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Design of the Automatic Control System for Restaurant Food Delivery Based On PLC

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Abstract: The paper designs an automatic control system for restaurant food delivery based on PLC, including the mechanical structure and automatic control system design. The mechanical structure of the system includes horizontal delivery subsystems and a vertical delivery subsystem. The automatic control system includes PLC control and the human-machine interface, which realizes the entire system's automation. At the end of the paper, we analyze the whole system's reliability and economy to reflect the characteristics and practicability of the automatic control system.

Keywords: Food delivery system; PLC control; human-machine interface; reliability

I. INTRODUCTION

There are already elevators and robots [1][2][3] to deliver dishes in restaurants. The dish delivery elevator system needs waiters to manually put dishes into the elevator and take them out in time, which requires many waiters. The dish delivery robots replace the traditional delivery. But the robot is not cost-effective, and its working time is limited because it needs batteries to provide power.

Driven by the above problems, we design a prototype system of the automatic restaurant food delivery, where there is an automatic control system to deliver dishes to the destination floors by distinguishing the dishes' color. The designed system solves the problem of delivering dishes to multi-floor and saves the workforce and time. Significantly, it improves the work efficiency of the restaurant and reduces the operating cost.

II. RELATED WORK

For this automatic control system, we designed and completed the whole system. Firstly, we designed its mechanical structure. Secondly, we completed the designation of the automatic control system, which mainly includes the hardware selection, circuit design, PLC programming, and human-machine interface design. Thirdly, we did many experiments to detect the whole system. Fourthly, we analyzed the reliability of the system.

III. MECHANICAL STRUCTURE DESIGN

Widely used in many disciplines [7]. For example, the

We take a two-floor restaurant as an example to design the system. The whole system structure is designed as Fig.1, which is divided into the following three parts:

1 First-floor horizontal delivery system:

① Placing area in the kitchen

② Testing area ③ waiting area

2 Second-floor horizontal delivery system:

④ waiting area

3 Vertical delivery system.

⑤ Elevator ⑥ tray ⑦ pull board

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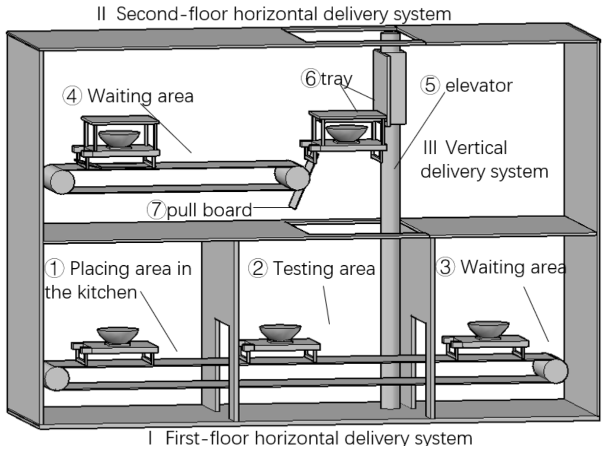

Fig.1. Mechanical structure

The automatic control system uses conveyor belts to deliver dishes horizontally, an elevator to deliver dishes vertically, and realizes actions of putting dishes into the elevator and taking them out through the design of trays and pull boards.

A. Design of trays

As shown in Fig. 2, structures of the elevator tray and dish tray simulate manual lifting action to ensure that dishes can be delivered to high floors smoothly.

