mayankgupta9968@gmail.com_23

January 31, 2020

[6]:
```
# Importing Libraries
```

[7]:
```
import pandas as pd
import numpy as np
```

[8]:
```
# 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'])
```

0.0.1 Data

[9]:
```
# Data directory
DATADIR = 'UCI_HAR_Dataset'
```

[10]:
```
# 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"
]
```

[11]:
```
# Utility function to read the data from csv file
def _read_csv(filename):
    return pd.read_csv(filename, delim_whitespace=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}/Inertial Signals/
 ↪{signal}_{subset}.txt'
        signals_data.append(
            _read_csv(filename).as_matrix()
        )

    # Transpose is used to change the dimensionality 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))
```

[12]:
```
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()
```

[13]:
```
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
```

[14]:
```
# Importing tensorflow
np.random.seed(42)
import tensorflow as tf
tf.set_random_seed(42)
```

[15]:
```
# Configuring a session
session_conf = tf.ConfigProto(
    intra_op_parallelism_threads=1,
    inter_op_parallelism_threads=1
)
```

[16]:
```
# Import Keras
from keras import backend as K
sess = tf.Session(graph=tf.get_default_graph(), config=session_conf)
K.set_session(sess)
```

[17]:
```
# Importing libraries
from keras.models import Sequential
from keras.layers import LSTM
from keras.layers.core import Dense, Dropout
from keras.layers.normalization import BatchNormalization
```

[18]:
```
# Initializing parameters
epochs = 30
batch_size = 16
n_hidden = 32
```

[19]:
```
# Utility function to count the number of classes
def _count_classes(y):
    return len(set([tuple(category) for category in y]))
```

[20]:
```
# Loading the train and test data
X_train, X_test, Y_train, Y_test = load_data()
```

```
/Users/mayankgupta/anaconda3/lib/python3.7/site-
packages/ipykernel_launcher.py:12: FutureWarning: Method .as_matrix will be
removed in a future version. Use .values instead.
  if sys.path[0] == '':
/Users/mayankgupta/anaconda3/lib/python3.7/site-
packages/ipykernel_launcher.py:11: FutureWarning: Method .as_matrix will be
removed in a future version. Use .values instead.
  # This is added back by InteractiveShellApp.init_path()
```

[21]:
```
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

[17]:
```
# 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 activation
model.add(Dense(n_classes, activation='sigmoid'))
model.summary()
```

```
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
_________________________________________________________________
```

[18]:
```
# Compiling the model
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

[19]:
```
# Training the model
model.fit(X_train,
          Y_train,
          batch_size=batch_size,
          validation_data=(X_test, Y_test),
```

```
          epochs=epochs)
```

```
WARNING:tensorflow:From /Users/mayankgupta/anaconda3/lib/python3.7/site-
packages/tensorflow/python/ops/math_grad.py:1250:
add_dispatch_support.<locals>.wrapper (from tensorflow.python.ops.array_ops) is
deprecated and will be removed in a future version.
Instructions for updating:
Use tf.where in 2.0, which has the same broadcast rule as np.where
WARNING:tensorflow:From /Users/mayankgupta/anaconda3/lib/python3.7/site-
packages/keras/backend/tensorflow_backend.py:422: The name tf.global_variables
is deprecated. Please use tf.compat.v1.global_variables instead.

Train on 7352 samples, validate on 2947 samples
Epoch 1/30
7352/7352 [==============================] - 15s 2ms/step - loss: 1.3008 -
accuracy: 0.4645 - val_loss: 1.0891 - val_accuracy: 0.5565
Epoch 2/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.9056 -
accuracy: 0.6171 - val_loss: 0.8277 - val_accuracy: 0.5942
Epoch 3/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.7434 -
accuracy: 0.6549 - val_loss: 0.7569 - val_accuracy: 0.6230
Epoch 4/30
7352/7352 [==============================] - 14s 2ms/step - loss: 0.6725 -
accuracy: 0.6800 - val_loss: 0.6941 - val_accuracy: 0.6651
Epoch 5/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.6236 -
accuracy: 0.7116 - val_loss: 0.6568 - val_accuracy: 0.7326
Epoch 6/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.5866 -
accuracy: 0.7333 - val_loss: 0.7696 - val_accuracy: 0.6763
Epoch 7/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.5055 -
accuracy: 0.7748 - val_loss: 0.6162 - val_accuracy: 0.7272
Epoch 8/30
7352/7352 [==============================] - 14s 2ms/step - loss: 0.4769 -
accuracy: 0.7791 - val_loss: 0.5323 - val_accuracy: 0.7465
Epoch 9/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.4243 -
accuracy: 0.7979 - val_loss: 0.6893 - val_accuracy: 0.7167
Epoch 10/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.4033 -
accuracy: 0.8096 - val_loss: 0.5631 - val_accuracy: 0.7326
Epoch 11/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.3785 -
accuracy: 0.8391 - val_loss: 0.5226 - val_accuracy: 0.7937
Epoch 12/30
```

```
7352/7352 [==============================] - 16s 2ms/step - loss: 0.3327 -
accuracy: 0.8791 - val_loss: 0.5721 - val_accuracy: 0.8694
Epoch 13/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.2857 -
accuracy: 0.9132 - val_loss: 0.4536 - val_accuracy: 0.8812
Epoch 14/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.2537 -
accuracy: 0.9207 - val_loss: 0.5414 - val_accuracy: 0.8748
Epoch 15/30
7352/7352 [==============================] - 17s 2ms/step - loss: 0.2421 -
accuracy: 0.9293 - val_loss: 0.4205 - val_accuracy: 0.8968
Epoch 16/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.2077 -
accuracy: 0.9331 - val_loss: 0.4868 - val_accuracy: 0.8785
Epoch 17/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.1950 -
accuracy: 0.9384 - val_loss: 0.5625 - val_accuracy: 0.8833
Epoch 18/30
7352/7352 [==============================] - 13s 2ms/step - loss: 0.1844 -
accuracy: 0.9419 - val_loss: 0.6079 - val_accuracy: 0.8738
Epoch 19/30
7352/7352 [==============================] - 14s 2ms/step - loss: 0.1846 -
accuracy: 0.9414 - val_loss: 0.4497 - val_accuracy: 0.8999
Epoch 20/30
7352/7352 [==============================] - 14s 2ms/step - loss: 0.1701 -
accuracy: 0.9459 - val_loss: 0.5215 - val_accuracy: 0.8795
Epoch 21/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.1723 -
accuracy: 0.9450 - val_loss: 0.4698 - val_accuracy: 0.8887
Epoch 22/30
7352/7352 [==============================] - 20s 3ms/step - loss: 0.1813 -
accuracy: 0.9448 - val_loss: 0.4783 - val_accuracy: 0.8795
Epoch 23/30
7352/7352 [==============================] - 20s 3ms/step - loss: 0.1579 -
accuracy: 0.9465 - val_loss: 0.4126 - val_accuracy: 0.8968
Epoch 24/30
7352/7352 [==============================] - 19s 3ms/step - loss: 0.1754 -
accuracy: 0.9448 - val_loss: 0.3679 - val_accuracy: 0.9111
Epoch 25/30
7352/7352 [==============================] - 17s 2ms/step - loss: 0.1827 -
accuracy: 0.9425 - val_loss: 0.9810 - val_accuracy: 0.8426
Epoch 26/30
7352/7352 [==============================] - 20s 3ms/step - loss: 0.1565 -
accuracy: 0.9489 - val_loss: 0.3639 - val_accuracy: 0.9043
Epoch 27/30
7352/7352 [==============================] - 20s 3ms/step - loss: 0.1508 -
accuracy: 0.9484 - val_loss: 0.3858 - val_accuracy: 0.8996
Epoch 28/30
```

```
7352/7352 [==============================] - 19s 3ms/step - loss: 0.1461 -
accuracy: 0.9470 - val_loss: 0.4374 - val_accuracy: 0.9013
Epoch 29/30
7352/7352 [==============================] - 21s 3ms/step - loss: 0.1558 -
accuracy: 0.9449 - val_loss: 0.3596 - val_accuracy: 0.9043
Epoch 30/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.1712 -
accuracy: 0.9433 - val_loss: 0.4166 - val_accuracy: 0.8955
```

[19]:
```
<keras.callbacks.callbacks.History at 0x117c463c8>
```

[20]:
```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                LAYING  SITTING  STANDING  WALKING  WALKING_DOWNSTAIRS  \
True
LAYING                 510        0        27        0                   0
SITTING                  2      381       105        1                   1
STANDING                 0       86       446        0                   0
WALKING                  0        0         0      454                  15
WALKING_DOWNSTAIRS       0        0         0        0                 419
WALKING_UPSTAIRS         0        7         0        4                  31

Pred                WALKING_UPSTAIRS
True
LAYING                             0
SITTING                            1
STANDING                           0
WALKING                           27
WALKING_DOWNSTAIRS                 1
WALKING_UPSTAIRS                 429
```

[21]:
```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================] - 1s 328us/step
```

[22]:
```
score
```

[22]:
```
[0.41655886096877154, 0.8954869508743286]
```

- With a simple 2 layer architecture we got approx. 89.54% accuracy and a loss of 0.4165
- We can further imporve the performace with Hyperparameter tuning

1. Assignment

1.1 Update LSTM Layer

[23]:
```
# update LSTM layers
n_hidden = 64
```

- Defining the Architecture of LSTM

[24]:
```
# 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 activation
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
_________________________________________________________________
```

[25]:
```
# Compiling the model
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

[26]:
```
# 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 samples
Epoch 1/30
7352/7352 [==============================] - 24s 3ms/step - loss: 1.2560 -
accuracy: 0.4470 - val_loss: 1.1326 - val_accuracy: 0.4825
Epoch 2/30
```

```
7352/7352 [==============================] - 26s 4ms/step - loss: 0.9495 -
accuracy: 0.6081 - val_loss: 0.8467 - val_accuracy: 0.6912
Epoch 3/30
7352/7352 [==============================] - 27s 4ms/step - loss: 0.8132 -
accuracy: 0.6473 - val_loss: 0.8576 - val_accuracy: 0.6322
Epoch 4/30
7352/7352 [==============================] - 21s 3ms/step - loss: 0.7342 -
accuracy: 0.6933 - val_loss: 0.7157 - val_accuracy: 0.7458
Epoch 5/30
7352/7352 [==============================] - 22s 3ms/step - loss: 0.5382 -
accuracy: 0.7784 - val_loss: 0.5688 - val_accuracy: 0.7984
Epoch 6/30
7352/7352 [==============================] - 19s 3ms/step - loss: 0.3811 -
accuracy: 0.8579 - val_loss: 0.5755 - val_accuracy: 0.8480
Epoch 7/30
7352/7352 [==============================] - 19s 3ms/step - loss: 0.3327 -
accuracy: 0.8900 - val_loss: 0.5255 - val_accuracy: 0.8487
Epoch 8/30
7352/7352 [==============================] - 24s 3ms/step - loss: 0.2582 -
accuracy: 0.9129 - val_loss: 0.4217 - val_accuracy: 0.8873
Epoch 9/30
7352/7352 [==============================] - 24s 3ms/step - loss: 0.2411 -
accuracy: 0.9207 - val_loss: 0.3309 - val_accuracy: 0.9046
Epoch 10/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1987 -
accuracy: 0.9325 - val_loss: 0.4274 - val_accuracy: 0.8711
Epoch 11/30
7352/7352 [==============================] - 24s 3ms/step - loss: 0.1965 -
accuracy: 0.9334 - val_loss: 0.3487 - val_accuracy: 0.8731
Epoch 12/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1784 -
accuracy: 0.9357 - val_loss: 0.3973 - val_accuracy: 0.8951
Epoch 13/30
7352/7352 [==============================] - 26s 4ms/step - loss: 0.1763 -
accuracy: 0.9391 - val_loss: 0.3849 - val_accuracy: 0.8979
Epoch 14/30
7352/7352 [==============================] - 23s 3ms/step - loss: 0.1544 -
accuracy: 0.9431 - val_loss: 0.4401 - val_accuracy: 0.9033
Epoch 15/30
7352/7352 [==============================] - 27s 4ms/step - loss: 0.1778 -
accuracy: 0.9421 - val_loss: 0.2845 - val_accuracy: 0.9131
Epoch 16/30
7352/7352 [==============================] - 26s 3ms/step - loss: 0.1749 -
accuracy: 0.9392 - val_loss: 0.3084 - val_accuracy: 0.9087
Epoch 17/30
7352/7352 [==============================] - 26s 4ms/step - loss: 0.1582 -
accuracy: 0.9436 - val_loss: 0.3808 - val_accuracy: 0.9108
Epoch 18/30
```

```
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1480 -
accuracy: 0.9487 - val_loss: 0.3502 - val_accuracy: 0.9138
Epoch 19/30
7352/7352 [==============================] - 21s 3ms/step - loss: 0.1504 -
accuracy: 0.9484 - val_loss: 0.4116 - val_accuracy: 0.9036
Epoch 20/30
7352/7352 [==============================] - 24s 3ms/step - loss: 0.1431 -
accuracy: 0.9494 - val_loss: 0.2973 - val_accuracy: 0.9050
Epoch 21/30
7352/7352 [==============================] - 22s 3ms/step - loss: 0.1542 -
accuracy: 0.9474 - val_loss: 0.3730 - val_accuracy: 0.9145
Epoch 22/30
7352/7352 [==============================] - 20s 3ms/step - loss: 0.1414 -
accuracy: 0.9502 - val_loss: 0.3996 - val_accuracy: 0.9158
Epoch 23/30
7352/7352 [==============================] - 22s 3ms/step - loss: 0.1364 -
accuracy: 0.9497 - val_loss: 0.3808 - val_accuracy: 0.9097
Epoch 24/30
7352/7352 [==============================] - 21s 3ms/step - loss: 0.1403 -
accuracy: 0.9512 - val_loss: 0.3501 - val_accuracy: 0.9036
Epoch 25/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.1381 -
accuracy: 0.9478 - val_loss: 0.4506 - val_accuracy: 0.9074
Epoch 26/30
7352/7352 [==============================] - 21s 3ms/step - loss: 0.1473 -
accuracy: 0.9491 - val_loss: 0.4966 - val_accuracy: 0.9006
Epoch 27/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.1539 -
accuracy: 0.9499 - val_loss: 0.3719 - val_accuracy: 0.9060
Epoch 28/30
7352/7352 [==============================] - 30s 4ms/step - loss: 0.1417 -
accuracy: 0.9508 - val_loss: 0.3556 - val_accuracy: 0.9057
Epoch 29/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1339 -
accuracy: 0.9512 - val_loss: 0.4193 - val_accuracy: 0.8928
Epoch 30/30
7352/7352 [==============================] - 26s 4ms/step - loss: 0.1781 -
accuracy: 0.9480 - val_loss: 0.3534 - val_accuracy: 0.9148
```

[26]:
```
<keras.callbacks.callbacks.History at 0x62f5f3518>
```

[27]:
```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                LAYING  SITTING  STANDING  WALKING  WALKING_DOWNSTAIRS  \
True
LAYING                 509        0        27        0                   0
SITTING                  0      365       126        0                   0
```

```
STANDING                0       47       485        0                   0
WALKING                 0        0         0      459                  25
WALKING_DOWNSTAIRS      0        0         0        0                 415
WALKING_UPSTAIRS        0        0         0        4                   4

Pred                WALKING_UPSTAIRS
True
LAYING                             1
SITTING                            0
STANDING                           0
WALKING                           12
WALKING_DOWNSTAIRS                 5
WALKING_UPSTAIRS                 463
```

[28]:
```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================] - 1s 411us/step
```

[30]:
```
score
```

[30]:
```
[0.35375094639873494, 0.9148286581039429]
```

- Updating LSTM layer from 32 to 64 increase the performance from 89.54% to 91.48% and reduce loss from 0.4165 to 0.3537

1.2 Update Dropout Rate
1.2.1 Use 64 LSTM Layer and Dropout rate 0.7

[31]:
```
# update LSTM layers
n_hidden = 64
```

- Defining the Architecture of LSTM

[32]:
```
# 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(0.7))
# Adding a dense output layer with sigmoid activation
model.add(Dense(n_classes, activation='sigmoid'))
model.summary()
```

```
WARNING:tensorflow:Large dropout rate: 0.7 (>0.5). In TensorFlow 2.x, dropout()
uses dropout rate instead of keep_prob. Please ensure that this is intended.
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
_________________________________________________________________
```

[33]:
```
# Compiling the model
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

[34]:
```
# 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 samples
Epoch 1/30
7352/7352 [==============================] - 21s 3ms/step - loss: 1.2668 -
accuracy: 0.4523 - val_loss: 1.0892 - val_accuracy: 0.5199
Epoch 2/30
7352/7352 [==============================] - 20s 3ms/step - loss: 0.9252 -
accuracy: 0.5966 - val_loss: 0.8212 - val_accuracy: 0.6244
Epoch 3/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.7997 -
accuracy: 0.6314 - val_loss: 0.8336 - val_accuracy: 0.6179
Epoch 4/30
7352/7352 [==============================] - 19s 3ms/step - loss: 0.7036 -
accuracy: 0.6722 - val_loss: 0.7824 - val_accuracy: 0.6216
Epoch 5/30
7352/7352 [==============================] - 20s 3ms/step - loss: 0.6839 -
accuracy: 0.7152 - val_loss: 0.6875 - val_accuracy: 0.7248
Epoch 6/30
7352/7352 [==============================] - 21s 3ms/step - loss: 0.5654 -
accuracy: 0.8130 - val_loss: 0.5180 - val_accuracy: 0.8273
Epoch 7/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.4122 -
accuracy: 0.8833 - val_loss: 0.6306 - val_accuracy: 0.8344
Epoch 8/30
```

```
7352/7352 [==============================] - 17s 2ms/step - loss: 0.4030 -
accuracy: 0.8911 - val_loss: 1.1381 - val_accuracy: 0.7255
Epoch 9/30
7352/7352 [==============================] - 17s 2ms/step - loss: 0.3243 -
accuracy: 0.9074 - val_loss: 0.3398 - val_accuracy: 0.8979
Epoch 10/30
7352/7352 [==============================] - 17s 2ms/step - loss: 0.2563 -
accuracy: 0.9255 - val_loss: 0.3548 - val_accuracy: 0.8914
Epoch 11/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.3041 -
accuracy: 0.9191 - val_loss: 0.3749 - val_accuracy: 0.8867
Epoch 12/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.2504 -
accuracy: 0.9257 - val_loss: 0.4726 - val_accuracy: 0.8761
Epoch 13/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.2604 -
accuracy: 0.9285 - val_loss: 0.5156 - val_accuracy: 0.8663
Epoch 14/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.2206 -
accuracy: 0.9331 - val_loss: 0.5957 - val_accuracy: 0.8612
Epoch 15/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.2023 -
accuracy: 0.9324 - val_loss: 0.3542 - val_accuracy: 0.8877
Epoch 16/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.1955 -
accuracy: 0.9385 - val_loss: 0.4524 - val_accuracy: 0.8836
Epoch 17/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.2068 -
accuracy: 0.9372 - val_loss: 0.3065 - val_accuracy: 0.9016
Epoch 18/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.2338 -
accuracy: 0.9358 - val_loss: 0.5638 - val_accuracy: 0.8860
Epoch 19/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.2166 -
accuracy: 0.9362 - val_loss: 0.4288 - val_accuracy: 0.8863
Epoch 20/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.1724 -
accuracy: 0.9431 - val_loss: 0.3221 - val_accuracy: 0.8985
Epoch 21/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.1826 -
accuracy: 0.9438 - val_loss: 0.3623 - val_accuracy: 0.9043
Epoch 22/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.1771 -
accuracy: 0.9430 - val_loss: 0.5044 - val_accuracy: 0.8931
Epoch 23/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.1904 -
accuracy: 0.9426 - val_loss: 0.3908 - val_accuracy: 0.8951
Epoch 24/30
```

```
7352/7352 [==============================] - 16s 2ms/step - loss: 0.1789 -
accuracy: 0.9426 - val_loss: 0.4822 - val_accuracy: 0.9118
Epoch 25/30
7352/7352 [==============================] - 16s 2ms/step - loss: nan -
accuracy: 0.8251 - val_loss: nan - val_accuracy: 0.1683
Epoch 26/30
7352/7352 [==============================] - 16s 2ms/step - loss: nan -
accuracy: 0.1668 - val_loss: nan - val_accuracy: 0.1683
Epoch 27/30
7352/7352 [==============================] - 16s 2ms/step - loss: nan -
accuracy: 0.1668 - val_loss: nan - val_accuracy: 0.1683
Epoch 28/30
7352/7352 [==============================] - 16s 2ms/step - loss: nan -
accuracy: 0.1668 - val_loss: nan - val_accuracy: 0.1683
Epoch 29/30
7352/7352 [==============================] - 16s 2ms/step - loss: nan -
accuracy: 0.1668 - val_loss: nan - val_accuracy: 0.1683
Epoch 30/30
7352/7352 [==============================] - 16s 2ms/step - loss: nan -
accuracy: 0.1668 - val_loss: nan - val_accuracy: 0.1683
```

[34]:
```
<keras.callbacks.callbacks.History at 0x6300a6438>
```

[35]:
```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                WALKING
True
LAYING                  537
SITTING                 491
STANDING                532
WALKING                 496
WALKING_DOWNSTAIRS      420
WALKING_UPSTAIRS        471
```

[36]:
```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================] - 1s 286us/step
```

[37]:
```
score
```

[37]:
```
[nan, 0.16830675303936005]
```

- With dropout 0.7 performance reduced drastically

1.2.2 Use 32 LSTM Layer and Dropout rate 0.7

[38]:
```
# update LSTM layers
n_hidden = 32
```

- Defining the Architecture of LSTM

[39]:
```
# 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(0.7))
# Adding a dense output layer with sigmoid activation
model.add(Dense(n_classes, activation='sigmoid'))
model.summary()
```

```
WARNING:tensorflow:Large dropout rate: 0.7 (>0.5). In TensorFlow 2.x, dropout()
uses dropout rate instead of keep_prob. Please ensure that this is intended.
Model: "sequential_4"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_4 (LSTM)                (None, 32)                5376
_________________________________________________________________
dropout_4 (Dropout)          (None, 32)                0
_________________________________________________________________
dense_4 (Dense)              (None, 6)                 198
=================================================================
Total params: 5,574
Trainable params: 5,574
Non-trainable params: 0
_________________________________________________________________
```

