NATIONAL INSTITUTE OF TECHNOLOGY KARNATAKA SURATHKAL
DEPARTMENT OF INFORMATION TECHNOLOGY
IT 301 Parallel Computing LAB 5
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Sequential implementation

```
#include <iostream>
#include <stdlib.h>
#include <cstdlib>
#include <time.h>
#include <vector>
#include <fstream>
#include <omp.h>
#define k 8
using namespace std;

struct Point {
    double x, y;
    int cluster;
    double minDist;

    Point() :
        x(0.0),
        y(0.0),
        cluster(-1),
        minDist(__DBL_MAX__) {}

    Point(double x, double y) :
        x(x),
        y(y),
        cluster(-1),
        minDist(__DBL_MAX__) {}

    double distance(Point p) {
        return (p.x - x) * (p.x - x) + (p.y - y) * (p.y - y);
    }
};

void kMeansClustering(vector<Point>* points)
{
    vector<Point> centroids;
    srand(time(0));
    double time_point1 = omp_get_wtime();
    for (int i = 0; i < k; ++i)
    {
        centroids.push_back(points->at(rand() % 1000));
        for (vector<Point>::iterator c = begin(centroids); c !=
end(centroids); ++c)
        {
            int clusterId = c - begin(centroids);
```

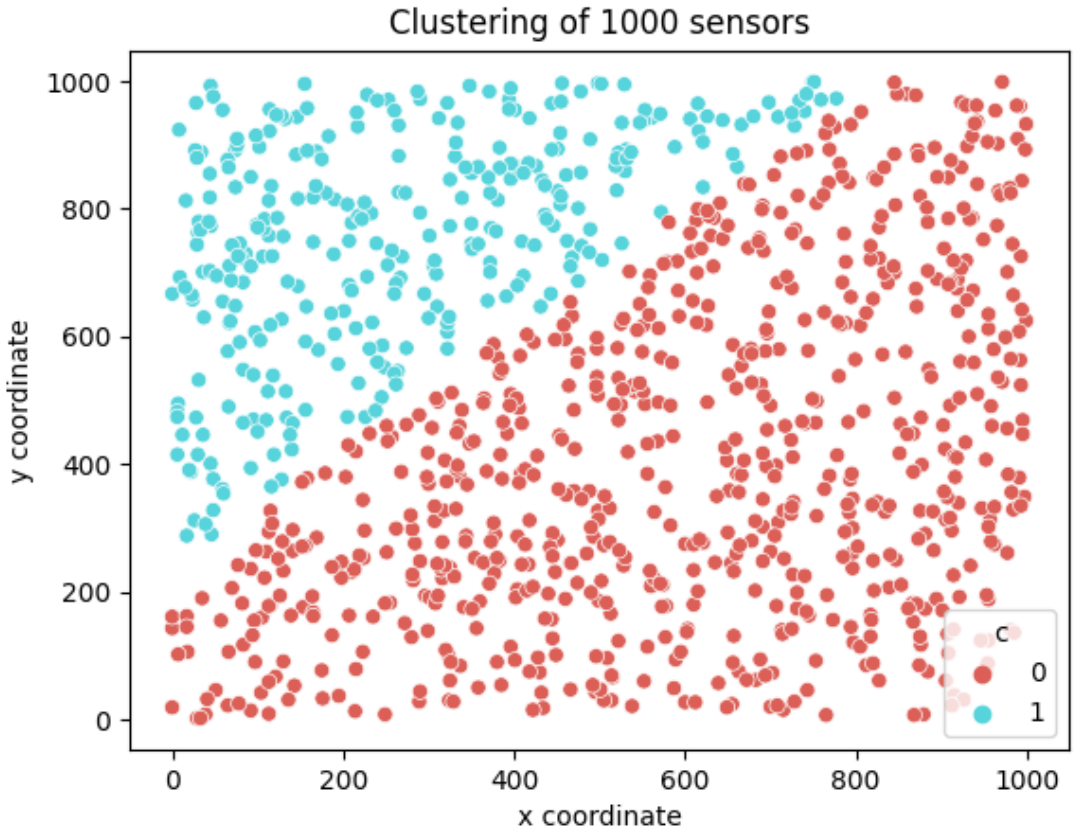
```
            for (vector<Point>::iterator it = points->begin(); it !=
points->end(); ++it)
            {
                Point p = *it;
                double dist = c->distance(p);
                if (dist < p.minDist)
                {
                    p.minDist = dist;
                    p.cluster = clusterId;
                }
                *it = p;
            }
        }
    }
    vector<int> nPoints;
    vector<double> sumX, sumY;

    for (int j = 0; j < k; ++j)
    {
        nPoints.push_back(0);
        sumX.push_back(0.0);
        sumY.push_back(0.0);
    }

    for (vector<Point>::iterator it = points->begin(); it != points-
>end(); ++it)
    {
        int clusterId = it->cluster;
        nPoints[clusterId] += 1;
        sumX[clusterId] += it->x;
        sumY[clusterId] += it->y;

        it->minDist = __DBL_MAX__;
    }
    double time_point2 = omp_get_wtime();
    double duration = time_point2 - time_point1;

    printf("Points and clusters generated in: %f seconds\n",
duration);

    for (vector<Point>::iterator c = begin(centroids); c !=
end(centroids); ++c)
    {
        int clusterId = c - begin(centroids);
        c->x = sumX[clusterId] / nPoints[clusterId];
        c->y = sumY[clusterId] / nPoints[clusterId];
    }

    double time_point3 = omp_get_wtime();
    duration = time_point3 - time_point2;

    printf("Total time: %f seconds\n",duration);

    ofstream myfile;
    myfile.open("seqoutput3.csv");
```

```
    myfile << "x,y,c" << endl;

    for (vector<Point>::iterator it = points->begin(); it != points-
>end(); ++it)
        myfile << it->x << "," << it->y << "," << it->cluster <<
endl;

    myfile.close();
}
int main()
{
    time_t t;
    srand((unsigned) time(&t));
    int x, y;
    vector<Point> points;
    for(int i = 0; i < 1000; i++)
    {
        x = rand() % 1000;
        y = rand() % 1000;
        points.push_back(Point(x, y));
    }

    Point p1 = Point(0.0, 0.0);
    Point p2 = Point(3.0, 4.0);
    kMeansClustering(&points);
    return 0;
}
```

