Pattern Recognition Exercise 2 Report

Group 5

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1 Introduction

This report presents the results of applying Support Vector Machines (SVM), Multilayer Perceptron (MLP), and Convolutional Neural Networks (CNN) to the MNIST dataset. The goal was to optimize each model's hyperparameters to achieve the best possible classification accuracy.

2 Methods

2.1 Dataset

The full MNIST dataset was used, consisting of:

- Training set: 60,000 images
- Test set: 10,000 images

The dataset was split into 80% training and 20% validation sets for model development, with the test set used only for final evaluation.

3 Results

3.1 Support Vector Machine (SVM)

The SVM was trained using two different kernels: linear and RBF. The hyperparameters were optimized using cross-validation.

3.1.1 Linear Kernel

- Hyperparameter: 'C': [0.1, 1, 10, 100]

3.1.2 RBF Kernel

- Hyperparameter: 'C': [0.1, 1, 10, 100]
- Hyperparameter: 'gamma': ['scale', 'auto', 0.01, 0.1]

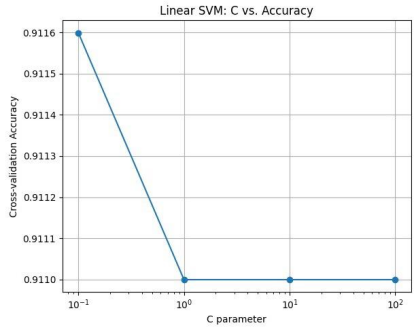

Figure 1: Linear SVM: C vs. Accuracy

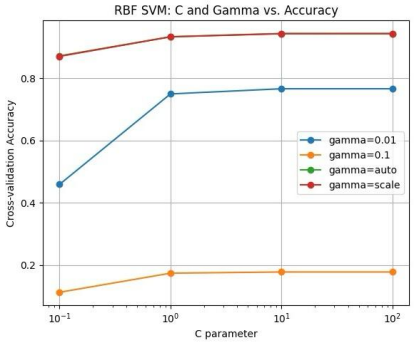

Figure 2: RBF SVM: C and Gamma vs. Accuracy

3.1.3 Final Performance

The best SVM model was the RBF kernel with parameters $C = 10$ and $\gamma = \text{auto}$. This model achieved the following accuracy on the test set:

- Test accuracy: 97.14%

3.2 Multilayer Perceptron (MLP)

The MLP was implemented with one hidden layer and the following hyperparameters:

- Hidden size: 128 neurons
- Learning rate: 0.001
- Batch size: 64
- Epochs: 10

3.2.1 Training Progress

The model showed consistent improvement across epochs (Table 1)

Table 1: MLP Training Metrics by Epoch

Epoch	Train Loss	Train Acc	Val Loss	Val Acc
1	0.3779	0.8984	0.2144	0.9399
2	0.1734	0.9501	0.1536	0.9536
3	0.1223	0.9645	0.1268	0.9622
4	0.0923	0.9727	0.1117	0.9663
5	0.0733	0.9785	0.1020	0.9702
6	0.0591	0.9823	0.0954	0.9728
7	0.0481	0.9857	0.0984	0.9708
8	0.0397	0.9881	0.0879	0.9748
9	0.0322	0.9912	0.0940	0.9733
10	0.0264	0.9925	0.0902	0.9746

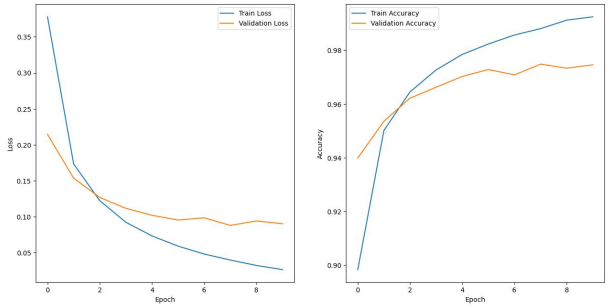

Figure 3: MLP training and validation metrics across epochs

3.2.2 Final Performance

The MLP achieved the following accuracies (Figure 3)

- Training accuracy: 99.25%
- Validation accuracy: 97.48%
- Test accuracy: 97.40%

The model demonstrated good generalization with minimal overfitting, as evidenced by the close training and validation accuracies.

3.3 Convolutional Neural Network (CNN)

The CNN was implemented with the following architecture and hyperparameters:

- Kernel size: 5
- Number of layers: 2
- Learning rate: 0.001
- Epochs: 5

3.3.1 Training Progress

The model showed consistent improvement across epochs, as shown in the plots:

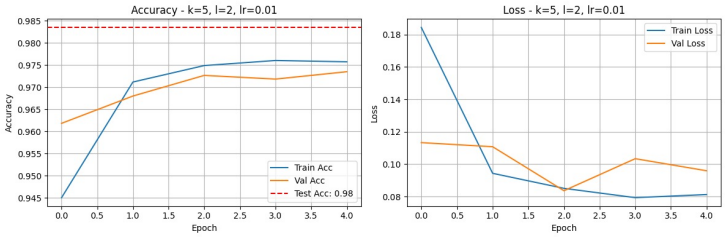

Figure 4: CNN training and validation metrics across epochs

3.3.2 Final Performance

The CNN achieved the following accuracies:

- Best validation accuracy: 98.85%
- Test accuracy: 99.07%

The model demonstrated strong performance and generalization, with high accuracy on both the validation and test sets.

4 Conclusion

In this study, we evaluated the performance of three models on the MNIST dataset. The MLP achieved a test accuracy of 97.40%, while the SVM, with the best parameters $C = 10$ and $\gamma = \text{auto}$, reached 97.14%. The CNN, however, outperformed both with a test accuracy of 99.07%. These results demonstrate the CNN's superior capability for image classification tasks, confirming its effectiveness for the MNIST dataset.