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Innovation in Interactive Design of Tele-robotic Welding in the Trend of Interaction Change

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Abstract:

At present, a new trend of change has occurred in the interaction between industrial robots and operators driven by the application of advanced sensor detection technology and AI technology. In this paper, the tele-robotic welding is studied to find out how to integrate advanced technology and build an effective information interaction system, so as to achieve efficient collaboration between the tele-robotic welding and the operator. Firstly, by analyzing the development trend of welding robot and its interaction, it is believed that the human-centered design concept should be adhered to in the design of robot interaction system, and the innovative idea of human-centered hybrid intelligent interaction design is proposed. Then, taking the interaction system and structural design innovation of a remote control wall climbing welding robot as an example, the specific application of the proposed ideas and methods in design practice are introduced and verified.

Keywords: *Interactive design, Tele-robotic welding, Human- computer interaction.*

I. INTRODUCTION

Interaction means alternating, reciprocity and mutual effect [1], focusing on the way in which information is transmitted between people and tools and the resulting impact in the field of production tools. The interactive relationship between people and tools develops from the original manipulator unilaterally operating tools to the interactive and collaborative work between them [2].

Welding is an important part of modern production, and the way its tools are used is also changing. Although there are many sources of welding energy, gas welding and electric arc welding are the most commonly used at present, which are operated in contact at very close distance by people holding welding gun with their eyes exposed to a harsh environment with high light, high heat and high-density polluted gas at a high working intensity, requiring a high level of proficiency and may cause potential hazards to operators. After the 21st century, welding robots have been widely used in various industrial production fields, which has changed the way of interaction between workers and welding torches from direct contact to indirect contact realized by controlling robots, greatly improving the operating environment and safety of operators, and also reducing the number of first-line welding workers in China. However, according to the data published by the National Bureau of Statistics on the annual increase in the production of welding materials, the welding workload in China is increasing year by year [3], which proves the extensive application of various types of welding robots.

According to the statistics, welding robots worldwide account for about 1/3 of the current number of industrial robots, revealing their important position in production. Therefore, the study on how to better use the interactive design ideas to construct a better form of human-machine interaction in the design of welding robot can further optimize the working conditions and improve the efficiency of work, which is also one of the important research points in the large development of intelligent manufacturing.

II. ANALYSIS AND INNOVATIVE THINKING

2.1 Types and Interaction Forms of Welding Robots

The development process of welding robot can be summarized into three stages [4]. First of all, in the stage of playback robot, the interaction mode is still dominated by the one-way transmission of operation information to the machine by human, and the feedback information in the production process needs to be observed by the operator himself. Therefore, the playback robot does not have the ability of external information feedback, cannot adapt to the changing operating environment, and is only suitable for the completely fixed program line. In the next stage, welding robots, as a current main stream application and with certain perception capabilities, can sense external information through detection functions such as machine vision and touch, have the human-machine interaction process in which not only control information is transmitted to the machine, but also information feedback can be provided to the machine, so that the operator can adjust the working state of the machine according to the feedback obtained, so as to ensure that work tasks can be completed in certain dynamic and changing environments. In the third stage, the intelligent welding robot has strong perception ability and relatively independent memory, judgment and reasoning ability at the same time, and can complete the welding task through independent decision-making and action by the task level programming ability and even machine learning ability, combined with multi-sensor information intelligent fusion technology, virtual reality technology, multi-intelligent welding robot system, and intelligent control technology, which is the future development direction of welding robot.

At the present stage of development of welding robots, there is a need to design special welding robots specifically for various welding needs. The design of welding robots on a large number of automated industrial production lines is mainly based on the third generation of

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autonomous control. However, there are still many difficulties in the research and application of autonomous control welding robots, such as the welding work in the presence of dynamic and unstructured factors, such as irregular and huge welded surfaces such as huge ships, high-rise buildings or future space stations, which is not suitable for human beings and can not be handled by the current technical level using the fully autonomous third generation intelligent welding robot. As a result, it is necessary to use tele-robotic welding to realize the remote monitoring and control of welding equipment and welding process in the safe environment of leaving the site, so as to complete the complete welding work. The tele-robotic welding needs to be real-time controlled by the operator according to the specific situation. Therefore, the coordination relationship between the control panel and the welding machine body should be considered in the interactive design, with relatively more complicated design content. Next, the innovative ideas and key points of its interactive design will be further explained in this paper.

