Summary

Discrete location problem is a very old and classic problem. With the publication of the first site selection theory by German scholar Weber in 1909 as the symbol, discrete site selection problem officially entered the scientific research era [1]. Discrete location problem mainly includes 8 subproblems: median problem, coverage problem, central problem, multi-product problem, dynamic problem, multi-objective problem, path location problem and network center location problem [2]. In this paper, the article we repeat belongs to the coverage problem. To be more specific, the coverage problem could be divided into the complete coverage problem and the maximum coverage problem. Our problem belongs to the complete coverage problem.

In the article, what we're going to do is we're going to find potential disaster recovery centers (DRCs) for Alachua County, Florida, which makes each customer supported by at least one DRC in the event of a disaster. This paper has completed the two main parts of the original paper [3]: using the pick-the Farthest Algorithm to cluster customers and using integer programming to find the optimal solution. In addition, we also improved the clustering algorithm of the original paper. We tried a new algorithm —-P-center algorithm. This algorithm is mentioned in the original paper but has not been implemented. We implemented p-center algorithm and compared the results obtained by the two algorithms. Further analysis is in our plans but not yet complete.

1 Analysis of the problem

In order to provide effective recovery assistance to disaster-stricken areas after natural disasters occur, the Federal Emergency Management Agency (FEMA) required each county in Florida to establish potential disaster recovery centers (DRCs). As a county in Florida, Alachua County is required to establish at least three sites. Hence, it is now necessary to make reasonable arrangements for the specific locations of these DRCs in Alachua County to better respond to natural disasters and provide aid to victims of areas affected by disasters in time.

Alachua County is a country located in the north central portion of the U.S. state of Florida. According to the 2005 data, the population in this country was approximately 96,000. The east-west direction of Alachua County is about 32 miles (51.52 kilometers), and the north-south direction is around 30 miles (48.3 kilometers). The land area is about 874 square miles (2266 square kilometers).

Our article tends to realize the objective that the number of DRCs required is minimized as much as possible, in the case that the distance between each resident of the county and the nearest DRC does not exceed r. This kind of problem is called a covering location problem. From the geometric perspective, our covering location problem tends to find the minimum number of unit spaces on the basis that each resident is covered by at least one unit space. As for the definition of unit space, we defined the spatial unit as a diamond, i.e., a square with diagonals 2r whose edges make 45 angles with both x and y axes, rather than a unit circle with radius r. Because of the measurement of the distance between any two points on the actual map, we use 1-norm distance (For any vector $m(x_1, y_1), n(x_2, y_2)$, the distance between them is $|x_1 - x_2| + |y_1 - y_2|$), instead of the general Euclidean distance. In terms of distance/radius r length selection, since our team collected raw data that is relatively similar to the published scientific article we found, and also the goal of our article is to replicate the model of the original paper as much as possible and get an approximate solution. Therefore, here we chose the same value of r as the original paper, i.e., r is 10,15 and 20.

Compared with the original document that tends to find the DRCs that meet the requirements of the problem in two steps, our article only focuses on the first stage, that is solving idealized covering location problems to obtain the best optimal solution. Our article does not intend to design a building grade card mainly for the following reasons. The first reason is that the scoring standard is too subjective. Besides, there is only little information available about the building grade, so it is quite difficult to implement this process. Finally, our article mainly focuses on solving the OR problem, but the building score is not strongly associated with the OR problem.

2 Data collection and processing

The raw data of Alachua County in 2005 we used all came from GIS website. The country data can be indexed by parcels of land. Parcels covers important information such as the number of buildings, the total square footage of the building, the x and y coordinates of the parcel center and so on. Then, we need to preprocess the raw data of 90,000 parcels in different counties of Florida in 2005.

At First, we extracted 6988 parcels (demand points) from the raw data of 90,000 parcels.

- Delete parcels with missing values on the x and y coordinate, on the total square footage of the building and on the number of buildings.
- Remove parcels including the outliers of x and y coordinates.
- Remove those data with the numbers of buildings equal to 0.

- Drop the data involving residential in category 2

By plotting and comparison, it was found that the distribution of some discrete areas in the graphs we got is significantly different from the original paper. And also, we cannot filter out the same points, according to the description in the original paper. After many times of our analysis, we found that if we try to get the same points, it is possible to lose a large number of the valid data used in the paper. This will reduce the accuracy of the data. Therefore, based on our observation, we screened about 4400 parcels (potential DRC sites) meeting the following conditions.

