In [1]:

```
import numpy as np
import matplotlib.pyplot as plt
from emnist import extract_training_samples, extract_test_samples
import tensorflow as tf
from tensorflow.keras import regularizers#type:ignore
from tensorflow.keras.models import Sequential#type:ignore
from tensorflow.keras.layers import Dense, Conv2D, MaxPooling2D, Flatten,BatchNormalizat
ion,Dropout#type:ignore
from tensorflow.keras.utils import to_categorical#type:ignore
from sklearn.metrics import classification_report, confusion_matrix, accuracy_score
from tensorflow.keras.preprocessing.image import ImageDataGenerator# type: ignore
import seaborn as sns
import pandas as pd
import cv2
```

In [2]:

```
train_images, train_labels = extract_training_samples('letters')
test_images, test_labels = extract_test_samples('letters')
```

In [3]:

```
train_images = train_images.reshape(train_images.shape[0], 28, 28, 1)
test_images = test_images.reshape(test_images.shape[0], 28, 28, 1)
```

In [4]:

```
train_images = train_images.astype('float32') / 255
test_images = test_images.astype('float32') / 255
```

In [5]:

```
train_labels = to_categorical(train_labels)
test_labels = to_categorical(test_labels)
```

In [6]:

```
print(f"Training data shape: {train_images.shape}")
print(f"Test data shape: {test_images.shape}")
```

```
Training data shape: (124800, 28, 28, 1)
Test data shape: (20800, 28, 28, 1)
```

In [7]:

```
datagen = ImageDataGenerator(
    rotation_range=9,
    width_shift_range=0.05,
    height_shift_range=0.05,
)

# Fit the generator to the data
datagen.fit(train_images)
```

In [8]:

```
test_datagen = ImageDataGenerator()
test_datagen.fit(test_images)
```

In [9]:

```
model = Sequential([
    MaxPooling2D(pool_size=(2, 2)),
    Conv2D(64, (3, 3), activation='relu',kernel_regularizer=regularizers.l2(0.0001)),
    BatchNormalization(),
    MaxPooling2D(pool_size=(2, 2)),
    Flatten(),
    Dense(128, activation='relu',kernel_regularizer=regularizers.l2(0.0001)),
    Dropout(0.5),
    Dense(27, activation='softmax',kernel_regularizer=regularizers.l2(0.0001))  # 26 letters + 1 extra class for indexing
])
```

In [10]:

```
model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
```

In [11]:

```
checkpoint_callback1 = tf.keras.callbacks.ModelCheckpoint(filepath='bestloss.keras', monitor='val_loss', save_best_only=True, verbose=1)
checkpoint_callback2 = tf.keras.callbacks.ModelCheckpoint(filepath='bestacc.keras', monitor='val_accuracy', save_best_only=True, verbose=1)
```

