Optimal Camera Layout to Take Pictures for Indoor Landscape Using GA

Ikuo YOSHIHARA[1)] Takumi NAKAGAWA[2)] Kunihito YAMAMORI[3)]
Haruo TAKEDA[4)]

ABSTRACT

Taking pictures including all the walls and materials is necessary to make video-based CG of indoor landscapes. These pictures must have a variety of conditions such as a distance between camera and wall, overlap of pictures to compose CG and so on. This paper treats a building as two dimensional model and finds layout which camera can take all the parts of the walls in the building using Genetic Algorithms. We find such layouts and can minimize the number of cameras.

Key Words:
Camera, Optimization, Genetic Algorithms

1 Introduction

This problem is based on research to produce 3-dimensional building image [1)]. A building image is reproduced with image processing technology by picture of whole walls inside a building. This paper aims at optimizing layout which camera can take pictures of every wall inside the building.

Generally, large number of layout can be considered, but there are some complex conditions to take a picture. Because to find appropriate layouts which meet such conditions is so difficult, we employ Genetic Algorithms(GAs) for finding solutions and come to the best layout. Genetic Algorithms are excellent in performing large scale search, and have a feature such that solution can be found only if fitness function is evaluated without having any special knowledge about the problem [2)].

This paper is organized as follows. In this Section, the purpose and outline of this research are explained. Section 2 presents conditions for optimization of camera layout and formulates this problems. Section 3 describes outline of our GA specialized in this problem, gene-coding, genetic-operation and so on. Section 4 presents experimental results for real building data, and finds the optimal camera layout. Section 5 gives conclusions and future works.

[1)] Professor, Dept. of Computer Science and Systems Engineering
[2)] Undergraduate student, Dept. of Computer Science and Systems Engineering
[3)] Associate Professor, Dept. of Computer Science and Systems Engineering
[4)] Director, Office of Strategic Planning, Systems Development Laboratory, Hitachi, Ltd.

2 Optimization of Camera Layout

There are several prerequisites and conditions to compose image. This section explains these prerequisites and conditions and sets up an objective function to find optimal camera layout which meets the conditions.

2.1 Prerequisites

The following conditions are considered to perform this research.

- *Two dimensional model of building*
  In this research, building is treated as two dimensional model. There are only walls which connected with next wall at right angles. Any objects, for example pillar, furniture and etc, don't exist in the building.

- *Angle which camera can take a picture*
  hspace*0.3cmCamera has a specific provincial point of view angle. This angle depends on lens of camera. Camera can only take a picture of object which exists inside this angle.(Fig.1) In this research, camera which can take a picture in 48 degrees is used.

- *Region which can be camera arranged*

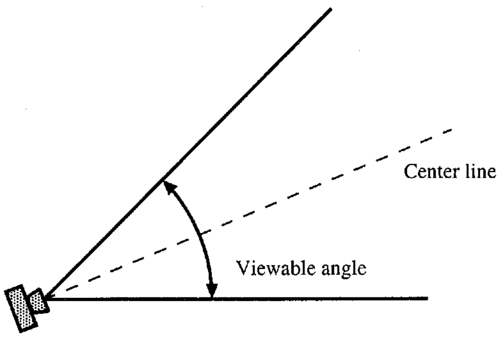

Fig. 1 Angle Which Camera Can Take a Picture

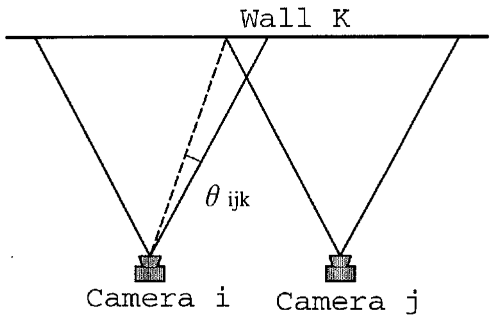

Fig. 2 Overlap angle

Space between camera and wall is necessary for cameraman and tripod. To keep this space more than 0.5 meter is defined as conditions.

2.2 Conditions to Compose Image

- *Pictures of all the parts of the walls inside a building*

  All the parts of the walls of a building must be taken picture to make a composite image. When

$$\mathbf{d} = (d_1 \cup d_2 \cup .... \cup d_n) \tag{1}$$

d_h : Wall region which is taken by camera h
then it requires that

$$Lw = length(\mathbf{d}) \tag{2}$$

Lw : Length of all wall

- *Overlap of pictures*

  All Picture should have certain degree of overlap with next picture to make a composite image. But picture with small overlap can't use for image composing.

When overlap angle θ_{ijk} is made by neighboring camera i,j at wall k, θ_{ijk} requires

$$5^\circ \leq \theta_{ijk} \leq 10^\circ$$

to compose image. And if

$$\theta_{ijk} < 5^\circ$$

or

$$\theta_{ijk} > 10^\circ$$

then picture can not be composed.(Fig.2)

- *Angle made by camera and wall*

  In a picture that taken from shallow angle which made by camera and wall, the back wall is distorted compared with the front wall. So angle must be kept certain degree. In this research, we set that angle more than 15 degrees.

2.3 Formulation to Optimize Layout

To find the optimal camera layout which meets limited conditions, all walls are taken pictures by one camera without overlap to compose image. So reduce section of wall which is not taken a picture by camera and taken by two cameras but too small to compose image. And also reduce section which is taken a picture by three or more cameras and taken by two cameras too large to compose image. Then, it formulates as follows.

$$F_L = \alpha L_0 + \beta L_{2u} + \gamma L_{2o} + \sum_{j \geq 3} \delta_j L_j \rightarrow min \tag{3}$$

L_0	:	Wall length not taken a picture by any camera
L_{2u}	:	Wall length taken a picture by two cameras but too small to compose image
L_{2o}	:	Wall length taken a picture by two cameras but too large to compose image
L_j	:	Wall length taken a picture by j cameras
α,β,γ,δ	:	Parameter which means strength of conditions

limiting condition

- *Taking pictures of all the parts of the walls*

$$Lw = length(\mathrm{d})$$

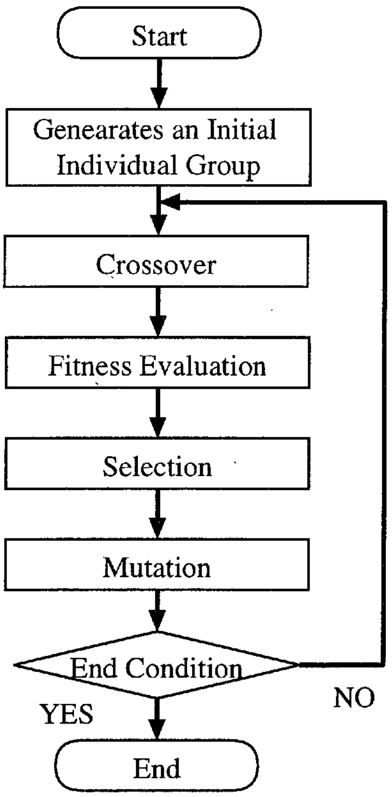

Fig. 3 Procedure of GA

- *Having overlap with next wall*

$$5^\circ \leq \theta_{ijk} \leq 10^\circ$$

- *Arranging cameras to the region which can arrange camera*

$$cam_i \in \mathbf{D}$$

3 Genetic Algorithms

GA is used to optimize camera layout. This algorithm models evolution of a living things, and known as suitable for global search [3) 4) 5)]. In this research we use GA improved by Yoshihara [6)]. Fig.3 shows procedure of GA.

3.1 Genetic Coding

An individual consists of cameras which arranged horizontally, and it has variable length, as shown in Fig.4. Camera consists of position(x coordinate, y coordinate) and direction which arranged vertically. In addition, direction of camera is described as radian, and all data are described as real value.

3.2 Initialization

In initialization, cameras are arranged in the room randomly. When cameras are arranged randomly, there is a

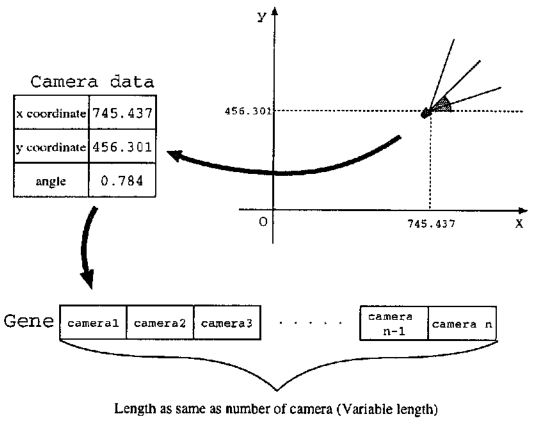

Fig. 4 Gene Structure

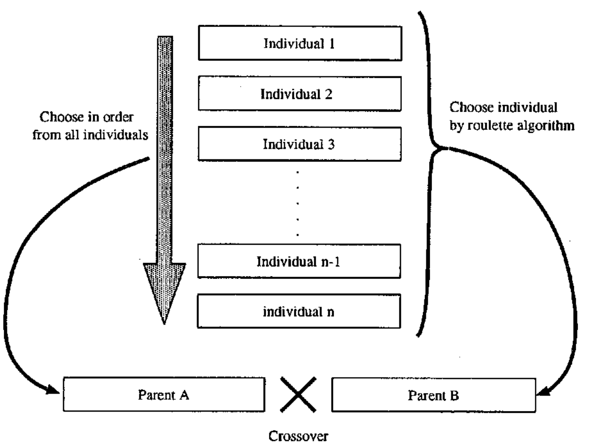

Fig. 5 Selection for Crossover

possibility that cameras concentrate in specific room. So in this operation, certain number of cameras are arranged to each room.

3.3 Genetic Operators

(1) Selection for Crossover

Two individuals A and B are chosen as parents A and B in this operation. One parent A is chosen in order, and B is chosen by roulette algorithm from all individuals. Every individual is selected as parent A only once, so group of individuals can be kept diversity. Subsequently a gene locus i is chosen randomly from parent A, and a gene locus j of parent B is determined by follow equation.

$$\sqrt{(x_{Ai} - x_{Bj})^2 + (y_{Ai} - y_{Bj})^2} \rightarrow min \quad (4)$$

This operation means determining camera B_j which is closest from camera A_i.

(2) Crossover

In this research, we use real-coded crossover. New offspring O which create in this crossover is applied follow operation

$$x_{Oi} = \lambda x_{Ai} + (1 - \lambda) x_{Bj} \tag{5}$$

or

$$y_{Oi} = \lambda y_{Ai} + (1 - \lambda) y_{Bj} \tag{6}$$

for not changing the parent's character rapidly. And we set

$$-0.2 < \lambda < 1.2 \tag{7}$$

for camera O_i can move both internally and externally dividing point between camera A_i and B_j . This time, locus which not be operated is duplicated same locus at parent A. In this crossover, camera can be located in a room freely, unlike discrete type crossover used in common GA.

(3) Selection

Individuals which can survive next generation are selected in descending order of fitness from whole individuals including parents and offsprings. The fitness is defined by following equation.

$$fitness = \frac{1}{F_L + \epsilon} \tag{8}$$

This equation is almost inverse of eq(3), and ϵ is small number for avoiding zero divide.

(4) Mutation

Angle of camera is modified at random. Then if the fitness increases before modification, the new angle is accepted. At that time, individuals are selected as candidates of mutation by constant probability. The angle of cameras in the selected individuals is also changed at random.

3.4 Elimination of Useless Camera

Through the above mentioned operations, the number of cameras in the individuals is constant. To reduce the number of cameras, some cameras which take a picture of the same wall area are eliminated as shown in Fig.6. The wall area taken a picture by camera$B$ is completely included in the wall area taken a picture by camera$A$. Camera$B$ is eliminated.

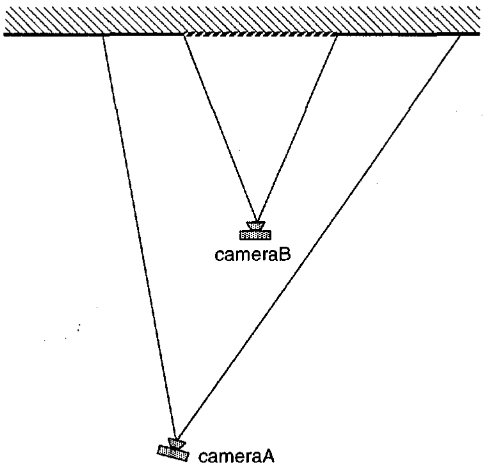

Fig. 6 Elimination of Useless Camera

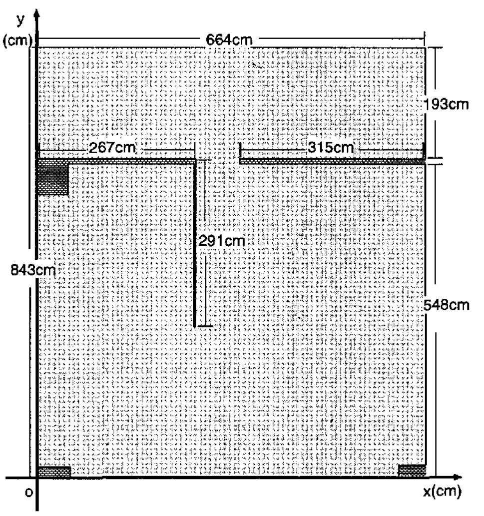

Fig. 7 Room Used in This Experiment

4 Experiment of Optimizing Camera Layout

We experiment optimizing camera layout at our laboratory's meeting room. We would find layout which minimized number of cameras at that room which divided by partitions. Fig.7 is the sketch of room.

4.1 Experimental Conditions

- The number of individuals 100
- Rate of crossover 100%
- Rate of mutation 10%
- The maximum number of the generations 500
- The number of cameras in initial layout 12

Conditions are determined experientially by pilot study. Number of cameras in initial layout is made into 4 times of the number of rooms. Usually one room is surrounded with four walls, so if one wall is

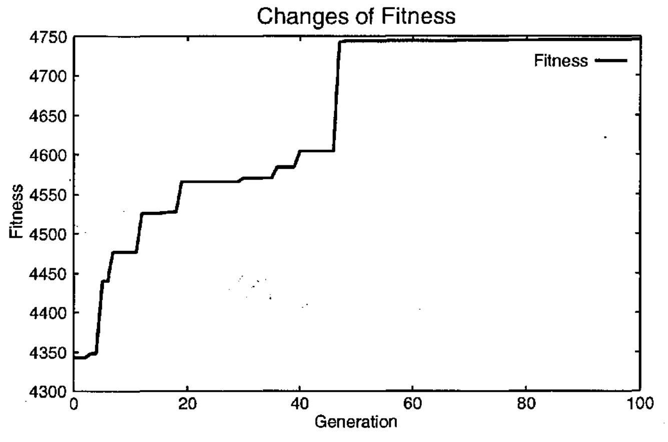

Fig. 8 Changes of Fitness

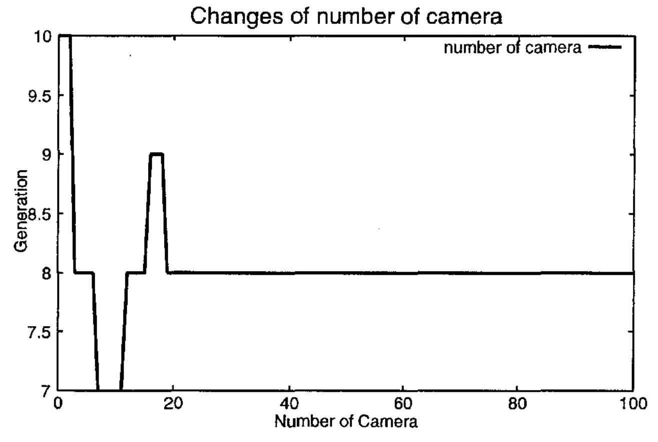

Fig. 9 Changes of the Number of Cameras

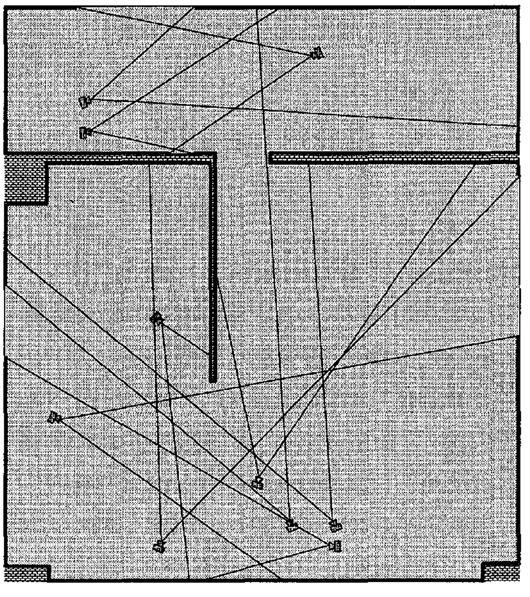

Fig. 10 Initial Layout

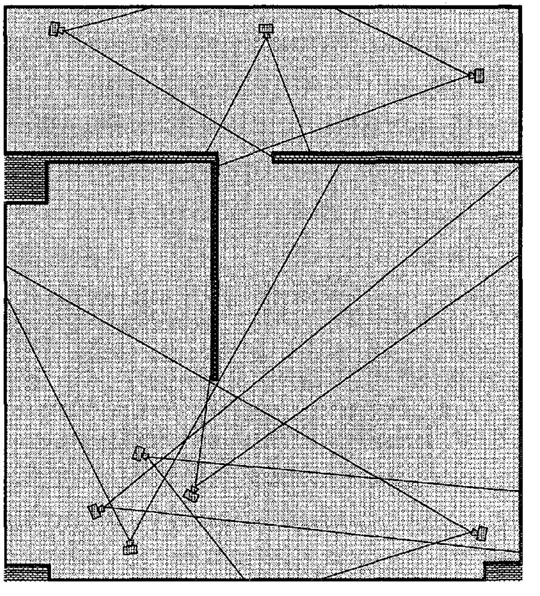

Fig. 11 Layout of the 500th Generation

photoed with one camera, it will be thought that all walls can be photoed.

4.2 Experimental Results

Fig.8 and Fig.9 express a fitness and changes of the number of cameras. Fig.10 and Fig.11 also express an initial layout and layout in the 500th generation. In addition, the bold line shows photoed wall.

4.3 Discussion

Fig.8 shows that the fitness rises gradually up to the 50th generation, but goes up seldom afterward. Fig.9 also shows that number of cameras changes to about 25th generation, but doesn't change afterward. Rough layout is determined about 50th generation. Subsequently adjusting overlap of pictures is performed.

Fig.10 shows that initial layout can't take pictures of all the parts of the walls. There are 10 cameras in initial layout, but some cameras have similar position or similar angle. These cameras are considered useless, so there is room for an improvement in the initial layout. After the 500th generation, all the parts of the walls can be taken a picture by 8 cameras. Layout in the 500th generation has enough overlap for composition and there is no camera which is too close to the wall. These things show that we minimize number of cameras in layout which can take pictures of all the parts of the walls of room.

5 Conclusion

This paper proposes a method to find the layout which camera can take all the parts of the walls in the building using GA.

Limiting conditions are set as taking pictures of every part of the walls inside the building, having overlap with next wall and keeping distances between walls and cameras no less than 0.5 meter for making video-based CG of indoor landscapes. To extend search space and improve the accuracy of solution, real-coded GA is used. In consequence, the layout which satisfies constraints is found.

Future works are improving the objective function and crossover, and developing a faster algorithm.

Reference

[1] H. Takeda, M. Yamasaki, T. Moriya, T. Minakawa, F. Beniyama and T. Koike, "A video-based virtual reality system", ACM VRST ' 99 (ACM Symposium on Virtual Reality Software and Technology), pp.19-25 (1999).

[2] H. Kitano, "Genetic Algorithm", Sangyo Tosho Publishing Co.,LTD. (1993) (in Japanese).

[3] Holland,J.H., "Adaptation in Natural and Artificial Systems", Unversity of Micigan Press (1975).

[4] Goldberg,D.E., "GeneticAlgorithms in Search, Optimization and Machine Learning", Addison Wesley (1989).

[5] M. Yamamura and S. Kobayashi, "Toward Application Methodology of Genetic Algorithms", Journal of the Japanese Society for Artificial Intelligence, Vol. 9, No.4,pp.30-35 (1994) (in Japanese).

[6] T. I. of Systems Control Information Engineers, M. Funahasi and I. Yoshihara, "Intelligent information processing for systems control", Asakura Tosho Publishing (1999) (in Japanese).