Visual positioning control of fuze detection manipulator

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Abstract: This paper designs a fuze automatic detection manipulator. Aiming at the problem of autonomous alignment and docking between operation manipulator and detection device, a visual positioning control algorithm for autonomous alignment between fuze and detection device based on fuzzy logic is proposed. Taking the relative position and deviation angle of fuze and detection device as control variables, a two-dimensional fuzzy controller is designed. Through the dynamic adjustment of the controller, the optimal motion parameters can be output. Compared with the traditional fuze detection method, the algorithm further improves the efficiency and positioning accuracy of fuze detection.

1. Introduction
With the comprehensive promotion and implementation of "Made in China 2025", China's manufacturing efficiency has increased rapidly, and the production of fuzes has also realized the transformation from small batch slow production to large batch rapid production. As the "brain" of ammunition, fuze detonates the warhead in appropriate time and space, which plays a vital role in implementing precision strike and efficient damage[1-2]. However, if there are problems in the production quality of fuze, it may cause safety accidents and economic losses, or it may bungle the military opportunity due to ammunition failure on the battlefield, so the performance of fuze must be guaranteed[3]. However, the ex factory detection technology of fuze is still relatively backward, and the traditional manual detection method can not meet the needs of rapid detection of tens of thousands of fuzes. Therefore, this paper designs a fuze automatic detection equipment, which reduces the labor intensity and detection cost, improves the fuze detection efficiency, and ensures the detection safety and fuze quality.

2. Key technologies of manipulator positioning control
There are 6 detection points at the bottom of the fuse, which are connected with the 6 probes of the detection device through the manipulator. The operation diagram is shown in Figure 1. The end effector of the manipulator is a pneumatic adsorption clamping claw, which can clamp the fuse to move above the detection device. The clamping claw can rotate around the central axis to align the detection point with the probe so as to press down. The positioning process of manipulator is mainly divided into three steps. Firstly, the manipulator coincides the central axis of the fuse with the central axis of the detection device, and then, the six detection points of the fuse coincide with the six probes of the detection device. Finally, the manipulator moves downward to connect the detection point with the probe. The whole operation process of fuze detection is completely completed by the manipulator without manual participation.
3. Visual positioning control method for autonomous alignment of manipulator

3.1 Center alignment of fuze and detection device

In the positioning process of manipulator, the positioning accuracy of manipulator will be affected by factors such as equipment vibration, wear or environmental interference [4-5]. Therefore, it is necessary to judge the direction and distance of deviation in order to make corresponding motion fine adjustment. A digital camera is installed at the end of the manipulator to obtain the relative position information of the fuse and the detection device through the video monitoring system, according to the imaging principle, the position relationship between the fuse and the detection device can be divided into the following three cases (as shown in Figure 2): In the first case, the fuze is offset longitudinally in the detection device. Let the distance between the central axis of the fuze and the central axis of the detection device be $h$. In the second case, the fuze is offset laterally in the detection device. Let the distance between the central axis of the fuze and the central axis of the detection device be $d$. The third case is that the central axis of the fuse coincides with the central axis of the detection device, which is the control target.

The offset is calculated by image processing (Equation 1), the filter is constructed by Gaussian function, the image to be processed is convoluted to obtain a smooth image, calculate the value and direction of the smooth image intensity gradient, the gradient information in X direction and Y direction is extracted, and the offset in the two directions is obtained by conversion. The two parameters are converted into the joint motion control parameters of the manipulator to realize the
center alignment between the fuze and the detection device. The visual positioning control flow chart of manipulator is shown in Figure 3.

