논문 2007-44IE-4-6

엘리베이터의 분산 제어 모델링에 관한 연구

(A Study on the Distributed Control Modeling of Elevator)

조 명 현*, 이 명 언*

(Myung-Hyun Cho and Myung-Un Lee)

요 약

본 논문은 엘리베이터의 분산 제어 시스템을 수학적으로 모델링 하여 이 모델을 기반으로 미리 정의된 제어 목적 하에서 보다 안정되고 향상된 성능을 보이는 제어 알고리즘을 설계하는 것을 목적으로 한다. 또한 승강장 요구 응답 시간 추정과 실제값을 분석하였다.

Abstract

Recently, buildings are constructed increasingly higher and even more people are using elevators every day. Therefore, more efficient means of vertical transportation are required. Most of high-rise buildings is equipped with elevators. Unlike one elevator system, a multi-elevator system requires a function, which can distribute multiple elevators effectively. This paper examines a multi-elevator system, which has been modeling mathematically, in order to reduce waiting time and use elevators more effectively.

Keywords : Distributed Control, Elevator, Modeling, Multi-Elevator System, Hall Call Response Time

I. Introduction

As buildings become higher and passengers want move even faster, efficient means of vertical transportation are getting even more important. Unlike a building with only one elevator, in a building with many elevators traffic management and control is required for efficient elevators' operation. To this end, a special controller is used, which is called an elevator group controller.

A system with multiple elevators and a group controller are called an elevator group control system. By way of analogy, the elevator is like a car and people traveling with the elevator are the passengers. A group control can be summarized as the subject that which car is allotted to calls by which passenger depending on the car state and passenger's call.

Here, the state of the car may be indicated as each car's movement, locations, etc. Passengers' calls are the calls to go up and down from each floor and the calls for which floor to go. Elevators with group control system must also meet the requirements of a single elevator operation.

In the group control system, there are many control purposes to be met by the group controller: minimized waiting time, minimized round time, minimized energy consumption, etc. Among them, minimized waiting time is the most important one[1~3].

Such a purpose of the group control is considered to optimize the performance given according to various control purposes, and also considered as multi-purpose optimization in this term.

At present, most of elevator manufacturers using logic-based group control for the group control.

* 정회원, 서일대학 전기과
(Seoil College Dept. Electrical Engineering)
접수일자:2007년9월6일, 수정완료일:2007년11월30일

Whenever there is a call, the corresponding rule is using If-then method. The decision about traffic pattern is also made by means of the fuzzy rule.

The reason of using fuzzy rule for the group control is that group control has a variety of control purposes, and also because of the uncertainty and nonlinearity of the elevator system itself. Control purposes include[4~6].

- Minimized waiting time.
- Minimized mean waiting time.
- Average boarding ratio.
- Minimized mean travel time.
- Reduced energy consumption.
- Maximized operation ratio of the entire group during rush hours.
- Immediate indication of the car, which is about to come.

Uncertainty, nonlinearity and disturbance include:

- We don't know in advance on which floor the car is, and where from the call comes.
- We don't know in advance to which floor the currently calling passenger is going.
- In case the car is full, further calls are rejected and the car goes up or down.
- The car frequently changes its direction during movement unlike expectation.
- Passenger's wrong platform and floor call.
- If one continues to press the OPEN button, the car is delayed.

With group controllers using fuzzy rule, the set of rules is normally pre-programmed in advance by the rule of thumb. Thus, the controller can reasonably cope with uncertainty, nonlinearity, and other ambiguities. Such controller, however, has the following shortcomings[7~8].

- Actual environment differs from the assumed.
- System performance depends on the skills of a person who programs the system.
- Heavy simulation is required because it's difficult to adjust fuzzy membership function.
- Developing a new rule or editing the existing one requires much time and effort.

This paper designs the control algorithm with more stable and improved performance under a predetermined control purpose on the basis of a model by mathematically modeling the distributed group control system of the elevator.

II. State Information of Distributed Group Control System

In order to accurately model a system, it is necessary to know its state information first of all. State information means data, which allow predicting next operation of the system by describing the current system state.

State information must include only data required for prediction of system operation, and no other information.

State information can be further categorized into predictable and non-predictable. Only the predictable data are used as actual state information. Generally, state information about an elevator system and its predictability are shown in Table 1. The number of a current floor can range from the ground floor to the highest number of floors. When the car is between the floors, this can be represented using decimal points. Movement directions are 5 divided into :

표 1. 엘리베이터 시스템의 상태정보
Table 1. State information of elevator system.

