

CS2510 Project 3 Report

Zhuolun Li, Yi Yang

Implementation

WorkFlow

- MapReduce1
 - Map
 - Calculate cell id by data point's coordination
 - Generate KeyValue Pair <cellId, 1>
 - Reduce
 - Count the number of points in each cell
 - Generate KeyValue Pair (CellId, number of points).
- CellMerge
 - Get the result from MapReduce1 from hdfs and copy and merge to the local file system.
 - If the number of points in the Cell $< k+1$, merge the surrounding cells.
 - Create a HashMap Object to store the shape of current cells, which contains the margins of each cell.
 - Serialize the HashMap Object, and save to MapReduce's Configuration.
- MapReduce2
 - Map
 - Calculate cell id by data point's coordination and the merged cells' shape
 - Generate KeyValue Pair (CellId, (pointId, X, Y))
 - Reduce
 - Reduce KeyValue Pair (CellId, (pointId, X, Y)), add points within the same cell to the point's knnList.
 - Generate KeyValue Pair (PointId, knnList).
- MapReduce3
 - Map
 - Test if there are potential knn points in neighbor cells, and create String based on the result.
 - Generate KeyValue Pair (PotentialCellId, (PointId, X, Y, OriginalCellId, boolean)).
 - Generate KeyValue Pair (CellId, (PointId, X, Y)).
 - Reduce
 - Reduce the KeyValue Pair (PotentialCellId, (PointId, X, Y, OriginalCellId, boolean)) and (CellId, (PointId, X, Y))

- Create a list of points in the cell.
 - Create a minimum heap, add potential points to the heap and get k points with the minimum distance.
 - Generate KeyValue Pair (PointId, (X, Y, CellId, knnList)).
- MapReduce4
 - Map
 - Generate KeyValue Pair (PointId, knnList).
 - Reduce
 - Reduce KeyValue Pair (CellId, (pointId, X, Y)), add points within the same cell to the point's knnList.
 - Generate KeyValue Pair (PointId, knnList).
- Save Result
 - Get the result from MapReduce1 from hdfs and copy and merge to the local file system.

Experiment

- n=50
 - Data Set:

```

0,87,47
1,49,45
2,37,49
3,55,57
4,48,21
5,2,31
6,35,67
7,15,67
8,20,36
9,85,50
10,49,42
11,16,5
12,38,29
13,15,63
14,9,41
15,81,49
16,2,11
17,63,92
18,33,18
19,83,41
20,32,44
21,52,26
22,43,80
23,72,51
24,97,93
25,64,79
26,6,88

```

```
27,31,61
28,78,80
29,70,16
30,11,33
31,65,57
32,6,31
33,94,18
34,97,81
35,21,33
36,12,51
37,90,3
38,72,70
39,80,91
40,42,91
41,14,70
42,57,98
43,5,13
44,27,4
45,73,82
46,18,65
47,77,90
48,80,6
49,47,75
```

- k=2 MapReduce1 Output:

```
0 3
1 3
2 1
3 3
4 6
5 5
6 1
7 3
8 5
9 2
10 4
11 1
12 1
13 3
14 4
15 5
```

- k=2 MapReduce2 Output:

```
14 9;41;0;[30=8.246211, 32=10.440307]
4 48;21;0;[12=12.806249, 18=15.297058]
```

20 32;44;0;[2=7.071068, 8=14.422205]
18 33;18;0;[12=12.083046, 44=15.231546]
16 2;11;0;[43=3.6055512, 11=15.231546]
1 49;45;0;[10=3.0, 2=12.649111]
5 2;31;0;[32=4.0, 30=9.219544]
8 20;36;0;[35=3.1622777, 30=9.486833]
2 37;49;0;[20=7.071068, 1=12.649111]
35 21;33;0;[8=3.1622777, 30=10.0]
32 6;31;0;[5=4.0, 30=5.3851647]
10 49;42;0;[1=3.0, 2=13.892444]
30 11;33;0;[32=5.3851647, 14=8.246211]
11 16;5;0;[44=11.045361, 43=13.601471]
44 27;4;0;[11=11.045361, 18=15.231546]
43 5;13;0;[16=3.6055512, 11=13.601471]
12 38;29;0;[18=12.083046, 4=12.806249]
29 70;16;1;[48=14.142136, 21=20.59126]
48 80;6;1;[37=10.440307, 29=14.142136]
9 85;50;1;[0=3.6055512, 15=4.1231055]
21 52;26;1;[29=20.59126, 48=34.4093]
33 94;18;1;[37=15.524175, 48=18.439089]
19 83;41;1;[0=7.2111025, 15=8.246211]
37 90;3;1;[48=10.440307, 33=15.524175]
15 81;49;1;[9=4.1231055, 0=6.3245554]
0 87;47;1;[9=3.6055512, 15=6.3245554]
49 47;75;2;[22=6.4031243, 6=14.422205]
46 18;65;2;[13=3.6055512, 41=6.4031243]
41 14;70;2;[7=3.1622777, 46=6.4031243]
40 42;91;2;[22=11.045361, 49=16.763054]
36 12;51;2;[13=12.369317, 46=15.231546]
27 31;61;2;[6=7.2111025, 46=13.601471]
26 6;88;2;[41=19.697716, 7=22.847319]
22 43;80;2;[49=6.4031243, 40=11.045361]
13 15;63;2;[46=3.6055512, 7=4.0]
7 15;67;2;[41=3.1622777, 46=3.6055512]
6 35;67;2;[27=7.2111025, 49=14.422205]
25 64;79;3;[45=9.486833, 38=12.0415945]
28 78;80;3;[45=5.3851647, 47=10.049875]
31 65;57;3;[23=9.219544, 3=10.0]
34 97;81;3;[24=12.0, 28=19.026299]
38 72;70;3;[28=11.661903, 25=12.0415945]
47 77;90;3;[39=3.1622777, 45=8.944272]
24 97;93;3;[34=12.0, 39=17.117243]
39 80;91;3;[47=3.1622777, 28=11.18034]
42 57;98;3;[17=8.485281, 25=20.248457]
3 55;57;3;[31=10.0, 23=18.027756]
17 63;92;3;[42=8.485281, 25=13.038404]
23 72;51;3;[31=9.219544, 3=18.027756]
45 73;82;3;[28=5.3851647, 47=8.944272]

