CNN Model

Step-1 Loading Dataset from zip file

```
from google.colab import drive
drive.mount('/content/drive')
```

```
Drive already mounted at /content/drive; to attempt to forcibly remount, call drive.mount("/content/drive", force_remoun
```

```
import zipfile
import os

zip_path = "/content/drive/MyDrive/signatures.zip"
extract_to = "/content/signs_dataset"

# Extract only if not already done
if not os.path.exists(extract_to):
    with zipfile.ZipFile(zip_path, 'r') as zip_ref:
        zip_ref.extractall(extract_to)

print("Extracted successfully to:", extract_to)
```

```
Extracted successfully to: /content/signs_dataset
```

```
Start coding or generate with AI.
```

Step-2 Implementiing Preprocessing techniques for CNN model

i)Remove Lines

```
import cv2
import numpy as np
from google.colab.patches import cv2_imshow

def remove_borders(img):

  #gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)

  # Threshold
  thresh = cv2.threshold(img, 0, 255, cv2.THRESH_BINARY_INV + cv2.THRESH_OTSU)[1]

  # Detect horizontal lines
  horizontal_kernel = cv2.getStructuringElement(cv2.MORPH_RECT, (40, 1))
  detect_horizontal = cv2.morphologyEx(thresh, cv2.MORPH_OPEN, horizontal_kernel, iterations=2)

  # Detect vertical lines
  vertical_kernel = cv2.getStructuringElement(cv2.MORPH_RECT, (1, 40))
  detect_vertical = cv2.morphologyEx(thresh, cv2.MORPH_OPEN, vertical_kernel, iterations=2)

  # Combine line masks
  lines = cv2.add(detect_horizontal, detect_vertical)

  # Inpaint to remove lines
  result = cv2.inpaint(img, lines, 3, cv2.INPAINT_TELEA)

  # Save output
  cv2.imwrite("output_no_lines.png", result)

  return result
```

ii) Binarization and Noise Removal

```
import numpy as np
import cv2

def binarize_and_denoise(image):
    # Apply a Gaussian blur to remove noise
    denoised_image = cv2.GaussianBlur(image, (5, 5), 0)

    # Use Otsu's thresholding to binarize the image
    _, binarized_image = cv2.threshold(denoised_image, 0, 255, cv2.THRESH_BINARY + cv2.THRESH_OTSU)
```

```
    # Invert the image if needed (to have the signature in white on a black background)
    # The paper's feature extraction might work better with this format
    inverted_image = cv2.bitwise_not(binarized_image)

    return inverted_image
```

iii) Scaling

```
def scale_signature(image):
    """
    Scale down signature if it occupies more than 80% of the image width.
    After scaling, center it on a canvas of original size to avoid cropping.
    """
    contours, _ = cv2.findContours(image.copy(), cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_SIMPLE)
    if not contours:
        return image

    largest_contour = max(contours, key=cv2.contourArea)
    x, y, w, h = cv2.boundingRect(largest_contour)

    if w > image.shape[1] * 0.6 or h > image.shape[0] * 0.6:
        scale_factor = 1 / math.sqrt(2)
        scaled_w = int(image.shape[1] * scale_factor)
        scaled_h = int(image.shape[0] * scale_factor)

        # Resize the image
        scaled = cv2.resize(image, (scaled_w, scaled_h), interpolation=cv2.INTER_AREA)

        # Create a blank canvas of original size
        canvas = np.zeros_like(image) * 255

        # Compute top-left corner to center the scaled image
        start_x = (canvas.shape[1] - scaled_w) // 2
        start_y = (canvas.shape[0] - scaled_h) // 2

        # Place the scaled image onto the canvas
        canvas[start_y:start_y+scaled_h, start_x:start_x+scaled_w] = scaled
        return canvas

    return image
```

