HAR_LSTM_A_21 (2)

June 4, 2019

```
In [0]: import pandas as pd
        import numpy as np
        import matplotlib.pyplot as plt

In [4]: from google.colab import drive
        drive.mount('/content/drive')

Drive already mounted at /content/drive; to attempt to forcibly remount, call drive.mount("/co

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

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

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

0.0.1 Data

```
In [0]: # Data directory
        DATADIR = 'drive/My Drive/HAR/UCI_HAR_Dataset'

In [0]: # Raw data signals
        # Signals are from Accelerometer and Gyroscope
        # The signals are in x,y,z directions
        # Sensor signals are filtered to have only body acceleration
        # excluding the acceleration due to gravity
```

```
# Triaxial acceleration from the accelerometer is total acceleration
SIGNALS = [
    "body_acc_x",
    "body_acc_y",
    "body_acc_z",
    "body_gyro_x",
    "body_gyro_y",
    "body_gyro_z",
    "total_acc_x",
    "total_acc_y",
    "total_acc_z"
]
```

In [0]:
```
# Utility function to read the data from csv 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'drive/My Drive/HAR/UCI_HAR_Dataset/{subset}/Inertial Signals/{sig
        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 [0]:
```
#content/drive/My Drive/HAR/UCI_HAR_Dataset/train/Inertial Signals/body_acc_x_train.tx
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'drive/My Drive/HAR/UCI_HAR_Dataset/{subset}/y_{subset}.txt'
    y = _read_csv(filename)[0]

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

In [0]:
```
def load_data():
    """
    Obtain the dataset from multiple files.
```

```
            Returns: X_train, X_test, y_train, y_test
            """
            X_train, X_test = load_signals('train'), load_signals('test')
            y_train, y_test = load_y('train'), load_y('test')

            return X_train, X_test, y_train, y_test
```

```
In [0]: # Importing tensorflow
        np.random.seed(42)
        import tensorflow as tf
        tf.set_random_seed(42)
```

```
In [0]: # Configuring a session
        session_conf = tf.ConfigProto(
            intra_op_parallelism_threads=1,
            inter_op_parallelism_threads=1
        )
```

```
In [13]: # Import Keras
         from keras import backend as K
         sess = tf.Session(graph=tf.get_default_graph(), config=session_conf)
         K.set_session(sess)
```

```
Using TensorFlow backend.
```

```
In [0]: # Importing libraries
        from keras.models import Sequential
        from keras.layers import LSTM
        from keras.layers.core import Dense, Dropout
```

```
In [0]: # Initializing parameters
        epochs = 15
        batch_size = 64
        n_hidden = 64
```

```
In [0]: # Utility function to count the number of classes
        def _count_classes(y):
            return len(set([tuple(category) for category in y]))
```

```
In [17]: # Loading the train and test data
         X_train, X_test, Y_train, Y_test = load_data()
```

```
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:11: FutureWarning: Method .as_mat
  # This is added back by InteractiveShellApp.init_path()
```

```
In [18]: 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
```

0.1 Single Layer LSTM Model with dropout

```
In [18]: # Initiliazing the sequential model
         model = Sequential()
         # Configuring the parameters
         model.add(LSTM(64, input_shape=(timesteps, input_dim), kernel_initializer = 'glorot_un
         # Adding a dropout layer
         model.add(Dropout(0.5))
         # Adding a dense output layer with sigmoid activation
         model.add(Dense(n_classes, activation='softmax'))
         model.summary()
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensorflow/python/framework/op_c
Instructions for updating:
Colocations handled automatically by placer.
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend
Instructions for updating:
Please use `rate` instead of `keep_prob`. Rate should be set to `rate = 1 - keep_prob`.
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_1 (LSTM)                (None, 64)                18944
_________________________________________________________________
dropout_1 (Dropout)          (None, 64)                0
_________________________________________________________________
dense_1 (Dense)              (None, 6)                 390
=================================================================
Total params: 19,334
Trainable params: 19,334
Non-trainable params: 0
_________________________________________________________________
```