○ k=2 MapReduce3 Output:

```
36 12;51;0:[14=10.440307, 13=12.369317]
14 9;41;0:[30=8.246211, 32=10.440307]
43 5;13;0:[16=3.6055512, 11=13.601471]
44 27;4;0:[11=11.045361, 18=15.231546]
11 16;5;0:[44=11.045361, 43=13.601471]
30 11;33;0:[32=5.3851647, 14=8.246211]
32 6;31;0:[5=4.0, 30=5.3851647]
35 21;33;0:[8=3.1622777, 30=10.0]
8 20;36;0:[35=3.1622777, 30=9.486833]
5 2;31;0:[32=4.0, 30=9.219544]
16 2;11;0:[43=3.6055512, 11=15.231546]
18 33;18;0:[12=12.083046, 44=15.231546]
23 72;51;0:[31=9.219544, 3=18.027756]
42 57;98;0:[17=8.485281, 25=20.248457]
3 55;57;0:[31=10.0, 1=13.416408]
31 65;57;0:[23=9.219544, 3=10.0]
21 52;26;0:[4=6.4031243, 12=14.3178215]
9 85;50;0:[0=3.6055512, 15=4.1231055]
23 72;51;1:[31=9.219544, 9=13.038404]
3 55;57;1:[31=10.0, 23=18.027756]
31 65;57;1:[23=9.219544, 3=10.0]
37 90;3;1:[48=10.440307, 33=15.524175]
19 83;41;1:[0=7.2111025, 15=8.246211]
33 94;18;1:[37=15.524175, 48=18.439089]
9 85;50;1:[0=3.6055512, 15=4.1231055]
48 80;6;1:[37=10.440307, 29=14.142136]
29 70;16;1:[48=14.142136, 21=20.59126]
4 48;21;1:[21=6.4031243, 12=12.806249]
1 49;45;1:[10=3.0, 2=12.649111]
12 38;29;1:[18=12.083046, 4=12.806249]
10 49;42;1:[1=3.0, 2=13.892444]
40 42;91;1:[22=11.045361, 49=16.763054]
36 12;51;1:[13=12.369317, 46=15.231546]
49 47;75;1:[22=6.4031243, 6=14.422205]
42 57;98;2:[17=8.485281, 40=16.552946]
3 55;57;2:[31=10.0, 23=18.027756]
6 35;67;2:[27=7.2111025, 49=14.422205]
7 15;67;2:[41=3.1622777, 46=3.6055512]
13 15;63;2:[46=3.6055512, 7=4.0]
22 43;80;2:[49=6.4031243, 40=11.045361]
26 6;88;2:[41=19.697716, 7=22.847319]
27 31;61;2:[6=7.2111025, 46=13.601471]
41 14;70;2:[7=3.1622777, 46=6.4031243]
46 18;65;2:[13=3.6055512, 41=6.4031243]
21 52;26;2:[29=20.59126, 48=34.4093]
0 87;47;2:[9=3.6055512, 15=6.3245554]
15 81;49;2:[9=4.1231055, 0=6.3245554]
20 32;44;2:[2=7.071068, 8=14.422205]
2 37;49;2:[20=7.071068, 1=12.649111]
15 81;49;3:[9=4.1231055, 0=6.3245554]
0 87;47;3:[9=3.6055512, 15=6.3245554]
45 73;82;3:[28=5.3851647, 47=8.944272]
17 63;92;3:[42=8.485281, 25=13.038404]
```

```

39 80;91;3;[47=3.1622777, 28=11.18034]
24 97;93;3;[34=12.0, 39=17.117243]
47 77;90;3;[39=3.1622777, 45=8.944272]
38 72;70;3;[28=11.661903, 25=12.0415945]
34 97;81;3;[24=12.0, 28=19.026299]
28 78;80;3;[45=5.3851647, 47=10.049875]
25 64;79;3;[45=9.486833, 38=12.0415945]
4 48;21;3;[12=12.806249, 18=15.297058]
1 49;45;3;[10=3.0, 2=12.649111]
2 37;49;3;[20=7.071068, 1=12.649111]
20 32;44;3;[2=7.071068, 8=14.422205]
10 49;42;3;[1=3.0, 2=13.892444]
12 38;29;3;[18=12.083046, 4=12.806249]
40 42;91;3;[22=11.045361, 42=16.552946]
49 47;75;3;[22=6.4031243, 6=14.422205]

```

○ k=2 MapReduce4 Output:

```

0 [9=3.6055512, 15=6.3245554]
1 [10=3.0, 2=12.649111]
2 [20=7.071068, 1=12.649111]
3 [31=10.0, 1=13.416408]
4 [21=6.4031243, 12=12.806249]
5 [32=4.0, 30=9.219544]
6 [27=7.2111025, 49=14.422205]
7 [41=3.1622777, 46=3.6055512]
8 [35=3.1622777, 30=9.486833]
9 [0=3.6055512, 15=4.1231055]
10 [1=3.0, 2=13.892444]
11 [44=11.045361, 43=13.601471]
12 [18=12.083046, 4=12.806249]
13 [46=3.6055512, 7=4.0]
14 [30=8.246211, 32=10.440307]
15 [9=4.1231055, 0=6.3245554]
16 [43=3.6055512, 11=15.231546]
17 [42=8.485281, 25=13.038404]
18 [12=12.083046, 44=15.231546]
19 [0=7.2111025, 15=8.246211]
20 [2=7.071068, 8=14.422205]
21 [4=6.4031243, 12=14.3178215]
22 [49=6.4031243, 40=11.045361]
23 [31=9.219544, 9=13.038404]
24 [34=12.0, 39=17.117243]
25 [45=9.486833, 38=12.0415945]
26 [41=19.697716, 7=22.847319]
27 [6=7.2111025, 46=13.601471]
28 [45=5.3851647, 47=10.049875]
29 [48=14.142136, 21=20.59126]
30 [32=5.3851647, 14=8.246211]
31 [23=9.219544, 3=10.0]
32 [5=4.0, 30=5.3851647]

