In [1]:

```
# Importing Libraries
```

In [1]:

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

In [2]:

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

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

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

Data

In [3]:

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

In [4]:

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

In [5]:

```
# 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))
```

In [6]:

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

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

In [7]:

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

    return X_train, X_test, y_train, y_test
```

In [9]:

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

In [10]:

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

In [11]:

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

```
Using TensorFlow backend.
```

In [12]:

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

In [13]:

```
# Initializing parameters
```

```
epochs = 30
batch_size = 16
n_hidden = 32
```

In [14]:

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

In [15]:

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

```
/home/lab12/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] == '':
```

In [16]:

```
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

In [91]:

```
# 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()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
lstm_3 (LSTM)                (None, 32)                5376      
_________________________________________________________________
dropout_3 (Dropout)          (None, 32)                0         
_________________________________________________________________
dense_3 (Dense)              (None, 6)                 198       
=================================================================
Total params: 5,574
Trainable params: 5,574
Non-trainable params: 0
_________________________________________________________________
```

In [22]:

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

In [23]:

```
# 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 [==============================] - 92s 13ms/step - loss: 1.3018 - acc: 0.4395 - val_loss
: 1.1254 - val_acc: 0.4662
Epoch 2/30
7352/7352 [==============================] - 94s 13ms/step - loss: 0.9666 - acc: 0.5880 - val_loss
: 0.9491 - val_acc: 0.5714
Epoch 3/30
7352/7352 [==============================] - 97s 13ms/step - loss: 0.7812 - acc: 0.6408 - val_loss
: 0.8286 - val_acc: 0.5850
Epoch 4/30
7352/7352 [==============================] - 95s 13ms/step - loss: 0.6941 - acc: 0.6574 - val_loss
: 0.7297 - val_acc: 0.6128
Epoch 5/30
7352/7352 [==============================] - 92s 13ms/step - loss: 0.6336 - acc: 0.6912 - val_loss
: 0.7359 - val_acc: 0.6787
Epoch 6/30
7352/7352 [==============================] - 94s 13ms/step - loss: 0.5859 - acc: 0.7134 - val_loss
: 0.7015 - val_acc: 0.6939
Epoch 7/30
7352/7352 [==============================] - 95s 13ms/step - loss: 0.5692 - acc: 0.7477 - val_loss
: 0.5995 - val_acc: 0.7387
Epoch 8/30
7352/7352 [==============================] - 96s 13ms/step - loss: 0.4899 - acc: 0.7809 - val_loss
: 0.5762 - val_acc: 0.7387
Epoch 9/30
7352/7352 [==============================] - 90s 12ms/step - loss: 0.4482 - acc: 0.7886 - val_loss
: 0.7413 - val_acc: 0.7126
Epoch 10/30
7352/7352 [==============================] - 90s 12ms/step - loss: 0.4132 - acc: 0.8077 - val_loss
: 0.5048 - val_acc: 0.7513
Epoch 11/30
7352/7352 [==============================] - 89s 12ms/step - loss: 0.3985 - acc: 0.8274 - val_loss
: 0.5234 - val_acc: 0.7452
Epoch 12/30
7352/7352 [==============================] - 91s 12ms/step - loss: 0.3378 - acc: 0.8638 - val_loss
: 0.4114 - val_acc: 0.8833
Epoch 13/30
7352/7352 [==============================] - 91s 12ms/step - loss: 0.2947 - acc: 0.9051 - val_loss
: 0.4386 - val_acc: 0.8731
Epoch 14/30
7352/7352 [==============================] - 90s 12ms/step - loss: 0.2448 - acc: 0.9291 - val_loss
: 0.3768 - val_acc: 0.8921
Epoch 15/30
7352/7352 [==============================] - 91s 12ms/step - loss: 0.2157 - acc: 0.9331 - val_loss
: 0.4441 - val_acc: 0.8931
Epoch 16/30
7352/7352 [==============================] - 90s 12ms/step - loss: 0.2053 - acc: 0.9366 - val_loss
: 0.4162 - val_acc: 0.8968
Epoch 17/30
7352/7352 [==============================] - 89s 12ms/step - loss: 0.2028 - acc: 0.9404 - val_loss
: 0.4538 - val_acc: 0.8962
Epoch 18/30
7352/7352 [==============================] - 93s 13ms/step - loss: 0.1911 - acc: 0.9419 - val_loss
: 0.3964 - val_acc: 0.8999
Epoch 19/30
7352/7352 [==============================] - 96s 13ms/step - loss: 0.1912 - acc: 0.9407 - val_loss
: 0.3165 - val_acc: 0.9030
Epoch 20/30
7352/7352 [==============================] - 96s 13ms/step - loss: 0.1732 - acc: 0.9446 - val_loss
: 0.4546 - val_acc: 0.8904
Epoch 21/30
7352/7352 [==============================] - 94s 13ms/step - loss: 0.1782 - acc: 0.9444 - val_loss
: 0.3346 - val_acc: 0.9063
Epoch 22/30
7352/7352 [==============================] - 95s 13ms/step - loss: 0.1812 - acc: 0.9418 - val_loss
: 0.8164 - val_acc: 0.8582
```

```
Epoch 23/30
7352/7352 [==============================] - 95s 13ms/step - loss: 0.1824 - acc: 0.9426 - val_loss
: 0.4240 - val_acc: 0.9036
Epoch 24/30
7352/7352 [==============================] - 94s 13ms/step - loss: 0.1726 - acc: 0.9429 - val_loss
: 0.4067 - val_acc: 0.9148
Epoch 25/30
7352/7352 [==============================] - 96s 13ms/step - loss: 0.1737 - acc: 0.9411 - val_loss
: 0.3396 - val_acc: 0.9074
Epoch 26/30
7352/7352 [==============================] - 96s 13ms/step - loss: 0.1650 - acc: 0.9461 - val_loss
: 0.3806 - val_acc: 0.9019
Epoch 27/30
7352/7352 [==============================] - 89s 12ms/step - loss: 0.1925 - acc: 0.9415 - val_loss
: 0.6464 - val_acc: 0.8850
Epoch 28/30
7352/7352 [==============================] - 91s 12ms/step - loss: 0.1965 - acc: 0.9425 - val_loss
: 0.3363 - val_acc: 0.9203
Epoch 29/30
7352/7352 [==============================] - 92s 12ms/step - loss: 0.1889 - acc: 0.9431 - val_loss
: 0.3737 - val_acc: 0.9158
Epoch 30/30
7352/7352 [==============================] - 95s 13ms/step - loss: 0.1945 - acc: 0.9414 - val_loss
: 0.3088 - val_acc: 0.9097
```