```
In [0]: # Compiling the model
        model.compile(loss='categorical_crossentropy',
                      optimizer='Adam',
                      metrics=['accuracy'])
```

```
In [20]: # Training the model
         history = model.fit(X_train,
                   Y_train,
                   batch_size=64,
                   validation_data=(X_test, Y_test),
                   epochs=15)
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensorflow/python/ops/math_ops.p
Instructions for updating:
Use tf.cast instead.
Train on 7352 samples, validate on 2947 samples
Epoch 1/15
7352/7352 [==============================] - 23s 3ms/step - loss: 1.4317 - acc: 0.3792 - val_lo
Epoch 2/15
7352/7352 [==============================] - 22s 3ms/step - loss: 1.3023 - acc: 0.4174 - val_lo
Epoch 3/15
7352/7352 [==============================] - 22s 3ms/step - loss: 1.1832 - acc: 0.4973 - val_lo
Epoch 4/15
7352/7352 [==============================] - 22s 3ms/step - loss: 0.9123 - acc: 0.6004 - val_lo
Epoch 5/15
7352/7352 [==============================] - 23s 3ms/step - loss: 0.7439 - acc: 0.6684 - val_lo
Epoch 6/15
7352/7352 [==============================] - 23s 3ms/step - loss: 0.5865 - acc: 0.7497 - val_lo
Epoch 7/15
7352/7352 [==============================] - 22s 3ms/step - loss: 0.5060 - acc: 0.7860 - val_lo
Epoch 8/15
7352/7352 [==============================] - 22s 3ms/step - loss: 0.4841 - acc: 0.8184 - val_lo
Epoch 9/15
7352/7352 [==============================] - 22s 3ms/step - loss: 0.4050 - acc: 0.8191 - val_lo
Epoch 10/15
7352/7352 [==============================] - 22s 3ms/step - loss: 0.3426 - acc: 0.8715 - val_lo
Epoch 11/15
7352/7352 [==============================] - 22s 3ms/step - loss: 0.3795 - acc: 0.8697 - val_lo
Epoch 12/15
7352/7352 [==============================] - 22s 3ms/step - loss: 0.3427 - acc: 0.8719 - val_lo
Epoch 13/15
7352/7352 [==============================] - 22s 3ms/step - loss: 0.2352 - acc: 0.9212 - val_lo
Epoch 14/15
7352/7352 [==============================] - 22s 3ms/step - loss: 0.2383 - acc: 0.9193 - val_lo
Epoch 15/15
7352/7352 [==============================] - 22s 3ms/step - loss: 0.1866 - acc: 0.9355 - val_lo
```

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

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

```
LAYING                    537       0  ...                  0                 0
SITTING                     1     394  ...                  0                 9
STANDING                    0      94  ...                  0                 0
WALKING                     0       0  ...                 28                17
WALKING_DOWNSTAIRS          0       0  ...                381                34
WALKING_UPSTAIRS            1       0  ...                 14               374

