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Optimal Facility Layout Problem Solution Using Genetic Algorithm

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***Abstract*—**Facility Layout Problem (FLP) is one of the essential problems of several types of manufacturing and service sector. It is an optimization problem on which the main objective is to obtain the efficient locations, arrangement and order of the facilities. In the literature, there are numerous facility layout problem research presented and have used meta-heuristic approaches to achieve optimal facility layout design. This paper presented genetic algorithm to solve facility layout problem; to minimize total cost function. The performance of the proposed approach was verified and compared using problems in the literature.

***Keywords*—**Facility Layout Problem, Genetic Algorithm, Material Handling Cost, Meta-heuristic Approach.

I. Introduction

FACILITY layout is an arrangement of everything needed for production of goods or delivery of services. A facility is an entity that facilitates the performance of any job. It may be a machine tool, a work center, a manufacturing cell, a machine shop, a department, a warehouse, etc. Layout problems are usually found in manufacturing systems which is related to the location of facilities in a plant. A good placement of facilities can contribute to the overall efficiency of operations, reduce manufacturing cost, decrease lead times, and increase productivity. Tompkins and White [1] discuss about 50% of total operating expenses can be reduced through a good placement of facilities. Aleisha and Lin [2] pointed out that simulation approaches are frequently applied to gauge the performance of the layout. Drira, Pierreval, and Hajri-Gabouj [3] presented a survey of resolution approaches in solving facility layout problems.

Genetic algorithm (GA) has been widely used in optimization with binary and continuous variable [4] and quite popular in solving facility layout problem.

Chan and Tansri [5] studied different genetic crossover operators to solve facility layout problem. They compared the partially mapped crossover (PMX), the order crossover (OX), and the cycle crossover (CX). The result shows that PMX operator provided excellent results. Mihajlovic, Zivkovic, Strbac, Zivkovic, and Jovanovic [6] proposed genetic algorithm to minimize material handling costs in manufacturing layout problem. Adel El-Baz [7] proposed genetic algorithm to solve the problem of optimal facilities layout in manufacturing systems design. He considers various material flow patterns of manufacturing environments. Mak, Wong, and Chan [8] developed a genetic algorithm to solve facility layout problems. Liu and Li [9] presented a genetic algorithms-based approach to solve supply chain-oriented and dynamic discrete facility layout problem. Liu, Bo, Ma, and Meng [10] presents a creative approach to solve dynamic planning and scheduling problems in hybrid distributed manufacturing execution system using single and parallel genetic algorithms. Kulkarni and Shanker [11] adopted a genetic algorithm methodology to solve quadratic assignment problems in order to minimize material handling cost. Zhang, Zhang, Xia, Lu, and Jiang [12] proposed an improved genetic algorithm to solve unidirectional loop layout to optimize the facility layout in workshop. They used multipoint crossover operator of parent and child competition. Ripon, Glette, Hovin, and Torresen [13] presented a genetic algorithm to solve the integrated job shop scheduling problem and facility layout problem considering multi-objective and pareto-optimality. Aiello, La Scalia, and Enea [14] developed a multi objective genetic algorithm to solve facility layout problem based on slicing structure encoding. They used four objective functions of the block layout problem but they did not incorporate it into single objective function.

In this paper, we used genetic algorithm to solve facility layout problem and hence minimizing the total material handling cost. The objective function is the total material handling cost. The difference of the proposed method to other works is the conversion of the objective values to its relative fitness before the selection operator. Most of the methods in the literature have codification difficulties. To make the coding of the GA simpler, swap mutation [6] and swapped crossover [11] was adopted.

II. Problem Formulation

In manufacturing systems, solving facility layout problem can minimize material handling cost of the system. To determine the material handling cost for a possible layout of the system, certain parameters have been known such as the amount of material flow or production volumes among equipment, the handling cost of per unit material in per unit distance between equipment, and the rectilinear distance between equipment.

