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Research on the Design and Application of Virtual and Real Integrated Training Platform Based on Intelligent Manufacturing

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Abstract: In this paper, we built a robot training platform using virtual simulation software, and the robot assembly, handling, and palletizing were realized. The workstation includes an industrial robot, gas control unit, track function module, assembly function module, palletizing function module, vision module, etc., and robot movement is achieved through language programming. The platform provides conditions for the practical ability training of application-oriented talents.

Keywords: Intelligent manufacturing; Training platform; Virtual simulation

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1. Overview

"Made in China 2025" defines the strategic goal of building a "manufacturing power," the state and government have also issued a series of manufacturing development planning documents, which reflect the characteristics of intelligent development of the manufacturing industry. Robot development has become an important force in the world's economic and industrial development [1]. The Manufacturing Talent Development Planning Guide, jointly issued by the Ministry of Education, the Ministry of Human Resources and Social Security, the Ministry of Industry and Information Technology, and other departments, predicts that by 2025, China will need 9 million talents in industrial robot-related fields, and the talent gap will reach 4.5 million. Consequently, the manufacturing industry will move towards a more information-based, intelligent, and networked development direction. The "14th Five-Year Plan" Robot Industry Development Plan jointly issued by the Ministry of Industry and Information Technology and other departments in 2021 has outlined China's high-end robot technology gathering place in advance [2,3]. The use and development of industrial robots have been increasingly highlighted [4]. However, there are relatively few theoretical knowledge abstractions, comprehensive practical training, and practical teaching platforms in the education and teaching of industrial robots in China's colleges and universities, and students have limited practical operation opportunities and learning materials [5]. Although some colleges and universities offer courses on industrial robot programming, these courses lack multidisciplinary integration and fail to demonstrate the intelligent manufacturing production process, which is not conducive to the training of applied talents.

Researchers have designed and applied research on practical training platforms in this context, and some schools use RobotStudio virtual simulation software to build workbenches [6-9]. However, these efforts often lack corresponding physical objects. Some schools have also built industrial robot training platforms to facilitate teaching but have not incorporated virtual simulation. Chen *et al.* [11] divided the training platform into mechanical, electrical, control, and other basic hardware modules based on modular division and redesigned the upper computer accordingly. However, this platform design focuses mainly on physical objects and lacks a virtual training component. Zhang *et al.* [12] studied the combination of smart robotic arms and digital twins, but the virtual simulation training platform built only included the robot arm, which was weak in the coverage of multidisciplinary and comprehensive practical training projects. Liu *et al.* [13] explored integrating various units such as robot assembly stations, feeding stations, processing stations, and logistics and storage stations into a comprehensive intelligent manufacturing experiment platform. Yang *et al.* [14] built a robot named NAO, which can realize the interactive practical training of speech and behavior, explore the multi-level teaching of experience, training, practice, and exploration, and improve students' innovation and practical ability. Zhu *et al.* [15] explored the construction of a communication network training platform in the transportation track. They built a platform based on the MVB bus standard and optimized the WTB bus and the troubleshooting module. This approach aimed to enhance students' knowledge comprehension and application abilities.

Combined with the characteristics of the above training platform, this paper uses virtual simulation technology to build a virtual and real robot training platform. The platform includes an industrial robot, air control unit, track function module, assembly function module, palletizing function module, vision module, etc., which can realize the synchronous operation of virtual and real practical training platforms.

2. Overall design of virtual and real training platform

The training platform mainly includes a model of the IRB120 ABB industrial robot, a pressure control unit module, a trajectory and coordinate system calibration module, a palletizing function module, a tangram assembly function module, an analog gear assembly function module, fixture quick change module, storage module, vision module and so on. The platform can perform palletizing, handling, welding, grinding, assembly, and other typical industrial application teaching. It is equipped with a machine vision system to guide the robot. The workstation features intelligent storage, allowing for sensor and PLC debugging and practical training operations. The work platform is shown in **Figure 1**, and the virtual platform schematic diagram is shown in **Figure 2**.

