Design of Communication Among Vision System, PLC and Industrial Robot based on Modbus-TCP protocol

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Abstract. In order to solve the problems of small system, single machine and single function operation of industrial robots and improve the automation of the system, Modbus-TCP protocol is used as communication platform to realize data exchange among industrial robot, vision system and main control PLC, and an automatic assembly control system composed of Siemens S7-1200 PLC, industrial robot, vision system, conveying line and assembly line is constructed. The application of the system in automatic identification and assembly line will improve production efficiency and reduce labor costs.

1. Introduction
Industrial robots are widely used in the fields of kinetic energy conversion and industrial upgrading. Typical applications include repetitive manual labor such as sorting, stacking, welding, spraying, gluing, assembling, loading and unloading of CNC machine tools, or industries that are harmful to human body\textsuperscript{[1]}. But in the practical application of industry, there are still some phenomena such as industrial robots running in small systems, single machines and simple functions. With the rapid development of Internet and intelligent manufacturing technology, industrial automation group control technology with industrial robots and PLC has been gradually promoted and applied in equipment manufacturing production and application industries. Network industrial robots, automatic production lines, visual inspection\textsuperscript{[2]}, automatic loading and unloading, AGV automatic guided car and other factory automation technologies are becoming mature, which can greatly improve the level of factory automation and intelligence, increase production efficiency and reduce personal injury and labor costs. The system takes Modbus-TCP protocol as data communication platform\textsuperscript{[3-6]}, Siemens PLC as main control unit, and establishes communication among industrial robot, vision system and main control unit to realize intelligent design and operation of automatic assembly production line.

2. System Principle and Work Flow
SIMATIC S7-1200 PLC is a new generation of integrated automation control unit with network control functions\textsuperscript{[7,8]}. The system takes Siemens S7-1200 CPU as the main control unit, and communicates with stack system, visual system and industrial robot system through Modbus-TCP protocol. The system principle is shown as Figure 1.
At the same time, the main control system also controls the pallet production line and the assembly line of the parts to realize the automatic control of the whole system. Siemens S7-1200 PLC and digital expansion modules are used as control units of the stack system. The Siemens frequency converter G120 and the induction motor drive three coordinate axes to move so as to realize automatic parts picking-up.

In the main control system and pallet system, Siemens TP700 touch screens are used to realize real-time display and variables setting. The six-axis industrial robot picks up parts by pneumatic hand and sucker. The tray production line is driven by frequency converter and asynchronous motor, and the assembly production line is driven by step motor. Finally the automatic assembly of parts is realized by combining the picking-up and placement of parts with industrial robots.

The parts automatic assembly process based on PLC and industrial robot is shown as Figure 2. Firstly, the parameters are initialized, including communication establishment, laser opening, robot entering the initial position, etc. Then the pallet production line starts. The parts are directed into the photographic area, and the specific position is obtained by taking photos. PLC communicates with the robot according to the type of parts, and the robot selects picking-up tools. Then, the automatic assembly process is completed through parts transfer, sorting, overlapping and rotating. After each part is removed, the empty pallet is placed on the pallet rack through double suckers for collection.
3. The Design of Communication

Modbus-TCP protocol is widely used in industrial control. Through the protocol, controllers communicate with other network devices. Siemens S7-1200 CPU has an integrated PROFINET port supporting Modbus-TCP protocol, which links industrial robots, visual systems and stacking systems. The Modbus address, PLC address and the corresponding data are shown as Table 1.

Table 1. The relation among Modbus address, PLC address and corresponding data.

| Modbus address | PLC address    | Corresponding Data     |
|---------------|---------------|------------------------|
| 00001-08192   | Q0.0-Q1023.7  | Digital output         |
| 10001-18192   | I0.0-I1023.7  | Digital input          |
| 30001-30512   | IW0-IW1022    | Analog input           |
| 40001-49999   | DBW0-DBW19998 | Data block             |
3.1. The Communication between PLC and Camera
There are four types of parts, and the parts can be assembled into motor models according to assembly sequence. The main function of vision system is to identify the type of part and the coordinate value of the position. The position coordinates of each part include X coordinate, Y coordinate, height of the part and placement angle relative to the center of pallet. When the visual script is programmed to obtain the object-related information, the data is transmitted to the PLC through the Modbus-TCP protocol for processing. The integrated communication module for data reading between S7-1200 and CCD camera vision system is shown as Figure 3.

![Figure 3. Modbus-TCP communication module between Siemens S7-1200 PLC and vision system.](image)

The TIA software is embedded with MB_CLIENT communication module, and the data communication with the camera is realized by Modbus-TCP protocol. After the hardware configuration of PLC, the IP address of PLC is 192.168.8.11, and the IP address of camera is 192.168.8.3. The IP addresses of both are in the same network segment. M0.0 of the PLC produces request access signal the frequency of which is 10 Hz. MB_MODE is equal to zero to indicate that the PLC reads the camera data. The data address MB_DATA_ADDR is the initial Modbus address of the camera storage data. It is set to 41001 here. MB_DATA_LEN is the data length. MB_DATA_PTR is the pointer of the PLC to store the camera data. In the software, the camera data is stored in DB2 database of the PLC. Beginning from DB2.DBW0, the length is 44 words.

3.2. The Communication between PLC and Industrial Robot
The integrated communication module of data exchange between main control S7-1200 and industrial robot system is shown as Figure 4. The data communication between S7-1200 and robot is also realized by Modbus-TCP protocol. The IP address of the robot controller is 192.168.8.103. The MB_MODE is 1, which means that the PLC writes the data to the industrial robot, and the address starts from 40001, which takes up 16 words. The MB_MODE is 0, which means that the PLC reads the industrial robot data. The Modbus address starts from 40017, and the length is 16 words. Data for reading and writing of industrial robots is stored in internal database DB 11 of the PLC.
Figure 4. Modbus-TCP communication module between Siemens S7-1200 PLC and industrial robot.

4. The Experimental Verification

Place the part on the pallet assembly line and start the assembly line. When the part reaches the photographing position, open the cylinder to realize the positioning of the object. After the location data is acquired by camera photography, the data is transmitted to Siemens PLC S7-1200 for processing. The data is stored in the self-built database DB1.DBW0 to DB1.DBW6 within Siemens PLC, which occupies a total of four words. The data is displayed on Siemens touch screen TP-700. Object location data is transmitted to industrial robot through Modbus-TCP protocol, and X coordinate value, Y coordinate value, Z value of object height and placing angle coordinate (data type: INT) are stored in the corresponding array channels IOIin [1], IOIin [2], IOIin [3] and IOIin [4] of the internal memory of industrial robots controller respectively. The information of part type and specific coordinate value, placement angle and height of each part after coordinate transformation are show as Figure 5. The parameter dialog box is used to set the linear transformation parameter between the object pixels captured by the camera and the position data of the PLC.

Figure 5. Part type and position coordinate value displayed on the Siemens touch screen.

5. Conclusions

An automatic detection and assembly system is designed based on Siemens PLC S7-1200, visual system and industrial robot. The data exchange among PLC, industrial robot and visual system is
realized by using the MB_CLIENT communication module embedded in S7-1200 PLC, which supports Modbus-TCP protocol communication. The touch screen is used to display the type and position of the parts. The system can realize rapid identification and intelligent assembly of parts and greatly improve production efficiency.

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7. References
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