DEVELOPMENT OF ELEVATOR GROUP SUPERVISORY SYSTEM WITH FUZZY MADM

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Abstract.

A elevator group supervisory system is designed to perform efficient operation of multiple elevators, and its basic function is to assign an appropriate elevator to a given hall-call. In this paper, in order to improve elevator group control performance, we propose a new dispatching system which includes fuzzy multi-attribute decision making(MADM). In most cases, the purpose of group control is to maximize control goals as much as possible. Unfortunately, the decision of optimal elevator to a given hall call is made with very uncertain information of the system, and some of control goals are related each other. The uncertainty is mainly resulted from car calls generated by serving hall calls. A fuzzy MADM algorithm is proposed to deal with these problems to improve system performance.

1. INTRODUCTION

An elevator group supervisory system is used to operate multiple elevators efficiently. In general, elevator group supervisory system consists of group controller and monitoring system. The group controller decides the service elevator for a new passenger waiting at a hall. The monitoring system dispalays and stores operation data and interfaces user's request for supporting group controller.

In conventional elevator group supervisory systems, when a hall call is generated in a certain floor , it is decided by certain evaluation function which one of the plural elevators is most suitalbe to serve the hall call generated, and the service to the hall call is assigned to a elevator evaluated as the most suitable one. The aforesaid evaluation is carried out by calculating evaluation values of group controlled elevators with respect to the hall call generated in accordance with a predetremined evaluation function. An elevator, which has the most desired evaluation value, is selected as an optimal one to serve the hall call. By this method, the group supervisory system does not cope with exchanges of traffic flow in building.

Lately, besides utilizing specific evaluation fuction, a fuzzy control method or knowledge base method is used in some systems. These systems, which have to deal with enormous knowledge and rules, have not a short response time that correspond to high speed elevator system. As these systems use crisp predicted values for inputs of fuzzy rules, can not come over the error of prediction.

This paper suggests a new group supervisory system with fuzzy multi-attribute decision making(Fuzzy MADM). This system satisfies several control goals, according to the user's request. The control goals of the elevator supervisory system are not only reducing averege waiting time but also reducing long waiting time and energy saving.

2. THE ELEVATOR GROUP SUPERVISORY SYSTEM

The elevator group supervisory system is used to supervise multiple elevators, ensuring that they are operated efficiently. An elevator hall is furnished with equipments such as hall buttons, hall lanterns and chimes. Micro-computers are mounted on the group controller and individual car controllers. As soon as a hall button in the elevator hall is pressed, a grorp controller registers the hall call, assigns the hall call to the optimum elevator in the group. Then, an assignment signal to the hall call is inputted to the car controller of the selected elevator. In the hall, as soon as the elevator hall button is pressed, the hall lantern is illuminated and the chime rings, by which the assigned car is predicted.

The most fundamental function of the group control is to find out a elevator which is considered most appropriate to serve the registered hall call among all elevators within the group. It is important to make the decision of the optimal elevator according to the traffic flow in the building.

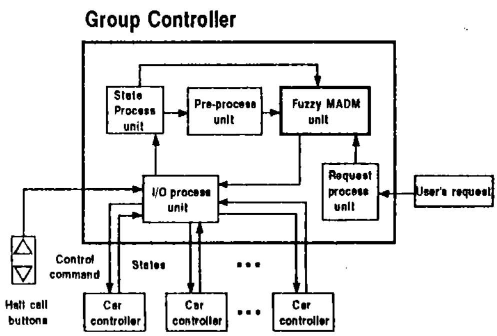


Fig. 1 Configuration of the group controller

Configuration of the elevator grorp controller is shown in Fig.1. The I/O process unit deals with time-varying traffic data, such as the number of passengers in each elevator cage and number of hall calls and each elevator status, call assignment and home landing command.

The learning unit classifies the present situation according to traffic modes, such as peak traffic, balanced traffic, etc, then calculates traffic flow data, such as stop probability and reversing floor and the predicted number of incoming/outgoing passengers.

The pre-process unit estimates evaluation fuzzy inputs of control goals with the uncertain information of the system. The uncertainty main results from and car call generated by serving hall calls. The new system has three control goals - minimizing average waiting time, minimizing long waiting time, saving encrage.

