Retraction Notice

The Editor-in-Chief and the publisher have retracted this article, which was submitted as part of a guest-edited special section. An investigation uncovered evidence of systematic manipulation of the publication process, including compromised peer review. The Editor and publisher no longer have confidence in the results and conclusions of the article.

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Virtual reality painting dexterous hand gesture control algorithm and simulation

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Abstract. With the expansion of the application field of robots and the complexity of the work environment and tasks, ordinary robots and various simple end-holding devices that cooperate with them are far from being able to meet the requirements of various dexterity and fine operation tasks. Immersion means that the process of painting is virtual immersion; the expression requirement for painting must be immersive. This research mainly discusses the posture control algorithm and simulation of dexterous hand in virtual reality painting. The research combines the related theoretical basis of the dexterous hand posture control algorithm with VR painting, and explores the immersive experience characteristics brought by VR immersive painting. This research will focus on the three aspects of the action state pattern recognition based on the surface electromyogram (EMG) signal, the algorithm of the dexterous hand virtual control system, and the simulation of the bionic dexterous hand EMG control system. The collection and processing of the surface EMG signal of the forearm were completed. The experiment verified the effectiveness and accuracy of the surface EMG signal feature extraction, feature dimensionality reduction, and classification algorithm, and realized the pattern recognition of eight action states. Using musculoskeletal simulation software and a finite state machine control model, an intelligent bionic dexterous hand virtual control system was established, which realized offline gesture recognition and performance evaluation of the virtual control system. In the environment of large time delay, many painting experiments were carried out, the tasks were successfully completed, and the average completion time was about 4 min. At this stage, most of the finger structures of dexterous hands are in series, and the accumulated error is large, which greatly affects the accuracy of dexterous hands. VR painting is an innovative form of painting with potential space in the future. The results of this research and exploration can reflect the potential possibilities of future painting creation forms. © *2022 SPIE and IS&T* [DOI: 10.1117/1.JEI.31.5.051422]

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1 Introduction

The artistic style of VR painting is closely related to the subjective characteristics of the artist and the objective characteristics of related themes, including the different contents and forms of the works, and is mainly influenced by the artist's personal subjective aspects and aesthetic needs. The current society has entered the information age, and virtual reality (VR) technology is one of the three frontier technologies of information technology. In recent years, relevant policies have begun to lay out the application research of VR technology, and promote the development of the VR industry with a positive guiding role. The application of VR in the field of robotics is very necessary. The dexterous hand has the characteristics of multiple degrees of freedom, high dexterity, and strong adaptability, and can complete a variety of operational tasks in complex environments.

The dexterous hand painting system simulation based on VR technology realizes a new method of painting production training, allowing users to experience dexterous hand painting

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production and training in a relaxed and real way in virtual scenes and natural interactions, and enhance their understanding of painting art, has far-reaching significance. The artistic styles of VR painting are still diverse, but because the development of VR technology is at an early stage, and VR painting is in an experimental and exploratory stage, the artistic style characteristics of VR painting art diversity have not yet emerged.

