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Elevator Control Simulation Using Fuzzy Logic Management

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Abstract — **Using a permanent magnet synchronous motor as an actuator in a ropeless elevator presents several difficulties that must be overcome for the system to be secure and stable. Detent force, one issue with stabilization systems, will be examined in terms of how well it functions under a fuzzy logic controller using a nonlinear test like changes in load and distance to obtain a policy suitable for application in the industrial sector or other human endeavors. The elevator technologies are designed to provide the necessary passenger floors while considering the highest elevator performance and passenger pleasure standards. This work addresses the problem by developing an elevator group controller using a fuzzy algorithm. This research is designed to handle the necessary passenger traffic density while maintaining acceptable waiting times by integrating a fuzzy controller into an elevator system. Within a set of fuzzy rules, three important linguistic variables are added to improve the performance of the elevator group. These include load capacity, priority, distance, and average waiting time (AWT). The necessity of floor priority is lessened when there is an excellent volume of passenger traffic; instead, the expected arrival time should be decreased. While the actual elevator prototype is being programmed using a PIC microcontroller acting as a controller, the simulation was completed to verify the fuzzy system's priority visually. Thus, a set of ambiguous guidelines was developed based on real-world issues, primarily reducing waiting times and energy usage. The elevator controller will select which elevator will service which incoming hall request when a few are registered. To maximize efficiency for financial reasons, high-rise buildings and the ensuing large number of elevators they require provide a significant logistical challenge regarding time and space conservation. Elevator group systems are built with complexity to run the elevators properly.**

Keywords — **Average waiting time; Elevator; Floor Traffic; Floor Priority; Fuzzy Logic Management.**

Simulasi Pengendalian Lift Menggunakan Manajemen Logika Fuzzy

Abstrak — **Penggunaan motor sinkron magnet permanen sebagai aktuator pada elevator tanpa tali menimbulkan beberapa kesulitan yang harus diatasi agar sistem menjadi aman dan stabil. Kekuatan penahan, salah satu masalah pada sistem stabilisasi, akan diperiksa dalam kaitannya dengan seberapa baik fungsinya di bawah pengontrol logika fuzzy menggunakan pengujian**

nonlinier seperti perubahan beban dan jarak untuk mendapatkan kebijakan yang sesuai untuk diterapkan di sektor industri atau upaya manusia lainnya. Teknologi elevator dirancang untuk menyediakan lantai yang dibutuhkan penumpang dengan tetap mempertimbangkan kinerja elevator tertinggi dan standar kesenangan penumpang. Riset ini mengatasi masalah tersebut dengan mengembangkan pengontrol grup elevator menggunakan algoritma fuzzy. Proyek ini dirancang untuk menangani kepadatan lalu lintas penumpang yang diperlukan sambil mempertahankan waktu tunggu yang dapat diterima dengan mengintegrasikan pengontrol fuzzy ke dalam sistem elevator. Dalam seperangkat aturan fuzzy, tiga variabel linguistik penting ditambahkan untuk meningkatkan kinerja kelompok elevator. Ini termasuk kapasitas muatan, prioritas, jarak, dan waktu tunggu rata-rata. Kebutuhan akan prioritas lantai berkurang ketika terdapat volume lalu lintas penumpang yang sangat baik; sebaliknya, perkiraan waktu kedatangan harus dikurangi. Sementara prototipe elevator sebenarnya sedang diprogram menggunakan mikrokontroler PIC yang bertindak sebagai pengontrol, simulasi diselesaikan untuk memverifikasi prioritas sistem fuzzy secara visual. Oleh karena itu, serangkaian pedoman yang ambigu dikembangkan berdasarkan permasalahan dunia nyata, terutama mengurangi waktu tunggu dan penggunaan energi. Pengontrol elevator akan memilih elevator mana yang akan melayani permintaan aula masuk ketika beberapa telah terdaftar. Untuk memaksimalkan efisiensi karena alasan keuangan, gedung-gedung bertingkat tinggi dan sejumlah besar elevator yang dibutuhkan memberikan tantangan logistik yang signifikan terkait konservasi waktu dan ruang. Sistem grup elevator dibangun dengan kompleksitas untuk menjalankan elevator dengan baik.

Kata Kunci — **Lalu Lintas Lantai; Lift; Manajemen Logika Fuzzy; Prioritas Lantai; Waktu Tunggu Rata-rata.**

I. INTRODUCTION

Skyscrapers, whose primary mode of transportation is the elevator, need a simplified control system for the elevators to effectively manage the complicated demand for transportation. Intelligent buildings have emerged in large cities to better utilize telecommunications infrastructure since the dawn of the era of heightened information flow. As a result, elevators are expected to have more advanced functions than before. The requirement for elevators has changed throughout time, moving from merely lower and more consistent wait times to better tenant comfort and convenience, prompt building administrator answers, and enhanced system dependability[1]. The elevator system is a standard technology used to move people from one floor of a building to another. In this case, passengers can make car and hall calls by pressing buttons on the elevator controller, which replies to their demands. A passenger requesting to move from the elevator foyer of their current floor to another floor is referred to as making a hall call.

