A REPORT ON

INTELLIGENT ELEVATOR CONTROL SYSTEM BY FUZZY LOGIC

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ABSTRACT

Current Elevator Control System has various shortcomings and drawbacks such as long waiting time, high energy consumption, frequent breakdowns, etc. The proposed system tries to minimize waiting time and riding time thereby reducing unnecessary power consumption and elevator breakdowns. This project aims at analyzing the features of elevators and how fuzzy logic could be used to increase the efficiency of elevator control system by minimizing the waiting time and riding time, and determining which floor has highest number of people waiting for the elevator. Thus, this control system can be used in high rise buildings which have multi group elevator system.

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INTRODUCTION

Due to scarcity and high price of land in urban areas, more and higher rising buildings are being constructed. Buildings with thirty floors or more are now a common sight in many cities around the world. With high rise buildings, there is a need for new techniques in building automation. One aspect of building automation is in the development of intelligent elevator systems. In every high rise building, the task of controlling a group of elevators is necessary in order to obtain optimum performance. Two of the main criteria for optimum performance of elevator systems are minimizing waiting time and riding time. Other criteria include loading with respect to the number of passengers in the elevator, safety measures, and also comfortability.

In a conventional elevator system, the task of controlling a large number of elevators is numerically evaluated by calculating a specified fixed-evaluation function. It has been realized that knowledge and experiential rules of experts can be incorporated in the elevator system to improve performance. However, such expert knowledge is fragmentary and fuzzy which are difficult to organize. Furthermore, the choice of “good” rules and evaluation functions are too complicated in many cases. It is difficult to adequately incorporate such knowledge into products using conventional software and hardware technology.

In order to overcome such problems as described above, a new elevator control system using fuzzy logic algorithm is proposed based on the ordinal structure theory. This system determines the optimum elevator within a group of elevators to answer a hall call using the knowledge and experiential rules of experts. Instead of using the simple up and down hall call buttons, destination oriented keypads at each floor is used. This system requires the passengers to enter their desired floors on the keypad before they enter the car. The system then assigns the passenger the respective optimal car to take through information displayed on dot matrix displays near the keypad. This new elevator supervisory control system has several objectives which can meet users’ satisfaction. It can improve not only the average waiting time, but also the riding time, load, energy and so on. This project discusses the design and operations of the proposed fuzzy logic elevator control system.

Fuzzy logic (FL) is a problem-solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multi-channel PC or workstation - based data acquisition and control systems. It can be implemented in hardware, software, or a combination of both.

Fuzzy logic concepts are used in elevator control systems to make decisions. It shortens the time for engineering development and sometimes, in the case of highly complex systems, is the only way to solve the problem. The design criterion includes optimizing movement of elevators with regard to several factors such as waiting time, riding time, energy, load, etc. Therefore, software simulation is done in order to capture the performance of the proposed system (Fuzzy Approach) which is compared to conventional approaches (Crisp Approach).

ELEVATOR CONTROL GROUP SYSTEM

The elevator group control system is designed based on centralized group control technology. A group controller is used to realize the registration and the allocation of the hall call. CAN-Bus serial communication between the group controller and the elevator's main controller ensures high speed and reliable transmission of massive data. A group controller board mounted with LED indicators, allows us to monitor the communication effectiveness between the group controller and the elevator's main controller, as well as the connection of the input ports. The elevator group control system can manage a maximum of 8 elevators and 48 landings, allowing a wide range of applications.

Working Principles of the Elevator Group Control System

After energized, the main controller of individual elevator will send the hall call button signal to the elevator group control system. The registered hall call signal will then be sent to the landing/indicator board of every floor to acknowledge a landing call and light the call button. If any of the main controllers loses power, the group controller will directly communicate with the call/indicator board, ensuring that the elevator continues to work effectively under group control.

According to the SHORTEST WAITING TIME principle, and considering the distance between the floors, registration status of hall call and car call, by-pass status, reversal running, etc., the elevator group control system performs an effective real allocation of the hall call signal. The system will choose the elevators with the fastest response, thus the transportation capability can be fully excavated and the elevator operation efficiency significantly improved.

