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A Review of Research on the Development of Elevator Group Control Technology

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Abstract

This paper introduces the growing demand for elevator traffic in the urbanization process in our country. It emphasizes the need for multiple elevators to be installed to meet this demand. If the elevators are unable to work in synchronization, it can result in multiple elevators responding to a single call signal. After analyzing the cause of the problem, we establish a mathematical model and use the objective function of the algorithm to optimize elevator group control. The main feature of this system is that it utilizes current elevator group control technology to collect statistical data on passenger flow and elevator usage frequency within the elevator group. Based on this data, a combination of fuzzy control optimization, expert system optimization, neural network optimization, and genetic algorithm optimization is selected to achieve efficient scheduling, tailored to the specific needs of the situation. The practical application of this technology demonstrates its ability to effectively address the issues of single response signal in traditional elevators, long waiting times, and significant energy loss. The technical model is more accurate, but the algorithm is complex and the solution takes a long time. Additionally, the timeliness problems affecting elevator group control technology will need to be further improved by introducing cloud computing in the future.

Keywords

Elevator group control technology, mathematical model, algorithm optimization

With the acceleration of urbanization, the Pearl River Delta region has attracted a large number of population inflows due to its geographical and industrial advantages, triggering a large area of land in rural areas to be expropriated for urbanization construction, and the original low-rise residential and office buildings and other buildings have been reduced, replaced by high-rise buildings, which are mainly used to solve the problems of rapid urbanization, large population inflow, and housing demand.

As a result, the land utilization rate has been greatly improved, resulting in problems such as the high density of existing buildings and high floors. Thus, compared with the height of the previous building, the height of the new floor increases exponentially, if people walk in the physical space of the high floor and only rely on the stairs to move, it will consume too much time and can not meet the needs of people such as the current fast passage speed, and can not meet the rapid development of urbanization, to solve this problem, improve the traffic efficiency of people in the high-rise building, which highlights the importance of elevator application, also makes the application of elevator more extensive. However, due to the better connectivity design between floors, the flow of people between floors is larger, the operating load of a single elevator is larger, and the per capita waiting time is long, it can not reflect the characteristics of low energy consumption and fast speed of the elevator, so the design of the elevator transportation system is proposed. The operation of the designed elevator can reduce people's time to take the elevator, ensure passenger safety and improve comfort and other functions, reduce the time of waiting for the elevator and the consumption of energy, to achieve these purposes, need to install a plurality of elevators in the same building, associate a plurality of elevators as a group, deploy in order to meet the established goals, utilize the microcomputer control system to carry out information normalization scheduling to the whole cluster, intelligently identify the current flow of people, and dispatch the elevator group, This method is also known as the group control technology of the elevator.

1. The development process of elevator group control technology

The application of elevator group control technology in elevators first appeared before 1970, mainly by Otis developed and used in the New York Building electronic control devices, which are mainly calle relay control [1]. The control mode is mainly the time sequence and the car assignment mode in the hoistway. This mode is mainly according to different call mode and frequency level, and use different instructions to work, this type belongs to the most basic method of elevator group control technology, called the determination of running direction, commonly used in the elevator group composed of three or less than three, wherein the running direction of each elevator is determined in advance, so that the elevator realizes driverless operation and solves the problem of uneven distribution of each car in the hoistway when the elevator is used at high frequency. This control mode has a more significant defect, when the car is located at the two end stations, will consume more waiting assignment time, will lead to waiting time too long, and cause more energy consumption.

Between 1971 and 1975, with the rapid development of information science and technology, integrated circuits were applied to elevator control to realize the digital control of elevators, transforming the original analog control into direct control process variables, which could complete more complex and large-scale operations, improve information processing capabilities, and increase the stability of the system. This period is used to complete the call processing and dispatch of the elevator by using independent signals, and the control system selects the elevator with higher efficiency to provide services for the call floor according to the actual hoistway operation environment and state, mainly to predict and control the waiting time of the floor. However, this approach is not comprehensive enough to consider the numerical range.

During the period from 1975 to 1988, the development of microelectronics accelerated dramatically, which led to the upgrading and iteration of integrated circuits, the invention of many types of computer control systems, and the application of computer technology to the control of multiple elevator clusters marked the formation of the first generation of elevator group control systems [2]. The system actually treats practical problems as dealing with the relationship between input variables, system transmission characteristics, and output results, with the ultimate goal of minimizing elevator waiting time and achieving ideal comprehensive evaluation functions.

Since 1988 until now, elevator group control technology has been greatly developed and upgraded according to the development of intelligent control, and today's research trend mainly uses intelligent algorithms, expert systems, neural networks, and modern physical technology to integrate and apply to elevator group control, or gradually join the Internet of Things under the promotion of 5G technology. The domestic elevator group control technology started late, and the earliest research literature appeared in 1990 [3].

2. Elevator group control system problem and mathematical model description

The elevator group control system ECGS refers to the use of an independent and autonomous control system to distribute and schedule each elevator in the group through overall consideration so that the response speed of the elevator to the elevator landing station in the hoistway is improved, the time for personnel to wait for the elevator at the landing station is shortened, the humanized service of the elevator is realized, and unnecessary energy loss is reduced [4].

In the early stage of elevator group control technology, the main goal was relatively simple, mainly to optimize the waiting time of the elevator to achieve the shortest waiting time of the elevator. At present, China's infrastructure modernization has been significantly improved, the height of the floor is getting higher and higher, and the height of the new commercial buildings in the Pearl River Delta region in recent years is generally more than 30 floors in height, and the number of elevators used in the building is generally more than 3. In this kind of high-rise building, assuming that each elevator completely serves each landing, this will lead to an increase in the frequency of the cars staying at the landing station during the travel process in the hoistway, which cannot reflect the overall performance of the elevator group, so the importance of elevator group control is highlighted.

The realization of elevator group control technology is to determine the goal that needs to be achieved, establish a mathematical model, and divide the mathematical model of elevator operation into four types based on statistical analysis by collecting a large number of passenger flow data in elevator operation. Because there are many factors considered in the dynamic movement of elevators in reality and not all of them have regularity, this paper mainly describes the static example model of elevators, that is, before the car is put into use and operated, according to the size and distribution of the waiting flow on each floor, the call signal has been preset in advance and the call signal is issued, the car responds to the call signal, and the latest call signal will not be input in the elevator cluster. Therefore, in ECGS, by analyzing the working flow time of people in the building and the peak flow time of commuting, it is known that the use of high-frequency time for elevators is logical, so the simplification method is in line with the actual situation to a certain extent.

For the statistics of the passenger flow in the elevator group, the floors in the building area are first divided into sections.

Assuming that all floors of the elevator can operate its number is $N(N\geqslant 1)$, it is divided into several intervals, wherein the base station and its upper 1~2 floors are regarded as an interval, and the top floor and its lower 1~2 floors are regarded as an interval, for the interval floors other than these two areas, it can be refined, and it is divided into intermediate intervals $i(i\geqslant 1)$ sequentially from bottom to top, and each intermediate intervals i contain 2~3 floors. The division of the interval is closely related to the magnitude of N. To a certain extent, it is in line with the actual situation.

Use relevant characters to define and describe the passenger flow, $X_{i,u}^{in}$ where the floor area i ($i\in${D,U,1,2,3...}, D represents the ground floor section, U represents the top floor section) represents the total number of people in the area who want to enter the car to take the elevator and run up the floor; $x_{i,d}^{in}$ represents the total number of people in area i who want to enter the car to take the elevator and run to the next floor; x_i^{out} characterizes the total number of people exiting the car between areas i.

(1) In the upward stage of passenger flow, most of the office buildings appear during working hours at this stage, and most of the passenger flow comes from the floor of the ground floor to enter the elevator car, and then leaves the car after reaching the target floor. At this stage, the operating load of the elevator is large and the frequency of use is high. The total number of people in the uplink preset call is expressed in P_U, the total number of people in the downward preset call is expressed in P_D, the total number of people waiting for the rest is represented by V, and the rated personnel in the car is represented by E, and the mathematical model is described as shown in Equation 2-1, where n represents the number of elevators in the elevator group.

$$\begin{cases} P_U \geq 85\%V \\ 80\%P_U \leq X_{D,U}^{in} \leq P_U \\ 55\%X_{D,U}^{in} \leq X_T^{out} \leq P_U \\ 0 \leq P_d \leq 15\%V \\ V \geq nV \end{cases} \tag{2-1}$$

(2) In the inter-floor exchange stage, the personnel in this stage flow more between the floor areas, the elevator is more balanced, and it is less likely to appear a large number of upward or downward movements, the personnel flow is small, and the elevator load is relatively small, this stage is more often used in the situation outside the peak stage, and the size of the personnel flow during the inter-floor interchange, the mathematical model can be expressed by equation 2-2, where M represents the number of floors in the floor.

$$\begin{cases} 0 \leq P_U \leq V \\ 0 \leq P_D \leq V \\ \sum_{i=1}^{M} X_{i,U}^{in} \geq 85\%P_U \\ \sum_{i=1}^{M} X_{i,D}^{out} \geq 85\%P_D \\ V \geq 15\%nE \end{cases} \tag{2-2}$$

(3) Passenger flow peak downward stage, in this stage is mostly the office building collective off-duty time, take the elevator personnel are to go down, most of the passenger flow from the top floor interval into the elevator car, down to the target floor after leaving the car, this stage of the elevator in the bottom section, less upward call signal. At this stage, the operating load of the elevator is large and the frequency of use is high. Similar to the peak upward phase of passenger flow, the mathematical model is described in Equation 2-3.

$$\begin{cases} P_D \leq 85\%V \\ 80\%P_D \leq X_{U,D}^{in} \leq P_D \\ 55\%X_{T,D}^{in} \leq X_D^{out} \leq P_D \\ 0 \leq P_U \leq 15\%V \\ V \geq nV \end{cases} \tag{2-3}$$

(4) In the idle stage, it mostly occurs at night, and the passenger flow is relatively scarce or even no passenger flow, and the cars in the shaft are in the stagnation stage without the call signal. In a small period of time, there will be people taking the elevator to generate a call signal, but the passenger flow is small, generally not greater than 15% of the rated

load of the car, and the passenger flow in the idle stage can be expressed as shown in Eq. 2-4 by a mathematical model.

$$P_U + P_D \leq 15\%E \tag{2-4}$$

(5) These four situations typically represent the actual passenger flow and can be approximated if the fuzzy logic control technology is not limited by the model. This technology relies on human logic and thinking patterns to address problems with unclear constraints or inaccurate models. The method involves continuously refining the control algorithm based on fuzzy approximation. Mainly according to the call information of different floors, combined with the actual situation, according to the different importance of the floor call prediction, the weight value is different, the multi-objective function is converted into an evaluation function, and the operation is completed to realize the multi-objective control. The implementation of the control method is mainly to use the logical thinking, experience and "membership function" of experts to determine the input and output variables of the ECGS controller to meet the requirements. It can effectively solve the problems of diversity, discrete randomness, and nonlinearity of elevator clusters [5]. So far, the fuzzy control theory mainly includes reducing waiting time, reducing the time of riding, reducing the congestion in the car, and reducing the long waiting time. The fuzzy logic control technology is not constrained by the model and is mainly realized by relying on the experience of human logic and thinking mode, and is mainly used to deal with the problem of unclear constraints or inaccurate models, and its method is to continuously approximate the control algorithm based on fuzzy. Mainly according to the call information of different floors, combined with the actual situation, according to the different importance of the floor call prediction, the weight value is different, the multi-objective function is converted into an evaluation function, and the operation is completed to realize the multi-objective control. The implementation of the control method is mainly to use the logical thinking, experience, and "membership function" of experts to determine the input and output variables of the ECGS controller to meet the requirements. It can effectively solve the problems of diversity, discrete randomness, and nonlinearity of elevator clusters [5]. So far, the fuzzy control theory mainly includes reducing waiting time, reducing the time of riding, reducing the congestion in the car, and reducing the long waiting time. not fully match.

3. Group control scheduling method

1) Fuzzy control-based scheduling

The fuzzy logic control technology is not constrained by the model, and is mainly realized by relying on the experience of human logic and thinking mode, and is mainly used to deal with the problem of unclear constraints or inaccurate models, and its method is to continuously approximate the control algorithm based on fuzzy. Mainly according to the call information of different floors, combined with the actual situation, according to the different importance of the floor call prediction, the weight value is different, the multi-objective function is converted into an evaluation function, and the operation is completed to realize the multi-objective control. The implementation of the control method is mainly to use the logical thinking, experience and "membership function" of experts to determine the input and output variables of the ECGS controller to meet the requirements. It can effectively solve the problems of diversity, discrete randomness, and nonlinearity of elevator clusters [5]. So far, the fuzzy control theory mainly includes reducing waiting time, reducing the time of riding, reducing the congestion in the car, and reducing the long waiting time.

Its main advantages are as follows:

a. Able to achieve multi-objective function control.

b. Complete the classification of the passenger flow stage of the car in the hoistway.

c. Deal with discrete randomness problems through the logical experience of experts.

Its shortcomings are mainly manifested in:

a. It mainly depends on the experience of the experts in the system, and the experience of the experts cannot be updated in real-time;

b. The fuzzy logic control is relatively simple, lacks self-learning and adaptive functions, and cannot adapt to complex changes;

c. It is difficult to modify the fuzzy rules and membership functions after they are determined.

2) Scheduling based on expert systems

There are some practical problems that cannot be accurately described by mathematical models, which requires an expert system formed with long-term accumulated empirical knowledge, which is to define and use the existing problems that cannot be accurately described by variables [6].

It is more suitable for the analysis of discrete and incomplete structure of the knowledge system, in the face of such a polynomial non-deterministic problem as ECGS, the use of expert system to deal with the analysis problem is a better choice, it can improve the singleness of the system to solve the control problem, can be predicted in the knowledge base according to the existing experience, obtain the predicted value and integrate the size of the collected passenger flow data to complete the programming of the control instruction, and finally realize the optimal dispatch of the elevator cluster. There are deficiencies in the expert system scheduling in the elevator cluster control, mainly because the control process relies too much on the source of knowledge, such as the knowledge is not comprehensive enough, the control rules can not meet the established requirements, and this situation mostly occurs when the number of elevators is large, and there is no good adaptability.

3) Neural network-based scheduling

The computational model of artificial neural network technology is mainly derived from biological neural networks, which are the main representatives of intelligent applications [7]. The advantage in elevator scheduling is to be able to use the self-learning and parallel processing information ability in the neural network, in the self-learning process to constantly adjust and adapt to the existing environment in combination with the actual situation, its learning ability can also continue to achieve and timely adjustment in the changing environment, that is, after the input value, by adjusting the interrelationship between the internal nodes to process the information and continuously fit the actual data, to improve the accuracy of the operation. The disadvantages are that it requires a large number of training books, and the controller convergence takes a long time and has a low probability.

4) Scheduling based on genetic algorithm

Genetic algorithm is a kind of intelligent algorithm derived from the mechanism of biological genetics and natural selection in nature, which searches to find the optimal result under a specific condition. The principle of optimization is to imitate the biological evolutionary mechanism and express it mathematically to find the optimal solution of the expression. This is very different from the traditional method of building mathematical models based on actual conditions. The genetic algorithm draws on the evolution mechanism of nature's survival of the fittest, projects the spatial range of the solution to be found into the genetic space, and encodes the suspected solution in the spatial range as a chromosome, and each unit in the chromosome is a gene. According to certain rules, the adaptation degree of each chromosome to the living space is obtained, so as to search for the chromosome with the strongest adaptability within the solution space and obtain the optimal solution.

The emergence of the algorithm provides a new perspective for solving the difficulty of establishing a mathematical model, and the calculation of the fitness function in the elevator group control is mainly based on the customer's goal, predicting the generation of the call signal between floors and the distribution of the car position. However, the optimization efficiency of this method is low, and the convergence time is longer when accurate optimization is required, on the contrary, the convergence speed can be accelerated by reducing the number of iterations and the number of populations, but it is easy to fall into local optimal solutions.

4. Summary

This paper summarizes the development of elevator group control technology, mainly introduces the development process of elevator group control technology and the common mathematical models of elevator group control technology, as well as the development process of researchers, and solves the optimization problem of elevator group control technology by combining various mathematical models and algorithms, reflecting the mutual integration and epochality of technologies. In future development, if cloud computing can be introduced into the algorithm-solving process, the problem of timeliness of elevator group control will be solved, and the elevator will be more humanized and intelligent.

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