Facility Layout System using Interactive Evolutionary Computation

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Abstract - In this paper, we propose a facility layout design system using Interactive Evolutionary Computation (IEC). Facility Layout Problem (FLP) is concerned with `finding the ``most efficient" arrangement of departments within a facility'. In much of the research, the 'efficiency' of the arrangement is measured by the material handling costs, that can be expressed as the product of distance times fows between departments. The facility layout planning in practice, however, needs different criteria considering productive, financial and environmental factors, and thus, the most algorithms are not directly applicable for most industrial application. In this paper, we applied IEC that optimizes the facility layout based on human subjective evaluation. We used the original fitness inference system that enables efficient reflection of evaluator's concept with less human evaluation effort.

Keywords - Facility Planning; Facility Layout; Interactive Evolutional Computation

I. INTRODUCTION

Facility Layout Problem (FLP) is one of the most important problems in facility planning. The goal of FLP is `finding the ``most efficient" arrangement of departments within a facility[8]'. In much of the research, the `efficiency' of the arrangement is measured by the material handling costs, that can be expressed as in equation (1)

$$\sum_{ij}^{N}\sum_{j>i}^{N} f_{ij}d_{ij} \quad (1)$$

where N is the number of departments, f_{ij} is the material flows between department i and j, and d_{ij} is the distance between department i and j.

In the practical business, however, the facility layout is evaluated from several perspectives such as production perspective, financial perspective, and environmental perspective. However these perspectives or considerations are not able to incorporate directly in the previous researches.

In this paper, we propose to apply IEC (Interactive Evolutionary Computation) to design the optimal facility layout based on human subjective evaluation. IEC is the technology that optimizes the target systems based on subjective human evaluation as fintess values for systme outputs. IEC has a wide variety of applications, such as graphic art & CG animation, music, speech processing & prosodic control, and work very well for such optimization that needs human evaluation. By using IEC, the designes is able to evaluate the layout alternatives the way they needs in their practical use.

A key successful factor in applying IEC is how to deal with limitation of human evaluations due to the evaluators fatigue. For example, the typical EC-based algorithm for FLP, such as LOGIC (Layout Optimization with Guillotine Induced Cut) or FLEX-BAY, contains at least several hundreds times iteration, and thus, are difficult to be applied to IEC directly. To overcome this weakness, we applied the fitness inference system to reduce such human evaluation fatigues. The fitness inference system is the prediction method that guesses the human evaluation of indivisuals based on the similarity with the past indivisuals in the history. By using these guesses, we can enables IEC to perform well with less human evaluation effort.

Furthermore, we propose to apply the RCGA (Real-coded Genetic Algorithm) for the genetic operation process in IEC. RCGA is an optimality technique using individuals coded by real-valued vector. In the typical EC-based method for FLP, layout alternatives are represented by custom encoling techniques. Those coding, however, has a problem that the similarity of chromosomes is not related with the similarity of the actual layouts. By using RCGA, on the other hand, alternative layouts are represented by the actual (x, y) -coordinate, and therefore, makes it possible to reflect a proper similarity of layout.

We call above-mentioned proposal a `Facility Layout System', as a set of interacting input/output between man and machine and forming an integrated whole design.

II. PROPOSED SYSTEM

In this chapter, we show how IEC is used to support facility layout design in the proposed method.

A. Interactive Evolutionary Computation

IEC is a methods of evolutionary computation that use human evaluation. There are some variations in the use of EC for alternative creation, but we applied IGA (Interactive Genetic Algorithm) in this paper. Basic concept of IGA is expressed in Figure 1. The flow chart of proposed system using IGA is shown in Figure 2.

The outline of IGA is as follows. It alternates the followin two steps;

- Evaluation Process
- Alternative Create Process (Genetic Opeartion)

For evaluation process, we applied inference system to reduce evaluation fatigues, and for alternativ create process, we applied RCGA to relect proper similarity used in the inference system. They are explained more in depth hereinafter.

