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Research Article

Automated Parking System Using PLC Technology

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Abstract: Parking infrastructure is an essential urban facility that must be adequately provided in all cities. However, the increasing number of vehicles has led to significant congestion, making it challenging for drivers to locate available parking spaces, particularly during peak hours. This situation underscores the growing need for fully automated parking systems, which have become a priority for modern cities globally. The primary objective of this paper is to propose and develop a fully automated parking system that minimizes human intervention while addressing these challenges and ensuring real-time parking availability in everyday life. A prototype system was designed using a programmable logic controller (PLC), incorporating a display screen located outside the parking area to monitor vacant spaces and provide drivers with real-time information on their locations. The system features two gates—one for entry and another for exit—along with two sensors to detect the presence of vehicles and multiple sensors to identify available parking spots. When space is available, the system triggers the gate to open, and if the parking facility is full, the PLC signals the gate to remain closed, marking the lot as fully occupied. This automated process significantly reduces the time and effort involved in searching for vacant parking spaces. The prototype underwent extensive testing in various scenarios and demonstrated robust performance, effectively addressing the issues associated with manual parking and congestion.

Keywords: Automatic Parking System; PLC; Sensors; Congestion.

1. Introduction

In the 21st century, the rapid surge in vehicle ownership and usage has profoundly intensified the challenge of securing parking spaces, particularly during weekends and public holidays [1]. Research suggests that up to 66% of drivers spend more than 10 minutes searching for parking in these periods. This issue is especially acute in high-traffic areas such as stadiums and shopping malls, where peak times exacerbate overcrowding and make the search for available parking slots increasingly difficult. The scarcity of parking in these environments not only contributes to severe traffic congestion but also elevates levels of driver frustration [2]. The global proliferation of vehicle ownership has, therefore, rendered the task of finding adequate parking increasingly complex and problematic.

Automated parking systems were first introduced in Paris in 1905 at the garage of "Rue de Ponthieu," driven by the need to accommodate a growing number of vehicles amidst a shortage of parking spaces. This early system was relatively rudimentary, employing stacked timber atop iron platforms to support vehicles, which were moved by wooden roads that required manual installation and removal [3]. The adoption of automated parking systems offers numerous advantages for urban planners, business owners, and drivers alike.

Automated parking systems provide significant benefits, including reductions in time and cost, more efficient use of limited parking spaces, and the simplification of the parking process. For example, they address common issues such as improper parking, where drivers inadvertently occupy multiple spaces. By ensuring a more orderly and efficient allocation of parking resources, automated systems contribute to both operational efficiency and improved user experience [4]. Typically, parking systems are categorized into two types: traditional and automated. Automated parking systems are projected to be more cost-effective and efficient over time compared to traditional parking systems. Additionally, there is a growing global trend towards adopting automated parking systems, which are designed to accurately calculate the available parking space for vehicles [5,6]. The initial Programmable Logic Controllers (PLCs) provided relay functionality, effectively replacing traditional hardwired relay logic. This conventional method employed electrically operated devices to mechanically switch electrical circuits. The adoption of programmable controllers subsequently began to expand across various industries [7,8].

A Programmable Logic Controller (PLC) integrates both analogy and digital inputs, with analogy inputs facilitating continuous monitoring and digital inputs managing data from sensors, as well as counters, timers, and programmable logic relays. In automated parking systems, PLCs play a critical role in monitoring space availability. The system's sensors transmit real-time data to the PLC, which governs the operation of gates and manages parking vacancies. This automation not only streamlines the parking process but also minimizes human error, maximizes space efficiency, and enhances the security of vehicles [9,11]. The PLC system supervises all parking-related operations, providing alerts to the operator in the event of malfunctions. Additionally, this automated approach contributes to fuel conservation and reduces the potential for accidents or vehicle damage typically associated with manual parking processes.

The article is structured as follows: **Section 2** highlights the Materials and Methods, detailing the tools, techniques, and processes employed in the study. **Section 3** discusses the practical implementation, focusing on the real-world application of the system or framework introduced. **Section 4** illustrates the results and discussion, providing a comprehensive analysis of the outcomes and their implications. Finally, **Section 5** presents the Conclusion, summarizing the key findings and their broader relevance.

2. Material and Methods

A. *PLCS7 1200 C.*

The PLC employed in this study is the Siemens SIMATIC S7-1200, specifically the CPU 1214C DC/DC/DC model. This central processing unit features a compact design with integrated input and output (I/O) capabilities, as illustrated in Figure 1. The modular architecture of the SIMATIC S7-1200 allows for expansion of configuration limits and adaptation to new tasks by adding Signal Boards or additional signal modules [12,13]. The system specifications are as follows: it includes 14 digital inputs, 10 digital outputs, 2 analog inputs, and no analog outputs.

Figure 1. PLC S7 1200 C.

B. *DC Motor*

A DC motor is an electrical machine that converts direct current (DC) into mechanical power, primarily operating through the forces generated by magnetic fields. Most DC motors include an internal mechanism—either electromechanical or electronic—that periodically reverses the current direction within the motor. In a brushed electric motor with a two-pole rotor (armature) and a permanent magnet stator, magnetic polarities are configured such that the internal faces of the magnets are designated as North (N) and South (S), with their external faces exhibiting opposite polarities. The red and black wires represent the points where DC power is supplied to the commutator, which then transfers current to the armature coils. In this study, two Yellow DC motors were utilized for operating the gate mechanisms. These motors are particularly suited for robotics and model vehicles due to their simplicity in assembly, as they can be directly connected without the need for additional couplings. Figure 2 illustrates the DC motor used in this application.

Figure 2. Yellow type DC motor.

C. Photoelectric Sensors

A photoelectric sensor, also known as a photo eye, is a device utilized to detect the distance, presence, or absence of an object through the use of a light transmitter, typically infrared, and a photoelectric receiver [13,14]. These sensors are extensively employed in industrial manufacturing applications. They are classified into three primary types: opposed (through beam), retro-reflective, and proximity-sensing (diffused). Figure 3 illustrates the various types of photoelectric sensors.

Figure 3. Types of photoelectric Sensors.

D. Relays

A relay is an electrically operated switch that enables the control of a circuit through a separate low-power signal. Relays are employed when it is necessary to activate a high-power circuit using a low-current signal, or when multiple circuits need to be controlled by a single signal [15,16]. In this system, four relays were utilized to regulate the direction of motor rotation. It is important to note that the relay coils operate at 24V DC and are controlled by a Programmable Logic Controller (PLC). Figure 4 depicts the SONGLE relay type used in this application.

Figure 4. SONGLE relay.

E. Limit switch.

The limit switch, illustrated in Figure 5, represents one of the most fundamental types of sensors. It is an electromechanical device designed to detect the presence or absence of an object. The switch functions by activating its set of contacts when its actuator makes physical contact with the object being sensed. The actuators come in various styles tailored to specific applications, including rollers, levers, springs, wands, and plungers.

Figure 5. Limit switch.

F. Power Supply.

The power supply is the one that adapts the electrical source from 220-volt ac to 24 v dc to feed the rest of the devices that need 24 v dc, as shown in Figure 6.

Figure 6. Power supply.

G. LED lamp

A LED lamp or LED light bulb is an electric light that produces light using light-emitting diodes (LEDs). LED lamps were used to indicate the state of the system. If the system is on or off. These lamps operate at 24-volt dc. They are controlled by the PLC [7]. The Figure 7 shows LED lamp.

Figure 7. LEDs lamp.

H. Pushbutton switch

A push switch (button) is a momentary or non-latching switch which causes a temporary change in the state of an electrical circuit only while the switch is physically actuated. An automatic mechanism (i.e., a spring) returns the switch to its default position immediately afterwards, restoring the initial circuit condition. There are two types: (i) push to make and (ii) push to break. Two switches used to turn on, off the system [7]. Figure 8 shows the switches.

Figure 8. Pushbutton switches.

3. Practical Implementation

All components of the system were connected to the PLC, and the TIA Portal program was used for programming, which was done using the ladder diagram language. Afterward, the system underwent testing and program adjustments to optimize performance and meet the system's objectives. The implementation process was carried out in four main phases: first, the design of the prototype; second, the design of the control panel; third, the creation of the wiring diagram and connection of wires; and finally, the development of the software.

A. Flowchart diagram.

ladder diagram language is used to execute the code for the automatic car park system, a TIA PORTAL V.14 software was used as an environment for developing the code. The code was programmed according to the sequence of the stages shown in the following flowchart in Figure 9.

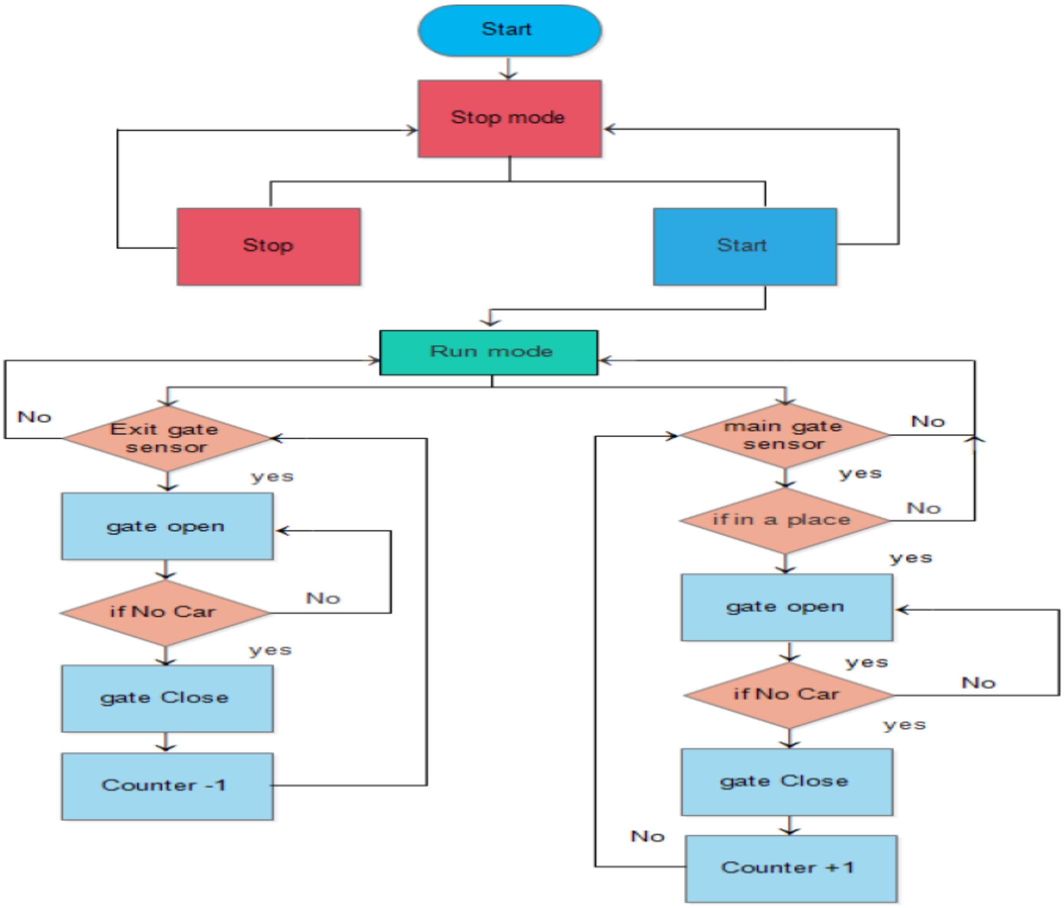

Figure 9. Flow chart.

B. The Prototype

The prototype is made of a wooden board with a length of 60 cm and a width of 60 cm surrounded by a wall of 8 cm high. that matches the real parking places Starting from the entrance gate to the parking spaces where cars can park and finally to the exit gate, Figure 10 shows the design of the prototype. The prototype contains also an electrical trunk used to protect and route the electrical wiring that used in the system.

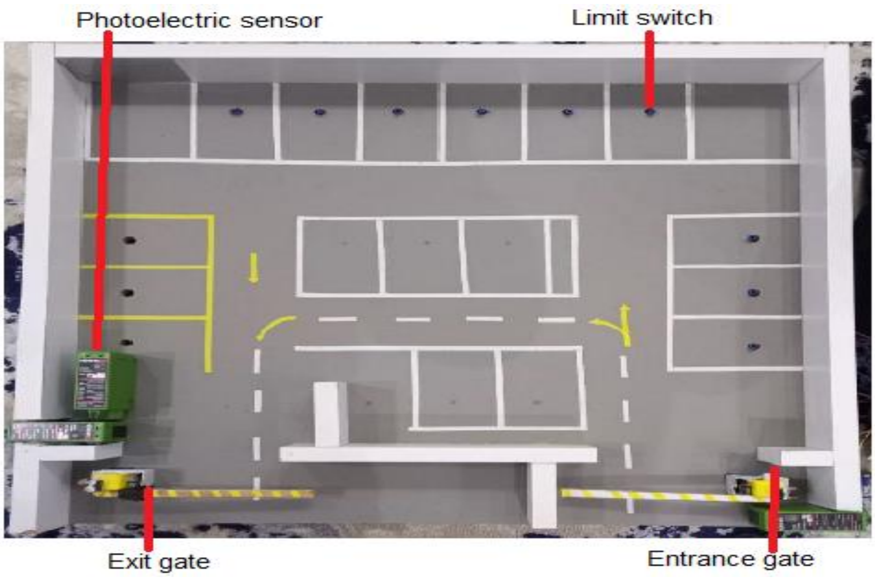

Figure 10. Prototype design.

C. Entry and Exit Gates

Entry and exit gates are designed using DC motor with two limit switches, and they were connected as in the Figure 11.

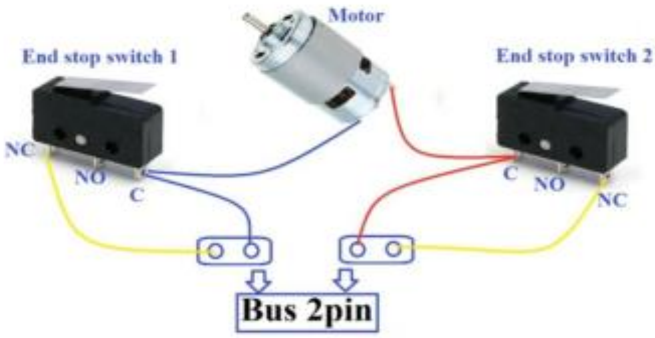

Figure 11. Connection circuit of the motor.

Four relays were used to control the opening and closing of the gates. Relays are installed on the printed circuit board with terminals as in the Figure 12.

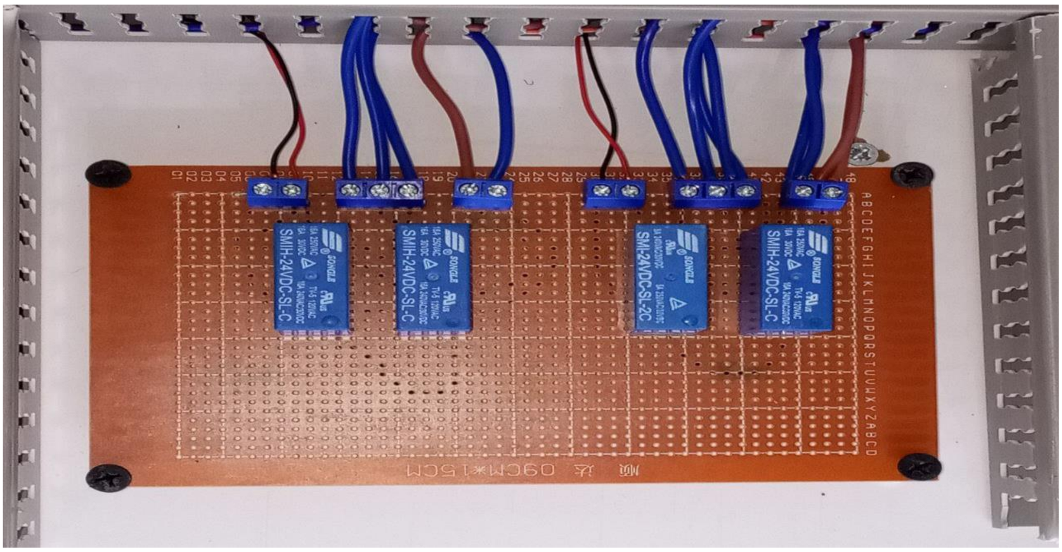

Figure 12. Relays on the printed circuit board.

A Photoelectric sensor was used to sense the presence of a vehicle in front of the gates, as shown in the Figure 13.

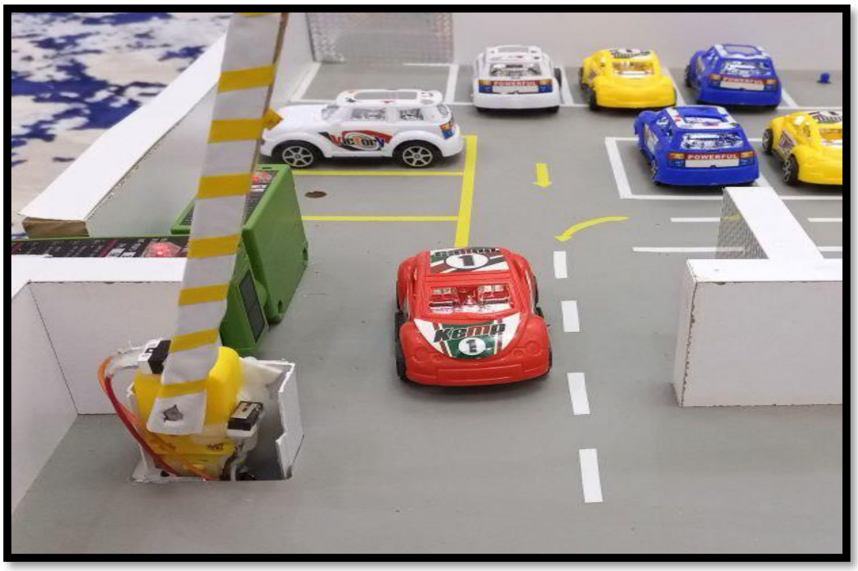

Figure 13. Light beam sensor.

D. Parking Spaces

Sensors (limit switches and Photoelectric sensors) were used to determine if the parking space was vacant or not.

E. Control Panel

The control panel is made of a wooden board with a length of 50 cm and a width of 40 cm for the installation of the control box, PLC and power supply with an electrical trunk used to protect and guide the electrical wiring used. Control box consisting of two on and off switches as well as two LED lights to indicate the status of the system on or off, as shown in Figure 14.

Figure 14. Control panel.

F. SCADA software

SCADA software has a significant role in the whole process analysis. The software that used in this system was (TIA Portal V.14) which include the SIMATIC WinCC V7 – Siemens as shown in Figure 15.

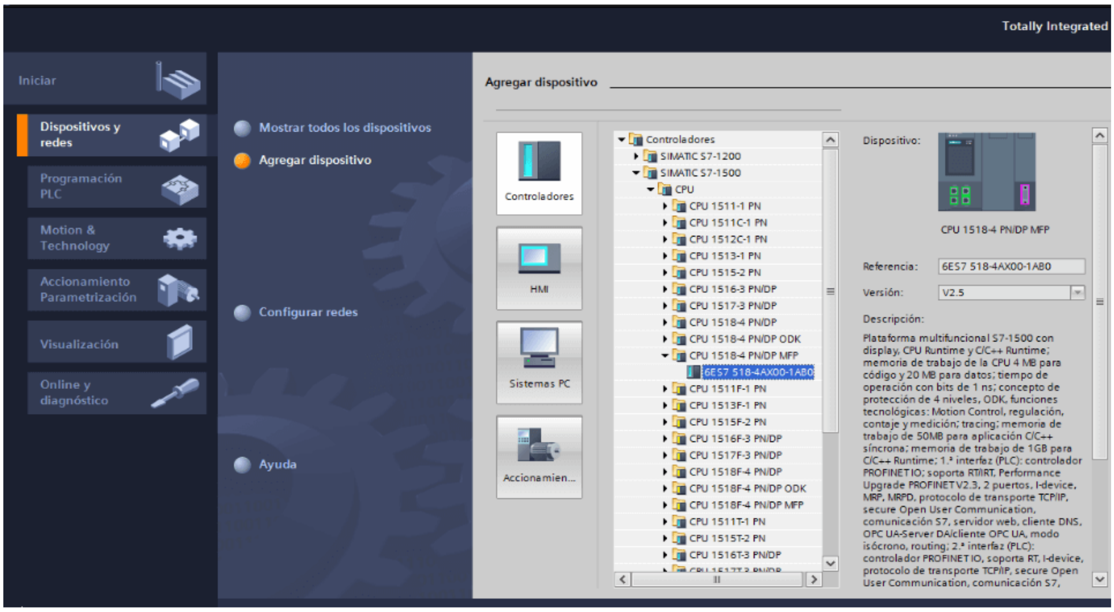

Figure 15. Tia portal.

Ladder Logic is the language that used for programing this system which is simple and easy to maintain, although there are other programming languages to programming the PLCs.

G. IDE (Integrated Development Environments)

A laptop computer with TIA portal software embedded was used to write the program and design the display and control windows, Figure 16 shows the location of writing the program with the download and compiler commands.

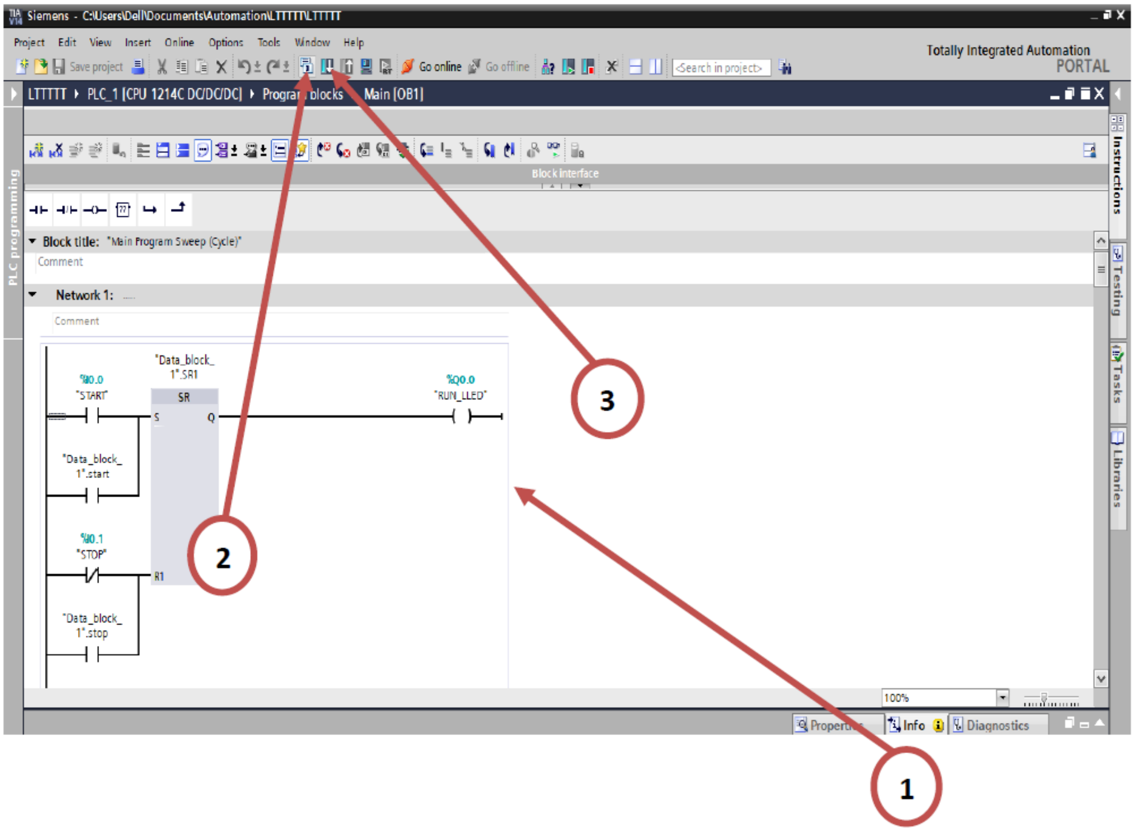

Figure 16. TIA portal software.

H. HMI Programming

In this system, HMI screen was added to PC as a software. Two HMI screens are created. The first screen is a screen consisting of two keys for ON and OFF and LED lamp as shown in Figure 17. Through this screen the system is controlled remotely. When RUN or STOP command is achieved by this screen, the signal goes to the PLC device, and then the programmed logic controller sends the signal to the output according to the programmed commands.

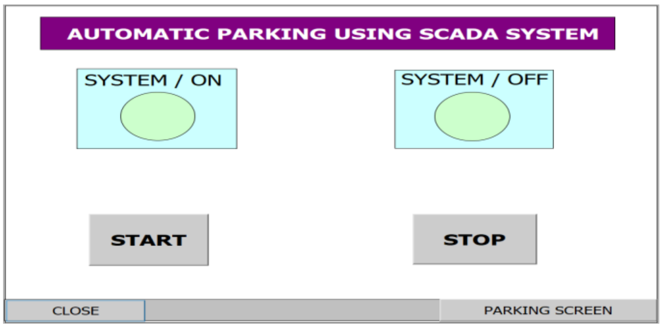

Figure 17. Control screen.

The second screen is the main screen that contains the entrance gate and exit gate as well as the counter and parking spaces, as shown in the Figure 18.

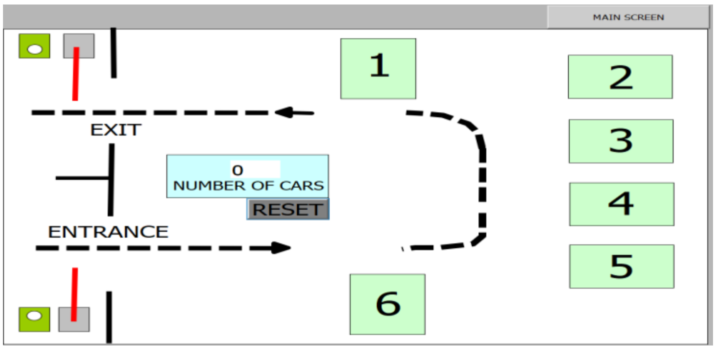

Figure 18. Display screen.

I. Wiring Diagram

The wiring diagram illustrate the whole wiring for the system, Figure 19 shows a block diagram overview of how the system components connected together, where PLC appears as a core for the whole system.

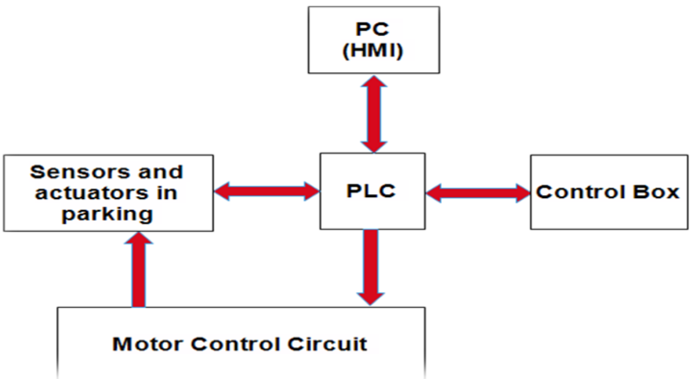

Figure 19. Block diagram of the system.

Figure 20 illustrates the wiring diagram for PLC digital inputs. The bottom lines indicate 24vDC power supply to feed switches/sensors which then can conduct the signal through switches/sensors to

PLC digital inputs in the top according to the state of switch/sensors (ON/Off). It can be noticed that the labeling system (X1: represents wiring in Control panel and X2: in (prototype)).

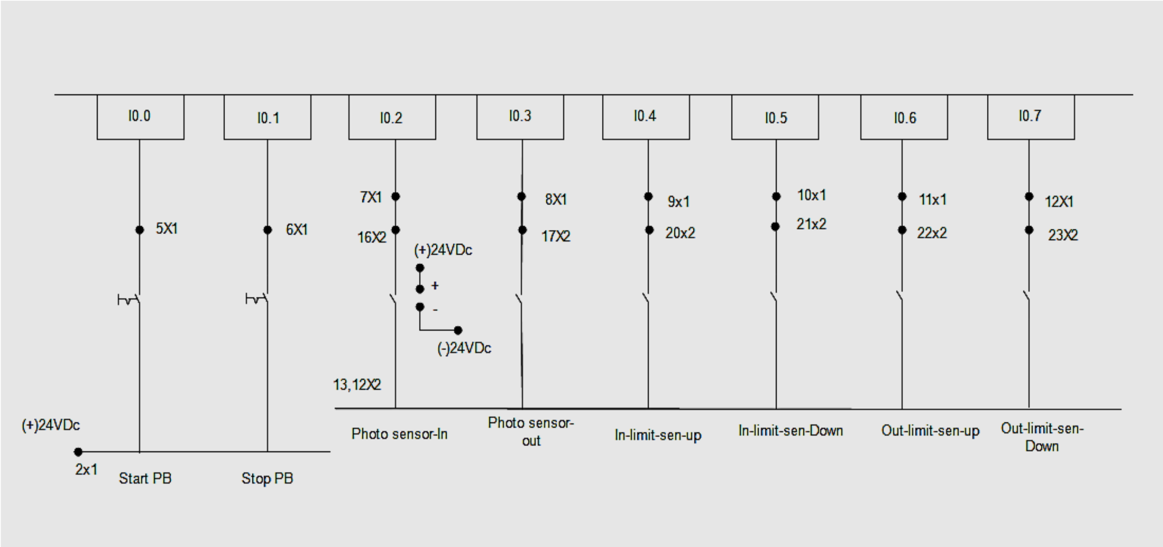

Figure 20. PLC Inputs.

The system uses two relays to control each motor direction either forward or reverse as shows in Figure 21. However, the code can decide which relay will work, for instance, the terminal of motor1 is normally connected to (-) 5vDc.Case1: If R1 is energized the left terminal of the motor1 is connected to (+) 5vDc which means that motor 1 is running forward representing opening action for the gate1. However limit switches are attached to gate 1 and gate 2 to serve the stop of motor1 movement by sending signal to PLC making R1 is de-energized Case2 : If R2 is energized the right terminal of motor 1 is connected to (+)5vDc,which means that the motor 1 is running reverse representing closing action for gate 1. However, limit switch is attached respectively to gate 1 and gate 2 in order to serve the stop action of motor1 movement by sending signal to PLC making R1 de-energized. motor2 works identically like motor1.

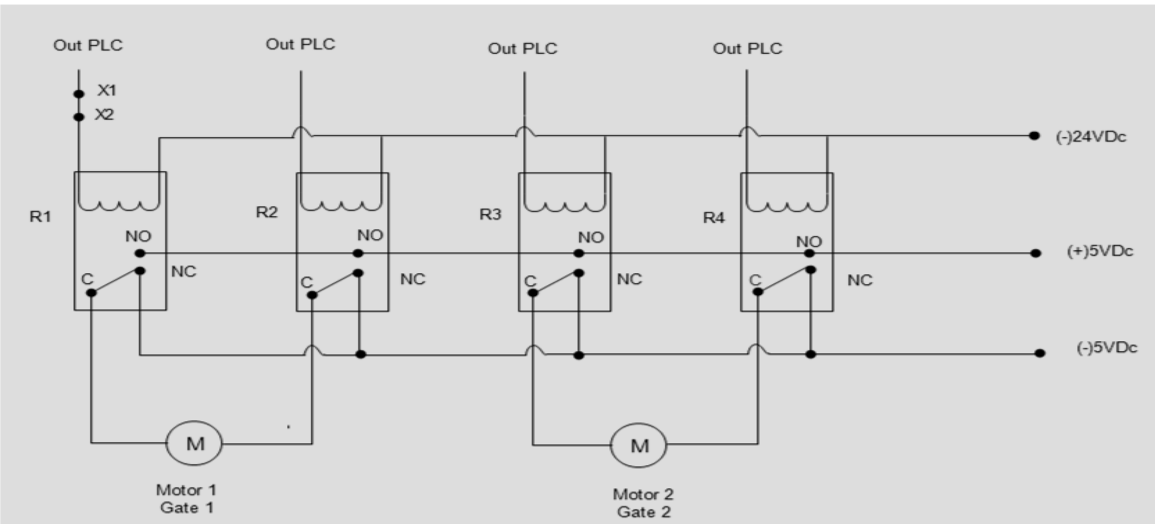

Figure 21. Motor control (PLC Outputs).

4. Results and Discussion

There are two main types of car parking systems: traditional and automated. In the long run, automated parking systems tend to be more cost-effective compared to conventional parking garages. Automated systems also contribute to reducing pollution, as vehicles are no longer idling or circling in search of parking spaces. These systems often rely on specialized hardened computers, known as

Programmable Logic Controllers (PLCs), which are used to synchronize the input flow from physical sensors with the output flow to actuators, allowing precise control over various industrial processes.

The findings of this paper demonstrated the feasibility of monitoring available parking spaces and informing drivers of vacant spots. Sensors were utilized to detect the presence of vehicles, and additional sensors identified the location of cars when parking spaces were available. The system was designed so that the gate automatically opens if parking is available, and if the lot is full, the PLC sends a signal to close the entrance gate and mark the space as reserved. This automation streamlines the parking process, saving both time and effort in finding vacant spaces.

5.Conclusion

The conclusions drawn from this paper are summarized as follows:

- The parking system has been successfully developed using a Programmable Logic Controller (PLC) to automate parking processes in high-traffic areas. The system effectively addresses the issue of insufficient parking space for vehicles, particularly four-wheelers.
- The implemented system is capable of detecting the presence of vehicles at the main parking gate using a photo sensor, ensuring efficient monitoring and control of vehicle entry.
- The proposed system offers several advantages, including its robustness under varying environmental conditions, scalability to accommodate larger parking facilities, compatibility with a wide range of sensors, and the ability to operate for extended periods without requiring software updates or system restarts.

In conclusion, the PLC-based automated parking system developed in this study effectively addresses the challenges of limited parking space in congested areas by efficiently detecting vehicle presence and managing entry through sensors. The system demonstrates robust performance, offering scalability, environmental resilience, and the ability to operate over extended periods without requiring frequent software updates or restarts, making it a reliable and adaptable solution for modern parking needs.

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