Journal of Engineering Research and Reports

22(3): 31-44, 2022; Article no.JERR.84937
ISSN: 2582-2926

Design of Lift Group Control Systems based on PLC

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/JERR/2022/v22i317528

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/84937

Original Research Article

Received 15 January 2022
Accepted 21 March 2022
Published 23 March 2022

ABSTRACT

Aims and Study Design: Lifts are presently inevitable requirements in modern day building complexes especially multiple floor buildings to keep up with human transportation. Due to this fact, efficient, cost-effective and reliable lift systems are required in these buildings. In this work, the design of a robust lift group control system based on programmable logic controllers (PLC) is introduced.
Methodology: To achieve this goal, good choices of a hardware platform comprising a PLC complex and a software platform to feed instructions (ladder logic) to the PLC are needed. These platforms are linked via a network connection over an Ethernet. The development of the control network based on fuzzy control is illustrated, which the lift controller uses to recognize traffic and respond to the detected traffic patterns. A simplified form of the algorithm from the moment of a hall call to the point of execution of this call command is presented with simulations demonstrating lift prioritization and scheduling based on dependence on interplay between the input fuzzy variables.
Results: The presented design method shows advantages in accounting for numerous factors such as priority fitting, space availability and lift proximity when calculating and implementing quicker hall call responses, which helps in minimizing waiting time of passengers as demonstrated with the 5 floor double lift system. .
Conclusion: The work is believed to set a basis for future PLC-based lift group control systems (PLC-LGCS).

Keywords: lift control system; PLC; fuzzy control; waiting time; priority; scheduling.

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1. INTRODUCTION

Rapid advancements in motor technology and control methods have led to programmable lift systems to steadily replace conventional relay-logic controlled systems for better and easier troubleshooting, for instance, employing smarter relays, embedded controllers, programmable automation controller (PAC), PLC and so on [1 – 6]. With the changes in metropolitan construction, the emergence of high-rise buildings and the expansion of building area, the use of lifts has become unavoidable and has increased the demand for higher quality lift services. As a result of this, large-scaled buildings are provided with a plurality of lifts so as to meet the in-building transportation demands. In the US alone, an approximate number of 18 billion passenger trips are estimated to be made per year [7].

Incorporating computing in controlling the running of more than two lifts is necessary to improve the running efficiency of the overall lift systems, which is important to implement the optimal transmission running mode, referred to as the lift group control system (LGCS). Hence, the LGCS are control systems that administer multiple lifts in a building in order to efficiently transport passengers. Evaluation of the performance of a LGCS is done by taking several criteria into account such as the average waiting time for passengers and total power consumption, which helps to effectively provide transportation services to various floors in the building. This level of efficiency in transportation requires an effective lift group control system. Numerous useful factors for determining the cost of a lift installation should also be taken into account, for example the passenger handling capacity, waiting interval, speed, location, number of floors and lift control technique used.

The goal of an efficient lift system is to have system that effectively determines scheduling priority based on numerous traffic conditions. As a result, the system has to be flexible enough to account for multiple input variables that could influence prioritization of lift delivery.

2. LITERATURE REVIEW AND RELATED WORKS

The aforementioned LGCS has replaced the previously centralized control system and are designed from several independent intelligent control units and modules which are realized using microcontrollers and microprocessor units, embedded PCs or PLC [8 – 10]. Mansur et al. [11] and Huseinbegovic et al. [12] have developed systems based on microcontrollers, with FPGA being a present trend. Few other studies have even proposed implementation of basic gates and integrated circuits (ICs) in a digital logic circuit as an alternative to PLC without any substantial advantage [13, 14]. Despite having these numerous control schemes, PLC still remains one of the most widely used [15 – 20]. The main advantages over other methods are that PLC provides better operational speed and it is more reliable and comparatively cheaper than other programmable control schemes, which also eases the input and output (I/O) monitoring.

Chiang et al. [15] proposed the design of a group lift system that responds to traffic through predicted behaviour of the arrival rate and car call probabilities from collected data evaluated based on their traffic database in order to assign hall call priority to designated lifts. Singh et al [16] demonstrated a PLC controlled system where ladder logic was fed as instructions to the PLC for the different floor levels. An extension to a nine storey two-lift system was further developed by Yang et al [17], where similarly to previous designs; a sensor is located on every floor to determine the position of the lift car. They proposed a minimum waiting time algorithm based on division zoning to predict response time of the lift in order to select the one with the shortest predicted response time. The use of the PLC has been widely demonstrated for multi-floor lift control systems [18, 19].