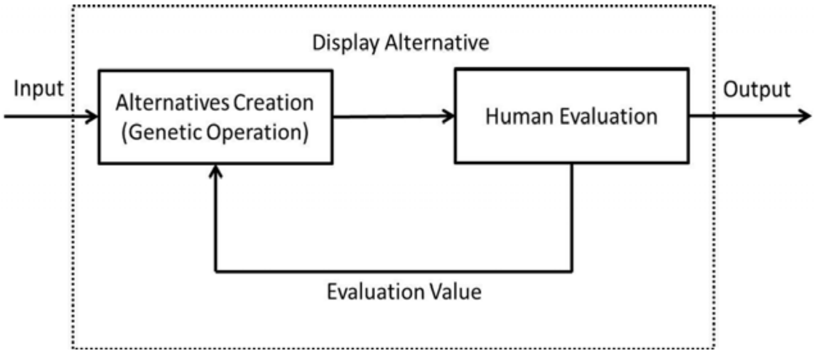

Fig 1. Scheme of Interactive Genetic Algorithm

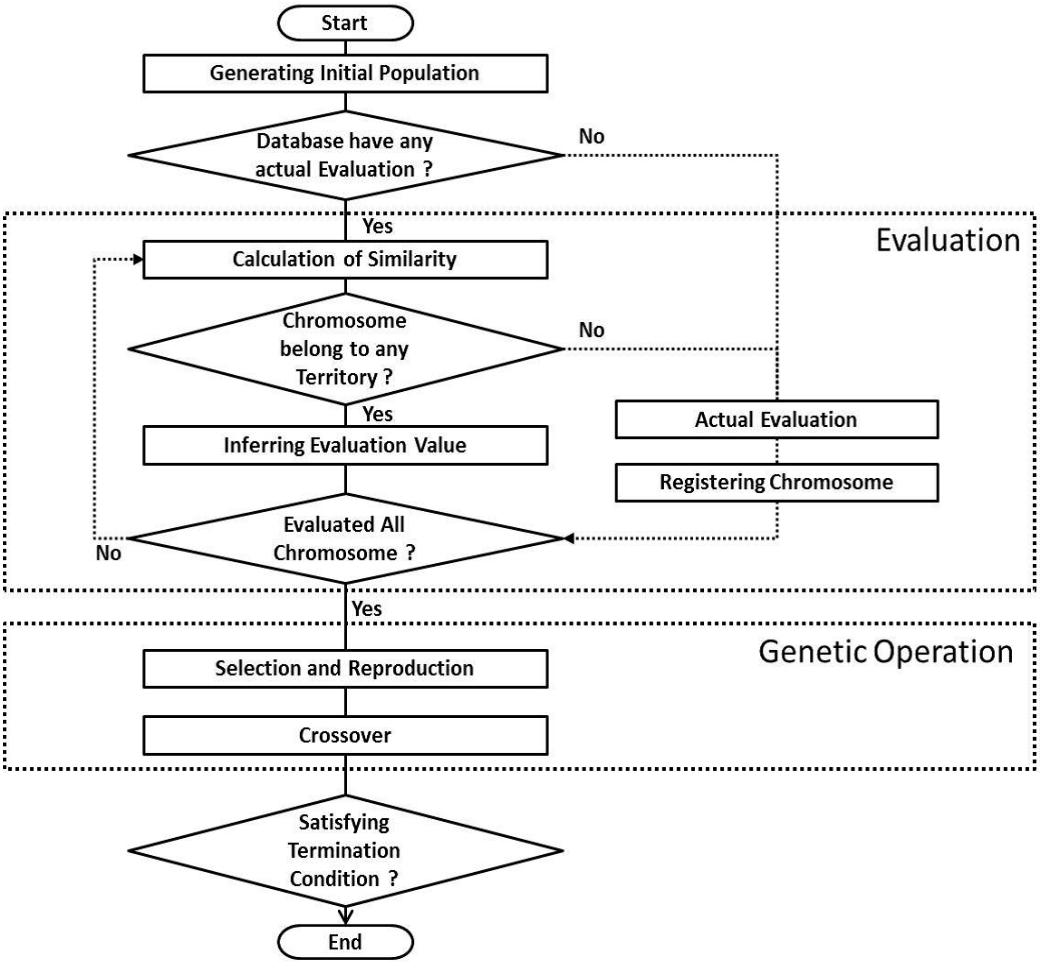

Fig 2. Flowchart of Proposed Algorithm

B. *Evaluation Process*

In this section, we show the detailed description of fitness inference system, and how the evaluator's effort could be reduced. Hereinafter, the fitness value evaluated actually by a human is called “actual evaluation value” and the fitness value evaluated by fitness inference system is called “inferential evaluation value”.