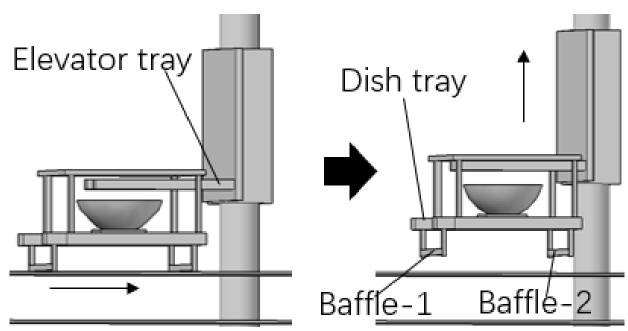

Fig.2. Design of trays

When a dish's color is recognized as white, the conveyor belt on the first floor stops and waits for the elevator descend to the designated position. Then, the conveyor belt on the first floor moves the dish to the elevator tray horizontally to the right. The vertical distance between the elevator tray and the dish tray is 1 cm to avoid friction and ensure the stability of the delivery process. When the dish is in place, the elevator rises 1cm. Its tray contacts the dish tray. Then the elevator tray pulls the top of the dish tray to rise steadily. With this method, the dish is automatically transferred from the conveyor belt to he elevator.

B. Design of pull boards

There are pull boards connected to the conveyor belt on the second floor. A pull board includes two parts: pull board-1 and pull board-2, which is shown in Fig. 3.

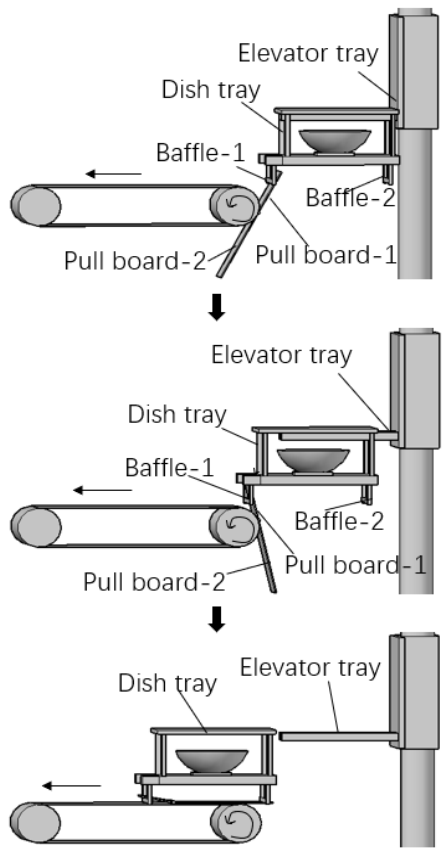

Fig.3. Design of pull board

After the elevator tray lifts the dish to the second floor, the conveyor belt on the second floor starts to move with pull boards. When the pull board-1 contacts the baffle-1 of the dish tray, the pull board-1 pulls the dish horizontally to the left. The conveyor belt supports the left end of the dish tray, while the right end is supported by the elevator tray to maintain the dish's stability. When the dish continues to move to the left, it is completely separated from the elevator tray. The pull board-2 supports it from the bottom of baffle-2 of the dish tray, which prevents the right end of the dish from losing support. With this method, the dish is automatically transferred from the elevator to the conveyor belt.

IV. MECHANICAL STRUCTURE DESIGN

The general framework of the automation control system is shown in Fig. 4. The automatic control system design includes PLC control and human-machine interface.

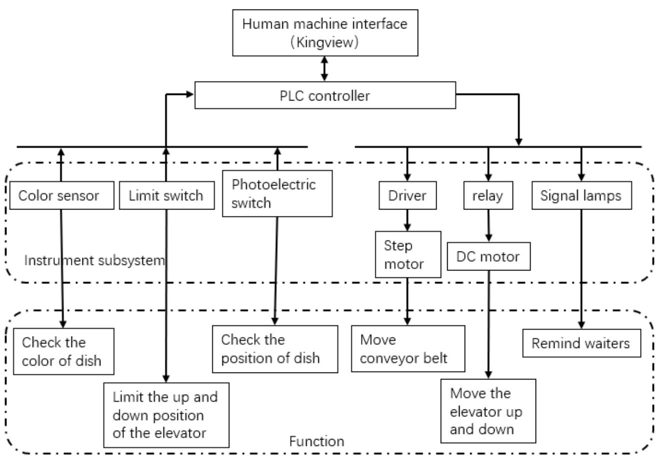

Fig.4. The general framework of automation control system

A. PLC control

The design of PLC control includes hardware selection and PLC programming.

1) Hardware selection

a) Photoelectric switches:

The photoelectric switches are used to detect whether a dish has reached the target area, and their specific installation positions are shown in Fig. 5. No. 1 switch detects whether a dish reaches the testing area. No. 2 switch detects whether the dish on the elevator tray is in place. When No. 3 and No. 6 switches detect a dish, the system will reduce the motor's rotation speed. When No. 3 and No. 7 switches detect a dish, the system will stop the rotation of the motor to prevent the dish from falling. The No. 5 switch detects whether the dish has been completely separated from the elevator tray.

The photoelectric switch has fast response speeds and can perform 5000 detections per second. Therefore, when an object is moving at a high speed, it can also be accurately sensed to achieve other controls [4]. In addition, the photoelectric switch has excellent hysteresis characteristics. Once an object is detected, it can maintain a stable output even if a small vibration occurs. In practical applications, it can maintain stable and precise control to prevent exceeding the limit or mechanical failure.

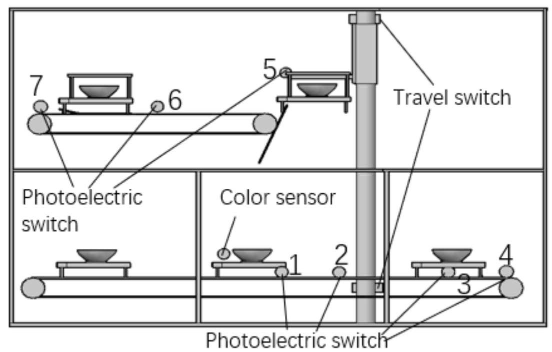

Fig.5. Sensor installation location diagram

a) Color sensor

The automatic control system selects a color sensor of the red light source to detect the dish's color. Dishes of different colors are delivered to different floors. Its installation position is shown in Fig. 5.

The color sensor can detect color from the absorption of light sources, the degree of reflection, and different surrounding materials. Then it generates different pulse signals. It belongs to one of the better diffuse reflection photoelectric switches. Color sensors are divided into many types according to different detection light sources, and their performances are different [5][6]. Among them, the color sensor with a green light source is sensitive to detect small color changes. The color sensor with a red light source can make different corresponding to different colors, and the detection distance is long. Therefore, the control system uses the color sensor with a red light source.

At present, we use the color sensor to identify the color of dishes. In future research, we will use the camera and image processing to identify the color. The details is introduced in section **Error! Reference source not found.**.

b) Motor

On each floor there is a step motor to drive a conveyor belt. The step motor's speed and rotation direction are controlled by changing the frequency and number of the pulse signal. It is an open-loop control motor without angle accumulation, because it directly controls the rotation of the motor through pulses without feedback [8][8][9]. So, the control for the motor is accurate and straightforward, and the error is small. The following is the motor's working principle. Firstly, the controller sends pulses to the driver. Secondly, the driver adjusts and distributes pulses to determine the magnitude of the current for each phase. Simultaneously, when there is a pulse signal coming, the motor can rotate some set angles under the cooperation of rotors and stators.

TABLE I. I/O PORTS ASSIGNMENT

Inputs	***Notes***	***Outputs***	***Notes***
X0	Color sensor	Y0	Pulse output for step motor 1
X1	Sensor of testing area on the first floor	Y1	Pulse output for step motor 2
X2	Sensor of deceleration area on the first floor	Y2	Direction control of step motor 1
X3	Sensor of terminal area on the first floor	Y3	Direction control of step motor 2
X4	Sensor of deceleration area on the second floor	Y4	Warning light in first floor
X5	Sensor of terminal area on the second floor	Y5	Stopping light in first floor
X6	Limit switch on the first floor	Y6	Warning light on the second floor
X7	Limit switch on the second floor	Y7	Stopping light on the first floor
X10	Sensor to test whether the dishes are in place	Y10	Control DC motor positive rotation
X11	Sensor to test pull boards	Y11	Control DC motor negative rotation
X12	RUN		
X13	STOP		
X14	RESET		

The elevator adopts DC motor and relays. The relay is directly connected with the controller. The controller controls the relay coil to be on or off, which can control the action of contact. Then the direction of the voltage is changed to drive the motor to rotate in a different direction. Primarily, we adopt an interlocking part in the circuit to prevent short circuits caused by the incomplete disappearance of the armature's magnetic effect.

2) Designation of PLC programming:

The controller uses Mitsubishi FX1S PLC, the programming software uses GX Developer V8, and it supports STL step ladder instructions.

We will introduce design of PLC programming from I/O ports assignment and automatic control program design.

a) I/O ports assignment of PLC

Take a two-floor restaurant system as an example, TABLE 1 is the PLC input and output distribution.

Step motor 1 controls the rotation of the conveyor belt of the first floor, and step motor 2 controls the rotation of the conveyor belt of the second floor.

b) Automatic control program designation

The whole system's program includes the following five parts: initial program, program to test dish's color, program to move the elevator up and down, program to decelerate or stop conveyor belt on each floor. Fig. 6 is a program flow chart.

Take a two-floor restaurant system as an example. White dishes are sent to the second floor, and black dishes are sent to the first floor.

We press the reset button, and the control system determines the position of the elevator. If the elevator is not in the upper limit position, it will first rise to the upper limit position and then wait for the start.

When the first-floor horizontal delivery system starts, the conveyor belt moves horizontally to the right. When a dish is detected in the testing area, there are two situations:

- Dish's color is white. Firstly the conveyor belt on the first floor will stop. Secondly, the elevator drops to the lower limit. Thirdly, the conveyor belt starts to send the dish to the elevator tray. Fourthly, the elevator begins to rise; at the same time, in order to prevent mechanical collisions, the second-floor horizontal system starts to control the pull board. Finally, the conveyor belt on the second floor pulls dishes to the left smoothly. During the ascent of the elevator, the sensor keeps testing whether there is a white dish. Once detected, the conveyor belt on the first floor will stop and wait for the elevator to transfer the next white dish. If there is a black dish or no dish, the conveyor belt on the first floor will continue moving until a white dish arrives at the testing area.

- Dish's color is black. When it is detected that the dish is black, the conveyor belt on the first floor continues to move. When there is a white dish on the testing area, the conveyor belt on the first floor will stop and waits for the elevator to descend.

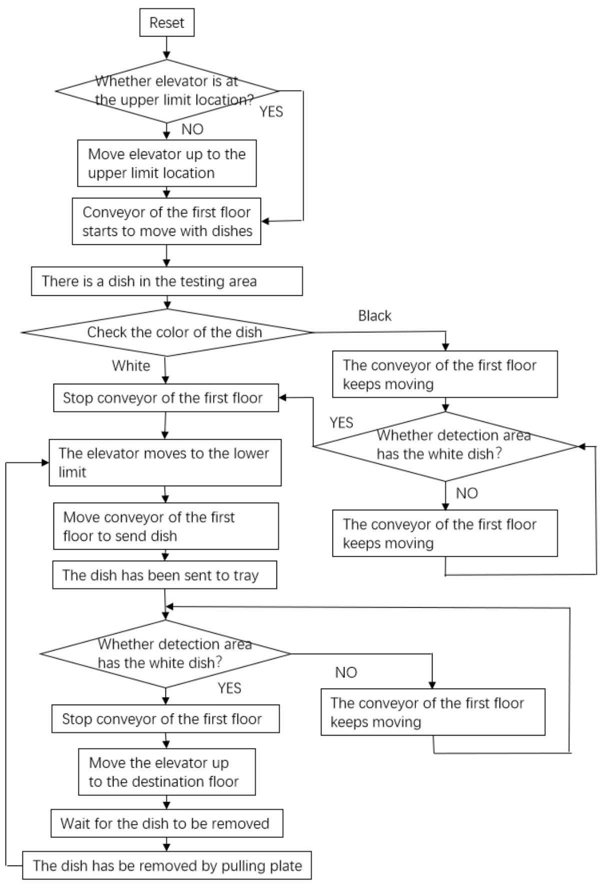

Fig.6. Program flow chart.

