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Visual positioning system for marine industrial robot assembly based on complex variable function

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Abstract

With the deepening of human understanding of marine resources and the acceleration of resource development, marine industrial robots have come to be widely used. Robots are not simply a substitute for manual labour, but a personified electronic and mechanical device that combines human and machine strengths. They have both the ability to react quickly and analyse and judge the state of the environment, and the ability of the machine to work continuously for a long time, with high accuracy and resistance to adverse conditions. In industrial machinery, the gravitational field exists in three-dimensional space, but if the distribution of the known field is independent of a coordinate, it is simplified to a two-dimensional field, which is called a plane scalar field. There are many two-dimensional field problems in the visual positioning system of assembly system. The exact solution can be obtained by using complex function theory to analyse two-dimensional field in complex plane. In this paper, the application of complex function theory in gravitational field is discussed. In the process of cooperative assembly of marine industrial robots, it is necessary to make the correct choice to improve the cooperative assembly method of marine industrial robots, so that the robot industry in China can undergo development and renewal.

Keywords: reset function, marine industrial robot assembly vision positioning system.**AMS 2010 codes:** 76U05

1 Introduction

The concept of the Marine industrial robot was born in the 20th century, with the needs of the military and marine engineering, as well as the development of electronic, computer, materials and other high and new technology. Marine industry has brought about the rapid growth of the number of robots, and robots have been widely used in ocean petroleum, fisheries, new energy industry, scientific research and teaching, ship industry

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overhaul and river dredging industry etc [1]. The contribution rate of the Marine economy to the national economy will continue to rise gradually. By 2020, the Marine GDP will account for $>12\%$ of the GDP, and by 2030 it will account for $>15\%$. Further, Marine industrial robots are most relevant to the Marine oil-gas industry [2], Marine fishery and Marine mining; and the proportion in GDP-contribution of these three big industries has grown significantly over time. Once new application areas have opened, Marine industrial robots will have huge market space; therefore, our country plays a strong role in promoting the speeding up of high-quality development of Marine industrial robots and equipment technology of the Marine economy. The research on industrial robots represents the trend and problem orientation of industrial development, and it is a problem worthy of social attention. Collaborative assembly of industrial robots is the front-end problem of robot development, which can have a significant impact on the sustenance and development of the robot industry and is of great significance for discussion. Marine industrial robots mainly include various types of industrial robots and their loaded industrial sensors and tools (manipulator), navigation and positioning sensors, underwater acoustic communication/positioning systems and industrial robot systems [3, 4]. Industrial robot systems have industrial, scientific research and military applications. From the perspective of technical composition, it can be divided into design technology, construction technology and equipment technology, involving many fields such as materials, machinery, electric power, electric power, navigation and communication. Development of Marine industrial robots is made possible as a result of the development of technology and material, energy, sensors, control, communications, artificial intelligence and other closely related fields. Usually, Marine industrial robots are equipped with a mechanical system, electrical system, power distribution and propulsion system such as system structure, divided into ontology structure system, control system, hydraulic system, the life support system, acoustic system, power distribution and propulsion system, manipulator and operating tool system and other subsystems. Subsystems are integrated by various components, and each component can be subdivided into specific product components. Product components are closely related to R&D, design, manufacturing and maintenance.

2 Methods

2.1 The complex function of gravitational field is established

Gravitational field exists in three-dimensional space. If the distribution of a known field is independent of some coordinate, it can be reduced to a two-dimensional field. Such field is called plane scalar field. In practical problems, there are many two-dimensional field problems, and the exact solution can be obtained by analysing two-dimensional field in complex plane by using the theory of complex variable function. In this paper, the application of complex function theory in gravitational field is discussed. In a rectangular coordinate system, if the plural z in the continuous change of the region in a complex plane, if $f(z)$ as analytic function, it is the real part and imaginary part of cauchy Riemann equation; if only for the xy plane changes in the gravitational field, and the z axis perpendicular to the x - y plane direction does not change, that field is called a parallel plane; the gravitational field of the equipotential surface is parallel to the bus in Oz axis of the cylindrical surface, but in xoy plane, curve equation is shown in Figure 1 [5–7]. The cylinder in the three-dimensional space will be represented as a two-dimensional image in the image, which can be restored through two parallax images. However, in the actual process, the complex shape obstacles detected by the image are not regular graphs. In this paper, the minimum enclosing circle method is adopted, that is, by fitting the minimum enclosing circle of the obstacle image, the localisation of obstacles is realised. The core of obstacle localisation is to obtain the minimum enclosing circle in the image, which is the model of the minimum enclosing circle of any shape.

