KNN FOR HANDWRITTEN DIGIT RECOGNITION:

FIVE-FOLD CROSS VALIDATION

- At each fold, the training data is divided into two sets.
- The first set has 33600 images for training purpose
- The second set has 8400 images for testing.
- Five-fold cross validation was performed by taking K = 3 and K = 5. The results were very similar.

```
*** FOLD  1  ***

Training_index:  [ 8400  8401  8402 ... 41997 41998 41999]
Testing_index:  [   0    1    2 ... 8397 8398 8399]
Size of the training data:  33600
Size of the testing data:  8400


*** FOLD  2  ***

Training_index:  [    0     1     2 ... 41997 41998 41999]
Testing_index:  [ 8400  8401  8402 ... 16797 16798 16799]
Size of the training data:  33600
Size of the testing data:  8400


*** FOLD  3  ***

Training_index:  [    0     1     2 ... 41997 41998 41999]
Testing_index:  [16800 16801 16802 ... 25197 25198 25199]
Size of the training data:  33600
Size of the testing data:  8400


*** FOLD  4  ***

Training_index:  [    0     1     2 ... 41997 41998 41999]
Testing_index:  [25200 25201 25202 ... 33597 33598 33599]
Size of the training data:  33600
Size of the testing data:  8400


*** FOLD  5  ***

Training_index:  [    0     1     2 ... 33597 33598 33599]
Testing_index:  [33600 33601 33602 ... 41997 41998 41999]
Size of the training data:  33600
Size of the testing data:  8400
```