[6 rows x 6 columns]
```

```
In [22]: score = model.evaluate(X_test, Y_test)
         print("Accuracy: %.2f%%" % (score[1]*100))
```

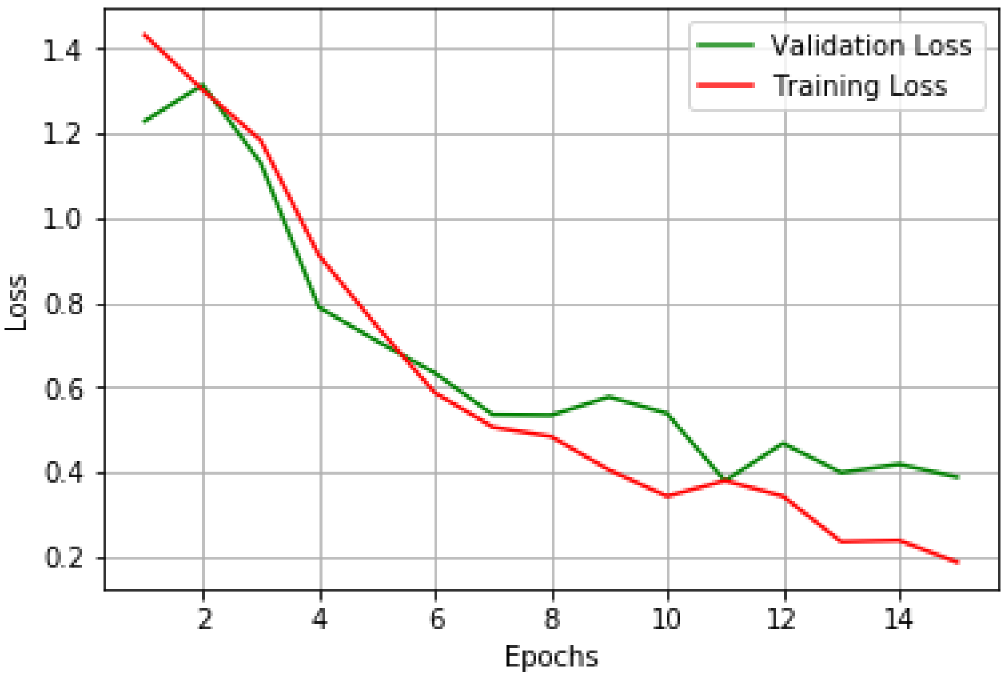
```
2947/2947 [==============================] - 6s 2ms/step
Accuracy: 87.28%
```

```
In [24]: fig,ax = plt.subplots(1,1)
         ax.set_xlabel('Epochs') ; ax.set_ylabel('Loss')

         # list of epoch numbers
         list_of_epoch = list(range(1,15+1))

         train_loss = history.history['loss']
         val_loss = history.history['val_loss']

         ax.plot(list_of_epoch, val_loss, 'g', label="Validation Loss")
         ax.plot(list_of_epoch, train_loss, 'r', label="Training Loss")
         plt.legend()
         plt.grid()
         plt.show();
```



0.2 3 Layers LSTM Model with Dropout

```
In [21]: # Initiliazing the sequential model
         model = Sequential()
         # Configuring the parameters
         model.add(LSTM(32, input_shape=(timesteps, input_dim), return_sequences=True))

         #Adding another layer
         model.add(LSTM(64, return_sequences=True))  # returns a sequence of vectors of dimens

         # Adding a dropout layer
         model.add(Dropout(0.5))


         model.add(LSTM(128))




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

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_7 (LSTM)                (None, 128, 32)           5376
_________________________________________________________________
lstm_8 (LSTM)                (None, 128, 64)           24832
_________________________________________________________________
dropout_4 (Dropout)          (None, 128, 64)           0
_________________________________________________________________
lstm_9 (LSTM)                (None, 128)               98816
_________________________________________________________________
dense_3 (Dense)              (None, 6)                 774
=================================================================
Total params: 129,798
Trainable params: 129,798
Non-trainable params: 0
_________________________________________________________________
```

```
In [0]: # Compiling the model
        import keras
        model.compile(loss='categorical_crossentropy',
                      optimizer='Adam',
                      metrics=['accuracy'])
```

```
In [25]: # Training the model
         history = model.fit(X_train,
                   Y_train,
                   batch_size=64,
                   validation_data=(X_test, Y_test),
                   epochs=15)
```

```
Train on 7352 samples, validate on 2947 samples
Epoch 1/15
7352/7352 [==============================] - 66s 9ms/step - loss: 1.2921 - acc: 0.4124 - val_lo
Epoch 2/15
7352/7352 [==============================] - 66s 9ms/step - loss: 1.2356 - acc: 0.4286 - val_lo
Epoch 3/15
7352/7352 [==============================] - 65s 9ms/step - loss: 1.0627 - acc: 0.5389 - val_lo
Epoch 4/15
7352/7352 [==============================] - 65s 9ms/step - loss: 0.8606 - acc: 0.6353 - val_lo
Epoch 5/15
7352/7352 [==============================] - 66s 9ms/step - loss: 0.6579 - acc: 0.6976 - val_lo
Epoch 6/15
7352/7352 [==============================] - 66s 9ms/step - loss: 0.5128 - acc: 0.7633 - val_lo
Epoch 7/15
7352/7352 [==============================] - 65s 9ms/step - loss: 0.4824 - acc: 0.7983 - val_lo
Epoch 8/15
```