For grasping operation, carrying capacity is the core issue, so it is of high research value to improve the carrying capacity of dexterous hands. To improve the carrying capacity of the dexterous hand, some experts have changed the transmission form of the finger mechanism, using gears and link mechanisms for transmission, but the structure is more complicated and the control difficulty is increased. Tactile exploration and grasping planning of dexterous hand robots are usually two separate research fields. Gu et al.[1] discussed determining the best grip configuration after tactile exploration of unknown objects. The tactile exploration information is used to select the initial grasping point and the corresponding robot configuration, which greatly improves the efficiency of the grasping planning process. The feasible search area on the object is obtained under the constraints of maneuverability and robot kinematics. Then, the optimization method based on the k-Nearest Neighbors search is applied to find the best grasping position in the feasible search area. Under the constraints of robot kinematics and maneuverability, he selected the best set of grasping points to achieve high grasping quality. The optimization method he researched combines multiple crawling quality indicators, which is fast and feasible in the search for optimal crawling points. Bastug et al.[2] believe that the concepts of wireless augmented reality (AR) and VR have swept the entire 5G ecosystem, stimulating unprecedented interest in academia, industry, and others. However, the success of immersive VR experiences depends on solving a large number of major challenges that span multiple disciplines. He emphasized the importance of VR technology as a disruptive use case for 5G (and higher) to utilize the latest developments in storage/memory, fog/edge computing, computer vision, artificial intelligence, etc. In particular, it describes the main requirements of wireless Internet VR, and then selects some key driving factors; then introduces the research approach and its potential major challenges. In addition, he reviewed three VR case studies and provided numerical results under various storage, computing, and network configurations. Finally, he revealed the limitations of the current network and provided reasons for more theories and innovations to lead the masses in VR. Lenoir et al.[3] investigated the current situation of rural centralized water supply disinfection in Sichuan Province, mastered the disinfection capacity and drinking water quality of centralized water supply units, and provided a basis for the development and management of rural centralized water supply. He investigated the water disinfection of 2067 rural centralized water supply projects in 183 counties (districts and cities) in 21 cities in Sichuan Province. According to the "Drinking Water Standard Test Method" (GB/T5750-2006), the microbial indicators (total number of bacteria, total coliforms, and fecal coliforms) and disinfection index (free chlorine or chlorine dioxide) of treated water and tap water samples) water is detected. As a result, in the 2607 centralized water supply projects, small projects accounted for the majority. Dascal et al.[4] evaluated the evidence supporting the use of VR in patients in acute hospitalization settings. He conducted a systematic review of randomized controlled trials that examined the use of VR in hospital settings from 2005 to 2015. He uses PsycINFO, PubMed, and Medline databases to determine the keywords VR, VR therapy, treatment, and inpatients. He identified 2024 citations, 11 of which met the inclusion criteria. The research involves three general areas: pain management, eating disorders, and cognitive and sports rehabilitation. The research is small and heterogeneous and uses different designs and measures. VR is usually well tolerated by patients, and most studies have proven clinical efficacy. According to the evaluation indicators developed by Reisch, Tyson, and Mize, the quality of the research is different. Tromp et al.[5] believe that when understanding language, often doing this in a rich environment, many clues can be used to understand what someone is saying. However, it has traditionally been difficult to design experiments with rich three-dimensional (3D) context similar to our daily environment, while maintaining control over available verbal and nonverbal information. Here, test the effectiveness of combining electroencephalogram (EEG) and VR to overcome this problem. In a well-controlled 3D virtual audio-visual environment, the brain electrical physiological activities in the process of language processing are recorded. Participants wore EEG equipment to immerse themselves in the virtual restaurant. In the restaurant, the participants met the guests of the virtual restaurant.

Each guest sits at a separate table with an object on it. Tanwani and Calinon[6] studied the semi-bound Gaussian mixture model for robust learning and adaptation of robot operation tasks. Instead of estimating the complete covariance matrix of each cluster in the mixture, he exploits the spatial and temporal correlations in the data by linking the covariance matrix of the mixed model with a common coordination direction/basis vector. This allows for the reuse of discovered synergies in different parts of tasks with similar coordination patterns. We extend the method to task parameterization and hidden semi-Markov models to automatically adapt to changing environmental conditions. The planned motion sequence in the model is smoothly followed by a finite horizontal linear quadratic tracking controller. The experiment of encoding the whole-body motion data in the simulation, followed by valve opening and picking and placement of obstacle avoidance tasks by the Baxter robot, shows that the improvement of the standard Gaussian mixture model has fewer parameters and better generalization ability. Combining the characteristics of parallel mechanism with high stiffness, strong bearing capacity, and small cumulative error, a dexterous hand with parallel structure is proposed. This method also improves the bearing capacity of the dexterous hand. The multifingered dexterous hand solves the various problems of the single-degree-of-freedom gripper, making the robot more flexible and enabling more precise operations. Each finger of a multifingered hand is equivalent to an independent micro-robot with multiple degrees of freedom, so that precise manipulation of different types of objects can be achieved by coordinating the mutual movement of the fingers. However, the use of multifingered hands at the same time increases the complexity of the entire system. The use of motor drive and artificial muscles, tendons, etc. for transmission reduces the weight of the fingers, but also reduces the accuracy and carrying capacity of the dexterous hand, making it unsuitable for heavy-load and high-precision occasions.

The intelligent bionic dexterous hand system is a complex electromechanical combined system, and it is difficult to analyze a certain core problem on a physical prototype. In this paper, an intelligent bionic dexterous hand control model is established in a highly simulated virtual environment. It can not only effectively avoid the impact of the physical prototype on the motion accuracy due to its own processing and assembly errors, but also reduce the investment in related manpower and material resources, and shorten the experimental period. It reduces experimental cost and improves experimental efficiency. It also provides a new simulation system and graphical interface for electromyogram (EMG) signal gesture recognition, which becomes an effective means to test the bionic dexterous hand control system. VR painting works will reflect the social nature of this era from the individuality of the artist, and reflect factors such as cultural characteristics and national characteristics.

