Research on Weld Tracking Based on Machine Vision

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Abstract: The era of Industry 4.0 has promoted the development of a large number of industrial industries, and it advocates and emphasizes the overall trend of most industries in terms of intelligence. Welding has become an indispensable part of industrial manufacturing, and improving the efficiency and accuracy of welding can significantly improve product quality, and machine welding is currently the mainstream new welding method. Through the research and development of a weld tracking system based on machine vision, the autonomy and intelligence of welding robots can be improved, and the problems existing in traditional welding methods can be solved. At present, there are still many problems in this field of welding robots, and how to solve these problems to improve the performance of welding robots is the main research direction at present. This paper mainly studies the application of machine vision in the field of weld tracking and verifies its feasibility and necessity..

1 INTRODUCTION

Welding, as a common material joining method, has been widely used in machinery manufacturing, aerospace and navigation, automobile and other manufacturing fields in the modern manufacturing industry (Xi, 2011). In the manufacturing industry, the welding process has become an indispensable means of processing. With the advent of Industry 4.0, all industries need to make improvements to meet the requirements of the new era. As a representative industrial technology, the development of automation and intelligence is an inevitable trend in the new industrial era.

Traditional welding methods often rely on manual operation. However, manual operation relies on the experience of the welder, is subjective, is labor-intensive, and can also produce deviations due to the influence of smoke and arc light (Jin et al, 2023). At present, the welding robot mainly used in welding operations solves the problems of manual welding to a certain extent. However, the current welding robots are still mainly teach-in robots. That is, repeated welding of a single welding path is achieved through the teach-in operation before welding (Dong et al, 2022). This does not completely solve the above problems. At the same time, due to the special working environment and special operation requirements of welding work, the teaching robot also has the problem of weak robustness and low welding accuracy. With the development of technology, new welding robots are gradually becoming popular. The new robot generally has high autonomy and robustness and a larger advantage range than the teach-in robot.

As the key in welding operations, the quality of the weld directly affects the strength and tightness of the weldment. Therefore, for the new welding robot, weld tracking is an important step in the process of welding operations, and machine vision is its main technical support. In order to solve the problems of teach-in robots and improve the automation degree of new welding robots, weld tracking technology based on machine vision has received extensive attention and application. As mentioned above, there are many difficulties in welding operations, such as welding seam tracking: the strong light and heat generated during the welding operation cause the workpiece to be thermally deformed, the strong light or spatter covers the vision sensor, and the error generated by each clamping workpiece, although the designers have taken a series of measures in terms of hardware, such as installing a baffle on the vision sensor to block splashes and smoke and installing a filter at the front end of the vision sensor to filter out arc light (Bing et al, 2020). However, including but not limited to the above-mentioned difficulties, it will still interfere

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with the welding robot's seam tracking process, and if the welding robot cannot make corresponding adjustments in time, the welding gun will deviate from the center of the weld, resulting in a decrease in welding quality (Lin et al, 2015). Therefore, research on welding robot seam tracking based on machine vision can improve the accuracy of welding operations and work efficiency. There is a need to enhance the robustness of welding robots so that they can adapt to more working environments. Promoting the development of automation and intelligence of welding robots, this trend has become inevitable, and efficient welding robots will be widely used in advanced manufacturing (Muhammad et al, 2017).

The purpose of this paper is to explore the enhancement effect of machine vision on the performance of weld tracking systems. This paper summarizes the current mainstream research direction by analyzing the structure, principle, and innovation of the new welding seam tracking system. At the same time, this paper points out the advantages and problems of the improved method of welding seam tracking system based on machine vision and gives relevant suggestions. This research has a positive effect on the realization of automatic welding.

2 PRINCIPLE AND WIDE APPLICATION OF MACHINE VISION

Since the concept of machine vision was first proposed in the 1960s, after research and development at home and abroad, it has gradually matured. Machine vision is a comprehensive technology that includes image processing, mechanical engineering techniques, aspects of control, electrical lighting, optical imaging, sensors, analog and digital video technology, computer hardware and software technology (image enhancement and analysis algorithms, image cards, I/O cards, etc.). A typical machine vision application system includes image capture, a light source system, an image digitization module, a digital image processing module, an intelligent judgment and decision module, and a mechanical control execution module. By analyzing targets acquired by charge-coupled devices (CCD) or complementary metal oxide semiconductors (CMOS), the object is converted into an image signal, transmitted to the image processing system, and finally converted into a digital signal. In this process, the machine vision system will extract the current various features to achieve automatic recognition.

Machine vision has great potential in agriculture, railway equipment, road traffic equipment, aircraft manufacturing, medicine and other fields. However, compared at home and abroad, the popularity of machine vision products in China is still not high, and there is still a certain gap with the developed countries represented by the United States, Japan and Europe. Especially in the international market, this aspect is still dominated by Japanese and American enterprises, which are superior to domestic enterprises in terms of talent, products and technology. At present, China is also trying to reduce the technical generation gap and has become the world's third largest machine vision market.