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For the optimization problem, the objective function TC is the total material handling cost of the system. The total material handling cost of the system is a measure of how the facilities are arranged in a minimized manner. The optimization problem is formulated as:

$$\min TC = \sum_{i=1}^{n}\sum_{j=1}^{n} F_{ij} C_{ij} D_{ij} \qquad (1)$$

where F_{ij} is the amount of material flow among equipment i and j, C_{ij} is the unit material handling cost between locations of equipment i and j, and D_{ij} is the rectilinear distance between the centroids of locations between equipment i and j and TC is the total material handling cost of the system.

III. Facility Layout Problem Using Genetic Algorithm

The starting operator of the GA is the generation of initial population, which was randomly generated. The representation of an individual is a single-level string. The length of chromosome string is equal to the number of position of the facilities. Fig. 1 shows how the initial parent is encoded.

Location	1	2	3	4	5	6	7	8	9	10	11	12
Facility	4	2	12	9	5	11	10	3	8	1	6	7
Parent	4	2	12	9	5	11	10	3	8	1	6	7

Fig. 1 Encoding of Chromosomes

After the generation of initial population, it will call the objective function, which is the total material handling cost, and passes the generated population as an input. For each individual, the objective function is then calculated.

The fitness function in this paper is given by [15]:

$$Fitness(x_i) = \frac{(Nind)(X^{(x_i - 1)})}{\sum_{i=1}^{Nind}(X^{(x_i - 1)})} \qquad (2)$$

$$0 = (MAX - 1)X^{Nind-1} + \sum_{n=2}^{Nind}(MAX)X^{Nind-n} \qquad (3)$$

where X is the computed real numbered root of the polynomial in (3), MAX is the selective pressure or bias towards the fittest individual, and $Nind$ is the number of individuals.

The selection used in this paper is the roulette wheel selection. This selection methodology is used to probabilistically select individuals based on total material handling cost.

The usual single point crossover was employed. The crossover used in this paper is swapped crossover based on [11]. This method works as a single parent instead of taking two parents as in other crossover methods to generate only feasible solution. It only changes the string of the original chromosome of one parent and swapped the remaining chromosome string in the crossover point. P and O denote parent and offspring respectively. Fig. 2 shows how the swapped crossover was employed:

P1	4	2	12	9	5	11	10	3	8	1	6	7
P2	8	11	3	12	2	6	5	1	7	10	4	9

Crossover Point

O1	5	11	10	3	8	1	6	7	4	2	12	9
O2	2	6	5	1	7	10	4	9	8	11	3	12

Fig. 2 Swapped Crossover

The mutation technique employed is swap mutation [6]. It simply selects two random chromosome strings and swapped their contents. Fig. 3 shows an example of swap mutation:

Before Mutation

Offspring	5	11	10	3	8	1	6	7	4	2	12	9

After Mutation

Offspring	5	11	10	7	8	1	6	3	4	2	12	9

Fig. 3 Swap Mutation

After the offspring are mutated, the objective value will be calculated. Fitness-based reinsertion combined with elitism was used in this paper. The termination depends on the maximum number of generations.

IV. Test Results and Discussions

The effectiveness of the proposed method is illustrated using two numerical examples described in the literature. The entire simulation was coded in MATLAB platform.

A. Numerical Example 1

A comparative evaluation of the proposed method is made using benchmark numerical example. This example is taken from [5] and compared with the works of [6]–[8] that used the same example to evaluate their work. The amount of material flow and the unit material handling cost between equipment are shown in Tables I and II respectively. The plant configuration layout is a 3x3 grid. The rectilinear distance between locations of equipment for the 3x3 grid is tabulated for simplicity and is shown in Table III.

TABLE I
MATERIAL FLOW BETWEEN EQUIPMENT

From/To	1	2	3	4	5	6	7	8	9
1	0	100	3	0	6	35	190	14	12
2	0	0	6	8	109	78	1	1	104
3	0	0	0	0	0	17	100	1	31
4	0	0	0	0	100	1	247	178	1
5	0	0	0	0	0	1	10	1	79
6	0	0	0	0	0	0	0	1	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	12
9	0	0	0	0	0	0	0	0	0

