Development of an Algorithm for Optimum Allocation of Multiple Teams to Borehole Drilling Sites

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Abstract: This research focuses on the allocation of teams to complete a set of time duration predefined borehole investigation jobs. An algorithm was developed, to output which team does which jobs and when. Initially, filtering the job list was done to group similar type of jobs together. Clustering the two dimensional drilling sites to a given number of teams were done to separate the jobs among the drilling teams. The total service time duration differences of the outcome drilling site clusters were minimized to a given accepted difference level by iteratively shifting jobs from the cluster, which has maximum total service time duration. The distance matrix of each drilling site locations cluster was modified by adding the 'office location' and replacing 'big M' values for main diagonal distances of each outcome cluster and, sent through the Hungarian method. The graphical representations of obtained sub routes were taken as a guide for designing of the shortest path of each clustered drilling sites. The developed algorithm was shown better optimization over the traditional practice of 'instant team allocation for the nearest location'.

Keywords: Clustering, Hungarian Method, Shortest Path

1. Introduction

Borehole drilling is one of the geotechnical investigations applied in the foundation designing process of the construction industry. The growth of the construction industry of Sri Lanka requires an effective utilization of borehole drilling teams for the borehole drilling sites. It is similar to sending multiple travelling salesmen for multiple locations under the minimum over all travelling distance. In the borehole drilling, there are mainly two types of borehole drilling teams: wash boring teams and wash boring/ core drilling teams. There are different accessible time periods for the sites. The service time of the locations are different and it can be predefined, based on the nature (number of holes, ground conditions, drilling length...etc.) of the drilling site job. It is expected that the difference of the total work duration among teams should be in an accepted level of difference.

As the research was expected to answer any data set, which has feasible solutions, the research outcome was to develop an algorithm

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to find the optimum allocation of borehole drilling teams for given job locations to minimize the travelling.

2. Material and Methods

2.1 Data Used

A real data set of a leading Sri Lankan Geotechnical Engineering company was used for testing the developed algorithm, with scale down the job locations to 100x100 grid (Figure 1). The data set included job list, number of borehole drilling teams, fixed starting time tolerance, service time for each job location as well as how the jobs were done by the company using their traditional method of instant nearest drilling team allocation criterion. The dataset was called "Geo".

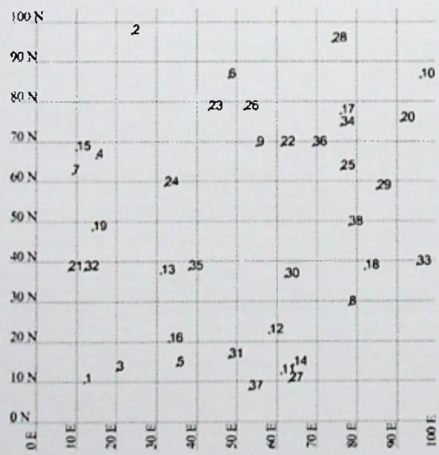

Figure 1 -2D graphical representation of Geo-Dataset job locations

Further analysis was done for auto generated, solutions feasible job lists with different start time tolerances, service time durations and various number of drilling teams.

2.2 Mathematical representation of data and process

Input data are;

J_i Job Index i= 1,2,3… n

Under the conditions:

Filter 1. J_i are representing only one type of jobs

Filter 2. Last completion date ≥ 42 days

n number of job locations

E_i , N_i Easting and Northing coordinates of job location i, respectively.

T_i predicted service time duration required to spend at job location i

G_i work group i=1,2,3… m

m number of working groups

D_{ij} distance from i^{th} job location to j^{th} job location

W the maximum accepted working load difference of the working teams.

Process of minimization of travelling;

Min $\sum k_{ij}D_{ij}$, where if travel from job location i to j, k_{ij}=1, otherwise k_{ij}=0

Subjected to

$$\text{Max} \sum_{p\epsilon G_q} T_p - \text{Min} \sum_{p\epsilon G_q} T_p \leq W$$

2.3 Proposed Algorithm

1. Get the list of job location easting, northing and service time into matrix J (no. of job locations X 3).
2. Get the list of initial cluster centroids easting, northing into matrix W (no. of working groups X 2).
3. Find the distance to each job location to each cluster and write to matrix D (no. of job locations X no. of working groups).
4. Find the minimum of each row of D and write to matrix M (no. of job locations).
5. Write the corresponding cluster number of matrix M to matrix MI (no. of job locations).
6. Write the matrix W* by mean values of each cluster easting and northing based on matrix J and matrix MI.
7. If W and W* matrix are equal move to step 8, else replace the matrix W with W* and go to step 3.

