The Research and Simulation on the Elevator Group Control System Scheduling Algorithm

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Abstract- **This paper has done comparison studies on many kinds of scheduling algorithms which have been used in the elevator group control system (EGCS). We focus on the use of fuzzy control algorithm. The process of the establishing simulation model using MATLAB has been given too. Under the same simulation conditions, when the passenger flow in a certain period of time, the number of lift layers and units are all changed, compared with other algorithms, fuzzy control algorithm has lower four evaluation index significantly. The result verify the proposed algorithm can achieve better control of the elevator group control optimization.**

Key words: EGCS、 fuzzy control algorithm 、MATLAB simulation

I. INTRODUCTION

EGCS--Elevator group control system is essential to high-level intelligent building [1]. The Elevator group control scheduling is essentially combinatorial optimization problems which combine an online scheduling, resource allocation and stochastic optimal control. Based on the comparing of the three kinds of algorithms which have been used in the elevator group control scheduling, we focus on the use of the fuzzy control algorithm and the establishing of the simulation model.

II. APPLIED RESEARCH ON EGCS CONTROL ALGORITHMS

A. EGCS Based on Genetic Algorithm

Genetic algorithm is an efficient parallel global search approach for the solution of the problem. It can search for the optimal scheduling solution in the case of multiple calls.

Using genetic algorithm to solve the problem, the variable coding using integer encoding, real number is generally set to the calls floor number. Maximum length of individual populations is 2m-2, (m is the number of the floors). Select two initial populations in order to achieve maximum efficiency. Construct the objective functions, they are the function of waiting time, elevator lift time and energy consumption, specifically described as equation (1), which 'mod' is AWT、ART、RPC respectively. And the objective function of the waiting time described as equation (2). The objective function of lifting time and energy consumption are described as equation (4) and equation (5).

$$F_{\text{mod}}(X)=\frac{1}{n}\sum_{i=1}^{n} f_{\text{mod}}(i,j) \tag{1}$$

$$f_{AWT}(i,j)=\begin{cases}1 & WT(i,j)\le 7\\ e^{-0.002(WT(i,j)-7)^2} & WT(i,j)>7\end{cases} \tag{2}$$

$$WT(i,j)=t_{mov}+t_{stop} \tag{3}$$

$$f_{ART}(i,j)=e^{-0.00077[FT(i,j)]^2} \tag{4}$$

$$f_{RPC}(i,j)=e^{-0.13[n(i)]^2} \tag{5}$$

In the equation(1-5): X is the individual in the populations, n is the length of X, i is the i-th position in X, j is the value of the i position in the X; *tmov, tstop* are the elevator car moving time and anchor time. $FT(i,j)$ is the estimated moving time when respond to the j-th floor elevator call. Time function of waiting elevator, time function of lifting elevator and the time function of energy consumption all can be calculated according to the elevator specific working conditions. $n(i)$ is the number of stops fitness function is constructed by a weighted combination of the objective function in the following equation(6):

$$F(i,j)=T_1F_{AWT}(X)+T_2F_{ART}(X)+T_3F_{RPC}(X) \tag{6}$$

In the equation(6):T_1 is the weight factor of waiting time function，T_2 is the weight factor of lift time function ,T_3 is the weight factor of energy consumption function. The weight factor determined by the elevator group environmental factors.

After the initial population is formed by coding, selection, crossover, mutation operation are put on the population individuals. Finally, when the iterations reach the maximum which is set in advance, the calculation is been terminated. An individual will be evaluated and selected as the optimal solution of the system which has the largest function value.

Genetic algorithm has large calculated workload. In order to ensure real-time scheduling, calculation time must be within the speed permitted, then dispatch the elevator according to the optimal solution.

B. EGCS Based on Forward Neural Network Algorithm

Neural network algorithm aim at the shorter average waiting time, lower long time wait probability and less energy consumption as the optimization target, constructed an evaluation function response group control elevator landing

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call. Use three variables with weighting factor, according to their maximum linear sum to determine elevator dispatching. The evaluation function is defined as equation (7):

$$S_i = W_1\mu_{AWTi} + W_2\mu_{LWPi} + W_3\mu_{RPCi} \tag{7}$$

In the equation : *Si* is the fit grade of the i-th elevator, the greater its value the more preferentially acceptable dispatching signal. *uAWTi* is average waiting time membership grade, the greater the value the greater the possibility to wait a short time. *uLWPi* is the membership grade of lower degree of long waits, the greater the value the lower rate of waiting longer than 60s. *uRPCi* is the membership grade of the less power consumption, the greater its value shows less power consumption. The performance indicators of the neural network learning process are defined in equation (8).