TABLE II
UNIT MATERIAL HANDLING COST

From/To	1	2	3	4	5	6	7	8	9
1	0	1	2	3	3	4	2	6	7
2	0	0	12	4	7	5	8	6	5
3	0	0	0	5	9	1	1	1	1
4	0	0	0	0	1	1	1	4	6
5	0	0	0	0	0	1	1	1	1
6	0	0	0	0	0	0	1	4	6
7	0	0	0	0	0	0	0	7	1
8	0	0	0	0	0	0	0	0	1
9	0	0	0	0	0	0	0	0	0

TABLE III
RECTILINEAR DISTANCE BETWEEN EQUIPMENT

From/To	1	2	3	4	5	6	7	8	9
1	0	1	2	1	2	3	2	3	4
2	1	0	1	2	1	2	3	2	3
3	2	1	0	3	2	1	4	3	2
4	1	2	3	0	1	2	1	2	3
5	2	1	2	1	0	1	2	1	2
6	3	2	1	2	1	0	3	2	1
7	2	3	4	1	2	3	0	1	2
8	3	2	3	2	1	2	1	0	1
9	4	3	2	3	2	1	2	1	0

Their work conducted 19 sets of experiments to determine the appropriate combination of the population size *P* and generation size *G*. The crossover and mutation probability are taken as 0.7 and 0.8 respectively for all simulations.

Table IV shows the resulting optimal facility layouts giving a total material handling cost of 4818 which was the same value to ones compared in the literature.

TABLE IV
OPTIMAL SOLUTIONS

Optimal Solutions	Facility								
	1	2	3	4	5	6	7	8	9
1	4	3	7	8	9	1	5	2	6
2	5	2	6	8	9	1	4	3	7
3	6	2	5	1	9	8	7	3	4
4	7	3	4	1	9	8	6	2	5
5	7	1	6	3	9	2	4	8	5
6	4	8	5	3	9	2	7	1	6
7	5	8	4	2	9	3	6	1	7
8	6	1	7	2	9	3	5	8	4

The experimental results are shown in Table V and are expressed in terms of the best total material handling cost among trials (Best) and the number of trials needed to obtain one of the optimal solutions (Trials).

The result of the simulation shows that the proposed method is much efficient than the four other approaches presented in the literature. The results show that the proposed method produces most of the optimal solution using 20 trials of any combination of *P* and *G*.

TABLE V
OPTIMAL SOLUTION COMPARISON

Exp.	GA Parameters		Proposed Method		Ref. [6]		Trials	Ref. [7]	Ref. [8]	Ref. [5]
	P	*G*	Trials	Best	Trials	Best		Best	Best	Best
1	20	10	20	4862	4050	5119	200	5039	5233	4938
2	40	10	20	4818	8595	5150	400	4818	5040	5039
3	100	10	20	4818	180	4872	1000	4818	4818	4938
4	200	10	20	4818	405	4818	2000	4818	4818	4818
5	500	10	20	4818	270	4818	5000	4818	4818	4818
6	20	20	20	4818	360	4818	400	4872	5225	4938
7	40	20	20	4818	2160	4939	800	4818	4927	4992
8	100	20	20	4818	1125	4990	2000	4818	4818	4818
9	200	20	20	4818	765	4818	4000	4818	4818	4818
10	20	40	20	4818	1485	4818	800	4818	5225	4938
11	40	40	20	4818	3105	4818	1600	4818	4927	4992
12	100	40	20	4818	990	4818	4000	4818	4818	4818
13	200	40	20	4818	2160	4818	8000	4818	4818	4818
14	20	100	20	4818	3105	4818	2000	4818	5225	4938
15	40	100	20	4818	225	4818	4000	4818	4818	4927
16	100	100	20	4818	2160	4818	10000	4818	4818	4818
17	20	200	20	4818	3015	4818	4000	4818	4818	4938
18	40	200	20	4818	3240	4818	8000	4818	4818	4862
19	10	500	20	4818	3600	4818	5000	4818	4818	4818

B. Numerical Example 2

Another example is twelve machines from [16]. The amount of material flow, the unit material handling cost, and the rectilinear distance between locations of equipment are shown in Tables VI, VII and VIII respectively.