Code for printing the graph

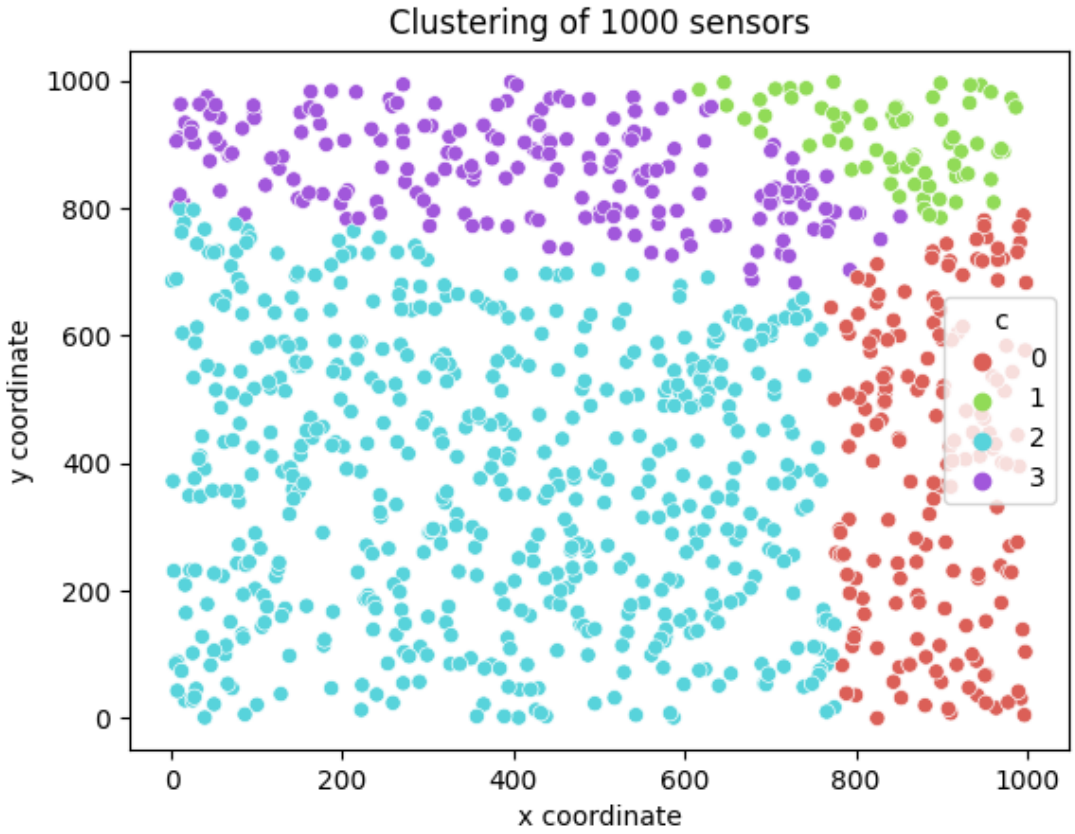
```
import matplotlib.pyplot as plt
import pandas as pd
import seaborn as sns

plt.figure()
df = pd.read_csv("seqoutput3.csv")
sns.scatterplot(x=df.x, y=df.y,
hue=df.c,palette=sns.color_palette("hls", n_colors=8))
plt.xlabel("x coordinate")
plt.ylabel("y coordinate")
plt.title("Clustering of 1000 sensors")

plt.savefig("seqgraph3.png")
```

