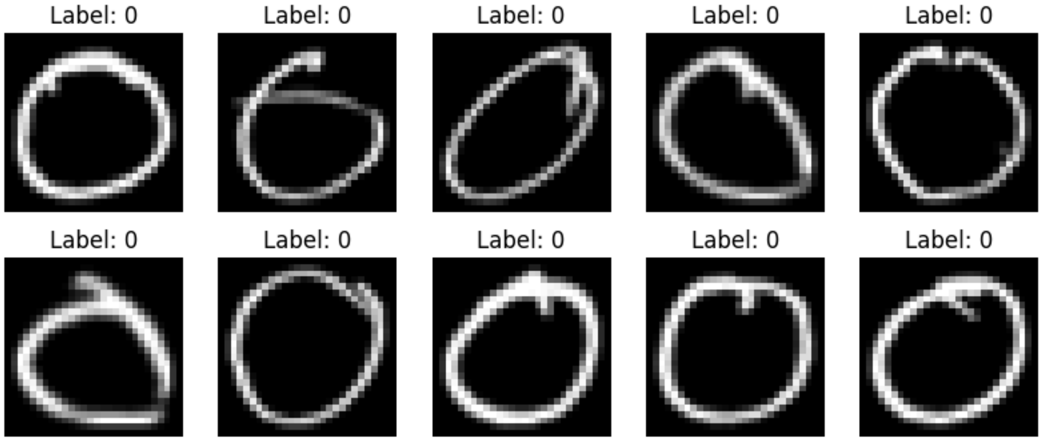
```
!unzip "/content/Copy of devnagari digit.zip"
```

```
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30446.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30448.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30449.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30450.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30451.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30452.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30453.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30454.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30455.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30456.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30457.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30458.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30459.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30460.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30461.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30462.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30463.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30464.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30465.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30466.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30467.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30468.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30469.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30470.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/30472.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41776.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41777.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41778.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41779.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41780.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41781.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41782.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41784.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41786.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41788.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41789.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41790.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41791.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41792.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41793.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41794.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41795.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41796.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41797.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41798.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41799.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41800.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41801.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41802.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41803.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41804.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41806.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41807.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41808.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41809.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41810.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41812.png
  inflating: DevanagariHandwrittenDigitDataset/Train/digit_7/41814.png
```

```
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/DevanagariHandwrittenDigitDataset/Train"
test_dir = "/content/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)
            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)
```



Task 1 (Data Preparation)

```
import zipfile
import os

# Define the path to the uploaded zip file and extraction directory
zip_path = '//content/Copy of devnagari digit.zip'
extraction_dir = '/content/DevanagariHandwrittenDigitDataset'

# Unzip the dataset
with zipfile.ZipFile(zip_path, 'r') as zip_ref:
    zip_ref.extractall(extraction_dir)

# List extracted folders to verify
extracted_folders = os.listdir(extraction_dir)
extracted_folders
```

```
['Train', 'Test', 'DevanagariHandwrittenDigitDataset']
```

Checking the contents inside folder

```
# Check the contents inside 'DevanagariHandwrittenDigitDataset' to find train/test folders
dataset_main_dir = os.path.join(extraction_dir, 'DevanagariHandwrittenDigitDataset')
dataset_contents = os.listdir(dataset_main_dir)
dataset_contents
```

```
['Train', 'Test']
```

Data Preparation of 'Train'

```
# List class folders inside the Train directory
train_dir = os.path.join(dataset_main_dir, 'Train')
class_folders = os.listdir(train_dir)
class_folders_sorted = sorted(class_folders)  # Ensure label order is consistent
class_folders_sorted
```

```
['digit_0',
 'digit_1',
 'digit_2',
 'digit_3',
 'digit_4',
 'digit_5',
 'digit_6',
 'digit_7',
 'digit_8',
 'digit_9']
```

