binodshahi-worksheet4-pdf

April 4, 2025

[ ]:
```
# Connect Google Drive to Google Colab
from google.colab import drive
drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

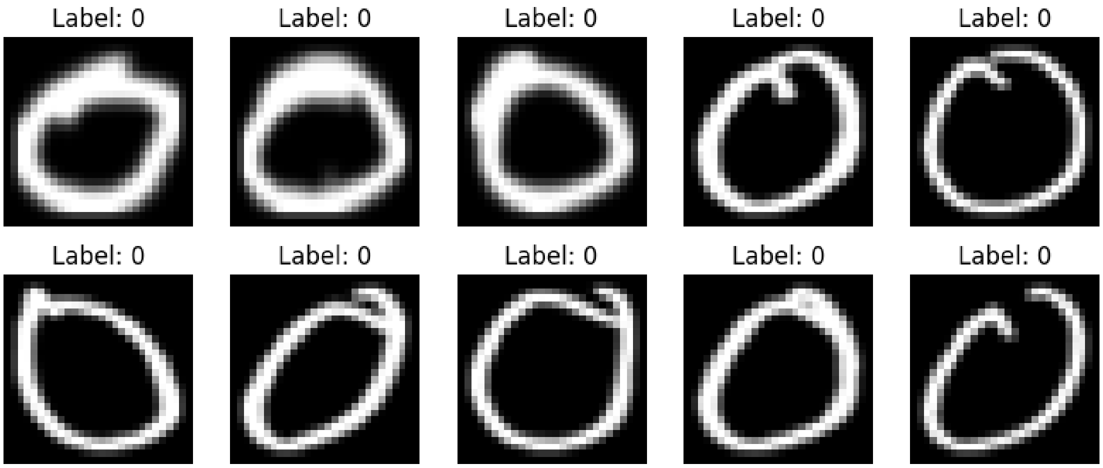
[ ]:
```
import tensorflow as tf
print(tf.keras.__version__)
```

```
3.8.0
```

[ ]:
```
import os
import numpy as np
import tensorflow as tf
from tensorflow.keras.utils import to_categorical
from sklearn.model_selection import train_test_split
import matplotlib.pyplot as plt
from PIL import Image  # Import Pillow

# Define dataset paths
train_dir = "/content/drive/MyDrive/AI-Shivkumar/
 ↪DevanagariHandwrittenDigitDataset/Train"
test_dir = "/content/drive/MyDrive/AI-Shivkumar/
 ↪DevanagariHandwrittenDigitDataset/Test"

# Define image size
img_height, img_width = 28, 28

# Function to load images and labels using PIL
def load_images_from_folder(folder):
    images = []
    labels = []
    class_names = sorted(os.listdir(folder))  # Sorted class names (digit_0,␣
 ↪digit_1, ...)
    class_map = {name: i for i, name in enumerate(class_names)}  # Map class␣
 ↪names to labels
```

```
    for class_name in class_names:
        class_path = os.path.join(folder, class_name)
        label = class_map[class_name]

        for filename in os.listdir(class_path):
            img_path = os.path.join(class_path, filename)
            # Load image using PIL
            img = Image.open(img_path).convert("L")  # Convert to grayscale
            img = img.resize((img_width, img_height))  # Resize to (28,28)
            img = np.array(img) / 255.0  # Normalize pixel values to [0,1]
            images.append(img)
            labels.append(label)

    return np.array(images), np.array(labels)

# Load training and testing datasets
x_train, y_train = load_images_from_folder(train_dir)
x_test, y_test = load_images_from_folder(test_dir)

# Reshape images for Keras input
x_train = x_train.reshape(-1, img_height, img_width, 1)  # Shape (num_samples,␣
 ↪28, 28, 1)
x_test = x_test.reshape(-1, img_height, img_width, 1)

# One-hot encode labels
y_train = to_categorical(y_train, num_classes=10)
y_test = to_categorical(y_test, num_classes=10)

# Print dataset shape
print(f"Training set: {x_train.shape}, Labels: {y_train.shape}")
print(f"Testing set: {x_test.shape}, Labels: {y_test.shape}")

# Visualize some images
plt.figure(figsize=(10, 4))
for i in range(10):
    plt.subplot(2, 5, i + 1)
    plt.imshow(x_train[i].reshape(28, 28), cmap='gray')
    plt.title(f"Label: {np.argmax(y_train[i])}")
    plt.axis("off")
plt.show()
```

