# An Expert System and Genetic Algorithm for Facility Layout Problem

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**Abstract:** This paper presents a system for facility layout problem using an expert system and a genetic algorithm. The practical facility layout design can be effected by characteristics of constructing model, slicing tree model, closeness weight metric and expert system. The genetic algorithm searches the result layout. An experimental system is implemented and produced desired layout.

## 1. Introduction

The facility layout problem is classified as NP-Completed problem. The facility layout problem is concerned with finding the most efficient arrangement of m indivisible departments with unequal area. The objective of facility layout problem is to minimize the material handling costs among all facilities [6].

There are many models proposed to handle the facility layout problem e.g. quadratic assignment problem (QAP) model [2], slicing tree structure model [10,11], construction model [9], graph model [7] and mix-integer programming model [8].

Among many Artificial Intelligence (AI) heuristic search techniques, the genetic algorithm (GA) is one of the most popular technique to handle the facility layout problem.

Kochhar [5] and Islier [3] proposed the GA for facility layout problems model by QAP. Tam [10] proposed the GA for facility layout problem with slicing tree structure model. Tam and Chan [11] proposed another GA method with slicing tree structure model, operated on SIMD machine. Al-Hakim [1] introduced the cloning operator of GA for Islier's [3] algorithm and Al-Hakim [2] introduced the Preserving and Transplanting operator of GA for Tam and Chan's algorithm [11]. Rajasekharan and Peters [8] proposed GA for facility layout problem model by mix-integer programming. Sirinaovakul, B., and Thajchayapong, P. [9] proposed the expert system decided on many factors by using the closeness weight metric.

In practical, there are factors among facilities and some specific positions, e.g. some region or some point in the location. This research proposed the characteristics and measurement processes to design the layout following some preference region of position.

The paper introduces additional details that can control positioning preference in facility layout. The expert system, closeness weight metric, characteristic of slicing tree structure. The adaptation of fitness measurement can control positioning preference in layout. The positioning preference is another feature that make the result layout suitable for the practical problem.

## 2. System Design

The facility layout can be measured by the material handling cost function equation 1. For details of equation formulation, readers are referred to Sirinaovakul, B., and Thajchayapong, P. [9].

$$\min E_{ab} = \frac{1}{2}\sum_{i=1}^{n}\sum_{j=i+1}^{n} W_{ij}(f(d_{ij})_{ab})^2 \qquad (1)$$

The expert system and genetic algorithm for facility layout problem composes of 2 parts, the expert system part and the genetic algorithm part. The expert system part gets information from user by question-answer system. The inference engine decides on the answers and expert system rules then generate the closeness weight metrics. The closeness weight metric and other parameters require to search the layout will pass to genetic algorithm part.

The genetic algorithm part performs layout and searches for the minimum fitness value. There are 2 layout types, constructing layout and cutting layout, depending on user requirement. Finally, the result layout with minimum fitness value is displayed.

## 3. Expert System

At first, the knowledge base gathers from the expert by a knowledge acquisition part. The knowledge acquisition part is the graphic user interface questions-answers system.

The knowledge base is composed of a set of prototype facilities and a set of rules. The set of rules are used for converting any factors to closeness weight. The format of expert system rule is illustrated in figure 1.

```
LABEL: If CONDITION
       Then Closeness Wight (W) = VALUE.
```

Figure 1. The expert system rule

More than one factor can be combined to generated single closeness weight metric. To combine more than one closeness weight value to be single closeness weight value of 2 facilities, the Mycin's belief function, equation 2-5 is used.

