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A New Hybrid Elevator Group Control System Scheduling Strategy Based on Particle Swarm Simulated Annealing Optimization Algorithm*

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***Abstract* - Particle Swarm Optimization(PSO) algorithm has been wiedly used in many areas due to the advantages of simple realization and fast convergence.While it will trap in local minimum easily.To overcome the shortcoming,this paper proposes a hybrid algorithm PSO-SA by introducing the simulated annealing(SA) algorithm to the standard PSO and applies it to hybrid elevator group control system for optimizing scheduling.The hybrid algorithm integrates PSO's fast convergence and the advantage of jumping out of the local optimization in SA .Comparing the hybrid algorithm with the standard PSO and Artificial Immune(AI) under the same condition, shows that the hybrid algorithm can overcome this shortcoming of PSO effectively, demonstrates the feasibility and superiority of PSO-SA in optimizing scheduling. This paper adds the new scheduling algorithms for elevator group control system, and expands the application of PSO.**

Index Terms - Particle Swarm Optimization, Simulated Annealing, EGCS, Hybrid Elevator Group Control System

I. INTRODUCTION

With the development of artificial intelligence and the increase of passenger flow, higher standards have been proposed to elevator group control system (EGCS), the important component of the building automation system. And the research in this field has been concerned by more and more researchers.

The scheduling algorithm, one of the most important part of EGCS, is a complex multi-objective optimization problem that is hard to deal with, as several dynamic performance indices should be considered including average waiting time (AWT), long wait percent (LWP), operational consumption (RNC), etc..[1]. An effective scheduling algorithm can greatly reduce AWT, LWP, RNC etc..

In previous studies,the research in elevator optimal scheduling is focused on Genetic Algorithm,Fuzzy Logics, Artificial Neural Networks and Expert System.Fitness function in GA is not easy to select,and it takes a long time to search the optimum when the time available is limited due to the combinatorial complexity[2].Fuzzy Logics has no learning ability because the control rules are dependent on the expertise embedded in Fuzzy Logics and the tuning of the fuzzy membership function in real-time is difficult [3].Artificial Neural Networks is a tractable algorithm in theory,but it has some inherent defects such as long training time, difficult selection of the network structure and algorithm parameters[4] .

In order to improve the comprehensive service level of elevator group control system, it is necessary to adopt high efficient scheduling algorithms in EGCS. The Particle Swarm Optimization (PSO) algorithm is the new intelligent stochastic optimization algorithm, originated from the social behavior of birds and fish. Because of the superiority of simple realization and fast convergence, it has been successfully applied to many fields: Multi-objective Optimization, Electronics, and Weights Modification of Neural Network, etc.[2]. In PSO, using "cooperative" strategy,the swarm is evolved by keeping track of two "best" particles in the search space, one is the personnel best (pbest) and the other is the global best (gbest)[5].While, this algorithm has the tendency of being trapped in local minimum easily and slow convergence, especially in the last stage of the evolution. The simulated annealing algorithm (SA) is a kind of general probabilistic algorithm.It is different from other traditional random searching algorithm, it can avoid trapping in the local optimum,because in the searching poocess,SA not only accepts the "better" solutions,but also the "worse"solutions at a definite probability,which increase the diversity of particle.

This paper proposes a hybrid algorithm PSO-SA by introducing the simulated annealing (SA) to the standard PSO and applies it to hybrid elevator group control system for optimizing scheduling .Comparing the hybrid algorithm with the standard PSO and Artificial Immune (AI) under the same condition, shows that the hybrid algorithm can overcome the shortcoming of PSO effectively, demonstrates the feasibility and superiority of PSO-SA in optimizing scheduling. This paper adds the new scheduling algorithms for elevator group control system, and expands the application of PSO.

II. MECHANISM OF PARTICLE SWARM OPTIMIZATION AND SIMULATED ANNEALING ALGORITHM

A. Particle Swarm Optimization algorithm

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Particle swarm optimization is a kind of evolutionary algorithm,it was first proposed by doctor Kennedy and Eberhart in 1995[6].The PSO is originated from the group behavior of birds, it imitates the foraging behavior of flocks,and searches for the optimun using "cooperation" strategy.