iv) Centralization

```
import cv2
import numpy as np

def center_signature(image):
    # Find contours
    contours, _ = cv2.findContours(image.copy(), cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_SIMPLE)
    if not contours:
        return image

    # Sort contours by area (largest first)
    contours = sorted(contours, key=cv2.contourArea, reverse=True)

    # Take top 3 largest contours
    top_contours = contours[:2]

    # Combine them into one mask
    mask = np.zeros_like(image)
    cv2.drawContours(mask, top_contours, -1, (255), thickness=cv2.FILLED)

    # Get bounding box of combined contours
    x, y, w, h = cv2.boundingRect(mask)

    # Create new blank canvas
    canvas = np.zeros_like(image) * 255

    # Center coordinates
    center_x = image.shape[1] // 2
    center_y = image.shape[0] // 2

    # Calculate new top-left corner for centering
    new_x = center_x - w // 2
    new_y = center_y - h // 2

    # Place the combined contour area on the centered canvas
    canvas[new_y:new_y+h, new_x:new_x+w] = image[y:y+h, x:x+w]
```

```
    return canvas
```

v) Rotation

```
import cv2
import numpy as np

def rotate_signature(image, angle_threshold=5):
    """
    Rotate signatures to horizontal without flipping upside down.
    Works for both tilted and vertical cases.
    """
    contours, _ = cv2.findContours(image.copy(), cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_SIMPLE)
    if not contours:
        return image

    # Filter out very thin/long contours
    contours = [c for c in contours if cv2.boundingRect(c)[2] > 5 and cv2.boundingRect(c)[3] > 5]
    if not contours:
        return image

    # Get largest contour
    largest_contour = max(contours, key=cv2.contourArea)
    pts = largest_contour.reshape(-1, 2).astype(np.float32)

    # PCA to find main orientation
    mean, eigenvectors = cv2.PCACompute(pts, mean=None)[:2]
    angle = np.degrees(np.arctan2(eigenvectors[0,1], eigenvectors[0,0]))

    # Skip tiny rotations
    if abs(angle) < angle_threshold:
        return image

    # Normalize angle to (-90, 90)
    if angle < -90:
        angle += 180
    elif angle > 90:
        angle -= 180

    # Rotate image
    (h, w) = image.shape[:2]
    center = (w // 2, h // 2)
    M = cv2.getRotationMatrix2D(center, angle, 1.0)
    rotated = cv2.warpAffine(image, M, (w, h), flags=cv2.INTER_LINEAR, borderValue=0)

    return rotated



import cv2
import math
import matplotlib.pyplot as plt

# Load image
img_path = "/content/signs_dataset/signatures/029/09201092.png"
img = cv2.imread(img_path, cv2.IMREAD_GRAYSCALE)

# Process steps
border_removed = remove_borders(img)
binarized_img = binarize_and_denoise(border_removed)
scaled_img = scale_signature(binarized_img)
centered_img = center_signature(scaled_img)
rotated_img = rotate_signature(centered_img)

# List of images and titles
images = [img,border_removed, binarized_img,scaled_img, centered_img, rotated_img]
titles = ["Original", "No Border", "Binarized","Scaled", "Centered", "Rotated"]

# Plot in horizontal line
plt.figure(figsize=(10, 4))
for i, (image, title) in enumerate(zip(images, titles)):
    plt.subplot(1, len(images), i+1)
    plt.imshow(image, cmap='gray')
    plt.title(title, fontsize=10)
    plt.axis("off")
plt.tight_layout()
plt.show()
```

Step - 3 Aligning all preprocessing steps

```
import cv2
import numpy as np

def preprocess_pipeline(image_path, target_size=(100, 100)):
    # Load image in grayscale
    image = cv2.imread(image_path, cv2.IMREAD_GRAYSCALE)
    if image is None: return np.zeros(target_size, dtype=np.uint8)

    # Apply preprocessing steps
    image = remove_borders(image)
    image = binarize_and_denoise(image)
    image = scale_signature(image)
    image = center_signature(image)
    image = rotate_signature(image)

    # Final binarization and inversion (as a safety measure)
    #_, binary_final = cv2.threshold(image, 128, 255, cv2.THRESH_BINARY_INV)

    # Resize to target size after all other preprocessing
    final_image = cv2.resize(image, target_size, interpolation=cv2.INTER_AREA)


    return final_image
```