If the elevator group control system identifies an elevator which keeps the door open after receiving the allocated hall call signal for long time, the system will cut off that elevator and re-allocate the hall call signals, ensuring the shortest waiting time for the passengers.

In case that the elevator group control system is broken down, under maintenance, or power off, every single elevator will keep simplex running, and automatically return to the group control mode after the group controller is restored.

Main Functions of the Elevator Group Control System

To meet different requirements and enhance the operation efficiency, the elevator group control system may offer multiple functions.

Up Peak Service and Down Peak Service

During the up peak time set manually or by the timer relay, when more than 3 commands are registered in the elevator that is running upwards above the main floor, up peak service function will be started by the elevator group control system. Elevators are allocated to the main floor waiting with door open (2 for 2-3 lift group, 3 for 4-5 lift group, 4 for 6-7 lift group and 8 for 8 lift group). When the up peak time is over, the elevator group control system will resume to normal status.

Similarly, down peak service starts during the down peak time, when the elevators are full-loaded and traveling downwards from the upper floors to the main floor. Elevators are allocated to the highest landing with the same number as the up peak service. When the down peak time is over or no full loading is detected for the elevators going downwards above the main floor for 2 consecutive minutes, the elevator group control system will resume to normal status.

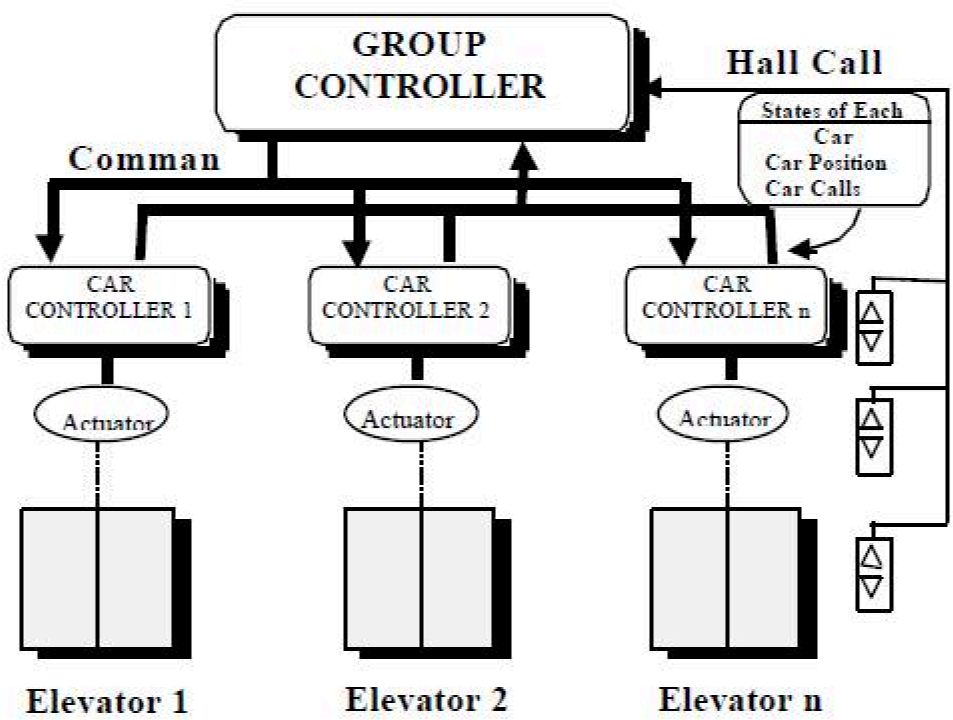


Fig. 1 A general structure of an elevator group supervisory control system.

FUZZY CONTROL SYSTEM DESIGN

In traditional control system design, there is usually only one performance criteria to be met, such as the optimum speed, position, minimum-time, etc. Due to the limitation of the configuration of the traditional control algorithms, it is difficult to design a system to meet multiple objectives. However, in fuzzy logic control systems, multiple objectives can be included in the design.

CRITERIA

The structure of the fuzzy logic controller makes it possible for a number of important objectives to be met simultaneously. In the design of our elevator group supervisory control system, the following objectives are considered:

- To minimise the waiting time of passengers at a floor.
- To minimise the time passengers need to spend in an elevator.
- To minimise crowding in the elevator.
- To minimise travelling distance of each elevator.