```

```

33 [37=15.524175, 48=18.439089]
34 [24=12.0, 28=19.026299]
35 [8=3.1622777, 30=10.0]
36 [14=10.440307, 13=12.369317]
37 [48=10.440307, 33=15.524175]
38 [28=11.661903, 25=12.0415945]
39 [47=3.1622777, 28=11.18034]
40 [22=11.045361, 42=16.552946]
41 [7=3.1622777, 46=6.4031243]
42 [17=8.485281, 40=16.552946]
43 [16=3.6055512, 11=13.601471]
44 [11=11.045361, 18=15.231546]
45 [28=5.3851647, 47=8.944272]
46 [13=3.6055512, 41=6.4031243]
47 [39=3.1622777, 45=8.944272]
48 [37=10.440307, 29=14.142136]
49 [22=6.4031243, 6=14.422205]

```

○ k=3 MapReduce1 Output:

```

0 3
1 3
2 1
3 3
4 6
5 5
6 1
7 3
8 5
9 2
10 4
11 1
12 1
13 3
14 4
15 5

```

○ k=3 MapReduce2 Output:

```

14 9;41;0;[30=8.246211, 32=10.440307, 8=12.083046]
4 48;21;0;[12=12.806249, 18=15.297058, 10=21.023796]
20 32;44;0;[2=7.071068, 8=14.422205, 35=15.556349]
18 33;18;0;[12=12.083046, 44=15.231546, 4=15.297058]
16 2;11;0;[43=3.6055512, 11=15.231546, 5=20.0]
1 49;45;0;[10=3.0, 2=12.649111, 20=17.029387]
5 2;31;0;[32=4.0, 30=9.219544, 14=12.206555]
8 20;36;0;[35=3.1622777, 30=9.486833, 14=12.083046]
2 37;49;0;[20=7.071068, 1=12.649111, 10=13.892444]
35 21;33;0;[8=3.1622777, 30=10.0, 14=14.422205]
32 6;31;0;[5=4.0, 30=5.3851647, 14=10.440307]
10 49;42;0;[1=3.0, 2=13.892444, 12=17.029387]

```

```

30 11;33;0;[32=5.3851647, 14=8.246211, 5=9.219544]
11 16;5;0;[44=11.045361, 43=13.601471, 16=15.231546]
44 27;4;0;[11=11.045361, 18=15.231546, 43=23.769728]
43 5;13;0;[16=3.6055512, 11=13.601471, 32=18.027756]
12 38;29;0;[18=12.083046, 4=12.806249, 20=16.155495]
29 70;16;1;[48=14.142136, 21=20.59126, 37=23.853722]
48 80;6;1;[37=10.440307, 29=14.142136, 33=18.439089]
9 85;50;1;[0=3.6055512, 15=4.1231055, 19=9.219544]
21 52;26;1;[29=20.59126, 48=34.4093, 19=34.43835]
33 94;18;1;[37=15.524175, 48=18.439089, 29=24.083189]
19 83;41;1;[0=7.2111025, 15=8.246211, 9=9.219544]
37 90;3;1;[48=10.440307, 33=15.524175, 29=23.853722]
15 81;49;1;[9=4.1231055, 0=6.3245554, 19=8.246211]
0 87;47;1;[9=3.6055512, 15=6.3245554, 19=7.2111025]
49 47;75;2;[22=6.4031243, 6=14.422205, 40=16.763054]
46 18;65;2;[13=3.6055512, 41=6.4031243, 27=13.601471]
41 14;70;2;[7=3.1622777, 46=6.4031243, 13=7.071068]
40 42;91;2;[22=11.045361, 49=16.763054, 6=25.0]
36 12;51;2;[13=12.369317, 46=15.231546, 7=16.27882]
27 31;61;2;[6=7.2111025, 46=13.601471, 13=16.124516]
26 6;88;2;[41=19.697716, 7=22.847319, 46=25.942244]
22 43;80;2;[49=6.4031243, 40=11.045361, 6=15.264338]
13 15;63;2;[46=3.6055512, 7=4.0, 41=7.071068]
7 15;67;2;[41=3.1622777, 46=3.6055512, 13=4.0]
6 35;67;2;[27=7.2111025, 49=14.422205, 22=15.264338]
25 64;79;3;[45=9.486833, 38=12.0415945, 17=13.038404]
28 78;80;3;[45=5.3851647, 47=10.049875, 39=11.18034]
31 65;57;3;[23=9.219544, 3=10.0, 38=14.764823]
34 97;81;3;[24=12.0, 28=19.026299, 39=19.723083]
38 72;70;3;[28=11.661903, 25=12.0415945, 31=14.764823]
47 77;90;3;[39=3.1622777, 45=8.944272, 28=10.049875]
24 97;93;3;[34=12.0, 39=17.117243, 47=20.22375]
39 80;91;3;[47=3.1622777, 28=11.18034, 45=11.401754]
42 57;98;3;[17=8.485281, 25=20.248457, 47=21.540659]
3 55;57;3;[31=10.0, 23=18.027756, 38=21.400934]
17 63;92;3;[42=8.485281, 25=13.038404, 47=14.142136]
23 72;51;3;[31=9.219544, 3=18.027756, 38=19.0]
45 73;82;3;[28=5.3851647, 47=8.944272, 25=9.486833]

