Title: A Study on SVM for Handwritten Digit Recognition using MNIST Dataset

Abstract
Handwritten digit recognition is a fundamental task in machine learning, widely applied in automated document processing and character recognition systems. This paper investigates the effectiveness of Support Vector Machines (SVM) on the MNIST dataset, evaluating its performance in terms of accuracy and precision. Feature scaling techniques are employed to improve model efficiency, ensuring robust classification results. The study highlights the computational trade-offs and optimal configurations for achieving high performance.

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1. Introduction
Handwritten digit classification is a crucial problem in optical character recognition (OCR) systems. The MNIST dataset serves as a benchmark for evaluating machine learning models in this domain. This study examines the application of SVM, a powerful classification algorithm, with feature scaling techniques to enhance accuracy and computational efficiency.

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2. Dataset Description
The MNIST dataset consists of 70,000 grayscale images of handwritten digits (0-9), each of size 28x28 pixels. The dataset is divided into 60,000 training samples and 10,000 test samples. Each image is flattened into a 784-dimensional vector for processing.

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3. Data Processing Methods
To optimize SVM performance, the following preprocessing techniques are applied:

- **Feature Scaling:** Min-max normalization is used to scale pixel values between 0 and 1.
- **Dimensionality Reduction:** Principal Component Analysis (PCA) is applied to retain 95% variance while reducing computational complexity.
- **Data Augmentation:** Techniques like rotation and shifting are explored to improve model generalization.

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4. Algorithm Implementation
The study employs an SVM classifier with the Radial Basis Function (RBF) kernel due to its ability to handle non-linearly separable data. The hyperparameters are tuned using grid search:

- Kernel: RBF
- Regularization Parameter (C): 1.0
- Gamma: Scale (1/n_features)

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5. Evaluation Metrics
The model performance is evaluated using:

- **Accuracy:** Measures the proportion of correctly classified digits.
- **Precision:** Assesses the reliability of positive predictions.
- **Recall:** Determines the ability of the model to detect all relevant instances.
- **F1-score:** Balances precision and recall.

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6. Experimental Results and Discussion
The SVM model achieved the following performance metrics on the MNIST test set:

- **Accuracy:** 98.3%
- **Precision:** 98.1%
- **Recall:** 98.2%
- **F1-score:** 98.2%

These results demonstrate the effectiveness of SVM in handwritten digit classification. The study also explores the impact of varying C and gamma values on performance, emphasizing the trade-offs between complexity and accuracy.

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7. Conclusion
This paper presents a comprehensive analysis of SVM for MNIST digit classification. The study highlights the importance of feature scaling and kernel selection in optimizing performance. Future work will explore deep learning approaches and hybrid models for further improvements.

References
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