In [12]:

```
model.fit(datagen.flow(train_images,train_labels,batch_size=97), epochs=12,
          validation_data=test_datagen.flow(test_images,test_labels, batch_size=97),
          callbacks=[checkpoint_callback1,checkpoint_callback2])
```

```
Epoch 1/12
   1/1287 ━━━━━━━━━━━━━━━━━━━━ 33:32 2s/step - accuracy: 0.0619 - loss: 5.8728
```

```
c:\Users\Asus\AppData\Local\Programs\Python\Python312\Lib\site-packages\keras\src\trainers\data_adapters\py_dataset_adapter.py:121: UserWarning: Your `PyDataset` class should call `super().__init__(**kwargs)` in its constructor. `**kwargs` can include `workers`, `use_multiprocessing`, `max_queue_size`. Do not pass these arguments to `fit()`, as they will be ignored.
  self._warn_if_super_not_called()
```

```
1286/1287 ━━━━━━━━━━━━━━━━━━━━ 0s 27ms/step - accuracy: 0.6241 - loss: 1.3268
Epoch 1: val_loss improved from inf to 0.47263, saving model to bestloss.keras

Epoch 1: val_accuracy improved from -inf to 0.86543, saving model to bestacc.keras
1287/1287 ━━━━━━━━━━━━━━━━━━━━ 38s 28ms/step - accuracy: 0.6243 - loss: 1.3261 - val_accuracy: 0.8654 - val_loss: 0.4726
Epoch 2/12
1286/1287 ━━━━━━━━━━━━━━━━━━━━ 0s 28ms/step - accuracy: 0.8492 - loss: 0.5223
Epoch 2: val_loss improved from 0.47263 to 0.35365, saving model to bestloss.keras

Epoch 2: val_accuracy improved from 0.86543 to 0.90346, saving model to bestacc.keras
1287/1287 ━━━━━━━━━━━━━━━━━━━━ 37s 28ms/step - accuracy: 0.8493 - loss: 0.5222 - val_accuracy: 0.9035 - val_loss: 0.3537
Epoch 3/12
1285/1287 ━━━━━━━━━━━━━━━━━━━━ 0s 28ms/step - accuracy: 0.8716 - loss: 0.4615
Epoch 3: val_loss improved from 0.35365 to 0.31103, saving model to bestloss.keras

Epoch 3: val_accuracy improved from 0.90346 to 0.92010, saving model to bestacc.keras
1287/1287 ━━━━━━━━━━━━━━━━━━━━ 37s 29ms/step - accuracy: 0.8716 - loss: 0.4615 - val_accuracy: 0.9201 - val_loss: 0.3110
Epoch 4/12
1286/1287 ━━━━━━━━━━━━━━━━━━━━ 0s 27ms/step - accuracy: 0.8854 - loss: 0.4239
Epoch 4: val_loss improved from 0.31103 to 0.30158, saving model to bestloss.keras

Epoch 4: val_accuracy improved from 0.92010 to 0.92260, saving model to bestacc.keras
1287/1287 ━━━━━━━━━━━━━━━━━━━━ 36s 28ms/step - accuracy: 0.8854 - loss: 0.4239 - val_accuracy: 0.9226 - val_loss: 0.3016
Epoch 5/12
1287/1287 ━━━━━━━━━━━━━━━━━━━━ 0s 28ms/step - accuracy: 0.8911 - loss: 0.4064
Epoch 5: val_loss did not improve from 0.30158
Epoch 6/12
1286/1287 ━━━━━━━━━━━━━━━━━━━━ 0s 29ms/step - accuracy: 0.8986 - loss: 0.3821
Epoch 6: val_loss improved from 0.30158 to 0.28016, saving model to bestloss.keras

Epoch 6: val_accuracy improved from 0.92260 to 0.92904, saving model to bestacc.keras
1287/1287 ━━━━━━━━━━━━━━━━━━━━ 38s 30ms/step - accuracy: 0.8986 - loss: 0.3821 - val_accu
racy: 0.9290 - val_loss: 0.2802
Epoch 7/12
1287/1287 ━━━━━━━━━━━━━━━━━━━━ 0s 29ms/step - accuracy: 0.9023 - loss: 0.3658
Epoch 7: val_loss improved from 0.28016 to 0.27630, saving model to bestloss.keras

Epoch 7: val_accuracy improved from 0.92904 to 0.93034, saving model to bestacc.keras
1287/1287 ━━━━━━━━━━━━━━━━━━━━ 38s 30ms/step - accuracy: 0.9023 - loss: 0.3658 - val_accu
racy: 0.9303 - val_loss: 0.2763
Epoch 8/12
1285/1287 ━━━━━━━━━━━━━━━━━━━━ 0s 28ms/step - accuracy: 0.9052 - loss: 0.3559
Epoch 8: val_loss did not improve from 0.27630

Epoch 8: val_accuracy did not improve from 0.93034
1287/1287 ━━━━━━━━━━━━━━━━━━━━ 36s 28ms/step - accuracy: 0.9051 - loss: 0.3559 - val_accu
racy: 0.9273 - val_loss: 0.2940
Epoch 9/12
1286/1287 ━━━━━━━━━━━━━━━━━━━━ 0s 27ms/step - accuracy: 0.9066 - loss: 0.3514
Epoch 9: val_loss did not improve from 0.27630

Epoch 9: val_accuracy did not improve from 0.93034
1287/1287 ━━━━━━━━━━━━━━━━━━━━ 36s 28ms/step - accuracy: 0.9066 - loss: 0.3514 - val_accu
racy: 0.9232 - val_loss: 0.3011
Epoch 10/12
1286/1287 ━━━━━━━━━━━━━━━━━━━━ 0s 27ms/step - accuracy: 0.9090 - loss: 0.3453
Epoch 10: val_loss did not improve from 0.27630

Epoch 10: val_accuracy did not improve from 0.93034
1287/1287 ━━━━━━━━━━━━━━━━━━━━ 36s 28ms/step - accuracy: 0.9090 - loss: 0.3453 - val_accu
racy: 0.9278 - val_loss: 0.2894
Epoch 11/12
1287/1287 ━━━━━━━━━━━━━━━━━━━━ 0s 27ms/step - accuracy: 0.9116 - loss: 0.3361
Epoch 11: val_loss improved from 0.27630 to 0.25282, saving model to bestloss.keras

Epoch 11: val_accuracy improved from 0.93034 to 0.93808, saving model to bestacc.keras
1287/1287 ━━━━━━━━━━━━━━━━━━━━ 36s 28ms/step - accuracy: 0.9116 - loss: 0.3361 - val_accu
racy: 0.9381 - val_loss: 0.2528
Epoch 12/12
1287/1287 ━━━━━━━━━━━━━━━━━━━━ 0s 27ms/step - accuracy: 0.9133 - loss: 0.3336
Epoch 12: val_loss did not improve from 0.25282

Epoch 12: val_accuracy did not improve from 0.93808
1287/1287 ━━━━━━━━━━━━━━━━━━━━ 36s 28ms/step - accuracy: 0.9133 - loss: 0.3336 - val_accu
racy: 0.9367 - val_loss: 0.2569
```