In the standard PSO, the swarm is initialized to a group of random solutions in D-dimensional search space.Each solution can be imagined as a bird in the search space, called particle which has a velocity to determine the flight direction and distance and a fitenss determined by the objective function. The *i*th particle is expressed as n-dimensional vector $X_i=(x_{il},x_{i2}...x_{in})$,$V_i=(v_{il},.v_{i2}.....v_{in})$, i=1,2…n. And the best previous position (the best fitness value) of the ith particle is recorded as $P_i=(p_{i1},p_{i2}.....p_{in})$, which is derived from the objective function.Comparing with its best previous position(pbest) and the global best position (gbest), each particle is updated according to the following equations:

$$V_{id}(t+1) = w * V_{id}(t) + c_1 r_1 (P_{id}(t) - X_{id}(t)) + c_2 r_2 (P_{gd}(t) - X_{id}(t))$$

$$X_{id}(t+1) = X_{id}(t) + V_{id}(t) \qquad (1)$$

i=1,2....n,d=1,2....D, where *w* is the inertial weighted value,which make the particles move inertial and have the trend to expand the search space that would help to search in new space[7]. c_1 and c_2 are positive constants, called acceleration constants. r_1 and r_2 are random number varied between [0,1].

B. Simulated Annealing algorithm

The Simulated Annealing algorithm (SA) is not noly a kind of heuristic random searching method,but also an effective global optimization algorithm.It was first applied to combinatorial optimization problems by Kirknatrick in 1983[8].

Its cogitation stems from the solid physical annealing process. The temperature and the internal energy are expressed as the possible states xi and the objective function value of $f(x_i)$ respectively. Controlled by the cooling schedule including the initial value of control parameter T and the attenuation factor , the objective function converges to a global approximate optimization in company with the temperature reduction.

SA adopts Metropolis acceptance criterion, it can be given by

$$P_t(i \to j) = \begin{cases} 1 & f(i) \le f(j) \\ e^{\Delta f / T} & f(i) > f(j) \end{cases} \qquad (2)$$

Where $\Delta f = f(i) - f(j)$, $f(i)$, $f(j)$ are the values of objective function at the state *i* and *j*.T is the annealing temperature,P_t is the acceptance probability transfering from state x_i to state x_j. The annealing process starts with the initial solution x_0 and the control parameter T.The current solutions are optimized ,with the temperature decreased ,by repeating the process "Generate a new solution—> Calculate the objective function difference—> Determine whether to accept—> accept or discard".When T reduces to the minimum,the approximate optimization could be derived from the current solutions.

The reason why the searching strategy of SA can avoid trapping in the local optimum is that,in the optimization process of SA,the better solution is accepted completely,the worse solution is accepted at a definite acceptance probability as well,which increase the diversity of solutions.

From above ,it can be concluded that the PSO algorithm and the SA algorithm make up each other,and they can be combined as Particle Swarm Simulated Annealing Hybrid Optimization algorithm (PSO-SA).The hybrid algorithm integrates the character of fast convergence in PSO and the character of jumping out of the local optimization in SA , so it not only guarantees the speed of convergence, but also has good global searching capability,that enhanced the performance and quality of the optimization greatly.

III. HYBRID ELEVATOR GROUP CONTROL SYSTEM STRATEGY BASED ON HYBRID OPTIMIZATION ALGORITHM

A. Hybrid Elevator Group Control System Model and scheduling regulations

The model this paper applies is derived from reference [9], in which EGCS is considered as a Hybrid System that is different from the traditional model. The operation in traditional elevator group control system is spatiotemporally discrete, and it will increase the hardness to forecast the current floor, to estimate the time.Hybrid group control system can avoid the disadvantages of the traditional model and simplify the system model[10].In the hybrid system, the speed and displacement are continuous variable, the call signals and scheduling orders are dynamic discrete events. The scheduling regulations are as follows:

1) If an elevator is leisure initially, and now responds to a signal from hall buttons which is one floor or two floors away from the elevator, new signals can not be inserted into the signal queue when the elevator is running.