Event	Details
STOP	STOP
UP-STOP	Floor stop when going up
UP-MOVING	Goes up
UP-DOOROPEN	Door opens at car stop when it goes up
UP-DOORCLOSE	Door closes at car stop when it goes up
DN-STOP	Floor stop when going down
DN-MOVING	Goes down
DN-DOOROPEN	Door opens at car stop when it goes down
DN-DOORCLOSE	Door closes at car stop when it goes down

UP-MOVING, DN-MOVING, UP-STOP, DN-STOP and IDLE. UP-MOVING and DN-MOVING mean the car is moving up or down, respectively.

The speed and acceleration of the car are indicated as car (i).vel and car (i).acc, respectively.

The car i′s predictable state information can be represented as follows.

$$S_i = (F_i, R_i, C_i, H_i, L_i, V_i) \tag{1}$$

where F_i is the current floor number of the i-th car, R_i is the direction of the car, C_i is a call to which floor to go, H_i is the hall call set, L_i is a load level of passengers, and V_i is the floor at which to stop next.

Ⅲ. Operation Model of Single Elevator Using Event Graph

The operation of a single elevator can be considered as a kind of a discrete phenomenon system. There are many models of discrete phenomenon system[9~10].

In this paper, however, an event graph model is used.

Since event graph modeling is carried out while graphically depicting the discrete phenomenon system,

표 2. 엘리베이터 동작 이벤트 리스트

Table 2. Elevator operation events.

Item	Symbol	Observ-ability	Meaning
Current floor number	car(i).floor	o	Car location
Movement and direction	car(i).dir	o	Car direction
Call set inside of a car	car(i).cc-set	o	Current call inside of a car
Hall call set	car(i).hc-set	o	Platform allotted call to a car
Door state	car(i).door	o	Door open/close
Over-weight	car(i).load	o	Excess of passengers
Car velocity	car(i).vel	o	Car velocity
Car acceleration	car(i).acc	o	Car acceleration

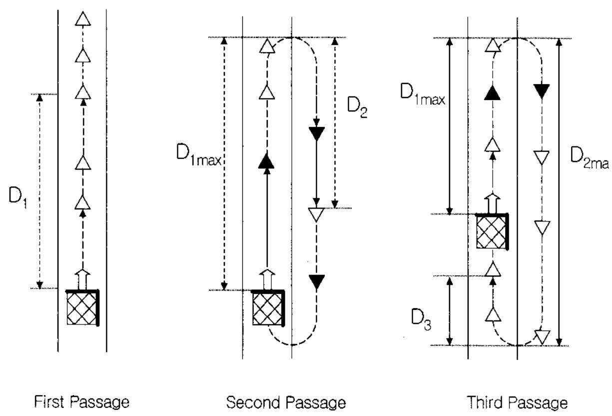
it improves modeling legibility and allows easy modeling verification. The elevator event graph model contains events shown in Table 2.

In order to indicate operation in connection with the above event, additional system state and specification information as shown below is required.

- MAX F : the highest floor
- MIN F : the lowest floor
- c.fr : the current floor of the car
- Q_h : the queue of hall call allotted to the car
- CC : call set inside car

The matter that should be noted here is how the sequence of the hall call is specified to Q_h. When several hall call are allotted to one car and when determining which call should be served first, the sequence to align the hall call to Q_h is important to meet the requirements of direction holding operation of the single elevator mentioned in the previous section. In order to align the hall call to Q_h as such, the passage concept shown in Figure 1 is used. This is indicated as a set, as follows.

$$Q_h = H_F \cup H_S \cup H_T \tag{2}$$



o - Calculation (considered) point D_1-First passage distance

▲ - Hall call up D_2-Second passage distance

▼ - Hall call down D_3-Third passage distance

△ . Car call up △ + ▲→△

▽ . Car call down

그림 1. 승강장 요구의 승객 그룹

Fig. 1. The passage groups of hall call.

Where, H_F is the first passage group, H_S is the second passage group, and H_T is the third passage group. CC is generated by a passenger creating a hall call. CC also aligns the calls from the floor first served depending on the progress direction of the corresponding elevator.

