

## ELEVATOR SYSTEM

## BACKGROUND OF THE INVENTION

5           The present invention relates to an elevator system, in particular, it relates to a control system which is effective for determining an optimum control method for group supervisory control equipment therefor.

10           In prior art elevator group supervisory controls, it is known to be able to determine control parameters by simulation as disclosed in JP-A Nos. 58-52162, 58-63668. Further, when an increasing number of parameters is required in simulation, the knowledge engineering technology is utilized to cope with an increased number of parameter sets, and determine an effective domain of control parameters and a search sequence for such control parameters as disclosed in JP-A Nos. 3-18566 and 3-297769.

20           On the other hand, what is called here a control method or control parameters include a variety of items such as a control parameter to be used mainly for assignment evaluation that has been described as the wait time control parameter, car crowding control parameter and the like in the foregoing JP-A-No. 3-297769, and a door-open set parameter at each service floor, as well as other control methods facilitating ease of use such as whether or not a reservation guide for a particular service car should be displayed in both

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directions of up and down simultaneously, and the like. By way of example, with respect to this ease of use, 32 items therefor that can be altered through the user command board are described in Hitachi Hyoron vol. 71, No. 5, pp115-122 (1989-5).

Further, with respect to the genetic algorithm for probabilistic optimum value search means, its technique is disclosed, for example, in "Genetic Algorithm" edited by Hiroaki Kitano (Sangyo Tosho, 1993-6).

The above-mentioned prior art methods are effective, for example, in reducing the computing time and the like so long as the number of parameters to be adjusted is limited, or any effect of a parameter change is predictable even if the number of parameters increases. However, when the number of parameters increases beyond a certain limit, a domain of parameters to be searched becomes enormously great, and its computing time to obtain a practical solution increases accordingly. In addition, when use conditions or associated constraints become versatile, the number of their combinations becomes enormous too. In the case of adopting the prior art knowledge engineering technology to limit a domain of search, it is necessary to acquire enormous amounts of knowledge in advance corresponding to such enormous numbers of combinations. The use conditions, however, differ according to each elevator, therefore, it is too difficult to acquire all of these enormous amounts of knowledge beforehand. Therefore,

since a heuristic search method using the knowledge engineering technology cannot be applied, a lot of simulations become necessary as described above, in consequence, increasing its computing time enormously.

5     Thereby, it becomes more difficult in practice to adapt effectively to follow any time-varying instance which varies with time of the day, week, month or year.

#### SUMMARY OF THE INVENTION

10     The main object of the invention is to provide a parameter adjustment method and an apparatus therefor which can minimize a time required for adapting to a change in the use conditions due to any time-varying instance taking place in the operation of the elevator.

15     In order to solve the aforementioned problems associated with the prior art, it is contemplated to carry out a parameter search by means of a probabilistic multipoint simultaneous search method or a multipoint simultaneous search method using a genetic algorithm that is a probabilistic multipoint simultaneous search  
20     method according to the invention.

It is also arranged to record a preceding search result from which to be able to continue a subsequent search in order to be able efficiently to follow time-dependent changes.

25     It is further arranged to evaluate whether any search result obtained is practical or not when evaluation conditions are altered within a predetermined extent. For example, such an evaluation is performed by

simulation by changing, for example, the number of people waiting at each floor in a predetermined domain.

In addition, it is contemplated to evaluate any parameter which has been obtained as a result of search and which has a top-ranking predetermined value under the condition that its evaluation conditions are being altered within a predetermined domain, so that a more desirable parameter can be determined in accordance with the result of evaluation.

Learning means learns use conditions of elevators. Simulation means simulates an operation of elevators using control parameters which have been set by search means under any use conditions of elevators learned by the learning means.

Search result memory means stores search results acquired by the search means.

The search means carries out a next search in accordance with the result of a preceding search or the results of previous searches that have been stored in the search result memory means, then produces a best value thereof to control method registration means.

Operation control means carries out operation control of elevators utilizing a control method or control parameter from the control method registration means.

Since a new search is enabled to start using the results of the previous searches, it is possible to determine an appropriate control method in regard of an influence resulting from any time-dependent change within a

practically allowable period of time.

A multipoint simultaneous search method such as genetic algorithm or the like is used for the search method of the search means, and a basic control method stored in basic control memory means is called in any time under a predetermined condition to be used in a search so that any undesirable status can be prevented from taking place which may limit the result of search to a localized optimum solution instead of a global optimum solution due to application of the previous search results as they are.

Verification means causes the simulation means to simulate a candidate best solution obtained by the search means by altering the use conditions learned by the learning means within a predetermined domain, and verifies a result of the simulation whether it will still satisfy a required performance or not, then, stores the result into control method registration means when verified to be satisfactory. Thereby, any control method that is selected for an actual operation control will be ensured not to deteriorate its performance due to a very small change in the use conditions or a minor difference from the actual use conditions. Thereby, a robust control method can be obtained according to the foregoing approach of the invention which will be robust or immune against very small changes.

In the case where the search means employs an approach to obtain a best value through repeating

evaluation of the genetic algorithm or the like, the verification means may be adapted to verify its result by evaluating the use conditions that have been obtained by the learning means once for every predetermined cycles to a certain extent such that a robust control method which is robust against a minor change is obtained in advance.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The advantages and merits of the present invention will be more clearly understood with reference to the accompanying drawings in which:

Fig. 1 is a schematic diagram illustrative of the present invention;

Fig. 2 is a schematic flowchart illustrative of operational steps of the invention;

Fig. 3 is a schematic flowchart indicative of an instance of using a genetic algorithm according to the invention;

Fig. 4 illustrates more in detail an instance of using the genetic algorithm of the invention;

Fig. 5 illustrates an instance of identifying and verifying some of the top ranking control methods;

Fig. 6 is an example for verifying the top ranking control method according to the invention;

Fig. 7 is a flowchart for verifying the top ranking control methods;

Fig. 8 is a flowchart for introducing a small change in use conditions for every predetermined cycles;

Fig. 9 illustrates an instance of adding a basic control method to be mixed at a certain ratio;

5 Fig. 10 is an embodiment of the invention for enabling the basic control method to be mixed;

Fig. 11 is a flowchart for allowing the basic control method to be mixed;

10 Fig. 12 is an example for performing a fuzzy evaluation of the invention;

Fig. 13 is an example of the learning result tables of the invention;

Fig. 14 is an example of the search result tables of the invention;

15 Fig. 15 is an example of the evaluation coefficient tables of the invention;

Fig. 16 illustrates an instance of using different equations for respective floors and elevator cars;

20 Fig. 17 is one embodiment of the invention for switching between respective search methods; and

Fig. 18 is an example of the control method tables of the invention.

Fig. 19 is a schematic system diagram of still another embodiment of the invention;

25 Fig. 20 is a schematic block diagram of the automatic adjustment unit of the invention;

Fig. 21 illustrates examples of control parameter sets and its effective domain setting;

Fig. 22 is a diagram indicative of an example of gene setting;

Fig. 23 is a general flowchart of still another embodiment of the invention;

5 Fig. 24 is a flowchart of an initial value generation subroutine of the invention;

Fig. 25 is a flowchart of an operation subroutine of the invention;

10 Fig. 26 is a diagram indicative of a crossover process of the invention;

Fig. 27 is a flowchart of a crossover subroutine of the invention;

Fig. 28 is a flowchart of a select function of the invention;

15 Fig. 29 is a diagram indicative of a mutation process of the invention;

Fig. 30 is a flowchart of a mutation subroutine of the invention;

20 Fig. 31 is a flowchart of a catastrophe subroutine of the invention;

Fig. 32 is a flowchart of an evaluation subroutine of the invention; and

Fig. 33 is a flowchart of a distance measurement subroutine of the invention.

## PREFERRED EMBODIMENTS

Figure 1 is a schematic block diagram indicative of one embodiment of the invention. Hall call information from hall call buttons 101-10n is sent through a transmission line 2 to a hall call collection unit 31 in a group supervisory control apparatus 3. Car information such as car call from car call buttons 41-44 is sent through car transmission lines 51-54 to car control apparatuses 61-64, from which the car information together with other car information is sent through car transmission line 7 to car information collection unit 32 and assignment control unit 33 both being provided in the group supervisory control apparatus 3. Operational data gathered in the hall call collection unit 31 and the car information collection unit 32 is sent to a learning unit 34, then is stored in a learning result table 35. A search unit 36 carries out a search for an optimum control method in reference to the learning result table 35 by means of a probabilistic or multipoint simultaneous search method. The search unit 36 sends a control method tentatively obtained to a simulation unit 37, in which is executed a simulation which simulates elevator operation under conditions given from the learning result table 35 and using the control method sent from the search unit 36, then the result of its simulation is sent to the search unit 36. In reference to the result of simulation from the

simulation unit 37, the search unit 36 repeats to search for a new candidate for an optimum control method to be simulated further in simulation unit 37 in repetition.

When an optimum control method is established in the manner as above, its result is sent to a search result table 38 and an evaluation equation table 39,

respectively. The assignment control unit 33 specifies a specific elevator car to be assigned to a specific hall call in accordance with the control method from the

evaluation equation table 39, contents of the hall call collection unit 31 and the car information collection unit 32 as well as car destination information, then, its result is sent to a car controller 61-64. In

response to this assignment signal, the car controller 61-64 is adapted to control a hoist 61-64 to put its corresponding elevator car 91-94 in service for the particular hall call.

Figure 2 is a schematic flow chart indicative of an operational flow of one embodiment of the invention.

First, the learning unit 34 gathers operational data and stores them in the learning result table 35 (step 201).

Then, the search unit 36 searches control methods in accordance with the contents of the learning result table 35 and the search result table 38 so as to specify more than one candidate of control methods (step 202).

The more than one candidate of control methods determined as above are sent to simulation unit 37 (step 203), to simulate respective control methods thereof

under particular use conditions stored in the learning result table (step 204), then, results of their simulation are sent to the search unit 36 (step 205).

The search unit 36 checks if a search complete condition

5 is satisfied by examining whether or not each of their results has converged through simulation, predetermined requirements have been met, and a predetermined number of search has been conducted (step 206), then, if the search complete condition is not satisfied, the flow

10 returns to the step 202, and if it is satisfied, one or more control methods having excellent results are entered into the search result table 38 (step 207), then the best control method having the top rating is written into the evaluation equation table 39 (step 208). By way

15 of example, the search result table 38 stores updated control methods selected for respective time zones, traffic volumes, and/or traffic flows. In response to a hall call, the assignment control unit 33 conducts an appropriate operational control to assign a particular

20 elevator car thereto and the like using the control method written in the evaluation equation table 39 (step 209). After this flow is repeated for a predetermined

cycle to allow for a task of processing to be able to handle a day's volume or a predetermined traffic volume or hall calls (step 210), it returns to the step 201 to

25 repeat searching of a new control method which is more appropriate. A search processing in step 202 after the second search inclusive is adapted to refer to the

contents of the search result table 38 as well.

According to this embodiment of the invention, a significant time reduction can be attained in the search time since the cumulative search results until the preceding search also can be utilized by reference as described above.

Figure 3 is a flowchart indicative of an instance of using a genetic algorithm, and Figure 4 is a diagram illustrative thereof in detail. First, a predetermined number of candidates are generated for a control method by a random number or according to the learning results in the learning result table 35 to be set as an initial value (301). Each candidate control method is expressed by a set of control parameters as indicated in Fig. 4(a). Here, for simplification of explanation, the candidate control method will be explained by way of example of an instance where six sets of candidate control methods are provided. Then, simulation unit 37 is enabled to obtain results of simulation for respective operational controls using respective candidate control methods (302). Respective candidate control methods are ranked according to the results of respective simulations (303). This step 303 corresponds to evaluation ratings of Fig. 4(c). Then, it is checked whether the search complete condition is satisfied or not (304), if satisfied, any one of the candidate control methods having satisfied is entered as a control method into the search result table 38 and the

evaluation equation table 39 (305). Candidate control methods in the upper rankings in case they have not satisfied the search complete condition are kept for further processing (306). This step 306 corresponds to selection of Fig. 4(d). Then, new candidate control methods to be examined in the next stage are generated through crossover of associated parameters therebetween and/or differing the combination of the parameters in the candidate control methods that have been kept for further processing (307). This step 307 corresponds to crossover processing of Fig. 4(e), 4(f). Then, through use of a random number, part of parameters in the candidate control methods is altered or transmuted (308). This step 308 corresponds to a mutation processing of Fig. 4(g). Then, the flow returns to the step 302 to repeat this subroutine.

The advantage of the multipoint simultaneous search enabled by using the genetic algorithm of the invention is capable of providing an optimum control method which can be obtained within a short computation time allowable in practice even if there are an increasing number of parameters that constitute the control method.

By way of example, in this embodiment of the invention, candidates for an optimum control method are generated by using random numbers or according to the learning result in the learning result table 35 as described above, however, such an optimum control method can be obtained in a shorter calculation time by

referring to the contents of the search result table 38 in the subsequent search for update candidates for an update optimum control method.

Figure 5 is a diagram illustrative of an instance of verifying the candidate control methods in the upper ranking. According to prior art methods such as the hill-climbing method as shown in Fig. 5(a), in particular, where a search domain and search sequence may be limited by knowledge acquired, since there holds that continuity and linearity in the resultant controls are substantially maintained against changes in the use conditions, there is ensured, to some extent, a robustness for an optimum control method against any small change in the use conditions that the resultant control will not deteriorate. However, such robustness or immunity of control parameters against small changes is not guaranteed in the case of any probabilistic multipoint simultaneous search, it is required further to verify robustness of any control method separately that has been obtained as an optimum value or optimum control method. For example, in the genetic algorithm as shown in Fig. 5(b), assuming that points 2a, 2b, 2c, 2d of update candidate control methods are newly generated from points 1a, 1b, 1c, 1d of update candidate control methods, it is very probable that a point 2d of a control method is selected as an optimum value. In this instance, the parameters are represented by control parameters, and any such control methods comprising such

control parameters often produce a significant effect which is very sensitive to a change in the use conditions. Therefore, it is contemplated that if a learning result is to be given as a traffic flow as shown in Fig 5(c), a predetermined number of traffic flows in which respective use conditions are altered to some extent are generated, for example, by slightly modifying an overall traffic volume while maintaining overall ratios of traffic volumes between floors as indicated in Fig. 5(d), or by changing respective ratios of traffic volumes between respective floors as indicated by Fig. 5(e), then under each of the predetermined number of traffic flows thus generated each corresponding control method being simulated, and the one that produces the best result of control is adopted as an optimum control method. Here, the method for altering the use conditions includes incrementing or decrementing of the traffic flows to some extent, increasing/decreasing of the number of users to some extent at respective floors as represented by Fig. 5(d) and (e), and combination thereof. Further, the one that produces the best control result described above includes such one that has a best average value in the results of simulation for respective use conditions and traffic flows, a minimum difference between the best value and the worst value or a minimum standard deviation, or a highest evaluation rating in the overall judgment thereof.

Figure 6 is one embodiment of an instance of verifying the candidate control methods in the upper ranking according to the invention. In accordance with the contents of learning result table 35, search unit 36 generates verifying traffic flows by altering their use conditions within a predetermined domain, then registers them in verification data table 310. Upon completion of search, the search unit 36 simulates respective candidate control methods in the upper ranking under respective traffic flows of the verification data table 310, then registers the control method that has produced the best result into search result table 38 and evaluation equation table 39 respectively.

Figure 7 is a flowchart of a verification process for verifying the control methods in the upper ranking. A subroutine from a step 701, in which verifying traffic flows are generated using the contents of the learning result table 35 to a step 304, in which the search complete condition is verified, is the same as that in Fig. 3. Before a step 305 for writing into the search result table 38 and evaluation equation table 39, verifying traffic flows are read in step 702, then in step 703 respective control methods rated in the upper ranking in the search result are simulated under respective verifying traffic flows. Then, the results of such simulations are subjected to statistical processing to obtain averages, standard deviations and the like (704). The best one is selected from these results in

step 705. The subsequent flow is the same as that in Fig. 3.

According to this embodiment of the invention, since the robustness of any control method to be updated can be evaluated in advance, it becomes possible to select an optimum control method within a predetermined domain which is less prone to deterioration in control performance even if there occurs some change in the use conditions, which normally introduces a significant effect in consequence.

Figure 8 is a flowchart for introducing a small change in the use conditions once for every predetermined cycles. In order to ensure a robust control method to be selected as described with reference to Figs. 5, 6, 7, it is contemplated, not to entirely rely on the verification of upper ranking search results alone after the completion of search as indicated in Figs. 5, 6, 7, but to cause such that respective traffic flows to be used in repetition are altered slightly in advance thereby to allow only the robust one that can withstand such changes to be obtained as its search result. A subroutine down to a step 308 is the same as in Fig. 3. In the next step 308-1 after each control method to be simulated having been generated, a verifying traffic flow in which a small change is introduced with random numbers in reference to the content of the learning result table 35 is generated to be used for simulation. A method for generating this

traffic flow to be used in simulation is the same as in Fig. 5. Then, the flow returns to step 302. The subsequent steps to follow are the same as in Fig. 3.

According to this embodiment of the present invention, a robust control method stable against minor changes in the use conditions can be advantageously predetermined.

Figure 9 illustrates instances in which basic control methods are introduced to be mixed in attempting a divergent search for an optimum control method at a predetermined ratio. When a past search result is substituted for a subsequent search result as described in reference to Fig. 2, a calculation time for obtaining an optimum or practical best solution can be substantially reduced since an effective convergence of probable solutions is expedited. However, let alone provided that the multipoint simultaneous search method is utilized, it may result in that probable or candidate solutions gradually converge into a localized extremum solution apart from a real optimum solution. In particular, with reference to Fig. 9(a), there occurs such an instance where a point  $x$  which was once a real optimum solution and a point  $y$  which was once a localized optimum solution, change as shown in Figs. 9(b) and (c) in accordance with changes in the traffic flows which represent changes in their use conditions due to any time-dependent changes. In the case where a real optimum solution and a localized optimum solution

are caused to be reversed, and where the past search result is used as reference, its search tends to be limited to an area designated by points i, j, k in the vicinity of point x, thereby failing to identify a real optimum solution. Therefore, it is contemplated

according to the invention such that predetermined basic control methods designated by points p, q and r in Fig. 9(c) are caused to be mixed with currently available search targets at a predetermined interval and a predetermined ratio thereby to facilitate to identify a real optimum solution within a predetermined domain even under a changing use condition.

Figure 10 is another embodiment of the invention illustrative of an instance of causing some basic control methods to be mixed. This another embodiment of the invention is the same as shown in Fig. 1 except for a basic control method table 311 the search unit refers to when mixing the basic control methods.

Figure 11 is a flowchart for mixing the basic control methods. The steps therein down to 308 in which part of parameters is crossed-over are the same as in Fig. 3. After having crossed-over part of control parameters, it is checked whether or not a predetermined number of cycles is repeated in step 308-2, if not, the flow returns directly to step 302, and if yes, the basic control methods are read out from the basic control method table 311 to be mixed in step 308-3. The subsequent steps are the same as in Fig. 3.

Advantageously, according to this embodiment of the invention, it becomes possible to obtain a real optimum solution while minimizing the calculation time by referring to the past search results.

5           With reference to Fig. 12, there is shown still another embodiment of the invention in which a fuzzy evaluation is provided. In such an instance where a control method with an optimum value is obtained through a daily search routine, it is more likely that a fuzzy  
10           evaluation allowing for a variety of solutions to be included instead of an exclusively strict evaluation is more capable of providing an improved performance of followability in adapting to time-dependent changes. Thereby, the search unit 36 at the time of evaluating  
15           probable control methods in step 303 of Fig. 3, is adapted to carry out a fuzzy evaluation utilizing a fuzzy rule in fuzzy table 312 in the drawing of Fig. 12.

Advantageously, according to this embodiment of the invention, an improved follow-up capability to  
20           adequately follow any time-dependent changes can be achieved since a wider scope of solutions to select therefrom are included.

Figure 13 is an example of the learning result tables of the invention. In this example, traffic flows  
25           are divided into time zones of the day, and the numbers of passengers getting on and off are recorded for respective floors, and going-up and down directions, however, it is not limited thereto, and it may be

recorded simply according to time zones.

Figure 14 is an example of the search result table of the invention. This example indicates an instance in which different control methods having different evaluation coefficients are selected differently for normal floors and specified floors. It is possible to offer different services to different floors by adopting different evaluation coefficients for the particular floor as above, and for particular zones or particular elevator cars. However, since the number of parameters in overall control methods increases greatly, it becomes prerequisite to adopt a certain optimization method by which a large number of control parameters can be searched efficiently as proposed by the invention.

Generation of a search table according to this embodiment of the invention will facilitate an efficient search of an optimum control method capable of assigning different services to different floors, elevator cars, and spatial/time zones.

Figure 15 is an example of the evaluation coefficient tables according to the invention. In this example, respective control methods and values of parameters to be used therein are stored in accordance with respective traffic flows, however, it is not limited thereto, and they may be stored in accordance with time zones.

Figure 16 is a diagram illustrative of an instance where different evaluation equations are used for

respective elevator cars and respective floors. In order to provide a different type of service or alter serviceability according to respective floors or zones as indicated in Fig. 16(a), or in order to assign different elevator cars having different attributes to respective floors as indicated in Fig. 16(b), it is required to adopt different control methods having different evaluation equations as indicated in Fig. 16(c) with respect to particular floors to be provided with particular services and particular cars to be assigned. In the drawing of Fig. 16(a), a priority zone is set between 42nd floor and 50th floor inclusive in which a wait time has the highest rating in evaluation: in this priority zone any wait time is controlled to fall within 20 seconds or less while in the other floors it is controlled to be less than 30 seconds.

On the other hand, Fig. 16(b) indicates an instance where different elevator cars with different attributes are assigned to different service floors. In this instance, the 10th floor has a priority in wait time, while the 6th floor has a priority in car crowding. When there arises a hall call on the 10th floor the priority of which floor is a shortest wait time, an elevator car A in the vicinity of the 10th floor having the shortest arrival time, will be assigned so long as it is not fully crowded. On the other hand, when there occurs a hall call on the 6th floor the priority of which floor is less-crowding, an elevator car C which is less

crowded although it takes a longer time to arrive will be assigned. In order to accomplish such a delicate control as above, it becomes necessary to use a plurality of evaluation equations as expressed in Fig.

5 16(c), in which the number of control parameters required for a single traffic flow or a single time zone will become several times of conventionally required number of parameters, and its alterable combination will grow in the number of several tens of thousands.

10 Thereby, it becomes prerequisite to employ such a probabilistic search approach as utilized in the present invention.

Figure 17 is an embodiment of the invention indicative of an instance for switching between the  
15 search methods in the search means in accordance with a control method which has been set. Each control method is set in control method setting table 313 by setting unit 21 for each traffic flow or time zone. Here, the control method includes a normal control, energy-saving  
20 control, a multi-objective control for controlling a plurality of control targets such as a wait time, riding time, car-crowding and the like, and respective floor or car controls, in which the number of parameters in respective control methods ranges from one, several, to  
25 a ten or more. In accordance with the control methods stored in control method table 313, search method switching unit 314 selects an appropriate search method for search unit 36. With reference to Fig. 18 an example

of such control method tables is illustrated. When a normal search or an energy-saving control using a single parameter is set, the search unit 36 carries out its search using a hill-climbing method 361. When a multi-objective control method using a plurality of parameters is set, a search by inference 362 is carried out. With a heuristic search method, a parameter search is conducted by using knowledge in knowledge base 362-1, as well as by defining a specific domain of parameters and the sequences of simulation by inference unit 362-2. When a control method requiring respective floor or car controls in which the number of parameters exceeds ten or more is set, or when no search knowledge exists in the knowledge base 362-1, a probabilistic search method such as the genetic algorithm is employed.

Still another embodiment of the invention will be described in the following with reference to the accompanying figures 19 to 33.

First, an overall system configuration will be described.

With reference to Fig. 19, there is shown a system configuration of the still another embodiment of the invention.

Group supervisory control apparatus 1 is coupled to car controller 2 via a communication line, through which data indicative of such as positions, car-loading and the like are transmitted from the car controller 2 to group supervisory controller 1, and command data

indicative of such as stop-over floors, directions of operation and the like are transmitted from the group supervisory controller 1 to the car controller 2 vice versa. In response to such commands, car controller 2 controls an associated car 3. Further, the group supervisory controller 1 is coupled to hall call buttons 4 as well.

Within the group supervisory controller 1, there are provided a learning unit 1-1, a search unit 1-2, a control method (or control parameter) 1-3, and an assignment control unit (group supervisory control unit) 1-4.

The learning unit 1-1 carries out statistical processing of signals from car controller 2, hall call buttons 4 or the like, then produces various data acquired by learning.

The control parameter (control method) 1-3 represents a data set of control parameters for a control method to be used in actual group supervisory control, which have been generated through processing in the automatic search unit 1-2 which will be described later.

The assignment control unit 1-4 operates elevator car 3 using the control method (parameters) 1-3 in response to a request from users.

An operational method of control parameter sets in the search unit (automatic adjusting unit) 1-2 which represents a main feature of the invention will be

described in detail in the following. Other related prior art as disclosed in JP-A No.3-297769 and the like will be omitted.

5        Figure 20 is a schematic block diagram of the search unit (automatic adjustment unit) 1-2.

      The search unit (automatic adjustment unit) 1-2 receives a learning data from the learning unit 1-1, then transmits the control method 1-3 to the assignment control unit 1-4.

10       Within the search unit 1-2 there are provided a main CPU 1-5, a parameters' effective domain data 1-6, evaluation data 1-7, and evaluation CPUs 1-8.

      The main CPU 1-5 executes major processing in the search unit 1-2 as well as its memory management and task management.

15       Parameter's effective domain data 1-6 corresponds to a control parameter data base, which stores an effective domain or extent for the control parameters or the like that may be covered in a particular building.

20       Genetic/evaluation data 1-7 is memory means for storing a plurality of control parameter sets (hereinafter referred to as a gene), and the result of evaluation thereof.

25       Evaluation CPUs 1-8 are dedicated computers to execute evaluation processing of genes, which will be detailed later. In the drawing of Fig. 20, the evaluation CPUs 1-8 are shown to be comprised of 3 sets, however, the number thereof is not limited thereto, and

may have any number of sets depending on quantity of calculation and required performance of CPUs.

With reference to Figs. 21 and 22, data structures of control parameters to be used in this embodiment will be described in the following.

Fig. 21 illustrates respective control parameters and their effective domains they may take.

Control method 1-3 for use in the group supervisory control comprises M pieces (elements) of parameters, each referred to as an area value, a ride coefficient, bi-directional reservations, or the like.

Parameter's effective domain data 1-6 stores data on a minimum value, a maximum value, and its incremental or decremental step for each of M elements of parameters. By way of example, the number of parameters is designated to be M, which ranges from 30 to 50 normally, however, it is not limited thereto, and it may take any number within the scope of the invention.

By way of example of Fig. 21, a control parameter in the field of area value is shown to have a minimum value of 0.0 and a maximum value of 5.0, and changes stepwise therebetween by 0.1. Also, in the case of ON/OFF type capable of bi-directional reservation, OFF is assumed to be 0 and ON to be 1.

The contents of this parameter's effective domain data 1-6 are set according to each service building. For example, in such a building where the bi-directional reservation is not included by the request of the user,

even if the automatic adjustment in the search unit is executed, the bi-directional reservation will be nullified always by setting both the minimum and maximum values to be OFF (0) and incremental steps to be 0. In addition, by arranging as above, M elements of parameter items can be utilized commonly throughout every buildings under the same vendor's service without requiring any particular amendment in its program with respect to each building. By way of example, a control parameter set here refers to a set of data comprising any respective data represented by any respective incremental steps described above. That is, with reference to Fig. 21, a set of parameters is produced having an area value of 0.0, a ride time of 0.0, a crowding of 20,...and a bidirectional reservation of 0 is generated, and there is produced another set, for example, having a area value of 0.1, a ride time of 0.5, a crowding of 25, ...and a bidirectional reservation 1, respectively.

Figure 22 illustrates an example of defining a gene which is represented as a set of control parameters.

Each gene is a data array having different control parameters of M (number or types), and each data array having a different combination thereof constitutes a control parameter (control method) set. This gene is prepared in N sets which normally mounts to about 100.

For simplification of the following description, a gene will be abridged to be gen, a gene at i-th

occurrence to be gen (i), and a control parameter set at j-th occurrence to be gen (i)(j). Thereby, with reference to Fig. 22, a combination at the second occurrence of genes and at the third occurrence of control parameter sets is expressed to be gen (2)(3) which has a value of 75. By way of example, each value in the control parameter sets is defined randomly in the initial stage.

In the next, the automatic adjustment in the search operation of the invention will be described with reference to Figs. 23 through 33.

Since the group supervisory control is implemented generally by software in the microcomputer, each step of automatic adjustment in the search operation will be described by way of example of such implementation through software.

Figure 23 is a general flowchart indicative of automatic adjustment processing to be executed in the search unit 1-2 of one embodiment of the invention.

The automatic adjustment processing is enabled by an accumulation and modification of the learning data in the learning unit 1-1, or routinely enabled at a predetermined time of the day. Further, the automatic adjustment operation is started corresponding to a particular traffic flow such as the morning rush hour, lunch time and the like.

In step 10-1, it is checked whether or not a control parameter set has been already produced, if not,

the step goes to an initial value generation subroutine 20, and if yes, the step goes to an operation subroutine 30.

5 Then, it advances to evaluation subroutine 80, and at step 10-2, a cycle of process is ended.

Figure 24 is a flowchart of the initial value generation subroutine 20 more in detail.

10 The initial value generation subroutine 20 corresponds to the control parameter set generation means of the invention.

Steps 20-1 and 20-5 relate to a loop processing for genes in the number of N. Steps 20-2 and 20-4 relate to a loop processing for control parameters in the number of M.

15 In step 20-3, a control parameter value at i-th occurrence of genes and at j-th occurrence of control parameters is produced.

20 Here, an initial value of the control parameter is assumed to be produced by random number, and a function  $\text{rand}(x,y,z)$  is assumed to produce any random number between the minimum value x and the maximum value y which changes stepwise by z.

25 After completing each loop processing in steps 20-4 and 20-5, a distance flag (d\_flag) is reset to OFF state in step 20-6, then in step 20-7, the subroutine returns to the main program 10.

Figure 25 is a flowchart of the operation subroutine 30 of the invention.

In step 30-1, it is checked whether the distance flag (d\_flag) is ON or OFF. When it is OFF, the flow advances to a crossover subroutine 40 and a mutation subroutine 60.

5        If the distance flag (d\_flag) is ON in step 30-1, the flow advances to a catastrophe subroutine 70.

Then, in step 30-2, the flow returns to the main program 10.

10        Figure 26 illustrates a crossover process in the crossover subroutine 40.

15        In this crossover process, a parent of control methods is selected from the currently available control methods (genes) of  $N$  ( $L^{\text{th}}$  generation), and two types of genes  $x$  and  $y$  are selected in accordance with a predetermined rule such that a new generation gene ( $L+1$ ) may be produced which inherits either value of the genes  $x$  and  $y$  from its parent in its respective control parameter arrays, and which may be utilized as a new breed gene in the subsequent search process.

20        In this instance, genes of the  $L^{\text{th}}$  generation in the number ( $N-1$ ) excepting one which has the top-ranking evaluation is subjected to crossover processing in repetition for their updating. In addition, by arranging such that the best gene with the top-rating in  
25        evaluation has the most probable chance of being selected in the descendant generation ( $L+1$ ), it is ensured that an improved gene having potentially a better quality is utilized in the  $L+1$  generation.

Figure 27 is a flowchart of the crossover subroutine 40 of the invention.

The crossover subroutine 40 corresponds to the control parameter set crossover means.

5 In step 40-1, a current generation gene (gen) is copied to a work array tmp. Thereby, the current generation gene becomes tmp, allowing a next generation gene to be produced in gen.

10 Steps 40-2 and 40-10 represent a loop process for updating genes from the second occurrence to N-th occurrence. As will be described later, since the genes (gen) are arranged in such an order that the one with the best evaluation result comes first, then one with the second best result, to be followed by ones with  
15 decreasing results, thereby, in step 40-2, the best rating gene is excluded from update processing thereof, to ensure the best rated gene identified at this instant to be utilized in the search of the next generation.

20 In step 40-3, one of genes of N is selected by a function (select) which will be explained later, and its number is designated to be x. Likewise, in step 40-4, another one is selected the number of which is designated to be y.

25 Steps 40-5 and 40-9 corresponds to a loop process for the control parameters of M.

In step 40-6, a value 0 or 1 is generated randomly. If its value is 0, in step 40-7, a control parameter gen (i)(j) at i-th occurrence of genes and at j-th

occurrence of control parameters is caused to be substituted by a control parameter  $\text{tmp}(x)(j)$  at  $x$ -th occurrence of the present generation genes and at  $j$ -th occurrence. On the other hand, if its value is 1 in step 40-6, in step 40-8,  $\text{gen}(i)(j)$  is substituted by a control parameter  $\text{tmp}(y)(j)$  at  $y$ -th row of the present generation genes and at  $j$ -th occurrence.

When a loop process from step 40-5 to step 40-9 is completed, at least one new breed gene is produced which inherits either  $x$  or  $y$  for a value of each control parameter thereof from its parent.

Further, when a loop process from step 40-2 to step 40-10 is completed, the genes of  $(N-1)$  excepting the best rated gene are updated by crossover processing.

Then, in step 40-11, the crossover subroutine returns to the main program 30. Fig. 28 is a flowchart of the select function which is used in the crossover process.

It is desirable in the crossover process that the higher rated genes are adapted to have a more significant effect on the descendant generation. Thereby, genes rated from the 1st to  $a^{\text{th}}$  are adapted such that those having a value nearer to 1 has a higher probability of selection, and those having a value nearer to  $a^{\text{th}}$  has a lower probability of selection through subjecting to a square function.

In step 50-1, a random fraction of number greater than 0 and less than 1 is produced stepwise by  $0.1/a$ ,

which is then squared.

In step 50-2, a value obtained in step 50-1 is multiplied by  $(a-0.1)$ , and to which is added 1. Then, in step 50-3, an integer part of the result is taken.

5 In step 50-4, it is examined whether the value obtained is greater than  $(a)$  or not, and if greater,  $(b)$  is substituted by  $(a)$  in step 50-5.

In step 50-6, the value  $(b)$  produced as above is returned to the crossover subroutine.

10 An expected value of probability of being selected according to the select function, for an instance when the number of genes  $N=100$ , is approximately 10 % for the top-ranking gene, approximately 4 % for the second-ranking gene, 0.7 % for the 50th ranking gene, and  
15 approximately 0.5 % for the 100th ranking gene.

Figure 29 illustrates a mutation process in the mutation subroutine 60 according to the invention.

In this mutation process, any gene string (or array) may be selected randomly from the group of gene  
20 strings in the number of  $N$ , then a certain portion of the control parameters in the selected gene string is altered by a random number to breed a new gene string which may be utilized in the subsequent processing.

Figure 30 is a flowchart of the mutation subroutine  
25 60 of the invention.

The mutation subroutine 60 corresponds to the control parameter set mutation means.

Steps 60-1 and 60-7 relate to a loop process for incurring a mutation in a predetermined number of gene strings (c) among N pieces of gene strings. In the case of gene strings N=100, this value c=5, for example.

5        In step 60-2, an x-th occurrence gene string is selected randomly from a group of the 2nd occurrence gene string to the N-th occurrence gene string.

10       Steps 60-3 and 60-6 are a loop process for incurring a mutation in a predetermined number of control parameters (d) among M pieces of control parameters. In the case of control parameters M=50, this value d=2, for example.

15       In step 60-4, a y-th occurrence control parameter is selected randomly from M pieces of control parameters.

      In step 60-5, a control parameter gen (x)(y) which occurs at x-th gene string and y-th control parameter is updated by a random number in accordance with the parameter's effective domain data 1-6.

20       Then, in step 60-8, the flow returns to the main program 30.       Figure 31 is a flowchart of the catastrophe subroutine 70 of the invention.

      The catastrophe subroutine 70 corresponds to the control parameter set regeneration means.

25       A principal concept underlying this catastrophe subroutine will be described below.

      When the automatic adjustment in the search process is repeated many times, it often occurs that most genes

tend to be concentrated around some potent extremum in spatial distribution in the domain of control parameters due to repetitive crossover processing. In such an event, the mutation process attempts to disperse the genes to a wider extent, however, the more potent the extremum is, it is more difficult to disperse.

It is, however, more likely that an optimum value exists other than such an extremum within the global domain defined therefor, or that the optimum value may change or shift within the domain along with changes in the use conditions in the building. Any tendency to concentrate around extrema as above will limit a capability of arriving at an optimum value by means of the probabilistic multipoint search approach.

Therefore, when the genes tend to distribute unevenly, the remaining genes except for top-ranking predetermined number of genes are regenerated thereby to solve the problem associated with the uneven distribution of genes.

The catastrophe subroutine 70 executes the same processing as the initial value generation subroutine for gene strings from e-th occurrence to N-th occurrence gene strings excepting (e-1) pieces of gene strings in step 70-1. In this instance, when N=100, e=4, for example.

Hereinabove, the operation subroutine 30 and its respective subroutines have been described with reference to Figs. 25 to 31.

Lastly, the evaluation subroutine 80 of the invention will be described in the following.

Figure 32 is a flowchart of the evaluation subroutine 80.

5        The evaluation subroutine 80 corresponds to the control parameter set selection means.

      Steps 80-1 and 80-5 are a loop process for processing N pieces of gene strings.

10        In step 80-2, an i-th control parameter set  $gen(i)$  is set in the simulator, then in step 80-3, it is simulated using the traffic flow data acquired by learning, then, in step 80-4, its result such as a wait time and the like is stored in  $dat(i)$ .

15        In this subroutine, steps from 80-1 to 80-5 are processed in parallel by means of a plurality of evaluation CPUs.

20        In step 80-6, genes ( $gen$ ) and result ( $dat$ ) are sorted to be arranged in the order from the top-ranking to lower ranking with respect to the result ( $dat$ ), then, its distance is measured in subroutine 90.

      Finally,  $gen(1)$  which is a control parameter set that has a best rating in the evaluation is set as a control method 1-3 to be used actually in the group supervisory controller 1-4.

25        Figure 33 is a flowchart of the distance measurement subroutine 90 of the invention.

      The distance measurement subroutine 90 corresponds to the difference measurement means.

In step 90-1, work variables  $w$  and  $v$  are initialized.

Steps 90-2 and 90-10 are a loop process for processing control parameter elements of  $M$ .

5        In step 90-3, a minimum value  $\min(j)$  and a maximum value  $\max(j)$  of a control parameter at  $j$ -th occurrence are compared. If they differ, the flow advances to a process of step 90-4 through step 90-9.

10       In step 90-4, where when it is indicated that its minimum value and its maximum value differ, a value 1 is added to counter  $v$  which represents the effective number of control parameters that allow effective changes in the building.

15       Steps 90-5 and 90-9, and steps 90-6 and 90-8 are double loop processes for processing each distance between respective genes of  $N$ .

20       In step 90-7, a distance between  $j$ -th control parameter in  $i$ -th occurrence gene string and  $j$ -th control parameter in  $k$ -th occurrence gene string is normalized by a distance between its maximum value and minimum value, and its resultant absolute value is added to a distance variable  $w$ .

25       When the process down to step 90-10 is completed, a sum of distances between respective genes currently available is obtained in a distance variable  $w$ . Further, a maximum value of distance becomes  $vN(N-1)/2$  from the effective control parameter number  $v$ .

In step 90-11, a sum of respective distances ( $w$ ) between corresponding genes is compared with a value obtained by multiplying a maximum distance value  $vN(N-1)/2$  by a predetermined value  $f$ . When the sum of  
5 respective distances ( $w$ ) between corresponding genes is smaller than the value thus obtained, the distance flag  $d\_flag$  is set ON state in step 90-12, and when it is greater,  $d\_flag$  is set OFF state in step 90-13. In this embodiment, the predetermined value  $f=0.1$ , for example.

10 The following advantages and merits have been accomplished according to this embodiment of the invention.

By providing the parameter effective domain data of the invention, program and data structures that can be  
15 shared in common throughout any types of service buildings have been designed and developed. Further, by simply modifying only a portion of the parameter effective domain data, any specific setting of control method appropriate to any specific service building can  
20 be readily implemented.

Further, by providing the plurality of evaluation CPUs, the automatic adjustment time is capable of being shortened substantially.

25 Still further, by providing the catastrophe process that can be enabled in accordance with the distances between respective control parameter sets, the automatic adjustment in the search process is ensured not to terminate at a local minimum or extremum which is not

optimum in the global domain. Further, it is also possible to prevent any inferior control parameters (genes) or inferior results to be inherited to the descendant generation through the automatic adjustment in the search process by means of the crossover, mutation and catastrophe processes of the invention without affecting genes having the best value currently available.

According to this embodiment of the invention, it is possible to determine parameters by any prior art search method when the prior art search method is judged to be adequate to optimize these parameters, as well as to minimize the calculation time required for calculation thereof, and further to ensure a high performance control capability similar to or greater than the prior art to be achieved.

According to the present invention, it has become possible to provide for a parameter adjustment method and an apparatus therefor which can reduce the time required for adapting to any changes in use conditions due to any time-dependent changes, and adjust control parameters and the like in a time allowable in practice.

What is claimed is:

1. An elevator system having a plurality of elevator cars, hall call buttons provided on each floor, and an elevator group supervisory control apparatus for controlling said plurality of elevator cars in response to call signals from said hall call buttons and car call signals, characterized by comprising:

use condition collection means for gathering information on use conditions of elevator cars;

learning means for learning said use conditions and/or elevator car operational results;

search means for searching an optimum control method in accordance with said use conditions acquired by said learning means or said operational results;

simulation means for simulating an elevator operation utilizing a learning result acquired by said learning means in order to verify a control method that has been searched by said search means; and

search result memory means for storing search results obtained by said search means, wherein

said search means is adapted to search a new and better control method in accordance with previous search results stored in said search result memory means.

2. An elevator system having a plurality of elevator cars, hall call buttons provided on each floor, and an elevator group supervisory control apparatus for controlling said plurality of elevator cars in response



to call signals from said hall call buttons and car call signals, characterized by comprising:

use condition collection means for gathering information on use conditions of elevator cars;

5        learning means for learning said use conditions and/or elevator car operational results;

search means for searching an optimum control method in accordance with said use conditions acquired by said learning means or said operational results; and

10       simulation means for simulating an elevator operation utilizing a learning result acquired by said learning means in order to verify a control method that has been searched by said search means; wherein

15       said search means enables a plurality of control methods to be simulated simultaneously for verification by means of the simulation means.

3.    An elevator system according to claims 1 or 2 wherein said search means comprises a genetic algorithm for searching for a plurality of control methods through  
20       steps of selection, crossover and mutation.

4.    An elevator system according to claims 1, 2 or 3 wherein said simulation means is arranged to simulate  
25       a predetermined number of control methods in higher ratings in evaluation that have been obtained by said search means, during the simulation the contents of learning acquired by said learning means corresponding



thereto being altered within a predetermined extent, and the result of simulation being judged by said search method.

5           5.    An elevator system according to claim 4 wherein a criterion of judgment for judging the simulation results by said search means is a statistical value such as an average, standard deviation, worst value, best value and the like.

10

          6.    An elevator system having a plurality of elevator cars, hall call buttons provided on each floor, and an elevator group supervisory control apparatus for controlling said plurality of elevator cars in response to call signals from said hall call buttons and car call signals, characterized by comprising:

15

          use condition collection means for gathering information on use conditions of elevator cars;

20

          learning means for learning said use conditions and/or elevator car operational results, or both thereof;

25

          search means for searching an optimum control method in accordance with said use conditions acquired by said learning means or said operational results;

          simulation means for simulating an elevator operation utilizing a learning result acquired by said learning means in order to verify a control method that has been searched by said search means; and



search result memory means for storing search results obtained by said search means, wherein

said simulation means is adapted to alter the use condition within a predetermined extent to be used in a simulation of a control method which has been selected by said search means upon repetition of a predetermined cycle of simulation.

7. An elevator system according to claims 1, 2 and 3 wherein said search means utilizes a fuzzy evaluation in judgment of said simulation results.

8. An elevator system according to claims 1, 2 and 3 further comprising basic control method register means for registering basic control methods in advance, wherein said simulation means is adapted to execute a simulation in which any basic control method stored in said basic control method register means may be added to an ongoing control method under verification under a predetermined condition.

9. An elevator system according to claims 1, 2 and 3 wherein said control method includes a different evaluation equation for each service floor and elevator car.

10. An elevator control system according to claims 1 or 2, wherein said search means further comprises:



control parameter set generation means for generating a plurality of control parameter sets each being a different combination of the plurality of control parameters;

5 control parameter set selection means for evaluating said plurality of control parameter sets and selecting an appropriate control parameter set suitable for use in an actual group supervisory control; and

at least control parameter set crossover means for  
10 selecting a pair of control parameter sets from said plurality of control parameter sets each being a different combination of the control parameters, and performing a crossover between any control parameters corresponding each other between said pair of control  
15 parameter sets; or

control parameter set mutation means for selecting any one of said plurality of control parameter sets each being a different combination of the control parameters and altering a portion of the control parameters in the  
20 set thus selected.

11. An elevator control system according to claims 1, 2 or 3, further comprising:

difference measurement means for measuring a  
25 difference between respective said plurality of control parameter sets each being a different combination of the control parameters; and



control parameter set regeneration means for  
regenerating the control parameter sets excepting for a  
predetermined number of top ranking control parameter  
set(s) when a measured difference is smaller than a  
predetermined value.

5

12. An elevator control system according to claims  
1, 2, 10 or 11, further comprising control parameter  
defining data base for storing a domain of control  
parameters definable in a building which utilizes the  
elevator group supervisory control system, wherein said  
control parameter set generation means, said control  
parameter set mutation means, said control parameter set  
regeneration means are characterized by producing  
respective control parameters within the definable  
domain of the control parameters stored in said control  
parameter defining data base.

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