Assignment 5 **Name**: Arnab Sen **Rol**: 510519006

In [1]:
```
import pandas as pad
import numpy as np
import matplotlib.pyplot as plt
import tensorflow as tf
from sklearn.model_selection import train_test_split
import keras
```

2. Loading the Data

In [2]:
```
from keras.datasets import mnist
(x_train, y_train), (x_test, y_test) = mnist.load_data()
print("Train data shape: ", x_train.shape, y_train.shape)
print("Test data shape: ", x_test.shape, y_test.shape)
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datas
ets/mnist.npz
11493376/11490434 [==============================] - 0s 0us/step
11501568/11490434 [==============================] - 0s 0us/step
Train data shape:  (60000, 28, 28) (60000,)
Test data shape:  (10000, 28, 28) (10000,)
```

3. Converting 28*28 images to 32*32

In [3]:
```
#defining the rbf function
def RBF(x, c, s):
  return np.exp(((x-c)**2)/(2*s**2))

#defining a function to transform the images
def transform(image):
  image = np.pad(image, (2,2))
  c = np.mean(image)
  s = np.std(image)
  return RBF(image, c, s).flatten()
#flatten reduces each image into a 1-D array by storing it in row-major format
```

In [4]:
```
x_train_tf = []
for image in x_train:
  x_train_tf.append(transform(image))
x_train_tf = np.array(x_train_tf)
print("Shape of x_train after transforming: ", x_train_tf.shape)
x_test_tf = []
for image in x_test:
  x_test_tf.append(transform(image))
x_test_tf = np.array(x_test_tf)
print("Shape of x_test after transforming: ", x_test_tf.shape)
```

```
Shape of x_train after transforming:  (60000, 1024)
Shape of x_test after transforming:  (10000, 1024)
```

In [5]:
```
#one hot encoding the labels to be predicted
#this converts each label into a vector with 10 fields, one corresponding to e
from sklearn.preprocessing import OneHotEncoder
encoder = OneHotEncoder()
```

```
y_train = encoder.fit_transform(y_train.reshape(-1,1)).toarray()
y_test = encoder.transform(y_test.reshape(-1,1)).toarray()

print("Shape of y_train after ohe: ", y_train.shape)
print("Shape of y_test after ohe: ", y_test.shape)
```

```
Shape of y_train after ohe:  (60000, 10)
Shape of y_test after ohe:  (10000, 10)
```

Running the network with different settings

In [6]:
```
from tensorflow.keras.layers import Input, Dense, Activation, Dropout, BatchNo
from tensorflow.keras.models import Model
from tensorflow.keras.optimizers import  Adam
from tensorflow.keras.callbacks import TensorBoard, ModelCheckpoint, EarlyStopp
from datetime import datetime
```

In [7]:
```
adam = Adam(learning_rate=0.001)
```

4. Number of Hidden Layers

4.1 Activation function: Sigmoid; Hidden neurons: [16]

In [8]:
```
#using the functional API approach
tf.keras.backend.clear_session()

input_layer = Input(shape = (1024, ))
dense_layer = Dense(16, activation='sigmoid')(input_layer)
output_layer = Dense(10, activation='softmax', kernel_initializer='glorot_norma

model = Model(inputs = input_layer, outputs = output_layer)
model.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 1024)]            0

 dense (Dense)               (None, 16)                16400

 dense_1 (Dense)             (None, 10)                170

=================================================================
Total params: 16,570
Trainable params: 16,570
Non-trainable params: 0
_________________________________________________________________
```

In [9]:
```
!mkdir model1_1
model_path = "model1_1/"
```

In [10]:
```
#Setting the filepath for the ModelCheckpoint callback to save the files
```

```
filepath=model_path+"{epoch:02d}.hdf5"
checkpoint = ModelCheckpoint(filepath=filepath, monitor='val_loss',  verbose=1

#We will use the EarlyStopping callback to prevent the model from training aft
earlystop = EarlyStopping(monitor = 'val_loss', patience = 7, verbose=1, mode =

#Passing validation data into the custom Metrics callback that we have created
validation_data=(x_test_tf,y_test)

model.compile(optimizer=adam, loss='categorical_crossentropy',metrics=['accurac
```

In [11]:
```
!rm -rf ./logs1_1/fit
tf.keras.backend.clear_session()
```

In [12]:
```
#Creating logs direcctory to store information about the fits
log_dir = "logs1_1/fit/" + datetime.now().strftime("%Y%m%d - %H%M%S")

tf.keras.utils.plot_model(model, to_file=model_path+'model.png', show_shapes=Tr

tbCallBack = TensorBoard(log_dir=log_dir, write_graph=True, write_grads=True, w

allCs = [tbCallBack, earlystop, checkpoint]

model.fit(x_train_tf,y_train,epochs=50, validation_data=validation_data, batch_
```

```
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `Te
nsorBoard` Callback.
```

```
Epoch 1/50
230/235 [============================>.] - ETA: 0s - loss: 1.6636 - accuracy:
0.5307
Epoch 1: val_loss improved from inf to 1.20430, saving model to model1_1/01.hd
f5
235/235 [==============================] - 2s 6ms/step - loss: 1.6547 - accura
cy: 0.5345 - val_loss: 1.2043 - val_accuracy: 0.7163
Epoch 2/50
233/235 [============================>.] - ETA: 0s - loss: 1.0015 - accuracy:
0.7657
Epoch 2: val_loss improved from 1.20430 to 0.82745, saving model to model1_1/0
2.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 1.0004 - accura
cy: 0.7660 - val_loss: 0.8274 - val_accuracy: 0.8092
Epoch 3/50
229/235 [============================>.] - ETA: 0s - loss: 0.7638 - accuracy:
0.8100
Epoch 3: val_loss improved from 0.82745 to 0.68943, saving model to model1_1/0
3.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.7618 - accura
cy: 0.8104 - val_loss: 0.6894 - val_accuracy: 0.8270
Epoch 4/50
228/235 [============================>.] - ETA: 0s - loss: 0.6561 - accuracy:
0.8247
Epoch 4: val_loss improved from 0.68943 to 0.59520, saving model to model1_1/0
4.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.6552 - accura
cy: 0.8251 - val_loss: 0.5952 - val_accuracy: 0.8370
Epoch 5/50
229/235 [============================>.] - ETA: 0s - loss: 0.5905 - accuracy:
0.8350
Epoch 5: val_loss improved from 0.59520 to 0.55600, saving model to model1_1/0
5.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.5901 - accura
cy: 0.8350 - val_loss: 0.5560 - val_accuracy: 0.8461
Epoch 6/50
230/235 [============================>.] - ETA: 0s - loss: 0.5593 - accuracy:
0.8402
Epoch 6: val_loss improved from 0.55600 to 0.54313, saving model to model1_1/0
6.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.5589 - accura
cy: 0.8404 - val_loss: 0.5431 - val_accuracy: 0.8476
Epoch 7/50
233/235 [============================>.] - ETA: 0s - loss: 0.5340 - accuracy:
0.8449
Epoch 7: val_loss improved from 0.54313 to 0.52960, saving model to model1_1/0
7.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.5344 - accura
cy: 0.8448 - val_loss: 0.5296 - val_accuracy: 0.8476
Epoch 8/50
230/235 [============================>.] - ETA: 0s - loss: 0.5153 - accuracy:
0.8486
Epoch 8: val_loss improved from 0.52960 to 0.50860, saving model to model1_1/0
8.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.5146 - accura
cy: 0.8489 - val_loss: 0.5086 - val_accuracy: 0.8504
Epoch 9/50
233/235 [============================>.] - ETA: 0s - loss: 0.5000 - accuracy:
0.8525
Epoch 9: val_loss improved from 0.50860 to 0.48787, saving model to model1_1/0
```

```
9.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.5006 - accura
cy: 0.8523 - val_loss: 0.4879 - val_accuracy: 0.8555
Epoch 10/50
229/235 [============================>.] - ETA: 0s - loss: 0.4870 - accuracy:
0.8561
Epoch 10: val_loss improved from 0.48787 to 0.48537, saving model to model1_1/
10.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.4870 - accura
cy: 0.8558 - val_loss: 0.4854 - val_accuracy: 0.8569
Epoch 11/50
228/235 [============================>.] - ETA: 0s - loss: 0.4817 - accuracy:
0.8556
Epoch 11: val_loss did not improve from 0.48537
235/235 [==============================] - 1s 5ms/step - loss: 0.4806 - accura
cy: 0.8558 - val_loss: 0.4879 - val_accuracy: 0.8524
Epoch 12/50
234/235 [============================>.] - ETA: 0s - loss: 0.4735 - accuracy:
0.8586
Epoch 12: val_loss improved from 0.48537 to 0.47314, saving model to model1_1/
12.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.4734 - accura
cy: 0.8586 - val_loss: 0.4731 - val_accuracy: 0.8560
Epoch 13/50
226/235 [===========================>..] - ETA: 0s - loss: 0.4707 - accuracy:
0.8590
Epoch 13: val_loss did not improve from 0.47314
235/235 [==============================] - 1s 5ms/step - loss: 0.4703 - accura
cy: 0.8592 - val_loss: 0.4736 - val_accuracy: 0.8583
Epoch 14/50
230/235 [============================>.] - ETA: 0s - loss: 0.4549 - accuracy:
0.8646
Epoch 14: val_loss improved from 0.47314 to 0.46186, saving model to model1_1/
14.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.4554 - accura
cy: 0.8645 - val_loss: 0.4619 - val_accuracy: 0.8628
Epoch 15/50
230/235 [============================>.] - ETA: 0s - loss: 0.4496 - accuracy:
0.8656
Epoch 15: val_loss improved from 0.46186 to 0.45915, saving model to model1_1/
15.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.4498 - accura
cy: 0.8658 - val_loss: 0.4591 - val_accuracy: 0.8622
Epoch 16/50
224/235 [===========================>..] - ETA: 0s - loss: 0.4507 - accuracy:
0.8646
Epoch 16: val_loss improved from 0.45915 to 0.45585, saving model to model1_1/
16.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.4518 - accura
cy: 0.8642 - val_loss: 0.4559 - val_accuracy: 0.8642
Epoch 17/50
234/235 [============================>.] - ETA: 0s - loss: 0.4511 - accuracy:
0.8648
Epoch 17: val_loss did not improve from 0.45585
235/235 [==============================] - 1s 4ms/step - loss: 0.4513 - accura
cy: 0.8647 - val_loss: 0.4585 - val_accuracy: 0.8640
Epoch 18/50
228/235 [============================>.] - ETA: 0s - loss: 0.4362 - accuracy:
0.8703
Epoch 18: val_loss improved from 0.45585 to 0.44458, saving model to model1_1/
```

```
18.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.4370 - accura
cy: 0.8702 - val_loss: 0.4446 - val_accuracy: 0.8677
Epoch 19/50
226/235 [===========================>..] - ETA: 0s - loss: 0.4370 - accuracy:
0.8674
Epoch 19: val_loss did not improve from 0.44458
235/235 [==============================] - 1s 5ms/step - loss: 0.4371 - accura
cy: 0.8676 - val_loss: 0.4527 - val_accuracy: 0.8659
Epoch 20/50
231/235 [============================>.] - ETA: 0s - loss: 0.4398 - accuracy:
0.8692
Epoch 20: val_loss did not improve from 0.44458
235/235 [==============================] - 1s 5ms/step - loss: 0.4388 - accura
cy: 0.8695 - val_loss: 0.4491 - val_accuracy: 0.8668
Epoch 21/50
225/235 [===========================>..] - ETA: 0s - loss: 0.4418 - accuracy:
0.8668
Epoch 21: val_loss improved from 0.44458 to 0.43694, saving model to model1_1/
21.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.4425 - accura
cy: 0.8664 - val_loss: 0.4369 - val_accuracy: 0.8691
Epoch 22/50
235/235 [==============================] - ETA: 0s - loss: 0.4354 - accuracy:
0.8664
Epoch 22: val_loss did not improve from 0.43694
235/235 [==============================] - 1s 5ms/step - loss: 0.4354 - accura
cy: 0.8664 - val_loss: 0.4396 - val_accuracy: 0.8677
Epoch 23/50
231/235 [============================>.] - ETA: 0s - loss: 0.4348 - accuracy:
0.8693
Epoch 23: val_loss improved from 0.43694 to 0.42786, saving model to model1_1/
23.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.4348 - accura
cy: 0.8691 - val_loss: 0.4279 - val_accuracy: 0.8728
Epoch 24/50
224/235 [===========================>..] - ETA: 0s - loss: 0.4211 - accuracy:
0.8737
Epoch 24: val_loss did not improve from 0.42786
235/235 [==============================] - 1s 5ms/step - loss: 0.4215 - accura
cy: 0.8736 - val_loss: 0.4308 - val_accuracy: 0.8709
Epoch 25/50
227/235 [===========================>..] - ETA: 0s - loss: 0.4180 - accuracy:
0.8743
Epoch 25: val_loss improved from 0.42786 to 0.42489, saving model to model1_1/
25.hdf5
235/235 [==============================] - 1s 4ms/step - loss: 0.4175 - accura
cy: 0.8745 - val_loss: 0.4249 - val_accuracy: 0.8756
Epoch 26/50
227/235 [===========================>..] - ETA: 0s - loss: 0.4145 - accuracy:
0.8760
Epoch 26: val_loss did not improve from 0.42489
235/235 [==============================] - 1s 4ms/step - loss: 0.4147 - accura
cy: 0.8759 - val_loss: 0.4417 - val_accuracy: 0.8668
Epoch 27/50
223/235 [===========================>..] - ETA: 0s - loss: 0.4204 - accuracy:
0.8730
Epoch 27: val_loss did not improve from 0.42489
235/235 [==============================] - 1s 4ms/step - loss: 0.4222 - accura
cy: 0.8726 - val_loss: 0.4374 - val_accuracy: 0.8676
```

```
Epoch 28/50
232/235 [============================>.] - ETA: 0s - loss: 0.4201 - accuracy:
0.8721
Epoch 28: val_loss did not improve from 0.42489
235/235 [==============================] - 1s 4ms/step - loss: 0.4200 - accura
cy: 0.8721 - val_loss: 0.4330 - val_accuracy: 0.8722
Epoch 29/50
227/235 [============================>..] - ETA: 0s - loss: 0.4085 - accuracy:
0.8762
Epoch 29: val_loss improved from 0.42489 to 0.42401, saving model to model1_1/
29.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.4084 - accura
cy: 0.8764 - val_loss: 0.4240 - val_accuracy: 0.8769
Epoch 30/50
231/235 [============================>.] - ETA: 0s - loss: 0.4039 - accuracy:
0.8772
Epoch 30: val_loss improved from 0.42401 to 0.41489, saving model to model1_1/
30.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.4037 - accura
cy: 0.8775 - val_loss: 0.4149 - val_accuracy: 0.8796
Epoch 31/50
228/235 [============================>.] - ETA: 0s - loss: 0.4016 - accuracy:
0.8780
Epoch 31: val_loss did not improve from 0.41489
235/235 [==============================] - 1s 5ms/step - loss: 0.4011 - accura
cy: 0.8783 - val_loss: 0.4189 - val_accuracy: 0.8727
Epoch 32/50
224/235 [============================>..] - ETA: 0s - loss: 0.4017 - accuracy:
0.8796
Epoch 32: val_loss did not improve from 0.41489
235/235 [==============================] - 1s 5ms/step - loss: 0.4011 - accura
cy: 0.8799 - val_loss: 0.4166 - val_accuracy: 0.8776
Epoch 33/50
232/235 [============================>.] - ETA: 0s - loss: 0.3996 - accuracy:
0.8803
Epoch 33: val_loss improved from 0.41489 to 0.41166, saving model to model1_1/
33.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.3999 - accura
cy: 0.8802 - val_loss: 0.4117 - val_accuracy: 0.8765
Epoch 34/50
234/235 [============================>.] - ETA: 0s - loss: 0.4016 - accuracy:
0.8803
Epoch 34: val_loss improved from 0.41166 to 0.40635, saving model to model1_1/
34.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.4015 - accura
cy: 0.8804 - val_loss: 0.4063 - val_accuracy: 0.8810
Epoch 35/50
235/235 [==============================] - ETA: 0s - loss: 0.3931 - accuracy:
0.8829
Epoch 35: val_loss did not improve from 0.40635
235/235 [==============================] - 1s 5ms/step - loss: 0.3931 - accura
cy: 0.8829 - val_loss: 0.4070 - val_accuracy: 0.8815
Epoch 36/50
228/235 [============================>.] - ETA: 0s - loss: 0.3935 - accuracy:
0.8826
Epoch 36: val_loss did not improve from 0.40635
235/235 [==============================] - 1s 5ms/step - loss: 0.3928 - accura
cy: 0.8827 - val_loss: 0.4167 - val_accuracy: 0.8757
Epoch 37/50
234/235 [============================>.] - ETA: 0s - loss: 0.3893 - accuracy:
```

```
0.8821
Epoch 37: val_loss did not improve from 0.40635
235/235 [==============================] - 1s 5ms/step - loss: 0.3892 - accura
cy: 0.8821 - val_loss: 0.4100 - val_accuracy: 0.8808
Epoch 38/50
224/235 [===========================>..] - ETA: 0s - loss: 0.3903 - accuracy:
0.8820
Epoch 38: val_loss improved from 0.40635 to 0.40364, saving model to model1_1/
38.hdf5
235/235 [==============================] - 1s 5ms/step - loss: 0.3911 - accura
cy: 0.8819 - val_loss: 0.4036 - val_accuracy: 0.8816
Epoch 39/50
231/235 [============================>.] - ETA: 0s - loss: 0.3915 - accuracy:
0.8807
Epoch 39: val_loss did not improve from 0.40364
235/235 [==============================] - 1s 5ms/step - loss: 0.3916 - accura
cy: 0.8806 - val_loss: 0.4180 - val_accuracy: 0.8757
Epoch 40/50
229/235 [============================>.] - ETA: 0s - loss: 0.4006 - accuracy:
0.8792
Epoch 40: val_loss did not improve from 0.40364
235/235 [==============================] - 1s 5ms/step - loss: 0.4014 - accura
cy: 0.8791 - val_loss: 0.4157 - val_accuracy: 0.8784
Epoch 41/50
228/235 [============================>.] - ETA: 0s - loss: 0.3913 - accuracy:
0.8831
Epoch 41: val_loss did not improve from 0.40364
235/235 [==============================] - 1s 5ms/step - loss: 0.3912 - accura
cy: 0.8834 - val_loss: 0.4131 - val_accuracy: 0.8786
Epoch 42/50
229/235 [============================>.] - ETA: 0s - loss: 0.3906 - accuracy:
0.8825
Epoch 42: val_loss did not improve from 0.40364
235/235 [==============================] - 1s 5ms/step - loss: 0.3896 - accura
cy: 0.8828 - val_loss: 0.4134 - val_accuracy: 0.8778
Epoch 43/50
234/235 [============================>.] - ETA: 0s - loss: 0.3959 - accuracy:
0.8792
Epoch 43: val_loss did not improve from 0.40364
235/235 [==============================] - 1s 5ms/step - loss: 0.3957 - accura
cy: 0.8792 - val_loss: 0.4266 - val_accuracy: 0.8725
Epoch 44/50
229/235 [============================>.] - ETA: 0s - loss: 0.3921 - accuracy:
0.8822
Epoch 44: val_loss did not improve from 0.40364
235/235 [==============================] - 1s 5ms/step - loss: 0.3916 - accura
cy: 0.8823 - val_loss: 0.4075 - val_accuracy: 0.8802
Epoch 45/50
229/235 [============================>.] - ETA: 0s - loss: 0.3839 - accuracy:
0.8840
Epoch 45: val_loss did not improve from 0.40364
235/235 [==============================] - 1s 5ms/step - loss: 0.3841 - accura
cy: 0.8839 - val_loss: 0.4126 - val_accuracy: 0.8761
Epoch 45: early stopping
```