Step-4 Creating Dataset Class

```
import torch
from torch.utils.data import Dataset
import cv2
import numpy as np
import os
import glob


import torch
from torch.utils.data import Dataset
import cv2
import numpy as np

# Make sure all your preprocessing functions (preprocess_pipeline, remove_noise, etc.)
# are defined and available in your notebook environment.

class SignatureDataset(Dataset):
    def __init__(self, image_paths, signer_ids, is_genuine_labels):
        self.image_paths = image_paths
        self.signer_ids = signer_ids
        self.is_genuine_labels = is_genuine_labels

        # Create a mapping for signer IDs to integer indices
        unique_signer_ids = sorted(list(set(signer_ids)))
        self.signer_id_map = {name: i for i, name in enumerate(unique_signer_ids)}

    def __len__(self):
        return len(self.image_paths)

    def __getitem__(self, idx):
        img_path = self.image_paths[idx]

        # Load image and apply the full preprocessing pipeline
        # (This assumes preprocess_pipeline is a single function that
        # orchestrates your other preprocessing functions)
        image = preprocess_pipeline(img_path)

        # Convert to float, normalize, and add a channel dimension
        image = image.astype(np.float32) / 255.0
        image = np.expand_dims(image, axis=0) # PyTorch expects [C, H, W]

        # Convert to a PyTorch tensor
        image_tensor = torch.from_numpy(image)

        # Get labels and convert to PyTorch tensors
```

```
        signer_id_label = self.signer_id_map[self.signer_ids[idx]]
        signer_id_tensor = torch.tensor(signer_id_label, dtype=torch.long)

        genuine_label = self.is_genuine_labels[idx]
        genuine_tensor = torch.tensor(genuine_label, dtype=torch.long)

        # Return the preprocessed image and both labels
        return image_tensor, signer_id_tensor, genuine_tensor
```

```
Start coding or generate with AI.
```

Step-5 Loading the dataset

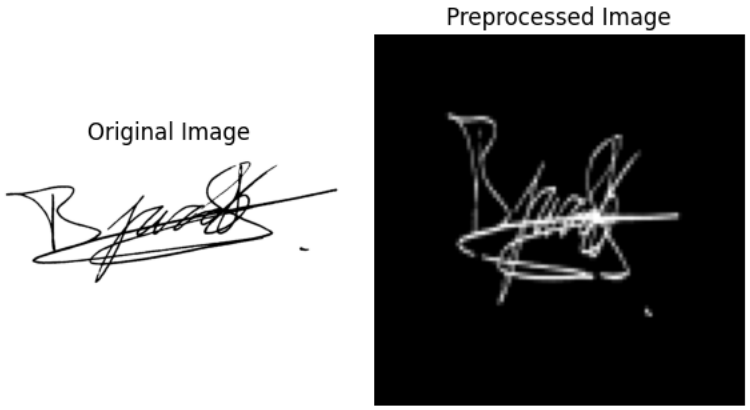
```
from torch.utils.data import DataLoader
from sklearn.model_selection import train_test_split
import glob
import os
import numpy as np
import cv2
import math



# Base directory where your data is extracted
base_dir = "/content/signs_dataset"
data_dir = os.path.join(base_dir, "signatures")

# Lists to store image paths, signer IDs, and forgery labels
image_paths = []
signer_ids = []
is_genuine = []

for folder_name in os.listdir(data_dir):
    folder_path = os.path.join(data_dir, folder_name)
    if os.path.isdir(folder_path):
        # Determine the signer ID and genuine flag from the folder name
        if "_forg" in folder_name:
            signer_id = folder_name.replace("_forg", "")
            genuine_flag = 0  # 0 for forged
        else:
            signer_id = folder_name
            genuine_flag = 1  # 1 for genuine

        for file_name in os.listdir(folder_path):
            if file_name.endswith(('.png', '.jpg', '.jpeg', '.PNG')):
                image_paths.append(os.path.join(folder_path, file_name))
                signer_ids.append(signer_id)
                is_genuine.append(genuine_flag)


train_dataset = SignatureDataset(image_paths, signer_ids, is_genuine)

# Create DataLoader objects
batch_size = 32
train_loader = DataLoader(train_dataset, batch_size=batch_size, shuffle=True)

print(f"Data loading is complete.")
print(f"Number of training batches: {len(train_loader)}")
```

```
Data loading is complete.
Number of training batches: 10
```

