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Office Layout Support System using Genetic Algorithm – Generation of Room Arrangement Plans for Polygonal Space –

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Abstract—In this paper, we propose an office layout support system using genetic algorithm. The proposed system has two phases; (1) generation of room arrangement plans and (2) generation of layout plans for workspace. In the proposed system, some conditions on rooms and furniture are given by a user, some room arrangement plans which satisfy the conditions are generated by genetic algorithm. After one of the generated room arrangement plans is selected by a user, and then some layout plans for workspace which satisfy the conditions are generated by genetic algorithm. In the proposed system, the combined genetic algorithm which is based on the adaptive genetic algorithm and the genetic algorithm with search area adaption is employed in order to improve the convergence speed and the diversity of layout plans. We carried out a series of computer experiments and confirmed the effectiveness of the proposed system.

1. Introduction

When we consider how fixture and furniture such as desks and shelves are arranged to the limited space such as an office and a laboratory, we arrange various kinds of furniture virtually on a paper. Moreover, the software for an office layout is also put on the market, and we can also think arranging furniture virtually on a screen using it. However, it is difficult to consider the layout plans which satisfy various conditions such as a size of room, the number of the furniture to be arranged and so on.

As the system which can generate layout plans which satisfy the conditions given by users automatically, the interior design layout support system[1] has been proposed. However, in the system, each desk is arranged individually, so the desks are sometimes arranged in disorder. As a result, it is difficult to generate a practical layout plan. In ref.[2], the interior design layout support system using evaluation agents has been proposed, however, the system sometimes generate layout plans which do not satisfy all conditions given by users.

Recently, we have proposed some office layout support systems using genetic algorithm[3][4]. In these systems, some conditions such as size and form of room, size and the number of desks are given by users, some layout plans which satisfy the conditions are generated by genetic algorithm. We have proposed an office layout support system considering floor using genetic algorithm[5][6]. These systems have two phases; (1) generation of room arrangement plans and (2) generation of layout plans of workspace. However, these systems generate layout plans for only rectangular space. Although genetic algorithm has the impressive ability in the combination optimization problem, it has some problems in the local searching ability and appropriate parameter setting for crossover and mutation.

In this paper, we propose an office layout support system using genetic algorithm which can generate layout plans for polygonal space. In the proposed system, the combined genetic algorithm which is based on the adaptive genetic algorithm (AGA)[7] and the genetic algorithm with search area adaption (GSA)[8] is employed in order to improve the convergence speed and the diversity of layout plans.

2. Office Layout Support System using Genetic Algorithm

The proposed office layout support system using genetic algorithm has two phases; (1) generation of room arrangement plans and (2) generation of layout plans of workspace. In the proposed system, some conditions on rooms and furniture are given by a user, some room arrangement plans which satisfy the conditions are generated by genetic algorithm. After one of the generated room arrangement plans is selected by a user, and then some layout plans for workspace which satisfy the conditions are generated by genetic algorithm. Figure 1 shows the outline of the proposed system.

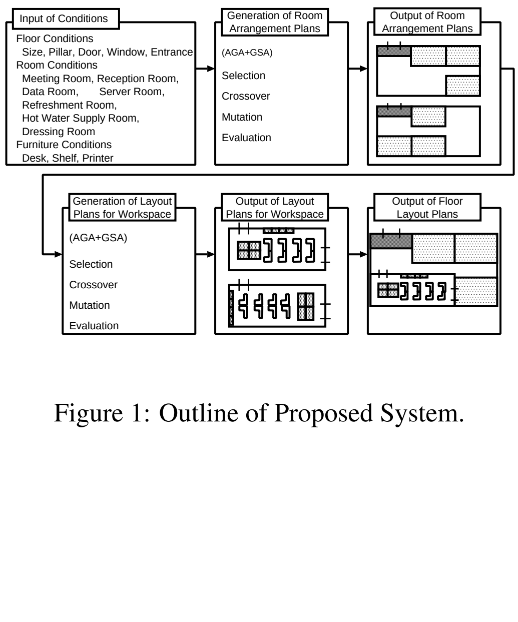


Figure 1: Outline of Proposed System.

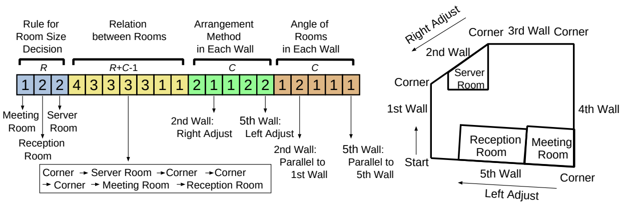


Figure 2: An Example of Gene and Room Arrangement Plan.