Out[12]: `<keras.callbacks.History at 0x7f4ef4099f50>`

In [13]:
```
%load_ext tensorboard
%tensorboard --logdir logs1_1
```

4.2 Activation function: Sigmoid; Hidden neurons: [32, 16]

In [14]:
```
tf.keras.backend.clear_session()

input_layer = Input(shape = (1024, ))
dense_layer_1 = Dense(32, activation='sigmoid')(input_layer)
dense_layer_2 = Dense(16, activation='sigmoid')(dense_layer_1)
output_layer = Dense(10, activation='softmax', kernel_initializer='glorot_norma

model = Model(inputs = input_layer, outputs = output_layer)
model.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 1024)]            0

 dense (Dense)               (None, 32)                32800

 dense_1 (Dense)             (None, 16)                528

 dense_2 (Dense)             (None, 10)                170

=================================================================
Total params: 33,498
Trainable params: 33,498
Non-trainable params: 0
_________________________________________________________________
```

In [15]:
```
!mkdir model1_2
model_path = "model1_2/"
```

In [16]:
```
model.compile(optimizer=adam, loss='categorical_crossentropy',metrics=['accurac
```

In [17]:
```
!rm -rf ./logs1_2/fit
tf.keras.backend.clear_session()
```

In [18]:
```
#Creating logs directory to store information about the fits
log_dir = "logs1_2/fit/" + datetime.now().strftime("%Y%m%d - %H%M%S")

tf.keras.utils.plot_model(model, to_file=model_path+'model.png', show_shapes=Tr

tbCallBack = TensorBoard(log_dir=log_dir, write_graph=True, write_grads=True, w

allCs = [tbCallBack, earlystop]

model.fit(x_train_tf,y_train,epochs=50, validation_data=validation_data, batch_
```

```
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `Te
nsorBoard` Callback.
```

```
Epoch 1/50
235/235 [==============================] - 2s 6ms/step - loss: 1.3123 - accura
cy: 0.6568 - val_loss: 0.8341 - val_accuracy: 0.7778
Epoch 2/50
235/235 [==============================] - 1s 5ms/step - loss: 0.7114 - accura
cy: 0.8053 - val_loss: 0.6228 - val_accuracy: 0.8270
Epoch 3/50
235/235 [==============================] - 1s 5ms/step - loss: 0.5863 - accura
cy: 0.8306 - val_loss: 0.5362 - val_accuracy: 0.8469
Epoch 4/50
235/235 [==============================] - 1s 5ms/step - loss: 0.5291 - accura
cy: 0.8442 - val_loss: 0.5065 - val_accuracy: 0.8495
Epoch 5/50
235/235 [==============================] - 1s 5ms/step - loss: 0.4923 - accura
cy: 0.8539 - val_loss: 0.4797 - val_accuracy: 0.8599
Epoch 6/50
235/235 [==============================] - 1s 5ms/step - loss: 0.4675 - accura
cy: 0.8610 - val_loss: 0.4578 - val_accuracy: 0.8641
Epoch 7/50
235/235 [==============================] - 1s 5ms/step - loss: 0.4461 - accura
cy: 0.8657 - val_loss: 0.4401 - val_accuracy: 0.8692
Epoch 8/50
235/235 [==============================] - 2s 7ms/step - loss: 0.4346 - accura
cy: 0.8698 - val_loss: 0.4330 - val_accuracy: 0.8725
Epoch 9/50
235/235 [==============================] - 2s 10ms/step - loss: 0.4269 - accur
acy: 0.8724 - val_loss: 0.4208 - val_accuracy: 0.8757
Epoch 10/50
235/235 [==============================] - 3s 12ms/step - loss: 0.4190 - accur
acy: 0.8726 - val_loss: 0.4172 - val_accuracy: 0.8753
Epoch 11/50
235/235 [==============================] - 2s 9ms/step - loss: 0.4145 - accura
cy: 0.8742 - val_loss: 0.4075 - val_accuracy: 0.8802
Epoch 12/50
235/235 [==============================] - 2s 10ms/step - loss: 0.3976 - accur
acy: 0.8797 - val_loss: 0.3996 - val_accuracy: 0.8804
Epoch 13/50
235/235 [==============================] - 2s 8ms/step - loss: 0.3899 - accura
cy: 0.8814 - val_loss: 0.4054 - val_accuracy: 0.8801
Epoch 14/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3881 - accura
cy: 0.8820 - val_loss: 0.4004 - val_accuracy: 0.8783
Epoch 15/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3893 - accura
cy: 0.8813 - val_loss: 0.3893 - val_accuracy: 0.8818
Epoch 16/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3823 - accura
cy: 0.8824 - val_loss: 0.3943 - val_accuracy: 0.8790
Epoch 17/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3746 - accura
cy: 0.8848 - val_loss: 0.3895 - val_accuracy: 0.8801
Epoch 18/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3724 - accura
cy: 0.8862 - val_loss: 0.3797 - val_accuracy: 0.8826
Epoch 19/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3635 - accura
cy: 0.8900 - val_loss: 0.3788 - val_accuracy: 0.8852
Epoch 20/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3590 - accura
cy: 0.8917 - val_loss: 0.3718 - val_accuracy: 0.8865
```

```
Epoch 21/50
235/235 [==============================] - 1s 6ms/step - loss: 0.3584 - accura
cy: 0.8913 - val_loss: 0.3679 - val_accuracy: 0.8894
Epoch 22/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3485 - accura
cy: 0.8942 - val_loss: 0.3665 - val_accuracy: 0.8886
Epoch 23/50
235/235 [==============================] - 1s 6ms/step - loss: 0.3493 - accura
cy: 0.8942 - val_loss: 0.3684 - val_accuracy: 0.8892
Epoch 24/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3444 - accura
cy: 0.8954 - val_loss: 0.3656 - val_accuracy: 0.8890
Epoch 25/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3447 - accura
cy: 0.8962 - val_loss: 0.3633 - val_accuracy: 0.8884
Epoch 26/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3408 - accura
cy: 0.8970 - val_loss: 0.3669 - val_accuracy: 0.8884
Epoch 27/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3409 - accura
cy: 0.8968 - val_loss: 0.3652 - val_accuracy: 0.8897
Epoch 28/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3340 - accura
cy: 0.8985 - val_loss: 0.3510 - val_accuracy: 0.8935
Epoch 29/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3272 - accura
cy: 0.9009 - val_loss: 0.3541 - val_accuracy: 0.8911
Epoch 30/50
235/235 [==============================] - 1s 6ms/step - loss: 0.3290 - accura
cy: 0.9000 - val_loss: 0.3583 - val_accuracy: 0.8906
Epoch 31/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3254 - accura
cy: 0.9017 - val_loss: 0.3463 - val_accuracy: 0.8943
Epoch 32/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3201 - accura
cy: 0.9029 - val_loss: 0.3511 - val_accuracy: 0.8929
Epoch 33/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3239 - accura
cy: 0.9026 - val_loss: 0.3504 - val_accuracy: 0.8945
Epoch 34/50
235/235 [==============================] - 1s 6ms/step - loss: 0.3209 - accura
cy: 0.9018 - val_loss: 0.3523 - val_accuracy: 0.8916
Epoch 35/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3163 - accura
cy: 0.9032 - val_loss: 0.3411 - val_accuracy: 0.8957
Epoch 36/50
235/235 [==============================] - 1s 6ms/step - loss: 0.3119 - accura
cy: 0.9043 - val_loss: 0.3439 - val_accuracy: 0.8958
Epoch 37/50
235/235 [==============================] - 1s 6ms/step - loss: 0.3157 - accura
cy: 0.9031 - val_loss: 0.3389 - val_accuracy: 0.8976
Epoch 38/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3083 - accura
cy: 0.9061 - val_loss: 0.3418 - val_accuracy: 0.8968
Epoch 39/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3078 - accura
cy: 0.9071 - val_loss: 0.3472 - val_accuracy: 0.8972
Epoch 40/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3061 - accura
cy: 0.9073 - val_loss: 0.3423 - val_accuracy: 0.8961
```

```
Epoch 41/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3029 - accura
cy: 0.9079 - val_loss: 0.3343 - val_accuracy: 0.8973
Epoch 42/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3019 - accura
cy: 0.9087 - val_loss: 0.3349 - val_accuracy: 0.8987
Epoch 43/50
235/235 [==============================] - 1s 5ms/step - loss: 0.3005 - accura
cy: 0.9086 - val_loss: 0.3299 - val_accuracy: 0.8993
Epoch 44/50
235/235 [==============================] - 1s 5ms/step - loss: 0.2999 - accura
cy: 0.9095 - val_loss: 0.3291 - val_accuracy: 0.9008
Epoch 45/50
235/235 [==============================] - 1s 5ms/step - loss: 0.2966 - accura
cy: 0.9097 - val_loss: 0.3335 - val_accuracy: 0.8991
Epoch 46/50
235/235 [==============================] - 1s 5ms/step - loss: 0.2944 - accura
cy: 0.9104 - val_loss: 0.3352 - val_accuracy: 0.8995
Epoch 47/50
235/235 [==============================] - 1s 5ms/step - loss: 0.2906 - accura
cy: 0.9119 - val_loss: 0.3333 - val_accuracy: 0.9008
Epoch 48/50
235/235 [==============================] - 1s 5ms/step - loss: 0.2879 - accura
cy: 0.9126 - val_loss: 0.3231 - val_accuracy: 0.9024
Epoch 49/50
235/235 [==============================] - 1s 5ms/step - loss: 0.2859 - accura
cy: 0.9131 - val_loss: 0.3237 - val_accuracy: 0.9020
Epoch 50/50
235/235 [==============================] - 1s 5ms/step - loss: 0.2835 - accura
cy: 0.9134 - val_loss: 0.3232 - val_accuracy: 0.9032
```

Out[18]: <keras.callbacks.History at 0x7f4eef68f610>

In [19]:
```
%load_ext tensorboard
%tensorboard --logdir logs1_2
```

```
The tensorboard extension is already loaded. To reload it, use:
  %reload_ext tensorboard
```

4.3 Activation Function: Sigmoid; Hidden Neurons: [64, 32, 16]

In [20]:
```
tf.keras.backend.clear_session()

input_layer = Input(shape = (1024, ))
dense_layer_1 = Dense(64, activation='sigmoid')(input_layer)
dense_layer_2 = Dense(32, activation='sigmoid')(dense_layer_1)
dense_layer_3 = Dense(16, activation='sigmoid')(dense_layer_2)
output_layer = Dense(10, activation='softmax', kernel_initializer='glorot_norma

model = Model(inputs = input_layer, outputs = output_layer)
model.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 1024)]            0

 dense (Dense)               (None, 64)                65600

 dense_1 (Dense)             (None, 32)                2080

 dense_2 (Dense)             (None, 16)                528

 dense_3 (Dense)             (None, 10)                170

=================================================================
Total params: 68,378
Trainable params: 68,378
Non-trainable params: 0
_________________________________________________________________
```

In [21]:
```
!mkdir model1_3
model_path = "model1_3/"
```

In [22]:
```
model.compile(optimizer=adam, loss='categorical_crossentropy',metrics=['accura
```