```
Training set: (17000, 28, 28, 1), Labels: (17000, 10)
Testing set: (3000, 28, 28, 1), Labels: (3000, 10)
```



[ ]:
```
x_train = x_train.reshape(-1, img_height, img_width, 1)
# Use with Cautions.
```

Loading and Preprocessing MNIST Handwritten Digit Dataset:

[ ]:
```
import numpy as np
import tensorflow as tf
from tensorflow.keras import layers, models
from tensorflow.keras.datasets import mnist
# Load the MNIST dataset
(x_train, y_train), (x_test, y_test) = mnist.load_data()
# Normalize the images to values between 0 and 1
x_train, x_test = x_train / 255.0, x_test / 255.0
# Flatten the 28x28 images into 784-dimensional vectors
x_train = x_train.reshape(-1, 28 * 28)
x_test = x_test.reshape(-1, 28 * 28)
# One-hot encode the labels (0-9) for classification
y_train = tf.keras.utils.to_categorical(y_train, 10)
y_test = tf.keras.utils.to_categorical(y_test, 10)
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-
datasets/mnist.npz
11490434/11490434            0s
0us/step
```

Build the Model:

1. Sequential API:

[ ]:
```
# Model parameters
import tensorflow as tf
from tensorflow import keras
```

```
num_classes = 10
input_shape = (28, 28, 1)
model = keras.Sequential(
[
keras.layers.Input(shape=input_shape),
keras.layers.Flatten(), # Flatten the 28x28 image to a 784-dimensional vector
keras.layers.Dense(64, activation="sigmoid"),
keras.layers.Dense(128, activation="sigmoid"),
keras.layers.Dense(256, activation="sigmoid"),
keras.layers.Dense(num_classes, activation="softmax"),
]
)
```

2. Functional API:

[ ]:
```
# Model parameters
import tensorflow as tf
from tensorflow import keras
num_classes = 10
input_shape = (28, 28, 1)
def build_functional_model():
# Input layer
  inputs = keras.Input(shape=input_shape)
  # Flatten layer
  x = keras.layers.Flatten()(inputs)
  # Hidden layers
  x = keras.layers.Dense(64, activation="sigmoid")(x)
  x = keras.layers.Dense(128, activation="sigmoid")(x)
  x = keras.layers.Dense(256, activation="sigmoid")(x)
  # Output layer
  outputs = keras.layers.Dense(num_classes, activation="softmax")(x)
  # Create model
  model = keras.Model(inputs=inputs, outputs=outputs)
  return model
# Build the model
functional_model = build_functional_model()
functional_model.summary()
```

```
Model: "functional_1"


 Layer (type)                     Output Shape                    ␣
↪Param #

 input_layer_1 (InputLayer)       (None, 28, 28, 1)                  ␣
↪   0
```

```
flatten_1 (Flatten)                    (None, 784)                          ␣
↪  0

dense_4 (Dense)                        (None, 64)                        ␣
↪50,240

dense_5 (Dense)                        (None, 128)                        ␣
↪8,320

dense_6 (Dense)                        (None, 256)                       ␣
↪33,024

dense_7 (Dense)                        (None, 10)                         ␣
↪2,570
```

```
Total params: 94,154 (367.79 KB)

Trainable params: 94,154 (367.79 KB)

Non-trainable params: 0 (0.00 B)
```

Exercise: Building a Fully Connected Network (FCN) for Devnagari Digit Classification.

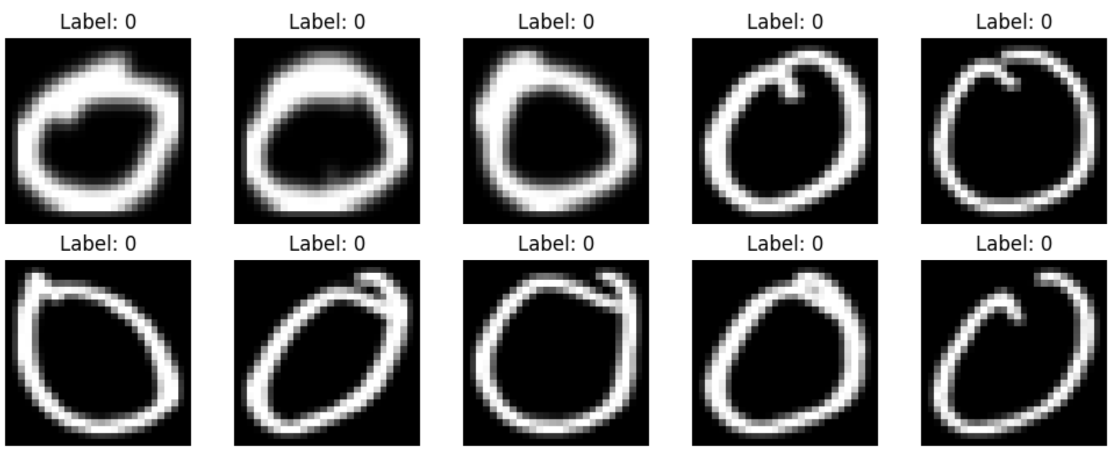
Task1: Data Preparation

[ ]:
```
import os
import numpy as np
import tensorflow as tf
from tensorflow.keras.utils import to_categorical
from sklearn.model_selection import train_test_split
import matplotlib.pyplot as plt
from PIL import Image