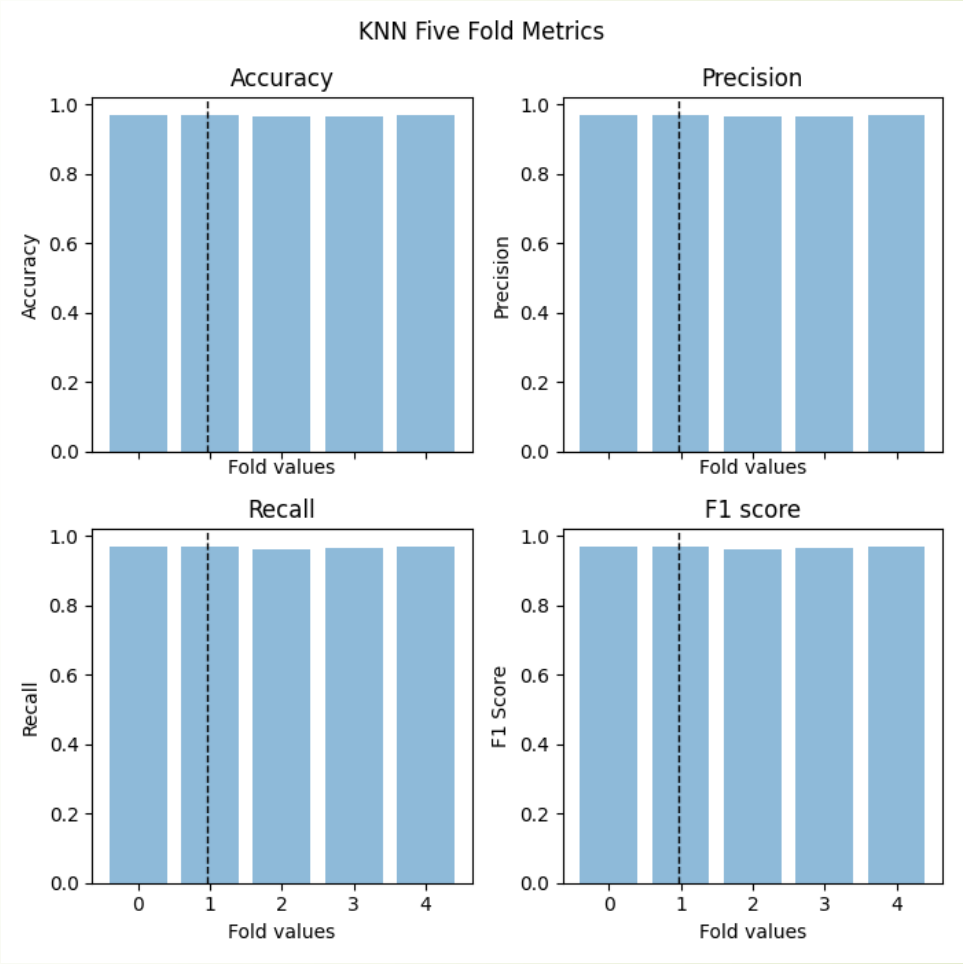
Evaluation Metrics over Five-Folds

- Accuracy, Precision, Recall and F1 score over five-folds when K = 3 and K = 5
- K = 3:

```
KNN Evaluation Metrics:
+------------+-------------+----------+------------+
|   Accuracy |   Precision |   Recall |   F1 Score |
|------------+-------------+----------+------------|
|   0.97     |    0.970315 | 0.9696   |   0.969857 |
|   0.967262 |    0.967701 | 0.966725 |   0.966979 |
|   0.962738 |    0.963169 | 0.9623   |   0.962517 |
|   0.96381  |    0.964318 | 0.963501 |   0.963685 |
|   0.969524 |    0.970346 | 0.968673 |   0.969279 |
+------------+-------------+----------+------------+
```

K = 5:

```
KNN Evaluation Metrics:
+------------+-------------+----------+------------+
|   Accuracy |   Precision |   Recall |   F1 Score |
|------------+-------------+----------+------------|
|   0.967857 |    0.968478 | 0.967389 |   0.967724 |
|   0.965238 |    0.965893 | 0.964614 |   0.965009 |
|   0.963571 |    0.964114 | 0.963134 |   0.963401 |
|   0.963214 |    0.963774 | 0.962926 |   0.96307  |
|   0.969048 |    0.969859 | 0.968245 |   0.968836 |
+------------+-------------+----------+------------+
```



Average Five-Fold Values

- The average values of accuracy, precision, recall and F1 score for K = 3 and K = 5 are shown.
- K = 3

```
Average metrics over five folds:

The average accuracy is: 0.9667
The average precision is: 0.9672
The average recall is: 0.9662
The average f1_score is: 0.9665
```

- K = 5

```
Average metrics over five folds:

The average accuracy is: 0.9658
The average precision is: 0.9664
The average recall is: 0.9653
The average f1_score is: 0.9656
```