TABLE VI
MATERIAL FLOW BETWEEN EQUIPMENT

From/To	1	2	3	4	5	6	7	8	9	10	11	12
1	0	3	2	2	1	3	0	2	1	4	2	1
2	3	0	2	3	2	4	1	0	0	3	1	2
3	2	2	0	1	0	2	2	3	2	0	3	2
4	2	3	1	0	2	3	3	2	1	0	2	1
5	1	2	0	2	0	1	3	0	1	2	2	1
6	3	4	2	3	1	0	2	1	0	3	1	1
7	0	1	2	3	3	2	0	2	3	0	1	3
8	2	0	3	2	0	1	2	0	3	2	2	0
9	1	0	2	1	1	0	3	3	0	2	2	3
10	4	3	0	0	2	3	0	2	2	0	2	1
11	2	1	3	2	2	1	1	2	2	2	0	2
12	1	2	2	1	1	1	3	0	3	1	2	0

TABLE VII
UNIT MATERIAL HANDLING COST

From/To	1	2	3	4	5	6	7	8	9	10	11	12
1	0	6	8	4	7	3	4	11	9	4	7	5
2	6	0	5	7	9	4	6	6	3	5	11	8
3	8	5	0	6	9	8	12	4	6	8	10	6
4	4	7	6	0	4	3	8	6	12	9	7	8
5	7	9	9	4	0	6	8	5	10	9	6	8
6	3	4	8	3	6	0	5	7	4	8	9	6
7	4	6	12	8	8	5	0	7	3	5	10	8
8	11	6	4	6	5	7	7	0	4	9	7	5
9	9	3	6	12	10	4	3	4	0	6	9	7
10	4	5	8	9	9	8	5	9	6	0	10	6
11	7	11	10	7	6	9	10	7	9	10	0	8
12	5	8	6	8	8	6	8	5	7	6	8	0

TABLE VIII
RECTILINEAR DISTANCE BETWEEN EQUIPMENT

From/To	1	2	3	4	5	6	7	8	9	10	11	12
1	0.0	1.0	1.8	1.5	1.2	1.4	2.0	1.3	1.6	1.5	2.0	1.0
2	1.0	0.0	2.0	1.6	1.0	1.8	1.4	1.0	1.8	1.2	1.0	2.0
3	1.8	2.0	0.0	1.2	1.6	1.4	2.0	1.4	1.4	2.0	1.2	1.0
4	1.5	1.6	1.2	0.0	1.5	1.0	1.4	1.6	1.0	1.6	1.4	1.5
5	1.2	1.0	1.6	1.5	0.0	1.2	2.0	1.8	1.0	2.0	1.7	1.0
6	1.4	1.8	1.4	1.0	1.2	0.0	1.4	1.0	1.5	1.2	1.4	1.9
7	2.0	1.4	2.0	1.4	2.0	1.4	0.0	2.0	1.2	1.4	1.0	1.6
8	1.3	1.0	1.4	1.6	1.8	1.0	2.0	0.0	2.0	1.3	1.4	1.2
9	1.6	1.8	1.4	1.0	1.0	1.5	1.2	2.0	0.0	1.4	1.6	1.3
10	1.5	1.2	2.0	1.6	2.0	1.2	1.4	1.3	1.4	0.0	2.0	1.5
11	2.0	1.0	1.2	1.4	1.7	1.4	1.0	1.4	1.6	2.0	0.0	1.6
12	1.0	2.0	1.0	1.5	1.0	1.9	1.6	1.2	1.3	1.5	1.6	0.0

In this example, the number of individuals and generations increase simultaneously to examine the behavior of optimal solution. The starting parameter of GA is 50 individuals and 50 generations. The crossover and mutation probability are taken as 0.7 and 0.8 respectively for all simulations. The optimal solution is compared in 20 trials. Table IX shows the objective value and the corresponding facility locations at different trials using 50 individuals and 50 generations. The best solution in this case is from trial number 19 which is 2058.2 and the facility locations are shown in Fig. 4.