[40]:
```
# Compiling the model
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

[41]:
```
# 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 samples
Epoch 1/30
7352/7352 [==============================] - 15s 2ms/step - loss: 1.4131 -
```

```
accuracy: 0.4053 - val_loss: 1.2057 - val_accuracy: 0.5199
Epoch 2/30
7352/7352 [==============================] - 16s 2ms/step - loss: 1.1514 -
accuracy: 0.5004 - val_loss: 1.0854 - val_accuracy: 0.5212
Epoch 3/30
7352/7352 [==============================] - 14s 2ms/step - loss: 1.0306 -
accuracy: 0.5483 - val_loss: 0.9328 - val_accuracy: 0.6186
Epoch 4/30
7352/7352 [==============================] - 14s 2ms/step - loss: 0.8413 -
accuracy: 0.6328 - val_loss: 0.8098 - val_accuracy: 0.6403
Epoch 5/30
7352/7352 [==============================] - 14s 2ms/step - loss: 0.7508 -
accuracy: 0.6718 - val_loss: 0.7237 - val_accuracy: 0.6481
Epoch 6/30
7352/7352 [==============================] - 14s 2ms/step - loss: 0.7021 -
accuracy: 0.7036 - val_loss: 0.7130 - val_accuracy: 0.6977
Epoch 7/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.6250 -
accuracy: 0.7408 - val_loss: 0.6587 - val_accuracy: 0.7218
Epoch 8/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.6306 -
accuracy: 0.7467 - val_loss: 0.9023 - val_accuracy: 0.6749
Epoch 9/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.5728 -
accuracy: 0.7552 - val_loss: 0.6066 - val_accuracy: 0.7370
Epoch 10/30
7352/7352 [==============================] - 17s 2ms/step - loss: 0.5665 -
accuracy: 0.7582 - val_loss: 0.6308 - val_accuracy: 0.7122
Epoch 11/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.5529 -
accuracy: 0.7632 - val_loss: 0.8747 - val_accuracy: 0.7129
Epoch 12/30
7352/7352 [==============================] - 17s 2ms/step - loss: 0.5008 -
accuracy: 0.7757 - val_loss: 0.5392 - val_accuracy: 0.7513
Epoch 13/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.5068 -
accuracy: 0.7767 - val_loss: 0.5349 - val_accuracy: 0.7448
Epoch 14/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.4965 -
accuracy: 0.7792 - val_loss: 0.7161 - val_accuracy: 0.7313
Epoch 15/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.6753 -
accuracy: 0.7588 - val_loss: 0.5898 - val_accuracy: 0.7448
Epoch 16/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.5031 -
accuracy: 0.7777 - val_loss: 0.7619 - val_accuracy: 0.7245
Epoch 17/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.4484 -
```

```
accuracy: 0.7890 - val_loss: 0.6495 - val_accuracy: 0.7336
Epoch 18/30
7352/7352 [==============================] - 17s 2ms/step - loss: 0.4806 -
accuracy: 0.7837 - val_loss: 0.5810 - val_accuracy: 0.7496
Epoch 19/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.4920 -
accuracy: 0.7875 - val_loss: 0.5989 - val_accuracy: 0.7855
Epoch 20/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.4532 -
accuracy: 0.8157 - val_loss: 0.5946 - val_accuracy: 0.8049
Epoch 21/30
7352/7352 [==============================] - 13s 2ms/step - loss: 0.4626 -
accuracy: 0.8255 - val_loss: 0.4647 - val_accuracy: 0.8317
Epoch 22/30
7352/7352 [==============================] - 13s 2ms/step - loss: 0.4284 -
accuracy: 0.8477 - val_loss: 0.4966 - val_accuracy: 0.8616
Epoch 23/30
7352/7352 [==============================] - 13s 2ms/step - loss: 0.4184 -
accuracy: 0.8561 - val_loss: 0.4365 - val_accuracy: 0.8636
Epoch 24/30
7352/7352 [==============================] - 13s 2ms/step - loss: 0.3954 -
accuracy: 0.8677 - val_loss: 0.4070 - val_accuracy: 0.8778
Epoch 25/30
7352/7352 [==============================] - 13s 2ms/step - loss: 0.3787 -
accuracy: 0.8750 - val_loss: 0.4029 - val_accuracy: 0.8761
Epoch 26/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.4372 -
accuracy: 0.8668 - val_loss: 0.4681 - val_accuracy: 0.8619
Epoch 27/30
7352/7352 [==============================] - 14s 2ms/step - loss: 0.4192 -
accuracy: 0.8783 - val_loss: 0.4248 - val_accuracy: 0.8833
Epoch 28/30
7352/7352 [==============================] - 17s 2ms/step - loss: 0.4191 -
accuracy: 0.8732 - val_loss: 1.1744 - val_accuracy: 0.7923
Epoch 29/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.3634 -
accuracy: 0.8832 - val_loss: 0.4041 - val_accuracy: 0.8907
Epoch 30/30
7352/7352 [==============================] - 14s 2ms/step - loss: 0.3713 -
accuracy: 0.8783 - val_loss: 0.5968 - val_accuracy: 0.8381
```

[41]:
```
<keras.callbacks.callbacks.History at 0x6309d69e8>
```

[42]:
```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                LAYING  SITTING  STANDING  WALKING  WALKING_DOWNSTAIRS  \
True
```

```
LAYING                510        0         0        0                 0
SITTING                 0      280       206        1                 1
STANDING                0       34       489        4                 2
WALKING                 0        0         0      360                33
WALKING_DOWNSTAIRS      0        0         0        3               416
WALKING_UPSTAIRS        1        3         0       28                24

Pred                WALKING_UPSTAIRS
True
LAYING                            27
SITTING                            3
STANDING                           3
WALKING                          103
WALKING_DOWNSTAIRS                 1
WALKING_UPSTAIRS                 415
```

[43]:
```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================] - 1s 243us/step
```

[44]:
```
score
```

[44]:
```
[0.596762544016313, 0.8381404876708984]
```

- Better than 64 layer with same dropout 0.7

1.2.3 Use 64 LSTM Layer and Dropout rate 0.6

[45]:
```
# update LSTM layers
n_hidden = 64
```

- Defining the Architecture of LSTM

[46]:
```
# 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(0.6))
# Adding a dense output layer with sigmoid activation
model.add(Dense(n_classes, activation='sigmoid'))
model.summary()
```

```
WARNING:tensorflow:Large dropout rate: 0.6 (>0.5). In TensorFlow 2.x, dropout()
uses dropout rate instead of keep_prob. Please ensure that this is intended.
Model: "sequential_5"
_________________________________________________________________
```

```
Layer (type)                 Output Shape              Param #
=================================================================
lstm_5 (LSTM)                (None, 64)                18944
_________________________________________________________________
dropout_5 (Dropout)          (None, 64)                0
_________________________________________________________________
dense_5 (Dense)              (None, 6)                 390
=================================================================
Total params: 19,334
Trainable params: 19,334
Non-trainable params: 0
_________________________________________________________________
```

[47]:
```
# Compiling the model
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

[48]:
```
# 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 samples
Epoch 1/30
7352/7352 [==============================] - 19s 3ms/step - loss: 1.2606 -
accuracy: 0.4646 - val_loss: 1.0564 - val_accuracy: 0.5443
Epoch 2/30
7352/7352 [==============================] - 19s 3ms/step - loss: 0.8792 -
accuracy: 0.6002 - val_loss: 0.8393 - val_accuracy: 0.6179
Epoch 3/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.7371 -
accuracy: 0.6447 - val_loss: 0.7495 - val_accuracy: 0.6183
Epoch 4/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.6515 -
accuracy: 0.7088 - val_loss: 0.6700 - val_accuracy: 0.7048
Epoch 5/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.4806 -
accuracy: 0.8392 - val_loss: 0.5685 - val_accuracy: 0.8073
Epoch 6/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.2974 -
accuracy: 0.9057 - val_loss: 0.4664 - val_accuracy: 0.8660
Epoch 7/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.2478 -
accuracy: 0.9236 - val_loss: 0.4457 - val_accuracy: 0.8738
Epoch 8/30
```

```
7352/7352 [==============================] - 18s 2ms/step - loss: 0.2243 -
accuracy: 0.9282 - val_loss: 0.2996 - val_accuracy: 0.8863
Epoch 9/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.2131 -
accuracy: 0.9249 - val_loss: 0.5138 - val_accuracy: 0.8792
Epoch 10/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.2012 -
accuracy: 0.9329 - val_loss: 0.2673 - val_accuracy: 0.8979
Epoch 11/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.1872 -
accuracy: 0.9353 - val_loss: 0.2656 - val_accuracy: 0.9101
Epoch 12/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.1965 -
accuracy: 0.9366 - val_loss: 0.3882 - val_accuracy: 0.9080
Epoch 13/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.1710 -
accuracy: 0.9404 - val_loss: 0.2497 - val_accuracy: 0.9091
Epoch 14/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.1621 -
accuracy: 0.9408 - val_loss: 0.3737 - val_accuracy: 0.8921
Epoch 15/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.1517 -
accuracy: 0.9456 - val_loss: 0.2366 - val_accuracy: 0.9165
Epoch 16/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.1870 -
accuracy: 0.9423 - val_loss: 0.2972 - val_accuracy: 0.9036
Epoch 17/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.1612 -
accuracy: 0.9418 - val_loss: 0.4051 - val_accuracy: 0.8890
Epoch 18/30
7352/7352 [==============================] - 19s 3ms/step - loss: 0.1619 -
accuracy: 0.9434 - val_loss: 0.3921 - val_accuracy: 0.8941
Epoch 19/30
7352/7352 [==============================] - 19s 3ms/step - loss: 0.1394 -
accuracy: 0.9493 - val_loss: 0.5242 - val_accuracy: 0.8985
Epoch 20/30
7352/7352 [==============================] - 20s 3ms/step - loss: 0.1573 -
accuracy: 0.9467 - val_loss: 0.3529 - val_accuracy: 0.9097
Epoch 21/30
7352/7352 [==============================] - 22s 3ms/step - loss: 0.1615 -
accuracy: 0.9499 - val_loss: 0.7128 - val_accuracy: 0.8789
Epoch 22/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.1429 -
accuracy: 0.9518 - val_loss: 0.3295 - val_accuracy: 0.9223
Epoch 23/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.1548 -
accuracy: 0.9479 - val_loss: 0.5361 - val_accuracy: 0.9063
Epoch 24/30
```

```
7352/7352 [==============================] - 20s 3ms/step - loss: 0.1543 -
accuracy: 0.9467 - val_loss: 0.2969 - val_accuracy: 0.9016
Epoch 25/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.1431 -
accuracy: 0.9471 - val_loss: 0.5244 - val_accuracy: 0.9050
Epoch 26/30
7352/7352 [==============================] - 21s 3ms/step - loss: 0.1457 -
accuracy: 0.9499 - val_loss: 0.3353 - val_accuracy: 0.9186
Epoch 27/30
7352/7352 [==============================] - 19s 3ms/step - loss: 0.1532 -
accuracy: 0.9510 - val_loss: 0.5023 - val_accuracy: 0.9074
Epoch 28/30
7352/7352 [==============================] - 20s 3ms/step - loss: 0.1357 -
accuracy: 0.9514 - val_loss: 0.2958 - val_accuracy: 0.9152
Epoch 29/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.1368 -
accuracy: 0.9490 - val_loss: 0.3224 - val_accuracy: 0.9189
Epoch 30/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.1569 -
accuracy: 0.9467 - val_loss: 0.4957 - val_accuracy: 0.9060
```

[48]:
```
<keras.callbacks.callbacks.History at 0x631129d68>
```

[49]:
```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                LAYING  SITTING  STANDING  WALKING  WALKING_DOWNSTAIRS  \
True
LAYING                 517        0        19        0                   0
SITTING                  0      416        74        0                   0
STANDING                 0       94       438        0                   0
WALKING                  0        0         0      495                   0
WALKING_DOWNSTAIRS       0        0         0       15                 377
WALKING_UPSTAIRS         0        0         0       41                   3

Pred                WALKING_UPSTAIRS
True
LAYING                             1
SITTING                            1
STANDING                           0
WALKING                            1
WALKING_DOWNSTAIRS                28
WALKING_UPSTAIRS                 427
```

[50]:
```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================] - 1s 283us/step
```

[51]:
```
score
```

[51]:
```
[0.4956902541945778, 0.9060060977935791]
```

- Better than 0.7 dropout

1.2.4 Use 32 LSTM Layer and Dropout rate 0.6

[52]:
```
# update LSTM layers
n_hidden = 32
```

- Defining the Architecture of LSTM

[53]:
```
# 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(0.6))
# Adding a dense output layer with sigmoid activation
model.add(Dense(n_classes, activation='sigmoid'))
model.summary()
```

```
WARNING:tensorflow:Large dropout rate: 0.6 (>0.5). In TensorFlow 2.x, dropout()
uses dropout rate instead of keep_prob. Please ensure that this is intended.
Model: "sequential_6"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_6 (LSTM)                (None, 32)                5376
_________________________________________________________________
dropout_6 (Dropout)          (None, 32)                0
_________________________________________________________________
dense_6 (Dense)              (None, 6)                 198
=================================================================
Total params: 5,574
Trainable params: 5,574
Non-trainable params: 0
_________________________________________________________________
```

[54]:
```
# Compiling the model
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

[55]:
```
# 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 samples
Epoch 1/30
7352/7352 [==============================] - 17s 2ms/step - loss: 1.3738 -
accuracy: 0.3864 - val_loss: 1.3047 - val_accuracy: 0.4381
Epoch 2/30
7352/7352 [==============================] - 15s 2ms/step - loss: 1.0837 -
accuracy: 0.5292 - val_loss: 1.0199 - val_accuracy: 0.5565
Epoch 3/30
7352/7352 [==============================] - 14s 2ms/step - loss: 0.8871 -
accuracy: 0.6268 - val_loss: 0.8298 - val_accuracy: 0.6121
Epoch 4/30
7352/7352 [==============================] - 14s 2ms/step - loss: 0.7479 -
accuracy: 0.6549 - val_loss: 0.7888 - val_accuracy: 0.6149
Epoch 5/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.7072 -
accuracy: 0.6639 - val_loss: 0.8324 - val_accuracy: 0.6020
Epoch 6/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.6625 -
accuracy: 0.6814 - val_loss: 0.8694 - val_accuracy: 0.5979
Epoch 7/30
7352/7352 [==============================] - 14s 2ms/step - loss: 0.6415 -
accuracy: 0.7081 - val_loss: 0.7401 - val_accuracy: 0.6614
Epoch 8/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.5871 -
accuracy: 0.7678 - val_loss: 0.6918 - val_accuracy: 0.7754
Epoch 9/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.4870 -
accuracy: 0.8341 - val_loss: 0.7611 - val_accuracy: 0.7540
Epoch 10/30
7352/7352 [==============================] - 14s 2ms/step - loss: 0.4380 -
accuracy: 0.8558 - val_loss: 0.6525 - val_accuracy: 0.8022
Epoch 11/30
7352/7352 [==============================] - 14s 2ms/step - loss: 0.4693 -
accuracy: 0.8546 - val_loss: 0.5199 - val_accuracy: 0.8636
Epoch 12/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.3959 -
accuracy: 0.8878 - val_loss: 0.6564 - val_accuracy: 0.8290
Epoch 13/30
7352/7352 [==============================] - 17s 2ms/step - loss: 0.3703 -
accuracy: 0.8953 - val_loss: 0.5741 - val_accuracy: 0.8324
Epoch 14/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.3400 -
accuracy: 0.9029 - val_loss: 0.5634 - val_accuracy: 0.8497
```

```
Epoch 15/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.3523 -
accuracy: 0.8976 - val_loss: 0.6537 - val_accuracy: 0.8449
Epoch 16/30
7352/7352 [==============================] - 17s 2ms/step - loss: 0.3631 -
accuracy: 0.8946 - val_loss: 0.4173 - val_accuracy: 0.8789
Epoch 17/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.3099 -
accuracy: 0.9123 - val_loss: 0.6522 - val_accuracy: 0.8490
Epoch 18/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.3181 -
accuracy: 0.9066 - val_loss: 0.4997 - val_accuracy: 0.8748
Epoch 19/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.2624 -
accuracy: 0.9219 - val_loss: 0.5491 - val_accuracy: 0.8700
Epoch 20/30
7352/7352 [==============================] - 18s 2ms/step - loss: 0.2779 -
accuracy: 0.9229 - val_loss: 0.5618 - val_accuracy: 0.8850
Epoch 21/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.2645 -
accuracy: 0.9272 - val_loss: 0.4384 - val_accuracy: 0.8941
Epoch 22/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.3439 -
accuracy: 0.9105 - val_loss: 0.4841 - val_accuracy: 0.8789
Epoch 23/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.2935 -
accuracy: 0.9139 - val_loss: 0.5743 - val_accuracy: 0.8870
Epoch 24/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.2599 -
accuracy: 0.9293 - val_loss: 0.4404 - val_accuracy: 0.8945
Epoch 25/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.2976 -
accuracy: 0.9149 - val_loss: 0.4465 - val_accuracy: 0.8836
Epoch 26/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.2633 -
accuracy: 0.9237 - val_loss: 0.4992 - val_accuracy: 0.8924
Epoch 27/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.2649 -
accuracy: 0.9261 - val_loss: 0.5707 - val_accuracy: 0.8711
Epoch 28/30
7352/7352 [==============================] - 17s 2ms/step - loss: 0.2830 -
accuracy: 0.9229 - val_loss: 0.4471 - val_accuracy: 0.8887
Epoch 29/30
7352/7352 [==============================] - 16s 2ms/step - loss: 0.2589 -
accuracy: 0.9263 - val_loss: 0.4967 - val_accuracy: 0.8843
Epoch 30/30
7352/7352 [==============================] - 15s 2ms/step - loss: 0.2628 -
accuracy: 0.9279 - val_loss: 0.5602 - val_accuracy: 0.8812
```

[55]:
```
<keras.callbacks.callbacks.History at 0x633723b70>
```

[56]:
```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                LAYING  SITTING  STANDING  WALKING  WALKING_DOWNSTAIRS  \
True
LAYING                 510        0        24        0                   0
SITTING                  3      434        29        7                   0
STANDING                 0      135       379        1                   0
WALKING                  0        1         0      409                  20
WALKING_DOWNSTAIRS       0        0         0        7                 399
WALKING_UPSTAIRS         0        0         0        5                   0

Pred                WALKING_UPSTAIRS
True
LAYING                             3
SITTING                           18
STANDING                          17
WALKING                           66
WALKING_DOWNSTAIRS                14
WALKING_UPSTAIRS                 466
```

[57]:
```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================] - 1s 256us/step
```

[58]:
```
score
```

[58]:
```
[0.5602035771178105, 0.8812351822853088]
```

- It's perform worse than 64 layer with dropout 0.6

1.3 Use 2 LSTM Layers with Larger Dropout
1.3.1 LSTM Layer (64,32) with 2 layer of dropout 0.7

[95]:
```
# update LSTM layers
n_hidden_1 = 64
n_hidden_2 = 32
```

- Initialize the LSTM Architecture

[96]:
```
# https://stackoverflow.com/questions/51763983/
 ↪error-when-checking-target-expected-dense-1-to-have-3-dimensions-but-got-array
# https://github.com/keras-team/keras/issues/7403
# 1. You need to set return_sequences=True from first LSTM
# 2. You need to set return_sequences=True from second LSTM
# Initiliazing the sequential model
```

```
model = Sequential()
# Configuring the parameters
model.add(LSTM(n_hidden_1, input_shape=(timesteps, input_dim),␣
 ↪return_sequences=True))
# Adding a dropout layer
model.add(Dropout(0.7))
# Configuring the parameters
model.add(LSTM(n_hidden_2 , return_sequences=False))
# Adding a dropout layer
model.add(Dropout(0.7))
# Adding a dense output layer with sigmoid activation
model.add(Dense(n_classes, activation='sigmoid'))
model.summary()
```

```
Model: "sequential_28"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_46 (LSTM)               (None, 128, 64)           18944
_________________________________________________________________
dropout_27 (Dropout)         (None, 128, 64)           0
_________________________________________________________________
lstm_47 (LSTM)               (None, 32)                12416
_________________________________________________________________
dropout_28 (Dropout)         (None, 32)                0
_________________________________________________________________
dense_12 (Dense)             (None, 6)                 198
=================================================================
Total params: 31,558
Trainable params: 31,558
Non-trainable params: 0
_________________________________________________________________
```

[97]:
```
# Compiling the model
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

