OPTIMIZATION OF ELEVATOR GROUP CONTROL SCHEDULING WITH MULTI-STRATEGY SWITCH

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Abstract:

Research on the elevator group control strategy has important significances towards to improving efficiency and reducing energy consumption of elevators. In order to optimize the performance of elevator group control system (EGCS) and offer excellent service to passengers, the elevator group control scheduling method based upon known-waiting passengers and multi-strategy switch is proposed in the paper. The number of the passengers who are waiting for elevators can be obtained through detecting device, which is called passive pyroedetric infrared sensor device for body detection. The feasibility of the scheme is validated by subarea experiment. In this way, the traffic mode of the EGCS can be judged in real time. There are two scheduling algorithms based on fuzzy control theory developed in the paper. The multi-strategy switch method is used to schedule elevators when there is new call according to traffic. So the optimization allocation of scheduling algorithm is realized. The results show that the performance indices of EGCS are optimized and the efficiency of EGCS is improved.

Keywords:

Elevator group control; Known-waiting passengers; Scheduling; Fuzzy control; Traffic mode

1. Introduction

Several elevators are installed in modern buildings, which compose of elevator group. The optimization control of elevator group is realized by elevator group control system (EGCS)[1~3]. Many kinds of solutions aiming at optimization scheduling for elevator group have been proposed, which are mainly on applying intelligent control methods, including fuzzy control[4~6], neural network[7], fuzzy neural network[8] and genetic algorithm[9]. With the purpose to improve the running efficiency of EGCS, paper [10] presents a fuzzy control method based on multi-rules with weights. As the states of passenger flows are not considered, an elevator group scheduling system like this could not meet the needs of every traffic mode. Paper [11] combines hall call assignment method with area control algorithm[12]. Meanwhile, fuzzy control is used to confirm area weight, and the system performance is enhanced by this way. Although the passenger flows are considered, it is the statistic value of former time which can't reflect the states of passenger flows in real time.

The elevator group control scheduling method based on known-waiting persons and multi-strategy switch is proposed in the paper. A set of passive pyroedetric infrared sensor device is installed on the top of hall door. The number of passengers waiting for elevators in the hall can be acquired in real time through the device. So the exact traffic information can be acquired further, the appropriate scheduling strategy will be adopted according to traffic. The infrared sensor devices have been widely used in military field, industry field, medicine and sanitary field, and environment monitor, but there aren't any reports on the applications of infrared sensor devices in EGCS. The research on the fuzzy multi-rules with weights and the fuzzy area control scheduling algorithm for EGCS has been done. The superiority between two algorithms is validated during up peak mode, balanced mode and down peak mode by simulations. As a result, a criterion is offered for the selection of control strategy due to different traffic states.

2. Visualization of waiting passengers

In the current scheduling strategy of elevator group, generally the assignment of elevators is according to hall call. While in the hall of floor corresponding to new call, the number of passengers waiting for elevators is not known. In other words, maybe there is one people waiting for elevator, and the system will send an elevator to carry him. But when there are more than 50 persons, an elevator is hardly enough, which will make efficiency fall off and probably affect the moods of passengers. In order to obtain

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the passenger flow, the former and the current passenger flow are used to predict future passenger flow by elevator researchers. On the basis of the results, the scheduling strategy is carried out. Obviously, as the passenger flow is achieved by prediction method, the error is existed and the real-time performance is not well. Hereon, the statistic data of passenger flow in real time are obtained by introducing passive pyroedetric infrared technique. Due to the quantity of passengers every time, the traffic mode is confirmed combining with the direction of passenger flow, which is attained by the direction of hall call, the running direction of car. The scheduling strategies are switched in different traffic mode further.