\[
G(x) = \frac{\exp\left(-x^2 / 2\sigma^2\right)}{2\pi\sigma^2}, \nabla I = \left(\frac{\partial I}{\partial x}, \frac{\partial I}{\partial y}\right)
\]

\[
(\nabla I)_m = \sqrt{\left(\frac{\partial I}{\partial x}\right)^2 + \left(\frac{\partial I}{\partial y}\right)^2}
\]

\[
(\nabla I)_d = \arctan\left(\frac{\left(\frac{\partial I}{\partial y}\right)}{\left(\frac{\partial I}{\partial x}\right)}\right)
\]

\[
h = \Delta y = \frac{x_b^2 - x_c^2 + y_b^2 - y_c^2}{x_a - x_b}(y_a - y_b) - (x_a - x_c)(y_a - y_b)
\]

\[
d = \Delta x = \frac{x_b^2 - x_a^2 + x_c^2 + y_b^2 - 2y_a^2 + y_c^2}{x_a - x_b}(y_a - y_c) - (x_a - x_c)(y_a - y_b)
\]

\[
\begin{align*}
\Delta y &= \frac{x_b^2 - x_c^2 + y_b^2 - y_c^2}{x_a - x_b}(y_a - y_b) - (x_a - x_c)(y_a - y_b) \\
\Delta x &= \frac{x_b^2 - x_a^2 + x_c^2 + y_b^2 - 2y_a^2 + y_c^2}{x_a - x_b}(y_a - y_c) - (x_a - x_c)(y_a - y_b)
\end{align*}
\]

(1)

Figure 3. Visual positioning control flow chart of manipulator

3.2 Automatic alignment control of detection point and probe

After the center of the fuze is aligned with the detection device, the fuze rotation angle compensation value needs to be calculated. As shown in Figure 4, in the Cartesian coordinate system XOY, set the coordinate of detection point program B as \((x', y')\), the included angle between the vertical line and Y axis of the interface between program A and B of the detection point is defined as the deviation angle \(\gamma\), by calculating the deviation angle, the angular displacement of the minimum rotation angle of the fuze is calculated \(\delta\) (Equation 2) to realize the automatic alignment between the detection point and probe.

\[
y = \frac{(x_a - x_0)(x - x_0) + y_0}{(y_0 - y_a)} + y_0
\]

\[
\gamma = \arctan\left(\frac{x'}{y'}\right), \quad \delta = \frac{\pi}{6} - \gamma
\]

(2)
4. Simulation experiment
In this paper, a two-dimensional fuzzy logic system is designed to control the end of the manipulator to realize autonomous positioning. Taking \( h(t) \) and \( d(t) \) as inputs of fuzzy control system, the output \( U(t) \) is the servo control command of the manipulator, the offset range is \([0,20\text{mm}]\). Membership Degree changes from 100\% to 0, Fig.5 (a) is a three-dimensional graph output by the manipulator. The fuzzy program is converted into real-time code and downloaded to the single chip microcomputer, and then the single chip microcomputer will run the manipulator based on the fuzzy control rules. Collect the information of offset and deviation angle during the autonomous positioning of manipulator, as shown in Fig. 5 (b).

![Simulation results](image1)

(a) Simulation results (b) Variation of offset and deviation angle

Figure 5. Visual positioning control of manipulator

From the simulation results, it can be seen that taking the offset and deviation angle of the fuze as the control variables, the designed two-dimensional fuzzy logic controller can obtain the motion control parameters of the manipulator and be used for the autonomous positioning control of the manipulator. The effectiveness and timeliness of the visual positioning control algorithm of the fuze detection manipulator based on fuzzy logic control are verified.

5. Conclusion
At present, some achievements have been made in the research on the key technologies such as configuration, control and platform of fuze detection manipulator, which reduces the labor intensity and detection cost, improves the fuze detection efficiency, and ensures the detection safety and fuze quality. However, in order to meet the complex and changeable detection environment and the detection requirements of many types of fuzes, there is still a lot of research work to be carried out. The follow-up research will focus on the needs of practical applications, combined with the forefront of scientific and technological development, such as big data, cloud computing, in-depth learning, intelligent manufacturing, etc., so as to improve the intelligence of fuze detection and better serve the modernization of national defense.

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