Digit Recognition Dataset:

In each of the model, various parameters are tuned by using Cross Validation. Various parameter settings are given below.

1) **Decision Tree Classification:**
   The decision tree implementation in Assignment 1 obtained its best accuracy, after pruning the decision tree with a maximum depth of 11 on the digit dataset.
   The training accuracy obtained is: 99.06%, the validation accuracy obtained is 88.05% and the testing accuracy obtained is 85.35%. (Reference: Assignment 1).
2) **Neural Network Classification:**
   The Neural Network implementation in Assignment 2 obtained a best accuracy by setting the following parameters: iterations = 200, number of hidden layers = 60, Activation function = RELU, Solver = SGD, Learning Rate = 0.0001, Regularization Parameter alpha-0.0001.
   The above settings gave a training accuracy of 99.6%, validation accuracy of 97.8% and testing accuracy of 95.9%. (Reference: Assignment 2).
3) **K-Nearest Neighbors Classification Model:**
   For K-Nearest Neighbor classification model, after hyperparameter tuning of K, the value of K =5 gives more accuracy on the validation dataset. Hence, K = 5 is considered as the tuned parameter. Hence it obtained an accuracy of 100% on the Training dataset, 98.08% on the validation dataset and 97.82% on the testing dataset. (Reference Assignment 3)
4) **Adaboosting Classification model:**
   After tuning the parameters of the n_estimators, the value n_estimator=350 gives a better accuracy which reduces the error on both the training as well as validation dataset.
   The above settings gave an accuracy of 100% on the training dataset, 95.98% on the validation dataset and 92.82% on the testing dataset.
5) **SVM Classification Model:**
   For the Support Vector Machine Classification model, the values gamma, C are tuned and comparison of various kernels is done. After tuning, the RBF Kernel seems to be the best fit and the values of gamma and C that are giving best accuracy are C=1.2 and gamma = 0.001.
   The above parameters on the SVM Classification model gave an accuracy of 99.77% on the Training dataset, 98.95% on the validation dataset and 98.27% on the testing dataset.
6) **Naïve Bayes Classification Model:**
   For the Naïve Bayes classification model, the priors are not needed to train the learning model. The Laplacian smoothing of 1.0 is applied to the Training dataset to estimate the value. The Multinomial NB gave a better training accuracy of 92.04% and validation accuracy of 91.71% and a testing accuracy of 89.20%.

Performance Measure Comparison on all Classification Models:

Various parameters are used for performance measures.

1) Precision: It is the ratio of true positives by summation of true positives and false positives.
2) Recall: It is the ratio of true positives by summation of true positives plus false negatives.
3) F1-Score: It is the harmonic mean of precision and recall.
4) Accuracy: It is the number of correct predictions divided by a total number of samples.
5) Sample Complexity: Total no. of training samples required for fast convergence.

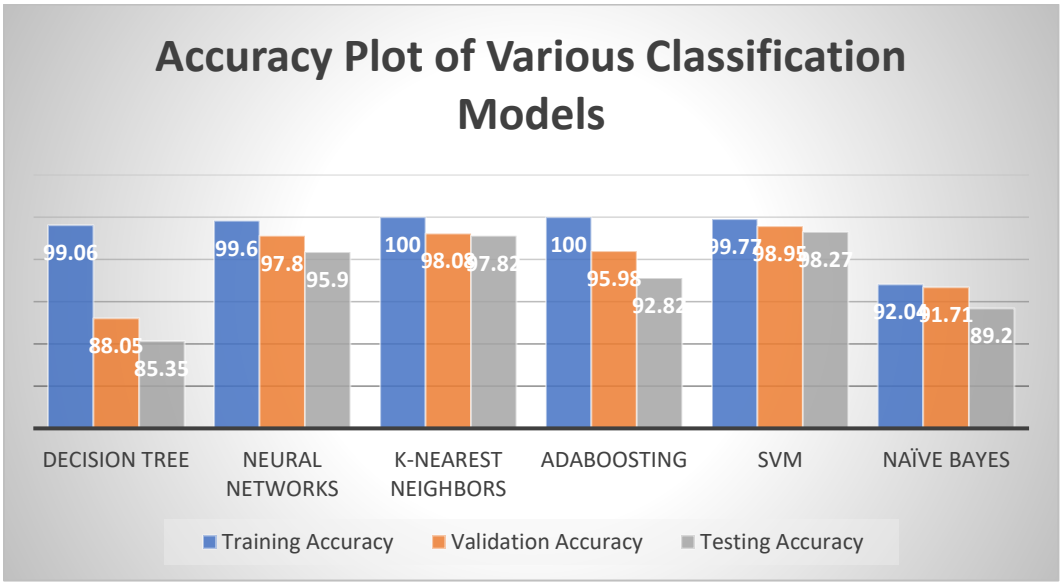
The below table consists of all the results of all the classification models that we have implemented till now. Also, the precision, recall, and F1-score of the Testing Accuracy are calculated and the sample complexity is used as performance measures to compare the results.

