Assignment 2

MTL782

Ashi Veerman 2021MT10241

Shreya Gupta 2021MT10906

Priyal Jain 2021MT60949

Contents

1 Introduction

1.1 Objective

- Implement (1) Decision Tree, (2) Random Forest, (3) Naive Bayes Classifier, (4) KNN classifier, and (5) Neural Network classifier on MNIST Handwritten digits Dataset and compare the performances using k-fold cross-validation and other tuning techniques to do multi-class classification where the idea is to classify the image to one of the ten digits (0-9).
- Exploration of Different Evaluation Metrics
- Parameter Tuning through Grid Search/Cross Validation. Tune the parameters using two powerful techniques of grid search and parameter search.

1.2 Data Preprocessing

The data was imported from the sci-kit learn datasets.

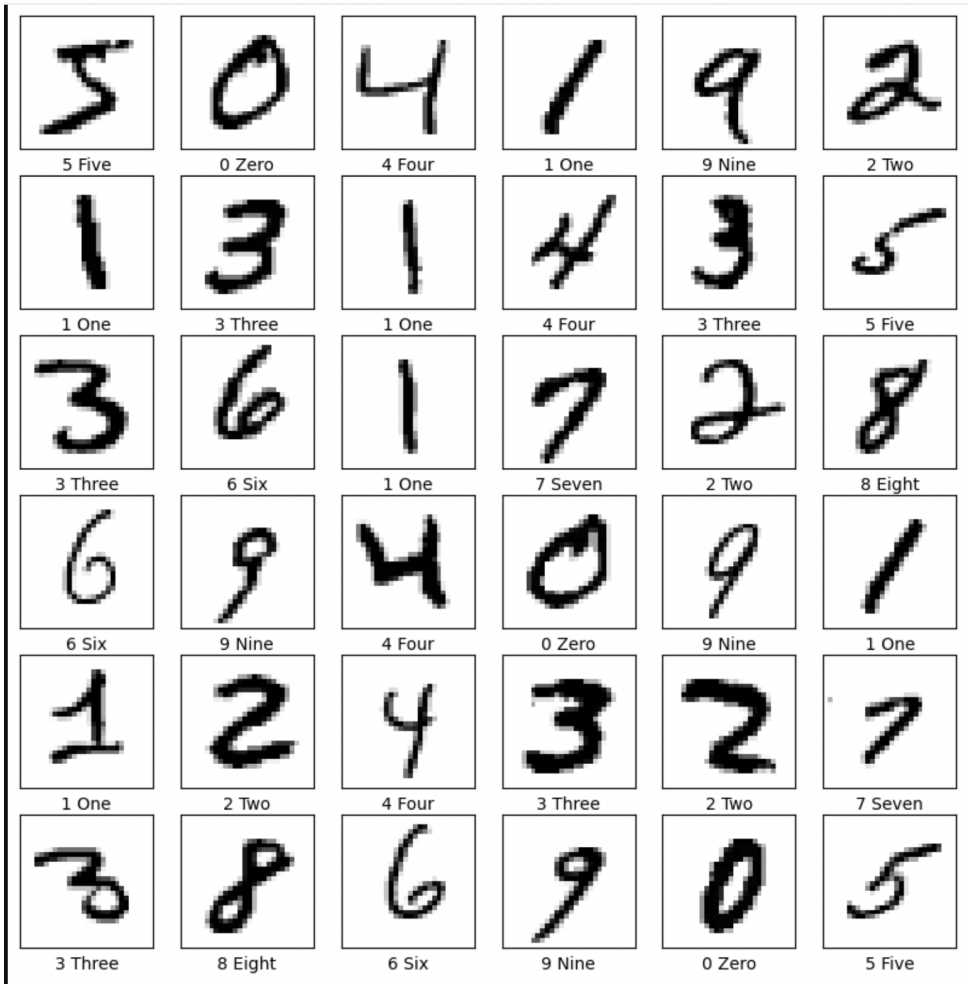

Figure 1: Data

The data was split into training and testing sets using 80-20 rule with shuffling enabled.

1.3 Helper Functions

For ease of implementation, we have constructed three helper functions to perform GridSearchCV, RandomSearchCV and Cross-Validation. These functions take model, model parameters, test and training data as input.
The evaluation metrics we are using are accuracy, f1 score, recall and precision.

2 Decision Tree Model

2.1 5-fold Cross-Validation

Avg validation accuracy : 0.8654107142857143
Avg validation f1 score : 0.8636310005561144
Avg validation precision score : 0.8636904910081803
Avg validation recall score : 0.8636746500664308
Testing accuracy : 0.8637857142857143
Testing f1 score : 0.8616281770344042
Testing precision : 0.861787961094846
Testing recall score : 0.8616175390660874

