Proceedings of the 6th International Conference on Computing and Data Science
DOI: 10.54254/2755-2721/65/20240476

Research on sensing recognition principle and motion control of industrial robot

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Abstract. In recent years, with the continuous development of science and technology and the pursuit of production efficiency, robots are more and more widely used in industrial production. Robot is a new production tool in industrial production. This paper mainly studies the sensing and recognition technology of industrial robots and their motion control principle. The purpose of this paper is to discuss the main research directions and important design methods of industrial robots. The research methods used in this paper are literature analysis, case analysis, and review. The research object is the sensing and recognition function of the industrial robot itself, as well as its motion and control parts. The main tools used in the study are various literature database websites, and the experimental data are also extracted from the papers in the database. This paper finds that the key research of industrial robots today is to make their recognition function powerful and strive to optimize their motion ability.

Keywords: Industrial robot, Sensing recognition, Motion control

1. Introduction

Industrial robots are multi-joint manipulators or multi-degree-of-freedom machine devices widely used in the industrial field. Industrial robots have a certain degree of automation, and can rely on their own power energy and control capabilities to achieve various industrial processing and manufacturing functions. Generally speaking, industrial robots are composed of three parts and six subsystems. The three parts are mechanical part, sensing part and control part. The six subsystems can be divided into mechanical structure system, driving system, sensing system, robot-environment interaction system, human-computer interaction system and control system. Compared with traditional industrial equipment, industrial robots have many advantages. For example, robots have the characteristics of ease of use, high level of intelligence, high production efficiency and safety, easy management and significant economic benefits, so that they can operate in high-risk environments.

Industrial robots usually include the following technical requirements: motor servo technology, control technology and kinematics analysis.

The known background information in the related fields studied in this paper is as follows: such as the recognition technology of industrial robots, with the help of computer deep learning technology, the recognition accuracy of robots is enhanced. The help of artificial intelligence for robot algorithm learning can make robots more intelligent.

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The importance of this research is to discuss and sort out the research process of industrial robot technology, and analyze the possibility and development trend of its improvement.

This paper introduces the research contents of industrial robots, including sensing, recognition, control and motion analysis. The research method of this paper is to consult various databases, search for relevant articles, and analyze and summarize the scientific research methods used. The significance of this paper is to summarize the existing methods in related industries and provide people with research ideas. For later researchers, this article can be used as a retrospective content to provide some value.

2. Sensing and recognition

2.1. Sensing technology

Sensing technology is a very important core technology in industrial robots. Various sensors act as their eyes, see obstacles, and search targets during the work of industrial robots. The sensor can also be their finger, which is the contact sensor, touching different objects and analyzing their characteristics to complete the instructions correctly. The same common sensor is the ultrasonic sensor, which is equivalent to the robot's ear, and analyzes the situation of the real situation by analyzing the feedback of the sound wave.

2.2. Ultrasonic sensing technology

The ultrasonic sensor determines the position and distance of the target by using the echo of the transmission and reflection of high-frequency sound waves in the medium after being affected by obstacles. Its basic working principle is that the transmitter absorbs the input electrical signal and converts it into an ultrasonic signal. These ultrasonic signals will propagate at high speed and be sent to the target object. The ultrasonic signal is reflected on the target and returned to the sensor. In the receiver, the received ultrasonic signal is converted into an electrical signal and the distance information is output after signal processing. In the design of an ultrasonic sensor module, two ultrasonic ranging IC chips are generally used. In general, the module where one chip is located is used to transmit signals, and the transmitted signals are changed and controlled according to different design requirements. Another module is used to receive the signal emitted by the former. In this process, the signal received by the module may be disturbed by different internal and external factors. Therefore, the receiving module needs to amplify this signal to simultaneously detect the difference between the target signal and other interference signals, minimize the external interference, and try to improve the sensitivity of the sensing system.

For the purpose of calculating the time of the ultrasonic wave from the transmitting end to the receiving end, the modules where the two chips are located need to be synchronized. The method of synchronization generally adopts the way of wireless signal. The way discussed here is to use electromagnetic wave signals for time synchronization [1]. The three-point measurement method is used for object positioning, which requires three sets of geometric data. The coordinates of the target object are calculated by the equation. Firstly, three ultrasonic transmitters and a receiver are arranged, and then the transmitting end and the receiving end are synchronized. Next, the transmitting end emitsan ultrasonic wave, and the receiving end opens the timer and receives the signal. After receiving the signal, the receiver will analyze and detect them, and then send them back to the transmitter. Finally, the transmitter sends them back to the processor. Suppose that the horizontal distance from the transmitter to the receiver is dx(x = 1,2,3). And hx(x=1,2,3)is the vertical distance between the planes of the transmitter and the receiver. rx is the distance from the transmitter to the receiver.These equations can be obtained [1]:

$$d_x = \left(r_x^2 - h_x^2\right)^{\frac{1}{2}} \tag{1}$$

$$\begin{aligned} (x_1 - x_t)^2 + (y_1 - y_t)^2 &= d_1^2 \\ (x_2 - x_t)^2 + (y_2 - y_t)^2 &= d_2^2 \\ (x_3 - x_t)^2 + (y_3 - y_t)^2 &= d_3^2 \end{aligned} \tag{2}$$