```

○ k=3 MapReduce3 Output:

```

36 12;51;0;[14=10.440307, 13=12.369317, 46=15.231546]
14 9;41;0;[30=8.246211, 32=10.440307, 8=12.083046]
43 5;13;0;[16=3.6055512, 11=13.601471, 32=18.027756]
44 27;4;0;[11=11.045361, 18=15.231546, 43=23.769728]
11 16;5;0;[44=11.045361, 43=13.601471, 16=15.231546]
30 11;33;0;[32=5.3851647, 14=8.246211, 5=9.219544]
32 6;31;0;[5=4.0, 30=5.3851647, 14=10.440307]
35 21;33;0;[8=3.1622777, 30=10.0, 14=14.422205]
8 20;36;0;[35=3.1622777, 30=9.486833, 14=12.083046]
5 2;31;0;[32=4.0, 30=9.219544, 14=12.206555]
16 2;11;0;[43=3.6055512, 11=15.231546, 5=20.0]
18 33;18;0;[12=12.083046, 44=15.231546, 4=15.297058]

```


23 72;51;0;[31=9.219544, 3=18.027756, 38=19.0]
 42 57;98;0;[17=8.485281, 25=20.248457, 47=21.540659]
 3 55;57;0;[31=10.0, 1=13.416408, 10=16.155495]
 31 65;57;0;[23=9.219544, 3=10.0, 38=14.764823]
 21 52;26;0;[4=6.4031243, 12=14.3178215, 10=16.27882]
 9 85;50;0;[0=3.6055512, 15=4.1231055, 19=9.219544]
 23 72;51;1;[31=9.219544, 9=13.038404, 19=14.866069]
 3 55;57;1;[31=10.0, 23=18.027756, 38=21.400934]
 31 65;57;1;[23=9.219544, 3=10.0, 38=14.764823]
 37 90;3;1;[48=10.440307, 33=15.524175, 29=23.853722]
 19 83;41;1;[0=7.2111025, 15=8.246211, 9=9.219544]
 33 94;18;1;[37=15.524175, 48=18.439089, 29=24.083189]
 9 85;50;1;[0=3.6055512, 15=4.1231055, 19=9.219544]
 48 80;6;1;[37=10.440307, 29=14.142136, 33=18.439089]
 29 70;16;1;[48=14.142136, 21=20.59126, 37=23.853722]
 4 48;21;1;[21=6.4031243, 12=12.806249, 18=15.297058]
 1 49;45;1;[10=3.0, 2=12.649111, 20=17.029387]
 12 38;29;1;[18=12.083046, 4=12.806249, 21=14.3178215]
 10 49;42;1;[1=3.0, 2=13.892444, 21=16.27882]
 40 42;91;1;[22=11.045361, 49=16.763054, 6=25.0]
 36 12;51;1;[13=12.369317, 46=15.231546, 7=16.27882]
 49 47;75;1;[22=6.4031243, 6=14.422205, 40=16.763054]
 42 57;98;2;[17=8.485281, 40=16.552946, 25=20.248457]
 3 55;57;2;[31=10.0, 23=18.027756, 49=19.697716]
 6 35;67;2;[27=7.2111025, 49=14.422205, 22=15.264338]
 7 15;67;2;[41=3.1622777, 46=3.6055512, 13=4.0]
 13 15;63;2;[46=3.6055512, 7=4.0, 41=7.071068]
 22 43;80;2;[49=6.4031243, 40=11.045361, 6=15.264338]
 26 6;88;2;[41=19.697716, 7=22.847319, 46=25.942244]
 27 31;61;2;[6=7.2111025, 46=13.601471, 13=16.124516]
 41 14;70;2;[7=3.1622777, 46=6.4031243, 13=7.071068]
 46 18;65;2;[13=3.6055512, 41=6.4031243, 27=13.601471]
 21 52;26;2;[29=20.59126, 48=34.4093, 19=34.43835]
 0 87;47;2;[9=3.6055512, 15=6.3245554, 19=7.2111025]
 15 81;49;2;[9=4.1231055, 0=6.3245554, 19=8.246211]
 20 32;44;2;[2=7.071068, 8=14.422205, 35=15.556349]
 2 37;49;2;[20=7.071068, 1=12.649111, 27=13.416408]
 40 42;91;3;[22=11.045361, 42=16.552946, 49=16.763054]
 49 47;75;3;[22=6.4031243, 6=14.422205, 40=16.763054]
 45 73;82;3;[28=5.3851647, 47=8.944272, 25=9.486833]
 17 63;92;3;[42=8.485281, 25=13.038404, 45=14.142136]
 39 80;91;3;[47=3.1622777, 28=11.18034, 45=11.401754]
 24 97;93;3;[34=12.0, 39=17.117243, 47=20.22375]
 47 77;90;3;[39=3.1622777, 45=8.944272, 28=10.049875]
 38 72;70;3;[28=11.661903, 25=12.0415945, 31=14.764823]
 34 97;81;3;[24=12.0, 28=19.026299, 39=19.723083]
 28 78;80;3;[45=5.3851647, 47=10.049875, 39=11.18034]
 25 64;79;3;[45=9.486833, 38=12.0415945, 17=13.038404]
 4 48;21;3;[12=12.806249, 18=15.297058, 10=21.023796]
 1 49;45;3;[10=3.0, 2=12.649111, 3=13.416408]
 2 37;49;3;[20=7.071068, 1=12.649111, 10=13.892444]
 20 32;44;3;[2=7.071068, 8=14.422205, 35=15.556349]
 10 49;42;3;[1=3.0, 2=13.892444, 3=16.155495]
 12 38;29;3;[18=12.083046, 4=12.806249, 20=16.155495]
 15 81;49;3;[9=4.1231055, 0=6.3245554, 19=8.246211]
 0 87;47;3;[9=3.6055512, 15=6.3245554, 19=7.2111025]

