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A methodology for solving facility layout problem considering barriers – genetic algorithm coupled with A* search

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1. INTRODUCTION

Facility Layout problem aims to place a set of facilities on a given area so that certain criteria are optimized. The most efficient layout can contribute to the overall efficiency of the operations and can reduce about 20- 50% of the final operating cost [Tarkesh et al. 2009]. The facility layout problem (FLP) has broad applications in real life situations including layout of schools, hospitals and manufacturing systems [Ahmadi et al.2017]. In this study, we will be interested by manufacturing perspective. The FLP can also be classified depending on the representation method. Generally, there are two representations [Tompkins et al., 2010]: (i) discrete representation, (ii) continuous representation. The discrete layout problem is the traditional approach to the FLP. It aims to place equal area facilities having rectangular shape in a predetermined locations [Chraïbi et al. 2014]. However, this discrete approach to FLP is even more unsuitable when facilities have unequal-area and shape or if there are different clearances between the facilities [Drira et al. 2007]. The existing FLP researches fall into several categories according to various criteria [Che et al. 2016]: equal-sized and unequal-sized FLPs [Azadeh et al. 2016], static and dynamic FLPs [Moslemipour and Lee 2012], single-floor and multi-floor layouts [Ahmadi et al. 2016], single-objective and multi-objective problems [Samarghandi et al. 2010].

Resolution of the facility layout problem (FLP) is based either on exact methods to reach optimal solutions, or heuristics and meta-heuristics to get near-optimal solutions. Exact methods cannot give optimal solutions for larger-size instances due to the NP-completeness of such FLPs. For this reason, heuristics or meta-heuristics are the most appropriate methods for solving the large size of this problem in a reasonable computational time to offer near optimal solutions. These meta-heuristics include Genetic Algorithm (GA), Tabu Search (TS), Simulated Annealing (SA), Ant Colony Optimization (ACO) and Particle Swarm Optimization (PSO). Interested readers can refer to Kundu and Dan (2012) for an in-depth analysis of the different metaheuristics methods applied in FLPs.

Our main motivation is to explore a more relevant way to find the most efficient layouts with a satisfactory MHC considering constraints that are more realistic. Most of the FLP resolution approaches use the rectilinear or Euclidean distance between facilities [Gonçalves et al. 2015; Xie et al. 2018]. These distances can miscalculate the actual traveled distance in the case of restricted workshop. For this reason, Authors propose a new methodology and mathematical formulation to answer the constrained Facility Layout Problem. The main idea is first to use the A* algorithm to identify the shortest path between equipment's in a more realistic way; in a facility area which contains obstacles and transportation routes. A Genetic algorithm is adapted and intertwined with A* algorithm to generate various candidate layouts. We study the effects of the GAs parameters on the quality of layout generation by using Monte Carlo Simulations. The best of class layouts obtained for every step of the simulation are collected

and studied to find out the most interesting set of parameters and operators for the GA. The obtained facility arrangements are deeply discussed based on their material handling cost. The quality of the found arrangements obtained by using A* algorithm is compared to the use of Euclidian and rectilinear distances. The mix of GA and A* gives better layouts.

2. PROBLEM FORMULATION

The problem is to assign "m" machines in a given space in order to minimize transport costs between different machines. We define our workshop as a two-dimensional grid consisting of a set of units called non-transformable units. The workshop has a rectangular shape with predefined dimensions: a length (L) and a width (W). In addition, there is a defined horizontal corridor for the permanent transport of products. This corridor is characterized by two vertical positions or two limits (y_{lower}) and (y_{upper}) that divide the workshop into two sections. We also find obstacles such as walls, stairs, other barriers or corridors that can not be occupied by a machine. The coordinates of each obstacle are defined by (x_o, y_o) . The machines have a rectangular shape and have the same size, they are defined by the horizontal (l_i) and vertical dimensions (w_i) and the coordinates of the centroid (x_i, y_i) , see figure 1. Among the constraints to be respected, we can mention that the assignment of the machines is done within the limits of the workshop, another set of constraints prevent the overlaps between the machines and guarantee the non-overlap between each machine and all obstacles. Other constraints ensure that no machine is assigned within the aisle.