$$-0.01 < J = [S_P(k) - S_m(k)] < 0.01 \tag{8}$$

After getting the output error J of the neural network, using the following equations to adjust the weight factors and make the corresponding network output is closer to expectations[2].

$$V_{ik}(new) = V_{ik}(old) + \alpha J X_{ik} \tag{9}$$

$$W_i(new) = W_i(old) + \alpha J Y_i \tag{10}$$

In the equation (9) and (10): Vik is the connection weight factor between the i-th input layer nodes and the k-th hidden layer nodes. Xik is the input value which from the i-th input layer nodes to the k-th hidden layer nodes .Yi is the input value from the i-th hidden layer nodes to the output layer. Set learning rate α =0.4. In the network learning process, for the three groups of sample data, if all the error J satisfy equation (8)'s determine conditions, the iteration reach the end.

C. EGCS Based on Fuzzy Control Algorithm

The elevator group control system took into account four key indicators which are the average waiting time (AWT), the average reaching time (ART), the long time waiting probability (LWP) and power consumption (RPC) in, and refer to their weighted average function as the evaluation function (11).

$$S_i = W_1 S_{AWT_i} + W_2 S_{LWP_i} + W_3 S_{RPC_i} + W_4 S_{ART_i} \tag{11}$$

Different weight factors on behalf of people's different needs to the elevator group control system under the different transport patterns. The specific parameter of different transport patterns of the elevator group in the building can be got through statistical analysis.

By analyzing the actual traffic type and traffic intensity in the building and with expert knowledge, the weight factors of the control target can be got under different traffic patterns as shown in Table 1.The changes of the traffic intensity impact on the *RPC* weight factor significantly. The change of the traffic type has greater impact on the *AWT\ART\LWP* weight factor significantly [3].

The fuzzy reasoning input variables are *DWT*(the passenger waiting time when the lift reached the call floor),*maxDWT*(the max *DWT*),*NRC*(the remaining capacity for the next call after the lift response to the new call),*LCR*(the concentration ratio of the a new call location in all layers which the elevator responded)and *UR*(the utilization ratio of the upward / down elevator car).

TABLE1 PART OF WEIGHT COEFFICIENT UNDER DIFFERENT TRAFFIC TYPE

Traffic pattern	**weight coefficient**			
	W1 AWT	***W2 LWP***	***W3 PRC***	***W4 ART***
Up rush hour	0.25	0.25	0.10	0.40
Down rush hour	0.40	0.30	0.10	0.20
Heavy between layer	0.35	0.30	0.10	0.25
Down traffic	0.30	0.30	0.20	0.20
Traffic between layer	0.30	0.25	0.25	0.20

After the obfuscation of the input variables ,the credibility of lesser *AWT* can be get by input variables *DWT,NRC* and *UR*, the credibility of smaller *ART* can be get by input variables *NRC* and *UR*, the credibility of lower *LWP* can be get by input variables *maxDWT* and *NRC*, the credibility of smaller *RPC* can be get by input variables *DWT,LCR* and *NRC*. The evaluation criteria *AWT, ART, LWP* and *RPC's* membership can be express by five fuzzy variables which are "very large (VL)", "large (*L*)", "middle (M)", "small (S)", "very small (VS) ",then the membership function of the every evaluation criteria can be obtained .The optimal scheduling algorithm program flow chart is as Fig.1:

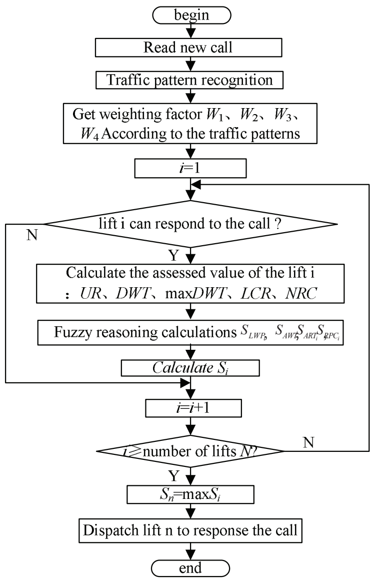

Figure 1. Fuzzy optimal scheduling algorithm flowchart

When a new floor call take place, group control system firstly calls the weight factors of the current traffic pattern to calculate the fuzzy reasoning input values of each elevator which probably response the call. The fuzzy value of each evaluation criteria can be calculated through fuzzy reasoning after obfuscation. Then according to the weight factor under current traffic pattern, the overall credibility for the call of each lift can be calculated, compare and select the lift which own the max credibility to answer the call to achieve optimal scheduling[4].

