

Research on "Robot+" Campus Intelligent Logistics Simulation Based on PQFactory Platform

Conghao Ruan, Wei Su

School of Information and Control Engineering, Jilin Institute of Chemical Technology, Jilin, Jilin, 132000, China

Abstract: With the intelligent transformation of campus logistics, the PQFactory platform, as an integrated and intelligent virtual simulation system, has shown great potential in improving research and development efficiency and product quality. This article is based on the PQFactory platform and conducts simulation research on intelligent delivery of campus express. Firstly, the scene layout and process flow of the campus express station are designed based on the PQFactory platform. Then, according to the workflow of the simulation workstation, process signals and robot variables are configured. At the same time, the robot running program is designed. Finally, the simulation workstation is integrated and debugged with the PLC program. The accuracy and reliability of intelligent campus express delivery have been verified through simulation, providing new exploration and reference for the application of "Robot+" technology in the field of campus smart logistics.

Keywords: PQFactory Platform; Robot+; Campus Smart Logistics; Simulation Study.

1. Introduction

In the context of the rapid development of modern information society, smart logistics, as an important product combining intelligence and modern logistics technology, is widely applied worldwide. Especially on university campuses, with the continuous increase in the number of students, logistics needs have become increasingly complex and diverse. Traditional manual operations are no longer able to meet the requirements of efficient, accurate, and low-cost logistics management. Therefore, smart logistics based on intelligent equipment and information technology has gradually become an important means to solve these problems. As a typical representative of intelligent equipment, the "Robot+" application has significant advantages in ensuring personal safety, improving the working environment, reducing labor intensity, and increasing labor productivity [1]. The PQFactory platform, as a comprehensive platform based on digital simulation technology, combines virtual simulation and the synergistic effect of actual hardware devices, and has been widely used in the fields of intelligent manufacturing and automation.

The current research on campus smart logistics mainly includes data and services provided by Fu Liqin and others [2] based on the smart campus cloud platform, which have improved the intelligent express cabinet system and strengthened its intelligence level and personalized service functions. Fang Lun and others [3] explored a campus express smart service solution of "1 smart service center platform+ N sets of smart express cabinets", building an optimized model of smart service platform, interconnection, and express delivery process. Huang Hao and others [4] designed an intelligent unmanned vehicle for campus express delivery to address issues such as accumulation and long pickup times. Zhang Liguo and others [5] developed a robotic arm with machine vision, an unmanned campus express system that uses machine vision to identify parcels, automatically disinfection and sterilization, and GPS navigation to deliver them to designated locations on campus.

Although the above research has optimized campus express delivery services to a certain extent, it cannot be widely

promoted and applied. This study aims to conduct simulation research on "Robot+" campus intelligent logistics through the PQFactory platform, explore how to optimize various aspects of campus logistics distribution through intelligent robot systems, propose specific improvement measures, and verify their feasibility and application prospects through simulation. Through this research, it is expected to provide an efficient, intelligent, and sustainable solution for future campus logistics management, promoting the modernization and intelligent development of campus logistics.

2. Overall Architecture Design of Campus Smart Logistics System

2.1. Scene Layout Design

The overall framework design of the campus intelligent logistics system is the foundation for achieving efficient operation of the system. The overall process framework of campus smart logistics designed in this article is shown in Figure 1. Firstly, the delivery information is inputted or entered into the human-machine interface of the smart terminal. Then, the robot will move to the designated location and compare the accuracy of the information through visual inspection to determine whether to drag the delivery or output incorrect information.

A scenario layout based on PQFactory platform was designed according to the overall process framework of campus smart logistics, as shown in Figure 2. It mainly includes robots equipped with 3D vision, automated stereoscopic warehouses, intelligent express delivery terminals, roller conveyor lines, AGV carts, lifting cylinders, safety fences, and indicator lights. Robots with vision have high flexibility and precision, which can ensure the accuracy and efficiency of handling tasks, while recognizing the accuracy of express information. Automated three-dimensional warehouses can improve the storage capacity and space utilization of express delivery, effectively saving costs; The intelligent delivery terminal ensures intelligent interaction between humans and machines, making it convenient for timely delivery and pickup of parcels; Other institutions ensure the smoothness and security of express

delivery transmission [6-7].