In [23]:
```
!rm -rf ./logs1_3/fit
tf.keras.backend.clear_session()
```

In [24]:
```
#Creating logs direcctory to store information about the fits
log_dir = "logs1_3/fit/" + datetime.now().strftime("%Y%m%d - %H%M%S")

tf.keras.utils.plot_model(model, to_file=model_path+'model.png', show_shapes=T

tbCallBack = TensorBoard(log_dir=log_dir, write_graph=True, write_grads=True, 

allCs = [tbCallBack, earlystop]

model.fit(x_train_tf,y_train,epochs=100, validation_data=validation_data, batc
```

```
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `
TensorBoard` Callback.
```

```
Epoch 1/100
235/235 [==============================] - 2s 7ms/step - loss: 1.3514 - ac
curacy: 0.6320 - val_loss: 0.7853 - val_accuracy: 0.8131
Epoch 2/100
235/235 [==============================] - 2s 7ms/step - loss: 0.6481 - ac
curacy: 0.8373 - val_loss: 0.5599 - val_accuracy: 0.8500
Epoch 3/100
235/235 [==============================] - 2s 7ms/step - loss: 0.5112 - ac
curacy: 0.8608 - val_loss: 0.4816 - val_accuracy: 0.8654
Epoch 4/100
235/235 [==============================] - 1s 6ms/step - loss: 0.4510 - ac
curacy: 0.8731 - val_loss: 0.4349 - val_accuracy: 0.8741
Epoch 5/100
235/235 [==============================] - 2s 6ms/step - loss: 0.4176 - ac
curacy: 0.8811 - val_loss: 0.4110 - val_accuracy: 0.8780
Epoch 6/100
235/235 [==============================] - 2s 7ms/step - loss: 0.3978 - ac
curacy: 0.8855 - val_loss: 0.3943 - val_accuracy: 0.8849
Epoch 7/100
235/235 [==============================] - 2s 7ms/step - loss: 0.3780 - ac
curacy: 0.8899 - val_loss: 0.3839 - val_accuracy: 0.8880
Epoch 8/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3650 - ac
curacy: 0.8933 - val_loss: 0.3749 - val_accuracy: 0.8893
Epoch 9/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3519 - ac
curacy: 0.8967 - val_loss: 0.3596 - val_accuracy: 0.8936
Epoch 10/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3430 - ac
curacy: 0.8986 - val_loss: 0.3505 - val_accuracy: 0.8944
Epoch 11/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3313 - ac
curacy: 0.9017 - val_loss: 0.3484 - val_accuracy: 0.8952
Epoch 12/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3298 - ac
curacy: 0.9020 - val_loss: 0.3419 - val_accuracy: 0.8977
Epoch 13/100
235/235 [==============================] - 2s 6ms/step - loss: 0.3183 - ac
curacy: 0.9043 - val_loss: 0.3316 - val_accuracy: 0.9020
Epoch 14/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3102 - ac
curacy: 0.9075 - val_loss: 0.3301 - val_accuracy: 0.9006
Epoch 15/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3023 - ac
curacy: 0.9101 - val_loss: 0.3227 - val_accuracy: 0.9064
Epoch 16/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2985 - ac
curacy: 0.9097 - val_loss: 0.3246 - val_accuracy: 0.9025
Epoch 17/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2924 - ac
curacy: 0.9122 - val_loss: 0.3172 - val_accuracy: 0.9041
Epoch 18/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2866 - ac
curacy: 0.9136 - val_loss: 0.3099 - val_accuracy: 0.9062
Epoch 19/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2827 - ac
curacy: 0.9161 - val_loss: 0.3065 - val_accuracy: 0.9103
Epoch 20/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2831 - ac
curacy: 0.9150 - val_loss: 0.3086 - val_accuracy: 0.9102
```

```
Epoch 21/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2779 - ac
curacy: 0.9163 - val_loss: 0.2961 - val_accuracy: 0.9122
Epoch 22/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2748 - ac
curacy: 0.9172 - val_loss: 0.2963 - val_accuracy: 0.9102
Epoch 23/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2678 - ac
curacy: 0.9191 - val_loss: 0.3005 - val_accuracy: 0.9082
Epoch 24/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2727 - ac
curacy: 0.9181 - val_loss: 0.2969 - val_accuracy: 0.9102
Epoch 25/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2661 - ac
curacy: 0.9202 - val_loss: 0.2902 - val_accuracy: 0.9111
Epoch 26/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2597 - ac
curacy: 0.9218 - val_loss: 0.2938 - val_accuracy: 0.9125
Epoch 27/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2586 - ac
curacy: 0.9223 - val_loss: 0.2881 - val_accuracy: 0.9153
Epoch 28/100
235/235 [==============================] - 2s 6ms/step - loss: 0.2557 - ac
curacy: 0.9233 - val_loss: 0.2836 - val_accuracy: 0.9139
Epoch 29/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2542 - ac
curacy: 0.9244 - val_loss: 0.2824 - val_accuracy: 0.9153
Epoch 30/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2508 - ac
curacy: 0.9243 - val_loss: 0.2812 - val_accuracy: 0.9169
Epoch 31/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2452 - ac
curacy: 0.9266 - val_loss: 0.2778 - val_accuracy: 0.9180
Epoch 32/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2422 - ac
curacy: 0.9273 - val_loss: 0.2710 - val_accuracy: 0.9198
Epoch 33/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2389 - ac
curacy: 0.9291 - val_loss: 0.2754 - val_accuracy: 0.9166
Epoch 34/100
235/235 [==============================] - 2s 6ms/step - loss: 0.2380 - ac
curacy: 0.9286 - val_loss: 0.2707 - val_accuracy: 0.9173
Epoch 35/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2361 - ac
curacy: 0.9285 - val_loss: 0.2653 - val_accuracy: 0.9216
Epoch 36/100
235/235 [==============================] - 2s 6ms/step - loss: 0.2335 - ac
curacy: 0.9304 - val_loss: 0.2654 - val_accuracy: 0.9174
Epoch 37/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2320 - ac
curacy: 0.9305 - val_loss: 0.2611 - val_accuracy: 0.9217
Epoch 38/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2304 - ac
curacy: 0.9307 - val_loss: 0.2742 - val_accuracy: 0.9166
Epoch 39/100
235/235 [==============================] - 2s 6ms/step - loss: 0.2316 - ac
curacy: 0.9294 - val_loss: 0.2629 - val_accuracy: 0.9212
Epoch 40/100
235/235 [==============================] - 2s 6ms/step - loss: 0.2285 - ac
curacy: 0.9311 - val_loss: 0.2649 - val_accuracy: 0.9214
```

```
Epoch 41/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2294 - ac
curacy: 0.9303 - val_loss: 0.2578 - val_accuracy: 0.9243
Epoch 42/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2239 - ac
curacy: 0.9312 - val_loss: 0.2608 - val_accuracy: 0.9227
Epoch 43/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2242 - ac
curacy: 0.9312 - val_loss: 0.2591 - val_accuracy: 0.9212
Epoch 44/100
235/235 [==============================] - 2s 6ms/step - loss: 0.2195 - ac
curacy: 0.9336 - val_loss: 0.2560 - val_accuracy: 0.9224
Epoch 45/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2201 - ac
curacy: 0.9330 - val_loss: 0.2529 - val_accuracy: 0.9244
Epoch 46/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2181 - ac
curacy: 0.9331 - val_loss: 0.2554 - val_accuracy: 0.9221
Epoch 47/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2155 - ac
curacy: 0.9337 - val_loss: 0.2623 - val_accuracy: 0.9219
Epoch 48/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2184 - ac
curacy: 0.9328 - val_loss: 0.2528 - val_accuracy: 0.9253
Epoch 49/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2132 - ac
curacy: 0.9346 - val_loss: 0.2545 - val_accuracy: 0.9264
Epoch 50/100
235/235 [==============================] - 2s 6ms/step - loss: 0.2115 - ac
curacy: 0.9352 - val_loss: 0.2578 - val_accuracy: 0.9242
Epoch 51/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2099 - ac
curacy: 0.9363 - val_loss: 0.2520 - val_accuracy: 0.9245
Epoch 52/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2073 - ac
curacy: 0.9359 - val_loss: 0.2541 - val_accuracy: 0.9249
Epoch 53/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2030 - ac
curacy: 0.9373 - val_loss: 0.2508 - val_accuracy: 0.9261
Epoch 54/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2041 - ac
curacy: 0.9373 - val_loss: 0.2430 - val_accuracy: 0.9276
Epoch 55/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2052 - ac
curacy: 0.9367 - val_loss: 0.2511 - val_accuracy: 0.9257
Epoch 56/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2009 - ac
curacy: 0.9385 - val_loss: 0.2427 - val_accuracy: 0.9286
Epoch 57/100
235/235 [==============================] - 1s 6ms/step - loss: 0.1968 - ac
curacy: 0.9398 - val_loss: 0.2425 - val_accuracy: 0.9284
Epoch 58/100
235/235 [==============================] - 1s 6ms/step - loss: 0.1963 - ac
curacy: 0.9395 - val_loss: 0.2447 - val_accuracy: 0.9268
Epoch 59/100
235/235 [==============================] - 1s 6ms/step - loss: 0.1946 - ac
curacy: 0.9403 - val_loss: 0.2424 - val_accuracy: 0.9288
Epoch 60/100
235/235 [==============================] - 2s 7ms/step - loss: 0.1931 - ac
curacy: 0.9410 - val_loss: 0.2444 - val_accuracy: 0.9287
```

```
Epoch 61/100
235/235 [==============================] - 2s 7ms/step - loss: 0.1940 - ac
curacy: 0.9407 - val_loss: 0.2457 - val_accuracy: 0.9296
Epoch 62/100
235/235 [==============================] - 1s 6ms/step - loss: 0.1928 - ac
curacy: 0.9411 - val_loss: 0.2387 - val_accuracy: 0.9288
Epoch 63/100
235/235 [==============================] - 1s 6ms/step - loss: 0.1929 - ac
curacy: 0.9409 - val_loss: 0.2411 - val_accuracy: 0.9281
Epoch 64/100
235/235 [==============================] - 1s 6ms/step - loss: 0.1920 - ac
curacy: 0.9413 - val_loss: 0.2399 - val_accuracy: 0.9276
Epoch 65/100
235/235 [==============================] - 1s 6ms/step - loss: 0.1892 - ac
curacy: 0.9420 - val_loss: 0.2397 - val_accuracy: 0.9290
Epoch 66/100
235/235 [==============================] - 1s 6ms/step - loss: 0.1885 - ac
curacy: 0.9429 - val_loss: 0.2375 - val_accuracy: 0.9292
Epoch 67/100
235/235 [==============================] - 1s 6ms/step - loss: 0.1837 - ac
curacy: 0.9443 - val_loss: 0.2375 - val_accuracy: 0.9304
Epoch 68/100
235/235 [==============================] - 1s 6ms/step - loss: 0.1878 - ac
curacy: 0.9428 - val_loss: 0.2408 - val_accuracy: 0.9283
Epoch 69/100
235/235 [==============================] - 1s 6ms/step - loss: 0.1878 - ac
curacy: 0.9426 - val_loss: 0.2309 - val_accuracy: 0.9323
Epoch 70/100
235/235 [==============================] - 2s 6ms/step - loss: 0.1838 - ac
curacy: 0.9437 - val_loss: 0.2340 - val_accuracy: 0.9317
Epoch 71/100
235/235 [==============================] - 1s 6ms/step - loss: 0.1862 - ac
curacy: 0.9423 - val_loss: 0.2384 - val_accuracy: 0.9292
Epoch 72/100
235/235 [==============================] - 1s 6ms/step - loss: 0.1820 - ac
curacy: 0.9436 - val_loss: 0.2342 - val_accuracy: 0.9303
Epoch 73/100
235/235 [==============================] - 1s 6ms/step - loss: 0.1805 - ac
curacy: 0.9444 - val_loss: 0.2339 - val_accuracy: 0.9311
Epoch 74/100
235/235 [==============================] - 1s 6ms/step - loss: 0.1812 - ac
curacy: 0.9442 - val_loss: 0.2383 - val_accuracy: 0.9281
Epoch 75/100
235/235 [==============================] - 1s 6ms/step - loss: 0.1784 - ac
curacy: 0.9458 - val_loss: 0.2347 - val_accuracy: 0.9311
Epoch 76/100
235/235 [==============================] - 1s 6ms/step - loss: 0.1758 - ac
curacy: 0.9465 - val_loss: 0.2396 - val_accuracy: 0.9294
Epoch 76: early stopping
```

Out[24]: `<keras.callbacks.History at 0x7f4eec0822d0>`

In [25]:
```
%tensorboard --logdir logs1_3 --port 6008
```

In [26]:
```
!kill 2336
```

```
/bin/bash: line 0: kill: (2336) - No such process
```

5. Varying the Activation Function

5.1 Activation function: Sigmoid

This model is same as the model in 4.3

5.2 Activation function: tanh

In [27]:
```
tf.keras.backend.clear_session()

input_layer = Input(shape = (1024, ))
dense_layer_1 = Dense(64, activation='tanh', kernel_initializer='glorot_normal
dense_layer_2 = Dense(32, activation='tanh', kernel_initializer='glorot_normal
dense_layer_3 = Dense(16, activation='tanh', kernel_initializer='glorot_normal
output_layer = Dense(10, activation='softmax', kernel_initializer='glorot_norma

model = Model(inputs = input_layer, outputs = output_layer)
model.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 1024)]            0

 dense (Dense)               (None, 64)                65600

 dense_1 (Dense)             (None, 32)                2080

 dense_2 (Dense)             (None, 16)                528

 dense_3 (Dense)             (None, 10)                170

=================================================================
Total params: 68,378
Trainable params: 68,378
Non-trainable params: 0
_________________________________________________________________
```

In [28]:
```
!mkdir model2_2
model_path = "model2_2/"
```

In [29]:
```
model.compile(optimizer=adam, loss='categorical_crossentropy',metrics=['accura
```

In [30]:
```
!rm -rf ./logs2_2/fit
tf.keras.backend.clear_session()
```

In [31]:
```
#Creating logs direcctory to store information about the fits
log_dir = "logs2_2/fit/" + datetime.now().strftime("%Y%m%d - %H%M%S")

tf.keras.utils.plot_model(model, to_file=model_path+'model.png', show_shapes=Tr

tbCallBack = TensorBoard(log_dir=log_dir, write_graph=True, write_grads=True, w

allCs = [tbCallBack, earlystop]
```

```
model.fit(x_train_tf,y_train,epochs=50, validation_data=validation_data, batch_
```

```
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `
TensorBoard` Callback.
```

```
Epoch 1/50
235/235 [==============================] - 2s 7ms/step - loss: 0.8424 - accu
racy: 0.7362 - val_loss: 0.5973 - val_accuracy: 0.8131
Epoch 2/50
235/235 [==============================] - 2s 7ms/step - loss: 0.5555 - accu
racy: 0.8269 - val_loss: 0.5075 - val_accuracy: 0.8422
Epoch 3/50
235/235 [==============================] - 2s 7ms/step - loss: 0.4976 - accu
racy: 0.8460 - val_loss: 0.4736 - val_accuracy: 0.8517
Epoch 4/50
235/235 [==============================] - 1s 6ms/step - loss: 0.4594 - accu
racy: 0.8578 - val_loss: 0.4434 - val_accuracy: 0.8622
Epoch 5/50
235/235 [==============================] - 2s 6ms/step - loss: 0.4329 - accu
racy: 0.8656 - val_loss: 0.4277 - val_accuracy: 0.8676
Epoch 6/50
235/235 [==============================] - 1s 6ms/step - loss: 0.4138 - accu
racy: 0.8719 - val_loss: 0.4168 - val_accuracy: 0.8704
Epoch 7/50
235/235 [==============================] - 2s 7ms/step - loss: 0.3984 - accu
racy: 0.8769 - val_loss: 0.4002 - val_accuracy: 0.8748
Epoch 8/50
235/235 [==============================] - 1s 6ms/step - loss: 0.3856 - accu
racy: 0.8815 - val_loss: 0.3948 - val_accuracy: 0.8771
Epoch 9/50
235/235 [==============================] - 1s 6ms/step - loss: 0.3766 - accu
racy: 0.8837 - val_loss: 0.3724 - val_accuracy: 0.8874
Epoch 10/50
235/235 [==============================] - 2s 6ms/step - loss: 0.3678 - accu
racy: 0.8862 - val_loss: 0.3772 - val_accuracy: 0.8843
Epoch 11/50
235/235 [==============================] - 2s 9ms/step - loss: 0.3610 - accu
racy: 0.8867 - val_loss: 0.3708 - val_accuracy: 0.8841
Epoch 12/50
235/235 [==============================] - 2s 9ms/step - loss: 0.3551 - accu
racy: 0.8893 - val_loss: 0.3680 - val_accuracy: 0.8859
Epoch 13/50
235/235 [==============================] - 2s 7ms/step - loss: 0.3442 - accu
racy: 0.8931 - val_loss: 0.3627 - val_accuracy: 0.8902
Epoch 14/50
235/235 [==============================] - 2s 7ms/step - loss: 0.3425 - accu
racy: 0.8936 - val_loss: 0.3647 - val_accuracy: 0.8925
Epoch 15/50
235/235 [==============================] - 2s 6ms/step - loss: 0.3359 - accu
racy: 0.8954 - val_loss: 0.3549 - val_accuracy: 0.8910
Epoch 16/50
235/235 [==============================] - 1s 6ms/step - loss: 0.3313 - accu
racy: 0.8980 - val_loss: 0.3542 - val_accuracy: 0.8950
Epoch 17/50
235/235 [==============================] - 1s 6ms/step - loss: 0.3216 - accu
racy: 0.9011 - val_loss: 0.3449 - val_accuracy: 0.8951
Epoch 18/50
235/235 [==============================] - 2s 6ms/step - loss: 0.3160 - accu
racy: 0.9024 - val_loss: 0.3424 - val_accuracy: 0.8983
Epoch 19/50
235/235 [==============================] - 1s 6ms/step - loss: 0.3143 - accu
racy: 0.9021 - val_loss: 0.3455 - val_accuracy: 0.8958
Epoch 20/50
235/235 [==============================] - 1s 6ms/step - loss: 0.3122 - accu
racy: 0.9046 - val_loss: 0.3343 - val_accuracy: 0.8944
```

```
Epoch 21/50
235/235 [==============================] - 2s 6ms/step - loss: 0.3051 - accu
racy: 0.9056 - val_loss: 0.3318 - val_accuracy: 0.8976
Epoch 22/50
235/235 [==============================] - 2s 7ms/step - loss: 0.2995 - accu
racy: 0.9070 - val_loss: 0.3321 - val_accuracy: 0.8991
Epoch 23/50
235/235 [==============================] - 2s 6ms/step - loss: 0.2991 - accu
racy: 0.9068 - val_loss: 0.3327 - val_accuracy: 0.9007
Epoch 24/50
235/235 [==============================] - 2s 7ms/step - loss: 0.2965 - accu
racy: 0.9087 - val_loss: 0.3297 - val_accuracy: 0.8967
Epoch 25/50
235/235 [==============================] - 2s 7ms/step - loss: 0.2968 - accu
racy: 0.9074 - val_loss: 0.3341 - val_accuracy: 0.8990
Epoch 26/50
235/235 [==============================] - 1s 6ms/step - loss: 0.2958 - accu
racy: 0.9088 - val_loss: 0.3224 - val_accuracy: 0.9043
Epoch 27/50
235/235 [==============================] - 1s 6ms/step - loss: 0.2907 - accu
racy: 0.9096 - val_loss: 0.3277 - val_accuracy: 0.8991
Epoch 28/50
235/235 [==============================] - 1s 6ms/step - loss: 0.2877 - accu
racy: 0.9108 - val_loss: 0.3192 - val_accuracy: 0.9051
Epoch 29/50
235/235 [==============================] - 2s 6ms/step - loss: 0.2810 - accu
racy: 0.9132 - val_loss: 0.3098 - val_accuracy: 0.9073
Epoch 30/50
235/235 [==============================] - 1s 6ms/step - loss: 0.2768 - accu
racy: 0.9153 - val_loss: 0.3084 - val_accuracy: 0.9075
Epoch 31/50
235/235 [==============================] - 2s 6ms/step - loss: 0.2738 - accu
racy: 0.9159 - val_loss: 0.3130 - val_accuracy: 0.9073
Epoch 32/50
235/235 [==============================] - 2s 7ms/step - loss: 0.2752 - accu
racy: 0.9165 - val_loss: 0.3076 - val_accuracy: 0.9053
Epoch 33/50
235/235 [==============================] - 2s 6ms/step - loss: 0.2732 - accu
racy: 0.9164 - val_loss: 0.3153 - val_accuracy: 0.9062
Epoch 34/50
235/235 [==============================] - 2s 6ms/step - loss: 0.2749 - accu
racy: 0.9162 - val_loss: 0.3097 - val_accuracy: 0.9059
Epoch 35/50
235/235 [==============================] - 2s 6ms/step - loss: 0.2696 - accu
racy: 0.9179 - val_loss: 0.2996 - val_accuracy: 0.9101
Epoch 36/50
235/235 [==============================] - 2s 6ms/step - loss: 0.2631 - accu
racy: 0.9201 - val_loss: 0.2909 - val_accuracy: 0.9140
Epoch 37/50
235/235 [==============================] - 1s 6ms/step - loss: 0.2613 - accu
racy: 0.9202 - val_loss: 0.2997 - val_accuracy: 0.9104
Epoch 38/50
235/235 [==============================] - 2s 6ms/step - loss: 0.2657 - accu
racy: 0.9188 - val_loss: 0.3025 - val_accuracy: 0.9075
Epoch 39/50
235/235 [==============================] - 1s 6ms/step - loss: 0.2606 - accu
racy: 0.9200 - val_loss: 0.2973 - val_accuracy: 0.9100
Epoch 40/50
235/235 [==============================] - 1s 6ms/step - loss: 0.2585 - accu
racy: 0.9196 - val_loss: 0.2974 - val_accuracy: 0.9104
```

```
Epoch 41/50
235/235 [==============================] - 1s 6ms/step - loss: 0.2585 - accu
racy: 0.9194 - val_loss: 0.2986 - val_accuracy: 0.9092
Epoch 42/50
235/235 [==============================] - 2s 6ms/step - loss: 0.2631 - accu
racy: 0.9180 - val_loss: 0.3034 - val_accuracy: 0.9077
Epoch 43/50
235/235 [==============================] - 1s 6ms/step - loss: 0.2598 - accu
racy: 0.9198 - val_loss: 0.3001 - val_accuracy: 0.9078
Epoch 43: early stopping
```

Out[31]: <keras.callbacks.History at 0x7f4eeecc36d0>

In [32]:
```
%load_ext tensorboard
%tensorboard --logdir logs2_2
```

```
The tensorboard extension is already loaded. To reload it, use:
  %reload_ext tensorboard
```