Lift control systems can even be further improved by introducing fuzzy logic control scheme, which implements the systems decisions based on expert reasoning [21 – 23] and improve lift scheduling. As an important issue, lift scheduling has been tackled by conventional LGCS using simple hall call assignment. However, genetic algorithms and other AI algorithms have been recently used in more efficient scheduling, destination control and priority assignation [24]. Fuzzy logic control, however, remains ubiquitous in lift control systems implementation due to its simplicity, flexibility and ease in modelling reasoning [25]. Zadeh introduced fuzzy logic control system which uses linguistic variables that serve as input variables in the fuzzy set. The control system is subdivided into fuzzification, fuzzy inference and defuzzification where these processes are carried out based on a set of fuzzy knowledge rules. The final traffic instructions are the evaluated and prioritized signals obtained after defuzzification process. Incorporation of fuzzy control into intelligent system experienced a boom in the 90s, particularly in lift systems. Numerous works including the ones of Kim et al., Dewen et al and Tobita demonstrated designs based on fuzzy control models which use a hall-call assignment method [26 – 29] that has been further extended using neural network models alongside the fuzzy control in LGCS to maintain optimal control parameter and achieve more adaptive control systems to the constantly changing traffic patterns [30]. Studies have shown different systems designs using fuzzy scheme and PLC [31 – 34]. For instance, Perez et al [35] proposed a Mamdani-type fuzzy controller based on Siemens PLC S7-1200 which was applied to servomotors for possible design applications in lift and other automated systems. Moreover, some PLC manufacturers offer additional fuzzy controller software packages or modules to facilitate their implementation, which is due to the adaptability of PLC to different automated systems such as robotic arm control and assembly line processes [36 – 38].

One known drawback in previous methods is that they do not present a very flexible design for adaptation to numerous traffic conditions. These previous techniques used in previous studies presents numerous issues regarding the adjustment of the parameters to optimize the lift system. In these different designs, parameters are set for concrete design as a result they limit the flexibility of lift systems when adapted to new parameters. The goal of this work is to combine the concept of PLC and fuzzy control model to develop a group control system that can be easily adapted to numerous traffic conditions. In the present work, only three factors have been considered for scheduling priority calculation, however, the design can be extended to include many more factor which will be represented as variables in the simulation described in section IV. In the end, the overall objective is to foster solving various tasks in order to (i) minimize passenger waiting time (ii) minimize system response time (which refers to the time between the registration of a hall-call until it is answered; this could be equated to the waiting time of the initial passenger, i.e. the initiator of the registered call. Some other goals include (iii) minimizing passenger journey time (if possible) (iv) reducing bunching (v) minimizing the variation (or variance in statistical terms) in passenger waiting time.

In this paper, the design of a lift group control system is discussed and the hardware and software platforms and their application in LGCS are presented in section III. Development of the network configuration is also illustrated. Fuzzy control system employed in the work which is needed for priority fitting value (F_p) calculation is presented in section IV which comprises of the fuzzy variables, the fuzzifier, fuzzy inference engine and defuzzifier. A simplified form of the algorithm discussed in more detail in previous work [34] is introduced and F_p is calculated for different traffic scenarios considering three input traffic variables with the possibility of extension to other traffic variables. It is important to note that for the algorithm to work, certain important information related to the lift system and the traffic to which it is subjected is needed.

3. DESIGN OF THE LIFT GROUP CONTROL SYSTEM

LGCS is said to systematically manage a group of lifts to achieve efficient passenger transportation [39]. As a result the LGCS is networked to different local control systems (LCS) which manages individual PLCs and is available for N number of lifts as seen in the fig. 1. The present design composes of a PC, PLC that serve as the main controller for the LCSs, an industrial network and serial connection ports to link the design with instrumentation devices like inverters, sensors and push-button panels. A system design as in the present scheme we are proposing, disturbances could hamper system performance and its overall safety [40], and hence, it is important to make provisions for a fail-safe control for cases of faults in the lift systems. In this section, the hardware and software platforms will be discussed. The network configuration will also be explained. These components of the system collaborate to perform specific tasks carried out by the lift group controller which could be sub-grouped into four: (a) Management of traffic information (b) Hall call input reception (c) Implementation of control strategy and execution of command (d) Data management and operation. This information can be stored via the memory provision of the selected PLC in the lift design.