○ k=3 MapReduce4 Output:

```
0 [9=3.6055512, 15=6.3245554, 19=7.2111025]
1 [10=3.0, 2=12.649111, 3=13.416408]
2 [20=7.071068, 1=12.649111, 27=13.416408]
3 [31=10.0, 1=13.416408, 10=16.155495]
4 [21=6.4031243, 12=12.806249, 18=15.297058]
5 [32=4.0, 30=9.219544, 14=12.206555]
6 [27=7.2111025, 49=14.422205, 22=15.264338]
7 [41=3.1622777, 46=3.6055512, 13=4.0]
8 [35=3.1622777, 30=9.486833, 14=12.083046]
9 [0=3.6055512, 15=4.1231055, 19=9.219544]
10 [1=3.0, 2=13.892444, 3=16.155495]
11 [44=11.045361, 43=13.601471, 16=15.231546]
12 [18=12.083046, 4=12.806249, 21=14.3178215]
13 [46=3.6055512, 7=4.0, 41=7.071068]
14 [30=8.246211, 32=10.440307, 8=12.083046]
15 [9=4.1231055, 0=6.3245554, 19=8.246211]
16 [43=3.6055512, 11=15.231546, 5=20.0]
17 [42=8.485281, 25=13.038404, 45=14.142136]
18 [12=12.083046, 44=15.231546, 4=15.297058]
19 [0=7.2111025, 15=8.246211, 9=9.219544]
20 [2=7.071068, 8=14.422205, 35=15.556349]
21 [4=6.4031243, 12=14.3178215, 10=16.27882]
22 [49=6.4031243, 40=11.045361, 6=15.264338]
23 [31=9.219544, 9=13.038404, 19=14.866069]
24 [34=12.0, 39=17.117243, 47=20.22375]
25 [45=9.486833, 38=12.0415945, 17=13.038404]
26 [41=19.697716, 7=22.847319, 46=25.942244]
27 [6=7.2111025, 46=13.601471, 13=16.124516]
28 [45=5.3851647, 47=10.049875, 39=11.18034]
29 [48=14.142136, 21=20.59126, 37=23.853722]
30 [32=5.3851647, 14=8.246211, 5=9.219544]
31 [23=9.219544, 3=10.0, 38=14.764823]
32 [5=4.0, 30=5.3851647, 14=10.440307]
33 [37=15.524175, 48=18.439089, 29=24.083189]
34 [24=12.0, 28=19.026299, 39=19.723083]
35 [8=3.1622777, 30=10.0, 14=14.422205]
36 [14=10.440307, 13=12.369317, 46=15.231546]
37 [48=10.440307, 33=15.524175, 29=23.853722]
38 [28=11.661903, 25=12.0415945, 31=14.764823]
39 [47=3.1622777, 28=11.18034, 45=11.401754]
40 [22=11.045361, 42=16.552946, 49=16.763054]
41 [7=3.1622777, 46=6.4031243, 13=7.071068]
42 [17=8.485281, 40=16.552946, 25=20.248457]
43 [16=3.6055512, 11=13.601471, 32=18.027756]
44 [11=11.045361, 18=15.231546, 43=23.769728]
45 [28=5.3851647, 47=8.944272, 25=9.486833]
46 [13=3.6055512, 41=6.4031243, 27=13.601471]
47 [39=3.1622777, 45=8.944272, 28=10.049875]
48 [37=10.440307, 29=14.142136, 33=18.439089]
49 [22=6.4031243, 6=14.422205, 40=16.763054]
```

Analyse For k=2 and k=3

- When k increases, only knnList size increase. The cells shape may be affected, which could result in longer execution time for MapReduce3.
- The execution is almost the same.
- n=100
 - Data Set:

0,48,12	50,73,99
1,96,61	51,70,29
2,0,21	52,22,30
3,84,70	53,84,70
4,59,77	54,84,65
5,24,54	55,3,53
6,25,44	56,93,14
7,7,51	57,12,14
8,11,95	58,81,18
9,55,54	59,74,42
10,90,72	60,37,79
11,72,84	61,35,37
12,25,39	62,58,10
13,58,3	63,46,29
14,58,14	64,11,68
15,45,17	65,0,9
16,96,27	66,1,55
17,15,31	67,69,78
18,72,8	68,62,86
19,52,10	69,15,14
20,1,72	70,93,77
21,19,43	71,71,58
22,2,27	72,10,98
23,32,54	73,28,42
24,49,74	74,80,15
25,67,67	75,77,11
26,27,51	76,71,86
27,48,0	77,30,58
28,97,91	78,85,52
29,28,0	79,19,62
30,20,85	80,28,10
31,87,81	81,52,16
32,46,41	82,7,98
33,92,47	83,50,44
34,14,7	84,73,98
35,79,98	85,19,35
36,3,48	86,33,40
37,64,91	87,69,45
38,30,25	88,23,16
39,13,15	89,73,76
40,10,94	90,77,28
41,86,87	91,65,51

42,86,28	92,67,18
43,81,13	93,29,51
44,28,9	94,94,19
45,84,64	95,63,22
46,18,70	96,51,36
47,53,11	97,7,16
48,37,38	98,86,79
49,57,13	99,84,97

- k=3 MapReduce1 Output:

0	8
1	6
2	10
3	6
4	6
5	9
6	5
7	4
8	8
9	5
10	4
11	7
12	5
13	1
14	9
15	7

- k=3 MapReduce2 Output:

88	23;16;0;[69=8.246211, 39=10.049875, 57=11.18034]
69	15;14;0;[39=2.236068, 57=3.0, 34=7.071068]
34	14;7;0;[69=7.071068, 57=7.28011, 39=8.062258]
39	13;15;0;[57=1.4142135, 69=2.236068, 97=6.0827627]
97	7;16;0;[57=5.3851647, 39=6.0827627, 69=8.246211]
57	12;14;0;[39=1.4142135, 69=3.0, 97=5.3851647]
80	28;10;1;[44=1.0, 38=15.132746, 15=18.384777]
15	45;17;1;[0=5.8309517, 38=17.0, 80=18.384777]
38	30;25;1;[80=15.132746, 44=16.124516, 15=17.0]
44	28;9;1;[80=1.0, 38=16.124516, 15=18.788294]
0	48;12;1;[15=5.8309517, 80=20.09975, 44=20.22375]
49	57;13;2;[14=1.4142135, 62=3.1622777, 47=4.472136]
95	63;22;2;[92=5.656854, 14=9.433981, 49=10.816654]
92	67;18;2;[95=5.656854, 14=9.848858, 49=11.18034]
81	52;16;2;[47=5.0990195, 49=5.8309517, 19=6.0]
62	58;10;2;[49=3.1622777, 14=4.0, 47=5.0990195]
47	53;11;2;[19=1.4142135, 49=4.472136, 81=5.0990195]
19	52;10;2;[47=1.4142135, 49=5.8309517, 81=6.0]
18	72;8;2;[92=11.18034, 62=14.142136, 13=14.866069]

14 58;14;2:[49=1.4142135, 62=4.0, 47=5.8309517]
 13 58;3;2:[62=7.0, 19=9.219544, 47=9.433981]
 94 94;19;3:[56=5.0990195, 58=13.038404, 43=14.3178215]
 75 77;11;3:[43=4.472136, 74=5.0, 58=8.062258]
 74 80;15;3:[43=2.236068, 58=3.1622777, 75=5.0]
 58 81;18;3:[74=3.1622777, 43=5.0, 75=8.062258]
 56 93;14;3:[94=5.0990195, 43=12.0415945, 58=12.649111]
 43 81;13;3:[74=2.236068, 75=4.472136, 58=5.0]
 21 19;43;4:[6=6.0827627, 12=7.2111025, 85=8.0]
 52 22;30;4:[85=5.8309517, 17=7.071068, 12=9.486833]
 6 25;44;4:[12=5.0, 21=6.0827627, 85=10.816654]
 22 2;27;4:[17=13.601471, 85=18.788294, 52=20.22375]
 12 25;39;4:[6=5.0, 85=7.2111025, 52=9.486833]
 85 19;35;4:[17=5.656854, 52=5.8309517, 12=7.2111025]
 36 3;48;4:[21=16.763054, 85=20.615528, 17=20.808653]
 17 15;31;4:[85=5.656854, 52=7.071068, 21=12.649111]
 63 46;29;5:[32=12.0, 48=12.727922, 61=13.601471]
 73 28;42;5:[86=5.3851647, 61=8.602325, 48=9.848858]
 61 35;37;5:[48=2.236068, 86=3.6055512, 73=8.602325]
 86 33;40;5:[61=3.6055512, 48=4.472136, 73=5.3851647]
 83 50;44;5:[32=5.0, 48=14.3178215, 63=15.524175]
 32 46;41;5:[83=5.0, 48=9.486833, 61=11.7046995]
 48 37;38;5:[61=2.236068, 86=4.472136, 32=9.486833]
 87 69;45;6:[59=5.8309517, 51=16.03122, 96=20.12461]
 51 70;29;6:[59=13.601471, 87=16.03122, 96=20.248457]
 96 51;36;6:[87=20.12461, 51=20.248457, 59=23.769728]
 59 74;42;6:[87=5.8309517, 51=13.601471, 96=23.769728]
 33 92;47;7:[42=19.924858, 16=20.396078, 90=24.207438]
 42 86;28;7:[90=9.0, 16=10.049875, 33=19.924858]
 16 96;27;7:[42=10.049875, 90=19.026299, 33=20.396078]
 90 77;28;7:[42=9.0, 16=19.026299, 33=24.207438]
 71 71;58;8:[91=9.219544, 25=9.848858, 9=16.492422]
 91 65;51;8:[71=9.219544, 9=10.440307, 25=16.124516]
 9 55;54;8:[91=10.440307, 71=16.492422, 25=17.691807]
 25 67;67;8:[71=9.848858, 91=16.124516, 9=17.691807]
 54 84;65;9:[45=1.0, 3=5.0, 10=9.219544]
 1 96;61;9:[45=12.369317, 10=12.529964, 54=12.649111]
 10 90;72;9:[3=6.3245554, 54=9.219544, 45=10.0]
 45 84;64;9:[54=1.0, 3=6.0, 10=10.0]
 78 85;52;9:[45=12.0415945, 54=13.038404, 1=14.21267]
 3 84;70;9:[53=0.0, 54=5.0, 45=6.0]
 53 84;70;9:[3=0.0, 54=5.0, 45=6.0]
 93 29;51;10:[26=2.0, 23=4.2426405, 5=5.8309517]
 77 30;58;10:[23=4.472136, 93=7.071068, 5=7.2111025]
 72 10;98;10:[82=3.0, 8=3.1622777, 40=4.0]
 66 1;55;10:[55=2.828427, 7=7.2111025, 64=16.40122]
 64 11;68;10:[46=7.28011, 79=10.0, 20=10.770329]
 5 24;54;10:[26=4.2426405, 93=5.8309517, 77=7.2111025]
 60 37;79;10:[24=13.0, 30=18.027756, 46=21.023796]
 55 3;53;10:[66=2.828427, 7=4.472136, 64=17.0]
 46 18;70;10:[64=7.28011, 79=8.062258, 30=15.132746]
 40 10;94;10:[8=1.4142135, 72=4.0, 82=5.0]
 30 20;85;10:[40=13.453624, 46=15.132746, 72=16.40122]
 26 27;51;10:[93=2.0, 5=4.2426405, 23=5.8309517]
 24 49;74;10:[60=13.0, 77=24.839485, 23=26.24881]
 23 32;54;10:[93=4.2426405, 77=4.472136, 26=5.8309517]

```

20 1;72;10;[64=10.770329, 66=17.0, 46=17.117243]
8 11;95;10;[40=1.4142135, 72=3.1622777, 82=5.0]
7 7;51;10;[55=4.472136, 66=7.2111025, 79=16.27882]
82 7;98;10;[72=3.0, 40=5.0, 30=18.384777]
79 19;62;10;[46=8.062258, 5=9.433981, 64=10.0]
89 73;76;11;[67=4.472136, 11=8.062258, 76=10.198039]
68 62;86;11;[37=5.3851647, 76=9.0, 4=9.486833]
76 71;86;11;[11=2.236068, 67=8.246211, 37=8.602325]
67 69;78;11;[89=4.472136, 11=6.708204, 76=8.246211]
37 64;91;11;[68=5.3851647, 76=8.602325, 11=10.630146]
4 59;77;11;[68=9.486833, 67=10.049875, 89=14.035668]
84 73;98;11;[50=1.0, 37=11.401754, 76=12.165525]
50 73;99;11;[84=1.0, 37=12.0415945, 76=13.152946]
11 72;84;11;[76=2.236068, 67=6.708204, 89=8.062258]
35 79;98;12;[99=5.0990195, 41=13.038404, 31=18.788294]
41 86;87;12;[31=6.0827627, 98=8.0, 99=10.198039]
98 86;79;12;[31=2.236068, 70=7.28011, 41=8.0]
99 84;97;12;[35=5.0990195, 41=10.198039, 28=14.3178215]
70 93;77;12;[31=7.2111025, 98=7.28011, 41=12.206555]
28 97;91;12;[41=11.7046995, 31=14.142136, 99=14.3178215]
31 87;81;12;[98=2.236068, 41=6.0827627, 70=7.2111025]
2 0;21;-1;[65=12.0, 29=35.0, 27=52.392746]
29 28;0;-1;[27=20.0, 65=29.410883, 2=35.0]
65 0;9;-1;[2=12.0, 29=29.410883, 27=48.83646]
27 48;0;-1;[29=20.0, 65=48.83646, 2=52.392746]

