_3"
_________________________________________________

_________________
Layer (type)                 Output Shape
Param #
=================================================
=================
lstm_3 (LSTM)                (None, 64)
18944

_________________________________________________

_________________
dropout_3 (Dropout)          (None, 64)
0

_________________________________________________

_________________
dense_3 (Dense)              (None, 6)
390
=================================================
=================
Total params: 19,334
Trainable params: 19,334
Non-trainable params: 0
```

```
__________________________________________
_________________________
```

In [0]:

```python
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

In [0]:

```python
# Training the model
model.fit(X_train,
          Y_train,
          batch_size=batch_size,
          validation_data=(X_test, Y_test),
          epochs=epochs)
```

```
Train on 7352 samples, validate on 2947 s
amples
Epoch 1/30
7352/7352 [==============================
=] - 34s 5ms/step - loss: 1.2662 - acc:
0.4358 - val_loss: 1.1064 - val_acc: 0.48
29
Epoch 2/30
7352/7352 [==============================
=] - 33s 5ms/step - loss: 0.9313 - acc:
0.5763 - val_loss: 0.8966 - val_acc: 0.56
91
Epoch 3/30
7352/7352 [==============================
=] - 33s 5ms/step - loss: 0.8923 - acc:
0.5998 - val_loss: 0.8434 - val_acc: 0.56
06
Epoch 4/30
7352/7352 [==============================
=] - 33s 4ms/step - loss: 0.7401 - acc:

0.6597 - val_loss: 0.9543 - val_acc: 0.58
74
```

```
Epoch 5/30
7352/7352 [=============================
=] - 33s 5ms/step - loss: 0.6950 - acc:
0.7016 - val_loss: 0.7862 - val_acc: 0.66
20
Epoch 6/30
7352/7352 [=============================
=] - 33s 5ms/step - loss: 0.6325 - acc:
0.7520 - val_loss: 0.5506 - val_acc: 0.79
57
Epoch 7/30
7352/7352 [=============================
=] - 33s 4ms/step - loss: 0.4968 - acc:
0.8251 - val_loss: 0.4399 - val_acc: 0.84
02
Epoch 8/30
7352/7352 [=============================
=] - 33s 4ms/step - loss: 0.3587 - acc:
0.8834 - val_loss: 0.5390 - val_acc: 0.81
74
Epoch 9/30
7352/7352 [=============================
=] - 33s 4ms/step - loss: 0.3000 - acc:
0.8981 - val_loss: 0.4513 - val_acc: 0.85
37
Epoch 10/30
7352/7352 [=============================
=] - 33s 4ms/step - loss: 0.3004 - acc:
0.9038 - val_loss: 0.5203 - val_acc: 0.85
21
Epoch 11/30
7352/7352 [=============================
=] - 33s 5ms/step - loss: 0.2405 - acc:
0.9176 - val_loss: 0.4774 - val_acc: 0.86
77
Epoch 12/30
```

```
7352/7352 [=============================
=] - 33s 5ms/step - loss: 0.2068 - acc:
0.9297 - val_loss: 0.4728 - val_acc: 0.88
50
Epoch 13/30
7352/7352 [=============================
=] - 33s 4ms/step - loss: 0.1869 - acc:
0.9358 - val_loss: 0.5209 - val_acc: 0.88
26
Epoch 14/30
7352/7352 [=============================
=] - 33s 4ms/step - loss: 0.1772 - acc:
0.9380 - val_loss: 0.4357 - val_acc: 0.89
38
Epoch 15/30
7352/7352 [=============================
=] - 33s 5ms/step - loss: 0.1866 - acc:
0.9363 - val_loss: 0.4698 - val_acc: 0.88
39
Epoch 16/30
7352/7352 [=============================
=] - 33s 4ms/step - loss: 0.1800 - acc:
0.9384 - val_loss: 0.3653 - val_acc: 0.89
21
Epoch 17/30
7352/7352 [=============================
=] - 33s 4ms/step - loss: 0.1860 - acc:
0.9343 - val_loss: 0.3209 - val_acc: 0.90
70
Epoch 18/30
7352/7352 [=============================
=] - 33s 4ms/step - loss: 0.1542 - acc:
0.9440 - val_loss: 0.2846 - val_acc: 0.90
33
Epoch 19/30
7352/7352 [=============================
=] - 33s 5ms/step - loss: 0.1413 - acc:
0.9479 - val_loss: 0.4094 - val_acc: 0.90
09
Epoch 20/30
7352/7352 [=============================
=] - 33s 5ms/step - loss: 0.1736 - acc:
0.9419 - val_loss: 0.3595 - val_acc: 0.91
35
Epoch 21/30
7352/7352 [=============================
=] - 33s 5ms/step - loss: 0.1597 - acc:
0.9461 - val_loss: 0.3361 - val_acc: 0.91
38
Epoch 22/30
7352/7352 [=============================
=] - 33s 4ms/step - loss: 0.1510 - acc:
0.9408 - val_loss: 0.3343 - val_acc: 0.90
70
Epoch 23/30
7352/7352 [=============================
=] - 34s 5ms/step - loss: 0.1526 - acc:
0.9470 - val_loss: 0.3147 - val_acc: 0.91
38
Epoch 24/30
7352/7352 [=============================
=] - 34s 5ms/step - loss: 0.1442 - acc:
0.9499 - val_loss: 0.4359 - val_acc: 0.90
40
Epoch 25/30
7352/7352 [=============================
=] - 33s 5ms/step - loss: 0.1662 - acc:
0.9460 - val_loss: 0.3513 - val_acc: 0.91
65
Epoch 26/30
7352/7352 [=============================
=] - 33s 5ms/step - loss: 0.1444 - acc:
```

```
0.9514 - val_loss: 0.3341 - val_acc: 0.91
14
Epoch 27/30
7352/7352 [==============================
=] - 33s 4ms/step - loss: 0.1575 - acc:
0.9468 - val_loss: 0.4065 - val_acc: 0.90
87
Epoch 28/30
7352/7352 [==============================
=] - 33s 5ms/step - loss: 0.1635 - acc:
0.9411 - val_loss: 0.4308 - val_acc: 0.91
28
Epoch 29/30
7352/7352 [==============================
=] - 34s 5ms/step - loss: 0.1606 - acc:
0.9486 - val_loss: 0.5718 - val_acc: 0.90
16
Epoch 30/30
7352/7352 [==============================
=] - 33s 5ms/step - loss: 0.1300 - acc:
0.9514 - val_loss: 0.3612 - val_acc: 0.91
55
```

