MACHINE LEARNING – CS6301

LAB PROJECT

BACHELOR OF ENGINEERING

in

COMPUTER SCIENCE AND ENGINEERING

COLLEGE OF ENGINEERING,

GUINDY ANNA UNIVERSITY: CHENNAI 600 025

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Submitted by,

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BASE PAPER SELECTED:

A Study of Garbage Classification with Convolutional Neural Networks.

PUBLISHED IN:

2020 Indo – Taiwan 2nd International Conference on Computing, Analytics and Networks (Indo-Taiwan ICAN)

LINK:

https://ieeexplore.ieee.org/document/9181311

DATASET:

Image data set that comprises a collection of different types of garbage

CLASSES : 9

INSTANCES : 1,30,050

LINK : Garbage dataset

GARBAGE CLASSIFICATION

ABSTRACT:

All nations already spend a lot of time recycling. Garbage sorting is the most important task in the recycling process since it makes recycling more affordable. In this study, we want to recognize a single piece of trash in an image and categories it into a recycling category. We research several methods and offer a thorough assessment. LSTM with Attention and with pre-trained models, basic Convolutional neural networks (CNN) with and without pre-trained models, SVM and trained the models for in-class classification are the models we employed.

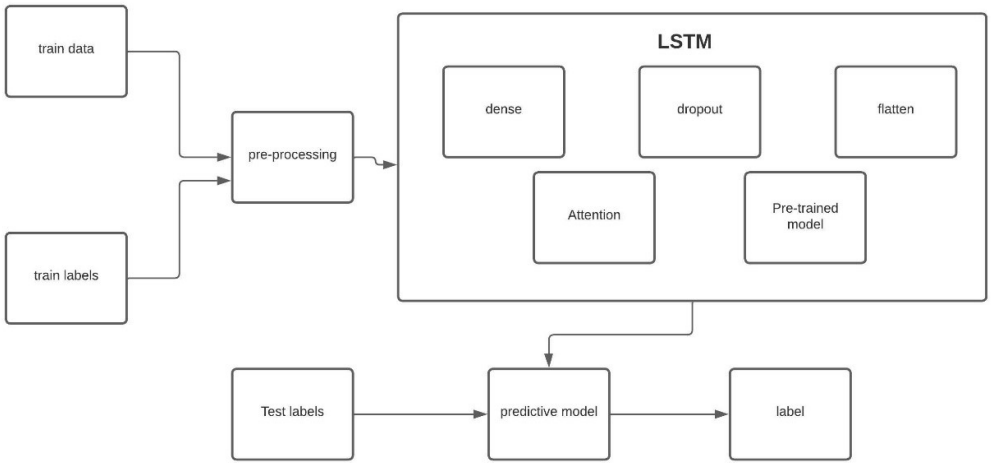
DEEP LEARNING ALGORITHMS:

I. LONG SHORT-TERM MEMORY (LSTM):

Methodology:

In this project, there are seven different Long Short-Term Memory (LSTM) models, including an attention layer, a pre-trained model as a layer, and using different layers like dropout layer, a dense layer, and a flatten layer. The dropout layer is deployed to overcome overfitting.

BLOCK DIAGRAM



Model with 2 LSTM layers

Methodology:

This model consists of 2 LSTM layers and this model got converged at 80th epoch and accuracy obtained is 74.49%.

This Neural Network model contains the layers:

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 lstm_2 (LSTM)               (None, 32, 50)            29400

 dropout_3 (Dropout)         (None, 32, 50)            0

 lstm_3 (LSTM)               (None, 50)                20200

 dropout_4 (Dropout)         (None, 50)                0

 flatten_1 (Flatten)         (None, 50)                0

 dense_2 (Dense)             (None, 50)                2550

 dropout_5 (Dropout)         (None, 50)                0

 dense_3 (Dense)             (None, 9)                 459

=================================================================
Total params: 52,609
Trainable params: 52,609
Non-trainable params: 0
_________________________________________________________________
```

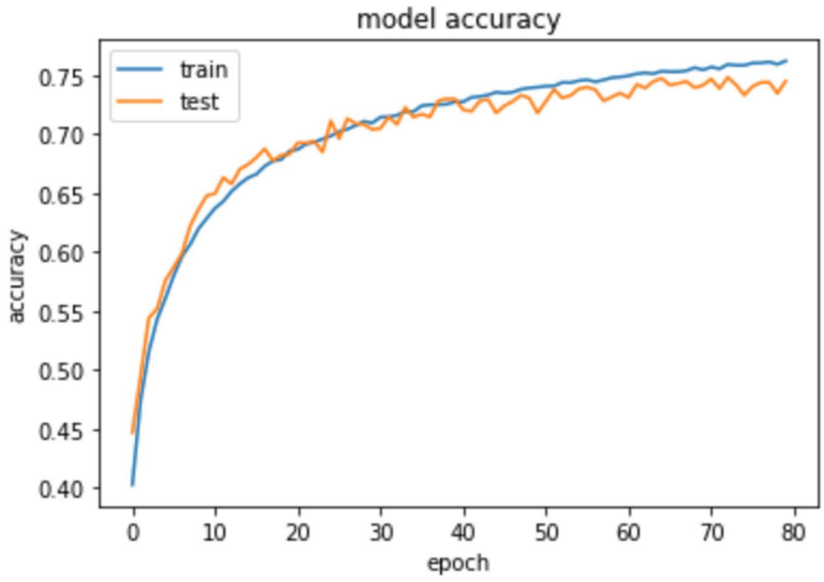
RESULTS:

Accuracy - 74.49%

```
Epoch 1/400

Epoch 1: val_accuracy improved from -inf to 0.44664, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal1.h5
3252/3252 - 30s - loss: 1.6292 - accuracy: 0.4025 - val_loss: 1.4985 - val_accuracy: 0.4466 - 30s/epoch - 9ms/step
Epoch 2/400

Epoch 2: val_accuracy improved from 0.44664 to 0.49458, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal1.h5
3252/3252 - 23s - loss: 1.4548 - accuracy: 0.4743 - val_loss: 1.3764 - val_accuracy: 0.4946 - 23s/epoch - 7ms/step
Epoch 3/400

Epoch 3: val_accuracy improved from 0.49458 to 0.54410, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal1.h5
3252/3252 - 25s - loss: 1.3558 - accuracy: 0.5155 - val_loss: 1.2794 - val_accuracy: 0.5441 - 25s/epoch - 8ms/step
Epoch 4/400

Epoch 4: val_accuracy improved from 0.54410 to 0.55186, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal1.h5
3252/3252 - 23s - loss: 1.2860 - accuracy: 0.5430 - val_loss: 1.2515 - val_accuracy: 0.5519 - 23s/epoch - 7ms/step
Epoch 5/400

Epoch 5: val_accuracy improved from 0.55186 to 0.57586, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal1.h5
3252/3252 - 23s - loss: 1.2346 - accuracy: 0.5607 - val_loss: 1.1819 - val_accuracy: 0.5759 - 23s/epoch - 7ms/step
Epoch 6/400

Epoch 6: val_accuracy improved from 0.57586 to 0.58704, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal1.h5
3252/3252 - 23s - loss: 1.1852 - accuracy: 0.5798 - val_loss: 1.1568 - val_accuracy: 0.5870 - 23s/epoch - 7ms/step
Epoch 7/400
```

```
Epoch 78: val_accuracy did not improve from 0.74817
3252/3252 - 24s - loss: 0.6790 - accuracy: 0.7612 - val_loss: 0.7432 - val_accuracy: 0.7440 - 24s/epoch - 7ms/step
Epoch 79/400

Epoch 79: val_accuracy did not improve from 0.74817
3252/3252 - 24s - loss: 0.6778 - accuracy: 0.7592 - val_loss: 0.7607 - val_accuracy: 0.7345 - 24s/epoch - 7ms/step
Epoch 80/400

Epoch 80: val_accuracy did not improve from 0.74817
3252/3252 - 25s - loss: 0.6745 - accuracy: 0.7620 - val_loss: 0.7351 - val_accuracy: 0.7449 - 25s/epoch - 8ms/step
Epoch 80: early stopping
```

Model accuracy graph:



Model with 3 LSTM layers

Methodology:

This model consists of 3 LSTM layers and this model got converged at 80th epoch and accuracy obtained is 78.48%.

This Neural Network model contains the layers:

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 lstm (LSTM)                 (None, 32, 50)            29400

 dropout (Dropout)           (None, 32, 50)            0

 lstm_1 (LSTM)               (None, 32, 50)            20200

 dropout_1 (Dropout)         (None, 32, 50)            0

 lstm_2 (LSTM)               (None, 50)                20200

 dropout_2 (Dropout)         (None, 50)                0

 flatten (Flatten)           (None, 50)                0

 dense (Dense)               (None, 50)                2550

 dropout_3 (Dropout)         (None, 50)                0

 dense_1 (Dense)             (None, 9)                 459

=================================================================
Total params: 72,809
Trainable params: 72,809
Non-trainable params: 0
_________________________________________________________________
```

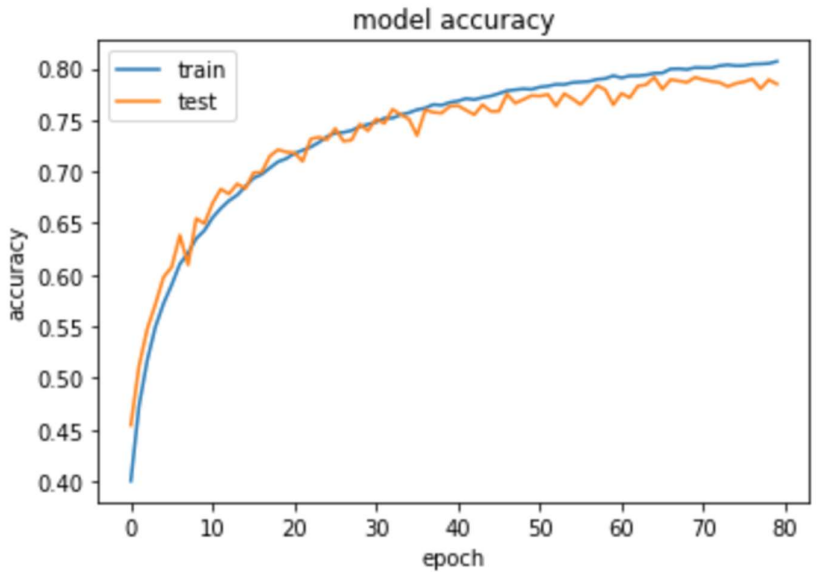
RESULTS:

Accuracy - 78.48%

```
Epoch 1/400

Epoch 1: val_accuracy improved from -inf to 0.45421, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal2.h5
3252/3252 - 39s - loss: 1.6236 - accuracy: 0.4002 - val_loss: 1.4877 - val_accuracy: 0.4542 - 39s/epoch - 12ms/step
Epoch 2/400

Epoch 2: val_accuracy improved from 0.45421 to 0.51126, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal2.h5
3252/3252 - 30s - loss: 1.4633 - accuracy: 0.4729 - val_loss: 1.3804 - val_accuracy: 0.5113 - 30s/epoch - 9ms/step
Epoch 3/400

Epoch 3: val_accuracy improved from 0.51126 to 0.54714, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal2.h5
3252/3252 - 30s - loss: 1.3615 - accuracy: 0.5167 - val_loss: 1.2839 - val_accuracy: 0.5471 - 30s/epoch - 9ms/step
Epoch 4/400

Epoch 4: val_accuracy improved from 0.54714 to 0.57124, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal2.h5
3252/3252 - 30s - loss: 1.2784 - accuracy: 0.5494 - val_loss: 1.2040 - val_accuracy: 0.5712 - 30s/epoch - 9ms/step
Epoch 5/400

Epoch 5: val_accuracy improved from 0.57124 to 0.59762, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal2.h5
3252/3252 - 30s - loss: 1.2151 - accuracy: 0.5721 - val_loss: 1.1458 - val_accuracy: 0.5976 - 30s/epoch - 9ms/step
Epoch 6/400
```

```
Epoch 79: val_accuracy did not improve from 0.79131
3252/3252 - 29s - loss: 0.5688 - accuracy: 0.8047 - val_loss: 0.6275 - val_accuracy: 0.7889 - 29s/epoch - 9ms/step
Epoch 80/400

Epoch 80: val_accuracy did not improve from 0.79131
3252/3252 - 29s - loss: 0.5656 - accuracy: 0.8067 - val_loss: 0.6409 - val_accuracy: 0.7848 - 29s/epoch - 9ms/step
Epoch 80: early stopping
```

Model accuracy graph:



Model with 4 LSTM layers

Methodology:

This model consists of 4 LSTM layers and this model got converged at 112th epoch and accuracy obtained is 81.58%.

This Neural Network model contains the layers:

```
Model: "sequential_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 lstm_8 (LSTM)               (None, 32, 50)            29400

 dropout_7 (Dropout)         (None, 32, 50)            0

 lstm_9 (LSTM)               (None, 32, 50)            20200

 dropout_8 (Dropout)         (None, 32, 50)            0

 lstm_10 (LSTM)              (None, 32, 50)            20200

 dropout_9 (Dropout)         (None, 32, 50)            0

 lstm_11 (LSTM)              (None, 50)                20200

 dropout_10 (Dropout)        (None, 50)                0

 flatten_1 (Flatten)         (None, 50)                0

 dense_2 (Dense)             (None, 50)                2550

 dropout_11 (Dropout)        (None, 50)                0

 dense_3 (Dense)             (None, 9)                 459

=================================================================
Total params: 93,009
Trainable params: 93,009
Non-trainable params: 0
_________________________________________________________________
```

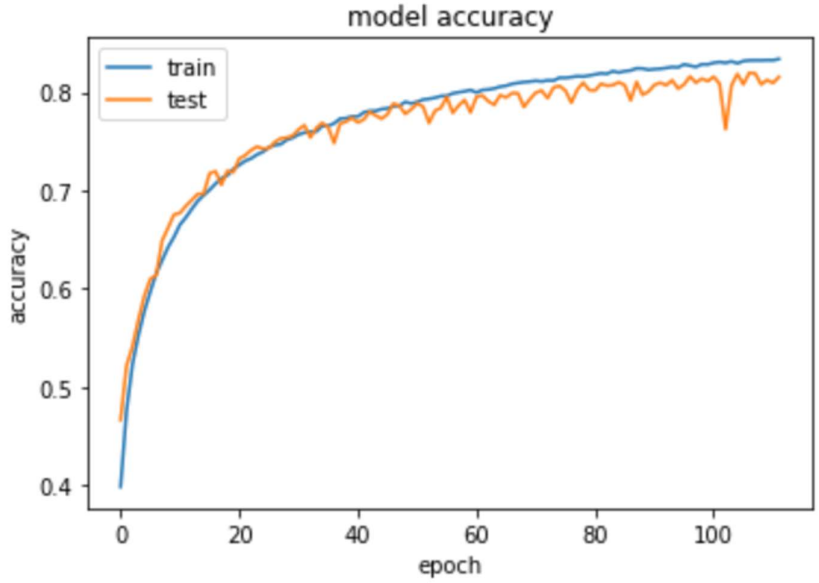
RESULTS:

Accuracy - 81.58%

```
Epoch 1/400

Epoch 1: val_accuracy improved from -inf to 0.46659, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal3.h5
3252/3252 - 46s - loss: 1.6425 - accuracy: 0.3986 - val_loss: 1.4972 - val_accuracy: 0.4666 - 46s/epoch - 14ms/step
Epoch 2/400

Epoch 2: val_accuracy improved from 0.46659 to 0.52153, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal3.h5
3252/3252 - 39s - loss: 1.4762 - accuracy: 0.4759 - val_loss: 1.3563 - val_accuracy: 0.5215 - 39s/epoch - 12ms/step
Epoch 3/400

Epoch 3: val_accuracy improved from 0.52153 to 0.54125, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal3.h5
3252/3252 - 38s - loss: 1.3583 - accuracy: 0.5229 - val_loss: 1.2890 - val_accuracy: 0.5413 - 38s/epoch - 12ms/step
Epoch 4/400

Epoch 4: val_accuracy improved from 0.54125 to 0.56836, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal3.h5
3252/3252 - 38s - loss: 1.2776 - accuracy: 0.5525 - val_loss: 1.2037 - val_accuracy: 0.5684 - 38s/epoch - 12ms/step
Epoch 5/400

Epoch 5: val_accuracy improved from 0.56836 to 0.59258, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal3.h5
3252/3252 - 38s - loss: 1.2082 - accuracy: 0.5771 - val_loss: 1.1449 - val_accuracy: 0.5926 - 38s/epoch - 12ms/step
Epoch 6/400
```

```
Epoch 111: val_accuracy did not improve from 0.81972
3252/3252 - 37s - loss: 0.4867 - accuracy: 0.8325 - val_loss: 0.5803 - val_accuracy: 0.8094 - 37s/epoch - 11ms/step
Epoch 112/400

Epoch 112: val_accuracy did not improve from 0.81972
3252/3252 - 37s - loss: 0.4857 - accuracy: 0.8338 - val_loss: 0.5604 - val_accuracy: 0.8155 - 37s/epoch - 11ms/step
Epoch 112: early stopping
```

Model accuracy graph:



Attention Layer:

Attention layer can help a neural network in memorizing the large sequences of data. A few crucial portions of the data may be overlooked by the models if we give them a huge dataset to learn from. It is crucial to pay attention to important facts, and doing so can help the model perform better.

```
class attention(layers.Layer):
    def __init__(self,**kwargs):
        super(attention,self).__init__(**kwargs)

    def build(self,input_shape):
        self.W=self.add_weight(name="att_weight",shape=(input_shape[-1],1),initializer="normal")
        self.b=self.add_weight(name="att_bias",shape=(input_shape[1],1),initializer="zeros")
        super(attention, self).build(input_shape)

    def call(self,x):
        et=K.squeeze(K.tanh(K.dot(x,self.W)+self.b),axis=-1)
        at=K.softmax(et)
        at=K.expand_dims(at,axis=-1)
        output=x*at
        return K.sum(output,axis=1)

    def compute_output_shape(self,input_shape):
        return (input_shape[0],input_shape[-1])

    def get_config(self):
        return super(attention,self).get_config()
```

Model with 2 LSTM and an Attention layer

Methodology:

This model consists of 2 LSTM layers and an attention layer. This model got converged at 78th epoch and accuracy obtained is 73.58%.

This Neural Network model contains the layers:

```
Model: "sequential_7"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 lstm_18 (LSTM)              (None, 32, 50)            29400

 dropout_23 (Dropout)        (None, 32, 50)            0

 lstm_19 (LSTM)              (None, 32, 50)            20200

 attention_1 (attention)     (None, 50)                82

 dropout_24 (Dropout)        (None, 50)                0

 flatten_6 (Flatten)         (None, 50)                0

 dense_12 (Dense)            (None, 50)                2550

 dropout_25 (Dropout)        (None, 50)                0

 dense_13 (Dense)            (None, 9)                 459

=================================================================
Total params: 52,691
Trainable params: 52,691
Non-trainable params: 0
_________________________________________________________________
```

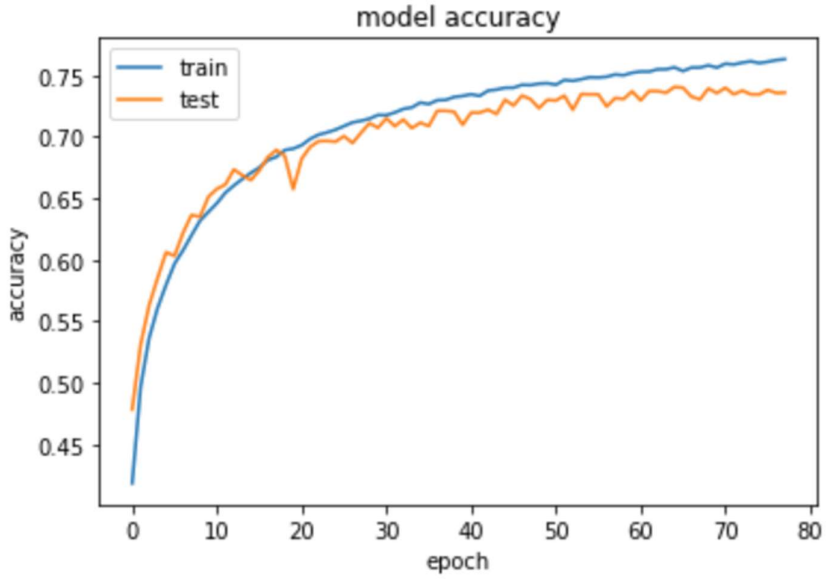
RESULTS:

Accuracy - 73.58%

```
Epoch 1/400

Epoch 1: val_accuracy improved from -inf to 0.47839, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal1at.h5
3252/3252 - 29s - loss: 1.5911 - accuracy: 0.4185 - val_loss: 1.4495 - val_accuracy: 0.4784 - 29s/epoch - 9ms/step
Epoch 2/400

Epoch 2: val_accuracy improved from 0.47839 to 0.53126, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal1at.h5
3252/3252 - 24s - loss: 1.4093 - accuracy: 0.4970 - val_loss: 1.3114 - val_accuracy: 0.5313 - 24s/epoch - 7ms/step
Epoch 3/400

Epoch 3: val_accuracy improved from 0.53126 to 0.56313, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal1at.h5
3252/3252 - 26s - loss: 1.3068 - accuracy: 0.5364 - val_loss: 1.2295 - val_accuracy: 0.5631 - 26s/epoch - 8ms/step
Epoch 4/400

Epoch 4: val_accuracy improved from 0.56313 to 0.58520, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal1at.h5
3252/3252 - 24s - loss: 1.2416 - accuracy: 0.5609 - val_loss: 1.1671 - val_accuracy: 0.5852 - 24s/epoch - 7ms/step
Epoch 5/400

Epoch 5: val_accuracy improved from 0.58520 to 0.60611, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal1at.h5
3252/3252 - 27s - loss: 1.1875 - accuracy: 0.5797 - val_loss: 1.1048 - val_accuracy: 0.6061 - 27s/epoch - 8ms/step
Epoch 6/400
```

```
Epoch 77: val_accuracy did not improve from 0.74041
3252/3252 - 24s - loss: 0.6844 - accuracy: 0.7622 - val_loss: 0.7752 - val_accuracy: 0.7355 - 24s/epoch - 7ms/step
Epoch 78/400

Epoch 78: val_accuracy did not improve from 0.74041
3252/3252 - 24s - loss: 0.6841 - accuracy: 0.7630 - val_loss: 0.7766 - val_accuracy: 0.7358 - 24s/epoch - 7ms/step
Epoch 78: early stopping
```

Model accuracy graph:



Model with 3 LSTM and an Attention layer

Methodology:

This model consists of 3 LSTM layers and an attention layer. The model got converged at 73th epoch and accuracy obtained is 78.14%.

This Neural Network model contains the layers:

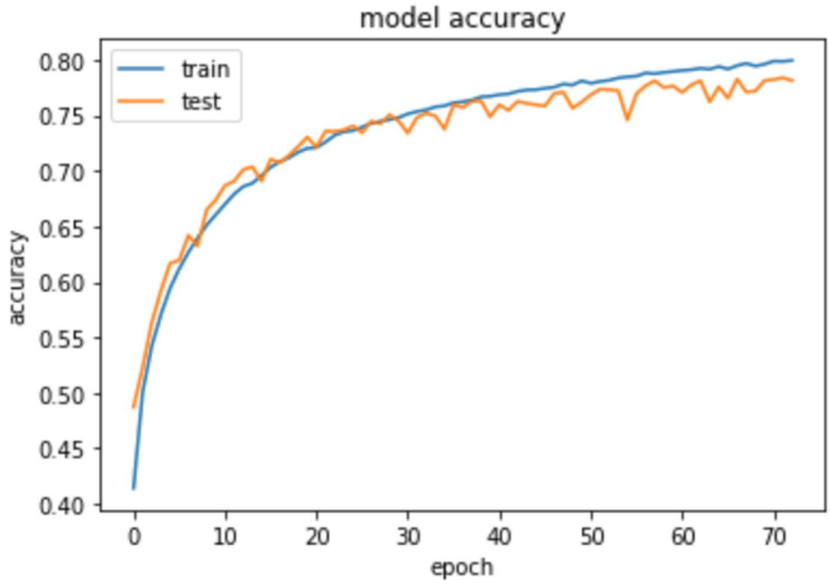
```
Model: "sequential_6"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 lstm_16 (LSTM)              (None, 32, 50)            29400

 dropout_16 (Dropout)        (None, 32, 50)            0

 lstm_17 (LSTM)              (None, 32, 50)            20200

 dropout_17 (Dropout)        (None, 32, 50)            0

 lstm_18 (LSTM)              (None, 32, 50)            20200

 attention_1 (attention)     (None, 50)                82

 dropout_18 (Dropout)        (None, 50)                0

 flatten_3 (Flatten)         (None, 50)                0

 dense_6 (Dense)             (None, 50)                2550

 dropout_19 (Dropout)        (None, 50)                0

 dense_7 (Dense)             (None, 9)                 459

=================================================================
Total params: 72,891
Trainable params: 72,891
Non-trainable params: 0
_________________________________________________________________
```

RESULTS:

Accuracy - 78.14%

```
Epoch 1/400

Epoch 1: val_accuracy improved from -inf to 0.48708, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal2at.h5
3252/3252 - 38s - loss: 1.5972 - accuracy: 0.4140 - val_loss: 1.4311 - val_accuracy: 0.4871 - 38s/epoch - 12ms/step
Epoch 2/400

Epoch 2: val_accuracy improved from 0.48708 to 0.52299, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal2at.h5
3252/3252 - 32s - loss: 1.4026 - accuracy: 0.5009 - val_loss: 1.3371 - val_accuracy: 0.5230 - 32s/epoch - 10ms/step
Epoch 3/400

Epoch 3: val_accuracy improved from 0.52299 to 0.56348, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal2at.h5
3252/3252 - 33s - loss: 1.2945 - accuracy: 0.5425 - val_loss: 1.2295 - val_accuracy: 0.5635 - 33s/epoch - 10ms/step
Epoch 4/400



Epoch 72: val_accuracy improved from 0.78266 to 0.78385, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal2at.h5
3252/3252 - 33s - loss: 0.5874 - accuracy: 0.7986 - val_loss: 0.6494 - val_accuracy: 0.7839 - 33s/epoch - 10ms/step
Epoch 73/400

Epoch 73: val_accuracy did not improve from 0.78385
3252/3252 - 33s - loss: 0.5826 - accuracy: 0.7995 - val_loss: 0.6546 - val_accuracy: 0.7814 - 33s/epoch - 10ms/step
Epoch 73: early stopping
```

Model accuracy graph:



Model with 4 LSTM and an Attention layer

Methodology:

This model consists of 4 LSTM layers and an attention layer. This model got converged at 91th epoch and accuracy obtained is 80.25%.

This Neural Network model contains the layers:

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 lstm (LSTM)                 (None, 32, 50)            29400

 dropout (Dropout)           (None, 32, 50)            0

 lstm_1 (LSTM)               (None, 32, 50)            20200

 dropout_1 (Dropout)         (None, 32, 50)            0

 lstm_2 (LSTM)               (None, 32, 50)            20200

 dropout_2 (Dropout)         (None, 32, 50)            0

 lstm_3 (LSTM)               (None, 32, 50)            20200

 attention (attention)       (None, 50)                82

 dropout_3 (Dropout)         (None, 50)                0

 flatten (Flatten)           (None, 50)                0

 dense (Dense)               (None, 50)                2550

 dropout_4 (Dropout)         (None, 50)                0

 dense_1 (Dense)             (None, 9)                 459

=================================================================
Total params: 93,091
Trainable params: 93,091
Non-trainable params: 0
_________________________________________________________________
```

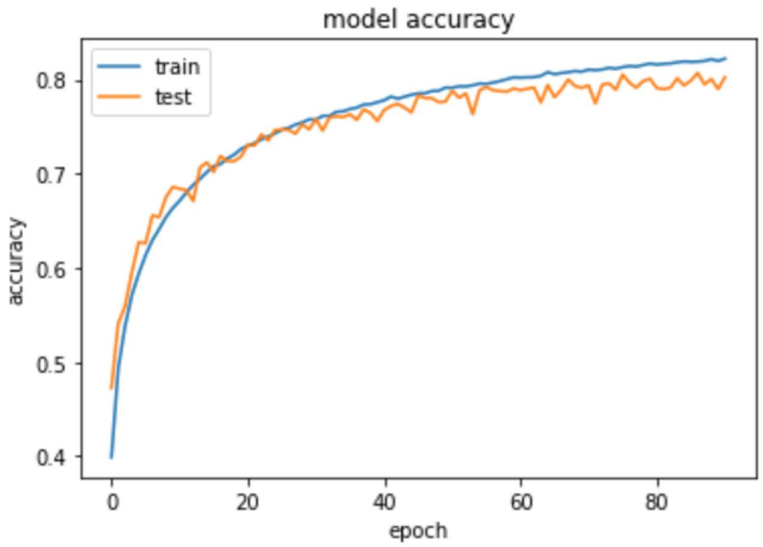
RESULTS:

Accuracy - 80.25%

```
Epoch 1/400

Epoch 1: val_accuracy improved from -inf to 0.47243, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal3at.h5
3252/3252 - 49s - loss: 1.6346 - accuracy: 0.3989 - val_loss: 1.4671 - val_accuracy: 0.4724 - 49s/epoch - 15ms/step
Epoch 2/400

Epoch 2: val_accuracy improved from 0.47243 to 0.54129, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal3at.h5
3252/3252 - 37s - loss: 1.4289 - accuracy: 0.4932 - val_loss: 1.3007 - val_accuracy: 0.5413 - 37s/epoch - 11ms/step
Epoch 3/400

Epoch 3: val_accuracy improved from 0.54129 to 0.55932, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal3at.h5
3252/3252 - 38s - loss: 1.3087 - accuracy: 0.5385 - val_loss: 1.2556 - val_accuracy: 0.5593 - 38s/epoch - 12ms/step
Epoch 4/400

Epoch 4: val_accuracy improved from 0.55932 to 0.59546, saving model to /content/drive/MyDrive/Garbage/model/best_model_8l_normal3at.h5
3252/3252 - 38s - loss: 1.2268 - accuracy: 0.5711 - val_loss: 1.1404 - val_accuracy: 0.5955 - 38s/epoch - 12ms/step
Epoch 5/400
```