2.2 Innovative Idea of Interactive Design for Tele-robotic Welding

Tele-robotic welding technology has been developed to a certain extent, and it has been successfully used to repair the leaking position of nuclear reactor as early as the 1970s in the nuclear leak accident of Douglus Point Nuclear Power Plant in Canada. Now with the introduction of advanced technologies such as visual sensor and artificial intelligence, tele-robotic welding will become more efficient, high quality and stable, and its application range is also expanding. The application of new technology has brought a new mode of human-computer cooperation interaction, in which the robot can obey the command of human while also assisting human, enhancing or expanding human intelligence, perception and physical performance.

Intelligent tele-robotic welding is the main development direction in the future, so the factors and points to be considered in their interaction design are very important. The main point of the interaction design of tele-robotic welding is human-centered at first, because in the interaction relationship between human and robot, human is still the main body of commands and needs, supplemented by the intelligence of robot and various interactive technologies, which cooperate with each other. Another key design point is that human intelligence participates in the control of machines and machine intelligence can help people to achieve better control for mutual combination and supplement, i.e. to exert the advantage of hybrid intelligence. Therefore, the development of tele-robotic welding focuses on human-machine interaction control plus intelligent assistance, that is, the operator controls the welding robot to complete tasks through remote control and instructions, while the machine assists the operator to better supervise, judge and operate by detecting sensor and intelligent computing ability. The above processes are implemented through appropriate human-computer interaction structure and processes.

2.3 Human-centered Hybrid Intelligence

In the future, a new way of human-machine interaction is "people-centered hybrid intelligence" by combining the detection, calculation of machines and human capabilities with

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various advanced technologies and devices, making the input and output of both be intuitively, naturally, implicitly, bi-directionally, fuzzily and directly controlled by establishing various channels for the transmission of real-time information between the operator and the machine, so that the process of machine assisting human to complete the work becomes more natural and smooth.

It is first necessary to construct the basic frame of human-machine interaction system through appropriate interaction channels in order to apply the idea of human-centered hybrid intelligence to the interactive design of tele-robotic welding. Specifically, the actual needs of welding work should be fully considered in the selection of interactive technology. Because the information expression is explicit, the channel for information feedback to human by machine (i.e. information display channel [5]), that is, the information output process realized by displays, loudspeakers and various wearable devices, has basically met the requirements of human-centered hybrid intelligence. In addition, progress has been made in research on wearable output devices in terms of information output methods such as touch, vibration and force changes.Conversely, it is difficult to achieve hybrid intelligence for the channels through which people input information to machine operation, because the information understanding is hidden.At present, the more commonly used input methods, including keyboard, mouse, touch screen, etc., have some problems such as low bandwidth, single mode, and insufficient natural human-machine interface.Besides, the input methods using somatosensory interaction technology, such as gesture input and line-of-sight tracking input, still have problems such as ambiguity, low input efficiency and high error rate caused by large information noise [6].In view of this situation, in the design of human-machine interaction of output mode (i.e. control information channel) of welding work, attention should be paid to how to select and utilize the unique effects of various interactive technologies to exert their advantages in the process of information transmission, and at the same time, to fully combine with AI technology such as machine learning to improve the accuracy, efficiency and naturalization of the interactive process of controlling information input [7].

In recent years, the rapid development of multi-channel interactive technology makes it possible to achieve this goal. Human-machine interactive information channel refers to the interactive means, methods, organs or equipment that a person or system can use to achieve its information communication goal. As mentioned above, it can be divided into display information channel and control information channel.In the process of human-machine interaction of tele-robotic welding, people always use a variety of sensations and effects simultaneously in parallel and complementary way, that is, the information interaction process is multi-channel, which not only reduces the information noise and improves the accuracy and efficiency of communication, but also facilitates the accurate judgment of the operator's intentions by artificial intelligence.In the long-distance welding control, not only the information of welding body such as environment, position, weldment condition, self-state and execution command etc. must be transmitted to the operator accurately and timely, but also the

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intention of the operator must be transmitted to the machine completely, quickly and efficiently. Obviously, it is difficult to meet this requirement by a single input or output channel.Therefore, multi-channel parallel input and output mode should be adopted for the typical human-oriented hybrid intelligent information transmission [8].