```

○ k=3 MapReduce3 Output:

```

29 28;0;0;[34=15.652476, 88=16.763054, 69=19.104973]
57 12;14;0;[39=1.4142135, 69=3.0, 97=5.3851647]
97 7;16;0;[57=5.3851647, 39=6.0827627, 69=8.246211]
39 13;15;0;[57=1.4142135, 69=2.236068, 97=6.0827627]
34 14;7;0;[69=7.071068, 57=7.28011, 39=8.062258]
69 15;14;0;[39=2.236068, 57=3.0, 34=7.071068]
12 25;39;0;[6=5.0, 85=7.2111025, 52=9.486833]
52 22;30;0;[85=5.8309517, 17=7.071068, 12=9.486833]
6 25;44;0;[12=5.0, 21=6.0827627, 85=10.816654]
22 2;27;0;[97=12.083046, 17=13.601471, 39=16.27882]
90 77;28;0;[42=9.0, 16=19.026299, 33=24.207438]
16 96;27;0;[42=10.049875, 90=19.026299, 33=20.396078]
42 86;28;0;[90=9.0, 16=10.049875, 33=19.924858]
51 70;29;0;[59=13.601471, 87=16.03122, 96=20.248457]
96 51;36;0;[87=20.12461, 51=20.248457, 59=23.769728]
63 46;29;0;[32=12.0, 48=12.727922, 61=13.601471]
73 28;42;0;[86=5.3851647, 61=8.602325, 48=9.848858]
60 37;79;0;[24=13.0, 30=18.027756, 46=21.023796]
38 30;25;0;[88=11.401754, 80=15.132746, 44=16.124516]
81 52;16;1;[47=5.0990195, 0=5.656854, 49=5.8309517]
30 20;85;1;[40=13.453624, 46=15.132746, 72=16.40122]
79 19;62;1;[46=8.062258, 5=9.433981, 64=10.0]
46 18;70;1;[64=7.28011, 79=8.062258, 30=15.132746]
5 24;54;1;[26=4.2426405, 93=5.8309517, 77=7.2111025]
80 28;10;1;[44=1.0, 38=15.132746, 15=18.384777]

```

```

44 28;9;1;[80=1.0, 38=16.124516, 15=18.788294]
38 30;25;1;[80=15.132746, 44=16.124516, 15=17.0]
21 19;43;1;[6=6.0827627, 12=7.2111025, 85=8.0]
22 2;27;1;[17=13.601471, 85=18.788294, 52=20.22375]
52 22;30;1;[85=5.8309517, 17=7.071068, 38=9.433981]
...