2.2 GridSearchCV

Max Depth	Min Samples Leaf	Min Samples Split	Testing Accuracies
5	1	2	0.66025
5	1	5	0.66025
5	1	10	0.66025
5	2	2	0.66025
5	2	5	0.66025
5	2	10	0.66025
5	4	2	0.66025
5	4	5	0.66025
5	4	10	0.66025
10	1	2	0.852036
10	1	5	0.850911
10	1	10	0.850964
10	2	2	0.850696
10	2	5	0.850464
10	2	10	0.850982
10	4	2	0.851625
10	4	5	0.851625
10	4	10	0.850982
15	1	2	0.867875
15	1	5	0.866571
15	1	10	0.865286
15	2	2	0.865214
15	2	5	0.865268
15	2	10	0.864946
15	4	2	0.866071
15	4	5	0.866071
15	4	10	0.866429

Table 1: GridSearchCV Results

The best accuracy is achieved with hyperparameters:
max_depth: 15
min_samples_leaf: 1
min_samples_split: 2
Testing accuracy: 0.8742142857142857
Testing f1 score: 0.8723324539185627
Testing precision: 0.8724218877529466
Testing recall score: 0.8723655423038871

2.3 RandomSearchCV

	params	mean_test_score
0	{'min_samples_split': 8, 'min_samples_leaf': 2...	0.836250
1	{'min_samples_split': 10, 'min_samples_leaf': ...	0.865143
2	{'min_samples_split': 2, 'min_samples_leaf': 4...	0.865661
3	{'min_samples_split': 8, 'min_samples_leaf': 2...	0.660250
4	{'min_samples_split': 6, 'min_samples_leaf': 4...	0.865661
5	{'min_samples_split': 6, 'min_samples_leaf': 1...	0.771036
6	{'min_samples_split': 6, 'min_samples_leaf': 2...	0.660250
7	{'min_samples_split': 2, 'min_samples_leaf': 3...	0.660250
8	{'min_samples_split': 2, 'min_samples_leaf': 2...	0.836286
9	{'min_samples_split': 10, 'min_samples_leaf': ...	0.865232

Figure 2: RandomSearchCV Results

The best accuracy is achieved with hyperparameters:
min_samples_split: 2
min_samples_leaf: 4
max_depth: 13
Testing accuracy : 0.8733571428571428
Testing f1 score : 0.8712980566312092
Testing precision : 0.8714382046279561
Testing recall score : 0.8713556534778736

3 Random Forest Model

3.1 5-Fold Cross Validation

Avg validation accuracy : 0.9668928571428571
Avg validation f1 score : 0.9665920613265022
Avg validation precision score : 0.9665648350520704
Avg validation recall score : 0.9666656252408868
Testing accuracy : 0.9646428571428571
Testing f1 score : 0.9644802292230386
Testing precision : 0.964402858629791
Testing recall score : 0.9645911394280974

3.2 GridSearchCV

Max Depth	Min Samples Leaf	Min Samples Split	Testing Accuracies
5	1	2	0.66025
5	1	5	0.66025
5	1	10	0.66025
5	2	2	0.66025
5	2	5	0.66025
5	2	10	0.66025
5	4	2	0.66025
5	4	5	0.66025
5	4	10	0.66025
10	1	2	0.852036
10	1	5	0.850911
10	1	10	0.850964
10	2	2	0.850696
10	2	5	0.850464
10	2	10	0.850982
10	4	2	0.851625
10	4	5	0.851625
10	4	10	0.850982
15	1	2	0.867875
15	1	5	0.866571
15	1	10	0.865286
15	2	2	0.865214
15	2	5	0.865268
15	2	10	0.864946
15	4	2	0.866071
15	4	5	0.866071
15	4	10	0.866429

Table 2: GridSearchCV Results

The best accuracy is achieved with hyperparameters:
max_depth: 15
n_estimators: 60
Testing accuracy : 0.9623571428571429
Testing f1 score : 0.962129774997831
Testing precision : 0.9620223601311245
Testing recall score : 0.9622966512307602

3.3 RandomSearchCV

Max Depth	Min Samples Leaf	Min Samples Split	Testing Accuracies
35	13	0.956661	
60	9	0.934554	
65	9	0.935268	
30	15	0.958161	
70	15	0.962696	
75	9	0.935411	
65	13	0.959589	
40	13	0.9575	
35	11	0.94825	
50	5	0.852107	

Table 3: RandomSearchCV Results

The best accuracy is achieved with hyperparameters:
n_estimators: 70
max_depth: 15
Testing accuracy : 0.9625714285714285
Testing f1 score : 0.9623623037124837
Testing precision : 0.9622202887872872
Testing recall score : 0.9625598639989464

4 KNN Classifier

4.1 5-Fold Cross Validation

Avg validation accuracy : 0.9689285714285715
Avg validation f1 score : 0.9687448022913541
Avg validation precision score : 0.9684867875142242
Avg validation recall score : 0.9693711524645933
Testing accuracy : 0.9680714285714286
Testing f1 score : 0.968045325787001
Testing precision : 0.9675849064511048
Testing recall score : 0.9688307587274734

4.2 GridSearchCV

N Neighobours	Testing Accuracies
1	0.969875
2	0.963339
3	0.970054
4	0.968375
5	0.968768
6	0.968
7	0.967929
8	0.966625
9	0.966411
10	0.965732