```
7352/7352 [==============================] - 65s 9ms/step - loss: 0.3947 - acc: 0.8504 - val_lo
Epoch 9/15
7352/7352 [==============================] - 65s 9ms/step - loss: 0.2674 - acc: 0.9087 - val_lo
Epoch 10/15
7352/7352 [==============================] - 65s 9ms/step - loss: 0.1910 - acc: 0.9328 - val_lo
Epoch 11/15
7352/7352 [==============================] - 66s 9ms/step - loss: 0.2482 - acc: 0.9124 - val_lo
Epoch 12/15
7352/7352 [==============================] - 65s 9ms/step - loss: 0.1845 - acc: 0.9376 - val_lo
Epoch 13/15
7352/7352 [==============================] - 65s 9ms/step - loss: 0.1662 - acc: 0.9377 - val_lo
Epoch 14/15
7352/7352 [==============================] - 65s 9ms/step - loss: 0.1637 - acc: 0.9408 - val_lo
Epoch 15/15
7352/7352 [==============================] - 66s 9ms/step - loss: 0.1476 - acc: 0.9433 - val_lo
```

In [26]:
```python
# Confusion Matrix
print(confusion_matrix(Y_test, model.predict(X_test)))
```

```
Pred                LAYING  SITTING  ...  WALKING_DOWNSTAIRS  WALKING_UPSTAIRS
True                                 ...
LAYING                 528        0  ...                   9                 0
SITTING                  1      421  ...                   1                 3
STANDING                 0      131  ...                   0                 0
WALKING                  0        0  ...                   7                28
WALKING_DOWNSTAIRS       0        0  ...                 401                19
WALKING_UPSTAIRS         0        0  ...                  17               428

[6 rows x 6 columns]
```

In [27]:
```python
score = model.evaluate(X_test, Y_test)
print("Accuracy: %.2f%%" % (score[1]*100))
```

```
2947/2947 [==============================] - 18s 6ms/step
Accuracy: 89.41%
```

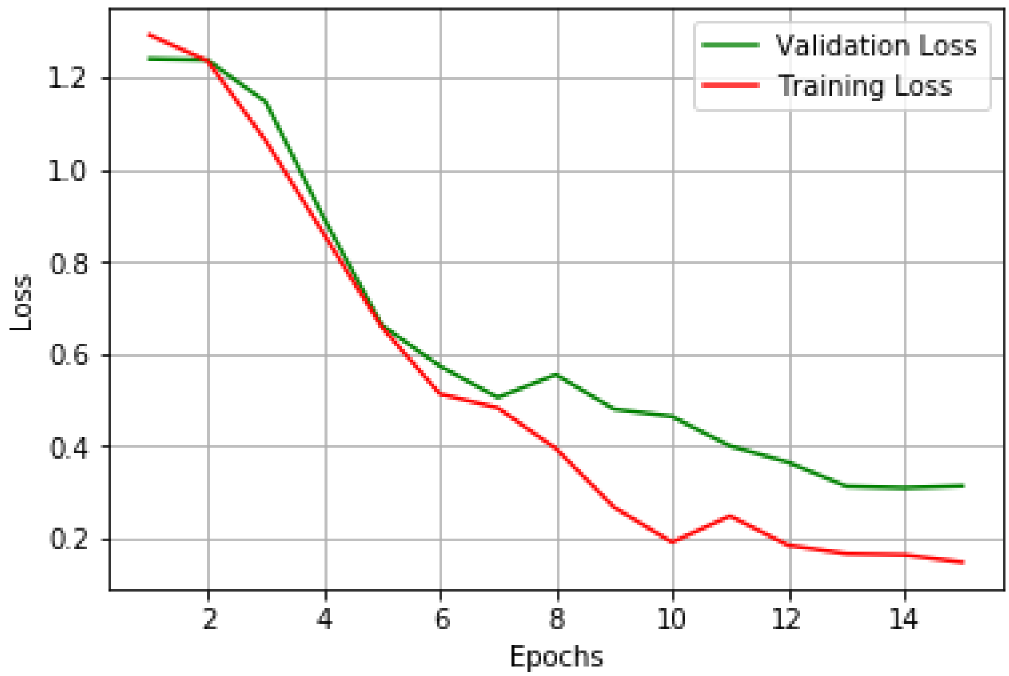
In [28]:
```python
fig,ax = plt.subplots(1,1)
ax.set_xlabel('Epochs') ; ax.set_ylabel('Loss')