5.3 Activation function: ReLU

In [33]:
```
tf.keras.backend.clear_session()

input_layer = Input(shape = (1024, ))
dense_layer_1 = Dense(64, activation='relu', kernel_initializer='he_normal')(in
dense_layer_2 = Dense(32, activation='relu', kernel_initializer='he_normal')(de
bn = BatchNormalization()(dense_layer_2)
dense_layer_3 = Dense(16, activation='relu', kernel_initializer='he_normal')(bn
dense_layer_3 = Dropout(0.5)(dense_layer_3)
output_layer = Dense(10, activation='softmax')(dense_layer_3)

model = Model(inputs = input_layer, outputs = output_layer)
model.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 1024)]            0

 dense (Dense)               (None, 64)                65600

 dense_1 (Dense)             (None, 32)                2080

 batch_normalization (BatchN  (None, 32)               128
 ormalization)

 dense_2 (Dense)             (None, 16)                528

 dropout (Dropout)           (None, 16)                0

 dense_3 (Dense)             (None, 10)                170

=================================================================
Total params: 68,506
Trainable params: 68,442
Non-trainable params: 64
_________________________________________________________________
```

In [34]:
```
!mkdir model2_3
model_path = "model2_3/"
```

In [35]:
```
#We will use the EarlyStopping callback to prevent the model from training aft
earlystop = EarlyStopping(monitor = 'val_loss', patience = 10, verbose=1, mode

#Passing validation data into the custom Metrics callback that we have created
validation_data=(x_test_tf,y_test)

model.compile(optimizer=adam, loss='categorical_crossentropy',metrics=['accura
```

In [36]:
```
!rm -rf ./logs2_3/fit
tf.keras.backend.clear_session()
```

In [37]:
```
#Creating logs directory to store information about the fits
log_dir = "logs2_3/fit/" + datetime.now().strftime("%Y%m%d - %H%M%S")

tf.keras.utils.plot_model(model, to_file=model_path+'model.png', show_shapes=T

tbCallBack = TensorBoard(log_dir=log_dir, write_graph=True, write_grads=True, w

allCs = [tbCallBack, earlystop]

model.fit(x_train_tf,y_train,epochs=100, validation_data=validation_data, batch
```

```
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `
TensorBoard` Callback.
```

```
Epoch 1/100
235/235 [==============================] - 3s 8ms/step - loss: 2.2523 - accu
racy: 0.1629 - val_loss: 2.3079 - val_accuracy: 0.1135
Epoch 2/100
235/235 [==============================] - 2s 7ms/step - loss: 1.9385 - accu
racy: 0.2786 - val_loss: 2.3197 - val_accuracy: 0.1037
Epoch 3/100
235/235 [==============================] - 2s 7ms/step - loss: 1.6294 - accu
racy: 0.3745 - val_loss: 2.3293 - val_accuracy: 0.1037
Epoch 4/100
235/235 [==============================] - 2s 7ms/step - loss: 1.4466 - accu
racy: 0.4445 - val_loss: 2.3291 - val_accuracy: 0.0980
Epoch 5/100
235/235 [==============================] - 2s 7ms/step - loss: 1.3383 - accu
racy: 0.4919 - val_loss: 2.3375 - val_accuracy: 0.0979
Epoch 6/100
235/235 [==============================] - 2s 7ms/step - loss: 1.2548 - accu
racy: 0.5246 - val_loss: 2.3796 - val_accuracy: 0.0984
Epoch 7/100
235/235 [==============================] - 2s 7ms/step - loss: 1.1838 - accu
racy: 0.5530 - val_loss: 2.3739 - val_accuracy: 0.1089
Epoch 8/100
235/235 [==============================] - 2s 7ms/step - loss: 1.1504 - accu
racy: 0.5650 - val_loss: 2.3804 - val_accuracy: 0.0991
Epoch 9/100
235/235 [==============================] - 2s 7ms/step - loss: 1.0941 - accu
racy: 0.5840 - val_loss: 2.3973 - val_accuracy: 0.0999
Epoch 10/100
235/235 [==============================] - 2s 7ms/step - loss: 1.0670 - accu
racy: 0.5910 - val_loss: 2.0476 - val_accuracy: 0.1612
Epoch 11/100
235/235 [==============================] - 2s 7ms/step - loss: 1.0371 - accu
racy: 0.6049 - val_loss: 1.8160 - val_accuracy: 0.4172
Epoch 12/100
235/235 [==============================] - 2s 7ms/step - loss: 1.0062 - accu
racy: 0.6135 - val_loss: 1.5266 - val_accuracy: 0.4648
Epoch 13/100
235/235 [==============================] - 2s 7ms/step - loss: 0.9872 - accu
racy: 0.6216 - val_loss: 1.4215 - val_accuracy: 0.4753
Epoch 14/100
235/235 [==============================] - 2s 6ms/step - loss: 0.9716 - accu
racy: 0.6273 - val_loss: 1.4995 - val_accuracy: 0.4541
Epoch 15/100
235/235 [==============================] - 2s 7ms/step - loss: 0.9549 - accu
racy: 0.6328 - val_loss: 1.5240 - val_accuracy: 0.3998
Epoch 16/100
235/235 [==============================] - 2s 7ms/step - loss: 0.9312 - accu
racy: 0.6406 - val_loss: 1.4764 - val_accuracy: 0.4561
Epoch 17/100
235/235 [==============================] - 2s 7ms/step - loss: 0.9218 - accu
racy: 0.6469 - val_loss: 1.3966 - val_accuracy: 0.4812
Epoch 18/100
235/235 [==============================] - 2s 6ms/step - loss: 0.8992 - accu
racy: 0.6515 - val_loss: 1.4394 - val_accuracy: 0.5365
Epoch 19/100
235/235 [==============================] - 2s 7ms/step - loss: 0.8958 - accu
racy: 0.6527 - val_loss: 1.3808 - val_accuracy: 0.5360
Epoch 20/100
235/235 [==============================] - 2s 7ms/step - loss: 0.8799 - accu
racy: 0.6584 - val_loss: 1.4236 - val_accuracy: 0.5337
```

```
Epoch 21/100
235/235 [==============================] - 2s 7ms/step - loss: 0.8624 - accu
racy: 0.6658 - val_loss: 1.3600 - val_accuracy: 0.5507
Epoch 22/100
235/235 [==============================] - 2s 7ms/step - loss: 0.8543 - accu
racy: 0.6702 - val_loss: 1.2423 - val_accuracy: 0.5861
Epoch 23/100
235/235 [==============================] - 2s 7ms/step - loss: 0.8445 - accu
racy: 0.6710 - val_loss: 1.1047 - val_accuracy: 0.6487
Epoch 24/100
235/235 [==============================] - 2s 7ms/step - loss: 0.8311 - accu
racy: 0.6773 - val_loss: 0.9537 - val_accuracy: 0.6943
Epoch 25/100
235/235 [==============================] - 2s 7ms/step - loss: 0.8443 - accu
racy: 0.6765 - val_loss: 0.8785 - val_accuracy: 0.7002
Epoch 26/100
235/235 [==============================] - 2s 7ms/step - loss: 0.8283 - accu
racy: 0.6780 - val_loss: 0.9450 - val_accuracy: 0.7045
Epoch 27/100
235/235 [==============================] - 2s 7ms/step - loss: 0.8134 - accu
racy: 0.6830 - val_loss: 0.9698 - val_accuracy: 0.6765
Epoch 28/100
235/235 [==============================] - 2s 7ms/step - loss: 0.8017 - accu
racy: 0.6891 - val_loss: 0.9387 - val_accuracy: 0.6839
Epoch 29/100
235/235 [==============================] - 2s 7ms/step - loss: 0.7986 - accu
racy: 0.6944 - val_loss: 0.9532 - val_accuracy: 0.6719
Epoch 30/100
235/235 [==============================] - 2s 7ms/step - loss: 0.7910 - accu
racy: 0.6952 - val_loss: 0.9427 - val_accuracy: 0.6865
Epoch 31/100
235/235 [==============================] - 2s 7ms/step - loss: 0.7763 - accu
racy: 0.7018 - val_loss: 0.9396 - val_accuracy: 0.6797
Epoch 32/100
235/235 [==============================] - 2s 7ms/step - loss: 0.7742 - accu
racy: 0.7062 - val_loss: 0.9685 - val_accuracy: 0.6712
Epoch 33/100
235/235 [==============================] - 2s 7ms/step - loss: 0.7564 - accu
racy: 0.7105 - val_loss: 0.9032 - val_accuracy: 0.7047
Epoch 34/100
235/235 [==============================] - 2s 7ms/step - loss: 0.7504 - accu
racy: 0.7154 - val_loss: 0.9192 - val_accuracy: 0.7112
Epoch 35/100
235/235 [==============================] - 2s 7ms/step - loss: 0.7473 - accu
racy: 0.7171 - val_loss: 0.9166 - val_accuracy: 0.6994
Epoch 35: early stopping
```

Out[37]:
```
<keras.callbacks.History at 0x7f4eef5bbf90>
```

In [38]:
```
%load_ext tensorboard
%tensorboard --logdir logs2_3
```

```
The tensorboard extension is already loaded. To reload it, use:
  %reload_ext tensorboard
```

6. Varying the Dropout Rate

6.1 Dropout = 0.9

In [39]:
```
tf.keras.backend.clear_session()

input_layer = Input(shape = (1024, ))
dense_layer_1 = Dense(64, activation='relu', kernel_initializer='he_normal')(in
dense_layer_2 = Dense(32, activation='relu', kernel_initializer='he_normal')(de
bn = BatchNormalization()(dense_layer_2)
dense_layer_3 = Dense(16, activation='relu', kernel_initializer='he_normal')(bn
dense_layer_3 = Dropout(0.9)(dense_layer_3)
output_layer = Dense(10, activation='softmax', kernel_initializer="glorot_norma

model = Model(inputs = input_layer, outputs = output_layer)
model.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 1024)]            0

 dense (Dense)               (None, 64)                65600

 dense_1 (Dense)             (None, 32)                2080

 batch_normalization (BatchN  (None, 32)               128
 ormalization)

 dense_2 (Dense)             (None, 16)                528

 dropout (Dropout)           (None, 16)                0

 dense_3 (Dense)             (None, 10)                170

=================================================================
Total params: 68,506
Trainable params: 68,442
Non-trainable params: 64
_________________________________________________________________
```

In [40]:
```
!mkdir model3_1
model_path = "model3_1/"
```

In [41]:
```
model.compile(optimizer=adam, loss='categorical_crossentropy',metrics=['accura
```

In [42]:
```
!rm -rf ./logs3_1/fit
tf.keras.backend.clear_session()
```

In [43]:
```
#Creating logs direcctory to store information about the fits
log_dir = "logs3_1/fit/" + datetime.now().strftime("%Y%m%d - %H%M%S")

tf.keras.utils.plot_model(model, to_file=model_path+'model.png', show_shapes=Tr

tbCallBack = TensorBoard(log_dir=log_dir, write_graph=True, write_grads=True, w

allCs = [tbCallBack, earlystop]

model.fit(x_train_tf,y_train,epochs=100, validation_data=validation_data, batch
```

```
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `Te
nsorBoard` Callback.
Epoch 1/100
235/235 [==============================] - 3s 8ms/step - loss: 2.3616 - accura
cy: 0.1097 - val_loss: 2.3009 - val_accuracy: 0.1135
Epoch 2/100
235/235 [==============================] - 2s 7ms/step - loss: 2.2941 - accura
cy: 0.1142 - val_loss: 2.3013 - val_accuracy: 0.1039
Epoch 3/100
235/235 [==============================] - 2s 7ms/step - loss: 2.2909 - accura
cy: 0.1224 - val_loss: 2.3694 - val_accuracy: 0.1133
Epoch 4/100
235/235 [==============================] - 2s 7ms/step - loss: 2.2827 - accura
cy: 0.1274 - val_loss: 5.7242 - val_accuracy: 0.1029
Epoch 5/100
235/235 [==============================] - 2s 7ms/step - loss: 2.2757 - accura
cy: 0.1266 - val_loss: 7.2752 - val_accuracy: 0.1029
Epoch 6/100
235/235 [==============================] - 2s 7ms/step - loss: 2.2612 - accura
cy: 0.1320 - val_loss: 3.5972 - val_accuracy: 0.1019
Epoch 7/100
235/235 [==============================] - 2s 7ms/step - loss: 2.2428 - accura
cy: 0.1433 - val_loss: 9.8990 - val_accuracy: 0.1021
Epoch 8/100
235/235 [==============================] - 2s 7ms/step - loss: 2.1843 - accura
cy: 0.1604 - val_loss: 2.3443 - val_accuracy: 0.1013
Epoch 9/100
235/235 [==============================] - 2s 7ms/step - loss: 2.1395 - accura
cy: 0.1712 - val_loss: 2.5086 - val_accuracy: 0.0983
Epoch 10/100
235/235 [==============================] - 2s 7ms/step - loss: 2.1114 - accura
cy: 0.1746 - val_loss: 2.3705 - val_accuracy: 0.1031
Epoch 11/100
235/235 [==============================] - 2s 7ms/step - loss: 2.0880 - accura
cy: 0.1826 - val_loss: 2.3414 - val_accuracy: 0.1030
Epoch 11: early stopping
```

Out[43]: `<keras.callbacks.History at 0x7f4eef37b650>`

In [44]:
```
%load_ext tensorboard
%tensorboard --logdir logs3_1
```

```
The tensorboard extension is already loaded. To reload it, use:
  %reload_ext tensorboard
```

6.2 Dropout = 0.75

In [45]:
```
tf.keras.backend.clear_session()

input_layer = Input(shape = (1024, ))
d = Dense(64, activation='relu', kernel_initializer='he_normal')(input_layer)
d = Dense(32, activation='relu', kernel_initializer='he_normal')(d)
bn = BatchNormalization()(d)
d = Dense(16, activation='relu', kernel_initializer='he_normal')(bn)
bn = BatchNormalization()(d)
d = Dropout(0.75)(bn)
output_layer = Dense(10, activation='softmax', kernel_initializer="glorot_norma
```

```
model = Model(inputs = input_layer, outputs = output_layer)
model.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 1024)]            0

 dense (Dense)               (None, 64)                65600

 dense_1 (Dense)             (None, 32)                2080

 batch_normalization (BatchN  (None, 32)               128
 ormalization)

 dense_2 (Dense)             (None, 16)                528

 batch_normalization_1 (Batc  (None, 16)               64
 hNormalization)

 dropout (Dropout)           (None, 16)                0

 dense_3 (Dense)             (None, 10)                170

=================================================================
Total params: 68,570
Trainable params: 68,474
Non-trainable params: 96
_________________________________________________________________
```

In [46]:
```
!mkdir model3_2
model_path = "model3_2/"
```

In [47]:
```
model.compile(optimizer=adam, loss='categorical_crossentropy',metrics=['accura
```

In [48]:
```
!rm -rf ./logs3_2/fit
tf.keras.backend.clear_session()
```

In [49]:
```
#Creating logs direcctory to store information about the fits
log_dir = "logs3_2/fit/" + datetime.now().strftime("%Y%m%d - %H%M%S")

tf.keras.utils.plot_model(model, to_file=model_path+'model.png', show_shapes=T

tbCallBack = TensorBoard(log_dir=log_dir, write_graph=True, write_grads=True, 

allCs = [tbCallBack, earlystop]

model.fit(x_train_tf,y_train,epochs=100, validation_data=validation_data, batc
```

```
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `Te
nsorBoard` Callback.
```

```
Epoch 1/100
235/235 [==============================] - 3s 8ms/step - loss: 2.3652 - accura
cy: 0.1284 - val_loss: 2.4319 - val_accuracy: 0.1134
Epoch 2/100
235/235 [==============================] - 2s 7ms/step - loss: 2.2530 - accura
cy: 0.1548 - val_loss: 3.0367 - val_accuracy: 0.1134
Epoch 3/100
235/235 [==============================] - 2s 7ms/step - loss: 2.1824 - accura
cy: 0.1955 - val_loss: 2.4089 - val_accuracy: 0.1134
Epoch 4/100
235/235 [==============================] - 2s 7ms/step - loss: 1.9547 - accura
cy: 0.2704 - val_loss: 2.4527 - val_accuracy: 0.1136
Epoch 5/100
235/235 [==============================] - 2s 7ms/step - loss: 1.7592 - accura
cy: 0.3195 - val_loss: 2.3778 - val_accuracy: 0.0987
Epoch 6/100
235/235 [==============================] - 2s 7ms/step - loss: 1.6204 - accura
cy: 0.3588 - val_loss: 2.5513 - val_accuracy: 0.1011
Epoch 7/100
235/235 [==============================] - 2s 7ms/step - loss: 1.4979 - accura
cy: 0.4011 - val_loss: 2.6412 - val_accuracy: 0.0985
Epoch 8/100
235/235 [==============================] - 2s 7ms/step - loss: 1.4545 - accura
cy: 0.4270 - val_loss: 2.7691 - val_accuracy: 0.1030
Epoch 9/100
235/235 [==============================] - 2s 7ms/step - loss: 1.3923 - accura
cy: 0.4539 - val_loss: 2.8500 - val_accuracy: 0.0983
Epoch 10/100
235/235 [==============================] - 2s 7ms/step - loss: 1.3363 - accura
cy: 0.4795 - val_loss: 2.9548 - val_accuracy: 0.0984
Epoch 11/100
235/235 [==============================] - 2s 7ms/step - loss: 1.2819 - accura
cy: 0.5051 - val_loss: 3.2507 - val_accuracy: 0.0984
Epoch 12/100
235/235 [==============================] - 2s 7ms/step - loss: 1.2703 - accura
cy: 0.5122 - val_loss: 3.3056 - val_accuracy: 0.1009
Epoch 13/100
235/235 [==============================] - 2s 7ms/step - loss: 1.2428 - accura
cy: 0.5211 - val_loss: 3.3505 - val_accuracy: 0.1115
Epoch 14/100
235/235 [==============================] - 2s 6ms/step - loss: 1.2183 - accura
cy: 0.5290 - val_loss: 2.9368 - val_accuracy: 0.1785
Epoch 15/100
235/235 [==============================] - 2s 7ms/step - loss: 1.2046 - accura
cy: 0.5385 - val_loss: 2.7341 - val_accuracy: 0.1956
Epoch 15: early stopping
```