```
Epoch 89: val_accuracy did not improve from 0.80715
3252/3252 - 37s - loss: 0.5199 - accuracy: 0.8217 - val_loss: 0.6166 - val_accuracy: 0.8008 - 37s/epoch - 11ms/step
Epoch 90/400

Epoch 90: val_accuracy did not improve from 0.80715
3252/3252 - 37s - loss: 0.5236 - accuracy: 0.8199 - val_loss: 0.6410 - val_accuracy: 0.7900 - 37s/epoch - 11ms/step
Epoch 91/400

Epoch 91: val_accuracy did not improve from 0.80715
3252/3252 - 37s - loss: 0.5196 - accuracy: 0.8223 - val_loss: 0.5964 - val_accuracy: 0.8025 - 37s/epoch - 11ms/step
Epoch 91: early stopping
```

Model accuracy graph:



Model with pre-trained model

Methodology:

This model consists of 2 LSTM layers and a pre-trained model as a sequential layer. This model got converged at 135th epoch and accuracy obtained is 80%.

This Neural Network model contains the layers:

```
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 lstm_14 (LSTM)              (None, 32, 50)            29400

 dropout_13 (Dropout)        (None, 32, 50)            0

 lstm_15 (LSTM)              (None, 32, 96)            56448

 sequential_3 (Sequential)   (None, 9)                 93009

 dropout_14 (Dropout)        (None, 9)                 0

 flatten_2 (Flatten)         (None, 9)                 0

 dense_4 (Dense)             (None, 50)                500

 dropout_15 (Dropout)        (None, 50)                0

 dense_5 (Dense)             (None, 9)                 459

=================================================================
Total params: 179,816
Trainable params: 179,816
Non-trainable params: 0
_________________________________________________________________
```

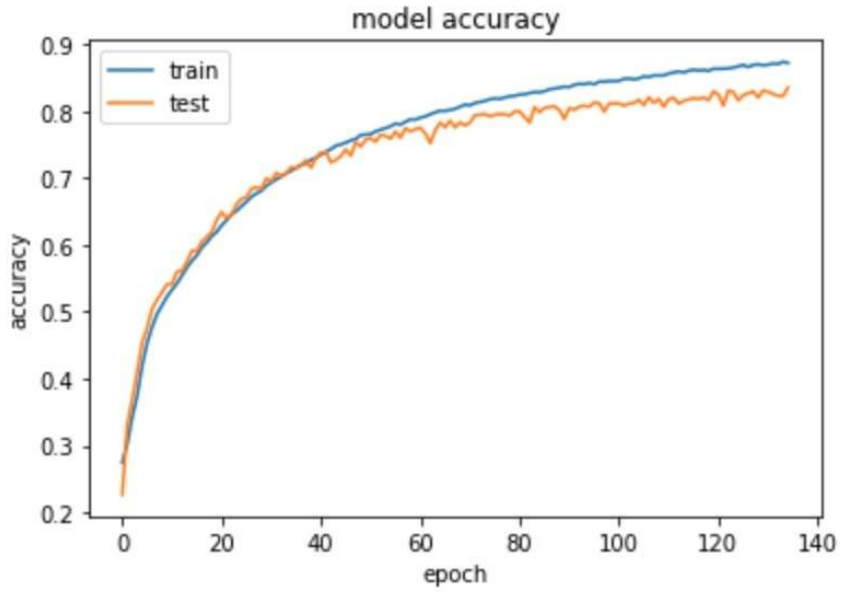
RESULTS:

Accuracy – 83.5%

```
Epoch 1/400

Epoch 1: val_accuracy improved from -inf to 0.22672, saving model to /content/drive/MyDrive/1,3,4/model/best_model_8l_normal1pr.h5
3252/3252 - 60s - loss: 1.8949 - accuracy: 0.2748 - val_loss: 1.9655 - val_accuracy: 0.2267 - 60s/epoch - 18ms/step
Epoch 2/400

Epoch 2: val_accuracy improved from 0.22672 to 0.33037, saving model to /content/drive/MyDrive/1,3,4/model/best_model_8l_normal1pr.h5
3252/3252 - 53s - loss: 1.8405 - accuracy: 0.3023 - val_loss: 1.7318 - val_accuracy: 0.3304 - 53s/epoch - 16ms/step
Epoch 3/400

Epoch 3: val_accuracy improved from 0.33037 to 0.36859, saving model to /content/drive/MyDrive/1,3,4/model/best_model_8l_normal1pr.h5
3252/3252 - 54s - loss: 1.7149 - accuracy: 0.3425 - val_loss: 1.6548 - val_accuracy: 0.3686 - 54s/epoch - 17ms/step
Epoch 4/400

Epoch 4: val_accuracy improved from 0.36859 to 0.40953, saving model to /content/drive/MyDrive/1,3,4/model/best_model_8l_normal1pr.h5
3252/3252 - 53s - loss: 1.6504 - accuracy: 0.3743 - val_loss: 1.6317 - val_accuracy: 0.4095 - 53s/epoch - 16ms/step
Epoch 5/400
```

```
Epoch 134: val_accuracy did not improve from 0.83114
3252/3252 - 48s - loss: 0.3879 - accuracy: 0.8742 - val_loss: 0.5923 - val_accuracy: 0.8229 - 48s/epoch - 15ms/step
Epoch 135/400

Epoch 135: val_accuracy improved from 0.83114 to 0.83556, saving model to /content/drive/MyDrive/1,3,4/model/best_model_8l_normal1pr.h5
3252/3252 - 49s - loss: 0.3901 - accuracy: 0.8727 - val_loss: 0.5555 - val_accuracy: 0.8356 - 49s/epoch - 15ms/step
Epoch 135: early stopping
```

Model accuracy graph:

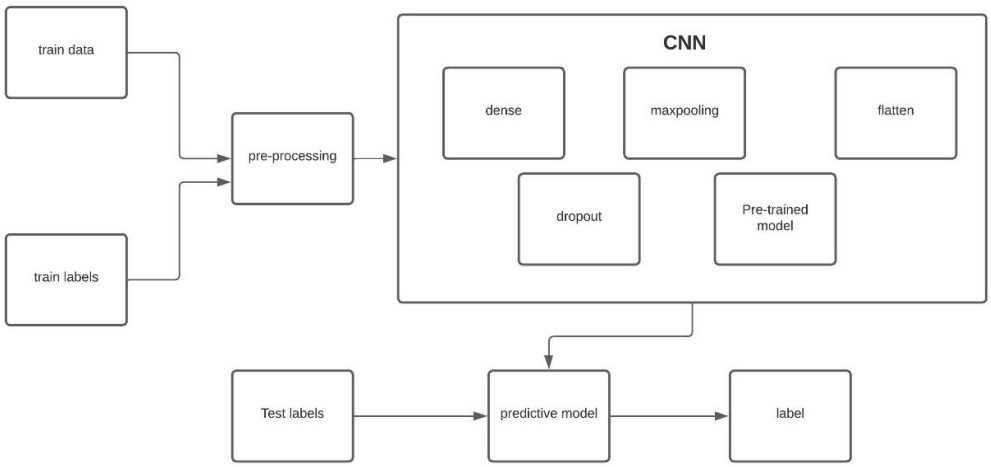


II. CNN (Convolutional Neural Network):

Methodology:

In this project, there are eight different Convolutional neural network (CNN) models, including a pre-trained model as a layer, using different layers like dropout layer, a dense layer, and a flatten layer. The dropout layer is deployed to overcome overfitting.

BLOCK DIAGRAM



CNN with 4 layers

Methodology:

This model consists of 4 CNN layers and this model got converged at 57th epoch and accuracy obtained is 74.6%.

This Neural Network model contains the layers:

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 30, 30, 64)        1792

 max_pooling2d (MaxPooling2D  (None, 15, 15, 64)       0
 )

 dropout (Dropout)           (None, 15, 15, 64)        0

 conv2d_1 (Conv2D)           (None, 13, 13, 64)        36928

 dropout_1 (Dropout)         (None, 13, 13, 64)        0

 max_pooling2d_1 (MaxPooling  (None, 6, 6, 64)         0
 2D)

 conv2d_2 (Conv2D)           (None, 4, 4, 64)          36928

 dropout_2 (Dropout)         (None, 4, 4, 64)          0

 conv2d_3 (Conv2D)           (None, 2, 2, 64)          36928

 dropout_3 (Dropout)         (None, 2, 2, 64)          0

 flatten (Flatten)           (None, 256)               0

 dense (Dense)               (None, 9)                 2313

=================================================================
Total params: 114,889
Trainable params: 114,889
Non-trainable params: 0
_________________________________________________________________
```

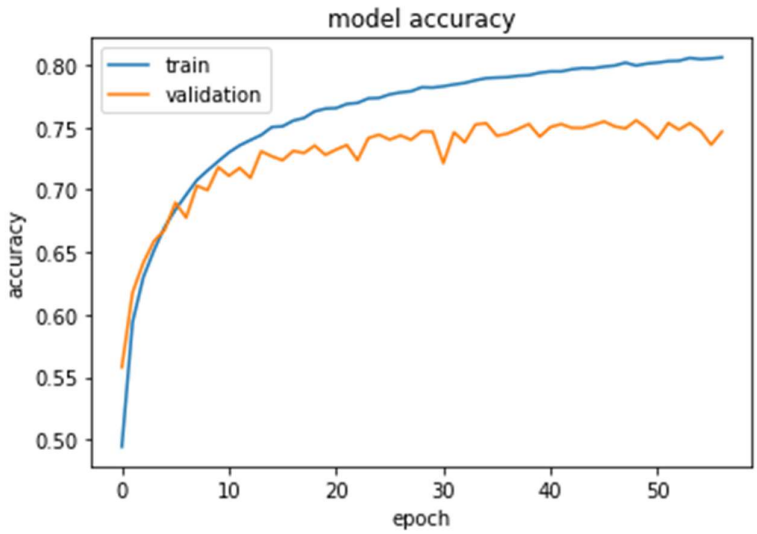
RESULTS:

Accuracy - 74.6%

```
Epoch 1/400

Epoch 1: val_accuracy improved from -inf to 0.55790, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/4cnn.h5
3252/3252 - 16s - loss: 1.4327 - accuracy: 0.4943 - val_loss: 1.2526 - val_accuracy: 0.5579 - 16s/epoch - 5ms/step
Epoch 2/400

Epoch 2: val_accuracy improved from 0.55790 to 0.61765, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/4cnn.h5
3252/3252 - 14s - loss: 1.1691 - accuracy: 0.5939 - val_loss: 1.1180 - val_accuracy: 0.6176 - 14s/epoch - 4ms/step
Epoch 3/400

Epoch 3: val_accuracy improved from 0.61765 to 0.64141, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/4cnn.h5
3252/3252 - 13s - loss: 1.0636 - accuracy: 0.6298 - val_loss: 1.0235 - val_accuracy: 0.6414 - 13s/epoch - 4ms/step
Epoch 4/400
```

```
Epoch 55: val_accuracy did not improve from 0.75544
3252/3252 - 14s - loss: 0.5465 - accuracy: 0.8044 - val_loss: 0.7675 - val_accuracy: 0.7471 - 14s/epoch - 4ms/step
Epoch 56/400

Epoch 56: val_accuracy did not improve from 0.75544
3252/3252 - 14s - loss: 0.5443 - accuracy: 0.8050 - val_loss: 0.8094 - val_accuracy: 0.7359 - 14s/epoch - 4ms/step
Epoch 57/400

Epoch 57: val_accuracy did not improve from 0.75544
3252/3252 - 14s - loss: 0.5438 - accuracy: 0.8058 - val_loss: 0.7593 - val_accuracy: 0.7464 - 14s/epoch - 4ms/step
Epoch 57: early stopping
3252/3252 - 8s - loss: 0.4385 - accuracy: 0.8418 - 8s/epoch - 3ms/step
813/813 - 2s - loss: 0.7593 - accuracy: 0.7464 - 2s/epoch - 3ms/step
Train: 0.842, Test: 0.746
```

Model accuracy graph:



CNN with 4 layers (tuning 1)

Methodology:

This model consists of 4 CNN layers with updated no. of filters in Conv2D layers and this model got converged at 25th epoch and accuracy obtained is 72.2%.

This Neural Network model contains the layers:

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_4 (Conv2D)           (None, 30, 30, 128)       3584

 dropout_4 (Dropout)         (None, 30, 30, 128)       0

 conv2d_5 (Conv2D)           (None, 28, 28, 128)       147584

 dropout_5 (Dropout)         (None, 28, 28, 128)       0

 max_pooling2d_2 (MaxPooling  (None, 14, 14, 128)      0
 2D)

 conv2d_6 (Conv2D)           (None, 12, 12, 64)        73792

 dropout_6 (Dropout)         (None, 12, 12, 64)        0

 conv2d_7 (Conv2D)           (None, 10, 10, 64)        36928

 dropout_7 (Dropout)         (None, 10, 10, 64)        0

 flatten_1 (Flatten)         (None, 6400)              0

 dense_1 (Dense)             (None, 9)                 57609

=================================================================
Total params: 319,497
Trainable params: 319,497
Non-trainable params: 0
```

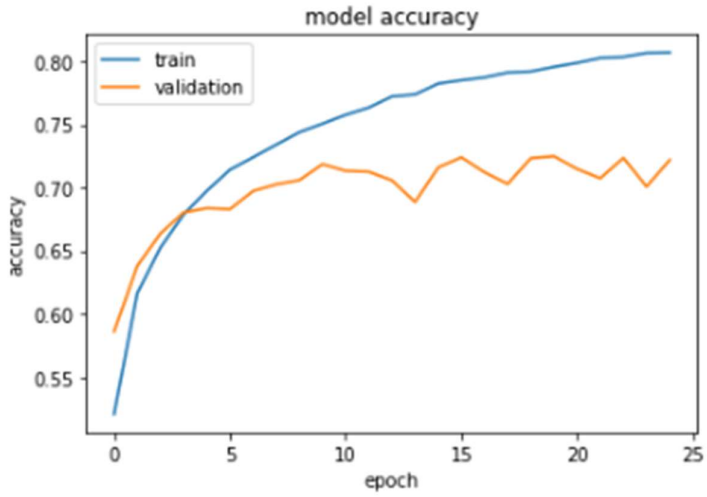
RESULTS:

Accuracy – 72.2%

```
Epoch 1/400

Epoch 1: val_accuracy improved from -inf to 0.58620, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/4cnn_1.h5
3252/3252 - 36s - loss: 1.3643 - accuracy: 0.5209 - val_loss: 1.1925 - val_accuracy: 0.5862 - 36s/epoch - 11ms/step
Epoch 2/400

Epoch 2: val_accuracy improved from 0.58620 to 0.63810, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/4cnn_1.h
3252/3252 - 30s - loss: 1.1054 - accuracy: 0.6165 - val_loss: 1.0514 - val_accuracy: 0.6381 - 30s/epoch - 9ms/step
Epoch 3/400

Epoch 3: val_accuracy improved from 0.63810 to 0.66363, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/4cnn_1.h
3252/3252 - 33s - loss: 0.9945 - accuracy: 0.6525 - val_loss: 0.9680 - val_accuracy: 0.6636 - 33s/epoch - 10ms/step
Epoch 4/400

Epoch 4: val_accuracy improved from 0.66363 to 0.68035, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/4cnn_1.h
3252/3252 - 31s - loss: 0.9230 - accuracy: 0.6787 - val_loss: 0.9080 - val_accuracy: 0.6804 - 31s/epoch - 9ms/step
Epoch 5/400
```

```
Epoch 24: val_accuracy did not improve from 0.72476
3252/3252 - 31s - loss: 0.5442 - accuracy: 0.8065 - val_loss: 0.9172 - val_accuracy: 0.7008 - 31s/epoch - 9ms/step
Epoch 25/400

Epoch 25: val_accuracy did not improve from 0.72476
3252/3252 - 33s - loss: 0.5375 - accuracy: 0.8068 - val_loss: 0.8565 - val_accuracy: 0.7218 - 33s/epoch - 10ms/step
Epoch 25: early stopping
3252/3252 - 11s - loss: 0.4038 - accuracy: 0.8556 - 11s/epoch - 3ms/step
813/813 - 3s - loss: 0.8565 - accuracy: 0.7218 - 3s/epoch - 3ms/step
Train: 0.856, Test: 0.722
```

Model accuracy graph:



CNN with 3 layers

Methodology:

This model consists of 3 CNN layers and this model got converged at 123rd epoch and accuracy obtained is 75.5%.

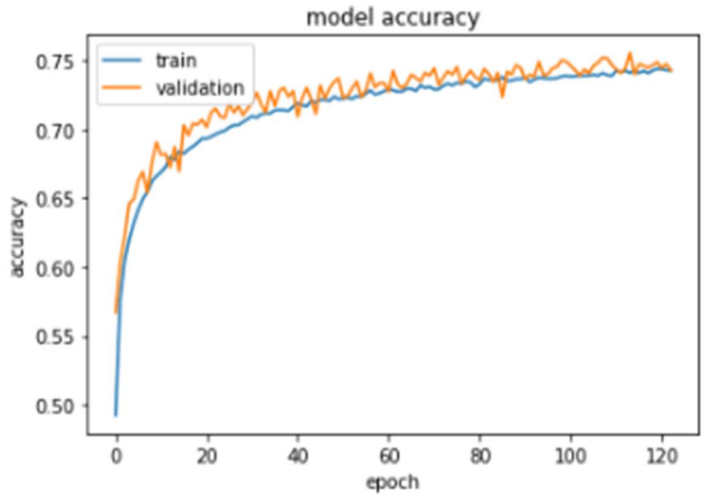
This Neural Network model contains the layers:

```
Model: "sequential_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_11 (Conv2D)          (None, 30, 30, 32)        896

 max_pooling2d_6 (MaxPooling  (None, 15, 15, 32)       0
 2D)

 dropout_12 (Dropout)        (None, 15, 15, 32)        0

 conv2d_12 (Conv2D)          (None, 13, 13, 30)        8670

 max_pooling2d_7 (MaxPooling  (None, 6, 6, 30)         0
 2D)

 dropout_13 (Dropout)        (None, 6, 6, 30)          0

 conv2d_13 (Conv2D)          (None, 4, 4, 30)          8130

 max_pooling2d_8 (MaxPooling  (None, 2, 2, 30)         0
 2D)

 dropout_14 (Dropout)        (None, 2, 2, 30)          0

 flatten_3 (Flatten)         (None, 120)               0

 dense_4 (Dense)             (None, 200)               24200

 dropout_15 (Dropout)        (None, 200)               0

 dense_5 (Dense)             (None, 9)                 1809

=================================================================
Total params: 43,705
Trainable params: 43,705
Non-trainable params: 0
```

```
Epoch 1/400

Epoch 1: val_accuracy improved from -inf to 0.56690, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/best_model_81_normal.h5
3252/3252 - 24s - loss: 1.4445 - accuracy: 0.4923 - val_loss: 1.2330 - val_accuracy: 0.5669 - 24s/epoch - 7ms/step
Epoch 2/400

Epoch 2: val_accuracy improved from 0.56690 to 0.60250, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/best_model_81_normal.h5
3252/3252 - 12s - loss: 1.2219 - accuracy: 0.5756 - val_loss: 1.1314 - val_accuracy: 0.6025 - 12s/epoch - 4ms/step
Epoch 3/400

Epoch 3: val_accuracy improved from 0.60250 to 0.62115, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/best_model_81_normal.h5
3252/3252 - 12s - loss: 1.1407 - accuracy: 0.6041 - val_loss: 1.0782 - val_accuracy: 0.6211 - 12s/epoch - 4ms/step
Epoch 4/400

Epoch 4: val_accuracy improved from 0.62115 to 0.64594, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/best_model_81_normal.h5
3252/3252 - 13s - loss: 1.0875 - accuracy: 0.6197 - val_loss: 1.0126 - val_accuracy: 0.6459 - 13s/epoch - 4ms/step
Epoch 5/400

Epoch 5: val_accuracy improved from 0.64594 to 0.64902, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/best_model_81_normal.h5
3252/3252 - 12s - loss: 1.0528 - accuracy: 0.6320 - val_loss: 1.0110 - val_accuracy: 0.6490 - 12s/epoch - 4ms/step
Epoch 6/400
```

```
Epoch 122: val_accuracy did not improve from 0.75513
3252/3252 - 11s - loss: 0.7269 - accuracy: 0.7427 - val_loss: 0.7111 - val_accuracy: 0.7471 - 11s/epoch - 4ms/step
Epoch 123/400

