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An design of robotic arm control algorithm for explosive disposal robots

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Abstract. Automatic explosive disposal robot have great potential to replace manual Explosive ordnance disposal(EOD) robots. In order to face the practical application scenarios of complex transformations, it is of great practical significance to study a fully automatic and autonomous EOD robot that can transfer dangerous goods to a safe area. In this paper, a mechanical arm algorithm based on the inverse kinematics of robot is presented. The relative position of the bomb is input by the electromagnetic induction device to guide the mechanical arm to the corresponding position. After obtaining the bomb, the deviation angle of the mechanical arm is input in real time by the gyroscope to achieve the relative stability of the object transportation. The experimental results indicate that the explosive disposal robot has certain practical significance.

Keywords: Explosive ordnance disposal robot, Mechanical arm, Kinematic analysis, Matlab.

1. Introduction

The continuous development of terrorism in today's society poses a great threat to the safety of people's lives. Among them, explosive terrorist attacks are the most common [1]. Countries are constantly researching counter-terrorism equipment and technology to achieve appropriate solutions to terrorist attacks. Among them, explosive disposal robots have become the main research object of anti-terrorism equipment due to their high efficiency and flexibility [2].

Explosion control utilizes various safe and scientific technical means and methods to effectively dispose of explosive devices. By reducing the explosion performance and explosion threat of explosives, the life and property safety of explosive disposal personnel and surrounding people can be protected. The whole process is extremely complicated and meticulous. Every time the explosive disposal mission fails, it means heavy casualties and property losses [3]. In order to reduce casualties and property losses as much as possible, people use explosive disposal robots to replace on-site security personnel for on-site investigation, transmit on-site images in real time, process and transfer suspected explosives and other hazardous substances, and use explosive destroyers to destroy mines instead of explosives, so as to avoid unnecessary casualties. Therefore, the application of explosive disposal robot can effectively reduce the risk of explosive disposal personnel, which has important research value and significance [4].

Small explosive disposal robots can operate in narrow spaces, such as aircraft cabin, train compartment, bus and other areas, including the transfer and on-site disposal of artificially installed explosive devices in stations, airports, office buildings and other environments. Or the transfer and on-

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site disposal of explosives found in abandoned factories, workshops and other environments [5]. The explosive disposal robot has a compact structure and is driven by two rows of six wheels. The wheels are covered with rubber tracks. The front end uses a long-distance explosive detector to detect explosives in real time [6]. After the explosive is detected, the robot will automatically navigate to the front of the explosive and transmit it to the mechanical arm to grab the explosive in real time. After grabbing, the mechanical arm will feed back the attitude of the explosive in real time through the built-in gyroscope and maintain relative stability through calculation.

At present, the commonly used explosive disposal robot in the world is the remote control robot, that is, the man is the operator, and the robot is the executor. It is usually detonated in situ and applied to open fields. With the increasingly complex explosive disposal environment, in-situ detonation is not the best method of explosive disposal. Moving the bomb to a safer place and detonating it will become a better solution.

Therefore, the use of robotic arms to grasp and transfer explosives has been adopted on many robots. This article studies the control algorithm of the robotic arm in this scenario and designs an efficient method for grasping explosives. The technical methods applied in this article are explained in Section 2, including kinematic analysis of the designed robotic arm and corresponding trajectory planning algorithms. Section 3 conducted simulation experiments on the control of the robotic arm of the explosive disposal robot, and analyzed the simulation results. The content of the entire article and the technology of mechanical control methods applied to explosive disposal robots are envisioned in Section 4.

2. Methodology

2.1. Kinematic analysis of robotic arms

The kinematic analysis of a robotic arm mainly studies factors such as the rotation angle, speed, and acceleration of each joint of the robotic arm. The kinematic analysis of robotic arms involves multidisciplinary knowledge, mainly including geometry, vector analysis, and matrix algebra.

In terms of geometry, a robotic arm can be seen as a series of configurations composed of multiple links and joints, with important features of length and connection mode for each configuration. Based on the configuration and geometric shape of the robotic arm, an analytical formula for the motion of the robotic arm can be derived, thereby obtaining the kinematic model of the robotic arm. In terms of vector analysis, the motion of a robotic arm can be described using vectors. Usually, the position and motion of a robotic arm can be represented by three-dimensional vectors. For chain manipulators, a vector chain model can be constructed. By using the vector chain model, the kinematic model of the robotic arm can be expressed through linear combinations of vectors, and combined with coordinate transformation to obtain the position analytical formula of the robotic arm. In terms of full matrix algebra, the matrix description of robotic arm kinematics is mainly for the convenience of calculation and control. By expressing the displacement and rotation relationships of each link and joint in the construction model in matrix form, combined with the angular displacement of each joint, the position of the robotic arm and the coordinate values of each joint can be calculated and used for robotic arm control [7].

