- **matplotlib. pyplot** is a collection of functions that make matplotlib work like MATLAB. Each pyplot function makes some change to a figure: e.g., creates a figure, creates a plotting area in a figure, plots some lines in a plotting area, decorates the plot with labels, etc.

- **OpenCV** is a great tool for image processing and performing computer vision tasks

- **NumPy** is a Python library used for working with arrays

- **Keras** is a high-level, deep learning API developed by Google for implementing neural networks. It is written in Python and is used to make the implementation of neural networks easy.

    - It is a tensor flow deep learning library to create a deep learning model for both regression and classification problems.
- **Sequential model:**

    - It allows us to create a deep learning model by adding layers to it. Here, every unit in a layer is connected to every unit in the previous layer.

In [1]:
```
import matplotlib.pyplot as plt
import cv2
import numpy as np
from keras.models import Sequential
from keras.layers import Dense, Flatten, Conv2D, MaxPool2D, Dropout
from tensorflow.keras.optimizers import SGD, Adam
from keras.callbacks import ReduceLROnPlateau, EarlyStopping
from tensorflow.keras.utils import to_categorical
import pandas as pd
import numpy as np
from sklearn.model_selection import train_test_split
from sklearn.utils import shuffle
```

In [2]:
```
data = pd.read_csv(r"A_Z Handwritten Characters Data.csv").astype('float32')

print(data.head(10))
```

```
     0  0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9  ...  0.639  0.640  0.641  \
0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  ...    0.0    0.0    0.0
1  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  ...    0.0    0.0    0.0
2  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  ...    0.0    0.0    0.0
3  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  ...    0.0    0.0    0.0
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
5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  ...    0.0    0.0    0.0
6  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  ...    0.0    0.0    0.0
7  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  ...    0.0    0.0    0.0
8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  ...    0.0    0.0    0.0
9  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  ...    0.0    0.0    0.0

   0.642  0.643  0.644  0.645  0.646  0.647  0.648
0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
1    0.0    0.0    0.0    0.0    0.0    0.0    0.0
2    0.0    0.0    0.0    0.0    0.0    0.0    0.0
3    0.0    0.0    0.0    0.0    0.0    0.0    0.0
4    0.0    0.0    0.0    0.0    0.0    0.0    0.0
5    0.0    0.0    0.0    0.0    0.0    0.0    0.0
6    0.0    0.0    0.0    0.0    0.0    0.0    0.0
7    0.0    0.0    0.0    0.0    0.0    0.0    0.0
8    0.0    0.0    0.0    0.0    0.0    0.0    0.0
9    0.0    0.0    0.0    0.0    0.0    0.0    0.0

[10 rows x 785 columns]
```

In [3]:
```
X = data.drop('0',axis = 1)
y = data['0']
```

In [4]:
```
train_x, test_x, train_y, test_y = train_test_split(X, y, test_size = 0.2)

train_x = np.reshape(train_x.values, (train_x.shape[0], 28,28))
test_x = np.reshape(test_x.values, (test_x.shape[0], 28,28))

print("Train data shape: ", train_x.shape)
print("Test data shape: ", test_x.shape)
```

```
Train data shape:  (297960, 28, 28)
Test data shape:  (74490, 28, 28)
```