[98]:
```
# 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 samples
Epoch 1/30
```

```
7352/7352 [==============================] - 85s 12ms/step - loss: 1.2737 -
accuracy: 0.4884 - val_loss: 0.9074 - val_accuracy: 0.5938
Epoch 2/30
7352/7352 [==============================] - 88s 12ms/step - loss: 0.8894 -
accuracy: 0.6167 - val_loss: 0.7144 - val_accuracy: 0.6206
Epoch 3/30
7352/7352 [==============================] - 85s 12ms/step - loss: 0.7967 -
accuracy: 0.6294 - val_loss: 0.7580 - val_accuracy: 0.6237
Epoch 4/30
7352/7352 [==============================] - 89s 12ms/step - loss: 0.7435 -
accuracy: 0.6506 - val_loss: 0.7531 - val_accuracy: 0.6216
Epoch 5/30
7352/7352 [==============================] - 89s 12ms/step - loss: 0.7146 -
accuracy: 0.6518 - val_loss: 0.7442 - val_accuracy: 0.6315
Epoch 6/30
7352/7352 [==============================] - 84s 11ms/step - loss: 0.7182 -
accuracy: 0.6578 - val_loss: 0.7171 - val_accuracy: 0.6328
Epoch 7/30
7352/7352 [==============================] - 86s 12ms/step - loss: 0.7103 -
accuracy: 0.6644 - val_loss: 0.8312 - val_accuracy: 0.6189
Epoch 8/30
7352/7352 [==============================] - 83s 11ms/step - loss: 0.6082 -
accuracy: 0.7271 - val_loss: 0.5815 - val_accuracy: 0.7472
Epoch 9/30
7352/7352 [==============================] - 89s 12ms/step - loss: 0.5212 -
accuracy: 0.7779 - val_loss: 0.6235 - val_accuracy: 0.7482
Epoch 10/30
7352/7352 [==============================] - 84s 11ms/step - loss: 0.4809 -
accuracy: 0.7831 - val_loss: 0.4557 - val_accuracy: 0.7560
Epoch 11/30
7352/7352 [==============================] - 89s 12ms/step - loss: 0.4502 -
accuracy: 0.7949 - val_loss: 0.5220 - val_accuracy: 0.7486
Epoch 12/30
7352/7352 [==============================] - 84s 11ms/step - loss: 0.4417 -
accuracy: 0.8214 - val_loss: 0.4750 - val_accuracy: 0.8195
Epoch 13/30
7352/7352 [==============================] - 91s 12ms/step - loss: 0.3882 -
accuracy: 0.8807 - val_loss: 0.6525 - val_accuracy: 0.8300
Epoch 14/30
7352/7352 [==============================] - 90s 12ms/step - loss: 0.3461 -
accuracy: 0.9051 - val_loss: 0.3229 - val_accuracy: 0.8856
Epoch 15/30
7352/7352 [==============================] - 93s 13ms/step - loss: 0.2932 -
accuracy: 0.9212 - val_loss: 0.3832 - val_accuracy: 0.8873
Epoch 16/30
7352/7352 [==============================] - 86s 12ms/step - loss: 0.2834 -
accuracy: 0.9229 - val_loss: 0.4894 - val_accuracy: 0.8565
Epoch 17/30
```

```
7352/7352 [==============================] - 87s 12ms/step - loss: 0.2440 -
accuracy: 0.9328 - val_loss: 0.3598 - val_accuracy: 0.9040
Epoch 18/30
7352/7352 [==============================] - 88s 12ms/step - loss: 0.2287 -
accuracy: 0.9357 - val_loss: 0.2449 - val_accuracy: 0.9070
Epoch 19/30
7352/7352 [==============================] - 90s 12ms/step - loss: 0.2432 -
accuracy: 0.9314 - val_loss: 0.2899 - val_accuracy: 0.9199
Epoch 20/30
7352/7352 [==============================] - 88s 12ms/step - loss: 0.2307 -
accuracy: 0.9343 - val_loss: 0.3551 - val_accuracy: 0.8948
Epoch 21/30
7352/7352 [==============================] - 117s 16ms/step - loss: 0.2071 -
accuracy: 0.9377 - val_loss: 0.3508 - val_accuracy: 0.9145
Epoch 22/30
7352/7352 [==============================] - 106s 14ms/step - loss: 0.2145 -
accuracy: 0.9353 - val_loss: 0.7906 - val_accuracy: 0.8666
Epoch 23/30
7352/7352 [==============================] - 91s 12ms/step - loss: 0.2291 -
accuracy: 0.9347 - val_loss: 0.3717 - val_accuracy: 0.9080
Epoch 24/30
7352/7352 [==============================] - 97s 13ms/step - loss: 0.1955 -
accuracy: 0.9402 - val_loss: 0.3518 - val_accuracy: 0.9182
Epoch 25/30
7352/7352 [==============================] - 77s 10ms/step - loss: 0.2144 -
accuracy: 0.9388 - val_loss: 0.4186 - val_accuracy: 0.9155
Epoch 26/30
7352/7352 [==============================] - 78s 11ms/step - loss: 0.2106 -
accuracy: 0.9389 - val_loss: 0.2988 - val_accuracy: 0.9165
Epoch 27/30
7352/7352 [==============================] - 79s 11ms/step - loss: 0.1955 -
accuracy: 0.9395 - val_loss: 0.3549 - val_accuracy: 0.9046
Epoch 28/30
7352/7352 [==============================] - 75s 10ms/step - loss: nan -
accuracy: 0.3413 - val_loss: nan - val_accuracy: 0.1683
Epoch 29/30
7352/7352 [==============================] - 76s 10ms/step - loss: nan -
accuracy: 0.1668 - val_loss: nan - val_accuracy: 0.1683
Epoch 30/30
7352/7352 [==============================] - 78s 11ms/step - loss: nan -
accuracy: 0.1668 - val_loss: nan - val_accuracy: 0.1683
```

[98]:
```
<keras.callbacks.callbacks.History at 0x63c6b10b8>
```

[99]:
```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                WALKING
```

```
True
LAYING                  537
SITTING                 491
STANDING                532
WALKING                 496
WALKING_DOWNSTAIRS      420
WALKING_UPSTAIRS        471
```

[100]:
```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================] - 4s 1ms/step
```

[101]:
```
score
```

[101]:
```
[nan, 0.16830675303936005]
```

- It's performance is worst

1.3.2 LSTM Layer (64,32) with 2 layer dropout 0.6

[102]:
```
# update LSTM layers
n_hidden_1 = 64
n_hidden_2 = 32
```

- Initialize the LSTM Architecture

[103]:
```
# https://stackoverflow.com/questions/51763983/
 ↪error-when-checking-target-expected-dense-1-to-have-3-dimensions-but-got-array
# https://github.com/keras-team/keras/issues/7403
# 1. You need to set return_sequences=True from first LSTM
# 2. You need to set return_sequences=True from second LSTM
# Initiliazing the sequential model
model = Sequential()
# Configuring the parameters
model.add(LSTM(n_hidden_1, input_shape=(timesteps, input_dim),␣
 ↪return_sequences=True))
# Adding a dropout layer
model.add(Dropout(0.6))
# Configuring the parameters
model.add(LSTM(n_hidden_2 , return_sequences=False))
# Adding a dropout layer
model.add(Dropout(0.6))
# Adding a dense output layer with sigmoid activation
model.add(Dense(n_classes, activation='sigmoid'))
model.summary()
```

```
Model: "sequential_29"
_________________________________________________________________
```

```
Layer (type)                 Output Shape              Param #
=================================================================
lstm_48 (LSTM)               (None, 128, 64)           18944
_________________________________________________________________
dropout_29 (Dropout)         (None, 128, 64)           0
_________________________________________________________________
lstm_49 (LSTM)               (None, 32)                12416
_________________________________________________________________
dropout_30 (Dropout)         (None, 32)                0
_________________________________________________________________
dense_13 (Dense)             (None, 6)                 198
=================================================================
Total params: 31,558
Trainable params: 31,558
Non-trainable params: 0
_________________________________________________________________
```

[104]:
```
# Compiling the model
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

[105]:
```
# 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 samples
Epoch 1/30
7352/7352 [==============================] - 78s 11ms/step - loss: 1.2568 -
accuracy: 0.4778 - val_loss: 1.2977 - val_accuracy: 0.4462
Epoch 2/30
7352/7352 [==============================] - 77s 10ms/step - loss: 0.8864 -
accuracy: 0.6138 - val_loss: 0.8237 - val_accuracy: 0.6179
Epoch 3/30
7352/7352 [==============================] - 79s 11ms/step - loss: 0.7344 -
accuracy: 0.6719 - val_loss: 0.7058 - val_accuracy: 0.6804
Epoch 4/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.6797 -
accuracy: 0.7223 - val_loss: 0.6778 - val_accuracy: 0.7411
Epoch 5/30
7352/7352 [==============================] - 78s 11ms/step - loss: 0.5348 -
accuracy: 0.8092 - val_loss: 0.4354 - val_accuracy: 0.8537
Epoch 6/30
7352/7352 [==============================] - 79s 11ms/step - loss: 0.3872 -
accuracy: 0.8938 - val_loss: 0.4438 - val_accuracy: 0.8799
```

```
Epoch 7/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.3565 -
accuracy: 0.9079 - val_loss: 0.4188 - val_accuracy: 0.8823
Epoch 8/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.2932 -
accuracy: 0.9203 - val_loss: 0.4461 - val_accuracy: 0.8850
Epoch 9/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.2624 -
accuracy: 0.9271 - val_loss: 0.4734 - val_accuracy: 0.8894
Epoch 10/30
7352/7352 [==============================] - 77s 11ms/step - loss: 0.2479 -
accuracy: 0.9272 - val_loss: 0.3673 - val_accuracy: 0.9023
Epoch 11/30
7352/7352 [==============================] - 77s 10ms/step - loss: 0.2425 -
accuracy: 0.9328 - val_loss: 0.4653 - val_accuracy: 0.8839
Epoch 12/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.2103 -
accuracy: 0.9389 - val_loss: 0.3446 - val_accuracy: 0.9030
Epoch 13/30
7352/7352 [==============================] - 74s 10ms/step - loss: 0.1988 -
accuracy: 0.9399 - val_loss: 0.3912 - val_accuracy: 0.9148
Epoch 14/30
7352/7352 [==============================] - 78s 11ms/step - loss: 0.1747 -
accuracy: 0.9414 - val_loss: 0.5197 - val_accuracy: 0.8921
Epoch 15/30
7352/7352 [==============================] - 74s 10ms/step - loss: 0.1786 -
accuracy: 0.9455 - val_loss: 0.6204 - val_accuracy: 0.8945
Epoch 16/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.1747 -
accuracy: 0.9426 - val_loss: 0.3647 - val_accuracy: 0.9087
Epoch 17/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.1764 -
accuracy: 0.9414 - val_loss: 0.7391 - val_accuracy: 0.8799
Epoch 18/30
7352/7352 [==============================] - 78s 11ms/step - loss: 0.1691 -
accuracy: 0.9440 - val_loss: 0.3439 - val_accuracy: 0.9053
Epoch 19/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.1668 -
accuracy: 0.9487 - val_loss: 0.4053 - val_accuracy: 0.9040
Epoch 20/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.1707 -
accuracy: 0.9430 - val_loss: 0.5533 - val_accuracy: 0.8904
Epoch 21/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.1765 -
accuracy: 0.9457 - val_loss: 0.4594 - val_accuracy: 0.9077
Epoch 22/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.2275 -
accuracy: 0.9396 - val_loss: 0.4258 - val_accuracy: 0.9169
```

```
Epoch 23/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.1920 -
accuracy: 0.9434 - val_loss: 0.4475 - val_accuracy: 0.9077
Epoch 24/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.1931 -
accuracy: 0.9445 - val_loss: 0.6805 - val_accuracy: 0.8799
Epoch 25/30
7352/7352 [==============================] - 77s 11ms/step - loss: 0.1535 -
accuracy: 0.9461 - val_loss: 0.4987 - val_accuracy: 0.9006
Epoch 26/30
7352/7352 [==============================] - 75s 10ms/step - loss: nan -
accuracy: 0.6254 - val_loss: nan - val_accuracy: 0.1683
Epoch 27/30
7352/7352 [==============================] - 77s 10ms/step - loss: nan -
accuracy: 0.1668 - val_loss: nan - val_accuracy: 0.1683
Epoch 28/30
7352/7352 [==============================] - 75s 10ms/step - loss: nan -
accuracy: 0.1668 - val_loss: nan - val_accuracy: 0.1683
Epoch 29/30
7352/7352 [==============================] - 79s 11ms/step - loss: nan -
accuracy: 0.1668 - val_loss: nan - val_accuracy: 0.1683
Epoch 30/30
7352/7352 [==============================] - 77s 10ms/step - loss: nan -
accuracy: 0.1668 - val_loss: nan - val_accuracy: 0.1683
```

[105]:
```
<keras.callbacks.callbacks.History at 0x63d0cecf8>
```

[106]:
```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                WALKING
True
LAYING                  537
SITTING                 491
STANDING                532
WALKING                 496
WALKING_DOWNSTAIRS      420
WALKING_UPSTAIRS        471
```

[107]:
```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================] - 4s 1ms/step
```

[108]:
```
score
```

[108]:
```
[nan, 0.16830675303936005]
```

- It's performance is worst

1.3.3 LSTM Layer (64,32) with 2 layer dropout 0.5

[110]:
```
# update LSTM layers
n_hidden_1 = 64
n_hidden_2 = 32
```

[111]:
```
# https://stackoverflow.com/questions/51763983/
 ↪error-when-checking-target-expected-dense-1-to-have-3-dimensions-but-got-array
# https://github.com/keras-team/keras/issues/7403
# 1. You need to set return_sequences=True from first LSTM
# 2. You need to set return_sequences=True from second LSTM
# Initiliazing the sequential model
model = Sequential()
# Configuring the parameters
model.add(LSTM(n_hidden_1, input_shape=(timesteps, input_dim),␣
 ↪return_sequences=True))
# Adding a dropout layer
model.add(Dropout(0.5))
# Configuring the parameters
model.add(LSTM(n_hidden_2 , return_sequences=False))
# 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_30"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_50 (LSTM)               (None, 128, 64)           18944
_________________________________________________________________
dropout_31 (Dropout)         (None, 128, 64)           0
_________________________________________________________________
lstm_51 (LSTM)               (None, 32)                12416
_________________________________________________________________
dropout_32 (Dropout)         (None, 32)                0
_________________________________________________________________
dense_14 (Dense)             (None, 6)                 198
=================================================================
Total params: 31,558
Trainable params: 31,558
Non-trainable params: 0
_________________________________________________________________
```

[112]:
```
# Compiling the model
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

[113]:
```
# 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 samples
Epoch 1/30
7352/7352 [==============================] - 96s 13ms/step - loss: 1.0873 -
accuracy: 0.5563 - val_loss: 0.7762 - val_accuracy: 0.7038
Epoch 2/30
7352/7352 [==============================] - 95s 13ms/step - loss: 0.6862 -
accuracy: 0.7337 - val_loss: 0.5855 - val_accuracy: 0.7299
Epoch 3/30
7352/7352 [==============================] - 118s 16ms/step - loss: 0.5282 -
accuracy: 0.7763 - val_loss: 0.5286 - val_accuracy: 0.7615
Epoch 4/30
7352/7352 [==============================] - 93s 13ms/step - loss: 0.4156 -
accuracy: 0.8392 - val_loss: 0.4071 - val_accuracy: 0.8819
Epoch 5/30
7352/7352 [==============================] - 81s 11ms/step - loss: 0.2848 -
accuracy: 0.9139 - val_loss: 0.4556 - val_accuracy: 0.8755
Epoch 6/30
7352/7352 [==============================] - 80s 11ms/step - loss: 0.2346 -
accuracy: 0.9327 - val_loss: 0.5155 - val_accuracy: 0.8731
Epoch 7/30
7352/7352 [==============================] - 83s 11ms/step - loss: 0.2368 -
accuracy: 0.9323 - val_loss: 0.4285 - val_accuracy: 0.8772
Epoch 8/30
7352/7352 [==============================] - 84s 11ms/step - loss: 0.2111 -
accuracy: 0.9358 - val_loss: 0.3157 - val_accuracy: 0.9057
Epoch 9/30
7352/7352 [==============================] - 82s 11ms/step - loss: 0.1866 -
accuracy: 0.9404 - val_loss: 0.4269 - val_accuracy: 0.9019
Epoch 10/30
7352/7352 [==============================] - 82s 11ms/step - loss: 0.1835 -
accuracy: 0.9389 - val_loss: 0.2840 - val_accuracy: 0.9108
Epoch 11/30
7352/7352 [==============================] - 82s 11ms/step - loss: 0.1625 -
accuracy: 0.9470 - val_loss: 0.3311 - val_accuracy: 0.9077
Epoch 12/30
7352/7352 [==============================] - 82s 11ms/step - loss: 0.1528 -
accuracy: 0.9460 - val_loss: 0.4299 - val_accuracy: 0.9145
Epoch 13/30
7352/7352 [==============================] - 82s 11ms/step - loss: 0.1541 -
accuracy: 0.9434 - val_loss: 0.3474 - val_accuracy: 0.9199
```

```
Epoch 14/30
7352/7352 [==============================] - 83s 11ms/step - loss: 0.1506 -
accuracy: 0.9464 - val_loss: 0.4714 - val_accuracy: 0.8968
Epoch 15/30
7352/7352 [==============================] - 83s 11ms/step - loss: 0.1506 -
accuracy: 0.9482 - val_loss: 0.4906 - val_accuracy: 0.9104
Epoch 16/30
7352/7352 [==============================] - 78s 11ms/step - loss: 0.1481 -
accuracy: 0.9486 - val_loss: 0.5460 - val_accuracy: 0.9023
Epoch 17/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.1604 -
accuracy: 0.9490 - val_loss: 0.4505 - val_accuracy: 0.9057
Epoch 18/30
7352/7352 [==============================] - 77s 10ms/step - loss: 0.1389 -
accuracy: 0.9510 - val_loss: 0.5048 - val_accuracy: 0.9036
Epoch 19/30
7352/7352 [==============================] - 77s 11ms/step - loss: 0.1574 -
accuracy: 0.9479 - val_loss: 0.6674 - val_accuracy: 0.8880
Epoch 20/30
7352/7352 [==============================] - 77s 10ms/step - loss: 0.1591 -
accuracy: 0.9509 - val_loss: 0.5377 - val_accuracy: 0.9118
Epoch 21/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.1516 -
accuracy: 0.9474 - val_loss: 0.3849 - val_accuracy: 0.9030
Epoch 22/30
7352/7352 [==============================] - 79s 11ms/step - loss: 0.1376 -
accuracy: 0.9524 - val_loss: 0.9215 - val_accuracy: 0.8877
Epoch 23/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.1471 -
accuracy: 0.9508 - val_loss: 0.5519 - val_accuracy: 0.9074
Epoch 24/30
7352/7352 [==============================] - 78s 11ms/step - loss: 0.1971 -
accuracy: 0.9373 - val_loss: 0.6929 - val_accuracy: 0.8823
Epoch 25/30
7352/7352 [==============================] - 78s 11ms/step - loss: 0.1533 -
accuracy: 0.9482 - val_loss: 0.6994 - val_accuracy: 0.8867
Epoch 26/30
7352/7352 [==============================] - 123s 17ms/step - loss: 0.1517 -
accuracy: 0.9510 - val_loss: 0.4023 - val_accuracy: 0.8948
Epoch 27/30
7352/7352 [==============================] - 88s 12ms/step - loss: 0.1306 -
accuracy: 0.9523 - val_loss: 0.4267 - val_accuracy: 0.9036
Epoch 28/30
7352/7352 [==============================] - 78s 11ms/step - loss: 0.1561 -
accuracy: 0.9476 - val_loss: 0.5926 - val_accuracy: 0.9114
Epoch 29/30
7352/7352 [==============================] - 84s 11ms/step - loss: 0.1539 -
accuracy: 0.9452 - val_loss: 0.5725 - val_accuracy: 0.9030
```

```
Epoch 30/30
7352/7352 [==============================] - 80s 11ms/step - loss: 0.1292 -
accuracy: 0.9533 - val_loss: 0.6457 - val_accuracy: 0.9002
```

[113]:
```
<keras.callbacks.callbacks.History at 0x63f20dd30>
```

[114]:
```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                LAYING  SITTING  STANDING  WALKING  WALKING_DOWNSTAIRS  \
True
LAYING                 510        0        27        0                   0
SITTING                  0      397        91        0                   0
STANDING                 0       92       440        0                   0
WALKING                  0        1         1      458                  28
WALKING_DOWNSTAIRS       0        0         0        1                 410
WALKING_UPSTAIRS         1        0         6       16                  10

Pred                WALKING_UPSTAIRS
True
LAYING                             0
SITTING                            3
STANDING                           0
WALKING                            8
WALKING_DOWNSTAIRS                 9
WALKING_UPSTAIRS                 438
```

[115]:
```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================] - 4s 1ms/step
```

[116]:
```
score
```

[116]:
```
[0.6456601167650766, 0.900237500667572]
```

- It's performance is better than 0.7 and 0.6 but loss is considerably high

1.3.4 LSTM Layer (64,32) with 1 layer of dropout 0.7

[117]:
```
# update LSTM layers
n_hidden_1 = 64
n_hidden_2 = 32
```

[118]:
```
# https://stackoverflow.com/questions/51763983/
 ↪error-when-checking-target-expected-dense-1-to-have-3-dimensions-but-got-array
# https://github.com/keras-team/keras/issues/7403
# 1. You need to set return_sequences=True from first LSTM
# 2. You need to set return_sequences=True from second LSTM
# Initiliazing the sequential model
```

```
model = Sequential()
# Configuring the parameters
model.add(LSTM(n_hidden_1, input_shape=(timesteps, input_dim),␣
 ↪return_sequences=True))
# Adding a dropout layer
# model.add(Dropout(0.5))
# Configuring the parameters
model.add(LSTM(n_hidden_2 , return_sequences=False))
# Adding a dropout layer
model.add(Dropout(0.7))
# Adding a dense output layer with sigmoid activation
model.add(Dense(n_classes, activation='sigmoid'))
model.summary()
```

```
Model: "sequential_31"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_52 (LSTM)               (None, 128, 64)           18944
_________________________________________________________________
lstm_53 (LSTM)               (None, 32)                12416
_________________________________________________________________
dropout_33 (Dropout)         (None, 32)                0
_________________________________________________________________
dense_15 (Dense)             (None, 6)                 198
=================================================================
Total params: 31,558
Trainable params: 31,558
Non-trainable params: 0
_________________________________________________________________
```

[119]:
```
# Compiling the model
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

[120]:
```
# 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 samples
Epoch 1/30
7352/7352 [==============================] - 97s 13ms/step - loss: 1.2252 -
accuracy: 0.4883 - val_loss: 0.9514 - val_accuracy: 0.5755
```