Step 0. Registering actual evaluation value and territory of initial population The first evaluation for the initial population has to be done by human, since the database is empty at initial generation. The actual evaluation value and territory with a certain scope (described in step 4) is registered in the database.

Step 1. Calculating similarity of chromosome A similarity of chromosome means a similarity of chromosome’s gene. Each locus is given with a weight according to a degree of influence on phenotype. A similarity of chromosome can be expressed as the sum of product of the vector distance of each locus and the weight of each locus (Equation (2)).

$$S_{ij} = 1.0 - \sum_k w_k \frac{|x_{ik} - x_{jk}|}{M_k} \tag{2}$$

$$\sum_k w_k = 1.0, \tag{3}$$

where S_{ij} : similarity of the chromosome i and j , w_k : weight of locus k , x_{ik} : value of locus k in the chromosome i , M_k : maximum of $|x_{ik} - x_{jk}|$

Step 2.} Judgment of whether the chromosome belong to any territory or not. Next step is comparison of the similarity of chromosomes calculated in Step1 and the territory, which means a threshold of similarity of chromosome in the database. If the chromosome belong to any territory (Chromosome A in Figure 3), the chromosome is judged similar to the chromosome in the territory of the database and go to Step3. If not (Chromosome B in Figure 3), algorithms proceed to Step4. Additionally, the territories shrink at a certain generation (Equation (4)). This will lead to effective search that makes the shift to a local search from a global search as generations proceed. Each parameter was selected by preliminary experiment.

$$T_k = \beta^{k-1} T_1, \tag{4}$$

where T_k : size of the territory of k th generation, β : reduction rate of territory.

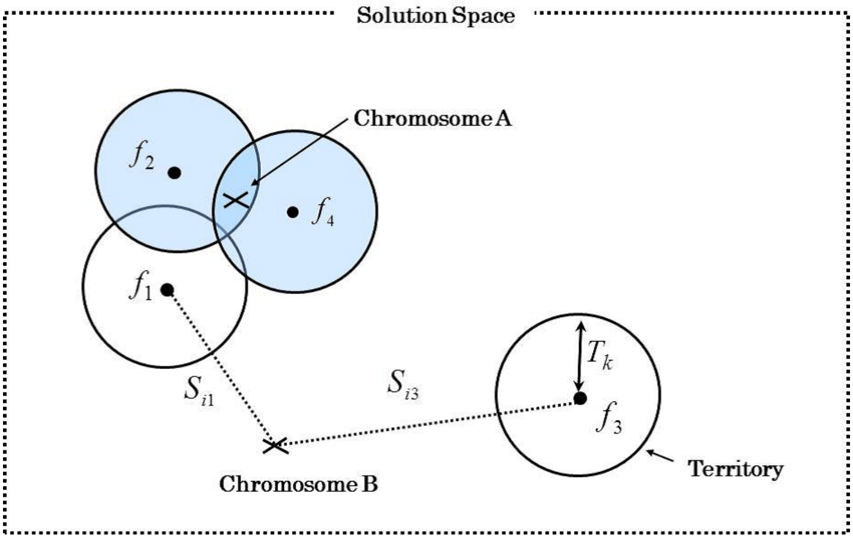

Fig 3. Similarity and territory

Step 3. Inferring the evaluation value The chromosome which was judged to belong to any territory and judged similar to the chromosome in the database is inferred from the actual evaluation value of the similar chromosome. Inferential evaluation value is calculated from a linear sum, weighted by similarity of chromosomes belong to the territory (Equation (5)).

$$f_x^* = \frac{\sum_i S_{ix} f_i}{\sum_i S_{ix}}, \quad (5)$$

where f_x^* : inferential evaluation value of chromosome x, S_{ix} : similarity of the chromosome i and x, f_i : actual evaluation value of chromosome i.