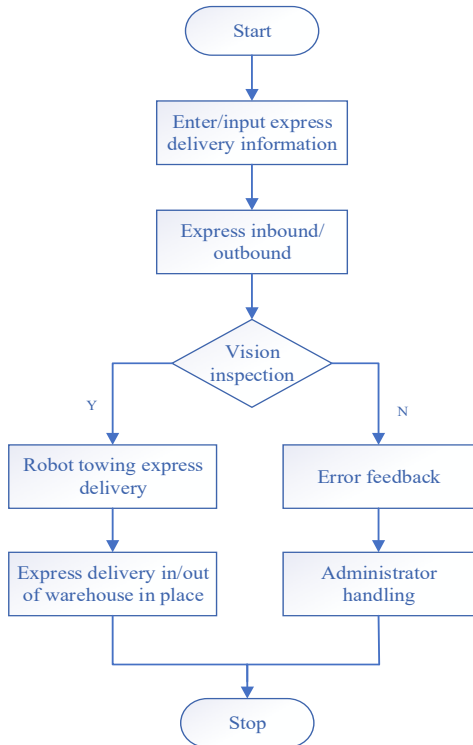


Fig 1. Overall process framework of campus smart logistics

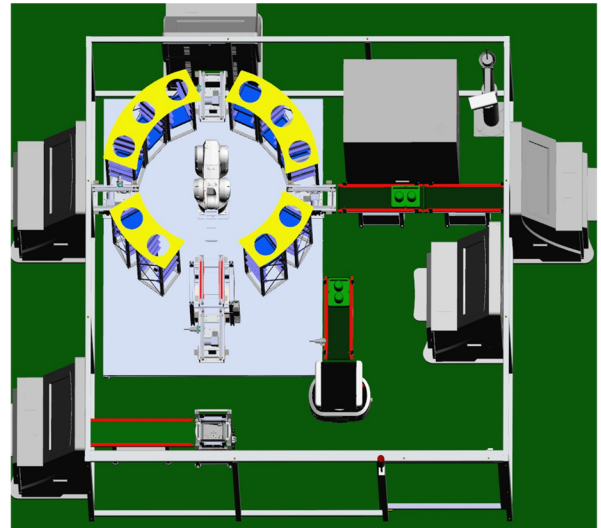
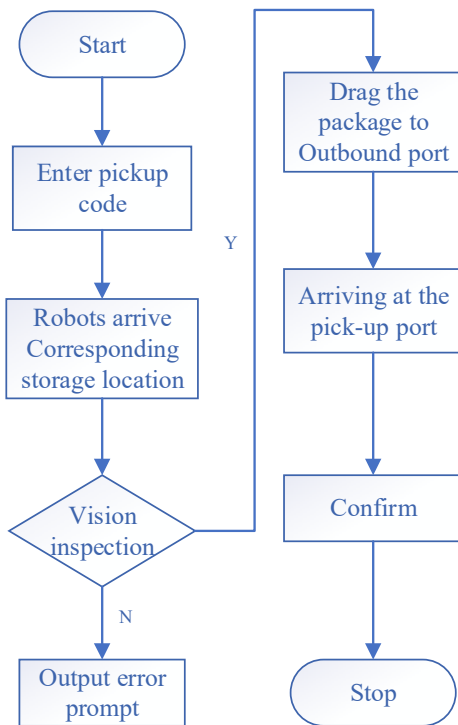


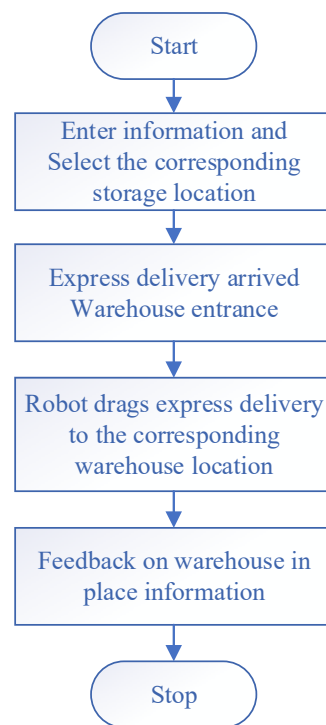
Fig 2. Campus smart logistics scene layout