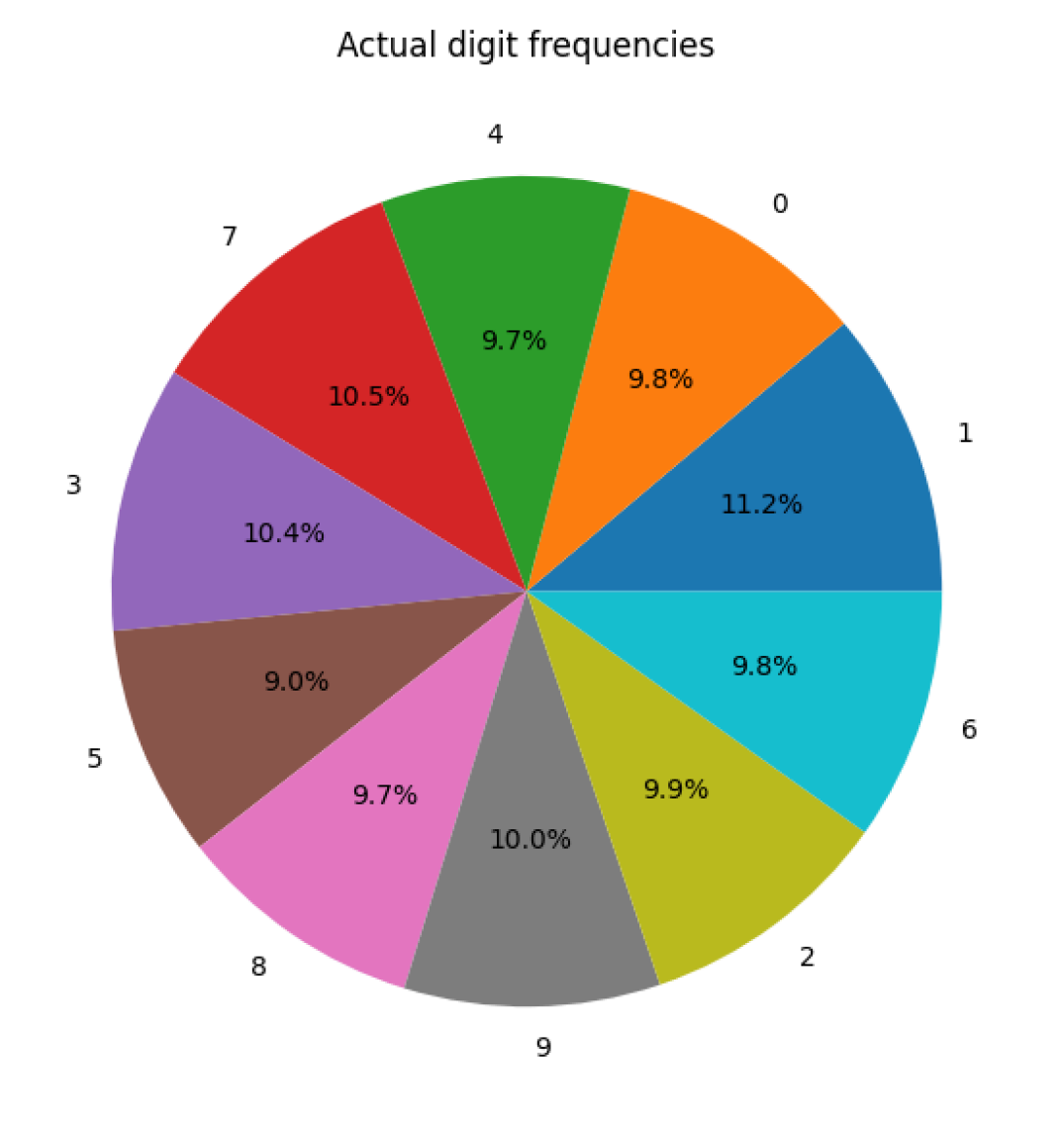
K = 3

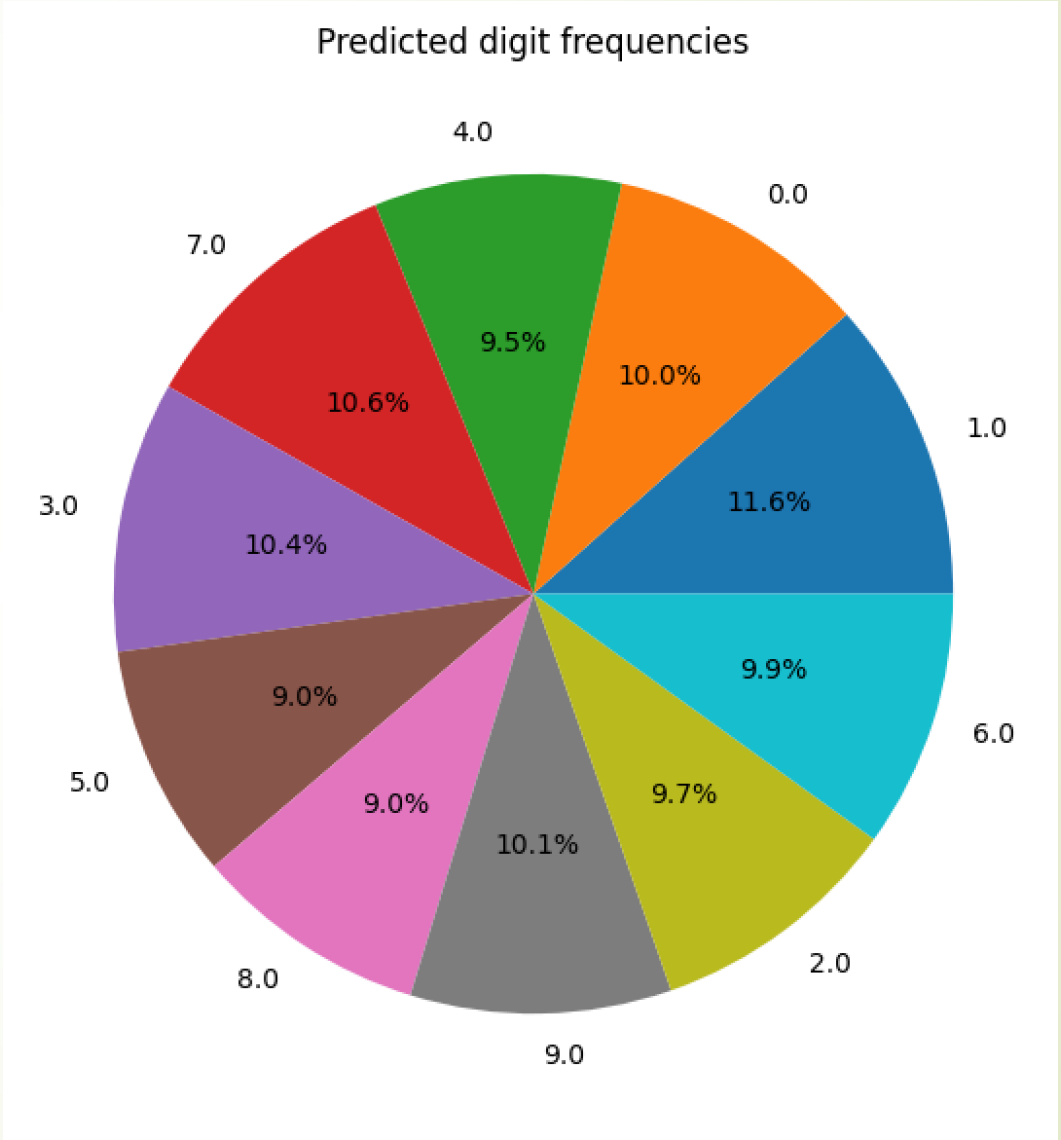
```
Actual Digit Frequencies
+---------+---------+
|   Digit |   Count |
|---------+---------|
|       0 |    4132 |
|       1 |    4684 |
|       2 |    4177 |
|       3 |    4351 |
|       4 |    4072 |
|       5 |    3795 |
|       6 |    4137 |
|       7 |    4401 |
|       8 |    4063 |
|       9 |    4188 |
+---------+---------+
Predicted Digit Frequencies
+---------+---------+
|   Digit |   Count |
|---------+---------|
|       0 |    4213 |
|       1 |    4869 |
|       2 |    4094 |
|       3 |    4383 |
|       4 |    4000 |
|       5 |    3790 |
|       6 |    4172 |
|       7 |    4466 |
|       8 |    3790 |
|       9 |    4223 |
+---------+---------+
```

