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Original Research Paper

The Realization of a Control Algorithm and its PLC Based Program Able to Authorize Four Different Ranks of Priority to Elevator Users

Mümine YILDIZ COŞKUN *[1], Mehmet KARALI [2]

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Abstract: Elevator software programs are currently unable to meet the required demand regarding elevator services of high-rise community and government buildings such as hospitals and social centers. Administrators, emergency room doctors and nurses in hospitals; authorities in public or governmental buildings (such as ministers, governors, rectors, deans); or managers, and staff working in community buildings wish privileged use of existing elevators. This isn't only a personal privileged, but an institutional necessity; resulting in a second elevator assigned to VIP use. Regrettably, while such elevators are empty, others become too crowded and queues form up, resulting in frequent breakdowns. Not to mention the unauthorized use of said elevators causing problems in instances where an emergency is at hand. The solution of card and/or key systems on the other hand has become tedious and inefficient. In this project, authorization rankings were assigned and special usage privileges given. Thus, in cases where VIP usage is needed, the elevator temporarily cancels out either totally or partially all other calls according to VIP ranking, resulting in the efficient use of elevators by preventing them from being inactive when there is no ongoing VIP usage. Algorithms have been written for authorized use and have been designed for flexible response using PLCs. This project utilizes a model encompassing a four rank authorization system (three VIP, and one normal) which, after a number of simulations, has been tested on a servomotor-powered mechanism. The project is planned to be expanded to incorporate up to a ten rank authorization system.

Keywords: *Elevator Control, PLC (Programmable Logic Controller), Privileged Use of Elevators.*

1. Introduction

The prime objective sought of elevators is providing services to the maximum amount of users in minimum waiting period [1]. Researchers have utilized different approaches in studies to reach this goal. In [2] the author explained that; an ambient intelligence application that can model a group elevator timing control system was optimized with the help of a fuzzy-artificial immune recognition system. In the designed system, by using the optimization aspect of clonal choice algorithms of the fuzzy-artificial immune recognition system, average waiting periods of users were aimed to be lessened. In [3] the author explained that; the developed system can adapt to traffic in different conditions. As such, it hosts maximum amount of users with minimum waiting periods and takes them to desired floor while also saving energy through this performance. Thanks to expert rule based fuzzy logic supervisors, distinct traffic hours are identified. Relating to this classification more specified fuzzy logic is realized regarding every one of the model classes. In [4] the author explained that; the traffic models in buildings used for various purposes differ. Thus, in order to carry the maximum amount of people in the minimum amount of time, the algorithm for elevator control should be developed with this circumstance in mind. In the elevator system, by monitoring changes in the number and direction of user calls, and through incorporating a suitable control algorithm, the designated goal of carrying maximum people in minimum time was tried to be reached. In [5] the author explained that; this paper describes the development of 2 nine-storey elevators control system for a residential building. The control system adopts PLC as controller, and uses a parallel connection dispatching rule based on "minimum waiting time" to run 2 elevators in parallel mode. In [6] the author explained that; an elevator group supervisory controller is a control system that manages systematically two or more elevators in order to serve passengers as required. The elevator cars are assigned accordingly in response to hall calls, so as to optimize waiting time, riding time, power consumption, passengers' comfort, etc. In this paper, the simplicity of ordinal structure fuzzy logic in making crucial supervisory control decisions is demonstrated. In addition, in order to further improve the performance, a new approach of ordinal structure fuzzy logic with context adaptation is demonstrated to implement an elevator group supervisory controller for a building with 15 floors and 4 elevator cars. Simulations comparing ordinal structure fuzzy logic algorithm with and without context adaptation, show that the former performs better.

As for this project; elevator traffic density was aimed to be lessened through the formulation of four different algorithms created for four differently ranked priority groups (rank1, rank2, rank3, normal), preventing VIP assigned elevators from being idle while providing for privileged (VIP) users through a password system the use of normal elevators and also allocating the call traffic of normal elevators to encompass all elevators. Problems which arise from the misuse of special purpose elevators in emergency situations were also prevented. Through a password system, the elevator, in case of VIP usage, temporarily cancels out either totally or partially all other calls and sends the elevator according to VIP ranking of the caller. Elevator Control Algorithms:

1) Rank1 Mode: Being the highest privileged rank, answers the call in fastest manner. All calls before and after are canceled until caller has reached destination.