Data Preparation of 'Test'

```
# List class folders inside the Train directory
train_dir = os.path.join(dataset_main_dir, 'Test')
class_folders = os.listdir(train_dir)
class_folders_sorted = sorted(class_folders)  # Ensure label order is consistent
class_folders_sorted
```

```
['digit_0',
 'digit_1',
 'digit_2',
 'digit_3',
 'digit_4',
 'digit_5',
 'digit_6',
 'digit_7',
 'digit_8',
 'digit_9']
```

```
class_folders = sorted(os.listdir(train_dir))
```

```
def load_images(base_dir, class_folders, image_size=(28, 28)):
    images = []
    labels = []
    for label_index, folder in enumerate(class_folders):
        folder_path = os.path.join(base_dir, folder)
        for filename in os.listdir(folder_path):
            if filename.endswith('.png'):
                img_path = os.path.join(folder_path, filename)
                img = Image.open(img_path).convert('L')  # Grayscale
                img = img.resize(image_size)
                img_array = np.array(img) / 255.0  # Normalize
                images.append(img_array)
                labels.append(label_index)
    return np.array(images), np.array(labels)
```

```
# Load data
X_train, y_train = load_images(train_dir, class_folders)
X_test, y_test = load_images(test_dir, class_folders)
```

```
X_train = X_train.reshape(-1, 28*28)
X_test = X_test.reshape(-1, 28*28)
```

```
y_train_ohe = to_categorical(y_train, num_classes=10)
y_test_ohe = to_categorical(y_test, num_classes=10)
```

```
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Input, Dense, Dropout

# --- Build FCN Model with Input Layer ---
model = Sequential([
    Input(shape=(784,)),  # Explicit input layer
    Dense(512, activation='relu'),
    Dropout(0.2),
    Dense(256, activation='relu'),
    Dropout(0.2),
    Dense(128, activation='relu'),
    Dense(10, activation='softmax')  # Output layer for 10 classes
])
```

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

```
model.fit(X_train, y_train_ohe, epochs=10, batch_size=64, validation_split=0.1)
```

```
Epoch 1/10
43/43 ━━━━━━━━━━━━━━━━━━━━ 7s 91ms/step - accuracy: 0.5831 - loss: 1.3019 - val_accuracy: 0.0000e+00 - val_loss: 7.4591
Epoch 2/10
43/43 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.9029 - loss: 0.2935 - val_accuracy: 0.0000e+00 - val_loss: 8.2516
Epoch 3/10
43/43 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.9512 - loss: 0.1722 - val_accuracy: 0.0000e+00 - val_loss: 9.5219
Epoch 4/10
43/43 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.9650 - loss: 0.1101 - val_accuracy: 0.0000e+00 - val_loss: 9.0143
Epoch 5/10
43/43 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.9782 - loss: 0.0740 - val_accuracy: 0.0000e+00 - val_loss: 10.0877
Epoch 6/10
43/43 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.9797 - loss: 0.0551 - val_accuracy: 0.0000e+00 - val_loss: 9.6307
Epoch 7/10
43/43 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.9885 - loss: 0.0399 - val_accuracy: 0.0000e+00 - val_loss: 10.4918
Epoch 8/10
43/43 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.9873 - loss: 0.0389 - val_accuracy: 0.0000e+00 - val_loss: 11.1245
Epoch 9/10
43/43 ━━━━━━━━━━━━━━━━━━━━ 0s 5ms/step - accuracy: 0.9944 - loss: 0.0239 - val_accuracy: 0.0000e+00 - val_loss: 11.1943
Epoch 10/10
43/43 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.9948 - loss: 0.0208 - val_accuracy: 0.0000e+00 - val_loss: 12.0127
<keras.src.callbacks.history.History at 0x7ba2521b5310>
```

```
test_loss, test_accuracy = model.evaluate(X_test, y_test_ohe)
print(f"Test Accuracy: {test_accuracy * 100:.2f}%")
```

```
94/94 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.9905 - loss: 0.0943
Test Accuracy: 89.73%
```

Task 2: Build the FCN Model (as per specs)

```
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Input, Dense

# --- Build FCN with specified architecture ---
model = Sequential([
    Input(shape=(784,)),  # 28x28 images flattened
    Dense(64, activation='sigmoid'),
    Dense(128, activation='sigmoid'),
    Dense(256, activation='sigmoid'),
    Dense(10, activation='softmax')  # Output layer for 10 classes
])

print("Model built successfully.")
model.summary()
```

```
Model built successfully.
Model: "sequential_1"
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                         ┃ Output Shape                ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ 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)
```