Figure 1. Schematic diagram of the real training platform

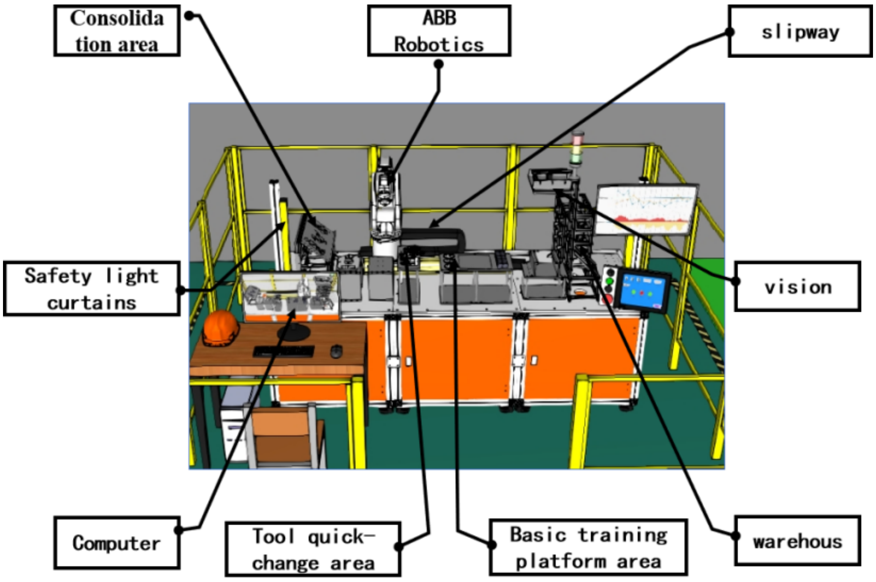

Figure 2. Schematic diagram of virtual training platform

3. Division design of virtual and real integrated training platform

3.1. Industrial robot

The six-axis industrial robot is a crucial component of the virtual and practical training platform, with all the projects provided requiring the participation of industrial robots. The model used in this paper is the ABB IRB120, which weighs only 25 kg and has a working reach of 580 mm. As the smallest six-axis industrial robot produced by ABB, it is lightweight, has a compact structure, and is primarily used for teaching purposes. It can move to each functional area with the assistance of a mobile slide base, and the robot is connected to the sliding platform via a chain to complete various operations.

3.2. Pneumatic control unit

The pneumatic control unit of the platform facilitates the quick change of robot tools and tool actions. It mainly consists of a pressure-reducing valve, solenoid valve, vacuum generator, and digital display pressure gauge. When the air compressor is activated, the air first passes through the pressure-reducing valve and then splits into two branches. One branch passes through two four-way single-control solenoid valves, which control the vacuum generator. The other branch passes through two five-way double-control solenoid valves, which control the clamping action of the air claw.

3.3. Material palletizing function module

The material block palletizing function module consists of 14 material blocks and 1 square product with an 8-shaped groove plane. This module can be used for various palletizing methods and sequence rules, as well as for teaching unpalletizing techniques.

3.4. Tangram assembly function module

The tangram assembly function module consists of multiple blocks, including triangles, parallelograms, and rectangles. These blocks must be assembled into a tangram according to the pattern slot on the assembly bench. The tangram pieces are thin, and the grooves on the assembly frame are narrow, increasing the difficulty of the operation.

3.5. Storage function module

The storage function module, depicted in **Figure 3**, comprises a three-dimensional warehouse and a workpiece tray. The three-dimensional warehouse is divided into upper, middle, and lower layers, with a total of 6 stations, while the workpiece tray has 6 slots. Initially, the robot grasps an empty tray, and then the materials are placed onto the tray. Subsequently, the industrial robot grasps the tray filled with materials using the jig and places it onto the storage shelf, thereby facilitating material tray storage.

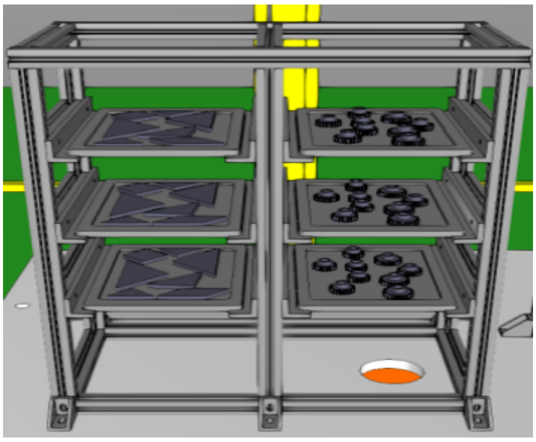

Figure 3. Storage function module

3.6. Fixture function module

The fixture function module, depicted in **Figure 4**, consists of three sets of jigs: pallet jigs, grasping jigs, and vacuum sucker jigs. The grasping jigs are equipped with a pointer pen and a simulated welding gun, allowing them to move and simulate welding along the training track.

