Analysis and Simulation of Passenger Flow Model of Elevator Group Control System

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***Abstract*—this paper proposes a method to analyze and simulate passenger flow model in elevator group control system (EGCS). Although stochastic passenger arrival process in EGCS is about to belong to Poisson process, the data we got are not perfect. We can obtain several standard passenger flow models by Monte-Carlo sampling, and we simulate this with MATLAB. Simulation experiments show that the design method of passenger flow is quite effective and it meets the demands of EGCS for passenger flow data. Moreover, it offers foundation for next step research of EGCS.**

Keywords-passenger flow model; elevator group control system; Monte-Carlo sampling; MATLAB

I. INTRODUCTION

Along with the fast development of construction, the emergence of high-rise buildings and the expanding of structure proportion in cities, elevator, as a vertical conveyance is more and more important. At the same time, people propose more and more high demand to the quality of service of elevators. So the elevator group control system (EGCS) is necessary. In short, EGCS is the system that systematically manages three or more elevators in order to efficiently transport passengers. It is a complex, discrete and dynamic system with the conditions of the environment where it serves is always in change. The initial floors of the passengers are stochastic and their destination floors are unknown. Generally, the information is not easy to be got by people. However, because of passenger flow model is the key basis to dispatch elevators for EGCS, we can obtain the initial and destination floors of passengers with Monte-Carlo sampling in several traffic flow patterns. And from the MATLAB simulation we can get accurate output data with all kinds of traffic flow patterns.

II. ANALYSIS OF TRAFFIC PASSENGER FLOW MODEL

Passenger flow has different characteristics for different functions of the building. The analysis and calculation of passenger flow characteristics of all kinds of buildings is the base to make reasonable elevator deployment and control method and strategy study. In the same kind of building, the situation of passenger flow may not very similar due to a variety of reasons. For example, the difference of specific situation of applications; the difference of local lifestyle rest system and changes of seasons, etc. However, statistics show that there are some passenger flow laws.

Generally speaking, the elevator group is divided into four traffic patterns according to the actual passenger flow in a typical office building. They are up-peak traffic mode, down-peak traffic mode, balance between floors traffic mode and idle traffic mode.

1) Up-peak traffic mode: The up-peak traffic mode is defined as: If the main or all direction of the passenger flow is upward, which means, all or the majority of passengers enter the elevator which locates in the hall of building are going up, then being distributed to the various floors of the building. In a typical office building, at the office-opening time, around 8:30 am, there may be the most passengers who will go to work from the first floor to any other floors. Morning up-peak traffic is a critical traffic situation in office buildings. For this reason performance requirements are often specified for an up-peak situation and elevator configurations are compared in an up-peak situation.

2) Down-peak traffic mode: The down-peak traffic mode is defined as: If the main or all direction of the passenger flow is downward, in other words, all or the majority of passengers down from different floors is going down to the first floor at the hall of building and leave elevator. In a certain sense, down-peak happens at off work time which is the reverse of morning up-peak. In this mode, passenger density is relatively large. It often makes elevator car full when it stops for one or two floors, so we should reasonably determine the destination floor of the upstream level car, before it goes down. Then the elevator group control system can serve evenly for down passengers at all floors.

3) Balance between floors traffic mode: The balance between floors traffic mode is difined as: About from 9:00 to 17:00 everyday, inter-floor traffic takes up a large proportion in the traffic of building. This traffic mode is a basic traffic condition and exists in the most time of a day. Balance between floors traffic needs reasonable stop strategy. We should consider which floor the car should stop at when there is no call signal assigned to it. At this time, we can ask free cars stop evenly among floors or stop at those floors with a lot

of passengers. In this mode, passengers' waiting time and running time are requested to be the least.

4) Idle traffic mode: The idle traffic mode is defined as: If the buildings passengers are sparse and passenger arrival interval time is very long. It usually happens at holidays, night and dawn, etc. In this mode, part of elevators work, while others are in the condition of idly waiting. Meanwhile, we should reduce start and stop times and the numbers of elevators in order to decrease energy consumption. Apparently, the whole number of passengers is very small. In particular, there is no calling signal within 90 seconds to 120 seconds.

III. DETERMINE THE INITIAL AND DESTINATION FLOORS OF PASSENGERS

Because passengers in idle traffic mode are very few, we just consider and analyze other modes.