III. METHOD AND CASE DEMONSTRATION

3.1 Structure Design of Interactive System for Tele-robotic Welding

Guided by the idea of human-centered hybrid intelligence, the interaction process of the tele-robotic welding is actually about the design of a human centered system. At present, the United States, Europe, Japan and other countries have conducted in-depth research on relevant content. The research work in this aspect has also been carried out in Harbin Institute of Technology, China, and the guiding ideology of "macro remote control, micro autonomy" has been put forward [9]. Consequently, a specific interactive design idea of tele-robotic welding is presented: detection and judgment functions can be distributed on the remote control station, working parts and detection parts, and then real-time interaction between human and machine can be realized through a multi-channel information transmission structure.On this basis, the basic interaction structure of Tele-Robotic Welding System (TRWS) is constructed, as shown in Fig 1.

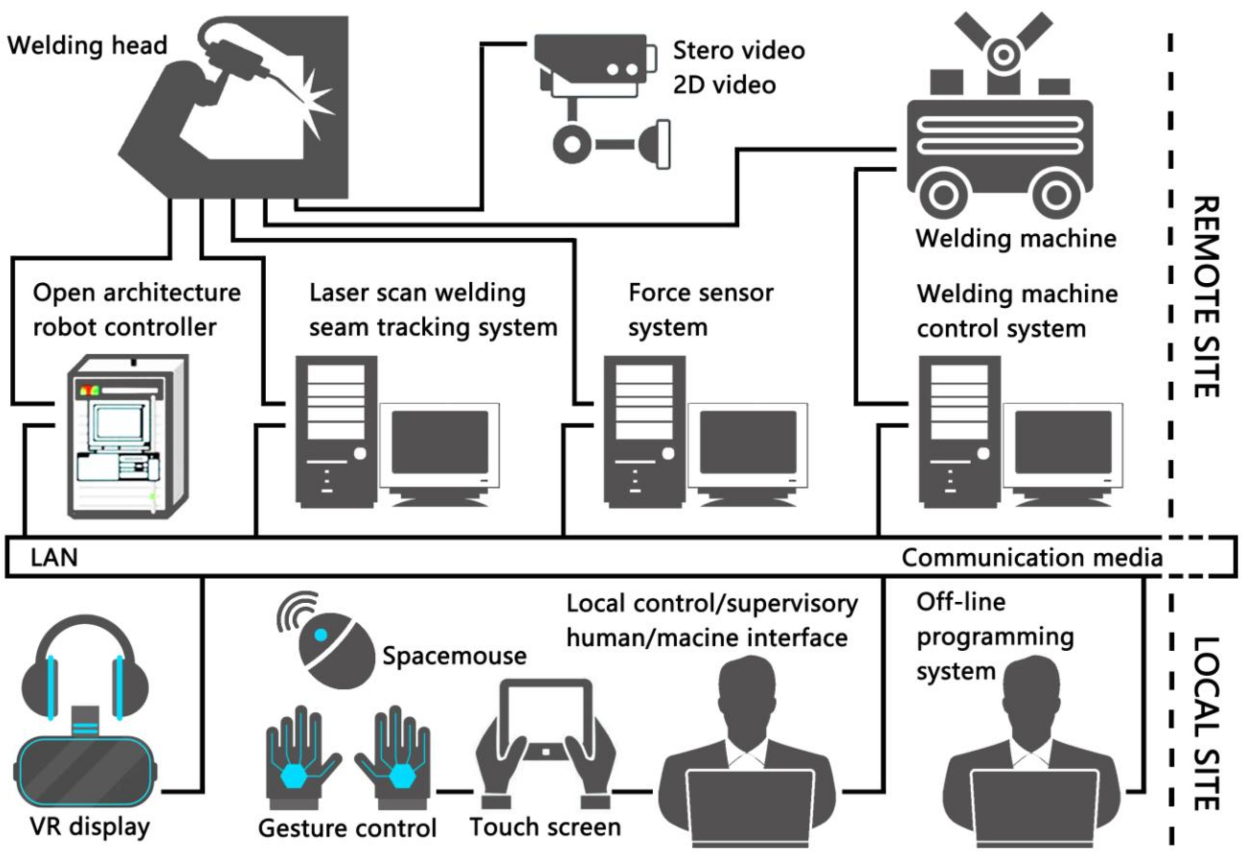

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Fig 1: TRWS Interaction Diagram