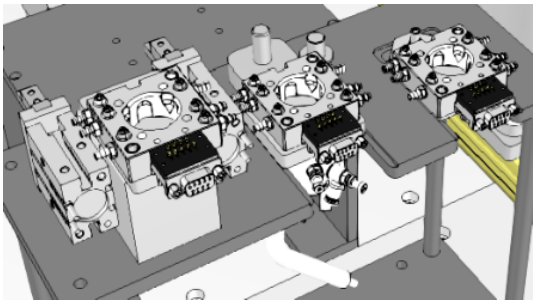

Figure 4. Fixture function module

3.7. Visual function module

The vision module mainly consists of the vision camera. It is used to detect the workpiece on the tray so that the robot can carry out sorting operations.

3.8. Monitoring function module

The monitoring functions of the real and virtual integrated training platform mainly include a human-computer interaction touch screen and a PC monitor. The touch screen console is used to perform workstation startup, reset, emergency stop, and mode selection, and visual workflow setting and monitoring can be realized on the color display screen.

3.9. Mobile worktable

The mobile workbench consists of 3 work surfaces, 3 work frames, 3 doors, and 12 casters. Industrial robots, control cabinets, and other functional modules are placed on the mobile workbench.

4. Virtual and real integrated practical training platform simulation process design

Once the integrated virtual and real training platform is established, enabling comprehensive teaching of typical industrial applications such as industrial robot palletizing, handling, welding, grinding, assembly, and more, it is crucial to consider the action sequences of industrial robots. Taking tool quick change, humanoid jigsaw assembly, bird assembly, figure-eight assembly, gear assembly, block palletizing, warehouse palletizing (inbound and outbound), and other tasks as examples, the corresponding robot action flows are designed to achieve the desired virtual simulation effect. The simulation process design is shown in **Figure 5**.