```
Epoch 2/30
7352/7352 [==============================] - 82s 11ms/step - loss: 0.8989 -
accuracy: 0.6023 - val_loss: 0.7508 - val_accuracy: 0.6498
Epoch 3/30
7352/7352 [==============================] - 81s 11ms/step - loss: 0.7873 -
accuracy: 0.6359 - val_loss: 0.7832 - val_accuracy: 0.6159
Epoch 4/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.7230 -
accuracy: 0.6726 - val_loss: 0.8069 - val_accuracy: 0.5959
Epoch 5/30
7352/7352 [==============================] - 78s 11ms/step - loss: 0.6513 -
accuracy: 0.6876 - val_loss: 0.7456 - val_accuracy: 0.6227
Epoch 6/30
7352/7352 [==============================] - 80s 11ms/step - loss: 0.5906 -
accuracy: 0.7155 - val_loss: 0.6538 - val_accuracy: 0.7469
Epoch 7/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.5490 -
accuracy: 0.7606 - val_loss: 0.5527 - val_accuracy: 0.7784
Epoch 8/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.5179 -
accuracy: 0.7835 - val_loss: 0.5049 - val_accuracy: 0.7720
Epoch 9/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.4791 -
accuracy: 0.8198 - val_loss: 0.5555 - val_accuracy: 0.8599
Epoch 10/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.4130 -
accuracy: 0.8700 - val_loss: 0.4166 - val_accuracy: 0.8751
Epoch 11/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.3465 -
accuracy: 0.9037 - val_loss: 0.3210 - val_accuracy: 0.8965
Epoch 12/30
7352/7352 [==============================] - 77s 11ms/step - loss: 0.2978 -
accuracy: 0.9174 - val_loss: 0.3080 - val_accuracy: 0.9067
Epoch 13/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.2804 -
accuracy: 0.9202 - val_loss: 0.3070 - val_accuracy: 0.9145
Epoch 14/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.2638 -
accuracy: 0.9248 - val_loss: 0.3665 - val_accuracy: 0.9057
Epoch 15/30
7352/7352 [==============================] - 77s 10ms/step - loss: 0.2558 -
accuracy: 0.9266 - val_loss: 0.3212 - val_accuracy: 0.9125
Epoch 16/30
7352/7352 [==============================] - 87s 12ms/step - loss: 0.2393 -
accuracy: 0.9369 - val_loss: 0.3172 - val_accuracy: 0.9148
Epoch 17/30
7352/7352 [==============================] - 93s 13ms/step - loss: 0.2349 -
accuracy: 0.9370 - val_loss: 0.3730 - val_accuracy: 0.9135
```

```
Epoch 18/30
7352/7352 [==============================] - 89s 12ms/step - loss: 0.2188 -
accuracy: 0.9378 - val_loss: 0.3914 - val_accuracy: 0.9030
Epoch 19/30
7352/7352 [==============================] - 92s 13ms/step - loss: 0.2022 -
accuracy: 0.9384 - val_loss: 0.3416 - val_accuracy: 0.9274
Epoch 20/30
7352/7352 [==============================] - 81s 11ms/step - loss: 0.1937 -
accuracy: 0.9403 - val_loss: 0.3226 - val_accuracy: 0.9199
Epoch 21/30
7352/7352 [==============================] - 80s 11ms/step - loss: 0.2018 -
accuracy: 0.9391 - val_loss: 0.3630 - val_accuracy: 0.9135
Epoch 22/30
7352/7352 [==============================] - 80s 11ms/step - loss: nan -
accuracy: 0.5140 - val_loss: nan - val_accuracy: 0.1683
Epoch 23/30
7352/7352 [==============================] - 86s 12ms/step - loss: nan -
accuracy: 0.1668 - val_loss: nan - val_accuracy: 0.1683
Epoch 24/30
7352/7352 [==============================] - 85s 12ms/step - loss: nan -
accuracy: 0.1668 - val_loss: nan - val_accuracy: 0.1683
Epoch 25/30
7352/7352 [==============================] - 110s 15ms/step - loss: nan -
accuracy: 0.1668 - val_loss: nan - val_accuracy: 0.1683
Epoch 26/30
7352/7352 [==============================] - 90s 12ms/step - loss: nan -
accuracy: 0.1668 - val_loss: nan - val_accuracy: 0.1683
Epoch 27/30
7352/7352 [==============================] - 87s 12ms/step - loss: nan -
accuracy: 0.1668 - val_loss: nan - val_accuracy: 0.1683
Epoch 28/30
7352/7352 [==============================] - 87s 12ms/step - loss: nan -
accuracy: 0.1668 - val_loss: nan - val_accuracy: 0.1683
Epoch 29/30
7352/7352 [==============================] - 120s 16ms/step - loss: nan -
accuracy: 0.1668 - val_loss: nan - val_accuracy: 0.1683
Epoch 30/30
7352/7352 [==============================] - 122s 17ms/step - loss: nan -
accuracy: 0.1668 - val_loss: nan - val_accuracy: 0.1683
```

[120]:
```
<keras.callbacks.callbacks.History at 0x640211cc0>
```

[121]:
```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                WALKING
True
LAYING                  537
```

```
SITTING                 491
STANDING                532
WALKING                 496
WALKING_DOWNSTAIRS      420
WALKING_UPSTAIRS        471
```

[122]:
```
score = model.evaluate(X_test, Y_test)
```

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

[123]:
```
score
```

[123]:
```
[nan, 0.16830675303936005]
```

- It's performance is worst

1.3.5 LSTM Layer (64,32) with 1 layer of dropout 0.6

[124]:
```
# update LSTM layers
n_hidden_1 = 64
n_hidden_2 = 32
```

[125]:
```
# https://stackoverflow.com/questions/51763983/
 ↪error-when-checking-target-expected-dense-1-to-have-3-dimensions-but-got-array
# https://github.com/keras-team/keras/issues/7403
# 1. You need to set return_sequences=True from first LSTM
# 2. You need to set return_sequences=True from second LSTM
# Initiliazing the sequential model
model = Sequential()
# Configuring the parameters
model.add(LSTM(n_hidden_1, input_shape=(timesteps, input_dim),␣
 ↪return_sequences=True))
# Adding a dropout layer
# model.add(Dropout(0.5))
# Configuring the parameters
model.add(LSTM(n_hidden_2 , return_sequences=False))
# Adding a dropout layer
model.add(Dropout(0.6))
# Adding a dense output layer with sigmoid activation
model.add(Dense(n_classes, activation='sigmoid'))
model.summary()
```

```
Model: "sequential_32"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_54 (LSTM)               (None, 128, 64)           18944
_________________________________________________________________
```

```
lstm_55 (LSTM)               (None, 32)                12416
_________________________________________________________________
dropout_34 (Dropout)         (None, 32)                0
_________________________________________________________________
dense_16 (Dense)             (None, 6)                 198
=================================================================
Total params: 31,558
Trainable params: 31,558
Non-trainable params: 0
_________________________________________________________________
```

[126]:
```
# Compiling the model
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

[127]:
```
# 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 samples
Epoch 1/30
7352/7352 [==============================] - 118s 16ms/step - loss: 1.2553 -
accuracy: 0.4732 - val_loss: 0.9856 - val_accuracy: 0.6434
Epoch 2/30
7352/7352 [==============================] - 108s 15ms/step - loss: 0.9545 -
accuracy: 0.6049 - val_loss: 0.8514 - val_accuracy: 0.6244
Epoch 3/30
7352/7352 [==============================] - 136s 18ms/step - loss: 0.7894 -
accuracy: 0.6738 - val_loss: 0.6679 - val_accuracy: 0.7408
Epoch 4/30
7352/7352 [==============================] - 119s 16ms/step - loss: 0.6387 -
accuracy: 0.7881 - val_loss: 0.5631 - val_accuracy: 0.7842
Epoch 5/30
7352/7352 [==============================] - 93s 13ms/step - loss: 0.4644 -
accuracy: 0.8754 - val_loss: 0.4742 - val_accuracy: 0.8548
Epoch 6/30
7352/7352 [==============================] - 80s 11ms/step - loss: 0.3441 -
accuracy: 0.9072 - val_loss: 0.3645 - val_accuracy: 0.8972
Epoch 7/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.3192 -
accuracy: 0.9155 - val_loss: 0.4117 - val_accuracy: 0.8904
Epoch 8/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.3052 -
accuracy: 0.9158 - val_loss: 0.4517 - val_accuracy: 0.8768
```

```
Epoch 9/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.2712 -
accuracy: 0.9221 - val_loss: 0.3708 - val_accuracy: 0.9002
Epoch 10/30
7352/7352 [==============================] - 77s 10ms/step - loss: 0.2295 -
accuracy: 0.9372 - val_loss: 0.3945 - val_accuracy: 0.9108
Epoch 11/30
7352/7352 [==============================] - 77s 11ms/step - loss: 0.2267 -
accuracy: 0.9385 - val_loss: 0.5272 - val_accuracy: 0.8935
Epoch 12/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.2112 -
accuracy: 0.9363 - val_loss: 0.4001 - val_accuracy: 0.9060
Epoch 13/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.2116 -
accuracy: 0.9414 - val_loss: 0.4747 - val_accuracy: 0.9023
Epoch 14/30
7352/7352 [==============================] - 82s 11ms/step - loss: 0.2028 -
accuracy: 0.9385 - val_loss: 0.4646 - val_accuracy: 0.9070
Epoch 15/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.1896 -
accuracy: 0.9414 - val_loss: 0.4164 - val_accuracy: 0.9033
Epoch 16/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.1874 -
accuracy: 0.9423 - val_loss: 0.2969 - val_accuracy: 0.9179
Epoch 17/30
7352/7352 [==============================] - 81s 11ms/step - loss: 0.1810 -
accuracy: 0.9399 - val_loss: 0.2758 - val_accuracy: 0.9182
Epoch 18/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.1782 -
accuracy: 0.9425 - val_loss: 0.5199 - val_accuracy: 0.8941
Epoch 19/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.1690 -
accuracy: 0.9476 - val_loss: 0.3118 - val_accuracy: 0.9213
Epoch 20/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.1558 -
accuracy: 0.9433 - val_loss: 0.4242 - val_accuracy: 0.9155
Epoch 21/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.1561 -
accuracy: 0.9505 - val_loss: 0.4087 - val_accuracy: 0.9026
Epoch 22/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.1585 -
accuracy: 0.9467 - val_loss: 0.4679 - val_accuracy: 0.9019
Epoch 23/30
7352/7352 [==============================] - 78s 11ms/step - loss: 0.1696 -
accuracy: 0.9452 - val_loss: 0.4305 - val_accuracy: 0.8999
Epoch 24/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.1605 -
accuracy: 0.9479 - val_loss: 0.4813 - val_accuracy: 0.9019
```

```
Epoch 25/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.1505 -
accuracy: 0.9480 - val_loss: 0.5688 - val_accuracy: 0.9016
Epoch 26/30
7352/7352 [==============================] - 77s 11ms/step - loss: 0.1430 -
accuracy: 0.9498 - val_loss: 0.5675 - val_accuracy: 0.8951
Epoch 27/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.1477 -
accuracy: 0.9498 - val_loss: 0.6166 - val_accuracy: 0.8989
Epoch 28/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.1605 -
accuracy: 0.9445 - val_loss: 0.3368 - val_accuracy: 0.9169
Epoch 29/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.1704 -
accuracy: 0.9456 - val_loss: 0.3571 - val_accuracy: 0.9175
Epoch 30/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.1643 -
accuracy: 0.9449 - val_loss: 0.5376 - val_accuracy: 0.9053
```

[127]:
```
<keras.callbacks.callbacks.History at 0x63edc1a58>
```

[128]:
```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                LAYING  SITTING  STANDING  WALKING  WALKING_DOWNSTAIRS  \
True
LAYING                 512        0        25        0                   0
SITTING                  2      400        87        0                   0
STANDING                 0       95       436        1                   0
WALKING                  0        0         0      450                   3
WALKING_DOWNSTAIRS       0        0         0        2                 414
WALKING_UPSTAIRS         1        0         0       11                   3

Pred                WALKING_UPSTAIRS
True
LAYING                             0
SITTING                            2
STANDING                           0
WALKING                           43
WALKING_DOWNSTAIRS                 4
WALKING_UPSTAIRS                 456
```

[129]:
```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================] - 4s 1ms/step
```

[130]:
```
score
```

[130]:
```
[0.5375813010956876, 0.9053274393081665]
```

- It's performance is better but loss is higher

1.3.6 LSTM Layer (64,32) with 1 layer of dropout 0.5

[131]:
```
# update LSTM layers
n_hidden_1 = 64
n_hidden_2 = 32
```

[132]:
```
# https://stackoverflow.com/questions/51763983/
 ↪error-when-checking-target-expected-dense-1-to-have-3-dimensions-but-got-array
# https://github.com/keras-team/keras/issues/7403
# 1. You need to set return_sequences=True from first LSTM
# 2. You need to set return_sequences=True from second LSTM
# Initiliazing the sequential model
model = Sequential()
# Configuring the parameters
model.add(LSTM(n_hidden_1, input_shape=(timesteps, input_dim),␣
 ↪return_sequences=True))
# Adding a dropout layer
# model.add(Dropout(0.5))
# Configuring the parameters
model.add(LSTM(n_hidden_2 , return_sequences=False))
# 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_33"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_56 (LSTM)               (None, 128, 64)           18944
_________________________________________________________________
lstm_57 (LSTM)               (None, 32)                12416
_________________________________________________________________
dropout_35 (Dropout)         (None, 32)                0
_________________________________________________________________
dense_17 (Dense)             (None, 6)                 198
=================================================================
Total params: 31,558
Trainable params: 31,558
Non-trainable params: 0
_________________________________________________________________
```

[133]:
```
# Compiling the model
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

[134]:
```
# 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 samples
Epoch 1/30
7352/7352 [==============================] - 80s 11ms/step - loss: 1.1323 -
accuracy: 0.5397 - val_loss: 0.8477 - val_accuracy: 0.6787
Epoch 2/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.7404 -
accuracy: 0.7203 - val_loss: 0.5979 - val_accuracy: 0.7699
Epoch 3/30
7352/7352 [==============================] - 74s 10ms/step - loss: 0.5092 -
accuracy: 0.8400 - val_loss: 1.2509 - val_accuracy: 0.6763
Epoch 4/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.3954 -
accuracy: 0.8917 - val_loss: 0.4537 - val_accuracy: 0.8300
Epoch 5/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.2696 -
accuracy: 0.9217 - val_loss: 0.3626 - val_accuracy: 0.8887
Epoch 6/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.2443 -
accuracy: 0.9300 - val_loss: 0.3439 - val_accuracy: 0.8975
Epoch 7/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.2122 -
accuracy: 0.9350 - val_loss: 0.4547 - val_accuracy: 0.8996
Epoch 8/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.2518 -
accuracy: 0.9225 - val_loss: 0.3921 - val_accuracy: 0.8982
Epoch 9/30
7352/7352 [==============================] - 78s 11ms/step - loss: 0.1827 -
accuracy: 0.9440 - val_loss: 0.3997 - val_accuracy: 0.9019
Epoch 10/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.1704 -
accuracy: 0.9460 - val_loss: 0.4512 - val_accuracy: 0.8782
Epoch 11/30
7352/7352 [==============================] - 73s 10ms/step - loss: 0.1747 -
accuracy: 0.9406 - val_loss: 0.3169 - val_accuracy: 0.9080
Epoch 12/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.1636 -
```

```
accuracy: 0.9459 - val_loss: 0.2829 - val_accuracy: 0.9162
Epoch 13/30
7352/7352 [==============================] - 77s 10ms/step - loss: 0.1427 -
accuracy: 0.9514 - val_loss: 0.3661 - val_accuracy: 0.9013
Epoch 14/30
7352/7352 [==============================] - 74s 10ms/step - loss: 0.1546 -
accuracy: 0.9475 - val_loss: 0.3250 - val_accuracy: 0.9128
Epoch 15/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.1498 -
accuracy: 0.9518 - val_loss: 0.4040 - val_accuracy: 0.9046
Epoch 16/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.1360 -
accuracy: 0.9525 - val_loss: 0.3080 - val_accuracy: 0.9087
Epoch 17/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.1641 -
accuracy: 0.9431 - val_loss: 0.3339 - val_accuracy: 0.9189
Epoch 18/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.1443 -
accuracy: 0.9497 - val_loss: 0.3439 - val_accuracy: 0.9084
Epoch 19/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.1435 -
accuracy: 0.9494 - val_loss: 0.2949 - val_accuracy: 0.9104
Epoch 20/30
7352/7352 [==============================] - 77s 10ms/step - loss: 0.1318 -
accuracy: 0.9543 - val_loss: 0.4108 - val_accuracy: 0.9074
Epoch 21/30
7352/7352 [==============================] - 74s 10ms/step - loss: 0.1448 -
accuracy: 0.9509 - val_loss: 0.3502 - val_accuracy: 0.9135
Epoch 22/30
7352/7352 [==============================] - 73s 10ms/step - loss: 0.1454 -
accuracy: 0.9495 - val_loss: 0.3810 - val_accuracy: 0.9101
Epoch 23/30
7352/7352 [==============================] - 77s 10ms/step - loss: 0.1220 -
accuracy: 0.9547 - val_loss: 0.4707 - val_accuracy: 0.9040
Epoch 24/30
7352/7352 [==============================] - 78s 11ms/step - loss: 0.1434 -
accuracy: 0.9487 - val_loss: 0.4171 - val_accuracy: 0.9087
Epoch 25/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.1398 -
accuracy: 0.9506 - val_loss: 0.3381 - val_accuracy: 0.9179
Epoch 26/30
7352/7352 [==============================] - 74s 10ms/step - loss: 0.1377 -
accuracy: 0.9504 - val_loss: 0.3495 - val_accuracy: 0.9114
Epoch 27/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.1352 -
accuracy: 0.9512 - val_loss: 0.3892 - val_accuracy: 0.9175
Epoch 28/30
7352/7352 [==============================] - 76s 10ms/step - loss: 0.1536 -
```

```
accuracy: 0.9480 - val_loss: 0.5848 - val_accuracy: 0.8985
Epoch 29/30
7352/7352 [==============================] - 77s 11ms/step - loss: 0.1492 -
accuracy: 0.9535 - val_loss: 0.4154 - val_accuracy: 0.9135
Epoch 30/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.1280 -
accuracy: 0.9525 - val_loss: 0.3805 - val_accuracy: 0.9141
```

[134]:
```
<keras.callbacks.callbacks.History at 0x64262e940>
```

[135]:
```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                LAYING  SITTING  STANDING  WALKING  WALKING_DOWNSTAIRS  \
True
LAYING                 510        0        25        0                   0
SITTING                  3      416        68        0                   2
STANDING                 0       96       434        1                   0
WALKING                  0        0         2      473                  20
WALKING_DOWNSTAIRS       0        0         0        4                 413
WALKING_UPSTAIRS         0        1         6       16                   0

Pred                WALKING_UPSTAIRS
True
LAYING                             2
SITTING                            2
STANDING                           1
WALKING                            1
WALKING_DOWNSTAIRS                 3
WALKING_UPSTAIRS                 448
```

[136]:
```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================] - 4s 1ms/step
```

[137]:
```
score
```

[137]:
```
[0.3804781971405892, 0.9141499996185303]
```

- It's perform much better compared to 0.6 and 0.7

1.3.7 LSTM Layer (64,16) with dropout 0.5

[141]:
```
# update LSTM layers
n_hidden_1 = 64
n_hidden_2 = 16
```

- Initialize the LSTM Architecture

[142]:
```
# https://stackoverflow.com/questions/51763983/
 ↪error-when-checking-target-expected-dense-1-to-have-3-dimensions-but-got-array
# https://github.com/keras-team/keras/issues/7403
# 1. You need to set return_sequences=True from first LSTM
# 2. You need to set return_sequences=True from second LSTM
# Initiliazing the sequential model
model = Sequential()
# Configuring the parameters
model.add(LSTM(n_hidden_1, input_shape=(timesteps, input_dim),␣
 ↪return_sequences=True))
# Adding a dropout layer
# model.add(Dropout(0.6))
# Configuring the parameters
model.add(LSTM(n_hidden_2 , return_sequences=False))
# 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_35"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_60 (LSTM)               (None, 128, 64)           18944
_________________________________________________________________
lstm_61 (LSTM)               (None, 16)                5184
_________________________________________________________________
dropout_37 (Dropout)         (None, 16)                0
_________________________________________________________________
dense_19 (Dense)             (None, 6)                 102
=================================================================
Total params: 24,230
Trainable params: 24,230
Non-trainable params: 0
_________________________________________________________________
```

[143]:
```
# Compiling the model
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