Ⅳ. The Example of Elevator Operation, and Application of Q_h and CC Model

Let's assume that a car call and a floor call are issued to the car moving up through the third floor as shown in Figure 2. That is, assume that on the 2nd, 7th and 9th floors, there are calls to go up and, on the 3rd and 7th floors there're calls to go down. There can be passengers' requests on the 5th and 10th floors. How Q_h and CC are determined? How do the respective passage groups consisting of Q_h change depending on the movement of the car? Thinking about this, H_F, H_S, H_T consisting of Q_h are determined, respectively, as follows.

$$H_F = \{7,\ 9\},\ H_S = \{7, 3\},\ H_T = \{2\} \tag{3}$$

CC is also as follows.

$$CC = \{\ 5,\ 7,\ 10\ \} \tag{4}$$

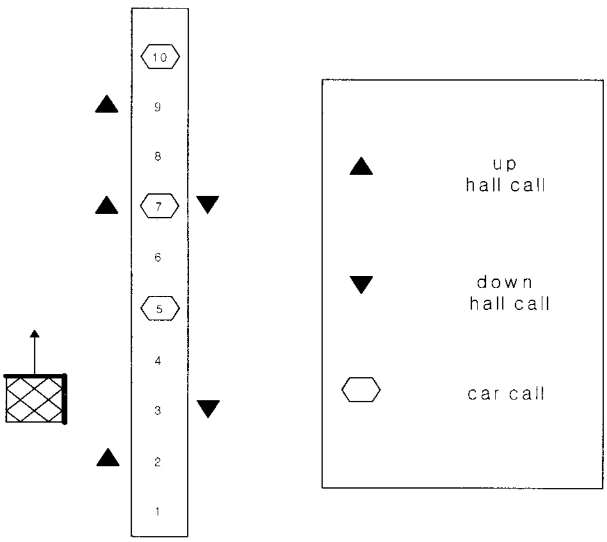


그림 2. 차의 이동과 할당된 승강장 요구 및 등록된 차 내부 요구의 예

Fig. 2. Example of car's moving, allotted hall call and registered car call.

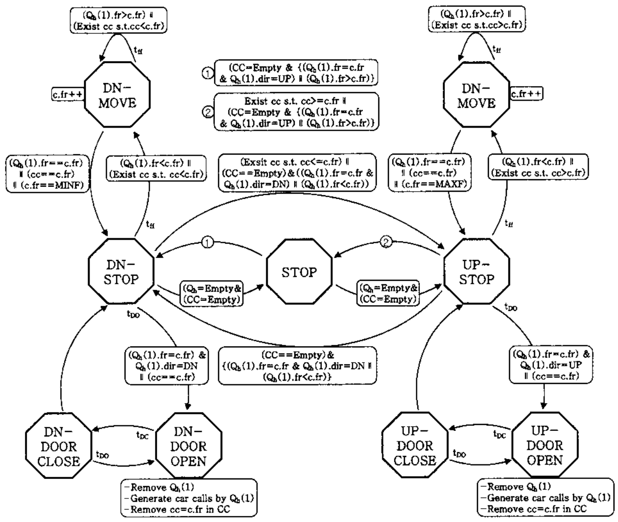


그림 3. 상태천이 그라프

Fig. 3. State transition graph.

The very moment the car accepts all the up-calls from the platform and the hall calls and the up-calls changes the direction of move me.

H_F is filled with hall calls of and H_S, H_S is filled with H_T, and H_T becomes a null set.

The event is transferred into another event satisfying conditions by the system state information. In this case, the time consumed for the transfer depends on each event.

If transfer occurs, system information is updated. The overall transfer model is shown in Figure 3.

In figure 3, t_{ff}, t_{DO} and t_{DC} show transfer delay time. For example, when the event A is under the condition that transfer can occur by the state information, the event B occurs after transfer delay time is over. Each transfer delay time exists between following events.

$$t_{ff}: Up(DN) - STOP \rightarrow Up(DN) - STOP \tag{5}$$

$$t_{DO}: Up(DN) - STOP \rightarrow Up(DN) - DOOROPEN \tag{6}$$

$$t_{DC}: Up(DN) - DOOROPEN \rightarrow Up(DN) - DOORCLOSE \tag{7}$$

Ⅴ. Adaptive Estimation of HCRT

The key question is how to control the service of hall call in a reliable way and as quick as possible.

To this end, it is necessary to predict in advance hall call response time(HCRT), which is a time span of a generated hall call from each car. It is known that the HCRT of the car call is a function of a total distance $D(h)$ in moving to serve the hall call and the number of stops $S(h)$ as shown below.

$$W(h) = f(D(h), S(h)) \quad (8)$$

HCRT, namely $W(h)$, is calculated by the following equation.