K = 5

```
Actual Digit Frequencies
+---------+---------+
|   Digit |   Count |
|---------+---------|
|       0 |    4132 |
|       1 |    4684 |
|       2 |    4177 |
|       3 |    4351 |
|       4 |    4072 |
|       5 |    3795 |
|       6 |    4137 |
|       7 |    4401 |
|       8 |    4063 |
|       9 |    4188 |
+---------+---------+
Predicted Digit Frequencies
+---------+---------+
|   Digit |   Count |
|---------+---------|
|       0 |    4212 |
|       1 |    4905 |
|       2 |    4055 |
|       3 |    4379 |
|       4 |    4002 |
|       5 |    3786 |
|       6 |    4185 |
|       7 |    4470 |
|       8 |    3780 |
|       9 |    4226 |
+---------+---------+
```

Digit Frequencies when K = 3





Predictions made on the Testing data:

- Screenshots from the CSV file:
- These screenshots show the first few and last few predictions from the output CSV file when K = 3.
- Comparing my result with 100% output accuracy, I got an accuracy of 96.80% (first with K = 3 and then K = 5) as shown in the screenshot below.

```
Accuracy of the testing dataset: 96.8036 %
```

```
Accuracy of the testing dataset: 96.7000 %
```

My GitHub link: Project_Checkpoint_2_submission

https://github.com/monicabernard/CAP-5610_Machine-Learning.git

ImageId	label
0	2
1	0
2	9
3	9
4	3
5	7
6	0
7	3
8	0
9	3
10	5
11	7
12	4
13	0
14	4
15	3
16	3
17	1
18	9
19	0
20	9
21	1
22	1
23	5
24	7
25	4
26	2
27	7
28	4
29	7
30	7

27969	3
27970	5
27971	0
27972	4
27973	8
27974	0
27975	3
27976	6
27977	0
27978	1
27979	9
27980	3
27981	1
27982	1
27983	0
27984	4
27985	5
27986	2
27987	2
27988	9
27989	6
27990	7
27991	6
27992	1
27993	9
27994	7
27995	9
27996	7
27997	3
27998	9
27999	2