Color coding depicts which are the best model and worse models on Digit Dataset.

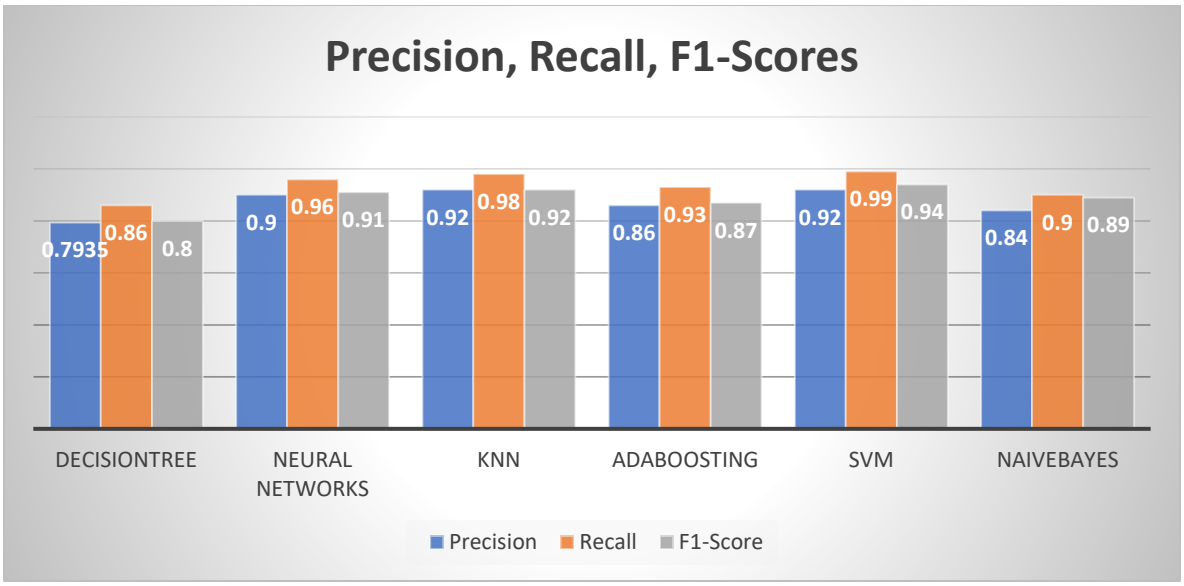
Classification Model	Training Accuracy	Validation Accuracy	Testing Accuracy	Precision	Recall	F1-Score	Sample Complexity
Decision Tree	99.06	88.05	85.35	0.7935	0.86	0.8	3823
Neural Networks	99.6	97.8	95.9	0.9	0.96	0.91	3823
K-Nearest Neighbors	100	98.08	97.82	0.92	0.98	0.92	3823
Adaboosting	100	95.98	92.82	0.86	0.93	0.87	3823
SVM	99.77	98.95	98.27	0.92	0.99	0.94	3823
Naïve Bayes	92.04	91.71	89.2	0.84	0.9	0.89	3823

Table Demonstrating various values of performance of each model.

The plot for accuracy comparison of each classification models:



The plot for various Performance Parameter comparison for each model:



From the above results and tables, one of the best classification model that perfectly classifies the given Digit Recognition dataset is Support Vector Machine Model which gives the highest Testing Accuracy of 98.27%.

Also, it contains the highest Precision, Recall and F1-score values which are some of the other measures for estimating the performance of the dataset. Hence from the above values, we can conclude SVM as the best classification model for the Digit Recognition Dataset.