Location	1	2	3	4	5	6	7	8	9	10	11	12
Facility	11	6	5	12	3	1	4	10	7	8	2	9

Fig. 4 Best Facility Locations for 50 Individuals and 50 Generations

TABLE IX
OBJECTIVE VALUE AND FACILITIES LOCATION FOR 50 INDIVIDUALS AND 50 GENERATIONS

Trial	Objective Value	Facility											
		1	2	3	4	5	6	7	8	9	10	11	12
1	**2080.4**	11	2	8	3	4	6	5	10	7	12	1	9
2	**2091.6**	12	5	1	11	7	6	4	10	3	9	2	8
3	**2075.0**	4	2	12	9	5	11	10	3	8	1	6	7
4	**2096.2**	4	1	7	12	2	11	10	3	5	9	8	6
5	**2081.0**	1	10	2	12	6	3	9	11	7	8	5	4
6	**2066.0**	4	7	10	8	5	11	9	6	1	3	12	2
7	**2068.0**	1	8	12	4	3	2	5	6	9	10	7	11
8	**2092.2**	9	12	8	2	11	4	10	7	1	5	6	3
9	**2083.6**	4	2	10	11	1	3	12	6	9	7	5	8
10	**2083.8**	9	12	8	11	6	3	2	7	1	5	4	10
11	**2086.4**	1	9	6	2	8	3	7	11	4	5	12	10
12	**2083.8**	2	10	12	11	5	1	8	3	4	6	9	7
13	**2085.6**	12	5	6	1	2	4	8	7	11	9	10	3
14	**2089.8**	12	10	7	11	9	3	1	2	8	6	5	4
15	**2100.8**	12	7	10	2	4	6	1	5	11	3	8	9
16	**2098.0**	1	3	10	2	11	5	12	6	4	7	9	8
17	**2068.4**	3	7	10	1	12	2	8	5	9	4	6	11
18	**2068.4**	12	7	10	1	9	2	3	5	8	4	6	11
19	**2058.2**	11	6	5	12	3	1	4	10	7	8	2	9
20	**2102.6**	8	11	12	2	3	6	5	1	7	10	4	9

The starting parameter of GA is gradually increased by 50 until it reaches 300 for both individuals and generations. Table X shows the optimal objective value at different individuals and generations.

TABLE X
OBJECTIVE VALUE AT DIFFERENT NUMBER OF INDIVIDUALS AND GENERATIONS

Individual/Generation	50	100	150	200	250	300
50	2058.2	2047.4	2045.6	2046	2046	2041.8
100	2046.4	2046.6	2044.4	2046.8	2041.8	2045.2
150	2048.4	2045.2	2045.2	2045.2	2043.4	2044.4
200	2043.4	2045.2	2043.4	2043.4	2040.2	2045.2
250	2045.2	2041.8	2043.4	2044.4	2041.8	2041.8
300	2045.2	2041.8	2040.2	2041.8	2040.2	2040.2

Based on Table X, the optimal solution is 2040.2 and the optimal facility locations are shown in Fig. 5. Fig. 6 shows the graphical representation of how the objective value behaves from an increase of individuals and generations. An increase of generation results to an improved objective value than an increase of individual.

Location	1	2	3	4	5	6	7	8	9	10	11	12
Facility	6	4	5	11	2	3	9	7	1	8	12	10

Fig. 5 Optimal Facility Locations

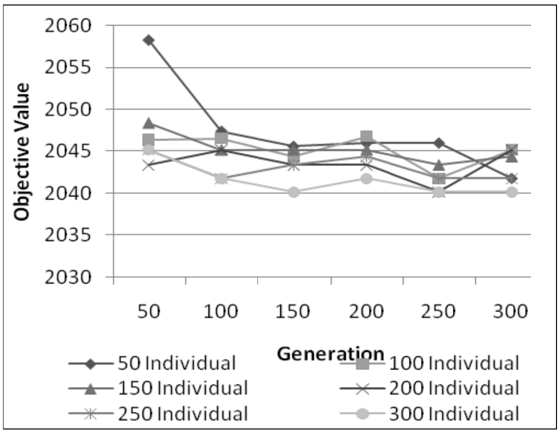

Fig. 6 Graphical Representation Comparing the Objective Values at Different Individuals and Generations

V. CONCLUSION AND FUTURE WORKS

In this paper, we developed a methodology that minimizes total material handling costs using genetic algorithm. The proposed method is much efficient than the four other methods in the literature as a comparison using benchmark numerical example. The solution shows that an increase in generation results to an improved objective value than in an increase of individual. Although the coding is simple, it shows robustness and generates good solution.