CONSTRAINT

However, the objectives mentioned above have several conflicting problems. For example, shortening of waiting time must be sacrificed to some extent for the sake of energy saving and also crowding in the elevators. Thus, the group supervisory control system is required to optimise the multiple design objectives with time and traffic flow constraints.

Similar to many practical elevator systems, the following constraints were assumed in the simulation of the proposed intelligent elevator control system:

- An elevator will not reverse direction if there is a passenger inside.
- The capacity of each elevator is 14 people and when capacity is met, it will bypass hall called floors.
- Each elevator travels at a constant speed of 0.5 floor per second.
- Serving a floor requires 4 seconds to accomplish. During this time a person may simply walk into or out of the elevator. To serve more than 4 people, 6 seconds is needed.
- An elevator must not bypass any car call.

HOW FUZZY LOGIC IS USED

Fuzzy logic is a combination of both numerical and symbolic techniques. It excels in producing exact results from imprecise data and is especially useful in computers and electronic applications. Fuzzy logic differs from classical logic in that statements are no longer black or white, true or false, on or off. In traditional logic an object takes on a value of either zero or one. In fuzzy logic, a statement can assume any real value between 0 and 1, representing the degree to which an element belongs to a given set. The human brain can reason with uncertainties, vagueness and judgments. Computers can manipulate precise valuations. Fuzzy logic is an attempt to combine these two techniques.

FUZZIFICATION

All the fuzzy inference rules are described in one dimensional space for each of the model's input and output. Co-ordination of the rules is done with weights attached to each rule. This model is easier in constructing or modifying fuzzy inference rules than the conventional fuzzy reasoning method as each rule is described in single dimensional space.

For an n-input one-output system, the ordinal structure model is described as follows :

R^i : If X_1 is A_{i1} then Y is B_i
R^j : If X_2 is A_{i2} then Y is B_j
(i, j = 1, 2, ..., n)

where, X_1 and X_2 are the inputs and Y is the output, R^i is the i-th fuzzy rule. A_{i1}, A_{j2}, B_i and B_j are the fuzzy variables and n is the number of rules.

$$y = \frac{\sum_{i=1}^{n} w_i u_i c_i S_i + \sum_{j=1}^{n} w_j u_j c_j S_j}{\sum_{i=1}^{n} w_i u_i S_i + \sum_{j=1}^{n} w_j u_j S_j}$$

Fig 2. Moment Method to find the output of the control system

where, w_i and w_j are the weights of rules R_i and R_j respectively. μ_i is the truth value of R_i in the premise. C_i and S_i are the central position and the area of the membership function with fuzzy variable B_i, respectively.

MEMBERSHIP FUNCTIONS

Depending on the fuzzy inputs and the rule bases, the output fuzzy set, ‘priority’ is computed using an inference scheme. Several inference schemes are available like Mamdani, Sugeno etc. For the present simulator, the Mamdani scheme has been adopted. In this application each rule has a single input mapped to a single output to avoid complexities involved by considering all the inputs in a single rule.

In order to achieve good traffic performance, the elevator fuzzy control system uses six kinds of parameters as the control inputs and one parameter for the output. These parameters represent the criteria or objectives to be optimized in this elevator systems which are as follows:

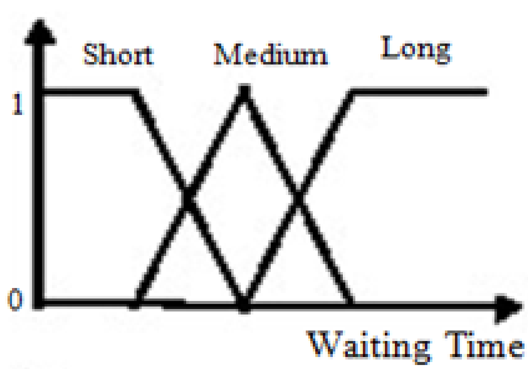
Waiting Time :-
• Total time an elevator needed to travel from its current position to the new hall call.
Riding Time :-
• Total time a passenger spent in the elevator until he reached as his destination.
Loading :-
• Number of passengers in an elevator.
Travelling Distance :-
• Distance between elevator position and new hall call in terms of number of floors.
Hall call Area Weight :-
• The area weight of the elevator which goes to the floor where a new hall call is generated.
Destination Area Weight :-
• The area weight of the elevator which goes to the floor where the destination of the new hall call is generated.
Priority :-
• Output of the fuzzy controller, where the elevator with highest value will be assigned.