2 Research Method of Dexterous Hand Posture Force Control Algorithm

2.1 *Structure Design of Flexible Composite Finger Driver*

A hinge, also known as a hinge, is a mechanical device used to connect two solids and allow relative rotation between them. The whole actuator can be regarded as a rigid metacarpal structure, hinge joint, and soft finger bone composite structure composed of three parts. The rigid metacarpal structure, as the hardest part of the flexible composite finger wheel, can be regarded as a hinge joint. Through the design and manufacture of 3D printing technology, the connection between the composite structure of the flexible finger is based on the characteristics of finger ratios of different sizes, retention slots, and holes: by connecting the hinge joint to the shaft of the rigid structure of the middle bone, which is also designed by 3D printing, the hinge joint is characterized by a simple structure. As one of the general mechanical structures, the hinge is driven by a set of independent spinal muscular atrophy (SMA) shuttle system, which enables the finger and bone to move relative to each other, and the biomimetic hand joint movement. 3D printing is a type of rapid prototyping technology, also known as additive manufacturing. It is a technology that builds objects by layer-by-layer printing based on digital model files and using bondable materials such as powdered metal or plastic.

Table 1 Joint size of flexible humanoid dexterous hand.

Finger name	Metacarpal length (mm)	Finger bone length (mm)	Total length (mm)	Length ratio
Index finger	73	83	156	1.14
Middle finger	70	97	167	1.34
Ring finger	61	92	153	1.50
(Little) thumb	58	72	130	1.24

The flexible phalangeal composite structure is used as the driving unit of the drive. In the design, the muscular system structure of natural animals is used for reference. Based on the original work, the existing flexible phalangeal composite structure is summarized and optimized. The middle embedded plate divides the flexible phalangeal composite structure into two parts, one part is fixed on the rigid metacarpal structure, and the main movement function is realized by the other part. The entire structure is driven by SMAs. To achieve greater deformation performance, the number and location of alloy wires need to be planned reasonably. The function of the elastic plate is to restore the flexible phalangeal composite structure to the initial position during the cooling process of the SMAs after the SMAs driving mechanism is deformed. The joint dimensions of the flexible human-like dexterous hand are shown in Table 1.

Therefore, in the dexterous hand teleoperation system of this article, the output of the base joint torque sensor and the knuckle torque sensor is used to calculate the fingertip force F[7]

$$F = J_F^{-T}\gamma, \tag{1}$$

where JF is a 3×3 finger force Jacobian matrix.[8,9]

It can be deduced from the geometric relationship

$$d = f\frac{a+l}{l} = \frac{bf}{l_a - l_b}. \tag{2}$$

The horizontal viewing angle is defined as the angle β, which is derived from the geometric relationship[10]

$$l_a - l_b = 2d\,\tan(\beta/2). \tag{3}$$

Therefore, within the scope of this work[11]

$$\beta = 2arctg\left(\frac{l_a - l_b}{2d}\right). \tag{4}$$

Control system design: The active vision platform is used to track human head movement in real time, so it needs to have better start-stop characteristics and higher control accuracy. This article uses Maxon DC brush motor, which can be realized at both high and low speeds. The high-performance servo control card HIT6503 based on the internet security and acceleration bus developed by our institute and the motor form a high-precision position servo system, and the proportional integral derivative (PID) and speed feedforward controller are used. The high precision requirements are shown in Table 2.

Table 2 High precision requirements.

Degree of freedom	Horizontal rotation	Pitch motion
Maximum speed	190 deg/s	190 deg/s
Maximum acceleration	1215 deg/s^2	1215 deg/s^2
Precision	0.8 deg	0.9 deg

2.2 *EMG Control of Virtual Bionic Dexterous Hand*

2.2.1 *Musculoskeletal virtual reality software MSMS*

This paper uses muscle skeleton modeling software (MSMS) to establish a five-finger bionic dexterous hand model. MSMS is a high-precision musculoskeletal simulation software that can be used for 3D modeling and motion simulation of human prostheses and virtual environments. It can independently complete the interactive control of the neural control system and the human body model.

The virtual process model of MSMS is connected to other process components of the actuator to realize the dynamic simulation of the model and the real-time simulation of the virtual environment, and the virtual animation can also be demonstrated in online or offline mode. MSMS can send and receive data through the user datagram protocol port to realize real-time control of the virtual system.

MSMS virtual modeling software is not only compatible, but also can import 3D modeling files based on Blender, OpenSim, SolidWorks, etc. In addition, Simulink simulation models can be generated directly. The whole simulation process is a closed-loop system with periodic adjustment. The output of the Simulink control system of MATLAB is the input signal of MSMS, which is used to control the virtual dexterous hand model based on MSMS. At the same time, the output signal of MSMS is provided to the Simulink module as the input signal of the controller. In this article, the Simulink simulation module based on the MSMS system generates the Simulink simulation system of the virtual bionic dexterous hand model.