Out[12]:

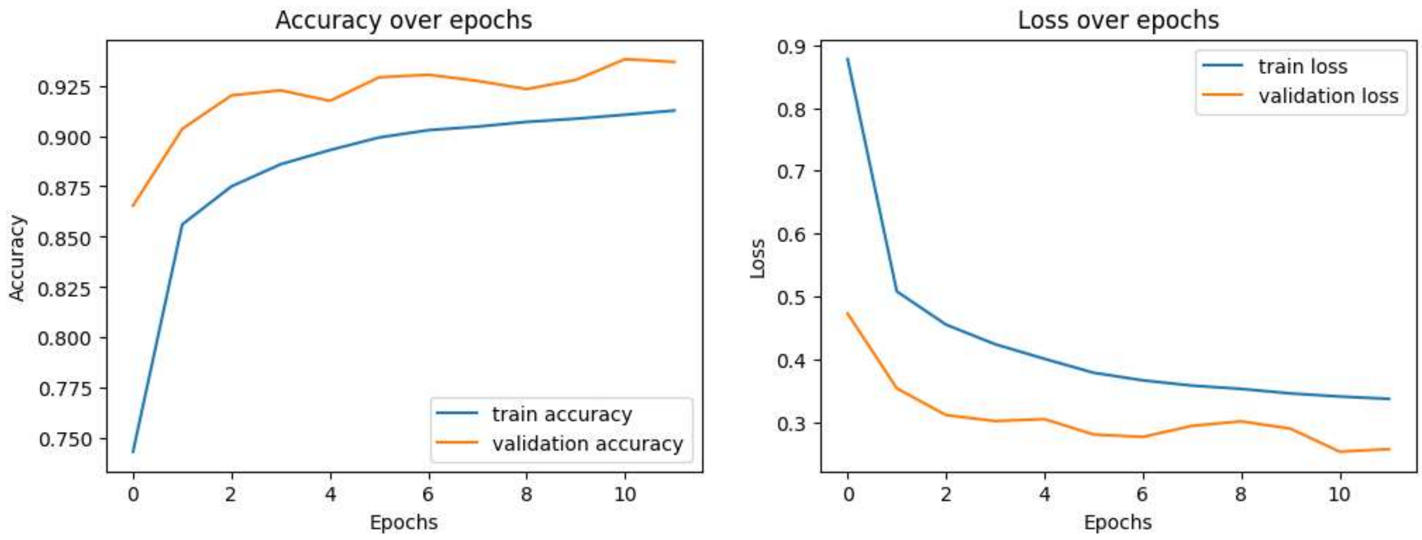
```
<keras.src.callbacks.history.History at 0x23a6446b050>
```

In [13]:

```python
plt.figure(figsize=(12, 4))
plt.subplot(1, 2, 1)
plt.plot(model.history.history['accuracy'], label='train accuracy')
plt.plot(model.history.history['val_accuracy'], label='validation accuracy')
plt.title('Accuracy over epochs')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()

# Plot loss over epochs
plt.subplot(1, 2, 2)
plt.plot(model.history.history['loss'], label='train loss')
plt.plot(model.history.history['val_loss'], label='validation loss')
plt.legend()

plt.show()
```