2) Rank2 Mode: Being a middle privileged rank, elevator answers Rank2 calls while higher privilege still remains with Rank1 calls. It answers cabin calls made before Rank2 call until Rank2 is reached, and answers Rank1 calls made afterwards, and Rank2 and

[1] *Dept. of Mechatronic Engineering Necmettin Erbakan University, Konya/Turkey*
* *Corresponding Author: Email: mumineyildiz@konya.edu.tr*
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Rank3 calls which are en route.
3) Rank3 Mode: Being a low privileged rank, Rank2 has higher priority. Calls made before Rank3 call are answered until Rank3 user is reached. Afterwards normal calls are not answered.
4) Normal Mode: Being the lowest rank, elevator calls matching elevator direction are answered with accordance to en route closeness, while calls in the opposite direction are answered after elevator course changes again accordingly with en route closeness. When answering calls with the same priority the rule used for Normal Mode has been determined.

2. Elevator Control Design

2.1. Hardware and Software

Designed elevator system is composed of mainly three parts; control system, interfacing for elevator system and elevator prototype.

2.1.1. Control Parts

Created algorithms were implemented with Panasonic FP-X programmable logic controller (PLC).
PLC's isolation is better than other controller system's isolation, because it is influenced less by temperature changes, moisture, noise and vibration. PLCs can also easily control many components in the market such as sensors, contactors and relays. It is easy to make revision on created systems. PLC devices provide the possibility of remote control. That is, it is possible to control the PLC control system device via the internet.
Panasonic FPX FPW Pro7 software is used to program the PLC. This software can write all FP series' PLCs programs. It has five programming languages, which are the instruction list, ladder diagram, function block diagram, sequential function chart, and structured text. In this project ladder diagram programming languages are used.

2.1.2. Interfacing For Elevator System

For the elevator system human-machine interface, WinTR SCADA was used. Production of this software has begun in 2009 by Fultek, a Turkish company. Among its advantages are that it allows communication between the PLC of many different brands and that it is free for non-profit use.
The SCADA interface allows monitoring the up and down movement of the elevator and the opening and closing of its doors without the use of a prototype and easily testing the developed program and the finding of errors and problems. It is possible to enlarge the system within SCADA without the need for physical hardware.

2.1.3. Elevator Prototype

By using a servo motor for the application of experimental studies a prototype elevator has been created. The prototype system design was simplified through position control by taking advantage of the position control feature of the servo motor, without using limit switches. A system that uses a different motor can be easily integrated to this program, since the motor control program was formed as motor control subroutine.

2.2. Elevator Control Algorithms

2.2.1. Normal Mode

Single elevator traffic algorithms used to control the elevator system can be one of the following: Car-switch Operation, Automatic Operation, Signal Operation, and Collective Operation. In this project, Collective Operation Logic, which gives the least wait-time, was used to create the Normal mode algorithm. Collective operation answers same direction calls according to proximity and stores to memory opposite direction calls to be answered after direction change.
Rather than a flow control diagram, a logical solution has been opted via Karnaugh map by evaluating all possible working conditions.
Desired output in line with system logic has been ensured by evaluating the situation between different variables, mainly: the data of the movement of elevator, the directional input of the calls and the proximity of the calls according to one another.
A part of the table showing the output according to the possibility table created according to these variables has been given in Table 1.
Output evaluation of the variables has been done as so: If elevator is going up, and if there is an up direction call, and it is also the closest call; then gives output. Every line in the probable situations table is evaluated according to this logic.
The Karnaugh solution which provides the result according to the created conditions is so:

|BCD|GE + |BCD|GF + B|C|H|GE + B|C|H|GF + AB|C|H|G + A|BCD|G + |BD|HGE + |BD|HGF + A|BD|HG + |BDH|GE + |BDH| GF + A|BDH|G‖

When the Karnaugh solution is applied to PLC the program is generally formed of the networks where the Karnaugh solution is applied and the networks where the necessary variables are produced. For example, the processes of committing incoming calls to memory and resetting or networks where the closest call proximities can be obtained. The Fig.1 represents this situation.