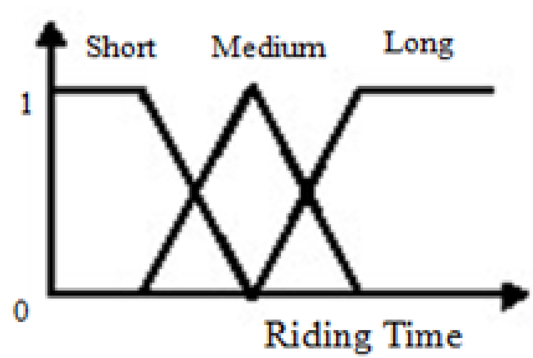
The proposed fuzzy inference rules are shown below and the membership function of the inputs and output variables are shown in Fig. 3 and Fig. 4.

A total of 18 fuzzy inference rules used:-

R[1]) If waiting time **short** then priority is **high**. (0.70)
R[2]) If waiting time is **medium** then priority is **medium**. (0.70)
R[3]) If waiting time is **long** then priority is **small**. (0.70)
R[4]) If riding time **short** then priority is **high**. (0.40)
R[5]) If riding time is **medium** then priority is **medium**. (0.40)
R[6]) If riding time is **long** then priority is **small**. (0.40)
R[7]) If loading is **small** then priority is **high**. (0.50)
R[8]) If loading is **medium** then priority is medium. (0.60)
R[9]) If loading is **high** priority is small. (0.60)
R[10]) If travelling distance is **close** then priority is **big.** (0.05)
R[11]) If travelling distance is **middle** then priority is **medium**. (0.05)
R[12]) If travelling distance is **far** then priority is **small**. (0.50)
R[13]) If hall call area is **close** priority is **high**. (0.50)
R[14]) If hall call area is **positively** far priority is **medium**. (0.50)
R[15]) If hall call area is **negatively** far priority is **small**. (0.50)
R[16]) If destination call area is **close** priority is **high**. (0.40)
R[17]) If destination call area is **positively** far priority is **medium**. (0.40)
R[18]) If destination call area is **negatively** far priority is **small**. (0.40)

Every rule has a weight (a number between 0 and 1), which is applied to the number given by the antecedent.