Display

```
import matplotlib.pyplot as plt

random_index = np.random.randint(0, len(image_paths))
random_image_path = image_paths[random_index]

# 1. Load the original image
original_image = cv2.imread(random_image_path, cv2.IMREAD_GRAYSCALE)

# 2. Apply the preprocessing pipeline
preprocessed_image = preprocess_pipeline(random_image_path)

# Display the images
fig, axes = plt.subplots(1, 2, figsize=(6, 5))

# Original Image
```

```
axes[0].imshow(original_image, cmap='gray')
axes[0].set_title('Original Image')

axes[0].axis('off') # Hide the axes

# Preprocessed Image
axes[1].imshow(preprocessed_image, cmap='gray')
axes[1].set_title('Preprocessed Image')
axes[1].axis('off') # Hide the axes

plt.tight_layout()
plt.show()
```




```
import cv2
import matplotlib.pyplot as plt

# Load image
img_path = image_paths[random_index]
img = cv2.imread(img_path, cv2.IMREAD_GRAYSCALE)

# Process steps
border_removed = remove_borders(img)
binarized_img = binarize_and_denoise(border_removed)
scaled_img = scale_signature(binarized_img)
centered_img = center_signature(scaled_img)
rotated_img = rotate_signature(centered_img)

# List of images and titles
images = [img,border_removed, binarized_img,scaled_img, centered_img, rotated_img]
titles = ["Original", "No Border", "Binarized","Scaled", "Centered", "Rotated"]

# Plot in horizontal line
plt.figure(figsize=(18, 6))
for i, (image, title) in enumerate(zip(images, titles)):
    plt.subplot(1, len(images), i+1)
    plt.imshow(image, cmap='gray')
    plt.title(title, fontsize=10)
    plt.axis("off")
plt.tight_layout()
plt.show()
```

Start coding or generate with AI.

Step-6 : Creating a CNN Model

```
import torch
import torch.nn as nn
import torchvision.models as models

class SignatureResNet(nn.Module):
    def __init__(self, num_classes):
        super(SignatureResNet, self).__init__()
```

```
        # Load pretrained ResNet18
        self.base_model = models.resnet18(pretrained=True)

        # Modify first conv layer to accept 1-channel grayscale input
        self.base_model.conv1 = nn.Conv2d(1, 64, kernel_size=7, stride=2, padding=3, bias=False)

        # Replace final fully connected layer with custom classifier
        self.base_model.fc = nn.Sequential(
            nn.Linear(self.base_model.fc.in_features, 256),
            nn.ReLU(),
            nn.Dropout(0.5),
            nn.Linear(256, num_classes)
        )

    def forward(self, x):
        return self.base_model(x)
```

Start coding or generate with AI.