In [14]:

```
y_pred = model.predict(test_images)
y_pred_classes = np.argmax(y_pred, axis=1)
y_true = np.argmax(test_labels, axis=1)
```

```
650/650 ━━━━━━━━━━━━━━━━━━━━ 1s 2ms/step
```

In [15]:

```
accuracy = accuracy_score(y_true, y_pred_classes)
print(f"Test Accuracy: {accuracy:}")
```

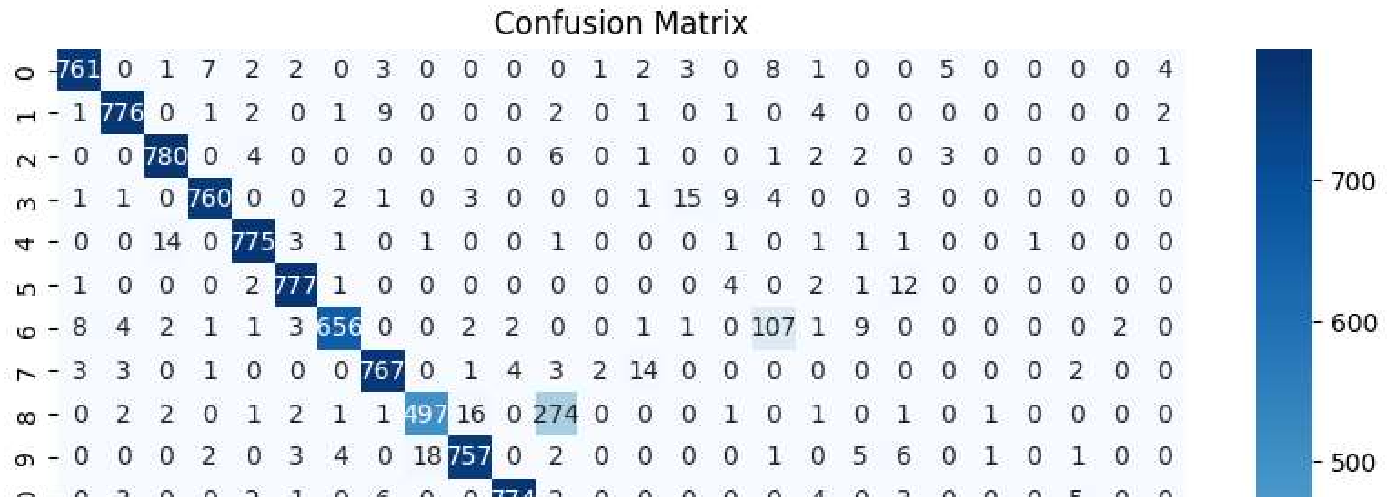
```
Test Accuracy: 0.9366826923076923
```