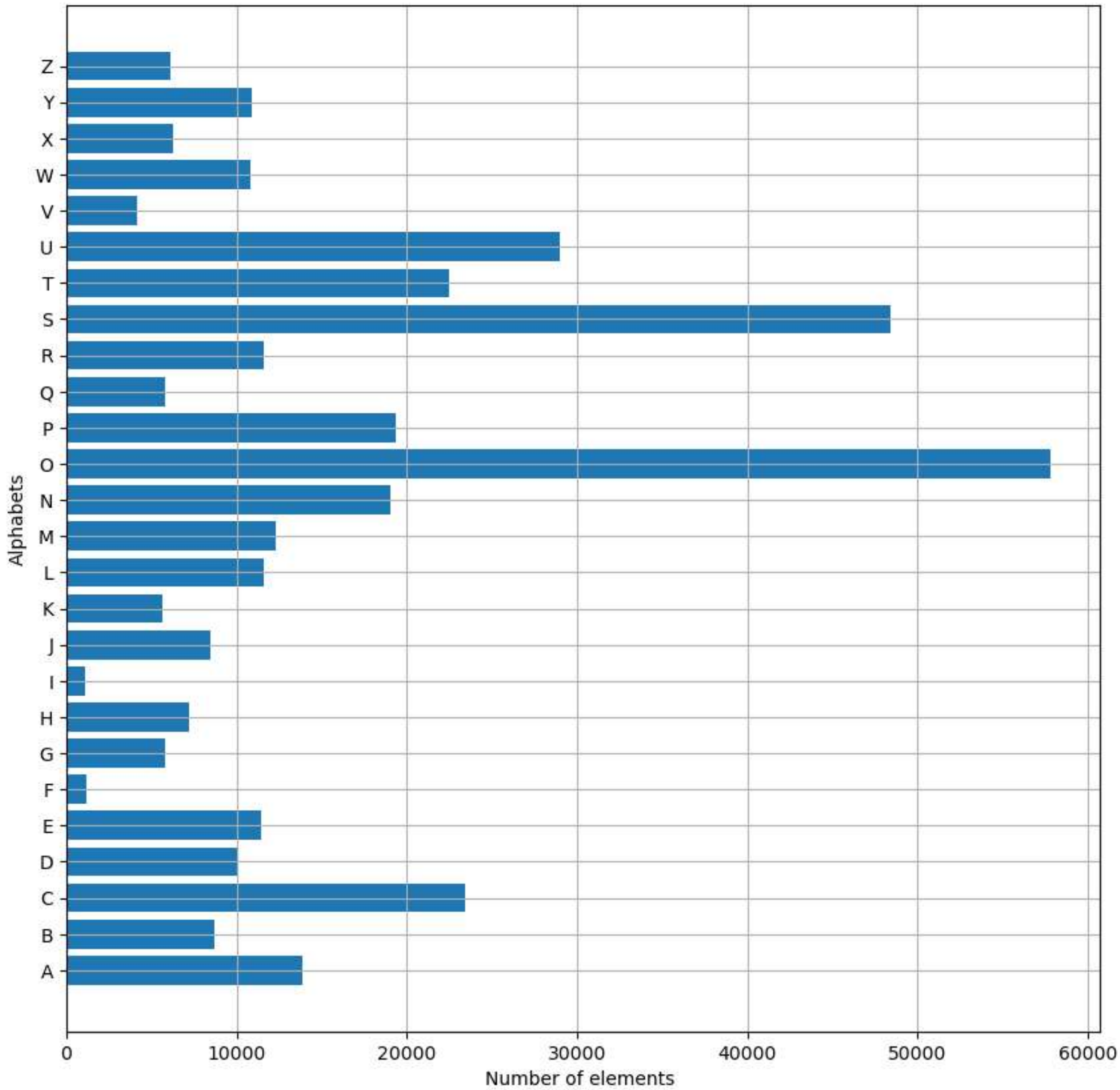
In [5]:
```
word_dict = {0:'A',1:'B',2:'C',3:'D',4:'E',5:'F',
             6:'G',7:'H',8:'I',9:'J',10:'K',11:'L',
             12:'M',13:'N',14:'O',15:'P',16:'Q',17:'R',
             18:'S',19:'T',20:'U',21:'V',22:'W',23:'X',
             24:'Y',25:'Z'}
```

In [6]:
```
y_int = np.int0(y)
count = np.zeros(26, dtype='int')
for i in y_int:
    count[i] +=1

alphabets = []
for i in word_dict.values():
    alphabets.append(i)

fig, ax = plt.subplots(1,1, figsize=(10,10))
ax.barh(alphabets, count)

plt.xlabel("Number of elements ")
plt.ylabel("Alphabets")
plt.grid()
plt.show()
```

