Model Performance, Observations & Conclusions

In this project, three classical machine learning models—K-Nearest Neighbours (KNN), Support Vector Machine (SVM), and Decision Tree—were trained to classify handwritten digits from the MNIST dataset. The dataset was normalized and split into training and testing sets to ensure fair evaluation.

KNN, implemented from scratch, achieved the highest accuracy of **95.3%**, demonstrating that distance-based classification performs very well for handwritten digit recognition when sufficient training data is available. SVM achieved an accuracy of **91.4%**, benefiting from its ability to construct optimal decision boundaries in high-dimensional pixel space. The Decision Tree achieved **87.0%**, but showed signs of overfitting, which reduced its generalization performance.

Most misclassifications occurred between visually similar digits such as **4 and 9**, **3 and 5**, and **0 and 8**, where pixel-level patterns overlap significantly. These errors occur because classical models rely purely on raw pixel intensities rather than learning higher-level shape features.

An ensemble voting approach combining the three models produced an accuracy of **0.839**, improving stability but not surpassing KNN. Further improvements could be achieved using PCA for dimensionality reduction and more extensive hyper parameter tuning.

Overall, this project demonstrates that classical machine learning techniques, when combined with proper pre-processing and evaluation, can effectively solve image classification problems.