Modeling and Optimizing of Elevator Group Control System with Destination Floor Guidance

Jianzhe Tai, Suying Yang, and Cheng Shao

Abstract—**This paper presents a new modeling of elevator group intelligent scheduling system with destination floor guidance. The traditional input mode of separate hall call registration and the destination selection is improved to a single-input mode that makes the acquired ensemble of hall call communication more determinate and integrated. Meanwhile, the ensemble of hall call communication is regrouped and classified, the prediction algorithms of multi-objective evaluation items are proposed based on destination floor guidance, and Fuzzy Neural Network optimized by Genetic Algorithm is constructed and applied further to fulfill the matching scheduling scheme. Simulated results show that the optimized scheduling algorithm efficiently ameliorates the evaluation items and the scheduling system has the advantaged improvement for overall performance.**

I. INTRODUCTION

The elevator group control system (EGCS) is a typical discrete event dynamic system [1] to which the modeling, analysis, and optimization is intricate to some extent. The dilemma of the traditional EGCS with scheduling strategy is the state information's imperfection and nondeterminacy, the system's randomness and nonlinearity, and the control objectives' diversity. Consequently, although some scheduling algorithms to point against traditional elevator passenger flow pattern have some effect to improve the system performance such as the minimization average waiting time algorithm [2], dynamic zoning algorithm [3], and Artificial Intelligent control techniques [4], they cannot completely resolve the restriction of traditional system itself. However the EGCS with destination floor guidance (DFG) can effectively solve the dilemma of nondeterminacy to destination floor. Simultaneously through maximized utilization to the complete and reliable hall call information it can reduce the system's travelling disturbance and optimize scheduling strategy. At the present time, many scholars have done some systemic researches on the algorithm of single-car elevator system with DFG [5-6]. Through their study, the operation efficiency of the single-car elevator system was improved remarkably under the differently heavy passenger flow patterns by combinatorial optimization to objective function, genetic network programming or dynamic optimization. On the part of EGCS, aiming at its DFG system, many scholars have put forward multi-objective evaluation items, for example passenger complex degree, outside or inside hall call influent factor, and repetition rate of hall call signal etc. The scheduling algorithm was optimized by utilizing some intelligent algorithm such as cellular automation theory and Fuzzy Neural Network (FNN). Yet their validity and optimization of control strategy and the completeness of simulation results require to be improved further.

In this study, based on the proposition of DFG in EGCS, ensemble of hall call communication is studied systematically by regrouping and classifying. Then multi-objective evaluation items are advanced and the model of evaluation items predication algorithm is set up. Since the fuzzy reasoning is lacking in learning capacity and the learning time of neural network is so long that it easily gets into local minimum, Genetic Algorithms (GA) are employed to conduct the training of FNN weights and the optimization of membership functions for EGCS with DFG. Finally, simulated experimental results show that this model can realize harmonious and effective scheduling control at the up-peak passenger flow pattern.

II. ELEVATOR GROUP SYSTEM (EGCS) WITH DESTINATION FLOOR GUIDANCE (DFG)

The management pattern of passenger flow information to traditional EGCS adopts twice-input method for hall call application which means direction selection of hall call registration outside the elevator halls and destination selection inside the elevator halls. This method leads to that the destination floor information of hall call application is uncertain before the passengers enter the elevator and the amount of waiting passengers for each hall call application is also unpredictable. This easily results in the phenomenon of "crowding centralization" and "over-capacity to loss" which reduces the efficiency of scheduling strategy. DFG of EGCS is designed to amalgamate the hall call registration and the destination selection to be a single-input mode with specified floor figure buttons outside the elevator halls for realizing the one-off management which is called destination call registration. Based on it, the system can attain nearly complete and reliable information aggregation in advance, which includes the information such as origination floor, destination floor and the number of passengers for the same destination call registration. Meantime at one hand the particular guidance function can indicate the assigned

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elevator ID timely, at the other hand it can set an operation route. So that passengers cannot randomly, whereas systematically enter into the specified elevator in terms of the systemic notification. It is obvious that EGCS with DFG has distinct improvement in terms of branching off the peak passenger flow and reduce the elevator congestion degree. The scheduling model of EGCS with DFG is shown as Fig. 1.