Out[49]: `<keras.callbacks.History at 0x7f4eeedcf690>`

In [50]:
```
%tensorboard --logdir logs3_2/
```

6.3 Dropout = 0.5

This is same as the model in part 5.3

6.4 Dropout = 0.25

In [51]:
```
tf.keras.backend.clear_session()

input_layer = Input(shape = (1024, ))
d = Dense(64, activation='relu', kernel_initializer='he_normal')(input_layer)
bn = BatchNormalization()(d)
d = Dense(32, activation='relu', kernel_initializer='he_normal')(bn)
bn = BatchNormalization()(d)
d = Dense(16, activation='relu', kernel_initializer='he_normal')(bn)
bn = BatchNormalization()(d)
d = Dropout(0.25)(bn)
output_layer = Dense(10, activation='softmax', kernel_initializer="glorot_norma

model = Model(inputs = input_layer, outputs = output_layer)
model.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 1024)]            0

 dense (Dense)               (None, 64)                65600

 batch_normalization (BatchN  (None, 64)               256
 ormalization)

 dense_1 (Dense)             (None, 32)                2080

 batch_normalization_1 (Batc  (None, 32)               128
 hNormalization)

 dense_2 (Dense)             (None, 16)                528

 batch_normalization_2 (Batc  (None, 16)               64
 hNormalization)

 dropout (Dropout)           (None, 16)                0

 dense_3 (Dense)             (None, 10)                170

=================================================================
Total params: 68,826
Trainable params: 68,602
Non-trainable params: 224
_________________________________________________________________
```

In [52]:
```
!mkdir model3_4
model_path = "model3_4/"
!rm -rf ./logs3_4/fit
tf.keras.backend.clear_session()
model.compile(optimizer=adam, loss='categorical_crossentropy',metrics=['accurac
```

In [53]:
```
#Creating logs directory to store information about the fits
log_dir = "logs3_4/fit/" + datetime.now().strftime("%Y%m%d - %H%M%S")

tf.keras.utils.plot_model(model, to_file=model_path+'model.png', show_shapes=Tr

tbCallBack = TensorBoard(log_dir=log_dir, write_graph=True, write_grads=True, w
```

```
allCs = [tbCallBack, earlystop]

model.fit(x_train_tf,y_train,epochs=100, validation_data=validation_data, batch
```

```
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `Te
nsorBoard` Callback.
Epoch 1/100
235/235 [==============================] - 3s 8ms/step - loss: 2.0862 - accu
racy: 0.2483 - val_loss: 3.3922 - val_accuracy: 0.1134
Epoch 2/100
235/235 [==============================] - 2s 7ms/step - loss: 1.5896 - accu
racy: 0.4442 - val_loss: 3.4249 - val_accuracy: 0.1134
Epoch 3/100
235/235 [==============================] - 2s 7ms/step - loss: 1.3585 - accu
racy: 0.5296 - val_loss: 2.7781 - val_accuracy: 0.1131
Epoch 4/100
235/235 [==============================] - 2s 7ms/step - loss: 1.2300 - accu
racy: 0.5907 - val_loss: 3.0011 - val_accuracy: 0.1133
Epoch 5/100
235/235 [==============================] - 2s 7ms/step - loss: 1.1535 - accu
racy: 0.6201 - val_loss: 3.0888 - val_accuracy: 0.1135
Epoch 6/100
235/235 [==============================] - 2s 7ms/step - loss: 1.0763 - accu
racy: 0.6485 - val_loss: 2.9387 - val_accuracy: 0.1032
Epoch 7/100
235/235 [==============================] - 2s 7ms/step - loss: 1.0312 - accu
racy: 0.6702 - val_loss: 2.8961 - val_accuracy: 0.1032
Epoch 8/100
235/235 [==============================] - 2s 8ms/step - loss: 0.9982 - accu
racy: 0.6843 - val_loss: 2.9715 - val_accuracy: 0.1034
Epoch 9/100
235/235 [==============================] - 2s 7ms/step - loss: 0.9428 - accu
racy: 0.7015 - val_loss: 3.0668 - val_accuracy: 0.1031
Epoch 10/100
235/235 [==============================] - 2s 7ms/step - loss: 0.9097 - accu
racy: 0.7161 - val_loss: 3.0112 - val_accuracy: 0.1134
Epoch 11/100
235/235 [==============================] - 2s 7ms/step - loss: 0.8907 - accu
racy: 0.7237 - val_loss: 3.2169 - val_accuracy: 0.1136
Epoch 12/100
235/235 [==============================] - 2s 7ms/step - loss: 0.8624 - accu
racy: 0.7353 - val_loss: 3.4567 - val_accuracy: 0.1135
Epoch 13/100
235/235 [==============================] - 2s 7ms/step - loss: 0.8417 - accu
racy: 0.7423 - val_loss: 3.2600 - val_accuracy: 0.1135
Epoch 13: early stopping
```

Out[53]:
```
<keras.callbacks.History at 0x7f4eeef44950>
```

In [54]:
```
%load_ext tensorboard
%tensorboard --logdir logs3_4
```

```
The tensorboard extension is already loaded. To reload it, use:
  %reload_ext tensorboard
```

6.5 Dropout = 0.1

In [55]:
```
tf.keras.backend.clear_session()
```

```
input_layer = Input(shape = (1024, ))
d = Dense(64, activation='relu', kernel_initializer='he_normal')(input_layer)
bn = BatchNormalization()(d)
d = Dense(32, activation='relu', kernel_initializer='he_normal')(bn)
bn = BatchNormalization()(d)
d = Dense(16, activation='relu', kernel_initializer='he_normal')(bn)
bn = BatchNormalization()(d)
d = Dropout(0.1)(bn)
output_layer = Dense(10, activation='softmax', kernel_initializer="glorot_norma

model = Model(inputs = input_layer, outputs = output_layer)
model.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 1024)]            0

 dense (Dense)               (None, 64)                65600

 batch_normalization (BatchN  (None, 64)               256
 ormalization)

 dense_1 (Dense)             (None, 32)                2080

 batch_normalization_1 (Batc  (None, 32)               128
 hNormalization)

 dense_2 (Dense)             (None, 16)                528

 batch_normalization_2 (Batc  (None, 16)               64
 hNormalization)

 dropout (Dropout)           (None, 16)                0

 dense_3 (Dense)             (None, 10)                170

=================================================================
Total params: 68,826
Trainable params: 68,602
Non-trainable params: 224
_________________________________________________________________
```

In [56]:
```
!mkdir model3_5
model_path = "model3_5/"
!rm -rf ./logs3_5/fit
tf.keras.backend.clear_session()
model.compile(optimizer=adam, loss='categorical_crossentropy',metrics=['accura
```

In [57]:
```
#Creating logs direcctory to store information about the fits
log_dir = "logs3_5/fit/" + datetime.now().strftime("%Y%m%d - %H%M%S")

tf.keras.utils.plot_model(model, to_file=model_path+'model.png', show_shapes=Tr

tbCallBack = TensorBoard(log_dir=log_dir, write_graph=True, write_grads=True, w

allCs = [tbCallBack, earlystop]
```

```
model.fit(x_train_tf,y_train,epochs=100, validation_data=validation_data, batch
```

```
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `Te
nsorBoard` Callback.
Epoch 1/100
235/235 [==============================] - 4s 8ms/step - loss: 1.8719 - accu
racy: 0.3358 - val_loss: 69.6855 - val_accuracy: 0.0960
Epoch 2/100
235/235 [==============================] - 2s 7ms/step - loss: 1.3447 - accu
racy: 0.5256 - val_loss: 2.6799 - val_accuracy: 0.0983
Epoch 3/100
235/235 [==============================] - 2s 7ms/step - loss: 1.1690 - accu
racy: 0.5942 - val_loss: 2.6409 - val_accuracy: 0.0983
Epoch 4/100
235/235 [==============================] - 2s 7ms/step - loss: 1.0433 - accu
racy: 0.6525 - val_loss: 2.8233 - val_accuracy: 0.0982
Epoch 5/100
235/235 [==============================] - 2s 7ms/step - loss: 0.9664 - accu
racy: 0.6850 - val_loss: 3.9562 - val_accuracy: 0.0981
Epoch 6/100
235/235 [==============================] - 2s 7ms/step - loss: 0.8939 - accu
racy: 0.7147 - val_loss: 4.7135 - val_accuracy: 0.1010
Epoch 7/100
235/235 [==============================] - 2s 7ms/step - loss: 0.8536 - accu
racy: 0.7293 - val_loss: 8.3081 - val_accuracy: 0.0981
Epoch 8/100
235/235 [==============================] - 2s 7ms/step - loss: 0.8113 - accu
racy: 0.7463 - val_loss: 3.6193 - val_accuracy: 0.0983
Epoch 9/100
235/235 [==============================] - 2s 8ms/step - loss: 0.7909 - accu
racy: 0.7555 - val_loss: 3.0285 - val_accuracy: 0.0984
Epoch 10/100
235/235 [==============================] - 2s 7ms/step - loss: 0.7486 - accu
racy: 0.7691 - val_loss: 3.0931 - val_accuracy: 0.0988
Epoch 11/100
235/235 [==============================] - 2s 7ms/step - loss: 0.7275 - accu
racy: 0.7779 - val_loss: 3.0446 - val_accuracy: 0.1032
Epoch 12/100
235/235 [==============================] - 2s 8ms/step - loss: 0.6969 - accu
racy: 0.7874 - val_loss: 2.8450 - val_accuracy: 0.1032
Epoch 13/100
235/235 [==============================] - 2s 7ms/step - loss: 0.6844 - accu
racy: 0.7930 - val_loss: 3.0757 - val_accuracy: 0.1031
Epoch 13: early stopping
```

Out[57]:
```
<keras.callbacks.History at 0x7f4eec038a50>
```

In [58]:
```
%tensorboard --logdir logs3_5
```

7. Varying the Learning rate

7.1 Learning Rate = 0.01

In [59]:
```
tf.keras.backend.clear_session()
```

```
input_layer = Input(shape = (1024, ))
d = Dense(64, activation='sigmoid')(input_layer)
d = Dense(32, activation='sigmoid')(d)
d = Dense(16, activation='sigmoid')(d)
output_layer = Dense(10, activation='softmax', kernel_initializer='glorot_norma

model = Model(inputs = input_layer, outputs = output_layer)
model.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 1024)]            0

 dense (Dense)               (None, 64)                65600

 dense_1 (Dense)             (None, 32)                2080

 dense_2 (Dense)             (None, 16)                528

 dense_3 (Dense)             (None, 10)                170

=================================================================
Total params: 68,378
Trainable params: 68,378
Non-trainable params: 0
_________________________________________________________________
```

In [60]:
```
!mkdir model4_1
model_path = "model4_1/"
!rm -rf ./logs4_1/fit
```

In [61]:
```
model.compile(optimizer=Adam(learning_rate=0.01), loss='categorical_crossentrop
```

In [62]:
```
#Creating logs direcctory to store information about the fits
log_dir = "logs4_1/fit/" + datetime.now().strftime("%Y%m%d - %H%M%S")

tf.keras.utils.plot_model(model, to_file=model_path+'model.png', show_shapes=T

tbCallBack = TensorBoard(log_dir=log_dir, write_graph=True, write_grads=True, 

allCs = [tbCallBack, earlystop]

model.fit(x_train_tf,y_train,epochs=100, validation_data=validation_data, batch
```

```
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `Te
nsorBoard` Callback.
```

```
Epoch 1/100
235/235 [==============================] - 2s 7ms/step - loss: 1.2337 - accu
racy: 0.6060 - val_loss: 0.7674 - val_accuracy: 0.7581
Epoch 2/100
235/235 [==============================] - 1s 6ms/step - loss: 0.7075 - accu
racy: 0.7746 - val_loss: 0.6526 - val_accuracy: 0.7943
Epoch 3/100
235/235 [==============================] - 1s 6ms/step - loss: 0.6321 - accu
racy: 0.7976 - val_loss: 0.5930 - val_accuracy: 0.8045
Epoch 4/100
235/235 [==============================] - 1s 6ms/step - loss: 0.5925 - accu
racy: 0.8103 - val_loss: 0.5502 - val_accuracy: 0.8283
Epoch 5/100
235/235 [==============================] - 1s 6ms/step - loss: 0.5542 - accu
racy: 0.8245 - val_loss: 0.5264 - val_accuracy: 0.8326
Epoch 6/100
235/235 [==============================] - 1s 6ms/step - loss: 0.5343 - accu
racy: 0.8313 - val_loss: 0.5106 - val_accuracy: 0.8433
Epoch 7/100
235/235 [==============================] - 1s 6ms/step - loss: 0.5137 - accu
racy: 0.8383 - val_loss: 0.5109 - val_accuracy: 0.8378
Epoch 8/100
235/235 [==============================] - 1s 6ms/step - loss: 0.4939 - accu
racy: 0.8423 - val_loss: 0.4761 - val_accuracy: 0.8475
Epoch 9/100
235/235 [==============================] - 2s 8ms/step - loss: 0.4820 - accu
racy: 0.8458 - val_loss: 0.4743 - val_accuracy: 0.8468
Epoch 10/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4751 - accu
racy: 0.8491 - val_loss: 0.4721 - val_accuracy: 0.8503
Epoch 11/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4617 - accu
racy: 0.8536 - val_loss: 0.4767 - val_accuracy: 0.8491
Epoch 12/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4703 - accu
racy: 0.8492 - val_loss: 0.4562 - val_accuracy: 0.8547
Epoch 13/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4517 - accu
racy: 0.8581 - val_loss: 0.4475 - val_accuracy: 0.8605
Epoch 14/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4518 - accu
racy: 0.8583 - val_loss: 0.4771 - val_accuracy: 0.8509
Epoch 15/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4586 - accu
racy: 0.8566 - val_loss: 0.4305 - val_accuracy: 0.8626
Epoch 16/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4214 - accu
racy: 0.8685 - val_loss: 0.4459 - val_accuracy: 0.8600
Epoch 17/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4301 - accu
racy: 0.8645 - val_loss: 0.4521 - val_accuracy: 0.8572
Epoch 18/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4313 - accu
racy: 0.8661 - val_loss: 0.4429 - val_accuracy: 0.8624
Epoch 19/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4345 - accu
racy: 0.8634 - val_loss: 0.4248 - val_accuracy: 0.8675
Epoch 20/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4386 - accu
racy: 0.8633 - val_loss: 0.4218 - val_accuracy: 0.8730
```

```
Epoch 21/100
235/235 [==============================] - 2s 10ms/step - loss: 0.4438 - acc
uracy: 0.8598 - val_loss: 0.4530 - val_accuracy: 0.8581
Epoch 22/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4246 - accu
racy: 0.8660 - val_loss: 0.4302 - val_accuracy: 0.8665
Epoch 23/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4175 - accu
racy: 0.8685 - val_loss: 0.4290 - val_accuracy: 0.8660
Epoch 24/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4136 - accu
racy: 0.8706 - val_loss: 0.4021 - val_accuracy: 0.8768
Epoch 25/100
235/235 [==============================] - 2s 9ms/step - loss: 0.3948 - accu
racy: 0.8760 - val_loss: 0.4081 - val_accuracy: 0.8758
Epoch 26/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4062 - accu
racy: 0.8737 - val_loss: 0.4092 - val_accuracy: 0.8750
Epoch 27/100
235/235 [==============================] - 2s 9ms/step - loss: 0.3980 - accu
racy: 0.8762 - val_loss: 0.3956 - val_accuracy: 0.8772
Epoch 28/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4039 - accu
racy: 0.8736 - val_loss: 0.4017 - val_accuracy: 0.8752
Epoch 29/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4058 - accu
racy: 0.8724 - val_loss: 0.4262 - val_accuracy: 0.8632
Epoch 30/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4148 - accu
racy: 0.8681 - val_loss: 0.4179 - val_accuracy: 0.8659
Epoch 31/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4153 - accu
racy: 0.8691 - val_loss: 0.4131 - val_accuracy: 0.8672
Epoch 32/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4104 - accu
racy: 0.8708 - val_loss: 0.4157 - val_accuracy: 0.8696
Epoch 33/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4051 - accu
racy: 0.8723 - val_loss: 0.4009 - val_accuracy: 0.8747
Epoch 34/100
235/235 [==============================] - 2s 9ms/step - loss: 0.3994 - accu
racy: 0.8747 - val_loss: 0.3920 - val_accuracy: 0.8780
Epoch 35/100
235/235 [==============================] - 2s 9ms/step - loss: 0.3998 - accu
racy: 0.8733 - val_loss: 0.4156 - val_accuracy: 0.8670
Epoch 36/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4106 - accu
racy: 0.8685 - val_loss: 0.4223 - val_accuracy: 0.8635
Epoch 37/100
235/235 [==============================] - 2s 10ms/step - loss: 0.4031 - acc
uracy: 0.8700 - val_loss: 0.4114 - val_accuracy: 0.8709
Epoch 38/100
235/235 [==============================] - 3s 11ms/step - loss: 0.3941 - acc
uracy: 0.8749 - val_loss: 0.4086 - val_accuracy: 0.8676
Epoch 39/100
235/235 [==============================] - 3s 11ms/step - loss: 0.3851 - acc
uracy: 0.8759 - val_loss: 0.3892 - val_accuracy: 0.8776
Epoch 40/100
235/235 [==============================] - 2s 10ms/step - loss: 0.3711 - acc
uracy: 0.8822 - val_loss: 0.3866 - val_accuracy: 0.8792
```

```
Epoch 41/100
235/235 [==============================] - 3s 11ms/step - loss: 0.3804 - acc
uracy: 0.8794 - val_loss: 0.4058 - val_accuracy: 0.8750
Epoch 42/100
235/235 [==============================] - 2s 9ms/step - loss: 0.4011 - accu
racy: 0.8748 - val_loss: 0.4157 - val_accuracy: 0.8677
Epoch 43/100
235/235 [==============================] - 2s 9ms/step - loss: 0.3915 - accu
racy: 0.8766 - val_loss: 0.4182 - val_accuracy: 0.8665
Epoch 44/100
235/235 [==============================] - 2s 10ms/step - loss: 0.3905 - acc
uracy: 0.8776 - val_loss: 0.4063 - val_accuracy: 0.8729
Epoch 45/100
235/235 [==============================] - 2s 10ms/step - loss: 0.4013 - acc
uracy: 0.8736 - val_loss: 0.4029 - val_accuracy: 0.8745
Epoch 46/100
235/235 [==============================] - 2s 9ms/step - loss: 0.3880 - accu
racy: 0.8769 - val_loss: 0.4137 - val_accuracy: 0.8703
Epoch 47/100
235/235 [==============================] - 2s 9ms/step - loss: 0.3898 - accu
racy: 0.8759 - val_loss: 0.4024 - val_accuracy: 0.8792
Epoch 48/100
235/235 [==============================] - 2s 9ms/step - loss: 0.3762 - accu
racy: 0.8824 - val_loss: 0.3787 - val_accuracy: 0.8852
Epoch 49/100
235/235 [==============================] - 2s 9ms/step - loss: 0.3752 - accu
racy: 0.8826 - val_loss: 0.3962 - val_accuracy: 0.8789
Epoch 50/100
235/235 [==============================] - 2s 9ms/step - loss: 0.3838 - accu
racy: 0.8791 - val_loss: 0.3897 - val_accuracy: 0.8772
Epoch 51/100
235/235 [==============================] - 2s 10ms/step - loss: 0.3752 - acc
uracy: 0.8816 - val_loss: 0.3814 - val_accuracy: 0.8822
Epoch 52/100
235/235 [==============================] - 2s 9ms/step - loss: 0.3800 - accu
racy: 0.8810 - val_loss: 0.4179 - val_accuracy: 0.8707
Epoch 53/100
235/235 [==============================] - 3s 11ms/step - loss: 0.3880 - acc
uracy: 0.8803 - val_loss: 0.4174 - val_accuracy: 0.8731
Epoch 54/100
235/235 [==============================] - 2s 10ms/step - loss: 0.3898 - acc
uracy: 0.8771 - val_loss: 0.4016 - val_accuracy: 0.8757
Epoch 55/100
235/235 [==============================] - 2s 10ms/step - loss: 0.3826 - acc
uracy: 0.8794 - val_loss: 0.4126 - val_accuracy: 0.8737
Epoch 56/100
235/235 [==============================] - 2s 10ms/step - loss: 0.3873 - acc
uracy: 0.8776 - val_loss: 0.4112 - val_accuracy: 0.8699
Epoch 57/100
235/235 [==============================] - 2s 10ms/step - loss: 0.3770 - acc
uracy: 0.8816 - val_loss: 0.3933 - val_accuracy: 0.8798
Epoch 58/100
235/235 [==============================] - 2s 10ms/step - loss: 0.3691 - acc
uracy: 0.8826 - val_loss: 0.3802 - val_accuracy: 0.8856
Epoch 58: early stopping
```

