System call Anomaly Detection- Deep Learning

Type *Markdown* and LaTeX: α^2

ADFA Dataset Preprocessing:

1. The system call language model estimates the probability distribution of the next call in a sequence given the sequence of previous calls.

2. We assume that the host system generates a finite number of system calls.

3. We index each system call by using an integer starting from 1 and denote the fixed set of all possible system calls in the system as S = {1, · · · , K}. Let x = x1x2 · · · xl(xi ∈ S) denote a sequence of l system calls.

LSTM Based Model :

1. At the Input Layer, the call at each time step xi is fed into the model in the form of one-hot encoding,
   in other words, a K dimensional vector with all elements zero except position xi.

2. At the Embedding Layer*, incoming calls are embedded to continuous space by multiplying embedding matrix W,
   which should be learned.

3. At the Hidden Layer*, the LSTM unit has an internal state, and this state is updated recurrently at each time step.

4. At the Output Layer, a softmax activation function is used to produce the estimation of normalized probability values of possible calls coming next in the sequence.

References for systemcalls:

1. http://osinside.net/syscall/system_call_table.htm
2. https://www.cs.unm.edu/~immsec/systemcalls.htm
3. https://github.com/karpathy/char-rnn
4. https://keras.io/losses/#categorical_crossentropy
5. http://karpathy.github.io/2015/05/21/rnn-effectiveness/

ADFA Dataset Preprocessing

In [1]:

```
# -*- coding: utf-8 -*-
"""
Created on Thu Aug  1 13:52:35 2019

@author: kuna
"""

#!/usr/bin/env python
# -*- coding: utf-8 -*-


import pickle
import sys

# import warnings filter
from warnings import simplefilter
# ignore all future warnings
simplefilter(action='ignore', category=FutureWarning)
# ignore all user warnings
simplefilter(action='ignore', category=UserWarning)

def saveintopickle(obj, filename):
    with open(filename, 'wb') as handle:
        pickle.dump(obj, handle, protocol=pickle.HIGHEST_PROTOCOL)

    print ("[Pickle]: save object into {}".format(filename))
    return



def loadfrompickle(filename):
    with open(filename, 'rb') as handle:
        b = pickle.load(handle)
    return b



#draw the  process bar
def drawProgressBar(percent, barLen = 20):
    sys.stdout.write("\r")
    progress = ""
    for i in range(barLen):
        if i < int(barLen * percent):
            progress += "="
        else:
            progress += " "
    sys.stdout.write("[ %s ] %.2f%%" % (progress, percent * 100))
    sys.stdout.flush()
```

In [2]:

```
import numpy as np
#import io_helper


random_data_dup = 10  # each sample randomly duplicated between 0 and 9 times, see drop


def dropin(X, y):
    """
    The name suggests the inverse of dropout, i.e. adding more samples. See Data Augmer
    http://simaaron.github.io/Estimating-rainfall-from-weather-radar-readings-using-rec
    :param X: Each row is a training sequence
    :param y: Tne target we train and will later predict
    :return: new augmented X, y
    """
    print("X shape:", X.shape)
    print("y shape:", y.shape)
    X_hat = []
    y_hat = []
    for i in range(0, len(X)):
        for j in range(0, np.random.random_integers(0, random_data_dup)):
            X_hat.append(X[i, :])
            y_hat.append(y[i])
    return np.asarray(X_hat), np.asarray(y_hat)



def preprocess():

    arrayfile = "./array_test.pickle"
    array = loadfrompickle(arrayfile)
    #print(type(array))
    #print(array)
    x_train = array[:,:-1]
    y_train = array[:,-1]

    print ("The train data size is that ")
    print (x_train.shape)
    print (y_train.shape)
    return (x_train,y_train)

def preprocess_val():

    arrayfile = "./array_val.pickle"
    array = loadfrompickle(arrayfile)
    #print(type(array))
    #print(array)
    x_test = array[:,:-1]
    y_test = array[:,-1]

    print ("The train data size is that ")
    print (x_test.shape)
    print (y_test.shape)
    return (x_test,y_test)

#if __name__ =="__main__":
#   preprocess()
```

In [3]:

```
#!/usr/bin/env python
# -*- coding: utf-8 -*-


import os
import sys
import numpy as np

#import io_helper

def readfilesfromAdir(dataset):
    #read a list of files
    files = os.listdir(dataset)
    files_absolute_paths = []
    for i in files:
        files_absolute_paths.append(dataset+str(i))
    return files_absolute_paths


file = "ADFA-LD/Training_Data_Master/UTD-0001.txt"
#this is used to read a char sequence from
def readCharsFromFile(file):
    channel_values = open(file).read().split()
    #print (len(channel_values))
    #channel_values is a list
    return channel_values
    #print (channel_values[800:819])

def get_attack_subdir(path):
    subdirectories = os.listdir(path)
    for i in range(0,len(subdirectories)):
        subdirectories[i] = path + subdirectories[i]

    print (subdirectories)
    return (subdirectories)


def get_all_call_sequences(dire):
    files = readfilesfromAdir(dire)
    allthelist = []
    print (len(files))

    for eachfile in files:
        if not eachfile.endswith("DS_Store"):
            allthelist.append(readCharsFromFile(eachfile))
        else:
            print ("Skip the file "+ str(eachfile))

    elements = []
    for item in allthelist:
        for key in item:
            if key not in elements:
                elements.append(key)

    elements = map(int,elements)
    elements = sorted(elements)

    print ("The total unique elements:")
```

```
    print (elements)

    print ("The maximum number of elements:")
    print (max(elements))

    #print ("The length elements:")
    #print (len(elements))
    print (len(allthelist))

    #clean the all list data set
    _max = 0
    for i in range(0,len(allthelist)):
        _max = max(_max,len(allthelist[i]))
        allthelist[i] = list(map(int,allthelist[i]))
        #print(allthelist[i])


    print ("The maximum length of a sequence is that {}".format(_max))

    return (allthelist)

## shift the data for analysis
def shift(seq, n):
    n = n % len(seq)
    return seq[n:] + seq[:n]


def convertToOneHot(vector, num_classes=None):
    """
    Converts an input 1-D vector of integers into an output
    2-D array of one-hot vectors, where an i'th input value
    of j will set a '1' in the i'th row, j'th column of the
    output array.

    Example:
        v = np.array((1, 0, 4))
        one_hot_v = convertToOneHot(v)
        print one_hot_v

        [[0 1 0 0 0]
         [1 0 0 0 0]
         [0 0 0 0 1]]
    """

    assert isinstance(vector, np.ndarray)
    assert len(vector) > 0

    if num_classes is None:
        num_classes = np.max(vector)+1
    else:
        assert num_classes > 0
        assert num_classes >= np.max(vector)

    result = np.zeros(shape=(len(vector), num_classes))
    result[np.arange(len(vector)), vector] = 1
    return result.astype(int)

"""
The num_class here is set as 341
"""

```

```
#one function do one thing
def sequence_n_gram_parsing(alist,n_gram=20,num_class=341):
    if len(alist) <= n_gram:
        return alist

    ans = []
    for i in range(0,len(alist)-n_gram+1,1):
        tmp = alist[i:i+n_gram]
        oneHot = convertToOneHot(np.asarray(tmp), num_class)
        #print(tmp)
        #print(np.asarray(tmp))
        #print(oneHot)
        ans.append(oneHot)

    #transform into nmup arrray
    ans = np.array(ans)
    return (ans)


def lists_of_list_into_big_matrix(allthelist,n_gram=20):

    print("lists_of_list_into_big_matrix")
    print(len(allthelist))
    array = sequence_n_gram_parsing(allthelist[0])
    #print(len(allthelist[0]))
    #print(allthelist[0])
    #print(len(array))
    #print(array)

    for i in range(1,len(allthelist),1):

        tmp = sequence_n_gram_parsing(allthelist[i])

        #print ("tmp shape")
        #print(tmp)
        #print (len(tmp))

        array = np.concatenate((array, tmp), axis=0)
        #print(allthelist[i])
        #print(array)

        percent = (i+0.0)/len(allthelist)
        #io_helper.drawProgressBar(percent)
        drawProgressBar(percent)

        if (len(array)> 20000):
            break
        #print ("array shape")
        #print (array.shape)
        #print(len(allthelist[1]))
        #print(allthelist[1])
        #print(len(array))
        #print(array)
        #break

    print (array.shape)
    print ("done")
    #io_helper.saveintopickle(array,"array_test.pickle")
    saveintopickle(array,"array_test.pickle")