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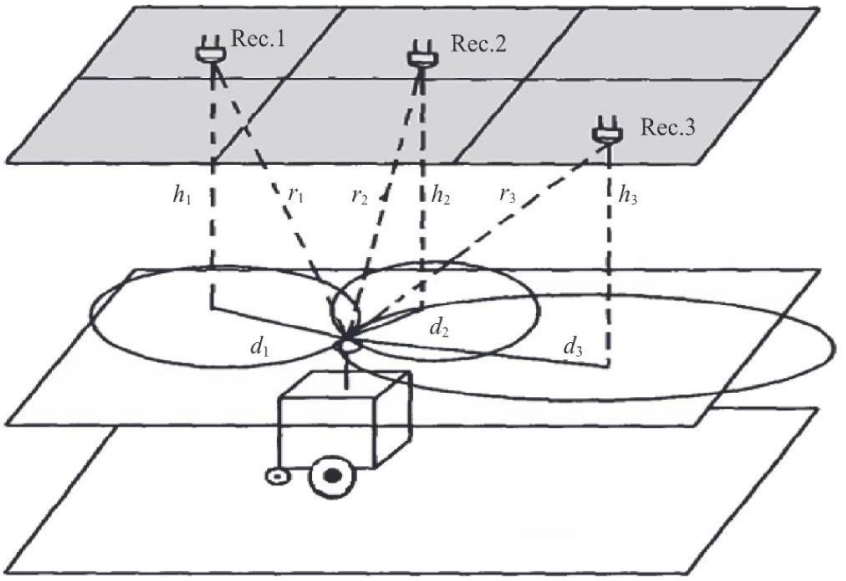

Figure 1. Obtaining coordinates by ultrasonic sensing [1]

As shown in Figure 1, After the coordinates are obtained, the reasonable operation route of the robot can be planned to achieve the production goal.

2.3. Recognition technology

The recognition technology introduced here is mainly based on the vision system, which is the recognition method adopted by most industrial robots today. The visual recognition system is generally composed of a computer, a camera, and an image processing device. The camera captures the image, and then transmits it to the computer and the image processing device and lets them identify the characteristics of these images. The most widely used technology today is the convolutional neural network algorithm based on deep learning. One algorithm emphasized in this paper is the Faster R-CNN(Regional Convolution Neural Network) network model [2].

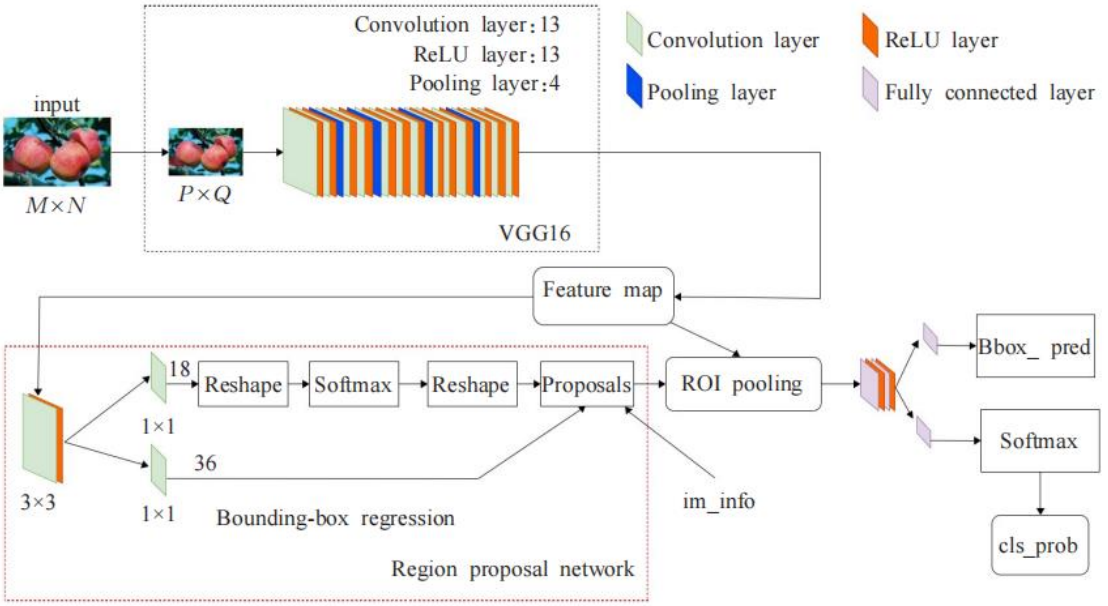

Figure 2. The working principle of Faster R-CNN network model [2]

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As shown in Figure 2, which is the basic operation principle flow chart of Faster R-CNN network model [2]. The camera on the robot takes pictures and then transmits them to the R-CNN and RPN(Region Proposal Network) modules. These two modules will analyze and extract the features of the input image and obtain the feature map. The RPN module also sets different proportions of anchors. The feature map in the RPN network generates a series of anchors by sliding windows, and each sliding window generates 9 anchors at the corresponding position of the original map. Then, the extracted features are subjected to bounding box regression and classification. Finally, after ROI pooling processing, the feature matrix is obtained, and the bounding box regression and category prediction are carried out. Finally, the analysis, recognition, classification and analysis of the target are realized.

Compared with the R-CNN algorithm and the common YOLO(You Only Look Once) algorithm, there is a more accurate algorithm called SSD(Single Shot MultiBox Detector) algorithm. The SSD algorithm can directly use the convolutional neural network to detect targets of different sizes. It is more accurate than the YOLO algorithm and faster than the R-CNN algorithm. Because the convolutional neural network with gradually decreasing scale participates in the additional framework of the SSD algorithm, this makes the object to be detected have different feature maps and different feature elements. The SSD algorithm also matches the default box and receptive field of different sizes for it. After a certain amount of model training, it is confirmed that the SSD is more excellent in recognition performance [3].

3. Motion and control

3.1. Kinematics simulation and analysis

The motion problems of industrial robots mainly focus on several points: The first is to calculate and simulate the geometric parameters of the working parts of the robot during operation. The industrial robot contains multiple coordinate axes to accurately express the coordinates of its working parts. Then, the kinematics equation is used to solve how these parts should rotate or scale to cooperate with each other to achieve the ultimate goal.

Generally, there are two kinds of academic analysis in sports research. One is the forward kinematics analysis, which first determines the joint rotation angle and offset of the robot through the coordinate axis system, and then solves the position and attitude of the end effector through the kinematics equation [4]. Using the D-H parameter table, the transformation matrix between the coordinates can be calculated by the formula, and finally substituted into the fkine function to verify whether the forward kinematics equation correctly reflects the working attitude of the robot and its changes [4].The inverse kinematics is to solve the variable value of the robot joint when the attitude and position of the end effector are known.

3.2. Robot control

It is necessary to design a control system that combines hardware and software. The system can selectively command the robot to take basic actions and achieve target functions. Add a communication module to the robot, and the robot will perform the action after receiving the command. In this link, it is also necessary to consider the anti-common-mode interference ability of the robot signal transceiver [5]. As shown in Figure 3, this is a communication module used in cleaning robots. Choosing different ports and receiving transmitters will have an impact on it.

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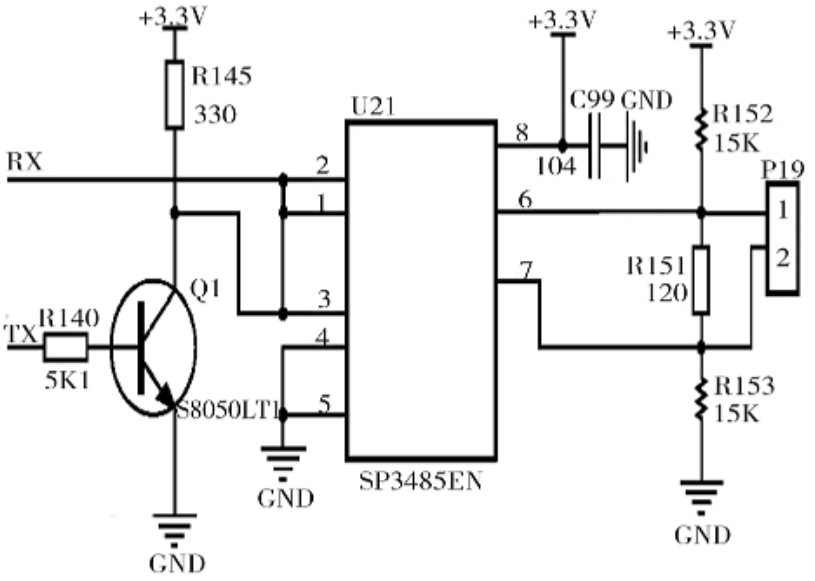

Figure 3. Network communication module [5]

In order to make the robot move and work, the motor drive module is necessary. As shown in Figure 4, similar modules are responsible for the movement of the robot.

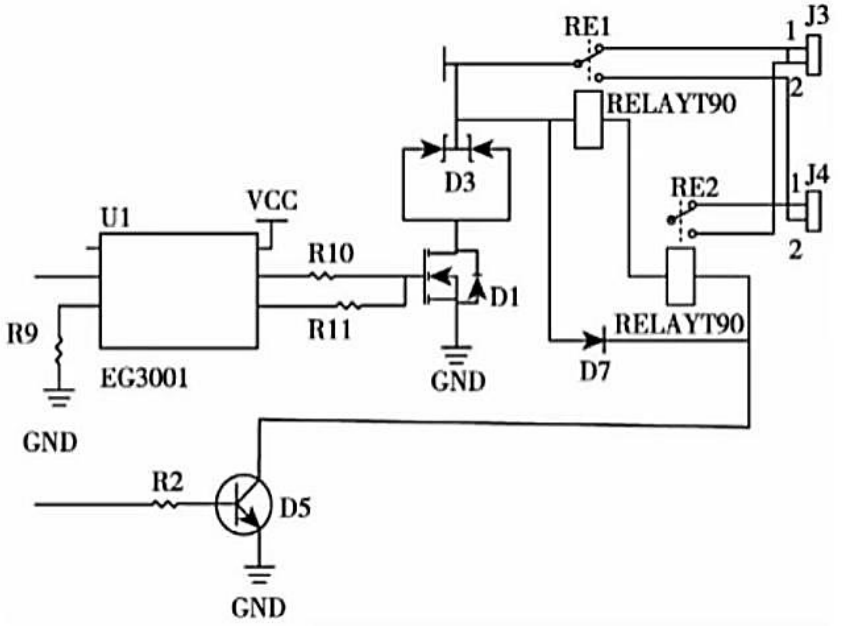

Figure 4. Motor drive and steering module circuit schematic [6]

The robot also needs to add a controller to control other modules and functions. Taking the LinuxCNC control system as an example, as shown in Figure 5, it is an architecture with a complete instruction processing flow. All signals and instructions are executed step by step in the prescribed order. In each step, there are other process architectures for dealing with unexpected situations or situations that require robots to make choices.

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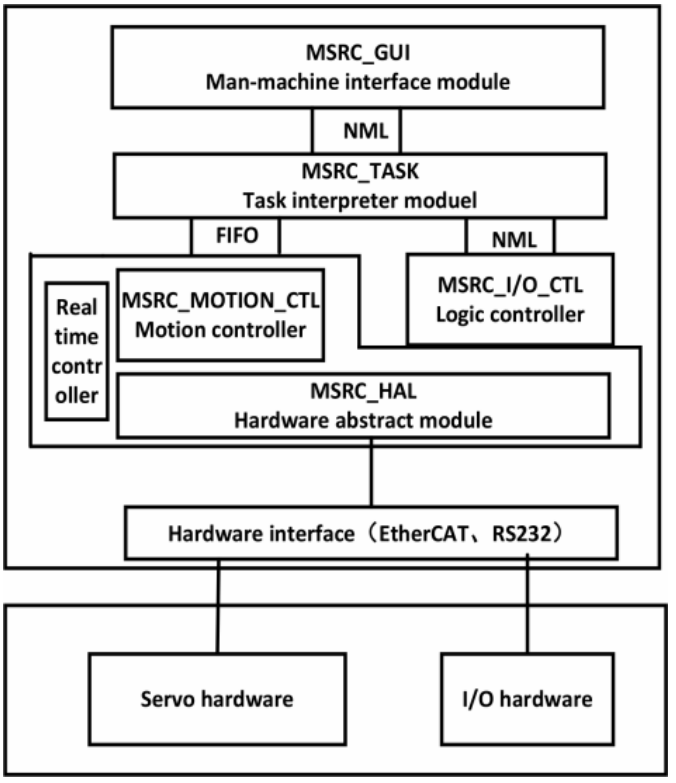

Figure 5. LinuxCNC system architecture [7]

4. Conclusion

The purpose of this paper is to discuss the main research directions and important design methods of industrial robots. The conclusion of this paper is that the main research direction of today's industrial robots is how to make robots more intelligent, such as using different algorithms to improve their logic or developing higher-end chips to make their computing power more powerful. At the same time, people are also focusing on improving the robot's sensing and recognition capabilities, so that the robot can be applied to more different fields. The space for improvement in this paper is that the software and hardware analysis of the robot control system can be further discussed. Future research on industrial robots may still focus on the exploration of their intelligence in order to apply them to more complex and difficult working environments. At the same time, it can better meet people's requirements and achieve higher working accuracy.

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