The driver is placed inside the dexterous hand or directly placed at the finger joints to drive the finger joints of the dexterous hand to move flexibly. The hardware structure of the dexterous hand controller also adopts a built-in method. The drive controller is placed inside the dexterous hand or at the joints of the fingers to directly drive the joint drivers of the fingers. The sensor system is also integrated with the dexterous hand or finger, the signal processor is placed near the sensor to collect and process the signal, and the signal is transmitted to the main controller through the high-speed communication system. The main controller can be placed inside or outside the dexterous hand to perform a real-time operation of the control algorithm. The target dynamics of the finger joints are described by the second-order differential equation [12]

$$\kappa = M(\theta_d - \theta_m) + B(\theta_d - \theta_m) + K(\theta_d - \theta_m), \tag{5}$$

where M is the target inertia of the impedance control system, and B is the target damping of the impedance control system.[13]

To achieve a smooth transition of the finger from free space to constrained space, the selection of target impedance parameters must first follow the following principles:[14]

$$\chi = B/(2\sqrt{K_d M}), \tag{6}$$

$$K/K_d \geq 1, \tag{7}$$

$$\chi \geq 0.5(\sqrt{1+2\mathrm{k}}) + 1. \tag{8}$$

Since in the actual control of a multifingered dexterous hand, only diagonal elements in the M and K matrices have actual effects on the control process, so the following diagonal damping term design can be used:[15]

$$D(\theta) = 2\chi(\mathrm{MK})^{-\frac{1}{2}}. \tag{9}$$

2.3 *Grabbing Sequence Planning*

In a dense scene, objects are arranged in a different distribution in the workspace, and each object in the field of view is successfully captured. This involves the problem of the capture order. How can the objects in the dense scene be more efficient? The crawl was successful. To solve this problem, this paper proposes a capture selection method based on the deep Q network, according

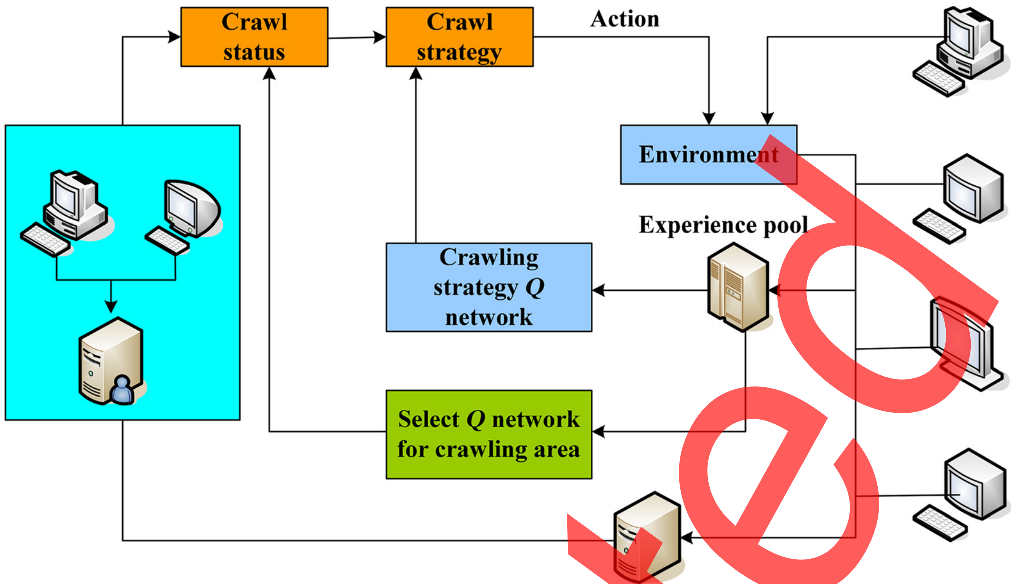

Fig. 1 Grab selection method based on deep Q network.

Table 3 Selected sensor performance parameters.

Sensitivity	0.6442 mN/N
Nonlinear	<0.1 %F.S
Hysteresis	<0.1 %F.S
Repeatability	<0.1 %F.S
Zero temperature drift	+1 %F.S
Creep	≤ 0.1 %.F.S/30 min
Range of working temperature	−20 ~ 60C

to the pixel Q value mapping value of each object obtained by training and learning in the deep Q network, and then the maximum value of each object in the scene Q value is compared, and the object with the largest pixel e value mapping value is selected, and the robot completes the grasping action according to the maximum mapping value of the object. By analogy, the robot will grab all the objects in the scene until it is finished. The grab selection method based on the deep Q network is shown in Fig. 1.

In the end force measurement of the flexible multifinger human-like dexterous hand each flexible composite finger driver, the driver responds quickly, and the output result is small. In this paper, the S-type tension and pressure sensor EVT-10C produced by Sensing Technology Co., Ltd. is selected. The sensor is made of alloy steel and stainless steel, suitable for tension and compression purposes, with high accuracy and stable performance. The performance parameters of the selected sensor are shown in Table 3.