B. Human-machine interface design

The human-machine interface is designed with King view software. Communication between PLC and King view adopts an optional programming port, which is convenient for operation and maintenance. It can realize the supervision and control of the system through the human-machine interface. It can also record and display each floor's number of dishes waiting to be taken away. Waiters can click on the dish in the picture to respond to the system at the waiting area, and then pick up the dish.

Fig.7. shows the human-machine interface. It includes the first-floor and second-floor delivery systems. It also shows the number of dishes. Each square represents a dish. It achieves supervision through a series of command languages, animation connections, and communication with PLC. We need to define the types of variables, connection devices, register types, data types, and read-write attributes in the data dictionary. In addition, when the acquisition frequency of two variables is set to the same parameter, KingView can only acquire one signal, so we should set the different I/O variable acquisition frequency. And we need auxiliary relays to stop and start the system remotely through Kingview because X of PLC can only be triggered by an external voltage.

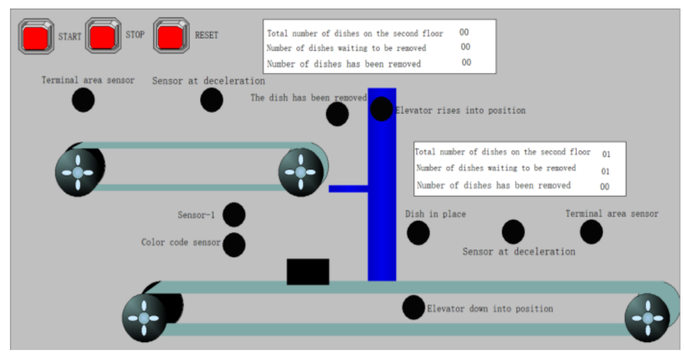

Fig.7. Human-machine interface design

V. RELIABILITY ANALYSIS

Based on the actual operating conditions and the control program designation, we analyze the system reliability on a few possible failure modes:

- When we press the reset button, the system is initialized. No matter where the elevator is, it will keep rising until it reaches the upper limit to avoid mechanical collision and damage equipment.
- When the power is cut off, the control system will immediately stop. The PLC will maintain the state of the status register after S500. Combining with the STL instruction, it automatically enters the state before the power off. The control system will continue to run after the power is turned on.
- When the elevator is dragging a dish up, the conveyor belt on the second floor may be transporting the dish. If a pull board passes the

right end of the conveyor system on the second floor, it will mechanically collide with the dish on the elevator. To avoid malfunction, we install a photoelectric switch at the bottom of the conveyor belt on the second floor. When the elevator rises and the photoelectric switch detects a pull board, the conveyor belt on the second floor will stop and wait for the elevator to reach the upper limit. Then the conveyor belt starts moving again.

- If waiters fail to remove the dish in time, the photoelectric switch on the terminal area will sense the dish and send signals to PLC. Then the PLC controls the motor to stop in time and reminds waiters through the signal light.

Through the above reliability analysis, it can be concluded that the program design and the cooperation of various components can effectively avoid the occurrence of failures. So our automatic control system has high reliability and strong stability.

VI. CONCLUSION

The restaurant food delivery system includes the mechanical subsystem and automatic control subsystem. The mechanical subsystem imitates the action of manually holding up dishes. The automatic control subsystem realizes the automatic recognition of the color of dishes through PLC control. It delivers dishes smoothly to each destination floor. The human-machine interface monitors the whole process of transferring dishes and displays the number of dishes waiting to be taken away in time.