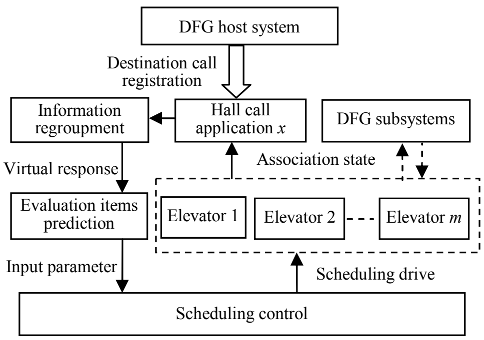

Fig. 1. Scheduling Model of EGCS with DFG

As the show of Fig. 1, DFG system includes the host system and the subsystems. DFG host system realizes the function of collection, storage, and management for destination call registrations and produces a relevant hall call application x to every valid destination call registration. DFG subsystems realize the operation and scheduling control for elevator group. In EGCS, elevator group usually consists of three or more elevators and the operation model of every elevator is identical. So the overall optimization problem of EGCS can be resolved into realize effective and accurate control to one elevator under the optimization of overall performance by analyzing the ensemble of hall call communication.

In EGCS with DFG, the implementation procedures to destination call registration are formulated as follows:

1) At any time t_n, when a destination call registration which is from floor i to floor j appears, DFG host system collects and stores it immediately then produces a hall call application x.

2) The assignment of hall call application x is related to m elevators. According to information regroupment, evaluation items prediction, and scheduling control, assignment information k is exported. Then the output and the hall call application x are shielded immediately to wait for the next destination call registration.

3) According to the feedback of assignment information k, DFG subsystems convert the relevant scheduling status of elevator k. Then procedure turns into the pretreatment phase.

4) After elevator k arrives at the floor i, DFG subsystems amend the relevant scheduling status of elevator k. Then procedure turns into the executing phase.

5) After elevator k arrives at the floor j, DFG subsystems reverts the relevant scheduling status of elevator k and then releases the memory space of hall call application x.

III. Ensemble of Hall Call Communication

The ensemble of hall call communication mainly includes hall call application information and elevator operation state information. Elevator operation state's characteristics determine its own parameters. Simultaneously, all elevator operation states are returned to hall call application in real time as the influence factors of scheduling strategy. The entire cycle period of hall call application starts when the destination call registration is produced, then passes through the period of scheduling response and execution until the course is over. The parameters of hall call application are determined by the characteristic of the entire cycle course. The parameters of elevator operation state and hall call application are shown in Table I and Table II.

TABLE I
OPERATION STATE PARAMETERS OF ELEVATOR *M*

Parameter	Specification
d_m	Operation direction of elevator m
f_m	Real-time floor ID of elevator m
$t_{ma}(i)$	Time when elevator m arrives at floor i
$t_{ml}(i)$	Time when elevator m leaves from floor i
$n_{me}(i)$	Number of passengers whose origination floor is i for elevator m
$n_{mo}(i)$	Number of passengers whose destination floor is i for elevator m
n_{mc}	Real-time number of carrying passengers of elevator m
$C_m(i,j)$	Scheduling state from floor i to floor j, $i,j \in n$, (n is floor ID)

TABLE II
PARAMETERS OF HALL CALL APPLICATION *X*

Parameter	Specification
f_{xb}	Origination floor ID of hall call application x
f_{xt}	Destination floor ID of hall call application x
t_{xb}	Occurring time of hall call application x
n_x	Number of passengers for hall call application x
ID_x	Assignment ID of hall call application x

From the Table I and Table II, it is known that hall call application x is related to elevator m by ID_x that means $m=ID_x$, and converts the scheduling state $C_m(f_{xb}, f_{xt})$ of elevator m. The parameters $n_{me}(i)$ and $n_{mo}(i)$ can be acquired by consulting n_x of hall call application x whose parameters are $f_{xb}=i, f_{xt}=i$ and then $n_{mc}= n_{(m-1)c}+ n_{me}(i)- n_{mo}(i)$.