```

```
def lists_of_list_into_big_matrix_val(allthelist,n_gram=20):

    array = sequence_n_gram_parsing(allthelist[0])

    for i in range(1,len(allthelist),1):
        tmp = sequence_n_gram_parsing(allthelist[i])

       # print ("tmp shape")
       # print (tmp.shape)

        array = np.concatenate((array, tmp), axis=0)


        percent = (i+0.0)/len(allthelist)
        #io_helper.drawProgressBar(percent)
        drawProgressBar(percent)

        if (len(array)> 20000):
            break
        #print ("array shape")
        #print (array.shape)


    print (array.shape)
    print ("done")
    #io_helper.saveintopickle(array,"array_test.pickle")
    saveintopickle(array,"array_val.pickle")


if __name__ == "__main__":
    dirc = "ADFA-LD/Training_Data_Master/"
    dirc_val = "ADFA-LD/Validation_Data_Master/"
    dic_attack ="ADFA-LD/Attack_Data_Master/Adduser_1/"
    #train1 = get_all_call_sequences(dirc)

    #test = [i for i in range(0,300)]
    #array = sequence_n_gram_parsing(test)
    #print (type(array))
    #print (array.shape)

    #get_attack_subdir(dic_attack)
    #print ("XxxxxxxXXXXXXXXXXX")
    #val1 = get_all_call_sequences(dirc_val)

    #dirc_test = "Test/"
    #att_test = get_all_call_sequences(dirc_test)
    #lists_of_list_into_big_matrix(att_test)

    att = get_all_call_sequences(dirc)
    lists_of_list_into_big_matrix(att)

    att_val = get_all_call_sequences(dirc_val)
    lists_of_list_into_big_matrix_val(att_val)

```

```
834
Skip the file ADFA-LD/Training_Data_Master/.DS_Store
The total unique elements:
[1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 19, 20, 21, 26, 27, 30, 33, 37,
38, 39, 40, 41, 42, 43, 45, 54, 57, 60, 63, 64, 65, 66, 75, 77, 78, 83, 85,
91, 93, 94, 96, 97, 99, 102, 104, 110, 114, 117, 118, 119, 120, 122, 125, 12
```

```
8, 132, 133, 140, 141, 142, 143, 144, 146, 148, 155, 157, 158, 159, 160, 16
2, 163, 168, 172, 174, 175, 176, 179, 180, 183, 184, 185, 191, 192, 194, 19
5, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 21
1, 212, 213, 214, 219, 220, 221, 224, 226, 228, 229, 230, 231, 233, 234, 24
0, 242, 243, 252, 254, 255, 256, 258, 259, 260, 264, 265, 266, 268, 269, 27
0, 272, 289, 292, 293, 295, 298, 300, 301, 307, 308, 309, 311, 314, 320, 32
2, 331, 332, 340]
The maximum number of elements:
340
833
The maximum length of a sequence is that 2948
lists_of_list_into_big_matrix
833
[ =                    ] 8.52%(20298, 20, 341)
done
[Pickle]: save object into array_test.pickle
4373
Skip the file ADFA-LD/Validation_Data_Master/.DS_Store
The total unique elements:
[1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 19, 20, 21, 22, 26, 27, 30, 33,
37, 38, 39, 40, 41, 42, 43, 45, 54, 57, 60, 61, 63, 64, 65, 66, 75, 77, 78,
79, 83, 85, 90, 91, 93, 94, 96, 97, 99, 102, 104, 110, 111, 114, 116, 117, 1
18, 119, 120, 122, 124, 125, 128, 132, 133, 136, 140, 141, 142, 143, 144, 14
6, 148, 150, 151, 154, 155, 156, 157, 158, 159, 160, 162, 163, 168, 172, 17
4, 175, 176, 177, 179, 180, 181, 183, 184, 185, 186, 187, 190, 191, 192, 19
4, 195, 196, 197, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 21
0, 211, 212, 213, 214, 215, 216, 219, 220, 221, 224, 226, 228, 229, 231, 23
4, 240, 243, 252, 254, 255, 256, 258, 259, 260, 264, 265, 266, 268, 269, 27
0, 272, 289, 292, 293, 295, 296, 298, 300, 301, 306, 307, 308, 309, 311, 31
4, 320, 324, 328, 331, 332, 340]
The maximum number of elements:
340
4372
The maximum length of a sequence is that 4494
[                      ] 1.26%(21238, 20, 341)
done
[Pickle]: save object into array_val.pickle
```

LSTM Based Model

In [4]:

```
#!/usr/bin/env python
# -*- coding: utf-8 -*-

import matplotlib.pyplot as plt
import numpy as np
import time
from keras.layers.core import Dense, Activation, Dropout
from keras.layers.recurrent import LSTM
from keras.models import Sequential
from keras.models import model_from_json
from keras.layers.embeddings import Embedding

#import preprocess

# Global hyper-parameters
sequence_length = 19
epochs = 1
batch_size = 50
feature_dimension = 341
top_words = 5000

def save_model_weight_into_file(model, modelname="model.json", weight="model.h5"):
    model_json = model.to_json()
    with open(modelname, "w") as json_file:
        json_file.write(model_json)
    # serialize weights to HDF5
    model.save_weights(weight)
    print("Saved model to disk in {} and {}".format(modelname,weight))


def load_model_and_wieght_from_file(modelname="model.json", weight="model.h5"):

    json_file = open(modelname, 'r')
    loaded_model_json = json_file.read()
    json_file.close()
    loaded_model = model_from_json(loaded_model_json)
    # load weights into new model
    loaded_model.load_weights(weight)
    print("Loaded model from disk, you can do more analysis more")

    pass


def build_model():
    model = Sequential()
    layers = {'input': feature_dimension, 'hidden1': 64, 'hidden2': 256, 'hidden3': 10

    model.add(LSTM(
            input_length=sequence_length,
            input_dim=layers['input'],
            output_dim=layers['hidden1'],
            return_sequences=True))
    model.add(Dropout(0.2))

    model.add(LSTM(
            layers['hidden2'],
            return_sequences=True))
    model.add(Dropout(0.2))

```

```
    model.add(LSTM(
            layers['hidden3'],
            return_sequences=False))
    model.add(Dropout(0.2))

    model.add(Dense(
            output_dim=layers['output'],activation='softmax'))
    #model.add(Activation("linear"))

    start = time.time()

    model.compile(loss="categorical_crossentropy", optimizer='rmsprop',  metrics=['acc
    #model.compile(loss="mse", optimizer="rmsprop")

    #print ("Compilation Time : "%(time.time() - start))
    return model

from keras.callbacks import EarlyStopping

def run_network(model=None, data=None):

    global_start_time = time.time()

    if data is None:
        print ('Loading data... ')
        # train on first 700 samples and test on next 300 samples (has anomaly)
        X_train, y_train  = preprocess()
    else:
        X_train, y_train = data

    print ("X_train, y_train,shape")
    print (X_train.shape)
    print (y_train.shape)
    print ('\nData Loaded. Compiling...\n')

    if model is None:
        model = build_model()
        #model = build_model_2()
        print("Training...")
        model.fit(
                X_train, y_train,
                batch_size=batch_size,
                epochs=epochs,
                validation_split=0.3)
        model.summary()
        print("Done Training...")

    #predicted = model.predict(X_test)
    #print("Reshaping predicted")
    #predicted = np.reshape(predicted, (predicted.size,))




    """
    except KeyboardInterrupt:
        print("prediction exception")
        print 'Training duration (s) : ', time.time() - global_start_time
        return model, y_test, 0

    try:
```

```
        plt.figure(1)
        plt.subplot(311)
        plt.title("Actual Test Signal w/Anomalies")
        plt.plot(y_test[:len(y_test)], 'b')
        plt.subplot(312)
        plt.title("Predicted Signal")
        plt.plot(predicted[:len(y_test)], 'g')
        plt.subplot(313)
        plt.title("Squared Error")
        mse = ((y_test - predicted) ** 2)
        plt.plot(mse, 'r')
        plt.show()
    except Exception as e:
        print("plotting exception")
        print (str(e))
    print ('Training duration (s) : '% (time.time() - global_start_time))

    return model, y_test, predicted
   """

#if __name__ == "__main__":
# run_network()
```

```
Using TensorFlow backend.
```

Train LSTM Model

In [5]:

```
global_start_time = time.time()

model=None

print ('Loading data... ')
# train on first 700 samples and test on next 300 samples (has anomaly)
X_train, y_train  = preprocess()

print ("X_train, y_train,shape")
print (X_train.shape)
print (y_train.shape)
print ('\nData Loaded. Compiling...\n')

if model is None:
    model = build_model()
    print("Training...")
    history = model.fit(
            X_train, y_train,
            batch_size=batch_size,
            epochs=epochs,
            validation_split=0.3,
            callbacks=[EarlyStopping(monitor='val_loss', patience=3, min_delta=0.0001)
    model.summary()
    print("Done Training...")