Future work may use the methodology described in this paper to a large number of facilities and apply to real-world case studies. Also, expand the method in multi-constraint and multi-objective optimization problem.

References

[1] J. A. Tompkins and J. A. White, *Facilities Planning*. 2nd Ed., New York, John Wiley, 1996

[2] E. E. Aleisha and L. Lin, “For Effectiveness Facilities Planning: Layout Optimization then simulation, or vice versa?”, *Proceedings of the 2005 Winter Simulation Conference*

[3] A. Drira, H. Pierreval, and S. Hajri-Gabouj, “Facility layout problems: A survey”, *Annual Reviews in Control 31*, 2007, pp. 255-267.

[4] R. Haupt and S. Haupt, *Practical Genetic Algorithms*, Second Edition, Copyright 2004 by John Wiley and Sons, Inc.

[5] K. C. Chan and H. Tansri, “A study of genetic crossover operations on the facility layout problem”, *Computers and Industrial Engineering*, 1994, 26(3), pp. 537-550.

[6] I. Mihajlovic, Z. Zivkovic, N. Strbac, D. Zivkovic, and A. Jovanovic, “Using Genetic Algorithms to Resolve Facility Layout Problem”, *Serbian Journal of Management*, 2(1), 2007, pp. 35-46.

[7] M. Adel El-Baz, “A genetic algorithm for facility layout problems of different manufacturing environments”, *Computers and Industrial Engineering*, 2004, 47, pp. 233-246.

[8] K. L. Mak, Y. S. Wong, and T. S. Chan, “A genetic algorithm for facility layout problems”, *Journal of Computer Integrated Manufacturing Systems*, 1998, 1 (1-2), pp. 113-123.

[9] X. Liu and X. Li, “An Improved Genetic Algorithms-based Approach on Supply Chain-oriented Facility Layout Scheduling System”, *Proceedings of the 6th World Congress on Intelligent Control and Automation*, China, June 2006, pp. 3081-3084.

[10] X. Liu, H. Bo, Y. Ma, and Q. Meng, “A New Approach for Planning and Scheduling Problems in Hybrid Distributed Manufacturing Execution System”, *Proceedings of the 6th World Congress on Intelligent Control and Automation*, China, June 2006, pp. 7357-7361.

[11] P. Kulkarni and K. Shanker, “A Genetic Algorithm for Layout Problems in Cellular Manufacturing Systems”, *IEEE*, 2007, pp. 694-698.

[12] Y. Zhang, H. Zhang, M. Xia, T. Lu, and L. Jiang, “Research on Applying Unidirectional Loop Layout to Optimize Facility Layout in Workshop Based on Improved Genetic Algorithms”, *IITA International Conference on Control, Automation and Systems Engineering*, 2009, pp. 144-147.

[13] K. S. N. Ripon, K. Glette, M. Hovin, and J. Torresen, “A Multi-Objective Evolutionary Algorithm for Solving Integrated Scheduling and Layout Planning Problems in Manufacturing Systems”, *IEEE*, 2013, pp. 157-163.

[14] G. Aiello, G. La Scalia, and M. Enea, “A multi objective genetic algorithm for the facility layout problem based upon slicing structure encoding”, *Expert Systems with Applications*, 2012.

[15] A. Chipperfield, P. Fleming, H. Pohlheim, and C. Ponseca, *Genetic Algorithm Toolbox for use with Matlab User’s Guide Version 1.2*, Department of Automatic Control and Systems Engineering of the University of Sheffield.

[16] L. Xu, S. Yang, A. Li, and A. Matta, “An adaptive genetic algorithm for facility layout problem in cylinder block line”, *IEEE*, 2011, pp. 749-753.