Out[23]:

```
<keras.callbacks.History at 0x29b5ee36a20>
```

In [24]:

```
# 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                  3      410        75        0                   0
STANDING                 0       87       445        0                   0
WALKING                  0        0         0      481                   2
WALKING_DOWNSTAIRS       0        0         0        0                 382
WALKING_UPSTAIRS         0        0         0        2                  18

Pred                WALKING_UPSTAIRS
True
LAYING                             0
SITTING                            3
STANDING                           0
WALKING                           13
WALKING_DOWNSTAIRS                38
WALKING_UPSTAIRS                 451
```

In [27]:

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

```
2947/2947 [==============================] - 4s 2ms/step
```

In [28]:

```
score
```

Out[28]:

```
[0.3087582236972612, 0.9097387173396675]
```

2 Layer LSTM Architecure

In [84]:

```python
# Initiliazing the sequential model
model = Sequential()
# Configuring the parameters
# Adding first LSTM layer
model.add(LSTM(100,input_shape=(timesteps, input_dim),return_sequences=True,dropout=0.3))

# Adding second LSTM layer
model.add(LSTM(100))
# Adding a dropout layer
model.add(Dropout(0.3))
# Adding a dense output layer with sigmoid activation
model.add(Dense(n_classes, activation='sigmoid'))
model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
lstm_35 (LSTM)               (None, 128, 100)          44000     
_________________________________________________________________
lstm_36 (LSTM)               (None, 100)               80400     
_________________________________________________________________
dropout_18 (Dropout)         (None, 100)               0         
_________________________________________________________________
dense_17 (Dense)             (None, 6)                 606       
=================================================================
Total params: 125,006
Trainable params: 125,006
Non-trainable params: 0
_________________________________________________________________
```

In [85]:

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

In [86]:

```python
# Training the model
model.fit(X_train,
          Y_train,
          batch_size=batch_size,
          validation_data=(X_test, Y_test),epochs=30)
```

```
Train on 7352 samples, validate on 2947 samples
Epoch 1/30
7352/7352 [==============================] - 113s 15ms/step - loss: 1.1610 - acc: 0.4874 - val_los
s: 0.9227 - val_acc: 0.6532
Epoch 2/30
7352/7352 [==============================] - 105s 14ms/step - loss: 0.8213 - acc: 0.6174 - val_los
s: 0.8074 - val_acc: 0.5996
Epoch 3/30
7352/7352 [==============================] - 105s 14ms/step - loss: 0.7097 - acc: 0.6848 - val_los
s: 0.7129 - val_acc: 0.7190
Epoch 4/30
7352/7352 [==============================] - 105s 14ms/step - loss: 0.4844 - acc: 0.8162 - val_los
s: 0.5726 - val_acc: 0.7825
Epoch 5/30
7352/7352 [==============================] - 105s 14ms/step - loss: 0.3839 - acc: 0.8599 - val_los
s: 0.3520 - val_acc: 0.8728
Epoch 6/30
7352/7352 [==============================] - 105s 14ms/step - loss: 0.3103 - acc: 0.8836 - val_los
s: 0.3176 - val_acc: 0.8819
Epoch 7/30
7352/7352 [==============================] - 105s 14ms/step - loss: 0.2783 - acc: 0.8968 - val_los
s: 0.3054 - val_acc: 0.8880
Epoch 8/30
7352/7352 [==============================] - 105s 14ms/step - loss: 0.2390 - acc: 0.9078 - val_los
s: 0.3837 - val_acc: 0.8809
Epoch 9/30
7352/7352 [==============================] - 105s 14ms/step - loss: 0.2426 - acc: 0.9150 - val_los
s: 0.3412 - val_acc: 0.8982
Epoch 10/30
```

```
Epoch 10/30
7352/7352 [==============================] - 105s 14ms/step - loss: 0.2197 - acc: 0.9170 - val_los
s: 0.3200 - val_acc: 0.8985
Epoch 11/30
7352/7352 [==============================] - 109s 15ms/step - loss: 0.2196 - acc: 0.9147 - val_los
s: 0.2507 - val_acc: 0.9111
Epoch 12/30
7352/7352 [==============================] - 105s 14ms/step - loss: 0.2063 - acc: 0.9217 - val_los
s: 0.3350 - val_acc: 0.9026
Epoch 13/30
7352/7352 [==============================] - 105s 14ms/step - loss: 0.2035 - acc: 0.9221 - val_los
s: 0.3739 - val_acc: 0.8884
Epoch 14/30
7352/7352 [==============================] - 105s 14ms/step - loss: 0.1929 - acc: 0.9241 - val_los
s: 0.2621 - val_acc: 0.9104
Epoch 15/30
7352/7352 [==============================] - 105s 14ms/step - loss: 0.1897 - acc: 0.9285 - val_los
s: 0.3772 - val_acc: 0.8985
Epoch 16/30
7352/7352 [==============================] - 105s 14ms/step - loss: 0.1918 - acc: 0.9272 - val_los
s: 0.3406 - val_acc: 0.9036
Epoch 17/30
7352/7352 [==============================] - 107s 15ms/step - loss: 0.1848 - acc: 0.9294 - val_los
s: 0.3606 - val_acc: 0.9067
Epoch 18/30
7352/7352 [==============================] - 106s 14ms/step - loss: 0.1793 - acc: 0.9308 - val_los
s: 0.2757 - val_acc: 0.9162
Epoch 19/30
7352/7352 [==============================] - 105s 14ms/step - loss: 0.1747 - acc: 0.9339 - val_los
s: 0.2602 - val_acc: 0.9179
Epoch 20/30
7352/7352 [==============================] - 105s 14ms/step - loss: 0.1734 - acc: 0.9346 - val_los
s: 0.2513 - val_acc: 0.9199
Epoch 21/30
7352/7352 [==============================] - 103s 14ms/step - loss: 0.1750 - acc: 0.9339 - val_los
s: 0.2656 - val_acc: 0.9169
Epoch 22/30
7352/7352 [==============================] - 102s 14ms/step - loss: 0.1819 - acc: 0.9325 - val_los
s: 0.2930 - val_acc: 0.9192
Epoch 23/30
7352/7352 [==============================] - 102s 14ms/step - loss: 0.1682 - acc: 0.9319 - val_los
s: 0.2848 - val_acc: 0.9182
Epoch 24/30
7352/7352 [==============================] - 103s 14ms/step - loss: 0.1629 - acc: 0.9320 - val_los
s: 0.2712 - val_acc: 0.9247
Epoch 25/30
7352/7352 [==============================] - 103s 14ms/step - loss: 0.1798 - acc: 0.9312 - val_los
s: 0.2568 - val_acc: 0.9233
Epoch 26/30
7352/7352 [==============================] - 103s 14ms/step - loss: 0.1694 - acc: 0.9355 - val_los
s: 0.3490 - val_acc: 0.8999
Epoch 27/30
7352/7352 [==============================] - 103s 14ms/step - loss: 0.1763 - acc: 0.9323 - val_los
s: 0.3075 - val_acc: 0.9260
Epoch 28/30
7352/7352 [==============================] - 103s 14ms/step - loss: 0.1625 - acc: 0.9361 - val_los
s: 0.3487 - val_acc: 0.9206
Epoch 29/30
7352/7352 [==============================] - 103s 14ms/step - loss: 0.1723 - acc: 0.9342 - val_los
s: 0.2697 - val_acc: 0.9199
Epoch 30/30
7352/7352 [==============================] - 103s 14ms/step - loss: 0.1643 - acc: 0.9380 - val_los
s: 0.2136 - val_acc: 0.9325
```

Out[86]:

```
<keras.callbacks.History at 0x7fcea6b841d0>
```

In [87]:

```
# 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      419        71        0                    1
STANDING                   0       82       450        0                    0
WALKING                    0        0         0      475                   19
WALKING_DOWNSTAIRS         0        0         0       10                  409
WALKING_UPSTAIRS           0        0         0        2                   11

Pred                WALKING_UPSTAIRS
True
LAYING                             0
SITTING                            0
STANDING                           0
WALKING                            2
WALKING_DOWNSTAIRS                 1
WALKING_UPSTAIRS                 458
```

In [88]:

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

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

In [89]:

```
score
```

Out[89]:

```
[0.21359348473787143, 0.9324737020699015]
```

Conclusion: With a 2 layer architecture we got 93.25% accuracy and loss of 0.30.