Step 4. Evaluating the chromosome not belonging to any territory The chromosome which is judged not belong to any territory in step2 is evaluated actually by a human and registered newly in the database.

Step 5. If all chromosomes are evaluated, Evaluation Process is end. If not, go to Step1.

By using these guesses, we can reduce the number of evaluations significantly, which leads to much less designers fatigue.

C. Alternative Creation Process

Real-coded Genetic Algorithm (RCGA) in applied in Genetic Operation Process. In the typical genetic-algorithm-based method used in FLP, encoding technique is used to apply GA. However, in FLP, there is a problem that the similarity of chromosomes is not related with the similarity of the layouts of those chromosomes. The detail of this problem and proposal including the countermeasure are written in the following.

1) Coding by the encoding technique:

In the previous researches of FLP, the encoding technique such as LOGIC (Layout Optimization using Guillotine-Induced Cut) [2] or FBS (Flexible Bay Structure) [3] is applied to make the layout into codes. Then the codes will lead to new solution by mutation and crossover in GA. As a description of the problem written in above, LOGIC is taken as an example here. In LOGIC, a facility layout is expressed by a combination of operand and operator in tree-structured called slicing tree, and the operator determines whether one set of department is placed on U (up), or R (right) of the other set of department (Figure 4). According to the slicing tree given, divide the facility recursively and place the department to express the layout plan. As an example, two layouts that have only one different locus are expressed in Figure 5. Since just one locus of five loci is different, the similarity is expected to be high. However when compared with the layouts, a shape of departments and locations are dissimilar. This example shows that a Conventional method has a problem that the similarity of chromosome is different from the similarity of layout.

2) Coding by coordinate of department

In proposed method, RCGA is applied. RCGA is an optimality technique using individuals coded by real-valued vector. When FLP is solved by RCGA, individuals are expressed according to x, y-coordinate as in Equation (4). Application of this technique overcomes the problem of a similarity of chromosome is different from a similarity of layout.

$$r^{n,k} = (x_1, \cdots, x_N, y_1, \cdots, y_N)^T, \quad (6)$$

where $r^{n,k}$: location of n th individual after k th generation.

We used RCGA-based layout technique proposed in \cite{RCGA} to optimize FLP represented in a continuous fashion as in (6). See [5] for more details.

Table I. Department Area

i	Department	Area
1	receipt area	15
2	handling area	20
3	material warehouse	70
4	manufacturing area	9
5	inspection room	35
6	products warehouse	35

Table II. Material Flows between Departments

i	department	Material Flows					
1	receipt area	0	4	0	0	0	0
2	handling area	0	0	5	2	0	0
3	material warehouse	0	0	0	4	5	0
4	manufacturing area	0	0	0	0	4	0
5	inspection room	0	0	0	0	0	5
6	products warehouse	0	0	0	1	1	0

Table III. Parameter Settings

Parameter	Value
Population Size	20
Number of Parents	4
Number of Children	20
Scaling Parameter	same as [5]
w	0.167

Table IV. Number of Evaluations (6 users average)

Method	Number of Evaluation
Without Infering	140
With Infereing	63.4

Table V. Comments for Obtained Layout (6 users)

Comments	Counts
Accept	0
Accept with minor revision	5
Accept with revision	1
Not Accepted	0