Conversely, a car call refers to a request made within an elevator. A two-level control hierarchy is the fundamental control mechanism of an elevator system. Each elevator's movement, including up and down, stop and start, and door opening and closing, is controlled by lower-level tasks. The movement of the elevator group is coordinated by a higher level using a set of logical rules designed to enhance system performance [2]. The control can improve the elevator's runtime, speed, vibration compensation, position accuracy, overshoot, reliability, safety, power consumption, and robustness [3] . Elevator group control (EGC) approaches are extensively explored because they can save operating costs and improve transit efficiency [4] .

EGC is the collective term for operating several elevator cabs in a building. Optimizing one or more parameters, including average waiting time, round-trip time, and building owners' preferences, including power usage, is accomplished by assigning hall calls to the most appropriate cab [5]. Fuzzy logic (FL) has gradually replaced traditional control engineering analysis and design approaches. These approaches are mainly based on mathematical models that use differential equations to characterize the control systems. FL has been extensively used in the quest for an alternate solution to elevator control issues because of its benefits in handling imprecision and uncertainty [6]. FL is used to find traffic patterns, which help choose the best course of action for control. After that, the control system is adjusted to different traffic situations. A distinct approach, known as the fuzzy elevator group control system, was released by [7], in which the system manager's requirements and passenger traffic classifications serve as the basis for the control strategy. The control strategy then decides the hall call assignment technique.

In this research, a fuzzy logic controller controlled the collection of elevator mobility. Fuzzy logic also minimizes waiting times, loading time, priority, distance, and energy dispersion depending on the track [8]. FEGCS (the fuzzy elevator group control system) is designed and implemented in this paper. When creating an accurate complex system model is difficult, the fuzzy theory has been utilized to approximate the system. Thus, there have been numerous reports of using fuzzy reasoning to build sophisticated controllers. In particular, we concentrate on the FEGCS's hall call assignment and control strategy generating components. The hall call assignment is prepared using the control strategy creation section through the request of the system manager and the section that assigns hall calls to the appropriate elevators. Comparing the FEGCS to the other systems, the results are more favorable[9].

II. MATERIAL AND METHOD

A. Fuzzy Parameters

Fuzzy logic is a combination of both numerical and symbolic techniques. It produces exact results from imprecise data and is especially useful in computers and electronic applications. Unlike classical logic, fuzzy logic allows statements to be neither true nor untrue, on or off. An object in conventional logic can have two values: zero or one. A statement in fuzzy logic can take any real value between 0 and 1, which indicates how much an element fits into a particular set. The human brain can reason with uncertainties, vagueness, and judgments. Computers can manipulate precise valuations [10]. Because of the technique used to determine the control parameters, fuzzy logic acts as a controller during elevator simulations, minimizing potential errors and enabling fast response [11].

Fuzzification is the initial phase of fuzzy control. Table 1 shows the parameters used in these simulations; these specifications are comparable to those from earlier studies [8]. These settings are utilized because the system has already been tested without any input alterations, and the existing system has successfully reduced detent force by using the PI controller.

TABLE 1
PARAMETER SIMULATION

Parameters	Value
Force	120 N
Load	20 kg
Current	10 A
Speed	0.2 m/sec
Distance	0.6m
Power	24w

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, such as Mamdani and Sugeno. The Mamdani scheme has been adopted for the present simulator. In this application, each rule has a single input mapped to a single output to avoid complexities by considering all the inputs in a single rule[9]. To simplify the calculation process, fuzzy rules are created using the triangle model and parameter simulation in Table 1, which is then divided into two outputs, as shown in Table 2. The membership function for each parameter is formed by the researcher using limit values for each fuzzy appearance and triangular membership functions for the linguistic expressions "Low", "Medium", "High", "Weak", "Normal" and "Strong" based on Table 2, as shown in Figure 1-4. The elevator fuzzy control employs one parameter for the output and four different types of control inputs to achieve good traffic performance [12].

TABLE 2
FUZZY PARAMETERS

Function	Variable	Fuzzy	Test Parameter	a	b	c
Input	Load	Light	20kg	-10	0	10
		Medium		0	10	20
		Heavy		10	20	30
	Distance	Near	0.6m	0	0.075	0.300
		Medium		0.075	0.300	0.525
		Far		0.300	0.525	0.750
Output	Velocity	Slow	0.2m/sec	0	0.030	0.060
		Medium		0.060	0.100	0.130
		Fast		0.130	0.160	0.200
Input	Power	Weak	24W	-9.600	0	9.600
		Normal		2.400	12	21.600
		Strong		14.400	24	33.600
	Current	Low	10A	-5	0	5
		Normal		0	5	10
		Hight		5	10	15
Output	Force	Low	120N	-25	0	35
		Normal		25	60	95
		Strong		85	120	155

The following criteria or goals are represented by these parameters, which indicate the elevator system's optimization objectives:

- Waiting Time: is the overall time an elevator took to move from its present location to the new hall call.
- Traveling Distance: The number of floors between the elevator position and the new hall call.
- Loading: The number of people occupying an elevator.
- Priority: the output of the fuzzy controller, identifying the elevator with the most significant value.

