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Design of HCR Interaction System Based on Multimodal Interaction Technology–Take Remote Control Welding Robot as an Example

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Abstract:

In the design of modern robots, the relationship between human and robots should be taken into account to establish an interaction system that allows smooth and efficient information delivery and presents a pleasant interface. Being based on Human Centered Robotics (HCR) theory, this paper combines the theory with the booming human-computer interaction techniques and the computer information process technology, thereby proposing the design of HCR interaction system based on multimodal interaction technology. Besides, the basic model of HCR interaction system is constructed and the thought of how to apply the model to design concrete interaction system is expounded in the paper. Finally, to give an example, we put the thought proposed in the paper into practice to upgrade a remote control welding robot by increasing or changing its information channel and the results are verified by operating tests.

***Keywords**: Human centered robotics, Multimodal interaction,Interaction system design.*

I. INTRODUCTION

Different from other machines, for one thing, robots simulate some human characteristics just as its name implies. For another, robots interact closely with humans. With more extensive application of robots, the human facets of robots call for increasing emphasis in the design of robots. In daily life and in the production process, there are many dynamic and non-structural environment and the tasks demanding cooperation between human and robots, in which the complicated computer-human interactions emerge. Therefore, the design of this kind of robot should focus on the person who interact with it rather than simply considering the robot itself.

The idea is compatible with the Human Centered Robotics (HCR) theory which had been put forward in the 1980s [1,2]. The theory successfully visions the relationship between human beings and robots, emphasizing the human oriented cooperation between people and robots. The cores of the theory are firstly, it's human centered. Humans are the subject of the command and demand of the whole task while robots should sense the environment and the demands of humans, react intelligently, provide corresponding service for humans and serve as the assistants or agents of humans. Secondly, it emphasizes the cooperation between the two. Human intelligence should be fully involved in machine control when performing tasks, while the perception, calculation and the mechanical function of robots is an effective supplement to the physical and mental capability of human beings. The two should fully combine with and complement each other to bring the advantage of mixed intelligence into the fullest extent, thereby fulfilling the tasks which cannot be accomplished by traditional robots and decreasing the complexity of robots designed for specific missions.

The theory has been discussed for more than ten years after its proposal, but how to perfectly apply it to the design of robots has not been figured out yet. That is because when the theory was first put forward, the human-computer interaction and the AI technology were still in the early stage of development, whereas the prerequisite for the realization of the Human Centered Robotics is that the robotic system can implement real-time and exact information transfer, analyze and judge accurately and make responses correctly [3]. Hence, mature interaction techniques and the information processing ability of the computer are the basic requirements for the design of practical HCR system.

In recent years, the human-computer interaction techniques have been developed rapidly which enables the occurrence of the robot conforming to HCR theory. Thus, studying HCR theory and the advanced technologies mentioned above and offering specific design idea of HCR interaction system would have significant value to the current fast-growing robot industry.

II. ANALYSIS AND METHODOLOGY

2.1 The Construction of the HCR Information Interaction System

At present, various interaction techniques obtain speedy development. For instance, the interaction technique that can transfer more abundant information through diversified non-contact interfaces is gradually replacing part of the traditional entitative interfaces [4]. Accordingly, choosing and combining various kinds of interaction techniques rationally will be the major means to achieve fast, efficient and reasonable information transfer in the design of HCR interaction system. To achieve the above purpose, the basic structure of the HCR interaction system should be grasped accurately.

After outlining and analyzing all kinds of human-computer interaction technologies, we summarize the HCR-based interaction relationship between human and machine into a two-way information system model composed of multiple channels, the basic structure of which is shown in Fig 1.

The basic structure of the system includes the information transfer process of two directions. To control robots, the first direction is from human to robot which delivers information that assists robots to judge the diverse behaviors and intentions of the operator. To present

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information to human, the other direction is from robot to human which enables the operator to receive the feedback of the operation and condition. There are multiple ways of information transfer can be chosen in each direction. When designing different sorts of HCR interaction systems, the most befitting technology and corresponding devices and components should be selected according to specific circumstances. Generally, in order to have better interaction effect, multiple information transfer channels are often adopted jointly and complement each other [5]. In this way, each transfer direction consists of many information transmission passages, which respectively adopt particular interaction technologies. During the working process of robots, the information flow forms a closed loop through the two-way multimodal transmission structure, realizing the real-time control and the immediate feedback in the operation. That is the HRC interaction system based on multi-modal technology.