[144]:
```
# 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 samples
Epoch 1/30
7352/7352 [==============================] - 87s 12ms/step - loss: 1.2980 -
accuracy: 0.5016 - val_loss: 1.0061 - val_accuracy: 0.5796
Epoch 2/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.9582 -
accuracy: 0.6060 - val_loss: 0.8328 - val_accuracy: 0.6495
Epoch 3/30
7352/7352 [==============================] - 80s 11ms/step - loss: 0.8071 -
accuracy: 0.7008 - val_loss: 0.6999 - val_accuracy: 0.7710
Epoch 4/30
7352/7352 [==============================] - 79s 11ms/step - loss: 0.6449 -
accuracy: 0.7953 - val_loss: 0.5793 - val_accuracy: 0.8297
Epoch 5/30
7352/7352 [==============================] - 82s 11ms/step - loss: 0.5014 -
accuracy: 0.8687 - val_loss: 0.5518 - val_accuracy: 0.8422
Epoch 6/30
7352/7352 [==============================] - 82s 11ms/step - loss: 0.4958 -
accuracy: 0.8734 - val_loss: 0.3736 - val_accuracy: 0.8860
Epoch 7/30
7352/7352 [==============================] - 81s 11ms/step - loss: 0.3628 -
accuracy: 0.9060 - val_loss: 0.4399 - val_accuracy: 0.8860
Epoch 8/30
7352/7352 [==============================] - 82s 11ms/step - loss: 0.3272 -
accuracy: 0.9119 - val_loss: 0.3274 - val_accuracy: 0.9030
Epoch 9/30
7352/7352 [==============================] - 79s 11ms/step - loss: 0.2879 -
accuracy: 0.9218 - val_loss: 0.3329 - val_accuracy: 0.9009
Epoch 10/30
7352/7352 [==============================] - 80s 11ms/step - loss: 0.2658 -
accuracy: 0.9252 - val_loss: 0.6884 - val_accuracy: 0.8347
Epoch 11/30
7352/7352 [==============================] - 77s 10ms/step - loss: 0.2757 -
accuracy: 0.9193 - val_loss: 0.4459 - val_accuracy: 0.8955
Epoch 12/30
7352/7352 [==============================] - 88s 12ms/step - loss: 0.2671 -
accuracy: 0.9245 - val_loss: 0.3746 - val_accuracy: 0.9070
Epoch 13/30
7352/7352 [==============================] - 92s 12ms/step - loss: 0.2660 -
accuracy: 0.9229 - val_loss: 0.3872 - val_accuracy: 0.9036
Epoch 14/30
7352/7352 [==============================] - 91s 12ms/step - loss: 0.2746 -
accuracy: 0.9197 - val_loss: 0.3580 - val_accuracy: 0.9091
Epoch 15/30
7352/7352 [==============================] - 89s 12ms/step - loss: 0.2464 -
accuracy: 0.9225 - val_loss: 0.4930 - val_accuracy: 0.8975
Epoch 16/30
7352/7352 [==============================] - 89s 12ms/step - loss: 0.2147 -
```

```
accuracy: 0.9320 - val_loss: 0.4268 - val_accuracy: 0.9063
Epoch 17/30
7352/7352 [==============================] - 84s 11ms/step - loss: 0.2211 -
accuracy: 0.9260 - val_loss: 0.4903 - val_accuracy: 0.8999
Epoch 18/30
7352/7352 [==============================] - 93s 13ms/step - loss: 0.2274 -
accuracy: 0.9261 - val_loss: 0.4916 - val_accuracy: 0.9063
Epoch 19/30
7352/7352 [==============================] - 85s 12ms/step - loss: 0.2101 -
accuracy: 0.9335 - val_loss: 0.5254 - val_accuracy: 0.9013
Epoch 20/30
7352/7352 [==============================] - 78s 11ms/step - loss: 0.2397 -
accuracy: 0.9218 - val_loss: 0.4428 - val_accuracy: 0.9186
Epoch 21/30
7352/7352 [==============================] - 81s 11ms/step - loss: 0.2112 -
accuracy: 0.9241 - val_loss: 0.4918 - val_accuracy: 0.9023
Epoch 22/30
7352/7352 [==============================] - 86s 12ms/step - loss: 0.2058 -
accuracy: 0.9283 - val_loss: 0.4324 - val_accuracy: 0.9175
Epoch 23/30
7352/7352 [==============================] - 89s 12ms/step - loss: 0.2068 -
accuracy: 0.9316 - val_loss: 0.5082 - val_accuracy: 0.8951
Epoch 24/30
7352/7352 [==============================] - 89s 12ms/step - loss: 0.2010 -
accuracy: 0.9325 - val_loss: 0.4982 - val_accuracy: 0.9026
Epoch 25/30
7352/7352 [==============================] - 92s 13ms/step - loss: 0.2106 -
accuracy: 0.9316 - val_loss: 0.6370 - val_accuracy: 0.8921
Epoch 26/30
7352/7352 [==============================] - 83s 11ms/step - loss: 0.2256 -
accuracy: 0.9276 - val_loss: 0.5423 - val_accuracy: 0.9023
Epoch 27/30
7352/7352 [==============================] - 84s 11ms/step - loss: 0.2045 -
accuracy: 0.9340 - val_loss: 0.5803 - val_accuracy: 0.9141
Epoch 28/30
7352/7352 [==============================] - 85s 12ms/step - loss: 0.2197 -
accuracy: 0.9323 - val_loss: 0.5890 - val_accuracy: 0.9050
Epoch 29/30
7352/7352 [==============================] - 95s 13ms/step - loss: 0.1964 -
accuracy: 0.9357 - val_loss: 0.5434 - val_accuracy: 0.9091
Epoch 30/30
7352/7352 [==============================] - 93s 13ms/step - loss: 0.1971 -
accuracy: 0.9308 - val_loss: 0.5415 - val_accuracy: 0.9057
```

[144]:
```
<keras.callbacks.callbacks.History at 0x644516ef0>
```

[145]:
```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                LAYING  SITTING  STANDING  WALKING  WALKING_DOWNSTAIRS  \
True
LAYING                 510        0         3        0                   0
SITTING                  5      425        57        2                   0
STANDING                 0      101       430        0                   0
WALKING                  0        0         0      444                  34
WALKING_DOWNSTAIRS       0        0         0        5                 401
WALKING_UPSTAIRS         0        0         0        0                  12

Pred                WALKING_UPSTAIRS
True
LAYING                            24
SITTING                            2
STANDING                           1
WALKING                           18
WALKING_DOWNSTAIRS                14
WALKING_UPSTAIRS                 459
```

[146]:
```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================] - 4s 1ms/step
```

[147]:
```
score
```

[147]:
```
[0.5414807511955393, 0.9056667685508728]
```

- It's performance is good but loss is high

1.3.8 LSTM Layer (32,16) with dropout 0.5

[148]:
```
# update LSTM layers
n_hidden_1 = 32
n_hidden_2 = 16
```

- Initialize the LSTM Architecture

[149]:
```
# https://stackoverflow.com/questions/51763983/
 ↪error-when-checking-target-expected-dense-1-to-have-3-dimensions-but-got-array
# https://github.com/keras-team/keras/issues/7403
# 1. You need to set return_sequences=True from first LSTM
# 2. You need to set return_sequences=True from second LSTM
# Initiliazing the sequential model
model = Sequential()
# Configuring the parameters
model.add(LSTM(n_hidden_1, input_shape=(timesteps, input_dim),␣
 ↪return_sequences=True))
# Adding a dropout layer
# model.add(Dropout(0.6))
```

```
# Configuring the parameters
model.add(LSTM(n_hidden_2 , return_sequences=False))
# 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_36"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_62 (LSTM)               (None, 128, 32)           5376
_________________________________________________________________
lstm_63 (LSTM)               (None, 16)                3136
_________________________________________________________________
dropout_38 (Dropout)         (None, 16)                0
_________________________________________________________________
dense_20 (Dense)             (None, 6)                 102
=================================================================
Total params: 8,614
Trainable params: 8,614
Non-trainable params: 0
_________________________________________________________________
```

[150]:
```
# Compiling the model
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

[151]:
```
# 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 samples
Epoch 1/30
7352/7352 [==============================] - 108s 15ms/step - loss: 1.3059 -
accuracy: 0.4993 - val_loss: 1.0121 - val_accuracy: 0.5724
Epoch 2/30
7352/7352 [==============================] - 113s 15ms/step - loss: 0.9606 -
accuracy: 0.5797 - val_loss: 0.7977 - val_accuracy: 0.6081
Epoch 3/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.8199 -
accuracy: 0.6274 - val_loss: 0.7922 - val_accuracy: 0.5938
```

```
Epoch 4/30
7352/7352 [==============================] - 72s 10ms/step - loss: 0.7544 -
accuracy: 0.6387 - val_loss: 0.7379 - val_accuracy: 0.6179
Epoch 5/30
7352/7352 [==============================] - 111s 15ms/step - loss: 0.7201 -
accuracy: 0.6538 - val_loss: 0.7295 - val_accuracy: 0.6315
Epoch 6/30
7352/7352 [==============================] - 93s 13ms/step - loss: 0.7087 -
accuracy: 0.6568 - val_loss: 0.7252 - val_accuracy: 0.6247
Epoch 7/30
7352/7352 [==============================] - 92s 13ms/step - loss: 0.6802 -
accuracy: 0.6673 - val_loss: 0.7158 - val_accuracy: 0.6172
Epoch 8/30
7352/7352 [==============================] - 91s 12ms/step - loss: 0.6422 -
accuracy: 0.6827 - val_loss: 0.6055 - val_accuracy: 0.6335
Epoch 9/30
7352/7352 [==============================] - 89s 12ms/step - loss: 0.6010 -
accuracy: 0.6967 - val_loss: 0.5963 - val_accuracy: 0.6345
Epoch 10/30
7352/7352 [==============================] - 84s 11ms/step - loss: 0.5590 -
accuracy: 0.7346 - val_loss: 0.5663 - val_accuracy: 0.7455
Epoch 11/30
7352/7352 [==============================] - 86s 12ms/step - loss: 0.5296 -
accuracy: 0.7776 - val_loss: 0.5300 - val_accuracy: 0.7645
Epoch 12/30
7352/7352 [==============================] - 84s 11ms/step - loss: 0.4499 -
accuracy: 0.8449 - val_loss: 0.4595 - val_accuracy: 0.8690
Epoch 13/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.3973 -
accuracy: 0.8825 - val_loss: 0.3912 - val_accuracy: 0.8748
Epoch 14/30
7352/7352 [==============================] - 69s 9ms/step - loss: 0.3332 -
accuracy: 0.8976 - val_loss: 0.3851 - val_accuracy: 0.8928
Epoch 15/30
7352/7352 [==============================] - 69s 9ms/step - loss: 0.3229 -
accuracy: 0.9115 - val_loss: 0.4235 - val_accuracy: 0.8772
Epoch 16/30
7352/7352 [==============================] - 71s 10ms/step - loss: 0.2927 -
accuracy: 0.9166 - val_loss: 0.3071 - val_accuracy: 0.9013
Epoch 17/30
7352/7352 [==============================] - 71s 10ms/step - loss: 0.2774 -
accuracy: 0.9210 - val_loss: 0.4124 - val_accuracy: 0.9019
Epoch 18/30
7352/7352 [==============================] - 89s 12ms/step - loss: 0.2632 -
accuracy: 0.9267 - val_loss: 0.3328 - val_accuracy: 0.9053
Epoch 19/30
7352/7352 [==============================] - 86s 12ms/step - loss: 0.2567 -
accuracy: 0.9286 - val_loss: 0.3363 - val_accuracy: 0.8921
```

```
Epoch 20/30
7352/7352 [==============================] - 85s 12ms/step - loss: 0.2283 -
accuracy: 0.9346 - val_loss: 0.3214 - val_accuracy: 0.9077
Epoch 21/30
7352/7352 [==============================] - 70s 9ms/step - loss: 0.2282 -
accuracy: 0.9357 - val_loss: 0.4113 - val_accuracy: 0.8965
Epoch 22/30
7352/7352 [==============================] - 64s 9ms/step - loss: 0.2258 -
accuracy: 0.9332 - val_loss: 0.3970 - val_accuracy: 0.8965
Epoch 23/30
7352/7352 [==============================] - 63s 9ms/step - loss: 0.2020 -
accuracy: 0.9400 - val_loss: 0.3651 - val_accuracy: 0.9077
Epoch 24/30
7352/7352 [==============================] - 63s 9ms/step - loss: 0.2156 -
accuracy: 0.9372 - val_loss: 0.2834 - val_accuracy: 0.9199
Epoch 25/30
7352/7352 [==============================] - 74s 10ms/step - loss: 0.2100 -
accuracy: 0.9369 - val_loss: 0.2916 - val_accuracy: 0.9145
Epoch 26/30
7352/7352 [==============================] - 70s 9ms/step - loss: 0.2071 -
accuracy: 0.9369 - val_loss: 0.3984 - val_accuracy: 0.9053
Epoch 27/30
7352/7352 [==============================] - 70s 10ms/step - loss: 0.2109 -
accuracy: 0.9388 - val_loss: 0.3134 - val_accuracy: 0.9172
Epoch 28/30
7352/7352 [==============================] - 85s 12ms/step - loss: 0.2009 -
accuracy: 0.9374 - val_loss: 0.3572 - val_accuracy: 0.9199
Epoch 29/30
7352/7352 [==============================] - 81s 11ms/step - loss: 0.2002 -
accuracy: 0.9377 - val_loss: 0.3658 - val_accuracy: 0.9128
Epoch 30/30
7352/7352 [==============================] - 74s 10ms/step - loss: 0.2017 -
accuracy: 0.9395 - val_loss: 0.3589 - val_accuracy: 0.9226
```

[151]:
```
<keras.callbacks.callbacks.History at 0x6456d7a20>
```

[152]:
```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                LAYING  SITTING  STANDING  WALKING  WALKING_DOWNSTAIRS  \
True
LAYING                 536        0         1        0                   0
SITTING                  1      414        71        2                   1
STANDING                 0       80       445        7                   0
WALKING                  0        0         0      458                   9
WALKING_DOWNSTAIRS       0        6         0        1                 403
WALKING_UPSTAIRS         0        1         0        4                   3
```

```
Pred                 WALKING_UPSTAIRS
True
LAYING                              0
SITTING                             2
STANDING                            0
WALKING                            29
WALKING_DOWNSTAIRS                 10
WALKING_UPSTAIRS                  463
```

[153]:
```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================] - 3s 1ms/step
```

[154]:
```
score
```

[154]:
```
[0.3589311393391746, 0.922633171081543]
```

- It's performance is best till now, I got 92.26% accuracy and loss 0.3589

1.3.9 LSTM Layer (32,8) with dropout 0.5

[155]:
```
# update LSTM layers
n_hidden_1 = 32
n_hidden_2 = 8
```

- Initialize the LSTM Architecture

[156]:
```
# https://stackoverflow.com/questions/51763983/
 ↪error-when-checking-target-expected-dense-1-to-have-3-dimensions-but-got-array
# https://github.com/keras-team/keras/issues/7403
# 1. You need to set return_sequences=True from first LSTM
# 2. You need to set return_sequences=True from second LSTM
# Initiliazing the sequential model
model = Sequential()
# Configuring the parameters
model.add(LSTM(n_hidden_1, input_shape=(timesteps, input_dim),␣
 ↪return_sequences=True))
# Adding a dropout layer
# model.add(Dropout(0.6))
# Configuring the parameters
model.add(LSTM(n_hidden_2 , return_sequences=False))
# 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_37"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_64 (LSTM)               (None, 128, 32)           5376
_________________________________________________________________
lstm_65 (LSTM)               (None, 8)                 1312
_________________________________________________________________
dropout_39 (Dropout)         (None, 8)                 0
_________________________________________________________________
dense_21 (Dense)             (None, 6)                 54
=================================================================
Total params: 6,742
Trainable params: 6,742
Non-trainable params: 0
_________________________________________________________________
```

[157]:
```
# Compiling the model
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

[158]:
```
# 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 samples
Epoch 1/30
7352/7352 [==============================] - 72s 10ms/step - loss: 1.4856 -
accuracy: 0.4123 - val_loss: 1.3371 - val_accuracy: 0.4608
Epoch 2/30
7352/7352 [==============================] - 71s 10ms/step - loss: 1.2285 -
accuracy: 0.5116 - val_loss: 1.0945 - val_accuracy: 0.5270
Epoch 3/30
7352/7352 [==============================] - 73s 10ms/step - loss: 1.0665 -
accuracy: 0.5305 - val_loss: 0.9436 - val_accuracy: 0.5541
Epoch 4/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.9660 -
accuracy: 0.5257 - val_loss: 0.9440 - val_accuracy: 0.4880
Epoch 5/30
7352/7352 [==============================] - 71s 10ms/step - loss: 0.9060 -
accuracy: 0.5547 - val_loss: 0.8240 - val_accuracy: 0.5684
Epoch 6/30
7352/7352 [==============================] - 74s 10ms/step - loss: 0.8786 -
accuracy: 0.5654 - val_loss: 0.7971 - val_accuracy: 0.6529
```

```
Epoch 7/30
7352/7352 [==============================] - 75s 10ms/step - loss: 0.8483 -
accuracy: 0.5914 - val_loss: 0.8113 - val_accuracy: 0.6586
Epoch 8/30
7352/7352 [==============================] - 68s 9ms/step - loss: 0.8286 -
accuracy: 0.6151 - val_loss: 0.8513 - val_accuracy: 0.6071
Epoch 9/30
7352/7352 [==============================] - 62s 8ms/step - loss: 0.8480 -
accuracy: 0.6223 - val_loss: 0.7308 - val_accuracy: 0.6508
Epoch 10/30
7352/7352 [==============================] - 62s 8ms/step - loss: 0.7699 -
accuracy: 0.6659 - val_loss: 0.6510 - val_accuracy: 0.7122
Epoch 11/30
7352/7352 [==============================] - 64s 9ms/step - loss: 0.7407 -
accuracy: 0.6878 - val_loss: 0.6161 - val_accuracy: 0.7282
Epoch 12/30
7352/7352 [==============================] - 63s 9ms/step - loss: 0.7204 -
accuracy: 0.7065 - val_loss: 0.6398 - val_accuracy: 0.7489
Epoch 13/30
7352/7352 [==============================] - 64s 9ms/step - loss: 0.6857 -
accuracy: 0.7171 - val_loss: 0.5320 - val_accuracy: 0.7818
Epoch 14/30
7352/7352 [==============================] - 63s 9ms/step - loss: 0.6436 -
accuracy: 0.7297 - val_loss: 0.5111 - val_accuracy: 0.7374
Epoch 15/30
7352/7352 [==============================] - 61s 8ms/step - loss: 0.6151 -
accuracy: 0.7432 - val_loss: 0.4787 - val_accuracy: 0.7296
Epoch 16/30
7352/7352 [==============================] - 62s 8ms/step - loss: 0.6339 -
accuracy: 0.7444 - val_loss: 0.4256 - val_accuracy: 0.7642
Epoch 17/30
7352/7352 [==============================] - 62s 8ms/step - loss: 0.5582 -
accuracy: 0.7655 - val_loss: 0.4290 - val_accuracy: 0.7560
Epoch 18/30
7352/7352 [==============================] - 61s 8ms/step - loss: 0.5327 -
accuracy: 0.7703 - val_loss: 0.4810 - val_accuracy: 0.7669
Epoch 19/30
7352/7352 [==============================] - 65s 9ms/step - loss: 0.5647 -
accuracy: 0.7677 - val_loss: 0.4285 - val_accuracy: 0.7516
Epoch 20/30
7352/7352 [==============================] - 72s 10ms/step - loss: 0.5090 -
accuracy: 0.7817 - val_loss: 0.3965 - val_accuracy: 0.7401
Epoch 21/30
7352/7352 [==============================] - 69s 9ms/step - loss: 0.5086 -
accuracy: 0.7835 - val_loss: 0.4745 - val_accuracy: 0.7418
Epoch 22/30
7352/7352 [==============================] - 71s 10ms/step - loss: 0.4800 -
accuracy: 0.7829 - val_loss: 0.4516 - val_accuracy: 0.7282
```

```
Epoch 23/30
7352/7352 [==============================] - 69s 9ms/step - loss: 0.4852 -
accuracy: 0.7777 - val_loss: 0.4051 - val_accuracy: 0.7533
Epoch 24/30
7352/7352 [==============================] - 69s 9ms/step - loss: 0.4614 -
accuracy: 0.7845 - val_loss: 0.3709 - val_accuracy: 0.7540
Epoch 25/30
7352/7352 [==============================] - 70s 10ms/step - loss: 0.4826 -
accuracy: 0.7795 - val_loss: 1.3639 - val_accuracy: 0.6037
Epoch 26/30
7352/7352 [==============================] - 71s 10ms/step - loss: 0.5301 -
accuracy: 0.7686 - val_loss: 0.8841 - val_accuracy: 0.6529
Epoch 27/30
7352/7352 [==============================] - 69s 9ms/step - loss: 0.4808 -
accuracy: 0.7758 - val_loss: 0.3784 - val_accuracy: 0.7472
Epoch 28/30
7352/7352 [==============================] - 68s 9ms/step - loss: 0.4476 -
accuracy: 0.7924 - val_loss: 0.4192 - val_accuracy: 0.7520
Epoch 29/30
7352/7352 [==============================] - 69s 9ms/step - loss: 0.4208 -
accuracy: 0.8067 - val_loss: 0.3983 - val_accuracy: 0.7496
Epoch 30/30
7352/7352 [==============================] - 69s 9ms/step - loss: 0.4232 -
accuracy: 0.7926 - val_loss: 0.3762 - val_accuracy: 0.7540
```

[158]:
```
<keras.callbacks.callbacks.History at 0x64672ce10>
```

[159]:
```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                LAYING  SITTING  STANDING  WALKING  WALKING_DOWNSTAIRS  \
True
LAYING                 534        0         0        0                   0
SITTING                  0      420        61        0                   0
STANDING                 0      122       405        0                   0
WALKING                  0        0         0        0                   0
WALKING_DOWNSTAIRS       0        0         0        4                 397
WALKING_UPSTAIRS         0        5         0        0                   0

Pred                WALKING_UPSTAIRS
True
LAYING                             3
SITTING                           10
STANDING                           5
WALKING                          496
WALKING_DOWNSTAIRS                19
WALKING_UPSTAIRS                 466
```

[160]:
```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================] - 3s 953us/step
```

[161]:
```
score
```

[161]:
```
[0.3761567989555303, 0.7539871335029602]
```

- Performance degraded for this combination of LSTM

1.4.0 Assignment feedback to improve accuracy > 94%
1.4.1 Increase dropout on the best LSTM combination

[17]:
```
# update LSTM layers
n_hidden_1 = 32
n_hidden_2 = 16
```

- Initialize the LSTM Architecture

[18]:
```
# https://stackoverflow.com/questions/51763983/
 ↪error-when-checking-target-expected-dense-1-to-have-3-dimensions-but-got-array
# https://github.com/keras-team/keras/issues/7403
# 1. You need to set return_sequences=True from first LSTM
# 2. You need to set return_sequences=True from second LSTM
# Initiliazing the sequential model
model = Sequential()
# Configuring the parameters
model.add(LSTM(n_hidden_1, input_shape=(timesteps, input_dim),␣
 ↪return_sequences=True))
# Adding a dropout layer
# model.add(Dropout(0.6))
# Configuring the parameters
model.add(LSTM(n_hidden_2 , return_sequences=False))
# Adding a dropout layer
model.add(Dropout(0.6))
# Adding a dense output layer with sigmoid activation
model.add(Dense(n_classes, activation='sigmoid'))
model.summary()
```

```
WARNING:tensorflow:Large dropout rate: 0.6 (>0.5). In TensorFlow 2.x, dropout()
uses dropout rate instead of keep_prob. Please ensure that this is intended.
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_1 (LSTM)                (None, 128, 32)           5376
_________________________________________________________________
```

```
lstm_2 (LSTM)                (None, 16)                3136
_________________________________________________________________
dropout_1 (Dropout)          (None, 16)                0
_________________________________________________________________
dense_1 (Dense)              (None, 6)                 102
=================================================================
Total params: 8,614
Trainable params: 8,614
Non-trainable params: 0
_________________________________________________________________
```

[19]:
```
# Compiling the model
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

[20]:
```
# Training the model
model.fit(X_train,
          Y_train,
          batch_size=batch_size,
          validation_data=(X_test, Y_test),
          epochs=epochs)
```

```
WARNING:tensorflow:From /Users/mayankgupta/anaconda3/lib/python3.7/site-
packages/tensorflow/python/ops/math_grad.py:1250:
add_dispatch_support.<locals>.wrapper (from tensorflow.python.ops.array_ops) is
deprecated and will be removed in a future version.
Instructions for updating:
Use tf.where in 2.0, which has the same broadcast rule as np.where
WARNING:tensorflow:From /Users/mayankgupta/anaconda3/lib/python3.7/site-
packages/keras/backend/tensorflow_backend.py:422: The name tf.global_variables
is deprecated. Please use tf.compat.v1.global_variables instead.