A. Initial density vector and start-target matrix

We assume the number of floors in one building is n, and the passenger flow of arrival and departure of a floor is proportional to the number of resident. We use x, y, z to represent the percentage of passenger flow upward, the percentage of passenger flow downward and the percentage of passenger flow between floors with the sum of the three percentage to be 1. Initial density vector is defined as:

$$\text{origin}(1) = x;$$

$$\text{origin}(i) = (y+z)\zeta_i \ (i=2, 3\ldots) \tag{1}$$

In (1),

$$\zeta_i = \frac{POP(i)}{\sum_{i=2}^{n} POP(i)}$$

Where POP (i) represent the population of the i-th floor.

In fact, initial density vector indicates that the relative traffic which starts from the i-th floor. Start-target matrix of passenger flow can be defined as:

$$\begin{bmatrix} od_{11} & od_{12} & \ldots & od_{1n} \\ od_{21} & od_{22} & \ldots & od_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ od_{n1} & od_{n2} & \ldots & od_{nn} \end{bmatrix} \tag{2}$$

Where od_{ij} is relative passenger flow from the i-th floor to the j-th floor. When i=j, od_{ij} = 0. And the formula of od_{ij} is:

$$od_{1j} = \begin{cases} 0, & j=1, \\ \zeta_i, & j=2,3,\ldots,n, \end{cases} \tag{3}$$

$$od_{i1} = \begin{cases} 0, & i=1, \\ y/(y+z), & i=2,3,\ldots,n, \end{cases} \tag{4}$$

$$od_{ij} = \begin{cases} 0, & i=j, \\ z\eta_{ij}/(y+z), & i\neq j. \end{cases} \tag{5}$$

Where, $\eta_{ij} = \dfrac{POP(j)}{\sum_{k=2,k\neq j}^{n} POP(k)}$

B. Calculation of the initial and destination floors of passengers

If the initial density vector of passengers is known, we can determine initial floors of passengers with Monte-Carlo sampling. Firstly, we make a roulette, on which we distribute n arc areas along the circumference. While n arc areas in turn corresponds to n floors, and every arc area is proportional to initial passenger density that see the floor as starting floor. For each passenger, we rotate roulette randomly to generate the starting floor. The floor corresponding to the arc area which is pointed to by the pointer is the starting floor of the passengers when it stops.

1) Specific steps as follows:

a) Compute the sum of initial density that belongs to all of N floors. F=sum (origin (*i*)); (*i*=1, 2… N)

b) Compute selection probability of each floor. p_i =origin (*i*)/F; (*i*=1, 2… N)

c) Compute cumulative probability of each floor. $q_i = \sum_{k=1}^{i} p_i$ (*i*=1, 2… N)

d) For each passenger, one evenly distributed random number r is generated within range [0, 1]. If r< q_1, we choose the first floor as the initial floor of the passenger. Otherwise, we choose the i-th floor as the initial floor of the passenger, and i must meet the condition $q_i \geq r > q_{i-1}$.

2) Destination floors of passengers can be determined according to start-target matrix. The way is similar to how determine initial floor. Specific steps as follows:

a) Determine initial floor i with the above method.

b) Compute the sum of target floors that belong to the i-th line but exclude i in start-target matrix.

c) Compute selection probability of the j-th floor as the passenger's target floor.

d) Compute cumulative probability of each floor. $q_{ij} = \sum_{k=1}^{j} p_{ij}$ (j=1, 2, … , N, $j \neq i$)

e) One evenly distributed random number s is generated within range [0, 1]. If s< q_{i1}, and $i \neq 1$, we choose the first floor as the destination floor of the passenger. Otherwise, we choose the j-th floor as the destination floor of the passenger, while j must meet the condition $q_{ij} \geq s > q_{ij-1}$, and $j \neq i$.

IV. SIMULATION OF PASSENGER FLOW AND RESULT ANALYSIS

The above model can be simulated on computer, especially, using MATLAB. And the flow diagram is designed as figure1.

Assume there are 20 floors in an office building, with its resident population to be 1259. In addition, we set the simulation time to start around 08:00 in the up-peak traffic mode, while around 17:00 in the down-peak traffic mode and around 10:00 in the balance between floors traffic mode. Then we give each percentage of passenger flow in all kinds of traffic modes as table1.