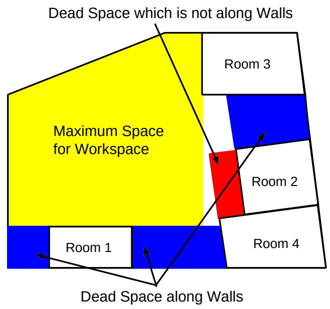


Figure 3: Each Space on a Floor.

2.1. Generation of Room Arrangement Plans

2.1.1. Expression in Gene of Room Arrangement Plans.

In this research, the room arrangement plan is expressed in the form of a gene. The length of the gene corresponding to the room arrangement plan in the polygonal space with C angles which has R rooms is $2R + 3C - 1$. The gene consists of 4 parts; (1) rule for room size decision, (2) relation between rooms, (3) arrangement method in each wall and (4) angle of rooms in each wall. Figure 2 shows an example of the gene and the corresponding room arrangement plan.

2.1.2. Evaluations.

In genetic algorithm, in order to leave better genes to the next generation, the degree of fitness is calculated, and genes are chosen according to the degree of their fitness. In this system, the fitness is represented by 4 elements; (1) floor space for workspace ($FitW$), (2) dead space along walls ($FitD$), (3) dead space that is not along walls ($FitI$) and (4) distance between reception room and entrance ($FitR$).

$FitW$ is determined by the percentage of the maximum space for the workspace (yellow area in Fig.3). $FitD$ is determined by the percentage of the dead space along walls (blue area in Fig.3). $FitI$ is determined by the percentage of the dead space not along walls (red area in Fig.3).

$FitR$ is calculated by

$$FitR = \frac{1}{\frac{1}{R_c} \sum_{i=1}^{R_c} \frac{D_{R(i)}}{F_w + F_d}} \tag{1}$$

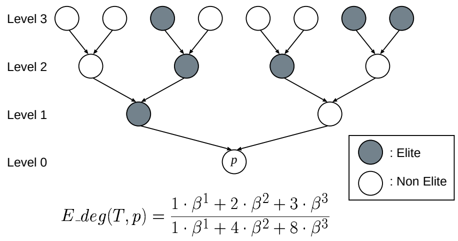


Figure 4: An Example of Calculation of Elite Degree ($l_{max} = 3$).

where $D_{R(i)}$ is the Manhattan distance between the center of the reception room i and the entrance, R_c is the number of reception rooms, F_w is the floor width and F_d is the floor depth.

2.1.3. Combined Genetic Algorithm

In the proposed system, the combined genetic algorithm which is based on the adaptive genetic algorithm[7] and the genetic algorithm with search area adaption[8] is employed in order to improve the convergence speed and the diversity of layout plans. In the adaptive genetic algorithm, two kinds of crossover methods are used.

(1) Crossover for Non-Elite Genes

If the elite degree of the one parent gene (or both parent genes) is smaller than the threshold, two-point crossover is used. Here, the elite degree of the gene p in the generation T is given by

$$E\_deg(T, p) = \frac{\sum_{j=0}^{l_{max}} \left\{ |Elite(p, j)| \cdot \beta^j \right\}}{\sum_{j=0}^{l_{max}} \left\{ |Anc(p, j)| \cdot \beta^j \right\}} \tag{2}$$

where l_{max} is the considered level depth, $|Elite(p, j)|$ is the number of the elite ancestors of the gene p in the generation $T - j$, $|Anc(p, j)|$ is the number of ancestors of the gene p, and β $(0 < \beta \leq 1)$ is the damping factors. Figure 4 shows the example of the calculation of the elite degree.

(2) Crossover for Elite Genes

If the elite degree of the both parent genes is larger than the threshold, the proposed crossover method (Common Sequence Preserving Crossover : CSPX) is used. In the proposed CSPX, the common relation between rooms can be preserved.

(1) In the part for relation between rooms of genes, S_{RR} (common relation between rooms) and S_{CR} (common relation between wall and rooms) are obtained.

(2) The part corresponding to S_{RR} are copied to the child genes.

