Fifth IFSA World Congress (1993), 1374-1377

Predictive Fuzzy Control for Elevator Group Supervisory System

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Abstract In this paper, a predictive fuzzy control algorithm to supervise the elevator system with plural elevator cars is developed and its performance is evaluated. Elevator group controller must decide which of the cars is suitable for responding the registered hall call and allocate it to the selected car controller. In most cases, the purpose of group control is to minimize waiting time of passengers and occurrence of long wait as much as possible. The proposed algorithm ensures the efficient operations of the group cars and provides the improved level of service, coping with multiple control objects and uncertainty of system state. The feasibility of the proposed control algorithm is evaluated by graphic simulator on computer.

I. Introduction

An elevator group supervisory system is used to supervise the operation of plural cars organically as a group on the purpose of enhancing the operation efficiency of the elevators[1]. In the elevator system with plural cars, the system performance is potently affected by the method of hall allocation. Elevator group controller must decide which of the cars is suitable for responding the hall call registered by a passenger pressing a button and allocate the hall call to the selected car controller. In most cases, the purpose of group control is to minimize waiting time of passengers and occurrence of long wait as much as possible.

By the popular hall allocation methods in conventional systems, the waiting time for each floor calculated by microprocessor is estimated and service elevator for the hall call is adopted at each hall call occurrence[2]. These methods does not follow change of the trafic flow[3] and have only one control object at a time. Furthermore, the informations of the system used to calculating waiting times are so uncertain that the decision of group controller may contain some errors.

A predictive fuzzy conrol algorithm is proposed to deal with these problems and to ensure improved system performance. General fuzzy control rules utilize the measurable values of system as control inputs of fuzzy rules. In predictive fuzzy control, real-time simulation is performed with respect to all possible modes of control, and the resultant controls are predicted. The predicted results are then utilized as the control inputs of fuzzy rules[4][5].

The feasibility of the proposed control algorithm is evaluated by graphic simulator on computer. This graphic simulator is operated according to traffic data of building, and waiting time and occurrence of long wait are obtained. This results is compared with those of conventional group control algorithm, and predictive fuzzy logic controller is implemented.

II. Elevator Group Control

The general structure of elevator group supervisory system is shown in Fig. 1. In an elevator system, there are two types of passengers' request; hall calls and car calls. A hall call is registered at each hall and represents only the direction to which a passenger at the hall want to move. A car call registered in a car represents the destination of passenger in the car.

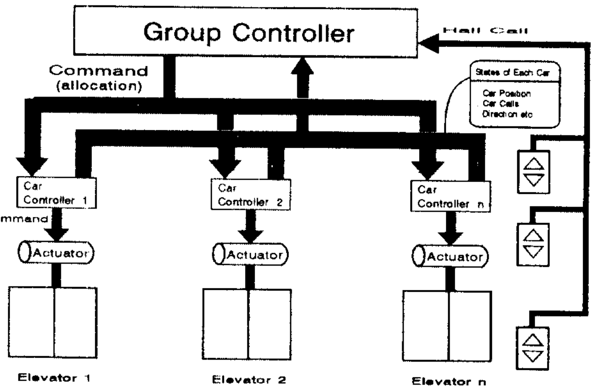


Fig. 1 General Structure of Elevator Group Supervisory System

A car controller in the system controls the motion of the corresponding car and transfers information about states of the elevator to group controller. The states of each elevator from car controller and hall calls from each floor are considered by group controller. Then group controller predicts the values to be estimated, decides the service elevator for each hall call according to control object, and allocate the hall call to the selected car controller.

In order that efficient operation of the system is ensured, group controller must take into consideration of the following three factors at the same time : 1) the current states of system(positions and directions of cars, car calls registered in each car, overlaoded car, etc.), 2) possible state in the case of allocating new hall call to a car, and 3) waiting time of each hall call. But, uncertainity of system state and trade-off relation among control objects make group control complicated.

For example, assume that a two-car sysem is on the situation as shown in Fig. 2; car 1 is passing the kth floor to serve a hall call at the ith floor, and car 2 is idle at the first floor.

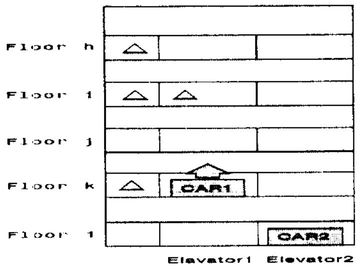


Fig. 2 The Operation of Two-car System

(1) If a hall call be registered at the hth floor(i < h), it will be very difficult and uncertain for group controller to predict waiting time of the new hall call in case that car 1 serve it. This difficulty result from lack of infomation. In that situation, group controller cannot know how many car calls are spread by serving hall call at the ith floor and where the car calls are sperad to. But, the numbers and the positions of the car calls to be spread may have an influence on waiting time of hall call at the hth floor.

(2) If a new up direction hall call be registered at the jth floor(k<j<i), the waiting times of the ith and the jth floor will have trade-off relation. The waiting time of the passenger at the jth floor is minimized by allocating the new hall call to car 1. It causes the waiting time of the passenger at the ith floor to be increased. To minimize the waiting time of hall call at the ith floor, the new hall call at the jth floor must be allocated to car 2. It makes the passenger at the jth floor wait more than allocating the new hall call to car 1.

(3) Let the new hall call at the jth floor in (2) be allocated to car 2 and the car start to serve it, then if a hall call be registered at the first floor, the waiting time of passenger at the first floor would be rather long.

The uncertainty mainly results from the mutual influences among all the hall calls and car calls in elevator system. To allocate a new hall call to a car may increase waiting time of some other hall calls of the car and cause longer waits. Car calls generated by serving a hall call have an influence on waiting time of other hall calls. The directions and positions of cars changed by allocation of a given hall call may also effect the waiting time of hall calls which will be registered after that time.

III. Predictive Fuzzy Control Algorithm

A predictive fuzzy conrol rule proposed in this paper may be expressed as follows:

$$\text{Rule } ij \quad \text{If } (u \leftarrow j,\ x \text{ is } A_i \text{ and } y \text{ is } B_i) \quad \text{then } u \leftarrow j \text{ is } C_i. \quad (j = 1, 2, \cdots, n) \tag{1}$$

This predictive fuzzy rule can be interpreted as "in the case of virtually allocating the new hall call to car j, if the parameter x is Ai and y is Bi then suitability of allocating the hall call to car j is Ci." Here, parameter x, y is predicted value through real-time simulation, Ai and Bi and Ci are linguistic variables of the fuzzy rule, and n is the number of elevators attatched to the system. The Schematic diagram of the proposed group control is shown in Fig. 3.

In this paper, the purposes of group control are minimizing average waiting time, minimizing occurrence of long wait, and energy saving. These three control objects have trade-off relation one another.

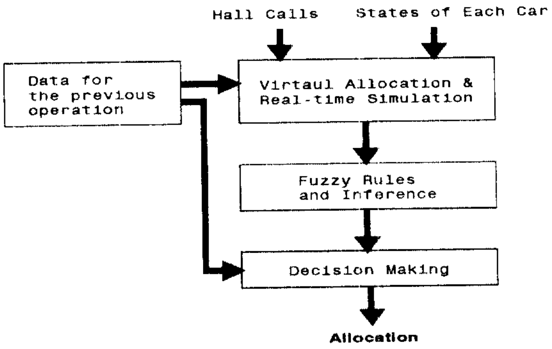


Fig. 3 A schematic diagram of the group control

1. *Real-time Simulation*

Real-time simulation is perfomed to predict the results of all possible modes of controls. Out of the results, the values to be estimated are obtained. The real-time simulation in this paper utilizes data for the previous operation to forecast the changes of system states.

In this paper, the forecasted system states are probability of stop for each floor and reverse floor. Probability of stop P_{ijk} is the probability which car i is to stop at the kth floor dur to car calls spread by hall call at the jth floor. Reverse floor F_i is the floor where direction of car i is reverted.

Referring the forecasted states of system, real-time simulation is accomplished by virtually allocating new hall call to every car and computing the values of desired parameters. Fuzzy control rules use the parameter values as the control inputs. In this paper, six kinds of papramer to be estimated are obtained by real-time simulation. In case that a new hall call is virtually allocated to car i, these parameters are as follows;

Waiting time of the new hall call(T_{1i}) : The parameter T_{1i} means the predicted waiting time of new hall call.

The longest waiting time(T_{2i}) : T_{2i} is the longest waiting time among the those of the hall calls already allocaed to car i.

Waiting time to be increased(T_{3i}) : T_{3i} is the total increment of waiting times of all hall calls already allocaed to car i.

Time of long wait to be increased(T_{4i}) : T_{4i} is the total increment of waiting times of all hall calls which are already allocaed to car i and will occur long wait.

Trajectory to be increased(T_{5i}) : T_{5i} is the increment of moving distance for car i due to the virtual allocation.

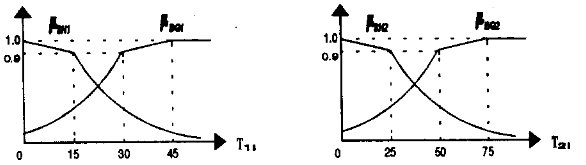
Bunching factor(T_{6i}) : T_{6i} is the evaluated value to represent the positons and the direction of cars. In this paper, T_{6i} has a real value between 0 and 40.

2. Fuzzy Rules and Inference

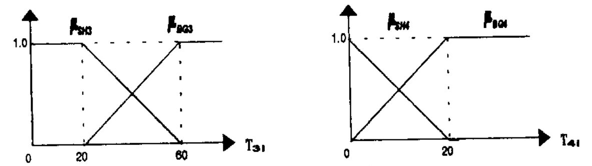
It is difficult that a fuzzy rule considers six kinds of parameter at a time. Thus, in this paper, only two kinds of contrastive parameter are involved in a fuzzy rule. The proposed fuzzy rules are represented in equations (2)~(13), and the membership functions of input and output variables are shown in Fig. 4. Let Number of cars attatched in system is n, then i = 1, 2, ⋯, n.

Rule 1i If (u <- i, T_{1i} is SM1 and T_{2i} is SM2) then u <- i is PB. (2)
Rule 2i If (u <- i, T_{1i} is SM1 and T_{2i} is BG2) then u <- i is PM. (3)
Rule 3i If (u <- i, T_{1i} is BG1 and T_{2i} is SM2) then u <- i is PS. (4)
Rule 4i If (u <- i, T_{1i} is BG1 and T_{2i} is BG2) then u <- i is ZR. (5)
Rule 5i If (u <- i, T_{3i} is SM3 and T_{4i} is SM4) then u <- i is PB. (6)
Rule 6i If (u <- i, T_{3i} is SM3 and T_{4i} is BG4) then u <- i is PM. (7)
Rule 7i If (u <- i, T_{3i} is BG3 and T_{4i} is SM4) then u <- i is PS. (8)
Rule 8i If (u <- i, T_{3i} is BG3 and T_{4i} is BG4) then u <- i is ZR. (9)
Rule 9i If (u <- i, T_{5i} is SM5 and T_{6i} is SM6) then u <- i is PB. (10)
Rule 10i If (u <- i, T_{5i} is SM5 and T_{6i} is BG6) then u <- i is PM. (11)
Rule 11i If (u <- i, T_{5i} is BG5 and T_{6i} is SM6) then u <- i is PS. (12)
Rule 12i If (u <- i, T_{5i} is BG5 and T_{6i} is BG6) then u <- i is ZR. (13)

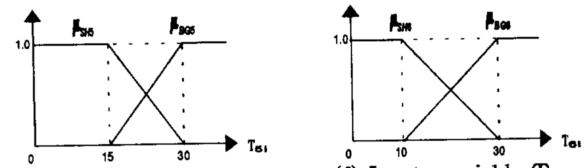
Utilizing the equations (2)~(13), We obtain 3 × n infered values ϕ_{ki}, ϕ_{ki}, ϕ_{ki}(k=1,2,3 and i=1,2,⋯,n). Let Res(x, y) be a resoning function which infers a output value from all fuzzy rules related with parameter x and y. then ϕ_{1i}, ϕ_{2i}, ϕ_{3i} are represented as equation (14) ~ (16).



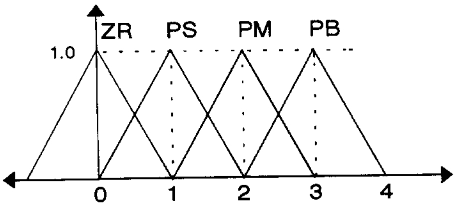
(a) Input varaiable T_{1i} (b) Input varaiable T_{2i}



(c) Input varaiable T_{3i} (d) Input varaiable T_{4i}



(e) Input varaiable T_{5i} (f) Input varaiable T_{6i}



(f) Control output varaiables

Fig. 4 Membership Functions of Control Variables

$$\phi_{1i} = \mathrm{Res}(T_{1i}, T_{2i}) \tag{14}$$

$$\phi_{2i} = \mathrm{Res}(T_{3i}, T_{4i}) \tag{15}$$

$$\phi_{3i} = \mathrm{Res}(T_{5i}, T_{6i}) \tag{16}$$

3. Decision of service elevator

Finally, the suitability of car i for serving a new hall call is represented as equation (17).

$$\Phi_i = \omega_1 \cdot \phi_{1i} + \omega_2 \cdot \phi_{2i} + \omega_3 \cdot \phi_{3i} \tag{17}$$

where, ω_1, ω_2, ω_{3i} are weighting coefficients according to the current traffic condition. Data for the previous operation is involved in determination of the coefficients. The decision of service elevator follows equation (18).

$$u = i, \text{ iff } \Phi_i = \min(\Phi_1, \Phi_2, \cdots, \Phi_n) \tag{18}$$

IV. Simulation

To evaluate the feasibility of the proposed algorithm, graphic simulation is performed on computer. The predictive fuzzy alogorithm is evluated in comparison with a conventional group control algorithm. Two case of traffic is tested and the conditions of simulation is shown in Table 1.

Table 2, 3 show the results of graphic simulation. From the results, average waiting time and occurrence of long wait are improved 27.7%, 68.0% respectivley.

The number of stop is slightly increased, but total moving distance of 4 cars is reduced to 87.5%. It means energy is saved. Fig. 5 shows that movement diagrams of two group control methods for simulation case 2.

Table 1. The Conditions of Simulation

	CASE 1	CASE 2
Number of cars	4 Car	4 Car
Capacity of one car	15 Persons per 10min.	15 Persons per 10min.
Floors	20 Floors	20 Floors
Distance between floors	3 M	3 M
Traffic mode	Balanced	Down-peak
Max. speed of car	120 M/Min.	120 M/Min.
Number of passengers	100 Persons	160 Persons

Table 2. Simulation Results of Case 1

	Conventional Method	Predictive Fuzzy Method
Average Waiting Time	22.3 Seconds	17.2 Seconds
Occurrence of long wait	4 Times	0 Times
Max. Waiting Time	73 Seconds	56 Seconds
Number of Stop	147 Times	147 Times
Total Moving Distance	590 Floors	574 Floors

Table 3. Simulation Results of Case 2

	Conventional Method	Predictive Fuzzy Method
Average Waiting Time	34.0 Seconds	23.5 Seconds
Occurrence of long wait	21 Times	8 Times
Max. Waiting Time	107 Seconds	77 Seconds
Number of Stop	172 Times	178 Times
Total Moving Distance	655 Floors	515 Floors

V. Conclusion

In this paper, a predictive fuzzy control algorithm for elevator gorup control is proposed and evaluated. The purposes of the alorithm are minimizing average waiting time, minimizing occurrence of long wait, and energy saving. These three control objects are at a time. As a results, the ystem efficiency is improved considerably. Average waiting time and occurrence of long wait are improved 27.7%, 68.0% respectivley. With the respect of energy saving, total moving distance of 4 cars is reduced to 87.5%.

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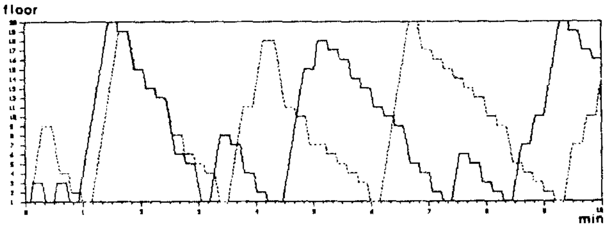
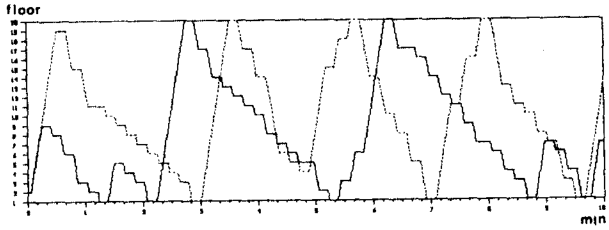
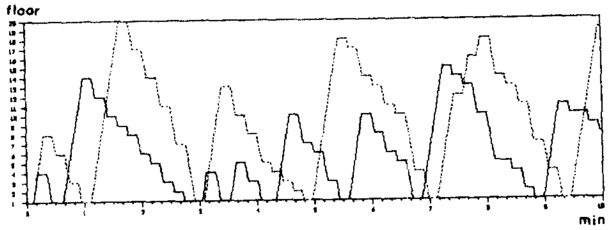


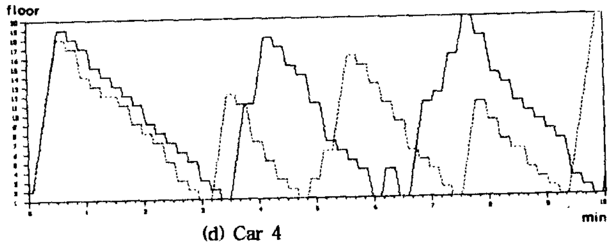
(a) Car 1



(b) Car 2



(c) Car 3



(d) Car 4

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Fig. 5 Movements Diagrams according to Group Control Methods