Table 4: GridSearchCV Results

The best accuracy is achieved with hyperparameters:
n_neighbors: 3
Testing accuracy : 0.9712857142857143
Testing f1 score : 0.9711991586660975
Testing precision : 0.9708657044620269
Testing recall score : 0.9717774214531696

4.3 RandomSearchCV

N Neighobours	Testing Accuracies
1	0.969875
2	0.963339
3	0.970054
4	0.968375
5	0.968768
6	0.968
7	0.967929
8	0.966625
9	0.966411
10	0.965732

Table 5: RandomSearchCV Results

The best accuracy is achieved with hyperparameters:
n_neighbors: 3
Testing accuracy : 0.9712857142857143
Testing f1 score : 0.9711991586660975
Testing precision : 0.9708657044620269
Testing recall score : 0.9717774214531696

5 Naive Bayes Classifier

5.1 5-Fold Cross Validation

Avg validation accuracy : 0.5493571428571429
Avg validation f1 score : 0.49456996199446673
Avg validation precision score : 0.5417040254703325
Avg validation recall score : 0.6629016203222802
Testing accuracy : 0.5505
Testing f1 score : 0.49235479061534093
Testing precision : 0.5402518100219911
Testing recall score : 0.6618619069951903

5.2 GridSearchCV

	params	mean_test_score
0	{'var_smoothing': 1.0}	0.732089
1	{'var_smoothing': 0.8111308307896871}	0.742518
2	{'var_smoothing': 0.657933224657568}	0.753018
3	{'var_smoothing': 0.533669923120631}	0.762232
4	{'var_smoothing': 0.4328761281083058}	0.770857
..	...	...
95	{'var_smoothing': 2.3101297000831578e-09}	0.554107
96	{'var_smoothing': 1.873817422860387e-09}	0.552911
97	{'var_smoothing': 1.519911082952933e-09}	0.551589
98	{'var_smoothing': 1.2328467394420633e-09}	0.550232
99	{'var_smoothing': 9.999999999999999e-10}	0.548946

Figure 3: GridSearchCV Results

The best accuracy is achieved with hyperparameters:
var_smoothing: 0.06579332246575678
Testing accuracy : 0.8055
Testing f1 score : 0.8036215602619391
Testing precision : 0.8006148278670201
Testing recall score : 0.822308122352797

5.3 RandomSearchCV

	params	mean_test_score
0	{'var_smoothing': 0.004328761281083057}	0.761464
1	{'var_smoothing': 1.519911082952933e-08}	0.566768
2	{'var_smoothing': 0.657933224657568}	0.753018
3	{'var_smoothing': 9.999999999999999e-06}	0.637429
4	{'var_smoothing': 1.519911082952933e-07}	0.586482
5	{'var_smoothing': 3.5111917342151273e-09}	0.556768
6	{'var_smoothing': 0.035111917342151314}	0.797839
7	{'var_smoothing': 2.3101297000831583e-07}	0.590768
8	{'var_smoothing': 1.2328467394420658e-05}	0.641054
9	{'var_smoothing': 2.3101297000831578e-09}	0.554107

Figure 4: RandomSearchCV Results

The best accuracy is achieved with hyperparameters:
var_smoothing: 0.035111917342151314
Testing accuracy : 0.8007142857142857
Testing f1 score : 0.7982823843037345
Testing precision : 0.7957605648282253
Testing recall score : 0.8171655400285476

6 Neural Network Classifier

6.1 5-Fold Cross Validation

Avg validation accuracy : 0.9618571428571429
Avg validation f1 score : 0.9614478421605208
Avg validation precision score : 0.9614204937958439
Avg validation recall score : 0.9616118269913162
Testing accuracy : 0.9595
Testing f1 score : 0.9590576425493401
Testing precision : 0.9592329103811551
Testing recall score : 0.9590504568656583

6.2 GridSearchCV

Hidden Layer Size	Activation	Testing Accuracies
tanh	10	0.883321
tanh	30	0.919911
tanh	40	0.927446
tanh	50	0.932304
tanh	70	0.937393
tanh	100	0.935679
relu	10	0.901071
relu	30	0.933232
relu	40	0.939179
relu	50	0.949446
relu	70	0.959232
relu	100	0.9615

Table 6: GridSearchCV Results

The best accuracy is achieved with hyperparameters:
activation: 'relu'
hidden_layer_sizes: 100
Testing accuracy : 0.9638571428571429
Testing f1 score : 0.9635230330617182
Testing precision : 0.9634759904998751
Testing recall score : 0.9636538537791282

6.3 RandomSearchCV

Hidden Layer Size	Activation	Testing Accuracies
10	relu	0.901071
100	relu	0.9615
70	tanh	0.937393
70	relu	0.959232
40	tanh	0.927446
40	relu	0.939179
30	tanh	0.91991
30	relu	0.933232
50	relu	0.949446
50	tanh	0.932304

Table 7: RandomSearchCV Results

The best accuracy is achieved with hyperparameters:
hidden_layer_sizes: 100
activation: 'relu'
Testing accuracy : 0.9638571428571429

Testing f1 score : 0.9635230330617182
Testing precision : 0.9634759904998751
Testing recall score : 0.9636538537791282