Output
For k=2



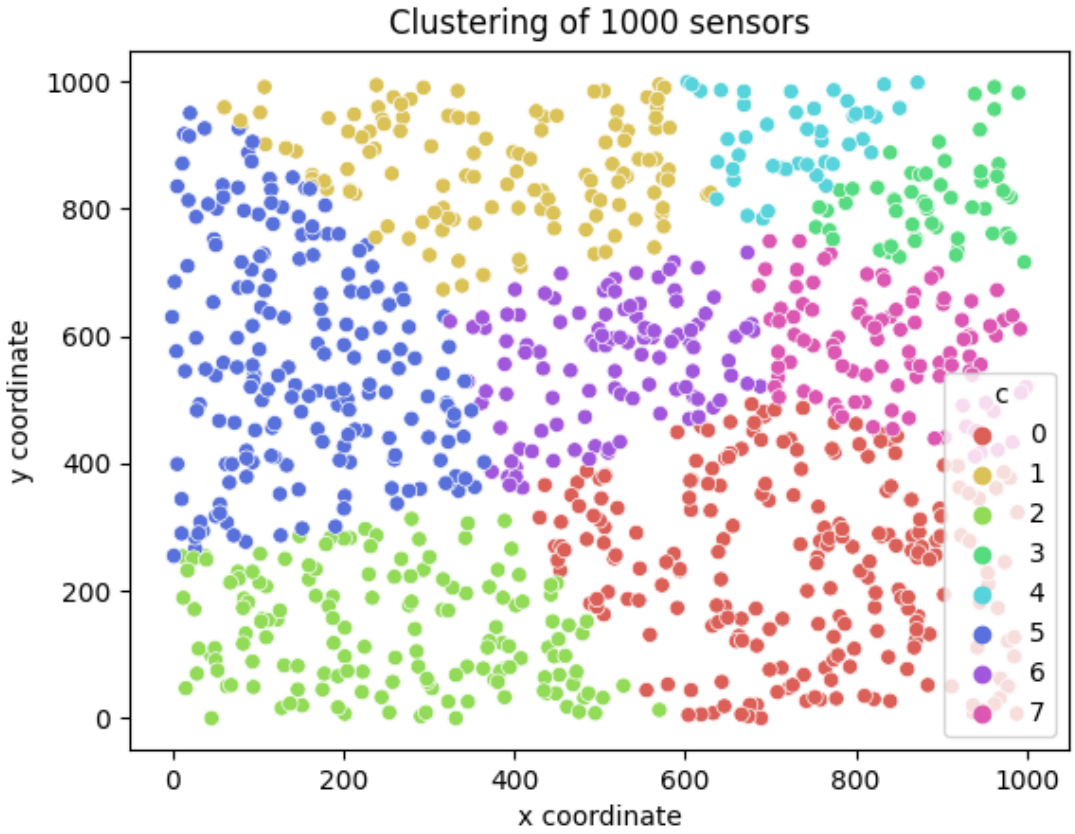

```
PS C:\Bhagyashri> g++ -o PC_Lab7 -fopenmp PC_Lab7.cpp
PS C:\Bhagyashri> ./PC_Lab7
Number of points 1000
Number of clusters 2
Points and clusters generated in: 0.000988
Total time: 0.001000 seconds
PS C:\Bhagyashri>
```

for K=4




```
PS C:\Bhagyashri> g++ -o PC_Lab7 -fopenmp PC_Lab7.cpp
PS C:\Bhagyashri> ./PC_Lab7
Number of points 1000
Number of clusters 4
Points and clusters generated in: 0.001011
Total time: 0.002000 seconds
PS C:\Bhagyashri>
```

For k=8




```
PS C:\Bhagyashri> ./PC_Lab7
Number of points 1000
Number of clusters 8
Points and clusters generated in: 0.000988
Total time: 0.002000 seconds
PS C:\Bhagyashri>
```

Parallel implementation

```
#include <iostream>
#include <cmath>
#include <fstream>
#include <chrono>
#include <omp.h>

using namespace std;
using namespace std::chrono;

double max_range = 1000;
int num_point = 1000;
int num_cluster = 8;
int max_iterations = 1000;
```

```
vector<Point> init_point(int num_point);
vector<Cluster> init_cluster(int num_cluster);
void compute_distance(vector<Point> &points, vector<Cluster>
&clusters);
double euclidean_dist(Point point, Cluster cluster);
bool update_clusters(vector<Cluster> &clusters);
void draw_chart_gnu(vector<Point> &points);

int main() {

    printf("Number of points %d\n", num_point);
    printf("Number of clusters %d\n", num_cluster);
    printf("Number of processors: %d\n", omp_get_num_procs());

    srand(int(time(NULL)));

    double time_point1 = omp_get_wtime();


    vector<Point> points;
    vector<Cluster> clusters;

#pragma omp parallel
    {
#pragma omp sections
        {
#pragma omp section
            {
                printf("Creating points..\n");
                points = init_point(num_point);
                printf("Points initialized \n");
            }
#pragma omp section
            {
                printf("Creating clusters..\n");
                clusters = init_cluster(num_cluster);
                printf("Clusters initialized \n");
            }
        }
    }

    double time_point2 = omp_get_wtime();
    double duration = time_point2 - time_point1;

    printf("Points and clusters generated in: %f seconds\n",
duration);

    bool conv = true;
    int iterations = 0;

    printf("Starting iterate...\n");

    while(conv && iterations < max_iterations){
```

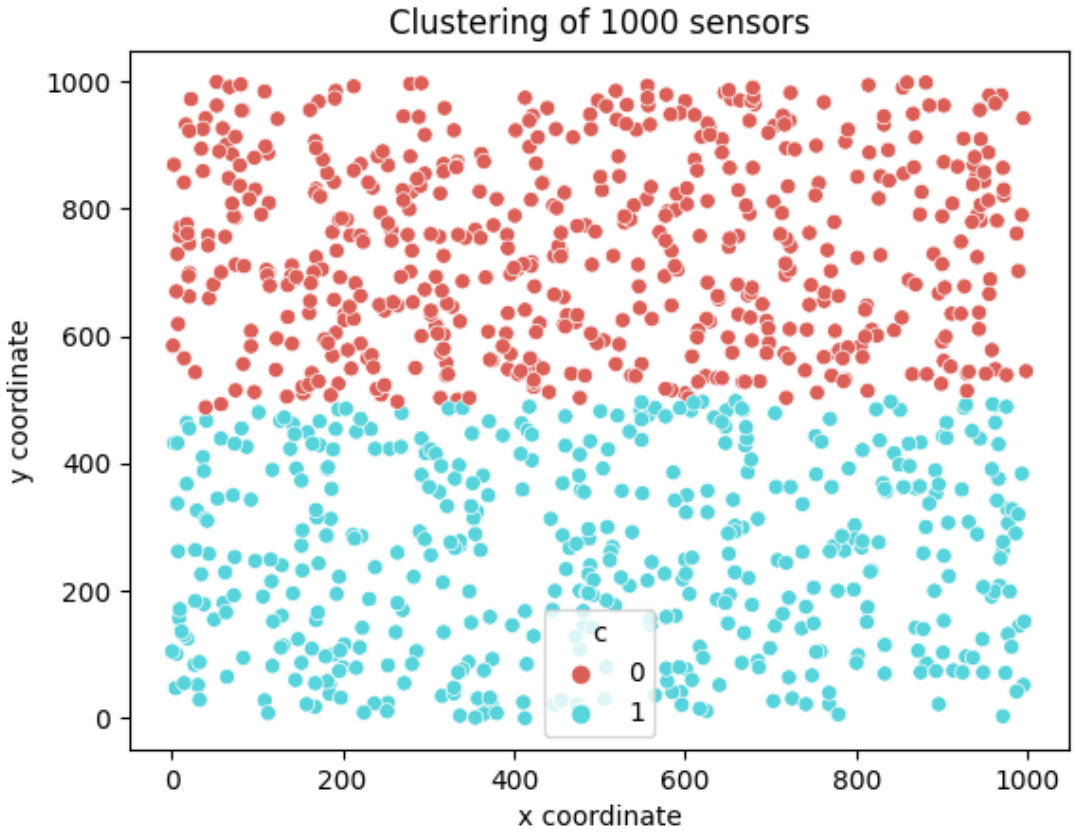
```
        iterations ++;

        compute_distance(points, clusters);

        conv = update_clusters(clusters);



    }

    double time_point3 = omp_get_wtime();
    duration = time_point3 - time_point2;

    printf("Number of iterations: %d, total time: %f seconds, time
per iteration: %f seconds\n",
           iterations, duration, duration/iterations);

    try{
        printf("Drawing the chart...\n");
        draw_chart_gnu(points);
    }catch(int e){
        printf("Chart not available, gnuplot not found");
    }

    return 0;


}

vector<Point> init_point(int num_point){

    vector<Point> points(num_point);
    Point *ptr = &points[0];


    for(int i = 0; i < num_point; i++){

        Point* point = new Point(rand() % (int)max_range, rand() %
(int)max_range);

        ptr[i] = *point;

    }

    return points;

}

vector<Cluster> init_cluster(int num_cluster){

    vector<Cluster> clusters(num_cluster);
    Cluster* ptr = &clusters[0];

    for(int i = 0; i < num_cluster; i++){
```

```
        Cluster *cluster = new Cluster(rand() % (int) max_range,
rand() % (int) max_range);

        ptr[i] = *cluster;

    }

    return clusters;
}

void compute_distance(vector<Point> &points, vector<Cluster>
&clusters){

    unsigned long points_size = points.size();
    unsigned long clusters_size = clusters.size();

    double min_distance;
    int min_index;


#pragma omp parallel default(shared) private(min_distance,
min_index) firstprivate(points_size, clusters_size)
    {
#pragma omp for schedule(static)
        for (int i = 0; i < points_size; i++) {

            Point &point = points[i];

            min_distance = euclidean_dist(point, clusters[0]);
            min_index = 0;

            for (int j = 1; j < clusters_size; j++) {

                Cluster &cluster = clusters[j];

                double distance = euclidean_dist(point, cluster);

                if (distance < min_distance) {

                    min_distance = distance;
                    min_index = j;
                }

            }
            point.set_cluster_id(min_index);
            clusters[min_index].add_point(point);

        }
    }
}

double euclidean_dist(Point point, Cluster cluster){

    double distance = sqrt(pow(point.get_x_coord() -
cluster.get_x_coord(),2) +
```

```
                            pow(point.get_y_coord() -
cluster.get_y_coord(),2));

    return distance;
}

bool update_clusters(vector<Cluster> &clusters){

    bool conv = false;

    for(int i = 0; i < clusters.size(); i++){
        conv = clusters[i].update_coords();
        clusters[i].free_point();
    }

    return conv;
}

void draw_chart_gnu(vector<Point> &points){

    ofstream outfile("out1.csv");
    outfile<<"x,y,c"<<endl;

    for(int i = 0; i < points.size(); i++){

        Point point = points[i];
        outfile << point.get_x_coord() << "," << point.get_y_coord()
<< "," << point.get_cluster_id() << std::endl;

    }

    outfile.close();


}
```