Task 3: Compile the Model

```
# --- Compile model ---
model.compile(optimizer='adam',
              loss='categorical_crossentropy',  # Since labels are one-hot encoded
              metrics=['accuracy'])

print("Model compiled.")
```

```
Model compiled.
```

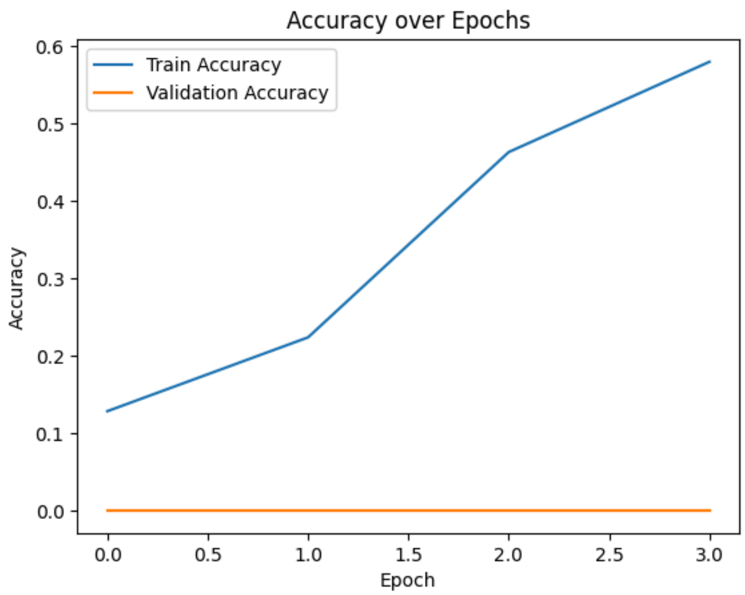
Task 4: Train the Model

```
from tensorflow.keras.callbacks import EarlyStopping, ModelCheckpoint
import matplotlib.pyplot as plt

# --- Callbacks ---
early_stop = EarlyStopping(monitor='val_loss', patience=3, restore_best_weights=True)
checkpoint = ModelCheckpoint('best_devnagari_model.h5', save_best_only=True, monitor='val_loss')

# --- Train the model ---
history = model.fit(X_train, y_train_ohe,
                    epochs=20,
                    batch_size=128,
                    validation_split=0.2,
                    callbacks=[early_stop, checkpoint])

print("Training complete.")
```

```
Epoch 1/20
19/19 ━━━━━━━━━━━━━━━━━━━━ 0s 75ms/step - accuracy: 0.1249 - loss: 2.4021WARNING:absl:You are saving your model as an HDF5 file via `moc
19/19 ━━━━━━━━━━━━━━━━━━━━ 5s 123ms/step - accuracy: 0.1251 - loss: 2.3936 - val_accuracy: 0.0000e+00 - val_loss: 5.5796
Epoch 2/20
19/19 ━━━━━━━━━━━━━━━━━━━━ 2s 6ms/step - accuracy: 0.2220 - loss: 2.0362 - val_accuracy: 0.0000e+00 - val_loss: 6.5759
Epoch 3/20
19/19 ━━━━━━━━━━━━━━━━━━━━ 0s 5ms/step - accuracy: 0.4345 - loss: 1.8918 - val_accuracy: 0.0000e+00 - val_loss: 6.7291
Epoch 4/20
19/19 ━━━━━━━━━━━━━━━━━━━━ 0s 6ms/step - accuracy: 0.5587 - loss: 1.6020 - val_accuracy: 0.0000e+00 - val_loss: 6.7781
Training complete.
```