```

○ k=3 MapReduce4 Output:

```

0 [19=4.472136, 47=5.0990195, 81=5.656854]
1 [45=12.369317, 10=12.529964, 54=12.649111]
2 [22=6.3245554, 65=12.0, 17=18.027756]
3 [53=0.0, 54=5.0, 45=6.0]
4 [68=9.486833, 67=10.049875, 24=10.440307]
5 [26=4.2426405, 93=5.8309517, 77=7.2111025]
6 [12=5.0, 21=6.0827627, 85=10.816654]
7 [55=4.472136, 36=5.0, 66=7.2111025]
8 [40=1.4142135, 72=3.1622777, 82=5.0]
9 [91=10.440307, 83=11.18034, 32=15.811388]
10 [70=5.8309517, 3=6.3245554, 98=8.062258]
11 [76=2.236068, 67=6.708204, 89=8.062258]
12 [6=5.0, 85=7.2111025, 52=9.486833]
13 [62=7.0, 19=9.219544, 47=9.433981]
14 [49=1.4142135, 62=4.0, 47=5.8309517]
15 [0=5.8309517, 81=7.071068, 19=9.899495]
16 [94=8.246211, 42=10.049875, 56=13.341664]
17 [85=5.656854, 52=7.071068, 21=12.649111]
18 [75=5.8309517, 43=10.29563, 74=10.630146]
19 [47=1.4142135, 49=5.8309517, 62=6.0]
20 [64=10.770329, 66=17.0, 46=17.117243]
21 [6=6.0827627, 12=7.2111025, 85=8.0]
22 [97=12.083046, 17=13.601471, 39=16.27882]
23 [93=4.2426405, 77=4.472136, 26=5.8309517]
24 [4=10.440307, 60=13.0, 68=17.691807]
25 [71=9.848858, 89=10.816654, 67=11.18034]
26 [93=2.0, 5=4.2426405, 23=5.8309517]
27 [13=10.440307, 19=10.770329, 47=12.083046]
28 [41=11.7046995, 31=14.142136, 99=14.3178215]
29 [34=15.652476, 88=16.763054, 69=19.104973]
30 [40=13.453624, 46=15.132746, 72=16.40122]
31 [98=2.236068, 41=6.0827627, 70=7.2111025]
32 [83=5.0, 96=7.071068, 48=9.486833]
33 [78=8.602325, 1=14.56022, 59=18.681541]
34 [69=7.071068, 57=7.28011, 39=8.062258]
35 [99=5.0990195, 84=6.0, 50=6.0827627]
36 [7=5.0, 66=7.28011, 21=16.763054]
37 [68=5.3851647, 76=8.602325, 11=10.630146]
38 [52=9.433981, 88=11.401754, 12=14.866069]
39 [57=1.4142135, 69=2.236068, 97=6.0827627]
40 [8=1.4142135, 72=4.0, 82=5.0]
41 [31=6.0827627, 98=8.0, 99=10.198039]
42 [90=9.0, 16=10.049875, 58=11.18034]
43 [74=2.236068, 75=4.472136, 58=5.0]

```

44 [80=1.0, 38=16.124516, 15=18.788294]
45 [54=1.0, 53=6.0, 10=10.0]
46 [64=7.28011, 79=8.062258, 30=15.132746]
47 [19=1.4142135, 49=4.472136, 62=5.0990195]
48 [61=2.236068, 86=4.472136, 32=9.486833]
49 [14=1.4142135, 62=3.1622777, 47=4.472136]
50 [84=1.0, 37=12.0415945, 76=13.152946]
51 [90=7.071068, 95=9.899495, 92=11.401754]
52 [85=5.8309517, 17=7.071068, 38=9.433981]
53 [3=0.0, 54=5.0, 45=6.0]
54 [45=1.0, 3=5.0, 10=9.219544]
55 [66=2.828427, 7=4.472136, 64=17.0]
56 [94=5.0990195, 43=12.0415945, 58=12.649111]
57 [39=1.4142135, 69=3.0, 97=5.3851647]
58 [74=3.1622777, 43=5.0, 75=8.062258]
59 [87=5.8309517, 51=13.601471, 90=14.3178215]
60 [24=13.0, 30=18.027756, 46=21.023796]
61 [48=2.236068, 86=3.6055512, 73=8.602325]
62 [49=3.1622777, 14=4.0, 47=5.0990195]
63 [96=8.602325, 32=12.0, 15=12.0415945]
64 [46=7.28011, 79=10.0, 20=10.770329]
65 [2=12.0, 29=29.410883, 27=48.83646]
66 [55=2.828427, 7=7.2111025, 64=16.40122]
67 [89=4.472136, 11=6.708204, 76=8.246211]
68 [37=5.3851647, 76=9.0, 4=9.486833]
69 [39=2.236068, 57=3.0, 34=7.071068]
70 [10=5.8309517, 31=7.2111025, 98=7.28011]
71 [91=9.219544, 25=9.848858, 87=13.152946]
72 [82=3.0, 8=3.1622777, 40=4.0]
73 [6=3.6055512, 12=4.2426405, 86=5.3851647]
74 [43=2.236068, 58=3.1622777, 75=5.0]
75 [43=4.472136, 74=5.0, 18=5.8309517]
76 [11=2.236068, 67=8.246211, 37=8.602325]
77 [23=4.472136, 93=7.071068, 5=7.2111025]
78 [33=8.602325, 45=12.0415945, 54=13.038404]
79 [46=8.062258, 5=9.433981, 64=10.0]
80 [44=1.0, 38=15.132746, 15=18.384777]
81 [47=5.0990195, 0=5.656854, 49=5.8309517]
82 [72=3.0, 40=5.0, 30=18.384777]
83 [32=5.0, 48=14.3178215, 63=15.524175]
84 [50=1.0, 37=11.401754, 76=12.165525]
85 [17=5.656854, 52=5.8309517, 12=7.2111025]
86 [61=3.6055512, 48=4.472136, 73=5.3851647]
87 [59=5.8309517, 91=7.2111025, 71=13.152946]
88 [80=7.81025, 69=8.246211, 44=8.602325]
89 [67=4.472136, 11=8.062258, 76=10.198039]
90 [51=7.071068, 42=9.0, 58=10.770329]
91 [87=7.2111025, 71=9.219544, 9=10.440307]
92 [95=5.656854, 14=9.848858, 49=11.18034]
93 [26=2.0, 23=4.2426405, 5=5.8309517]
94 [56=5.0990195, 58=13.038404, 43=14.3178215]
95 [92=5.656854, 14=9.433981, 51=9.899495]
96 [32=7.071068, 83=8.062258, 63=8.602325]
97 [57=5.3851647, 39=6.0827627, 69=8.246211]
98 [31=2.236068, 70=7.28011, 41=8.0]
99 [35=5.0990195, 41=10.198039, 28=14.3178215]

Analyse For $n=50$ and $n=100$

- When n increases, the length of the output of MapReduce2, MapReduce3 and MapReduce4 increase. Because there're more points to be processed. And the length of the MapReduced3 is non-linear growing, because there will be more potential knn points nearby.
- The execution time is more than 1 time longer when n is 1 time larger.