Step-7 Training the Model

```
import torch
import torch.nn as nn
import torch.optim as optim
from sklearn.metrics import accuracy_score
import os

# Device
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")

# Model
num_classes = len(train_dataset.signer_id_map)
model = SignatureResNet(num_classes=num_classes).to(device)

# Weight Initialization
def init_weights(m):
    if isinstance(m, nn.Conv2d) or isinstance(m, nn.Linear):
        nn.init.kaiming_normal_(m.weight)
        if m.bias is not None:
            nn.init.constant_(m.bias, 0)

model.apply(init_weights)

# Loss & Optimizer
criterion = nn.CrossEntropyLoss()
optimizer = optim.Adam(model.parameters(), lr=0.001)

# Save Path
save_dir = "/content/drive/MyDrive/new_saved_models"
os.makedirs(save_dir, exist_ok=True)
model_path = os.path.join(save_dir, "signature_cnn_best.pth")

# Training Loop with Early Stopping
num_epochs = 100
patience = 10
best_acc = 0.0
epochs_no_improve = 0

for epoch in range(num_epochs):
    model.train()
    train_loss = 0.0
    train_preds = []
    train_labels = []

    for images, signer_labels, _ in train_loader:
        images, signer_labels = images.to(device), signer_labels.to(device)

        optimizer.zero_grad()
        outputs = model(images)
        loss = criterion(outputs, signer_labels)
        loss.backward()
        optimizer.step()

        train_loss += loss.item() * images.size(0)
        train_preds.extend(outputs.argmax(1).cpu().numpy())
        train_labels.extend(signer_labels.cpu().numpy())

    train_acc = accuracy_score(train_labels, train_preds)
    avg_train_loss = train_loss / len(train_dataset)
```

```
    print(f"Epoch [{epoch+1}/{num_epochs}] "
          f"Train Loss: {avg_train_loss:.4f} | Train Acc: {train_acc:.4f}")

    # Check for improvement
    if train_acc > best_acc:
        best_acc = train_acc
        epochs_no_improve = 0
        torch.save(model.state_dict(), model_path)
        print(f"Best model saved at epoch {epoch+1} with acc: {train_acc:.4f}")
    else:
        epochs_no_improve += 1
        print(f"No improvement for {epochs_no_improve} epoch(s)")

    # Early stopping
    if epochs_no_improve >= patience:
        print(f"Early stopping triggered at epoch {epoch+1}")
        break
```

```
Epoch [37/100] Train Loss: 0.8536 | Train Acc: 0.7200
Best model saved at epoch 37 with acc: 0.7200
Epoch [38/100] Train Loss: 0.7304 | Train Acc: 0.7533
Best model saved at epoch 38 with acc: 0.7533
Epoch [39/100] Train Loss: 0.7146 | Train Acc: 0.7967
Best model saved at epoch 39 with acc: 0.7967
Epoch [40/100] Train Loss: 0.6730 | Train Acc: 0.8000
Best model saved at epoch 40 with acc: 0.8000
Epoch [41/100] Train Loss: 0.7548 | Train Acc: 0.7700
No improvement for 1 epoch(s)
Epoch [42/100] Train Loss: 0.6691 | Train Acc: 0.8100
Best model saved at epoch 42 with acc: 0.8100
Epoch [43/100] Train Loss: 0.4953 | Train Acc: 0.8333
Best model saved at epoch 43 with acc: 0.8333
Epoch [44/100] Train Loss: 0.3875 | Train Acc: 0.8800
Best model saved at epoch 44 with acc: 0.8800
Epoch [45/100] Train Loss: 0.3529 | Train Acc: 0.8700
No improvement for 1 epoch(s)
Epoch [46/100] Train Loss: 0.3558 | Train Acc: 0.8667
No improvement for 2 epoch(s)
Epoch [47/100] Train Loss: 0.2528 | Train Acc: 0.9100
Best model saved at epoch 47 with acc: 0.9100
Epoch [48/100] Train Loss: 0.2353 | Train Acc: 0.9000
No improvement for 1 epoch(s)
Epoch [49/100] Train Loss: 0.2775 | Train Acc: 0.9067
No improvement for 2 epoch(s)
Epoch [50/100] Train Loss: 0.3186 | Train Acc: 0.8967
No improvement for 3 epoch(s)
Epoch [51/100] Train Loss: 0.2548 | Train Acc: 0.9267
Best model saved at epoch 51 with acc: 0.9267
Epoch [52/100] Train Loss: 0.1858 | Train Acc: 0.9367
Best model saved at epoch 52 with acc: 0.9367
Epoch [53/100] Train Loss: 0.1730 | Train Acc: 0.9300
No improvement for 1 epoch(s)
Epoch [54/100] Train Loss: 0.1244 | Train Acc: 0.9500
Best model saved at epoch 54 with acc: 0.9500
Epoch [55/100] Train Loss: 0.1731 | Train Acc: 0.9333
No improvement for 1 epoch(s)
Epoch [56/100] Train Loss: 0.2011 | Train Acc: 0.9167
No improvement for 2 epoch(s)
Epoch [57/100] Train Loss: 0.2102 | Train Acc: 0.9200
No improvement for 3 epoch(s)
Epoch [58/100] Train Loss: 0.2110 | Train Acc: 0.9200
No improvement for 4 epoch(s)
Epoch [59/100] Train Loss: 0.2037 | Train Acc: 0.9200
No improvement for 5 epoch(s)
Epoch [60/100] Train Loss: 0.2843 | Train Acc: 0.8867
No improvement for 6 epoch(s)
Epoch [61/100] Train Loss: 0.2685 | Train Acc: 0.9067
No improvement for 7 epoch(s)
Epoch [62/100] Train Loss: 0.2711 | Train Acc: 0.9100
No improvement for 8 epoch(s)
Epoch [63/100] Train Loss: 0.2561 | Train Acc: 0.9400
No improvement for 9 epoch(s)
Epoch [64/100] Train Loss: 0.1925 | Train Acc: 0.9367
No improvement for 10 epoch(s)
Early stopping triggered at epoch 64
```

Start coding or generate with AI.

