



## UNIVERSITY OF TEHRAN

### COLLEGE OF ENGINEERING

### DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

### NEURAL NETWORK & DEEP LEARNING

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## TEXT GENERATION

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In this part we intend to implement a Recurrent Neural Network which can be used to generate text.

First of all, it's so important to fit **an appropriate model** to our train-data which is the "**HARRY POTTER AND THE GOBLET OF FIRE**".

### Designing the Model

In this part we are going to analyse the loss and accuracy of model and investigate whether the model is an appropriate one or not.

In this section we will develop a simple LSTM network to learn sequences of characters from **HARRY POTTER AND THE GOBLET OF FIRE**. In the next section we will use this model to generate new sequences of characters.

Further you can see the architecture of model:

```
model = Sequential()
model.add(LSTM(256, input_shape=(100, 1), stateful=False, return_sequences=True))
model.add(Dropout(0.2))
model.add(LSTM(256))
model.add(Dropout(0.2))
model.add(Dense(len(chars)))
model.add(Activation('softmax'))
```

**Figure1.** simple LSTM network to learn sequences of characters

### Some notes about our model:

we define a **single hidden LSTM layer with 256 memory units**. The network **uses dropout with a probability of 0.2**. The output layer is a **Dense layer using the softmax activation function** to output a probability prediction for each of **the 54 characters between 0 and 1**.

The problem is really a single character classification problem with 54 classes and as such is defined as optimizing the log loss (cross entropy), here **using the ADAM optimization algorithm for speed**.

we have trained the model **using the dataset** and further you can find **the results**:

## training process:

```

Total Characters: 1107542
Total Vocab: 54
Total Patterns: 1107442
Epoch 1/40
8652/8652 [=====] - ETA: 0s - loss: 2.7356 - accuracy: 0.2304
Epoch 1: loss improved from inf to 2.73558, saving model to weights-improvement-01-2.7356.hdf5
8652/8652 [=====] - 133s 15ms/step - loss: 2.7356 - accuracy: 0.2304
Epoch 2/40
8651/8652 [=====>.] - ETA: 0s - loss: 2.4502 - accuracy: 0.3004
Epoch 2: loss improved from 2.73558 to 2.45016, saving model to weights-improvement-02-2.4502.hdf5
8652/8652 [=====] - 130s 15ms/step - loss: 2.4502 - accuracy: 0.3004
Epoch 3/40
8650/8652 [=====>.] - ETA: 0s - loss: 2.2866 - accuracy: 0.3434
Epoch 3: loss improved from 2.45016 to 2.28662, saving model to weights-improvement-03-2.2866.hdf5
8652/8652 [=====] - 130s 15ms/step - loss: 2.2866 - accuracy: 0.3434
Epoch 4/40
8651/8652 [=====>.] - ETA: 0s - loss: 2.1831 - accuracy: 0.3714
Epoch 5: loss improved from 2.18313 to 2.11050, saving model to weights-improvement-05-2.1105.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 2.1105 - accuracy: 0.3919
Epoch 6/40
8649/8652 [=====>.] - ETA: 0s - loss: 2.0561 - accuracy: 0.4070
Epoch 6: loss improved from 2.11050 to 2.05615, saving model to weights-improvement-06-2.0562.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 2.0562 - accuracy: 0.4070
Epoch 7/40
8650/8652 [=====>.] - ETA: 0s - loss: 2.0115 - accuracy: 0.4189
Epoch 7: loss improved from 2.05615 to 2.01147, saving model to weights-improvement-07-2.0115.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 2.0115 - accuracy: 0.4189
Epoch 8/40
8650/8652 [=====>.] - ETA: 0s - loss: 1.9762 - accuracy: 0.4285
Epoch 8: loss improved from 2.01147 to 1.97620, saving model to weights-improvement-08-1.9762.hdf5
8652/8652 [=====] - 128s 15ms/step - loss: 1.9762 - accuracy: 0.4285
Epoch 9/40
8649/8652 [=====>.] - ETA: 0s - loss: 1.9471 - accuracy: 0.4362
Epoch 9: loss improved from 1.97620 to 1.94710, saving model to weights-improvement-09-1.9471.hdf5
8652/8652 [=====] - 128s 15ms/step - loss: 1.9471 - accuracy: 0.4362
Epoch 10/40
8651/8652 [=====>.] - ETA: 0s - loss: 1.9230 - accuracy: 0.4427
Epoch 10: loss improved from 1.94710 to 1.92295, saving model to weights-improvement-10-1.9230.hdf5
8652/8652 [=====] - 128s 15ms/step - loss: 1.9230 - accuracy: 0.4427
Epoch 11/40
8649/8652 [=====>.] - ETA: 0s - loss: 1.9013 - accuracy: 0.4482
Epoch 11: loss improved from 1.92295 to 1.90136, saving model to weights-improvement-11-1.9014.hdf5
8652/8652 [=====] - 128s 15ms/step - loss: 1.9014 - accuracy: 0.4482
Epoch 12/40
8652/8652 [=====] - ETA: 0s - loss: 1.8822 - accuracy: 0.4531
Epoch 12: loss improved from 1.90136 to 1.88222, saving model to weights-improvement-12-1.8822.hdf5
8652/8652 [=====] - 128s 15ms/step - loss: 1.8822 - accuracy: 0.4531
Epoch 13/40
8652/8652 [=====] - ETA: 0s - loss: 1.8652 - accuracy: 0.4578
Epoch 13: loss improved from 1.88222 to 1.86518, saving model to weights-improvement-13-1.8652.hdf5
8652/8652 [=====] - 128s 15ms/step - loss: 1.8652 - accuracy: 0.4578
Epoch 14/40
8652/8652 [=====] - ETA: 0s - loss: 1.8503 - accuracy: 0.4617
Epoch 14: loss improved from 1.86518 to 1.85031, saving model to weights-improvement-14-1.8503.hdf5
8652/8652 [=====] - 128s 15ms/step - loss: 1.8503 - accuracy: 0.4617