As shown in the figure, in a typical tele-robotic welding system, a variety of sensor means such as force sense, vision, distance measurement and seam tracking are applied to the welding body, and the information obtained is effectively transmitted to the operator through computer analysis. In addition, the operator completes the control welding work through the control of the operating platform and the computer auxiliary function, and uses multi-channel information transmission in the whole system. Finally, human, computer and robot work together to complete the operation.Such an interactive structure can extend human's perception and behavior abilities in physical space, connect the remote mobile robot and the operator in a closed loop at the information level, and control the movement of the remote mobile robot in real time, so as to maximize the use of equipment and resources at the far and near end and the intelligence and experience of the operator, thus realizing the optimal allocation of resources and completing specific tasks.Of course, with the development of AI technology, the next step is to realize the full autonomy of the remote robot [10], and the role of the operator is to supervise and guide the normal work of the remote robot.

3.2 Design Cases

Next, a remote control wall climbing welding robot interaction system designed in this subject is taken as an example to carry out specific analysis, as shown in Fig 2.

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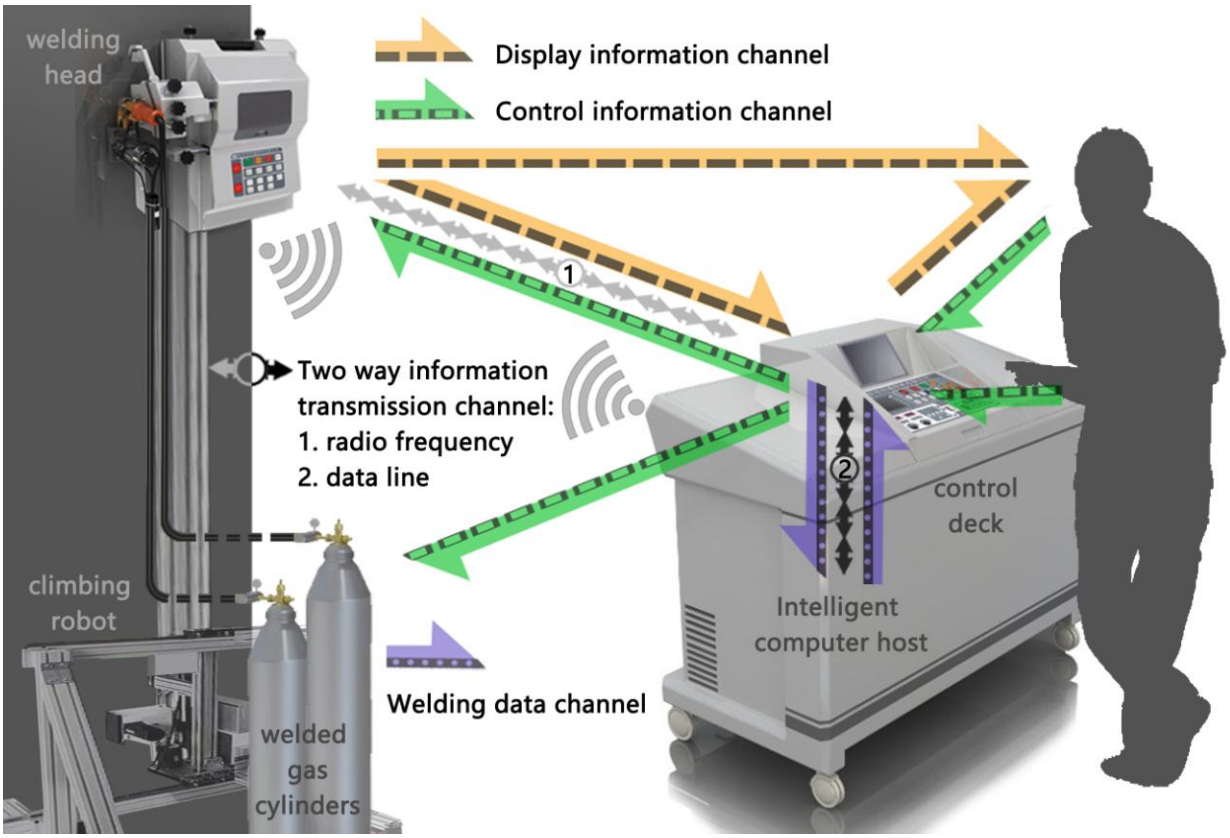