$$W_{total} = W_1 + W_2 - \frac{W_1 W_2}{10} \qquad if\ W_1\ and\ W_2 \geq 0 \qquad (2)$$

$$W_{total} = W_1 + W_2 + \frac{W_1 W_2}{10} \qquad if\ W_1\ and\ W_2 \leq 0 \qquad (3)$$

$$W_{total} = \frac{10(W_1 + W_2)}{10 - \min(|W_1|, |W_2|)} \qquad if\ W_1 < 0 < W_2 \qquad (4)$$

$$W_{total} = 10 \qquad if\, W_1 W_2 = -100 \qquad (5)$$

## 4. Genetic Algorithm

The GA process for facility layout problem is adapted from Tam [10]. At first, the algorithm created the slicing tree template, then the GA searched for the set of operators in slicing tree template, which has minimum material handling cost function. Tam [10] generated the slicing tree template from an average-linkage clustering algorithm. In this paper, the slicing tree template was generated by using equations 2-5 and the closeness weight metric, which was the result of the expert system part.

### 4.1 Chromosome Coding

There are 2 chromosome formats depend on layout type, a chromosome format for cutting layout and a chromosome format for construction layout.

In constructing layout, there are 3 factors effected the layout design, the set of operators in the slicing tree, the orientation of each facility and the slicing condition. Figure 2 is illustrated the possibilities of each factor.

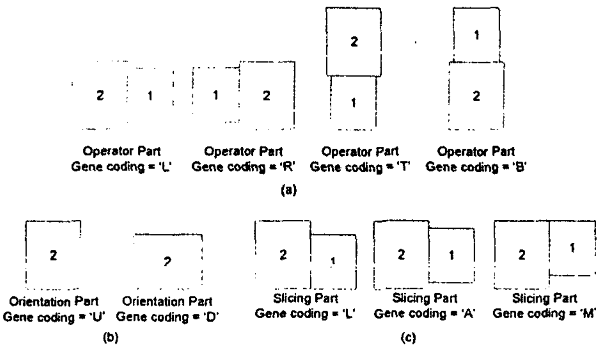



Figure 2. (a) 4 possibilities of operator effect to layout.
(b) 2 possibilities of orientation effect to layout.
(c) 3 possibilities of slicing effect to layout.

In cutting layout, the chromosome is coding only the operation between facilities. The layout is created by divided area and assigned to the facilities. The changing of layout design effects by the set of operators in slicing tree. The orientation and shape of facility is defined as condition to decision on each facility. Figure 3 illustrates the 4 possibilities operators in slicing tree effected to layout design.

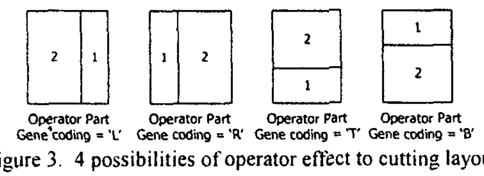



Figure 3. 4 possibilities of operator effect to cutting layout.

Figure 4 illustrates the slicing tree structure and chromosome coding of the constructing layout system. While figure 5 illustrates the slicing tree structure and chromosome coding of cutting layout system.

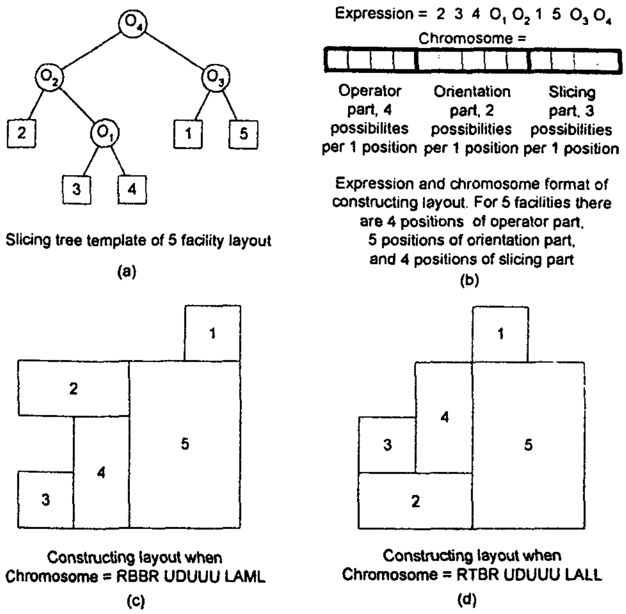



Figure 4. The chromosome coding and constructing layouts.