# list of epoch numbers
list_of_epoch = list(range(1,15+1))

train_loss = history.history['loss']
val_loss = history.history['val_loss']

ax.plot(list_of_epoch, val_loss, 'g', label="Validation Loss")
```

```
ax.plot(list_of_epoch, train_loss, 'r', label="Training Loss")
plt.legend()
plt.grid()
plt.show();
```



0.3 2 Layer LSTM Model with Dropout and Batch Normalization

In [0]:
```
from keras.layers.normalization import BatchNormalization

model = Sequential()

model.add(LSTM(32, return_sequences=True,kernel_initializer='glorot_uniform'))
model.add(Dropout(0.5))
model.add(BatchNormalization())
model.add(LSTM(64,kernel_initializer='glorot_uniform'))
model.add(Dropout(0.5))

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

In [0]:
```
# Compiling the model
model.compile(loss='categorical_crossentropy',
              optimizer='Adam',
              metrics=['accuracy'])
```

```
In [0]: # Training the model
        model.fit(X_train,
                  Y_train,
                  batch_size=batch_size,
                  validation_data=(X_test, Y_test),
                  epochs=15)
```

```
Train on 7352 samples, validate on 2947 samples
Epoch 1/15
7352/7352 [==============================] - 178s 24ms/step - loss: 0.0954 - acc: 0.9668 - val_
Epoch 2/15
7352/7352 [==============================] - 176s 24ms/step - loss: 0.0729 - acc: 0.9730 - val_
Epoch 3/15
7352/7352 [==============================] - 175s 24ms/step - loss: 0.0645 - acc: 0.9757 - val_
Epoch 4/15
7352/7352 [==============================] - 174s 24ms/step - loss: 0.0623 - acc: 0.9768 - val_
Epoch 5/15
7352/7352 [==============================] - 174s 24ms/step - loss: 0.0512 - acc: 0.9803 - val_
Epoch 6/15
7352/7352 [==============================] - 174s 24ms/step - loss: 0.0526 - acc: 0.9792 - val_
Epoch 7/15
7352/7352 [==============================] - 174s 24ms/step - loss: 0.0459 - acc: 0.9810 - val_
Epoch 8/15
7352/7352 [==============================] - 173s 24ms/step - loss: 0.0571 - acc: 0.9769 - val_
Epoch 9/15
7352/7352 [==============================] - 173s 23ms/step - loss: 0.0438 - acc: 0.9817 - val_
Epoch 10/15
7352/7352 [==============================] - 173s 24ms/step - loss: 0.0553 - acc: 0.9801 - val_
Epoch 11/15
7352/7352 [==============================] - 172s 23ms/step - loss: 0.0467 - acc: 0.9817 - val_
Epoch 12/15
7352/7352 [==============================] - 172s 23ms/step - loss: 0.0513 - acc: 0.9814 - val_
Epoch 13/15
7352/7352 [==============================] - 171s 23ms/step - loss: 0.0477 - acc: 0.9815 - val_
Epoch 14/15
7352/7352 [==============================] - 172s 23ms/step - loss: 0.0432 - acc: 0.9834 - val_
Epoch 15/15
7352/7352 [==============================] - 172s 23ms/step - loss: 0.0443 - acc: 0.9837 - val_
```

```
Out[0]: <keras.callbacks.History at 0x7f5e6d002d68>
```

```
In [0]: scores = model.evaluate(X_test, Y_test, verbose=1)
        print("Accuracy: %.2f%%" % (scores[1]*100))
```