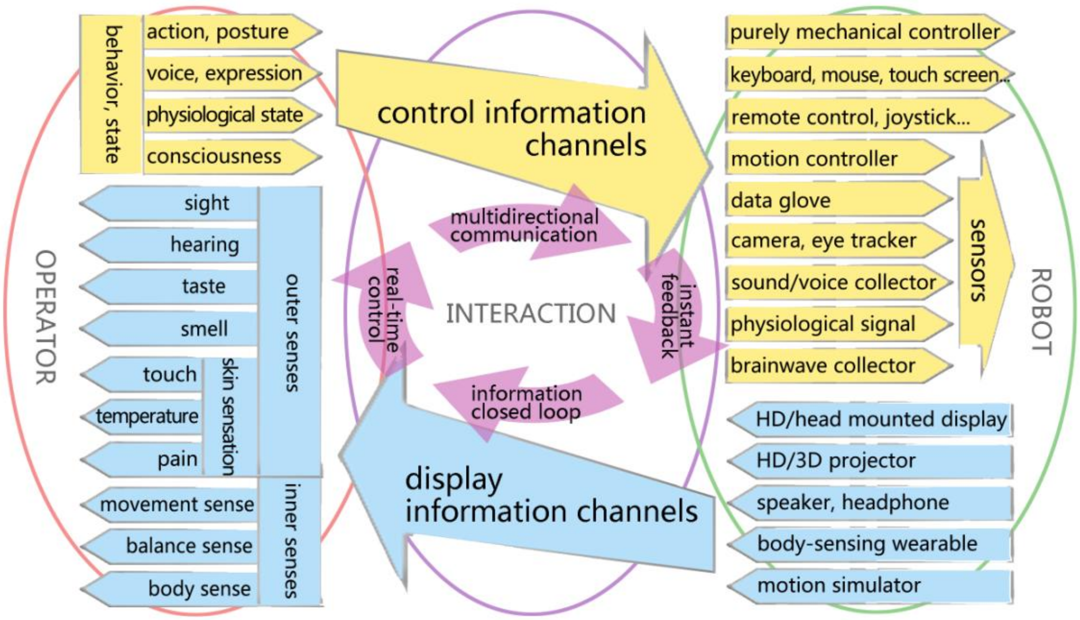

Fig 1: The Model of HCR Information Interaction System

When taking Fig 1 as the reference of the model of HCR interaction system, people should also notice that the forms of the interaction interfaces for operator and robot are different. The interface refers to the part receiving and sending information in an interaction system. From the human side, it implies the body parts that giving out information and the sense organs that receiving messages. And for robots, interaction interface means devices and components which send and accept information. Apparently, the type and the characteristic of human interfaces are more fixed, the comparatively complete classifications of which have been made in Fig 1. In design work of the interaction system, the possibilities of each classification should be taken into consideration. However, the techniques applied to robotic interfaces may change with the development of technology. Thus, in the design of HCR interaction system, the precondition for a reasonable choice of interaction technology is having a good command of mainstream

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technological development and the status quo of technological application.

2.2 The Selection of Interaction Technology for HCR Information System

According to Fig 1, from the perspective of the direction of the information transmission, the optional interaction techniques and corresponding devices can be classified into two categories.

The first category includes techniques that transmit human information to robots actively or passively. Except the primary mechanical button, pull rod, pedal etc., and comparatively mature mechatronic keyboard, mouse, touch screen and handle, contact-type interactive devices operated actively by humans also cover diverse booming wearable devices such as somatosensory control equipment, data gloves etc. The non-contact devices are mainly composed of various components that can receive long-distance transmission signals such as light, radio frequency and sound wave. In terms of control, in addition to the operator's active control through active operation of various controllers, voice commands or gestures, the behavior and intention of the operator can also be detected and analyzed by the machine relying on various sensors, including physiological information monitoring, brain wave recognition, facial recognition, expression recognition, eye tracking, motion capture, posture recognition, etc.

The above technologies should be selected according to the specific situation in the design. Mechanical control is the oldest way, but it has high safety and low cost, which can be used when coming across particular needs. Various mechatronic control methods, including touch screen, are the mainstream currently [6]. Nonetheless, with the enhancement of the judgment ability of HCR interaction system with the aid of machine computing, the speech recognition, gesture recognition and motion capture technology has become increasingly mature, and are applied to the interaction system of new robots progressively. Besides, computer vision technology can also be used for face recognition, expression recognition, eye tracking, etc. In recent years, with the remarkable progress of face detection and face recognition technology, the research hotspot has gradually turned to emotional analysis and physical strength evaluation and other more refined contents. Now, the contact with the human body is still needed for most of the physiological signal monitoring and brain wave recognition technologies. A variety of monitoring technologies of physiological signals such as blood pressure, heart rate, respiratory rate etc. have been widely used in medical treatment, sports and other fields. The measurement and application of brain wave signal is still in the stage of technological accumulation. But it is believed that with the advancement of technology, these technologies can all be used in HCR interaction system in the future.