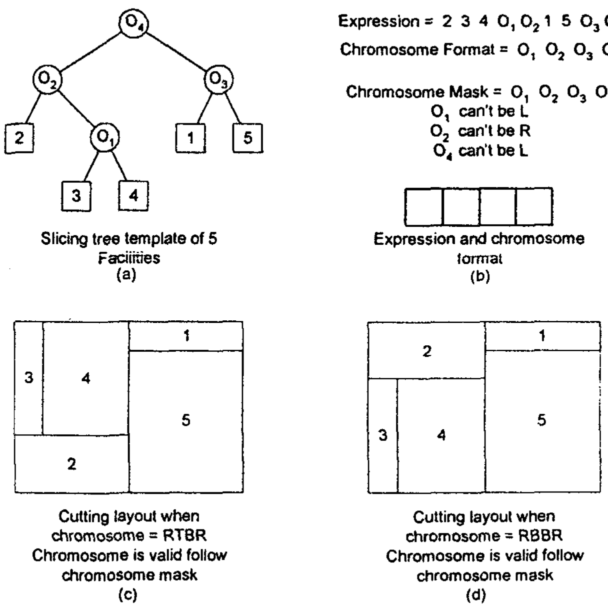
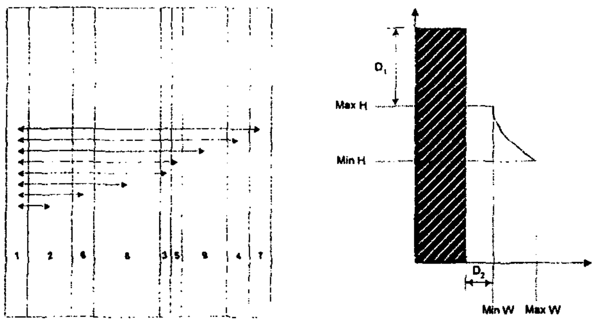



Figure 5. (a) The slicing tree template.
(b) The chromosome mask.
(c), (d) Examples of valid chromosome.

### 4.2 Control Shape Violation

In the cutting layout. If the shape of facilities is not specify the acceptable region, the best layout will be the layout that all facilities concatenate on the short side of location as illustrate in figure 6(a).

The closeness weight factor and expert system rule can handle the shape violation of facility. Figure 6(b) illustrates the shape violation of one facility. The expert system rule using to handle shape violation is define in figure 7




(a) (b)

Figure 6. (a) Expert system rule for control shape violation.

Shape Violated:
If "Shape of Facility i is Violated"
Then Weight ( $W_{ii}$ ) = 10.
Distance ( $D_{ii}$ ) = ( N x $(D_1^2 + D_2^2))^{1/2}$
Else Weight ( $W_{ii}$ ) = 1.
Distance ( $D_{ii}$ ) = 0

Figure 7. The expert system rule use to control shape violation.

### 4.3 Border Preference Evaluation

Border preference of facility in layout design defines by rules apply to slicing tree structure. The rules derived from characteristic of slicing tree structure. By using following rules, facility can be defined the preference on any specific boundary of the layout, which will satisfy some of layout problem preferences e.g.:

"Designing the layout of 10 departments to have most efficiency and the showroom must be in front of the location."

**Definition:**

T : the slicing tree represent the layout.
N : the set of leaf node in slicing tree T.
O : the set of non-leaf node of slicing tree T.
$o_0$ : the root node of slicing tree T.
$o_i$ : the non-root node and non-leaf node of the slicing tree T.