Train on 7352 samples, validate on 2947 samples
Epoch 1/30
7352/7352 [==============================] - 28s 4ms/step - loss: 1.3771 -
accuracy: 0.4679 - val_loss: 1.2075 - val_accuracy: 0.5063
Epoch 2/30
7352/7352 [==============================] - 29s 4ms/step - loss: 1.0661 -
accuracy: 0.5615 - val_loss: 0.9215 - val_accuracy: 0.6546
Epoch 3/30
7352/7352 [==============================] - 28s 4ms/step - loss: 0.9246 -
accuracy: 0.6035 - val_loss: 0.7882 - val_accuracy: 0.6474
Epoch 4/30
7352/7352 [==============================] - 30s 4ms/step - loss: 0.8082 -
accuracy: 0.6484 - val_loss: 0.9662 - val_accuracy: 0.6223
Epoch 5/30
7352/7352 [==============================] - 28s 4ms/step - loss: 0.7176 -
```

```
accuracy: 0.7084 - val_loss: 0.7233 - val_accuracy: 0.6702
Epoch 6/30
7352/7352 [==============================] - 30s 4ms/step - loss: 0.6610 -
accuracy: 0.7329 - val_loss: 0.6340 - val_accuracy: 0.7268
Epoch 7/30
7352/7352 [==============================] - 32s 4ms/step - loss: 0.5957 -
accuracy: 0.7606 - val_loss: 0.4884 - val_accuracy: 0.7458
Epoch 8/30
7352/7352 [==============================] - 42s 6ms/step - loss: 0.5444 -
accuracy: 0.7705 - val_loss: 0.4884 - val_accuracy: 0.7547
Epoch 9/30
7352/7352 [==============================] - 29s 4ms/step - loss: 0.5301 -
accuracy: 0.7749 - val_loss: 0.5527 - val_accuracy: 0.7448
Epoch 10/30
7352/7352 [==============================] - 29s 4ms/step - loss: 0.4985 -
accuracy: 0.7761 - val_loss: 0.5010 - val_accuracy: 0.7489
Epoch 11/30
7352/7352 [==============================] - 30s 4ms/step - loss: 0.4811 -
accuracy: 0.7811 - val_loss: 0.5013 - val_accuracy: 0.7706
Epoch 12/30
7352/7352 [==============================] - 29s 4ms/step - loss: 0.4723 -
accuracy: 0.7758 - val_loss: 0.5427 - val_accuracy: 0.7384
Epoch 13/30
7352/7352 [==============================] - 28s 4ms/step - loss: 0.4699 -
accuracy: 0.7801 - val_loss: 0.5415 - val_accuracy: 0.7638
Epoch 14/30
7352/7352 [==============================] - 29s 4ms/step - loss: 0.4475 -
accuracy: 0.7879 - val_loss: 0.5366 - val_accuracy: 0.7564
Epoch 15/30
7352/7352 [==============================] - 29s 4ms/step - loss: 0.4817 -
accuracy: 0.7795 - val_loss: 0.9002 - val_accuracy: 0.6841
Epoch 16/30
7352/7352 [==============================] - 32s 4ms/step - loss: 0.4505 -
accuracy: 0.7894 - val_loss: 0.4372 - val_accuracy: 0.7798
Epoch 17/30
7352/7352 [==============================] - 29s 4ms/step - loss: 0.4303 -
accuracy: 0.7878 - val_loss: 0.4430 - val_accuracy: 0.7845
Epoch 18/30
7352/7352 [==============================] - 29s 4ms/step - loss: 0.4273 -
accuracy: 0.7950 - val_loss: 0.4931 - val_accuracy: 0.7672
Epoch 19/30
7352/7352 [==============================] - 30s 4ms/step - loss: 0.4387 -
accuracy: 0.7996 - val_loss: 0.4052 - val_accuracy: 0.7927
Epoch 20/30
7352/7352 [==============================] - 29s 4ms/step - loss: 0.4401 -
accuracy: 0.8062 - val_loss: 0.4650 - val_accuracy: 0.7774
Epoch 21/30
7352/7352 [==============================] - 28s 4ms/step - loss: 0.4293 -
```

```
accuracy: 0.8244 - val_loss: 0.5555 - val_accuracy: 0.7587
Epoch 22/30
7352/7352 [==============================] - 29s 4ms/step - loss: 0.3975 -
accuracy: 0.8384 - val_loss: 0.4290 - val_accuracy: 0.7665
Epoch 23/30
7352/7352 [==============================] - 31s 4ms/step - loss: 0.3760 -
accuracy: 0.8474 - val_loss: 0.4030 - val_accuracy: 0.8836
Epoch 24/30
7352/7352 [==============================] - 28s 4ms/step - loss: 0.3758 -
accuracy: 0.8453 - val_loss: 0.4144 - val_accuracy: 0.9057
Epoch 25/30
7352/7352 [==============================] - 26s 4ms/step - loss: 0.3429 -
accuracy: 0.8659 - val_loss: 0.4352 - val_accuracy: 0.8948
Epoch 26/30
7352/7352 [==============================] - 27s 4ms/step - loss: 0.3329 -
accuracy: 0.8802 - val_loss: 0.4077 - val_accuracy: 0.8914
Epoch 27/30
7352/7352 [==============================] - 29s 4ms/step - loss: 0.3310 -
accuracy: 0.8977 - val_loss: 0.3974 - val_accuracy: 0.8948
Epoch 28/30
7352/7352 [==============================] - 26s 3ms/step - loss: 0.3205 -
accuracy: 0.9048 - val_loss: 0.3721 - val_accuracy: 0.8897
Epoch 29/30
7352/7352 [==============================] - 26s 4ms/step - loss: 0.2805 -
accuracy: 0.9168 - val_loss: 0.4258 - val_accuracy: 0.8833
Epoch 30/30
7352/7352 [==============================] - 26s 4ms/step - loss: 0.2897 -
accuracy: 0.9117 - val_loss: 0.3616 - val_accuracy: 0.9101
```

[20]:
```
<keras.callbacks.callbacks.History at 0x629ebef60>
```

[21]:
```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                LAYING  SITTING  STANDING  WALKING  WALKING_DOWNSTAIRS  \
True
LAYING                 510        0         2        0                   0
SITTING                  0      404        87        0                   0
STANDING                 0       81       450        1                   0
WALKING                  0        0         0      450                  44
WALKING_DOWNSTAIRS       0        0         0        0                 414
WALKING_UPSTAIRS         1        0        10        0                   6

Pred                WALKING_UPSTAIRS
True
LAYING                            25
SITTING                            0
STANDING                           0
```

```
WALKING                          2
WALKING_DOWNSTAIRS               6
WALKING_UPSTAIRS               454
```

[22]:
```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================] - 1s 402us/step
```

[23]:
```
score
```

[23]:
```
[0.36157595883878874, 0.9100780487060547]
```

1.4.2 Decrease dropout on the best LSTM combination

[24]:
```
# update LSTM layers
n_hidden_1 = 32
n_hidden_2 = 16
```

- Initialize the LSTM architecture

[25]:
```
# https://stackoverflow.com/questions/51763983/
 ↪error-when-checking-target-expected-dense-1-to-have-3-dimensions-but-got-array
# https://github.com/keras-team/keras/issues/7403
# 1. You need to set return_sequences=True from first LSTM
# 2. You need to set return_sequences=True from second LSTM
# Initiliazing the sequential model
model = Sequential()
# Configuring the parameters
model.add(LSTM(n_hidden_1, input_shape=(timesteps, input_dim),␣
 ↪return_sequences=True))
# Adding a dropout layer
# model.add(Dropout(0.6))
# Configuring the parameters
model.add(LSTM(n_hidden_2 , return_sequences=False))
# Adding a dropout layer
model.add(Dropout(0.4))
# 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_3 (LSTM)                (None, 128, 32)           5376
_________________________________________________________________
lstm_4 (LSTM)                (None, 16)                3136
_________________________________________________________________
```

```
dropout_2 (Dropout)          (None, 16)                0
_________________________________________________________________
dense_2 (Dense)              (None, 6)                 102
=================================================================
Total params: 8,614
Trainable params: 8,614
Non-trainable params: 0
_________________________________________________________________
```

[26]:
```
# Compiling the model
model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
```

[27]:
```
# 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 samples
Epoch 1/30
7352/7352 [==============================] - 30s 4ms/step - loss: 1.2955 -
accuracy: 0.5092 - val_loss: 0.9788 - val_accuracy: 0.5667
Epoch 2/30
7352/7352 [==============================] - 29s 4ms/step - loss: 0.9335 -
accuracy: 0.6260 - val_loss: 0.8553 - val_accuracy: 0.5850
Epoch 3/30
7352/7352 [==============================] - 26s 4ms/step - loss: 0.7509 -
accuracy: 0.6903 - val_loss: 0.6851 - val_accuracy: 0.6875
Epoch 4/30
7352/7352 [==============================] - 26s 4ms/step - loss: 0.6576 -
accuracy: 0.7371 - val_loss: 0.6529 - val_accuracy: 0.7153
Epoch 5/30
7352/7352 [==============================] - 28s 4ms/step - loss: 0.5653 -
accuracy: 0.7776 - val_loss: 0.5315 - val_accuracy: 0.7598
Epoch 6/30
7352/7352 [==============================] - 28s 4ms/step - loss: 0.4963 -
accuracy: 0.7875 - val_loss: 0.5693 - val_accuracy: 0.7397
Epoch 7/30
7352/7352 [==============================] - 28s 4ms/step - loss: 0.4593 -
accuracy: 0.8021 - val_loss: 0.8562 - val_accuracy: 0.6997
Epoch 8/30
7352/7352 [==============================] - 32s 4ms/step - loss: 0.4336 -
accuracy: 0.8022 - val_loss: 0.4901 - val_accuracy: 0.7733
Epoch 9/30
7352/7352 [==============================] - 30s 4ms/step - loss: 0.4291 -
```

```
accuracy: 0.8105 - val_loss: 0.4846 - val_accuracy: 0.8344
Epoch 10/30
7352/7352 [==============================] - 26s 4ms/step - loss: 0.3871 -
accuracy: 0.8746 - val_loss: 0.4090 - val_accuracy: 0.8626
Epoch 11/30
7352/7352 [==============================] - 26s 4ms/step - loss: 0.3232 -
accuracy: 0.9104 - val_loss: 0.3683 - val_accuracy: 0.8884
Epoch 12/30
7352/7352 [==============================] - 26s 4ms/step - loss: 0.2601 -
accuracy: 0.9312 - val_loss: 0.4261 - val_accuracy: 0.8789
Epoch 13/30
7352/7352 [==============================] - 27s 4ms/step - loss: 0.2371 -
accuracy: 0.9312 - val_loss: 0.3696 - val_accuracy: 0.8955
Epoch 14/30
7352/7352 [==============================] - 29s 4ms/step - loss: 0.2219 -
accuracy: 0.9354 - val_loss: 0.3854 - val_accuracy: 0.8897
Epoch 15/30
7352/7352 [==============================] - 26s 4ms/step - loss: 0.2124 -
accuracy: 0.9388 - val_loss: 0.3734 - val_accuracy: 0.8890
Epoch 16/30
7352/7352 [==============================] - 30s 4ms/step - loss: 0.1963 -
accuracy: 0.9403 - val_loss: 0.4284 - val_accuracy: 0.8887
Epoch 17/30
7352/7352 [==============================] - 29s 4ms/step - loss: 0.1849 -
accuracy: 0.9396 - val_loss: 0.3498 - val_accuracy: 0.9016
Epoch 18/30
7352/7352 [==============================] - 29s 4ms/step - loss: 0.1981 -
accuracy: 0.9415 - val_loss: 0.4388 - val_accuracy: 0.8924
Epoch 19/30
7352/7352 [==============================] - 27s 4ms/step - loss: 0.1978 -
accuracy: 0.9408 - val_loss: 0.4307 - val_accuracy: 0.8911
Epoch 20/30
7352/7352 [==============================] - 27s 4ms/step - loss: 0.1884 -
accuracy: 0.9377 - val_loss: 0.4191 - val_accuracy: 0.8948
Epoch 21/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1669 -
accuracy: 0.9444 - val_loss: 0.5406 - val_accuracy: 0.8901
Epoch 22/30
7352/7352 [==============================] - 27s 4ms/step - loss: 0.1731 -
accuracy: 0.9442 - val_loss: 0.4263 - val_accuracy: 0.8921
Epoch 23/30
7352/7352 [==============================] - 27s 4ms/step - loss: 0.1697 -
accuracy: 0.9459 - val_loss: 0.4441 - val_accuracy: 0.8904
Epoch 24/30
7352/7352 [==============================] - 26s 4ms/step - loss: 0.1615 -
accuracy: 0.9474 - val_loss: 0.4375 - val_accuracy: 0.8955
Epoch 25/30
7352/7352 [==============================] - 28s 4ms/step - loss: 0.1651 -
```

```
accuracy: 0.9448 - val_loss: 0.6645 - val_accuracy: 0.8826
Epoch 26/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1563 -
accuracy: 0.9475 - val_loss: 0.6143 - val_accuracy: 0.8890
Epoch 27/30
7352/7352 [==============================] - 28s 4ms/step - loss: 0.1582 -
accuracy: 0.9489 - val_loss: 0.5653 - val_accuracy: 0.8958
Epoch 28/30
7352/7352 [==============================] - 28s 4ms/step - loss: 0.1520 -
accuracy: 0.9465 - val_loss: 0.3868 - val_accuracy: 0.9111
Epoch 29/30
7352/7352 [==============================] - 28s 4ms/step - loss: 0.1610 -
accuracy: 0.9465 - val_loss: 0.4674 - val_accuracy: 0.9033
Epoch 30/30
7352/7352 [==============================] - 32s 4ms/step - loss: 0.1460 -
accuracy: 0.9489 - val_loss: 0.3913 - val_accuracy: 0.9067
```

[27]:
```
<keras.callbacks.callbacks.History at 0x62b400e10>
```

[28]:
```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                LAYING  SITTING  STANDING  WALKING  WALKING_DOWNSTAIRS  \
True
LAYING                 537        0         0        0                   0
SITTING                  4      387        78        0                   4
STANDING                 0       98       432        0                   0
WALKING                  0        0         0      448                  10
WALKING_DOWNSTAIRS       0        0         0        0                 413
WALKING_UPSTAIRS         0        0         0        7                   9

Pred                WALKING_UPSTAIRS
True
LAYING                             0
SITTING                           18
STANDING                           2
WALKING                           38
WALKING_DOWNSTAIRS                 7
WALKING_UPSTAIRS                 455
```

[29]:
```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================] - 1s 397us/step
```

[30]:
```
score
```

[30]:
```
[0.39125852214684165, 0.9066847562789917]
```

1.4.3 Increase layer size to 128 and lesser dropout

[37]:
```
# update LSTM layers
n_hidden_1 = 128
# n_hidden_2 = 16
```

- Initialize LSTM

[38]:
```
# https://stackoverflow.com/questions/51763983/
 ↪error-when-checking-target-expected-dense-1-to-have-3-dimensions-but-got-array
# https://github.com/keras-team/keras/issues/7403
# 1. You need to set return_sequences=True from first LSTM
# 2. You need to set return_sequences=True from second LSTM
# Initiliazing the sequential model
model = Sequential()
# Configuring the parameters
model.add(LSTM(n_hidden_1, input_shape=(timesteps, input_dim)))#,␣
 ↪return_sequences=True
# Adding BatchNormalization
model.add(BatchNormalization())
# Adding a dropout layer
# model.add(Dropout(0.6))
# Configuring the parameters
# model.add(LSTM(n_hidden_2 , return_sequences=False))
# Adding a dropout layer
model.add(Dropout(0.25))
# Adding a dense output layer with sigmoid activation
model.add(Dense(n_classes, activation='sigmoid'))
model.summary()
```

```
Model: "sequential_6"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_8 (LSTM)                (None, 128)               70656
_________________________________________________________________
batch_normalization_3 (Batch (None, 128)               512
_________________________________________________________________
dropout_5 (Dropout)          (None, 128)               0
_________________________________________________________________
dense_5 (Dense)              (None, 6)                 774
=================================================================
Total params: 71,942
Trainable params: 71,686
Non-trainable params: 256
_________________________________________________________________
```

[39]:
```
# Compiling the model
model.compile(loss='categorical_crossentropy',
```

```
              optimizer='rmsprop',
              metrics=['accuracy'])
```

[40]:
```
# 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 samples
Epoch 1/30
7352/7352 [==============================] - 29s 4ms/step - loss: 0.9291 -
accuracy: 0.5952 - val_loss: 0.7638 - val_accuracy: 0.6359
Epoch 2/30
7352/7352 [==============================] - 30s 4ms/step - loss: 0.6998 -
accuracy: 0.6602 - val_loss: 0.6965 - val_accuracy: 0.6481
Epoch 3/30
7352/7352 [==============================] - 29s 4ms/step - loss: 0.5196 -
accuracy: 0.7916 - val_loss: 0.3441 - val_accuracy: 0.8907
Epoch 4/30
7352/7352 [==============================] - 30s 4ms/step - loss: 0.2674 -
accuracy: 0.9101 - val_loss: 0.3433 - val_accuracy: 0.8989
Epoch 5/30
7352/7352 [==============================] - 30s 4ms/step - loss: 0.1985 -
accuracy: 0.9293 - val_loss: 0.3900 - val_accuracy: 0.8772
Epoch 6/30
7352/7352 [==============================] - 30s 4ms/step - loss: 0.1990 -
accuracy: 0.9279 - val_loss: 0.3218 - val_accuracy: 0.9121
Epoch 7/30
7352/7352 [==============================] - 28s 4ms/step - loss: 0.1790 -
accuracy: 0.9362 - val_loss: 0.2864 - val_accuracy: 0.9108
Epoch 8/30
7352/7352 [==============================] - 29s 4ms/step - loss: 0.1543 -
accuracy: 0.9412 - val_loss: 0.2592 - val_accuracy: 0.9199
Epoch 9/30
7352/7352 [==============================] - 26s 4ms/step - loss: 0.1592 -
accuracy: 0.9404 - val_loss: 0.3458 - val_accuracy: 0.9158
Epoch 10/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1445 -
accuracy: 0.9436 - val_loss: 0.2678 - val_accuracy: 0.9199
Epoch 11/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1397 -
accuracy: 0.9395 - val_loss: 0.2976 - val_accuracy: 0.9155
Epoch 12/30
7352/7352 [==============================] - 26s 4ms/step - loss: 0.1523 -
accuracy: 0.9392 - val_loss: 0.2769 - val_accuracy: 0.9070
Epoch 13/30
```

```
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1375 -
accuracy: 0.9415 - val_loss: 0.3131 - val_accuracy: 0.9087
Epoch 14/30
7352/7352 [==============================] - 26s 3ms/step - loss: 0.1459 -
accuracy: 0.9433 - val_loss: 0.3071 - val_accuracy: 0.9152
Epoch 15/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1451 -
accuracy: 0.9455 - val_loss: 0.3450 - val_accuracy: 0.9169
Epoch 16/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1497 -
accuracy: 0.9460 - val_loss: 0.3297 - val_accuracy: 0.9158
Epoch 17/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1425 -
accuracy: 0.9489 - val_loss: 0.3909 - val_accuracy: 0.9192
Epoch 18/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1529 -
accuracy: 0.9465 - val_loss: 0.3178 - val_accuracy: 0.9220
Epoch 19/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1487 -
accuracy: 0.9456 - val_loss: 0.3939 - val_accuracy: 0.9104
Epoch 20/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1389 -
accuracy: 0.9483 - val_loss: 0.3776 - val_accuracy: 0.9179
Epoch 21/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1451 -
accuracy: 0.9449 - val_loss: 0.3028 - val_accuracy: 0.9233
Epoch 22/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1386 -
accuracy: 0.9465 - val_loss: 0.3515 - val_accuracy: 0.9247
Epoch 23/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.2044 -
accuracy: 0.9280 - val_loss: 0.3435 - val_accuracy: 0.9226
Epoch 24/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1235 -
accuracy: 0.9521 - val_loss: 0.3666 - val_accuracy: 0.9230
Epoch 25/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1276 -
accuracy: 0.9504 - val_loss: 0.3031 - val_accuracy: 0.9182
Epoch 26/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1243 -
accuracy: 0.9520 - val_loss: 0.3607 - val_accuracy: 0.9257
Epoch 27/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1223 -
accuracy: 0.9502 - val_loss: 0.3756 - val_accuracy: 0.9155
Epoch 28/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1273 -
accuracy: 0.9525 - val_loss: 0.3839 - val_accuracy: 0.9186
Epoch 29/30
```

```
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1620 -
accuracy: 0.9433 - val_loss: 0.2694 - val_accuracy: 0.9294
Epoch 30/30
7352/7352 [==============================] - 25s 3ms/step - loss: 0.1218 -
accuracy: 0.9510 - val_loss: 0.3121 - val_accuracy: 0.9257
```

[40]:
```
<keras.callbacks.callbacks.History at 0x62db041d0>
```

[41]:
```
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                LAYING  SITTING  STANDING  WALKING  WALKING_DOWNSTAIRS  \
True
LAYING                 537        0         0        0                   0
SITTING                  0      418        71        0                   0
STANDING                 0      101       431        0                   0
WALKING                  0        0         0      470                  24
WALKING_DOWNSTAIRS       0        0         0        1                 417
WALKING_UPSTAIRS         0        1         0       13                   2

Pred                WALKING_UPSTAIRS
True
LAYING                             0
SITTING                            2
STANDING                           0
WALKING                            2
WALKING_DOWNSTAIRS                 2
WALKING_UPSTAIRS                 455
```

[42]:
```
score = model.evaluate(X_test, Y_test)
```