- Select parcels satisfying the total square footage greater than 2000 square feet and acres exceeding 0.0459.
- Choose parcels with stories and activity year all exceeding 0.

The 6988 demand points (Figure 1) and 4400 potential DRC sites (Figure 2) are respectively distributed like below:

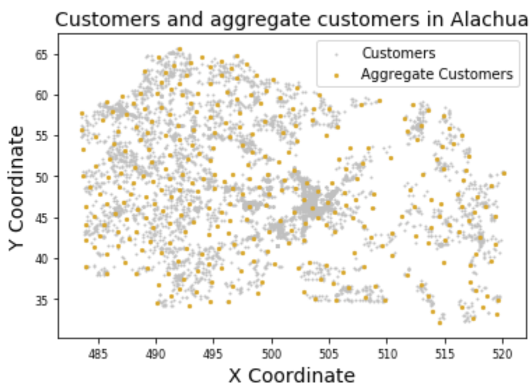

Figure 1

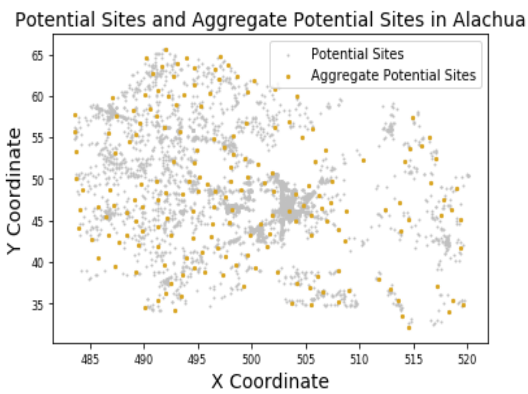

Figure 2

3 Data aggregation

Here, we would like to use the following PTF Algorithm to aggregate the demand points, and the error generated by this method can be considered to be ignored.

One of reasons that we would like to choose Pick-the-Farthest (PTF) algorithm is that the number of violations can be controlled, even if some covering constraints might be violated during analysis. Apart from that, another important reason is that the DRCs can be quite appropriately distributed in the country, if we use this method to aggregate demand points. That means any two DRCs would not be built too close. Therefore, while the disaster happens, residents in the country can get the same degree of rescue and assistance. Therefore, the location of each DRC is fair and reasonable for all residents. In addition, the situation that multiple DRCs can be affected by a disaster would be reduced.

Step 1 Find an arbitrary demand point q, and then put this point into an aggregated demand point set Q.

Step 2 Pick $c \in C$, $C = \Omega \setminus Q$. Then, calculate the distance from c to the set Q, i.e. $\text{distance(c,Q)} = \min_{q \in Q}(\text{distance(c,q)})$, for $\forall c \in C$.

Step 3 Select the maximum value d of the distance obtained in step 2 and consider the corresponding point c as the demand point. Then, put it into the set Q. So far, the next demand point into the set Q is found.

Step 4 Repeat the above steps until $\mathrm{d} \geq \mathrm{b}$, an aggregation error parameter b equal to 1.5 miles. Hence, any the distance from any demand point to its nearest center cannot exceed the covering radius *r* plus *b*.

4 Model

About the covering-facility-location problem, we can model it as an integer-programming problem: min $\sum_j x_j$ s.t. $\mathrm{AX} \geq \mathrm{e}$.

Assume A is a matrix with rows for customers and columns for potential DRC sites. If the 1-norm distance between customer i and potential DRC site *j* is less than r, $a_{ij} = 1$. Otherwise, $a_{ij} = 0$. Then, suppose $X = (x_j)$ is a vector of 0–1 variable. If the DRC site *j* is picked to provide aid, $x_j = 1$. Otherwise, $x_j = 0$. Besides, *e* is a vector with all elements equal to 1. In this way, we can optimize the problem to obtain the minimum number of DRCs covering each customer.

5 Result

It can be seen from the results that although there are a small number of sites in the upper left corner of the figure 1 not covered by the diamond-shaped area, because of the error term b, the three DRC sites can still provide assistance to them. In addition, the coverage of customers for the three sites (Figure 4) is basically the same as that of the nine sites (Figure 5), so the minimum number of DRC sites covering each customer is three.

