ELECENG 4OI6

Engineering Design

2023 Group 3

Final Report

Intelligent Parking System

Background

Parking in North America faces a significant challenge despite the vast land dedicated to it. On average, each car has access to seven parking spots, yet finding parking in high-demand areas like downtown Toronto remains difficult due to outdated city planning.[1] With only 20,000 parking spaces available, traffic congestion and driver frustration are rampant. As car ownership increases, traditional flat parking lots become insufficient. To address these issues, our innovative solution introduces an intelligent parking garage system with a mechanical lift, enabling vertical stacking of cars across multiple levels. This design maximizes parking capacity within the same spatial footprint, optimizing space efficiency, enhancing security, and improving the parking experience by eliminating the need to navigate crowded lots. By alleviating parking shortages, reducing search time, relieving traffic congestion, and promoting efficient land use, our solution aligns with sustainable urban development goals and meets the needs of evolving urban centers.

Abstract

The objective of this project is to address the pressing issue of urban parking space shortages by introducing an innovative parking facility that utilizes mechanical lift systems. The project involves developing a smart, space-saving parking lot simulation system capable of efficiently stacking cars both vertically and horizontally, akin to books on a shelf. This approach significantly enhances the parking lot's capacity to accommodate more vehicles.

The final system is structured for three-dimensional parking, comprising three levels, with each level capable of accommodating three cars. In total, the parking garage can accommodate nine vehicles. The underlying logic features a PLC-controlled system to manage multiple motors for the operation of the parking lot. Accessing the vehicle can be monitored by peripheral equipment such as a laptop. Upon receiving a command, the system automatically transports the vehicle to its designated parking space or retrieves it to the exit.

Project goals

Bronze Level:

The primary goal at the Bronze level is to design a parking lot module using Autodesk Inventor (CAD) at a 1:24 scale. This module consists of a rectangular building with hollow rectangular rooms, each serving as a parking space. The implementation involves utilizing 3-axis motorized linear stages linked and monitored by Raspberry Pi to lift and place vehicles into available parking areas. The algorithm for parking dictates placing vehicles in the lowest empty space. Additionally, an interactive system is planned, where users receive a password upon storing their car, which they later use for retrieval.

Silver Level:
At the Silver level, the focus shifts towards optimization and enhancement of the interactive system. This involves replacing the simple display with a website that provides more information, including available parking space and estimated waiting time. Furthermore, machine learning algorithms are incorporated to analyze vehicle features and predict parking times. Based on this analysis, vehicles are assigned parking locations accordingly, aiming to minimize waiting time. While these features are essential, they hold lesser importance compared to those at the Bronze level.

Gold Level:
The Gold level of achievement aims to elevate the interactive system's functionality and user experience. Firstly, a service is introduced to send vehicle retrieval passwords to users' phones via mail or email, reducing the likelihood of forgetting or mistaking passwords. This feature is facilitated by connecting to an online server. Secondly, a payment system is integrated, utilizing collected parking time data to calculate parking fees. This addition not only ensures the benefits of the design but also enables users to conveniently pay fees through the parking area's website. Together, these innovative features enhance user convenience and signify a gold-level service.

Schedule

1. Mechanical Assembly(finished):

- - Drafting of all mechanical drawings has been completed.
- - All mechanical assemblies has been successfully put together.
- - The final testing has been conducted to ensure mechanical integrity.

2. Electrical Hardware Installation(finished):

- The planning for the electrical circuit and hardware layout has been completed.
- All electrical hardware assembly and circuit connection have been finished.

3. Programming and Debugging(finished):

- Finished PLC programming and interaction with touch screen
- Finished the touch screen design and apply interaction with PLC
- Finished the test for the whole system working process

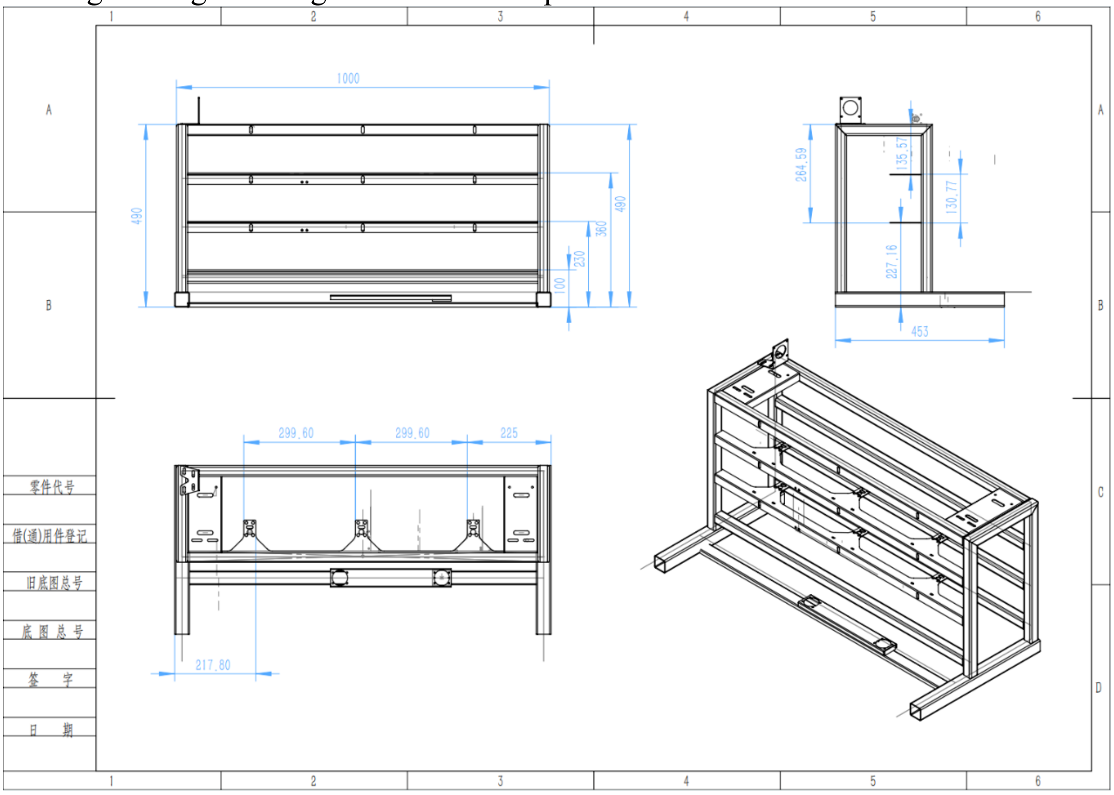
Actual implementation

Item	Description	Brand	Model	Quantity	Unit Price
Controller	Main power circuit breaker	DELIXI	DZ47PLE C16	1	8
Relay	Main control parking spaces forward and reverse	DELIXI	CDZ9-52PL	1	1.8
Relay	Control each parking space forward and reverse	DELIXI	CDZ9-52PL	9	1.8
Switching Power Supply	220V to 24V	MEANWELI	DR-120-24	1	15
Stepping Motor	57 stepping motor	PFDE	1.2n/mDM542S	2	39
Programmable Logic Controller	Automation control	Misubishi	FX3SA-30MT	1	152
Communication Module	Communication between PLC and touch screen	MCGSTPC		1	104
Touch Screen	Touch IoT screen, achieve network control	MCGSTPC	TPC7022NI 4G	1	
Photoelectric Switch	Transport platforms position detection		PNP SN-4PUO	1	6
Photoelectric Switch	Parking platforms position detection		PNP TL-W5MB1	9	7
DC Reduction Motor	Driving the movement of each parking platform	SZCM	JGY370	9	3.2
Hardware Manufacturing	Stainless steel and acrylic plexiglass			1	515
Express Fee				1	436.5
Total					**1424.3**

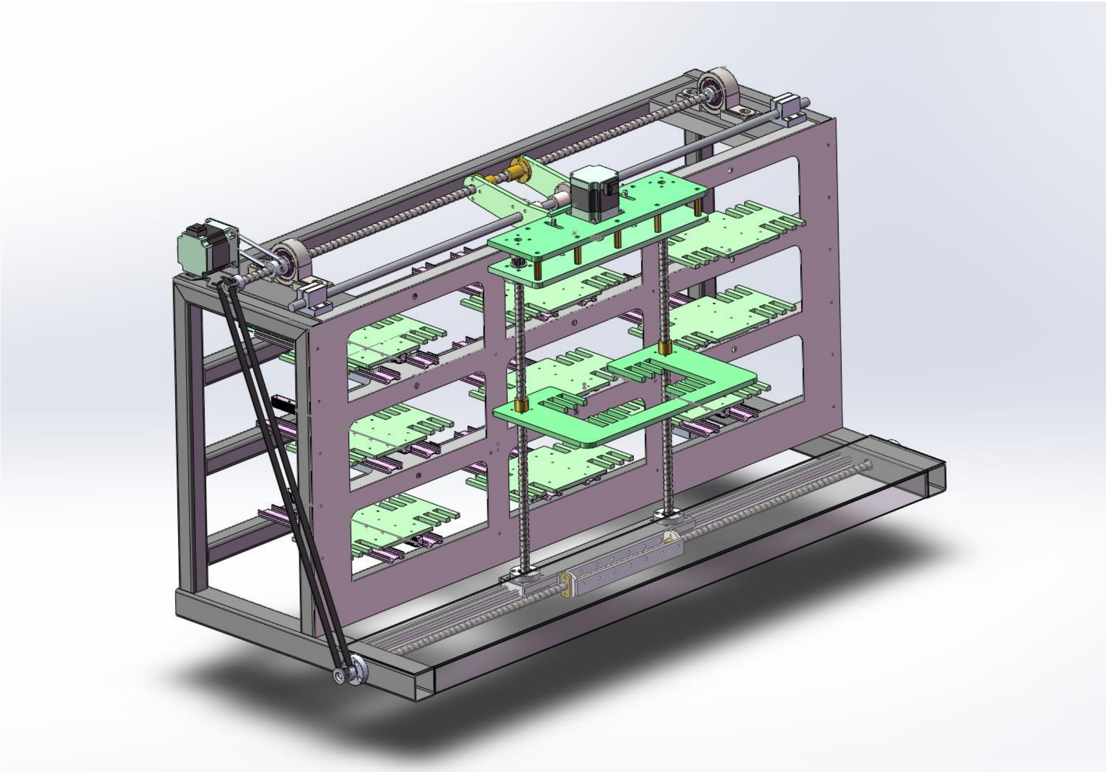
Expenditure

1 Module design and assembly

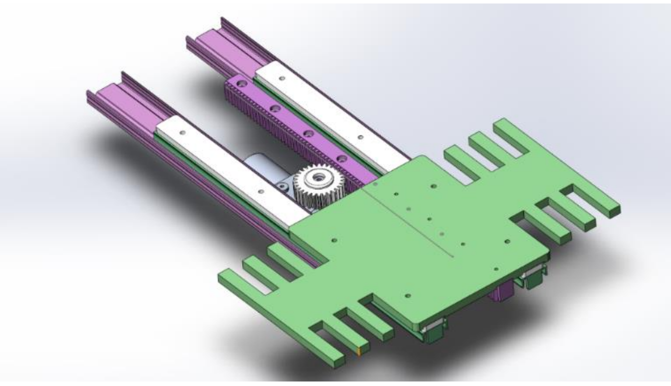
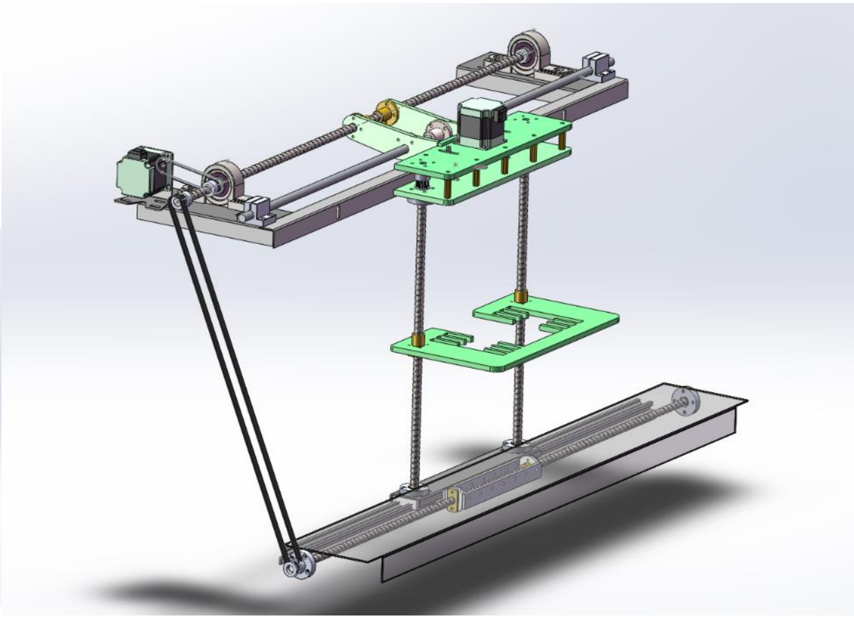
3D Engineering Drawing and List of Component



Framework	Main Framework
	Front Panel,Internal Panel,Top Panel
	Bottom Platform
Lifting Device	Platform Panel
	2*Vertical Threaded Rod
	Bottom Track & Slider & Threaded Rod (& Gear)
	Upper Threaded Rod (& Gear) & Upper Smooth Rod
	2* Tension Gear, 4* Belt Gear
9* Gripping Device	Track & Slider
	Platform Panel
	Motor & Gear & Rack



Cad module

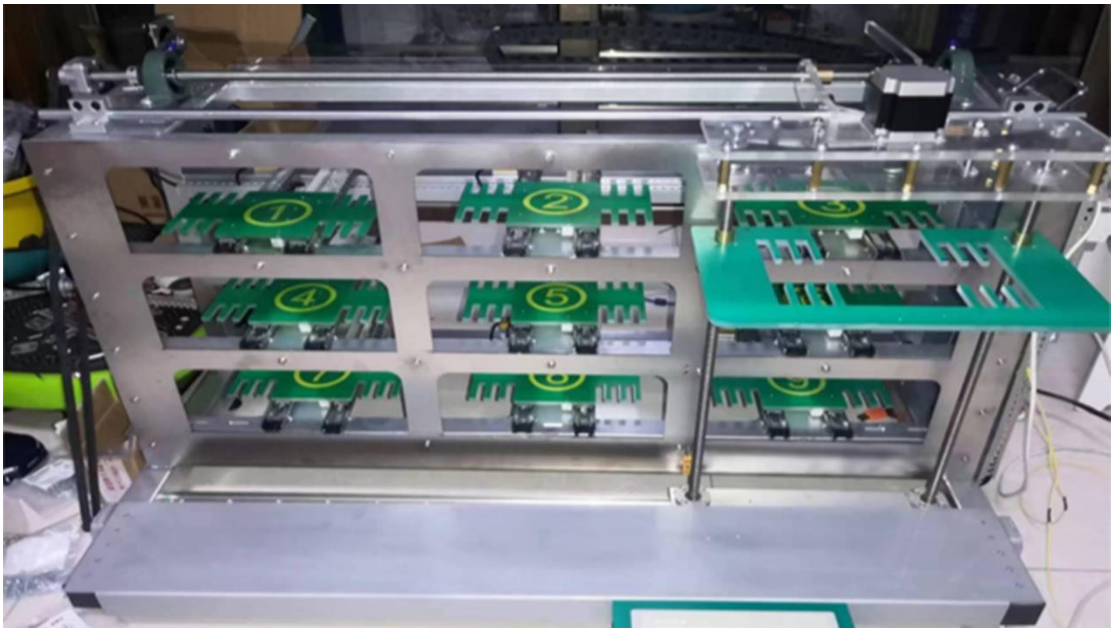



Principal of movement

The lifting platform can move in the X-axis (horizontal movement) and the Z-axis (vertical movement) controlled by stepper motors and belts. The X-axis adopts the connection of two main screws with a synchronous belt for simultaneous operation, avoiding synchronization issues caused by height differences. The Z-axis uses two screws directly connected to a stepper motor with a synchronous belt to prevent asynchronous lifting and lowering issues.For

the parking platform, a gear motor is used to move the platform in Y-axis (in and out

movement). Each platform's entry/exit adopts two segments of telescopic tracks, one on the left and one on the right. The extension and retraction are achieved by using a motor with gears on top and racks on the lower part of the parking platform.
Both the lifting platform and parking platform feature a comb structure. During the parking process, the lifting platform is guided to its designated parking space along the X-axis and the Z-axis (on the top of the parking platform). Subsequently, the parking platform is activated, extending towards the position of the movable lifting platform. The comb structures on both platforms are then employed. Following the descent along the Y-axis, the parking platform retracts, and the vehicle is positioned into its designated parking space.



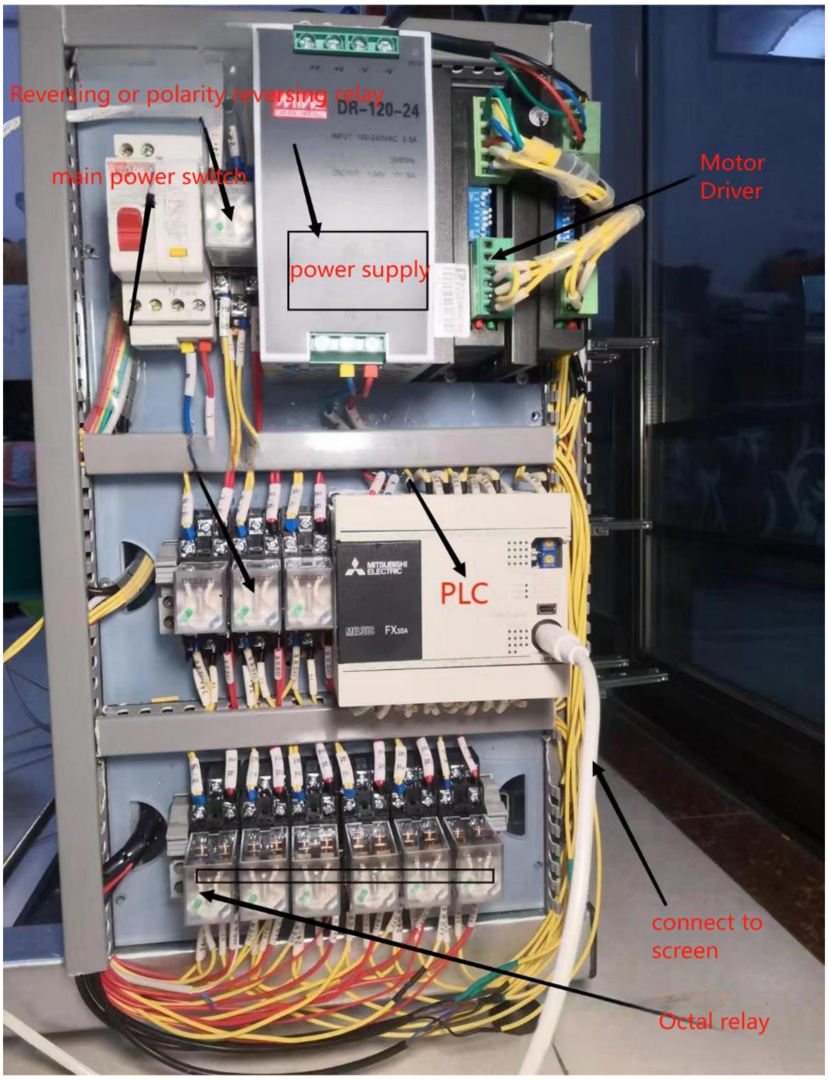
Final assembly

2 Electrical component and circuit design

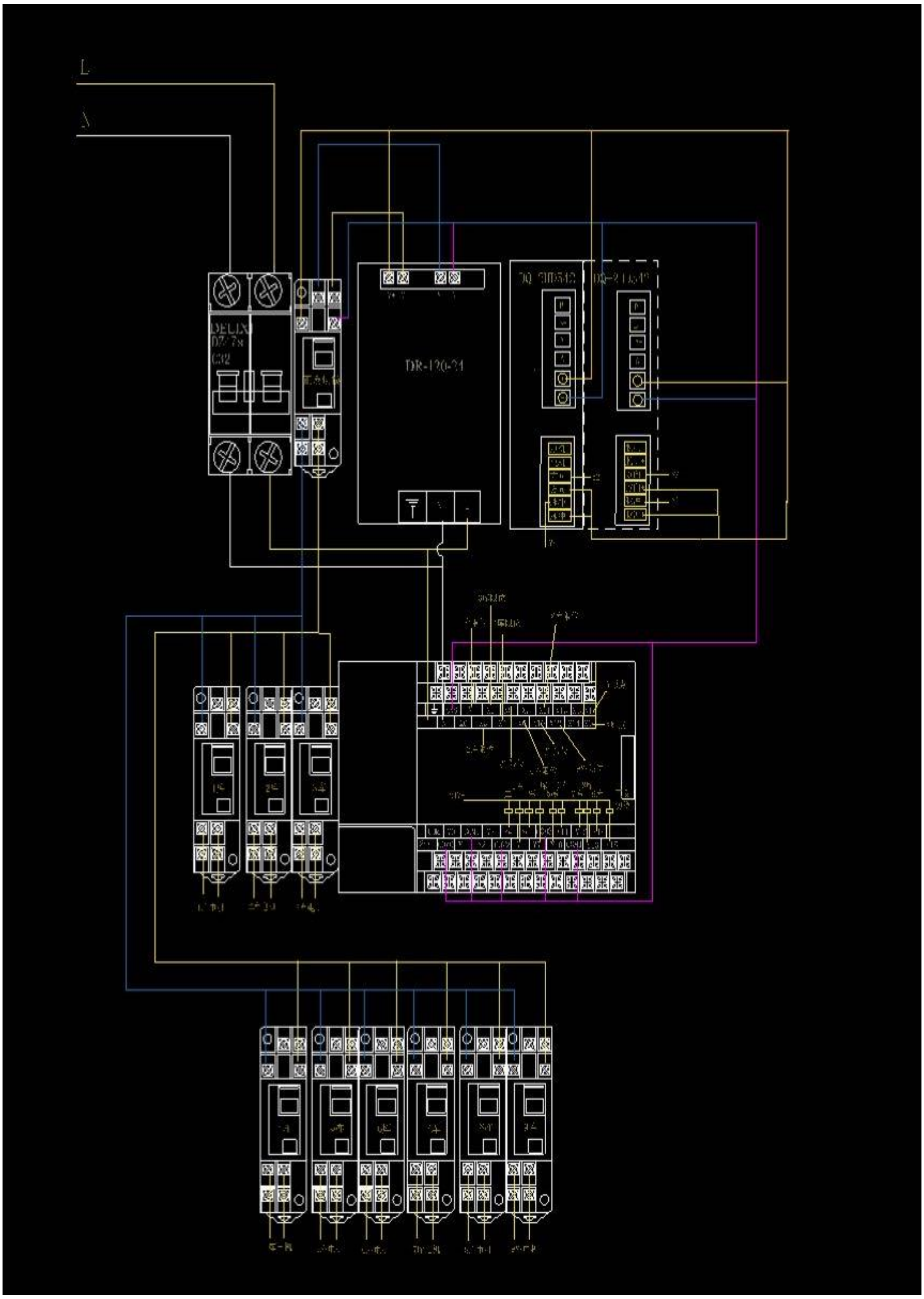
Type	Model	Quantity	Company	Description
Controller	DZ47PLE C16	1	DELIXI	Main Power circuit breaker
Relay	CDZ9-52PL	1	DELIXI	Main control parking space forward and reverse
Switching Power Supply	DR-120-24	1	Mean Well	220V to 24V
Stepping Driver	1.2n/mDM542S	2	PFDE	57 stepping motor
Relay	CDZ9-52PL	9	DELIXI	control each parking space forward and reverse

PLC	FX3SA-30MT	1	Mitsubishi	Programmable Logic Controller
Communication Module	Mitsubishi / MCGSTPC	1		Communication between PLC and Touch Screen
Touch Screen	TPC7022Ni 4G	1	MCGSTPC	Touch IoT screen, achieve network control
Photoelectric switch	PNP TL-W5MB1	9	PNP	For the signal input
Photoelectric switch	SN-4PUO	2	PNP	For X-axis/Y-axis home position
DC geared motor	JGY370	9	18 cycles/min	Control each platfrom

Electrical Distribution Materials List



Circuit setup image



Wiring diagram

Based on the layout of the inputs and outputs and the individual appliances that we had planned in the previous phase; We first wired in the drawings and finally connected them as drawings.

Within the system, a specific set of relays is responsible for dynamically switching the motor's direction. Specifically, a single-pole reversing relay manages the transition between vehicle entry and exit modes. During vehicle entry, the relay remains de-energized, resulting in the motor rotating in the forward direction; conversely, during vehicle exit, the relay is energized, causing the motor to reverse. This process is accomplished by altering the polarity of the motor supply lines, utilizing the normally open and normally closed contacts of the relay to switch states.

Given that the load required to start and run the motors is substantial, it is impractical for the PLC to directly control the output. Therefore, we have employed a series of relays to act as intermediary amplifiers, enhancing the strength of the control signals to drive the high-power motors. The selection and configuration of these relays ensure the system’s stability and reliability.

The power supply is used to transfer 110volt to 24 volts for the whole system. In terms of electrical wiring, we have differentiated the power lines and control signal lines with distinct color markings. Additionally, color-labeled terminals are attached to the end of each wire, facilitating the installation, and debugging process, as well as augmenting the system's maintainability. The entire connection process adheres strictly to the detailed schematic design, ensuring that all components are correctly connected and operate smoothly according to the predetermined logic.

During the system's debugging phase, the color markings on the wire terminals significantly simplified the fault diagnosis and problem-solving process.

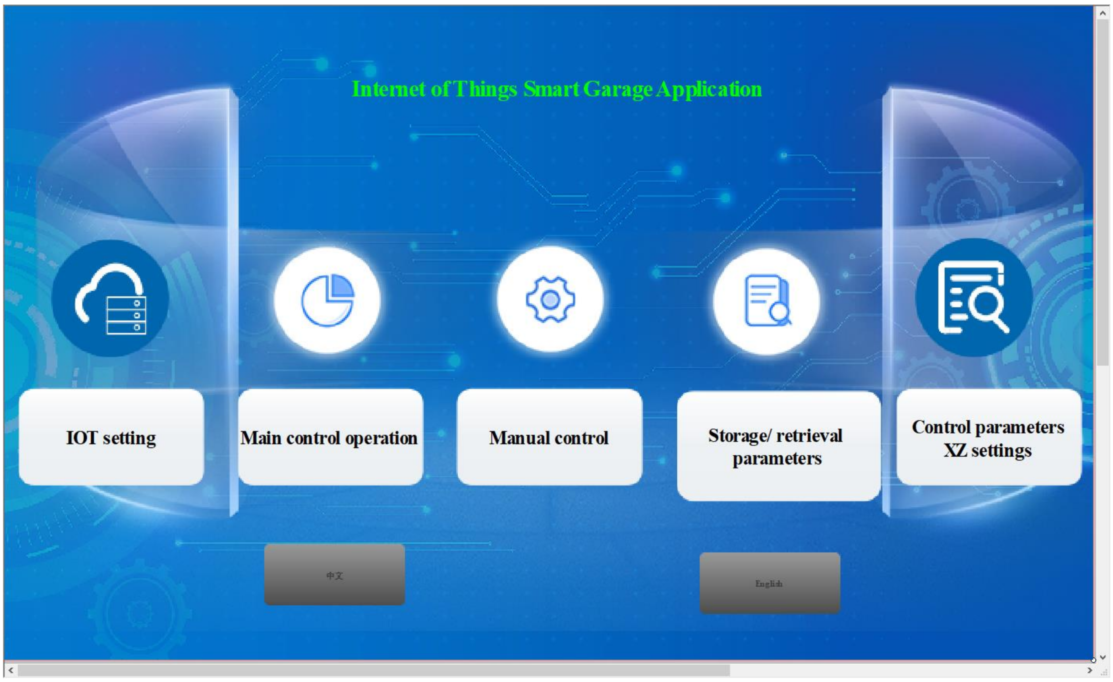
3 Touch screen programming

MCGSPro software is used to create and manage graphical interfaces that allow operators to interact with industrial control systems and machines. The software supports communication with programmable logic controllers (PLCs) and other automation devices to exchange data and control processes. It offers features such as drag-and-drop interface design, customizable widgets, data visualization, data logging, alarm management, recipe management, and remote access capabilities.

Data exchange and mapping: We need to synchronize the variables on the HMI software with those in the PLC's code, ensuring that the PLC's states during simulation accurately reflect on the interface. This synchronization allows the interface to successfully activate and control the PLC's variables. This step is crucial for real-time monitoring and control of the system. During the development phase, both the HMI and PLC must be configured to communicate effectively, with each variable on the HMI linked to its corresponding element in the PLC. This setup ensures that any changes in the PLC's status are immediately updated on the HMI, providing a reliable and intuitive control interface for the user. Additionally, this allows operators to perform actions through the HMI that directly affect the PLC's operations, such as manual overrides, adjustments to process parameters, or triggering specific sequences.

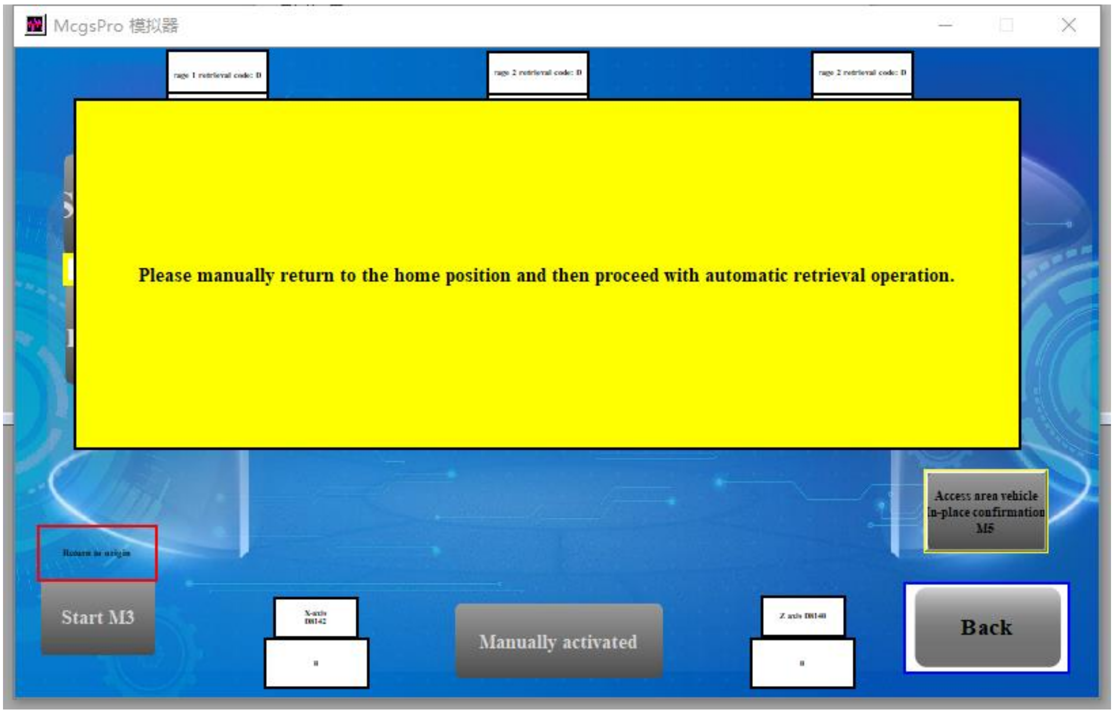
Communication protocols: Ensure that the communication protocols used are compatible with the PLC. For serial communications, Modbus protocol is widely utilized due to its robustness and reliability. For networked communications, Ethernet/IP protocol is commonly chosen for its high-speed data transfer and compatibility with industrial networks.

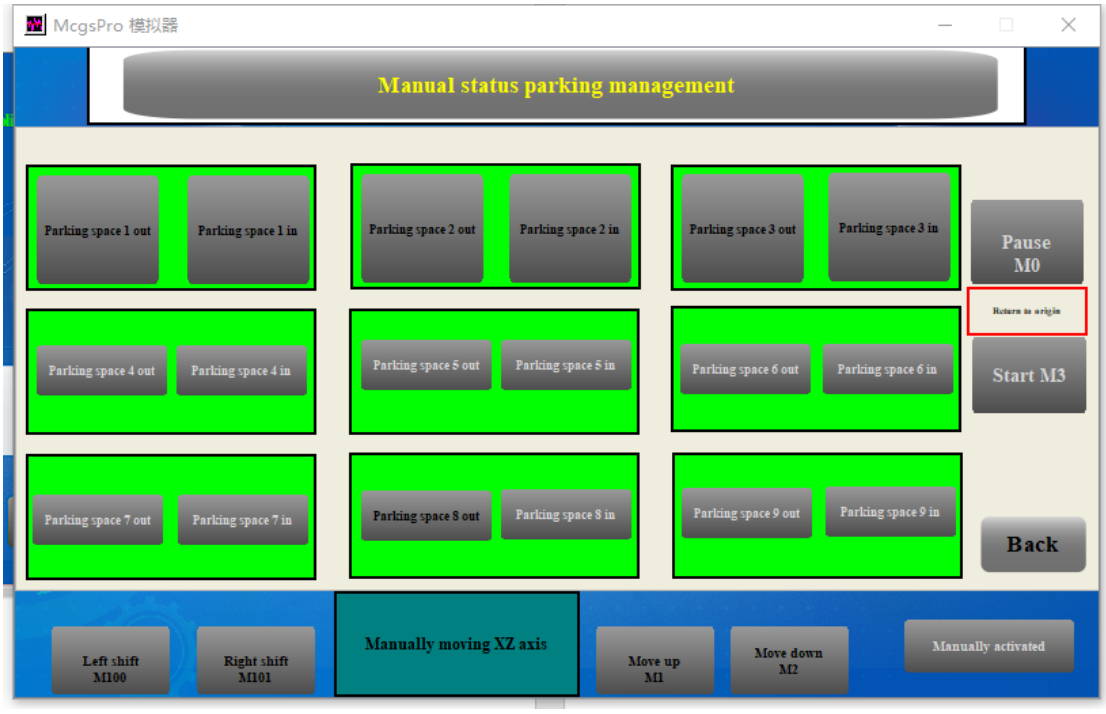
User Interface Design: Design an intuitive, easy-to-use user interface so that operators can easily interact with the system. Interactive elements are responded promptly and provide feedback to indicate successful operation or to alert the operator in case of input errors.



Home page

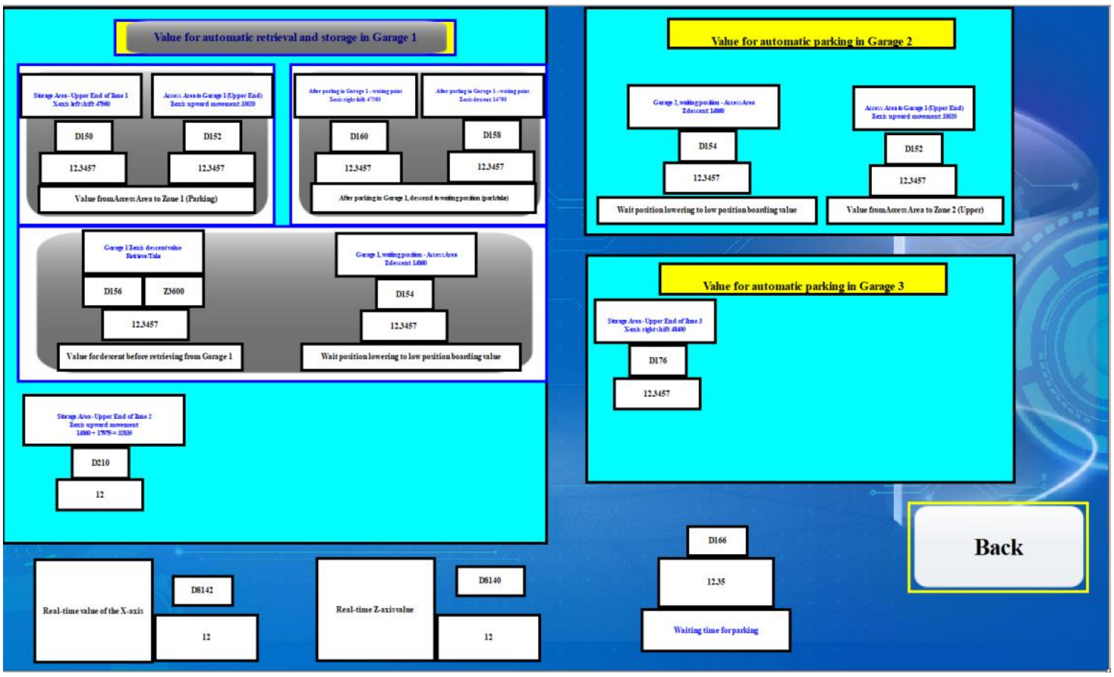
The homepage includes options for both automatic storage and manual mode. It is required to use the manual mode for the initial setup before any automated processes can be initiated. During this manual setup, values that are to be stored are entered and saved into a storage page.





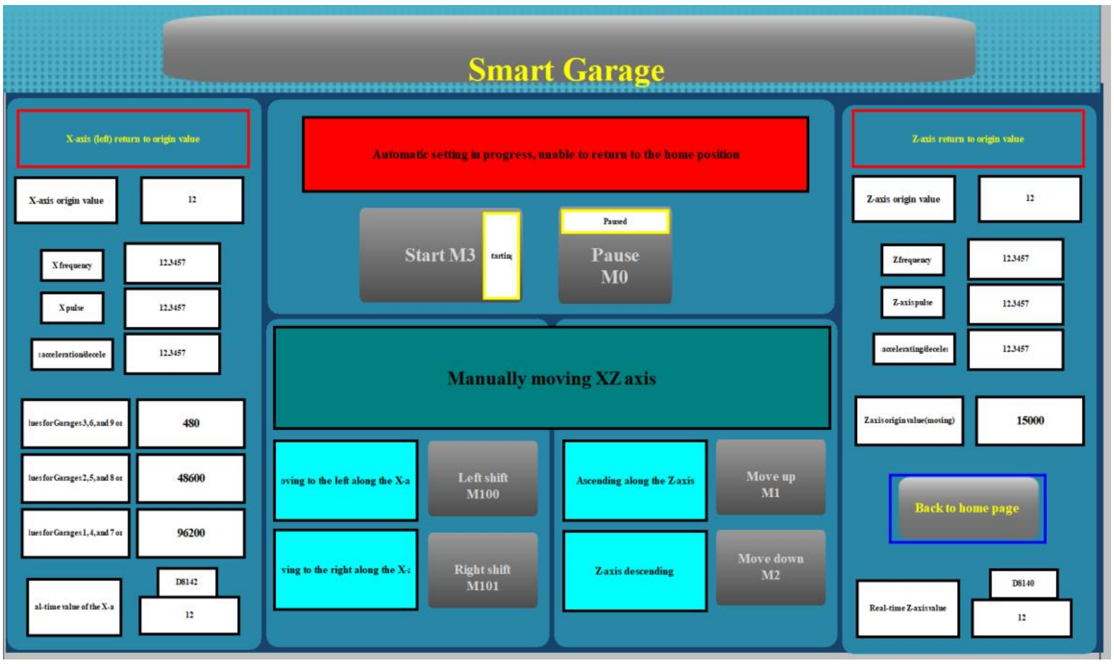
Automatic Control Page

This page is customer-facing and primarily includes operations such as retrieving cars, parking cars, and providing passwords. In the management page, we can see the status of each garage.



Storage page

The storage will also hold the coordinate values of each garage, as well as the home position values.



Manual Control Page

This page allows for the independent control of each axis and displays real-time data for various coordinates, which is crucial during the debugging phase.

4 PLC programming

First, the PLC is programmed for manual control, utilizing inputs such as X_left_move, X_right_move, Z_up_move, and Z_down_move(in image5 and 6). These inputs are linked to buttons on the touchscreen to manipulate the lifting and parking platforms. By operating the lifting platform, the necessary data for automated movement are recorded. Utilizing this data, the automated parking process is completed. This report details the coding process specifically for storing in parking platform 1, as the logic involved is complex.

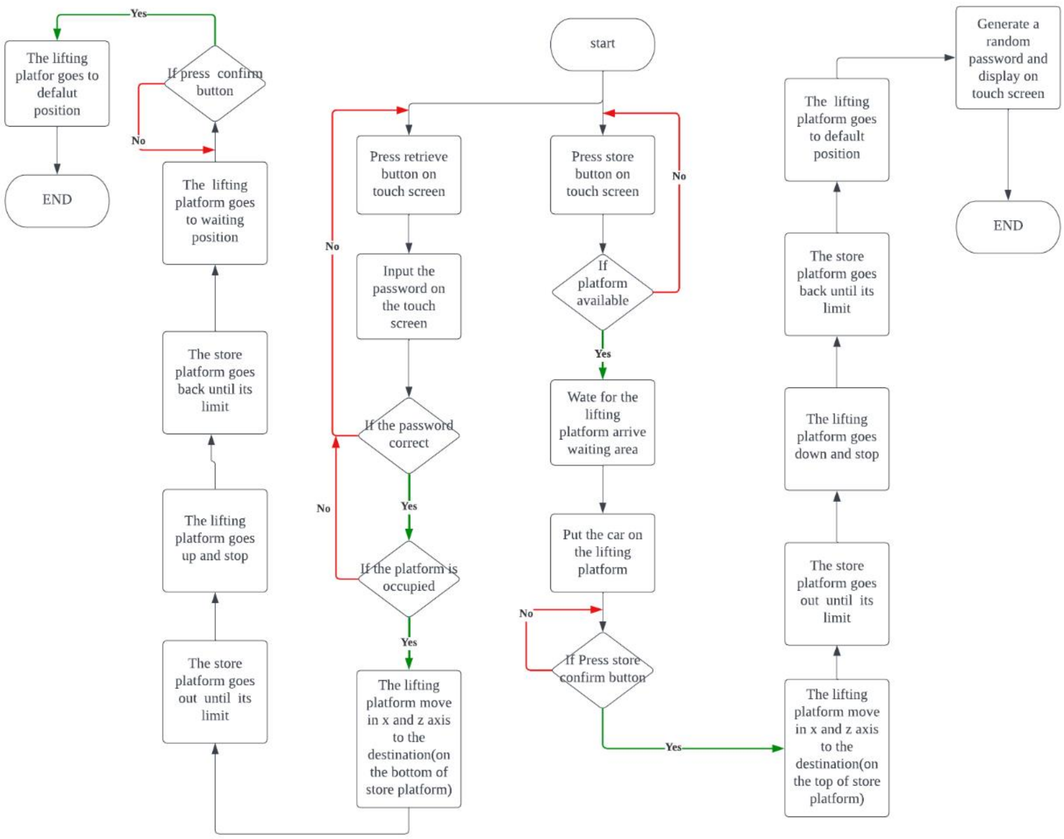
Before initiating the parking process, the X-axis and Z-axis configurations are reviewed. For Y1, the motor moves the lifting platform to the right, while Y3 triggers reverse direction impulse, moving the platform to the left when activated together. Similarly, Y0 moves the platform upward, and Y2 moves it downward for the Z-axis. The frequency and acceleration of the motor remain constant, with impulse value adjustments controlling the moving distance.

Upon pressing the "Car Parking 1" button, M20 activates, indicating the start of the process. M384 records whether platform 1 is occupied, and M18 ensures the platform is at its default location. The "Automatic" button toggles between automatic and manual control. When all conditions are met, "Store_start" activates, entering block function 1.

Block function 1 assigns calculated values to the motor, rotating it via M30 to move the lifting platform from its default to waiting position. Subsequently, the XZ value for the parking position is provided, located at the top of the parking space platform. Pressing the "M5" confirmation button initiates movement towards the parking position by activating M31 and M32.

After M32 deactivates, Block function 2 begins. When activated, "Gear_Motor" and Y4 initiate movement for the parking platform. Y4 to Y7 control platforms 1 to 4, and Y10 to Y14 control platforms 10 to 14. Individual activation of these Ys causes the gear motor to rotate, moving the platform out. Simultaneous activation with Y15 initiates reverse movement. The platform stops when the infrared sensor connected to X1 signals the limit. "OutOver" triggers, returning to Block function 1 as "P_O_over" activates. A new impulse value is added for the lifting platform to reach the bottom of the parking platform. When the lifting platform reaches its position, and the car is on the parking platform, "Platform_in" activates, proceeding to Block function 2. A similar process returns the parking platform. Infrared sensor input X1 detects the position, activating "InOver" upon completion. Block function 1 moves the lifting platform to its default position. When M36 activates, a random password is generated

and stored in D162, displayed on the touchscreen. M384 indicates platform 1 is occupied.
The process for storing a car on Parking Platform 1 is detailed here, and this process is similar for other platforms with some variations. For the retrieval process, the overall steps are similar, with the main differences highlighted in the block diagram below.



Block diagram

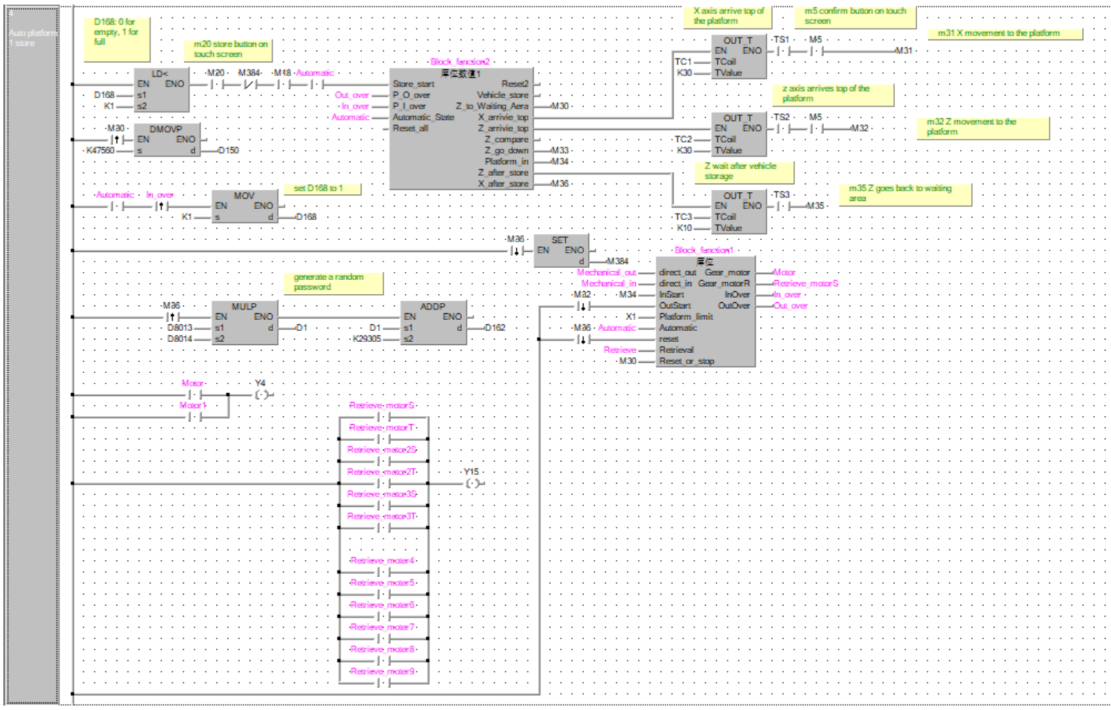
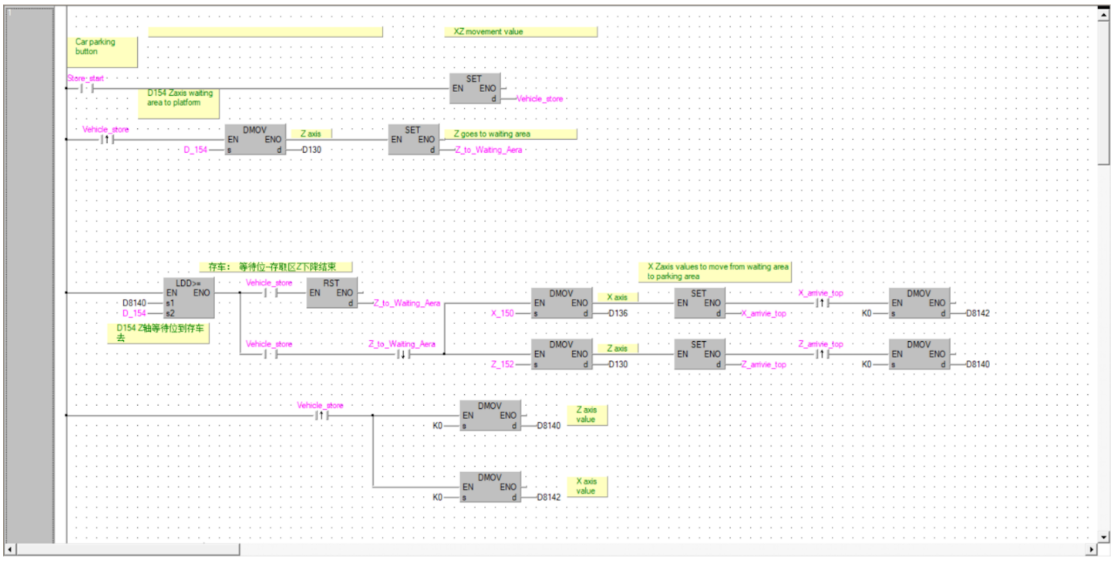
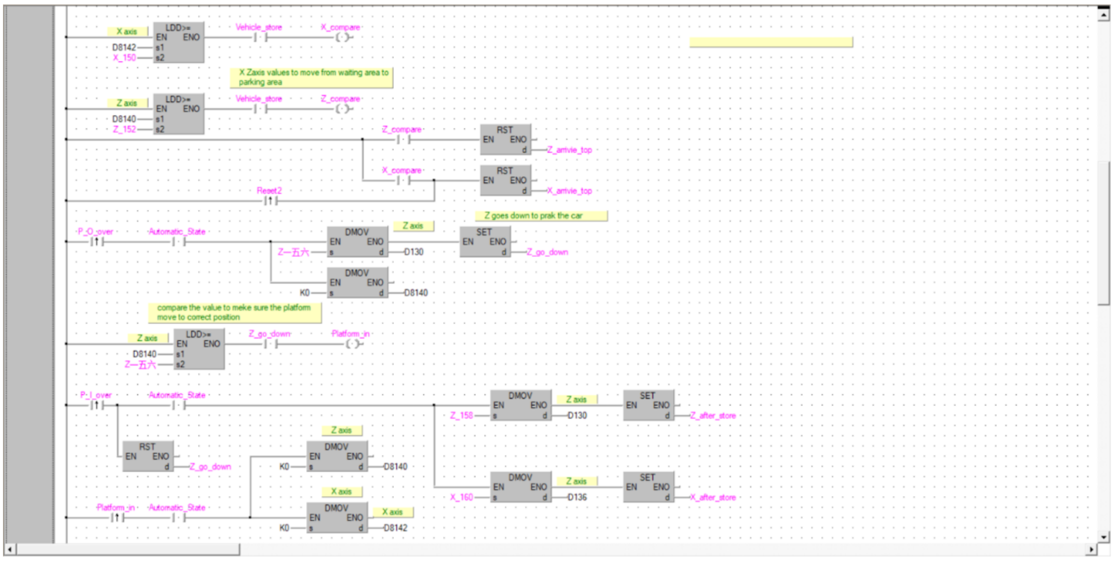


Image1(Car Parking main body)





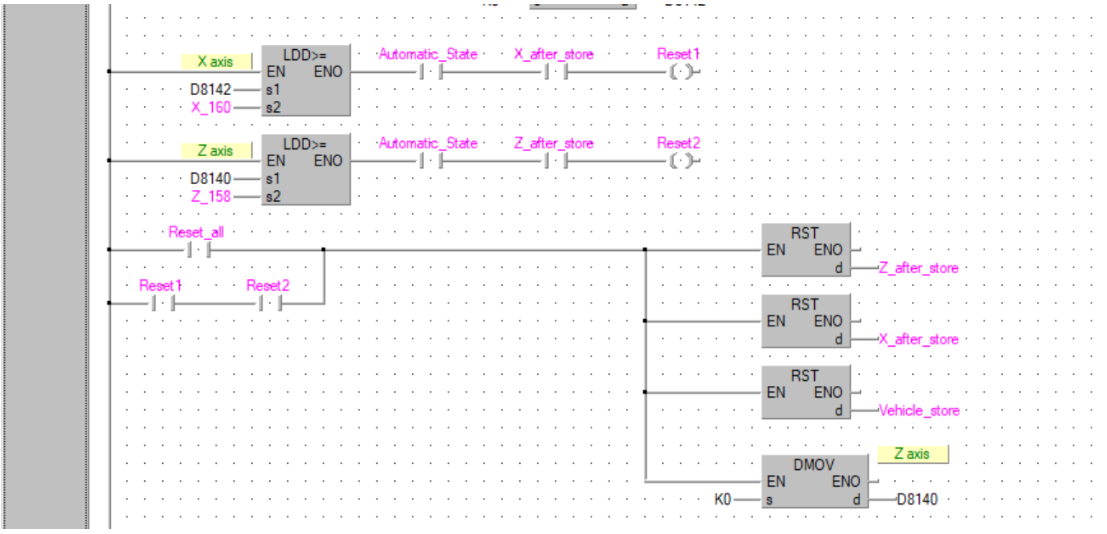


Image2-4(block function1)

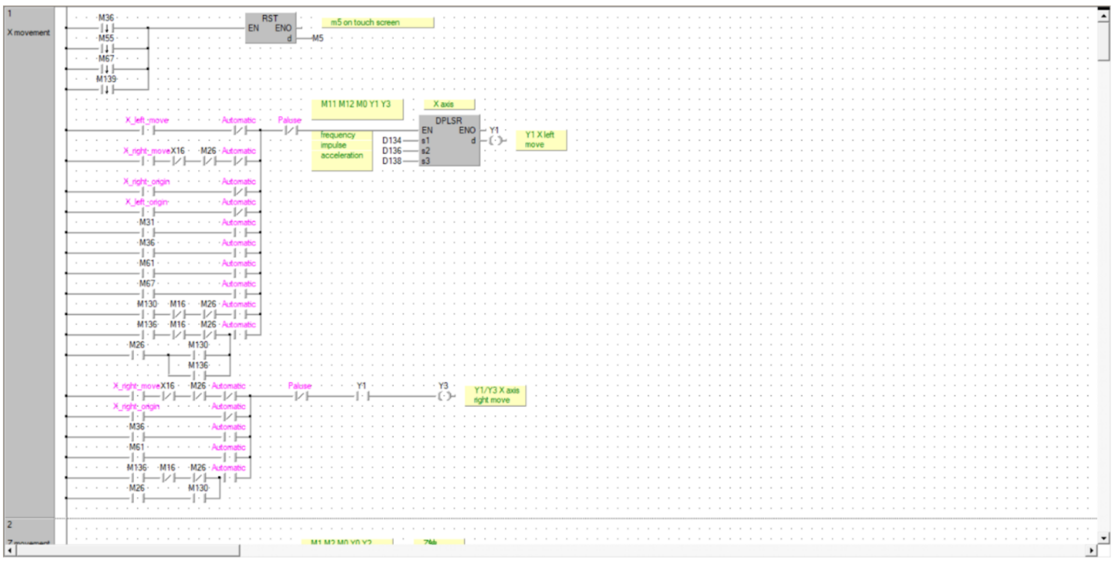


Image5(x axis movement)

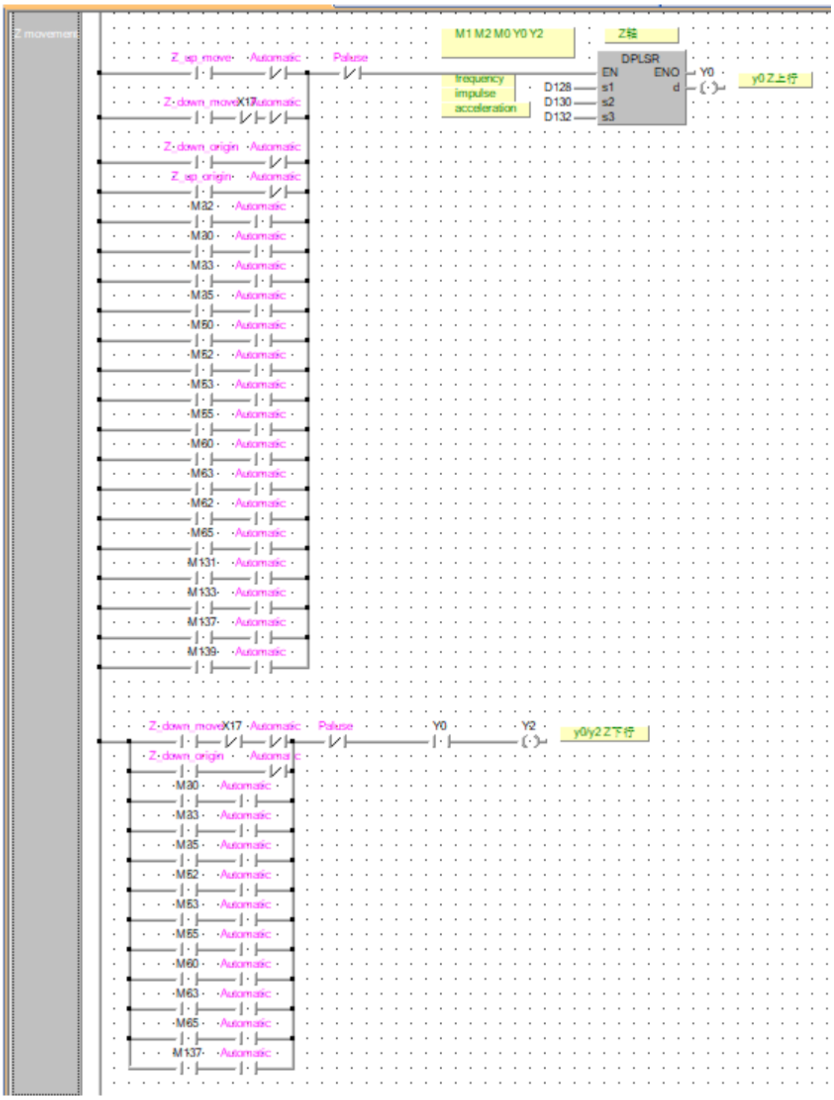


Image6(z axis movement)

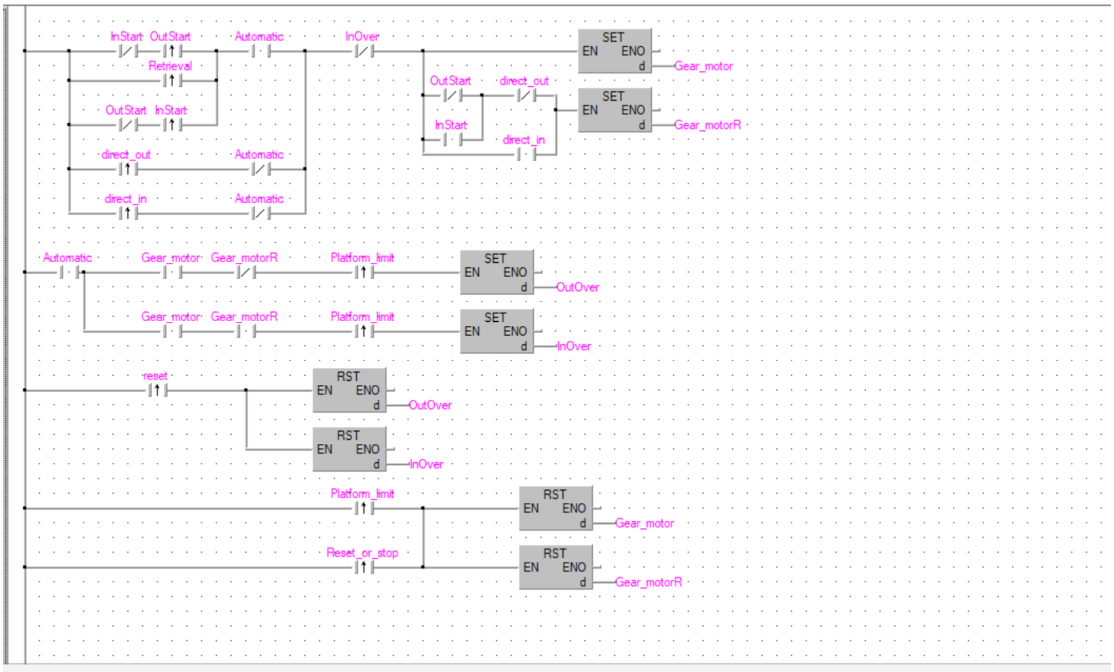


Image7(Block function2)

Critical problems solved

In the initial plan, we intended to employ a 3-axis motorized linear stage to elevate the platform, as outlined in the proposal. However, in practical implementation, we discovered that this structure not only proved to be unstable but also incurred higher costs, given its prevalent usage in industrial engineering. Following thorough research and discussions, we have opted for an alternative solution involving a threaded rod and motor to maneuver the platform, which is affixed to the framework.
The advantages of this revised design are manifold. Firstly, the control of movement is simplified; we can utilize the clockwise and counterclockwise rotation of the motor to manage the platform's upward and downward motion. Additionally, this modification results in a reduction in costs, making the overall structure more cost-effective and integrative. However, the integrated design scheme poses significant challenges in hardware design. We have to design the entire model, divide it into different parts for modeling and procurement, and then assemble it. During this process, inaccurate estimations of actual object sizes often lead to errors in the component dimensions, resulting in incomplete assembly or misalignment between components. Consequently, we have to redesign or modify the models to address these issues.

After determining the mechanism, another issue has arisen. Initially, we planned to utilize Raspberry Pi for controlling the 3-axis motorized linear stage in the proposal. However, our research indicates that employing coding languages on Raspberry Pi for motor system control can be excessively tedious and challenging.

Consequently, we have decided to opt for PLC (Programmable Logic Controllers), a more commonly used method in mechanism control.
PLCs offer several advantages in this context. They allow for the representation of circuit logic in a clearer manner through the use of ladder logic. Additionally, programming PLCs for motor control is generally more straightforward, making it a more accessible and efficient solution for our specific application. This shift in technology will contribute to a more streamlined and effective control system for our circuit.

The primary challenge we encountered was insufficient memory space to accommodate all nine parking platforms. Unfortunately, we overlooked this limitation when selecting the PLC, and it's now too late to rectify the issue. The PLC FX3SA-30MT, which we chose, offers only 4000 lines of memory space. Currently, we've utilized approximately 3700 lines for programming three platforms. While time constraints prevented us from addressing this problem immediately, we are committed to exploring solutions. Moving forward, we aim to reduce line usage and develop new algorithms that can effectively optimize memory usage.

Conclusion and future plan

In the final deliverable, we have successfully completed the programming for the automatic control of the top three parking platforms, enabling seamless management of parking and retrieval operations via touchscreen interface. Furthermore, we will demonstrate this functionality using a remote control car that attendees can operate. Upon parking their virtual vehicle, each participant will receive a unique password, which they can input to initiate the retrieval process. This simulation will provide the audience with a comprehensive overview of our parking solution's operation.

Our solution relies on advanced mechanical lift systems to vertically stack vehicles, effectively transforming conventional single-level parking lots into multi-tiered structures. This innovative design optimizes space utilization and significantly increases parking capacity without the need for ground expansion.

Looking ahead, we plan to upgrade the PLC with a more advanced version, allowing us to implement additional algorithms and enhance the functionality of the parking system. A key aspect of our future development involves integrating machine learning algorithms into the parking platform. By analyzing real-time parking data, the system will be able to autonomously determine the optimal platform for parking vehicles, thereby reducing overall parking process time. This innovative feature has the potential to significantly increase the market value of our design, offering a solution to the challenges of parking place shortages and long waiting times in real-world parking systems.

Reference

【1】 Margolies, J. (2023, March 7). Awash in asphalt, cities rethink their parking needs. The New York Times. https://www.nytimes.com/2023/03/07/business/fewer-parking-spots.html