Fig 2: Diagram of interactive system of remote control wall climbing welding robot

In the design of the interaction system of this product, the first thing to consider is that the product entity can be divided into the remote control, the body and the control panel. The tele-robotic welding body also has the functions of welding, wall climbing, detection, control and data transmission. The robot mainly uses the gas welding technique. Considering the light and thermal environment during welding, in order to protect the parts of the mechanism, these parts are integrated into a shell as far as possible in the overall modeling. Meanwhile, considering the operation requirements of the robot such as startup and closing, as well as the operation requirements under various special circumstances, it keeps the direct control interface in the main welding body. In addition, the welding gun installed on one side of the body can change the direction precisely, and the lower connector part of the gun can ensure the continuous welding demand for various raw materials and energy through the gas supply and power supply pipelines. The control panel integrates all TRWS human-computer interaction interfaces into the central control area to make the operation interface as simple and convenient as possible. Display information interface includes display screen and speaker. The control information interface includes keys, touch screen, and voice control. In order to meet the requirement of fine tele-robotic welding operation when encountering special welding parts, a data interface of a connectable wearable display device and an inductive hand-ring type somatosensory interactive

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control device is specially added. The operation platform mainly includes remote control data receiving and signal sending devices, and intelligent computer host with task-level programming.

Next, considering the mode and technology of information transmission, because of the relative complexity of the welding environment and various high temperature and high heat conditions, the information transmission channel between the welding body and the console uses wireless communication technology to reduce various connection pipelines, which further reflects the design idea of maximizing the integration of various human-computer interaction channels. Another reason is that the amount of information that people can receive and process at the same time is limited. Although multichannel technology is used in TRWS structure, the information conveyed by these channels in the final interactive interface should be as concise and orderly as possible.

During the working process, the position and direction information of the robot during crawling can be detected by sensors such as gravity and displacement installed on the crawling parts. Details of weldment and various states of welding process are monitored by sensors such as vision, heat and air composition. Monitoring information is first converted into data signals in a simple processor on the tele-robotic welding body, and then sent to the console receiver by wireless signals for the intelligent computer host inside the console to process and analyze the signals. Finally, combined with the monitoring results, the information that the operator needs to know or handle is displayed through different display interfaces. In this process, the computer first screens and judges the information, and then highlights the important information in the dominant position. The operator can judge and operate the information again, so that the robot can then continuously improve its judgment ability by machine learning which reacts to the operator, which reflects the computer's intelligent assistance to human, and is a typical human-computer hybrid intelligent mode.

The operation information from the operator and the automatic control information from the computer are transmitted to the tele-robotic welding body that is manipulated to perform different operations and handle different situations. In this way, the whole information transfer process forms a closed loop, in which the human and computer work together to control the work of the robot, all of which are attributable to the human-centered hybrid intelligent interactive system.

IV. CONCLUSION

In this study, the interactive system design of tele-robotic welding is designed to best meet the characteristics of human-machine natural interaction, so as to effectively improve the efficiency, effect and safety of operation, with the design idea of human-centered hybrid intelligence. On the basis of human-centerness, advanced interactive technology is fully used to give full play to the assistance of computer intelligence to human intelligence and physical fitness in a simple and natural way. Thus, an interactive system structure of remote control wall-climbing welding robot is designed based on this idea, and has been applied in production practice in combination with enterprise requirements, which also preliminarily verifies the validity of the design ideas and methods proposed in this study.

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