2.1. Visualization device of waiting passengers

The device is composed of the pyroedetric infrared sensors and the fresnel lens. The infrared ray which is send out by the body is utilized by the pyroedetric infrared sensor, and the electrical signal is engendered through the induction. When there is no electrical signal, there is no person before the sensor. Then whether there is a man or not can be judged by the change of the electrical signal. While the fresnel lens are one of the indispensable part to the pyroedetric infrared sensors, the infrared ray sent out by the body is focused on the sensors by the lens. And bland area and high sensitive area come into being in front of the detector. When there are persons going across before the lens, the switch between the bland area and the high sensitive area will be made by the infrared ray sent out by the body. Then the pulse signals are formed, which are sometimes strong and sometimes weak. The sensitivity of the detection is improved with the increasing of the energy range by the better focusing of the infrared ray.

2.2. Subarea experiment

The purpose of the subarea experiment is to establish the subarea for the hall, and every subarea is supervised by a passive pyroedetric infrared sensor device for body detection to show if there is a person or not. The number of the passengers waiting for the elevators can be obtained by summing up the signals from the device.

2.2.1. Subarea scheme

The subarea scheme for a waiting hall of the double elevator is given. The detection range is 3m×6.4m. There are sixteen detectors in all, which are distributed into two rows of eight lines. The range of every subarea is 0.8m × 1.5m. The size of the elevator is supposed as 0.8m×2.1m, and the installed heights of the detectors are 2.15m and 2.2m respectively. The height of the people is supposed as 1.7m, and the detection position is mainly on the head of the passenger. The side view of the subarea is shown as Figure 1.

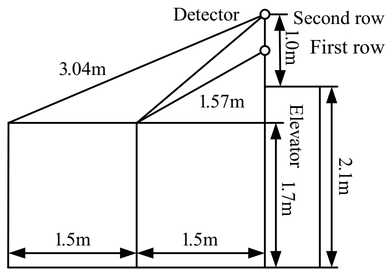

Figure 1. Side view of subarea for hall

The detection range of every detector is ascertained after the scheme is done. Take the character of the fresnel lens and the shape of the field of view into account, the opacity paper is used to cover in the surface of the fresnel lens to prevent the human radiation signal in certain position. The detection range is reduced to a certain area to realize the identification of the human.

2.2.2. Subarea experiment and result analysis

The experiment process is divided into two stages. First, the transverse widths of the detection area are confirmed through the lengthways widths and the narrow gap widths. Then the narrow gap lengths of the first row and the second row are confirmed according to the lengthways widths. The results of the experiments are shown in Table 1 and Table 2.

Table 1 Data of the transverse width in the subarea

Transverse Width (m)		Gap Width (mm)		
		9.3	5.1	5.0
Lengthways Width (m)	0.5	1.90	0.96	0.9
	1.0	1.88	0.9	0.84
	1.5	1.55	0.91	0.8
	2.0	1.20	0.93	0.8
	2.5	1.20	0.84	0.79
	3.0	1.18	0.8	0.78

Table 2 Data of the lengthways width in the subarea

Gap Length (mm)	First Row				Second Row			
	45.0	44.0	42.0	41.4	45.0	44.5	44.0	43.5
Lengthways Width (m)	2.5	2.1	1.7	1.5	2.1	1.9	1.5	1.5

The detection shapes of the detectors are not fan-shaped after the coverage. Along with the increasing of the lengthways width, the transverse width is decreasing gradually. But when the narrow gap is small enough, the transverse width of the detection range no longer changes too much along with the change of the lengthways width.

The sixteen passive pyroedetric infrared sensor devices for body detection which are installed on the top of the hall doors, have a certain area to supervise. When there is a passenger, the high level is sent out. According to the quantity of the high level, the size of the passengers waiting for the elevator can be obtained.

3. Elevator group control scheduling algorithm based on fuzzy control

3.1. Scheduling algorithm of multi-rules with weights using fuzzy control

The EGCS is complicated, nonlinear and multi-objective. Meanwhile, it is also a MIMO control system. Combining with the multi-objective quality, the MIMO system is described by several SISO systems. The performance indices are achieved by the linear weighting of the SISO systems. The evaluation function is:

$$PR(k) = \omega_1 WT(k) + \omega_2 RN(k) + \omega_3 SN(k) + \omega_4 RD(k) \quad (1)$$

Where k is number of the elevator. $PR(k)$ is priority of elevator k. ω_i is weight coefficient.

