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A New Modeling Method with Cellular Automata for Elevator Group Control System

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1 Introduction

The elevator group control system (EGCS) is a discrete event dynamic system that works to systematically manage three or more elevators to efficiently transport the passengers. With the increase of buildings' height in recent years, the elevator industry has put their focus on the performance improvement and the service quality that the EGCS should possess. In order to find effective elevator group control methods and verify these methods, we need a suitable EGCS model to factually describe the elevator dynamic behaviors and the elevator group cooperating activity.

Many theories, such as Time Logic theory and Petri net, have been used for the establishment of the EGCS model [1~5]. These models become excessively complicated with floor numbers of the building and car numbers increased in the model. With the characteristics of discrete, stochastic and parallel-distributed, the cellular automata
makes it possible of a better done result with less effort.

2 Cellular Automata

A cellular automaton has characteristics as follows, (1) it is made of a discrete lattice of cells; (2) the cell state is described by a set of discrete or continuous parameters;(3) the new color value of the updated cell data is based solely on its old color values and its nearest neighbors.(4) each cell is updated according to the same rules. Paper [6~10] introduced the theory in detail.

Cellular automata can be defined as the following mathematics language:

Let

L_d be a regular lattice (the elements of L we call cells), d be the dimension of cells space,

S be a finite set of states,

N be a finite set (of size |N|=n) of neighborhood indices such that for all c in N, all r in L_d : r+c in L, $N = (s_1, s_2, \ldots s_n)$, $s_i \in Z, i = 1,2,\ldots n$,

f: $S^n \rightarrow S$ a transition function.

Then we call the 4-tuple (L_d, S, N, f) a cellular automaton.

3 Modeling of EGCS

We present the model of EGCS in this part, Fig.1 is an overview of our EGCS structure.

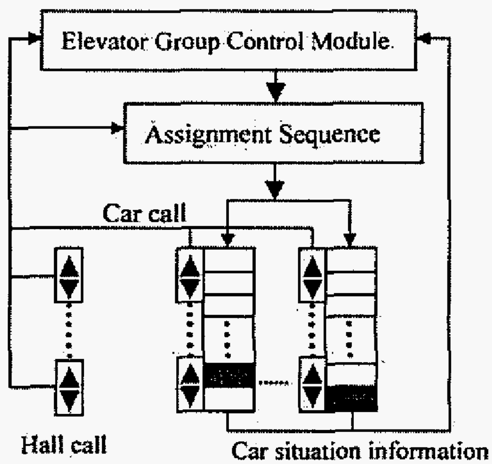

Figure 1 System Structure

The proposed system is composed of three modules shown in Fig.1: group control module elevator movement module and assignment sequence module.The task of the group control module is to select a suitable elevator for each hall calling according to the system information. The elevator movement module describes multiple elevators' dynamic behaviors by cellular automata. Next we shall interpret the application of cellular automata in EGCS modeling process.

3.1 Elevator Movement Module

we know, from the system structure, that every elevator has the same moving mechanism and is independent to each other. So, we can set up the same model for each elevator. The Multi- elevator model could be realized by operating several elevator models synchronously. In addition each cell contact only with its nearby cells and increase of cells doesn't affect the structure of the whole model, so parameters of the whole model is easy to change, such as layer, elevator number.

We analyze the elevator moving behavior and find that the movement of every elevator car could be divided into several parts: running (including acceleration, uniform speed and deceleration), waiting (including open/close door, load/unload passengers) and stopping (means no call order).

The cellular automata model takes place in fixed discrete time steps. We regard T, the minimum periodical time of the cellular automata evolution, as our system period, which depends on the particular movement parameters of elevators and the model's precision requirement.

At first, we define some parameters needed in our model: See Fig.2

Layer, elevator car current floor, t current moment, t+T, next moment,

S[layer][t], the current state of the cell,

S[layer-1][t], the state of the lower level neighboring cell,

S[layer+1][t], the state of the upper level neighboring cell,

Assignment[], assignment sequence.