Out[62]: `<keras.callbacks.History at 0x7f4eeb74c050>`

In [63]:
```
%tensorboard --logdir logs4_1/
```

7.2 Learning rate = 0.001

We have already used a learning rate of 0.001 with all the previous models

7.3Learning Rate = 0.005

In [64]:
```
tf.keras.backend.clear_session()

input_layer = Input(shape = (1024, ))
d = Dense(64, activation='sigmoid')(input_layer)
d = Dense(32, activation='sigmoid')(d)
d = Dense(16, activation='sigmoid')(d)
output_layer = Dense(10, activation='softmax', kernel_initializer='glorot_norma

model = Model(inputs = input_layer, outputs = output_layer)
model.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 1024)]            0

 dense (Dense)               (None, 64)                65600

 dense_1 (Dense)             (None, 32)                2080

 dense_2 (Dense)             (None, 16)                528

 dense_3 (Dense)             (None, 10)                170

=================================================================
Total params: 68,378
Trainable params: 68,378
Non-trainable params: 0
_________________________________________________________________
```

In [65]:
```
!mkdir model4_3
model_path = "model4_3/"
!rm -rf ./logs4_3/fit
```

In [66]:
```
model.compile(optimizer=Adam(learning_rate=0.005), loss='categorical_crossentro
```

In [67]:
```
#Creating logs direcctory to store information about the fits
log_dir = "logs4_3/fit/" + datetime.now().strftime("%Y%m%d - %H%M%S")

tf.keras.utils.plot_model(model, to_file=model_path+'model.png', show_shapes=Tr

tbCallBack = TensorBoard(log_dir=log_dir, write_graph=True, write_grads=True, w

allCs = [tbCallBack, earlystop]

model.fit(x_train_tf,y_train,epochs=100, validation_data=validation_data, batch
```

```
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `Te
nsorBoard` Callback.
```

```
Epoch 1/100
235/235 [==============================] - 2s 7ms/step - loss: 1.3591 - accu
racy: 0.5851 - val_loss: 0.8290 - val_accuracy: 0.7529
Epoch 2/100
235/235 [==============================] - 1s 6ms/step - loss: 0.7383 - accu
racy: 0.7730 - val_loss: 0.6570 - val_accuracy: 0.7983
Epoch 3/100
235/235 [==============================] - 1s 6ms/step - loss: 0.6119 - accu
racy: 0.8098 - val_loss: 0.5579 - val_accuracy: 0.8284
Epoch 4/100
235/235 [==============================] - 1s 6ms/step - loss: 0.5361 - accu
racy: 0.8352 - val_loss: 0.5130 - val_accuracy: 0.8411
Epoch 5/100
235/235 [==============================] - 1s 6ms/step - loss: 0.5002 - accu
racy: 0.8435 - val_loss: 0.4909 - val_accuracy: 0.8460
Epoch 6/100
235/235 [==============================] - 1s 6ms/step - loss: 0.4781 - accu
racy: 0.8518 - val_loss: 0.4546 - val_accuracy: 0.8620
Epoch 7/100
235/235 [==============================] - 1s 6ms/step - loss: 0.4543 - accu
racy: 0.8602 - val_loss: 0.4594 - val_accuracy: 0.8540
Epoch 8/100
235/235 [==============================] - 1s 6ms/step - loss: 0.4272 - accu
racy: 0.8676 - val_loss: 0.4234 - val_accuracy: 0.8677
Epoch 9/100
235/235 [==============================] - 1s 6ms/step - loss: 0.4253 - accu
racy: 0.8670 - val_loss: 0.4207 - val_accuracy: 0.8683
Epoch 10/100
235/235 [==============================] - 2s 6ms/step - loss: 0.4054 - accu
racy: 0.8751 - val_loss: 0.3936 - val_accuracy: 0.8770
Epoch 11/100
235/235 [==============================] - 2s 6ms/step - loss: 0.4099 - accu
racy: 0.8715 - val_loss: 0.4007 - val_accuracy: 0.8747
Epoch 12/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3938 - accu
racy: 0.8774 - val_loss: 0.3966 - val_accuracy: 0.8765
Epoch 13/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3849 - accu
racy: 0.8796 - val_loss: 0.3792 - val_accuracy: 0.8823
Epoch 14/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3684 - accu
racy: 0.8847 - val_loss: 0.4108 - val_accuracy: 0.8730
Epoch 15/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3751 - accu
racy: 0.8835 - val_loss: 0.3693 - val_accuracy: 0.8865
Epoch 16/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3543 - accu
racy: 0.8894 - val_loss: 0.3637 - val_accuracy: 0.8844
Epoch 17/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3501 - accu
racy: 0.8908 - val_loss: 0.3610 - val_accuracy: 0.8926
Epoch 18/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3564 - accu
racy: 0.8882 - val_loss: 0.3610 - val_accuracy: 0.8889
Epoch 19/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3501 - accu
racy: 0.8907 - val_loss: 0.3642 - val_accuracy: 0.8861
Epoch 20/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3499 - accu
racy: 0.8908 - val_loss: 0.3542 - val_accuracy: 0.8920
```

```
Epoch 21/100
235/235 [==============================] - 2s 8ms/step - loss: 0.3478 - accu
racy: 0.8916 - val_loss: 0.3532 - val_accuracy: 0.8901
Epoch 22/100
235/235 [==============================] - 2s 10ms/step - loss: 0.3421 - acc
uracy: 0.8932 - val_loss: 0.3455 - val_accuracy: 0.8943
Epoch 23/100
235/235 [==============================] - 2s 9ms/step - loss: 0.3418 - accu
racy: 0.8928 - val_loss: 0.3479 - val_accuracy: 0.8905
Epoch 24/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3406 - accu
racy: 0.8937 - val_loss: 0.3562 - val_accuracy: 0.8865
Epoch 25/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3446 - accu
racy: 0.8904 - val_loss: 0.3595 - val_accuracy: 0.8859
Epoch 26/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3449 - accu
racy: 0.8916 - val_loss: 0.3672 - val_accuracy: 0.8852
Epoch 27/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3463 - accu
racy: 0.8912 - val_loss: 0.3687 - val_accuracy: 0.8862
Epoch 28/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3411 - accu
racy: 0.8928 - val_loss: 0.3563 - val_accuracy: 0.8900
Epoch 29/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3364 - accu
racy: 0.8962 - val_loss: 0.3485 - val_accuracy: 0.8923
Epoch 30/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3397 - accu
racy: 0.8935 - val_loss: 0.3436 - val_accuracy: 0.8933
Epoch 31/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3332 - accu
racy: 0.8967 - val_loss: 0.3387 - val_accuracy: 0.8960
Epoch 32/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3253 - accu
racy: 0.8992 - val_loss: 0.3360 - val_accuracy: 0.8951
Epoch 33/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3287 - accu
racy: 0.8976 - val_loss: 0.3280 - val_accuracy: 0.8957
Epoch 34/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3284 - accu
racy: 0.8978 - val_loss: 0.3344 - val_accuracy: 0.8936
Epoch 35/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3258 - accu
racy: 0.8982 - val_loss: 0.3364 - val_accuracy: 0.8941
Epoch 36/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3263 - accu
racy: 0.8986 - val_loss: 0.3383 - val_accuracy: 0.8943
Epoch 37/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3166 - accu
racy: 0.9021 - val_loss: 0.3345 - val_accuracy: 0.8955
Epoch 38/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3158 - accu
racy: 0.9009 - val_loss: 0.3236 - val_accuracy: 0.9018
Epoch 39/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3127 - accu
racy: 0.9031 - val_loss: 0.3224 - val_accuracy: 0.9003
Epoch 40/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3143 - accu
racy: 0.9038 - val_loss: 0.3403 - val_accuracy: 0.8965
```

```
Epoch 41/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3155 - accu
racy: 0.9012 - val_loss: 0.3264 - val_accuracy: 0.8963
Epoch 42/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3105 - accu
racy: 0.9044 - val_loss: 0.3185 - val_accuracy: 0.9015
Epoch 43/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3067 - accu
racy: 0.9052 - val_loss: 0.3254 - val_accuracy: 0.8997
Epoch 44/100
235/235 [==============================] - 2s 6ms/step - loss: 0.3133 - accu
racy: 0.9022 - val_loss: 0.3244 - val_accuracy: 0.8977
Epoch 45/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3053 - accu
racy: 0.9046 - val_loss: 0.3161 - val_accuracy: 0.9002
Epoch 46/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2976 - accu
racy: 0.9083 - val_loss: 0.3192 - val_accuracy: 0.8984
Epoch 47/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2980 - accu
racy: 0.9073 - val_loss: 0.3128 - val_accuracy: 0.9017
Epoch 48/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3007 - accu
racy: 0.9062 - val_loss: 0.3160 - val_accuracy: 0.9016
Epoch 49/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2941 - accu
racy: 0.9085 - val_loss: 0.3064 - val_accuracy: 0.9055
Epoch 50/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2915 - accu
racy: 0.9104 - val_loss: 0.3103 - val_accuracy: 0.9044
Epoch 51/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2901 - accu
racy: 0.9093 - val_loss: 0.3086 - val_accuracy: 0.9061
Epoch 52/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2867 - accu
racy: 0.9111 - val_loss: 0.3085 - val_accuracy: 0.9053
Epoch 53/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2980 - accu
racy: 0.9074 - val_loss: 0.3209 - val_accuracy: 0.9003
Epoch 54/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3017 - accu
racy: 0.9047 - val_loss: 0.3265 - val_accuracy: 0.8992
Epoch 55/100
235/235 [==============================] - 2s 6ms/step - loss: 0.2985 - accu
racy: 0.9052 - val_loss: 0.3190 - val_accuracy: 0.9003
Epoch 56/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2945 - accu
racy: 0.9076 - val_loss: 0.3207 - val_accuracy: 0.9004
Epoch 57/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2810 - accu
racy: 0.9126 - val_loss: 0.3010 - val_accuracy: 0.9067
Epoch 58/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2822 - accu
racy: 0.9123 - val_loss: 0.3140 - val_accuracy: 0.9006
Epoch 59/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2829 - accu
racy: 0.9115 - val_loss: 0.3027 - val_accuracy: 0.9056
Epoch 60/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2749 - accu
racy: 0.9153 - val_loss: 0.2927 - val_accuracy: 0.9078
```

```
Epoch 61/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2832 - accu
racy: 0.9115 - val_loss: 0.3007 - val_accuracy: 0.9075
Epoch 62/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2772 - accu
racy: 0.9136 - val_loss: 0.2954 - val_accuracy: 0.9095
Epoch 63/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2760 - accu
racy: 0.9134 - val_loss: 0.3022 - val_accuracy: 0.9083
Epoch 64/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2747 - accu
racy: 0.9139 - val_loss: 0.2876 - val_accuracy: 0.9095
Epoch 65/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2784 - accu
racy: 0.9121 - val_loss: 0.3063 - val_accuracy: 0.9010
Epoch 66/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2844 - accu
racy: 0.9096 - val_loss: 0.3084 - val_accuracy: 0.9047
Epoch 67/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2736 - accu
racy: 0.9133 - val_loss: 0.2948 - val_accuracy: 0.9087
Epoch 68/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2720 - accu
racy: 0.9144 - val_loss: 0.2863 - val_accuracy: 0.9107
Epoch 69/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2752 - accu
racy: 0.9144 - val_loss: 0.2910 - val_accuracy: 0.9078
Epoch 70/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2708 - accu
racy: 0.9147 - val_loss: 0.2993 - val_accuracy: 0.9097
Epoch 71/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2782 - accu
racy: 0.9128 - val_loss: 0.3083 - val_accuracy: 0.9071
Epoch 72/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2785 - accu
racy: 0.9134 - val_loss: 0.3009 - val_accuracy: 0.9049
Epoch 73/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2743 - accu
racy: 0.9154 - val_loss: 0.2980 - val_accuracy: 0.9082
Epoch 74/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2733 - accu
racy: 0.9151 - val_loss: 0.2902 - val_accuracy: 0.9110
Epoch 75/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2683 - accu
racy: 0.9165 - val_loss: 0.2892 - val_accuracy: 0.9090
Epoch 76/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2615 - accu
racy: 0.9187 - val_loss: 0.2912 - val_accuracy: 0.9095
Epoch 77/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2622 - accu
racy: 0.9172 - val_loss: 0.2953 - val_accuracy: 0.9084
Epoch 78/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2598 - accu
racy: 0.9185 - val_loss: 0.2900 - val_accuracy: 0.9098
Epoch 78: early stopping
```

Out[67]: `<keras.callbacks.History at 0x7f4eeb743e90>`

In [68]:
```
%tensorboard --logdir logs4_3
```

In [68]:

7.4 Learning Rate = 0.0001

In [69]:
```
tf.keras.backend.clear_session()

input_layer = Input(shape = (1024, ))
d = Dense(64, activation='sigmoid')(input_layer)
d = Dense(32, activation='sigmoid')(d)
d = Dense(16, activation='sigmoid')(d)
output_layer = Dense(10, activation='softmax', kernel_initializer='glorot_norma

model = Model(inputs = input_layer, outputs = output_layer)
model.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 1024)]            0

 dense (Dense)               (None, 64)                65600

 dense_1 (Dense)             (None, 32)                2080

 dense_2 (Dense)             (None, 16)                528

 dense_3 (Dense)             (None, 10)                170

=================================================================
Total params: 68,378
Trainable params: 68,378
Non-trainable params: 0
_________________________________________________________________
```

In [70]:
```
!mkdir model4_4
model_path = "model4_4/"
!rm -rf ./logs4_4/fit
```

In [71]:
```
model.compile(optimizer=Adam(learning_rate=0.0001), loss='categorical_crossenti
```