The other category includes techniques that transfer machine information to human. Except the mature high-definition display screen, stereo speaker, vibration warning device, etc., at present, technologies that are the most concerned and have high practical value and frontier development space mainly include: augmented reality, virtual reality, three-dimensional display and naked-eye 3D technology [7]. For example, in the development of virtual reality

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technology, Japan, South Korea, Europe and the United States etc. have started the basic research on three-dimensional display since the 1980s and developed various technologies and products [8]. Domestic 3D display technology started late, but many scientific research institutions and enterprises have carried out research on three-dimensional display technology and achieved certain results [9]. Right now, in addition to the patented software developed by large enterprises such as EMC, Microsoft, Google etc., there are numerous open-source virtual reality platforms that can be used [10]. In terms of hardware, many enterprises are developing equipment like large projection system, head-mounted 3D image and sound display and so forth [11].

When selecting the corresponding technology, not only should the reliability, maturity, cost and effect of the equipment or components adopting the technology be considered, the role of the information channel in the whole system and its relationship with other channels should also be taken into account. While ensuring the timeliness and accuracy of information transmission, the excessive information receiving from the operator side ought to be avoided as well [12]. In the design practice, the actual interaction effect of the combination modes of different channels are able to be examined and compared by testing, which can be taken as the basis for the final design scheme.

III. CASE DEMONSTRAYTO AND TEST

3.1 Design Case of the Improvement of HCR Interaction System

In previous project, our research group has already designed a remote control wall-climbing welding robot which can be used for complex welding operation in various unstructured environments. It is a typical HCR system, the interactive system interface design of which is illustrated in Fig 2.

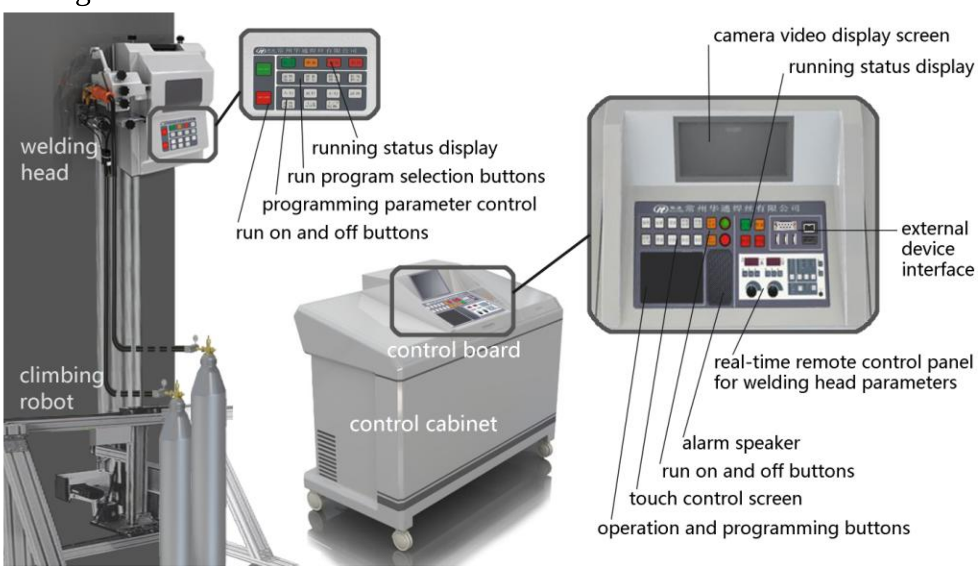

Fig 2: The Interactive System Interface Design of theWelding Robot

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The robot mainly consists of a wall climbing welding body and a console. The operator controls the robot with the touch screen, buttons and welding parameter control panel on the console. Moreover, parts of the function setting buttons are arranged on the welding body, considering the need for close operation during inspection and maintenance. Being detected by the distance, displacement, temperature detector and anti-glare camera installed on the welding body, the signals are transmitted wirelessly and analyzed and processed by the computer. Then, the required information is output on the display screen, indicator light and alarm loudspeaker of the console.

The robot has been put into production and achieved excellent results. However, with the rise of new interactive technologies and devices, we tried to increase or change the original information interaction channel, hoping to further improve the welding quality of the robot. Two changes have been developed in this study. The first is to take advantage of the reserved interface for external equipment on the console to allow the operator to use the external head mounted display to replace the original display screen when operating the welding joint, which makes the picture taken by the camera on the welding body larger and clearer. The other change is to replace the touch screen on the original control panel with a directional joystick. In this way, adding the original interactive interface design, there can be a total of four groups of different interaction modes A, B, C, D, as revealed in TABLE I.