$WT(k)$ is waiting time. When elevator k responses the new call, $WT(k)$ is time from the current position to the position where the new call happens needed by the elevator.

$RN(k)$ is number of the passengers. When the new call is happening, the number of the passengers in the elevator car is $RN(k)$.

$SN(k)$ is times of the stop. The times of the stop from the current position to the position where the new call is happening needed by the elevator is $SN(k)$.

$RD(k)$ is relative distance. The relative distance from the current position of the elevator to the position where the new call is happening is $RD(k)$.

ω_i represents the importance of the corresponding parameter. According to the experience, the primary performance index is to decrease the waiting time during the peak passenger flow, while in other period the energy saving is the main consideration. The weight value assignments of two traffic modes are shown in Table 3.

Table 3 Weight coefficient of two traffic modes

Parameters	WT	RN	SN	RD
Busy (ω_i)	0.4	0.3	0.1	0.2
Balanced (ω_i)	0.3	0.1	0.3	0.3

When a new hall call is happening, firstly waiting time, number of the passengers, times of stop and relative distance of every elevator corresponding to the new call are predicted through the method designed. Then the priorities on the four parameters are calculated. Finally the priorities of the elevators are compared, and the elevator which has the biggest priority is chose to response the new call. The model of the fuzzy scheduling is shown in Figure 2.

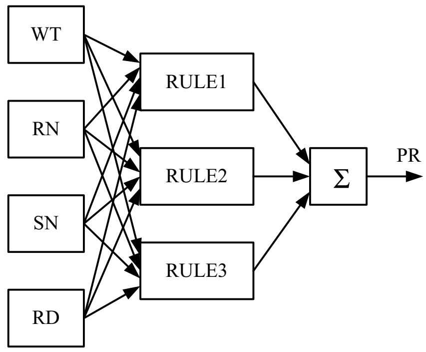

Figure 2. Diagram of multi-rules with weights fuzzy interference system

The input variables and the output variables of the fuzzy rules are given. The triangular membership function is introduced.

$RULE\ 1: IF\ A_i\ is\ S\ THEN\ B_i\ is\ L$;

$RULE\ 2: IF\ A_i\ is\ M\ THEN\ B_i\ is\ M$;

$RULE\ 3: IF\ A_i\ is\ L\ THEN\ B_i\ is\ S$ 。

Where A_i represents the input variable of the fuzzy control, and B_i represents the corresponding priority.

3.2. Scheduling algorithm of area control

3.2.1. Description of area control

Several floors or part of the floors are served by one elevator, and the floors which are not always near to each other constitute the service areas. Every service area has an elevator to serve, and this manner is called area control. The main advantage is that the centralized service can be given to the passengers who have the same terminal. The transportation ability for the passenger flow is improved by this way. In order to describe the area control algorithm, the evaluation function is introduced. Corresponding to every hall call, the evaluation function for every elevator is calculated. And the elevator which has the smallest evaluation function value is chose to response the hall call. The evaluation function is:

$$\phi(k) = T_{AVR}(k) - \alpha T_{\alpha}(k) + T_E(k) \quad (2)$$

Where α is the area weight. $T_{\alpha}(k)$ is area value. $T_{AVR}(k)$ is estimated arrival time, which is the waiting time when the new call is assigned to elevator k.

$$T_{AVR}(k) = \sum_{stop} T_{stop}(k) + \sum_{drive} T_{drive}(k) \quad (3)$$

$$T_{stop}(k) = T_{speed\_down}(k) + T_{get\_on/off}(k) + T_{speed\_up}(k) \quad (4)$$

The movement process of the elevator is divided into run and stop. Run means the floor is not assigned any call to the elevator, while stop means the floor is assigned hall call or car call to the elevator.

$T_E(k)$ is state value of the elevator. When there is a special call (VIP call) or elevator k is in standby state, $T_E(k)$ is increased to reduce the possibility to choose elevator k.