In [72]:
```
#Creating logs direcctory to store information about the fits
log_dir = "logs4_4/fit/" + datetime.now().strftime("%Y%m%d - %H%M%S")

tf.keras.utils.plot_model(model, to_file=model_path+'model.png', show_shapes=Tr

tbCallBack = TensorBoard(log_dir=log_dir, write_graph=True, write_grads=True, w

allCs = [tbCallBack, earlystop]

model.fit(x_train_tf,y_train,epochs=100, validation_data=validation_data, batch
```

```
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `Te
nsorBoard` Callback.
```

```
Epoch 1/100
235/235 [==============================] - 2s 7ms/step - loss: 2.3186 - accu
racy: 0.0993 - val_loss: 2.2568 - val_accuracy: 0.1035
Epoch 2/100
235/235 [==============================] - 2s 6ms/step - loss: 2.2151 - accu
racy: 0.2004 - val_loss: 2.1666 - val_accuracy: 0.4092
Epoch 3/100
235/235 [==============================] - 2s 6ms/step - loss: 2.1199 - accu
racy: 0.4627 - val_loss: 2.0661 - val_accuracy: 0.4811
Epoch 4/100
235/235 [==============================] - 2s 6ms/step - loss: 2.0148 - accu
racy: 0.4803 - val_loss: 1.9591 - val_accuracy: 0.4853
Epoch 5/100
235/235 [==============================] - 1s 6ms/step - loss: 1.9077 - accu
racy: 0.4983 - val_loss: 1.8528 - val_accuracy: 0.5094
Epoch 6/100
235/235 [==============================] - 1s 6ms/step - loss: 1.8033 - accu
racy: 0.5328 - val_loss: 1.7499 - val_accuracy: 0.5420
Epoch 7/100
235/235 [==============================] - 1s 6ms/step - loss: 1.7026 - accu
racy: 0.5693 - val_loss: 1.6526 - val_accuracy: 0.5842
Epoch 8/100
235/235 [==============================] - 1s 6ms/step - loss: 1.6068 - accu
racy: 0.6039 - val_loss: 1.5585 - val_accuracy: 0.6231
Epoch 9/100
235/235 [==============================] - 1s 6ms/step - loss: 1.5153 - accu
racy: 0.6416 - val_loss: 1.4700 - val_accuracy: 0.6554
Epoch 10/100
235/235 [==============================] - 1s 6ms/step - loss: 1.4293 - accu
racy: 0.6732 - val_loss: 1.3881 - val_accuracy: 0.6806
Epoch 11/100
235/235 [==============================] - 1s 6ms/step - loss: 1.3486 - accu
racy: 0.6977 - val_loss: 1.3106 - val_accuracy: 0.7083
Epoch 12/100
235/235 [==============================] - 1s 6ms/step - loss: 1.2737 - accu
racy: 0.7160 - val_loss: 1.2395 - val_accuracy: 0.7261
Epoch 13/100
235/235 [==============================] - 1s 6ms/step - loss: 1.2043 - accu
racy: 0.7321 - val_loss: 1.1745 - val_accuracy: 0.7406
Epoch 14/100
235/235 [==============================] - 1s 6ms/step - loss: 1.1401 - accu
racy: 0.7459 - val_loss: 1.1124 - val_accuracy: 0.7541
Epoch 15/100
235/235 [==============================] - 1s 6ms/step - loss: 1.0800 - accu
racy: 0.7585 - val_loss: 1.0563 - val_accuracy: 0.7641
Epoch 16/100
235/235 [==============================] - 1s 6ms/step - loss: 1.0252 - accu
racy: 0.7707 - val_loss: 1.0053 - val_accuracy: 0.7729
Epoch 17/100
235/235 [==============================] - 1s 6ms/step - loss: 0.9741 - accu
racy: 0.7814 - val_loss: 0.9568 - val_accuracy: 0.7858
Epoch 18/100
235/235 [==============================] - 1s 6ms/step - loss: 0.9279 - accu
racy: 0.7918 - val_loss: 0.9146 - val_accuracy: 0.7916
Epoch 19/100
235/235 [==============================] - 1s 6ms/step - loss: 0.8850 - accu
racy: 0.8002 - val_loss: 0.8723 - val_accuracy: 0.8036
Epoch 20/100
235/235 [==============================] - 1s 6ms/step - loss: 0.8455 - accu
racy: 0.8083 - val_loss: 0.8365 - val_accuracy: 0.8078
```

```
Epoch 21/100
235/235 [==============================] - 1s 6ms/step - loss: 0.8098 - accu
racy: 0.8159 - val_loss: 0.8025 - val_accuracy: 0.8164
Epoch 22/100
235/235 [==============================] - 1s 6ms/step - loss: 0.7765 - accu
racy: 0.8229 - val_loss: 0.7718 - val_accuracy: 0.8206
Epoch 23/100
235/235 [==============================] - 1s 6ms/step - loss: 0.7451 - accu
racy: 0.8302 - val_loss: 0.7448 - val_accuracy: 0.8250
Epoch 24/100
235/235 [==============================] - 1s 6ms/step - loss: 0.7169 - accu
racy: 0.8353 - val_loss: 0.7176 - val_accuracy: 0.8305
Epoch 25/100
235/235 [==============================] - 1s 6ms/step - loss: 0.6903 - accu
racy: 0.8411 - val_loss: 0.6943 - val_accuracy: 0.8375
Epoch 26/100
235/235 [==============================] - 1s 6ms/step - loss: 0.6656 - accu
racy: 0.8457 - val_loss: 0.6716 - val_accuracy: 0.8403
Epoch 27/100
235/235 [==============================] - 1s 6ms/step - loss: 0.6431 - accu
racy: 0.8500 - val_loss: 0.6510 - val_accuracy: 0.8441
Epoch 28/100
235/235 [==============================] - 1s 6ms/step - loss: 0.6233 - accu
racy: 0.8524 - val_loss: 0.6330 - val_accuracy: 0.8473
Epoch 29/100
235/235 [==============================] - 1s 6ms/step - loss: 0.6038 - accu
racy: 0.8566 - val_loss: 0.6155 - val_accuracy: 0.8504
Epoch 30/100
235/235 [==============================] - 1s 6ms/step - loss: 0.5855 - accu
racy: 0.8596 - val_loss: 0.5991 - val_accuracy: 0.8521
Epoch 31/100
235/235 [==============================] - 1s 6ms/step - loss: 0.5690 - accu
racy: 0.8613 - val_loss: 0.5847 - val_accuracy: 0.8543
Epoch 32/100
235/235 [==============================] - 1s 6ms/step - loss: 0.5524 - accu
racy: 0.8648 - val_loss: 0.5705 - val_accuracy: 0.8579
Epoch 33/100
235/235 [==============================] - 1s 6ms/step - loss: 0.5372 - accu
racy: 0.8666 - val_loss: 0.5571 - val_accuracy: 0.8574
Epoch 34/100
235/235 [==============================] - 1s 6ms/step - loss: 0.5234 - accu
racy: 0.8693 - val_loss: 0.5464 - val_accuracy: 0.8588
Epoch 35/100
235/235 [==============================] - 1s 6ms/step - loss: 0.5106 - accu
racy: 0.8712 - val_loss: 0.5360 - val_accuracy: 0.8606
Epoch 36/100
235/235 [==============================] - 1s 6ms/step - loss: 0.4988 - accu
racy: 0.8734 - val_loss: 0.5249 - val_accuracy: 0.8619
Epoch 37/100
235/235 [==============================] - 1s 6ms/step - loss: 0.4877 - accu
racy: 0.8744 - val_loss: 0.5152 - val_accuracy: 0.8620
Epoch 38/100
235/235 [==============================] - 1s 6ms/step - loss: 0.4767 - accu
racy: 0.8769 - val_loss: 0.5063 - val_accuracy: 0.8669
Epoch 39/100
235/235 [==============================] - 1s 6ms/step - loss: 0.4666 - accu
racy: 0.8797 - val_loss: 0.4986 - val_accuracy: 0.8662
Epoch 40/100
235/235 [==============================] - 1s 6ms/step - loss: 0.4580 - accu
racy: 0.8802 - val_loss: 0.4908 - val_accuracy: 0.8688
```

```
Epoch 41/100
235/235 [==============================] - 1s 6ms/step - loss: 0.4490 - accu
racy: 0.8821 - val_loss: 0.4849 - val_accuracy: 0.8683
Epoch 42/100
235/235 [==============================] - 1s 6ms/step - loss: 0.4419 - accu
racy: 0.8835 - val_loss: 0.4771 - val_accuracy: 0.8682
Epoch 43/100
235/235 [==============================] - 1s 6ms/step - loss: 0.4343 - accu
racy: 0.8849 - val_loss: 0.4718 - val_accuracy: 0.8701
Epoch 44/100
235/235 [==============================] - 1s 6ms/step - loss: 0.4267 - accu
racy: 0.8870 - val_loss: 0.4669 - val_accuracy: 0.8708
Epoch 45/100
235/235 [==============================] - 1s 6ms/step - loss: 0.4198 - accu
racy: 0.8881 - val_loss: 0.4622 - val_accuracy: 0.8720
Epoch 46/100
235/235 [==============================] - 1s 6ms/step - loss: 0.4129 - accu
racy: 0.8900 - val_loss: 0.4572 - val_accuracy: 0.8716
Epoch 47/100
235/235 [==============================] - 1s 6ms/step - loss: 0.4064 - accu
racy: 0.8912 - val_loss: 0.4523 - val_accuracy: 0.8718
Epoch 48/100
235/235 [==============================] - 1s 6ms/step - loss: 0.4009 - accu
racy: 0.8918 - val_loss: 0.4471 - val_accuracy: 0.8735
Epoch 49/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3945 - accu
racy: 0.8940 - val_loss: 0.4433 - val_accuracy: 0.8739
Epoch 50/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3901 - accu
racy: 0.8946 - val_loss: 0.4410 - val_accuracy: 0.8752
Epoch 51/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3855 - accu
racy: 0.8958 - val_loss: 0.4370 - val_accuracy: 0.8756
Epoch 52/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3802 - accu
racy: 0.8967 - val_loss: 0.4331 - val_accuracy: 0.8766
Epoch 53/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3758 - accu
racy: 0.8973 - val_loss: 0.4304 - val_accuracy: 0.8786
Epoch 54/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3713 - accu
racy: 0.8989 - val_loss: 0.4266 - val_accuracy: 0.8774
Epoch 55/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3671 - accu
racy: 0.8999 - val_loss: 0.4260 - val_accuracy: 0.8774
Epoch 56/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3635 - accu
racy: 0.9003 - val_loss: 0.4224 - val_accuracy: 0.8779
Epoch 57/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3595 - accu
racy: 0.9011 - val_loss: 0.4208 - val_accuracy: 0.8780
Epoch 58/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3560 - accu
racy: 0.9018 - val_loss: 0.4175 - val_accuracy: 0.8804
Epoch 59/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3514 - accu
racy: 0.9031 - val_loss: 0.4167 - val_accuracy: 0.8803
Epoch 60/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3478 - accu
racy: 0.9044 - val_loss: 0.4137 - val_accuracy: 0.8810
```

```
Epoch 61/100
235/235 [==============================] - 2s 7ms/step - loss: 0.3441 - accu
racy: 0.9056 - val_loss: 0.4135 - val_accuracy: 0.8791
Epoch 62/100
235/235 [==============================] - 2s 6ms/step - loss: 0.3414 - accu
racy: 0.9058 - val_loss: 0.4095 - val_accuracy: 0.8821
Epoch 63/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3380 - accu
racy: 0.9068 - val_loss: 0.4084 - val_accuracy: 0.8823
Epoch 64/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3351 - accu
racy: 0.9075 - val_loss: 0.4064 - val_accuracy: 0.8835
Epoch 65/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3318 - accu
racy: 0.9082 - val_loss: 0.4031 - val_accuracy: 0.8845
Epoch 66/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3288 - accu
racy: 0.9090 - val_loss: 0.4009 - val_accuracy: 0.8856
Epoch 67/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3258 - accu
racy: 0.9100 - val_loss: 0.3985 - val_accuracy: 0.8853
Epoch 68/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3232 - accu
racy: 0.9108 - val_loss: 0.3980 - val_accuracy: 0.8851
Epoch 69/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3205 - accu
racy: 0.9111 - val_loss: 0.3946 - val_accuracy: 0.8870
Epoch 70/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3181 - accu
racy: 0.9118 - val_loss: 0.3933 - val_accuracy: 0.8872
Epoch 71/100
235/235 [==============================] - 2s 6ms/step - loss: 0.3159 - accu
racy: 0.9127 - val_loss: 0.3923 - val_accuracy: 0.8872
Epoch 72/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3130 - accu
racy: 0.9130 - val_loss: 0.3900 - val_accuracy: 0.8892
Epoch 73/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3103 - accu
racy: 0.9140 - val_loss: 0.3891 - val_accuracy: 0.8887
Epoch 74/100
235/235 [==============================] - 2s 6ms/step - loss: 0.3080 - accu
racy: 0.9146 - val_loss: 0.3879 - val_accuracy: 0.8883
Epoch 75/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3056 - accu
racy: 0.9154 - val_loss: 0.3879 - val_accuracy: 0.8883
Epoch 76/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3041 - accu
racy: 0.9152 - val_loss: 0.3858 - val_accuracy: 0.8894
Epoch 77/100
235/235 [==============================] - 1s 6ms/step - loss: 0.3023 - accu
racy: 0.9156 - val_loss: 0.3852 - val_accuracy: 0.8893
Epoch 78/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2999 - acc
uracy: 0.9164 - val_loss: 0.3842 - val_accuracy: 0.8885
Epoch 79/100
235/235 [==============================] - 2s 9ms/step - loss: 0.2973 - accu
racy: 0.9169 - val_loss: 0.3824 - val_accuracy: 0.8896
Epoch 80/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2956 - accu
racy: 0.9174 - val_loss: 0.3803 - val_accuracy: 0.8904
```

```
Epoch 81/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2928 - accu
racy: 0.9184 - val_loss: 0.3784 - val_accuracy: 0.8909
Epoch 82/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2911 - accu
racy: 0.9190 - val_loss: 0.3803 - val_accuracy: 0.8902
Epoch 83/100
235/235 [==============================] - 2s 6ms/step - loss: 0.2886 - accu
racy: 0.9199 - val_loss: 0.3791 - val_accuracy: 0.8903
Epoch 84/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2869 - accu
racy: 0.9196 - val_loss: 0.3777 - val_accuracy: 0.8900
Epoch 85/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2848 - accu
racy: 0.9206 - val_loss: 0.3758 - val_accuracy: 0.8913
Epoch 86/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2822 - accu
racy: 0.9214 - val_loss: 0.3748 - val_accuracy: 0.8921
Epoch 87/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2820 - accu
racy: 0.9216 - val_loss: 0.3742 - val_accuracy: 0.8926
Epoch 88/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2802 - accu
racy: 0.9223 - val_loss: 0.3735 - val_accuracy: 0.8916
Epoch 89/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2789 - accu
racy: 0.9224 - val_loss: 0.3746 - val_accuracy: 0.8916
Epoch 90/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2763 - accu
racy: 0.9234 - val_loss: 0.3730 - val_accuracy: 0.8921
Epoch 91/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2741 - accu
racy: 0.9242 - val_loss: 0.3716 - val_accuracy: 0.8932
Epoch 92/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2729 - accu
racy: 0.9243 - val_loss: 0.3717 - val_accuracy: 0.8916
Epoch 93/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2716 - accu
racy: 0.9246 - val_loss: 0.3679 - val_accuracy: 0.8929
Epoch 94/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2696 - accu
racy: 0.9250 - val_loss: 0.3689 - val_accuracy: 0.8935
Epoch 95/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2674 - accu
racy: 0.9257 - val_loss: 0.3681 - val_accuracy: 0.8936
Epoch 96/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2664 - accu
racy: 0.9260 - val_loss: 0.3676 - val_accuracy: 0.8937
Epoch 97/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2647 - accu
racy: 0.9262 - val_loss: 0.3674 - val_accuracy: 0.8928
Epoch 98/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2629 - accu
racy: 0.9271 - val_loss: 0.3661 - val_accuracy: 0.8934
Epoch 99/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2608 - accu
racy: 0.9278 - val_loss: 0.3656 - val_accuracy: 0.8947
Epoch 100/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2597 - accu
racy: 0.9282 - val_loss: 0.3658 - val_accuracy: 0.8953
```

Out[72]:
```
<keras.callbacks.History at 0x7f4eecb2ef10>
```

In [73]:
```
%tensorboard --logdir logs4_4
```

7.5 Learning Rate = 0.0005

In [74]:
```
tf.keras.backend.clear_session()

input_layer = Input(shape = (1024, ))
d = Dense(64, activation='sigmoid')(input_layer)
d = Dense(32, activation='sigmoid')(d)
d = Dense(16, activation='sigmoid')(d)
output_layer = Dense(10, activation='softmax', kernel_initializer='glorot_norma

model = Model(inputs = input_layer, outputs = output_layer)
model.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 1024)]            0

 dense (Dense)               (None, 64)                65600

 dense_1 (Dense)             (None, 32)                2080

 dense_2 (Dense)             (None, 16)                528

 dense_3 (Dense)             (None, 10)                170

=================================================================
Total params: 68,378
Trainable params: 68,378
Non-trainable params: 0
_________________________________________________________________
```

In [75]:
```
!mkdir model4_5
model_path = "model4_5/"
!rm -rf ./logs4_5/fit
```

In [76]:
```
model.compile(optimizer=Adam(learning_rate=0.0005), loss='categorical_crossenti
```