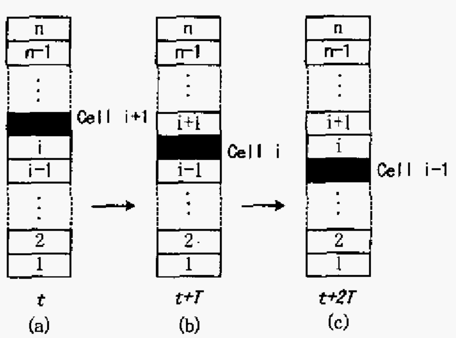

Figure 2 Cellular Automata Model Structure

The Cellular automata model definition is as follows:

a) Dimension: the dimension of cells space is 1 and building floor number is n;
b) States: each cell has 4 states: s[layer][t]= 0, cell empty; s[layer][t]= 1, cell with car and no movement; s[layer][t]= 2, cell with car and moving up; s[layer][t]= 3, cell with car and moving down;
c) Neighbors: each cell has two neighboring cells. In Fig.2 (b), cell i has one neighboring cell i+1 above it and the other i-1 under it;
d) Local rules:

As we know in practice, one elevator has only one car. It means that in the single cellular automata model there is only one cell denoted to a car and the other cells are empty. The state of the cell with car at the next moment is only correlated with the state of this cell, its two neighboring cells and the external input but no correlation with other cells. So, other cells keep their former states during the cellular automata model evolution. Assignment sequence controls every moving behavior of the elevator car. It is from group control module order or from inner calls. Control module order is prior to inner calls. In each evolutional step, assignment sequence refresh itself. Movement module compares the destination floor with the current floor where the car is on, and then decides the next state of the cell based on the local rules. Even though group control module isn't at work, Movement module and Assignment sequence can operate independently.

Local rules for cells in detail are shown as follows:

1) When s[layer][t]=1, the cell with car and not moving at time t: If at the next moment t+T, waiting time is over and no new call order in the assignment sequence, the car stops , s[layer][t+T]=1; if waiting time is not over, the car continues to wait, s[layer][t+T]=1; if waiting time is over and assignment sequence has new call, the car moves up or down according to the call's direction, s[layer][t+T]=0, s[layer+1][t+T]=2 or s[layer][t+T]=0, s[layer-1][t+T]=3.
2) When s[layer][t]=2, the cell with car and moving up at time t: if at the next moment t+T, the car doesn't reach the destination floor, it continues going up, s[layer][t+T]=0, s[layer+1][t+T]=2; if the car reaches the floor, it stops and begins to wait, s[layer][t+T]=0, s[layer+1][t+T]=1;
3) When s[layer][t]=3, the cell with car and moving down at time t: if at the next moment t+T, the car

hasn't reached its destination floor, it continues going down , s[layer][t+T]=0, s[layer-1][t+T]=3; if the car reaches the floor, it stops and begins to wait, s[layer][t+T]=0, s[layer-1][t+T]=1;

4) When s[layer][t]=0, s[layer-1][t]= 0 and s[layer+1][t]=0, the cell and its neighboring cells are all empty at time t: At the next moment t+T, these three cells keep their current states.

There are some special rules for the cells at the boundary. The cell with car on the top floor can only move down and the cell with car on the bottom floor can only move up as in practice.

Fig.2 (a), (b) and (c) shows a car in the elevator running down in uniform speed from floor i+1 to floor i-1 during time t to t+2T.

In the elevator movement module, there also defines a parameter over_loading, which is a signal to report whether the current car is over load during the moving process.

3.2 group control module

Since fuzzy concepts are prevailing theory used in most elevator control, it is appropriate to use fuzzy control as elevator control. Fuzzy control helps to enhance the controllability and adaptability of the system.

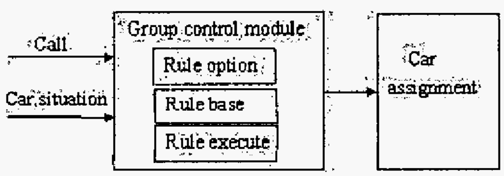

Figure 3 Group control module structure

Rule base is the most important part of fuzzy control module. The module chooses suited rules to assign the car. The rule option is determined by passenger flow status. we list some basic rules below[11]:

1) If car A overload ;
   Then car A is not assigned;
2) If call from layer n wait long;
   Then the call priority from layer n increases;
3) If [call occur upstairs] And [car aA run upward];
   Then priority of car A increase;

Conditions of these rules are expressed with membership functions, for example:

Passenger waiting time is sorted into level of short, medium and long. Expressed respectively, passenger waiting time is short, passenger waiting time is of medium level, passenger waiting time is long. The symbols of membership functions of the above said are μ_s, μ_m, μ_l shown in Fig 4.