TABLE I. Information Channels Used in Four Interaction Modes

INFORMATION CHANNELS	INFORMATION CONTENT	A	B	C	D
display information	pictures of camera	display screen	display screen	head-mounted display	head-mounted display
control information	movement of welding head	touch screen	joystick	touch screen	joystick

3.2 The Comparison Test and Result Analysis

In order to test the actual effect of the four interaction modes, corresponding experiments are designed. To approach the scene of human-computer cooperation in the actual welding, the experimental site is set in the workshop of the welding robot manufacturer, and the experimental materials are the commonly used 6mm pattern steel in welding. Beforehand, a 350-mm-long line shape with a corner, an arc and two straight lines is designed as the complicated weldment to simulate. Then a total of 120 such lines are cut out on several steel plates with a notching machine. Hang the steel plate on the wall 5 meters away from the operation platform, under the distance of which the operator cannot see the cutting edges clearly by naked eyes and must control the welding with the operation platform. Six skilled workers with more than 3 years of experience are selected as operators for the test. In order to avoid the

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circumstance that the former control mode which operators get familiar with influences the latter, two-day test is arranged every other week, and the order of the four interaction modes used by six operators in four weeks was different. On the first day of the test each week, the operators should learn and practice the robot operation in one interactive mode until they master it. On the second day, each worker welds five prepared slits and numbers each completed welding line. At the end of the four-week experiment, two experts with over 10 years' experience are invited to score the quality of the 120 completed welding lines. Without knowing the operator and the interaction mode used, they only score according to the number. As the standard, the piece with the best welding quality is scored 100 points and the welding line of the worst quality gets 0 point. Then, experts compare and score, and finally calculate the average score of 5 welding lines welded by each method, taking one decimal place. The results are exhibited in TABLE II.

TABLE II. Evaluation of Welding Quality

Interaction Mode	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6	Average Score
A	79.5	79.8	73.1	77.6	67.8	76.4	75.7
B	78.7	83.9	86.2	78.5	83.3	81.5	81.7
C	35.1	41.8	26.9	50.2	29.5	37.7	37.7
D	89.4	93.5	91.2	89.3	87.0	90.8	90.2
Average Score	70.7	74.8	69.4	73.9	66.9	72.3	71.3

It can be suggested that the overall average score of welding quality is about 71 points, which is because we grade the worst of 120 welding lines as the standard of 0 point. From the perspective of the average level, there is no significant difference in the average score for each of the six operators, indicating that the differences of operation level of the six operators are nearly unnoticeable. However, among the four interaction modes, the score of mode C is obviously lower. After studying, the main reason is that the picture outside the helmet cannot be seen when using the head-mounted display in mode C, so workers can only operate blindly while the touch screen is not suitable for blind operation. Mode A also uses the touch screen, but its operational effect is better than mode C, because the screen display on the console is adopted. Therefore, the operator can not only observe the touch screen but also watch the display screen out of the corner of their eyes simultaneously. This phenomenon exactly proves what was mentioned above: when selecting from all sorts of channels, whether the channels can coordinate with each other needs to be estimated. Similar to mode C, mode D adopts a head-mounted display as well, but goes with the joystick which is suitable for blind operation and provides better guidance comparing with the touch screen. Consequently, operators can make full use of the larger and clearer images presented by the head-mounted display. Mode D

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enables the best welding effect among four modes. Meanwhile, it should be noted that the operator looks at the display screen and moves the wall climbing welding robot to the place where welding is needed before wearing the helmet for operation. Strictly speaking, mode D is applied in the welding operation which needs precise positioning, while the process of moving the welding robot to the welding location still calls for mode B. That is why the score of welding line where mode B is employed in the whole process is high, but switching to mode D in welding process gains even higher score.

Based on the analyses above, the means that can effectively improve the quality of work of the original wall-climbing welding robot has been found. On the ground of the original interaction mode, replacing the touch screen with the joystick would help to enhance the welding quality to some extent. Furthermore, installing an external head-mounted display while reserving the display screen on the console and employing the two display modes respectively under different stage of operation can boost the welding quality remarkably. This case attests to the feasibility of the idea and method of HCR interaction system given by the research in this paper.

IV. CONCLUSION

In the design of human-computer interaction system which embraces complicated human-computer cooperation, being tested by the design practice case, the HCR information interaction system model proposed by this research turns out to be an effective tool for design. With the mastery of applicable technologies of diversified interaction channels and the development of devices, designers can flexibly choose the structure of the system provided by the model and establish a HCR interaction system based on the multimodal interaction technology. In the meantime, the relationship between the channels should be noted. Only the wise selection and collocation of relevant technologies and devices can give full play to the performance of the designed interactive system.

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