Assuming that an estimated fuzzy input of goal 1(minimizing average waiting time) is indicated by U_{1i} and each hall call's increased waiting time after serving new hall call is TW_{ik}. U_{1i} and TW_{ik} are represented by triangular fuzzy number consisted of min, mean, max value. U_{1i} is expressed by the following formula.

$$U_{1i} = \sum_{k} TW_{ik} \qquad (1)$$

wherein i denotes alternative elevator and Σ denotes fuzzy sum and k denotes the floor number of registered hall call.
Assuming that an estimated fuzzy input of goal 2(minimizing long waiting time) is indicated by U_{2i}. It is expressed by the following formula.

$$U_{2i} = \sum_{k} LW_{ik} \qquad (2)$$

wherein LW_{ik} denotes fuzzy set of each hall call's increased long waiting time which is longer than reference time of long waiting after serving new hall call.
Assuming that an estimated fuzzy input of goal 3(energy saving) is indicated by U_{3i}. It is represented by triangular fuzzy number consisted of min, mean, max value of increased riding length.

The request unit caculates goal's weight corresponding to user's request by Saaty's AHP method using eigenvector. User's requests are described numerically in exprecession as weighted norm.

The fuzzy MADM unit decides which of the elevator is suitable for responding the hall call registered by passenger. Fuzzy rating of each control goal can be obtained by projecting fyzzy input to goal function. The goal function of each goal is changed by traffic situation. Then, the fuzzy final rating, which indicates the degree of desirability with respect to relevant goals, is obtained by using fuzzy ratings and weight of goals. The fuzzy final rating of alternative elevator has to be ordered, because it is represented by fuzzy set. This process is called ranking. Finally, it is decided that the optimal alternative elevator which has maximal final rank.

3. FUZZY MADM METHOD

The aim of fuzzy MADM is to determine the optimal alternative elevator with the highest degree of desirability with respect to all relevant goals. The elevator group control model of multi-attribute decision making can be described as follows. Let A = $\{a_i\}$, i = 1,2,...n, be a set of alternative elevators, and X = $\{x_j\}$, j = 1,2,3, be a set of goals(minimizing average waiting time, minimizing long waiting time, energy saving), and G = $\{g_j\}$, $g_j = \{(u_j, \mu_{gj}(u_j))\}$, be a set of goal functions, and R_{ij} be the fuzzy rating of alternative a_i with respect to goal x_j, and W_j be a fuzzy set of goal weight which is decieded by user request.

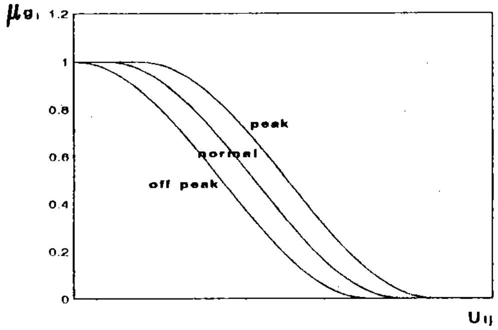


Fig. 2 The goal function

The goal function g_j is shown in Fig.2. The goal function g_j is changed with traffic mode. This means the degree of desirability to goal is changed according to the traffic mode.

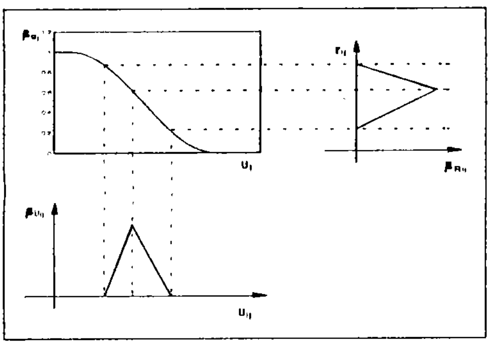


Fig. 3 The relation between the fuzzy rating and the fuzzy input

The fuzzy rating R_{ij} can be obtained by projecting fuzzy input $U_{ij} = \{(u_{ij}, \mu_{U_{ij}}(u_{ij}))\}$ represented fuzzy triangular number to goal function. The fuzzy rating R_{ij} is represented in unit interval I. Assuming that N(l,m,n) is a set of triangular fuzzy number , then it's membership function is as follows.

$$\mu_{N'}(x) = \begin{cases} \frac{1}{m-l}x - \frac{1}{m-l} & , x \in [l,m] \\ \frac{1}{m-n}x - \frac{n}{m-n} & , x \in [m,n] \\ 0 & , otherwise \end{cases} \quad (3)$$

The relation between the fuzzy rating and the fuzzy input is shown in Fig.3. The membership grade of fuzzy rating R_{ij} means that alternative elevator a_i has the degree of desirability with respect to goal x_j. In the case that R_{ij} and W_j are crisp value, final rating R_i which indicates the degree of desirability of alternative elevator a_i with respect to all relevant goals can be obtained easily using Kahn's model as follows.

$$R_i = \frac{\sum_{j=1}^{m} w_j r_{ij}}{\sum_{j=1}^{m} w_j} \quad (4)$$

In this case, the optimal alterative is that for which R_i is maximal. But fuzzy final rating $R_i = \{(r, \mu_{R_i}(r))\}$ is represented by fuzzy set, because fuzzy rating and weight are fuzzy set. If the weight of control goal is inputed by comparative weight, the comparative weight has to be converted into absolute weight using AHP method. The element c_{ij} of comparative matrix C represents the importance of goal i compared with j. The geometric average of each control goal, m_i, can be obtained as follows.

$$m_i = \left(\prod_{j=1}^{3} c_{ij}\right)^{1/3} \quad (5)$$

The weight of each goal can be represented as following formula.

$$w_i = \frac{m_i}{\sum_{i=0}^{3} m_i} \quad (6)$$

The consistency index (CI) of comparative matric C is defined as follows.

$$CI = \frac{\sum_{i=1}^{3} w_i/3 - 3}{2} \quad (7)$$

When CI is less than 0.15, the comparative matrix C can be converted.

In the case that weight is presented by fuzzy set ,to obtain R_i, mapping fuction $f(z)$: R^{2m}-> R is defined as follows.

$$f(z) = \frac{\sum_{j=1}^{m} w_j r_{ij}}{\sum_{j=1}^{m} w_j} \quad (8)$$

where $z = (w_1, w_2, \ldots, w_m, r_{i1}, r_{i2}, \ldots, r_{im})$.

In space R^{2m}, membership function μ_{Z_i} is defined as follows.

$$\mu_{Z_i}(z) = \min\{\min_{j=1}^{m}(\mu_{W_j}(w_j)), \min_{j=1}^{m}(\mu_{R_{ij}}(r_{ij}))\} \quad (9)$$

Fuzzy final rating R_i can be obtained using mapping function as follows.

$$\mu_{R_i}(r) = \max_{z:f(z)=r} \mu_{Z_i}(z) \quad (10)$$

It is laborious to obtain fuzzy rating R_i by using above fomulas. As fuzzy rating and weight are represented by fuzzy triangular number, can be described as follows.

$$R_{ij} = N(rl_{ij}, rm_{ij}, rn_{ij})$$
$$W_j = N(wl_j, wm_j, wn_{ij}) \quad (11)$$

Fuzzy-final rating R_i can be obtained easily as follows. bv epresented by We modify Kahn's model as follows to deal with fuzzy rating R_{ij}.

$$R_i = N(rl_i, rm_i, rn_i)$$

$$rl_i = \frac{\sum_{j=1}^{m} rl_{ij}\, wl_j}{\sum_{j=1}^{m} wl_j}$$

$$rm_i = \frac{\sum_{j=1}^{m} rm_{ij}\, wm_j}{\sum_{j=1}^{m} wm_j} \quad (12)$$

$$rn_i = \frac{\sum_{j=1}^{m} rn_{ij}\, wl_j}{\sum_{j=1}^{m} wn_j}$$

A $R_{i\alpha}$, α-level set of R_i, can be expressed as follows.

$$R_{i\alpha} = [\alpha(rm_i - rl_i) + rl_i,\ \alpha(rm_i - rn_i) + rn_i] \quad (13)$$

Assuming that $Av(R_{i\alpha})$ is the average value of $R_{i\alpha}$, order set $O = \{(a_i, \mu_O(a_i))\}$ with membership function

$$\mu_O(a_i) = \int_0^1 Av(R_{i\alpha})\, d\alpha = \frac{2rm_i + rl_i + rn_i}{4} \quad (14)$$

can be obtained.