Out[0]:

```
<keras.callbacks.History at 0x7ff6848d30f
0>
```

In [0]:

```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_
test)))
```

```
Pred                    LAYING  SITTING  ...
WALKING_DOWNSTAIRS  WALKING_UPSTAIRS
True                                     ...
LAYING                     533        0  ...
0                  4
SITTING                      0      430  ...
```

```
0                 1
STANDING                 0      120  ...
0                 2
WALKING                  0        0  ...
27                17
WALKING_DOWNSTAIRS       0        0  ...
416                 1
WALKING_UPSTAIRS         0        0  ...
6               457

[6 rows x 6 columns]
```

In [0]:

```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [=============================
=] - 1s 422us/step
```

In [0]:

```
score
```

Out[0]:

```
[0.3611737099244576, 0.9155072955548015]
```

Model-3: 2 LSTM Layers + larger dropout(0.7)

In [0]:

```
# code from https://keras.io/regularizers/
from keras.regularizers import L1L2
from keras.models import load_model
from keras.callbacks import ModelCheckpoint
from keras.layers import LSTM , BatchNormalizat
ion
reg = L1L2(0.01, 0.01)
```

In [0]:

```
model = Sequential()
```

```
model.add(LSTM(132, input_shape=(timesteps, input_dim), kernel_initializer='glorot_normal' , return_sequences=True, bias_regularizer=reg))
model.add(BatchNormalization())
model.add(Dropout(0.70))
model.add(LSTM(68))
model.add(Dropout(0.70))
model.add(Dense(n_classes, activation='sigmoid'))
model.summary()
```

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

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

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

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:3733: calling dropout (from tensorflow.python.ops.nn_ops) with keep_prob is deprecated and will be removed in a future version.
```

```
Instructions for updating:
Please use `rate` instead of `keep_prob`.
Rate should be set to `rate = 1 - keep_pr
ob`.
WARNING:tensorflow:Large dropout rate: 0.
7 (>0.5). In TensorFlow 2.x, dropout() us
es dropout rate instead of keep_prob. Ple
ase ensure that this is intended.
WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso
rflow_backend.py:4432: The name tf.random
_uniform is deprecated. Please use tf.ran
dom.uniform instead.