```
2947/2947 [==============================] - 2s 542us/step
```

[43]:
```
score
```

[43]:
```
[0.31214076887265046, 0.9256871342658997]
```

1.4.4 Implement Divide and Conquer Technique

[ ]:
```
# Citation: https://github.com/UdiBhaskar/
 ↪Human-Activity-Recognition--Using-Deep-NN
```

In the dataset, Y_labels are represented as numbers from 1 to 6 as their identifiers.
WALKING as 1
WALKING_UPSTAIRS as 2
WALKING_DOWNSTAIRS as 3
SITTING as 4
STANDING as 5
LAYING as 6

- in Data exploration section we observed that we can divide the data into dynamic and static type so divided walking, walking_upstairs and walking_downstairs into category 0 i.e Dynamic and sitting, standing and laying into category 1 i.e. static. - Will use 2 more classifiers separately for classifying classes of dynamic and static activities. so that model can learn differnt features for static and dynamic activities

referred below paper

Divide and Conquer-Based 1D CNN Human Activity Recognition Using Test Data Sharpening (https://www.mdpi.com/1424-8220/18/4/1055/pdf)

[38]:
```
import os
os.environ['PYTHONHASHSEED'] = '0'
import numpy as np
import tensorflow as tf
import random as rn
np.random.seed(0)
rn.seed(0)
tf.set_random_seed(0)
session_conf = tf.ConfigProto(intra_op_parallelism_threads=1,
                              inter_op_parallelism_threads=1)

from keras import backend as K

# The below tf.set_random_seed() will make random number generation
# in the TensorFlow backend have a well-defined initial state.
# For further details, see:
# https://www.tensorflow.org/api_docs/python/tf/set_random_seed

tf.set_random_seed(0)

sess = tf.Session(graph=tf.get_default_graph(), config=session_conf)
K.set_session(sess)

# Importing libraries
import pandas as pd
from matplotlib import pyplot
from sklearn.preprocessing import StandardScaler
from keras.models import Sequential
from keras.layers import Dense
from keras.layers import Flatten
from keras.layers import Dropout
from keras.layers.convolutional import Conv1D
from keras.layers.convolutional import MaxPooling1D
from keras.utils import to_categorical
from keras.models import Sequential
from keras.layers import LSTM
from keras.layers.core import Dense, Dropout
import pickle
```

[39]:
```
## Classifying data as 2 class dynamic vs static
##data preparation
def data_scaled_2class():
    """
    Obtain the dataset from multiple files.
    Returns: X_train, X_test, y_train, y_test
    """
    # Data directory
    DATADIR = 'UCI_HAR_Dataset'
    # 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"
        ]
    from sklearn.base import BaseEstimator, TransformerMixin
    class scaling_tseries_data(BaseEstimator, TransformerMixin):
        from sklearn.preprocessing import StandardScaler
        def __init__(self):
            self.scale = None

        def transform(self, X):
            temp_X1 = X.reshape((X.shape[0] * X.shape[1], X.shape[2]))
            temp_X1 = self.scale.transform(temp_X1)
            return temp_X1.reshape(X.shape)

        def fit(self, X):
            # remove overlaping
            remove = int(X.shape[1] / 2)
            temp_X = X[:, -remove:, :]
            # flatten data
            temp_X = temp_X.reshape((temp_X.shape[0] * temp_X.shape[1], temp_X.
↪shape[2]))
            scale = StandardScaler()
            scale.fit(temp_X)
            ##saving for furter usage
```

```
            ## will use in predicton pipeline
            pickle.dump(scale,open('Scale_2class.p','wb'))
            self.scale = scale
            return self

    # Utility function to read the data from csv file
    def _read_csv(filename):
        return pd.read_csv(filename, delim_whitespace=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}/Inertial Signals/
↪{signal}_{subset}.txt'
            signals_data.append( _read_csv(filename).as_matrix())

        # Transpose is used to change the dimensionality 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))

    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]
        y[y<=3] = 0
        y[y>3] = 1
        return pd.get_dummies(y).as_matrix()

    X_train_2c, X_val_2c = load_signals('train'), load_signals('test')
    Y_train_2c, Y_val_2c = load_y('train'), load_y('test')
    ###Scling data
    Scale = scaling_tseries_data()
    Scale.fit(X_train_2c)
    X_train_2c = Scale.transform(X_train_2c)
    X_val_2c = Scale.transform(X_val_2c)
    return X_train_2c, Y_train_2c, X_val_2c,  Y_val_2c
```

[40]:
```
X_train_2c, Y_train_2c, X_val_2c,  Y_val_2c = data_scaled_2class()
```

```
/Users/mayankgupta/anaconda3/lib/python3.7/site-
packages/ipykernel_launcher.py:62: FutureWarning: Method .as_matrix will be
removed in a future version. Use .values instead.
/Users/mayankgupta/anaconda3/lib/python3.7/site-
packages/ipykernel_launcher.py:80: FutureWarning: Method .as_matrix will be
removed in a future version. Use .values instead.
```

[41]:
```
print(Y_train_2c.shape)
print(Y_val_2c.shape)
```

```
(7352, 2)
(2947, 2)
```

1.4.4.1 Model for classifying data into Static and Dynamic activities

[42]:
```
K.clear_session()
np.random.seed(0)
tf.set_random_seed(0)
sess = tf.Session(graph=tf.get_default_graph())
K.set_session(sess)
model = Sequential()
model.add(Conv1D(filters=32, kernel_size=3,␣
 ↪activation='relu',kernel_initializer='he_uniform',input_shape=(128,9)))
model.add(Conv1D(filters=32, kernel_size=3,␣
 ↪activation='relu',kernel_initializer='he_uniform'))
model.add(Dropout(0.6))
model.add(MaxPooling1D(pool_size=2))
model.add(Flatten())
model.add(Dense(50, activation='relu'))
model.add(Dense(2, activation='softmax'))
model.summary()
```

```
WARNING:tensorflow:Large dropout rate: 0.6 (>0.5). In TensorFlow 2.x, dropout()
uses dropout rate instead of keep_prob. Please ensure that this is intended.
WARNING:tensorflow:From /Users/mayankgupta/anaconda3/lib/python3.7/site-
packages/keras/backend/tensorflow_backend.py:4070: The name tf.nn.max_pool is
deprecated. Please use tf.nn.max_pool2d instead.

Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv1d_1 (Conv1D)            (None, 126, 32)           896
_________________________________________________________________
conv1d_2 (Conv1D)            (None, 124, 32)           3104
```

```
_________________________________________________________________
dropout_1 (Dropout)          (None, 124, 32)           0
_________________________________________________________________
max_pooling1d_1 (MaxPooling1 (None, 62, 32)            0
_________________________________________________________________
flatten_1 (Flatten)          (None, 1984)              0
_________________________________________________________________
dense_1 (Dense)              (None, 50)                99250
_________________________________________________________________
dense_2 (Dense)              (None, 2)                 102
=================================================================
Total params: 103,352
Trainable params: 103,352
Non-trainable params: 0
_________________________________________________________________
```

[44]:
```
import keras
import math
adam = keras.optimizers.Adam(lr=0.001)
```

[45]:
```
model.compile(loss='categorical_crossentropy', optimizer=adam,␣
 ↪metrics=['accuracy'])
model.fit(X_train_2c,Y_train_2c, epochs=20,␣
 ↪batch_size=16,validation_data=(X_val_2c, Y_val_2c), verbose=1)
```

```
WARNING:tensorflow:From /Users/mayankgupta/anaconda3/lib/python3.7/site-
packages/keras/backend/tensorflow_backend.py:422: The name tf.global_variables
is deprecated. Please use tf.compat.v1.global_variables instead.

Train on 7352 samples, validate on 2947 samples
Epoch 1/20
7352/7352 [==============================] - 4s 578us/step - loss: 0.0539 -
accuracy: 0.9786 - val_loss: 0.0119 - val_accuracy: 0.9980
Epoch 2/20
7352/7352 [==============================] - 4s 537us/step - loss: 0.0016 -
accuracy: 0.9993 - val_loss: 0.0181 - val_accuracy: 0.9959
Epoch 3/20
7352/7352 [==============================] - 4s 509us/step - loss: 0.0029 -
accuracy: 0.9990 - val_loss: 0.0088 - val_accuracy: 0.9983
Epoch 4/20
7352/7352 [==============================] - 4s 554us/step - loss: 5.9931e-05 -
accuracy: 1.0000 - val_loss: 0.0124 - val_accuracy: 0.9980
Epoch 5/20
7352/7352 [==============================] - 4s 517us/step - loss: 4.5958e-05 -
accuracy: 1.0000 - val_loss: 0.0099 - val_accuracy: 0.9983
Epoch 6/20
7352/7352 [==============================] - 4s 511us/step - loss: 2.1727e-05 -
accuracy: 1.0000 - val_loss: 0.0145 - val_accuracy: 0.9980
```

```
Epoch 7/20
7352/7352 [==============================] - 4s 555us/step - loss: 2.7385e-05 -
accuracy: 1.0000 - val_loss: 0.0118 - val_accuracy: 0.9983
Epoch 8/20
7352/7352 [==============================] - 4s 535us/step - loss: 6.7310e-06 -
accuracy: 1.0000 - val_loss: 0.0129 - val_accuracy: 0.9980
Epoch 9/20
7352/7352 [==============================] - 4s 492us/step - loss: 3.7717e-06 -
accuracy: 1.0000 - val_loss: 0.0134 - val_accuracy: 0.9980
Epoch 10/20
7352/7352 [==============================] - 3s 454us/step - loss: 3.5783e-06 -
accuracy: 1.0000 - val_loss: 0.0144 - val_accuracy: 0.9980
Epoch 11/20
7352/7352 [==============================] - 4s 500us/step - loss: 3.2247e-06 -
accuracy: 1.0000 - val_loss: 0.0134 - val_accuracy: 0.9983
Epoch 12/20
7352/7352 [==============================] - 4s 477us/step - loss: 2.1792e-06 -
accuracy: 1.0000 - val_loss: 0.0141 - val_accuracy: 0.9980
Epoch 13/20
7352/7352 [==============================] - 3s 446us/step - loss: 2.4201e-06 -
accuracy: 1.0000 - val_loss: 0.0139 - val_accuracy: 0.9983
Epoch 14/20
7352/7352 [==============================] - 3s 441us/step - loss: 7.1608e-06 -
accuracy: 1.0000 - val_loss: 0.0108 - val_accuracy: 0.9980
Epoch 15/20
7352/7352 [==============================] - 3s 474us/step - loss: 4.0267e-05 -
accuracy: 1.0000 - val_loss: 0.0266 - val_accuracy: 0.9922
Epoch 16/20
7352/7352 [==============================] - 3s 458us/step - loss: 5.3435e-06 -
accuracy: 1.0000 - val_loss: 0.0277 - val_accuracy: 0.9929
Epoch 17/20
7352/7352 [==============================] - 3s 447us/step - loss: 8.3254e-08 -
accuracy: 1.0000 - val_loss: 0.0262 - val_accuracy: 0.9929
Epoch 18/20
7352/7352 [==============================] - 3s 442us/step - loss: 6.1464e-08 -
accuracy: 1.0000 - val_loss: 0.0255 - val_accuracy: 0.9929
Epoch 19/20
7352/7352 [==============================] - 3s 442us/step - loss: 3.2607e-08 -
accuracy: 1.0000 - val_loss: 0.0255 - val_accuracy: 0.9929
Epoch 20/20
7352/7352 [==============================] - 3s 449us/step - loss: 9.2603e-08 -
accuracy: 1.0000 - val_loss: 0.0233 - val_accuracy: 0.9936
```

[45]: `<keras.callbacks.callbacks.History at 0x1a2d0be160>`

[46]:
```
_,acc_val = model.evaluate(X_val_2c,Y_val_2c,verbose=0)
_,acc_train = model.evaluate(X_train_2c,Y_train_2c,verbose=0)
print('Train_accuracy',acc_train,'test_accuracy',acc_val)
```

```
Train_accuracy 1.0 test_accuracy 0.9935527443885803
```

[47]:
```
##saving model
model.save('final_model_2class.h5')
```

- Classification of Static and Dynamic Activities is Perfect, We got 99.35% accuracy on test data

1.4.4.2 Model for Classifying Static Activities

[48]:
```
##data preparation
def data_scaled_static():
    """
    Obtain the dataset from multiple files.
    Returns: X_train, X_test, y_train, y_test
    """
    # Data directory
    DATADIR = 'UCI_HAR_Dataset'
    # 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"
        ]
    from sklearn.base import BaseEstimator, TransformerMixin
    class scaling_tseries_data(BaseEstimator, TransformerMixin):
        from sklearn.preprocessing import StandardScaler
        def __init__(self):
            self.scale = None

        def transform(self, X):
            temp_X1 = X.reshape((X.shape[0] * X.shape[1], X.shape[2]))
            temp_X1 = self.scale.transform(temp_X1)
            return temp_X1.reshape(X.shape)

        def fit(self, X):
            # remove overlaping
```

```
            remove = int(X.shape[1] / 2)
            temp_X = X[:, -remove:, :]
            # flatten data
            temp_X = temp_X.reshape((temp_X.shape[0] * temp_X.shape[1], temp_X.
↪shape[2]))
            scale = StandardScaler()
            scale.fit(temp_X)
            #for furter use at prediction pipeline
            pickle.dump(scale,open('Scale_static.p','wb'))
            self.scale = scale
            return self

    # Utility function to read the data from csv file
    def _read_csv(filename):
        return pd.read_csv(filename, delim_whitespace=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}/Inertial Signals/
↪{signal}_{subset}.txt'
            signals_data.append( _read_csv(filename).as_matrix())

        # Transpose is used to change the dimensionality 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))

    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]
        y_subset = y>3
        y = y[y_subset]
        return pd.get_dummies(y).as_matrix(),y_subset

    Y_train_s,y_train_sub = load_y('train')
    Y_val_s,y_test_sub = load_y('test')
```

```
    X_train_s, X_val_s = load_signals('train'), load_signals('test')
    X_train_s = X_train_s[y_train_sub]
    X_val_s = X_val_s[y_test_sub]

    ###Scling data
    Scale = scaling_tseries_data()
    Scale.fit(X_train_s)
    X_train_s = Scale.transform(X_train_s)
    X_val_s = Scale.transform(X_val_s)

    return X_train_s, Y_train_s, X_val_s,  Y_val_s
```

[49]:
```
X_train_s, Y_train_s, X_val_s,  Y_val_s = data_scaled_static()
```

```
/Users/mayankgupta/anaconda3/lib/python3.7/site-
packages/ipykernel_launcher.py:78: FutureWarning: Method .as_matrix will be
removed in a future version. Use .values instead.
/Users/mayankgupta/anaconda3/lib/python3.7/site-
packages/ipykernel_launcher.py:60: FutureWarning: Method .as_matrix will be
removed in a future version. Use .values instead.
```

[50]:
```
print('X Shape of train data',X_train_s.shape, 'Y shape', Y_train_s.shape)
print('X Shape of val data',X_val_s.shape,'Y shape',Y_val_s.shape)
```

```
X Shape of train data (4067, 128, 9) Y shape (4067, 3)
X Shape of val data (1560, 128, 9) Y shape (1560, 3)
```

- Model to distinguish Static Activities

[55]:
```
np.random.seed(0)
tf.set_random_seed(0)
sess = tf.Session(graph=tf.get_default_graph())
K.set_session(sess)
model = Sequential()
model.add(Conv1D(filters=64, kernel_size=7,␣
 ↪activation='relu',kernel_initializer='he_uniform',input_shape=(128,9)))
model.add(Conv1D(filters=32, kernel_size=3,␣
 ↪activation='relu',kernel_initializer='he_uniform'))
model.add(Dropout(0.6))
model.add(MaxPooling1D(pool_size=3))
model.add(Flatten())
model.add(Dense(30, activation='relu'))
model.add(Dense(3, activation='softmax'))
model.summary()
```

```
WARNING:tensorflow:Large dropout rate: 0.6 (>0.5). In TensorFlow 2.x, dropout()
uses dropout rate instead of keep_prob. Please ensure that this is intended.
```

```
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv1d_1 (Conv1D)            (None, 122, 64)           4096
_________________________________________________________________
conv1d_2 (Conv1D)            (None, 120, 32)           6176
_________________________________________________________________
dropout_1 (Dropout)          (None, 120, 32)           0
_________________________________________________________________
max_pooling1d_1 (MaxPooling1 (None, 40, 32)            0
_________________________________________________________________
flatten_1 (Flatten)          (None, 1280)              0
_________________________________________________________________
dense_1 (Dense)              (None, 30)                38430
_________________________________________________________________
dense_2 (Dense)              (None, 3)                 93
=================================================================
Total params: 48,795
Trainable params: 48,795
Non-trainable params: 0
_________________________________________________________________
```

[56]:
```
import math
adam = keras.optimizers.Adam(lr=0.004)
model.compile(loss='categorical_crossentropy', optimizer=adam,␣
 ↪metrics=['accuracy'])
model.fit(X_train_s,Y_train_s, epochs=20,␣
 ↪batch_size=32,validation_data=(X_val_s, Y_val_s), verbose=1)
# K.clear_session()
```

```
Train on 4067 samples, validate on 1560 samples
Epoch 1/20
4067/4067 [==============================] - 2s 512us/step - loss: 0.3530 -
accuracy: 0.8832 - val_loss: 0.3818 - val_accuracy: 0.8769
Epoch 2/20
4067/4067 [==============================] - 2s 453us/step - loss: 0.2075 -
accuracy: 0.9201 - val_loss: 0.2615 - val_accuracy: 0.9071
Epoch 3/20
4067/4067 [==============================] - 2s 486us/step - loss: 0.1686 -
accuracy: 0.9339 - val_loss: 0.2577 - val_accuracy: 0.9083
Epoch 4/20
4067/4067 [==============================] - 2s 470us/step - loss: 0.1643 -
accuracy: 0.9380 - val_loss: 0.2115 - val_accuracy: 0.9186
Epoch 5/20
4067/4067 [==============================] - 2s 470us/step - loss: 0.1443 -
accuracy: 0.9474 - val_loss: 0.2745 - val_accuracy: 0.8910
```

```
Epoch 6/20
4067/4067 [==============================] - 2s 471us/step - loss: 0.3227 -
accuracy: 0.9066 - val_loss: 0.3478 - val_accuracy: 0.8936
Epoch 7/20
4067/4067 [==============================] - 2s 478us/step - loss: 0.1945 -
accuracy: 0.9280 - val_loss: 0.2830 - val_accuracy: 0.9058
Epoch 8/20
4067/4067 [==============================] - 2s 544us/step - loss: 0.1619 -
accuracy: 0.9442 - val_loss: 0.2203 - val_accuracy: 0.9212
Epoch 9/20
4067/4067 [==============================] - 2s 451us/step - loss: 0.1364 -
accuracy: 0.9481 - val_loss: 0.2200 - val_accuracy: 0.9333
Epoch 10/20
4067/4067 [==============================] - 2s 481us/step - loss: 0.1266 -
accuracy: 0.9521 - val_loss: 0.2404 - val_accuracy: 0.9423
Epoch 11/20
4067/4067 [==============================] - 3s 828us/step - loss: 0.1197 -
accuracy: 0.9518 - val_loss: 0.2196 - val_accuracy: 0.9301
Epoch 12/20
4067/4067 [==============================] - 2s 578us/step - loss: 0.1089 -
accuracy: 0.9557 - val_loss: 0.2015 - val_accuracy: 0.9429
Epoch 13/20
4067/4067 [==============================] - 2s 525us/step - loss: 0.1163 -
accuracy: 0.9592 - val_loss: 0.2243 - val_accuracy: 0.9115
Epoch 14/20
4067/4067 [==============================] - 2s 516us/step - loss: 0.0980 -
accuracy: 0.9614 - val_loss: 0.1789 - val_accuracy: 0.9391
Epoch 15/20
4067/4067 [==============================] - 2s 516us/step - loss: 0.1119 -
accuracy: 0.9604 - val_loss: 0.2233 - val_accuracy: 0.9026
Epoch 16/20
4067/4067 [==============================] - 2s 568us/step - loss: 0.1072 -
accuracy: 0.9616 - val_loss: 0.2737 - val_accuracy: 0.9237
Epoch 17/20
4067/4067 [==============================] - 2s 493us/step - loss: 0.1385 -
accuracy: 0.9567 - val_loss: 0.1999 - val_accuracy: 0.9506
Epoch 18/20
4067/4067 [==============================] - 2s 551us/step - loss: 0.0941 -
accuracy: 0.9648 - val_loss: 0.1996 - val_accuracy: 0.9141
Epoch 19/20
4067/4067 [==============================] - 2s 524us/step - loss: 0.0780 -
accuracy: 0.9693 - val_loss: 0.1935 - val_accuracy: 0.9372
Epoch 20/20
4067/4067 [==============================] - 3s 623us/step - loss: 0.0796 -
accuracy: 0.9727 - val_loss: 0.2464 - val_accuracy: 0.9263
```

[56]: `<keras.callbacks.callbacks.History at 0x1a2e467828>`

[57]:
```
_,acc_val = model.evaluate(X_val_s, Y_val_s,verbose=0)
_,acc_train = model.evaluate(X_train_s,Y_train_s,verbose=0)
print('Train_accuracy',acc_train,'test_accuracy',acc_val)
```

```
Train_accuracy 0.9675436615943909 test_accuracy 0.9262820482254028
```

[58]:
```
##saving model
model.save('final_model_static.h5')
```

[62]:
```
# clear tf session
K.clear_session()
```

- Simple model gives us approx. 93% accuracy for classifying Static Activities

1.4.4.3 Model for Classifying Dynamic Activities

[59]:
```
##data preparation
def data_scaled_dynamic():
    """
    Obtain the dataset from multiple files.
    Returns: X_train, X_test, y_train, y_test
    """
    # Data directory
    DATADIR = 'UCI_HAR_Dataset'
    # 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"
        ]
    from sklearn.base import BaseEstimator, TransformerMixin
    class scaling_tseries_data(BaseEstimator, TransformerMixin):
        from sklearn.preprocessing import StandardScaler
        def __init__(self):
            self.scale = None

        def transform(self, X):
```

```
            temp_X1 = X.reshape((X.shape[0] * X.shape[1], X.shape[2]))
            temp_X1 = self.scale.transform(temp_X1)
            return temp_X1.reshape(X.shape)

        def fit(self, X):
            # remove overlaping
            remove = int(X.shape[1] / 2)
            temp_X = X[:, -remove:, :]
            # flatten data
            temp_X = temp_X.reshape((temp_X.shape[0] * temp_X.shape[1], temp_X.
↪shape[2]))
            scale = StandardScaler()
            scale.fit(temp_X)
            pickle.dump(scale,open('Scale_dynamic.p','wb'))
            self.scale = scale
            return self

    # Utility function to read the data from csv file
    def _read_csv(filename):
        return pd.read_csv(filename, delim_whitespace=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}/Inertial Signals/
↪{signal}_{subset}.txt'
            signals_data.append( _read_csv(filename).as_matrix())