The service area is ascertained when the new call is engendered. Meanwhile $T_{\alpha}(k)$ is determined, which is defined by trapezoidal method or triangular method. As shown in Figure 3, the area value function of elevator k on floor n is given. The dashed represents triangular method, while the solid line represents trapezoidal method. Corresponding to trapezoidal method, $T_{\alpha}(n-1) = T_{\alpha}(n) = T_{\alpha}(n+1) = 1$, $T_{\alpha}(n-2) = T_{\alpha}(n+2) = 0.5$, the area value of other floors are zero.

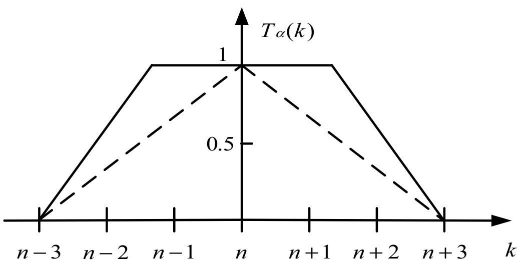

Figure 3. Function of area value

3.2.2. Fuzzy area control scheduling algorithm

The target of the EGCS is to choose an appropriate elevator to response the hall call for passengers. The criterion is to decrease the average waiting time, long waiting percentage and energy consumption. In the traditional area control algorithm, the area weights which are fixed are given only according to the traffic mode. The service needs of the passengers are not considered, which make the service effects worse. Take the passenger flow and the performance indices into account, the area weight is achieved by fuzzy control in order to realize the optimum scheduling for the elevator group.

First, according to traffic mode (including up mode and down mode), the antecedent of the area weight α_1 is obtained. Then according to control target, the consequent of the area weight α_2 is obtained. The evaluation function when the new call is assigned to the elevator k is achieved by equation (2). Finally, compared with the evaluation value of every elevator, the elevator which has the smallest value is chose to response the new call.

The antecedent of the area weight is calculated mainly by considering the effects of the traffic flow, which can be obtained by the quantity of up passengers and down passengers. The quantity of up passengers, the quantity of down passengers and the antecedent of the area weight α_1 are fuzzed, and the fuzzy rule table is given. The triangular membership function is introduced as the membership function. α_1 is divided into five parts, including very small, small, medium, large and very large.

Table 4 Fuzzy rule table of fuzzy area control scheduling

α_1		Up			
		SM	MD	LR	VL
Down	SM	VL	VL	MD	VS
	MD	LR	SM	SM	VS
	LR	MD	SM	VS	VS
	VL	SM	VS	VS	VS

The consequent of the area weight is calculated mainly by considering the service indices of the EGCS, including the average waiting time, the long waiting percentage, and the energy consumption. The energy consumption is indicated by the stop times of the car. The three variables and the antecedent of the area weight α_2 are fuzzed, and the fuzzy rule table is given. The triangular membership function is introduced as the membership function. α_2 is divided into five parts, including negative big, negative small, zero, positive small and positive big.

Table 5 Fuzzy rule

Service Indices	VS	SM	MD	LR	VL
Rule 1: α_2 of AWT	PB	PB	ZO	NS	NB
Rule 2: α_2 of LWP	PB	PB	ZO	NS	NB
Rule 3: α_2 of RNC	NB	NB	ZO	NS	PB

The consequent of the area weight can be achieved by the fuzzy inference above. The detailed description is shown in Figure 4.

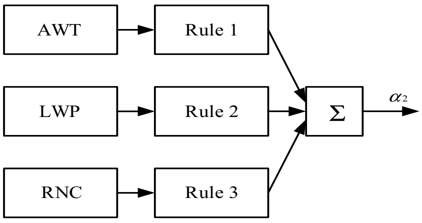

Figure 4. Interference diagram of area weight consequent

4. Simulation research

The simulation experiment is carried through on the simulation platform for the elevator group control. Under the condition that the building and the elevator parameters are accorded, the simulations on the two fuzzy scheduling algorithms and the minimum waiting time strategy are processed. The parameters of the object are set up.