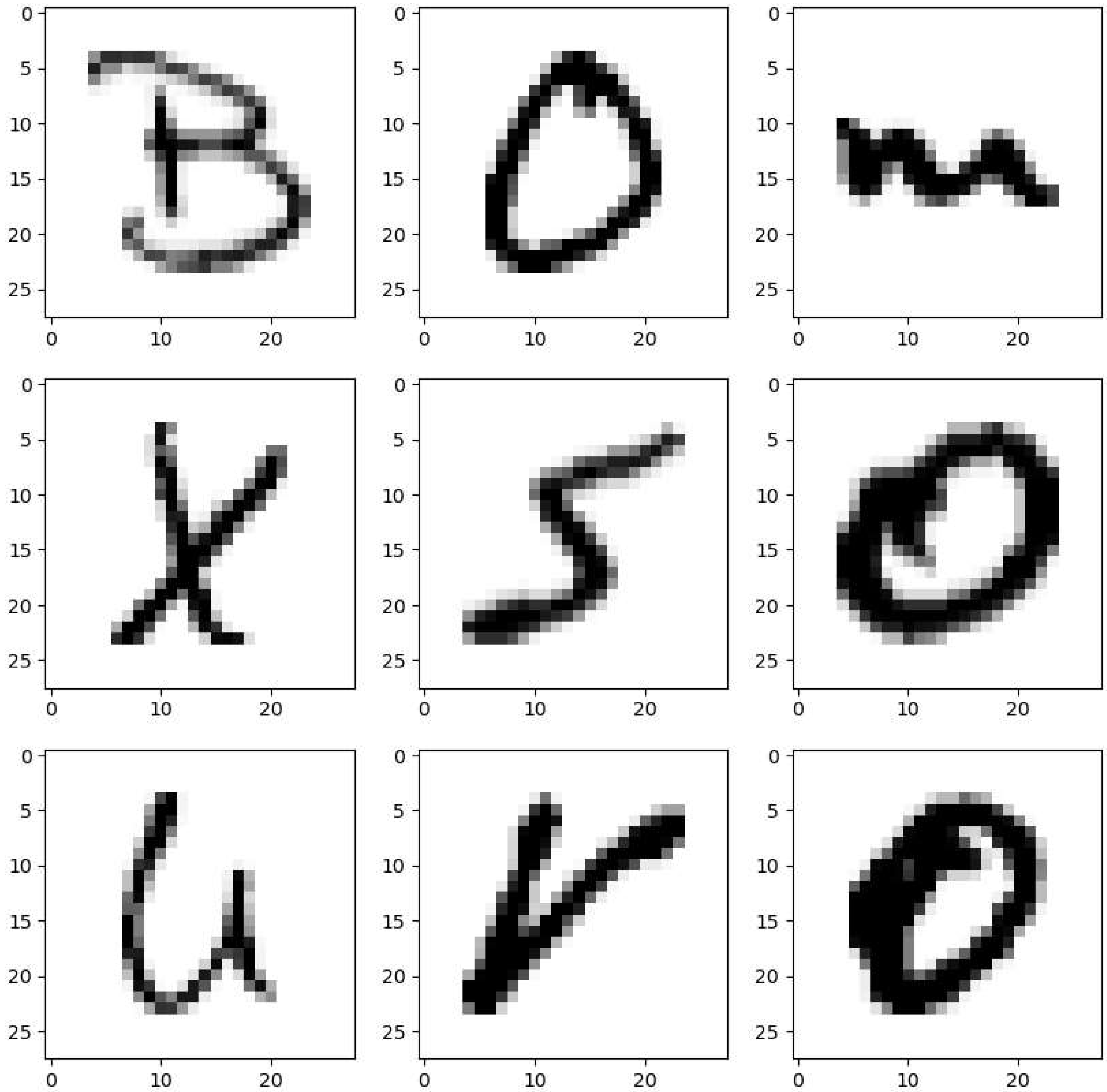


In [7]:

```
shuff = shuffle(train_x[:100])

fig, ax = plt.subplots(3,3, figsize = (10,10))
axes = ax.flatten()

for i in range(9):
    _, shu = cv2.threshold(shuff[i], 30, 200, cv2.THRESH_BINARY)
    axes[i].imshow(np.reshape(shuff[i], (28,28)), cmap="Greys")
plt.show()
```



In [8]:
```
train_X = train_x.reshape(train_x.shape[0],train_x.shape[1],train_x.shape[2],1)
print("New shape of train data: ", train_X.shape)

test_X = test_x.reshape(test_x.shape[0], test_x.shape[1], test_x.shape[2],1)
print("New shape of train data: ", test_X.shape)
```

```
New shape of train data:  (297960, 28, 28, 1)
New shape of train data:  (74490, 28, 28, 1)
```

