Building a Fully Connected Feedforward Neural Network (FCFNN) for 10-Class MNIST Classification

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1 Introduction

The MNIST dataset is a benchmark dataset in machine learning that contains handwritten digits from 0 to 9. It consists of 60,000 training images and 10,000 testing images, each of size 28×28 pixels. The goal of this report is to build a Fully Connected Feedforward Neural Network (FCFNN) to classify these digits into 10 classes.

2 Dataset

The MNIST dataset can be loaded directly from Keras datasets:

- Training set: 60,000 images with labels.

- Testing set: 10,000 images with labels.

Each image is grayscale with pixel values in the range $[0, 255]$.

3 Model Architecture

The FCFNN model consists of the following layers:

1. **Input layer:** Accepts images of shape 28×28.

2. **Flatten layer:** Converts the 2D image into a 1D vector of size 784.

3. **Hidden layers:** Six dense layers with ReLU activation:

    - Dense(128)
    - Dense(256)
    - Dense(512)
    - Dense(256)

- Dense(128)

4. **Output layer:** Dense(10) with softmax activation to predict probabilities for 10 classes.

The model diagram can be represented as:

$$28 \times 28 \rightarrow 784 \rightarrow 128 \rightarrow 256 \rightarrow 512 \rightarrow 256 \rightarrow 128 \rightarrow 10$$

4 Model Compilation and Training

The model is compiled using:

- Optimizer: Adam

- Loss function: Sparse Categorical Crossentropy

- Metrics: Accuracy

Training is performed with:

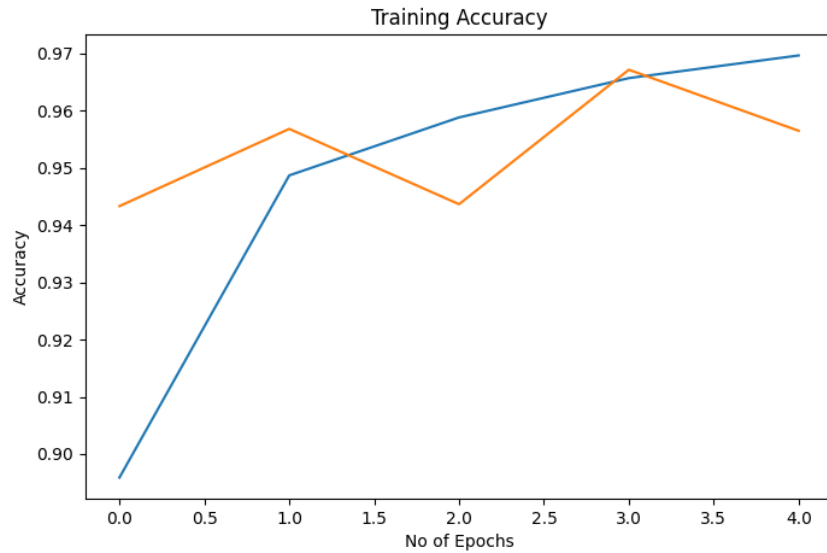- Epochs: 20

- Batch size: 32

- Validation split: 10%

Figure 1: Training and validation accuracy over epochs.

5 Evaluation

The trained model is evaluated on the test set. The test accuracy is:

$$\text{Test Accuracy} = 0.9513$$

Predictions are generated using the softmax outputs, and the predicted label is the class with the highest probability.

6 Results Visualization

6.1 Predicted Labels

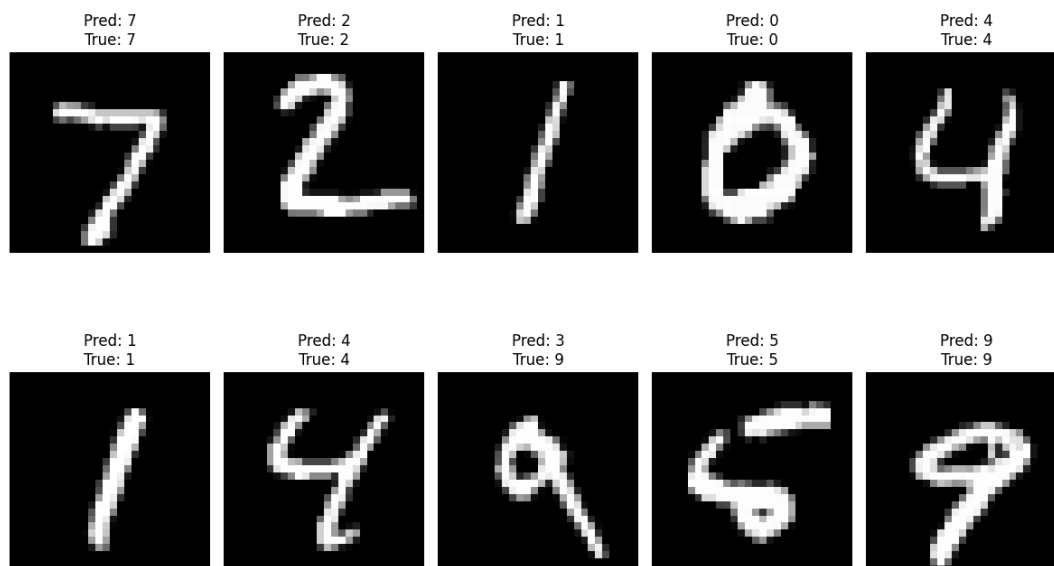Ten test images with predicted and true labels are visualized in Figure 2.

Figure 2: Sample test images with predicted and true labels.

6.2 Observations

- The model achieves high accuracy on the MNIST dataset, showing the effectiveness of fully connected layers.

- Misclassifications mostly occur for digits with similar shapes, such as 3 and 5 or 4 and 9.

7 Conclusion

This report demonstrated the construction, training, and evaluation of a Fully Connected Feedforward Neural Network (FCFNN) for handwritten digit classification using

the MNIST dataset. Despite the simplicity of the FCFNN architecture, it can achieve reasonable accuracy and provide a baseline for more complex models such as Convolutional Neural Networks (CNNs).

8 Code Resources

The implementation of the 10-class MNIST classification model, including training and evaluation scripts, is available through the following platforms:

- GitHub: Click here

- Google Colab: Click here