

# Optimization of Discrete Camera Position for Taking All Scenery Inside Buildings by GA

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## ABSTRACT

Minimizing the number of cameras is search for optimal all location for taking all scenery inside buildings. It is necessary to take the conditions of a camera and walls into consideration. We proposed a GA-based method to minimize the number of cameras to take images all scenery inside buildings. We used an actual map, and experimented based on GA. It was able to ask for the number of a camera considered to be close to the minimum as a result.

Key Words:

Genetic Algorithm

## 1 Introduction

Recently, Computer Graphics (CG) are used in many fields such as used in movies, games and so on.

Many researchers have been developed new technologies to produce photo-realistic CG images. In particular, movies are using many CG image to synthesize the scenes those are hard to film by human. In the movie field, it is needed the easy way to synthesize the scene inside the entire building. For this object, some researchers propose the way to synthesize a continuous image from the multiple photographs take by the multiple viewpoints. In this case, it is the problem how many photographs (cameras) are needed to synthesize a continuous image, and how to set the camera parameters such as the camera position or camera angle. Of course the movie maker require the way to synthesize a continuous image from the fewest number of photographs.

To synthesize the continuous image, each photograph has to include an appropriate overlap between the photographs. In this research we try to synthesize a continuous image from the fewest number of photographs that taken from the optimum camera parameters derived by

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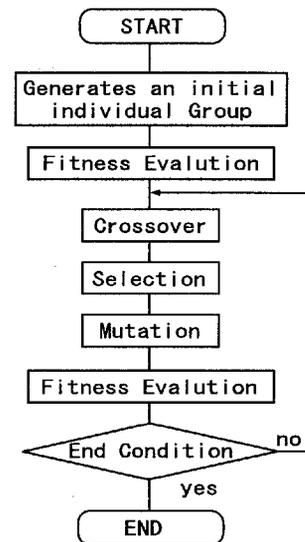


Fig. 1 The Flow Chart of GA

the genetic algorithm.

This paper is organized as follows; Section 2 introduces the genetic algorithm. Section 3 defines the problem that the optimization of the discrete camera position to take pictures inside the building. The optimization method of the camera position is also described. Section 4 discuss the experimental results through computer simulations. Section 5 concludes this paper.

## 2 Genetic Algorithm

Genetic Algorithm (GA) is a kind of search algorithm base on the evolution process in life. A life has the genome that describe the features of that life. <sup>1)2)</sup>These

genome inherit from their ancestors. In every generation, the genome is modified by the genetic operations such as crossover, mutation and so on. Only the lives with higher flexibility to the environment remain the next generation. As same as the biological evolution, genetic algorithm modify the artificial genome (individual) by the genetic operations. These individuals encode the candidate of the solution, only the individuals with higher fitness value are remained to the next generation. <sup>3)</sup>Fig.?? shows the flowchart of the GA.

### 3 Definition of the problem

As described in Section 1, we try to make a continuous image from the fewest number of photographs taken by the different camera position. This continuous image shows all the scene inside the building. For this objectives, we define the problem as following.

- A continuous image synthesized of the multiple photographs represent all scene inside the building.
- The photographs have overlap to use the reference at the synthesise of the image.
- The camera is only placed on the mesh point to simplify the problem.

In usual case the scene inside the building have some furniture such as desk, chair, etc. However, we ignore these objects to simplify the problem. In addition we also ignore the height of the camera position. Therefore the building is expressed by the 2-dimensional floor plan (floor map).

#### 3.1 Discrete camera position

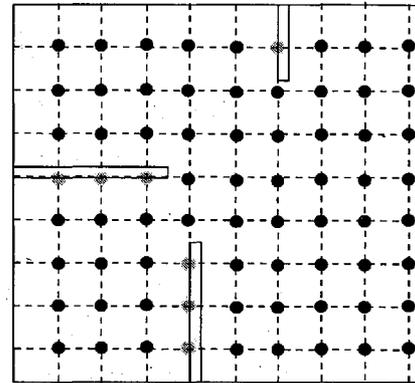
Virtual mesh is set on the floor map, and the cameras are placed only on the mesh point as shown in Fig.2.

Since the mesh point has the integer address, the data size if a individual becomes small. In addition the processing time will become short by the limitation of the camera position.

#### 3.2 The conditions of photography

##### 3.2.1 Overlap between photographs

To synthesize a continuous photographs in the building, overlaps between images are used as references. Since the overlap taken by more than two cameras is redundant, it is not used to synthesize the continuous image. In addition, a photograph is completely included in



- The place on which a camera is put
- The place on which a camera is not put

Fig. 2 mass

the other photograph, that is redundant. So these photographs are not used for the reference, too.

If a photograph has a large overlap, it causes more photographs to synthesize a continuous image. Therefore, we give a penalty in the fitness function of GA if a photograph includes a large overlap.

The floor map has some thin partition wall. The short side of the partition wall does not consider as the wall.

#### 3.2.2 Camera Conditions

Cameras have various view angle. In this research, The view angle of a camera is 46 degree that is similar to human view angle. The focus range of the camera depends on the kind of camera and the lenses. In this research, the focus range is given by the user. Fig.2 also shows the discrete camera position. In Fig.2 the black dot means the point that can place the camera. The gray dot in Fig.2 means the point that can not place the camera because it is too near to place the camera, or it is in the wall.

#### 3.3 Gene Coding

A camera has three parameters; the horizontal position, the vertical position and the angle from the horizontal axis. The set of these three parameters are arranged as a individual as shown in Table 1. In Table 1  $X_i$  and  $Y_i$  denotes the horizontal and vertical position of the camera  $i$ , respectively. The  $X_i$  and  $Y_i$  is the integer that mean the address of the crossing point on the virtual mesh. The  $\theta_i$  denotes the angle from the horizontal axis of the camera  $i$ . The range of  $\theta_i$  is  $\pm 180$  degree from the horizontal axis.

Table. 1 An arrangement of camera parameters in an individual

Position of a camera (X coordinates)	$X(v_0, w_0)$	$X(v_1, w_1)$	...	$X(v_n, w_n)$
Position of a camera (Y coordinates)	$Y(v_0, w_0)$	$Y(v_1, w_1)$	...	$Y(v_n, w_n)$
Direction of a camera	$\theta_0$	$\theta_1$	...	$\theta_n$

3.4 Gene operations

3.4.1 Crossover

The number of cameras in a individual are affected by the crossover operation. To reduce the number of cameras, it is desired that a camera takes more area of the walls. For this reason, the crossover is operated as follows;

1. "Parent-A" is chosen from the individuals in order of high fitness defined by Equation 1 in Section 3.
2. A provisional individual A' is made from the "Parent-A". The individual A' is almost the same as the "Parent-A", but some cameras taking the wall that has the smallest area in the photograph are removed. The wall taking by the removed cameras is called as the "WorstWall-A" in this paper.
3. A individual including the camera that takes a photograph including the largest area of the "WorstWall-A" is called as the "BestCamera-B".
4. A provisional individual B' is made from the "Parent-B". The individual B' only includes the "BestCamera-B".
5. The provisional individual A' and B' is merged to new offspring.

3.4.2 Fitness Function

Fitness Function of the individual is defined by Equation (1) where  $j$  is the wall 2D.  $N$  is the number of all walls in floor map.

$$f_g = \frac{\sum_j (P_j + Q_j)}{N}, \quad (1)$$

$$P_j = \frac{l_a + l_b - \lambda}{L_j} \times 100 (\%), \quad (2)$$

$$Q_j = \begin{cases} 100 & P_j=100(\%) \text{ and} \\ & (1 - \alpha)M \leq \lambda \leq (1 + \alpha)M, \\ 0 & \text{other} \end{cases} \quad (3)$$

In Equation (2),  $l_a$  and  $l_b$  denote the length on the wall  $j$  taken by the camera A and the camera B, respectively.

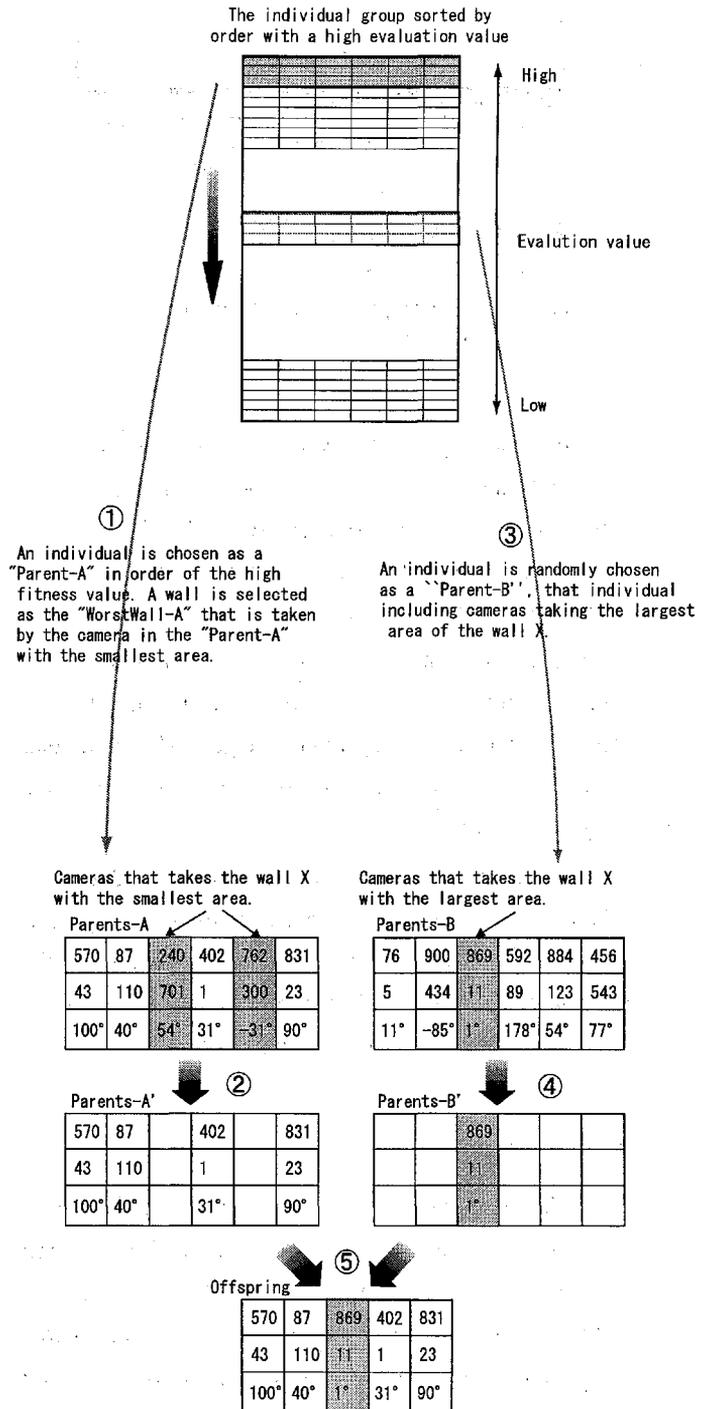


Fig. 3 Crossover

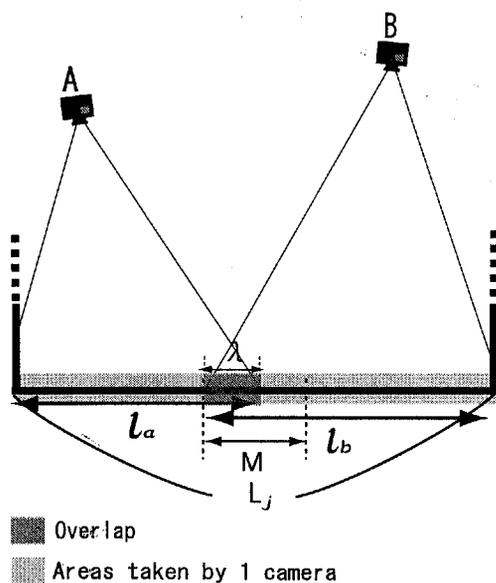


Fig. 4 The example which is taking the wall by two cameras

$\lambda$  denotes the length on the wall  $j$  taken by the both of the camera A and the camera B.  $L_j$  is the length of the wall  $j$ . These parameters are also described in the Fig 4. When the wall  $j$  is completely taken by the camera A and the camera B,  $P_j$  becomes 100.

$Q_j$  becomes 100 if the wall  $j$  is completely taken, and the photographs include desirable length of overlap to synthesize a continuous image. The parameter  $\alpha$  ( $0 \leq \alpha \leq 1$ ) and  $M$  is set by users where  $M$  is the length on the floor map.

Thus the maximum fitness of an individual is 200 when all the walls are taken by cameras, and there are appropriate overlaps between photographs in the building. If the same area of a wall is taken by more than two cameras, the area does not use as the overlap to reduce the number of cameras.

### 3.4.3 Mutation

In GA, the contents of a individual are randomly changed by the mutation. It means that the direction and the position of the camera are changed by the mutation in this application. However, this mutation causes low fitness at the last stage of evolutionary process. Therefore we use other operation as the mutation.

If a camera takes only one wall, this camera is deleted from an individual to reduce the number of cameras. This operation is called as the mutation in this research.

### 3.4.4 Local search

Since GA is a kind of the probabilistic search, it does not guarantee to find the optimum solution. To improve the quality of solution, local search operation is employed. The local search is operated as follows;

#### 1. Change of the direction of the camera

- (a) The angle of all cameras are changed from 0 to 360 degree by 10 degree steps. The angle with the highest fitness value is set to the new angle for each camera.
- (b) After above operation, the cameras that have more than 99% of the highest fitness value are selected. The angle of these cameras is changed within  $\pm 10$  degree by one degree step, then the angle that leads the highest fitness value is selected.

#### 2. Change of the camera position

At first, the camera is provisionally moved to the eight neighbor of the current position. If the fitness value increase, the camera is moved to the position with the highest fitness value.

The local search is repeated until fitness will not increase.

## 4 Experiments and Discussions

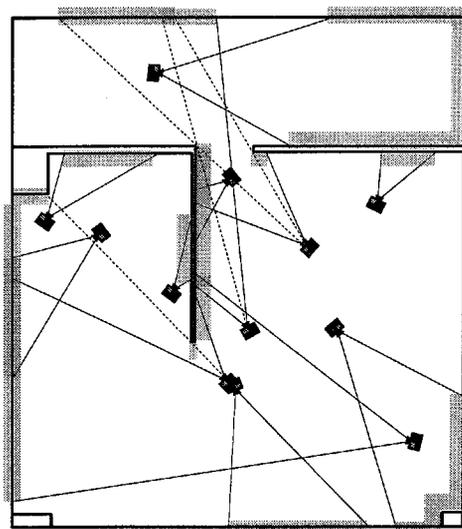
### 4.1 Experimental conditions

For the experiments, we prepare a floor map based on the actual building, A325 meeting room of the Faculty of Engineering, University of Miyazaki. From the simulation results, we take photographs from the viewpoint derived by the GA, then try to synthesize a continuous image.

### 4.2 The parameter of GA

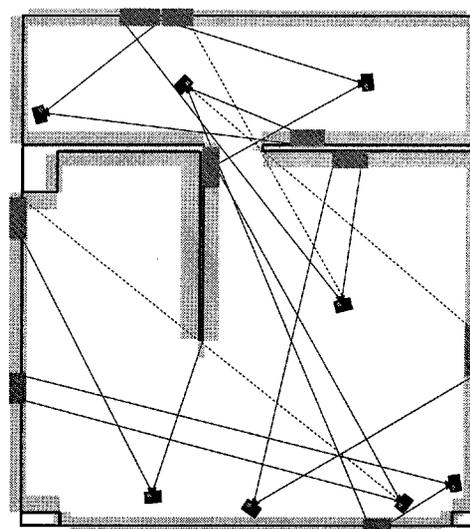
Parameters of GA for the experiments are described in below. These parameters are derived from the preliminary computer simulations.

- The maximum number of generations : 100
- The number of individuals : 100
- The number of offspring generated by Crossover : 100
- The initial number of cameras : 12



■ Areas were taken by 1 camera  
 ■ Areas were taken by two or more cameras

Fig. 5 A camera layout at the 0-th generation



■ Areas were taken by 1 camera  
 ■ Areas for composite image

Fig. 6 A camera layout at 100-th generation

- The interval of crossing point of the mesh : 0.01
- M : 0.03 (m)
- $\alpha$  : 0.3

### 4.3 Experiments Results

Fig.5 shows the initial position of the cameras. In the 0-th generation, Some walls are taken by more than two cameras, and some walls are taken by no cameras. Fig. 6 shows the camera position of a individual after 100 generations. As shown in Fig. 6, all cameras take more than two walls with suitable overlap. In addition the number of cameras was decreased into 8. In this case, the fitness of the individual was arrived at 200, that is the maximum value. As a result, it is showed that out method could take multiple photographs including desirable overlap to synthesize a continuous image inside the building.

### 5 Conclusion

Recent progress of image processing technology leads many applications in real world. In particular synthesize of a continuous image from the multiple

photographs taken from many viewpoint attracts attentions in the movie fields. In this paper we propose a method to synthesize a continuous image by the fewest number of photographs. For this objective, we employed the genetic algorithm to find an appropriate layout of the cameras.

At that time we allowed to place the cameras on the discrete point to reduce the computation time, and the powerful local search method are also used to find the better camera layout. Simulations results showed that our method could derive the camera layout that make be possible to synthesize of a continuous image. However, powerful local search led a long computation time.

Improvement of the local search and automatic synthesize of a continuous image from the images are remains as a future works.

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