For realizing optimized assignment to hall call application and reasonable scheduling to elevator, the parameter $C_m(i,j)$ ($i,j=1,2,...,n$ and $i\neq j$) of elevator m whose application is from floor i to floor j is classified as the rule of the assignment state. The classification is shown as follows:

1) CR: the assignments which have already been scheduled and also are being executed;

2) CU: idle assignments;

3) CD: the assignments which have already been scheduled but not been responded;

4) CE: the assignments which are being executed and then are scheduled again.

Further, classifying the hall call applications in $C_m(i,j)$ which belong to CR, CD, CE as the rule of executing orders.

1) m_1*:* the hall call applications corresponded with the assignments which have already been scheduled and also are being executed, in other words all of the assignments CR and CE;

2) m_2: the hall call applications corresponded with the assignments CD whose parameters are $f_{xb}>f_{xt}$, d_m is downwards and $f_m>f_{xb}$ or $f_{xb}<f_{xt}$, d_m is upwards and $f_m<f_{xb}$;

3) m_3: the hall call applications corresponded with the assignments CD whose parameters are $f_{xb}>f_{xt}$ and d_m is upwards or $f_{xb}<f_{xt}$ and d_m is downwards;

4) m_4: the hall call applications corresponded with the assignments CD whose parameters are $f_{xb}>f_{xt}$, d_m is downwards and $f_m<f_{xb}$ or $f_{xb}<f_{xt}$, d_m is upwards and $f_m>f_{xb}$.

IV. Evaluation Items Prediction

The control objectives of EGCS embody in three aspects. They are service quality (low waiting time and journey time), service quantity (strong capacity of carrying passengers), and energy conservation (saving energy for elevator operation). Obviously it is a typical problem of multi-objective optimization. So according to the characteristics of passenger flow pattern and self requests of EGCS, we adopt four evaluation items including the average waiting time (T_w), the average journey time (T_r), long waiting percentage (P_{lw}), and power consumption (R_e). Furthermore the prediction of evaluation items can be modelled exactly on the basis of regrouping and classification to the ensemble of hall call communication.

A. Average Waiting Time (T_w)

Waiting time means the time interval between the production of a destination call registration and the arriving of assigned elevator to origination floor. T_w prediction algorithm considers not only the waiting time of new destination call registration, but also the waiting time of all the hall call applications whose waiting time are increased because of responding the new destination call registration, of which the prediction of real-time waiting time for each hall call application can be calculated by surveying the practical range ability and required stop floor ID between the current floor of elevator and the origination floor of hall call application. In the meantime characteristic parameter defined as waiting influent factor is proposed, which indicates the influence for waiting passengers because of virtual response to new destination call registration.

If defining $t_w(x)$ as the waiting time of hall call application x, the prediction equation of $t_w(x)$ is calculated as in (1), (2).

$$t_w(x)=\begin{cases}\left[|f_m-f_{xb}|-n_s(f_m,f_{xb})\right]\times T_h+\left[n_s(f_m,f_{xb})-1\right]\times T_s & ,x\in m_2\\ t_1+\left[|f_1-f_{xb}|-n_s(f_1,f_{xb})\right]\times T_h+\left[n_s(f_1,f_{xb})-1\right]\times T_s & ,x\in m_3\\ t_2+\left[|f_2-f_{xb}|-n_s(f_2,f_{xb})\right]\times T_h+\left[n_s(f_2,f_{xb})-1\right]\times T_s & ,x\in m_4\end{cases}. \quad (1)$$

Where,

$$\begin{cases}t_1=\left[|f_m-f_1|-n_{s1}\right]\times T_h+n_{s1}\times T_s\\ t_2=t_1+\left[|f_1-f_2|-n_{s2}\right]\times T_h+n_{s2}\times T_s\end{cases}. \quad (2)$$

$n_s(i,j)$: Required stop number for elevator from floor i to floor j;

f_1: Highest or lowest floor ID for the first time reverse of elevator which can be calculated by all the f_{xt} of hall call applications which belong to m_1, m_2 and all the f_{xb} of hall call applications which belong to m_3;

n_{s1}: Required stop number for elevator from current floor to f_1;

f_2: Highest or lowest floor ID for the second time reverse of elevator which can be calculated by all the f_{xt} of hall call applications which belong to m_3 and all the f_{xb} of hall call applications which belong to m_4;

n_{s2}: Required stop number for elevator from f_1 to f_2;

T_s: Time for every time required stop of elevator which can be estimated by passenger flow;

T_h: Time for elevator passing a floor not required stop.

For a new hall call application x, the prediction equation of $T_w(x)$ is calculated as in (3).

$$T_w(x)=\frac{\sum_{i=1}^{m_j'}(t_w(i)\times n_i)+\sum_{i=1}^{m_{j+1}}(t_w(i)\times n_i)+\sum_{i=1}^{m_{j+2}}(t_w(i)\times n_i)}{\sum_{i=1}^{m_j'}n_i+\sum_{i=1}^{m_{j+1}}n_i+\sum_{i=1}^{m_{j+2}}n_i}. \quad ,x\in m_j,\ j=2,3,4 \quad (3)$$

In the equation, m_j' indicates the ensemble of hall call applications in m_j whose waiting time are increased by the influence of new hall call application x.

B. Average Journey Time (T_r)

Journey time means the time interval between the arriving of assigned elevator to origination floor and to destination floor. T_r prediction algorithm considers not only the journey time of new destination call registration, but also the journey time of all the hall call applications whose journey time are increased because of responding the new destination call registration, of which the prediction of real-time journey time for each hall call application can be calculated by surveying the practical range ability and required stop floor ID between the origination floor and the destination floor of hall call application. In the meantime characteristic parameter defined as journey influent factor is proposed, which indicates the influence for waiting and journey passengers because of virtual response to new destination call registration.

If defining $t_r(x)$ as the journey time of hall call application x, the prediction equation of $t_r(x)$ is calculated as in (4).

$$t_r(x)=\left[|f_{xt}-f_{xb}|-n_s(f_{xt},f_{xb})\right]\times T_h+\left[n_s(f_{xt},f_{xb})-1\right]\times T_s. \quad (4)$$

For a new hall call application x, the prediction equation of $T_r(x)$ is calculated as in (5).

$$T_r(x)=\frac{\sum_{i=1}^{m_{j-1}'}(t_r(i)\times n_i)+\sum_{i=1}^{m_j'}(t_r(i)\times n_i)}{\sum_{i=1}^{m_{j-1}'}n_i+\sum_{i=1}^{m_j'}n_i}\quad ,x\in m_j,\ j=2,3,4. \quad (5)$$

In the equation, m_j' indicates the ensemble of hall call applications in m_j whose journey time are increased by the influence of new hall call application x.

C. Long Waiting Percentage (P_{lw})

P_{lw} means the percentage of passengers whose waiting time is longer than 60s in the sum of current waiting passengers. P_{lw} prediction algorithm considers not only the new destination call registration whose waiting time is longer than 60s, but also all the hall call applications whose increased waiting time is longer than 60s because of responding the new destination call registration.

For a new hall call application x, the prediction equation of $P_{lw}(x)$ is calculated as in (6).

$$P_{lw}(x)=\frac{\sum_{i=1}^{m_j^{'}} n_i+\sum_{i=1}^{m_{j+1}^{'}} n_i+\sum_{i=1}^{m_{j+2}^{'}} n_i}{N(t_n)} \quad ,x\in m_j,t_w(m_j^{'})>60, j=2,3,4\cdot \tag{6}$$

In the equation, $m_j^{'}$ indicates the ensemble of hall call applications in m_j whose waiting time is longer than 60s by the influence of new hall call application x. $N(t_n)$ indicates the amount of waiting passengers in the time of t_n.

D. Power Consumption (R_e)

R_e mainly embodies in the process of acceleration and deceleration of elevator. So energy conservation could be realized by reducing the number of required stop. In the EGCS with DFG, because of the advance acquirement of origination floor and destination floor of hall call application, system can assign the same elevator to serve the hall call applications which come from or arrive to the same or near floors in order to reduce the number of required stop. R_e prediction algorithm is described by passenger complex degree (R_s), repetition rate of hall call application (R_p), and the number of passengers in elevator.

R_s indicates the ratio of required stop number of floors to the amount of waiting and journey passengers for assigned hall call applications in $C_m(i,j)$ of elevator.

$$R_s(m)=f(C_m(i,j))/\sum_{k=1}^{C_m(i,j)} n_k \cdot \tag{7}$$

R_p indicates the repetition degree of f_{xb}, f_{xt} of new hall call application x and the required stop floor ID of assigned hall call applications in $C_m(i,j)$ of elevator.

According to the practical operation condition of elevator, the lower of R_s, the higher of R_p, and the fewer number of passengers, the fewer required stop number is and the lower waste of energy is.

V. Modeling of Fuzzy Neural Network Optimized by Genetic Algorithm

When system receives a new hall call application, it would be virtually assigned to every elevator for selecting the fittest one to respond. Then through real-time prediction to evaluation items, taking the prediction results as the inputs of FNN and setting $U(x)$ which is defined as matching degree for scheduling to the output of FNN. The structure of FNN is shown as Fig. 2.

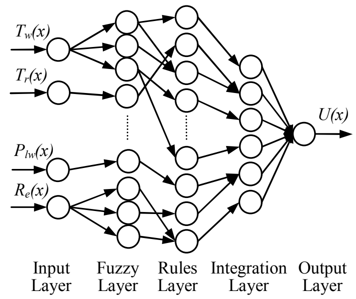

Fig. 2. The Structure of FNN

The first layer is input layer and every node represents a characteristic parameter. $f_k^{(1)}=u_k^{(1)}$, where, $u_k^{(1)}$ indicates the value of the k^{th} input node of the first layer; The second layer is fuzzification and every node represents a fuzzy subset whose membership function is described by Gaussian function.

$$f_k^{(2)}=\exp\left|-\frac{(u_i^{(2)}-m_{ij}^{(2)})^2}{(\sigma_{ij}^{(2)})^2}\right| \cdot \tag{8}$$

Where, $m_{ij}^{(2)}$ and $\sigma_{ij}^{(2)}$ is the centre and width of membership function of the j^{th} fuzzy subset of the i^{th} input parameter; The third layer is rules layer and every node represents a fuzzy logic rule. So all the nodes constitute a fuzzy rule base which has the logic AND function, $f_k^{(3)}=\min(u_{kj}^{(3)})$;The forth layer is integration layer and every node executes the logic OR operation to integrate some similar rules.

$$a_k^{(4)}=\sum_j u_{kj}^{(4)}, \quad f_k^{(4)}=\min(1,a_k^{(4)}) \cdot \tag{9}$$

The fifth layer is defuzzification and this layer calculates the definite value based on the membership grade of fuzzy subset of every output parameter.

$$a_k^{(5)}=\sum_j (m_{kj}^{(5)}*\sigma_{kj}^{(5)})*u_{kj}^{(5)}, \quad f_k^{(5)}=\frac{a_k^{(5)}}{\sum_j \sigma_{kj}^{(5)}*u_{kj}^{(5)}} \cdot \tag{10}$$

FNN inherits the learning capacity of Neural Network and meantime can automatically dispose fuzzy information, summarize fuzzy rules, and fulfill fuzzy reasoning. But because essentially this network adopts gradient descending method, it has the disadvantage of slow convergence speed and is usually lost in local minimum values. Whereas GA is the theory of global optimization method of random search which simulates the process of biologic evolution. Thus it can avoid the disadvantages of FNN and enhance self-learning function and robustness of fuzzy reasoning by utilizing GA to train and optimize the global network parameters of FNN.

In FNN, the centre m and width σ of Gaussian function which is global parameters can be optimized by GA, whereas weight ω in reasoning rules which has more locality can be adjusted by BP algorithm.

At first, make the genetically encoding for centre m and width σ of the second and the fifth layer of FNN. The string of chromosome is shown as follows:

$$\varphi_{ij} = \varphi_{\min} + \frac{k}{2^l - 1}(\varphi_{\max} - \varphi_{\min}) \cdot \tag{11}$$

Where, k is one bit binary integer of string, $[\varphi_{min}, \varphi_{max}]$ is variation range of parameters. Because of the crossover rate P_c and mutation rate P_m has a great effect on the performance of GA, the calculation of P_c and P_m adopt an adaptive method.

$$P_c = \frac{K_1}{(f_{\max} - \overline{f})} \qquad P_m = \frac{K_2}{(f_{\max} - \overline{f})} \cdot \tag{12}$$

Where, f_{max} and $\overline{f}$ represent the maximal fitness and average fitness of colony. From the obtained sampled data (e_i, Δe_i, y_i^*), optimal parameters of membership function can be found to meet the equation shown as follows:

$$\min\{E\} = \frac{1}{2}\sum_{i=1}^{m}(d_i - y_i)^2 \cdot \tag{13}$$

Where, d_i is desired output, y_i is the output of FNN. Furthermore through the way of online learning style, the weight of FNN can be adjusted by utilizing improved BP gradient descending method.

$$J = \frac{1}{2}\sum_{i=1}^{m}(y_i - \widehat{y_i})^2 \cdot \tag{14}$$

$$\omega(t+1) = \omega(t) + \eta(-\frac{\partial J}{\partial \omega(t)}) + \alpha \Delta\omega(t) \cdot \tag{15}$$

Where, η is learning rate, α is factor of momentum. After the training of GA, N possibly global evolution solutions are selected in the last colony in terms of adaptive value. Then use these solutions as original weight and use BP algorithm to solving. Finally, compare N optimal solutions acquired from FNN and obtain the global optimal solution.

VI. Simulation and Analysis

The simulations are done under the common office building and the parameters of elevator simulation condition are set in Table III. The passenger flow pattern selects the complex up-peak pattern which means most passengers enter at the entrance hall and want upwards transportation. The parameters of passenger flow are shown in Table IV. The sample data of up-peak pattern is generated by Poisson distribution and Monte Carlo random testing method.

TABLE III
Parameters of Elevator Simulation Condition

Item	Value
Number of Floors	16
Height of Entrance Hall (m)	4.0
Height of Other Floors (m)	3.0
Number of Elevators	4
Max. Velocity (m/s)	2.5
Max. Acceleration (m/s^2)	0.7
Jerk (m/s^3)	0.7
Elevator Capacity (*person*)	15
Time for Opening and Closing Door (s)	4.0
Average Transfer Time for Passenger (s)	1.0

TABLE IV
Parameters of Passenger Flow in Up-peak Pattern

Item	Value
Passenger Density (*person/5 min*)	100
Time of System Simulation (s)	1800
Percentage of Upward Passenger Flow from Entrance Hall (%)	80
Percentage of Downward Passenger Flow to Entrance Hall (%)	10
Percentage of Passenger Flow of Inter Floors (%)	10

At first the network is trained based on the principle of overall minimum error. The number of original sample in training package is 30, the learning rate is 0.30 and the precision of training error is 10^{-3}. Then after 150 times training, the network can meet the range of permissible error. Simultaneously through inputting testing sample the generalization ability of network is confirmed. The network training error curve is shown as Fig. 3.

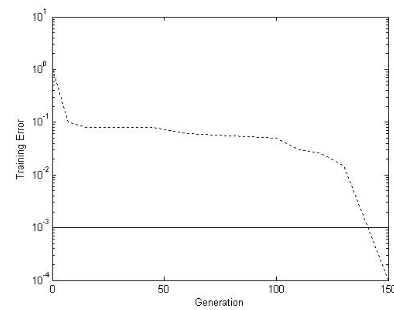

Fig. 3. Network Training Error Curve

In the same simulation condition, compare and analyze FNN algorithm optimized by GA based on DFG (GAFNN) with minimization average waiting time algorithm (MinTime), static zoning algorithm (Static), robust optimization algorithm based on GA [7] (RO), and multi-objective optimization algorithm based on DFG [8] (MutiObject). The scheduling performances are shown in Table V.

TABLE V
Scheduling Performances of Different Algorithms

Algorithm	T_w (s)	T_r (s)	P_{lw} (%)	R_e (%)
MinTime	27.44	74.88	19.2	78
Static	16.42	41.65	12.3	60
RO	22.49	62.57	18.1	72
MutiObject	20.20	39.60	9.6	56
GAFNN	17.06	34.80	7.4	42

In up-peak pattern, the scheduling performances of GAFNN and MutiObject based on DFG are obviously superior to the scheduling performances of the algorithm of

MinTime, Static, and RO based on the traditional elevator system. Where, MinTime controls as the principle of minimization waiting time of every passenger. But it cannot consider the changing feature of passenger flow pattern, so MinTime is not fit for the complex up-peak pattern. Based on MinTime, RO is imposed in the costing thought. But because of the limitation of the traditional hall call information, the improvement is little. The control result to average waiting time in Static is optimal. This is because through shunting the crowd of high arrival rate to generate multiple waiting queues, only the passengers whose destination floor is in the service area of a certain elevator can enter this elevator. So that this is a indirect way to obtain the information of destination floors. Otherwise in the EGCS with DFG it is obvious to know that the performance of GAFNN is superior to the performance of MutiObject.

In the overall control process, the stability of two primary evaluation items of T_w and T_r also get well control. The control curves T_w and T_r are shown as Fig. 4.

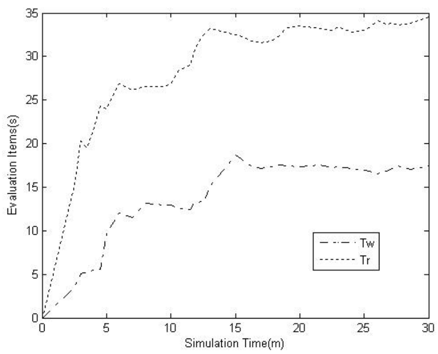

Fig. 4. Control Curves of T_w and T_r

Because the simulation passenger flow is up-peak pattern, the origination floors of all the hall call applications are relatively concentrated whereas the destination floors are various. This leads to the fluctuation frequency of T_r is more rapid than T_w. Along with the increment of time, the intensity of passenger flow is also gradually strengthened. As a result the overall trend of T_w and T_r is rising, especially in $t_n \leq 6min$, the amount of passenger flow is obviously increased. Later the control process still has some time points whose corresponding evaluation items are steep rise, for example, T_r corresponding with $t_n=13min$ and T_w corresponding with $t_n=15min$. This means the amount of instantaneous passenger flow is large, but through the adjustment of GAFNN the uptrend of T_w and T_r can be suppressed rapidly and trend into new stable state. In the relatively stable period of time such as $t \in [25, 30]$, the simulation data of T_w and T_r is shown in Table VI.

TABLE VI
SIMULATION DATA OF T_W AND T_R IN $T \in [25, 30]$

Simulation Time *(m)*	$T_w (s)$	$T_r (s)$
25.0	16.98	33.00
25.4	16.84	33.34
26.0	16.50	34.12
26.7	16.81	33.67
27.2	17.12	33.81
27.6	17.04	33.66
28.6	17.00	33.78
29.4	17.03	34.21
30.0	17.06	34.80

From the Table VI, it is known that the fluctuation process of T_w and T_r is mostly in inverse trend. This changing regularity corresponds with the practical elevator scheduling condition, in other words, T_w and T_r are a pair of conflicting evaluation items. GAFNN based on DFG can well control T_w and T_r to avoid influencing one of them appear wide fluctuation for steadying the other. In the meantime, along with the stability of passenger flow, T_w and T_r all come up to the stable state eventually. Therefore, it can be confirmed that the GAFNN based on DFG has better performance in the up-peak pattern.

VII. CONCLUSIONS

In this paper, the elevator group control system with destination floor guidance is proposed. This new type of passenger flow control pattern resolves the problem of imperfection and nondeterminacy about hall call information in traditional elevator system. Through analysing the characteristics of hall call application under the mechanism of destination floor guidance, the ensemble of hall call communication is regrouped and classified according to the rules of the assignment state and executing orders. Based on the prediction models of evaluation items, Genetic Algorithm is used to optimize the Fuzzy Neural Network.

In the simulations, through comparing the performances of GAFNN with other scheduling algorithms and analysing the control process of evaluation items, a large amount of improvement of EGCS with DFG in the up-peak pattern is confirmed. This means the advantage of modeling DFG and the effectiveness of FNN optimized by GA.

REFERENCES

[1] Yang Zhenshan and Shao Cheng, "On the present situation and developing trends of elevator group supervisory control technologies," *Control and Decision J.*, vol. 20, no. 12, pp. 1321-1331, Dec. 2005.

[2] D. Nikovski and M. Brand, "Exact calculation of expected waiting times for group elevator control," *IEEE Trans. Automatic Control*, vol. 49, no. 10, Oct. 2004, pp. 1820-1823.

[3] A. T. P. So, J. K. L. Yu, and W. L. Chan, "Dynamic zoning based supervisory control for elevators," in *1999 Proc. IEEE Int. Conf. Control Applications*, vol. 2, Aug. 1999, pp. 1591-1596.

[4] Li Dong, Wang Wei, and Shao Cheng, "Elevator group supervisory control systems and intelligent control techniques," *Control and Decision J.*, vol. 16, no. 5, pp. 513-517, Sep. 2001.

[5] S. Tanaka, Y. Innami, and M. Araki, "A study on objective functions for dynamic operation optimization of a single-car elevator system with destination hall call registration," in *2004 IEEE Int. Conf. Systems, Man and Cybernetics*, vol. 7, Oct. 2004, pp. 6274-6279.

[6] H. N. Psaraftis, "Dynamic programming solution to the single vehicle many-to-many immediate request dial-a-ride problem," *Transportation Science J.*, vol. 14, no. 2, pp. 130-154, May 1980.

[7] Zong Qun, Li Shengtao, and Wang Weijia, "Robust optimization model of elevator group scheduling based on genetic algorithm," *Journal of Tianjin University J.*, vol. 40, no. 9, pp. 1019-1024, Sep. 2007.

[8] Luo Fei, Xu Yuge, and Cao Jianzhong, "Modeling and control in elevator group control system with destination registration," *Control and Decision J.*, vol. 21, no. 10, pp. 1159-1162, Oct. 2006.