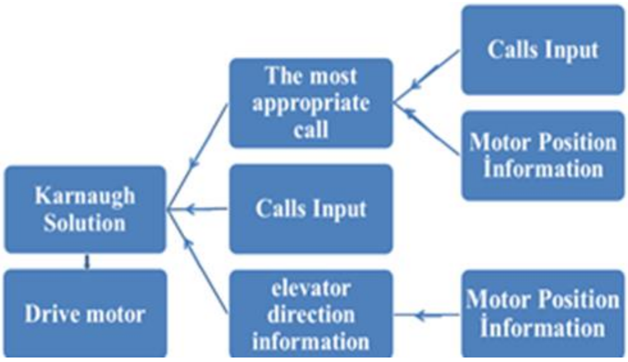

Figure. 1 Process of PLC Program

2.2.2. Privileged Modes

By observing the same method to write the Normal mode program, the probable possibilities for Rank1, Rank2, Rank3 have been evaluated according to the required conditions and outputs were obtained. For the obtained results the Karnuogh analysis was used. The program blocks created were combined into an integrated program for four modes.
The transition conditions from normal mode to privileged mode, and from any privileged mode to another rank have been set. When in privileged mode, the collective operation will be used for other calls on the same rank. For example, when in Rank2, another Rank2 call will be accepted if on the way, if not it will be left for later.
2.2.2.1. Rank1: When in either Rank2, Rank3 or Normal mode, in order to respond to the Rank1 call, the elevator stops on the nearest floor and an announcement is made for the passengers to evacuate the elevator. Then, the elevator goes directly to the Rank1 user and performs the cabin call for Rank1 users. No calls other than another Rank1 call are accepted. When in Rank1, collective operation logic is used for incoming Rank1 calls. After the Rank1 call has been fulfilled, the elevator returns to Normal mode if there are no other Rank1 calls.

Table 1. Table for normal mode output condition

Elevator Down	Elevator Up	Elevator Halt	Elevator Stop	Down Call	Up Call	Cabin Call	The Most Appropriate Call	Normal mode output
0	0	0	1	0	0	1	1	1
0	0	0	1	1	0	0	1	1
0	0	0	1	1	0	1	1	1
0	0	0	1	1	1	0	1	1
0	0	1	0	0	0	1	1	1
0	0	1	0	0	1	0	1	1
0	0	1	0	1	0	0	1	1
0	0	1	0	1	1	0	1	1
0	1	0	0	0	0	1	1	1
0	1	0	0	0	1	0	1	1
0	1	0	0	0	1	1	1	1
0	1	0	0	1	0	1	1	1
0	1	0	0	1	1	1	1	1
0	1	1	0	0	0	1	1	1
0	1	1	0	0	1	0	1	1
0	1	1	0	0	1	1	1	1
0	1	1	0	1	0	1	1	1
0	1	1	0	1	1	0	1	1
0	1	1	0	1	1	1	1	1
1	0	0	0	0	0	1	1	1
1	0	0	0	0	1	1	1	1
1	0	0	0	1	0	0	1	1

2.2.2.2. *Rank2:* When in Normal mode, the cabin calls before the Rank2 call will be performed, other floor calls will be canceled. After reaching Rank2 user, no calls other than Rank1 and Rank2 will be accepted. When in Rank2, collective operation logic is used for incoming Rank2 calls.

2.2.2.3. Rank3: When in Normal mode, all calls before the Rank3 call will be performed until the Rank3 user is reached. In Rank3, only Normal calls will not be accepted. If there is an incoming Rank2 call during Rank3 mode, the Rank3 user will be dropped off on a requested floor if it is en route. If in the opposite direction, the user will be dropped off at the nearest floor.

A comparison of elevator activity during the different rankings is given in Table 2.

Table 2. Comparison of priority user rankings

	Rank1	Rank2	Rank3
Cancels floor calls made before	+	+	-
Cancels cabin calls made before	+	-	-
Accepts Rank1 calls made afterwards	+	+	+
Accepts Rank2 calls made afterwards	-	+	+
Accepts Rank3 calls made afterwards	-	-	+
Accepts Normal calls made afterwards	-	-	-

3. Results

In this study, by transforming privileged-use-only elevators into normal-use elevators, the traffic density on normal-use elevators has been distributed among all elevators, thus reducing elevator traffic. Furthermore, a PLC based controller has been added allowing four different ranks of privileged use with password. Elevator flexibility and a lower-cost solution for special use and possible emergency situations have been achieved through privileged use.

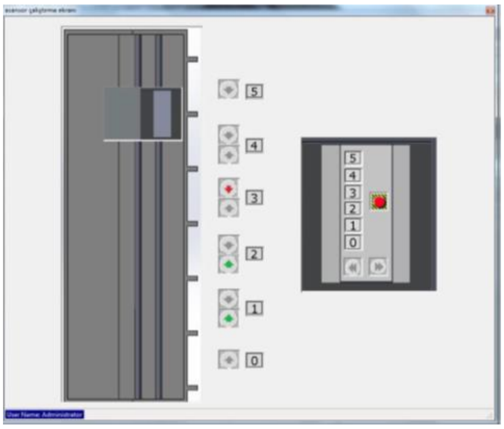

Figure 2. Simulation images-1.

The created algorithms have been tested on the designed simulation program and prototype. Below is a scenario for testing and a simulation interface where the scenario movement can be observed.
Figure 2: When elevator is on the 5th floor, an upwards call from the 2nd floor and a downwards call from the 3rd floor comes.

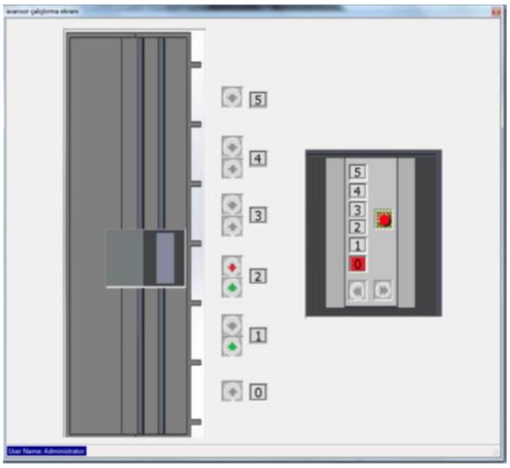

Figure 3. Simulation images-2.

Figure 3: When elevator reaches the 3rd floor, a cabin call from ground floor and a downwards call from the 2nd floor comes.

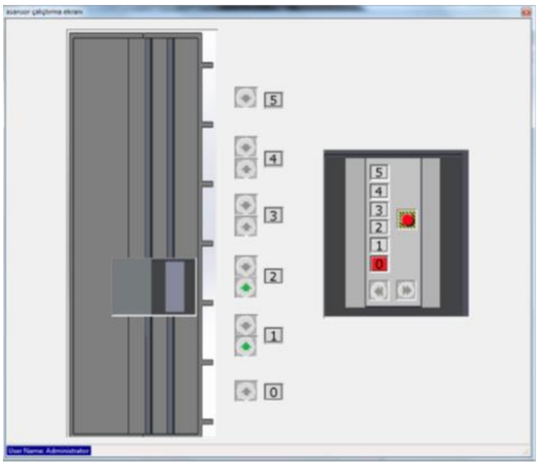

Figure 4. Simulation images-3.

Figure 4: The figure shows the elevator downwards movement to answer cabin call from ground floor.

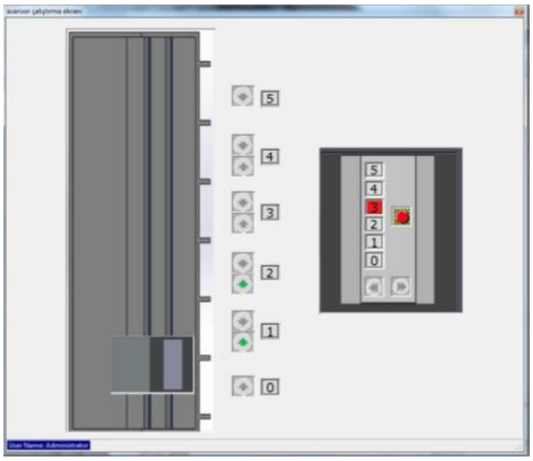

Figure 5. Simulation images-4.

Figure 5: After elevator reaches ground floor it moves upwards to answer the 1st floor call. Meanwhile, a cabin call from the 3rd floor comes.

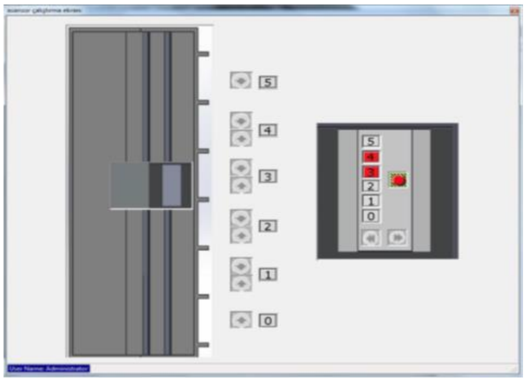

Figure 6. Simulation images-5.

Figure 6: After elevator reaches the 2nd floor, it takes cabin call from the 4th floor. It starts to move. It halts on the 3rd floor and it moves the 4th floor.
In the following studies, it is planned to increase the number of ranks of privileged use, and to add privileged use to group elevator systems.

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