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Office Layout Plan Evaluation System for Normal Use and Emergency by Multiagent

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***Abstract*—In this paper, we propose an office layout evaluation system for normal use and emergency by multiagent. The proposed system evaluates office layout plans generated by the office layout support system using genetic algorithm. This office layout support system can generate layout plans which satisfy some conditions given by users. However, the flow of office workers can not considered in the system. In the proposed system, the office layout plan generated by the office layout support system using genetic algorithm and the conditions for agents are given, and then the agents move under the conditions. Based on the behavior of agents, the evaluation for the movement time of agents, bias of agent flow and so on are carried out. We carried out a series of computer experiments in order to demonstrate the effectiveness of the proposed system and confirmed that the proposed system can evaluate layout plans.**

***Index Terms*—Office Layout, Multiagent System**

I. 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. However, the flow of office workers can not considered in the system.

In this paper, we propose an office layout evaluation system for normal use and emergency by multiagent. The proposed system evaluates office layout plans generated by the office layout support system using genetic algorithm. This office layout support system can generate layout plans which satisfy some conditions given by users. However, the flow of office workers can not considered in the system. In the proposed system, the office layout plan generated by the office layout support system using genetic algorithm and the conditions for agents are given, and then the agents move under the conditions. Based on the behavior of agents, the evaluation for the movement time of agents, bias of agent flow and so on are carried out.

II. Office Layout Evaluation System by Multiagent (Normal Use)

Here, we explain the proposed office layout evaluation system by multiagent. This system evaluates office layout plans generated by the office layout support system using genetic algorithm[3][4]. In the proposed system, the office layout plan and conditions for agents are given, and then the agents move under the conditions. Based on the behavior of agents, the evaluation for the movement time of agents, bias of agent flow and so on are carried out.

A. Setting of Conditions for Agents

In the proposed system, each agent is an office worker. In the real world, the actions of office workers are different individually. However, the load of the user becomes too large if the user sets the condition for every agent individually. Therefore, in the proposed system, the user does not set a condition for an individual agent, the user sets the conditions for agents per group. In the simulation, each agent moves to printer/entrance/shelf/meeting room/reception room/server room/ refreshment room/hot-water supply room/locker room/data room/seat. So, the movement frequency for each area is set in $1 \sim N_f$. And, the minimum and maximum sojourn time at the destination $dest$ T_{min}^{dest} and T_{max}^{dest} are set.

$$dest = \{Pr,\ En,\ Gs,\ Sf,\ Mt,\ Rc,\\ Sv,\ Rf,\ Ht,\ Dr,\ Da,\ G_k\} \qquad (1)$$

where Pr is printer, En is entrance, Gs is shelf for group, Sf is shelf, Mt is meeting room, Rc is reception room, Sv is server room, Rf is refresh room, Ht is hot-water supply room, Dr is locker room,Da is data room, G_k is the seat of the group k. The minimum and maximum sojourn time at the entrance $T_{min}^{En}(i)$ and $T_{max}^{En}(i)$ are set per group.

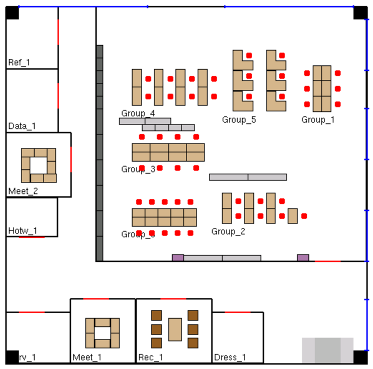


Fig. 1. Initial Position of Agents.

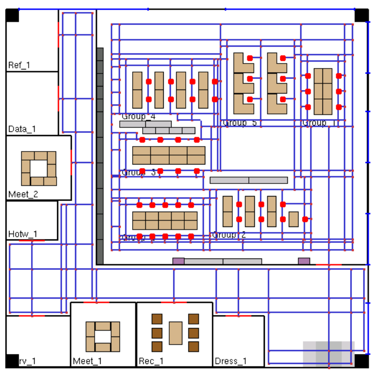


Fig. 2. An example of Paths.

For the guest agent, the frequency to go to the reception room is set in 1$\sim N_f$. And the minimum and maximum sojourn time at the reception T^{guest}_{min} and T^{guest}_{max} are set.

B. Behavior of Agents

1) Initial Position of Agents: Each agent is assigned in front of own desk as shown in Fig.1.

2) Setting of Agent Path: In this system, agents move in the paths decided beforehand. The paths that agents can move are set as shown in Fig. 2.

C. Decision of Start Time of Agents

In the real world, the office worker does not decide when and where they go beforehand. In the proposed system, when and where the agents to start are decided to satisfy the conditions in advance.

Here, we explain the decision method of start time of the agents.

Step 1 : Decision of Number of Movements

Based on the movement frequency decided in **II-A**, the number of movements is decided.

The number of times when the agent j of the group i goes to the destination $dest$, N^{dest}_{ij} is decided at random in a range from $N^{dest}_{min}(F^{dest}_i)$ to $N^{dest}_{max}(F^{dest}_i)$. Here, F^{dest}_i is the movement frequency to the destination $dest$ for the agents of the group i, $N^{dest}_{min}(x)$ and $N^{dest}_{max}(x)$ are the minimum and maximum number of times to go to the destination $dest$ when the frequency is x.

Step 2 : Decision of Movement Order

The agent j of the group i moves to the destinations $N^{all}_{ij}(= N^{Pr}_{ij} + N^{En}_{ij} + N^{Gs}_{ij} + N^{Sf}_{ij} + N^{Mt}_{ij} + N^{Rc}_{ij} + N^{Sv}_{ij} + N^{Rf}_{ij} + N^{Ht}_{ij} + N^{Dr}_{ij} + N^{Da}_{ij} + \sum_{k=1}^{N} N^{G_k}_{ij})$ times. Here, the movement order is decided randomly.

For example, in the case where $N^{Pr}_{ij} = 2$, $N^{En}_{ij} = 1$, $N^{Mt}_{ij} = 1$, $N^{G_1}_{ij} = 1$, $N^{G_2}_{ij} = 1$, the order such as

printer $\to$ desk (group 1) $\to$ meeting room $\to$ desk (group 2) $\to$ entrance $\to$ printer

is obtained.

Step 3 : Decition of Start Time

The start time for each action is determined randamly.

D. Action of Agents

Agents moves on paths decided in **III-B2** under the conditions given by a user.

The action of agetns can be divided into three cases.

(1) agent is in own seat.
(2) agent is in destination.
(3) agent is moving.

(1) Case when Agent is Own Seat

If the agent is own seat, it waits until next start time. If the agent backs to the own seat from the previous destination after the next start time, it starts to the next destination immidiately. The route to the next destination is determined based on the Dijkstra method[5].

(2) Case when Agent is in Destination

When the agent arrives at the destination such as printer, door and shelf, the sojourn time is determined randomly. After the agent stays there for a while, it backs to the own seat.

(3) Case when Agent is Moving

(a) Agent is at Crossroads

If the agent is at a crossroads, it starts to move the next crossroads.

(b) Agent is in Any Place Other Than Crossroads

If the agent is in any place other than crossroads, the agent moves till it arrives at the next crossroads.

E. Evaluation by Agents

The following four items are evaluated based on the movement of agents.

(1) time for movement
(2) agent flow around seats
(3) bias of agent flow
(4) average number of times that guest agents passed the other agents

(1) Time for Movement

The layout plans that agents need short times for movement can be considered as appropriate plans. In the proposed system, the evaluation value for the time when each agent needed for movement E_{time} is calculated as follows.

$$E_{time} = \sum_{i=1}^{N} \sum_{j=1}^{a(i)} \frac{T_{ij} N_{ij}^{all}}{\sum_{k=1}^{N} \sum_{l=1}^{a(k)} N_{kl}^{all}} \quad (2)$$

where N is the number of groups, $a(i)$ is the number of agents of the group i, N_{ij}^{all} is the action number of the agent j of the group i, T_{ij} is the amount time for movement of the agent j of the group i.

(2) Agent Flow around Seats

The evaluation value for the agent flow around seats E_{pass} is calculated as follows.

$$E_{pass} = \frac{\sum_{i=1}^{N} \sum_{j=1}^{a(i)} B_{ij}}{\sum_{i=1}^{N} a(i)} \quad (3)$$

where B_{ij} is the number of times that other agents passed the back of the seat of the agent j of the group i.

(3) Bias of Agent Flow

(a) Times that Other Agents Passed Back of Seats

The evaluation value for the bias of agent flow E_{bias1} is calculated as the variance of the number of times that other agents passed back of seats.

$$E_{bias1} = \frac{\sum_{i=1}^{N} \sum_{j=1}^{a(i)} (B_{ij} - E_{pass})^2}{\sum_{i=1}^{N} a(i)} \quad (4)$$

where B_{ij} is the time that other agents passed back of the seat of the agent j of the group i, and E_{pass} is the average of B_{ij} given by Eq.(3).

(b) Times that Agent Passed Other Agents

The evaluation value for the bias of traffic E_{bias2} is calculated as the variance of the number of times that an agent passed other agents.

$$E_{bias2} = \frac{\sum_{i=1}^{N} \sum_{j=1}^{a(i)} C_{ij}}{\sum_{i=1}^{N} a(i)} \quad (5)$$

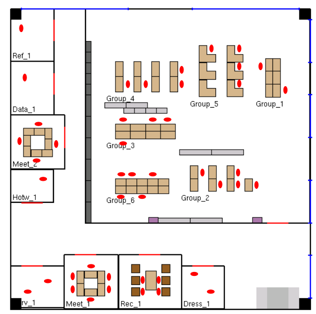
where C_{ij} is the number of times that the agent j of the group i passed other agents.

(4) Average Number of Times that Guest Agent Passed Other Agents

The average number of times that guest agents passed other agents E_{guest} is given by

$$E_{guest} = \frac{\sum_{i=1}^{N^G} D_i}{N^G} \quad (6)$$

(a)



(b)

Fig. 3. Initial Position of Agents (2).

where D_i is the number of times that the guest agent i passed other agents, and N^G is the number of guest agents.

III. Office Layout Evaluation System by Multiagent in Emergency

Here, we explain the proposed office layout evaluation system by multiagent in emergency. This system evaluates office layout plans generated by the office layout support system using genetic algorithm[3][4]. In the proposed system, the agents move to the entrance, and based on the behavior of agents, the evaluation for the time, distance, speed for escape and so on are carried out.

A. Initial Setting

(1) Initial Position of Agents

Each agent is assigned in front of own desk (Fig.3(a)) or random place (Fig.3(b)).

(2) Impassable Space

In the proposed system, impassable spaces are generated randomly. The number of the impassable spaces N_d is determined from 0 to N_d^{max} randomly. Here, N_d^{max} is given by

$$N_d^{max} = \lceil C_d S_f \rceil \quad (7)$$

where $S_f(m^2)$ is the floor size, and C_d is the coefficient. The positions of N_d impassable spaces are determined randomly, and each area is set as the square whose length of each side takes 1∼3(m).

Figure 4 shows an example of impassable spaces.

Fig. 4. Impassable Spaces.

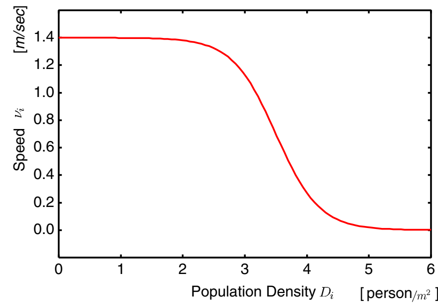
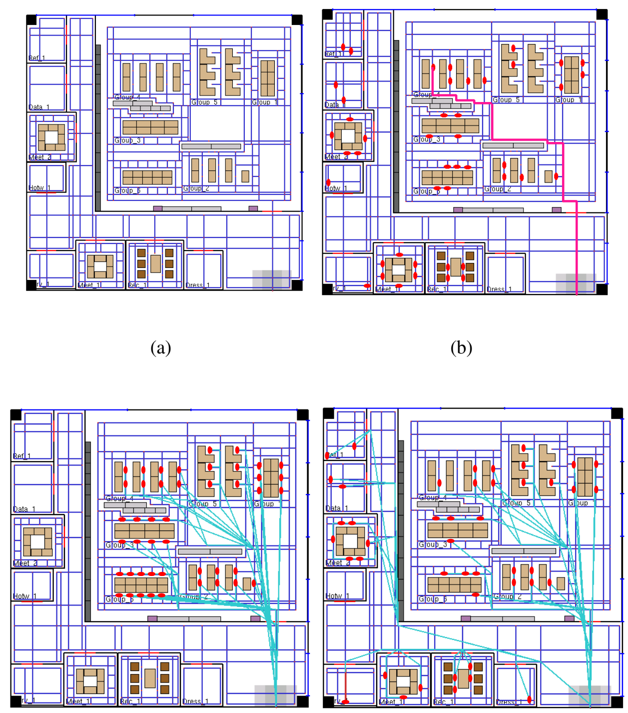


Fig. 5. Relation between Population Density and Agent Speed.



(a) (b) (c)

Fig. 6. Escape Route.

B. Escape Simulation

The action of agents can be divided into two cases.

(1) agent is in initial position.
(2) agent is moving.

(1) Case when Agent is in Initial Position

If the agent is in the initial position, the agent determines the route to the entrance by the Dijkstra method[5], and starts to the entrance.

(2) Case when Agent is Moving

The action of agents can be divided into three cases when the agent is moving.

(a) Case when the agent bumps against the other agent in next step
(b) Case when the agent see impassable spaces in corridor
(c) Case except (a) and (b)

In the cases (a) and (b), the agent modifies own escape route.

1) Agent Speed: The speed of each agent is determined based on the population density. In the proposed system, based on the population density, the following three cases are considered.

(a) Normal Area ($D_i < 1.5$)
(b) Crowd Walking Area ($1.5 \leq D_i < 6.0$)
(c) Difficulty Walking Area ($6.0 \leq D_i$)

where D_i is the population density around the agent i.

The speed of the agent i, ν_i is given by

$$\nu_i = \left(\frac{1.0}{1.0 + \exp((D_i - a)/b)} \right) \nu_0 \quad (8)$$

where ν_0 is the speed in the normal area, a and b are the coefficients. In the proposed system, ν_0 is set to $1.4 m/s$, a is set to 3.5, and b is set to 0.35.

Figure 5 shows the relation between the population density and speed of the agent.

2) Setting of Agent Path: In this system, agents move in the paths decided beforehand. The paths that agents can move are set as follows.

(1) Path candidates composed of lines parallel to walls are made (Fig.6(a)).
(2) Tentative escape route is determined by the Dijkstra method (Fig.6(b)).
(3) Escape route is shortened if possible (Fig.6(c)).

C. Evaluation by Agents

The following five items are evaluated based on the movement of agents.

(1) time for escape
  (a) average time for escape
  (b) maximum time for escape
(2) average distance for escape
(3) average speed

(4) the number of agents who could not reach entrance
(5) frequency of crowd/difficulty walking area
  (a) frequency of crowd walking area
  (b) frequency of difficulty walking area

(1) Time for Escape

(a) Average Time for Escape

In the proposed system, the evaluation value for the average time for escape $E_{ave-time}$ is calculated as follows.

$$E_{ave-time} = \frac{\sum_{k=1}^{N_{all}} T_k}{N_{all}} \quad (9)$$

where N_{all} is the number of agents who can reach the entrance, and T_k is the time for escape of the agent k.

(b) Maximum Time for Escape

The evaluation value for the maximum time for escape $E_{last-time}$ is calculated as follows.

$$E_{last-time} = \max_k T_k \quad (10)$$

(2) Average Distance for Escape

The evaluation value for the average distance for escape $E_{ave-dis}$ is calculated as follows.

$$E_{ave-dis} = \frac{\sum_{k=1}^{N_{all}} D_k}{N_{all}} \quad (11)$$

where D_k is the distance for escape of the agent k.

(3) Average Speed

The evaluation value for the average speed $E_{ave-speed}$ is calculated by

$$E_{ave-speed} = \frac{E_{ave-dis}}{E_{ave-time}} = \frac{\sum_{k=1}^{N_{all}} D_k}{\sum_{k=1}^{N_{all}} T_k}. \quad (12)$$

(4) The Number of Agents Who Could Not Reach Entrance

The number of agents who could not reach the entrance is used as the evaluation value $E_{failed-agent}$.

(5) Frequency of Crowd/Difficulty Walking Area

(a) Frequency of Crowd Walking Area

The evaluation value for the frequency of the crowd walking area $E_{slow-zone}$ is given by

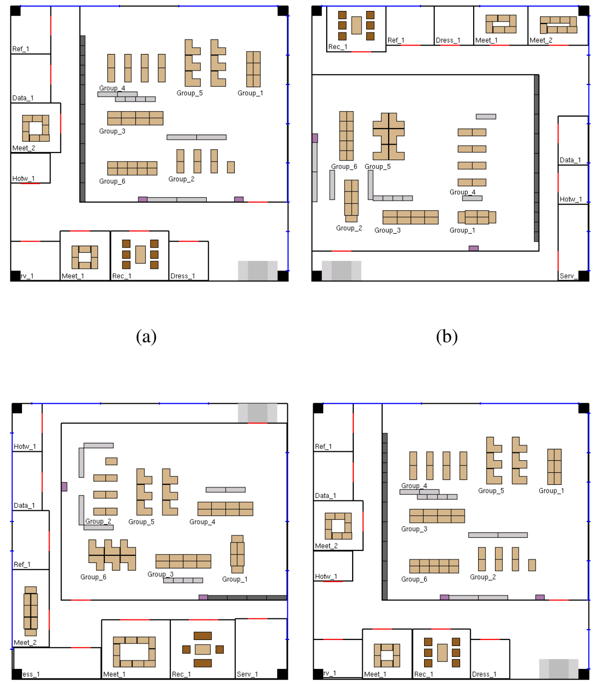
$$E_{slow-zone} = \sum_{k=1}^{N_{all}} N_k^{slow} \quad (13)$$

where N_k^{slow} is the number of steps that the agent k in the crowd walking area.

(b) Frequency of Difficulty Walking Area

The evaluation value for the frequency of the difficult walking area $E_{stop-zone}$ is given by

$$E_{stop-zone} = \sum_{k=1}^{N_{all}} N_k^{stop} \quad (14)$$



(a) (b) (c) (d)

Fig. 7. An example of Layout Plans.

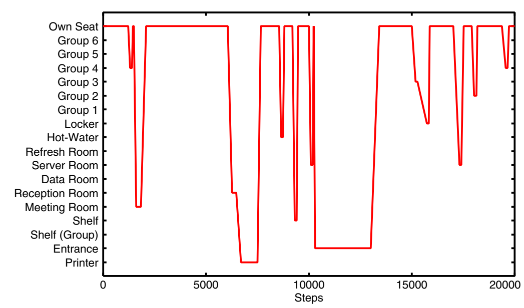


Fig. 8. Action of Agent.

where N_k^{stop} is the number of steps that the agent k in the difficult walking area.

IV. Computer Experiment Results

In this section, we show the computer experiment result to demonstrate the effectiveness of the proposed system. In this experiment, the layout plans shown in Fig.7 were used.

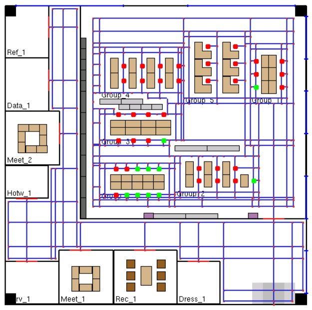
A. Action of Agents

Figure 8 shows an example of the action of a agent.

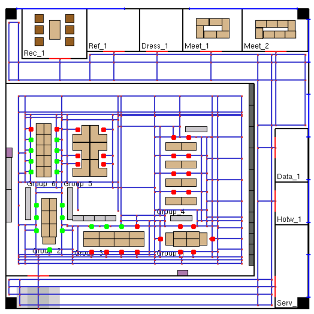
B. Evaluations (Normal Use)

Here, we examined in the layout plans (a) and (b) in Fig.7.

The evaluation value for time E_{time} for the layout plan (a) was 2703.1, and that for the layout plan (b) was 3276.9.



(a)



(b)

Fig. 9. Seats where Agents Often Passes.

TABLE I
EVALUATION (IN EMERGENCY).

Layout Plan	Initial Position	Trial No.	$E_{ave-time}$[sec]
Layout Plan (c)	Own Seat	1	31.7
	Random	30	26.1
Layout Plan (d)	Own Seat	1	41.6
	Random	30	30.4

Layout Plan	Initial Position	Trial No.	$E_{last-time}$[sec]
Layout Plan (c)	Own Seat	1	52.0
	Random	30	41.2
Layout Plan (d)	Own Seat	1	69.0
	Random	30	49.5

Layout Plan	Initial Position	Trial No.	$E_{ave-dis}[m]$
Layout Plan (c)	Own Seat	1	12.5
	Random	30	19.2
Layout Plan (d)	Own Seat	1	17.2
	Random	30	21.9

Layout Plan	Initial Position	Trial No.	$E_{ave-speed}[m$/sec]
Layout Plan (c)	Own Seat	1	0.30
	Random	30	0.77
Layout Plan (d)	Own Seat	1	0.50
	Random	30	0.72

Layout Plan	Initial Position	Trial No.	$E_{failed-agent}$[person]
Layout Plan (c)	Random	30	4.3
Layout Plan (d)	Random	30	5.7

Layout Plan	Initial Position	Trial No.	$E_{slow-zone}$[times]
Layout Plan (c)	Own Seat	1	965.0
	Random	30	774.6
Layout Plan (d)	Own Seat	1	863.0
	Random	30	734.9

Layout Plan	Initial Position	Trial No.	$E_{stop-zone}$[times]
Layout Plan (c)	Own Seat	1	146.0
	Random	30	29.5
Layout Plan (d)	Own Seat	1	532.0
	Random	30	93.7

Figure 9 shows the seats where the agents passed more than 60 times (green circle). The evaluation value for agent flow E_{pass} for the layout plan (a) was 12.2, and that for the layout plan (b) was 26.8.

The evaluation value for bias E_{bias1} for the layout plan (a) was 411.9, and that for the layout plan (b) was 1026.1. And the evaluation value for bias E_{bias2} for the layout plan (a) was 24.1, and that for the layout plan (b) was 53.9.

The evaluation value for guest agent E_{guest} for the layout plan (a) was 14.7, and that for the layout plan (b) was 56.2.

C. Evaluations (Emergency)

Table I shows the evaluation results in emergency. Here, we examined in the layout plans (c) and (d) in Fig.7.

V. CONCLUSION

In this paper, we have proposed the office layout evaluation system for normal use and emergency by multiagent. The proposed system evaluates office layout plans generated by the office layout support system using genetic algorithm. This office layout support system can generate layout plans which satisfy some conditions given by users. However, the flow of office workers can not considered in the system. In the proposed system, the office layout plan generated by the office layout support system using genetic algorithm and the conditions for agents are given, and then the agents move under the conditions. Based on the behavior of agents, the evaluation for the movement time of agents, bias of agent flow and so on are carried out. We carried out a series of computer experiments in order to demonstrate the effectiveness of the proposed system and confirmed that the proposed system can evaluate layout plans.

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