Epoch 123: val_accuracy did not improve from 0.75513
3252/3252 - 11s - loss: 0.7237 - accuracy: 0.7426 - val_loss: 0.7303 - val_accuracy: 0.7424 - 11s/epoch - 4ms/step
Epoch 123: early stopping
3252/3252 - 7s - loss: 0.5565 - accuracy: 0.8080 - 7s/epoch - 2ms/step
813/813 - 2s - loss: 0.7036 - accuracy: 0.7551 - 2s/epoch - 2ms/step
Train: 0.808, Test: 0.755
```

Model accuracy Graph:



RESULTS:

Accuracy – 75.5%

CNN with 3 layers (tuning 1)

Methodology:

This model consists of 3 CNN layers with updated no. of filters in Conv2D layers and this model got converged at 19th epoch and accuracy obtained is 67.3%.

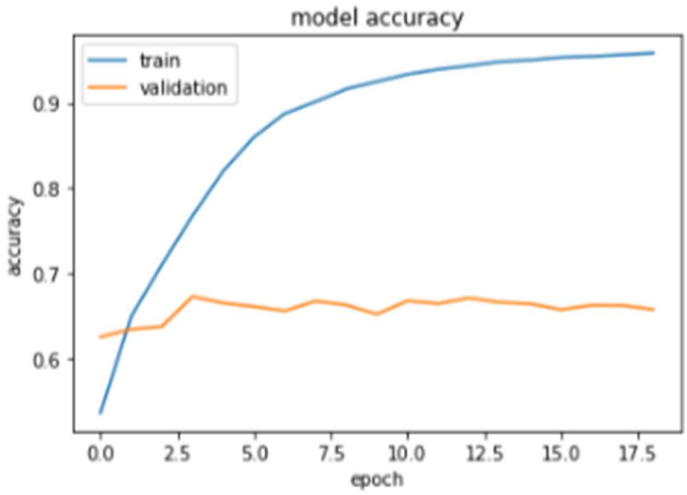
This Neural Network model contains the layers:

```
Model: "sequential_4"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_14 (Conv2D)          (None, 30, 30, 40)        1120

 dropout_16 (Dropout)        (None, 30, 30, 40)        0

 conv2d_15 (Conv2D)          (None, 28, 28, 64)        23104

 dropout_17 (Dropout)        (None, 28, 28, 64)        0

 conv2d_16 (Conv2D)          (None, 26, 26, 64)        36928

 dropout_18 (Dropout)        (None, 26, 26, 64)        0

 flatten_4 (Flatten)         (None, 43264)             0

 dense_6 (Dense)             (None, 200)               8653000

 dropout_19 (Dropout)        (None, 200)               0

 dense_7 (Dense)             (None, 9)                 1809

=================================================================
Total params: 8,715,961
Trainable params: 8,715,961
Non-trainable params: 0
_________________________________________________________________
```

```
Epoch 1/400

Epoch 1: val_accuracy improved from -inf to 0.62591, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/best_model_8l_1.h5
3252/3252 - 33s - loss: 1.3205 - accuracy: 0.5370 - val_loss: 1.0713 - val_accuracy: 0.6259 - 33s/epoch - 10ms/step
Epoch 2/400

Epoch 2: val_accuracy improved from 0.62591 to 0.63510, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/best_model_8l_1.h5
3252/3252 - 32s - loss: 1.0126 - accuracy: 0.6499 - val_loss: 1.0752 - val_accuracy: 0.6351 - 32s/epoch - 10ms/step
Epoch 3/400

Epoch 3: val_accuracy improved from 0.63510 to 0.63829, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/best_model_8l_1.h5
3252/3252 - 33s - loss: 0.8295 - accuracy: 0.7106 - val_loss: 1.1008 - val_accuracy: 0.6383 - 33s/epoch - 10ms/step
Epoch 4/400

Epoch 4: val_accuracy improved from 0.63829 to 0.67324, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/best_model_8l_1.h5
3252/3252 - 32s - loss: 0.6535 - accuracy: 0.7679 - val_loss: 1.0026 - val_accuracy: 0.6732 - 32s/epoch - 10ms/step
```

```
Epoch 18: val_accuracy did not improve from 0.67324
3252/3252 - 29s - loss: 0.1367 - accuracy: 0.9562 - val_loss: 2.3310 - val_accuracy: 0.6628 - 29s/epoch - 9ms/step
Epoch 19/400

Epoch 19: val_accuracy did not improve from 0.67324
3252/3252 - 31s - loss: 0.1318 - accuracy: 0.9581 - val_loss: 2.4475 - val_accuracy: 0.6582 - 31s/epoch - 10ms/step
Epoch 19: early stopping
3252/3252 - 10s - loss: 0.4380 - accuracy: 0.8567 - 10s/epoch - 3ms/step
813/813 - 2s - loss: 1.0026 - accuracy: 0.6732 - 2s/epoch - 3ms/step
Train: 0.857, Test: 0.673
```

Model accuracy graph:



RESULT:

Accuracy – 67.3%

CNN with 3 layers (tuning 2)

Methodology:

This model consists of 3 CNN layers with updated no. of filters in Conv2D layers and this model got converged at 111th epoch and accuracy obtained is 79.8%.

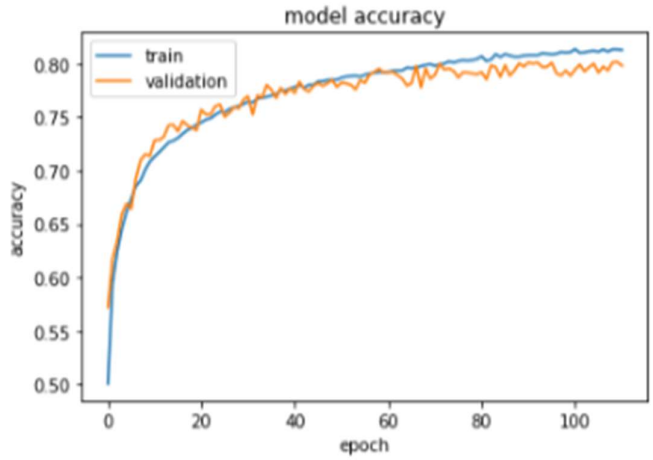
This Neural Network model contains the layers:

```
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_17 (Conv2D)          (None, 30, 30, 50)        1400

 max_pooling2d_9 (MaxPooling  (None, 15, 15, 50)       0
 2D)

 dropout_20 (Dropout)        (None, 15, 15, 50)        0

 conv2d_18 (Conv2D)          (None, 13, 13, 50)        22550

 max_pooling2d_10 (MaxPoolin  (None, 6, 6, 50)         0
 g2D)

 dropout_21 (Dropout)        (None, 6, 6, 50)          0

 conv2d_19 (Conv2D)          (None, 4, 4, 50)          22550

 max_pooling2d_11 (MaxPoolin  (None, 2, 2, 50)         0
 g2D)

 dropout_22 (Dropout)        (None, 2, 2, 50)          0

 flatten_5 (Flatten)         (None, 200)               0

 dense_8 (Dense)             (None, 300)               60300

 dropout_23 (Dropout)        (None, 300)               0

 dense_9 (Dense)             (None, 9)                 2709

=================================================================
Total params: 109,509
Trainable params: 109,509
Non-trainable params: 0
```

```
Epoch 1/400

Epoch 1: val_accuracy improved from -inf to 0.57228, saving model to /content/drive/MyDrive/ml/models/best_model_8l_2.h5
3252/3252 - 15s - loss: 1.4133 - accuracy: 0.5009 - val_loss: 1.2239 - val_accuracy: 0.5723 - 15s/epoch - 5ms/step
Epoch 2/400

Epoch 2: val_accuracy improved from 0.57228 to 0.61753, saving model to /content/drive/MyDrive/ml/models/best_model_8l_2.h5
3252/3252 - 14s - loss: 1.1689 - accuracy: 0.5945 - val_loss: 1.1111 - val_accuracy: 0.6175 - 14s/epoch - 4ms/step
Epoch 3/400

Epoch 3: val_accuracy improved from 0.61753 to 0.63410, saving model to /content/drive/MyDrive/ml/models/best_model_8l_2.h5
3252/3252 - 13s - loss: 1.0764 - accuracy: 0.6238 - val_loss: 1.0328 - val_accuracy: 0.6341 - 13s/epoch - 4ms/step
Epoch 4/400

Epoch 4: val_accuracy improved from 0.63410 to 0.65944, saving model to /content/drive/MyDrive/ml/models/best_model_8l_2.h5
3252/3252 - 13s - loss: 1.0086 - accuracy: 0.6459 - val_loss: 0.9663 - val_accuracy: 0.6594 - 13s/epoch - 4ms/step
```

```
Epoch 110: val_accuracy improved from 0.80119 to 0.80150, saving model to /content/drive/MyDrive/ml/models/best_model_8l_2.h5
3252/3252 - 13s - loss: 0.5279 - accuracy: 0.8132 - val_loss: 0.5818 - val_accuracy: 0.8015 - 13s/epoch - 4ms/step
Epoch 111/400

Epoch 111: val_accuracy did not improve from 0.80150
3252/3252 - 13s - loss: 0.5306 - accuracy: 0.8128 - val_loss: 0.5753 - val_accuracy: 0.7982 - 13s/epoch - 4ms/step
Epoch 111: early stopping
3252/3252 - 8s - loss: 0.3410 - accuracy: 0.8850 - 8s/epoch - 2ms/step
813/813 - 2s - loss: 0.5753 - accuracy: 0.7982 - 2s/epoch - 2ms/step
Train: 0.885, Test: 0.798
```

Model accuracy graph:



RESULTS:

Accuracy – 79.8%

CNN with 2 layers

Methodology:

This model consists of 3 CNN layers with updated no. of filters in Conv2D layers and this model got converged at 116th epoch and accuracy obtained is 69.5%.

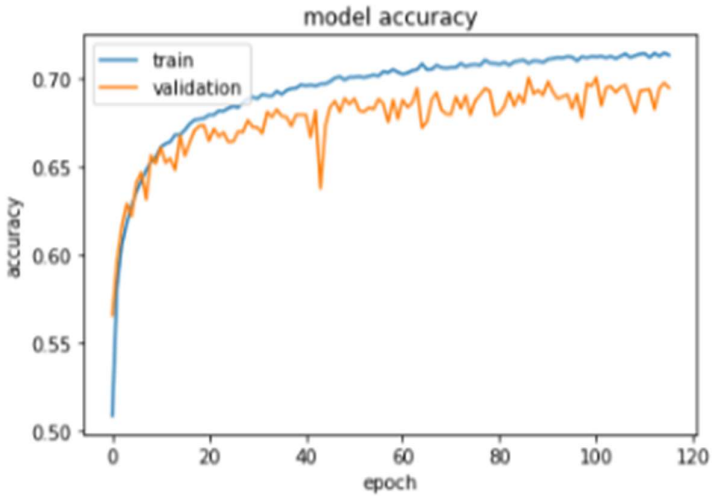
This Neural Network model contains the layers:

```
Model: "sequential_6"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_20 (Conv2D)          (None, 30, 30, 32)        896

 max_pooling2d_12 (MaxPoolin  (None, 15, 15, 32)       0
 g2D)

 dropout_24 (Dropout)        (None, 15, 15, 32)        0

 conv2d_21 (Conv2D)          (None, 13, 13, 40)        11560

 max_pooling2d_13 (MaxPoolin  (None, 6, 6, 40)         0
 g2D)

 dropout_25 (Dropout)        (None, 6, 6, 40)          0

 flatten_6 (Flatten)         (None, 1440)              0

 dense_10 (Dense)            (None, 9)                 12969

=================================================================
Total params: 25,425
Trainable params: 25,425
Non-trainable params: 0
_________________________________________________________________
```

```
Epoch 1/400

Epoch 1: val_accuracy improved from -inf to 0.56547, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/cnn_41.h5
3252/3252 - 11s - loss: 1.3937 - accuracy: 0.5083 - val_loss: 1.2670 - val_accuracy: 0.5655 - 11s/epoch - 3ms/step
Epoch 2/400

Epoch 2: val_accuracy improved from 0.56547 to 0.59627, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/cnn_41.h5
3252/3252 - 10s - loss: 1.2095 - accuracy: 0.5808 - val_loss: 1.1685 - val_accuracy: 0.5963 - 10s/epoch - 3ms/step
Epoch 3/400

Epoch 3: val_accuracy improved from 0.59627 to 0.61596, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/cnn_41.h5
3252/3252 - 10s - loss: 1.1416 - accuracy: 0.6055 - val_loss: 1.1059 - val_accuracy: 0.6160 - 10s/epoch - 3ms/step
Epoch 4/400

Epoch 4: val_accuracy improved from 0.61596 to 0.62910, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/cnn_41.h5
3252/3252 - 11s - loss: 1.1000 - accuracy: 0.6181 - val_loss: 1.0691 - val_accuracy: 0.6291 - 11s/epoch - 4ms/step
```

```
Epoch 115: val_accuracy did not improve from 0.70088
3252/3252 - 11s - loss: 0.8114 - accuracy: 0.7148 - val_loss: 0.8765 - val_accuracy: 0.6977 - 11s/epoch - 3ms/step
Epoch 116/400

Epoch 116: val_accuracy did not improve from 0.70088
3252/3252 - 11s - loss: 0.8111 - accuracy: 0.7136 - val_loss: 0.8835 - val_accuracy: 0.6950 - 11s/epoch - 3ms/step
Epoch 116: early stopping
3252/3252 - 7s - loss: 0.7290 - accuracy: 0.7503 - 7s/epoch - 2ms/step
813/813 - 2s - loss: 0.8835 - accuracy: 0.6950 - 2s/epoch - 2ms/step
Train: 0.750, Test: 0.695
```

Model accuracy graph:



RESULTS:

Accuracy – 69.5%

CNN with 2 layers (tuning 1)

Methodology:

This model consists of 3 CNN layers with updated no. of filters in Conv2D layers and this model got converged at 27th epoch and accuracy obtained is 77%.

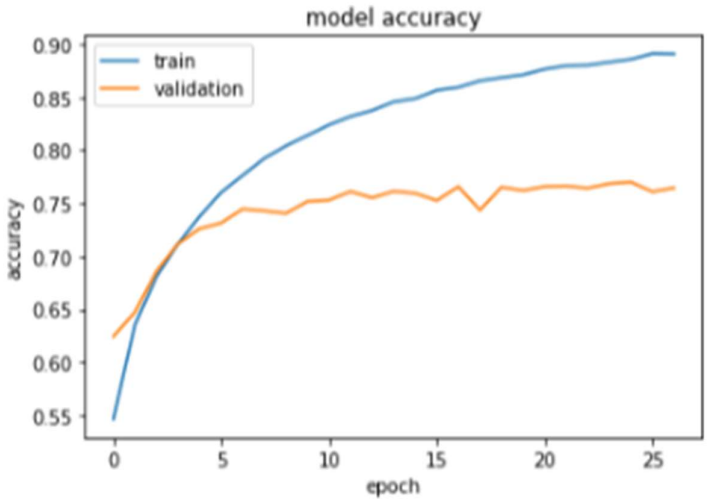
This Neural Network model contains the layers:

```
Model: "sequential_7"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_22 (Conv2D)          (None, 30, 30, 32)        896

 max_pooling2d_14 (MaxPoolin  (None, 15, 15, 32)       0
 g2D)

 dropout_26 (Dropout)        (None, 15, 15, 32)        0

 conv2d_23 (Conv2D)          (None, 13, 13, 64)        18496

 max_pooling2d_15 (MaxPoolin  (None, 6, 6, 64)         0
 g2D)

 dropout_27 (Dropout)        (None, 6, 6, 64)          0

 flatten_7 (Flatten)         (None, 2304)              0

 dense_11 (Dense)            (None, 200)               461000

 dropout_28 (Dropout)        (None, 200)               0

 dense_12 (Dense)            (None, 9)                 1809

=================================================================
Total params: 482,201
Trainable params: 482,201
Non-trainable params: 0
```

```
Epoch 1/400

Epoch 1: val_accuracy improved from -inf to 0.62445, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/best_model_{
3252/3252 - 24s - loss: 1.2964 - accuracy: 0.5466 - val_loss: 1.1019 - val_accuracy: 0.6245 - 24s/epoch - 7ms/step
Epoch 2/400

Epoch 2: val_accuracy improved from 0.62445 to 0.64725, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/best_mode
3252/3252 - 11s - loss: 1.0465 - accuracy: 0.6353 - val_loss: 1.0055 - val_accuracy: 0.6473 - 11s/epoch - 4ms/step
Epoch 3/400

Epoch 3: val_accuracy improved from 0.64725 to 0.68593, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/best_mode
3252/3252 - 12s - loss: 0.9155 - accuracy: 0.6806 - val_loss: 0.8959 - val_accuracy: 0.6859 - 12s/epoch - 4ms/step
Epoch 4/400

Epoch 4: val_accuracy improved from 0.68593 to 0.71192, saving model to /content/drive/MyDrive/Colab Notebooks/Garbage model/models/best_mode
```

```
Epoch 26: val_accuracy did not improve from 0.76990
3252/3252 - 12s - loss: 0.3085 - accuracy: 0.8910 - val_loss: 0.8758 - val_accuracy: 0.7609 - 12s/epoch - 4ms/step
Epoch 27/400

Epoch 27: val_accuracy did not improve from 0.76990
3252/3252 - 11s - loss: 0.3101 - accuracy: 0.8907 - val_loss: 0.8560 - val_accuracy: 0.7645 - 11s/epoch - 3ms/step
Epoch 27: early stopping
3252/3252 - 7s - loss: 0.1538 - accuracy: 0.9489 - 7s/epoch - 2ms/step
813/813 - 2s - loss: 0.8598 - accuracy: 0.7699 - 2s/epoch - 2ms/step
Train: 0.949, Test: 0.770
```

Model accuracy graph:



RESULT:

Accuracy – 77%

CNN Pretraining with best model

Methodology:

This model consists of a pretrained model which is a 3 layers CNN neural networked with 79.8% accuracy and this resultant model got converged at 27th epoch and accuracy obtained is 77%.

Neural network layers of model used for pretraining:

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_2 (Conv2D)           (None, 30, 30, 50)        1400

 max_pooling2d_2 (MaxPooling  (None, 15, 15, 50)       0
 2D)

 dropout (Dropout)           (None, 15, 15, 50)        0

 conv2d_3 (Conv2D)           (None, 13, 13, 50)        22550

 max_pooling2d_3 (MaxPooling  (None, 6, 6, 50)         0
 2D)

 dropout_1 (Dropout)         (None, 6, 6, 50)          0

 conv2d_4 (Conv2D)           (None, 4, 4, 50)          22550

 max_pooling2d_4 (MaxPooling  (None, 2, 2, 50)         0
 2D)

 dropout_2 (Dropout)         (None, 2, 2, 50)          0

 flatten_1 (Flatten)         (None, 200)               0

 dense_1 (Dense)             (None, 300)               60300

 dropout_3 (Dropout)         (None, 300)               0

=================================================================
Total params: 106,800
Trainable params: 106,800
Non-trainable params: 0
```

This Neural Network model contains the layers:

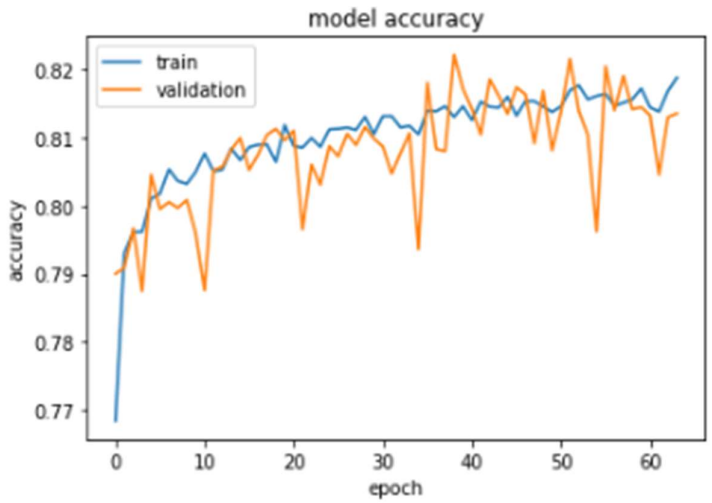
```
_________________________________________________________________
Model: "sequential_10"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 sequential_1 (Sequential)   (None, 300)               106800

 flatten_10 (Flatten)        (None, 300)               0

 dense_17 (Dense)            (None, 500)               150500

 dropout_31 (Dropout)        (None, 500)               0

 dense_18 (Dense)            (None, 9)                 4509

=================================================================
Total params: 261,809
Trainable params: 261,809
Non-trainable params: 0
```

```
Epoch 1/200

Epoch 1: val_accuracy improved from -inf to 0.79000, saving model to /content/drive/MyDrive/ml/models/cnnpre_81.h5
3252/3252 - 21s - loss: 0.6763 - accuracy: 0.7684 - val_loss: 0.6081 - val_accuracy: 0.7900 - 21s/epoch - 6ms/step
Epoch 2/200

Epoch 2: val_accuracy improved from 0.79000 to 0.79089, saving model to /content/drive/MyDrive/ml/models/cnnpre_81.h5
3252/3252 - 14s - loss: 0.5938 - accuracy: 0.7931 - val_loss: 0.6004 - val_accuracy: 0.7909 - 14s/epoch - 4ms/step
Epoch 3/200

Epoch 3: val_accuracy improved from 0.79089 to 0.79669, saving model to /content/drive/MyDrive/ml/models/cnnpre_81.h5
3252/3252 - 14s - loss: 0.5845 - accuracy: 0.7961 - val_loss: 0.5873 - val_accuracy: 0.7967 - 14s/epoch - 4ms/step
Epoch 4/200
```

```
Epoch 63: val_accuracy did not improve from 0.82218
3252/3252 - 14s - loss: 0.5402 - accuracy: 0.8169 - val_loss: 0.5541 - val_accuracy: 0.8130 - 14s/epoch - 4ms/step
Epoch 64/200

Epoch 64: val_accuracy did not improve from 0.82218
3252/3252 - 14s - loss: 0.5329 - accuracy: 0.8188 - val_loss: 0.5464 - val_accuracy: 0.8136 - 14s/epoch - 4ms/step
Epoch 64: early stopping
```

```
3252/3252 - 8s - loss: 0.2801 - accuracy: 0.9065 - 8s/epoch - 2ms/step
813/813 - 2s - loss: 0.5193 - accuracy: 0.8222 - 2s/epoch - 3ms/step
Train: 0.906, Test: 0.822
```

Training accuracy graph:

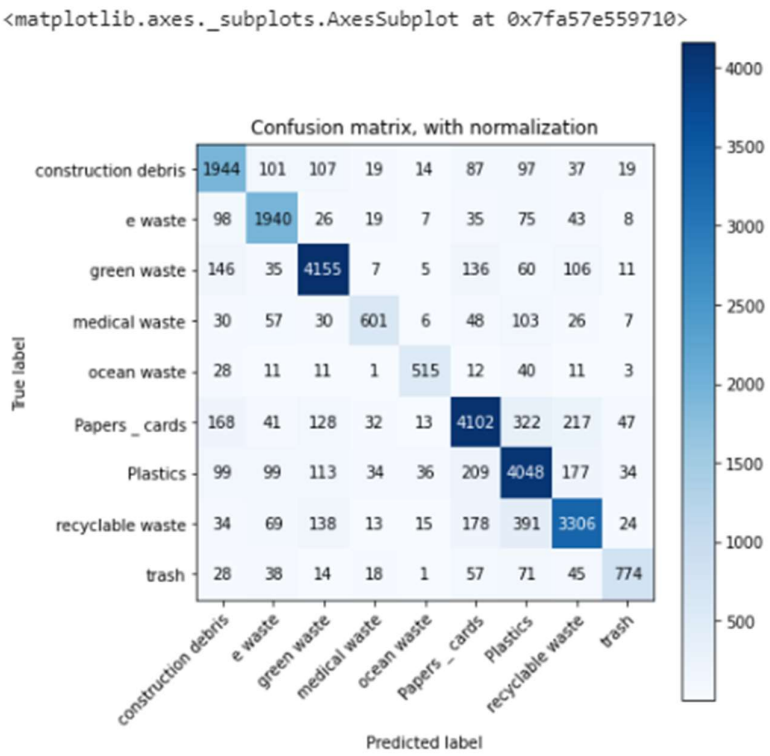


RESULT:

Accuracy – 82.2%

Hence, in CNN we achieved a maximum validation accuracy of 82.2% from a pretrained CNN model (i.e., through transfer learning).

Confusion matrix for maximum accuracy model with CNN.



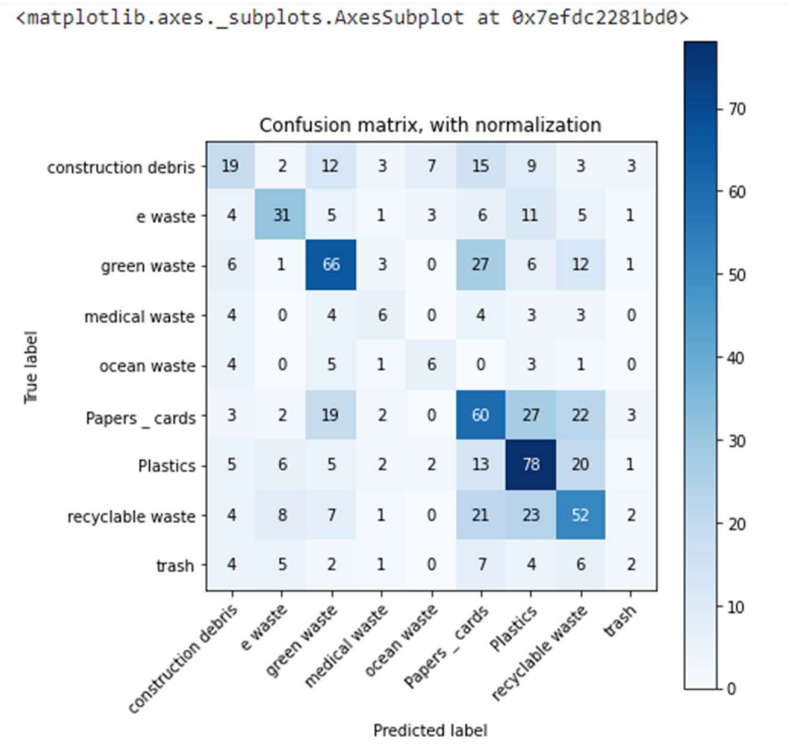
III. SVM:

Linear Kernel

This SVM model was trained with linear kernel and having an accuracy of **44.13%**

```
[38] accuracy_score(pred_labels,testlabels)
0s

     0.4413793103448276
```

Confusion matrix



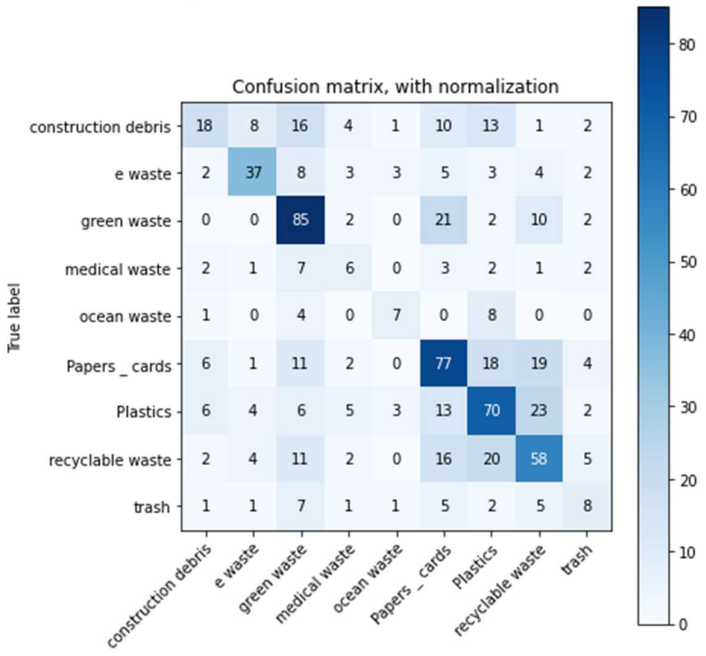
Poly Kernel

This SVM model was trained with Poly Kernel and having an accuracy of **50.4%.**

```
[42] accuracy_score(pred_labels,testlabels)
0s

0.5048275862068966
```

Confusion matrix

```
Confusion matrix, with normalization
<matplotlib.axes._subplots.AxesSubplot at 0x7efdc4a9fed0>
```



IV. INCLASS CLASSIFICATION:

For LSTM the best model is the Model with 4 LSTM layers

By running the model with in-class data set the results are as follows:

RESULTS:

Accuracy - 34.8%

```
3/3 - 2s - loss: 4.9110 - accuracy: 0.3478 - 2s/epoch - 686ms/step
Test: 0.348
```

For CNN the best model is the Model with 3 CNN layers

By running the model with in-class data set the results are as follows:

RESULTS:

Accuracy – 26.1%

```
3/3 - 1s - loss: 5.9605 - accuracy: 0.2609 - 579ms/epoch - 193ms/step
Inclass Test Accuracy: 0.261
```

INFERENCES:

1) LSTM

- Attention layer does not give more accuracy than normal LSTM models.
- Pretrained LSTM model gives accuracy than all models when pre-trained with best model.
- Maximum no. of LSTM layer gives better performance (2 layers < 3 layers < 4 layers)

2) CNN

- With more epochs accuracy increases.
- Maximum no. of CNN layers not necessarily gives greater accuracy. (Since 3 layers CNN performs better than 4 layers CNN)
- Pretrained CNN model gives greater accuracy than all models when pre-trained with best model.

3) SVM

- Poly Kernel gives better result than Linear Kernel.
- Gives less accuracy when compared with results of LSTM and CNN.

4) In-class classification

- Got less results when compared to normal dataset testing both in LSTM and CNN.
- Comparatively LSTM perform slightly better than CNN.

REFERENCES:

1) https://www.analyticsvidhya.com/blog/2021/06/image-classification-using-convolutional-neural-network-with-python/
2) https://www.kaggle.com/datasets/mostafaabla/garbage-classification
3) https://chrome.google.com/webstore/detail/download-all-images/ifipmflagepipjokmbdecpmjbibjnakm?hl=en