2) If an elevator is leisure initially, and now responds to a signal from hall buttons which is three floors or more than three floors away from the elevator, new proper signals are allowed to insert into the signal queue when the elevator is running. The rule for inserting the new signals is that the fully loaded elevators can not respond to the new signals and making least of the crowed rate and attack frequency among the elevators[10].

3) Elevator can only run between the possible floors(Elevator at the bottom could only run up, Elevator at the top could only run down); Elevator can't change the running direction until it finish the service,and the same request must be serviced by one and only one elevator;

4) Destination request has higher priority than call request,that is to say,when destination request is in conflict with call request, the elevator should serve the destination request first[11].

B. Hybrid Elevator Group Control System Scheduling Strategy Based on Hybrid Optimization Algorithm

According to the random, non-line characters of EGCS and the demands of passengers both in psychological and physiological, the dynamic performance indices considered in this paper are average waiting time(AWT), probability of long waiting time (LWP),operational frequency(RNC).

Average Waiting Time (AWT): the average value of all passengers' waiting time in a period.It is one of the most importment indice of EGCS. Reduce LWP can meet the demands of passengers in psychology[7].

Long Wait Percent (LWP): the percent of the passengers whose waiting time is more than some value (60s generally) in a period.

Operational consumption (RNC): the frequency of the elevators' start/stop in a period. The elevator's energy consumption is mainly caused in start/stop phase, so the sum of start/stop times is selected as the indce of elevator's energy consumption.

Weighting the several factors above, the objective function is given:

$$J = \sum_{i=0}^{m} \lambda_1 T_i + \lambda_2 P_i + \lambda_3 R_i \qquad (3)$$

Where i=1.2.3…..m, m :the total number of call singals. T_i, P_i, R_i respectively represent the Waiting Time, Long Wait Percent, Operation Consumption. And J means the corresponding pre-estimated evaluation. λ_1 , λ_2 , λ_3 are weighting factors, $\lambda_1 + \lambda_2 + \lambda_3 = 1$.According to the different focus of the objective function, $\lambda_1, \lambda_2, \lambda_3$ could be regulated moderately.

The concrete steps are as follows (flow chart as Fig. 1):

Step1: Initialize the parameters of the elevators, building and the hybrid algorithm;

Step2: According to the call signals and the current state of the elevators, the swarm (values of objective function) is achieved from formula (3);

Step3: Update the swarm using update equation with inertial weighted value, and accelerate the speed of convergence.

Step4: According to the acceptance criteria, decide whether to accept those new particles or not, increase the diversity of particles,and avoid trapping in the local optimum.The annealing equation applied in this paper is as follow: $T_k = \frac{L-k}{L} T_0$,where L is the total attenuation times of the conrol parameters, T_0 is the initial temperature, and $T_0 = K * \delta$, $\delta = \max(J_i) - \min(J_i)$,where K is positive constant large enough.

Step5: If the iteration is ended, then search the global optimal solution, determine the objective floor, sent the elevator, and update the elevators'state; If not, loop step(3).

Step6: Loop to step (2) until the simulating time is ended, then output the result.

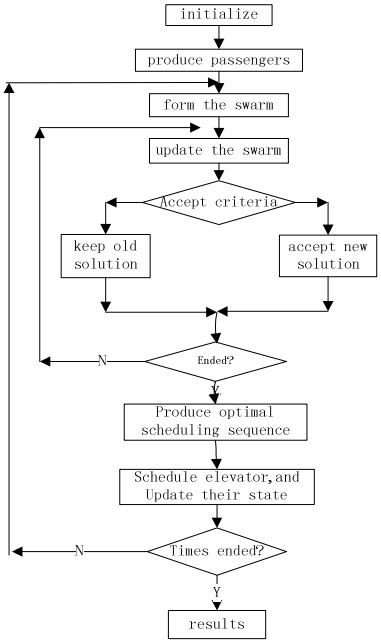

Fig. 1 Elevator group control system application flow chart

IV. SIMULATION AND ANALYSIS

Select the 4 elevators and 16 floors building as the simulating object. The simulating codes are compiled in Matlab7.0 platform.The concrete parameters are showed in table I. In the simulation, the passenger flow is produced randomly, and there are more passengers in/out of the first floor than other floors.

Table I PARAMETERS OF THE EGCS

Number-of-elevator-	4-
Number-of-floor-	16-
Average-time-of-in/out-	2s-
Average-time-of-open/close-door-	2s-
Maximum-velocity-	3m/s-
Maximum-acceleration-	1.2m/s^2-
Maximum-Jerk-	1m/s^3-
Average-height-of-floors-	3.5m-
Rated-load-	1000kg(15persons)-

The parameters of PSO-SA algorithm are set as: c_1=0.15,c_2=0.3,V_i=65,K=1000, L=20.As the simulation graph (Fig. 2) showed, most of the waiting time is 20 seconds approximately, the average waiting time is 19.6 seconds, and the probability of long waiting time is 3.1%. So, the graph demonstrates that applying the PSO-SA optimization algorithm on the elevator group control system can make relatively good effect.

Compared the Hybrid Algorithm with the standard PSO and AI under the same conditions, the simulation results are shown in table II III IV.

1) Comparison of PSO-SA and PSO

The simulation data show that the Hybrid Algorithm algorithm uses less 1.97(s) average waiting time, 2.78% probability of long waiting time and 2.4 times operational consumption than the standard PSO algorithm. In all, using PSO-SA optimization algorithm, the performance of hybrid elevator group control system is improved. But the reduction of average operational consumption is only 2.4 times, that needs to be improved.

2) Comparison of PSO-SA and AI

From the data in Table II, we could conclude that the Hybrid Algorithm algorithm is superior to AI too.The PSO-SA algorithm uses less 2.39(s) average waiting time, 2.59% probability of long waiting time and 4.2 times of operational consumption than the AI algorithm. The Hybrid algorithm is superior to AI obviously.

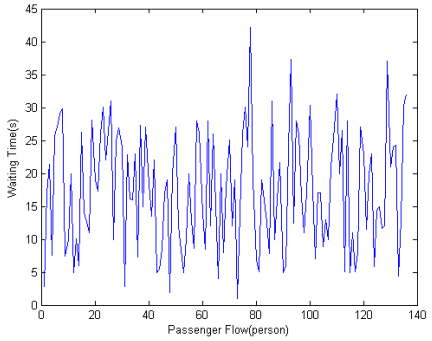

Fig .2 Passengers waiting time graph

Table II AVERAGE WAITING TIME /S

Control mode	First	Second	Third	Fouth	Fifth	Average
PSO	21.45	21.26	21.66	20.58	20.14	21.02
AI	22.14	21.99	21.94	21.06	20.70	21.44
PSO-SA	19.48	18.65	18.95	19.98	18.18	19.05

Table III LONG WAITING PERCENT /%

Control mode	First	Second	Third	Fouth	Fifth	Average
PSO	6.06	5.84	6.67	6.21	5.66	6.11
AI	6.00	5.97	5.66	6.51	5.47	5.92
PSO-SA	3.75	3.20	3.17	3.40	3.14	3.33

Table IV OPERATIONALCONSIUMPTION/TIME

Control mode	First	Second	Third	Fouth	Fifth	Average
PSO	31	30	30	31	28	30
AI	31	31	36	30	31	31.8
PSO-SA	29	28	27	28	26	27.6

V. CONCLUSION

In this paper,the Hybrid Algorithm(PSO-SA) is proposed by combined the Particle Swarm Optimization and the Simulated Annealing,and applied to hybrid elevator group control system for optimizing scheduling. By comparing the Hybrid Algorithm with the standard Particle Swarm Optimization and the Artificial Immune Algorithm, it shows superiority in improving the performance of eleverator group control system. But the saving of power needs to be improved in the future.

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