MNIST Handwritten Digit Classification using Neural Networks

Abstract

This project focuses on classifying handwritten digits from the MNIST dataset using a deep learning model built with Keras. The network is trained to identify digits 0–9 from grayscale images. A feedforward neural network was implemented, achieving a training accuracy of **98.9%** and a test accuracy of **97.1%**. The evaluation also includes confusion matrix analysis to highlight class-specific performance.

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1. Introduction

Handwritten digit recognition is a foundational problem in computer vision and machine learning. The MNIST dataset is a benchmark for evaluating classification algorithms. This project demonstrates the application of a neural network model for MNIST digit classification, covering the entire pipeline from data loading to performance evaluation.

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2. Dataset Details

- **Source:** MNIST dataset from keras.datasets
- **Training set:** 60,000 images
- **Test set:** 10,000 images
- **Image size:** 28 × 28 pixels
- **Channels:** 1 (grayscale)
- **Classes:** Digits from 0 to 9

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3. Data Preprocessing

1. **Loading Data:** Dataset loaded using keras.datasets.mnist.load_data().
2. **Normalization:** Pixel values scaled from [0, 255] to [0, 1].
3. **Flattening:** Images reshaped from 28×28 to 784-element vectors for input to the dense layers.
4. **One-Hot Encoding:** Class labels transformed into one-hot vectors for multi-class classification.

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4. Model Architecture

The neural network was designed as follows:

Layer	Type	Units/Filters	Activation	Input Shape
Dense (1)	Fully Connected	128	ReLU	(784,)
Dense (2)	Fully Connected	64	ReLU	—
Dense (3)	Fully Connected	10	Softmax	—

- **Loss function:** categorical_crossentropy
- **Optimizer:** adam
- **Metrics:** accuracy

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5. Training Setup & Hyperparameters

- **Epochs:** 10
- **Batch size:** 32
- **Validation split:** 20% of training data used for validation
- **Framework:** TensorFlow + Keras

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6. Results & Performance

- **Training Accuracy:** 98.9%
- **Test Accuracy:** 97.1%
- **Observation:** The model generalized well with minimal overfitting.

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7. Confusion Matrix & Analysis

The confusion matrix revealed strong performance across all classes, with occasional misclassification between similar digits such as **4 and 9**, or **3 and 5**. This is typical in MNIST classification due to similarities in handwritten styles.

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8. Conclusion

The project successfully demonstrates a high-accuracy neural network classifier for MNIST handwritten digits. While accuracy is already high, improvements could be made by:

- Using Convolutional Neural Networks (CNNs) for better spatial feature extraction
- Applying data augmentation to improve robustness
- Hyperparameter tuning