2.4 *Hierarchical Control of Local Autonomous Grasping Operation*

The upper control can also be called the grasping planning layer, which mainly uses the grasping operation experience of the operator to guide the grasping of the heterojunction with intrinsic thin-layer/dynamic language runtime dexterous hand. In this layer, first, the operator uses the grasping experience to determine the grasping category of the dexterous hand according to the grasped object and task description; then, according to the grasping category, determines the

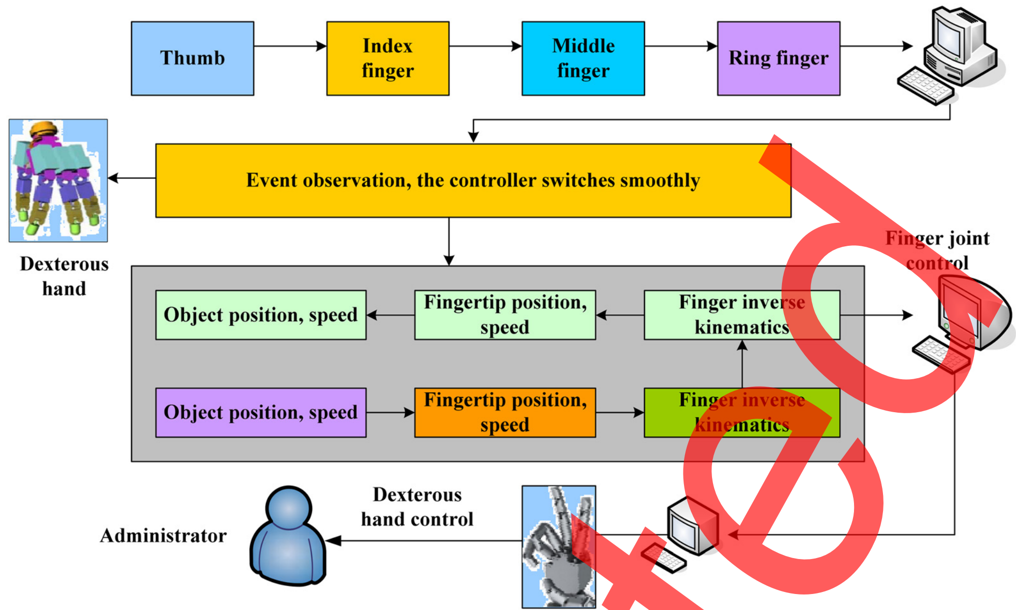

Fig. 2 Hierarchical control process.

corresponding pregrabbing posture of the dexterous hand; finally, based on the experience and knowledge precontact point determines the corresponding position of the dexterous hand and the object. The bottom-level control mainly includes the local autonomous finger motion planning and fingertip force planning of the dexterous hand, and according to the different stages of the grasping operation, the corresponding finger controller is designed to complete the free space movement, contacting the grasping object, and operating the object in three stages task. The middle control layer is mainly to design a system observer to monitor the trigger events of each stage in the operation of the dexterous hand, and determine the switching of the finger controller according to the trigger event. The hierarchical control process is shown in Fig. 2.

2.5 *VR Dexterous Hand Drawing Module*

VR painting uses two handles to replace brushes and hand-painted pens. Take Google's TiltBrush application as an example. After entering the software, the left-hand handle will virtualize a cube menu. By sliding the handle on the touchpad to rotate the cube, you can choose different tools to generate brush strokes. Select and adjust the color and overall painting style at the same time. According to the needs of the picture style, you can switch various different brushes at will. In addition to static brush strokes, the tiltbrush tool also includes rainbow (Rainbow), luminous band (Streamers), and dynamic effect brushes such as Snow, these brushes are also pressure-sensitive.[16]

Human-machine interface subsystem: The interface between the task planning layer and the control layer can be the joint layer, the fingertip Cartesian space layer (TCP), and the object operation space layer. The corresponding control layer control strategies are joint control impedance control, Cartesian space fingertip impedance control, and multifinger object layer space coordinated impedance control with object attitude and position as the control target.[3,17]

Visual feedback and standard stator system: The actual environment video image is collected by the on-site global binocular vision system and hand-eye vision system, and fed back to the operating terminal. The calibration part mainly uses visual information to calibrate the position of the operated object.

Remote actual robot subsystem: consists of remote robot, sensor system, global camera, hand-eye system, and working environment.

Large delay communication subsystem: The communication system has two channels, the former channel mainly transmits the control information of the remote teleoperation robot, and the latter channel mainly feeds back the robot's pose information, force and torque information, and video information. In the two channels before and after the simulation of the space robot operating environment, the use of data buffer technology to achieve a delay of 3 s, the total loop 6 s of large delay communication.[18]

3 Simulation Results of Dexterous Hands

In this paper, a simulation test experiment for grasping cones, spheres, and ordinary objects in V-REP is carried out. Each test is carried out 30 times. The position and posture of the objects are random each time. The final experimental result is shown in Table 4.