Specifically, machine vision technology combines the efficiency and replicability of computers with the high intelligence and recognition ability of human vision, so it can solve many highly repetitive and highly intelligent tasks. At the same time, with the progress of artificial intelligence, computer algorithm models are becoming more and more mature, and the two are usually combined and applied in many fields.

In industrial inspection, machine vision, with its non-contact, strong anti-interference ability and other advantages, can reduce the risks caused by manual inspection and complete the work that is difficult to complete with artificial vision. At the same time, in some high-volume production operations, machine vision can also greatly improve production efficiency. In the consumer electronics industry, due to the high quality standards of components and small size, the use of traditional manual visual inspection methods has many drawbacks, and in this field, based on machine vision and representative printed circuit board (PCB) defect detection technology, can give the operator timely operational feedback and information processing results, greatly reducing the circuit component repair or waste. In terms of image recognition, there is often a wide variety of objects that need to be identified at present, and machine vision has a powerful ability to process, analyze and understand images. The introduction of machine vision is of great help to the efficiency and accuracy of image recognition.

3 RESEARCH STATUS OF WELD TRACKING

Weld tracking technology obtains weld images through industrial cameras, sensors, etc., and after further processing, obtains features such as the shape and position of the weld, and controls the movement of the welding gun to adjust to the correct position (Hui et al, 2022). In the field of weld tracking, there is also a certain gap at home and abroad. Foreign companies such as Meta in the United Kingdom, Scansoic in Germany, Worthington Industries in the United States, Fanuc in Japan, and General Electric in Sweden are all enterprises with deep technical accumulation in weld tracking. After a series of studies in recent years, certain results have been achieved. The image processing algorithm has been improved and perfected, which makes the image information obtained by the final processing more accurate, and at the same time, drives the development of weld tracking technology and improves the real-time performance of the system. Up to now, the future development trend of weld seam tracking in China mainly includes overcoming the shortcomings of single signal acquisition of sensors so as to improve the effectiveness and accuracy of information tracking, innovative image processing algorithms focusing on the research of multi-sensor deposition tracking system, and summarizing welding tracking algorithms suitable for different jobs according to different working characteristics.

According to the above-summarized trends, domestic and foreign scholars have carried out some research and development innovations. In terms of the tracking problem of diagonal welds, Wang SW (Wei, 2019) designed a weld tracking system based on laser vision. It collects image information through laser vision sensors and adopts image filtering, image enhancement, adaptive threshold segmentation, linear complement and other technologies and means to achieve real-time automatic and high-precision weld tracking. The initial phase of the system involves calibrating the vision system. This entails establishing the conversion relationship between various coordinate systems, including the world, camera, image, and imaging plane coordinates. High-quality images of weld tracking are then collected and utilized for hand-eye calibration, resulting in the derivation of the conversion matrix between the camera coordinate system and the robot end coordinate system. In the subsequent phase, noise in the image is effectively reduced using a Gaussian filter. Furthermore, histogram equalization techniques are applied to enhance the laser stripe information within the image. Employing local adaptive threshold segmentation facilitates the segmentation of the weld image, generating a binary image. This process effectively separates the laser fringe information from the background information. In the third step, the improved upper and lower average method and Hough transform are combined to preliminarily extract the center line of the fringe, and the straight line correction based on the least squares method is carried out to obtain the accurate center line equation, and the feature points of the weld are obtained by simultaneous solution. Through the analysis of experimental data, the system and its supporting image processing algorithm have good real-time, high recognition accuracy, and high stability. Its detection accuracy is within 1.2mm, and the average time is less than 22 ms.

In order to realize the automatic height adjustment function of the industrial camera and the welding gun, Han D (Han, 2022) designed a weld positioning and tracking system with an initial height guidance module. The initial altitude guidance module of the system adopts the No-Reference Visual System Index (NRVSI), a defocus image clarity evaluation method based on the human eye vision system, and the evaluation results of this method are in good agreement with the subjective evaluation results of the human eye and the relationship between image acquisition height and clarity can be accurately established. At the same time, the weld tracking module of the system uses a deep learning method to segment the weld image, and after analyzing the weld image, the attention mechanism is introduced on the basis of the ENet network and the loss function is adjusted to form a weld image segmentation network. It can better cope with the problem of uneven positive and negative categories in the weld image, and its segmentation accuracy is high and its anti-interference ability is strong.

