CSE 421 – Embedded Machine Learning

Q4: Handwritten Digit Recognition from Digital Images

Can Sarp Aridogan
Ahmet Renda Sendag

1. Introduction

This task implements a handwritten digit recognition system using grayscale image data. The problem is formulated as a binary classification task that distinguishes the digit zero from all other digits.

2. Dataset

The MNIST dataset is used in this experiment. It contains 28×28 grayscale images of handwritten digits. The dataset is split into a training set and a test set. Labels are converted into a binary form: zero is class 0, and all other digits are grouped as class 1 (not zero).

3. Feature Extraction

For each image, Hu invariant moments are computed. These moments capture the global shape characteristics of the digit and provide a compact, translation- and scale-invariant feature representation. Seven Hu moments are extracted per image and normalized using z-score normalization.

4. Model

A single-neuron model with sigmoid activation is trained on the extracted features. This model corresponds to logistic regression and is suitable for embedded deployment due to its minimal complexity. Binary cross-entropy loss and the Adam optimizer are used, with class weighting applied to emphasize the zero class.

5. Results

On the MNIST test set, the model achieved an accuracy of 0.8441. The number of false negatives (zero classified as not zero) is 33.

Confusion Matrix (rows = true label, columns = predicted label):
[[947 33]

[1526 749]]

6. Embedded Implementation Plan

After training, the model parameters are exported to C source code. On an STM32 microcontroller, Hu moments are computed from the input image, normalized using the stored mean and standard deviation, and passed to the single-neuron classifier. The output probability is thresholded at 0.5 to obtain the final decision.

7. Conclusion

The results demonstrate that Hu moment features combined with a very small neural network can effectively distinguish the digit zero from other digits. The approach is computationally efficient and well suited for embedded systems.