In [9]:
```
train_yOHE = to_categorical(train_y, num_classes = 26, dtype='int')
print("New shape of train labels: ", train_yOHE.shape)

test_yOHE = to_categorical(test_y, num_classes = 26, dtype='int')
print("New shape of test labels: ", test_yOHE.shape)
```

```
New shape of train labels:  (297960, 26)
New shape of test labels:  (74490, 26)
```

In [10]:
```
model = Sequential()

model.add(Conv2D(filters=32, kernel_size=(3, 3), activation='relu', input_shape=(28
model.add(MaxPool2D(pool_size=(2, 2), strides=2))

model.add(Conv2D(filters=64, kernel_size=(3, 3), activation='relu', padding = 'same
model.add(MaxPool2D(pool_size=(2, 2), strides=2))

model.add(Conv2D(filters=128, kernel_size=(3, 3), activation='relu', padding = 'va
```

```python
model.add(MaxPool2D(pool_size=(2, 2), strides=2))

model.add(Flatten())

model.add(Dense(64,activation ="relu"))
model.add(Dense(128,activation ="relu"))

model.add(Dense(26,activation ="softmax"))
```

In [11]:
```python
model.compile(optimizer = Adam(learning_rate=0.001), loss='categorical_crossentropy

history = model.fit(train_X, train_yOHE, epochs=1,  validation_data = (test_X,test_
```

```
9312/9312 [==============================] - 222s 24ms/step - loss: 0.1548 - accur
acy: 0.9581 - val_loss: 0.0691 - val_accuracy: 0.9815
```

In [12]:
```python
model.summary()
model.save(r'model_hand.h5')
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 conv2d (Conv2D)             (None, 26, 26, 32)        320       
                                                                 
 max_pooling2d (MaxPooling2D  (None, 13, 13, 32)       0         
 )                                                               
                                                                 
 conv2d_1 (Conv2D)           (None, 13, 13, 64)        18496     
                                                                 
 max_pooling2d_1 (MaxPooling  (None, 6, 6, 64)         0         
 2D)                                                             
                                                                 
 conv2d_2 (Conv2D)           (None, 4, 4, 128)         73856     
                                                                 
 max_pooling2d_2 (MaxPooling  (None, 2, 2, 128)        0         
 2D)                                                             
                                                                 
 flatten (Flatten)           (None, 512)               0         
                                                                 
 dense (Dense)               (None, 64)                32832     
                                                                 
 dense_1 (Dense)             (None, 128)               8320      
                                                                 
 dense_2 (Dense)             (None, 26)                3354      
                                                                 
=================================================================
Total params: 137,178
Trainable params: 137,178
Non-trainable params: 0
_________________________________________________________________
```