WARNING:tensorflow:Large dropout rate: 0.
7 (>0.5). In TensorFlow 2.x, dropout() us
es dropout rate instead of keep_prob. Ple
ase ensure that this is intended.
Model: "sequential_1"
_________________________________________
________________________
Layer (type)                 Output Shape
Param #
=========================================
========================
lstm_1 (LSTM)                (None, 128,
132)          74976
_________________________________________
________________________
batch_normalization_1 (Batch (None, 128,
132)          528
_________________________________________
________________________
dropout_1 (Dropout)          (None, 128,
132)          0
_________________________________________
```

```
________________________
lstm_2 (LSTM)                (None, 68)
54672
_________________________________________
________________________
dropout_2 (Dropout)          (None, 68)
0
_________________________________________
________________________
dense_1 (Dense)              (None, 6)
414
=========================================
========================
Total params: 130,590
Trainable params: 130,326
Non-trainable params: 264
_________________________________________
________________________
```

In [0]:

```python
# Compiling the model
model.compile(loss='binary_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

```
WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/optimizers.p
y:793: The name tf.train.Optimizer is dep
recated. Please use tf.compat.v1.train.Op
timizer instead.

WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/keras/backend/tenso

rflow_backend.py:3657: The name tf.log is
deprecated. Please use tf.math.log instea
d.
```

```
WARNING:tensorflow:From /usr/local/lib/py
thon3.6/dist-packages/tensorflow_core/pyt
hon/ops/nn_impl.py:183: where (from tenso
rflow.python.ops.array_ops) is deprecated
and will be removed in a future version.
Instructions for updating:
Use tf.where in 2.0, which has the same b
roadcast rule as np.where
```