Xi T (Xi, 2022) aimed at the problem of poor adaptability of welding robots to many unfavorable factors, such as the complex shape of the workpiece, machining error, clamping error and welding thermal deformation, and carried out research on the key technologies of weld detection, three-dimensional positioning, and weld trajectory and attitude tracking based on deep learning and laser binocular vision. This paper proposes an improved CenterNet network method for the detection of the starting vector of the weld and the solution of the starting point position of the weld, which can still accurately and stably extract the characteristics of the initial vector of the weld under the conditions of complex background and variable posture and type of weld, which not only realizes the detection of the starting position of the weld but also realizes the solution of the attitude of the workpiece and the welding gun. At the same time, in order to reduce the tracking drift error of the ordinary target tracking algorithm under the background of strong noise, the Kernel Correlation Filter (KCF) target tracking algorithm was combined with the image segmentation algorithm based on deep learning to integrate a weld feature point detection algorithm, which can still maintain high detection accuracy and accuracy under the condition of severe noise. A real-time weld tracking system was designed for the synchronization of weld detection, point cloud creation, welding path and attitude online planning, which can maintain high adaptability in the environment of different degrees of welding noise and meet the requirements of welding production for tracking accuracy, stability and real-time.

4 SUGGESTION

Although domestic and foreign scholars have made a lot of research and development improvements, in the current context of the Industry 4.0 era, there are still some problems that need to be solved in the welding seam tracking technology based on machine vision. With the continuous development of industry, the operating environment and requirements in various fields gradually show special differentiation. The corresponding welds have different shapes, and there may be deformation and wrong weld texture in actual welding, which increases the difficulty of machine vision sensors to identify welds. At the same time, in the welding process, welding speed, welding Angle, welding wire diameter and other parameters will show different trends with the shape of the workpiece, material, and thickness, which is a huge challenge for the adaptability of the weld tracking system. At present, in actual production, it is still necessary to detect and control the welding process in real time to find welding defects and correct them, but some systems still have a certain delay, which cannot meet the requirements of high real-time.

In view of the existing problems, more algorithm models based on deep learning and neural network technology are introduced to identify various welds through some training. In the aspect of feature extraction and classification of welds, a convolutional neural network is used to improve the robustness of the system. They combine with other sensor technologies to obtain more comprehensive and accurate welding process data. Carry out a large number of welding experiments, enrich the welding database set, and improve the system's generalization ability. The adaptive control algorithm is introduced to detect the changes in conditions and parameters in the welding process in real time and realize the adaptive tracking. Using sectional computing and edge computing technology reduces dependence on the central server and improves real-time performance.

In recent years, due to the rapid development of the artificial intelligence industry, the future welding seam tracking technology will pay more attention to integration with the artificial intelligence industry. The weld tracking system can be adapted to a variety of different welding conditions and different weld shapes by introducing more flexible and complex neural network structures. At the same time, reinforcement learning and other technologies can enable the weld tracking system to continuously optimize its own performance and improve stability and accuracy. With the continuous improvement of computer power through the optimization algorithm, hardware equipment upgrade, and other channels, the real-time detection and instant feedback of the welding process can be gradually realized so as to improve production efficiency and reduce the risk of error. In the future, weld tracking technology will not be limited to visual sensing but will be more inclined to multi-modal fusion technology. By combining multiple sensing information such as vision, sound, and temperature, the system is able to perceive all aspects of the welding process more comprehensively.

5 CONCLUSION

In order to solve the problems of low efficiency, poor accuracy and high cost of traditional manual welding and the still common teach-repeat model welding robots, this paper analyzes a weld tracking scheme based on machine vision.

At present, there is still a certain gap at home and abroad in the field of machine vision and the field of weld tracking supported by its technology. There is a large amount of demand in the foreign market, and well-known foreign enterprises have deep technical accumulation, occupying most of the economic market. China started late, and the application of machine vision and weld tracking is still in a relatively basic stage. The same is true in terms of market demand because the development of products in this field is still insufficient. New products can not completely replace traditional products, resulting in a relatively small demand for machine vision and weld tracking products in the domestic market. Although China started late, in recent years, the attention to this field has made China develop rapidly, and it has now become the third largest machine vision market in the world.

The machine vision system will use all kinds of optical systems, analysis systems and control systems to realize the function of automatic identification and can realize automatic and intelligent weld tracking in welding. It mainly converts the image signal obtained by the sensor into a digital signal and analyzes it, outputs the result, and controls the rest of the components to work. In this process, multiple technologies work together. Image filtering, adaptive threshold segmentation and other technologies can eliminate the noise information in the original image and enhance the laser strip information to ensure the quality of the collected weld tracking image. The computer algorithm model based on deep learning can train various systems through massive amounts of data to improve their adaptability and efficiency. The algorithm represented by KCF target tracking can help the weld tracking system accurately extract the weld feature points and improve the system's overall accuracy and stability.

By adopting the weld tracking system based on machine vision, the performance of the welding robot has been greatly improved, but there are still problems, such as difficulty in identifying welds with special properties, lack of adaptability, and lack of real-time performance. Increasing the training amount of deep learning models, using volume neural networks combined with other sensing technologies, and introducing adaptive algorithms and edge computing technologies can solve the above problems to a certain extent. At the same time, it is actively combined with artificial intelligence technology to realize the autonomy of the welding process and comprehensive perception to meet higher technical requirements.

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