Layout Design for Large Scale Problems with a Hybridized Clustering Based Heuristic Method

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Abstract – In this paper we develop a new efficient heuristic method for facility layout problems. This heuristic method contains two phases. In the first phase, a clustering method based on the SOFM[1] is used for clustering of data in similar groups and in the second phase, an exact solution approach is applied for designing of a layout in each cluster. As an alternative solution, the ALDEP[2] algorithm is used for layout design of each cluster. For validity checking of the proposed approach, layout of small instances are designed by the ALDEP as well as the proposed method to be compared. While for large instances we use the mathematical programming to find the optimal layout design. The results are compared with the results of the proposed approach. Numerical analysis confirms that the proposed two phase approach has better efficiency comparing to the classic single phase approach in both quality and computational time.

Keywords - Clustering*, Facility layout, Neural network*

I. INTRODUCTION

facility layout problem (FLP) is one of the classical problems in which the planning for assigning the different types of facilities such as machines, employee workstations, utilities, customer service areas, restrooms, material storage areas, lunchrooms, drinking fountains, offices, and internal walls is discussed [1]. Solving FLP is a strategic decision and it has a great impact on total operating expenses, lead times and productivity. According to [2], [3] and [4] a well-designed layout can reduce operating costs up to 50 percent.

Because of NP-Hard nature [5] of this problem there are various algorithms and models for solving FLP. These algorithms are categorized in classical methods and heuristics. ALDEP, PLANET, CRAFT and etc. are some examples of the classical methods while, Genetic algorithm, Tabu search, Simulated annealing and Neural network (NN) are categorized as heuristic methods for the layout planning.

Heuristic methods should be applied in replacement for the limitations of the classical methods.

Among these heuristics, the Neural Network has gained more attention attractiveness in different fields of research [6]. Neural networks have applications on simulating intelligence in pattern-recognition, prediction and etc. [7, 8]. They have been used in applications requiring diagnosis, detection, and forecasting [9, 10, 11].

[1] Self-Organizing Feature Map
[2] Automatic Layout Design Program

SOFM is one of the most important types of Neural network because of the learning feature and inherent parallel structure. A few articles have been published to show the application of the Neural network in layout problems, for example Tuschiya et al. (1996) [12] used an artificial two-dimensional maximum neural network for an *N*-facility layout problem. In 1995 Yeh, I-Cheng [13], combined Simulated annealing and Hopfield neural network for solving a layout design and in 2006 [14] used an Annealing neural network for finding an optimal design layout. Jang Inho, Rhee (1997) [15] used SOFM for layout by considering material flow. Rossin et al. (1999) [16] solved the quadratic assignment problem by combining classic methods and the neural network. Tam et al. (1991) [17] used the neural network for facility layout problems.

According to the previous works, it seems that the layout design for large scale instances has enough advantages to be considered. So in this paper we try to develop a heuristic algorithm based on the neural network to solve the layout problem in large instances.

The structure of this paper has been organized as following: the proposed methodology is presented in section 2. Section 3 includes numerical results and some comparisons and finally the concluding remarks are presented in section 4.

II. METHODOLOGY

The methodology is composed of four steps: (1) Solving the problem with ALDEP algorithm where there is a limitation for the maximum number of facilities. (2) Clustering of units considering required data and then using the ALDEP algorithm or an exact solution method for designing a layout in each cluster. (3) Using a mathematical model (ABSMODEL3) for designing a layout in each cluster in case of ALDEP limitations (4) Comparison of the results for assuring the proposed approach validity. Mentioned steps are described as follows.

2.1. Solving the problem with ALDEP algorithm

ALDEP algorithm is a classical method which constructs final layout by itself. Inputs of this algorithm includes: parts relation diagram, Plant ground dimensions, each part dimension and area, number of departments, minimum degree of relationship, minimum total closeness rating, number of layouts in each iterations.

Part relations diagram in ALDEP shows the relation between different parts in a layout which is shown with alphabetical and quantitative orders.

A=64, *E*=16, *I*=4, *O*=1, *U*=0, *X*=-1024.
Where, *A* shows the strongest and *X* shows the weakest relations between parts.
After defining inputs for each problem, ALDEP gives an output to designs facilities based on their relations *in a* row. Finally if we want to calculate the efficiency of ALDEP the equation below shows that Ri,j is the relation score between neighbor parts *i* and *j*:

$$Aleff = 2 * \sum_{i \succ j} R_{i,j} \quad (1)$$

The layout with largest *Aleff* value is preferred comparing to others.