In [77]:
```
#Creating logs direcctory to store information about the fits
log_dir = "logs4_5/fit/" + datetime.now().strftime("%Y%m%d - %H%M%S")

tf.keras.utils.plot_model(model, to_file=model_path+'model.png', show_shapes=Tr

tbCallBack = TensorBoard(log_dir=log_dir, write_graph=True, write_grads=True, w

allCs = [tbCallBack, earlystop]

model.fit(x_train_tf,y_train,epochs=100, validation_data=validation_data, batch
```

```
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `Te
nsorBoard` Callback.
```

```
Epoch 1/100
235/235 [==============================] - 3s 9ms/step - loss: 2.1819 - accu
racy: 0.2271 - val_loss: 1.9485 - val_accuracy: 0.4572
Epoch 2/100
235/235 [==============================] - 2s 8ms/step - loss: 1.7044 - accu
racy: 0.6156 - val_loss: 1.4784 - val_accuracy: 0.6751
Epoch 3/100
235/235 [==============================] - 2s 8ms/step - loss: 1.3056 - accu
racy: 0.7178 - val_loss: 1.1520 - val_accuracy: 0.7514
Epoch 4/100
235/235 [==============================] - 2s 8ms/step - loss: 1.0424 - accu
racy: 0.7443 - val_loss: 0.9493 - val_accuracy: 0.7491
Epoch 5/100
235/235 [==============================] - 2s 8ms/step - loss: 0.8755 - accu
racy: 0.7620 - val_loss: 0.8189 - val_accuracy: 0.7788
Epoch 6/100
235/235 [==============================] - 2s 8ms/step - loss: 0.7667 - accu
racy: 0.7871 - val_loss: 0.7318 - val_accuracy: 0.8065
Epoch 7/100
235/235 [==============================] - 2s 8ms/step - loss: 0.6828 - accu
racy: 0.8227 - val_loss: 0.6499 - val_accuracy: 0.8409
Epoch 8/100
235/235 [==============================] - 2s 8ms/step - loss: 0.6114 - accu
racy: 0.8523 - val_loss: 0.5821 - val_accuracy: 0.8615
Epoch 9/100
235/235 [==============================] - 2s 8ms/step - loss: 0.5491 - accu
racy: 0.8648 - val_loss: 0.5295 - val_accuracy: 0.8650
Epoch 10/100
235/235 [==============================] - 2s 8ms/step - loss: 0.5002 - accu
racy: 0.8728 - val_loss: 0.4788 - val_accuracy: 0.8772
Epoch 11/100
235/235 [==============================] - 2s 8ms/step - loss: 0.4608 - accu
racy: 0.8801 - val_loss: 0.4544 - val_accuracy: 0.8793
Epoch 12/100
235/235 [==============================] - 2s 8ms/step - loss: 0.4332 - accu
racy: 0.8839 - val_loss: 0.4280 - val_accuracy: 0.8832
Epoch 13/100
235/235 [==============================] - 2s 8ms/step - loss: 0.4096 - accu
racy: 0.8893 - val_loss: 0.4116 - val_accuracy: 0.8861
Epoch 14/100
235/235 [==============================] - 2s 8ms/step - loss: 0.3934 - accu
racy: 0.8923 - val_loss: 0.3955 - val_accuracy: 0.8902
Epoch 15/100
235/235 [==============================] - 2s 8ms/step - loss: 0.3797 - accu
racy: 0.8957 - val_loss: 0.3854 - val_accuracy: 0.8943
Epoch 16/100
235/235 [==============================] - 2s 8ms/step - loss: 0.3643 - accu
racy: 0.9002 - val_loss: 0.3734 - val_accuracy: 0.8984
Epoch 17/100
235/235 [==============================] - 2s 8ms/step - loss: 0.3507 - accu
racy: 0.9022 - val_loss: 0.3709 - val_accuracy: 0.8966
Epoch 18/100
235/235 [==============================] - 2s 8ms/step - loss: 0.3435 - accu
racy: 0.9039 - val_loss: 0.3600 - val_accuracy: 0.8975
Epoch 19/100
235/235 [==============================] - 2s 8ms/step - loss: 0.3365 - accu
racy: 0.9049 - val_loss: 0.3571 - val_accuracy: 0.8999
Epoch 20/100
235/235 [==============================] - 2s 8ms/step - loss: 0.3270 - accu
racy: 0.9079 - val_loss: 0.3525 - val_accuracy: 0.8976
```

```
Epoch 21/100
235/235 [==============================] - 2s 8ms/step - loss: 0.3175 - accu
racy: 0.9101 - val_loss: 0.3409 - val_accuracy: 0.9016
Epoch 22/100
235/235 [==============================] - 2s 8ms/step - loss: 0.3136 - accu
racy: 0.9117 - val_loss: 0.3418 - val_accuracy: 0.9015
Epoch 23/100
235/235 [==============================] - 2s 8ms/step - loss: 0.3047 - accu
racy: 0.9138 - val_loss: 0.3341 - val_accuracy: 0.9042
Epoch 24/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2977 - accu
racy: 0.9154 - val_loss: 0.3297 - val_accuracy: 0.9051
Epoch 25/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2926 - accu
racy: 0.9169 - val_loss: 0.3220 - val_accuracy: 0.9060
Epoch 26/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2847 - accu
racy: 0.9189 - val_loss: 0.3140 - val_accuracy: 0.9096
Epoch 27/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2792 - accu
racy: 0.9200 - val_loss: 0.3126 - val_accuracy: 0.9121
Epoch 28/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2777 - accu
racy: 0.9205 - val_loss: 0.3091 - val_accuracy: 0.9106
Epoch 29/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2746 - accu
racy: 0.9220 - val_loss: 0.3040 - val_accuracy: 0.9121
Epoch 30/100
235/235 [==============================] - 1s 6ms/step - loss: 0.2703 - accu
racy: 0.9213 - val_loss: 0.3065 - val_accuracy: 0.9117
Epoch 31/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2623 - accu
racy: 0.9252 - val_loss: 0.3001 - val_accuracy: 0.9123
Epoch 32/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2602 - accu
racy: 0.9260 - val_loss: 0.2949 - val_accuracy: 0.9155
Epoch 33/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2541 - accu
racy: 0.9275 - val_loss: 0.2938 - val_accuracy: 0.9153
Epoch 34/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2520 - accu
racy: 0.9272 - val_loss: 0.2882 - val_accuracy: 0.9157
Epoch 35/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2473 - accu
racy: 0.9288 - val_loss: 0.2885 - val_accuracy: 0.9162
Epoch 36/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2419 - accu
racy: 0.9298 - val_loss: 0.2874 - val_accuracy: 0.9147
Epoch 37/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2407 - accu
racy: 0.9304 - val_loss: 0.2842 - val_accuracy: 0.9161
Epoch 38/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2365 - accu
racy: 0.9311 - val_loss: 0.2836 - val_accuracy: 0.9182
Epoch 39/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2336 - accu
racy: 0.9323 - val_loss: 0.2837 - val_accuracy: 0.9174
Epoch 40/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2348 - accu
racy: 0.9317 - val_loss: 0.2799 - val_accuracy: 0.9185
```

```
Epoch 41/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2316 - accu
racy: 0.9324 - val_loss: 0.2827 - val_accuracy: 0.9181
Epoch 42/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2277 - accu
racy: 0.9338 - val_loss: 0.2816 - val_accuracy: 0.9175
Epoch 43/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2240 - accu
racy: 0.9345 - val_loss: 0.2765 - val_accuracy: 0.9196
Epoch 44/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2202 - accu
racy: 0.9357 - val_loss: 0.2726 - val_accuracy: 0.9235
Epoch 45/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2172 - accu
racy: 0.9367 - val_loss: 0.2750 - val_accuracy: 0.9192
Epoch 46/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2158 - accu
racy: 0.9369 - val_loss: 0.2723 - val_accuracy: 0.9203
Epoch 47/100
235/235 [==============================] - 2s 7ms/step - loss: 0.2134 - accu
racy: 0.9382 - val_loss: 0.2769 - val_accuracy: 0.9204
Epoch 48/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2112 - accu
racy: 0.9392 - val_loss: 0.2754 - val_accuracy: 0.9203
Epoch 49/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2097 - accu
racy: 0.9394 - val_loss: 0.2770 - val_accuracy: 0.9173
Epoch 50/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2084 - accu
racy: 0.9390 - val_loss: 0.2745 - val_accuracy: 0.9187
Epoch 51/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2057 - accu
racy: 0.9399 - val_loss: 0.2674 - val_accuracy: 0.9199
Epoch 52/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2059 - accu
racy: 0.9396 - val_loss: 0.2688 - val_accuracy: 0.9217
Epoch 53/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2040 - accu
racy: 0.9404 - val_loss: 0.2603 - val_accuracy: 0.9229
Epoch 54/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2006 - accu
racy: 0.9411 - val_loss: 0.2650 - val_accuracy: 0.9223
Epoch 55/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2009 - accu
racy: 0.9410 - val_loss: 0.2651 - val_accuracy: 0.9220
Epoch 56/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1974 - accu
racy: 0.9432 - val_loss: 0.2633 - val_accuracy: 0.9240
Epoch 57/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1963 - accu
racy: 0.9428 - val_loss: 0.2670 - val_accuracy: 0.9213
Epoch 58/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1949 - accu
racy: 0.9429 - val_loss: 0.2644 - val_accuracy: 0.9218
Epoch 59/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1934 - accu
racy: 0.9434 - val_loss: 0.2602 - val_accuracy: 0.9251
Epoch 60/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1943 - accu
racy: 0.9430 - val_loss: 0.2593 - val_accuracy: 0.9231
```

```
Epoch 61/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1927 - accu
racy: 0.9438 - val_loss: 0.2601 - val_accuracy: 0.9237
Epoch 62/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1942 - accu
racy: 0.9427 - val_loss: 0.2611 - val_accuracy: 0.9252
Epoch 63/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1893 - accu
racy: 0.9454 - val_loss: 0.2607 - val_accuracy: 0.9232
Epoch 64/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1900 - accu
racy: 0.9444 - val_loss: 0.2592 - val_accuracy: 0.9240
Epoch 65/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1904 - accu
racy: 0.9445 - val_loss: 0.2634 - val_accuracy: 0.9233
Epoch 66/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1878 - accu
racy: 0.9449 - val_loss: 0.2666 - val_accuracy: 0.9205
Epoch 67/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1870 - accu
racy: 0.9451 - val_loss: 0.2608 - val_accuracy: 0.9234
Epoch 68/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1842 - accu
racy: 0.9460 - val_loss: 0.2620 - val_accuracy: 0.9253
Epoch 69/100
235/235 [==============================] - 2s 9ms/step - loss: 0.1827 - accu
racy: 0.9461 - val_loss: 0.2647 - val_accuracy: 0.9245
Epoch 70/100
235/235 [==============================] - 3s 13ms/step - loss: 0.1819 - acc
uracy: 0.9461 - val_loss: 0.2571 - val_accuracy: 0.9247
Epoch 71/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1778 - acc
uracy: 0.9478 - val_loss: 0.2537 - val_accuracy: 0.9245
Epoch 72/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1793 - accu
racy: 0.9467 - val_loss: 0.2579 - val_accuracy: 0.9239
Epoch 73/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1770 - accu
racy: 0.9481 - val_loss: 0.2553 - val_accuracy: 0.9249
Epoch 74/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1743 - accu
racy: 0.9494 - val_loss: 0.2532 - val_accuracy: 0.9249
Epoch 75/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1738 - accu
racy: 0.9493 - val_loss: 0.2518 - val_accuracy: 0.9267
Epoch 76/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1723 - accu
racy: 0.9498 - val_loss: 0.2529 - val_accuracy: 0.9282
Epoch 77/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1717 - accu
racy: 0.9488 - val_loss: 0.2554 - val_accuracy: 0.9249
Epoch 78/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1698 - accu
racy: 0.9495 - val_loss: 0.2531 - val_accuracy: 0.9232
Epoch 79/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1727 - accu
racy: 0.9483 - val_loss: 0.2538 - val_accuracy: 0.9255
Epoch 80/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1714 - accu
racy: 0.9493 - val_loss: 0.2536 - val_accuracy: 0.9274
```

```
Epoch 81/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1692 - accu
racy: 0.9494 - val_loss: 0.2565 - val_accuracy: 0.9264
Epoch 82/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1680 - accu
racy: 0.9498 - val_loss: 0.2475 - val_accuracy: 0.9289
Epoch 83/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1675 - accu
racy: 0.9500 - val_loss: 0.2522 - val_accuracy: 0.9294
Epoch 84/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1682 - accu
racy: 0.9509 - val_loss: 0.2474 - val_accuracy: 0.9288
Epoch 85/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1626 - accu
racy: 0.9521 - val_loss: 0.2465 - val_accuracy: 0.9299
Epoch 86/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1633 - accu
racy: 0.9519 - val_loss: 0.2548 - val_accuracy: 0.9283
Epoch 87/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1622 - accu
racy: 0.9518 - val_loss: 0.2523 - val_accuracy: 0.9272
Epoch 88/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1604 - accu
racy: 0.9523 - val_loss: 0.2503 - val_accuracy: 0.9274
Epoch 89/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1617 - accu
racy: 0.9520 - val_loss: 0.2514 - val_accuracy: 0.9272
Epoch 90/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1591 - accu
racy: 0.9535 - val_loss: 0.2471 - val_accuracy: 0.9296
Epoch 91/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1614 - accu
racy: 0.9531 - val_loss: 0.2513 - val_accuracy: 0.9286
Epoch 92/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1582 - accu
racy: 0.9536 - val_loss: 0.2455 - val_accuracy: 0.9297
Epoch 93/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1560 - accu
racy: 0.9540 - val_loss: 0.2461 - val_accuracy: 0.9300
Epoch 94/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1573 - accu
racy: 0.9537 - val_loss: 0.2438 - val_accuracy: 0.9301
Epoch 95/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1553 - accu
racy: 0.9542 - val_loss: 0.2450 - val_accuracy: 0.9285
Epoch 96/100
235/235 [==============================] - 1s 6ms/step - loss: 0.1560 - accu
racy: 0.9546 - val_loss: 0.2371 - val_accuracy: 0.9303
Epoch 97/100
235/235 [==============================] - 1s 6ms/step - loss: 0.1547 - accu
racy: 0.9554 - val_loss: 0.2398 - val_accuracy: 0.9303
Epoch 98/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1527 - accu
racy: 0.9557 - val_loss: 0.2448 - val_accuracy: 0.9304
Epoch 99/100
235/235 [==============================] - 2s 7ms/step - loss: 0.1531 - accu
racy: 0.9552 - val_loss: 0.2472 - val_accuracy: 0.9296
Epoch 100/100
235/235 [==============================] - 2s 7ms/step - loss: 0.1505 - accu
racy: 0.9567 - val_loss: 0.2453 - val_accuracy: 0.9323
```

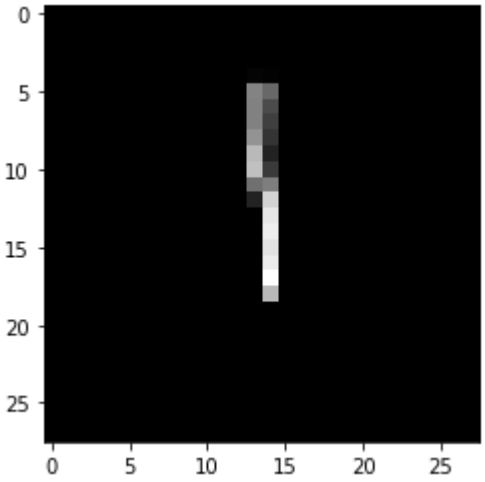
Out[77]:
```
<keras.callbacks.History at 0x7f4eeeaf08d0>
```

In [78]:
```
%tensorboard --logdir logs4_5/
```

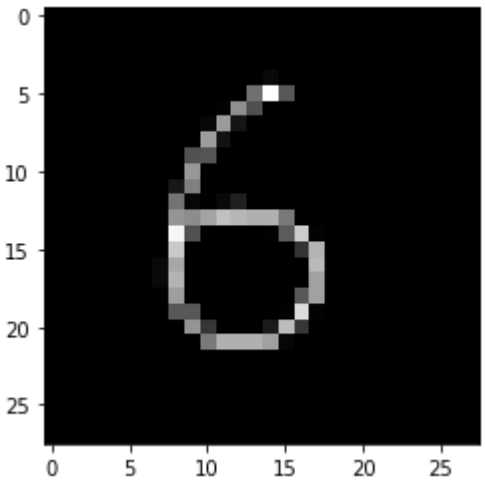
8. Classifying digits written in own handwriting:

In [80]:
```
import cv2
for i in range(1,6):
  img = cv2.imread(str(i)+'.jpg')
  img = img[:,:,2]
  img = cv2.resize(img, (28,28), interpolation = cv2.INTER_AREA)
  img = 255-img
  imgplot = plt.imshow(img, cmap = "gray")
  img = transform(img)
  img = np.expand_dims(img, axis=0)
  print(img.shape)
  pred = model.predict(img)
  print(np.argmax(pred))
  plt.show()
```

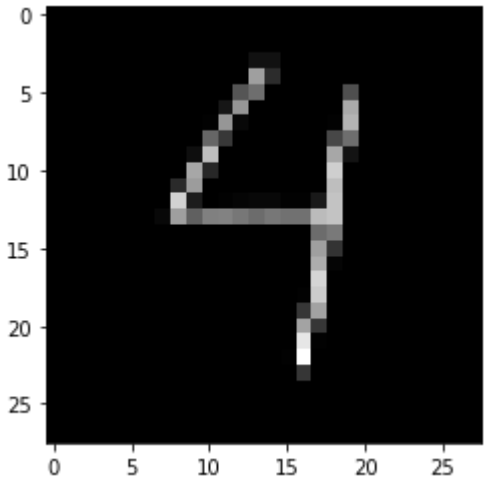
```
(1, 1024)
4
```



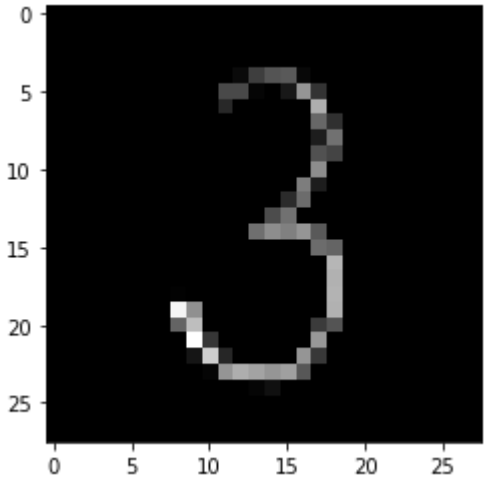

```
(1, 1024)
1
```



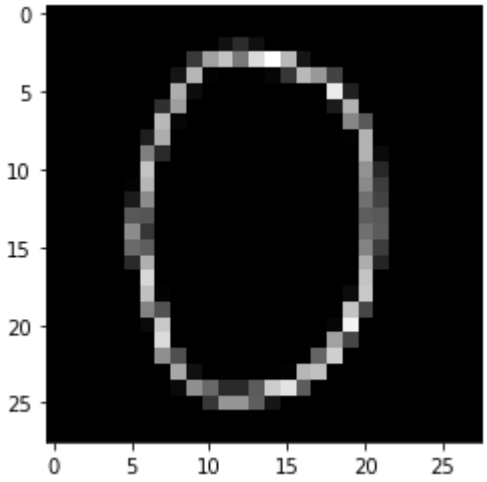
```
(1, 1024)
1
```



```
(1, 1024)
3
```



```
(1, 1024)
3
```



In [ ]: