System for emergency centres for optimized service and routing

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Abstract: The p-center problem seeks the location of p facilities. Each demand point receives its service from the closest facility. The objective is to minimize the maximal distance for all demand points. In this report , the p-center location problem for demand originating in an area is investigated. This problem is equivalent to covering every point in the area by p circles with the smallest possible radius. The second half of the project is about routing a path to cover demand points deliveries in minimum time and cost. Given a collection of points and the distance of travel between each pair of them, the problem is to find the shortest way of visiting all of the points and returning to the facility. Though the statement is simple to state it is more difficult. This is similar to the traveling salesman problem.

1. INTRODUCTION

In a world of on-demand everything, it's never been more important to make sure your business is ready to deliver. In large or medium retail enterprises, the downstream of the supply chain is usually composed of distribution centers or various warehouses. Since the distance of each distribution route is large, so the optimization of the path is essential for the cost control and profit maximization of the enterprise.

In our project, we focus on minimizing distribution centers and reducing paths for each demand point such that the overall covered path is minimum and optimized in terms of cost and profit. The first half of the project is a classic problem in combinatorial mathematics known as a p-center problem. The p-center problem seeks the location of p facilities. Each demand point receives its service from the closest facility. The objective is to minimize the maximal distance for all demand points. This is equivalent to covering every point in the area with p circles with the smallest possible radius (the facilities are located at the centers of these circles). In the real world, p-centers can be assumed as emergency points such as hospitals and clinics, pharmaceutical centers, fire departments, holes in drainage systems, etc. Such an application for warning sirens is discussed in Current and O'Kelly (1992). We assume that a set of potential sites is available and the selection of sites from this set is modeled as a set covering the problem.

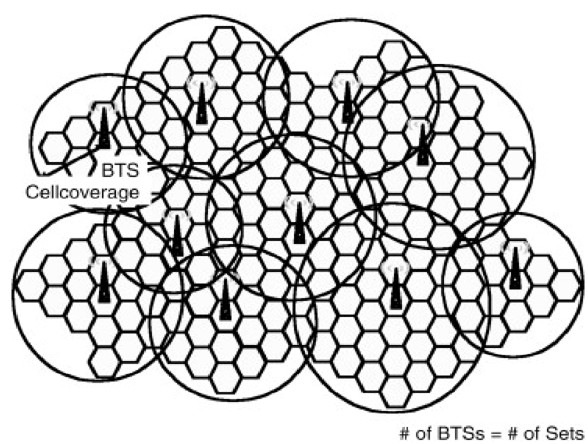


Fig [1]: P-center problem.

The second half of the project is about routing a path to cover demand points deliveries in minimum time and cost. Given a collection of points and the distance of travel between each pair of them, the problem is to find the shortest way of visiting all of the points and returning to the facility. Though the statement is simple to state it is more difficult. This is similar to the traveling salesman problem. The traveling Salesman Problem is an optimization problem and has a vast search space and is said to be NP-hard, which means it cannot be solved in polynomial time. The area we are assuming to be covered will be rectangular or square in shape but there is further scope to implement it in the real world for any polygonal area. In the second part, the distance between the facility and demand points is euclidean considering the delivery will be through the drone.

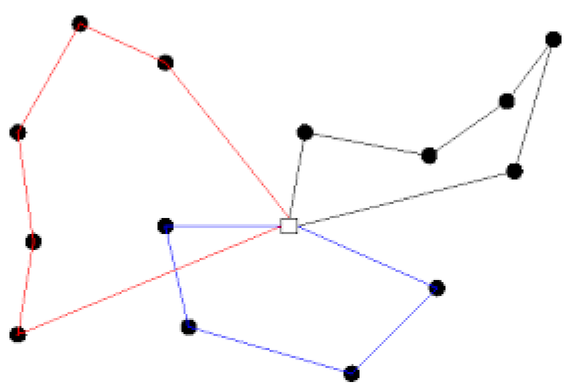


Fig [2]: Travelling salesman problem with service point at the center.

The solution of the above two parts is combined together and implemented in CPP. Section 2 is a literature survey. Then, we will be discussing the algorithms and approaches we used to solve the above problem. The rest of the report is organized as follows: Section 4 contains the core code with input and output examples. Section 5 is a comparison and results of our solution with other algorithms already present in the market.

2. LITERATURE SURVEY

The p-center location problem over a continuous area of demand is an interesting practical problem with various applications. The problem is equivalent to covering a given area in the plane with p identical circles which have the smallest possible radius (the facilities are located at the centers of these circles). In the literature (e.g. Handler, 1990; Tansel et al., 1990), it is usually assumed that demand for the required service originates from a finite set of "demand points". In many cases, assuming that an area represents the set of demand points is more realistic. Demand originating in an area rather than in a finite set of demand points applies to the location of mobile demand. For example, the location of stations for cellular telephones requires a continuous approach.

A relaxation method for the Euclidean p-center problem has been described. The method is capable of solving large-scale problems. Furthermore, the method offers the possibility for substantial improvement to solutions found by heuristic methods in very large problems that cannot be solved optimally.

Further research efforts are needed to consolidate the results attained thus far. In particular, the efficiency of the method can be substantially improved by the use of an up-to-date set-covering algorithm and by more efficient computer programming. Finally, more extensive computational experiments are required to characterize the efficiency of the proposed method.

During the COVID-19 pandemic, it was essential to transport medical supplies to specific locations accurately, safely, and promptly on time. The application of drones for medical supplies delivery can break ground traffic restrictions, shorten delivery time, and achieve the goal of contactless delivery to reduce the likelihood of contacting COVID-19 patients. However, the existing optimization model for drone delivery is cannot meet the requirements of medical supplies delivery in public health emergencies. In this paper, they propose yet a newer approach to the nonlinear programming model that can further shorten the total delivery time by shifting the centers of clusters after applying a K-means clustering algorithm (MacQueen, 1967) and TSP modeling (Dantzig et al., 1954).

3. ALGORITHM APPLICATION

Putting forward the problem:

i) First part: There are n-number of service points available in an area. We need to minimize the service points as much as possible it may in real-world situations. These services will be having a circular range in which they will be providing service such that the whole area will get covered. In the solution of the first part, we will get a minimum no. of service points with their coordinates and minimum coverage radius.

ii) Second part: Now we have our minimum service points in our hands. For each facility, there will be no. of demand points. We need a route that starts and ends at the service point covering all demand points such that overall delivery cost is minimum and profit is maximum.

Modeling the problem:

i) P-center / set covering problem: The rectangular or square shape area is a matrix/grid considered as a vector of vectors. Where each block in the grid would be a vector of sets. In the beginning, the range is initialized with the maximum possible value. We have to minimize this radius.

ii) Routing problem: All the demand and service points are considered nodes in a fully connected graph. The service point is the start and end point of travel. We have to visit each demand point and return to the base.

Solution of the problem:

i) First Part:

Steps:

- ➢ Applying Breadth-First Search on each service point.

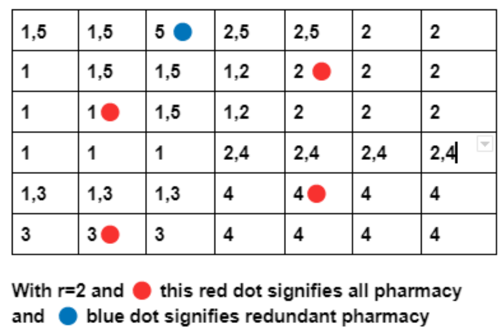


Fig [3]: Area coverage by facilities.

- ➢ Checking whether the whole area is getting covered or not. If not, increase the radius “r” and return to step 1.
- ➢ For choosing the perfect radius to apply a binary search algorithm.

  It works by repeatedly dividing in half the portion of the list that could contain the item until you've narrowed down the possible locations to just one

  Mid = (low + high) / 2

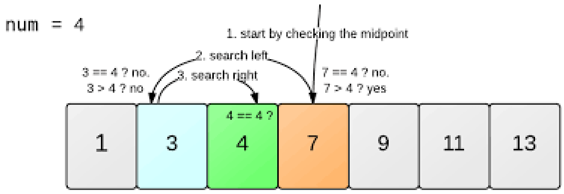


Fig [4]: Binary search space.

$$d(\mathbf{p}, \mathbf{q}) = \sqrt{\sum_{i=1}^{n} (q_i - p_i)^2}$$

Fig [6]: Calculating the distance between each pair of points

➢ If step 2 is yes, by the technique of relaxation remove the service point which is redundant.

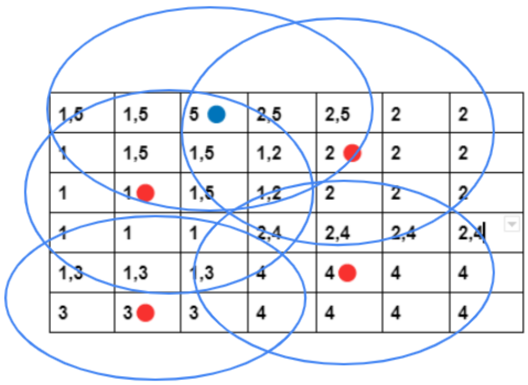
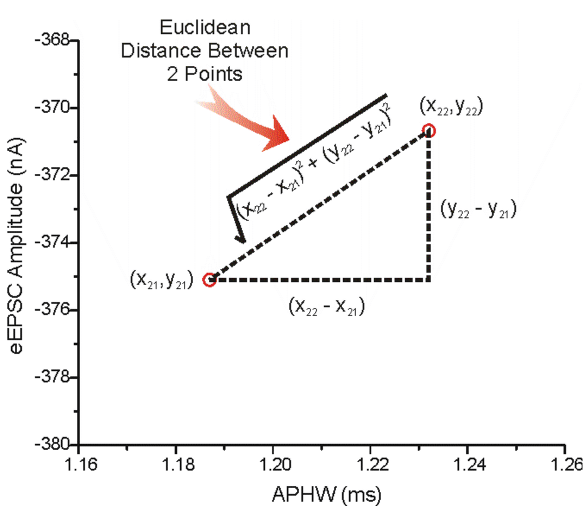


Fig [5]: Redundant facility points

➢ Now, we get the minimum radius and minimum no. of service points needed.

➢ Calculate the euclidean distance between each pair of points.



Approach of multisource BFS:

1. Initially, the set contains the sources with distance = 0 and all the other vertices with distance = infinity.

2. On each step, we will go to the vertex with minimum distance(d) from the source, i.e, the first element of the set (the source itself in the first step with distance = 0).

3.We go through all it’s adjacent vertices and if the distance of any vertex is > r + 1 we replace its entry in the set with the new distance.

4. Then we remove the current vertex from the set. We continue this until the set is empty.

Routing Path Algorithm:

1. Consider the service point as the starting and ending point.
2. Calculate the euclidean distance for each pair of points.
3. Generate all (n-1)! permutations of demand and service points.
4. Calculate the cost of every permutation and keep track of the minimum cost permutation.
5. Return the permutation with minimum cost.
6. We get our desired minimum path for delivery.

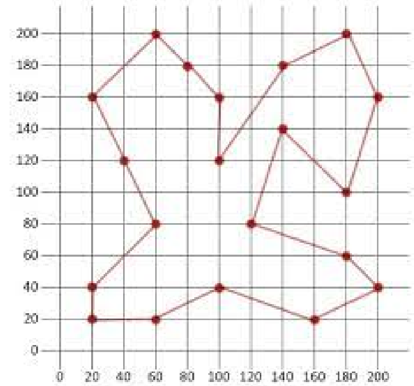


Fig [7]: Desired minimum path for delivery

4. CODE

```
while(l <= r)
{
    int mid = (l+r)/2;  // current coverage radius
    vector<vector<set<int>>> mat(n,vector<set<int>>(m));
    for(int i = 0; i < shop_num; i++)
    {
     vector<vector<int>> vis(n,vector<int>(m));
     queue<pair<int,int>> q;
     q.push(v[i]);
     while(!q.empty())
     {
       pair<int,int> op = q.front();
       q.pop();
       if(vis[op.first][op.second] == 1)
       continue;
       mat[op.first][op.second].insert(i+1);
       vis[op.first][op.second] = 1;
       vector<int> x = {1,-1,0,0}, y = {0,0,1,-1};
       for(int j = 0; j < 4; j++)
       {
        int pp = x[j]+op.first,qq = y[j]+op.second;
        int d = dis(pp,qq,v[i].first,v[i].second);
        if(valid(pp,qq,n,m) && d <= mid)
        q.push({pp,qq});
       }
     }
    }
```

5. RESULTS

Output:

- Required facilities after removing redundant facilities will be printed.
- Which area of the city will be covered by which facility will also get printed.
- Which demand point will get served by which facility will also get printed along with the minimum cost of delivery.

6. Input And Output Images:

```
Enter the size of City :
8 8
Enter number of Pharmacy :
4
Enter the coordinates of each Pharmacy :
0 7
7 0
0 0
7 7
Min coverage radius: 4
Min number of shops: 4
Requried shops after removing redundant pharmacy :
0 0
0 7
7 0
7 7
List of shops that cover a part of city :
1 1 1 2 2 2 2 2
1 1 1 2 2 2 2 2
1 1 1 2 2 2 2 2
3 3 3 1 2 4 4 4
3 3 3 3 4 4 4 4
3 3 3 4 4 4 4 4
3 3 3 4 4 4 4 4
3 3 3 4 4 4 4 4
```

```
Enter number of Customers :
2 1
clustering pharmacy with customers
0 0        1 1        1 2        2 1
0 7        1 6
7 0        6 1
7 7        6 6
P1 ( 0 0) - Total Cost is :6.0645
P2 ( 0 7) - Total Cost is :2.82843
P3 ( 7 0) - Total Cost is :2.82843
P4 ( 7 7) - Total Cost is :2.82843
```

6. CONCLUSION

The combined solution of the P-centre problem and traveling salesman problem gives us the answer to our problem statement i.e. optimized routing and delivery system for emergency centers through drones. In our first part, we find out which facilities are redundant, and in the next part we find out the desired minimum path for routing and optimized delivery.

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