2.2. Process Design

After the overall framework and scene layout design of the campus intelligent logistics system were completed, the express delivery inbound and outbound process flow as shown in Figure 3 was determined. When picking up the package, the intelligent service terminal inputs the pickup code or



(a) Express pickup process



(b) Express warehousing process

Fig 3. Campus smart logistics process flow

facial recognition to confirm the identity information. Then, the robot arrives at the corresponding storage location, and the visual detection unit will further confirm whether the package is accurate through the barcode on the package box. If the information does not match, the system will pop up an error message and contact the administrator. If the information matches, the package will be dragged to the outbound port, and it will be transported through the lifting

cylinder, AGV car, and conveyor belt to the pickup port. Finally, after confirmation by the recipient, photos will be taken for retention. After the package is taken out, the entire pickup process ends. When the package is received into the warehouse, the courier scans and enters the package information into the system, selects the corresponding storage location, and then places the package on the conveyor belt. It is transported by AGV car and lifting cylinder to the storage

port. The robot will then drag the package to the corresponding storage location. After the sensor sends out the package's arrival information, the robot returns to its initial position, and the entire storage process ends.

3. Design of Campus Smart Logistics Simulation Workstation System

3.1. Workflow of Simulation Workstation

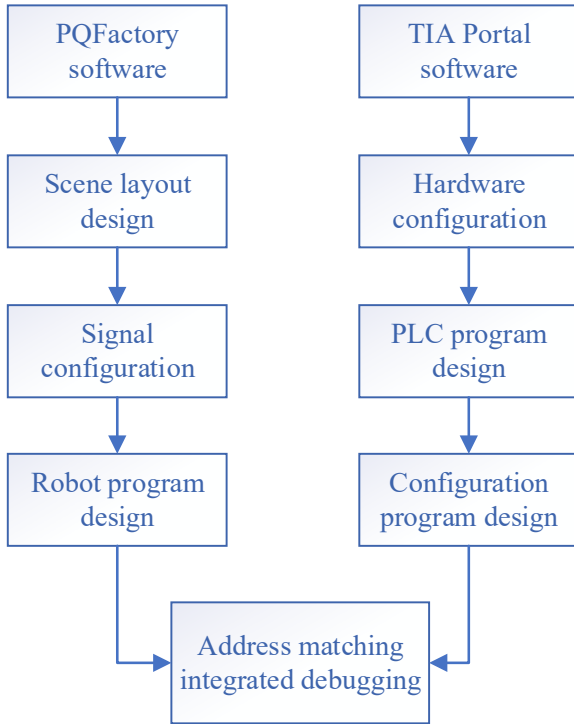


Fig 4. Workflow diagram of simulation workstation

The campus intelligent logistics system mainly consists of PQFactory software and PLC. The task allocation is shown in Figure 4. The PQFactory platform is responsible for building smart logistics scenarios and designing corresponding robot programs, while the PLC platform uses Botu software for the design and development of PLC and configuration programs. Through address matching, connect the virtual signal of PQFactory with the actual signal of PLC, and achieve overall debugging of the campus intelligent logistics unit according to the task list [8].

3.2. Simulation Workstation Signal Configuration

Signal configuration is one of the important steps in PQFactory virtual debugging, which aims to ensure that the addresses in the virtual software match the addresses defined in the PLC program. Through signal configuration, a mapping relationship can be established between the two, enabling virtual software to correctly receive PLC instructions and make corresponding simulated responses. In the signal configuration process, the names, data types, and initial values of internal variables can be flexibly set according to actual needs to adapt to different application scenarios. This article presents the names, addresses, and signal types of some signals in the simulation workstation, as shown in Table 1.

