GA Based Soft Computing Approach for Open-Field Detail Layout Design

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Abstract— Any organization, whether it may be a manufacturing, chemical, process, construction site or an office needs to organize their physical goods within their available space to achieve certain objectives. In manufacturing perspective each facility (department, cell or machine) that needs to be placed in two dimensional shop floor region to achieve the distance based cost objective that is called facility layout problem (FLP). Minimizing the material handling cost is the most considered objective, but qualitative as well as quantitative objectives are also considered together to solve FLP. In this work the detail layout design of FLP that comprises layout design of departments within the shop floor, locations of input and output (I/O) stations and the material transport path that connects the I/O stations of departments along the department perimeter. Solving these issues simultaneously in an integrated manner will yield a near optimal solution for FLP. Due to NP-hard nature of the integrated FLP traditional approaches becomes much less useful and therefore an Elitist Strategy Genetic Algorithm (ESGA) is developed and tested with the test problem instances available in the literature.

Key words: Genetic Algorithm, Detail Layout Design, Bi-criteria Optimization, Elitist Strategy

I. INTRODUCTION

The Facility Layout Problem (FLP) has broad applications such as the construction of new workshop, service centre and design of very large scale integration (VLSI) chip (Samarghandi and Eshghi, 2010). In manufacturing perspective, the facility layout design involves the determination of how to design the physical layout of manufacturing units such as departments, machines and so on to provide the best support for production. A well laid out facility contributes 20 to 50 percent reduction in material handling cost (Tompkins et al. 2003), however the poor facility arrangement leads to increase in work in process (WIP), setup time and queues (Ariafar and Ismail, 2009; Raman et al. 2009).

This research focuses on designing inter-cell layout and flow path layout of the material handling system (MHS) simultaneously in cellular manufacturing system (CMS) environment under open field configuration, the open-field type layout where there is no predetermined layout pattern, is difficult to solve and is the primary focus of this chapter (Luggen, 1991). An attempt is also made to minimize the cost based objective, namely total material handling cost (TMHC).Due to NP-Hard complexity of the problem, for optimization purpose an elitist strategy genetic algorithm (ESGA) is developed and tested with two test problems of different sizes reported in the literatures.

The remainder of this paper is organized as follows. In Section 2, we present the detail layout design approach describing the elitist strategy genetic algorithm (ESGA), the genetic encoding and decoding and the fitness function evaluation. In Section 4, we present numerical experiments and in Section 4 make concluding remarks.

II. THE DETAIL LAYOUT DESIGN APPROACH

Layout planning is considered a key factor for plants to improve their productivity. The traditional layout plan focuses on reducing material handling costs. Reduced material movement lowers work-in-process levels and throughput times, less product damage, simplified material control and scheduling, and less overall congestion. Hence, when minimizing material handling cost, other objectives are achieved simultaneously. However, for efficient layout design the factors related to degree of closeness between departments should be also considered at the layout-planning phase.

A. The mathematical model

Genetic algorithm is usually used to solve optimization problems. Several algorithms such as local search, simulated annealing and tabu search is widely applied with GA in order to improve the search ability of GA. In this section, An elitist strategy based genetic algorithm (ESGA) is proposed to solve the optimization problem.

$$\text{Minimize}: \quad f = \sum_{i=1}^{N}\sum_{j=1}^{N} c_{ij} f_{ij} d_{ij} + \mathrm{P}$$

s. t.

$$x_i' = x_i + (1-u_i)w_i + u_i h_i \qquad \forall i \tag{1}$$

$$y_i' = y_i + (1-u_i)h_i + u_i w_i \qquad \forall i \tag{2}$$

$$x_i^{I(O)} = x_i + (1-u_i)(1-v_i)I(O_i^x) + I(O_i^y)u_i(1-v_i) + (w_i - I(O_i^x))(1-u_i)v_i + (h_i - I(O_i^y))u_i v_i \qquad \forall i \tag{3}$$

$$y_i^{I(O)} = y_i + (1-u_i)(1-v_i)I(O_i^y) + (w_i - I(O_i^x))u_i(1-v_i) + (h_i - I(O_i^y))(1-u_i)v_i + I(O_i^x))u_i v_i \qquad \forall i \tag{4}$$

$$l_{ij} + l_{ji} + b_{ij} + b_{ji} \geq 1 \qquad \forall i \tag{5}$$

$$x_i' \leq l_{ij} x_j + W(1-l_{ij}) \qquad \forall i < j \tag{6}$$

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$$y'_i \le b_{ij} y_j + H(1 - b_{ij}) \qquad \forall i < j \qquad (7)$$

$$d_{ij} = \begin{cases} \sum d_{k,l} & \text{if } i \ne j \\ 0 & \text{if } i = j \end{cases} \qquad (8)$$

$$x'_i, y'_i, x^{I(O)}_i, y^{I(O)}_i \ge 0 \qquad \forall i \qquad (9)$$

$$u_i, v_i \in \{0,1\} \qquad \forall i \qquad (10)$$

$$l_{ij}, b_{ij} \in \{0,1\} \qquad \forall i,j \qquad (11)$$

Constraints (1) and (2) define the *x*-coordinate of the right boundary and the *y*-coordinate of the upper boundary of each facility. Constraints (3) and (4) are used to specify the *x*-*y* coordinates of I/O stations for each facility. These coordinates are expressed in generalized terms with respect to the lower-left corner point of the facility under the horizontal configuration, i.e., before considering rotation.