In the experiment, there are a total of three operators, and each operator performs 10 experiments. In 30 experiments, the operator can accurately judge 28 times, with an accuracy rate of 93.3%. The result of a force feedback experiment after the index finger of a dexterous hand is in contact with two balls of different stiffness is shown in Fig. 3. The left side is the movement angle of the base joint of the index finger. A certain distance of continued movement, so the angle of joint movement is larger than the angle of movement when it is in contact with the tennis ball, but the completion time is the same. The right one is the fingertip force feedback. It can be seen that the fingertip contacting with the foam ball has a small feedback force and the curve is relatively smooth. The fingertip contacting with the hard ball has a large feedback force and a steep curve. The two force feedback curves are continuous and smooth.

Table 4 Final experimental results.

Object	0.6442 mN/N
Small cone	78%
Big cone	79%
Small ball	97%
Big ball	98%
Cuboid	100%
Cube	100%

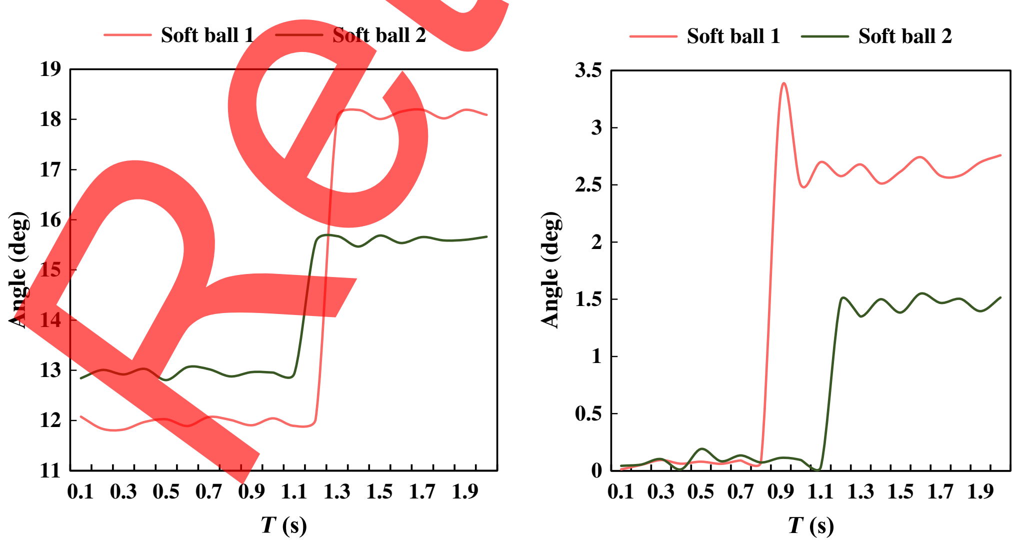

Fig. 3 Result of a force feedback experiment after the index finger of a dexterous hand is in contact with two balls of different stiffness.

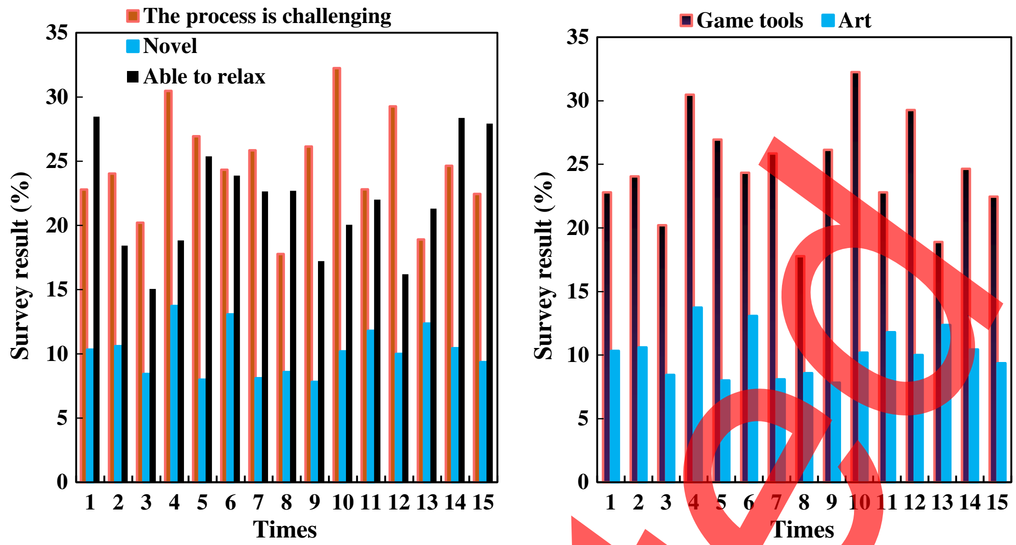

Fig. 4 Understanding of VR painting.