Table 1. Signal configuration table of simulation workstation

Name	PLC address	Type	PLC equipment name	Internal variables	Category
Lift cylinder	M20.0	Bool	WL02	M200	External signal
Cylinder down	M20.1	Bool	WL02	M201	External signal
Cylinder up	M20.2	Bool	WL02	M202	External signal
Tray turntable 1	M21.0	Bool	WL02	M210	External signal
90 degrees	M21.1	Bool	WL02	M211	External signal
0 degrees	M21.2	Bool	WL02	M212	External signal
Start 1	M1.0	Bool	WL02	QD1	External signal
Complete 1	M1.1	Bool	WL02	WC1	External signal
Start 2	M2.0	Bool	WL02	QD2	External signal
Complete 2	M2.1	Bool	WL02	WC2	External signal
Sensor1	M30.0	Bool	WL02	M300	External signal
Signal 0	0	Bool	WL02	M1	Internal signal
Signal 1	1	Bool	WL02	M2	Internal signal
Signal 2	2	Bool	WL02	M3	Internal signal
Signal 3	3	Bool	WL02	M4	Internal signal
Signal 4	4	Bool	WL02	M5	Internal signal
Signal 5	5	Bool	WL02	M6	Internal signal
Signal 6	6	Bool	WL02	M7	Internal signal
Signal 7	7	Bool	WL02	M8	Internalsignal

3.3. Simulation Workstation Robot Variable Setting

In the campus intelligent logistics simulation workstation, robot variables are used to represent parameters such as the robot's position, speed, acceleration, and working status. The setting of these variables is crucial to ensure that the robot

executes its predetermined tasks. When setting these variables, first determine their type (such as integers, floating-point numbers, Boolean values, etc.) and purpose (such as position, velocity, state, etc.), then choose clear and easy to understand names for the variables, and finally declare and initialize them according to the syntax rules of the programming language. During program runtime, variable assignment can be

achieved in various ways, such as direct assignment, function or return value assignment, and user input assignment [9]. This article demonstrates the setting of robot variables,

covering the entire process of express delivery and pickup, with some names and types shown in Table 2.

Table 2. Simulation workstation robot variable setting table

Variable name	Variable type	Address	Variable Declaration
QD1	DI	0	Start signal 1
QD2	DI	0	Start signal 2
WC1	DO	0	Complete signal 1
WC2	DO	0	Complete signal 2
M200	DO	0	Cylinder lifting signal
M201	DI	0	Cylinder down to position signal
M202	DI	0	Cylinder up to position signal
M210	DO	0	Tray turntable 1
M211	DI	0	Tray turntable 1 (0 degrees)
M212	DI	0	Tray turntable 1 (90 degrees)
M1	DO	0	Outbound waiting signal
M3	DO	0	Capture signal
M4	DI	0	Waiting signal
M5	DO	0	Outbound arrival signal
M6	DO	0	Storage waiting signal
M8	DI	0	Waiting signal

4. Simulation and Debugging of Campus Intelligent Logistics Workstation

4.1. Robot Programming

According to the campus intelligent logistics express delivery process, the robot's operating trajectory and corresponding robot operating program have been designed. When the express delivery enters the warehouse, the robot starts the servo axis after receiving the start signal. The robot then goes to the entrance of the automated warehouse to drag the incoming express delivery to the corresponding warehouse. After the system receives the signal of arrival, the robot returns to its initial position and waits for the next signal. When the express delivery is sent out of the warehouse, the robot first runs to the front of the corresponding warehouse after receiving the start signal. After confirming the correctness through machine vision, it drags the express delivery to the exit of the automated warehouse and then returns to the initial position. The main robot programs are as follows:

```

PROC main()
  WAITDI QD1,1;
  RaMainGroup;
  WAITDI QD2,1;
  RaMainGroup1;
  ENDPROC
PROC RaMainGroup()
  ConfL\on;
  ConfT\on;
  SET M3;
  WAITDI M4,1;
  SET M5;
  SET M20;
  WAITDI M21,1;
  RESET M5;
  SET M6;
  SET M1;
  WAITDI M8,1;