# Define dataset paths
train_dir = "/content/drive/MyDrive/AI-Shivkumar/
 ↪DevanagariHandwrittenDigitDataset/Train"
test_dir = "/content/drive/MyDrive/AI-Shivkumar/
 ↪DevanagariHandwrittenDigitDataset/Test"

# Define image size
img_height, img_width = 28, 28

# Function to load images and labels using PIL
def load_images_from_folder(folder):
```

```
    images = []
    labels = []

    # Check if directory exists
    if not os.path.exists(folder):
        print(f"Error: Directory '{folder}' not found!")
        return np.array([]), np.array([])

    class_names = sorted(os.listdir(folder))  # Sorted class names
    class_map = {name: i for i, name in enumerate(class_names)}  # Map class␣
↪names to labels

    for class_name in class_names:
        class_path = os.path.join(folder, class_name)
        label = class_map[class_name]

        for filename in os.listdir(class_path):
            img_path = os.path.join(class_path, filename)

            # Load image using PIL
            img = Image.open(img_path).convert("L")  # Convert to grayscale
            img = img.resize((img_width, img_height))  # Resize to (28,28)
            img = np.array(img) / 255.0  # Normalize pixel values to [0,1]

            images.append(img)
            labels.append(label)

    return np.array(images), np.array(labels)

# Load training and testing datasets
x_train, y_train = load_images_from_folder(train_dir)
x_test, y_test = load_images_from_folder(test_dir)

# Ensure data is loaded correctly
if x_train.size == 0 or x_test.size == 0:
    raise ValueError("Dataset loading failed. Check dataset structure.")

# Reshape images for Keras input
x_train = x_train.reshape(-1, img_height, img_width, 1)  # Shape (num_samples,␣
↪28, 28, 1)
x_test = x_test.reshape(-1, img_height, img_width, 1)

# One-hot encode labels
y_train = to_categorical(y_train, num_classes=10)
y_test = to_categorical(y_test, num_classes=10)

# Print dataset shape
```

```python
print(f"Training set: {x_train.shape}, Labels: {y_train.shape}")
print(f"Testing set: {x_test.shape}, Labels: {y_test.shape}")

# Visualize some images
plt.figure(figsize=(10, 4))
for i in range(10):
    plt.subplot(2, 5, i + 1)
    plt.imshow(x_train[i].reshape(28, 28), cmap="gray")  # Fixed quotes
    plt.title(f"Label: {np.argmax(y_train[i])}")
    plt.axis("off")

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

```
Training set: (17000, 28, 28, 1), Labels: (17000, 10)
Testing set: (3000, 28, 28, 1), Labels: (3000, 10)
```



Task2: Build the FCN Model

[ ]:
```python
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Flatten

# Define the model
model = Sequential([
    Flatten(input_shape=(28, 28, 1)),  # Flatten the 28x28 image into a 784-dimensional vector
    Dense(64, activation="sigmoid"),   # 1st hidden layer
    Dense(128, activation="sigmoid"),  # 2nd hidden layer
    Dense(256, activation="sigmoid"),  # 3rd hidden layer
    Dense(10, activation="softmax")    # Output layer (10 classes)
])
```

```
# Display model architecture
model.summary()
```

```
/usr/local/lib/python3.11/dist-
packages/keras/src/layers/reshaping/flatten.py:37: UserWarning: Do not pass an
`input_shape`/`input_dim` argument to a layer. When using Sequential models,
prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(**kwargs)
```

Model: "sequential_1"