III. ESTABLISHING THE SIMULATION SYSTEM

A. Establishing Assumptions Constraints

The establishment of the simulation system is based on five points: (1) there is no wrong registration of floor call or the target floor. (2) lift car move at a uniform speed and not fully loaded. (3) The 'internal select dominant' principle. (4) the open time and close time of the lift door are fixed, each passenger has same weight and same time of get in and out. (5) Elevator call response signal must follow the 'direction of the first, forward section ladder' principle.

B. Design of the Smulation Passenger Ttraffic Generator

Passenger traffic generator simulates a real passenger flow on a computer, and provides the group control system with the input data. Passenger information, including arrival time, departure floor, the target floor, which are necessary to the elevator group control system for traffic analysis, group control scheduling and system simulation. Based on parameters set by the users, passenger information can be generated by compiling passenger traffic generator program.

Factor1: the model of passengers' arrival time. Passenger arrival time is the most important passenger information. Elevator passenger arrival process is an approximate Poisson random process. According to the simulation time and the total time, statistics interval number n can be confirmed. Calculate probability of x which take 1 to n according to the Poisson distribution table. The n multiplied by the total number of simulations in turn, then determine the number of passengers on the each time interval, and generate the arrival time of each passenger in the each interval at last, which followed the principle of random distribution [5].

Factor2: the model of passengers' starting floor. Establish the starting floor model , first establish the initial density vector and the start-target matrix. Assume there are N floors in a building, the number of passengers on each floor is $pop(i), i=1,2,\ldots N$. The number of arrival and departure is proportional to the total number of each floor. X,Y,Z respectively on behalf of the percentage of three kinds of passenger traffic, that are upstream traffic, downstream traffic and the traffic between floors. Then the initial density vector and the other station density vector of other layers such as formula (12) and (13) as shown.

$$origin(1) = X \tag{12}$$

$$origin(i) = (Y+Z)\xi_i \quad (i = 2,3,\cdots,N) \tag{13}$$

$$\xi_i = pop(i) / \sum_{i=2}^{n} pop(i) \tag{14}$$

In the formula (13), i denotes the floor number, the first layer is the base station, N is the top station, origin (i) mean the relative traffic flow starting from the i-layer.

The data generating process of the starting floor : calculate Pi ($i=1,2,\ldots N$) --the probability of passengers' request floor.

$$p_i = origin(i) / \sum_{j=1}^{N} origin(j) \tag{15}$$

N-1 range are constructed that are [$0,p1$],[$p1,p2$],[$p1+p2,p3$],…,[$p1+p2+L+PN$-$1,PN$].Generate a random number in interval [0,1] followed the uniform distribution principle. Which interval it falls on, the initial floor of the passengers is just same.

Factor3: the model of passengers' target floor. After determining the density vector of the initial station. Set the start - target matrix as shown in equation (16)

$$\mathrm{OD} = \begin{bmatrix} od(1,1) & od(1,2) & \cdots & od(1,N) \\ od(2,1) & od(2,2) & \cdots & od(2,N) \\ \cdots & \cdots & \cdots & \cdots \\ od(N,1) & od(N,2) & \cdots & od(N,N) \end{bmatrix} \tag{16}$$

Among them, $od(i,j)(i,j=1,2,\ldots,N)$ denotes relatively traffic flow from i-th floor to j-th. When the initial floor i = 1, the elements of distribution matrix are:

$$od(1,j) = \begin{cases} 0 & j=1 \\ \xi_j & j=2,3,\cdots,N \end{cases} \tag{17}$$

When the target floor j= 1, the elements of distribution matrix are:

$$od(i,1) = \begin{cases} 0 & i=1 \\ Y/(Y+Z) & i=2,3,\cdots,N \end{cases} \tag{18}$$

When the initial layer is not same as the target layer, the elements of distribution matrix are:

$$od(i,j) = \begin{cases} 0 & i=j \\ Z\eta_{ij}/(Y+Z) & i \neq j \end{cases} \tag{19}$$

$$\eta_{ij} = pop(j) / \sum_{\substack{i=2 \\ i\neq j}}^{N} pop(i) \tag{20}$$

After making sure the starting floor i, then calculate the selection probability Pij when the target floor is j.

$$p_{ij} = od(i,j) / \sum_{\substack{k=1 \\ k\neq i}}^{n} od(i,k) \tag{21}$$

Calculate the cumulative probability of each floor, construct N-2 intervals, Generate a random number in interval [0,1] followed the uniform distribution principle. Which interval it falls on, the target floor of the passengers is just the same one.

IV. THE SIMULAITON OF EGCS

EGCS simulation models mainly include: parameter setting module, passenger traffic generator module, pattern recognition module, group control algorithm module, simulation module, data recording module and the simulation results analysis module [6].

Building height: 25m,elevator speed: 2.5m/s,car rated load 15 peoples, acceleration 2m/s^2; door open time 0.8s, door close time 0.8s ,passenger transfer time 0.8s, system simulation time 5 minutes. Traffic pattern is the mode between layers, passenger traffic parameters are as follows: $X = 0.3$, $Y = 0.4$, $Z = 0.4$.First enter the number of the elevators and floors number of the building; enter passengers number; record the location of new call and it's target floor. Secondly simulate call signal, including call time, starting floor, the number of passengers and target floor. Estimate the average waiting time, the maximum waiting time, the average lift time and the total number of runs after new call, then the degree of belief be confirm. [5]Call different elevator group control scheduling algorithm, compare evaluation function of each single elevator, dispatching elevator begin with the one whose evaluation function is highest. Finally, the simulation results were analyzed, the algorithm simulation results are listed in table(2)~table(4):

TABLE2 FUZZY CONTROL ALGORITHM SIMULATION DATA SHEET

Arrivals /5min	*average waiting time (s)*	*Max waiting time (s)*	*average lift time (s)*	*total operation number*
20	8.53	32.74	24.10	11
40	18.46	50.82	26.22	19
60	19.47	59.30	31.22	27
80	27.75	70.28	36.16	34
100	49.32	92.54	43.17	47

TABLE3 GENETIC ALGORITHM SIMULATION DATA SHEET

arrivals /5min	*average waiting time (s)*	*Max waiting time (s)*	*average lift time (s)*	*total operation number*
20	8.7	32.93	24.5	9
40	19.56	51.30	27.54	18
60	21.5	61.18	33.78	25
80	29.12	73.32	39.48	33
100	52.26	94.76	46.85	46

TABLE4 FORWARD NEURAL NETWORK ALGORITHM SIMULATION DATA SHEET

arrivals /5min	*average waiting time (s)*	*Max waiting time (s)*	*average lift time (s)*	*total operation number*
20	9.81	35.83	27.54	16
40	21.68	57.65	29.62	22
60	23.75	65.86	37.21	30
80	32.46	79.63	45.33	35
100	56.82	102.23	54.26	51

Figure 3,4,5 respectively show the average waiting time, maximum waiting time, average lifting time and total number of operation by the case of 16-floor and 4 elevators through different algorithms. The compare of some main index of the elevator service performance and service quality is done which showed in figure. With the increase of the passenger arrival rate , the value of various performance indicators were tested exponential growth.

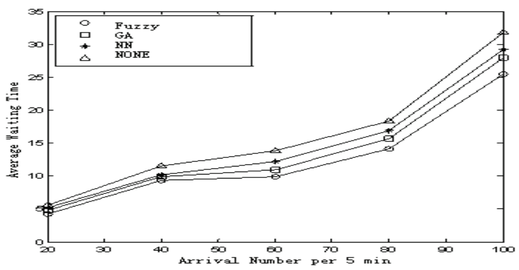

Figure 3 Average waiting time

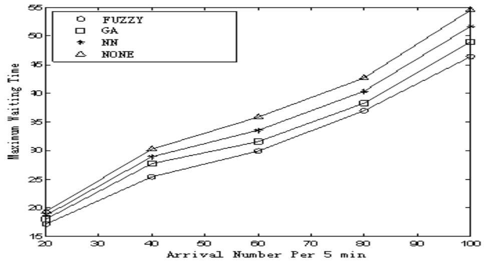

Figure 4 Maximum waiting time

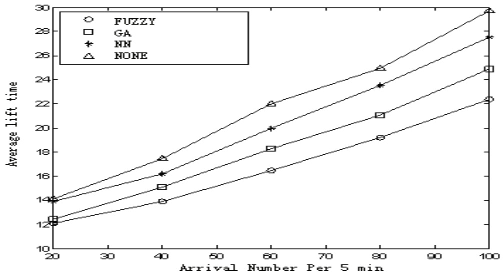

Figure 5 Average lifting time

V. THE CONCLUSION

Based on the in-depth study of several EGCS algorithms. Focus on the design of fuzzy elevator group control algorithm , and the MATLAB comparison simulation done at the same time. Simulation results show that under the same simulation conditions, when the passenger flow in a certain period of time, the number of lift layers and units are all changed, fuzzy control algorithm compared with other algorithms, four evaluation index significantly lower .This result verify the proposed algorithm can achieve better control of the elevator group control optimization.

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