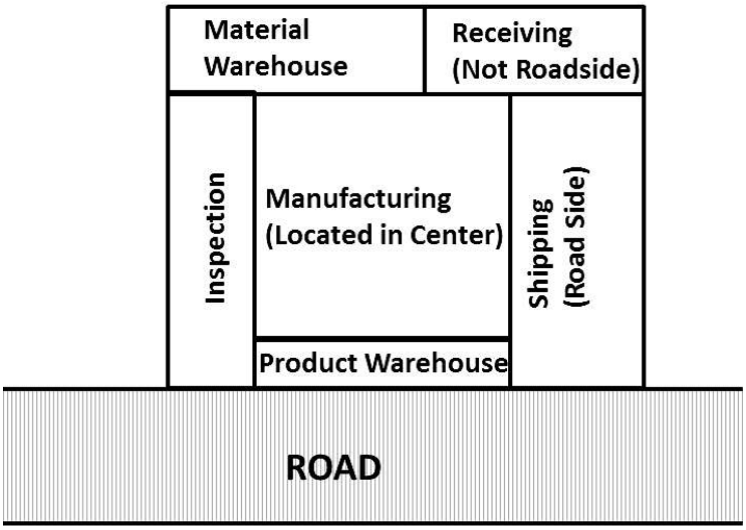

Fig 4. Obtained Layout from Our Proposed System

III. EXPERIMENT

A. Experimental Outline

To verify the effectiveness of the tool, we performed a user test of 6 students majoring in the facility planning in the graduate school. A test problem is a 6 department problem, the data of which comes from a sigle-floor factory for the electronic component in Japan. The outline of this experiment is explained below.

- Facility: sigle-floor factory for the electronic component
- Examinee: 6 students majoring in the Facility planning in the graduate school.
- Number of department: 6
- Department: receipt area, handling area, material warehouse, manufacturing area, inspection room, products warehouse
- Area of department: table I.
- Upper and lower limit of aspect ratio of department: [0.25,4]
- Material flow between departments: table II.
- Parameters: table III.

Evaluation criteria are material flow, congestion, dust-proof, noise. For congestion receipt area and handling area should not be placed roadside (north of factory area) for prevention avoidance. For noise, manufacturing area is to be located near the center of the factory.

B. Result

The number of evaluation is summarized in table IV. From the reult of this experiment, the examinee needs only 63.4 times evaluations on avarage with fitness infering system, insetad of 140 times evaluations without it. Hence, our proposed fitness infering system has a positive effect in terms of reducing the evaluators fatigues.

Table IV summarizes the comment of reviewers for the obtained layout over the course of the computaion. There are 5 students who think the layout from our proposed system can be accepted with minor revisions, and 1 student who think it's accepted with revisions. This can be interpreted our propozed system, in some way, sartisfy the users, and thus, can be applicable to support layout designe in practical situation.

Figure 4 is the layout output, that one of students created by adjusting the obtained layout from our system. We can see that the obtained layout satisfied all qualititative criteria with respect to congestion and noise.

IV. CONCLUSION

In this paper, Facility layout system using IEC was proposed, which enabls the designer to consider unformulated criteria and human subjective evaluation. Moreover fitness inference system is applied to IGA and made it possible to reduce human evaluation repetition. Additionally, RCGA was used at Genetic Operation Process in EC to reflect similarity of chromosome in layout, which makes it possible to calculate the similarity properly. For further works, we might consider improvement of the interface to make the evaluation easier, espacially for larger size of problems.

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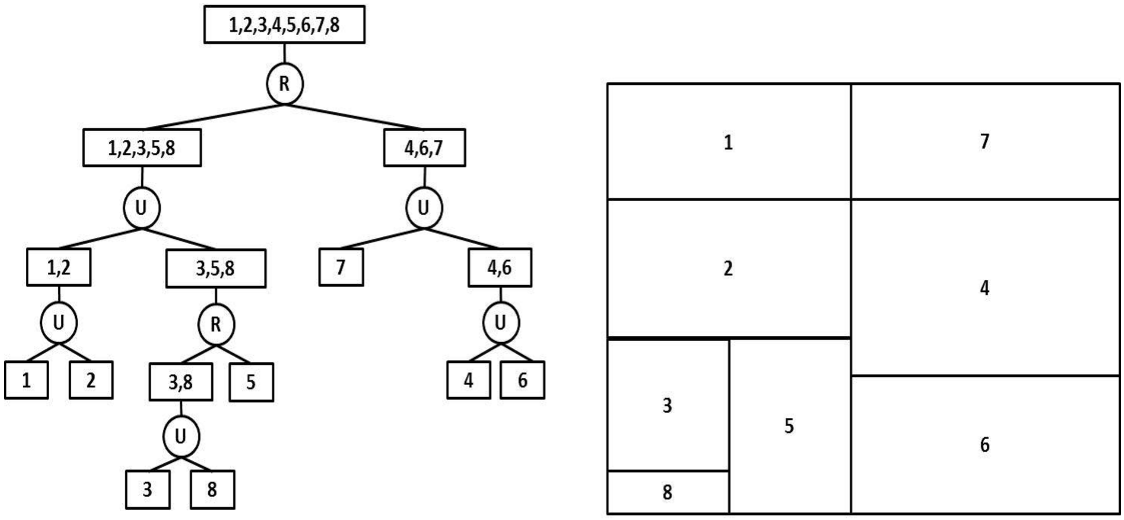