Among the interviewees, 79 people think VR painting is a type of game tool, accounting for 57.9%, and 41 people think VR painting is a form of artistic creation, accounting for 33.9%. This set of data shows that In terms of public cognition, VR painting is mainly used as a game to provide people with an entertaining experience. The public, respectively, believes that the reasons for VR painting as a game are the process is challenging (33.3%), novel and fun (30.3%), and the ability to relax and regulate emotions (27.3%). This reflects that VR painting should be used during the appreciation experience. Pay attention to the interaction with the audience to meet the psychological expectations of the audience. The understanding of VR painting is shown in Fig. 4.

Under the 6-s long-delay simulation communication, the dexterous hand system is used to move from the initial state to the place where the tool is placed. After drawing on the drawing board, the robot system returns to the initial position. In the environment of large time delay, many painting experiments were carried out, the tasks were successfully completed, and the average completion time was about 4 min. The dexterous hand drawing is shown in Fig. 5.

In the user experience test of the painting virtual system, a questionnaire survey was conducted on the experience of 30 users. Among the 30 users who participated in the test, 18 were boys, 12 were girls, and 30 users had learned sand painting gestures before or mastered painting gestures for this system test. Statistics on the speed, coordination, aesthetics, and completeness of the system is made. From the analysis in Fig. 6, the system can meet the painting needs of

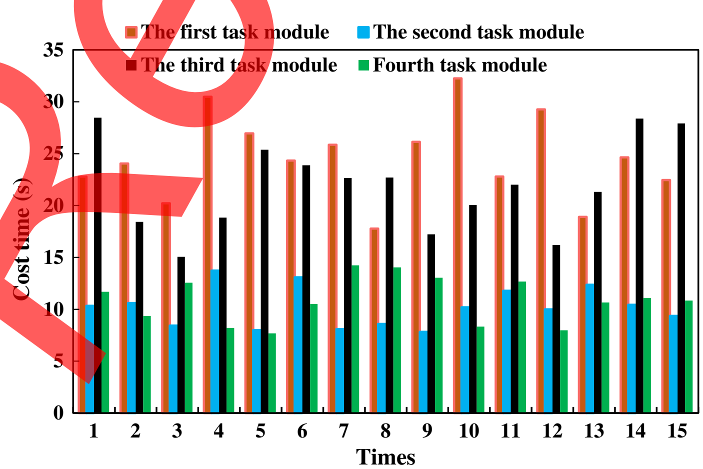

Fig. 5 Time to draw with dexterous hands.

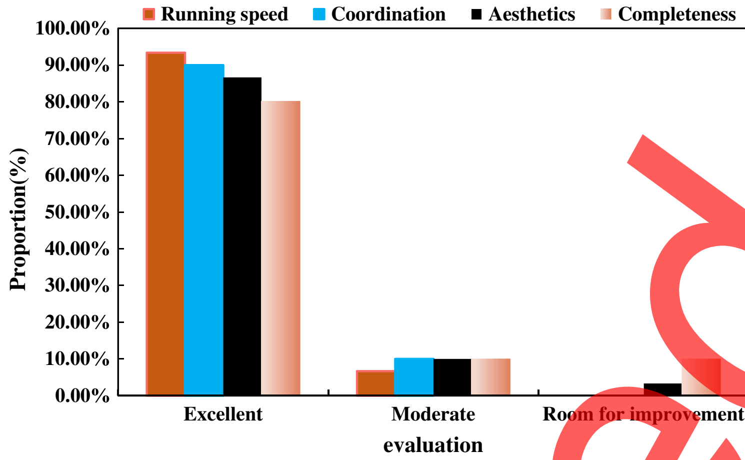

Fig. 6 Survey and test results of the painting virtual system.

virtual painting in terms of operating speed, coordination, aesthetics, and completeness, but the system needs to be greatly improved in terms of aesthetics and completeness. Coordination also needs to be improved. The survey and test results of the painting virtual system are shown in Fig. 6.