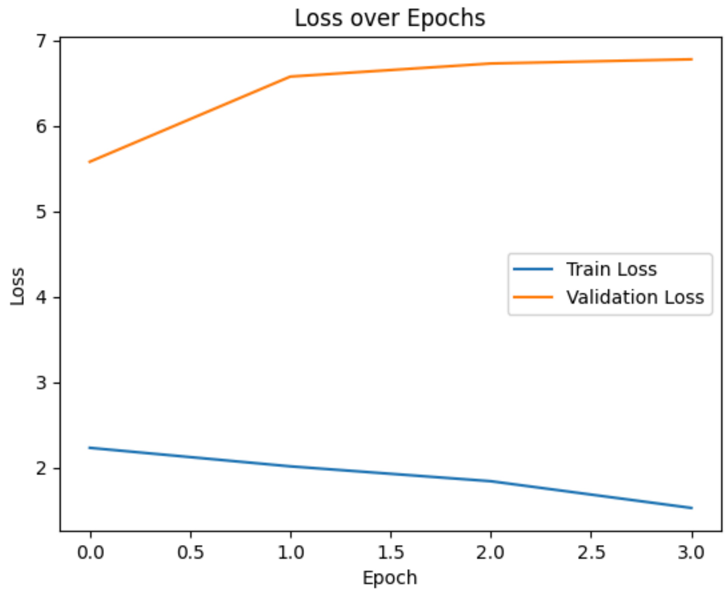
Plot accuracy

```
# --- Plot accuracy ---
plt.plot(history.history['accuracy'], label='Train Accuracy')
plt.plot(history.history['val_accuracy'], label='Validation Accuracy')
plt.title('Accuracy over Epochs')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.legend()
plt.show()
```



Plot Loss

```
# --- Plot loss ---
plt.plot(history.history['loss'], label='Train Loss')
plt.plot(history.history['val_loss'], label='Validation Loss')
plt.title('Loss over Epochs')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.legend()
plt.show()
```



Task 5: Evaluate the Model on Test Data

```
# --- Evaluate on test set ---
test_loss, test_acc = model.evaluate(X_test, y_test_ohe)
print(f"Test Accuracy: {test_acc * 100:.2f}%")
print(f"Test Loss: {test_loss:.4f}")
```

```
94/94 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - accuracy: 0.1916 - loss: 2.0849
Test Accuracy: 10.20%
Test Loss: 2.7605
```

Task 6: Save and Load the Model

Save the Model

```
# --- Save model ---
model.save('devnagari_digit_model.keras')
print("Model saved as 'devnagari_digit_model.keras'")
```

```
Model saved as 'devnagari_digit_model.keras'
```

Load the Model and Re-evaluate

```
from tensorflow.keras.models import load_model

# --- Load model ---
loaded_model = load_model('devnagari_digit_model.keras')
print("Model loaded.")

# --- Recompile model ---
loaded_model.compile(optimizer='adam',
                     loss='categorical_crossentropy',
                     metrics=['accuracy'])

# --- Re-evaluate ---
loss, accuracy = loaded_model.evaluate(X_test, y_test_ohe)
print(f"Loaded Model Test Accuracy: {accuracy * 100:.2f}%")
print(X_test.shape)  # Should be (num_samples, 784)
print(X_test.min(), X_test.max())  # Should be 0.0 and 1.0
print(y_test_ohe.shape)  # Should be (num_samples, 10) for one-hot
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/saving/saving_lib.py:757: UserWarning: Skipping variable loading for optimizer 'rmsprc
  saveable.load_own_variables(weights_store.get(inner_path))
Model loaded.
94/94 ━━━━━━━━━━━━━━━━━━━━ 1s 4ms/step - accuracy: 0.1916 - loss: 2.0849
Loaded Model Test Accuracy: 10.20%
(3000, 784)
0.0 1.0
(3000, 10)
```

Task 7: Make Predictions

```
import numpy as np

# --- Predict on test images ---
predictions = loaded_model.predict(X_test)

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

# --- Display first 10 predictions and true labels ---
print("Predicted labels:", predicted_labels[:10])
print("True labels     :", np.argmax(y_test_ohe[:10], axis=1))
```

```
94/94 ━━━━━━━━━━━━━━━━━━━━ 1s 3ms/step
Predicted labels: [1 1 1 1 1 1 1 1 1 1]
True labels     : [0 0 0 0 0 0 0 0 0 0]
```