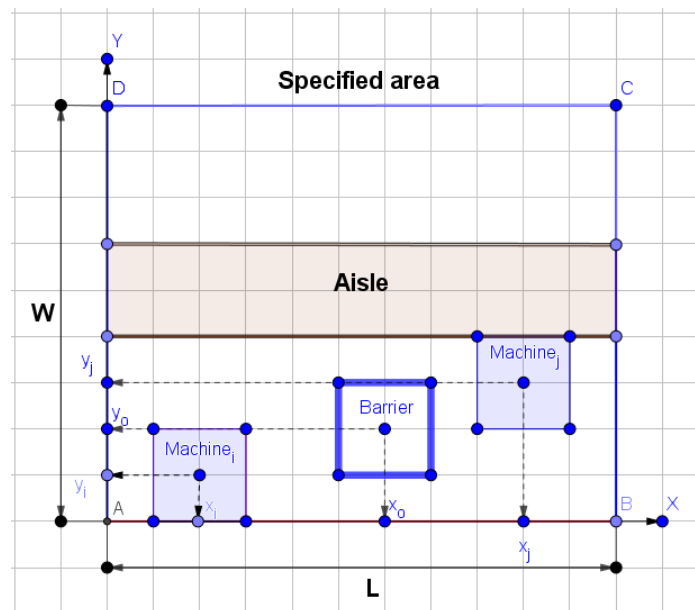


Figure1. Representation of the layout problem

3. AN OVERVIEW OF OUR PROPOSED APPROACH

As shown in Figure 2, our proposed approach is based on the combination of the genetic algorithm with A* search algorithm. Genetic algorithm is used to generate various candidates' layouts. A* algorithm is used to determine the shortest path between two equipment is taking into account the different inner structure. In the following sections, a definition of the different specifications of each algorithm is introduced.

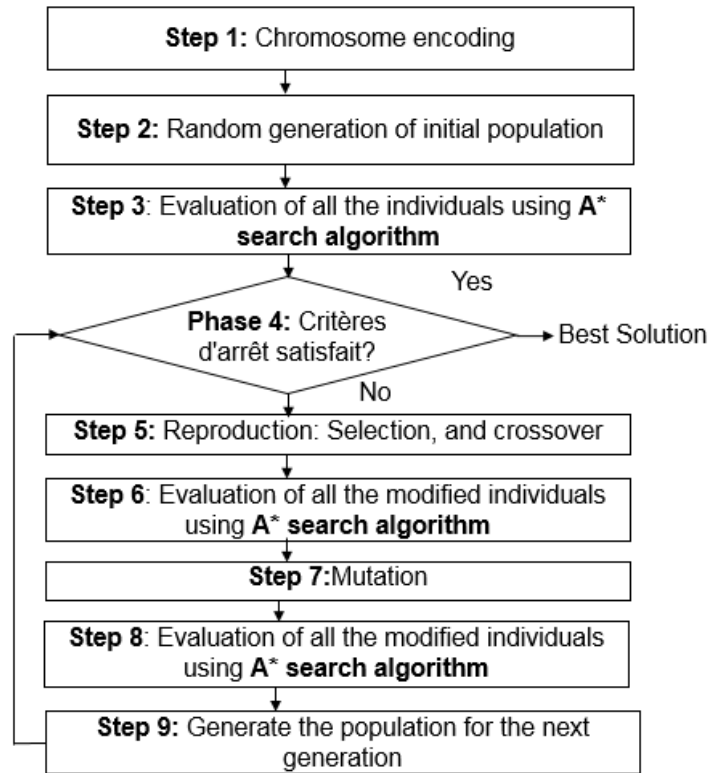


Figure2. Our proposed approach

3.1. Overview of genetic algorithms (GAs)

Genetic algorithm is a random search algorithm developed by Holland (1975). Genetic algorithms operate with populations, which are named chromosomes and encoded solutions of the problem [Mazinani et al. 2013]. The initial population is randomly generated and at each iteration, the population is updating by producing new individuals which replace some of the old ones. The reproduction uses a crossing and mutation process to create new ones. In our case, the evolution process is terminated when maximum number of iterations is attained. Crossover operators exchange the proprieties of two parents to create two new offspring. Mutation operators integrate new genetic structures in the population by simple modification applied to an individual. A selection strategy is applied to select best individuals to participate to crossover and mutation process.