```

```
Epoch 15/40
8651/8652 [=====>.] - ETA: 0s - loss: 1.8373 - accuracy: 0.4655
Epoch 15: loss improved from 1.85031 to 1.83727, saving model to weights-improvement-15-1.8373.hdf5
8652/8652 [=====] - 128s 15ms/step - loss: 1.8373 - accuracy: 0.4655
Epoch 16/40
8650/8652 [=====>.] - ETA: 0s - loss: 1.8247 - accuracy: 0.4685
Epoch 16: loss improved from 1.83727 to 1.82468, saving model to weights-improvement-16-1.8247.hdf5
8652/8652 [=====] - 128s 15ms/step - loss: 1.8247 - accuracy: 0.4685
Epoch 17/40
8649/8652 [=====>.] - ETA: 0s - loss: 1.8136 - accuracy: 0.4712
Epoch 17: loss improved from 1.82468 to 1.81362, saving model to weights-improvement-17-1.8136.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.8136 - accuracy: 0.4712
Epoch 18/40
8650/8652 [=====>.] - ETA: 0s - loss: 1.8039 - accuracy: 0.4740
Epoch 18: loss improved from 1.81362 to 1.80392, saving model to weights-improvement-18-1.8039.hdf5
8652/8652 [=====] - 128s 15ms/step - loss: 1.8039 - accuracy: 0.4740
Epoch 19/40
8649/8652 [=====>.] - ETA: 0s - loss: 1.7947 - accuracy: 0.4768
Epoch 19: loss improved from 1.80392 to 1.79467, saving model to weights-improvement-19-1.7947.hdf5
8652/8652 [=====] - 128s 15ms/step - loss: 1.7947 - accuracy: 0.4768
Epoch 20/40
8649/8652 [=====>.] - ETA: 0s - loss: 1.7861 - accuracy: 0.4788
Epoch 20: loss improved from 1.79467 to 1.78615, saving model to weights-improvement-20-1.7861.hdf5
8652/8652 [=====] - 128s 15ms/step - loss: 1.7861 - accuracy: 0.4788

Epoch 21/40
8652/8652 [=====] - ETA: 0s - loss: 1.7779 - accuracy: 0.4807
Epoch 21: loss improved from 1.78615 to 1.77785, saving model to weights-improvement-21-1.7779.hdf5
8652/8652 [=====] - 128s 15ms/step - loss: 1.7779 - accuracy: 0.4807
Epoch 22/40
8651/8652 [=====>.] - ETA: 0s - loss: 1.7694 - accuracy: 0.4835
Epoch 22: loss improved from 1.77785 to 1.76937, saving model to weights-improvement-22-1.7694.hdf5
8652/8652 [=====] - 128s 15ms/step - loss: 1.7694 - accuracy: 0.4835
Epoch 23/40
8651/8652 [=====>.] - ETA: 0s - loss: 1.7625 - accuracy: 0.4842
Epoch 23: loss improved from 1.76937 to 1.76254, saving model to weights-improvement-23-1.7625.hdf5
8652/8652 [=====] - 128s 15ms/step - loss: 1.7625 - accuracy: 0.4842
Epoch 24/40
8651/8652 [=====>.] - ETA: 0s - loss: 1.7556 - accuracy: 0.4867
Epoch 24: loss improved from 1.76254 to 1.75562, saving model to weights-improvement-24-1.7556.hdf5
8652/8652 [=====] - 128s 15ms/step - loss: 1.7556 - accuracy: 0.4867
Epoch 25/40
8649/8652 [=====>.] - ETA: 0s - loss: 1.7484 - accuracy: 0.4891
Epoch 25: loss improved from 1.75562 to 1.74839, saving model to weights-improvement-25-1.7484.hdf5
8652/8652 [=====] - 128s 15ms/step - loss: 1.7484 - accuracy: 0.4891
Epoch 26/40
8650/8652 [=====>.] - ETA: 0s - loss: 1.7433 - accuracy: 0.4896
Epoch 26: loss improved from 1.74839 to 1.74327, saving model to weights-improvement-26-1.7433.hdf5
```

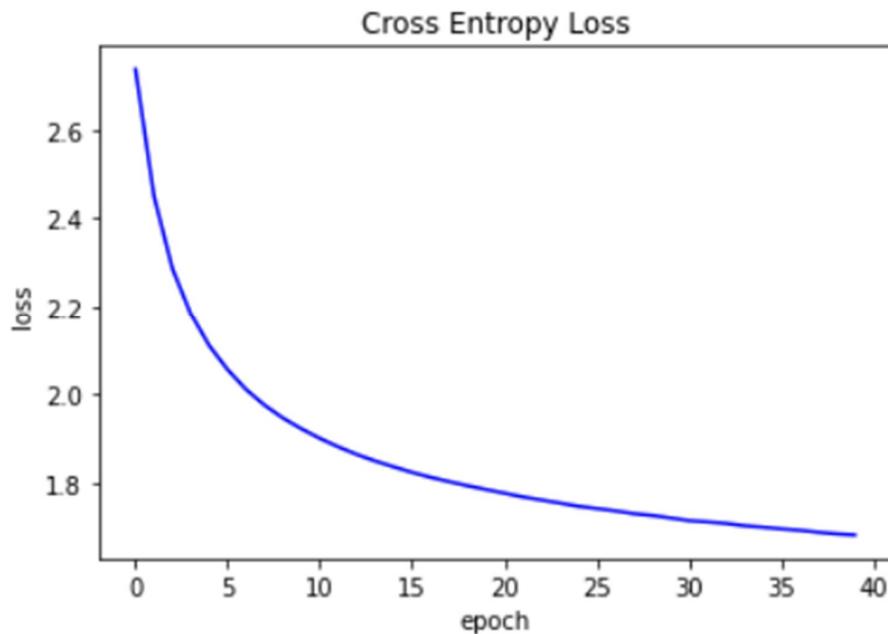
```

8652/8652 [=====] - 128s 15ms/step - loss: 1.7433 - accuracy: 0.4896
Epoch 27/40
8651/8652 [=====>.] - ETA: 0s - loss: 1.7380 - accuracy: 0.4913
Epoch 27: loss improved from 1.74327 to 1.73799, saving model to weights-improvement-27-1.7380.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.7380 - accuracy: 0.4913
Epoch 28/40
8652/8652 [=====] - ETA: 0s - loss: 1.7318 - accuracy: 0.4928
Epoch 28: loss improved from 1.73799 to 1.73181, saving model to weights-improvement-28-1.7318.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.7318 - accuracy: 0.4928
Epoch 29/40
8652/8652 [=====] - ETA: 0s - loss: 1.7276 - accuracy: 0.4940
Epoch 29: loss improved from 1.73181 to 1.72761, saving model to weights-improvement-29-1.7276.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.7276 - accuracy: 0.4940
Epoch 30/40
8652/8652 [=====] - ETA: 0s - loss: 1.7220 - accuracy: 0.4951
Epoch 30: loss improved from 1.72761 to 1.72201, saving model to weights-improvement-30-1.7220.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.7220 - accuracy: 0.4951
Epoch 31/40
8649/8652 [=====>.] - ETA: 0s - loss: 1.7160 - accuracy: 0.4973
Epoch 31: loss improved from 1.72201 to 1.71603, saving model to weights-improvement-31-1.7160.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.7160 - accuracy: 0.4973
Epoch 32/40
8650/8652 [=====>.] - ETA: 0s - loss: 1.7131 - accuracy: 0.4981

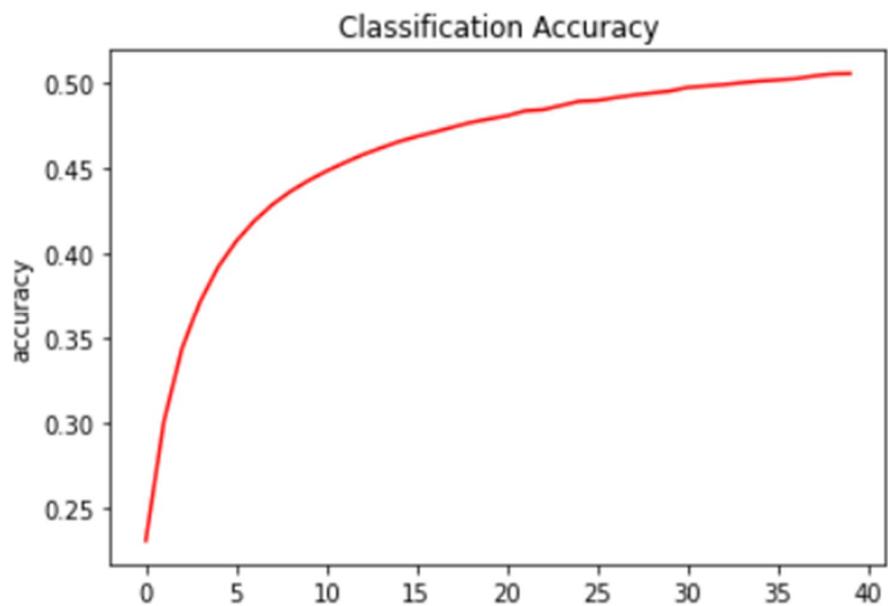

---


Epoch 33/40
8649/8652 [=====>.] - ETA: 0s - loss: 1.7098 - accuracy: 0.4989
Epoch 33: loss improved from 1.71308 to 1.70980, saving model to weights-improvement-33-1.7098.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.7098 - accuracy: 0.4989
Epoch 34/40
8652/8652 [=====] - ETA: 0s - loss: 1.7044 - accuracy: 0.5000
Epoch 34: loss improved from 1.70980 to 1.70438, saving model to weights-improvement-34-1.7044.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.7044 - accuracy: 0.5000
Epoch 35/40
8652/8652 [=====] - ETA: 0s - loss: 1.7012 - accuracy: 0.5010
Epoch 35: loss improved from 1.70438 to 1.70121, saving model to weights-improvement-35-1.7012.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.7012 - accuracy: 0.5010
Epoch 36/40
8649/8652 [=====>.] - ETA: 0s - loss: 1.6973 - accuracy: 0.5017
Epoch 36: loss improved from 1.70121 to 1.69733, saving model to weights-improvement-36-1.6973.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.6973 - accuracy: 0.5017
Epoch 37/40
8651/8652 [=====>.] - ETA: 0s - loss: 1.6943 - accuracy: 0.5024
Epoch 37: loss improved from 1.69733 to 1.69428, saving model to weights-improvement-37-1.6943.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.6943 - accuracy: 0.5024
Epoch 38/40
8650/8652 [=====>.] - ETA: 0s - loss: 1.6898 - accuracy: 0.5040
Epoch 38: loss improved from 1.69428 to 1.68982, saving model to weights-improvement-38-1.6898.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.6898 - accuracy: 0.5040
Epoch 39/40
8649/8652 [=====>.] - ETA: 0s - loss: 1.6862 - accuracy: 0.5051
Epoch 39: loss improved from 1.68982 to 1.68615, saving model to weights-improvement-39-1.6861.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.6861 - accuracy: 0.5052
Epoch 40/40
8652/8652 [=====] - ETA: 0s - loss: 1.6836 - accuracy: 0.5054
Epoch 40: loss improved from 1.68615 to 1.68356, saving model to weights-improvement-40-1.6836.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.6836 - accuracy: 0.5054

