DL Assignment 2

Name : Ankita Singh || Roll no: 57

Problem Statement: Classification using Deep neural network Multiclass classification using Deep Neural Networks: Example: Use the OCR letter recognition dataset https://archive.ics.uci.edu/ml/datasets/letter+recognition

In [1]:

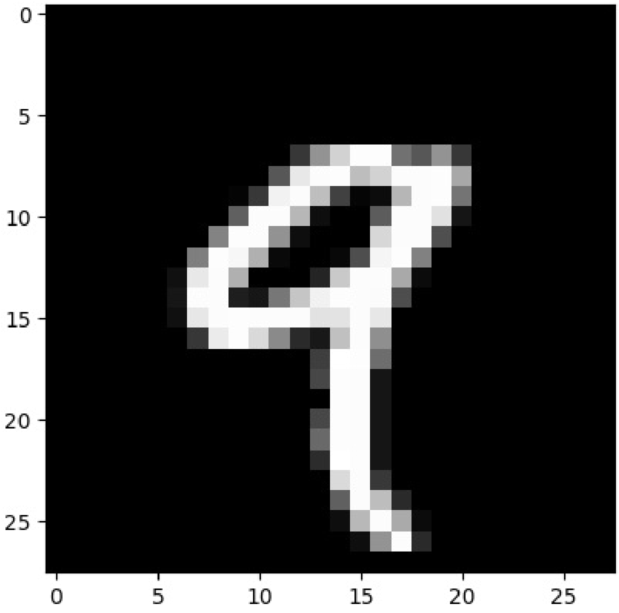
```
import numpy as np
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Dropout
from tensorflow.keras.optimizers import RMSprop
from tensorflow.keras.datasets import mnist
import matplotlib.pyplot as plt
from sklearn import metrics
```

In [2]:

```
(x_train, y_train), (x_test, y_test) = mnist.load_data()
```

In [3]:

```
plt.imshow(x_train[4], cmap='gray')
plt.show()
```



In [4]:

```
print(x_train[4])
```

```
[[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0  55 148 210 253 253 113
   87 148  55   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0  87 232 252 253 189 210 252
  252 253 168   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   4  57 242 252 190  65   5  12 182
  252 253 116   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0  96 252 252 183  14   0   0  92 252
  252 225  21   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0 132 253 252 146  14   0   0   0 215 252
  252  79   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0 126 253 247 176   9   0   0   8  78 245 253
  129   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0  16 232 252 176   0   0   0  36 201 252 252 169
   11   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0  22 252 252  30  22 119 197 241 253 252 251  77
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0  16 231 252 253 252 252 252 226 227 252 231   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0  55 235 253 217 138  42  24 192 252 143   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0  62 255 253 109   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0  71 253 252  21   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0 253 252  21   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0  71 253 252  21   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0 106 253 252  21   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0  45 255 253  21   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0 218 252  56   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0  96 252 189  42
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0  14 184 252 170
   11   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  14 147 252
   42   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]]
```

In [5]:

```
# Reshape the data to fit the model
print("X_train shape", x_train.shape)
print("y_train shape", y_train.shape)
print("X_test shape", x_test.shape)
print("y_test shape", y_test.shape)
```

```
X_train shape (60000, 28, 28)
y_train shape (60000,)
X_test shape (10000, 28, 28)
y_test shape (10000,)
```

In [6]:

```
x_train = x_train.reshape(60000, 784)
x_test = x_test.reshape(10000, 784)
x_train = x_train.astype('float32')
```

In [7]:

```
x_test = x_test.astype('float32')
x_train /= 255 # Each image has Intensity from 0 to 255
x_test /= 255
```

In [8]:

```
x_train[4]
```

Out[8]:

```
array([0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.21568628, 0.5803922 ,
0.8235294 , 0.99215686, 0.99215686, 0.44313726, 0.34117648,
0.5803922 , 0.21568628, 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.34117648, 0.9098039 , 0.9882353 , 0.99215686, 0.7411765 ,
0.8235294 , 0.9882353 , 0.9882353 , 0.99215686, 0.65882355,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.01568628, 0.22352941, 0.9490196 , 0.9882353 ,
0.74509805, 0.25490198, 0.01960784, 0.04705882, 0.7137255 ,
0.9882353 , 0.99215686, 0.45490196, 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.3764706 ,
0.9882353 , 0.9882353 , 0.7176471 , 0.05490196, 0.        ,
0.        , 0.36078432, 0.9882353 , 0.9882353 , 0.88235295,
0.08235294, 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.5176471 , 0.99215686, 0.9882353 , 0.57254905,
0.05490196, 0.        , 0.        , 0.        , 0.84313726,
0.9882353 , 0.9882353 , 0.30980393, 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.49411765, 0.99215686,
0.96862745, 0.6901961 , 0.03529412, 0.        , 0.        ,
0.03137255, 0.30588236, 0.9607843 , 0.99215686, 0.5058824 ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.0627451 , 0.9098039 , 0.9882353 , 0.6901961 , 0.        ,
0.        , 0.        , 0.14117648, 0.7882353 , 0.9882353 ,
0.9882353 , 0.6627451 , 0.04313726, 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.08627451, 0.9882353 ,
0.9882353 , 0.11764706, 0.08627451, 0.46666667, 0.77254903,
0.94509804, 0.99215686, 0.9882353 , 0.9843137 , 0.3019608 ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.0627451 , 0.90588236, 0.9882353 , 0.99215686,
0.9882353 , 0.9882353 , 0.9882353 , 0.8862745 , 0.8901961 ,
0.9882353 , 0.90588236, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.21568628, 0.92156863, 0.99215686, 0.8509804 , 0.5411765 ,
       0.16470589, 0.09411765, 0.7529412 , 0.9882353 , 0.56078434,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.24313726,
       1.        , 0.99215686, 0.42745098, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.2784314 , 0.99215686, 0.9882353 ,
       0.08235294, 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.99215686, 0.9882353 , 0.08235294, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.2784314 , 0.99215686,
       0.9882353 , 0.08235294, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.41568628, 0.99215686, 0.9882353 , 0.08235294,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.1764706 ,
       1.        , 0.99215686, 0.08235294, 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.85490197, 0.9882353 ,
       0.21960784, 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.3764706 , 0.9882353 , 0.7411765 , 0.16470589,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.05490196,
       0.72156864, 0.9882353 , 0.6666667 , 0.04313726, 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.05490196, 0.5764706 ,
       0.9882353 , 0.16470589, 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        ], dtype=float32)
```