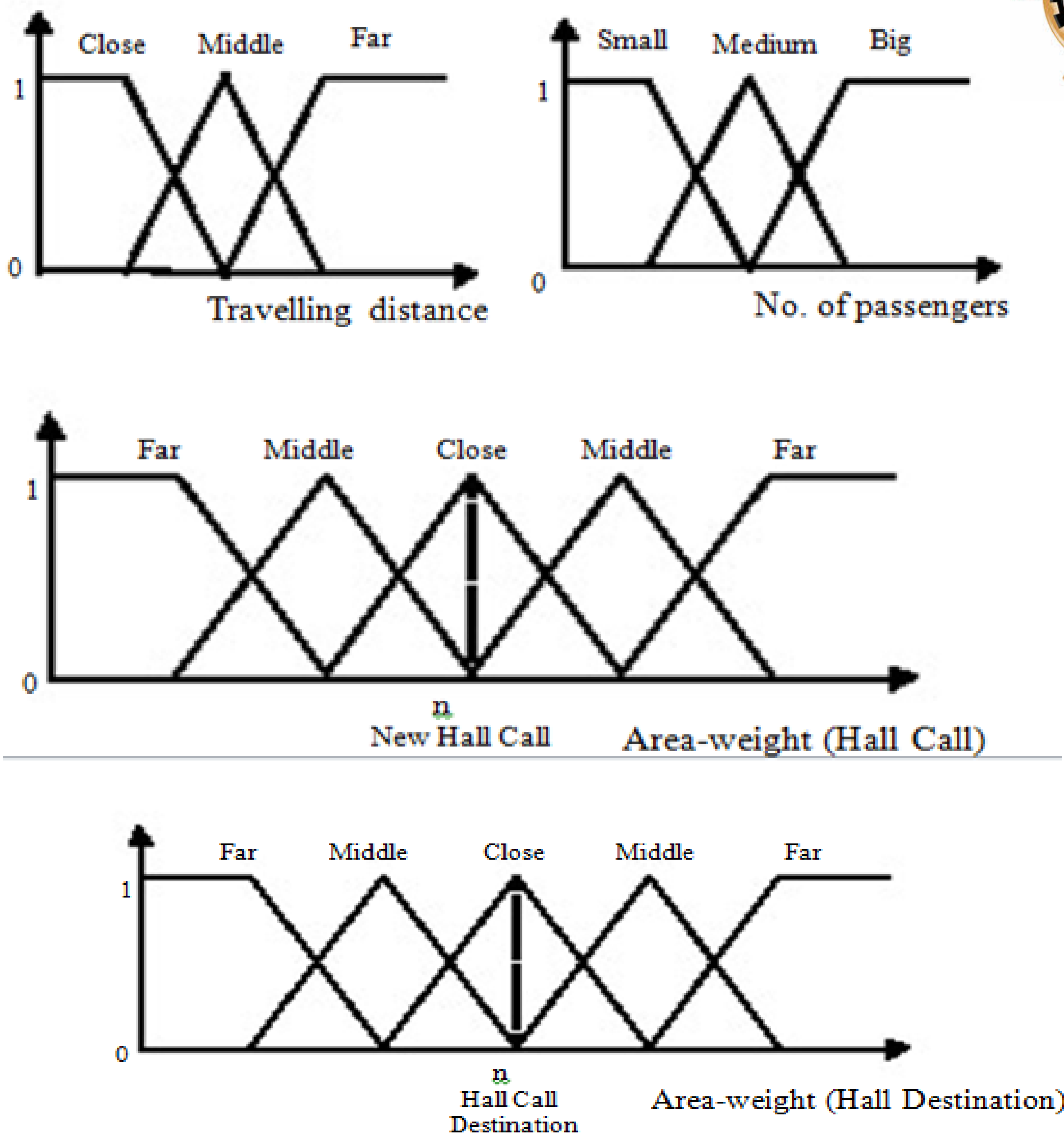


Fig. 3 Membership functions of the elevator system inputs.

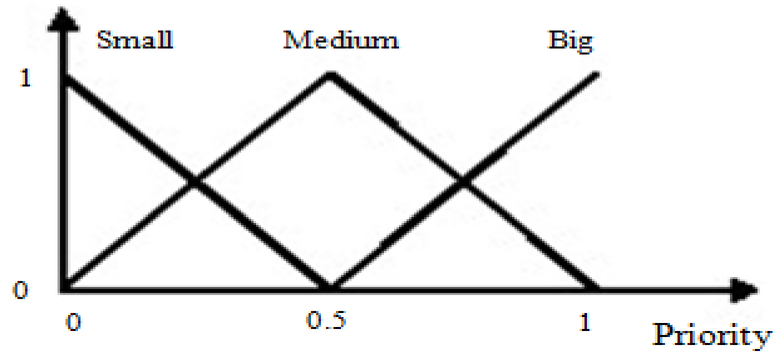


Fig. 4 The membership function of the output of the elevator system.

DEFUZZIFICATION

The input for the defuzzification process is a fuzzy set (the aggregate output fuzzy set) and the output is a single number. As much as fuzziness helps the rule evaluation during the intermediate steps, the final desired output for each variable is generally a single number. However, the aggregate of a fuzzy set encompasses a range of output values, and so must be defuzzified in order to resolve a single output value from the set.

RESULT

To evaluate the feasibility of the proposed fuzzy control system, a highly interactive graphic simulation program is written on an IBM PC compatible system. This simulation simulates the movements of the cars as in a practical elevator system. The software was written in Visual Basic 3.0 using event-driven programming techniques with interactive graphical environment as shown in Fig. 5. This software has a number of facilities for easy manipulation and also analysis of the performance of the fuzzy and conventional elevator systems. Three cases of traffic patterns were experimented and the results of the simulations are given in this section.