| | |
|---|---|
| Generation of the initial population | The initial-solution individuals are randomly generated. Each solution represents the coordinates (x_i, y_i) of the centroid of each machine in the workshop. The length of the chromosome corresponds to the number of machines. |
| Evaluation of initial individuals | Evaluation of the transportation costs associated to the shortest distances between facilities. Erreur ! Source du renvoi introuvable. |
| Selection of parents | Roulette wheel and tournament selection method. |
| Crossover process | |
| Crossover probability (P_c) | A normal distribution with $\mu = 0.7$ and $\sigma = 0.1$. |
| Crossover operator | One point crossover, two point crossover, three point |

Table 2. Input data of obstacles

| | Coordinates (x,y) | Width | Length |
|------------|-------------------|-------|--------|
| Obstacle 1 | (12,3) | 2 | 4 |
| Obstacle 2 | (7,18) | 4 | 2 |

Discussion of the obtained results:

Regarding all the experimentations performed over 100 simulations; the combination of GA parameters that produces the best results is the following:

- Selection operator is tournament
- Population size is 194
- Crossover probability is 0.8049
- Mutation probability is 0.1024

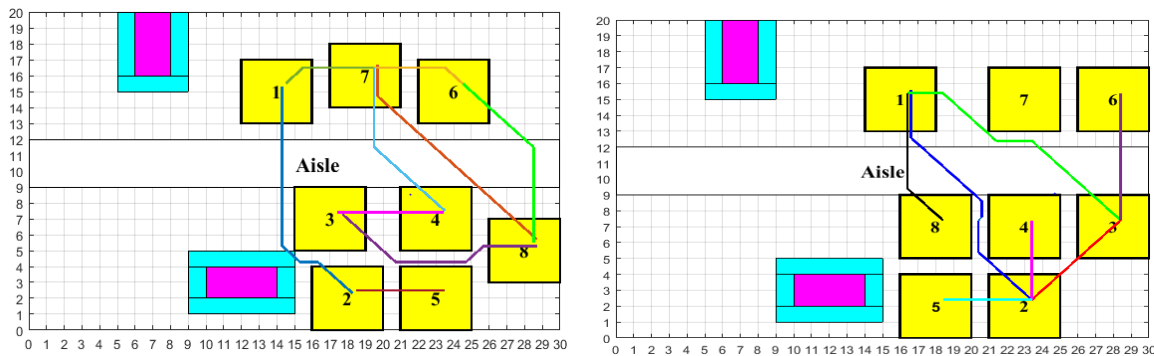


Figure.3 Monte Carlo simulations and product flow obtained by A* algorithm: best configurations founded via roulette wheel selection method and tournament method

The best layout show the practicability of the proposed method. Further, they show that the suggested method is efficient for the arrangement of a set of rectangular machines within a planar site without overlapping respecting a set of others constraints. The main advantage of the suggested approach is its ability to explore a large space of solutions, by considering more realistic distances between the machines. As illustrated in Fig.3, the different machines are concentrated in a specific zone, which allows companies to invest more for other projects.

5. CONCLUSION

This paper provides a new approach to find the most efficient layout in a given area. The main idea is to place machines in a restricted area while taking into consideration several kinds of geometric facility requirements. The objective function is to minimise the MHC which is associated to distance between different machines. A GA integrated with A* allows to explore the solution space. The A* algorithm allows to determine the shortest distance between two machines. The GA is used to generate different layout over a set of iterations. The proposed algorithm parameters are calibrated using Monte Carlo simulations. Our proposed approach is applied on an illustrative case and the obtained results demonstrate the applicability of the proposed model. For future study, authors aims to generalize the formulation of the problem by considering various shape of machines as well as of plant floor.

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