Fig 5. Layout Coding via Guilotine-Induced Cut (figure taken from [9])

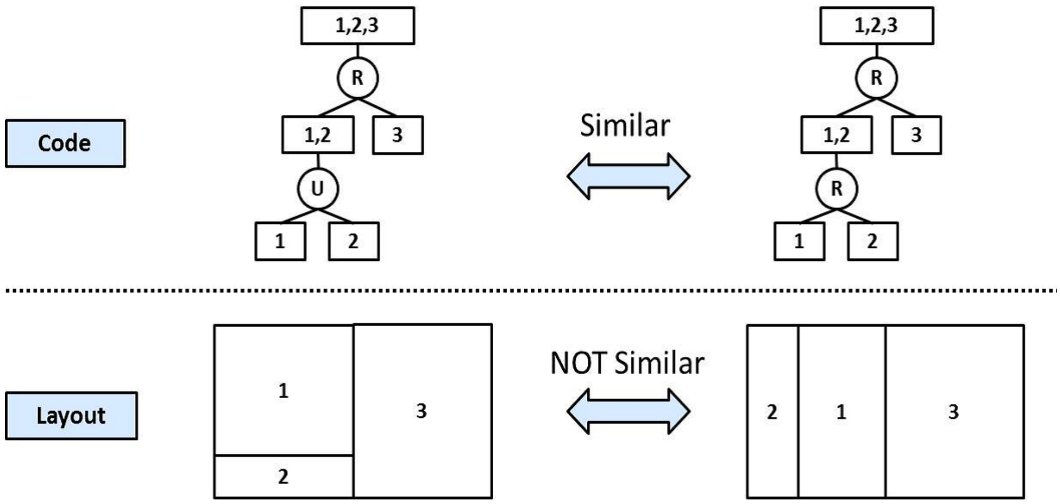

Fig 6. Coding difference and layout difference

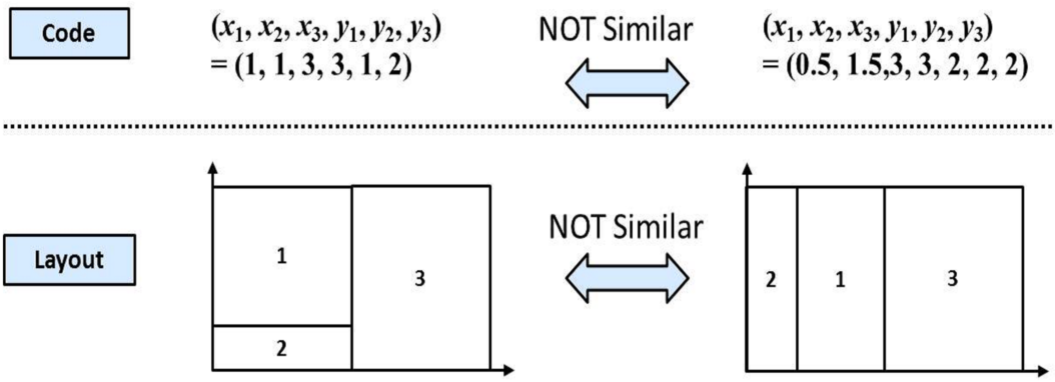

Fig 7. Layouts coding via real numbers