Testing

```
# Device
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")

# Model
```

```
num_classes = len(train_dataset.signer_id_map)
model = SignatureResNet(num_classes=num_classes).to(device)
```

```
/usr/local/lib/python3.11/dist-packages/torchvision/models/_utils.py:208: UserWarning: The parameter 'pretrained' is dep
  warnings.warn(
/usr/local/lib/python3.11/dist-packages/torchvision/models/_utils.py:223: UserWarning: Arguments other than a weight enu
  warnings.warn(msg)
Downloading: "https://download.pytorch.org/models/resnet18-f37072fd.pth" to /root/.cache/torch/hub/checkpoints/resnet18-
100%|██████████| 44.7M/44.7M [00:00<00:00, 175MB/s]
```

```
model_path = "/content/drive/MyDrive/new_saved_models/signature_cnn_best.pth"
```

```
import torch
from sklearn.metrics import accuracy_score

# Load the best saved model
model.load_state_dict(torch.load(model_path))
model.eval()

# Move model to device
model.to(device)

# Evaluation loop
test_preds = []
test_labels = []

with torch.no_grad():
    for images, signer_labels, _ in train_loader:  # Reusing train_loader
        images = images.to(device)
        signer_labels = signer_labels.to(device)

        outputs = model(images)
        preds = outputs.argmax(1)

        test_preds.extend(preds.cpu().numpy())
        test_labels.extend(signer_labels.cpu().numpy())

# Compute accuracy
test_acc = accuracy_score(test_labels, test_preds)
print(f" Evaluation Accuracy on Training Data: {test_acc:.4f}")
```

```
 Evaluation Accuracy on Training Data: 0.9633
```

```
Start coding or generate with AI.
```

Testing by giving and input signature

```
signer_id_map = train_dataset.signer_id_map
```

```
reverse_map = {v: k for k, v in signer_id_map.items()}
```

```
print(train_dataset.signer_id_map)
```

```
{'001': 0, '002': 1, '003': 2, '004': 3, '005': 4, '006': 5, '007': 6, '008': 7, '009': 8, '010': 9, '011': 10, '012': 1
```

```
print(reverse_map)
```

```
{0: '001', 1: '002', 2: '003', 3: '004', 4: '005', 5: '006', 6: '007', 7: '008', 8: '009', 9: '010', 10: '011', 11: '012
```

```
model = SignatureResNet(num_classes=num_classes).to(device)
model.load_state_dict(torch.load(model_path))
```

```
/usr/local/lib/python3.11/dist-packages/torchvision/models/_utils.py:208: UserWarning: The parameter 'pretrained' is dep
  warnings.warn(
/usr/local/lib/python3.11/dist-packages/torchvision/models/_utils.py:223: UserWarning: Arguments other than a weight enu
  warnings.warn(msg)
<All keys matched successfully>
```

```
def predict_signer(image_path):
    # Load and preprocess the image
    image = preprocess_pipeline(image_path)
    image = image.astype(np.float32) / 255.0
    image = np.expand_dims(image, axis=0)  # [1, H, W] → channel dimension
    image = np.expand_dims(image, axis=0)  # [1, 1, H, W] → batch dimension
```

```
    image = np.expand_dims(image, axis=0)  # [1, 1, H, W] - batch dimension

    image_tensor = torch.from_numpy(image).to(device)

    with torch.no_grad():
        output = model(image_tensor)
        predicted_id = output.argmax(1).item()

    #print(f"Predicted Signer ID: {predicted_id}")
    return predicted_id


model = SignatureResNet(num_classes=num_classes).to(device)
model.load_state_dict(torch.load(model_path))
model.eval()
```

```
        )
        (1): BasicBlock(
          (conv1): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
          (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        )
      )
      (layer3): Sequential(
        (0): BasicBlock(
          (conv1): Conv2d(128, 256, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
          (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
          (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (downsample): Sequential(
            (0): Conv2d(128, 256, kernel_size=(1, 1), stride=(2, 2), bias=False)
            (1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          )
        )
        (1): BasicBlock(
          (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
          (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        )
      )
      (layer4): Sequential(
        (0): BasicBlock(
          (conv1): Conv2d(256, 512, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
          (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
          (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (downsample): Sequential(
            (0): Conv2d(256, 512, kernel_size=(1, 1), stride=(2, 2), bias=False)
            (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          )
        )
        (1): BasicBlock(
          (conv1): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
          (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        )
      )
      (avgpool): AdaptiveAvgPool2d(output_size=(1, 1))
      (fc): Sequential(
        (0): Linear(in_features=512, out_features=256, bias=True)
        (1): ReLU()
        (2): Dropout(p=0.5, inplace=False)
        (3): Linear(in_features=256, out_features=30, bias=True)
      )
    )
  )
```

```
image_path = "/content/signs_dataset/signatures/002_forg/02102002.png"
predicted_id = predict_signer(image_path)
print(predicted_id)
```

```
1
```

```
predicted_signer_name = reverse_map[predicted_id]
print(f"🖋️ Predicted Signer ID: {predicted_id}")
print(f"🔍 Predicted Signer Name: {predicted_signer_name}")
```

```
🖋️ Predicted Signer ID: 1
🔍 Predicted Signer Name: 002
```

```
Start coding or generate with AI.
```