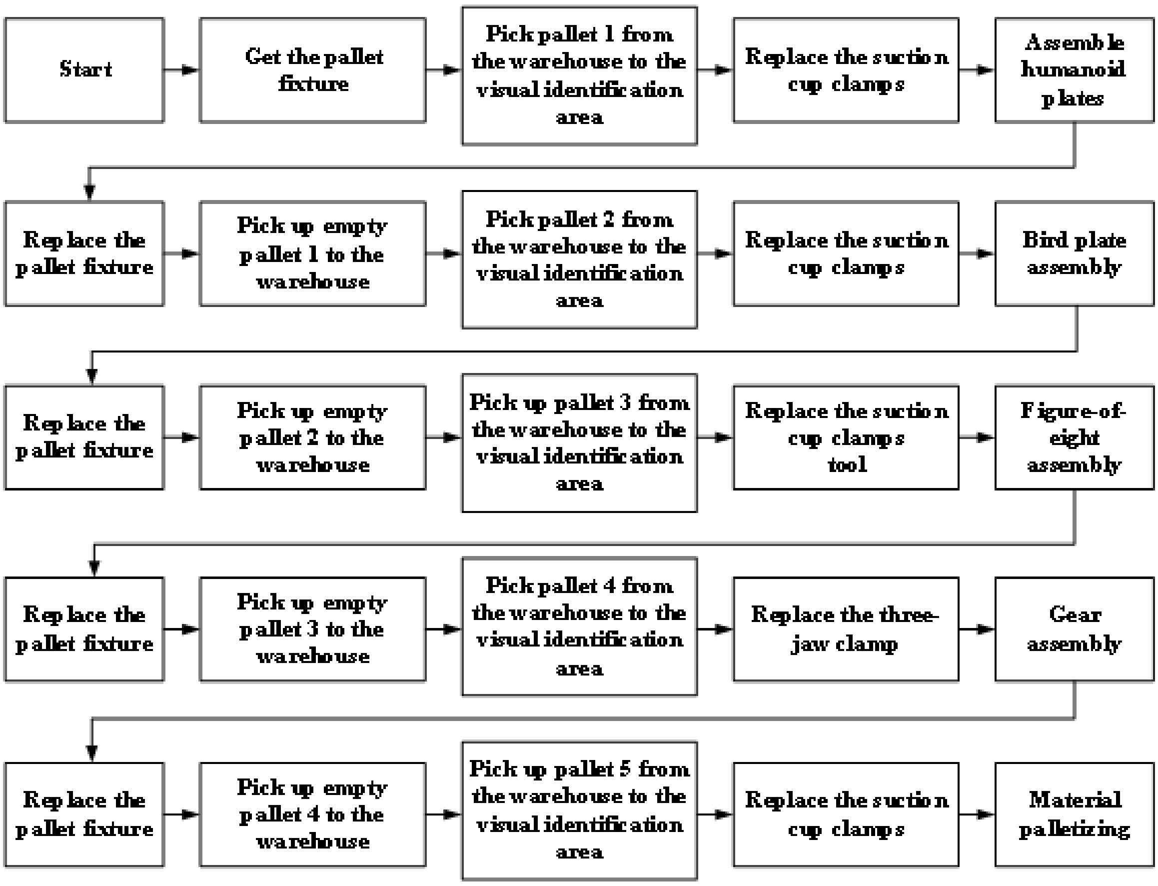

Figure 5. Simulation process design

To execute the tool quick change for installing the tray fixture, the industrial robot first moves to the fixture functional area and locates the fixture designed to clamp the tray. The gas control device is activated by aligning the sixth axis flange with the tray fixture assembly port. The robot's quick change device then moves the tray fixture's steel ball into the sleeve. Subsequently, the gas control device is closed, securing the tray fixture onto the sixth axis flange of the industrial robot.

After the pallet fixture is installed, the assembly of the humanoid tangram proceeds as follows: the industrial robot is affixed onto the pallet fixture and maneuvered to the warehouse function module. From there, the pallet is clamped and moved from warehouse 1 to the visual identification area. Once positioned below the camera platform, the pallet, equipped with the humanoid tangram, falls within the camera's capture range. Subsequently, the clamp claw of the fixture is released, allowing the robot to relocate to the fixture function area. Here, the clamp claw is replaced with a sucker tool, which is installed onto the robot. The robot then moves back to the top of tray 1, where it absorbs the corresponding humanoid tangram according to the required shape and relocates it to the appropriate humanoid groove.

Following the assembly of the humanoid jigsaw puzzle, the bird-shaped assembly process begins by replacing the sucker fixture with a tray fixture. Initially, the empty tray 1 is removed from the visual identification area and returned to the warehouse. Next, tray 2 containing the bird shape is located, unclipped, and moved to the visual identification area, where it is placed on the platform beneath the camera. Once the clamp claw is released, the robot transitions to the fixture function area to replace it with a suction cup tool. After installing the suction cup tool, the robot moves back to the top of tray 2. Following this, the robot absorbs the corresponding bird shape according to the required shape and transports it to the designated bird groove.

During the figure-eight assembly following the bird assembly, the initial step involves replacing the suction fixture with a tray fixture. Subsequently, the empty tray 2 located in the visual identification area is clamped and returned to the warehouse. Following this, tray 3, featuring the figure-eight shape, is located and clamped before being moved to the visual identification area. Once positioned on the platform beneath the camera, the clamp claws are released, allowing the robot to transition to the fixture function area. Here, the suction cup tool is replaced and installed onto the robot. The robot then moves to the top of tray 3, where it absorbs the corresponding figure-eight shape as per the required shape and transports it to the designated figure-eight groove.

Following the gear assembly within the figure-eight assembly process, the initial step involves replacing the sucker fixture with a tray fixture. Subsequently, the empty tray 3 located in the visual identification area is clamped and returned to the warehouse. Following this, tray 4, equipped with gears, is located and moved to the visual identification area after removing the clamp. Once positioned on the platform beneath the camera, the clamp claws are released, enabling the robot to transition to the fixture function area. Here, the three-claw clamp is replaced and installed onto the robot. After installing the three-claw fixture, the robot moves back to the top of tray 4. According to the positioning position of the gear, the size of the gear is installed into its designated installation position.

Following the gear assembly, the next step involves replacing the sucker fixture with a tray fixture. Initially, the empty tray 4 located in the visual identification area is retrieved and returned to the warehouse. Subsequently, tray 5, equipped with a cube, is located, and the clamp is moved to the workbench after being removed. Once positioned, the clamp claw of the fixture is loosened, allowing the robot to transition to the fixture's functional area. Here, the clamp is replaced with a sucker fixture. After installing the sucker fixture, the robot moves back to the cuboid material above tray 4. Initially, it carries a layer of cuboid blocks and then completes the second and third layers of cuboid block palletizing. Upon completion of palletizing, the sucker tool is placed in the fixture functional area, and the industrial robot returns to the initial position to conclude the task.

5. Conclusion

Virtual simulation software was employed to construct a robot workstation training platform, comprising units such as the industrial robot, gas control unit, track function module, assembly function module, palletizing function module, vision module, and other modules. Each project's operation was accomplished through program design, enabling the realization of robot assembly, handling, and palletizing functions. The integration of virtual and real elements in the platform facilitates the teaching of intelligent manufacturing courses, enhances students' practical skills, and offers insights for cultivating talent in intelligent manufacturing-related industries.

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Disclosure statement

The authors declare no conflict of interest.

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