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Fuzzy approach to elevator group control system

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Abstract: *The elevator group control systems are the control systems that manage systematically three or more elevators in order to efficiently transport the passingers. In the elevator group control system, the area-weight which determines the load biases of elevators is a control parameter closely related to the system performance. This paper proposes a fuzzy model based method to determine the area-weight. The proposed method uses a two-stage fuzzy inference model which is built by the study of area-weight properties and expert knowledge. The proposed method shows the more desirable results than the conventional method in the simulations that use real traffic data.*

1 Introduction

The elevator group control system is a control system that manages systematically three or more elevators in a group to increase the service for passengers and reduces the cost such as power consumptions. Most of the elevator group control systems have used the hall call assignment method which assigns elevators in response to the passenger's call. In this case, the elevator group control system considers the current situation of a building to select the most appropriate elevator.

The hall call assignment method assigns a new hall call to the elevator having the smallest evaluation function value among the all elevators. The area-weight is a parameter which decreases the evaluation-function value of the elevators in the area close to the hall call. The area-weight is one of the most important variable in the evaluation function which affects the system performance.

Some methods to obtain the area-weight have been proposed in [5][6][7]. [5] and [6] used the area-weight defined in advance according to passenger's traffic patterns. In [7], the area-weight is determined by simulation method. However these methods have some problems in determining the appropriate area-weight because of not only the system complexity but also the uncertain factors such as a passenger's arriving time on each floor, the destination floors of passengers and the time for taking on and off elevators.

In general, when the system complexity is high and the correct prediction of system state is not easy, it is difficult to make a model to control the system. Therefore, the approximation methods based on the fuzzy theory have been used[1]. In this paper, the fuzzy model is used in describing the system state and expert knowledge, and the fuzzy inference method is used in determining the area-weight parameter. In the experiment, the inference methods using fuzzy theory have shown good results[2][3].

In section 2, we describe the elevator group control system and the area-weight of the control system. In section 3, we propose a fuzzy model to determine the area-weight, and its performance is analyzed through the simulation in section 4.

2 Elevator group control system

2.1 The elevator group control system

In the elevator group control system, there are two types of calls. The hall call is given through buttons on the hall of building, and the car call in the elevator by the passingers. An elevator group control system has a pair of hall call buttons on each floor. One for up hall call and the other for down hall call. If a passenger presses a button, an elevator is selected by the group control system for the passinger. The elevator group control system has to consider many informations about both the current and future state of the elevator system. In this step, we can know the current informations such as the position of each elevator and the hall call's and car call's allocation states , but not the informations such as the number of passingers where a hall call happened. Futhermore the information about the future hall calls and car calls are uncertain. Therefore it is difficult to determine a appropriate service elevator when a call is happened.

The most important thing of elevator group control system is to select a suitable elevator for each passenger's hall call. This selection is made in order to minimize the average waiting time of passingers, the long wait probability(the probability which a passinger waits for a long time), and the power consumption. This selection method is called the hall call assignment method. In the hall call assignment method, the evaluation function is used to achieve the above multiple objects.

The function is evaluated for each elevator and the elevator with the smallest function value is selected. Let $\phi(k)$ be the evaluating function value for the k-th elevator, then this function is represented as following formula.

$$\phi(k) = k_1 \cdot T_{AVR}(k) - \alpha \cdot T_\alpha(k) + k_2 \cdot T_E(k)$$

When a new hall call is given, the function value is evaluated for the k-th elevator where k=1,...,n. In the above formula, $T_{AVR}(k)$ is the estimated arriving time of the k-th elevator, which is the service time of the elevator for the new hall call. $T_\alpha(k)$ is the area value. If a new hall call is generated on the floor where the k-th elevator is going to stop, the area value is subtracted from the evaluating function value of k-th elevator. Therefore the probability of selection of k-th elevator is increased. We call $T_\alpha(k)$ the area value and α the area-weight and it is determined when a hall call is generated. $T_E(k)$ is the elevator's status value. This value is added to prevent to select the k-th elevator if there exists wheelchair call(handicaped person's call) or the k-th elevator is not running.

2.2 The area-weight

If an elevator k is going to a floor n, the area of the elevator k for the floor n is defined. When a hall call is happened in this area, our fundamental strategy is to select the considered elevator k for the call. The area represents the range(floors) which can be served easily by the elevator. The area-weight is the value to increase the assignment probability for the elevator which is going to the floor where the hall call was generated.

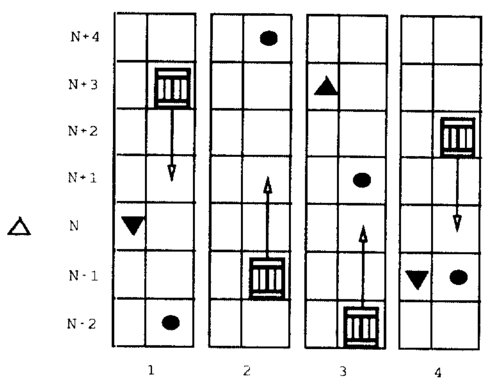

Figure 2.1: example of the area-control

Figure 2.1 shows a situation of 4-grouped elevator system. In this figure the arrow represents direction of each elevator. The black circle indicates where the car call was happened for the elevator. The black triangle represents the hall call which will be serve by the elevator. Finally, the new hall call generated on the floor is marked by the white triangle. For example in the figure 2.1 the 1-st elevator has a car call on the n-2 floor and is assigned to the hall call of N floor. A new hall call is happened on the floor N, but it is not yet assigned to any elevator.

If an elevator is assigned to serve a call on a floor, the area of the elevator on the floor is defined. In general the area is defined in the form of a triangle or a trapezoidal as shown in Figure 2.2. In figure 2.2(b), the trapezoidal area of elevator k on the floor n is given. We can see that the area value $T_\alpha(k) = 1$ for the floor $n, n+1, n-1$, $T_\alpha(k) = 0.5$ for floor $n+2, n-2$, and $T_\alpha(k) = 0$ for the others. The area value $T_\alpha(k)$is defined for the floors where a call(hall and car) is happened.

The following formula shows evaluating function values of 2-th and 3-th elevator to select a service elevator. In this case the area value $T_\alpha(k)$ for the 2-th elevator is zero, i.e., $T_\alpha(2) = 0$.

$$\begin{aligned}\phi(2) &= T_{AVR}(2) - \alpha \cdot T_\alpha(2) + T_E(2)\\ &= T_{AVR}(2) + T_E(2)\\ \phi(3) &= T_{AVR}(3) - \alpha \cdot T_\alpha(3) + T_E(3)\end{aligned}$$

Here, let's have assumptions on the state value $T_E(k)$ and the estimated service time $T_{AVR}(k)$ such that $T_E(2) = T_E(3)$ and $T_{AVR}(2) < T_{AVR}(3)$. If $\alpha \cdot T_\alpha(3) < T_{AVR}(3) - T_{AVR}(2)$ then the elevator 2 is assigned, in the contrary case the elevator 3 is assigned.

In the previous example, we can see that $T_\alpha(3)$ is fixed value, and $T_{AVR}(2)$ and $T_{AVR}(3)$ are estimated values. However the value α is calculated whenever a call is generated. Therefore the determination of the value α is important in the hall call assignment method.

If the value α is big, the possibility that the elevator close to the relevant floor can be selected is increased. Consequently, the transportation load may be assigned to a specific elevator which is in the area. Furthermore, the average waiting time increases and the total running frequency of elevators decreases. Therefore the power consumption is reduced. However if α is small, the average waiting time decreases and the running frequency increases.

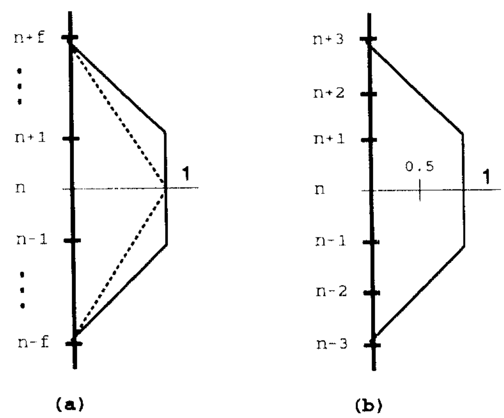

Figure 2.2: example of the area value

In [6], the pre-defined area-weight is used and it is defined according to the traffic modes classified by the passinger's traffic pattern. In this case, it is difficult to reflect traffic changes in the same traffic mode and this method can not consider some important characteristics of different buildings. In [7], the simulation method is used to determine the area-weight. In this method, they simulate the future situation of the system with some predefined area weights and then select the area-weight giving the best performance. As this method simulates with a fixed number of area-weights, we cannot expect a precise control. Furthermore, because the hall call data used in the simulation is forecasted, the simulation may differ from the real situation and the uncertainty of the data reduces the reliability of the model. Therefore, in this study we use the fuzzy approach to model the uncertain situation of the system and to determine the area-weight.

3 A fuzzy model to determine the area-weight

3.1 Fuzzy rules

We classify the facts related with the determination of area-weight into two groups. The first group includes the up-going and down-going traffic amount, and the second group includes the average waiting time, long wait probability and power consumption. However we can see that the area-weight is determined mainly according to the first group factors.

The passenger's traffic varies from hour to hour, and we can see that it is classified into some basic patterns.

- up-peak pattern
  This pattern is the case of which the up-going traffic is very large but the down-going traffic is very small.
- down-peak pattern
  In this pattern, the down-going traffic is much more than the up-going traffic,

Let UP, DN and α' be the up-going traffic, down-going traffic and area-weight respectively. We can represent the traffic (UP, DN) knowledge related to the area weight in the form of fuzzy rules as follows. In the fuzzy rules the words such as VL(Very Large), SM(Small) and MD(Medium) are fuzzy linguistic terms as show in figure 3.2.

If UP is VL and DN is SM Then α' is VS
If UP is MD and DN is SM Then α' is MD
If UP is MD and DN is SM Then α' is VL
If UP is SM and DN is VL Then α' is SM
If UP is SM and DN is SM Then α' is VS
⋮
If UP is MD and DN is MD Then α' is SM

When the traffic is fixed, the average waiting time and long wait probability decrease as the area-weight becomes smaller, on the contrary the power consumption decreases if the area-weight increase. After the first step of determination by the first group factors, the area-weight is adjusted according the second group factors.

Let AWT be the average waiting time, PC be the power consumption and LWP be the long wait probability. And we introduce an adjustment value k which represents the influence of the second group factors. This adjust value will be added to the area-weight α' and give new area-weight α. Then we can represent fuzzy rules as follows. Here, the words NL(Negative Large), ZE(ZEro), PL(Positive Large) are fuzzy linguistic terms as show in figure 3.2.

- average waiting time – area-weight rules($AWT - k$)
  If AWT is VL Then k is NL
  If AWT is SM Then k is PL
  ⋮
  If AWT is MD Then k is ZE
- power consumption – area-weight rules($PC - k$)
  If PC is VL Then k is PL
  If PC is SM Then k is NL
  ⋮
  If PC is MD Then k is ZE
- long wait probability – area-weight rules($LWP - k$)
  If LWP is VL Then k is NL
  If LWP is SM Then k is PL
  ⋮
  If LWP is SM Then k is ZE

3.2 A Fuzzy model

We propose a fuzzy model to determine the area-weight through the two step fuzzy inferences. The inference system uses the fuzzy rules described in the previous section.

The adjust value k is determined through the second step inference using the average waiting time, long wait probability, and power consumption. Finally the addition of the predetermined area-weight α' and the adjust value k will produce a definite area-weight α. Such two step inference improves the system's stability from the external accidents and reduce the complexity of system. Figure 3.1 shows the two step fuzzy inference mechanism.

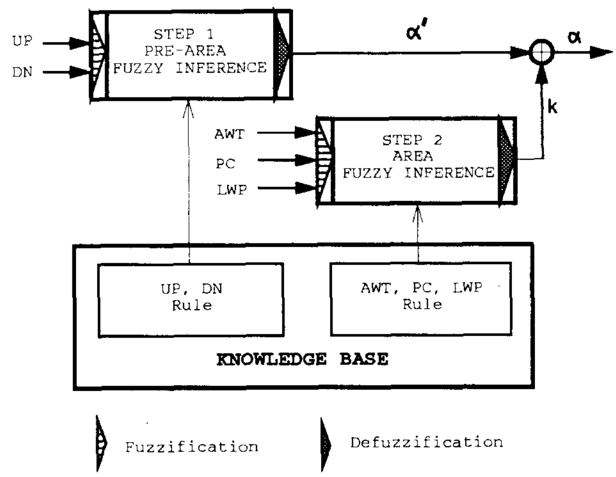

Figure 3.1: The fuzzy model to determine the area weight

In step 1 fuzzy inference engine, the predetermined area-weight $\alpha'$is calculated by using the up-going(UP) and down-going(DN) traffic. In this step the Mamdani's max-min inference method is used with the rules presented in section 3.1. The result of the inference is obtained through defuzzification using the center of gravity method[4].

In Step 2 th adjust value k is determined through the fuzzy inference using the average waiting time, the long wait probability and the power consumption. After the defuzzification of the result of second inference, this value is added to the predetermined area-weight.

The figure 3.2 shows a inference example of the proposed fuzzy model when the up-going traffic is 200, down-traffic 800, average waiting time 40, long wait probability 60 and power consumption 60.

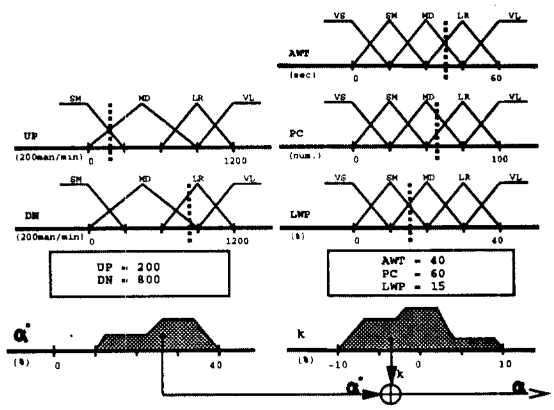

Figure 3.2: A inference example of the proposed fuzzy model

4 Experimental results and analysis

We implemented a simulation environment to evaluate the proposed elevator group control system's performance. In the simulation environment we used the real hardware of an elevator group control system and developed a car emulator which simulates the elevator's moving and operations.

We simulated our fuzzy model based elevator group control system and the conventional system in our simulation environment and compared them. The conventional system is a product which used the pre-defined area-weight method[6]. For the simulation, the real traffic data of the Twin building in Seoul was used.

table 4.1: The condition of simulation

number of floors	18
number of elevators	6
elevator speed	180 m/min
elevator capacity	24 man
simulation time	12:00 ~ 15:00
simulation data	twin building, April, 1992

table 4.2: The simulation result

		conv.	prop.	improve(%)
AWT (0.1sec)	12:00~12:40	238	202	17
	12:40~13:20	248	246	1
	13:20~15:00	240	218	10
	12:00~15:00	242	221	9
PC (# of run)	12:00~12:40	44	48	-9
	12:40~13:20	47	46	2
	13:20~15:00	54	51	5
	12:00~15:00	50	48	4
LWP (0.1%)	12:00~12:40	83	51	62
	12:40~13:20	94	86	9
	13:20~15:00	69	68	1
	12:00~15:00	82	68	20

The condition of simulation is shown in the table 4.1. According to the traffic pattern, the simulation situation is divided into some periods such as before lunch time(12:00 ~ 12:40), after lunch time(12:40 ~ 13:20) and common time(13:20 ~ 15:00). The evaluation factors are mean of the average waiting time, power consumption and average long wait probability. The simulation results represented by these evaluation factors are shown in the table 4.2.

As shown in table 4.2, in the case of heavy traffic(for example, before and after lunch time) our model shows a tendency that the average waiting time and long wait probability are decreased but the power consumption is increased a little. But in the small traffic(common time) we can see that all factors are improved. The comparison in total region from 12 hours to 15 hours shows that the average waiting time is improved by 9%, the power consumption by 4% and the long wait probability by 20%.

5 Conclusions

In this study the fuzzy approach was used to determine the area-weight which is one of the most important parameter of the hall call assigment method in the elevator group control system. We examined effects of the area-weight on the elevator group control system and represented the expert's knowledge about it. By using the knowledge the fuzzy inference model was built to determine the area-weight. To analyze the performance of the system, we simulated the proposed system and conventional system. We could see that our system improved in the system performance by 10 ~ 20% comparing with the conventional method.

The developed system was commercialized in 1992 by the GoldStar industry system co. and this product has the good reputation in the market. In this study, the area-weight was determined by the fuzzy approach. In the further study we will apply the same approach to other variables.

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