2.2. Solving the problem with combining SOFM and ALDEP algorithm.
In this step, we combine SOFM and ALDEP algorithm to decrease size limitations. as an example in a four facility situation, at first we divide 4 facilities into 2 clusters by SOFM.

Fig. 1. Clustering 4 facilities into 2 clusters

As it is shown in Fig.1, facilities 2 and 4 are in cluster 1 and facilities 1 and 3 are in cluster 2. For designing the layout, at first each cluster is supposed as a facility to design the layout of clusters, then the design of the layout inside each cluster is performed by ALDEP. The final layout efficiency is calculated by equation (1).

2.3. Solving the problem with a mathematical model
In steps 1 and 2, ALDEP algorithm contains a limitation of number of facilities and it cannot solve the problem with more than fourteen facilities. To solve this problem, we need to use ABSMODEL3 which has been coded by GAMS. Inputs of this algorithm includes facilities dimension and material flow matrices between facilities.
Mathematical formulation of this model is shown as following [18]:
N : Number of facilities
c_{ij} : Transportation cost between facilities *i* and *j*
f_{ij} : Number of barters between facilities *i* and *j*
l_i : Horizontal dimension of facility *i*
b_i: Vertical dimension of facility *i*
dh_{ij}: Horizontal empty space between facility *i* and *j*
dv_{ij}: Vertical empty space between facility *i* and *j*
d_{ij} : Minimum horizontal space between *i* and *j*
H : Plant ground dimension
Decision variables: x_i, y_i, *are continuous and* z_{ij} *is binary variable.*

$$minimize \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} c_{ij} f_{ij} (|x_i - x_j| + |y_i - y_j|) \quad (2)$$

Subject.to:

$$|x_i - x_j| + Mz_{ij} \geq \frac{1}{2}(l_i + l_j) + dh_{ij} \quad (3)$$

$$|y_i - y_j| + M(1 - z_{ij}) \geq \frac{1}{2}(b_i + b_j) + dv_{ij} \quad (4)$$

$$Z_{ij}(1 - Z_{ij}) = 0 \quad (5)$$

Objective function (2) minimizes the total transportation cost between facility *i* and *j*. Constraints (3), (4) and (5) ensure that facilities in horizontal or vertical dimension does not overlap. Constraint (5) ensures that Z_{ij} is a binary variable and ensures that constraints (3) and (4) are antonym.
This formulation has been coded in GAMS software and used to solve FLP with more than fourteen facilities. Outputs of this model will be coordinates of the facilities centers. With these coordinates it will be possible to calculate the distance between facilities and use this distance in the objective function of the ABSMODEL3. For doing a comparison, the mentioned objective function (2) is considered as another measure which is called TTeff and because of the minimum nature of this problem, a layout with lower value of *TTeff* is preferred.

2.4. Solving the problem with combining SOFM and ABSMODEL 3
In this article, we would like to solve the FLP in large scales. None of the aforementioned methods are not efficient for large scale problems. ALDEP does not work when the number of facilities exceed fourteen. In case of increased number of facilities, modeling ABSMODEL3 by GAMS, takes a long time to give a solution. Therefore in this situation, we need a method that is capable to of solving large scale problems in a reasonable amount of time. For this reason, we need a combination of SOFM and ABSMODEL3.
With this method we can design the layout of common facilities in a metropolitan area as an example. We know that there are lots of facilities such as libraries, shopping centers, sport complexes and etc. in a city and should be optimally designed. For this purpose, at first we cluster our facilities into predefined number of clusters. For example, we have 20 facilities and divide them into 5 clusters as shown in fig 2.

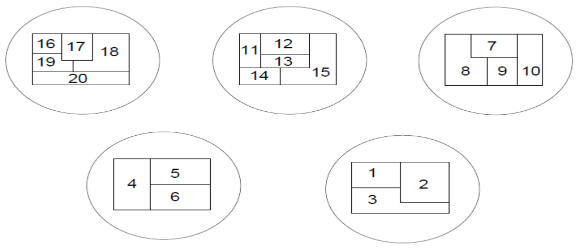

Fig.2. Clustering 20 facilities into five clusters

We suppose each cluster as a facility and the area of this facility is the summation of areas of all facilities in clusters. Then, we design the layout inside each cluster. Finally, efficiency measure is calculated for this case and ~~it~~ is compared with previous results. A better layout is a layout with less calculated measure.

III. NUMERICAL ANALYSIS AND RESULTS

In this section, we discuss numerical results for each step and compare them.
In table 1 we calculate the efficiency of step 1 to solve the FLP only by ALDEP.