4 Discussion

VR painting is essentially a kind of "virtual immersive painting." Immersion is a very important value of VR painting. It is mainly monitored by sensors such as vision, hearing, and touch in the VR headset, so that the experiencer is inserted into the virtual environment. Excellent VR painting works must create a very good immersive experience, while some VR painting works do not really attract the audience, and even make the audience negatively resistant, which is the result of the creator's insufficient understanding of immersion.[19,20]

In recent years, with the continuous innovation and maturity of robotics technology, the application of robotics has been enriched and the opportunities for application have continued to expand. More and more robots appear in different industries and gradually enter people's daily lives. As an efficient machine that performs complex operations at the end, mechanical dexterous hands have attracted more and more attention from scholars. Under complex task conditions, compared with previous industrial robots that also have end effectors, manipulators with high flexibility and universality and a wide range of operating tasks have stronger applicability. The factory can be combined with the robot's own operating system. This research first gives a comprehensive introduction to the definition of painting, painting environment, painting posture, etc. Next, I will briefly introduce many problems in the development of painting, the emergence of outstanding painting artists and their representative works in recent years, and the current status of painting development. In addition, it also includes the research history and research results of computer simulation painting technology and multitouch technology.[21]

In the research based on rigid palm dexterous hand grasping, scholars generally focus on how to use arm motion planning to move the end effector, namely the rigid palm, to a specified position, and finally complete the grasping action through finger movements. For traditional mechanical dexterous hands, its flexibility is reflected in how to improve the layout of the fingers and increase the extra freedom of the fingers. This design method does not break through the design limitations of the palm as a rigid structure. The completion of the movement of the dexterous hand limits the grasping flexibility of the dexterous hand after reaching the predetermined grasping position.[22,23]

Regardless of whether the environment is dangerous or complex, the robot can better adapt to a variety of complex and subtle operating tasks. Therefore, the end effector needs to have good dexterity. The intelligent robot system represented by mechanical legs and mechanical dexterous hands has become the most advanced technology in the field of robotics engineering. Moreover, the human hand is the most flexible, and many robot enthusiasts have conducted research and analysis on its dexterity. To meet the needs of the times and work, the multifinger dexterous hand that imitates humans was born in this era. This research proposes a manipulator control platform oriented to flexible operation tasks. Smart hand-controlled operation requires a simple and friendly operation connection interface, which is various.[24]

Now, dexterous hand robots are also increasing in the fields of energy development, expansive space exploration, disaster relief, engineering, and construction. Other industrial industries also have dexterous hands. In these fields, compared with previous manufacturing procedures, robots must have the ability to operate flexibly in response to various emergencies due to the huge changes in objects and environments. Moreover, due to the development of dexterous hands, robots can do more work instead of humans, making work more concise and efficient. The use of human-like dexterous hands continues to expand in the fields of production and manufacturing. For example, a human-shaped dexterous hand is installed at the end of the robot to replace tasks in a toxic, high temperature, dangerous, and harsh environment, and to perform difficult operation tasks. The traditional robot with dexterous hands installed at the end of the machine device has a simple structure and simple control. However, facing the changes in complex environments such as homes, factories, hospitals, etc., a robot composed of a single scene cannot meet the production requirements.[25]

The current human-like dexterous hands ignore the design of the two degrees of freedom structure of the dexterous wrist swing. The design of the traditional industrial robot wrist is generally two degrees of freedom in series, so the transmission error is superimposable, and the size of the mechanism is large. In this paper, the two swing degrees of freedom are connected in parallel. From the level of mechanical structure, two-degree-of-freedom transmission without interference is realized, which improves the reliability of wrist structure transmission and reduces the size of the dexterous wrist. To realize the multifinger grasping operation of human-like dexterous hand, its kinematics and dynamics analysis is one of the most basic problems. Because finger kinematics describes the mapping relationship between finger joint space and Cartesian space, the range of motion space of a dexterous hand can be analyzed with the help of kinematics; finger dynamics is to describe the relationship between the motion and force between the finger and the object, through dynamic analysis driving torque required by the dexterous hand under load can also be obtained. To adapt to various application scenarios, the humanoid dexterous hand mainly needs to meet two requirements. On the one hand, the dimensions, mass, finger structure, and degree of freedom of the human-like dexterous hand need to be optimized to ensure that the human-like dexterous hand can have excellent grasping and operating functions for objects of any shape.[26,27]

5 Conclusion

This research analyzes a teleoperation control framework based on VR technology, designs and implements a long-delay teleoperation system for dexterous hands based on VR technology, including virtual environment modeling, position calibration of visual virtual environment models, and points segment compound control method, man-machine interface design, reconstruction of virtual scene, etc. Explore the media changes of painting art, combine the characteristics of VR technology tools and immersive experience, analyze the feasibility of VR painting, and provide theoretical support for the practical creation and exploration of VR painting. Through the analysis of the related cases of VR painting, it explores the creation method of VR immersive painting, which is used to guide the successful completion of research and creation. In future research, hope to further deepen the algorithm research of the intelligent bionic dexterous hand control system, and use the forearm surface electromyography signal to establish a drive system to realize the real-time control of the intelligent bionic dexterous hand.

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