8. Calculate each cluster total service time based on matrix J and matrix MI, and write to matrix S (no. of working groups).
9. Find the maximum and minimum values of matrix S and if it is less than or equal to the accepted difference level go to step 12 else go to step 10.
10. Find the best job location to move from the maximum total service time holding cluster to one of the others with following conditions.
    a. Changing Job location is from maximum service time holding cluster
    b. The changing job locations new cluster is the second best minimum distance holder of the job location.
    c. The change produces the maximum minimum service time difference of the clusters less than the step 10 entry difference.
11. Update the matrix S and matrix MI with the change of the step 10. Go to step 9.
12. Print the final solution -service time balanced working groups, based on matrix J and matrix MI.

    Get the above algorithm output balanced clusters separately follow the procedure given below separately for each cluster job locations to find out the optimum path within the cluster.
13. Add an additional 2D point (office location) to the cluster 1 job locations list and call it completedCluster1PointsList.
14. Find the distance matrix for the completedCluster1PointsList.
15. Replace the diagonal of the distance matrix (*A* to *A* distance) with big M value.
16. Run the Hungarian algorithm and get the solution.
17. Interpret the Hungarian solution in graphically.
18. If there is a sub-tour within two locations, replace one of two distances of between these two locations in the distance matrix by big M.
19. Run the Hungarian algorithm again on the modified distance matrix.
20. Interpret the modified Hungarian solution graphically.
21. Combine the sub-tours such that the single path gives the shortest path traversing all the points of the cluster.
22. Continue the process for the remaining balanced clusters.

2.4 Testing and analysis

The developed algorithm was coded using Java programming language and tested for "Geo Dataset" and auto generated data sets.

3. Results

Table 1– Comparison of the algorithms

Algorithm	Total travelling distance	Total travelling between job locations	Service Time difference
Existed	1040.60	532.12	{8(=40-32)}
Service time adjusted Existed	1071.98	563.50	{3(=37-34)}
Improved Service time adjusted Existed	966.50	556.46	{3(=37-34)}
Developed	950.58	484.36	{4(=38-34)}

Table 1 summarises the comparison among the existed system, service time difference adjusted existed system, improved service time adjusted existed system and the developed algorithm, results for the total travelling distance including/ excluding office location and service time difference.

Travelling is an idling time period for the labourers. Travel time reduces effective labour hours. Labour idling time reduction rate by the developed algorithm can be calculated from the data inTable 1.

{(Existed method labour hours for travelling - developed algorithm labour hours for travelling)/ex. method labour hours for travelling} X 100%
= {(Existed method labour travelling distance– developed algorithm labour travelling distance)/ex. method labour travelling distance} X 100%
= {(532.12-484.36)/532.12}X 100%
= 8.97%

It implies that, the developed method secures approximately 9% labour idling hours over the existing method due to travelling.

4. Discussion

This research was focused particularly on, how to generate "the balanced clusters" effectively. The balanced clusters were defined as the clusters which obey the constraint that maximum weight difference between highest and the lowest weight clusters are within the acceptable difference level. The weight of the cluster was the total service time of the two dimensional job locations of the cluster.

In this research the main finding was separation of the job locations into given number of working groups by two steps, first building clusters irrespective of the service time, second balance the clusters with minimum effect to cluster centroids.

The shortest path for each cluster visiting their job locations including the office location was guided by Hungarian algorithm. The use of this method twice on the same cluster, first on initial balanced cluster, then big M replaced for a one location of two locations sub route and run Hungarian algorithm provides a guide to manual searching of the shortest path. This method was possible with Geo-Data set as each cluster carries less than ten job locations. As the time duration between two vacations (shutdowns) of geotechnical investigation teams allows less than ten different job locations task, the manual calculation with the guidance of Hungarian algorithm is practicable.

5. Conclusion

The heuristic solution provided for allocating drilling teams for job locations, has a specific feature of filtering and, removing or answering one of the constraints of the research problem in each filtering stage. In this research, developing an algorithm for grouping adjacent job locations by keeping the total service time duration under an accepted level was the main phase. From the developed algorithm, the job locations clustering gave better solution compared to the existed practice of moving the teams for the instant nearest job location. Clustering is best fit for the region, which has geographically uniform development, and receiving the jobs from all over the region randomly.

The introduced shortest path finding guideline combined manual method was practical for this research problem solving.

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