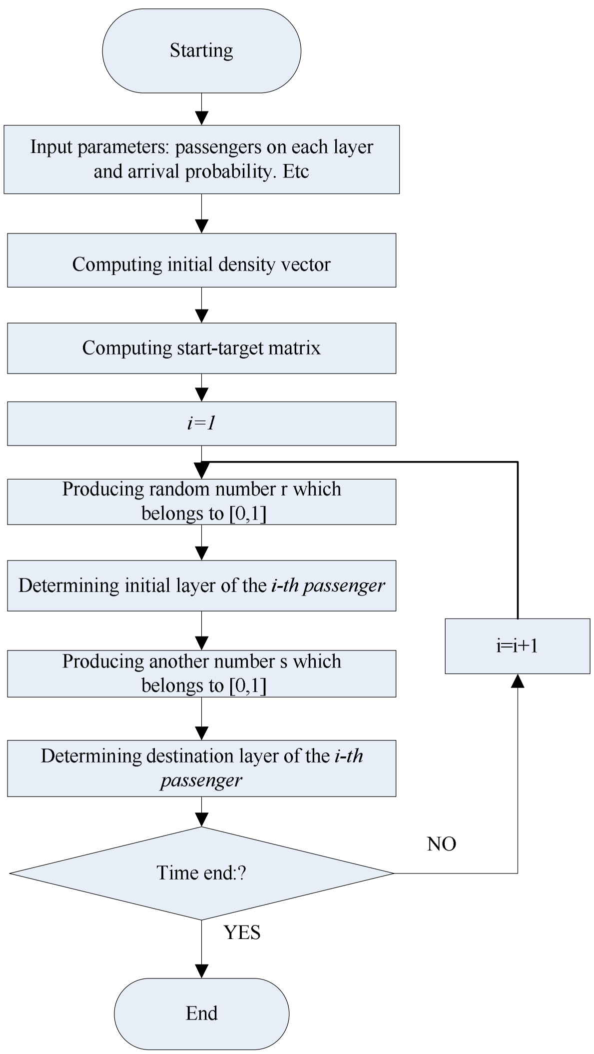

Fig. 1 Simulation of passenger flow of passenger traffic.

Based on the above conditions, we can obtain data of passenger flow in those three typical traffic modes. And the results produced by simulation as table2, table3, table4.

Table1. Each percentage of passenger flow

Passenger flow mode	Up-peak mode	Down-peak mode	Balance between floors mode
Percentage of up passenger	0.90	0.05	0.45
Percentage of down passenger	0.05	0.90	0.45
Percentage of inter-floor passenger	0.05	0.05	0.10

Table2. Data of passenger flow in the mode of up-peak

Up-peak traffic mode		
passenger	Initial floor	Destination floor
1	1	5
2	1	2
3	1	14
4	1	17
5	1	3
6	1	4
7	1	19
8	1	17
9	1	13
10	1	15
11	1	20
12	1	13
13	1	17
14	7	6
…	…	…
592	1	17

Table3. Data of passenger flow in the mode of down-peak

down-peak traffic mode		
passenger	Initial floor	Destination floor
1	9	1
2	12	1
3	10	1
4	4	1
5	14	1
6	15	10
7	1	1
8	19	1
9	14	9
10	1	1
11	10	1
12	4	9
13	10	1
14	16	1
…	...	...
701	17	1

Table4. Data of passenger flow in the mode of balance between floors

Balance between floors traffic mode		
passenger	Initial floor	Destination floor
1	9	1
2	20	1
3	1	13
4	16	1
5	1	12
6	19	1
7	7	1
8	1	9
9	1	18
10	1	5
11	12	17
12	3	17
13	10	1
14	1	6
…	…	…
109	1	8

V. CONCLUSIONS

The core of elevator group control system is the elevator group scheduling algorithm, while the method that is most effective, least costly of human and financial strength to verify the dispatching algorithm performance, advantages and disadvantages is using standard passenger model as input. In the simulation environment, the algorithm is applied to simulate elevator group control system operation. For elevator group control system, passenger flow model must be consistent with the traffic situation of real elevator traffic system. However, passenger flow always changes throughout the day, so elevator traffic is quite complex.

In this paper, the analysis and simulation of passenger flow model of elevator group control system is introduced. Firstly, several typical traffic modes are discussed first. Then initial and destination floors of passengers are obtained by Monte-Carlo sampling. Computer simulation was run for up-peak, down-peak and balance between floors conditions and the output showed satisfactory results in passenger flow. These data of passenger flow provide a very good foundation for further research of elevator group control system. Using the data we got can we build more convenient research intelligent control of elevator group control system.

ACKNOWLEDGMENT

This work is finished in the Control Theory and Engineering Development Lab located in Shenyang Ligong University. I would like to thank Dr. Qing Yang, Chong Zhou and other teachers and classmates in the lab. Especially I would like to thank Chong Zhou who played a significant role in this research.

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