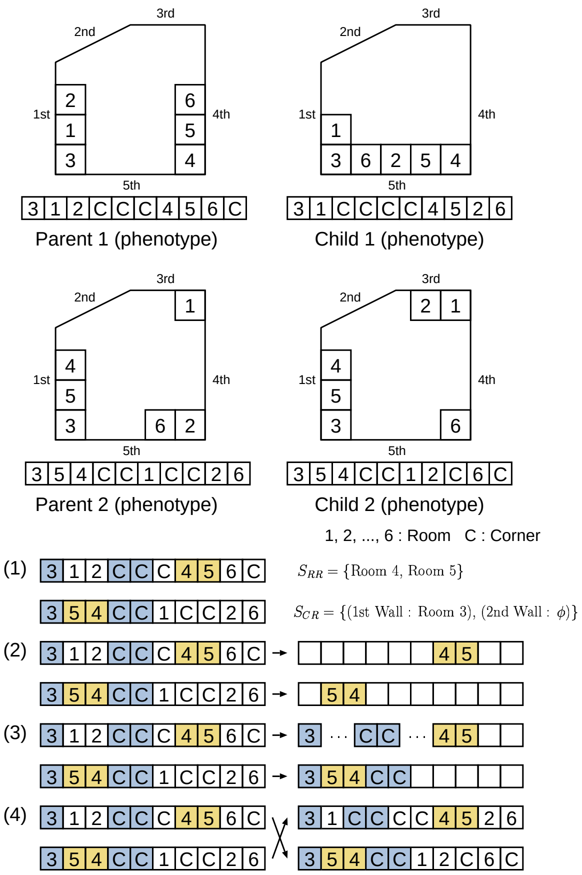


Figure 5: An Example of CSPX.

(3) The part corresponding to S_{CR} are copied to the child genes.

(4) The parts other than S_{RR} and S_{CR} are copied based on the order of the another parent gene.

(5) For the part except the relation between rooms, two-point crossover is carried out.

Figure 5 shows an example of the CSPX.

2.2. Generation of Layout Plans for Workspace

2.2.1. Expression in Gene of Layout Plans.

In this research, the layout plan is expressed in the form of a gene. The length of the gene corresponding to the layout plan which has N groups, N_S groups which has own shelves and M printers is $4N + M + 4$ (when all shelves are arranged along walls) or $4N + 9N_S + M + 4$ (when shelves are used as partition). The gene consists of 8 (or 9) parts; (1) relation between groups, (2) group arrangement plan number, (3) rotation of group arrangement plan, (4) group number which has printer, (5) shelf arrangement plan number, (6) shelf arrangement method (shelves for groups), (7) printer arrangement plan number (8) angle of groups and (9) shelf arrangement method (shelves as partition for groups).

2.2.2. Evaluation.

When all shelves are arranged along walls, the fitness is represented by (1) position of printers ($FitP$) and (2) relation between group and own shelves ($FitS$). When shelves are used as partitions, the fitness is represented by (1) position of printers ($FitP$) and (2) access between groups ($FitG$).

3. Computer Experiments

In this section, we show the computer experiment result to demonstrate the effectiveness of the proposed system.

3.1. Generation of Room Arrangement Plans

In this experiment, room arrangement plans in the hexagonal space are generated by the proposed system. Figure 6 shows an example of generated room arrangement plans.

3.2. Comparison with Other Algorithms

3.2.1. Transition of Fitness

Figure 7 shows the transition of maximum and average fitness. In this figure, the transition of fitness in the system which uses normal genetic algorithm/AGA/GSA for reference. As shown in this figure, the fitness in the proposed system (which uses combined genetic algorithm) is larger than that in the systems based on the normal genetic algorithm and the AGA.

3.2.2. Variation of Generated Plans & Execution Time

Figure 8 shows the variation of generated plans. As shown in this figure, the proposed system can generate various plans as similar as the systems based on the normal genetic algorithm and the AGA. In contrast, only few plans were generated in the system based on the GSA although the fitness in the same trials was high (See Fig.7).

Table 1 shows the average number of the generated plans and the execution time in each system.