```

```
Loading data...
The train data size is that
(20298, 19, 341)
(20298, 341)
X_train, y_train,shape
(20298, 19, 341)
(20298, 341)

Data Loaded. Compiling...

WARNING:tensorflow:From C:\Users\kuna\AppData\Local\Continuum\anaconda3\li
b\site-packages\tensorflow\python\framework\op_def_library.py:263: colocat
e_with (from tensorflow.python.framework.ops) is deprecated and will be re
moved in a future version.
Instructions for updating:
Colocations handled automatically by placer.
WARNING:tensorflow:From C:\Users\kuna\AppData\Local\Continuum\anaconda3\li
b\site-packages\keras\backend\tensorflow_backend.py:3445: calling dropout
(from tensorflow.python.ops.nn_ops) with keep_prob is deprecated and will
be removed in a future version.
Instructions for updating:
Please use `rate` instead of `keep_prob`. Rate should be set to `rate = 1
- keep_prob`.
Training...
WARNING:tensorflow:From C:\Users\kuna\AppData\Local\Continuum\anaconda3\li
b\site-packages\tensorflow\python\ops\math_ops.py:3066: to_int32 (from ten
sorflow.python.ops.math_ops) is deprecated and will be removed in a future
version.
Instructions for updating:
Use tf.cast instead.
Train on 14208 samples, validate on 6090 samples
Epoch 1/1
14208/14208 [==============================] - 32s 2ms/step - loss: 2.7770
```

```
- acc: 0.2367 - val_loss: 2.8779 - val_acc: 0.2154

_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_1 (LSTM)                (None, 19, 64)            103936
_________________________________________________________________
dropout_1 (Dropout)          (None, 19, 64)            0
_________________________________________________________________
lstm_2 (LSTM)                (None, 19, 256)           328704
_________________________________________________________________
dropout_2 (Dropout)          (None, 19, 256)           0
_________________________________________________________________
lstm_3 (LSTM)                (None, 100)               142800
_________________________________________________________________
dropout_3 (Dropout)          (None, 100)               0
_________________________________________________________________
dense_1 (Dense)              (None, 341)               34441
=================================================================
Total params: 609,881
Trainable params: 609,881
Non-trainable params: 0
_________________________________________________________________
Done Training...
```

In [6]:

```
#import pandas as pd

#def loadData(file):
    # for reading also binary mode is important
#    dbfile = open(file, 'rb')
#    db = pickle.load(dbfile)
#    for keys in db:
#        print(keys, '=>', db[keys])
#    dbfile.close()

#if __name__ == '__main__':
#    loadData("./array_test.pickle")
#df_val = pd.read_pickle("./array_val.pickle")
#df_val.head()
```

Run model on Validation Data

In [7]:

```
# https://towardsdatascience.com/multi-class-text-classification-with-lstm-1590bee1bd1

X_test, y_test = preprocess_val()

print ("X_test, y_test,shape")
print (X_test.shape)
print (y_test.shape)

print("Validating...")
predicted = model.predict(X_test)
print("Done Validating...")
print(predicted)

```

```
The train data size is that
(21238, 19, 341)
(21238, 341)
X_test, y_test,shape
(21238, 19, 341)
(21238, 341)
Validating...
Done Validating...
[[2.8147128e-05 3.8867351e-02 5.9301241e-05 ... 3.2527638e-05
  4.0639268e-05 6.0572522e-04]
 [2.7337572e-05 4.2425249e-02 5.7118334e-05 ... 3.0709063e-05
  3.9311104e-05 5.8961258e-04]
 [3.2080068e-05 4.1573644e-02 6.1957377e-05 ... 3.6363443e-05
  4.3218708e-05 6.0780835e-04]
 ...
 [1.8595829e-06 1.2511486e-03 3.5294606e-06 ... 2.1812916e-06
  1.6237399e-06 6.7461682e-05]
 [1.8240867e-06 1.3079355e-03 3.5116327e-06 ... 2.1674750e-06
  1.6114174e-06 6.7553679e-05]
 [1.8013474e-06 1.3025296e-03 3.4824586e-06 ... 2.1350809e-06
  1.6007832e-06 6.6800356e-05]]
```

How did our model perform?

In [8]:

```

score, accuracy = model.evaluate(X_test, y_test, verbose=2, batch_size=batch_size)
print('Score : %.2f'%(score))
print('Validation Accuracy : %.2f'%(accuracy))
```

```
Score : 3.08
Validation Accuracy : 0.19
```

In [9]:

```
#plt.title('Loss')
#plt.plot(history.history['loss'], label='train')
#plt.plot(history.history['val_loss'], label='test')
#plt.legend()
#plt.show();
```

In [10]:

```
history.history
```

Out[10]:

```
{'val_loss': [2.8778519998434535],
 'val_acc': [0.21543513882556573],
 'loss': [2.776978516363883],
 'acc': [0.23669763501452468]}
```

In [11]:

```
#plt.title('Accuracy')
#plt.plot(history.history['acc'], label='train')
#plt.plot(history.history['val_acc'], label='test')
#plt.legend()
#plt.show();
```

How to Test with new systemcall sequence ??

In [ ]:

```

```

Train LSTM simpler model

In [12]:

```
# https://towardsdatascience.com/choosing-the-right-hyperparameters-for-a-simple-lstm-

word_vec_length = 19
char_vec_length = 341
output_labels = 341


#hidden_nodes = 4000 # int(2/3 * (word_vec_length * char_vec_length))
hidden_nodes = 100
print(f"The number of hidden nodes is {hidden_nodes}.")

def build_model_2():
    # Build the model
    print('Build model...')
    model = Sequential()
    model.add(LSTM(hidden_nodes, return_sequences=False, input_shape=(word_vec_length,
    model.add(Dropout(0.2))
    model.add(Dense(units=output_labels))
    model.add(Activation('softmax'))
    model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['acc'])
    #print ("Compilation Time : "%(time.time() - start))
    return model
```

```
The number of hidden nodes is 100.
```

In [13]:

```
global_start_time = time.time()

model=None

print ('Loading data... ')
# train on first 700 samples and test on next 300 samples (has anomaly)
X_train, y_train  = preprocess()

print ("X_train, y_train,shape")
print (X_train.shape)
print (y_train.shape)
print ('\nData Loaded. Compiling...\n')

batch_size=32
model = build_model_2()
print("Training...")
model.fit(X_train, y_train, batch_size=batch_size, epochs=10, validation_data=(X_test,
model.summary()
print("Done Training...")

```

```
Loading data...
The train data size is that
(20298, 19, 341)
(20298, 341)
X_train, y_train,shape
(20298, 19, 341)
(20298, 341)

Data Loaded. Compiling...

Build model...
Training...
Train on 20298 samples, validate on 21238 samples
Epoch 1/10
20298/20298 [==============================] - 22s 1ms/step - loss: 2.8397 -
acc: 0.2396 - val_loss: 2.5586 - val_acc: 0.4236
Epoch 2/10
20298/20298 [==============================] - 21s 1ms/step - loss: 1.9795 -
acc: 0.4184 - val_loss: 2.1248 - val_acc: 0.4901
Epoch 3/10
20298/20298 [==============================] - 21s 1ms/step - loss: 1.6778 -
acc: 0.5024 - val_loss: 2.0376 - val_acc: 0.5023
Epoch 4/10
20298/20298 [==============================] - 21s 1ms/step - loss: 1.5040 -
acc: 0.5570 - val_loss: 1.9283 - val_acc: 0.5027
Epoch 5/10
20298/20298 [==============================] - 20s 977us/step - loss: 1.3988
- acc: 0.5863 - val_loss: 1.9624 - val_acc: 0.5107
Epoch 6/10
20298/20298 [==============================] - 20s 1ms/step - loss: 1.3225 -
acc: 0.6038 - val_loss: 1.9617 - val_acc: 0.5203
Epoch 7/10
20298/20298 [==============================] - 21s 1ms/step - loss: 1.2664 -
acc: 0.6213 - val_loss: 1.9898 - val_acc: 0.5073
Epoch 8/10
20298/20298 [==============================] - 20s 998us/step - loss: 1.2196
- acc: 0.6373 - val_loss: 2.0098 - val_acc: 0.5102
Epoch 9/10
```

```
20298/20298 [==============================] - 21s 1ms/step - loss: 1.1759 -
acc: 0.6471 - val_loss: 2.0388 - val_acc: 0.5134
Epoch 10/10
20298/20298 [==============================] - 20s 980us/step - loss: 1.1451
- acc: 0.6549 - val_loss: 2.0311 - val_acc: 0.5157

_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_4 (LSTM)                (None, 100)               176800
_________________________________________________________________
dropout_4 (Dropout)          (None, 100)               0
_________________________________________________________________
dense_2 (Dense)              (None, 341)               34441
_________________________________________________________________
activation_1 (Activation)    (None, 341)               0
=================================================================
Total params: 211,241
Trainable params: 211,241
Non-trainable params: 0
_________________________________________________________________
Done Training...
```