```

**The Results :**

**Figure2.** cross-entropy loss during the epochs



**Figure3.** Classification accuracy during the epochs

## TEXT PREDICTION RESULTS:

Here is some output from the stateless recurrent neural network that takes predicts characters one at a time, using a seed text of 100 characters (with some autocorrect applied):

```

SEED TEXT: behind them. at the same moment, bill, charlie, and percy emerged from the boys' tent, fully dress
PREDICTED TEXT: ed as though he was standing at him i was standing at the goblet of forest to the triwizard tourn
SEED TEXT: le divination this afternoon," harry groaned, looking down. divination was his least favorite subje
PREDICTED TEXT: CTT he was standing at the compartment and stared at him i was standing at the dark lord and he w
SEED TEXT: t because we know the dementors are standing guard at azkaban!" "the rest of us sleep less soundly i
PREDICTED TEXT: n the triwizard tournament i was standing at the goblet of forest to the triwizard tournament to
SEED TEXT: ccupied the carriages in front were already hurrying up the stone steps into the castle. harry, ron,
PREDICTED TEXT: and Hermione was standing at the compartment and stared at him i was standing at the goblet of fo
SEED TEXT: 've got more points on the second task," said cedric mulishly. "you stayed behind to get all the ho
PREDICTED TEXT: use of the triwizard tournament i was standing at the stands on the grounds he was standing at t

```

**Figure4.** Text Prediction Results

### Why pre-processing can improve the model performance?

- 1) we need to load the ASCII text for the book into memory and convert all of the characters to lowercase **to reduce the vocabulary that the network must learn.**
- 2) when that the book is loaded, we must **prepare the data for modeling by the neural network.** We cannot model the characters directly, **instead we must convert the characters to integers.** We can do this easily by first creating a set of all of the distinct characters in the book, **then creating a map of each character to a unique integer.**
- 3) Next, we need to **rescale the integers to the range 0-to-1** to make the patterns **easier to learn by the LSTM network** that uses the sigmoid activation function by default.
- 4) Finally, we need to convert the output patterns (single characters converted to integers) into a **one hot encoding.** This is so that we can configure the network to predict the probability of each of the 54 different characters in the vocabulary (an easier representation) rather than trying **to force it to predict precisely the next character.** Each y value is converted into a sparse vector with a length of 54, full of zeros except with a 1 in the column for the letter (integer) that the pattern represents.

## Using Different Loss-Function

In this section, we are going to use another loss-function in our optimizer and investigate is it a good deal or not.

A loss function is going to serve as a measurement of how far our current set of predictions are from the corresponding true values.

**First-one** : Mean-Squared-Error

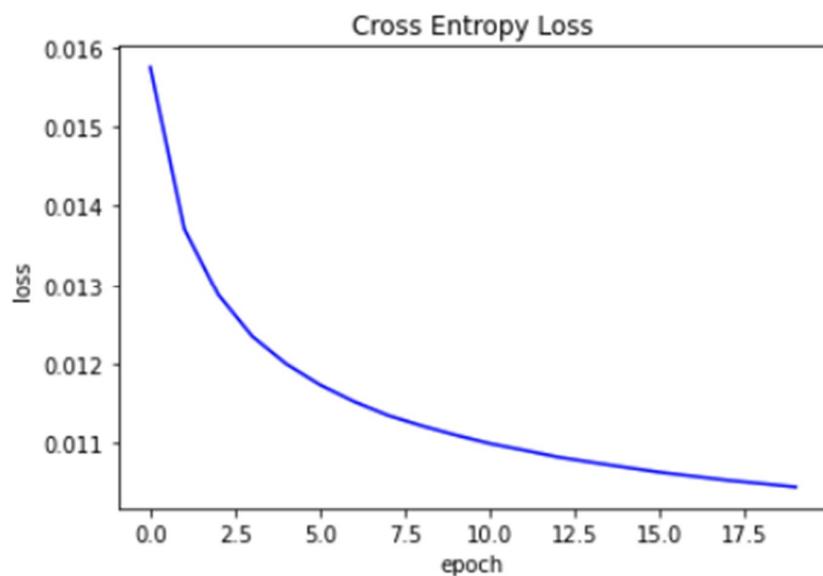
### Model-evaluation:

**accuracy curve** and **loss curve** during epochs have been attached:

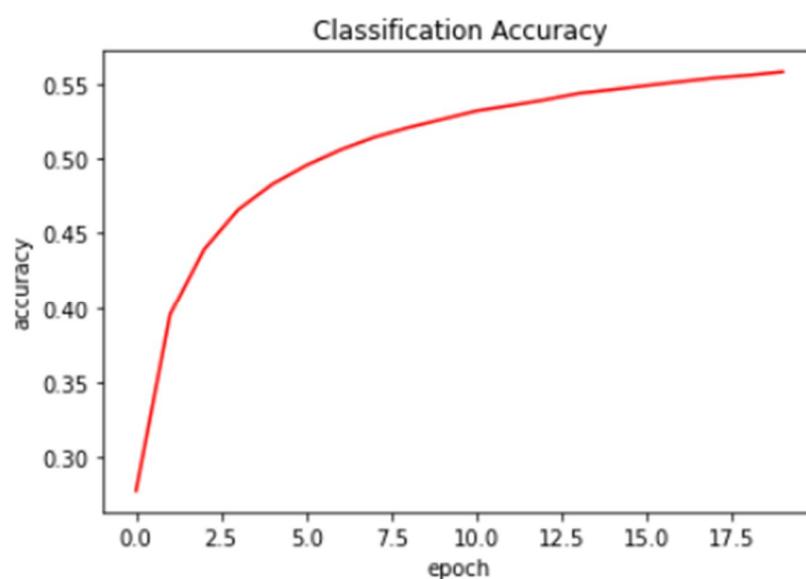
```
Total Characters: 1107542
Total Vocab: 54
Total Patterns: 1107442
Epoch 1/20
8652/8652 [=====] - ETA: 0s - loss: 0.0157 - accuracy: 0.2780
Epoch 1: loss improved from inf to 0.01575, saving model to weights-improvement-01-0.0157.hdf5
8652/8652 [=====] - 288s 32ms/step - loss: 0.0157 - accuracy: 0.2780
Epoch 2/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0137 - accuracy: 0.3953
Epoch 2: loss improved from 0.01575 to 0.01371, saving model to weights-improvement-02-0.0137.hdf5
8652/8652 [=====] - 281s 33ms/step - loss: 0.0137 - accuracy: 0.3953
Epoch 3/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0129 - accuracy: 0.4392
Epoch 3: loss improved from 0.01371 to 0.01288, saving model to weights-improvement-03-0.0129.hdf5
8652/8652 [=====] - 282s 33ms/step - loss: 0.0129 - accuracy: 0.4392
Epoch 4/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0123 - accuracy: 0.4658
Epoch 4: loss improved from 0.01288 to 0.01235, saving model to weights-improvement-04-0.0123.hdf5
8652/8652 [=====] - 283s 33ms/step - loss: 0.0123 - accuracy: 0.4658
Epoch 5/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0120 - accuracy: 0.4828
Epoch 5: loss improved from 0.01235 to 0.01200, saving model to weights-improvement-05-0.0120.hdf5
8652/8652 [=====] - 286s 33ms/step - loss: 0.0120 - accuracy: 0.4828
Epoch 6/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0117 - accuracy: 0.4953
Epoch 6: loss improved from 0.01200 to 0.01174, saving model to weights-improvement-06-0.0117.hdf5
8652/8652 [=====] - 285s 33ms/step - loss: 0.0117 - accuracy: 0.4953
Epoch 7/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0115 - accuracy: 0.5057
Epoch 7: loss improved from 0.01174 to 0.01153, saving model to weights-improvement-07-0.0115.hdf5
8652/8652 [=====] - 285s 33ms/step - loss: 0.0115 - accuracy: 0.5057
```

```
Epoch 7: loss improved from 0.01174 to 0.01153, saving model to weights-improvement-07-0.0115.hdf5
8652/8652 [=====>.] - 285s 33ms/step - loss: 0.0115 - accuracy: 0.5057
Epoch 8/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0114 - accuracy: 0.5142
Epoch 8: loss improved from 0.01153 to 0.01135, saving model to weights-improvement-08-0.0114.hdf5
8652/8652 [=====>.] - 284s 33ms/step - loss: 0.0114 - accuracy: 0.5142
Epoch 9/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0112 - accuracy: 0.5207
Epoch 9: loss improved from 0.01135 to 0.01122, saving model to weights-improvement-09-0.0112.hdf5
8652/8652 [=====>.] - 281s 33ms/step - loss: 0.0112 - accuracy: 0.5207
Epoch 10/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0111 - accuracy: 0.5262
Epoch 10: loss improved from 0.01122 to 0.01111, saving model to weights-improvement-10-0.0111.hdf5
8652/8652 [=====>.] - 282s 33ms/step - loss: 0.0111 - accuracy: 0.5262
Epoch 11/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0110 - accuracy: 0.5318
Epoch 11: loss improved from 0.01111 to 0.01100, saving model to weights-improvement-11-0.0110.hdf5
8652/8652 [=====>.] - 282s 33ms/step - loss: 0.0110 - accuracy: 0.5318
Epoch 12/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0109 - accuracy: 0.5354
Epoch 12: loss improved from 0.01100 to 0.01092, saving model to weights-improvement-12-0.0109.hdf5
8652/8652 [=====>.] - 282s 33ms/step - loss: 0.0109 - accuracy: 0.5354
Epoch 13/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0108 - accuracy: 0.5391
Epoch 13: loss improved from 0.01092 to 0.01083, saving model to weights-improvement-13-0.0108.hdf5
8652/8652 [=====>.] - 282s 33ms/step - loss: 0.0108 - accuracy: 0.5391

Epoch 14/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0108 - accuracy: 0.5434
Epoch 14: loss improved from 0.01083 to 0.01076, saving model to weights-improvement-14-0.0108.hdf5
8652/8652 [=====>.] - 282s 33ms/step - loss: 0.0108 - accuracy: 0.5434
Epoch 15/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0107 - accuracy: 0.5460
Epoch 15: loss improved from 0.01076 to 0.01070, saving model to weights-improvement-15-0.0107.hdf5
8652/8652 [=====>.] - 281s 33ms/step - loss: 0.0107 - accuracy: 0.5460
Epoch 16/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0106 - accuracy: 0.5488
Epoch 16: loss improved from 0.01070 to 0.01064, saving model to weights-improvement-16-0.0106.hdf5
8652/8652 [=====>.] - 282s 33ms/step - loss: 0.0106 - accuracy: 0.5488
Epoch 17/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0106 - accuracy: 0.5513
Epoch 17: loss improved from 0.01064 to 0.01059, saving model to weights-improvement-17-0.0106.hdf5
8652/8652 [=====>.] - 283s 33ms/step - loss: 0.0106 - accuracy: 0.5513
Epoch 18/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0105 - accuracy: 0.5538
Epoch 18: loss improved from 0.01059 to 0.01054, saving model to weights-improvement-18-0.0105.hdf5
8652/8652 [=====>.] - 282s 33ms/step - loss: 0.0105 - accuracy: 0.5538
Epoch 19/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0105 - accuracy: 0.5556
Epoch 19: loss improved from 0.01054 to 0.01050, saving model to weights-improvement-19-0.0105.hdf5
8652/8652 [=====>.] - 282s 33ms/step - loss: 0.0105 - accuracy: 0.5556
Epoch 20/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0105 - accuracy: 0.5579
Epoch 20: loss improved from 0.01050 to 0.01045, saving model to weights-improvement-20-0.0105.hdf5
8652/8652 [=====>.] - 284s 33ms/step - loss: 0.0105 - accuracy: 0.5579
```