**Rule 1:** Facility A always stay on the left side of the layout if, for the set of operators in slicing tree T path from A to $o_0$
if A is the left leaf node of $o_i$ then $o_i$ can't be the "L"
if A is the right leaf node of $o_i$ then $o_i$ can't be the "R"

**Rule 2:** Facility A always stay on the right side of the layout if, for the set of operators in slicing tree T path from A to $o_0$
if A is the left leaf node of $o_i$ then $o_i$ can't be the "R"
if A is the right leaf node of $o_i$ then $o_i$ can't be the "L"

**Rule 3:** Facility A always stay on the top of the layout if, for the set of operators in slicing tree T path from A to $o_0$
if A is the left leaf node of $o_i$ then $o_i$ can't be the "T"
if A is the right leaf node of $o_i$ then $o_i$ can't be the "B"

**Rule 4:** Facility A will always stay on the bottom of the layout if, for the set of operators in slicing tree T path from A to $o_0$
if A is the left leaf node of $o_i$ then $o_i$ can't be the "B"
if A is the right leaf node of $o_i$ then $o_i$ can't be the "T"

### 4.4 Genetic Algorithm Operation

The simple crossover and mutation are using in these system. In the constructing layout, the genetic crossover and mutation is performed on 3 parts of the chromosome by random the crossover and mutation point. Figure 8 illustrates the crossover and mutation operation of facility constructing layout.

For cutting layout, which chromosome code only the operator set in slicing tree template, the crossover and mutation is performed single time.

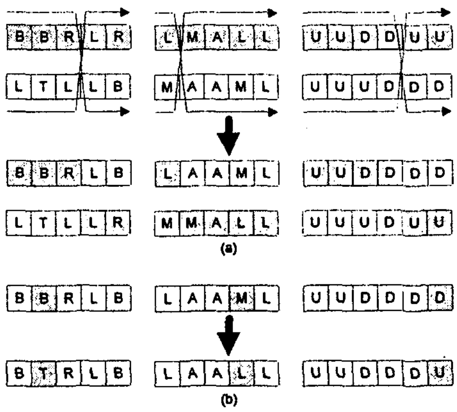


Figure 8. (a) Crossover operation of the constructing layout.
(b) Mutation operation of the constructing layout.

### 4.5 Fitness Evaluation

For constructing layout, the fitness function of genetic algorithm is the material handling cost function, illustrated in equation 1.

For cutting layout, the fitness function of genetic algorithm is the material handling cost function. Illustrated in equation 6. The shape violation correction can succeed by using position i = j in metrics and expert system rule in figure 6.

$$\min E_{ab} = \frac{1}{2}\sum_{i=1}^{n}\sum_{j=i}^{n} W_{ij}(f(d_{ij})_{ab})^2 \qquad (6)$$

## 5. Experimental Result

The expert system part is implement in Delphi 5.0 and the genetic algorithm part is implement in Matlab 6.0.

For example, Objective is to layout 7 facilities with the constructing layout. The information of 7 facilities is illustrated in figure 9.

| ID | Description | Short Side | Long Side |
|---|---|---|---|
| 1 | Manager Room | 1 | 1 |
| 2 | Office Room | 2 | 2 |
| 3 | Product Show Room | 1 | 2 |
| 4 | Production Work Area | 3 | 4 |
| 5 | Packaging Area | 1 | 2 |
| 6 | Material Store | 1 | 2 |
| 7 | Product Stock | 1 | 2 |

Figure 9. Information of example problem

The traffic flow among facilities is illustrated in traffic flow metric (F) and closeness weight metric (W) after pass the expert system is illustrated in figure 10(a) and (b) respectively.

| F | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 10 | 4 | 3 | 2 | 2 | 1 | 1 |
| 2 | 4 | 10 | 3 | 5 | 5 | 3 | 7 |
| 3 | 3 | 3 | 10 | 1 | 1 | 1 | 3 |
| 4 | 2 | 5 | 1 | 10 | 8 | 8 | 3 |
| 5 | 2 | 5 | 1 | 8 | 10 | 3 | 8 |
| 6 | 1 | 3 | 1 | 8 | 3 | 10 | 3 |
| 7 | 1 | 7 | 3 | 3 | 8 | 3 | 10 |