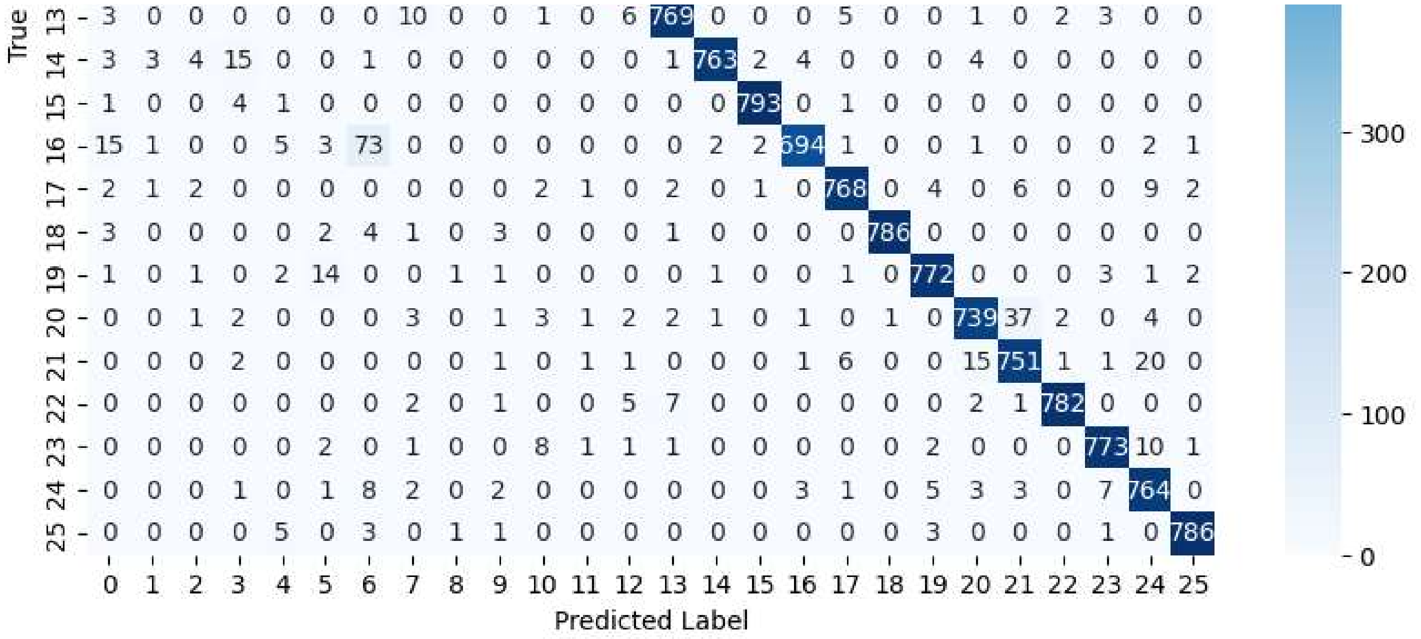
In [16]:

```
model.save("acc0933lo0273.keras")
```

In [17]:

```
conf_matrix = confusion_matrix(y_true, y_pred_classes)
plt.figure(figsize=(10, 8))
sns.heatmap(pd.DataFrame(conf_matrix), annot=True, fmt="g", cmap='Blues')
plt.title('Confusion Matrix')
plt.ylabel('True Label')
plt.xlabel('Predicted Label')
plt.show()
```





In [18]:

```
class_report = classification_report(y_true, y_pred_classes)
print("Classification Report:")
print(class_report)
```

```
Classification Report:
              precision    recall  f1-score   support

           1       0.95      0.95      0.95       800
           2       0.98      0.97      0.97       800
           3       0.96      0.97      0.97       800
           4       0.95      0.95      0.95       800
           5       0.97      0.97      0.97       800
           6       0.96      0.97      0.96       800
           7       0.87      0.82      0.84       800
           8       0.94      0.96      0.95       800
           9       0.80      0.62      0.70       800
          10       0.96      0.95      0.95       800
          11       0.97      0.97      0.97       800
          12       0.70      0.84      0.76       800
          13       0.98      0.99      0.98       800
          14       0.96      0.96      0.96       800
          15       0.97      0.95      0.96       800
          16       0.97      0.99      0.98       800
          17       0.84      0.87      0.85       800
          18       0.96      0.96      0.96       800
          19       0.98      0.98      0.98       800
          20       0.95      0.96      0.96       800
          21       0.96      0.92      0.94       800
          22       0.94      0.94      0.94       800
          23       0.99      0.98      0.98       800
          24       0.97      0.97      0.97       800
          25       0.94      0.95      0.95       800
          26       0.98      0.98      0.98       800

    accuracy                           0.94     20800
   macro avg       0.94      0.94      0.94     20800
weighted avg       0.94      0.94      0.94     20800
```

In [19]:

```
def preprocess_image(img):
    """Preprocess the input image to the required format (28x28, grayscale)."""
    img = cv2.resize(img, (28, 28))   # Resize the image to 28x28 pixels
```

In [20]:

```
def segment_characters(word_image):
    """Segment the word image into individual character images."""
    # Convert to grayscale and apply binary threshold
    gray = cv2.cvtColor(word_image, cv2.COLOR_BGR2GRAY)
    _, binary_img = cv2.threshold(gray, 128, 255, cv2.THRESH_BINARY_INV)

    # Apply dilation to separate characters more clearly
    kernel = np.ones((2, 2), np.uint8)
    dilated = cv2.dilate(binary_img, kernel, iterations=1)

    # Find contours in the image
    contours, _ = cv2.findContours(dilated, cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_SIMPLE)

    # Sort contours left-to-right (based on x-coordinate)
    contours = sorted(contours, key=lambda ctr: cv2.boundingRect(ctr)[0])

    char_images = []

    # Extract individual character images from contours
    for ctr in contours:
        x, y, w, h = cv2.boundingRect(ctr)
        # Filter out noise or very small contours by setting a minimum size
        if w > 4 and h > 6:  # Adjust these values based on the character sizes
            char_img = binary_img[y:y+h, x:x+w]
            char_img = preprocess_image(char_img)  # Preprocess individual character
            char_images.append(char_img)

    return char_images
```