**Figure5.** cross-entropy loss during the epochs



**Figure6.** Classification accuracy during the epochs

**Second-one :** Mean-Absolute-Error

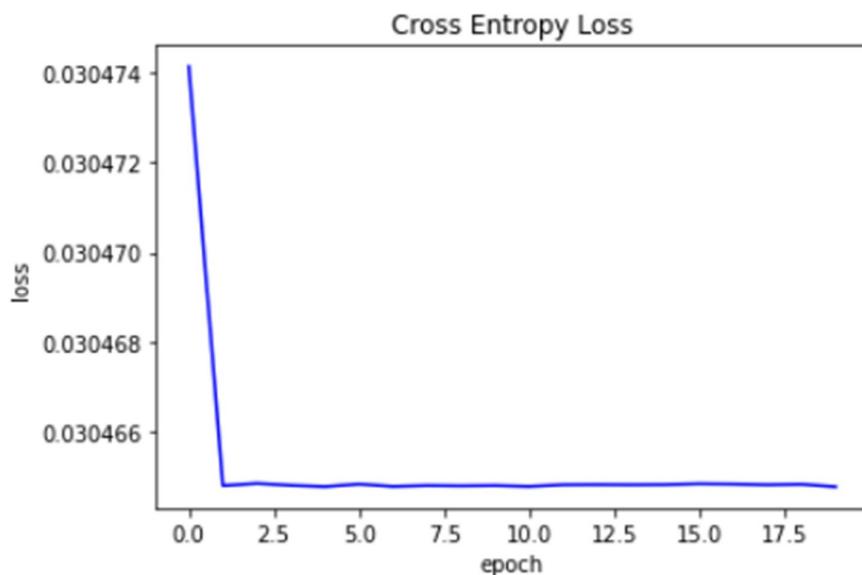
**Model-evaluation:**

**accuracy curve** and **loss curve** during epochs have been attached:

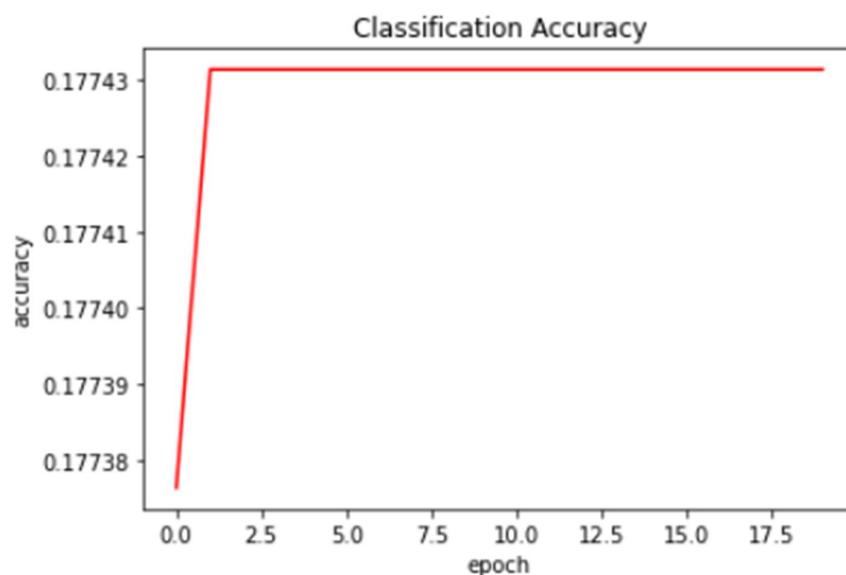
```
Total Characters: 1107542
Total Vocab: 54
Total Patterns: 1107442
Epoch 1/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 1: loss improved from inf to 0.03047, saving model to weights-improvement-01-0.0305.hdf5
8652/8652 [=====] - 283s 32ms/step - loss: 0.0305 - accuracy: 0.1774
Epoch 2/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 2: loss improved from 0.03047 to 0.03046, saving model to weights-improvement-02-0.0305.hdf5
8652/8652 [=====] - 275s 32ms/step - loss: 0.0305 - accuracy: 0.1774
Epoch 3/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 3: loss did not improve from 0.03046
8652/8652 [=====] - 276s 32ms/step - loss: 0.0305 - accuracy: 0.1774
Epoch 4/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 4: loss did not improve from 0.03046
8652/8652 [=====] - 275s 32ms/step - loss: 0.0305 - accuracy: 0.1774
Epoch 5/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 5: loss improved from 0.03046 to 0.03046, saving model to weights-improvement-05-0.0305.hdf5
8652/8652 [=====] - 276s 32ms/step - loss: 0.0305 - accuracy: 0.1774
Epoch 6/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 6: loss did not improve from 0.03046
8652/8652 [=====] - 275s 32ms/step - loss: 0.0305 - accuracy: 0.1774
Epoch 7/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 7: loss did not improve from 0.03046
```

```
8652/8652 [=====] - 276s 32ms/step - loss: 0.0305 - accuracy: 0.1774
Epoch 8/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 8: loss did not improve from 0.03046
8652/8652 [=====] - 276s 32ms/step - loss: 0.0305 - accuracy: 0.1774
Epoch 9/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 9: loss did not improve from 0.03046
8652/8652 [=====] - 277s 32ms/step - loss: 0.0305 - accuracy: 0.1774
Epoch 10/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 10: loss did not improve from 0.03046
8652/8652 [=====] - 276s 32ms/step - loss: 0.0305 - accuracy: 0.1774
Epoch 11/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 11: loss did not improve from 0.03046
8652/8652 [=====] - 276s 32ms/step - loss: 0.0305 - accuracy: 0.1774
Epoch 12/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 12: loss did not improve from 0.03046
8652/8652 [=====] - 275s 32ms/step - loss: 0.0305 - accuracy: 0.1774
Epoch 13/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 13: loss did not improve from 0.03046
8652/8652 [=====] - 277s 32ms/step - loss: 0.0305 - accuracy: 0.1774
Epoch 14/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 14: loss did not improve from 0.03046
8652/8652 [=====] - 276s 32ms/step - loss: 0.0305 - accuracy: 0.1774
Epoch 15/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 15: loss did not improve from 0.03046
8652/8652 [=====] - 276s 32ms/step - loss: 0.0305 - accuracy: 0.1774

Epoch 15: loss did not improve from 0.03046
8652/8652 [=====] - 276s 32ms/step - loss: 0.0305 - accuracy: 0.1774
Epoch 16/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 16: loss did not improve from 0.03046
8652/8652 [=====] - 276s 32ms/step - loss: 0.0305 - accuracy: 0.1774
Epoch 17/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 17: loss did not improve from 0.03046
8652/8652 [=====] - 277s 32ms/step - loss: 0.0305 - accuracy: 0.1774
Epoch 18/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 18: loss did not improve from 0.03046
8652/8652 [=====] - 276s 32ms/step - loss: 0.0305 - accuracy: 0.1774
Epoch 19/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 19: loss did not improve from 0.03046
8652/8652 [=====] - 277s 32ms/step - loss: 0.0305 - accuracy: 0.1774
Epoch 20/20
8651/8652 [=====>.] - ETA: 0s - loss: 0.0305 - accuracy: 0.1774
Epoch 20: loss improved from 0.03046 to 0.03046, saving model to weights-improvement-20-0.0305.hdf5
8652/8652 [=====] - 277s 32ms/step - loss: 0.0305 - accuracy: 0.1774
```