Detection

getting the embeddings

```
import torch.nn.functional as F
import os

def get_embedding(image_path):
    image = preprocess_pipeline(image_path)
    image = image.astype(np.float32) / 255.0
    image = np.expand_dims(image, axis=0)  # [1, H, W]
    image = np.expand_dims(image, axis=0)  # [1, 1, H, W]
    image_tensor = torch.from_numpy(image).to(device)

    with torch.no_grad():
        features = model.base_model.avgpool(model.base_model.layer4(model.base_model.layer3(
            model.base_model.layer2(model.base_model.layer1(model.base_model.relu(
                model.base_model.bn1(model.base_model.conv1(image_tensor))))))))
        embedding = features.view(features.size(0), -1)  # Flatten
    return embedding.squeeze(0)  # Remove batch dimension


from sklearn.metrics.pairwise import cosine_similarity
import numpy as np

def verify_signature(input_path, signer_id):
    base_path = "/content/signs_dataset/signatures"
    genuine_folder = os.path.join(base_path, signer_id)
    forged_folder = os.path.join(base_path, signer_id + "_forg")

    input_embedding = get_embedding(input_path)

    genuine_scores = []
    forged_scores = []

    # Compare with genuine samples
    for fname in os.listdir(genuine_folder):
        if fname.endswith(('.png', '.jpg', '.jpeg')):
            emb = get_embedding(os.path.join(genuine_folder, fname))
            score = cosine_similarity([input_embedding.cpu().numpy()], [emb.cpu().numpy()])[0][0]
            genuine_scores.append(score)

    # Compare with forged samples
    for fname in os.listdir(forged_folder):
        if fname.endswith(('.png', '.jpg', '.jpeg')):
            emb = get_embedding(os.path.join(forged_folder, fname))
            score = cosine_similarity([input_embedding.cpu().numpy()], [emb.cpu().numpy()])[0][0]
            forged_scores.append(score)

    avg_genuine = np.mean(genuine_scores)
    avg_forged = np.mean(forged_scores)

    #print(f"Avg Genuine Similarity: {avg_genuine:.4f}")
    #print(f"Avg Forged Similarity: {avg_forged:.4f}")

    if avg_genuine > avg_forged:
        #print("Prediction: Signature is likely GENUINE")
        return True, avg_genuine, avg_forged
    else:
        #print("Prediction: Signature is likely FORGED")
        return False, avg_genuine, avg_forged



is_real = verify_signature(image_path, predicted_signer_name)
```

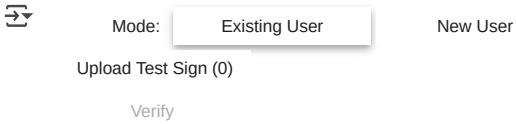
```
Start coding or generate with AI.
```