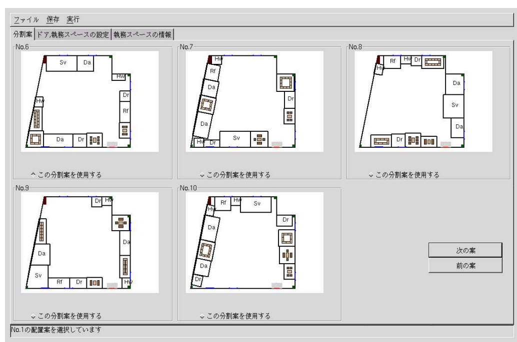
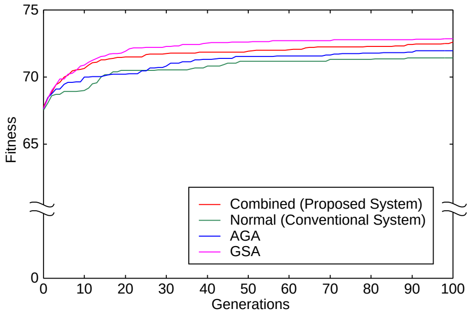
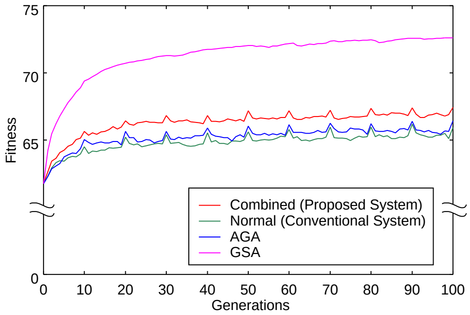


Figure 6: Generated Room Arrangement Plans.

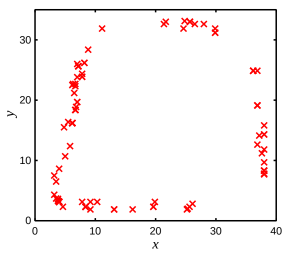


(a) Maximum Fitness

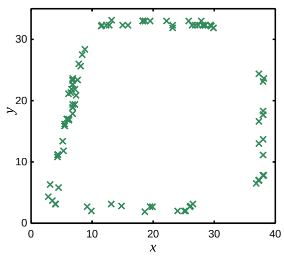


(b) Average Fitness

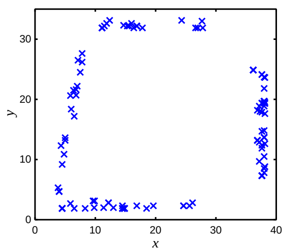
Figure 7: Transition of Fitness (Comparison with Other Algorithms).



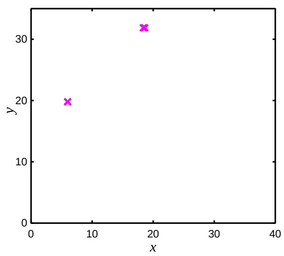
(a) Combined (Proposed)



(b) Normal



(c) AGA



(d) GSA

Figure 8: Center Position of Room 1.

Table 1: Average Number of Generated Plans and Execution Time.

Algorithm	Execution Time (min : sec)	Average Number of Generated Plans
Combined	7:29.00	89.4
Normal	4:21.00	108.5
AGA	4:17.20	106.8
GSA	19:29.00	9.8

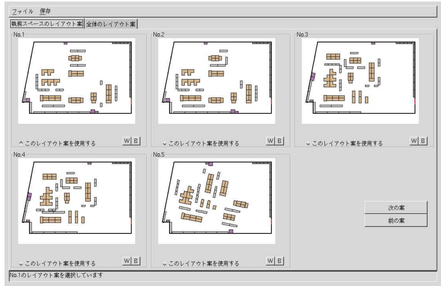


Figure 9: Generated Layout Plans for Workspace.

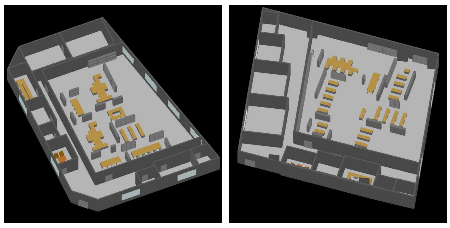


Figure 10: Generated Layout Plans (3D).

3.3. Generation of Layout Plans for Workspace

In this experiment, the layout plans for workspace were generated in the proposed system. Figures 9 and 10 show examples of the generated layout plans.

4. Conclusions

In this paper, we have proposed the office layout support system using genetic algorithm. In the proposed system, the combined genetic algorithm which is based on the adaptive genetic algorithm and the genetic algorithm with search area adaption is employed in order to improve the convergence speed and the diversity of layout plans. We carried out a series of computer experiments and confirmed the effectiveness of the proposed system.

References

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