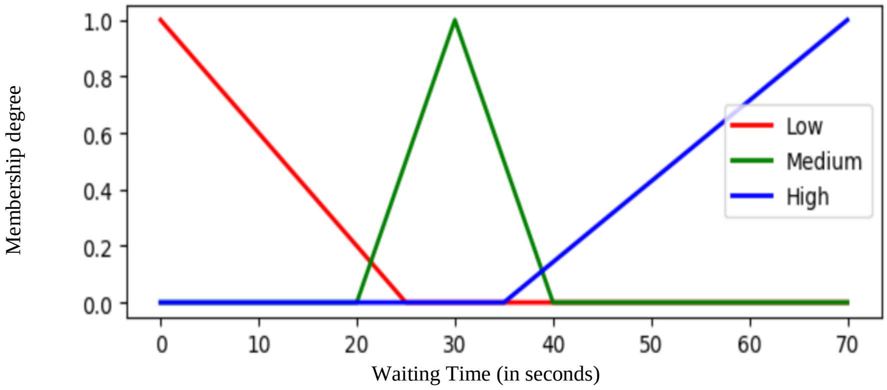


Figure 1. Waiting Time function.

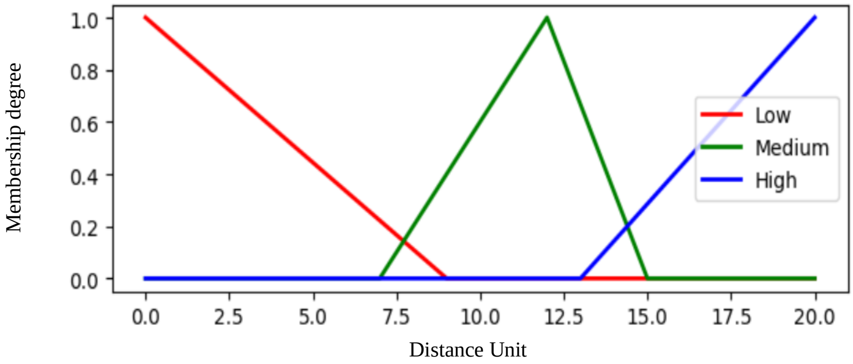


Figure 2. Distance membership function.

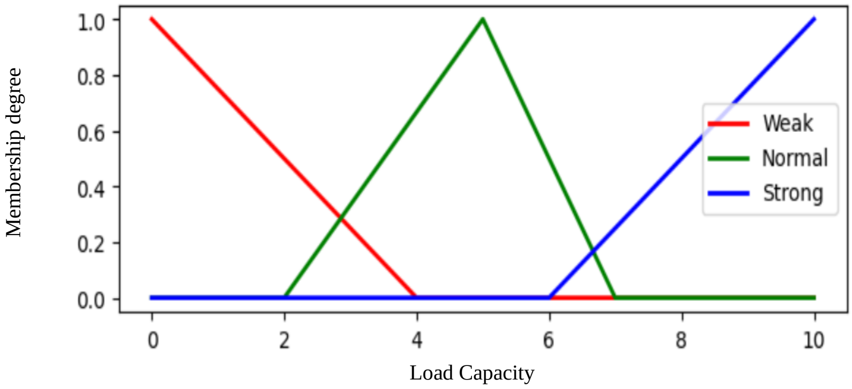


Figure 3. Load capacity membership function.

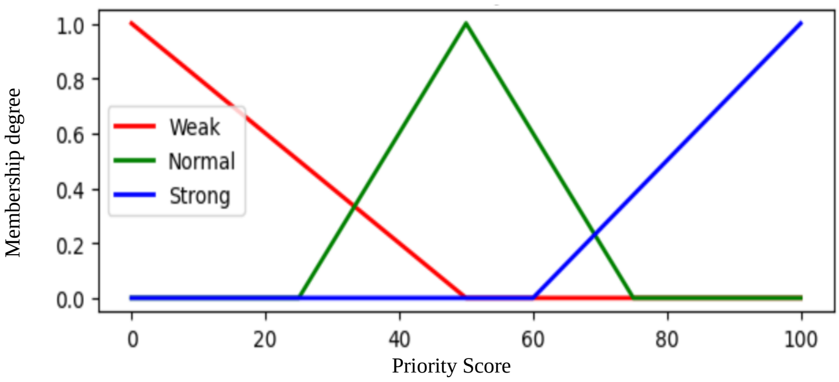


Figure 4. Priority membership function.

B. *Elevator Group Control System (EGCS)*

EGCS, or Elevator group control system, is a control system that effectively moves people between different elevators in a building. The average wait time for passengers, the percentage of travelers who had to wait more than sixty seconds, and power usage are some metrics used to evaluate EGGS's performance [13]. Elevator control and scheduling (EGCS) minimize evaluation criteria; however, trade-offs between criteria make it hard to fulfill all at once. System managers determine the significance of EGCS evaluation criteria based on passenger traffic patterns. For example, average waiting time matters more in rush hour, whereas electricity usage matters at other times.

An EGCS consists of a group controller, elevators, automobiles, and hall call buttons. A passenger uses the direction (hall call) button to request a different level, then waits for the elevator to arrive before entering and pressing the floor (car call) button. When a passenger clicks the hall call button at this point, the group controller chooses an appropriate elevator. In this instance, the group controller chooses the group elevator that best suits the building's current conditions.

The following factors make choosing an appropriate elevator in the EGCS difficult. The EGCS is highly complicated at the start. A group controller evaluates n times p $(n \times p)$cases if it oversees n elevators and gives the elevators p hall calls. The controller must also consider the hall calls that the near feature will produce. Thirdly, it has to consider many unknowns, such as how many people are on the floors where automobile and hallway calls are made. Fourthly, the control approach must be modified by a system manager. While some managers seek to minimize passenger wait times, others prefer to limit electricity usage.

Examine an example of an elevator group control process to comprehend the EGCS. Figure 5 shows several elevators and a few hall calls (up, down) buttons on a floor. Upon arriving at a hall, a person will push a hall call button to summon an elevator. In a hall call, the passenger's elevator is chosen by EGCS. The designated elevator goes to the passenger's floor in response to the hall call in the following sequence:

1. A traveler clicks the up hall call button to proceed to the 15th level from the 2nd floor.
2. The EGCS receives the signal for the hall call.
3. An elevator chosen by the EGCS serves the passenger.
4. The chosen elevator receives a message from the EGCS.
5. After the passenger selects the elevator, it advances to the second floor.
6. The passenger hits the fifteen-car call button.
7. After reaching the fifteenth level, the elevator notifies the EGCS of its location.
8. When the elevator reaches the fifteenth floor, the passenger exits the vehicle.

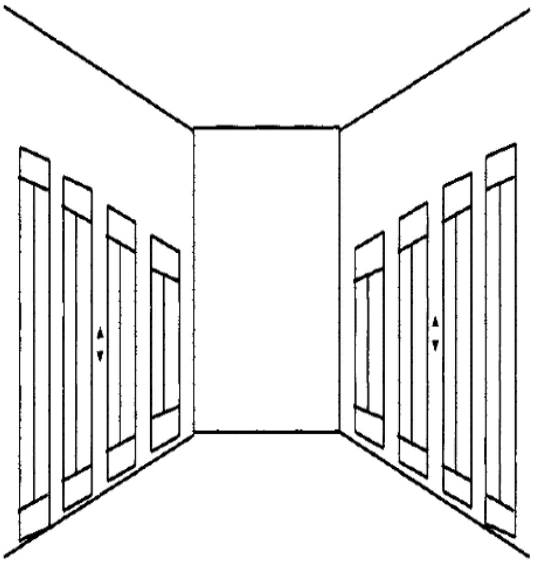


Figure 5. A floor in a building where the EGCS is installed[13].

The EGCS repeats the procedure of choosing service elevators for hall calls. The choice is referred to as the "hall call assignment." The hall call assignment mechanism is crucial in the EGCS, affecting the performance [14]. The performance of the EGCS is estimated using a variety of evaluation criteria. The three most crucial EGCS criteria are average waiting time, percentage of passengers waiting more than 60 seconds, and power usage with the following definitions:

1. AWT, or average waiting time, is when a passenger must wait on a floor until the service elevator arrives after pressing a hall call button. All passenger’s wait times are averaged into one unit of time, called AWT.
2. LWP, or long waiting percentage, is the proportion of passengers who have wait times longer than sixty seconds within a given time frame.
3. RNC is the majority of energy used in the elevator system. It starts or stops the elevators when estimating a system's power usage. RNC—the number of elevators that move in a given amount of time—is utilized.

Figure 6 shows the EGCS's main configuration. In Figure 6, eight elevators in a building are managed by the EGCS. Individual elevator controllers, denoted by CCs (car controllers), communicate with elevator group controllers. The EGCS consists of three main components and other modules. The three main parts are traffic data management, the hall call assignment, and the control strategy formulation. The traffic data management division collects a wide range of traffic data information, such as the number of car calls, hall calls, and passenger enters and exits. This section analyzes the available traffic data and projects future traffic [15].

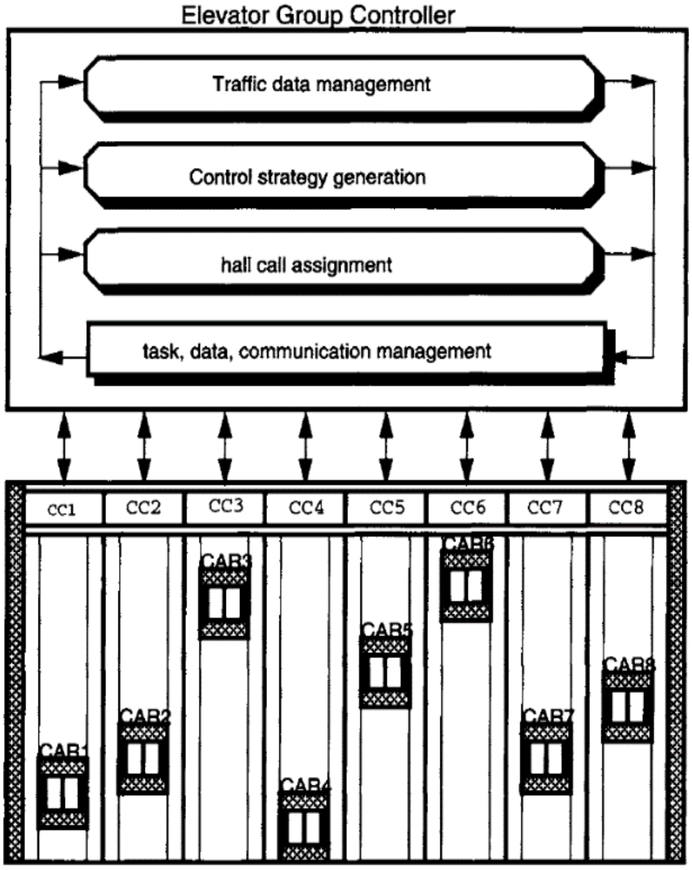


Figure 6. General structure of the EGCS.

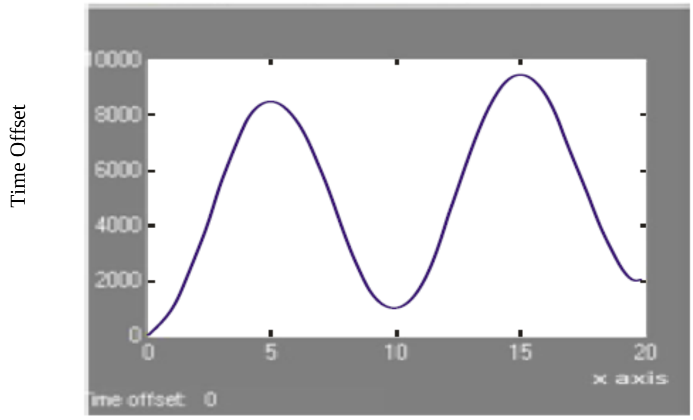
The control strategy generation component segregates the traffic into various modes and selects the most appropriate hall call assignment mechanism for the given traffic type. Finally, the technique employed by the hall call assignment component to select service elevators for hall calls is the control strategy generating section. Various subsidiary modules, such as task, data, and communication management, support the main portions.

The two most important components of EGCS are assigning hall calls and developing control plans. To create a control plan, EGCS classifies the passenger movement through the facility and chooses which hall calls to associate with each traffic pattern. This section generates the evaluation criteria for the hall call assignment, together with their respective weighting factors and relative importance. According to the control strategy generation section's values, elevator statuses, and assignment algorithms, hall calls are assigned to elevators in the hall call assignment section.

III. RESULT AND DISCUSSION

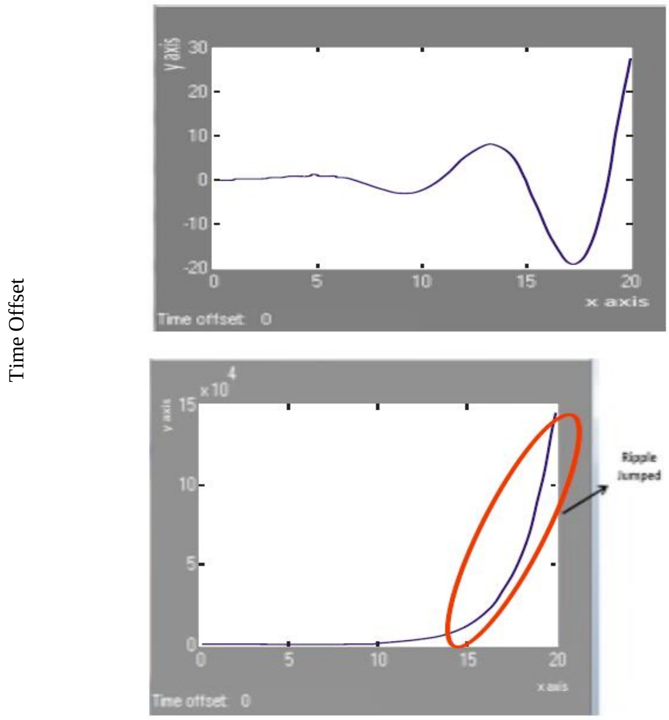
The results of the first parameter presentations before the Fuzzy-PID process have supported previous studies on input curve graphs [16]. On the other hand, the 'Output' curve, which represents the result of the Fuzzy-PID process, demonstrates a clear and significant difference between the input and the output, with the output having a Y-axis value of only 30 and the input having a high Y-axis value of 9000. It follows that signal control and fluctuation curve reduction are two areas where fuzzy-PID control can be effective.

A change in the load parameter will result in a shift in fluctuation. When the passenger load rises, for instance, the matrix splits into two coefficients: $x =\propto L + \beta$, and $y = \gamma L + \delta$. Here, L represents the load parameter reflecting the amount of load or weight being considered. For example, this could be a passenger load or any other factor that affects the system's performance. The α and γ coefficients represent how the load parameter L influences the variables x and y, respectively. The β and δ are constants that adjust the baseline values of x and y, respectively. The researcher must first identify the value of the matrix to calculate the parameter. For instance, if the weight is 3 kg, the matrix value is $f(x) = x - 2y$, and the parameter value equals the graph's outcomes. The output of the "Input" graph, which has not undergone the Fuzzy-PID process, is displayed in Figure 7. The y-axis, visible at intervals of 15-20, exhibits a sharp spike with the $y = 15$ axis at $x = 20$, indicating the higher *y*-axis value at interval *x* next. When a fuzzification technique is applied to the visual findings, as shown in Figure 8, the *y*-axis spikes become less acute and more steady, as shown in *y* = 4, 5, and *x* = 20, as shown in Figure 9.



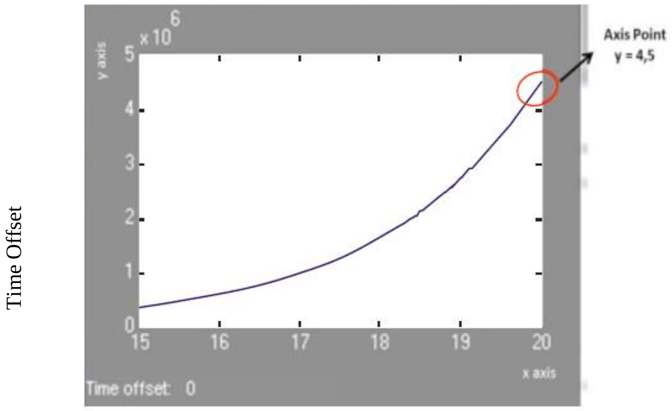
Output

Figure 7. Graph response systems without a controller.



Output after fuzzification

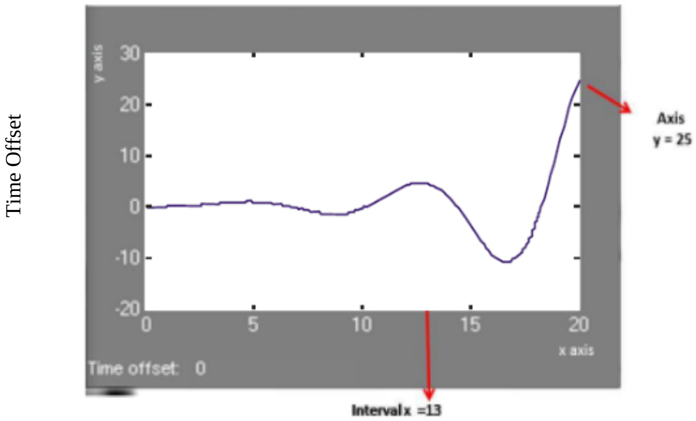
Figure 8. Graph response system with controller.



Output after fuzzification

Figure 9. Fuzzy response graph.

Furthermore, the process in Figure 10’s graph output following the Fuzzy-PID is relatively steady until the interval point $x = 13$, which experiences a spike up to $y = 5$ axes. After that, it decreases to the y-axis point at interval $x = 17$, and finally jumps dramatically at range $x = 20$. It indicates that the PID's operation is prone to variation and d-error, which causes the error position to decrease and vice versa. This causes the Fuzzy-PID process to fluctuate more and more. The Fuzzy-PID controller appears good because this PID process has improved error detection.



Output after fuzzification

Figure 10. Fuzzy-PID response graph.

Test of fuzzy PID with four inputs: The researcher runs simulations with four inputs—strength, current, load, and velocity—that likewise provide four outputs, as shown in Figure 11, to more comfortably examine how the ripple behavior reflects the detent force.

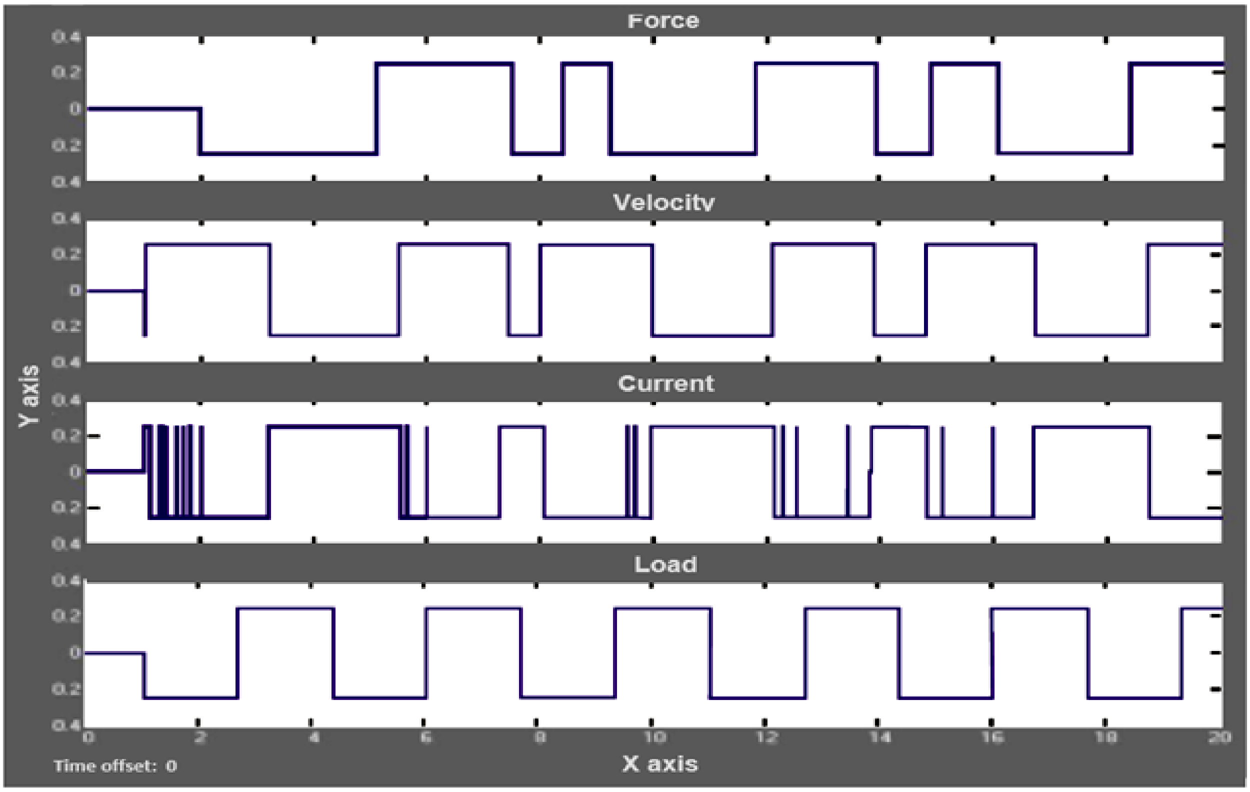


Figure 11. Output curve.

The input curve graph: Displays force, current, load, and velocity, which is the outcome of the initial parameter presentation before the Fuzzy-PID process. Concurrently, the output curve figure represents the outcome of the display following the Fuzzy-PID procedure. The data indicates a notable variation in the y-axis value between the input and output, with the input on average reaching ten and the output's y-axis not exceeding 0.5. Figures 9 and 10 demonstrate how Fuzzy-PID control can affect signal control and increase the stability of curve ripple.

Force, current, load, and speed are shown in Figure 11 from top to bottom, demonstrating that the force ripple is minimal owing to changes in weight and distance. On the other hand, an opposite event occurred with a current that displayed numerous ripples, substantial losses, and robust thermal effects on the cabin or systems. Other oddities also occurred, as demonstrated by the speed graph, which has fewer waves than the others and suggests that the rate must be linear as the load and current change. The findings of the analysis of Figure 11 show that they differ somewhat from the previous simulation, which just used a fuzzy controller.

Comparison of PI controller and fuzzy controller test: The fuzzy PID controller, which has proved effective in reducing the detent force when used in conjunction with the PI controller, is tested using a simulation. Figure 12 displays the outcomes of a simulation run using the models from the [16] study using PI controllers. The Graph Model Block's PI controller results have four ripples in the block model. Starting from 1.8, the graph rises, falls, climbs again at -1.9, rises again at 1.55, dips, rises again at 1.15, declines at -14, and rises again at 1.4. Figure 13 illustrates how a ripple in current can cause vibrations in force, noise, and noise over distance.

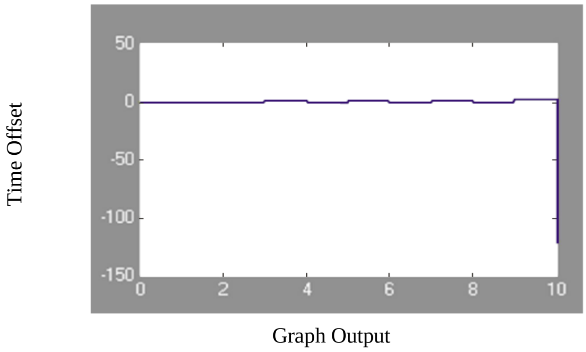


Figure 12. PI controller simulation.

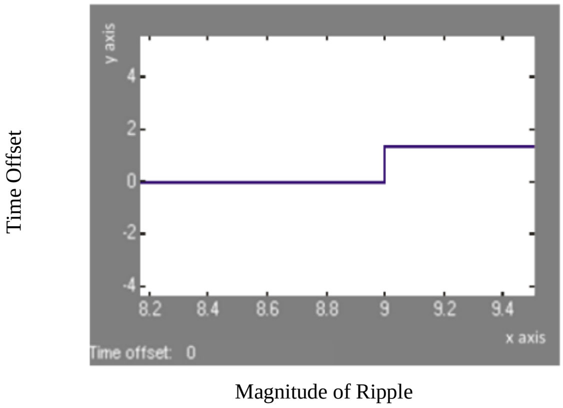


Figure 13. Fuzzy controller.

Fuzzy-PID controller model block: Using the diagram block shown in Figure 14, a basic simulation runs on systems with a fuzzy-PID controller. The Fuzzy-PID Controller in the block model is experiencing one ripple, and the graph shows a decrease at -7-time point 9. Figure 13 shows that the ripple is relatively less than in the previous figure. According to the simulation result, a system with a high-level controller can decrease ripple without changing the method structure, increasing production efficiency and lowering costs.

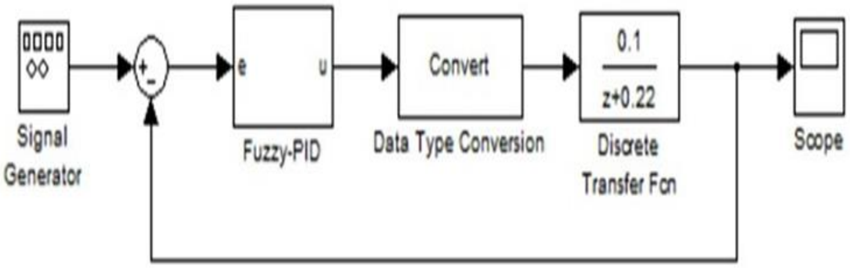


Figure 14. Fuzzy-PID diagram block.

IV. CONCLUSION

This study aims to improve elevator system performance through the design and implementation of the EGCS. The most crucial components of the EGCS, hall call assignment and control strategy generation, are established, and computer simulation is used to test the EGCS. The passenger traffic patterns are classified in the control strategy generation section, and the classified traffic mode and importance levels of the assessment criteria determine the membership functions employed at the hall call assignment. The appropriate elevators are assigned to handle the hall calls to serve passengers.

The fuzzy inference determines whether an elevator is suitable for a hall call, and the system chooses an elevator based on the rank of the overall suitability. Different manufacturers' control methods and principles have approached each other with microprocessor technology. The producers have adapted the best features of the new controls. Nowadays, all advanced group controls utilize statistical forecasts, fuzzy logic, and artificial intelligence. The control principles described in this report were first applied in the TMS9000 control for high-rise buildings, but later on, they were adapted also to the controls for mid-rise buildings.

The group control adapts to the prevailing traffic pattern. Control actions, such as returning cars automatically to busy traffic floors or parking cars during light traffic, follow the forecast traffic pattern. Fuzzy logic is applied to recognize the prevailing traffic patterns according to the forecast traffic component and passenger arrival rates. Passenger arrival rates at and exiting rates from each floor and in each direction are forecast for each time. Statistical forecasts of the passenger traffic are made in 15-minute periods for a typical day or separately for every weekday. Contrary to conventional controls, the peak traffic periods are predicted in advance. Before implementing a forecast traffic pattern, the validity of the forecast is confirmed by comparing the forecasted data with real-time or recent historical data to ensure that the predictions are accurate and reliable.

Comparing forecast values to actual values involves generating predictions based on historical data, monitoring real-time data to gather actual performance metrics, and comparing these forecasts with observed results to check their accuracy. Based on this comparison, control strategies are adjusted to ensure the system operates effectively and adapts to real-time conditions. If the forecast conflicts with the short-term statistics, the forecast is not applied in the control.

The simulation investigated the effect of changing the degrees of importance on the evaluation criteria and produced favorable results. The simulation indicates that assigning high relevance to an evaluation criterion improves its performance. The outcome indicates that the EGCS can function following the specified control plan. The EGCS's overall performance was evaluated under various traffic scenarios. The simulation's outcome shows that the EGCS's overall performance has improved over all periods. Star Industrial Systems Corporation is currently in charge of EGCS commercialization.

The performance of elevator control can be examined using fuzzy logic by comparing the outcomes of several block diagram model outlines. The choice of fuzzy rules and membership functions can impact the output results. Fuzzy logic produces meaningful solutions with exact value accuracy. Control simulation testing of the load and mileage value significantly affects the graphics output in a big lift with strong ripple waves. The fuzzy-PID controller can minimize detent force relatively with a fast response. Using the controller might be one of the best choices to reduce the detent force without changing the system's structure.

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