```

4.2. PLC Program Design

The PLC selected in this article is the 1214DC/DC from the Siemens S7-1200 series, which is widely used in industrial production due to its small size, fast speed, powerful network communication function, and high reliability. The PLC can immediately send signals to the PQFactory software upon receiving system instructions, and the sensors in the software quickly respond to the signals and immediately provide confirmation information to the PLC. Taking the express delivery warehousing process as an example, first press the start button, and the PLC will immediately transmit the signal to the PQFactory software. At the same time, the indicator light will flash at a frequency of 1 Hz. After the warehousing is completed, the sensor built into the PQFactory software will immediately transmit the completion signal back to the PLC. The indicator light will stop flashing and remain on, and the warehousing process will end [10]. As shown in Figure 5, it is a partial PLC ladder diagram of the campus intelligent logistics simulation workstation in this article.

4.3. Integrated Debugging

The joint debugging of PQFactory and PLC is one of the core technologies in campus intelligent logistics systems, which combines virtual simulation and real-time communication technology to comprehensively simulate and optimize production lines. This technology effectively shortens project development time, improves engineering quality, and reduces costs, while significantly reducing risks in actual debugging. This article implements the physical connection between PQFactory and actual PLC through KingIOServer engineering designer, and imports the variables set in PQFactory into KingIOServer, while keeping the PLC address in the software consistent with the local PLC address. In order to meet the design requirements of the express delivery process described in this article, during joint debugging, relevant information is first inputted into the intelligent terminal, and a connection is established between the PLC and PQFactory. Then, the docking positions of the robot, automated warehouse, conveyor belt, AGV car, and lifting cylinder on the simulation workstation are confirmed to ensure that the express delivery can accurately reach the

designated position. Finally, at the end of the simulation, the end signal will be transmitted to the PLC. Figure 6 shows the human-computer interaction interface of the virtual simulation workstation, where users can manually select the

warehouse and warehouse locations for express delivery, and customize buttons as needed to observe the current status of the system.