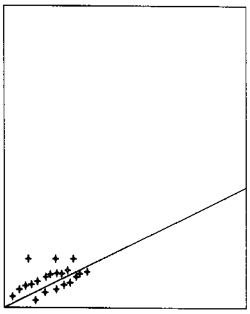
$$W(h) = P_T\ t_l + P_U\ t_u + S(h)(t_{DC} + t_{DO} + t_{ff} - t_v) + D(h)\,t_v \quad (9)$$

However, P_T is the number of passengers getting in the car before the call h is served, and P_U is the number of passengers getting off the car. and t_l is time to load one passenger, t_u is time to unload one passenger, t_v is transit time between two floors at contract speed.

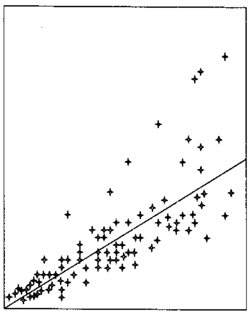
Figure 4 (a) and (b), compare estimated and actual value of $W(h)$ when group control is used according to the following equation.

$$W(h) = S(h)(t_{DC} + t_{DO} + t_{ff} - t_v) + D(h)t_v \quad (10)$$

Figure 4(a) shows a traffic call situation of intermediate level with traffic density of 60 passengers/5 min. Figure 4(b) shows a situation with high traffic density of 150 passengers/5 min. The point marked with + in figure 4 (a), (b) shows the



(a) 60 승객/5분
(a) 60 passengers/5min



(b) 150 승객/5분
(b) 150 passengers/5min

그림 4. 승강장 요구 응답시간 추정과 실제 값

Fig. 4. Estimation and real value of response time of hall call.

표 3. 모의 실험시 설정값

Table 3. Establishment value use in an imitation experiment.

Establishment item	Establishment value
Building number of floor	20
Number of car	6
1 floor height	3 m
Elevator average speed	2.5 m/s

표 4. 제안한 값과 모의실험 결과 값의 비교

Table 4. Imitation experiment result of existent and imitation experiment result comparison of proposed.

	Imitation experiment result of existent	Imitation experiment result of proposed
Average of HCRT	33.67s	25.53s
Distributed of HCRT	4.12s	15.41s

time when the elevator arrives at the called floor wherein X-axis show estimated and U-axis show actual value. As can be seen from the figures 4 the higher the traffic density is, the more difference is between the value calculated by the equation 10(estimation) and the actual value.

Figure 4 shows the estimation and real value of hall call response time.

And establishment item and establishment value that use in an Imitation experiment have showed in table 3.

The experiment result from table 4 shows that this proposed method decreases average HCRT, whereas it increases HCRT distributed. Still the result whose the value of HCRT distributed is relatively bigger than the one of existing result needs further study in terms of effectiveness and improvement[11].

VI. Conclusion

In this paper, we distributed control group system of elevator was mathematically modeling and under the predefined control purpose based on this model, it was purpose to design the control algorithm that have the more stable and improving performance.

Also, analyzed both the estimated response time for requests on the platforms and the real value.

References

[1] A.T.P. So and S.K. Liu, An Overall Review of Advanced Elevator Technologies, Elevator World, June, 1996, pp 99-103
[2] J. W. Fortune, Mega High-Rise Elevators, Elevator World, July, 1995, pp 64-69
[3] G. R. Strakosch, Vertical Transportation: Elevator and Escalators, John Wiley& Sons, Feb, 1983.
[4] W.L Chan and A.T.P. So, Dynamic Zoning in Elevator Traffic Control, Elevator Technology 6, IAEE, 1995, pp 132-140.
[5] A.T.P. So and W.L.Chan, Comprehensive Dynamic Zoning Algorithms, Elevator World, September, 1997, pp 99-109
[6] M. Amano, M.Yamazaki, and H. Ikejima, The Latest Elevator Group Supervisory Control System, Elevator Technology, IAEE, 6, 1995, pp 88-95
[7] C. G. Cassandras, Discrete Event Systems: Modeling and Performance Analysis, IRWIN, 1993.
[8] A. H. Buss, Modeling with Event Graphs, IEEE Press, 1998.
[9] G. K. H. Pang, Elevator Scheduling System Using Blackboard Architecture, IEE Proceeding, 138, 1991, pp 337-346
[10] B. Hayes-Roth, A Blackboard Architecture for Control, IEEE Artificial Intelligence, 26, 1985, pp 251-321
[11] S. Markon, H. Kita,and Y. Nishikawa. "Reinforcement Learning for Stochastic System Control by Using Feature Extraction with BP Neural Networks," NC91-126, Fujitec Research Centre Ltd. 1992, pp 209-21

저 자 소 개

조 명 현(정회원)
제43권 TE편 제4호 참조

이 명 언(정회원)
제43권 TE편 제4호 참조