Number of the elevators: $n = 4$ (carrying 15 people)
Nominal cage speed: 3 m/s
Building: 16 stories
Height per floor: 3 m
Maximum acceleration: 1 m/s^2
Door open time: 2.5 s
Door closed time: 1.5 s

The simulation results are shown in table 6, table 7 and table 8. Where algorithm Ⅰ represents minimum waiting time strategy, algorithm Ⅱ represents Scheduling algorithm of multi-rules with weights using fuzzy control, algorithm Ⅲ represents fuzzy area scheduling algorithm. The output parameters includes average waiting time (AWT), maximum waiting time(MWT), long waiting percentage(LWP), average travel time(ATT) and times of stop(TOS).

Table 6 Up-peak traffic mode

	Algorithm Ⅰ	Algorithm Ⅱ	Algorithm Ⅲ
AWT(s)	47.01	42.69	38.34
MWT(s)	73.83	66.23	52.01
LWP(%)	25.90	10.90	9.10
ATT(s)	51.99	32.27	31.62
TOS(time)	173	204	189

Table 7 Balanced traffic mode

	Algorithm Ⅰ	Algorithm Ⅱ	Algorithm Ⅲ
AWT(s)	34.73	32.04	36.37
MWT(s)	85.29	52.00	44.36
LWP(%)	8.70	6.30	7.60
ATT(s)	25.09	22.24	24.32
TOS(time)	211	202	198

Table 8 Down-peak traffic mode

	Algorithm Ⅰ	Algorithm Ⅱ	Algorithm Ⅲ
AWT(s)	53.96	42.44	46.58
MWT(s)	72.10	46.79	57.52
LWP(%)	27.10	13.20	14.30
ATT(s)	30.27	25.93	24.15
TOS(time))	181	203	195

During the heavy traffic mode (up peak and down peak), two fuzzy scheduling strategies are better, all of the performance indices besides the times of the stop are smaller comparing with the minimum waiting time scheduling strategy. While in the balanced traffic mode, all of the performance indices are smaller. Meanwhile, excellent performances are put up during all of the three scheduling algorithms.

The characters of the passengers during the up peak are emphasized particularly on area control strategy based on fuzzy control, so the performance indices are better. The multi-objective is take account on the scheduling algorithm of fuzzy multi-rules with weights, so the whole control effects are better. The average waiting time of minimum waiting time strategy is not the smallest, because the single objective method is adopted. And the waiting time of the passengers is the only control variable, in addition, the finally purpose is to make the waiting time least. Whether the load is reasonable or the journey time is longer are not considered, this is not consistent with the principle of multi-objective control. In a word, the minimum waiting time strategy is only appropriate with the general passenger flow, such as balanced traffic mode.

5. Conclusion

(1) The fuzzy control is applied in the elevator group control system. Meanwhile, two control strategies are developed, including scheduling algorithm of multi-rules with weights using fuzzy control and fuzzy area control scheduling algorithm for EGCS. The traffic information is achieved by adopting the visualization device of waiting passengers, which is called passive pyroedetric infrared

sensor device for body detection. The elevator group scheduling is optimized by the switch of two control strategies according to the traffic information.

(2) When there are much more passengers waiting for the elevators in the entrance hall, this is the up peak traffic mode. When there are much more passengers waiting for the elevators in hall of most floors and most passengers ask for down, this is the down peak traffic mode. Fuzzy area control scheduling strategy is better to adopt in peak traffic mode to obtain better control performance.

(3) When there are less passengers waiting for the elevators in hall of most floors, and the number of the passengers who ask for down or up is approximately the same, this is the balanced traffic mode. Scheduling algorithm of fuzzy multi-rules with weights is better to adopt to obtain better control performance.

(4) The number of the passengers waiting for the elevators in every hall of the floors can be identified in real time by the visualization device of waiting passengers. Based on this, the better results will be obtained to the optimization strategy for elevator group control when the passenger flow is also identified exactly. Furthermore, the structure of the device is simple, and the cost is low. In conclusion, the device of visualization of waiting passengers has the excellent application value.

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