**Figure7.** cross-entropy loss during the epochs



**Figure8.** Classification accuracy during the epochs

## Using Different Metrics ( Batch-size & Number of Epochs )

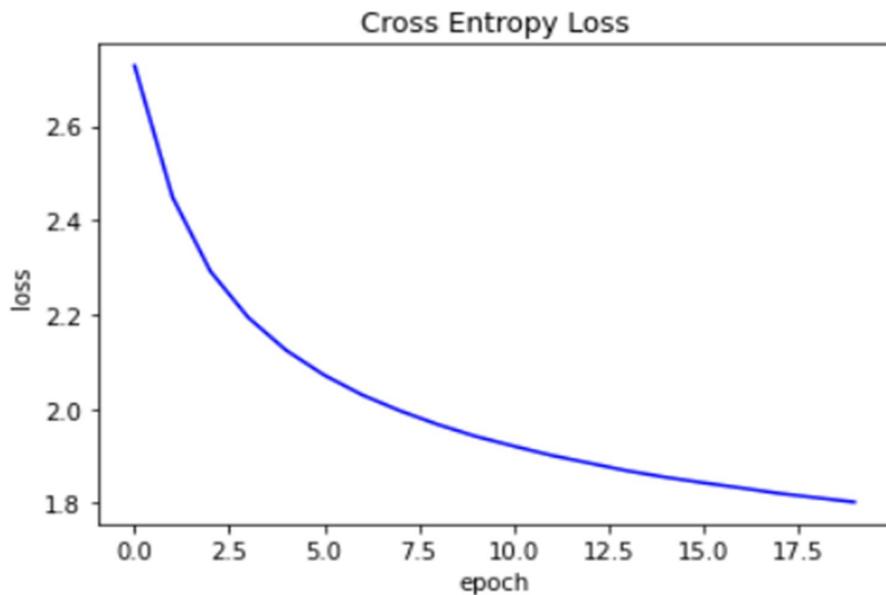
### NUMBER OF EPOCHS # 20 :

```
Total Characters: 1107542
Total Vocab: 54
Total Patterns: 1107442
Epoch 1/20
8650/8652 [=====>.] - ETA: 0s - loss: 2.7279 - accuracy: 0.2328
Epoch 1: loss improved from inf to 2.72788, saving model to weights-improvement-01-2.7279.hdf5
8652/8652 [=====] - 131s 14ms/step - loss: 2.7279 - accuracy: 0.2329
Epoch 2/20
8650/8652 [=====>.] - ETA: 0s - loss: 2.4492 - accuracy: 0.3017
Epoch 2: loss improved from 2.72788 to 2.44918, saving model to weights-improvement-02-2.4492.hdf5
8652/8652 [=====] - 128s 15ms/step - loss: 2.4492 - accuracy: 0.3017
Epoch 3/20
8652/8652 [=====] - ETA: 0s - loss: 2.2917 - accuracy: 0.3430
Epoch 3: loss improved from 2.44918 to 2.29173, saving model to weights-improvement-03-2.2917.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 2.2917 - accuracy: 0.3430
Epoch 4/20
8649/8652 [=====] - ETA: 0s - loss: 2.1936 - accuracy: 0.3695
Epoch 4: loss improved from 2.29173 to 2.19358, saving model to weights-improvement-04-2.1936.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 2.1936 - accuracy: 0.3695
Epoch 5/20
8652/8652 [=====] - ETA: 0s - loss: 2.1242 - accuracy: 0.3879
Epoch 5: loss improved from 2.19358 to 2.12422, saving model to weights-improvement-05-2.1242.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 2.1242 - accuracy: 0.3879
Epoch 6/20
8649/8652 [=====>.] - ETA: 0s - loss: 2.0720 - accuracy: 0.4021
Epoch 6: loss improved from 2.12422 to 2.07192, saving model to weights-improvement-06-2.0719.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 2.0719 - accuracy: 0.4021
Epoch 7/20
8651/8652 [=====>.] - ETA: 0s - loss: 2.0300 - accuracy: 0.4133
Epoch 7: loss improved from 2.07192 to 2.03000, saving model to weights-improvement-07-2.0300.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 2.0300 - accuracy: 0.4133
Epoch 8/20
8651/8652 [=====>.] - ETA: 0s - loss: 1.9962 - accuracy: 0.4224
Epoch 8: loss improved from 2.03000 to 1.99621, saving model to weights-improvement-08-1.9962.hdf5
8652/8652 [=====] - 130s 15ms/step - loss: 1.9962 - accuracy: 0.4224
Epoch 9/20
8652/8652 [=====] - ETA: 0s - loss: 1.9671 - accuracy: 0.4308
Epoch 9: loss improved from 1.99621 to 1.96713, saving model to weights-improvement-09-1.9671.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.9671 - accuracy: 0.4308
Epoch 10/20
8650/8652 [=====>.] - ETA: 0s - loss: 1.9420 - accuracy: 0.4366
Epoch 10: loss improved from 1.96713 to 1.94198, saving model to weights-improvement-10-1.9420.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.9420 - accuracy: 0.4366
Epoch 11/20
8652/8652 [=====] - ETA: 0s - loss: 1.9213 - accuracy: 0.4425
Epoch 11: loss improved from 1.94198 to 1.92135, saving model to weights-improvement-11-1.9213.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.9213 - accuracy: 0.4425
Epoch 12/20
8651/8652 [=====>.] - ETA: 0s - loss: 1.9017 - accuracy: 0.4478
Epoch 12: loss improved from 1.92135 to 1.90170, saving model to weights-improvement-12-1.9017.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.9017 - accuracy: 0.4478
```