In [14]:

```
score, accuracy = model.evaluate(X_train, y_train, verbose=2, batch_size=batch_size)
print('Train Score : %.2f'%(score))
print('Train Validation Accuracy : %.2f'%(accuracy))
```

```
Train Score : 1.05
Train Validation Accuracy : 0.68
```

In [15]:

```
score, accuracy = model.evaluate(X_test, y_test, verbose=2, batch_size=batch_size)
print('Test Score : %.2f'%(score))
print('Test Validation Accuracy : %.2f'%(accuracy))
```

```
Test Score : 2.03
Test Validation Accuracy : 0.52
```

In [16]:

```
## k-fold validation
from sklearn.model_selection import StratifiedKFold
import numpy

# fix random seed for reproducibility
seed = 7
numpy.random.seed(seed)

# split into input (X) and output (Y) variables
X = X_train
Y = y_train
Y
```

Out[16]:

```
array([[0, 1, 0, ..., 0, 0, 0],
       [0, 1, 0, ..., 0, 0, 0],
       [0, 1, 0, ..., 0, 0, 0],
       ...,
       [0, 0, 0, ..., 0, 0, 0],
       [0, 0, 0, ..., 0, 0, 0],
       [0, 0, 0, ..., 0, 0, 0]])
```

In [17]:

```
# define 10-fold cross validation test harness
#kfold = StratifiedKFold(n_splits=10, shuffle=True, random_state=seed)
#cvscores = []
#for train, test in kfold.split(X, Y):
#  # create model
#   model = Sequential()
#   model.add(Dense(12, input_dim=341, activation='relu'))
#   model.add(Dense(8, activation='relu'))
#   model.add(Dense(1, activation='sigmoid'))
#   # Compile model
#   model.compile(loss='binary_crossentropy', optimizer='adam', metrics=['accuracy'])
#   # Fit the model
#   model.fit(X[train], Y[train], epochs=150, batch_size=10, verbose=0)
#   # evaluate the model
#   scores = model.evaluate(X[test], Y[test], verbose=0)
#   print("%s: %.2f%%" % (model.metrics_names[1], scores[1]*100))
#   cvscores.append(scores[1] * 100)
#print("%.2f%% (+/- %.2f%%)" % (numpy.mean(cvscores), numpy.std(cvscores)))
```

In [18]:

```
# https://towardsdatascience.com/choosing-the-right-hyperparameters-for-a-simple-lstm-

word_vec_length = 19
char_vec_length = 341
output_labels = 341


hidden_nodes = 100 # int(2/3 * (word_vec_length * char_vec_length))
print(f"The number of hidden nodes is {hidden_nodes}.")

def build_model_3():
    # Build the model
    print('Build model...')
    model = Sequential()
    model.add(LSTM(hidden_nodes, return_sequences=False, input_shape=(word_vec_length,
    model.add(Dropout(0.5))
    model.add(Dense(units=output_labels))
    model.add(Activation('softmax'))
    model.compile(loss='binary_crossentropy', optimizer='adam', metrics=['acc'])
    #print ("Compilation Time : "%(time.time() - start))
    return model

global_start_time = time.time()

model=None

print ('Loading data... ')
# train on first 700 samples and test on next 300 samples (has anomaly)
X_train, y_train  = preprocess()

print ("X_train, y_train,shape")
print (X_train.shape)
print (y_train.shape)
print ('\nData Loaded. Compiling...\n')

batch_size=32
model = build_model_3()
print("Training...")
model.fit(X_train, y_train, batch_size=batch_size, epochs=10, validation_data=(X_test,
model.summary()
print("Done Training...")
```

```
The number of hidden nodes is 100.
Loading data...
The train data size is that
(20298, 19, 341)
(20298, 341)
X_train, y_train,shape
(20298, 19, 341)
(20298, 341)

Data Loaded. Compiling...

Build model...
Training...
Train on 20298 samples, validate on 21238 samples
Epoch 1/10
20298/20298 [==============================] - 24s 1ms/step - loss: 0.0118 -
acc: 0.9971 - val_loss: 0.0100 - val_acc: 0.9973
```

```
Epoch 2/10
20298/20298 [==============================] - 20s 1ms/step - loss: 0.0086 -
acc: 0.9973 - val_loss: 0.0086 - val_acc: 0.9976 0.99 - ETA: 5s - loss: 0. -
ETA: 4s - loss: 0.00 - ETA: 3s - loss: 0.0087 - acc: 0.9 - ETA: 3s - loss:
0.0087 - - ETA: 2s - loss: 0. - ETA: 1s - loss: 0.
Epoch 3/10
20298/20298 [==============================] - 23s 1ms/step - loss: 0.0076 -
acc: 0.9975 - val_loss: 0.0083 - val_acc: 0.9977
Epoch 4/10
20298/20298 [==============================] - 24s 1ms/step - loss: 0.0070 -
acc: 0.9977 - val_loss: 0.0080 - val_acc: 0.9978
Epoch 5/10
20298/20298 [==============================] - 22s 1ms/step - loss: 0.0059 -
acc: 0.9980 - val_loss: 0.0078 - val_acc: 0.9977
Epoch 9/10
20298/20298 [==============================] - 20s 1ms/step - loss: 0.0058 -
acc: 0.9981 - val_loss: 0.0077 - val_acc: 0.9978
Epoch 10/10
20298/20298 [==============================] - 20s 994us/step - loss: 0.0056
- acc: 0.9981 - val_loss: 0.0078 - val_acc: 0.9978
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_5 (LSTM)                (None, 100)               176800
_________________________________________________________________
dropout_5 (Dropout)          (None, 100)               0
_________________________________________________________________
dense_3 (Dense)              (None, 341)               34441
_________________________________________________________________
activation_2 (Activation)    (None, 341)               0
=================================================================
Total params: 211,241
Trainable params: 211,241
Non-trainable params: 0
_________________________________________________________________
Done Training...
```

In [19]:

```
def build_model_4():
    # Build the model
    print('Build model...')
    model = Sequential()
    model.add(LSTM(hidden_nodes, return_sequences=False, input_shape=(word_vec_length,
    model.add(Dropout(0.2))
    model.add(Dense(units=output_labels))
    model.add(Activation('softmax'))
    model.compile(loss='binary_crossentropy', optimizer='adam', metrics=['acc'])
    #print ("Compilation Time : "%(time.time() - start))
    return model

global_start_time = time.time()

model=None

print ('Loading data... ')
# train on first 700 samples and test on next 300 samples (has anomaly)
X_train, y_train  = preprocess()

print ("X_train, y_train,shape")
print (X_train.shape)
print (y_train.shape)
print ('\nData Loaded. Compiling...\n')

batch_size=32
model = build_model_4()
print("Training...")
model.fit(X_train, y_train, batch_size=batch_size, epochs=10, validation_data=(X_test,
model.summary()
print("Done Training...")
```

```
Loading data...
The train data size is that
(20298, 19, 341)
(20298, 341)
X_train, y_train,shape
(20298, 19, 341)
(20298, 341)

Data Loaded. Compiling...

Build model...
Training...
Train on 20298 samples, validate on 21238 samples
Epoch 1/10
20298/20298 [==============================] - 23s 1ms/step - loss: 0.0112 -
acc: 0.9971 - val_loss: 0.0099 - val_acc: 0.9975
Epoch 2/10
20298/20298 [==============================] - 20s 986us/step - loss: 0.0082
- acc: 0.9974 - val_loss: 0.0085 - val_acc: 0.9977
Epoch 3/10
20298/20298 [==============================] - 20s 996us/step - loss: 0.0071
- acc: 0.9976 - val_loss: 0.0080 - val_acc: 0.9978
Epoch 4/10
20298/20298 [==============================] - 21s 1ms/step - loss: 0.0065 -
acc: 0.9978 - val_loss: 0.0078 - val_acc: 0.9978
Epoch 5/10
20298/20298 [==============================] - 22s 1ms/step - loss: 0.0061 -
```

```
acc: 0.9979 - val_loss: 0.0078 - val_acc: 0.9978
Epoch 6/10
20298/20298 [==============================] - 22s 1ms/step - loss: 0.0058 -
acc: 0.9980 - val_loss: 0.0078 - val_acc: 0.9977
Epoch 7/10
20298/20298 [==============================] - 21s 1ms/step - loss: 0.0056 -
acc: 0.9981 - val_loss: 0.0079 - val_acc: 0.9977
Epoch 8/10
20298/20298 [==============================] - 21s 1ms/step - loss: 0.0054 -
acc: 0.9981 - val_loss: 0.0080 - val_acc: 0.9977
Epoch 9/10
20298/20298 [==============================] - 22s 1ms/step - loss: 0.0053 -
acc: 0.9982 - val_loss: 0.0080 - val_acc: 0.9977
Epoch 10/10
20298/20298 [==============================] - 20s 994us/step - loss: 0.0051
- acc: 0.9982 - val_loss: 0.0080 - val_acc: 0.9977

_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_6 (LSTM)                (None, 100)               176800
_________________________________________________________________
dropout_6 (Dropout)          (None, 100)               0
_________________________________________________________________
dense_4 (Dense)              (None, 341)               34441
_________________________________________________________________
activation_3 (Activation)    (None, 341)               0
=================================================================
Total params: 211,241
Trainable params: 211,241
Non-trainable params: 0
_________________________________________________________________
Done Training...
```

In [20]:

```
def build_model_5():
    # Build the model
    print('Build model...')
    model = Sequential()
    model.add(LSTM(hidden_nodes, return_sequences=False, input_shape=(word_vec_length,
    #model.add(Dropout(0.2))
    model.add(Dense(units=output_labels))
    model.add(Activation('softmax'))
    model.compile(loss='binary_crossentropy', optimizer='adam', metrics=['acc'])
    #print ("Compilation Time : "%(time.time() - start))
    return model

global_start_time = time.time()

model=None

print ('Loading data... ')
# train on first 700 samples and test on next 300 samples (has anomaly)
X_train, y_train  = preprocess()

print ("X_train, y_train,shape")
print (X_train.shape)
print (y_train.shape)
print ('\nData Loaded. Compiling...\n')

batch_size=32
model = build_model_5()
print("Training...")
model.fit(X_train, y_train, batch_size=batch_size, epochs=10, validation_data=(X_test,
model.summary()
print("Done Training...")
```

```
Loading data...
The train data size is that
(20298, 19, 341)
(20298, 341)
X_train, y_train,shape
(20298, 19, 341)
(20298, 341)

Data Loaded. Compiling...

Build model...
Training...
Train on 20298 samples, validate on 21238 samples
Epoch 1/10
20298/20298 [==============================] - 28s 1ms/step - loss: 0.0111 -
acc: 0.9971 - val_loss: 0.0100 - val_acc: 0.9973
Epoch 2/10
20298/20298 [==============================] - 21s 1ms/step - loss: 0.0080 -
acc: 0.9974 - val_loss: 0.0085 - val_acc: 0.9977
Epoch 3/10
20298/20298 [==============================] - 22s 1ms/step - loss: 0.0069 -
acc: 0.9977 - val_loss: 0.0081 - val_acc: 0.9978
Epoch 4/10
20298/20298 [==============================] - 21s 1ms/step - loss: 0.0062 -
acc: 0.9979 - val_loss: 0.0080 - val_acc: 0.9978
Epoch 5/10
20298/20298 [==============================] - 21s 1ms/step - loss: 0.0059 -
```

```
acc: 0.9980 - val_loss: 0.0079 - val_acc: 0.9978
Epoch 6/10
20298/20298 [==============================] - 22s 1ms/step - loss: 0.0056 -
acc: 0.9981 - val_loss: 0.0080 - val_acc: 0.9977
Epoch 7/10
20298/20298 [==============================] - 22s 1ms/step - loss: 0.0054 -
acc: 0.9982 - val_loss: 0.0081 - val_acc: 0.9977
Epoch 8/10
20298/20298 [==============================] - 22s 1ms/step - loss: 0.0052 -
acc: 0.9982 - val_loss: 0.0081 - val_acc: 0.9977
Epoch 9/10
20298/20298 [==============================] - 21s 1ms/step - loss: 0.0050 -
acc: 0.9983 - val_loss: 0.0080 - val_acc: 0.9977
Epoch 10/10
20298/20298 [==============================] - 21s 1ms/step - loss: 0.0049 -
acc: 0.9983 - val_loss: 0.0082 - val_acc: 0.9978
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_7 (LSTM)                (None, 100)               176800
_________________________________________________________________
dense_5 (Dense)              (None, 341)               34441
_________________________________________________________________
activation_4 (Activation)    (None, 341)               0
=================================================================
Total params: 211,241
Trainable params: 211,241
Non-trainable params: 0
_________________________________________________________________
Done Training...
```

In [21]:

```
score, accuracy = model.evaluate(X_train, y_train, verbose=2, batch_size=batch_size)
print('Train Score : %.2f'%(score))
print('Train Validation Accuracy : %.2f'%(accuracy))
```

```
Train Score : 0.00
Train Validation Accuracy : 1.00
```

In [22]:

```
score, accuracy = model.evaluate(X_test, y_test, verbose=2, batch_size=batch_size)
print('Test Score : %.2f'%(score))
print('Test Validation Accuracy : %.2f'%(accuracy))
```

```
Test Score : 0.01
Test Validation Accuracy : 1.00
```

LSTM for Binary Classification of SystemCalls

In [244]:

```
def preprocess():

    arrayfile = "./array_test.pickle"
    array = loadfrompickle(arrayfile)
    #print(type(array))
    #print(array)
    x_train = array[:,:]
    print (x_train.shape)
    x_train = x_train.reshape(40099, 20, 1)
    y_train = np.zeros((40099,1))

    print ("The train data size is that ")
    print (x_train.shape)
    print (y_train.shape)
    return (x_train,y_train)

def preprocess_val():

    arrayfile = "./array_val.pickle"
    array = loadfrompickle(arrayfile)
    #print(type(array))
    #print(array)
    x_test = array[:,:]
    print (x_test.shape)
    x_test = x_test.reshape(40142, 20, 1)
    y_test = np.zeros((40142,1))

    print ("The validation data size is that ")
    print (x_test.shape)
    print (y_test.shape)
    return (x_test,y_test)

def preprocess_attack():

    arrayfile = "./array_attack.pickle"
    array = loadfrompickle(arrayfile)
    #print(type(array))
    #print(array)
    x_attack = array[:,:]
    x_attack = x_attack.reshape(6184, 20, 1)
    y_attack = np.ones((6184,1))

    print ("The attack data size is that ")
    print (x_attack.shape)
    print (y_attack.shape)
    return (x_attack,y_attack)


"""
The num_class here is set as 1
"""

#one function do one thing
def sequence_n_gram_parsing_noencoding(alist,n_gram=20,num_class=1):
    if len(alist) <= n_gram:
        return alist

    ans = []
    for i in range(0,len(alist)-n_gram+1,1):
```

```
60          tmp = alist[i:i+n_gram]
61          #oneHot = convertToOneHot(np.asarray(tmp), num_class)
62          #print(tmp)
63          #print(np.asarray(tmp))
64          #print(oneHot)
65          ans.append(tmp)
66
67      #transform into nmup arrray
68      ans = np.array(ans)
69      return (ans)
70
71
72  def lists_of_list_into_big_matrix(allthelist,n_gram=20):
73
74      #print("lists_of_list_into_big_matrix train")
75      #print(len(allthelist))
76      array = sequence_n_gram_parsing_noencoding(allthelist[0])
77      #print(len(allthelist[0]))
78      #print(allthelist[0])
79      #print(len(array))
80      #print(array)
81
82      for i in range(1,len(allthelist),1):
83
84          tmp = sequence_n_gram_parsing_noencoding(allthelist[i])
85
86          #print ("tmp shape")
87          #print(tmp.shape)
88          #print(array.shape)
89          #print (len(tmp))
90
91          array = np.concatenate((array, tmp), axis=0)
92          #print(allthelist[i])
93          #print(array)
94
95          percent = (i+0.0)/len(allthelist)
96          #io_helper.drawProgressBar(percent)
97          drawProgressBar(percent)
98
99          if (len(array)> 40000):
100             break
101         #print ("array shape")
102         #print (array.shape)
103         #print(len(allthelist[1]))
104         #print(allthelist[1])
105         #print(len(array))
106         #print(array)
107         #break
108
109     print (array.shape)
110     print ("done")
111     #io_helper.saveintopickle(array,"array_test.pickle")
112     saveintopickle(array,"array_test.pickle")
113
114
115 def lists_of_list_into_big_matrix_val(allthelist,n_gram=20):
116
117     #print("lists_of_list_into_big_matrix validation")
118     #print(len(allthelist))
119     array = sequence_n_gram_parsing_noencoding(allthelist[0])
120     #print(len(allthelist[0]))
```

```
    #print(allthelist[0])
    #print(len(array))
    #print(array)

    for i in range(1,len(allthelist),1):
        tmp = sequence_n_gram_parsing_noencoding(allthelist[i])

       # print ("tmp shape")
       # print (tmp.shape)

        array = np.concatenate((array, tmp), axis=0)


        percent = (i+0.0)/len(allthelist)
        #io_helper.drawProgressBar(percent)
        drawProgressBar(percent)

        if (len(array)> 40000):
            break
        #print ("array shape")
        #print (array.shape)


    print (array.shape)
    print ("done")
    #io_helper.saveintopickle(array,"array_test.pickle")
    saveintopickle(array,"array_val.pickle")

def get_all_call_sequences_attack(dire):
    # list of attacks
    attack = ['Adduser','Hydra_FTP','Hydra_SSH','Java_Meterpreter','Meterpreter','Web_
    #attack = ['Adduser' ,'Hydra_FTP']
    for term in attack:
        in_address = dire+term
        for i in range (1,11):
            files = readfilesfromAdir(in_address+"_"+str(i)+"/")

    allthelist = []
    #print(files)
    #print (len(files))

    for eachfile in files:
        if not eachfile.endswith("DS_Store"):
            allthelist.append(readCharsFromFile(eachfile))
        else:
            print ("Skip the file "+ str(eachfile))

    elements = []
    for item in allthelist:
        for key in item:
            if key not in elements:
                elements.append(key)

    elements = map(int,elements)
    elements = sorted(elements)

    print ("The total unique elements:")
    print (elements)

    print ("The maximum number of elements:")
    print (max(elements))
```

```
182
183     #print ("The length elements:")
184     #print (len(elements))
185     print (len(allthelist))
186
187     #clean the all list data set
188     _max = 0
189     for i in range(0,len(allthelist)):
190         _max = max(_max,len(allthelist[i]))
191         allthelist[i] = list(map(int,allthelist[i]))
192         #print(allthelist[i])
193
194
195     print ("The maximum length of a sequence is that {}".format(_max))
196
197     return (allthelist)
198
199 def lists_of_list_into_big_matrix_attack(allthelist,n_gram=20):
200
201     array = sequence_n_gram_parsing_noencoding(allthelist[0])
202
203     for i in range(1,len(allthelist),1):
204         tmp = sequence_n_gram_parsing_noencoding(allthelist[i])
205
206        # print ("tmp shape")
207         #print (tmp.shape)
208         #print (array.shape)
209
210         array = np.concatenate((array, tmp), axis=0)
211
212
213         percent = (i+0.0)/len(allthelist)
214         #io_helper.drawProgressBar(percent)
215         drawProgressBar(percent)
216
217         if (len(array)> 40000):
218             break
219         #print ("array shape")
220         #print (array.shape)
221
222
223     print (array.shape)
224     print ("done")
225     #io_helper.saveintopickle(array,"array_test.pickle")
226     saveintopickle(array,"array_attack.pickle")
227     #pickle2csv("array_attack.pickle", "attack.csv")
228
229
230
231
232 if __name__ == "__main__":
233     dirc = "ADFA-LD/Training_Data_Master/"
234     dirc_val = "ADFA-LD/Validation_Data_Master/"
235     dic_attack ="ADFA-LD/Attack_Data_Master/"
236
237     att = get_all_call_sequences(dirc)
238     lists_of_list_into_big_matrix(att)
239
240     att_val = get_all_call_sequences(dirc_val)
241     lists_of_list_into_big_matrix_val(att_val)
242
```

```
    att_attack = get_all_call_sequences_attack(dic_attack)
    lists_of_list_into_big_matrix_attack(att_attack)

    test_split = 0.2

    X_train_p, y_train_p = preprocess()

    X_test_p, y_test_p = preprocess_val()

    X_attack_p, y_attack_p = preprocess_attack()

    X_a1, X_a2 = np.array_split(X_attack_p, 2)
    y_a1, y_a2 = np.array_split(y_attack_p, 2)

    X_train = np.concatenate([X_train_p, X_a1])
    y_train = np.concatenate([y_train_p, y_a1])

    X_test = np.concatenate([X_test_p, X_a2])
    y_test = np.concatenate([y_test_p, y_a2])
```

```
269, 270, 272, 289, 292, 293, 295, 296, 298, 300, 301, 306, 307, 308, 309,
311, 314, 320, 324, 328, 331, 332, 340]
The maximum number of elements:
340
4372
The maximum length of a sequence is that 4494
[                      ] 2.13%(40142, 20)
done
[Pickle]: save object into array_val.pickle
The total unique elements:
[3, 4, 5, 6, 7, 13, 19, 33, 43, 45, 54, 60, 78, 91, 102, 104, 119, 120, 12
2, 140, 142, 146, 162, 168, 175, 183, 192, 195, 196, 197, 220, 221, 240, 2
65, 268, 292, 331, 340]
The maximum number of elements:
340
16
The maximum length of a sequence is that 2161
[ ==================   ] 93.75%(6184, 20)
done
[Pickle]: save object into array_attack.pickle
```

In [252]:

```
X_train_t = np.concatenate((X_train, y_train[:,None]), axis=1)#np.random.shuffle
X_train_t.shape
np.random.shuffle(X_train_t)
y_train = X_train_t[:,-1]
X_train = X_train_t[:,:20,:]
```

In [253]:

```
X_test_t = np.concatenate((X_test, y_test[:,None]), axis=1)#np.random.shuffle
X_test_t.shape
np.random.shuffle(X_test_t)
y_test = X_test_t[:,-1]
X_test = X_test_t[:,:20,:]
```

In [254]:

```
pprint.pprint(X_train_t[0,:20,:])
type(X_train_t[:,:20,:])
X_train_t[:,:20,:].shape
```

```
array([[ 33.],
       [192.],
       [  6.],
       [ 33.],
       [  6.],
       [192.],
       [125.],
       [197.],
       [197.],
       [197.],
       [197.],
       [ 85.],
       [ 85.],
       [174.],
       [174.],
       [174.],
       [174.],
       [195.],
       [  3.],
       [  3.]])
```

Out[254]:

```
(43191, 20, 1)
```

In [255]:

```
X_train.shape, y_train.shape, X_test.shape, y_test.shape , X_attack.shape, y_attack.sh
```

Out[255]:

```
((43191, 20, 1),
 (43191, 1),
 (43234, 20, 1),
 (43234, 1),
 (6184, 20, 1),
 (6184, 1))
```

In [290]:

```
word_vec_length = 20
char_vec_length = 1
output_labels = 1
hidden_nodes = 13 # int(2/3 * (word_vec_length * char_vec_length))
epochs = 10
batch_size = 32


def build_model_6():
    # Build the model
    print('Build model...')
    model = Sequential()
    model.add(LSTM(hidden_nodes, return_sequences=False, input_shape=(word_vec_length,
    #model.add(Dropout(0.2))
    model.add(Dense(units=output_labels))
    #model.add(Activation('softmax'))
    model.add(Dense(units=output_labels, activation='sigmoid'))
    model.compile(loss='binary_crossentropy', optimizer='adam', metrics=['acc'])
    #print ("Compilation Time : "%(time.time() - start))
    return model




global_start_time = time.time()

model=None

print ('Loading data... ')
# train on first 700 samples and test on next 300 samples (has anomaly)

print ("X_train, y_train,shape")
print (X_train.shape)
print (y_train.shape)
print ('\nData Loaded. Compiling...\n')



batch_size=32
model = build_model_6()
print("Training...")
history = model.fit(
            X_train, y_train,
            batch_size=batch_size,
            epochs=epochs,
            validation_split=0.01,
            callbacks=[EarlyStopping(monitor='val_loss', patience=3, min_delta=0.0001)

model.summary()
print("Done Training...")
```

```
Loading data...
X_train, y_train,shape
(43191, 20, 1)
(43191, 1)

Data Loaded. Compiling...
```

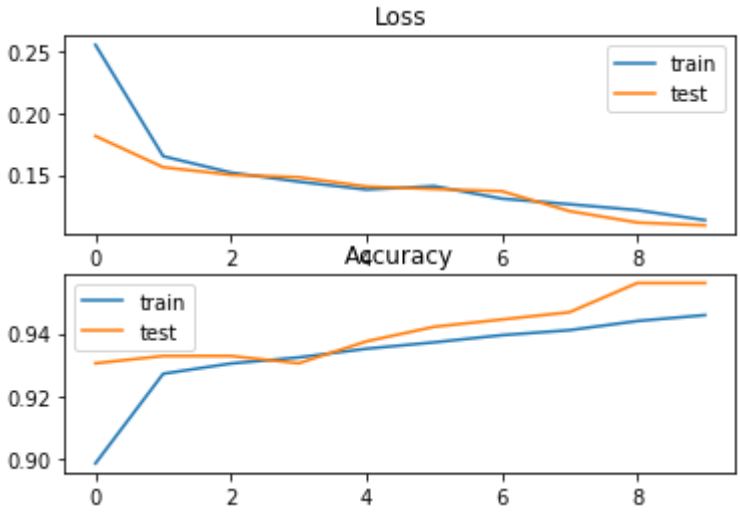
```
Build model...
Training...
Train on 42759 samples, validate on 432 samples
Epoch 1/10
42759/42759 [==============================] - 27s 627us/step - loss: 0.25
58 - acc: 0.8988 - val_loss: 0.1816 - val_acc: 0.9306
Epoch 2/10
42759/42759 [==============================] - 21s 496us/step - loss: 0.16
51 - acc: 0.9272 - val_loss: 0.1562 - val_acc: 0.9329
Epoch 3/10
42759/42759 [==============================] - 22s 503us/step - loss: 0.15
18 - acc: 0.9305 - val_loss: 0.1500 - val_acc: 0.9329
Epoch 4/10
42759/42759 [==============================] - 22s 510us/step - loss: 0.14
45 - acc: 0.9324 - val_loss: 0.1481 - val_acc: 0.9306
Epoch 5/10
42759/42759 [==============================] - 22s 512us/step - loss: 0.13
80 - acc: 0.9352 - val_loss: 0.1405 - val_acc: 0.9375
Epoch 6/10
42759/42759 [==============================] - 22s 520us/step - loss: 0.14
08 - acc: 0.9372 - val_loss: 0.1384 - val_acc: 0.9421
Epoch 7/10
42759/42759 [==============================] - 22s 523us/step - loss: 0.13
06 - acc: 0.9395 - val_loss: 0.1367 - val_acc: 0.9444
Epoch 8/10
42759/42759 [==============================] - 22s 509us/step - loss: 0.12
61 - acc: 0.9411 - val_loss: 0.1205 - val_acc: 0.9468
Epoch 9/10
42759/42759 [==============================] - 22s 523us/step - loss: 0.12
13 - acc: 0.9440 - val_loss: 0.1112 - val_acc: 0.9560
Epoch 10/10
42759/42759 [==============================] - 22s 515us/step - loss: 0.11
31 - acc: 0.9458 - val_loss: 0.1089 - val_acc: 0.9560
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_41 (LSTM)               (None, 13)                780
_________________________________________________________________
dense_59 (Dense)             (None, 1)                 14
_________________________________________________________________
dense_60 (Dense)             (None, 1)                 2
=================================================================
Total params: 796
Trainable params: 796
Non-trainable params: 0
_________________________________________________________________
Done Training...
```

In [291]:

```
### Plotting the change in the loss over the epochs.
# https://machinelearningmastery.com/how-to-calculate-precision-recall-f1-and-more-for
```

In [292]:

```
# plot loss during training
from matplotlib import pyplot

pyplot.subplot(211)
pyplot.title('Loss')
pyplot.plot(history.history['loss'], label='train')
pyplot.plot(history.history['val_loss'], label='test')
pyplot.legend()
# plot accuracy during training
pyplot.subplot(212)
pyplot.title('Accuracy')
pyplot.plot(history.history['acc'], label='train')
pyplot.plot(history.history['val_acc'], label='test')
pyplot.legend()
pyplot.show()
```



In [293]:

```
# predict probabilities for test set
yhat_probs = model.predict(X_test, verbose=0)
# predict crisp classes for test set
yhat_classes = model.predict_classes(X_test, verbose=0)
```

In [294]:

```
# reduce to 1d array
yhat_probs = yhat_probs[:, 0]
yhat_classes = yhat_classes[:, 0]
```

In [295]:

```
from sklearn import metrics

print(metrics.classification_report(yhat_classes, y_test))
```

```
              precision    recall  f1-score   support

           0       0.91      0.94      0.92     39123
           1       0.20      0.15      0.17      4111

   micro avg       0.86      0.86      0.86     43234
   macro avg       0.56      0.54      0.55     43234
weighted avg       0.85      0.86      0.85     43234
```

In [296]:

```
from sklearn.metrics import (confusion_matrix, precision_recall_curve, auc,
                             roc_curve, recall_score, classification_report, f1_score,
                             precision_recall_fscore_support)

from sklearn.metrics import cohen_kappa_score
from sklearn.metrics import roc_auc_score
from sklearn.metrics import confusion_matrix

# accuracy: (tp + tn) / (p + n)
accuracy = accuracy_score(y_test, yhat_classes)
print('Accuracy: %f' % accuracy)
# precision tp / (tp + fp)
precision = precision_score(y_test, yhat_classes, average='weighted', labels=np.unique
print('Precision: %f' % precision)
# recall: tp / (tp + fn)
recall = recall_score(y_test, yhat_classes, average='weighted', labels=np.unique(yhat_
print('Recall: %f' % recall)
# f1: 2 tp / (2 tp + fp + fn)
f1 = f1_score(y_test, yhat_classes, average='weighted', labels=np.unique(yhat_classes)
print('F1 score: %f' % f1)
```

```
Accuracy: 0.862261
Precision: 0.880766
Recall: 0.862261
F1 score: 0.871119
```

In [297]:

```
# kappa
kappa = cohen_kappa_score(y_test, yhat_classes)
print('Cohens kappa: %f' % kappa)