(a)

| W | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 4 | 9 | 2 | -5 | 7 | 3 |
| 2 | 4 | 0 | 8 | 6 | 3 | 8 | 9 |
| 3 | 9 | 8 | 0 | 8 | 5 | 5 | 7 |
| 4 | 2 | 6 | 8 | 0 | 8 | 5 | 5 |
| 5 | -5 | 3 | 5 | 8 | 0 | 9 | 9 |
| 6 | 7 | 8 | 5 | 5 | 9 | 0 | 5 |
| 7 | 3 | 9 | 7 | 5 | 9 | 5 | 0 |

(b)

Figure 10. (a) Flow metric of example problem.
(b) Closeness weight metric of example problem.

In case of no border preference specification, the result layout is illustrated in figure 11. The GA system using the probability of crossover is 0.65, probability of mutation is 0.5, the number of population is 100 chromosomes and the number of generation is 50 generations.

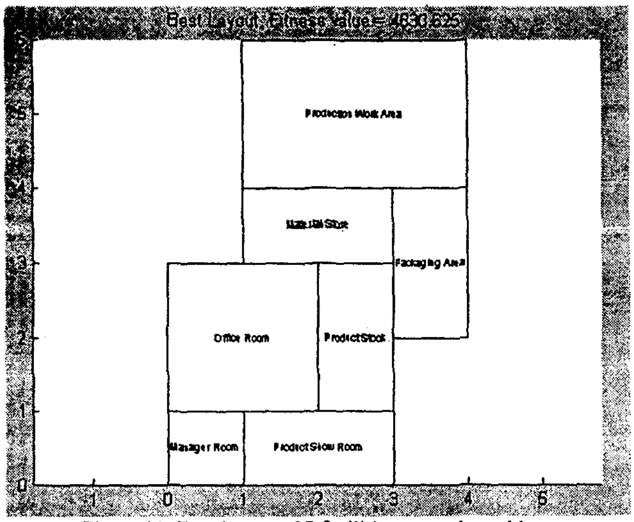



Figure 11. Best layout of 7 facilities example problem.

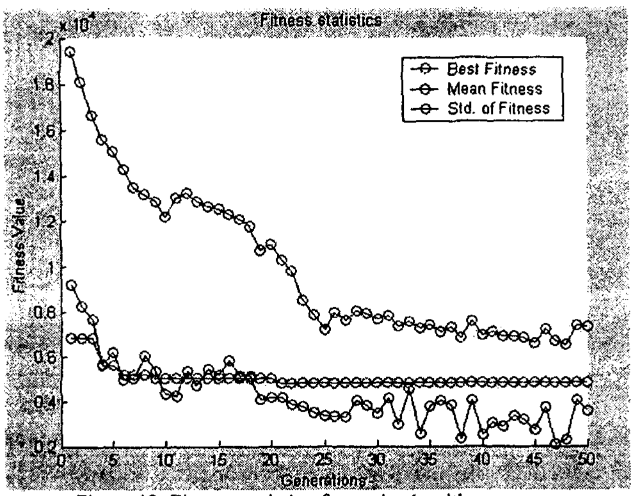



Figure 12. Fitness statistic of genetic algorithm process.

## 6. Conclusion

This paper presents the system to solve facility layout problem using expert system and genetic algorithm which layout decision can rely on practical requirements. Many relative factors among facilities effect to layout design can converge to closeness weight metric to measure the layout. The positioning preference also effect to layout decision in real world can represent by characteristic of slicing tree. The using of expert system and closeness weight metric as fitness function in genetic algorithm can cover all factors effect to the quality of layout. The well define of fitness function should be complete in itself and reduce any penalty part.

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