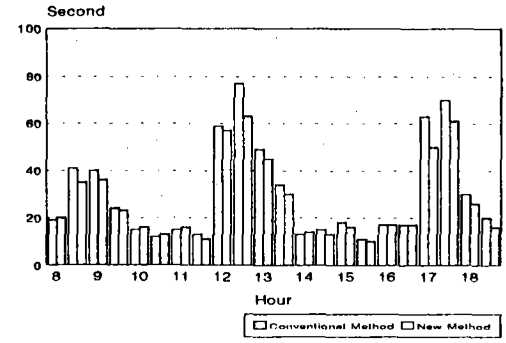
The optimal elevator, a^o, having the biggest membership grad can be determined as follows.

$$a^o = \max_i \ \mu_O(a_i) \quad (15)$$

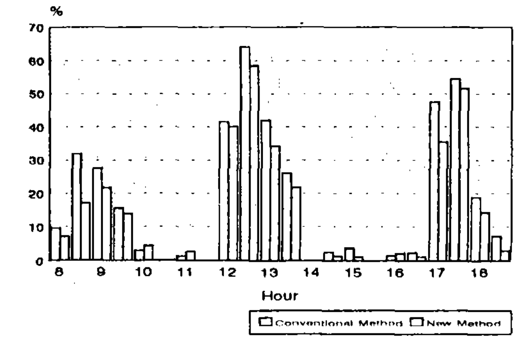
4. SIMULATION RESULT

Since the movements of groups of elevators responding to traffic flow within a building are complicated, the computer simulation of elevator operation is effective for the evaluation of group supervisory control system.

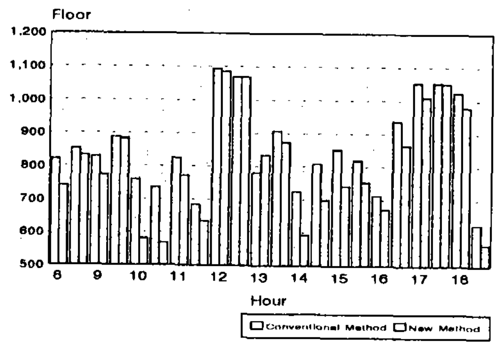
Simulation condition is shown in Table 1, simulation result is shown in Table 2. Simulation was performed with the real traffic data of certain office building.



(a) Average Waiting Time



(b) Occurrence of Long Wait



(c) Moving Distance

Fig. 4 Comparison of Control Goals

Table 1. Simulation Conditions

Item	Condition
Number of elevators	4
Elevator speed	150 m/min
Elevator capacity	24 person
Number of survice floors	17 (B1 , 1-16)
Robby floor	1st floor

Table 2. Simulation Result

	Conventional System	New System	Percentage of reduction
Average waiting time	39.03 sec	34.50 sec	11.61 %
Occurrence of long wait	611 hc	518 hc	15.22 %
Moving Distance	18849 fl	16876 fl	10.47 %

Comparing the proposed method to conventional method using fuzzy rule base, average waiting time was reduced about 12%, the occurrence of long wait was reduced about 15%, moving distance was reduced about 10%. Fig. 4 shows the comparision of control goals for one day, (a) shows average waiting time (a), and (b) shows occurrence of long wait, and (c) shows moving distance. In Fig. 4 the formal bars indicate conventional system using fuzzy rule base, and the later bars indicate new system using fuzzy MADM.

5. CONCLUSION

In this paper, the new elevator group supervisory method which controls selection of cars assigned for hall calls through fuzzy MADM has been proposed. The new system reduces not only average wating time but also long wating time and energy saving. This system satisfies several control goals, according to user's request. The elevator group supervisory control system with fuzzy MADM have a short response time that correspond to high elevator system, because it does not treat the knowledge base or fuzzy rule base which takes time.

6. REFERENCES

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