Fig. 6 shows the condition of the 3 elevators for the first case. In this figure the arrow represents the direction of each elevator. The black circle indicates where the car call was initiated for the respective elevators. The black triangle represents a hall call which will be served by the elevator. Finally, a new hall call and its destination generated on the floor are marked by the white triangle and white circle, respectively. For example, in the same figure, it can be observed that elevator 1 is currently located on the 3rd floor and is moving upwards. It has two car calls on the 8th and 9th floors. A new hall call is then initiated on the 5th floor where its destination is the 14th floor; however no elevator is assigned yet to it.

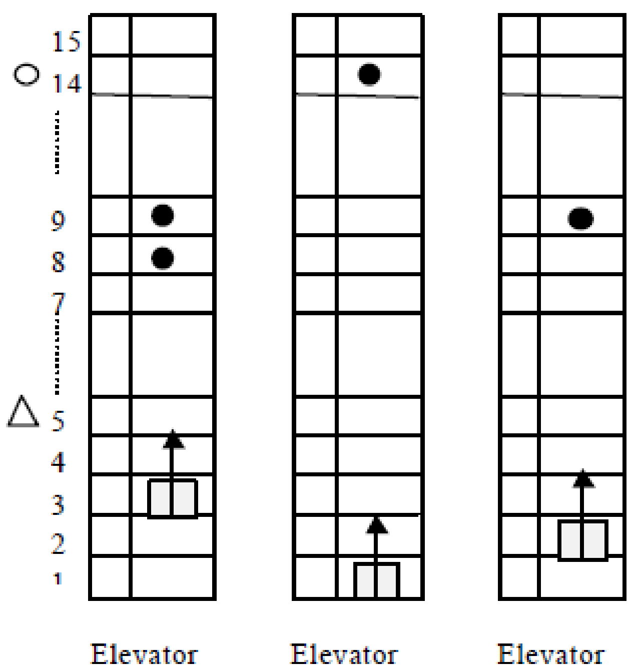


Fig. 6 Initial condition of case 1 simulation.

Using the conventional elevator system which is distance oriented, the elevator closest to the new hall call would, thus, be assigned which in this case is elevator 1. However, the proposed fuzzy system assigned this hall call to the elevator 2. As we find from the initial conditions in Fig. 6, elevator 2 has a car call on the 14^{th} floor. It means that elevator 2 will serve that floor instead of elevator 1. Thus, the destination area weight parameter of elevator 2 will contribute a higher priority in the evaluation function as given by inference rule no.16 in Table 1. In terms of travelling distance, there is a reduction as compared to the conventional system since elevator 1 will finally stop at the 9^{th} floor and not at the 14^{th} floor. Due to this performance, another advantage can be obtained in terms of energy saved.

In the second simulation, all conditions are the same as case 1 except that elevator 1 has three car calls, at 8^{th}, 9^{th} and 14^{th} floor. If a new hall call happens at the 5^{th} floor and its destination is the 14^{th} floor, elevator 1 will thus be selected as the candidate for this assignment. This is because the waiting time of elevator 1 is the shortest and thus contributes a “high” priority to the evaluation function. In this case, the destination area weight parameter gives the same effect to both elevators 1 and 2.

In the third simulation, a hall call is assigned to elevator 1 at the 7floor and the rest of the conditions are the same as the previous case. For this case, elevator 2 has been assigned to answer the new hall call instead of elevator 1 even through elevator 1 already has a car call to the 14^{th} floor (see Fig. 7). As we know, elevator 1 will stop three times before it arrives at the 14^{th} floor, thus it is not economical to use this elevator. On the other hand, elevator 2 will move non-stop to the 14^{th} floor after picking up the new passenger. Here, it means that the riding time of the passengers is shorter if they travel using elevator 2 compared to elevator 1.