Robot is widely used in various aspects of life, production accessories and simple reproduction are widely used and the use of robots is people's pursuit of high quality life of the first and most important step; therefore the means to formulate the visual Angle of industrial robot assembly is the duty of every staff engaged in this task. Therefore, as an important technical index of assembly system, assembly precision directly determines the performance of the whole system. It combines the complex function and uses the visual positioning method to

Fig. 1 Distribution of equations.

achieve the target object position measurement. By introducing visual positioning technology to the industrial robot, the position information of the target point to be moved to can be obtained by the industrial robot without teaching. However, the motion trajectory of the industrial robot from the starting point to the target point cannot be determined. Therefore, the means to make the robotic arm avoid obstacles and solve the obstacles' avoidance in the assembly process is a key problem.

There are many ways of obstacle avoidance path planning for the robotic arm. According to the motion form of obstacles, it can be divided into static obstacle avoidance path planning and dynamic obstacle avoidance path planning. From the perspective of workspace, it can be divided into global path planning and local path planning. Generally, the global path planning environment is completely known, while the local path planning environment is partially known or completely unknown. Artificial potential field makes path planning for obstacle avoidance of the robot arm, and defines the working environment of the robot arm as an abstract potential field [8]. The gravitational field function between the target point and the end of the manipulator is defined as follows:

$$U_{att}(q) = \frac{1}{2} \xi \rho^2(q, q_{goal}) \quad (1)$$

Where the gravitational field coefficient constant ξ is >0 , the q represents the current position coordinate at the end of the manipulator; q_{goal} represents the position coordinate of the target point.

The negative gradient of the complex function of gravitational field is the gravitational function:

$$F_{att}(q) = -\nabla U_{att}(q) = \xi(q_{goal} - q) \quad (2)$$

Define repulsion field functions:

$$U_{rep}(q) = \begin{cases} \frac{1}{2} \eta \left(\frac{1}{\rho(q, q_{obs})} - \frac{1}{\rho_0} \right)^2, \rho(q, q_{obs}) \leq \rho_0 \\ 0, \rho(q, q_{obs}) > \rho_0 \end{cases} \quad (3)$$

The negative gradient of repulsive field complex function is repulsive function:

$$F_{rep}(q) = -\nabla U_{rep}(q) = \begin{cases} \eta \left(\frac{1}{\rho(q, q_{obs})} - \frac{1}{\rho_0} \right) \frac{1}{\rho^2(q, q_{obs})}, \rho(q, q_{obs}) \leq \rho_0 \\ 0, \rho(q, q_{obs}) > \rho_0 \end{cases} \quad (4)$$

Therefore, in the virtual artificial Potential field, the resultant force of the robot is:

$$F(q) = F_{att}(q) + F_{rep}(q) \quad (5)$$

If the target point is far away from the manipulator, the gravity function can be modified to increase the range limit. By introducing threshold d_{goal}^* , the distance between the target point and the end of the manipulator can be limited, and the gravity is too large because it is too far from the target point. The modified gravitational field function is as follows:

$$U_{att}(q) = \begin{cases} \frac{1}{2}\xi\rho^2(q, q_{goal}), \rho(q, q_{obs}) \leq d_{goal}^* \\ d_{goal}^*\xi\rho^2(q, q_{goal}) - \frac{1}{2}\xi\rho^2(d_{goal}^*)^2, \rho(q, q_{obs}) > d_{goal}^* \end{cases} \quad (6)$$

The corresponding gravitational function is:

$$F_{att}(q) = -\nabla U_{att}(q) = \begin{cases} \xi(q_{goal} - q), \rho(q, q_{obs}) \leq d_{goal}^* \\ \frac{d_{goal}^*\xi(q_{goal} - q)}{\rho(q, q_{obs})}, \rho(q, q_{obs}) > d_{goal}^* \end{cases} \quad (7)$$

When there are obstacles in the attachment of the target point, the problem that the manipulator can not reach the target point can be solved by modifying the repulsion field function, adding the influence of the distance between the target and the end of the manipulator on the basis of the original repulsion force. The modified repulsion field function is as follows:

$$U_{att}(q) = \begin{cases} \frac{1}{2}\xi\rho^2(q, q_{goal}), \rho(q, q_{obs}) \leq d_{goal}^* \\ d_{goal}^*\xi\rho^2(q, q_{goal}) - \frac{1}{2}\xi\rho^2(d_{goal}^*)^2, \rho(q, q_{obs}) > d_{goal}^* \end{cases} \quad (8)$$

The corresponding repulsion function becomes:

$$F_{rep}(q) = -\nabla U_{rep}(q) = \begin{cases} \eta\left(\frac{1}{\rho(q, q_{obs})} - \frac{1}{\rho_0}\right)\frac{\rho^n(q, q_{obs})}{\rho^2(q, q_{obs})} + \frac{n}{2}\eta\left(\frac{1}{\rho(q, q_{obs})} - \frac{1}{\rho_0}\right)^2 \\ \rho^{n-1}, \rho^n(q, q_{obs}) \leq \rho_0 \\ 0, \rho(q, q_{obs}) > \rho_0 \end{cases} \quad (9)$$

The gravitational potential energy function of the virtual target point can be represented by a quadratic function:

$$E_{vir} = k_{vir}[-(d - \mu)^2 + \mu^2] \quad (10)$$

The flux function v and allele function in the electric field u satisfy the Laplace equation. Therefore, the complex function can be directly introduced to study the modified gravitational field function.

3 Experiment

3.1 Marine industrial robot assembly visual positioning system

The whole assembly system is mainly divided into two parts, namely the vision processing part and the robot motion control part. The visual processing part is responsible for obtaining the location and size information of target objects and obstacles in the working environment. The motion control part of the robot realises the motion control of the industrial mechanical arm and the execution of assembly tasks. The workflow of the whole system is shown in Figure 2.

According to the overall scheme design of the system, the visual system in this paper includes binocular vision system and monocular vision system, and adopts camera for image acquisition. In the application of

Fig. 2 Structure of Marine Industrial Robot Assembly Visual Positioning System.

machine vision system, industrial cameras are usually used for image acquisition, and the resolution, focal length, aperture, interface, depth of field and other factors need to be considered when selecting cameras and lenses. For the binocular vision system responsible for coarse positioning in the system, the camera is fixed on the bracket. When selecting the camera and lens, it should be noted that all parameters of the left and right cameras and lenses are exactly the same. For the monocular vision system in the system, which is responsible for precise positioning, the camera is fixed at the end of the robot arm, and its main function is to achieve accurate positioning of the two-dimensional information of the target. In the process of selecting industrial robots, it is necessary to take into account the factors such as the degree of freedom, repeatable positioning accuracy, load and motion range of industrial robots. The system structure of the industrial robot is composed of a sensing system, a control system, a driving device, a transmission device and an actuator, as shown in the structural form of the industrial robot [9].

3.2 System action experiment

Marine industrial robot collaborative assembly is mainly used in Marine industrial robot collaborative handling operations. The experimental task is: the Marine industrial robot moves the experimental object, moving the object from the starting point to the end point. It is known that the motion path of the experimental robot is an arc with a diameter of 10 cm and the rotation Angle is 120° . The experimental steps are as follows, as shown in Figure 3. Step 1: Establish the cooperative motion system model of Marine industrial robots, and set three feature points (A, B, c) in the virtual object coordinate system. Step 2: According to the task requirements of cooperative handling rigid objects, the constraint matrix of tool coordinate system of Marine industrial robots is listed. Step 3: The path constraint model is established according to the constraint matrix relation, so that the contour of the path model satisfies the constraint relation at every point. The path model is established as shown in Figure 4.

Step 4: Pick up the inside and outside arc contours X and Y of the path model as the trajectory information, and adjust the path through the path rotation and translation command, so that the path satisfies the constraint matrix, and analyse the results.

Step 5: Calibrate the object coordinate system of the Marine industrial robot. The offline trajectory of the Marine industrial robot is transformed into the actual trajectory according to the transformation matrix.

Step 6: Manually adjust the Marine industrial robot.

Fig. 3 Flow chart of experimental action.

4 Results

By using the method of offline path planning based on complex function, the route of Marine industrial robot can be intuitively planned through the model without complex matrix calculation and programming, and

Fig. 4 Model trajectory.

the collaborative path planning of Marine industrial robot can be quickly completed. When the collaborative assembly task of Marine industrial robots not only moves in space but also rotates around space, model-based offline path planning is not applicable because it cannot change the interpolation speed with the path. The path of the robot is a spatial spline curve, and the posture of the tool end changes with the path surface. By adjusting the assembly position of the path model, the position of the assembly trajectory of the Marine industrial robot in the world coordinate system can be adjusted, and the collaborative position of the robot can be rapidly modified and planned.

5 Conclusion

Robots are widely used in various aspects of life, and find application in production accessories and simple reproduction; the use of robots is people's pursuit of high quality life of the first and most important step; the assembly of mechanical arm in the process of obstacle avoidance problem is studied, and through the double function in three-dimensional space, we realise the obstacles of visual positioning, combined with an obstruction to obtain information about the target object; using a quick and intuitive Marine industrial robot coordinated motion path planning, it becomes possible to avoid the relationship between the robot base frame and trivial movement calculation.

References

- [1] Meng, F., Zhang, Y., & Yang, D.. (2019). Design of communication among vision system, plc and industrial robot based on modbus-tcp protocol. *Journal of Physics: Conference Series*, 1288(1), 012083 (6pp).
- [2] Gao, H., Shi, G., Wang, K., Xie, G., & Liu, Y.. (2019). Research on decision-making of autonomous vehicle following based on reinforcement learning method. *Industrial Robot*, 46(12).
- [3] Xiao, J., Zeng, F., Zhang, Q., & Liu, H.. (2019). Research on the forcefree control of cooperative robots based on dynamic parameters identification. *Industrial Robot*, ahead-of-print(3).
- [4] Slavkovic, N., Zivanovic, S., & Milutinovic, D.. (2018). An indirect method of industrial robot programming for

- machining tasks based on step-nc. *International Journal of Computer Integrated Manufacturing*, 1-15.
- [5] Hong, L., Wang, B., Yang, X. L., Wang, Y., & Lin, Z.. (2020). Offline programming method and implementation of industrial robot grinding based on vtk. *Industrial Robot*, ahead-of-print (ahead-of-print).
- [6] Yi, J., Yu, B., Du, L., Li, C., & Hu, D.. (2008). Research on the selectable disassembly strategy of mechanical parts based on the generalized cad model. *International Journal of Advanced Manufacturing Technology*, 37(5-6), 599-604.
- [7] Horgan, J., Riordan, J., & Toal, D.. (2008). Experimental setups for vision-based navigation of unmanned underwater vehicles in near intervention operations. *Ifac Proceedings Volumes*, 41(1), 149-154.
- [8] Guijian Xiao, Yun Huang, & Jiachao Yin. (2017). An integrated polishing method for compressor blade surfaces. *International Journal of Advanced Manufacturing Technology*.
- [9] Woerz, R.. (2015). Design of transport system with an industrial robot based on stereo vision. *Mechatronics*.