In [21]:

```
def predict_word(model, word_image):
    """Predicts the characters in a word image by segmenting the characters first."""
    char_images = segment_characters(word_image)
    predicted_chars = [np.argmax(model.predict(img.reshape(1, 28, 28, 1)), axis=-1)[0] f
or img in char_images]
    # Convert numerical predictions back to characters (1: 'A', 26: 'Z')
    return ''.join([chr(65 + pred - 1) for pred in predicted_chars])
```

In [22]:

```
#model = load_model('path_to_your_model.h5')
```

In [23]:

```
word_image = cv2.imread('a.jpg')
```

In [24]:

```
predicted_word = predict_word(model, word_image)
print("Predicted Word:", predicted_word)
```

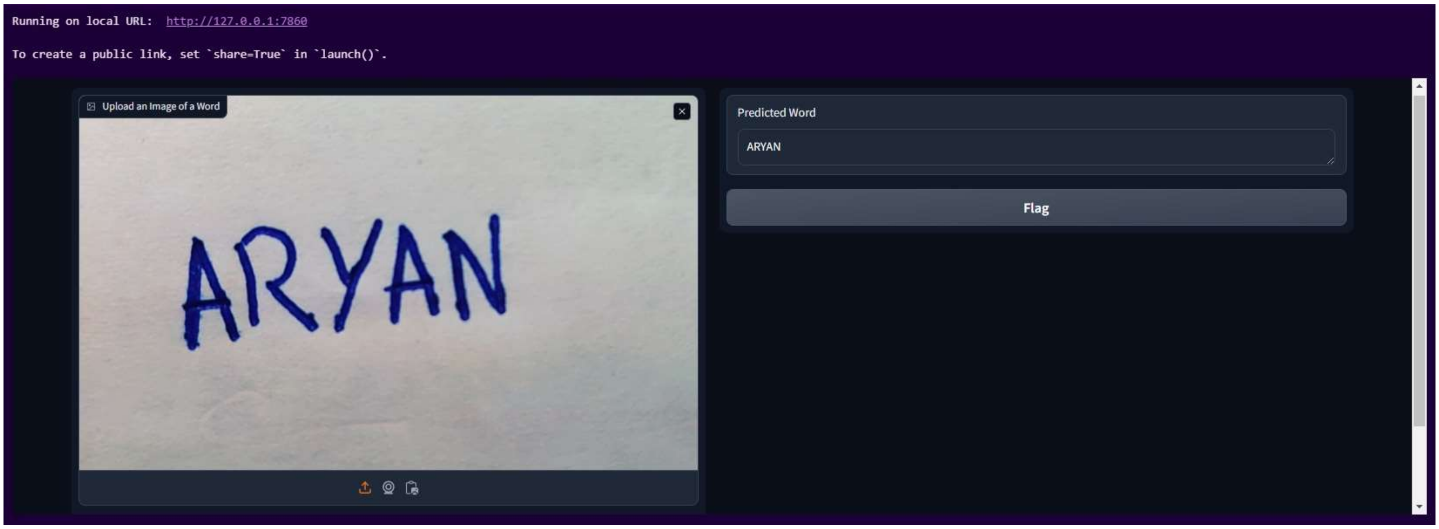
```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 65ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 15ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 15ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 16ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 26ms/step
Predicted Word: ARYAN
```

In [25]:

```
def predict_from_image(word_image):
    """Wrapper function to take an input image and return the predicted word."""
    predicted_word = predict_word(model, word_image)
    return predicted_word
```

```
import gradio as gr
interface = gr.Interface(fn=predict_from_image,
                         inputs=gr.Image(type="numpy", label="Upload an Image of a Word"
),
                         outputs=gr.Textbox(label="Predicted Word"))

# Launch the Gradio app
interface.launch()
```



```
Running on local URL:  http://127.0.0.1:7860

To create a public link, set `share=True` in `launch()`.
```

Predicted Word: ARYAN