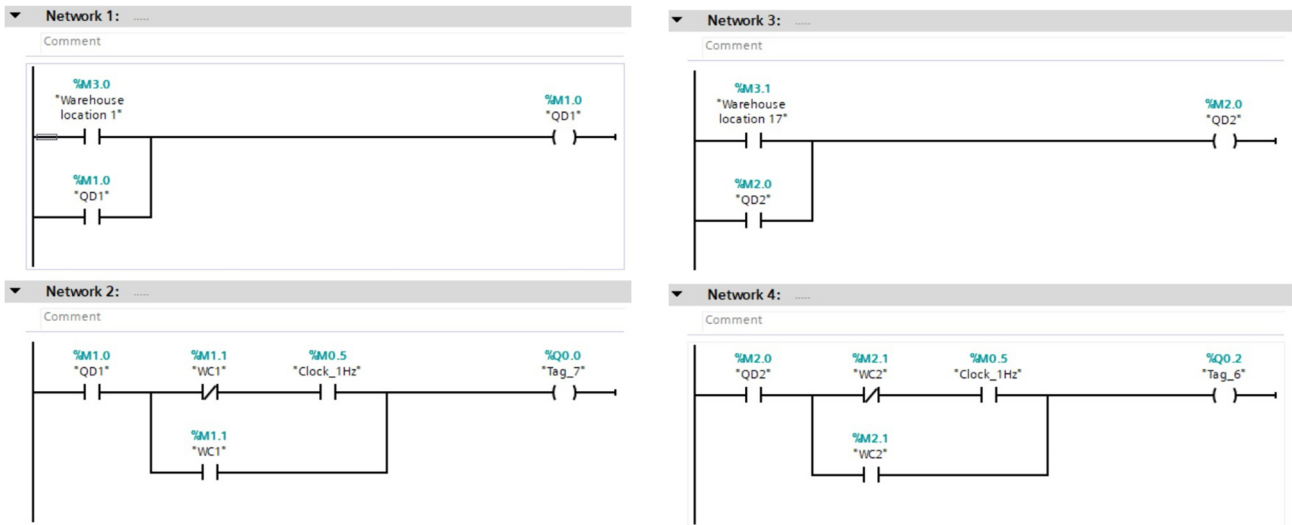


Fig 5. PLC ladder diagram of campus intelligent logistics

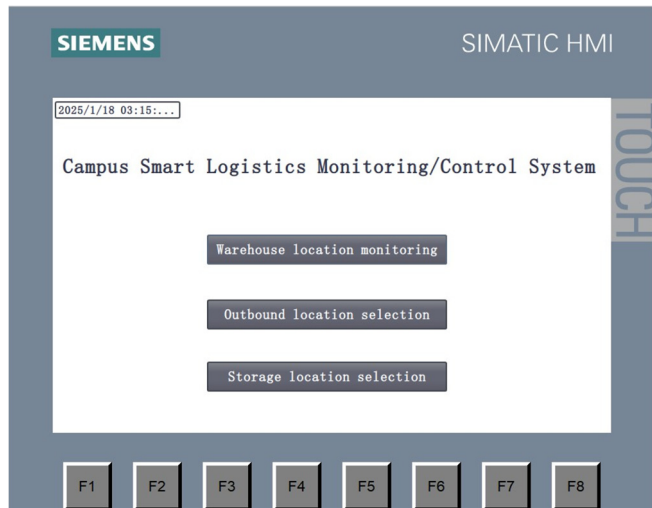


Fig 6. HMI interface of simulation workstation

5. Conclusion

This article explores the application and development prospects of smart logistics technology in campus environments by studying the "Robot+" campus intelligent logistics simulation system based on the PQFactory platform. By combining the advantages of PQFactory platform and PLC system, seamless integration between virtual simulation and actual operation has been successfully achieved, demonstrating the potential of robots in campus intelligent logistics. This article elaborates on key technical aspects such as system architecture, signal configuration, and robot variable settings, highlighting the core role of signal configuration and robot program design in achieving task automation.

With the continuous advancement of technology, the application of robots in campus logistics will be further deepened. Through the introduction of virtual simulation technology, the operability, debuggability, and flexibility of the system can be effectively improved, laying the foundation for the popularization of intelligent logistics. In the future, with the further integration of hardware facilities and artificial

intelligence technology, the "Robot+" intelligent logistics simulation system based on the PQFactory platform will usher in a wider range of application scenarios and continuously promote the intelligent and automated process of campus logistics management.

References

- [1] Chen Yan. Research on the design and control of loading and unloading robots for CNC machine tool groups [D]. Jiangsu University, 2013.
- [2] Fu Liqin, Hou Jiali. Design of campus smart logistics platform [J]. Internet of Things Technology, 2021, 11 (04): 81-83+88.
- [3] Fang Lun, Chen Kunjie, Li Lingxiao, et al. Exploration of college students' innovation and entrepreneurship based on campus express smart logistics [J]. Engineering Technology Research, 2020,5 (16): 224-228.
- [4] Huang Hao, Wei Siyang, Han Caixia. Design of campus express intelligent unmanned vehicle delivery system [J]. Microcomputer Application, 2024, 40 (11): 27-31.
- [5] Zhang Liguang, Gao Haikuo, Li Jie, et al. Design and implementation of campus express delivery system with visual robot arm [J]. Information Recording Materials, 2024, 25 (02): 168-170.
- [6] Lv Liqiang, Yang Shuangxing. Application of robot technology in intelligent logistics material sorting [J]. Logistics Engineering and Management, 2023, 45 (10): 1-3.
- [7] Zhao Yantong. Research on the collaborative development of robot industry and smart logistics - review of "smart logistics and smart supply chain" [J]. Business Economics Research, 2022, (07):2.
- [8] Yan Xiaoyong. Application of IOT based PQFactory simulation and siemens S7-1200 PLC digital twin integration [J]. Electronic Manufacturing, 2024, 32 (12): 107-109.
- [9] Xiao Han, Meng Wen, Mao Yuhua. Simulation study on intelligent manufacturing unit for wheel grinding based on PQFactory platform [J]. Electronic Manufacturing, 2024, 32 (20): 85-88+46.
- [10] Jiang Hao, Zhang Yifan, Wei Changzhou. Research on digital twin integration technology of torch shell polishing equipment based on PQFactory platform [J]. Mechanical Management Development, 2023, 38 (9): 237-241.