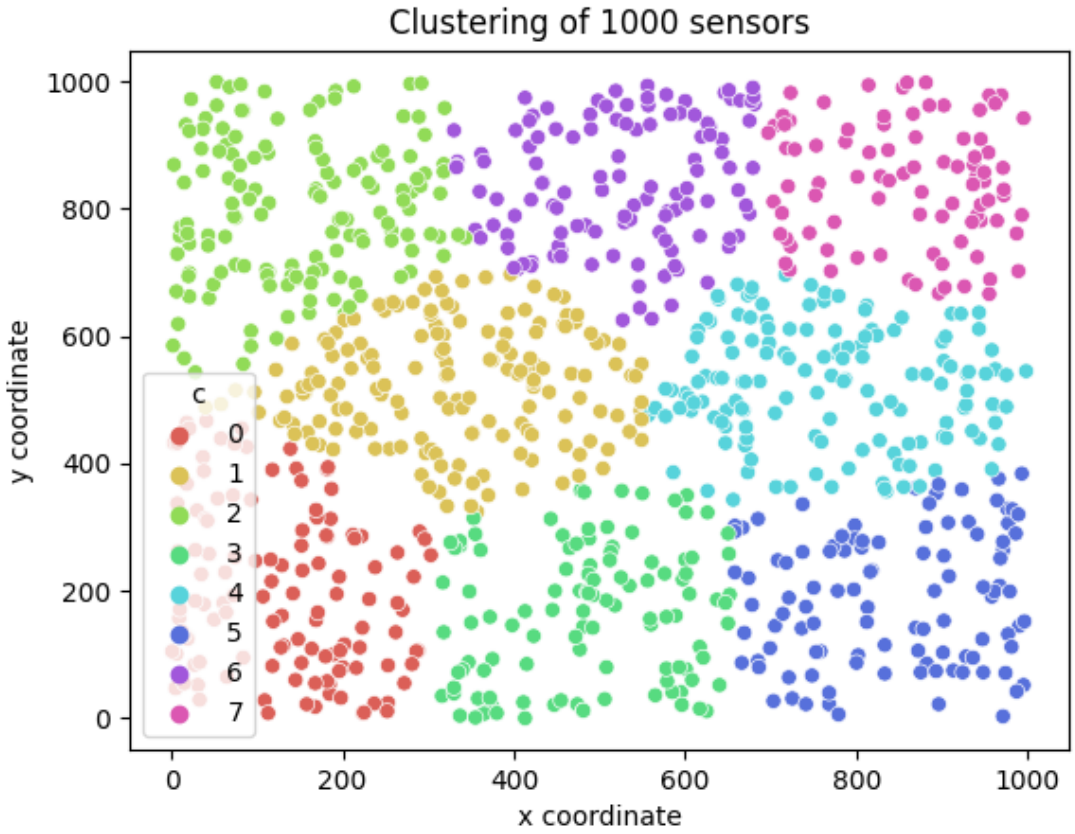
Output

For k=2



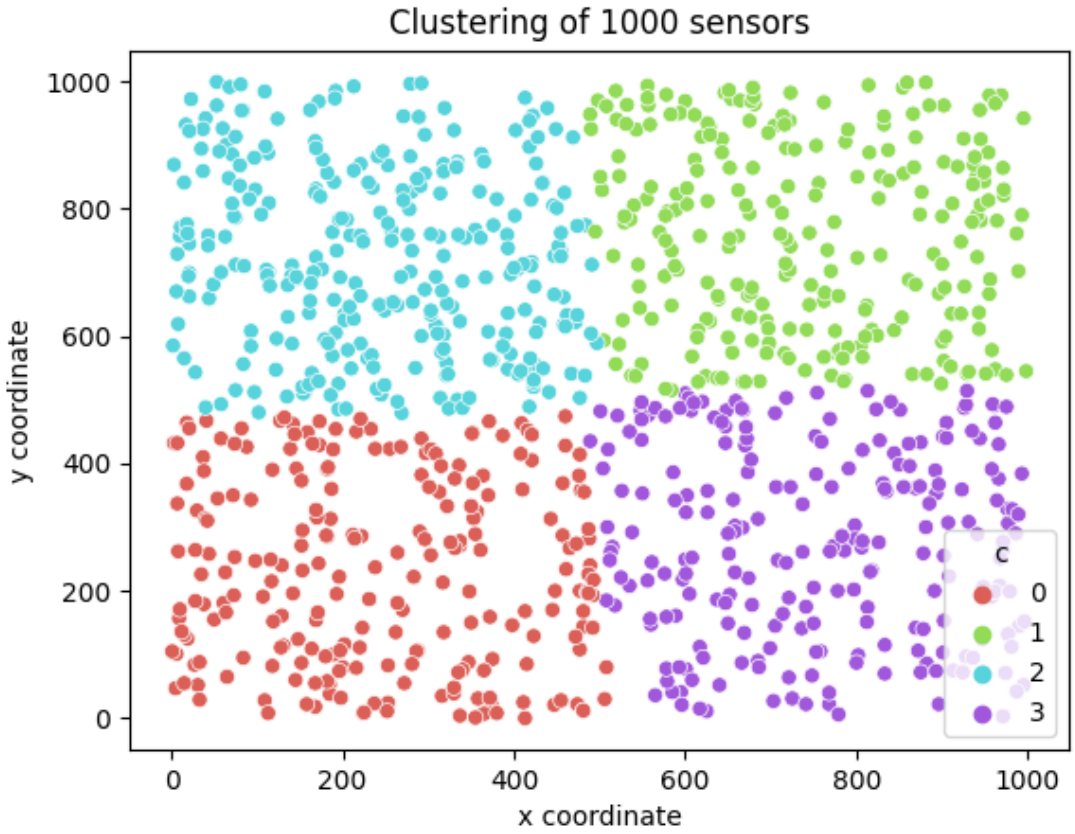

```
PS C:\Bhagyashri> g++ -o K-means -fopenmp K-means.cpp
PS C:\Bhagyashri> ./K-means
Number of points 1000
Number of clusters 2
Number of processors: 8
Creating points..
Creating clusters..
Points initialized
Clusters initialized
Points and clusters generated in: 0.004000 seconds
Starting iterate...
Number of iterations: 9, total time: 0.005000 seconds, time per iteration: 0.000556 seconds
Drawing the chart...
PS C:\Bhagyashri>
```

For k=8




```
PS C:\Bhagyashri> g++ -o K-means -fopenmp K-means.cpp
PS C:\Bhagyashri> ./K-means
Number of points 1000
Number of clusters 8
Number of processors: 8
Creating points..
Creating clusters..
Points initialized
Clusters initialized
Points and clusters generated in: 0.003000 seconds
Starting iterate...
Number of iterations: 11
, total time: 0.004000 seconds
```

For K=4




```
PS C:\Bhagyashri> ./K-means
Number of points 1000
Number of clusters 4
Number of processors: 8
Creating points..
Creating clusters..
Points initialized
Clusters initialized
Points and clusters generated in: 0.003000 seconds
Starting iterate...
Number of iterations: 8
, total time: 0.003000 seconds
PS C:\Bhagyashri>
```

Why parallel implementation is better than Sequential?

Different sections have been used to allot the section to threads without encountering race conditions. The two for loops have been declared as two sections. Schedule(static) has been used to compute distances to allot fixed number of chunks to the threads. This ensures that each thread gets some amount of task and they can work efficiently. For greater number of clustering, parallel execution takes lesser time than sequential execution.