In [9]:

```
# Convert class vectors to binary class matrices
num_classes = 10
y_train = np.eye(num_classes)[y_train]
y_test = np.eye(num_classes)[y_test]
```

In [10]:

```
# Define the model architecture
model = Sequential()
model.add(Dense(512, activation='relu', input_shape=(784,)))
model.add(Dropout(0.2))
model.add(Dense(512, activation='relu')) #returns a sequence of another vectors of dimension 512
model.add(Dropout(0.2))
model.add(Dense(num_classes, activation='softmax'))
```

In [11]:

```
model.compile(loss='categorical_crossentropy'
In [11]: model.compile(loss='categorical_crossentropy',
         optimizer=RMSprop(),
         metrics=['accuracy'])
```

```
In [12]: # Train the model
         batch_size = 128
         epochs = 15
         history = model.fit(x_train, y_train,
         batch_size=batch_size,
         epochs=epochs,
         verbose=1,
         validation_data=(x_test, y_test))
```

```
Epoch 1/15
469/469 [==============================] - 5s 9ms/step - loss: 0.2554 - accuracy: 0.9204 - val_loss: 0.1043 - va
l_accuracy: 0.9674
Epoch 2/15
469/469 [==============================] - 4s 9ms/step - loss: 0.1029 - accuracy: 0.9683 - val_loss: 0.0826 - va
l_accuracy: 0.9744
Epoch 3/15
469/469 [==============================] - 4s 9ms/step - loss: 0.0753 - accuracy: 0.9772 - val_loss: 0.0697 - va
l_accuracy: 0.9795
Epoch 4/15
469/469 [==============================] - 4s 9ms/step - loss: 0.0561 - accuracy: 0.9827 - val_loss: 0.0640 - va
l_accuracy: 0.9807
Epoch 5/15
469/469 [==============================] - 4s 9ms/step - loss: 0.0461 - accuracy: 0.9854 - val_loss: 0.0599 - va
l_accuracy: 0.9827
Epoch 6/15
469/469 [==============================] - 5s 10ms/step - loss: 0.0404 - accuracy: 0.9876 - val_loss: 0.0736 - v
al_accuracy: 0.9811
Epoch 7/15
469/469 [==============================] - 5s 11ms/step - loss: 0.0331 - accuracy: 0.9894 - val_loss: 0.0646 - v
al_accuracy: 0.9838
Epoch 8/15
469/469 [==============================] - 5s 11ms/step - loss: 0.0291 - accuracy: 0.9909 - val_loss: 0.0816 - v
al_accuracy: 0.9793
Epoch 9/15
469/469 [==============================] - 5s 11ms/step - loss: 0.0265 - accuracy: 0.9921 - val_loss: 0.0674 - v
al_accuracy: 0.9831
Epoch 10/15
469/469 [==============================] - 5s 11ms/step - loss: 0.0228 - accuracy: 0.9925 - val_loss: 0.0660 - v
al_accuracy: 0.9841
Epoch 11/15
469/469 [==============================] - 5s 11ms/step - loss: 0.0202 - accuracy: 0.9938 - val_loss: 0.0662 - v
al_accuracy: 0.9847
Epoch 12/15
469/469 [==============================] - 5s 11ms/step - loss: 0.0178 - accuracy: 0.9944 - val_loss: 0.0741 - v
al_accuracy: 0.9839
Epoch 13/15
469/469 [==============================] - 5s 11ms/step - loss: 0.0155 - accuracy: 0.9952 - val_loss: 0.0834 - v
al_accuracy: 0.9831
Epoch 14/15
469/469 [==============================] - 5s 11ms/step - loss: 0.0153 - accuracy: 0.9951 - val_loss: 0.0872 - v
al_accuracy: 0.9810
Epoch 15/15
469/469 [==============================] - 5s 11ms/step - loss: 0.0127 - accuracy: 0.9958 - val_loss: 0.0790 - v
al_accuracy: 0.9835
```

```
In [14]: # Evaluate the model
         score = model.evaluate(x_test, y_test, verbose=0)
         print('Test loss:', score[0])
         print('Test accuracy:', score[1])
```

```
Test loss: 0.07899940758943558
Test accuracy: 0.9835000038146973
```

```
In [20]: pred = model.predict(np.expand_dims(x_train[4], axis=0))
         print("Predicted Digit:", np.argmax(pred))
```

```
1/1 [==============================] - 0s 17ms/step
Predicted Digit: 9
```

Loading [MathJax]/jax/output/CommonHTML/fonts/TeX/fontdata.js