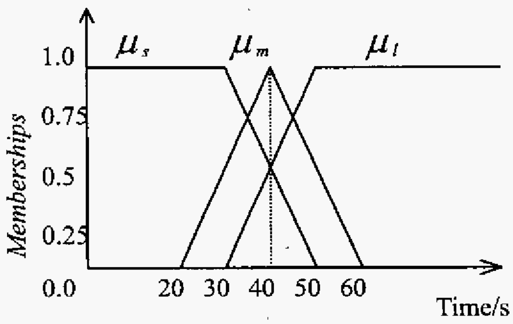

Figure 4 membership functions(Waiting time)

It is remarkable that the efficiency of the elevator group could be disturbed by many disorders. For example, car block results in a long waiting time. We can check this instance with a fuzzy rule :

If [car A stay on layer n too long] and [car A keep open];
Then car A is blocked on layer n.

Usually we can draw a final conclusion with MAX-MIN method.

1) calculate the grade of membership condition one by one;
2) if it is on the base of multi-condition, such as
   If ([condition n_1] and [condition n_2] or [condition n_3]) ,
   grade of membership is
   $C_n=\min\{C_{n1}\max\{C_{n2},C_{n3}\}\}$,
   C_{n1}, C_{n2},C_{n3} are grade of membership condition n_1, n_2, n_3 respectively.
3) maximize all rule, the rule with maximal grade of membership is the result.

4 Simulation

The simulation conditions are shown in Table 1.The data of passenger traffic flow is simulated according to the routine method [13. The number of passenger arrivals in random interval is generated through a Poisson process. Monte Carlo examination generates the data such as from which floor the hall call issues and to which floor the passenger wants.

Items	Settings
Moving speed	2m/s
Acceleration/deceleration	1m/s^s
Open/close door time	3s
Average load/unload time	3s
Average height of floor	3.3m
Capacity	15 persons

Table 1 Simulation Conditions

To verify accuracy of the EGCS model, we builds 2 simple model, model A has 3 elevators and 10 floors. model B has 6 elevators and 30 floors.

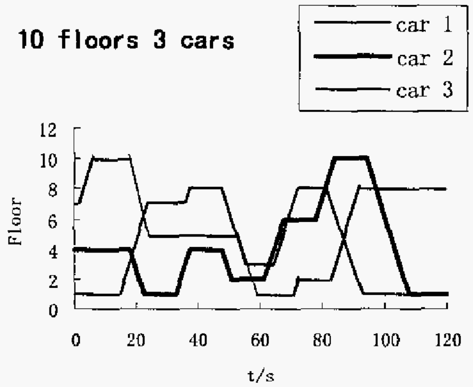

Figure 5 Simulations of Model A

In Fig.5, 3 cars respectively stop at 1,4,7 floor at first and 10 hall calls are input the simple model in 80 seconds. Then we compare the performance with or without group control in Table 2 and Table 3. Average waiting time, average riding time , maximal waiting time and long waiting time rate are defined as AWT, ART , MWT and LTR.

Group control	AWT	ART	MWT	LTR
No	21.8s	18.4s	91.3s	12%
Yes	17.2s	15.9.s	52s	6%

Table 2 10 floors , 3 elevators

Group control	AWT	ART	MWT	LTR
No	58.8s	40.4s	237s	26%
Yes	39.2s	31.5s	110s	11%

Table 3 30 floors , 6 elevators

These simulation results demonstrate that the proposed EGCS model based on the cellular automata can accurately describe the dynamic behaviors of the multiple elevators. After fuzzy control program is adopted, EGCS model also respond skillfully. Fuzzy control helps remarkably reduce maximal waiting time and long waiting time rate. It is proved that this modeling method for EGCS is effective.

5 Conclusion

this paper has discussed the theory and properties of cellular automata, therefore we propose in detail a new modeling method for elevator group control system. The model of EGCS consists of three modules: group control module, elevator movement module and assignment sequence module. Computer simulations confirmed the validity of the proposed method.

Cellular automata is good at simulating discrete, stochastic and parallel-distributed systems. Although the study of applying cellular automata theory to ECGS model is just at the beginning, we believe it to be a powerful and useful tool in the modeling fields of EGCS.

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