TABLE1
Results for ALDEP in small instances

Size	Efficiency *Aleff*
4	384
5	512
6	640
7	768
8	896
9	928
10	1056
11	1280
12	1408
13	1536
14	1664

In table 2 we combine ALDEP and SOFM to be able to compare these two methods:

TABLE 2
Clustering results for small instances

Size	Efficiency *Aleff*	
	Min	Max
4	72	288
5	104	416
6	256	424
7	672	672
8	768	576
9	644	712
10	928	928
11	992	840
12	1184	1288
13	1312	680
14	1410	1576

In this table ~~2~~, we divide facilities into 2 clusters. For example, for 5 facilities, we suppose 2 and 4 clusters, 2 clusters as a minimum cluster and 4 as a maximum. If we suppose size of facility as n we can say that minimum number of clusters is (2) and maximum number is n-1.
We conclude that:

1. In table 1 with increasing size of facilities solution becomes bigger
2. In table 2 the solutions with maximum number of clusters is preferred.
3. Comparing the two tables shows that ALDEP algorithm has better efficiency than the clustering method in small sized problems up to fourteen facilities.

Table 3 shows the results for using the ABSMODEL3 for large problems up to 1000 facilities:

TABLE 3
ABSMODL3 results for medium and large instances

Size	Efficiency *TTeff*10⁶*
15	1350
20	0.378
25	0.839
30	0.839
40	1.88
50	2.4
55	2.92
60	3.44
100	4006
200	14.1
300	10^6
400	10^{11}
500	10^{11}
600	20
700	80
1000	320

Table 4 shows a combination of SOFM and ABSMODEL3:

TABLE 4
Clustering and mathematical modelling results for large sized instances

Size	Efficiency *$TTeff*10^6$*	
	Min	Max
15	1350	1350
20	0.411	0.387
25	0.837	0.849
30	1.36	1.37
40	1.88	1.89
50	2.4	2.41
55	2.93	2.93
60	3.45	3.45
100	4.03	4.05
200	14.1	14.1
300	10^6	10^6
400	10^{11}	10^{11}
500	$2*10^{11}$	$2*10^{11}$
600	0.902	0.905
700	$8.5*10^{17}$	$9.5*10^{19}$
1000	$1.55*10^{36}$	$1.08*10^5$

Tables 3 and 4 confirm that the results extracted by the proposed hybrid method has better efficiency for large scale problems. in many cases especially for problems with more than one hundred facilities, ABSMODEL3 does not work properly. From these results, it can be concluded that the proposed method is one of the most efficient solution methods in layout designing of cases with large number of facilities.

IV. DISCUSSION

In this section, we are going to discuss articles that used clustering or classic or similar methods to the proposed model of this paper.
Melody Kiang et al. (2015) [19] used clustering tool of SOFM for group technology. Their cluster machines based on multi dimensional data includes operation's similarities and processing sequence. Yahyaei et al. (2014) [20] used clustering in finding the best location for a hub and compared it with DEA method. Results show the validity of the proposed model. Sergio Barreto et al. (2007) [21] used clustering in location-allocation problems with huge scales. They used four grouping techniques and six proximity measures for their clustering. Comparison of the method with pervious methods shows the good performance and acceptable gap. Abdolhamid Modares et al. (1999) [22] used SOFM for traveling salesman problems and vehicle routing. They applied this method for numerical tests and concluded that this method has a significant improvement in solutions for both problems.
Review of similar papers shows that the proposed method has enough reasonability and confirm that the proposed methods hybridized with a clustering method will act efficiently in layout design problems.

V. CONCLUSION

Facility layout is an applicable problem in both factories and social applications. Classical layout deign methods include some limitations in number of facilities however there are lots of facilities in real life applications. Clustering in facility layout problems has a great impact on enhancing system efficiency with lower computational time.
In this paper we discussed a combination of classics and heuristics methods for solving facility layout problems in a short time with better efficiency. This method contains 4 Steps:

1. Solving the problem with ALDEP
2. combining ALDEP and SOFM to solve the problem.
3. applying ABSMODEL3
4. combining ABSMODEL3 and SOFM

We used these steps for numerical examples and compared the results. Numerical analysis shows the efficiency and validity of the proposed method in large scale problems. In this paper, we used material flow matrices and dimensions of facilities and the relation between facilities. One of the major concerns of the proposed method is extracting a relationship matrix between the clusters, therefore extracting cluster and between cluster features can be a proper direction of future research to design layout of clusters more efficiently. This work can decrease the gap between the exact and proposed solution approaches.

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