Layer (type)	Output Shape	Param #
flatten_2 (Flatten)	(None, 784)	0
dense_8 (Dense)	(None, 64)	50,240
dense_9 (Dense)	(None, 128)	8,320
dense_10 (Dense)	(None, 256)	33,024
dense_11 (Dense)	(None, 10)	2,570

Total params: 94,154 (367.79 KB)

Trainable params: 94,154 (367.79 KB)

Non-trainable params: 0 (0.00 B)

Task3: Compile the Model

[ ]:
```
# Compile the model
model.compile(
    optimizer="adam",
    loss="categorical_crossentropy",
    metrics=["accuracy"]
)
```

Task4: Train the Model

```
[ ]: # Set training parameters
batch_size = 128
epochs = 500

# Define callbacks
callbacks = [
    tf.keras.callbacks.ModelCheckpoint(filepath="best_model.keras",␣
 ↪save_best_only=True),
    tf.keras.callbacks.EarlyStopping(monitor="val_loss", patience=4,␣
 ↪restore_best_weights=True)
]

# Train the model
history = model.fit(
    x_train, y_train,
    batch_size=batch_size,
    epochs=epochs,
    validation_split=0.2,
    callbacks=callbacks
)
```

```
Epoch 1/500
107/107             6s 27ms/step -
accuracy: 0.2838 - loss: 1.9929 - val_accuracy: 0.0000e+00 - val_loss: 6.9178
Epoch 2/500
107/107             0s 4ms/step -
accuracy: 0.8022 - loss: 0.6499 - val_accuracy: 0.0000e+00 - val_loss: 8.0809
Epoch 3/500
107/107             1s 3ms/step -
accuracy: 0.9007 - loss: 0.3138 - val_accuracy: 0.0000e+00 - val_loss: 8.6364
Epoch 4/500
107/107             0s 3ms/step -
accuracy: 0.9344 - loss: 0.2116 - val_accuracy: 0.0000e+00 - val_loss: 9.0252
Epoch 5/500
107/107             0s 3ms/step -
accuracy: 0.9585 - loss: 0.1459 - val_accuracy: 0.0000e+00 - val_loss: 9.3932
```

Task5: Evaluate the Model

```
[ ]: # Evaluate the model on test data
test_loss, test_acc = model.evaluate(x_test, y_test, verbose=2)
print(f"Test accuracy: {test_acc:.4f}")
```

```
94/94 - 0s - 3ms/step - accuracy: 0.6157 - loss: 2.0677
Test accuracy: 0.6157
```

Task6: Save and Load the Model

```
[ ]: # Import TensorFlow
import tensorflow as tf

# Save the trained model in the native Keras format (.keras)
model.save("devnagari_fcn_model.keras")

# Load the saved model
loaded_model = tf.keras.models.load_model("devnagari_fcn_model.keras")

# Re-evaluate the loaded model on the test set
loaded_test_loss, loaded_test_acc = loaded_model.evaluate(x_test, y_test,␣
 ↪verbose=2)
print(f"Loaded model test accuracy: {loaded_test_acc:.4f}")
```

```
94/94 - 1s - 9ms/step - accuracy: 0.6157 - loss: 2.0677
Loaded model test accuracy: 0.6157
```

Task7: Making Predictions

```
[ ]: # Make predictions on test images
predictions = model.predict(x_test)

# Convert probabilities to class labels
predicted_labels = np.argmax(predictions, axis=1)

# Print first prediction
print(f"Predicted label for first image: {predicted_labels[0]}")
print(f"True label for first image: {np.argmax(y_test[0])}")
```

```
94/94              0s 1ms/step
Predicted label for first image: 0
True label for first image: 0
```

Visualize

```
[ ]: # Extracting training and validation loss and accuracy
train_loss = history.history['loss']
val_loss = history.history['val_loss']
train_acc = history.history['accuracy']
val_acc = history.history['val_accuracy']

# Plotting training and validation loss and accuracy
plt.figure(figsize=(12, 6))

plt.subplot(1, 2, 1)
plt.plot(train_loss, label="Training Loss", color="blue")
plt.plot(val_loss, label="Validation Loss", color="orange")
plt.xlabel("Epochs")
plt.ylabel("Loss")
```

```
plt.title("Training and Validation Loss")
plt.legend()

plt.subplot(1, 2, 2)
plt.plot(train_acc, label="Training Accuracy", color="blue")
plt.plot(val_acc, label="Validation Accuracy", color="orange")
plt.xlabel("Epochs")
plt.ylabel("Accuracy")
plt.title("Training and Validation Accuracy")
plt.legend()

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