In [0]:

```
# Training the model
model.fit(X_train,
          Y_train,
          batch_size=batch_size,
          validation_data=(X_test, Y_test),
          epochs=epochs)
```

```
Train on 7352 samples, validate on 2947 s
amples
Epoch 1/30
7352/7352 [=============================
=] - 242s 33ms/step - loss: 0.0849 - acc:
0.9711 - val_loss: 0.1123 - val_acc: 0.96
14
Epoch 2/30
7352/7352 [=============================
=] - 242s 33ms/step - loss: 0.0774 - acc:
0.9745 - val_loss: 0.1079 - val_acc: 0.97
01
Epoch 3/30
7352/7352 [=============================
=] - 242s 33ms/step - loss: 0.0744 - acc:
0.9748 - val_loss: 0.1355 - val_acc: 0.96
33
Epoch 4/30
7352/7352 [=============================
=] - 241s 33ms/step - loss: 0.0705 - acc:
0.9756 - val_loss: 0.0909 - val_acc: 0.97
55
Epoch 5/30
7352/7352 [=============================
=] - 241s 33ms/step - loss: 0.0722 - acc:
0.9749 - val_loss: 0.0942 - val_acc: 0.97
16
Epoch 6/30
7352/7352 [=============================
=] - 242s 33ms/step - loss: 0.0700 - acc:
0.9754 - val_loss: 0.0961 - val_acc: 0.97
00
Epoch 7/30
7352/7352 [=============================
=] - 240s 33ms/step - loss: 0.0646 - acc:
0.9766 - val_loss: 0.0714 - val_acc: 0.97
46
Epoch 8/30
7352/7352 [=============================
=] - 239s 33ms/step - loss: 0.0649 - acc:
0.9775 - val_loss: 0.1337 - val_acc: 0.97
31
Epoch 9/30
7352/7352 [=============================
=] - 240s 33ms/step - loss: 0.0687 - acc:
0.9761 - val_loss: 0.1083 - val_acc: 0.97
04
Epoch 10/30
7352/7352 [=============================
=] - 239s 33ms/step - loss: 0.0623 - acc:
0.9776 - val_loss: 0.0659 - val_acc: 0.97
53
Epoch 11/30
7352/7352 [=============================
=] - 238s 32ms/step - loss: 0.0649 - acc:
```

```
0.9776 - val_loss: 0.0968 - val_acc: 0.97
31
Epoch 12/30
7352/7352 [=============================
=] - 240s 33ms/step - loss: 0.0636 - acc:
0.9781 - val_loss: 0.0949 - val_acc: 0.97
33
Epoch 13/30
7352/7352 [=============================
=] - 239s 33ms/step - loss: 0.0624 - acc:
0.9784 - val_loss: 0.0776 - val_acc: 0.97
55
Epoch 14/30
7352/7352 [=============================
=] - 240s 33ms/step - loss: 0.0643 - acc:
0.9781 - val_loss: 0.1075 - val_acc: 0.97
36
Epoch 15/30
7352/7352 [=============================
=] - 239s 32ms/step - loss: 0.0611 - acc:
0.9781 - val_loss: 0.0787 - val_acc: 0.97
44
Epoch 16/30
7352/7352 [=============================
=] - 240s 33ms/step - loss: 0.0612 - acc:
0.9780 - val_loss: 0.1536 - val_acc: 0.96
83
Epoch 17/30
7352/7352 [=============================
=] - 239s 33ms/step - loss: 0.0615 - acc:
0.9781 - val_loss: 0.1438 - val_acc: 0.96
11
Epoch 18/30
7352/7352 [=============================
=] - 239s 33ms/step - loss: 0.0659 - acc:
0.9776 - val_loss: 0.0816 - val_acc: 0.97
```

```
27
Epoch 19/30
7352/7352 [=============================
=] - 239s 33ms/step - loss: 0.0612 - acc:
0.9796 - val_loss: 0.0984 - val_acc: 0.97
35
Epoch 20/30
7352/7352 [=============================
=] - 240s 33ms/step - loss: 0.0616 - acc:
0.9781 - val_loss: 0.1140 - val_acc: 0.97
51
Epoch 21/30
7352/7352 [=============================
=] - 239s 33ms/step - loss: 0.0594 - acc:
0.9790 - val_loss: 0.0783 - val_acc: 0.97
50
Epoch 22/30
7352/7352 [=============================
=] - 239s 33ms/step - loss: 0.0597 - acc:
0.9799 - val_loss: 0.1295 - val_acc: 0.97
57
Epoch 23/30
7352/7352 [=============================
=] - 238s 32ms/step - loss: 0.0574 - acc:
0.9807 - val_loss: 0.1490 - val_acc: 0.96
90
Epoch 24/30
7352/7352 [=============================
=] - 239s 33ms/step - loss: 0.0614 - acc:
0.9777 - val_loss: 0.1395 - val_acc: 0.97
13
Epoch 25/30
7352/7352 [=============================
=] - 239s 33ms/step - loss: 0.0595 - acc:
0.9795 - val_loss: 0.1253 - val_acc: 0.97
60
```

```
Epoch 26/30
7352/7352 [=============================
=] - 239s 33ms/step - loss: 0.0590 - acc:
0.9808 - val_loss: 0.1138 - val_acc: 0.97
48
Epoch 27/30
7352/7352 [=============================
=] - 240s 33ms/step - loss: 0.0614 - acc:
0.9799 - val_loss: 0.0948 - val_acc: 0.97
55
Epoch 28/30
7352/7352 [=============================
=] - 239s 33ms/step - loss: 0.0618 - acc:
0.9798 - val_loss: 0.0883 - val_acc: 0.97
10
Epoch 29/30
7352/7352 [=============================
=] - 239s 32ms/step - loss: 0.0630 - acc:
0.9790 - val_loss: 0.0965 - val_acc: 0.97
44
Epoch 30/30
7352/7352 [=============================
=] - 237s 32ms/step - loss: 0.0605 - acc:
0.9805 - val_loss: 0.1373 - val_acc: 0.96
83
```

Out[0]:

```
<keras.callbacks.History at 0x7f0c162ef97
8>
```

In [0]:

```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_
test)))
```

```
Pred                   LAYING  SITTING  ...
WALKING_DOWNSTAIRS  WALKING_UPSTAIRS
True                                    ...
```

```
LAYING                      537        0   ...
0                  0
SITTING                       1      448   ...
0                  6
STANDING                      0      159   ...
0                 10
WALKING                       0        6   ...
12                  2
WALKING_DOWNSTAIRS            0        0   ...
416                  2
WALKING_UPSTAIRS              0       15   ...
7                434

[6 rows x 6 columns]
```

In [0]:

```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================
=] - 17s 6ms/step
```

In [0]:

```
score
```

Out[0]:

```
[0.13728767729193367, 0.9683293742894075]
```

Conclusion

In [3]:

```
from prettytable import PrettyTable
x = PrettyTable()
x.field_names = ["Model","Description","Dropou
t","Test loss", "Test Accuracy"]
x.add_row([1,"1 Layer of LSTM(32)",0.5,0.3297,
0.9087])
x.add_row([2,"1 Layer of LSTM(48)",0.5,0.2968,
```