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Report about Handwritten Digit Recognition with SVM

Master 1 Artificial Intelligence

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1. Introduction

The objective of this project is to classify images of handwritten digits into their respective numerical values (0 to 9) using the "Digits" dataset available in scikit-learn. This report summarizes the steps undertaken, results obtained, and key insights gained from applying Support Vector Machine (SVM) models for this task.

2. Data Exploration and Pre-processing

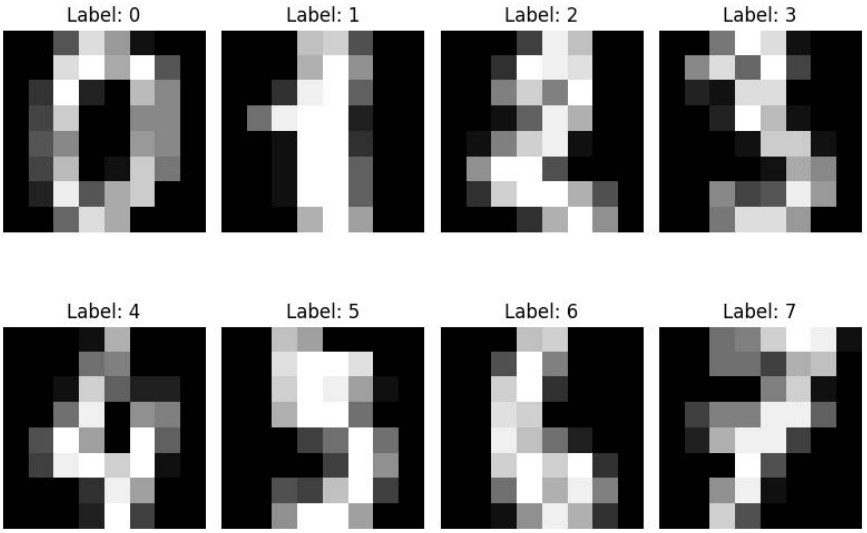
Dataset Information:

- ✓ **Dataset Shape:** (1797, 64)
- ✓ Number of Classes: 10
- ✓ Sample Labels: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]

The dataset consists of 1,797 samples, each represented by a flattened 8x8 grayscale image (64 features). The dataset is balanced, with an approximately equal number of samples per class.

Data Preprocessing:

1. Normalization: Pixel values were normalized to the range [0, 1] to ensure uniform scaling and better performance.
2. Train-Test Split: The dataset was split into 80% training and 20% testing data to evaluate model generalization.



2. Train an SVM Model

Implementation

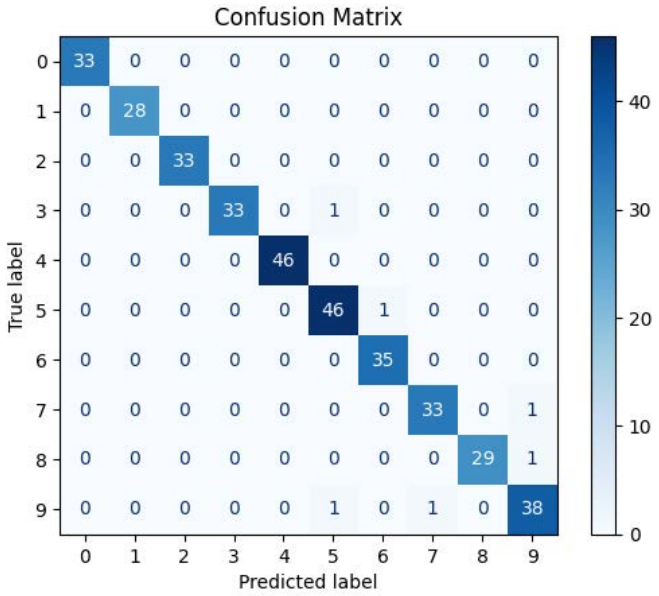
1. **Custom SVM:** Implemented a Support Vector Machine from scratch (as explained in class).
2. **Scikit-learn SVM:** Used the SVM implementation from scikit-learn with the RBF kernel for non-linear classification.

3. Model Evaluation

Scikit-learn SVM:

- ✓ **Accuracy:** 0.98
- ✓ **F1 Score:** 0.98
- ✓ **Performance Analysis:** The scikit-learn SVM achieved near-perfect classification due to the RBF kernel's ability to capture non-linear relationships in the data.

Confusion Matrix:

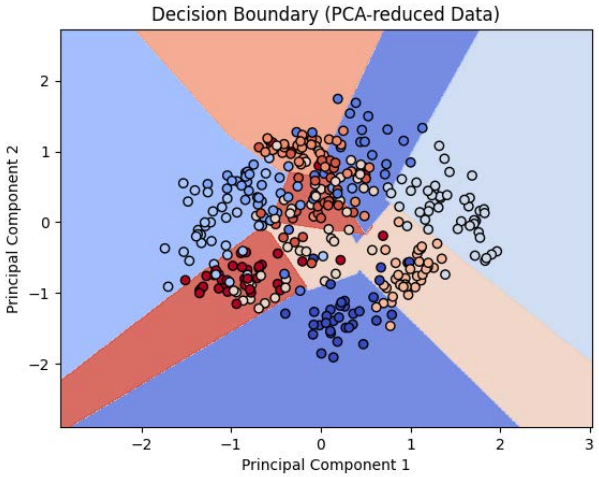


Insights:

- The confusion matrix shows the number of correct and incorrect predictions for each digit class.
- Most predictions lie along the diagonal, indicating accurate classification.
- Few misclassifications occurred, often between visually similar digits.

4. Visualize the Decision Boundary

PCA-Reduced Data Visualization



Commentary:

- ✓ The visualization showcases the decision boundaries learned by the scikit-learn SVM model after PCA dimensionality reduction.
- ✓ **Insights:**
  - **Clear Separation: T**he boundaries effectively separate most classes, indicating the model's ability to handle multi-class problems.
  - **Overlapping Regions: S**ome ambiguity exists in overlapping areas, particularly for classes with similar features (e.g., digits 4 and 9).
  - **Dimensionality Reduction:** Reducing to two principal components helped simplify visualization while preserving class separability.

Conclusion

The scikit-learn SVM model demonstrated excellent performance on the digits dataset, achieving 98% accuracy and an F1 score of 0.98. Visualization of the decision boundaries and confusion matrix provided further insights into the model's strengths and weaknesses. Further improvements can be made through data augmentation and fine-tuning to ensure robustness and adaptability to new data. This project highlights the effectiveness of SVMs in image classification tasks, especially when paired with well-preprocessed data and appropriate kernel selection.