For New User verification

```
# Verification method
def verify_signature_test(genuine_paths, test_path, threshold=0.9):
    genuine_embeddings = [get_embedding(path) for path in genuine_paths]
```

```
        test_embedding = get_embedding(test_path)

        similarities = [
            F.cosine_similarity(test_embedding.unsqueeze(0), g.unsqueeze(0)).item()
            for g in genuine_embeddings
        ]
        avg_similarity = sum(similarities) / len(similarities)

        result = "Genuine" if avg_similarity > threshold else "Forged"
        return result, avg_similarity


    Start coding or generate with AI.


    import ipywidgets as widgets
    from IPython.display import display, clear_output
    import tempfile
    import os

    # Widgets
    mode_selector = widgets.ToggleButtons(options=["Existing User", "New User"], description="Mode:")
    existing_upload = widgets.FileUpload(accept='.png,.jpg,.jpeg', description="Upload Test Sign", multiple=False)
    new_genuine_upload = widgets.FileUpload(accept='.png,.jpg,.jpeg', description="Genuine Signs-5+", multiple=True
    new_test_upload = widgets.FileUpload(accept='.png,.jpg,.jpeg', description="Upload Test Sign", multiple=False)
    verify_button = widgets.Button(description="Verify", button_style='success')
    output = widgets.Output()

    # Helper to save uploaded bytes to temp file
    def save_temp_file(file_bytes, suffix=".png"):
        temp = tempfile.NamedTemporaryFile(delete=False, suffix=suffix)
        temp.write(file_bytes)
        temp.close()
        return temp.name

    # 🧹 Helper to reset widgets
    def reset_widgets():
        existing_upload.value.clear()
        new_genuine_upload.value.clear()
        new_test_upload.value.clear()
        existing_upload._counter = 0
        new_genuine_upload._counter = 0
        new_test_upload._counter = 0

    # Main logic
    def on_verify_clicked(b):
        output.clear_output()
        mode = mode_selector.value

        with output:
            if mode == "Existing User":
                if not existing_upload.value:
                    print("Upload a test signature.")
                    return
                test_bytes = list(existing_upload.value.values())[0]['content']
                test_path = save_temp_file(test_bytes)

                predicted_id = predict_signer(test_path)
                predicted_name = reverse_map[predicted_id]
                print(f"Predicted Signer ID: {predicted_id}")
                print(f"Predicted ID: {predicted_id}")
                print(f"Predicted Name: {predicted_name}")

                is_real, gen_sim, forg_sim = verify_signature(test_path, predicted_name)
                print(f"Avg Genuine Similarity: {gen_sim:.4f}")
                print(f"Avg Forged Similarity: {forg_sim:.4f}")
                print(f"Prediction: Signature is likely {'GENUINE' if is_real else 'FORGED'}")
                print(f"Result: {'Genuine ✅' if is_real else 'Forged ❌'}")

                os.remove(test_path)

            else:  # New User
                if len(new_genuine_upload.value) < 5:
                    print("Upload at least 5 genuine samples.")
                    return
                if not new_test_upload.value:
                    print("Upload a test signature.")
                    return

                genuine_paths = [save_temp_file(file['content']) for file in new_genuine_upload.value.values()]
                test_bytes = list(new_test_upload.value.values())[0]['content']
                test_path = save_temp_file(test_bytes)
```

```
            result, avg_sim = verify_signature_test(genuine_paths, test_path)
            print(f"Similarity: {avg_sim:.4f}")
            print(f"Result: {result} {'✅' if result == 'Genuine' else '❌'}")

            for path in genuine_paths:
                os.remove(path)
            os.remove(test_path)

        reset_widgets()
        print("\n✅ Verification complete. Ready for next input.")


verify_button.on_click(on_verify_clicked)

# 🔄 Dynamic visibility
def update_visibility(change):
    if change['new'] == "Existing User":
        existing_upload.layout.display = 'block'
        new_genuine_upload.layout.display = 'none'
        new_test_upload.layout.display = 'none'
    else:
        existing_upload.layout.display = 'none'
        new_genuine_upload.layout.display = 'block'
        new_test_upload.layout.display = 'block'

mode_selector.observe(update_visibility, names='value')
update_visibility({'new': mode_selector.value})  # Initial setup

# 📦 Display interface
display(widgets.VBox([
    mode_selector,
    existing_upload,
    new_genuine_upload,
    new_test_upload,
    verify_button,
    output
]))
```




```
Predicted Signer ID: 3
Predicted ID: 3
Predicted Name: 004
Avg Genuine Similarity: 0.9914
Avg Forged Similarity: 0.9654
Prediction: Signature is likely GENUINE
Result: Genuine ✅

✅ Verification complete. Ready for next input.
```

Start coding or generate with AI.

```
!jupyter nbconvert --ClearMetadataPreprocessor.enabled=True --to notebook --inplace /content/Signature_Recognition_and_Verif
```

```
[NbConvertApp] Converting notebook /content/Signature_Recognition_and_Verification.ipynb to notebook
[NbConvertApp] Writing 263157 bytes to /content/Signature_Recognition_and_Verification.ipynb
```

Start coding or generate with AI.