The whole delivery process from the kitchen to the waiting area no longer requires manual participation. This improves work efficiency and reduces the operating costs. And the reliability analysis shows that the system is of high reliability

VII. FUTURE WORK

A. Deliver the empty dishes

Although the system has realized the automatic delivery of the food dishes, we didn't discuss the delivery of the empty dishes. In the future, we may improve the system to solve the problem so that the automation level of the restaurant can be increased and the workload can be reduced further.

B. Distinguish the dish color by image processing

We have selected the color sensors to distinguish the dish colors. In future research, we may use the camera to replace the color sensor [13]. The camera can catch both the dish colors and shapes. Then the system can analyze both the dish colors and shapes by image processing. In this way, the system will get more information about the dishes. Furthermore, the system may distinguish the different food in different dishes by image recognition, and so on. Anyway, distinguishing the dishes by image processing and image recognition will make the system more intelligent and more powerful.

ired to find specific odor molecules, and also save a lot of post-user experience investigations. At the same time, it may be possible to identify the specific odor in the future. Molecules in the odor. In the following research, the odor types and odor chemical structure attributes of the sample data set will be further increased, and the algorithm model will be optimized to make the model more rigorous and more accurate.

REFERENCES

[1] C. Junjie, W. Yifei, X. Hangyu, and Z. Wei. Design and Implementation of Control System for a Restaurant Service Robot. Computer Measurement & Control, 2017, pp.77-80.

[2] Deng B, Li S, Zhang B, Wang F, Li D, Lin H. IoT intelligent restaurant system design. In Proceedings of the 3rd International Conference on Computer Science and Application Engineering, 2019, pp. 1-7.

[3] G. Min, C. Tian, Y. Zhang, and Q. Wen. Research on the Design of Automatic Food-Passing Machine with Single Rail Hanging. Journal of Pingxiang University, 2017, pp. 109–112.

[4] H. Nakashima and K. Komai. Photoelectric sensor: U.S. Patent 10,338,087[P], 2019.

[5] A. Soetedjo, M I. Ashari and C. Ardiles. Development Of Industrial Control Training Module Using Distance and Color Sensors for Detecting Objects[J]. IJEM (International Journal Of Engineering And Management), 2017, pp. 1-8.

[6] Caramida, M. S. Automatic Sorting System. Journal of Electrical Engineering, Electronics, Control and Computer Science, 2017, pp. 5-10.

[7] Di. Jingyan. Stepping motor's control based on PLC to write and program [J]. Electronic world, 2016.

[8] C. Yujie, X. Changjie, F.Haimei, S. Xin, L. Jie, D. Chang and W. Junhong. One Kind of Control Method Based on PLC of Stepper Motor[C]. Information Engineering Research Institute, USA. Proceedings of 2015 2nd International Conference on Civil, Materials and Environmental Sciences (CMES 2015). Information Engineering Research Institute, 2015,pp. 438-441.

[9] B.L. Oladapo, V.A. Balogun, A.O. Adeoye, C.O. Ijagbemi, A.S. Oluwole, I.A. Daniyan, & A.P. Simeon. Model design and simulation of automatic sorting machine using proximity sensor. Engineering science and technology, an international journal, 2016, pp.1452-1456

[10] C. Lepeng, Z. Xiaoxiong and Y. Qianyue. Application Research of PLC Technology in Electrical Engineering Automation Control. Research in Science and Engineering, 2019, pp. 81-83.

[11] Ö. Şengül, S. Öztürk & M. Kuncan. Color Based Object Separation in Conveyor Belt Using PLC. Avrupa Bilim ve Teknoloji Dergisi, 2020, pp. 401-412.

[12] H. Mokjun. Image Processing and PLC Based Conveyor Belt System For Industrial Automation and Control[J]. Universiti Teknikal Malaysia Melaka.2013

[13] P. Thirumurugan., R. Aravind, M. Kumar, S.D. Manjunath, & R. Kalaiselvan. Automatic Sorting in Process Industries using PLC. GRD Journals- Global Research and Development Journal for Engineering, 2018, pp. 8–13.