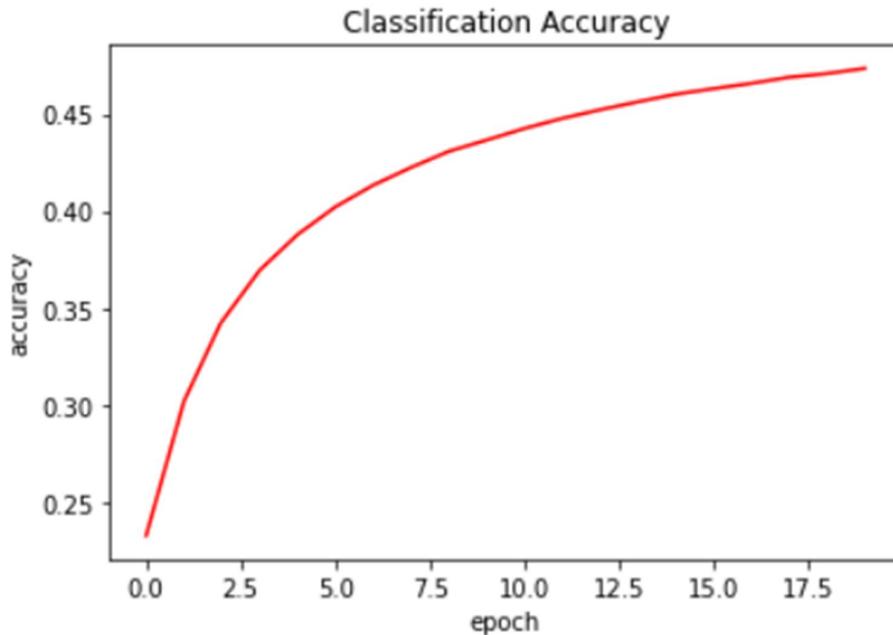
```

Epoch 13/20
8650/8652 [=====>.] - ETA: 0s - loss: 1.8853 - accuracy: 0.4522
Epoch 13: loss improved from 1.90170 to 1.88533, saving model to weights-improvement-13-1.8853.hdf5
8652/8652 [=====] - 130s 15ms/step - loss: 1.8853 - accuracy: 0.4522
Epoch 14/20
8651/8652 [=====>.] - ETA: 0s - loss: 1.8689 - accuracy: 0.4563
Epoch 14: loss improved from 1.88533 to 1.86894, saving model to weights-improvement-14-1.8689.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.8689 - accuracy: 0.4563
Epoch 15/20
8650/8652 [=====>.] - ETA: 0s - loss: 1.8555 - accuracy: 0.4602
Epoch 15: loss improved from 1.86894 to 1.85545, saving model to weights-improvement-15-1.8554.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.8554 - accuracy: 0.4602
Epoch 16/20
8650/8652 [=====>.] - ETA: 0s - loss: 1.8437 - accuracy: 0.4631
Epoch 16: loss improved from 1.85545 to 1.84365, saving model to weights-improvement-16-1.8437.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.8437 - accuracy: 0.4631
Epoch 17/20
8651/8652 [=====>.] - ETA: 0s - loss: 1.8326 - accuracy: 0.4658
Epoch 17: loss improved from 1.84365 to 1.83267, saving model to weights-improvement-17-1.8327.hdf5
8652/8652 [=====] - 129s 15ms/step - loss: 1.8327 - accuracy: 0.4658
Epoch 18/20
8649/8652 [=====>.] - ETA: 0s - loss: 1.8212 - accuracy: 0.4689
Epoch 18: loss improved from 1.83267 to 1.82119, saving model to weights-improvement-18-1.8212.hdf5
8652/8652 [=====] - 132s 15ms/step - loss: 1.8212 - accuracy: 0.4689
Epoch 19/20
8651/8652 [=====>.] - ETA: 0s - loss: 1.8119 - accuracy: 0.4709
Epoch 19: loss improved from 1.82119 to 1.81191, saving model to weights-improvement-19-1.8119.hdf5
8652/8652 [=====] - 131s 15ms/step - loss: 1.8119 - accuracy: 0.4709
Epoch 20/20
8649/8652 [=====>.] - ETA: 0s - loss: 1.8027 - accuracy: 0.4735
Epoch 20: loss improved from 1.81191 to 1.80268, saving model to weights-improvement-20-1.8027.hdf5
8652/8652 [=====] - 130s 15ms/step - loss: 1.8027 - accuracy: 0.4735