Choosen travel limit radius:	10 miles	15 miles	20 miles
Maximum travel distance (miles):	10.8	15.74	20.93
Average travel distance (miles):	4.799	8.817	8.721
% parcels within travel limit radius of a centre:	0.9986	0.9993	0.9993
Average distance in excess of travel-limit for parcels farther from any center than the travel limit (miles):	0.2001	0.314	0.6242

Figure 3

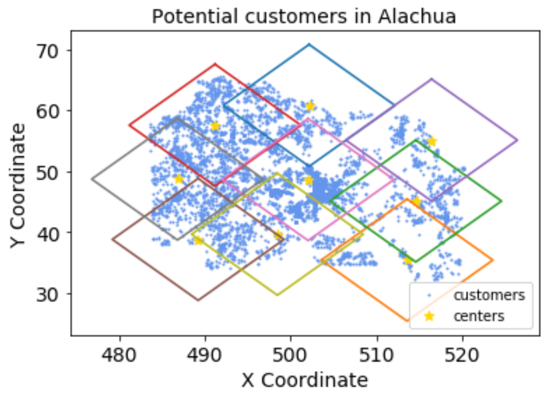

Figure 4

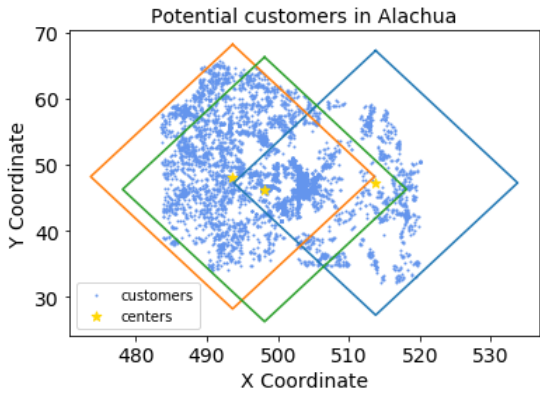

Figure 5

6 Sensitivity analysis

7 Improvement

Compared to the termination criterion above mentioned, we also used another method to stop choosing aggregate demand points. That is, repeat step 1-3 and stop until we get approximately 200 demand points inside the Q set, which is called a 2-approximate problem for the *p*-center problem. The minimum number of DRC sites obtained after aggregation in this way is also three (Figure 7), and these three DRC sites can cover all the customers like Figure 6.

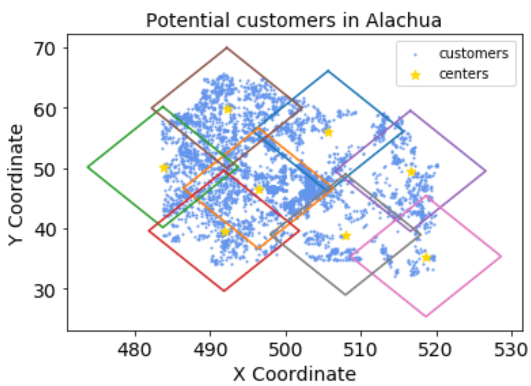

Figure 6

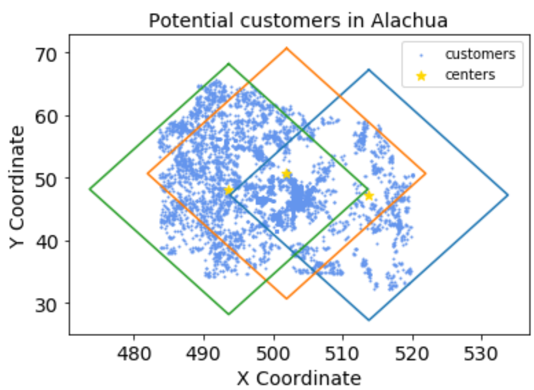

Figure 7

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Choosen travel limit radius:              10 miles   |   15 miles   |   20 miles
Maximum travel distance (miles):          10.86          15.74          20.93
Average travel distance (miles):          6.281          8.698          8.606
% parcels within travel limit
radius of a centre:                       0.9991         0.9991         0.9993
Average distance in excess of travel-
limit for parcels farther from any
center than the travel limit (miles):     0.4156         0.2858         0.6242
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Figure 8

8 Conclusion

Reference

[1] Brandeau M L, Chiu S S. An Overview of Representative Problems in Location Research[J]. Management Science, 1989, 35(6):645-674.

[2] Wang Fei, Xu Yu, Li Yixue. Review of Natural Sciences-Mathemates-Operations Research - Discrete Facility Location Problem [J]. Chinese Journal of Academic Journal Abstracts, 2007, 13(7):1-1.

[3] Dekle J, Lavieri M S, Martin E, et al. A Florida County Locates Disaster Recovery Centers[J]. Interfaces, 2005, 35(2):133-139.