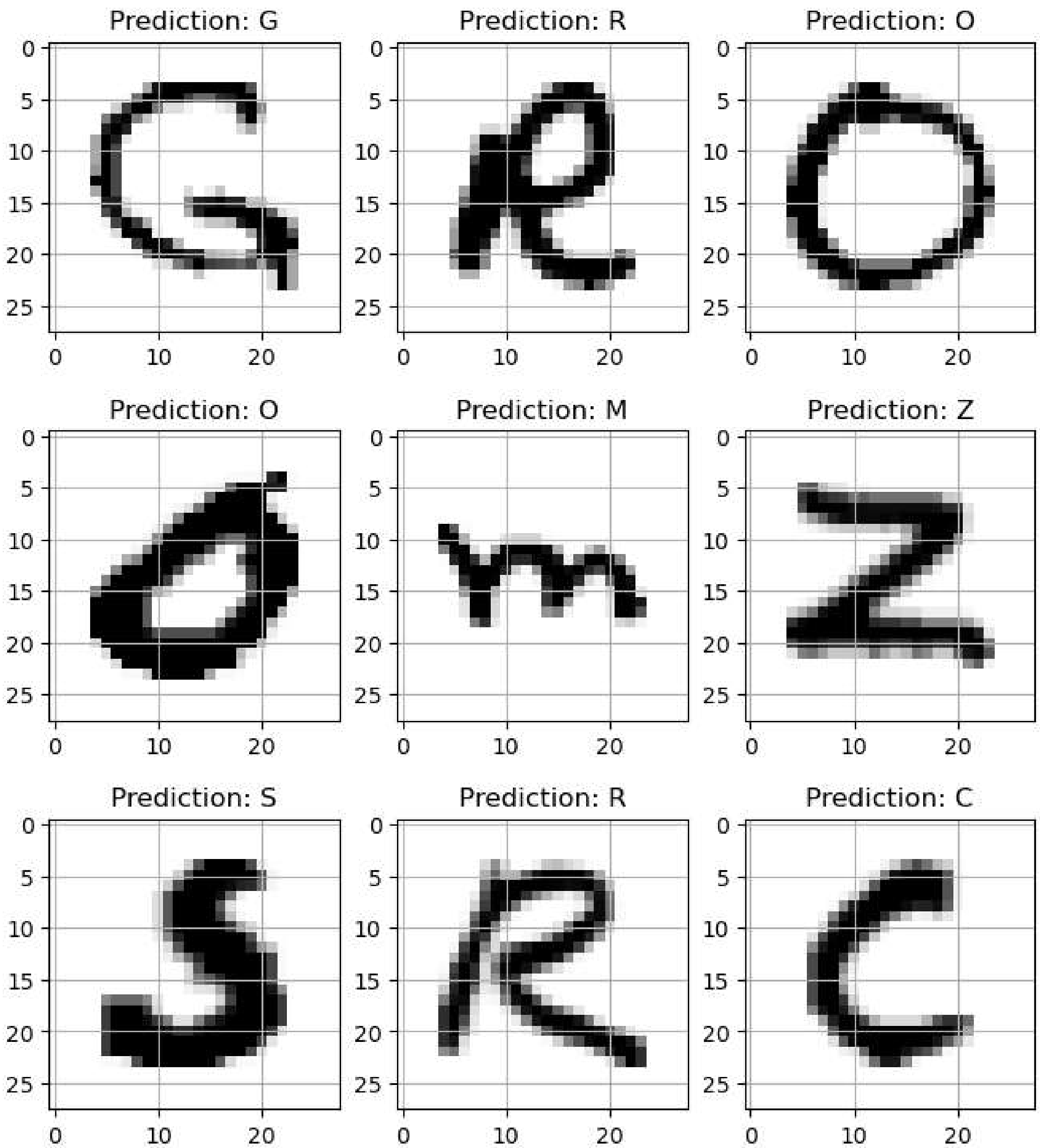
In [13]:
```python
print("The validation accuracy is :", history.history['val_accuracy'])
print("The training accuracy is :", history.history['accuracy'])
print("The validation loss is :", history.history['val_loss'])
print("The training loss is :", history.history['loss'])
```

```
The validation accuracy is : [0.9815142750740051]
The training accuracy is : [0.9580850005149841]
The validation loss is : [0.06907927989959717]
The training loss is : [0.15480975806713104]
```

In [14]:
```python
fig, axes = plt.subplots(3,3, figsize=(8,9))
axes = axes.flatten()
```

```
for i,ax in enumerate(axes):
    img = np.reshape(test_X[i], (28,28))
    ax.imshow(img, cmap="Greys")

    pred = word_dict[np.argmax(test_yOHE[i])]
    ax.set_title("Prediction: "+pred)
    ax.grid()
```



In [15]:
```
img = cv2.imread(r'D:\NIET\YEAR II\SEM IV\Mini Project\Images\img_a.jpg')
img_copy = img.copy()

img = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)
img = cv2.resize(img, (450,500))
```

In [16]:
```
img_copy = cv2.GaussianBlur(img_copy, (7,7), 0)
img_gray = cv2.cvtColor(img_copy, cv2.COLOR_BGR2GRAY)
_, img_thresh = cv2.threshold(img_gray, 100, 255, cv2.THRESH_BINARY_INV)

img_final = cv2.resize(img_thresh, (28,28))
img_final =np.reshape(img_final, (1,28,28,1))
```

In [17]:
```
img_pred = word_dict[np.argmax(model.predict(img_final))]

cv2.putText(img, "Image _ _ _ ", (20,25), cv2.FONT_HERSHEY_TRIPLEX, 0.7, color = ((
cv2.putText(img, "Prediction: " + img_pred, (20,410), cv2.FONT_HERSHEY_DUPLEX, 1.3
cv2.imshow('Characters(handwritten) Recognition _ _ _ ', img)
```

```
1/1 [==============================] - 0s 125ms/step
```

In [ ]:
```
while (1):
    k = cv2.waitKey(1) & 0xFF
    if k == 27:
        break
cv2.destroyAllWindows()
```

In [ ]:
```
```