```

```
Cohens kappa: 0.099771
```

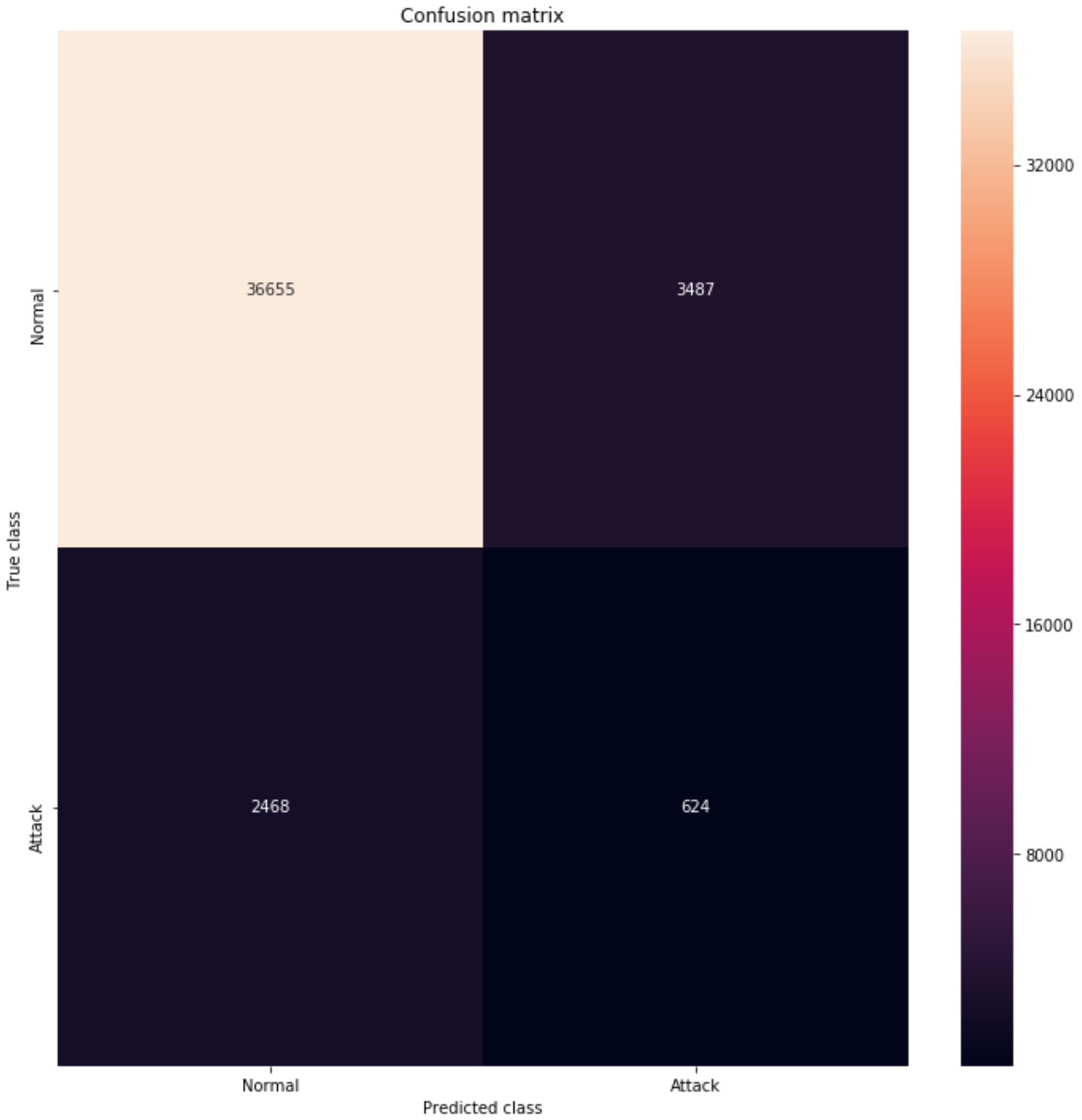
In [298]:

```
# ROC AUC
auc = roc_auc_score(y_test, yhat_probs)
print('ROC AUC: %f' % auc)

```

```
ROC AUC: 0.601735
```

In [299]:

```
# confusion matrix
import seaborn as sns
LABELS = ["Normal","Attack"]

matrix = confusion_matrix(y_test, yhat_classes)
plt.figure(figsize=(12, 12))
sns.heatmap(matrix, xticklabels=LABELS, yticklabels=LABELS, annot=True, fmt="d");
plt.title("Confusion matrix")
plt.ylabel('True class')
plt.xlabel('Predicted class')
plt.show()
```



Input/Output Data to LSTM for Sequence Prediction

In [36]:

```python
#https://stackabuse.com/solving-sequence-problems-with-lstm-in-keras/
import numpy
numpy.set_printoptions(threshold=numpy.nan)

def int_to_onehot(n, n_classes):
    v = [0] * n_classes
    v[n] = 1
    return v

def onehot_to_int(v):
    return v.index(1)

X_train, y_train, X_test, y_test
import pprint

pprint.pprint(X_train[:1,:,:])

# systemcall trace-1 length = 819,
# [6, 6, 63, 6, 42, 120, 6, 195, 120, 6, 6, 114, 114, 1, 1, 252, 252,
# 252, 1, 1, 1, 1, 1, 1, 1, 1, 1, 252, 252, 252, 252, 252, 252, 252,
# 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 1, 1, 252, 1,
# 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 252, 1, 1, 1, 1, 1, 1, 252,
# 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 1, 1, 1, 1, 1, 1,
# 1, 1, 1, 1, 252, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
# 1, 252, 1, 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 252,
# 252, 252, 252, 252, 252, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 252, 252, 1,
# 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 252, 252, 252, 1, 252, 1, 1, 1,
# 1, 252, 1, 1, 1, 1, 1, 1, 1, 1, 1, 252, 252, 252, 252, 252, 1, 1, 1, 1,
# 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
# 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
# 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
# 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
# 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 252, 252, 252, 252, 252, 252,
# 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 1, 1, 1, 1, 1,
# 252, 252, 252, 1, 1, 1, 1, 1, 1, 1, 1, 1, 252, 1, 1, 1, 1, 1, 1, 1, 1,
# 1, 1, 252, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
# 1, 1, 1, 1, 1, 1, 252, 252, 252, 252, 252, 1, 1, 252, 1, 252, 252, 252,
# 252, 252, 1, 1, 252, 252, 252, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
# 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
# 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
# 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 252, 1, 1, 1, 1, 1,
# 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
# 1, 1, 1, 1, 252, 1, 1, 252, 1, 1, 252, 1, 1, 252, 252, 1, 1, 1, 1, 1, 1,
# 1, 1, 1, 252, 1, 1, 1, 1, 1, 1, 252, 252, 252, 1, 1, 1, 1, 1, 1, 1, 1,
# 1, 1, 1, 1, 1, 1, 1, 1, 252, 1, 1, 1, 1, 1, 252, 1, 1, 1, 1, 1, 1, 1,
# 252, 1, 1, 1, 1, 1, 1, 252, 252, 1, 1, 1, 1, 1, 252, 252, 252, 252, 1,
# 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 252, 252, 252, 252, 252, 252, 252,
# 252, 252, 252, 252, 252, 252, 252, 252, 252, 1, 252, 252, 252, 252, 252,
# 252, 252, 252, 1, 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 252,
# 252, 252, 252, 252, 252, 1, 252, 252, 1, 252, 252, 1, 1, 252, 252, 252,
# 1, 1, 252, 252, 252, 252, 1, 1, 1, 1, 1, 1, 1, 1, 252, 252, 252, 252,
# 252, 252, 252, 1, 252, 252, 252, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
# 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 252,
# 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 252,
# 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 1, 252, 252, 1,
# 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 1,
# 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 252, 1, 1, 1, 1, 252, 252, 252, 252,
# 252, 252, 252, 1, 252, 1, 1, 252, 1, 1, 252, 1, 252, 252, 252, 252, 252,
# 252, 252, 252, 252, 252, 1, 252, 1, 1, 252, 1, 252, 252, 252, 1, 252,
```

```
# 252, 252, 1, 1, 252, 252, 252, 252, 252, 252, 252, 252, 252, 252, 252,
# 252, 252, 252, 1, 1, 252]

```

```
array([[[0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0],
        [0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0],
        [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0],
        [0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
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[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
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 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
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 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
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 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 0, 0, 0, 0, 0]]])
```

In [40]:

```
# Sequence [6, 6, 63, 6, 42, 120, 6, 195, 120, 6]
# [X -> 6, 6, 63, 6, 42, 120, 6, 195, 120, Y-> 6]
pprint.pprint(y_train[:1,:])
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array([[0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0]])
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In [38]:

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# Sequence [114 ,162, 114, 114 ,162, 114, 162, 162]
# [X ->114, 162 ,114, 114 ,162, 114, 162  Y-> 162]

test_input = array([[[0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0],
         [0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
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          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0],
         [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
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          1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
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          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0],
         [0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
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 60          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 61          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
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 63          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 64          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 65          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 66          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 67          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 68          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
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 70          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
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 72          0, 0, 0, 0, 0],
 73         [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 74          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 75          1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 76          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 77          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 78          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 79          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 80          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 81          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 82          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 83          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 84          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 85          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 86          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 87          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 88          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 89          0, 0, 0, 0, 0],
 90         [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 91          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 92          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 93          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 94          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 95          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0,
 96          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 97          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 98          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
 99          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
100          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
101          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
102          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
103          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
104          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
105          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
106          0, 0, 0, 0, 0],
107         [0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
108          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
109          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
110          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
111          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
112          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
113          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
114          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
115          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
116          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
117          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
118          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
119          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
120          0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
```

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            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0],
           [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0],
           [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
            0, 0, 0, 0, 0]]])

test_input = test_input.reshape((1, 19, 341))
test_output = model.predict(test_input, verbose=0)
print(test_output)
```

```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
<ipython-input-38-7154605aa8d8> in <module>
      3 # [X ->114, 162 ,114, 114 ,162, 114, 162  Y-> 162]
      4 
----> 5 test_input = array([[[0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0,
 0, 0, 0, 0, 0, 0,
      6             0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
0,
      7             0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
0,

NameError: name 'array' is not defined
```

In [ ]:

```
# https://towardsdatascience.com/step-by-step-understanding-lstm-autoencoder-layers-ff
# https://towardsdatascience.com/lstm-autoencoder-for-extreme-rare-event-classificatio
```