2.2. Motion Planning Algorithm

The D-H method was adopted to establish a mathematical model of the robotic arm. The robotic arm constructed in this article is shown in figure 1.

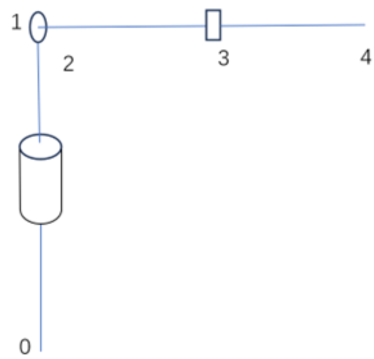

Figure 1. Mechanical arm structure diagram.

The direction of the coordinate system in the mathematical model should be consistent with the joint axis of the robot; The first coordinate system should correspond to the robot base; The origin of the coordinate system should be defined as the intersection point of the robot joint axes; The x-axis of the coordinate system should point towards the projection of the origin of the next coordinate system along the z-axis direction of the previous coordinate system; The y-axis should be determined along the right-hand rule [8].

The coordinate system transformation relationship is as follows:

$$^{i-1}A_i(\theta_i, \mathrm{d}_i, a_i, \alpha_i) = T_{Rz}(\theta_i)T_Z(d_i)T_x(a_i)T_{Rx}(\alpha_i) \tag{1}$$

The above formula shows the relationship between coordinate system i and $i-1$ coordinate system. In the formula $\sin\theta_i = S_i$,$\cos\theta_i = C_i$.

$$^{0}T_i = 0T_{i-1} \quad {}^{i-1}A_i \tag{2}$$

For an n-axis rigidly connected manipulator, the position and pose of the end link coordinate system can be solved through forward kinematics. Reuse the above formula to obtain:

$$T_n = A_1 \cdot A_2 \cdot A_3 \cdot \cdots \cdot A_n = \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$
$$= \begin{bmatrix} C_4S_1 - C_1S_4S_{23} & -S_1S_4 - C_1C_4S_{23} & C_1C_{23} & (H + l_3 + d_4)C_1C_{23} + l_2C_1C_2 + l_1C_1 \\ -C_1C_4 - S_1S_4S_{23} & C_1S_4 - C_4S_1S_{23} & S_1C_{23} & (H + l_3 + d_4)S_1C_{23} + l_2C_2S_1 + l_1S_1 \\ -S_4C_{23} & -C_4C_{23} & -S_{23} & d_1 - l_2S_2 - (H + l_3 + d_4)S_{23} \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{3}$$

The coordinate system of each link of the three degrees of freedom manipulator is established [9]. The end coordinates are (x, y, z) and the homogeneous change matrix of each joint is:

The total change matrix is

$$^{0}_{4}T = {}^{0}_{1}T\,{}^{1}_{2}T\,{}^{2}_{3}T\,{}^{3}_{4}T$$
$$= \begin{bmatrix} C_1 & -S_1 & 0 & b_3\,C_{123} - b_3\,S_{12}\,C_3 + b_2\,C_{12} - b_2\,S_{12} \\ S_1 & C_1 & 0 & b_3\,S_1\,C_{23} + b_3\,C_{13}\,S_2 + b_3\,S_1\,C_2 + b_3\,S_2\,C_1 \\ 0 & 0 & 1 & b_3\,S_3 + d \\ 0 & 0 & 0 & 0 \end{bmatrix} \tag{4}$$

So

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$$
\begin{gathered}
x = b_3\, C_{123} - b_3\, S_{12}\, C_3 + b_2\, C_{12} - b_2\, S_{12} \\
y = b_3\, S_1\, C_{23} + b_3\, C_{13}\, S_2 + b_3\, S_1\, C_2 + b_3\, S_2\, C_1 \\
z = b_3\, S_3 + d
\end{gathered} \tag{5}
$$

3. Experiment and analysis

3.1. Experimental setup

Matlab is a convenient and simple simulation tool and is widely used in the kinematic simulation of manipulator [10]. The simulation of a three-axis manipulator using this tool can directly display the parameters and motion posture of the manipulator.

The robotics toolbox plug-in is used, which simplifies the steps of modeling and reverse motion analysis. Using transl, rotx, roty and rotz in the plug-in, the translation and rotation transformations can be represented by matrix. The link and robot functions can be used to model the manipulator simply [11].

3.2. Manipulator control experiment

According to the mechanical structure and motion law of the three degrees of freedom manipulator, the motion simulation of the manipulator can be carried out in MATLAB. The robot toolbox can be used to simulate the kinematics of the manipulator, and the steps are as follows. Firstly, the link function is used to create joints and connect the joints to form a complete manipulator; Initialize the joint variable. Secondly, the drivebot function is used to draw the manipulator and the ikine function is used to obtain the pose matrix of the end. Then, after selecting the joint variable value q, the pose matrix t at the end of the manipulator can be calculated through the value of q, so as to operate the manipulator to reach the specified position to operate the explosives accordingly [12]. The simulation of explosive capture process based on manipulator is shown in Figure 2-5.

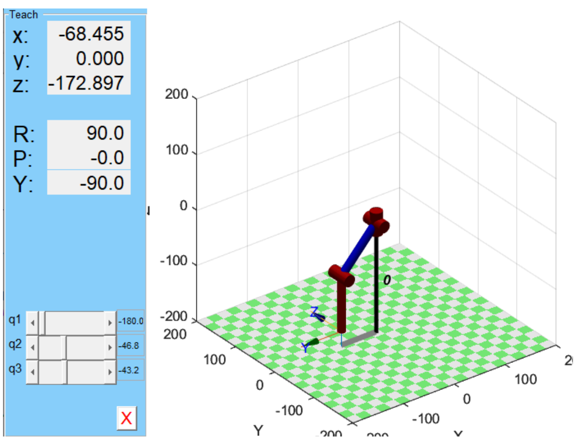

Figure 2. Explosive capture.

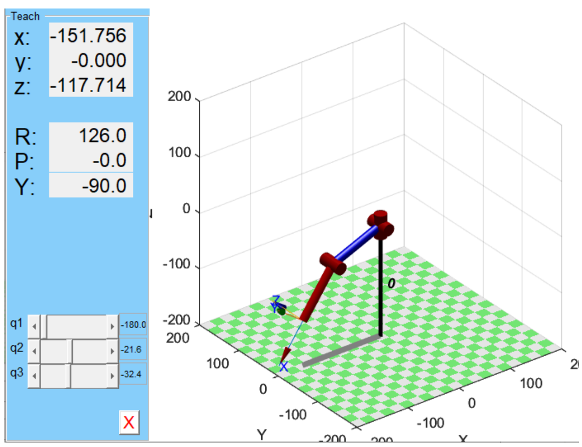

Figure 3. Explosive transfer step 1.

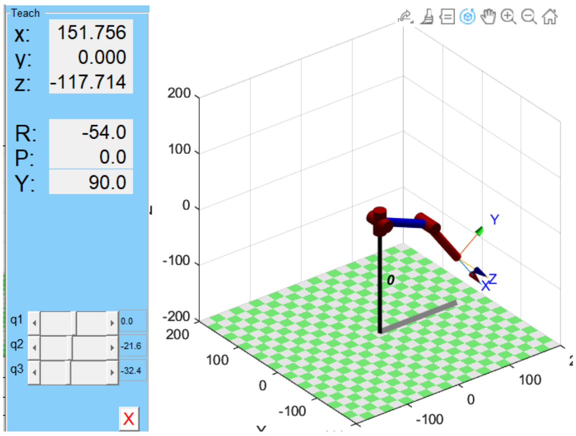

Figure 4. Explosive transfer step 1.

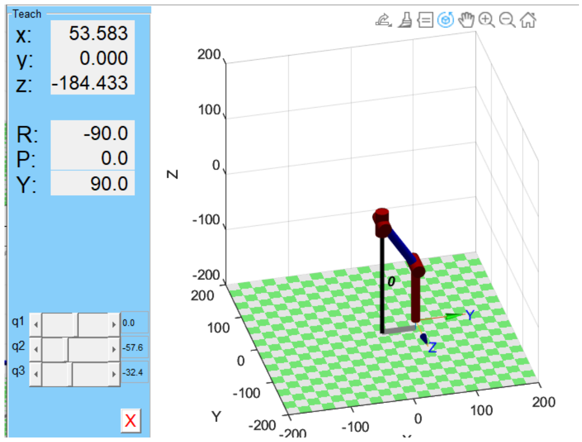

Figure 5. Explosive placement.

As shown in the figures, figure 2 shows the process of capturing explosives; figure 3 and figure 4 is the explosive transfer process; figure 5 is the placement process of explosives. The simulation results provide some validation for the method designed in this paper.

4. Conclusion

This paper designs a manipulator with three degrees of freedom. The purpose is to apply it to the real explosion removal scene to realize the smooth explosion removal under the condition of ensuring personal safety and property safety. The position and posture of the end of the manipulator are obtained through kinematics analysis, so as to effectively control the manipulator to clamp and remove explosives. In this paper, the positions of different manipulator ends that the blasting robot may encounter in the actual blasting scene are analyzed. Finally, the designed manipulator is simulated by MATLAB, and the attitude of the manipulator at the above positions is simulated, and then the explosive capture system based on the manipulator is verified.

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