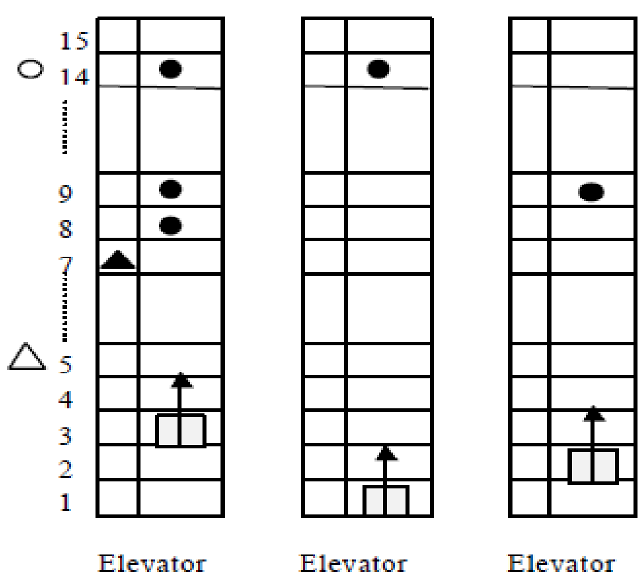


Fig. 7 Initial condition of case 3 simulation.

CONCLUSION

In this report, a fuzzy control algorithm for elevator group control has been proposed and evaluated. Fuzzy Logic provides a completely different, unorthodox way to approach a control problem. This method focuses on what the system should do rather than trying to understand how it works. One can concentrate on solving the problem rather than trying to model the system mathematically, if that is even possible. This almost invariably leads to quicker, cheaper solutions. Once understood, this technology is not difficult to apply and the results are usually quite surprising and pleasing.

This new intelligent elevator control system is developed to improve multiple control objectives. The performance of the proposed elevator system is simulated through an interactive graphic simulator that has been developed. It was observed that as compared to conventional system, the proposed elevator system performed better in terms of minimizing waiting time, travelling time as well as comfortability in terms of loading.

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APPENDIX

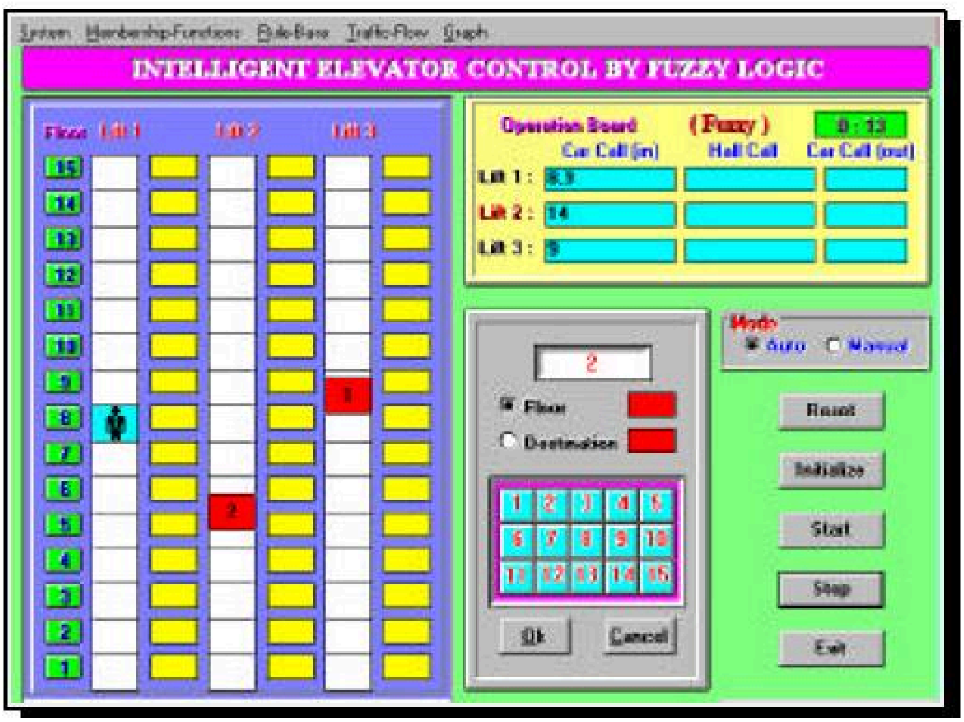

Fig. 5 Simulation of the intelligent elevator control system.