Constraints (5) (6) and (7) ensure that there is no overlap between any pair of departments by letting each pair of departments be separated in the *x* or *y* direction. Constraints (9) (10) and (11) specify the bounds for each variable. The shortest distance (d_{ij}) between the I/O stations along the department perimeter is computed using constraint (8).

B. The Elitist Strategy Genetic Algorithm

The proposed genetic algorithm and its operators are developed with the elitist strategy of (Cochran et al. 2003).

1) Genetic Encoding

The genetic encoding includes three parts: the first part (sequence-pair) of the chromosome is a permutation of facilities which is from left to right and from bottom to top. The second part (orientation string) is binary codes of 2N bits of the chromosome express the orientation of each department/machines. The third part (B_i^x, B_i^y) binary codes of 2*N* bytes indicate the information used to find out the offset distances of each department in *x* and *y* directions (*see* Figure 1 the genetic encoding below).

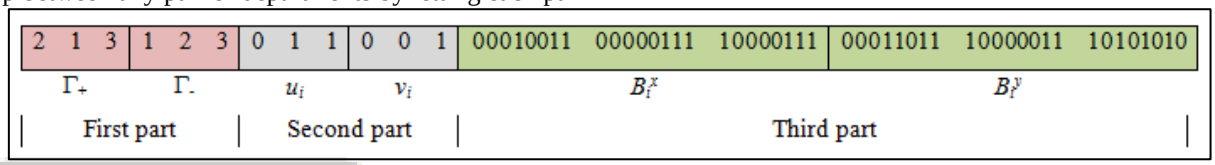


Fig. 1: the genetic encoding

2) Crossover

Crossover operation is exercised on the chromosomes of the intermediate population with a probability, known as crossover probability (p_c).

3) Mutation

If the mutation probability (p_m) < random number(r), then the particular individual undergoes mutation process.

4) Elitist Strategy

In this work the best solution is preserved in each generation. For each generation, if the best solution is worse than the preserved one, a worst string will be replaced with the preserved solution (Jerin et al. 2013).

III. Numerical Experiments

A. Computational Results

In this section we report the results obtained with a set of experiments conducted to evaluate the performance of the Elitist-Strategy Genetic Algorithm (ESGA) developed for this research.

The effectiveness of ESGA is evaluated by solving the two test problem instances reported in the previous literatures. These problem instances are: The test problems with 6 and 12 departments (Welgama and Gibson, 1996).

Population size (P_s)	$5 \times N$
Crossover probability (p_c)	0.5
Mutation Probability (p_m)	0.20
Number of elitist preserved populations	1 (one for preserving best solutions of COF)
Elitism Rate (R_e)	$0.2 \times P_s$
Exchange of information with the current generation	Every 20 generations
Stopping Criterion	Stop after 500 generations

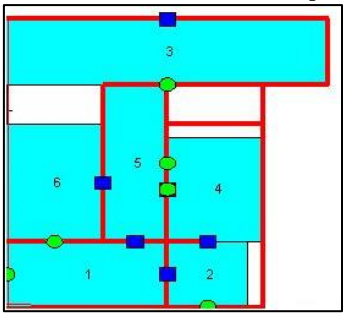
Table 1: Configuration used on all runs in computational experiments

The proposed genetic algorithm is coded in Matlab and experiments were conducted using Dual core processor, 2GB RAM in windows machine. For each test problem instances 10 different initial population set, each population sets having 20 different initial solutions are generated at random. The experiment with each initial population is repeated 10 times.

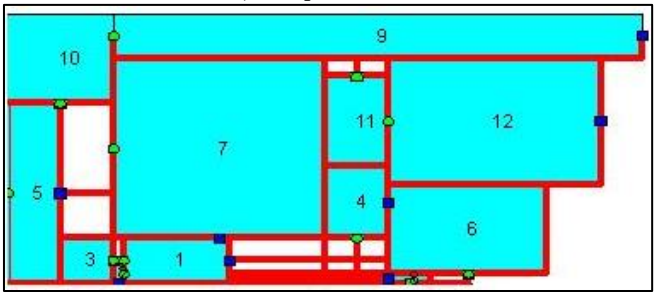
The obtained best solution is reported in table 2 and shown in figure 2

# of departments	TMHC
6 department	553
12 department	6670

Table 2: Best solutions for the test problems



1) 6 department



2) 12 department

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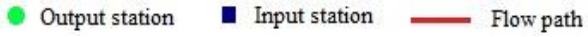

Fig. 2: The best layouts obtained by ESGA

IV. CONCLUDING REMARKS

To overcome the limitations out of sequential design procedure in this research work and integrated layout design approach was adopted to design inter-cell layout and flow path of the MHS simultaneously. From our experimentation, it was understood that, since so many layout combinations has to be explored and evaluated in particular for larger size problems, the outcome of this research leaves scope for further research towards employing a local search mechanism in finding best solutions.

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