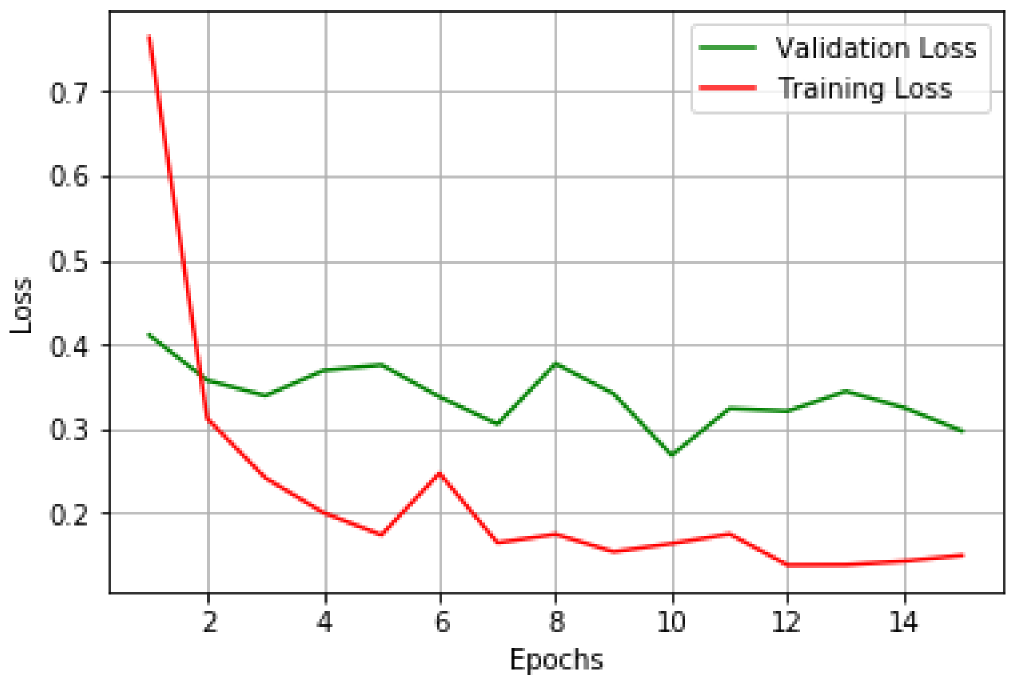
```
2947/2947 [==============================] - 12s 4ms/step
Accuracy: 96.35%
```

```
In [33]: fig,ax = plt.subplots(1,1)
         ax.set_xlabel('Epochs') ; ax.set_ylabel('Loss')

         # list of epoch numbers
         list_of_epoch = list(range(1,15+1))

         train_loss = history.history['loss']
         val_loss = history.history['val_loss']

         ax.plot(list_of_epoch, val_loss, 'g', label="Validation Loss")
         ax.plot(list_of_epoch, train_loss, 'r', label="Training Loss")
         plt.legend()
         plt.grid()
         plt.show();
```



1 Conclusion

- The use of simply a 2 Layer LSTM model with Batch Normalization and Dropout rate of 0.5 gives 96.35% accuracy which is comparable to those of the best performing ML models.

```
In [34]: from prettytable import PrettyTable

         x = PrettyTable()
```

```
x.field_names = ["Number of Layers", "BN","Dropout", "Accuracy"]

x.add_row(["1", 'NO',0.5, '87.28%'])
x.add_row(["3", 'NO',0.5, '89.41%'])
x.add_row(["2", 'YES',0.5, '96.35%'])


print(x)
```

```
+------------------+-----+---------+----------+
| Number of Layers |  BN | Dropout | Accuracy |
+------------------+-----+---------+----------+
|        1         |  NO |   0.5   |  87.28%  |
|        3         |  NO |   0.5   |  89.41%  |
|        2         | YES |   0.5   |  96.35%  |
+------------------+-----+---------+----------+
```