```



**Figure9.** cross-entropy loss during the epochs



**Figure10.** Classification accuracy during the epochs

#### BATCH-SIZE # 64 :

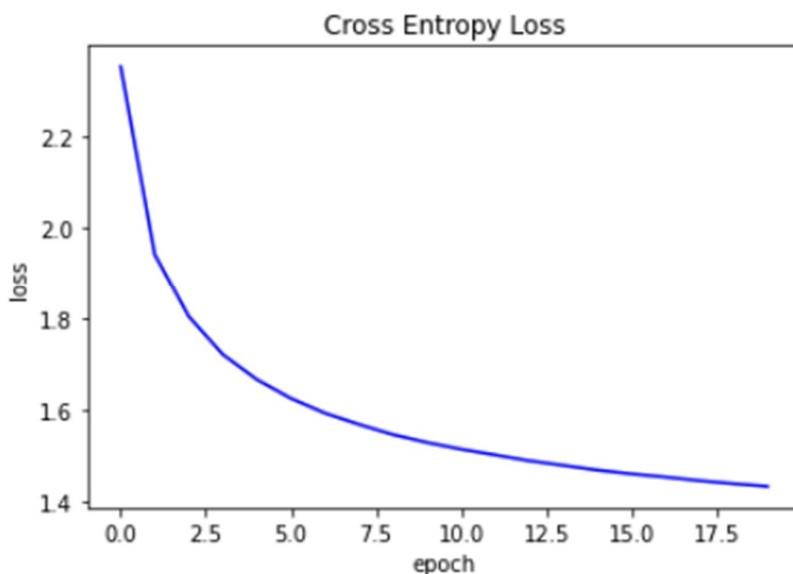
```
Total Characters: 1107542
Total Vocab: 54
Total Patterns: 1107442
Epoch 1/20
17304/17304 [=====] - ETA: 0s - loss: 2.3529 - accuracy: 0.3289
Epoch 1: loss improved from inf to 2.35287, saving model to weights-improvement-01-2.3529.hdf5
17304/17304 [=====] - 338s 19ms/step - loss: 2.3529 - accuracy: 0.3289
Epoch 2/20
17304/17304 [=====] - ETA: 0s - loss: 1.9421 - accuracy: 0.4373
Epoch 2: loss improved from 2.35287 to 1.94207, saving model to weights-improvement-02-1.9421.hdf5
17304/17304 [=====] - 341s 20ms/step - loss: 1.9421 - accuracy: 0.4373
Epoch 3/20
17303/17304 [=====>.] - ETA: 0s - loss: 1.8051 - accuracy: 0.4737
Epoch 3: loss improved from 1.94207 to 1.80515, saving model to weights-improvement-03-1.8051.hdf5
17304/17304 [=====] - 340s 20ms/step - loss: 1.8051 - accuracy: 0.4737
Epoch 4/20
17302/17304 [=====>.] - ETA: 0s - loss: 1.7224 - accuracy: 0.4955
Epoch 4: loss improved from 1.80515 to 1.72237, saving model to weights-improvement-04-1.7224.hdf5
17304/17304 [=====] - 340s 20ms/step - loss: 1.7224 - accuracy: 0.4955
Epoch 5/20
17304/17304 [=====] - ETA: 0s - loss: 1.6677 - accuracy: 0.5103
Epoch 5: loss improved from 1.72237 to 1.66774, saving model to weights-improvement-05-1.6677.hdf5
```

```

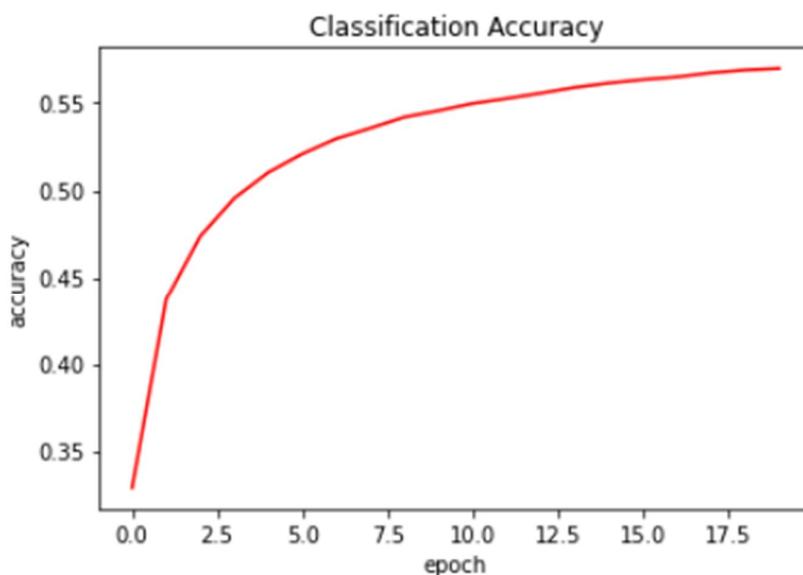
17304/17304 [=====] - 340s 20ms/step - loss: 1.6677 - accuracy: 0.5103
Epoch 6/20
17302/17304 [=====>.] - ETA: 0s - loss: 1.6268 - accuracy: 0.5209
Epoch 6: loss improved from 1.66774 to 1.62675, saving model to weights-improvement-06-1.6268.hdf5
17304/17304 [=====] - 340s 20ms/step - loss: 1.6268 - accuracy: 0.5209
Epoch 7/20
17303/17304 [=====>.] - ETA: 0s - loss: 1.5946 - accuracy: 0.5296
Epoch 7: loss improved from 1.62675 to 1.59461, saving model to weights-improvement-07-1.5946.hdf5
17304/17304 [=====] - 341s 20ms/step - loss: 1.5946 - accuracy: 0.5296
Epoch 8/20
17303/17304 [=====>.] - ETA: 0s - loss: 1.5700 - accuracy: 0.5356
Epoch 8: loss improved from 1.59461 to 1.56999, saving model to weights-improvement-08-1.5700.hdf5
17304/17304 [=====] - 341s 20ms/step - loss: 1.5700 - accuracy: 0.5356
Epoch 9/20
17303/17304 [=====>.] - ETA: 0s - loss: 1.5478 - accuracy: 0.5420
Epoch 9: loss improved from 1.56999 to 1.54780, saving model to weights-improvement-09-1.5478.hdf5
17304/17304 [=====] - 340s 20ms/step - loss: 1.5478 - accuracy: 0.5420

Epoch 10/20
17302/17304 [=====>.] - ETA: 0s - loss: 1.5305 - accuracy: 0.5456
Epoch 10: loss improved from 1.54780 to 1.53057, saving model to weights-improvement-10-1.5306.hdf5
17304/17304 [=====] - 341s 20ms/step - loss: 1.5306 - accuracy: 0.5456
Epoch 11/20
17302/17304 [=====>.] - ETA: 0s - loss: 1.5161 - accuracy: 0.5497
Epoch 11: loss improved from 1.53057 to 1.51610, saving model to weights-improvement-11-1.5161.hdf5
17304/17304 [=====] - 341s 20ms/step - loss: 1.5161 - accuracy: 0.5497
Epoch 12/20
17303/17304 [=====>.] - ETA: 0s - loss: 1.5035 - accuracy: 0.5526
Epoch 12: loss improved from 1.51610 to 1.50351, saving model to weights-improvement-12-1.5035.hdf5
17304/17304 [=====] - 340s 20ms/step - loss: 1.5035 - accuracy: 0.5526
Epoch 13/20
17303/17304 [=====>.] - ETA: 0s - loss: 1.4909 - accuracy: 0.5556
Epoch 13: loss improved from 1.50351 to 1.49084, saving model to weights-improvement-13-1.4908.hdf5
17304/17304 [=====] - 340s 20ms/step - loss: 1.4908 - accuracy: 0.5556
Epoch 14/20
17303/17304 [=====>.] - ETA: 0s - loss: 1.4809 - accuracy: 0.5589
Epoch 14: loss improved from 1.49084 to 1.48088, saving model to weights-improvement-14-1.4809.hdf5
17304/17304 [=====] - 341s 20ms/step - loss: 1.4809 - accuracy: 0.5589
Epoch 15/20
17304/17304 [=====] - ETA: 0s - loss: 1.4706 - accuracy: 0.5614
Epoch 15: loss improved from 1.48088 to 1.47056, saving model to weights-improvement-15-1.4706.hdf5
17304/17304 [=====] - 339s 20ms/step - loss: 1.4706 - accuracy: 0.5614
Epoch 16/20
17302/17304 [=====>.] - ETA: 0s - loss: 1.4623 - accuracy: 0.5634
Epoch 16: loss improved from 1.47056 to 1.46225, saving model to weights-improvement-16-1.4623.hdf5
17304/17304 [=====] - 340s 20ms/step - loss: 1.4623 - accuracy: 0.5634
Epoch 17/20
17304/17304 [=====] - ETA: 0s - loss: 1.4553 - accuracy: 0.5649
Epoch 17: loss improved from 1.46225 to 1.45534, saving model to weights-improvement-17-1.4553.hdf5
17304/17304 [=====] - 340s 20ms/step - loss: 1.4553 - accuracy: 0.5649
Epoch 18/20
17303/17304 [=====>.] - ETA: 0s - loss: 1.4476 - accuracy: 0.5672
Epoch 19/20
17302/17304 [=====>.] - ETA: 0s - loss: 1.4410 - accuracy: 0.5689
Epoch 19: loss improved from 1.44757 to 1.44098, saving model to weights-improvement-19-1.4410.hdf5
17304/17304 [=====] - 341s 20ms/step - loss: 1.4410 - accuracy: 0.5689
Epoch 20/20
17303/17304 [=====>.] - ETA: 0s - loss: 1.4351 - accuracy: 0.5698
Epoch 20: loss improved from 1.44098 to 1.43511, saving model to weights-improvement-20-1.4351.hdf5
17304/17304 [=====] - 341s 20ms/step - loss: 1.4351 - accuracy: 0.5698

```



**Figure11.** cross-entropy loss during the epochs



**Figure12.** Classification accuracy during the epochs

## **How Memory of Neural nets in RNN can be helpful in Model Performance?**

The main difference between the functioning of neural networks and the biological neural network is memory. While both the human brain and neural networks have the ability to read and write from the memory available, the brain can create/store the memory as well.

Memory in neural networks is required to store input data, weight parameters and activations as an input propagates through the network. In training, activations from a forward pass must be retained until they can be used to calculate the error gradients in the backwards pass.

NNs effectively have an internal memory that allows the previous inputs to affect the subsequent predictions. It's much easier to predict the next word in a sentence with more accuracy, if you know what the previous words were.

All of above statements lead to have better performance when we are dealing with RNNs.