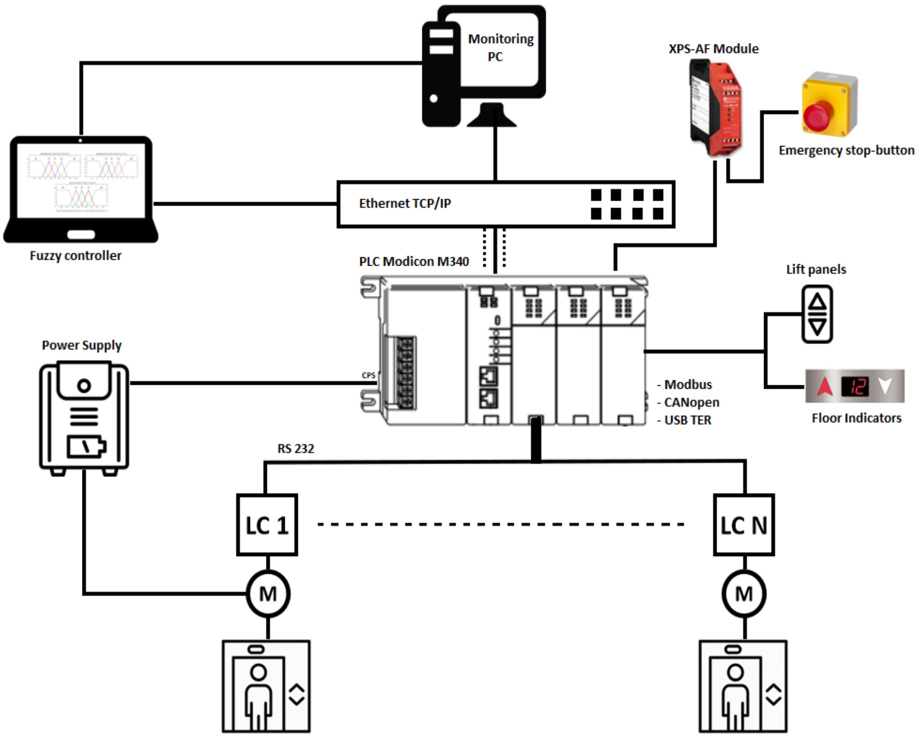


Fig. 1. Design of the overall lift system showing how the LGCS manages the local control systems responsible for individual lift vehicles 1 to N for destination control of N-number of lifts. The configuration includes a monitoring PC, fuzzy control system connected to the PLC via an Ethernet, an emergency stop module, HMI terminals, motors to control the lift vehicles and power supply module for the operation of the entire system

3.1 Hardware Platform

The hardware platform of the LGCS includes PLC-based complex which comprises; (a) PLC Modicon M340 (b) Remote I/O module Flex I/O (c) Frequency Inverter Altivar 71 by Schneider Electric is recommended (d) Lift position sensors (in our work, Memco lift indicator system) and human machine interaction devices like LED indicators.

LCS units are connected through the Modicon X80 I/O modules, TCP and IP communication modules, which connect actuators and motors powered to control the motion of the lift vehicles. Power supply is also provided via a CPS slot in the module. The processors are also supplied with memory card to back up programs, wiring instructions and configuration settings from the Unity Pro XL. A fused emergency stop control safety module is linked to the PLC. This configuration considers the XPSAF which mainly provides a fail-safe protection. However, more flexible-software based controllers are also available where safety data can be protected in non-safe environments and displayed on a local HMI or supervisory control and data acquisition (SCADA) system. One of the advantages of using the present configuration is that the M340 can easily be replaced by a more complex Modicon M580 or Quantum which could provide higher safety options like fault tolerance through the SIL3 module.

3.1.1 Operation of PLC Modicon M340 in lift systems

PLC application in lift system is already well-known and earlier introduced in section 1. PLC acts as the master controller, firstly by collecting a variety of input signals of the lift, which includes the location of the lift, state of the signal from the internal and external buttons, the door lock signal, door zone signal and other safety signals. Secondly, it runs calculation of fitting values to control the operation of the lift based on obtained signal information like floor signal, speed signal and directional relays. In a functional lift application, the operation is divided into several functional blocks such as normal acceleration, steady speed and slowed-down speed [10]. When powered, PLC starts its working cycle by scanning for inputs and deciding how to execute the command.

3.1.2 Network configuration for PC-PLC communication

We are using a three-layer network, including three networks, respectively being Ethernet/IP, ControlNet (via Modbus RTU) and DeviceNet (over a CANopen fieldbus). Ethernet can be equipped with the system master device. System administrators can monitor the system and modify the program of the controller in this layer to make the computer system access the on-site operational data to implement real-time monitoring purpose and provide support for programmable controllers.

The ControlNet completes the high-speed and real-time intelligent control. Computers allow raw data to be collected from the system for processing to enable sophisticated approaches to group control [41]. This allows fast, flexible and adaptive responses to traffic situations in the building. A simple but well designed algorithm can easily be adapted to changes in use of floors, building and population without the need for excessive manufacturer modifications in the system. Also, other modules are important. For instance, Flex I/O converts the analogue signals of lift into digital signals, sends the digital signals to the corresponding network through an adapter, and finally transmits the signals to the PLC, which sends the digital signals through the network to the corresponding Flex I/O for digital-analogue conversion so as to control the lift floors. On the other hand, the Modicon X80 module implements the control of the motor of lift model and ensures the lift is running on the basis of the ideal given speed.

The operation of the lift system is commenced by a call on each floor in the building. There are panels provided inside and outside the lift vehicle. Inside the vehicle, we have a manual door open and closure buttons, N-floor destination request input buttons depending on the number of lifts and an emergency call button to contact technical administrators. Outside the lift system a direction indication button and LED or digital indicators to inform passenger what floor the lift is currently on and if the lift is still busy, which is demonstrated in fig. 2. The design in fig. 2 shows a push panel system that is compatible with the the present PLC design.

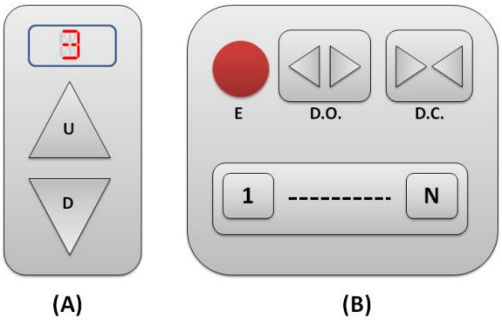


Fig. 2. Lift push button panels showing (a) the outside panel with up and down button to make a hall-call and digital indication of floor where lift is presently located and (b) inside panel of the lift with push-buttons 1 to N for choosing different floors, D.O. and D.C. buttons for manual door opening and closing respectively and E for emergency call. This panel in (b) is meant for making car calls

The computer can process the following information which are available as input to provide optimal group control for the lifts. This information can be classified into operational, landing and group information [41]. I. Operational information for each lift may include factors such as: (a) operational mode (b) running state (moving or stationary) (c) position (d) intended direction of movement (e) if stationary, door status (opening, open, closing, closed) (f) number of lift calls (g) lift vehicle load (h) rated speed of the lift (i) current system response time to each landing call. II. Landing information may include: (a) number and direction of landing calls (b) waiting time of each landing call (c) computed traffic intensity at each floor. III. Group information include: (a) measured maximum landing call waiting times (b) measured average landing call waiting times.

3.2 Software Platform

As advancement in machine design continues, numerous methods of artificial intelligence (AI) are adopted to perceive and use knowledge and assemble intelligent systems. In this work, the intelligent part of the lift group control system is described. Ladder logic is one of the most used programming languages to feed instructions into the PLC. To achieve this, the most suitable software platform had to be considered for this present configuration, which was Unity Pro XL. Communication between PLC and Unity Pro XL is initiated through a network connection over an Ethernet, then linking the network object to a physical port and finally setting up PLC registers assigned for communication [42].

Unity Pro contains libraries responsible for creating control loops for machine control that can be easily supplemented with specialized libraries that meet specific needs such as predictive and fuzzy logic control. However, other available fuzzy logic software can be configured to ones desired application.

4. LIFT DISPATCH ALGORITHM AND FUZZY CONTROL NETWORK

As we know, in lift scheduling there are two types of calls, the hall call and the car call. Fuzzy logic control systems have been widely used to tackle the problem of lift scheduling due to its fast system response which is highly advantageous for group lift systems. Igarashi et al [43] employed fuzzy group system which uses a self-adjusting area-based control algorithm allowing membership functions to be self adjusted with an optimization goal of reducing waiting time. The works of Ishikawa and Kaneko [44, 45] further considered the travelling time based on the degree of daily traffic flow to optimize scheduling using the fuzzy area-based control method. Gudwin et al [46] implemented a linear context adaptation by building the queueing of lifts and evaluating priority before assigning according to calls. They were able to achieve a significant reduction of 7.84% in average waiting time. Despite the effectiveness in using fuzzy logic in improving scheduling optimization, once a request are allocated, it cannot be undone and remains fixed until executed. Fernandez et al [47] proposed a more dynamic solution to this landing call problem where they considered more input variables.

The present study is a traffic flow-based lift scheduling which goes further to consider more fuzzy input variable and incorporate division zoning to address queueing of requests in zones which could be attended to in a more optimized manner. In dynamic zoning, the LGCS collects all request calls of each floor and predicts the most prioritized traffic requests and allocates distribution from one point to a destination floor within its zones. However, this zoning is flexible depending on the time of the day. Combining zoning with fuzzy logic helps to make it more robust through optimal dispatch policy and reduction in the complexity in implementation as compared to other algorithms such as neural network techniques. As like other system, the scheme in this work is waiting time reduction targeted, moreover zoning can contribute in energy conservation as well by optimizing traffic patterns. However, the scope of the work does not cover energy consumption. It focuses on calculating fitting values for quicker hall-calls and waiting time reduction.

The controller uses the fuzzy identifier to recognize traffic pattern while the zoning technique adjusts the controller according to the fuzzy traffic patterns. The fuzzy logic controller functions in different blocks as demonstrated in fig. 3a; (i) knowledge basis – fuzzy rules (ii) fuzzifier (iii) fuzzy inference (iv) defuzzifier. Traffic input data is classified by the fuzzifier into sets of fuzzy variables and further translated into linguistic terms. In this work, the three main input variables are (1) distance between floors from where the hall calls are made (2) space availability, which is the total capacity minus the current load of lift and (3) waiting time of passengers as estimated in the work of Yu et al. [48] as shown in equation 1.

$$W.T = (\text{Stop Number}) \times T_D + (\text{Distance}) \times T_N \quad (1)$$

Where, T_D = Door opening time + Door closing time and T_N = time of travel between neighbouring lifts.

The fuzzy inference engine functions as the decision block as this information is used to calculate the priority fitting values based on rules seen in table 1 [34] and this calculated information is prioritized for 1 to N lifts by the defuzzifier and a single output is generated, which serves as traffic control instructions for lift system operation.

Table 1. Fuzzy knowledge rules for the set of input variables and the corresponding output

IF	**Distance**	High	Medium	Less
	Waiting Time	Short	Medium	Long
	Space Availability	Small	Medium	Large
THEN	**Priority (F_P)**	Low	Medium	High

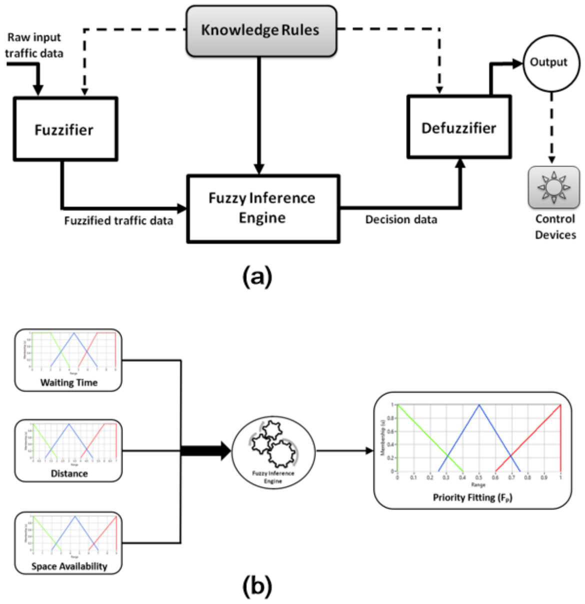


Fig. 3. (a) Fuzzy control system showing the different functioning blocks – fuzzifier, inference engine, defuzzifier and fuzzy rules. The raw data is fed to the fuzzifier while the output is passed on to the control device as traffic control instructions (b) Calculation of fitted values via the fuzzy inference engine with information like space availability in the lift, distance between lifts and waiting time. Membership functions of input and output variables as implemented in the simulation

As seen in previous studies [34, 49], the fuzzy control system is initiated immediately a hall-call is made to estimate the fitting values in order to respond accurately to different calls by estimating for all N number of lifts and executing the response in order of the time when the hall-calls were made.

The membership functions of the input variables and the generated output are shown in fig. 3b. The fuzzy logic processing function in Unity Pro is used to carry out the fuzzy inference algorithm which was simulated in this work using a fuzzy system designer by implementing same parameters. The fuzzy algorithm works by reading numerical values of the input variables, evaluating each membership function (fuzzification) and each designated Mamdani-type fuzzy rule. It then calculates the resulting membership function of the output variable and its corresponding numerical value (defuzzification).

The present dispatch algorithm of the lift control system described in this work, as mentioned earlier, uses a fuzzy controller and zoning division scheme. The goal is to achieve effective communication within the lift system from the reception of a hall-call to execution of this call task and ready to attend to a new signal. PLC is linked to the controller through the algorithm and data is exchanged on an open platform communication (OPC), which enables easy signal reception from HMI devices and push button panels like in fig. 2. In order to implement tailoring of traffic conditions in the lift group controller, the traffic patterns during the day have to be taken into account as the input traffic data. This work implements zoning into three types; I. Up-peak traffic, which in reality describes the highest upward direction traffic happening in the early parts of the morning when workers are arriving; II. Down-peak traffic which is at its highest during the end of work hours or closing time of the building and III. The business and lunch time, when workers are going up and down at undetermined rates. The fuzzy traffic identifier takes into account the upward traffic, downward traffic and a ratio of the upward and downward traffic between business and lunch hours, which helps in identifying the variations during this period by the controller and achieving proper implementation during hall call assignment and lift scheduling. The scheduler used in this work is described in fig. 4 and the simplified flowchart of the algorithm is shown in fig. 5. In the figure, as a signal is picked from a hall-call, zoning and priority is done by carrying out calculations in the inference engine based on fuzzy rules. Output is translated as traffic instructions to respond and dispatch to the floor thereby attending to the prioritized floor. This is usually based on order which the call was made but also based on other factors like the load capacity and distance between floors. The time between the moment hall-call was made by a passenger to the moment of response, when the floor is sent out to this passenger can be seen as equivalent to the waiting time of the passenger. A reduction in this time is a characteristic of a good lift system. Once passengers on the floor which the hall-call was made are attended to and assignment is executed, the algorithm comes to an end and the lift is deemed free until another signal is received. The algorithm is divided into three phases. The first is the zoning and information analysis phase, where zones are assigned by identifying free lifts, analysing traffic information and direction of hall calls. The second phase is associated with priority fitting value calculation and the final stage is hall call attendance, lift dispatch or scheduling depending on if the lifts are occupied.

4.1 Scheduling and Priority Calculation Algorithm

Lift scheduling problem is an important optimization issue involving a stochastic process based on the uncertainty in traffic patterns [50]. The complexity of this said optimization problem constitutes a search domain, $Ø(N^R)$ where R is the number of requests made and N is the number of available lift cars, which means there are N^R possible distribution of request calls to lift cars. In scheduling task, there are normally certain goals such as minimizing average waiting time, loading and energy consumption. The scheduler needs the aid of an intelligent monitoring system. Using the fuzzy controller based on division zoning, hall call assignment based on fuzzy knowledge and priority calculation, efficient scheduling is promoted. Information about scheduled hall-calls and the lift position are sorted by the algorithm according to priority and availability of free lifts.

Scheduling in this work, as described in fig. 4, starts when a call is made and traffic related information is collected which is shared with the control system, which handles data management and elevators are assigned to hall calls which is stored in the message queue. Zoning helps to assign the elevator into zones for more optimized dispatching and priority is calculated and its output is sent to the control system for lift allocation, which in this case is the fuzzy LGCS. The highest priority elevator is then dispatched and this process continues with aid of the algorithm described in fig. 5 until there is no remaining request.

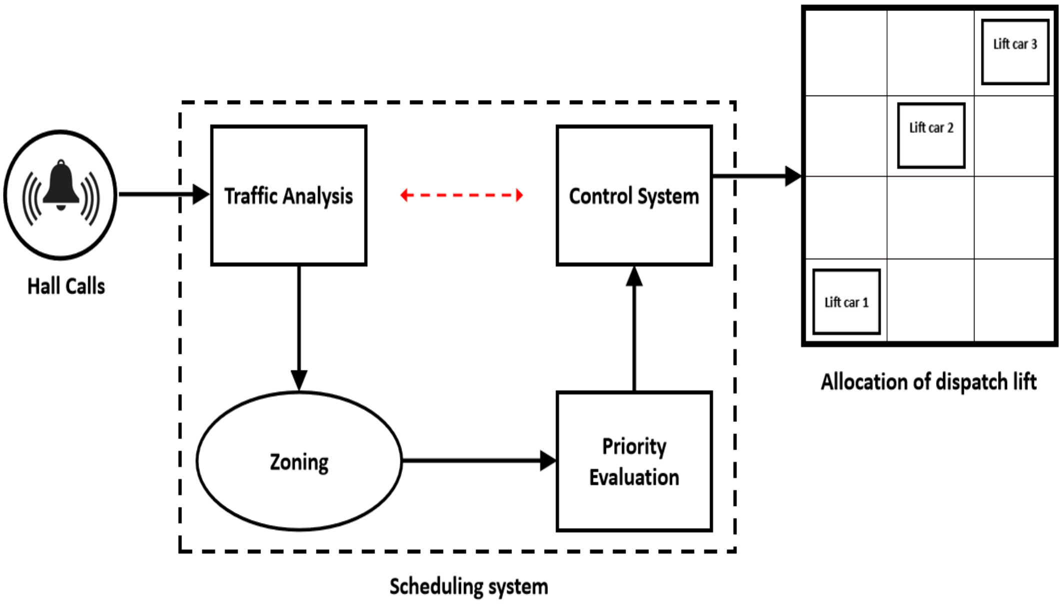


Fig. 4. LGCS scheduling using zoning division and priority evaluation in allocating lift cars

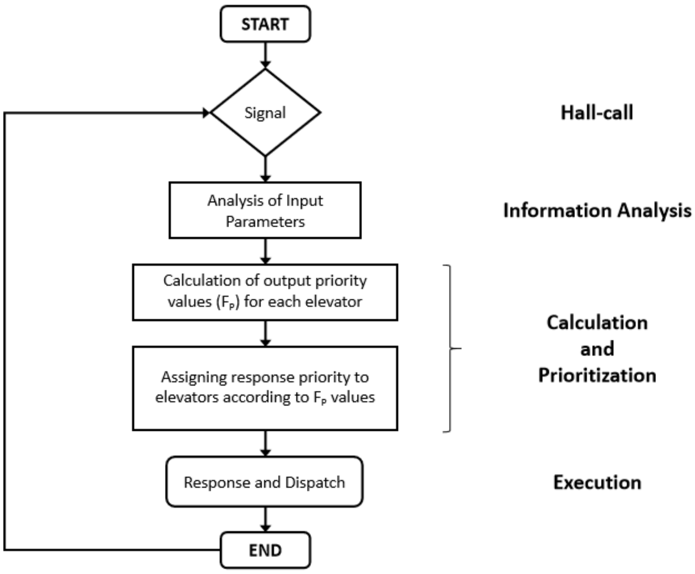


Fig. 5. A simplified algorithm demonstrating operational command from lift hall-call to execution of command after fuzzy traffic analysis and lift prioritization

5. SIMULATION

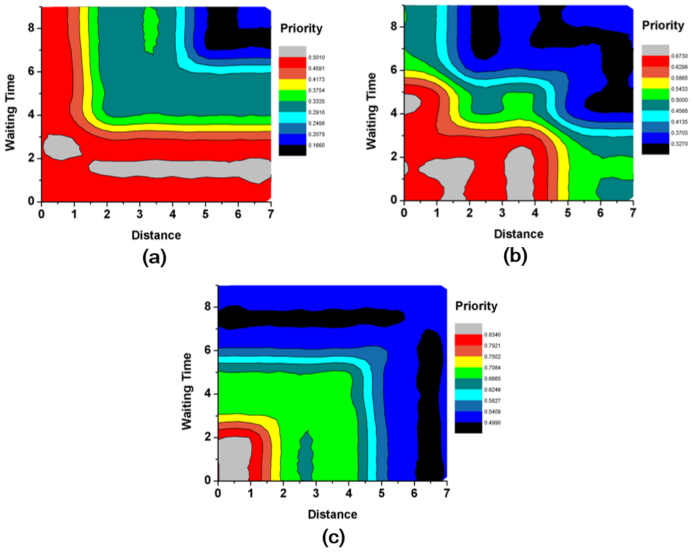
A fuzzy system with multi inputs such as the present one described requires calculating a multidimensional space output based on intelligent reasoning rules. An interactive fuzzy system design was implemented in Lab View using the Fuzzy System Designer tool by first defining the variables (input and output) parameters and the designated rules for the fuzzy system as described in section 4.

Finally, simulation was carried out to determine priority, $\mathrm{F_p} \in \{\mathrm{Low}, \mathrm{Medium}, \mathrm{High}\}$assigned under different scenarios based on calculation made under the centre of gravity defuzzification method after assigning numerical values to each input variable to generate values for the output fitting between 0 and 1 using the rules given in table 1. Table 2 shows numerical range of values for the membership functions of the input and output variables as seen in fig. 3b and used in the fuzzy control simulation and priority fitting values calculation.

As a standard of comparison, space availability is kept constant at SA = 1 (small), SA = 4 (medium) and SA = 9 (large) and contour maps of F_p in fig. 5 that demonstrate the dependence of priority fitting values on an interplay between waiting time and distance in the range seen in Table 2.

Table 2. Numerical values for different linguistic terms of the input variables (distance, waiting time and space availability)

Input			
Distance	**Less**	**Medium**	**High**
	0 - 2	1 - 5	4 - 7
Waiting Time	**Short**	**Medium**	**Long**
	0 - 4	2 - 7	5 - 9
Space Availability	**Small**	**Medium**	**Large**
	0 - 3	2 - 7	6 - 9
Output			
Priority (F_P)	**Low**	**Medium**	**High**
	0 - 0.4	0.25 - 0.75	0.6 - 1.0



(a)

(b)

(c)

Fig. 6. Priority values between 0 and 1 as a function of waiting time and distance at different space availability values (a) minimal space availability (SA = 1) (b) average space availability (SA = 4) (c) maximum space availability (SA = 9)

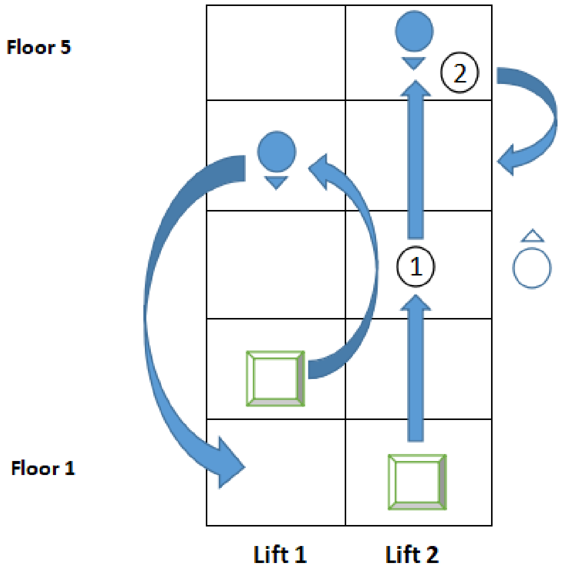


Fig. 7. A 5-floor 2 lift group control system, lift 1 and lift 2 are on floor 2 and floor 1 respectively. The response to the hall call are based on the direction of the hall call, time which the call was made and the overall waiting time. First two calls were made on floor 4 and 5 whereas the latter call was made on floor 3. The arrows represent the directions of lift car movement

Priority fitting value (F_p) was plotted as a function of waiting time and distance in the contour maps in fig. 6. From fig. 6a, which represents a scenario of low space availability due to excess loading, the minimum $F_{p\text{-min}}$ and maximum $F_{p\text{-max}}$ are 16% and 51% respectively. In a case of average loading (fig. 6b), these values increase to 32% ($F_{p\text{-min}}$) and 68% ($F_{p\text{-max}}$). The final and most optimal case is that of large space availability, where $F_{p\text{-min}}$ is 49% and $F_{p\text{-max}}$ is 85%. As predicted in previous work [34], priority is assigned to a lift under the condition with optimal scenario such as smaller loading, shorter waiting time and closer proximity between current floor of lift and floor of hall calls. Moreover, image processing tools and algorithms can be implemented as seen in [51,52] for face detection and counting the number of passengers waiting for a lift to maximize loading conditions.

The concept of priority based on the simulation can be described in a practical case of scheduling and dispatch for a 5-floor 2-lift group control system as seen in Fig. 7.

In comparison to conventional lift group control systems, which are mainly based on distance between lifts, the current fuzzy system takes into account other factors such as direction of the call, scheduled order of the hall calls and the waiting time. fig. 7 describes a 5 floor 2 lift group system where the first lift is on the second floor and the second is on the first floor. Imagine a hall call had already been made on floor 4 and 5 heading downwards before a call was made on floor 3 heading upwards to floor 5. Assuming both lifts were free instead of assigning lift 1 to the late hall call on floor 3 which is the closest, it assigns lift 2 which stops by in floor 3 before going to floor 5 due to the waiting time which contributes to its priority evaluation, whereas lift 1 is sent to floor 4 going downwards which hence reduces the waiting time of the passenger and energy consumption. This assumption is made based on normal business hour, however, based on zoning priority would be assigned to the ground floor during up-peak traffic and the downward directions during down-peak traffic.

6. CONCLUSION

The design of a lift group control system is discussed in this paper. A configuration accounting for the hardware, software (Unity Pro and ladder logic) and network platforms to achieve successful communication is presented and illustrated. The goal is to achieve efficient hall-call responses for larger sized buildings through optimized scheduling, in areas where lifts play a central role in human transportation, by increasing the lift system performance through reduced waiting time. The work demonstrates a robust and flexible design allowing for multiple traffic inputs to calculate scheduling priority for effective lift dispatch.

Moreover, the advantages of using this current design such as OPC, provided industrial bus technologies and PLC include improving the robustness, efficient connectivity and achieving higher scalability of lift systems in modern buildings. A synergy between PLC and fuzzy control logic is illustrated in order to achieve a more intelligent and reliable lift group control design based on expert reasoning. The fuzzy lift control algorithm is also introduced in a simplified form with simulations carried out to demonstrate lift assigning priority based on calculations made using numerical values of the input variables under the aforementioned fuzzy rules. Higher priority is demonstrated to be assigned to a lift with the most optimal conditions. The system design in this work is very simple and adaptable in numerous implementations in automated systems, especially lifts. The present work sets a foundational basis for future work on efficient and cost-effective PLC-based lift group control systems designs using fuzzy logic.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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