        # Transpose is used to change the dimensionality 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))

    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]
        y_subset = y<=3
```

```
        y = y[y_subset]
        return pd.get_dummies(y).as_matrix(),y_subset

    Y_train_d,y_train_sub = load_y('train')
    Y_val_d,y_test_sub = load_y('test')
    X_train_d, X_val_d = load_signals('train'), load_signals('test')
    X_train_d = X_train_d[y_train_sub]
    X_val_d = X_val_d[y_test_sub]

    ###Scling data
    Scale = scaling_tseries_data()
    Scale.fit(X_train_d)
    X_train_d = Scale.transform(X_train_d)
    X_val_d = Scale.transform(X_val_d)

    return X_train_d, Y_train_d, X_val_d,  Y_val_d
```

[60]:
```
X_train_d, Y_train_d, X_val_d,  Y_val_d = data_scaled_dynamic()
```

```
/Users/mayankgupta/anaconda3/lib/python3.7/site-
packages/ipykernel_launcher.py:77: FutureWarning: Method .as_matrix will be
removed in a future version. Use .values instead.
/Users/mayankgupta/anaconda3/lib/python3.7/site-
packages/ipykernel_launcher.py:59: FutureWarning: Method .as_matrix will be
removed in a future version. Use .values instead.
```

[61]:
```
print('Train X shape',X_train_d.shape,'Test X shape',X_val_d.shape)
print('Train Y shape',Y_train_d.shape,'Test Y shape',Y_val_d.shape)
```

```
Train X shape (3285, 128, 9) Test X shape (1387, 128, 9)
Train Y shape (3285, 3) Test Y shape (1387, 3)
```

- Model to distinguish Dynamic Activities

[70]:
```
np.random.seed(0)
tf.set_random_seed(0)
sess = tf.Session(graph=tf.get_default_graph())
K.set_session(sess)
model = Sequential()
model.add(Conv1D(filters=64, kernel_size=7,␣
 ↪activation='relu',kernel_initializer='he_uniform',input_shape=(128,9)))
model.add(Conv1D(filters=32, kernel_size=3,␣
 ↪activation='relu',kernel_initializer='he_uniform'))
model.add(Dropout(0.6))
model.add(MaxPooling1D(pool_size=3))
model.add(Flatten())
model.add(Dense(30, activation='relu'))
```

```
model.add(Dense(3, activation='softmax'))
model.summary()
```

```
WARNING:tensorflow:Large dropout rate: 0.6 (>0.5). In TensorFlow 2.x, dropout()
uses dropout rate instead of keep_prob. Please ensure that this is intended.
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv1d_1 (Conv1D)            (None, 122, 64)           4096
_________________________________________________________________
conv1d_2 (Conv1D)            (None, 120, 32)           6176
_________________________________________________________________
dropout_1 (Dropout)          (None, 120, 32)           0
_________________________________________________________________
max_pooling1d_1 (MaxPooling1 (None, 40, 32)            0
_________________________________________________________________
flatten_1 (Flatten)          (None, 1280)              0
_________________________________________________________________
dense_1 (Dense)              (None, 30)                38430
_________________________________________________________________
dense_2 (Dense)              (None, 3)                 93
=================================================================
Total params: 48,795
Trainable params: 48,795
Non-trainable params: 0
_________________________________________________________________
```

[71]:
```
import math
adam = keras.optimizers.Adam(lr=0.004)
model.compile(loss='categorical_crossentropy', optimizer=adam,␣
 ↪metrics=['accuracy'])
model.fit(X_train_d,Y_train_d, epochs=20,␣
 ↪batch_size=32,validation_data=(X_val_d, Y_val_d), verbose=1)
# K.clear_session()
```

```
Train on 3285 samples, validate on 1387 samples
Epoch 1/20
3285/3285 [==============================] - 2s 457us/step - loss: 0.4220 -
accuracy: 0.8311 - val_loss: 0.1392 - val_accuracy: 0.9575
Epoch 2/20
3285/3285 [==============================] - 1s 370us/step - loss: 0.0158 -
accuracy: 0.9951 - val_loss: 0.1695 - val_accuracy: 0.9416
Epoch 3/20
3285/3285 [==============================] - 1s 429us/step - loss: 0.0051 -
accuracy: 0.9997 - val_loss: 0.1024 - val_accuracy: 0.9719
Epoch 4/20
```

```
3285/3285 [==============================] - 2s 464us/step - loss: 0.0278 -
accuracy: 0.9927 - val_loss: 0.0937 - val_accuracy: 0.9697
Epoch 5/20
3285/3285 [==============================] - 1s 427us/step - loss: 0.0287 -
accuracy: 0.9906 - val_loss: 0.4331 - val_accuracy: 0.9063
Epoch 6/20
3285/3285 [==============================] - 1s 400us/step - loss: 0.0362 -
accuracy: 0.9884 - val_loss: 0.1671 - val_accuracy: 0.9668
Epoch 7/20
3285/3285 [==============================] - 1s 404us/step - loss: 0.0066 -
accuracy: 0.9979 - val_loss: 0.1580 - val_accuracy: 0.9603
Epoch 8/20
3285/3285 [==============================] - 1s 380us/step - loss: 0.0021 -
accuracy: 0.9988 - val_loss: 0.1128 - val_accuracy: 0.9697
Epoch 9/20
3285/3285 [==============================] - 1s 370us/step - loss: 2.2523e-04 -
accuracy: 1.0000 - val_loss: 0.1300 - val_accuracy: 0.9704
Epoch 10/20
3285/3285 [==============================] - 1s 374us/step - loss: 0.0170 -
accuracy: 0.9939 - val_loss: 0.2181 - val_accuracy: 0.9301
Epoch 11/20
3285/3285 [==============================] - 1s 386us/step - loss: 0.0238 -
accuracy: 0.9951 - val_loss: 0.1424 - val_accuracy: 0.9474
Epoch 12/20
3285/3285 [==============================] - 1s 377us/step - loss: 0.0117 -
accuracy: 0.9960 - val_loss: 0.1054 - val_accuracy: 0.9668
Epoch 13/20
3285/3285 [==============================] - 1s 375us/step - loss: 0.0013 -
accuracy: 0.9997 - val_loss: 0.1528 - val_accuracy: 0.9632
Epoch 14/20
3285/3285 [==============================] - 1s 395us/step - loss: 0.0032 -
accuracy: 0.9994 - val_loss: 0.1311 - val_accuracy: 0.9625
Epoch 15/20
3285/3285 [==============================] - 1s 362us/step - loss: 5.3622e-04 -
accuracy: 1.0000 - val_loss: 0.1327 - val_accuracy: 0.9567
Epoch 16/20
3285/3285 [==============================] - 1s 404us/step - loss: 2.1511e-04 -
accuracy: 1.0000 - val_loss: 0.1358 - val_accuracy: 0.9618
Epoch 17/20
3285/3285 [==============================] - 1s 365us/step - loss: 0.0189 -
accuracy: 0.9954 - val_loss: 0.2842 - val_accuracy: 0.9603
Epoch 18/20
3285/3285 [==============================] - 2s 464us/step - loss: 0.0798 -
accuracy: 0.9839 - val_loss: 0.1521 - val_accuracy: 0.9553
Epoch 19/20
3285/3285 [==============================] - 1s 336us/step - loss: 8.9970e-04 -
accuracy: 0.9997 - val_loss: 0.1204 - val_accuracy: 0.9712
Epoch 20/20
```

```
3285/3285 [==============================] - 1s 309us/step - loss: 1.5743e-04 -
accuracy: 1.0000 - val_loss: 0.0843 - val_accuracy: 0.9755
```

[71]:
```
<keras.callbacks.callbacks.History at 0x1a2f9728d0>
```

[72]:
```
_,acc_val = model.evaluate(X_val_d, Y_val_d,verbose=0)
_,acc_train = model.evaluate(X_train_d,Y_train_d,verbose=0)
print('Train_accuracy',acc_train,'test_accuracy',acc_val)
```

```
Train_accuracy 1.0 test_accuracy 0.9754866361618042
```

[73]:
```
##saving model
model.save('final_model_dynamic.h5')
```

[74]:
```
# clear tf session
K.clear_session()
```

1.4.4.4 Load and Split whole data

[75]:
```
def data():
    """
    Obtain the dataset from multiple files.
    Returns: X_train, X_test, y_train, y_test
    """
    # Data directory
    DATADIR = 'UCI_HAR_Dataset'
    # 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"
        ]
    # Utility function to read the data from csv file
    def _read_csv(filename):
        return pd.read_csv(filename, delim_whitespace=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}/Inertial Signals/
↪{signal}_{subset}.txt'
            signals_data.append( _read_csv(filename).as_matrix())

        # Transpose is used to change the dimensionality 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))

    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 y

    X_train, X_val = load_signals('train'), load_signals('test')
    Y_train, Y_val = load_y('train'), load_y('test')

    return X_train, Y_train, X_val,  Y_val
```

[76]:
```
X_train, Y_train, X_val,  Y_val = data()
```

```
/Users/mayankgupta/anaconda3/lib/python3.7/site-
packages/ipykernel_launcher.py:35: FutureWarning: Method .as_matrix will be
removed in a future version. Use .values instead.
```

[78]:
```
print('shape of train X',X_train.shape, 'shape of train Y',Y_train.shape)
print('shape of test X', X_val.shape, 'shape of test Y', Y_val.shape)
```

```
shape of train X (7352, 128, 9) shape of train Y (7352,)
shape of test X (2947, 128, 9) shape of test Y (2947,)
```

1.4.4.5 Final prediction pipeline

[79]:
```
##loading keras models and picle files for scaling data
from keras.models import load_model
import pickle
model_2class = load_model('final_model_2class.h5')
model_dynamic = load_model('final_model_dynamic.h5')
```

```
model_static = load_model('final_model_static.h5')
scale_2class = pickle.load(open('Scale_2class.p','rb'))
scale_static = pickle.load(open('Scale_static.p','rb'))
scale_dynamic = pickle.load(open('Scale_dynamic.p','rb'))
```

[80]:
```
##scaling the data
def transform_data(X,scale):
    X_temp = X.reshape((X.shape[0] * X.shape[1], X.shape[2]))
    X_temp = scale.transform(X_temp)
    return X_temp.reshape(X.shape)
```

[81]:
```
#predicting output activity
def predict_activity(X):
    ##predicting whether dynamic or static
    predict_2class = model_2class.predict(transform_data(X,scale_2class))
    Y_pred_2class =  np.argmax(predict_2class, axis=1)
    #static data filter
    X_static = X[Y_pred_2class==1]
    #dynamic data filter
    X_dynamic = X[Y_pred_2class==0]
    #predicting static activities
    predict_static = model_static.predict(transform_data(X_static,scale_static))
    predict_static = np.argmax(predict_static,axis=1)
    #adding 4 because need to get inal prediction lable as output
    predict_static = predict_static + 4
    #predicting dynamic activites
    predict_dynamic = model_dynamic.
 ↪predict(transform_data(X_dynamic,scale_dynamic))
    predict_dynamic = np.argmax(predict_dynamic,axis=1)
    #adding 1 because need to get inal prediction lable as output
    predict_dynamic = predict_dynamic + 1
    ##appending final output to one list in the same sequence of input data
    i,j = 0,0
    final_pred = []
    for mask in Y_pred_2class:
        if mask == 1:
            final_pred.append(predict_static[i])
            i = i + 1
        else:
            final_pred.append(predict_dynamic[j])
            j = j + 1
    return final_pred
```

[82]:
```
##predicting
final_pred_val = predict_activity(X_val)
final_pred_train = predict_activity(X_train)
```

[83]:
```
##accuracy of train and test
from sklearn.metrics import accuracy_score
print('Accuracy of train data',accuracy_score(Y_train,final_pred_train))
print('Accuracy of validation data',accuracy_score(Y_val,final_pred_val))
```

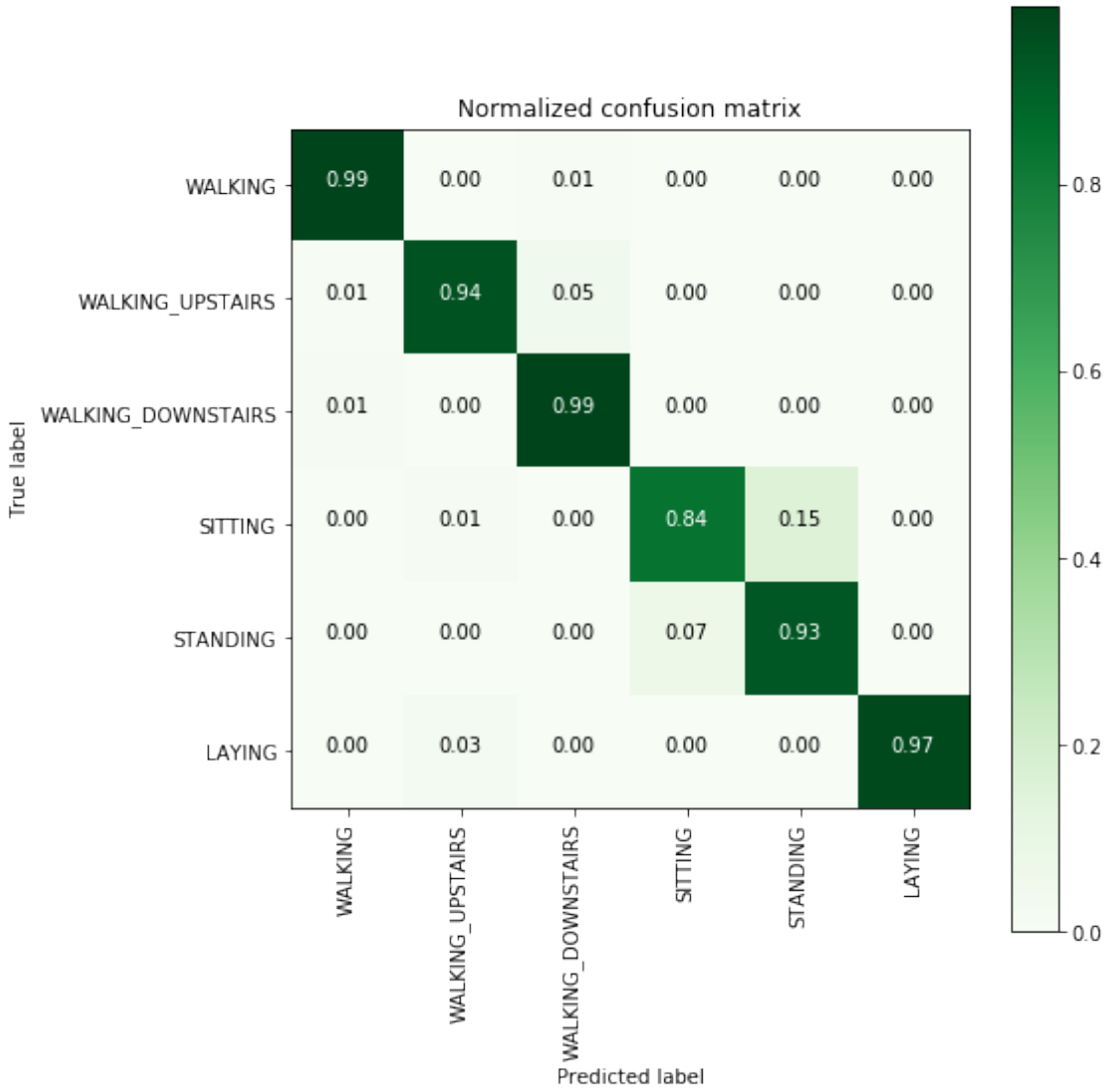
```
Accuracy of train data 0.9820457018498367
Accuracy of validation data 0.9443501866304717
```

[96]:
```
import itertools
import numpy as np
import matplotlib.pyplot as plt
from sklearn.metrics import confusion_matrix

def plot_confusion_matrix(cm, classes,
                          normalize=False,
                          title='Confusion matrix',
                          cmap=plt.cm.Blues):
    if normalize:
        cm = cm.astype('float') / cm.sum(axis=1)[:, np.newaxis]

    plt.imshow(cm, interpolation='nearest', cmap=cmap)
    plt.title(title)
    plt.colorbar()
    tick_marks = np.arange(len(classes))
    plt.xticks(tick_marks, classes, rotation=90)
    plt.yticks(tick_marks, classes)

    fmt = '.2f' if normalize else 'd'
    thresh = cm.max() / 2.
    for i, j in itertools.product(range(cm.shape[0]), range(cm.shape[1])):
        plt.text(j, i, format(cm[i, j], fmt),
                 horizontalalignment="center",
                 color="white" if cm[i, j] > thresh else "black")

    plt.tight_layout()
    plt.ylabel('True label')
    plt.xlabel('Predicted label')
```

[97]:
```
#confusion metric
cm = confusion_matrix(Y_val, final_pred_val,labels=range(1,7))
cm
```

[97]:
```
array([[492,   1,   3,   0,   0,   0],
       [  3, 445,  23,   0,   0,   0],
       [  4,   0, 416,   0,   0,   0],
       [  1,   4,   0, 411,  75,   0],
       [  0,   0,   0,  36, 496,   0],
       [  0,  14,   0,   0,   0, 523]])
```

[98]:
```
import matplotlib.pyplot as plt
plt.figure(figsize=(8,8))
labels=['WALKING','WALKING_UPSTAIRS','WALKING_DOWNSTAIRS','SITTING','STANDING','LAYING']
plot_confusion_matrix(cm, classes=labels,
                      normalize=True, title='Normalized confusion matrix', cmap␣
 ↪= plt.cm.Greens)
plt.show()
```



2. Conclusion

2.1 Models Output

[104]:
```
from prettytable import PrettyTable

table = PrettyTable()
table.field_names = ['LSTM Layer', 'Dropout', 'Loss', 'Accuracy']

table.add_row([32, 0.5, 0.41655886096877154, 0.8954869508743286])
table.add_row([64, 0.5, 0.35375094639873494, 0.9148286581039429])
table.add_row([64, 0.7, 'nan', 0.16830675303936005])
table.add_row([32, 0.7, 0.596762544016313, 0.8381404876708984])
table.add_row([64, 0.6, 0.4956902541945778, 0.9060060977935791])
table.add_row([32, 0.6, 0.5602035771178105, 0.8812351822853088])
table.add_row(['64+32', '2*0.7', 'nan', 0.16830675303936005])
table.add_row(['64+32', '2*0.6', 'nan', 0.16830675303936005])
table.add_row(['64+32', '2*0.5', 0.6456601167650766, 0.900237500667572])
table.add_row(['64+32', 0.7, 'nan', 0.16830675303936005])
table.add_row(['64+32', 0.6, 0.5375813010956876, 0.9053274393081665])
table.add_row(['64+32', 0.5, 0.3804781971405892, 0.9141499996185303])
table.add_row(['64+16', 0.5, 0.5414807511955393, 0.9056667685508728])
table.add_row(['32+16', 0.5, 0.3589311393391746, 0.922633171081543])
table.add_row(['32+8', 0.5, 0.3761567989555303, 0.7539871335029602])
table.add_row(['32+8', 0.5, 0.3761567989555303, 0.7539871335029602])
table.add_row(['32+8', 0.5, 0.3761567989555303, 0.7539871335029602])
table.add_row(['32+16', 0.6, 0.36157595883878874, 0.9100780487060547])
table.add_row(['32+16', 0.4, 0.39125852214684165, 0.9066847562789917])
table.add_row(['128', 0.25, 0.31214076887265046, 0.9256871342658997])
table.add_row(['Divide and Conquer', 'N/A', '-', 0.9443501866304717])

print(table)
```

```
+--------------------+---------+---------------------+---------------------+
|     LSTM Layer     | Dropout |         Loss        |       Accuracy      |
+--------------------+---------+---------------------+---------------------+
|         32         |   0.5   | 0.41655886096877154 |  0.8954869508743286 |
|         64         |   0.5   | 0.35375094639873494 |  0.9148286581039429 |
|         64         |   0.7   |         nan         | 0.16830675303936005 |
|         32         |   0.7   |  0.596762544016313  |  0.8381404876708984 |
|         64         |   0.6   |  0.4956902541945778 |  0.9060060977935791 |
|         32         |   0.6   |  0.5602035771178105 |  0.8812351822853088 |
|       64+32        |  2*0.7  |         nan         | 0.16830675303936005 |
|       64+32        |  2*0.6  |         nan         | 0.16830675303936005 |
|       64+32        |  2*0.5  |  0.6456601167650766 |  0.900237500667572  |
|       64+32        |   0.7   |         nan         | 0.16830675303936005 |
|       64+32        |   0.6   |  0.5375813010956876 |  0.9053274393081665 |
|       64+32        |   0.5   |  0.3804781971405892 |  0.9141499996185303 |
|       64+16        |   0.5   |  0.5414807511955393 |  0.9056667685508728 |
|       32+16        |   0.5   |  0.3589311393391746 |  0.922633171081543  |
|        32+8        |   0.5   |  0.3761567989555303 |  0.7539871335029602 |
```

```
|        32+8        |   0.5   |  0.3761567989555303 |  0.7539871335029602 |
|        32+8        |   0.5   |  0.3761567989555303 |  0.7539871335029602 |
|       32+16        |   0.6   | 0.36157595883878874 |  0.9100780487060547 |
|       32+16        |   0.4   | 0.39125852214684165 |  0.9066847562789917 |
|        128         |   0.25  | 0.31214076887265046 |  0.9256871342658997 |
| Divide and Conquer |   N/A   |          -          |  0.9443501866304717 |
+--------------------+---------+---------------------+---------------------+
```

2.2 Steps I followed

- Did EDA on dataset
- Run classical machine learning models on 561 handcrafted features
- Run different LSTMs on raw time series data
- Tried 2 LSTMs with larger dropout, increase layer of LSTM from 32 to 64
- Above table contains different permutation and combination of LSTM that i tried
- Implement Divide and Conquer technique for classifying Static and Dynamic Activities and Merge Models for Activities Prediction

2.3 Divide and Conquer

- First classify static and dynamic activities, if label > 3 then static else dynamic
- Classify static activities (Sitting, Standing and Laying)
- Classify dynamic activities (Walking, Walking Upstairs and Walking Downstairs)
- Classify whole data on above three models

2.4 Best Model

- Divide and Conquer gives me 94.43% accuracy

[ ]: