Virtual display of intelligent human-computer interaction products based on attention matrix

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Abstract: In order to solve the problems of low accuracy and poor effect of gesture recognition in traditional virtual display methods of intelligent human-computer interaction products, an advanced virtual display method of intelligent human-computer interaction products based on attention matrix was proposed. Process involves to determine the NUI interaction mode, select the appropriate motion sensing interaction device Kinect and use this device for gesture recognition. The information of intelligent human-computer interaction products such as gesture recognition results is saved through array. The attention matrix of intelligent human-computer interaction products is established, the virtual display model of intelligent human-computer interaction products is constructed combined with the change of viewpoints, so as to realise the virtual display of products. Experimental results show that the accuracy of the proposed method can be maintained above 80% for difficult gesture recognition, and the accuracy of simple gesture recognition can reach 100% and the virtual display effect of products is good.

Keywords: attention matrix; intelligent human-computer interaction; product virtual display; somatosensory interactive equipment; array.

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1 Introduction

Internet technology emerged in the mid-1990s. It aims to achieve comprehensive information sharing through reasonable and effective integration of scattered internet resources, so that all audience groups can obtain the required information transparently and openly and use it reasonably. This technology also promotes the further development of somatosensory interaction technology and product display design (Petrick, 2020). Somatosensory interaction technology means that users can directly use body movements to interact with the surrounding devices or environment without using any complex control devices. Gesture recognition is an important means for users to interact with the environment. It mainly means that users can use simple gestures to control or interact with the device, let the computer understand the human behaviour, so as to improve the user's experience and make the user have a more comprehensive understanding of the product (Klumpp et al., 2019). In this context, the birth of intelligent human-computer interaction products, in order to improve user experience, the need for intelligent human-computer interaction products for virtual display, so the study of a virtual display method of intelligent human-computer interaction products has very important research significance (Hazer-Rau et al., 2020).

The research on the virtual display method of intelligent human-computer interaction products has made some progress, in order to improve the user experience and product sales (Li et al., 2020). For example, Liu, S. and Xia (2019) proposed a virtual display method of intelligent human-computer interaction products based on Web environment. This paper analyses the commonly used product virtual display technology and design tools, and puts forward the virtual display method of intelligent human-computer interaction products in web environment. On the web browser side, the three-dimensional model and two-dimensional engineering drawing of the product are displayed through ActiveX control, and rotation, translation, zooming and other operations are allowed. At the same time, by calling the secondary development interface of three-dimensional CAD software such as Solid Edge, the online driving of products is realised, so as to realise the virtual display of intelligent human-computer interaction products. However, the accuracy rate of gesture recognition is low, and the actual application effect is not good. Wu et al. (2018) proposed a virtual display method of intelligent human-computer interaction products based on virtual reality technology. This method discusses how to use virtual reality technology to establish a virtual environment for product display and customisation on WWW, and describes in detail the implementation methods and technologies of the article model, spatial relationship model and network communication model in the virtual environment involved in the system development, In order to realise the virtual display method of intelligent human-computer interaction products, but after the application, it is found that the virtual display effect of the method is not good. Mou (2018) proposed a design method of virtual display system for intelligent human-computer interaction products based on gesture recognition is proposed. Firstly, the gesture and its motion information obtained by Leap Motion device are used, and the feature vector based on corner domain division is extracted, and the feature vector is used for gesture recognition and tracking. Then, 3Ds Max technology is used to build the virtual hand model, and Unity 3D software is used to display the intelligent human-computer interaction products. However, the accuracy of gesture recognition is low, and the actual application effect is not good.

This article in view of the current market the present situation of the interactive experience, fully analysing the characteristics of virtual reality technology and limitations, and the product awareness and gesture recognition to consider, as the key to solve the problems existing in the traditional methods, improve product virtual display effect as the research target, this paper proposes an intelligent human-computer interaction based on attention matrix product virtual display method, This method has the characteristics of high accuracy of gesture recognition and good virtual display effect of products. The overall technical route of this method is as follows:

1) Determine the NUI interaction mode, select the appropriate motion-sensory interaction device Kinect and use the device for gesture recognition to save the gesture recognition result and other intelligent human-computer interaction product information through Array.
2) According to the saved information, the attention matrix of intelligent human-computer interaction products is established, and the virtual display model of intelligent human-computer interaction products is constructed with the change of viewpoints, so as to realise the virtual display of intelligent human-computer interaction products.
3) The accuracy of high difficulty and simple gesture recognition of the method in this paper and the effect of virtual display of products were tested through simulation experiments.

2 Virtual display method for intelligent human-computer interaction products

2.1 User gesture recognition based on motion sensing interactive devices

Human-computer interaction has gone through a long process of development and has been widely used in practice so far (Brinkley et al., 2019). People can use movement, gesture and body posture to issue commands to the device of somatosensory interaction, so as to achieve more efficient somatosensory interaction (Maloca et al., 2020). Not only that, the technology can also be used in mobile devices, such as switch songs and adjust the screen, with the gradually mature of the technology and the rapid development of computer technology, other body feeling interactive technology will gradually tend to be perfect, to change people's life in a more intelligent way, provide a better user experience for people (Brivio et al., 2020).

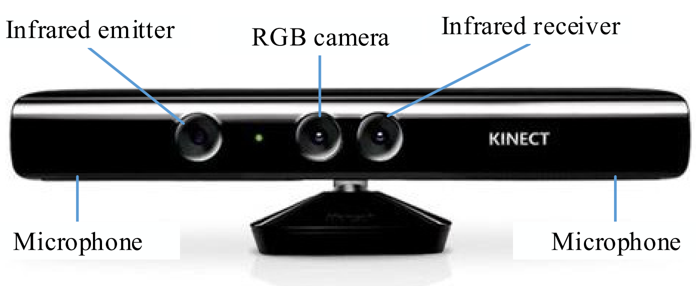
Figure 1 Sensory interactive game

Gesture is a means of interaction in line with the daily habits of human beings. In daily life, people's communication is usually supplemented by gestures to convey some information or express some specific intention. Gesture technology has been widely applied to VR and AR fields, and has gradually attracted the attention of scientists and researchers. Gesture products have also been gradually applied to health, medical and other fields (Zibrek et al., 2020).

Until now, data gloves have been able to accurately pick up sensing information to recognise gestures, but wearing them at the same time has been a hassle for operators. Therefore, the study of natural hand becomes the trend of gesture recognition in the future. Visual-based gesture recognition is to collect images or videos by one or more cameras, and analyse and recognise gesture information by video image processing method. Characterised by markless, contactless gesture recognition. Besides, there are no conditions attached to human's natural hands, so that human-computer interaction tends to be more natural. Besides ordinary cameras, human-computer interaction information can be collected through cameras, such as the depth camera released by Microsoft Kinect.

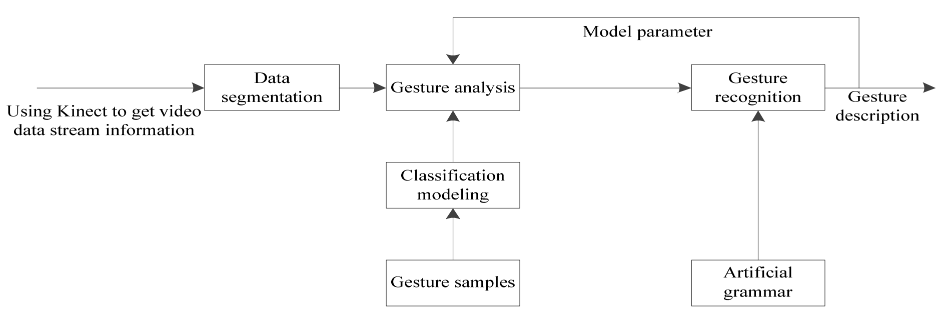
Therefore, according to the above analysis, Kinect is selected as the basis for gesture recognition in the virtual display of intelligent human-computer interaction products in this paper. It is a 3D motion-sensing camera with various functions, such as real-time dynamic capture, image resolution, speech recognition, group interaction, etc., and users can also communicate with other users on the internet platform (Gabriele and Lamberti, 2021). The specific structure is shown in Figure 2.

Figure 2 Kinect structure diagram



Kinect has been widely used in various fields due to its good interactive experience and high degree of equipment (Guzsvinecz et al., 2021). The overall architecture of gesture recognition based on Kinect is shown in Figure 3.

Figure 3 Overall architecture of gesture recognition based on Kinect



The process of gesture recognition based on Kinect is as follows: firstly, the video data stream information is obtained through Kinect. Then, if it is for static gestures, these information flows need to be processed to determine whether there is a static gesture, while for dynamic gestures, it needs whether the gesture has started or ended. If there is a gesture, the gesture should be segmented from the video signal, and then the trained gesture model should be selected for gesture analysis. The analysis process includes extraction of eigenvalues, identification and evaluation of these eigenvalues and finally generation of gesture description. Finally, the system converts these descriptions into concrete operations to be completed by the computer, and the computer outputs the final gesture recognition results.

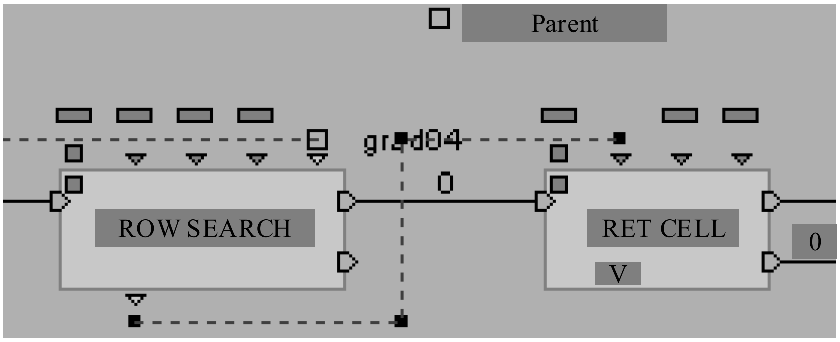
2.2 Information access of intelligent human-computer interaction products

Based on the gesture recognition results in the application process of intelligent human-computer interaction products, the design information, models, materials and gesture recognition results of human-computer interaction product components are stored in the database array, and the array is used to save the information and data generated in the design process.

1) *Create information records for the new component*: In front of the input data, the Array will related components in the database to find the product information, if found in the library without the component information records, would this component as a new component, the need for the new components to create records, using the Array load module for system identification, location, the father of the component identification information, such as the relevant information is entered into a list in the Array database (Guo et al., 2020). According to the parent-child relationship between the information in the new component model, it is processed hierarchically. The layered module is used to mark the information of each layer of the newly built component into the stack one by one, and the marked data is transmitted to the input end. If the phenomenon of data loading fails, the platform can restore the original data in Relation Array according to the marked information. In the file storage path information of the existing product component in the database, there are file name variable and file format constant, and the file format constant is .doc. Addition operation is performed on the parameters of the two kinds of information to obtain the file path information with the same file name and format as the component. Set the values of the Pins Target, File, Append and First Column stored in the load module to the same File information as the component name, so that the component information can be loaded efficiently in the subsequent use process and the loaded information is stored in the Group module. In the data update link, the iterator in the system is used to search for component information in the Group. At this time, the input end of the iterator will get the mark number before each piece of information to judge whether the information is missing or not (Hantao et al., 2020).

2) *Store the design information of components*: After setting the updated component information, the data should be reintegrated. After determining the corresponding information, the corresponding values should be set according to the requirements of enterprise customers, as shown in Figure 4.

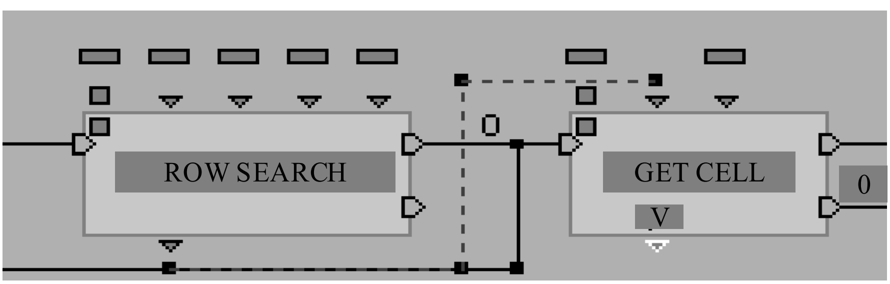
Figure 4 Shows a script that stores component design information



The value of the input parameter pin Row Index of SetCell BB is obtained from the output parameter pin First RowFound of Row Seareh BB, and the Value of the input parameter pin of SetCell BB shall meet the specified requirements.

3) *Read the design information of the component*: When looking up the content of a component, the component tag number of the system can Search the corresponding serial number in Array through the Row Search BB. In the form of Get Cell BB, the information value is collected in the corresponding unit system and sent back to the system, as shown in Figure 5.

Figure 5 Shows a script that reads the component design information



First Row Found with the GET CELL BB reference Row Index, decode the information and reassemble the GET CELL BB.

2.3 *Virtual display of products based on attention matrix*

The information of intelligent human-computer interaction products, such as gesture recognition results, is saved through Array. The attention matrix of intelligent human-computer interaction products is established according to the saved data, and the virtual display model of intelligent human-computer interaction products is constructed combined with the changes of viewpoints, so as to realise the virtual display of products.

In the process of virtual display of intelligent human-computer interaction products, the degree to which an object is paid attention by visitors' viewpoint is called Attention Degree. 0–1 denote its value, which is called Attention Degree Value (ADV). Where 0 means no concern at all and 1 means complete concern. The curve drawn is called the Attention Degree Curve (ADC) of this column, with row spacing as the abscess coordinate unit and ADV as the ordinate. According to the attention curve, the attention matrix representation of intelligent human-computer interaction products is proposed in this paper, and the virtual display model of intelligent human-computer interaction products is built according to the attention matrix, so as to improve the virtual display effect and people's realistic experience for the virtual display of intelligent human-computer interaction products.

Firstly, each element of the intelligent human-computer interaction product array is corresponding to the matrix element to form array matrix A, where a_{ij} represents the intelligent human-computer interaction product element. The matrix A is expressed by the following formula:

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \tag{1}$$

Secondly, according to the definition of attention, ADV value of each element in A is formed to generate a new matrix ADV.

$$ADV = \begin{bmatrix} 0.86 & \frac{0.86}{d_1} & \frac{0.86}{d_2} \\ 1.00 & \frac{1.00}{d_1} & \frac{1.00}{d_2} \\ 0.95 & \frac{0.95}{d_1} & \frac{0.95}{d_2} \end{bmatrix} \tag{2}$$

where d_1 represents the distance between column 2 and column 1, and d_2 represents the distance between column 3 and column 1.

Finally, the attention values generated in the previous step are used as a curve in column units to form the attention curve of the column. These attention curves are used as elements, namely ADC vector.

$$ADC = [b_1, b_2, b_3]^T \tag{3}$$

Among them, b_1, b_2 and b_3, respectively represent the attention curve of each column.

The above three steps complete the mathematical representation of intelligent human-computer interaction product array, and each element in the product array can be understood as an object with mathematical attributes. The relevant mathematical attributes include element matrix A, attention value matrix ADV based on A and attention curve vector ADC based on ADV.

The above is the attention curve under the static point of view. In the actual process, when people's point of view is changing, there will be the dynamic change of attention curve and the mathematical representation of cultural relics array, and this process is marked as η. Assume that η is a constant speed process, then:

$$S = S_0 + VT \tag{4}$$

Among them, S_0 represents the initial displacement of a viewing point, S represents the current displacement, V represents the change speed of the viewing point, T starts the timing when the viewing point leaves and the people watch the chronograph pauses and continues the continuous timing.

Considering that people watch along a column of $A_{(ic)}$, where c of ic is constant and $1 < i < m$, the mathematical representation matrix of intelligent human-computer interaction product array is called $m \times n$ matrix, and the current displacement can be expressed as:

$$S = S_0 + (i-2)r \tag{5}$$

where r represents the distance between the arrays of different viewpoints.

In combination with formulas (5) and (6), the solution is i, and when T is obtained, the object of complete concern $A_{(ic)}$ is obtained and $A_{(ic)}$ is used to re-represent A, ADV and ADC. Thus, the constant velocity process η is denoted as:

$$\eta = \{S_0 + VT; S_0 + (i-2)r\} \tag{6}$$

Combined with the calculation results of η-value, a virtual display model of intelligent human-computer interaction products is built. The specific representation of the model is as follows:

$$Q(i) = \sum_{i=1}^{n} A_{(ic)} + \eta + \frac{ADC}{ADV} \tag{7}$$

To sum up, the NUI interaction mode is determined, the appropriate motion sensing interaction device Kinect is selected and gesture recognition is performed with this device. The information of intelligent human-computer interaction products such as gesture recognition results is saved through Array. The attention matrix of intelligent human-computer interaction products is established, and the virtual display model of intelligent human-computer interaction products is constructed combined with the change of viewpoints, so as to realise the virtual display of products. In the next step, the validity of the method needs to be tested to test the scientificity and effectiveness of the method.

3 Simulation experiment simulation and results

3.1 Experimental scheme design

In order to test the overall effectiveness of the virtual display method of intelligent human-computer interaction products based on attention matrix, an experimental test is required. The specific experimental scheme is as follows:

1) *Hardware requirements*:

   CPU: Pentium III or above

   Memory: more than 128 MB

   CD-ROM: DVD ordinary CD-ROM drive or above

Display: 1024*768 display resolution, 16 bit colour quality above

Pointing equipment: ordinary mouse, trackball control ball, etc.

Graphics card: over 8M and Direct3D compatible

Sound card: No need to use a sound card

2) *Software requirements*:

Operating System: Microsoft Windows (2000, XP)

Hardware acceleration: Microsoft DirectX 7.0, 8.0 or 9.0c, using DirectX technology for 3D graphics

Speed display

OpenGL: If the work is displayed in OpenGL mode, an OpenGL 1.5 supporting graphics card and related drivers are required

Compiling language support environment: C#,.NET Framework 2.0

Web application server: IIS 5.0

Database management system: Microsoft SQL Server 2005

Virtools Browser Plug-in: 3DVIA Player or 3D Life Player

3) *Experimental data*: An e-commerce website is taken as the research object, all the data in the website is taken as experimental sample data and the collected data is cleaned and repaired. The product category table and picture information table of the website are as follows:

Table 1 Commodity category table

Fieldname	*Type*	*Size*	*Whether is empty*	*Describe*
ClassID	int	10	No	Commodity Category ID
ClassName	varchar	40	No	Product Category Name
CategoryUrl	varchar	40	No	Picture of Product Category

Table 2 Commodity picture information table

Fieldname	*Type*	*Size*	*Whether is empty*	*Describe*
ImageID	int	10	No	Photo ID
ImageName	varchar	40	No	Image name
ImageUrl	varchar	40	No	Picture address

4) *Evaluation index*: The accuracy of difficult gesture recognition and the accuracy of simple gesture recognition in the virtual display of intelligent human-computer interaction products are taken as evaluation indexes. The accuracy is higher and the result of gesture recognition is more accurate. On this basis, the virtual display effect of intelligent human-computer interaction products of the method in this paper is verified, with higher definition and better display effect.

3.2 Accuracy test of gesture recognition for somatosensory interactive devices

In terms of the content of the somatosensory interaction test, one of the important criteria for verifying the gesture recognition results is to achieve a high accuracy rate. On this basis, it is necessary to pay attention to the simplicity of the gesture and the integrity of the matching degree, and finally the gesture recognition results can be used through the evaluation report. To be specific, gestures play an important role in the somatosensory interaction experience. Every action is commanded and achieved through gestures, so the degree of semantic matching and memory difficulty of interactive gestures will be emphasised in the usability test.

Test subjects: college students and related personnel not majoring in design. Because the student group of younger or the ability to accept new things, they are more willing to try new type of interactive products, at the same time as the multimedia equipment using internet proficiency, they will be a new generation of interactive internet product audience, so watch their level of use and gesture contrast can be found that the existing problems.

Number of people tested: 5. Research shows that the usability research test by five to eight people, can be found that 80% of the problem, carries on the usability test after more than eight people, because the artificial cost and energy will rise significantly, results in the decrease of efficiency of returns, so the number of test control in 5 people, choose five college students to participate in the usability testing.

Test process:

(1) To the subjects focus on the body feeling the meaning and main content of interactive testing, at the same time provide testing features list, containing ten interaction gestures multimedia display content testing, after the interpretation of the unified gestures for testers to show consistency, let the subjects to guess the meaning of gestures and function, the researchers calculated gesture recognition of the time.

(2) Inform the test subjects of the functions and meanings corresponding to the ten interactive gestures, and let them learn each interactive gesture through explanation. Each page of PowerPoint has its own function. When the PowerPoint is playing, the subjects need to make gestures corresponding to the text on the PowerPoint. Each page of PowerPoint will stop for 2 seconds during the playback. If there is an error, the calculation will start again until all gestures correspond correctly. This stage of the test is completed, and the researchers calculate the accuracy rate of the tested person.

(3) After the completion of the test, the subjects completed an interactive practicability reportable questionnaire. The questionnaire adopted a specific information processing planning mode to test and integrate interactive gestures. The content covered 1–5 from the highest to the bottom of the scoring criteria, in order to determine whether gestures can be used for interactive experience.

This test of motion-sensing interactivity requires about 30 minutes to pass the usability test. Through this test, researchers analyse the problems existing in gesture design:

In the testing process, the subjects need to complete the random display test of 20 gestures and the researchers need to measure the accuracy rate of gesture recognition of the subjects. The interactive gesture is correct if it accurately corresponds to its function. The calculation method of accuracy is the number of correct guesses minus the total number of gestures. The result of accuracy of gestures is shown in Table 3.

Table 3 Gesture accuracy

Gesture	*Identify the number correctly*	*Accuracy/%*
Previous page (horizontal)	5	100
Previous page (vertical)	5	100
Next page (horizontal)	5	100
Next page (vertical)	5	100
Suspend	5	100
Close	5	100
Help	5	100
Open	5	100
Volume up	5	100
Volume down	5	100
Enlarge	5	100
Narrow	4	80
Yes	4	80
No	4	80
Mute	4	80
Delete	4	80
Maximise	4	80
Minimise	4	80
Choice	4	80
Return	4	80
Play	4	80

From then on, the following conclusions can be test in the chart, the operation of oneness of gesture interaction identification accuracy reached 100%, simple operation in the gesture just level and move up and down, its corresponding to the previous page, page, help, shut down, pause a few interactive gestures, suggest that the design meets customer of gestures everyday cognitive habits and the way of daily life, there are no mistakes in understanding simple gestures; Degree of difficulty in testing, more interactive gestures, there is no accuracy up to 100%, only 80%, this is because in the face of confusing and difficulty of movement increases the interaction of the gesture, the subject can't accurately understanding the meaning of gestures to represent, interactive gestures is more, a variety of forms, the content of the great confusion of gestures. For example, the subjects showed errors in the corresponding contents of various gestures, such as volume, increase or decrease, silence, etc., which reflected the disadvantages of tedious and repetitive interactive gestures. Therefore, the accuracy of gesture recognition of the method presented in this paper can be maintained above 80%, and the accuracy of simple gesture recognition can reach 100%. The reason is that this method has a high accuracy of gesture recognition by determining the NUI interaction mode, selecting the appropriate motion sensing interaction device Kinect and using this device for gesture recognition.

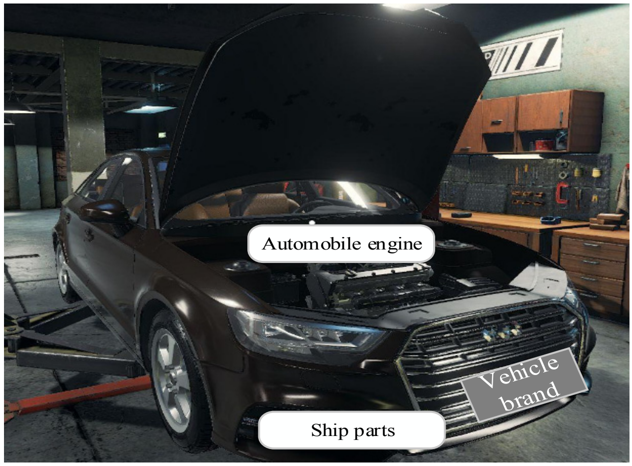
3.3 Virtual display effect of intelligent human-computer interaction products

This experiment takes automobile simulation demonstration as an example to test the effectiveness of the virtual display platform for intelligent human-computer interaction products designed in this paper based on somatosensory interaction devices. The specific display results are shown in Figures 6 to 8.

Figure 6 User experience of intelligent human-computer interaction vehicle

Figure 7 Intelligent human-computer interaction car display home page

Figure 8 Interior display of intelligent human-computer interaction vehicle



According to the display effect of intelligent human-computer interaction vehicles in Figures 6 to 8, the virtual display platform of intelligent human-computer interaction products designed in this paper based on motion sensing interaction equipment can fully display the inside and outside of the car, and the details are clearly displayed, which proves that the virtual display effect of intelligent human-computer interaction products in this method is better. The reason is that the method saves intelligent human-computer interaction product information such as gesture recognition result through Array. The attention matrix of intelligent human-computer interaction products is established, and the virtual display model of intelligent human-computer interaction products is constructed in combination with the change of viewpoints, so as to realise the virtual display of products, so it has a good display effect.

4 Conclusions

This article focuses on the intelligent man-machine interactive environment, combining virtual reality display design and product, by reasonable and efficient interactive design approach, to add to make mutual inductance and make up for the defect of traditional virtual display technology, will be to their advantage to maximise, in order to further enhance the intelligent human-computer interaction products virtual display effect, this paper presents a research on virtual display of intelligent human-computer interaction products based on attention matrix. By determining the NUI interaction mode, the appropriate motion-sensory interaction device Kinect was selected for gesture recognition. The information of intelligent human-computer interaction products is saved by Array. According to the saved information, the attention matrix of intelligent human-computer interaction products is established, and the virtual display model of intelligent human-computer interaction products is constructed with the change of viewpoints. Simulation experiment results show that the method of difficult gesture recognition precision can keep in 80% above, a simple gesture recognition accuracy can reach 100% and product virtual display effect is better, show that the method has high gesture recognition accuracy and the effect of virtual display, etc., can fully solve the problems existing in the traditional method, It can be further popularised and used in practice. In the next step, it is necessary to continue to explore the practical application of the virtual display method of intelligent human-computer interaction products, so as to improve the experience effect, enable users to have a more comprehensive understanding of the products and promote the further improvement of the performance of intelligent human-computer interaction products.

References

Brinkley, J., Posadas, B. and Sherman, I. et al. (2019) 'An open road evaluation of a self-driving vehicle human-machine interface designed for visually impaired users', *International Journal of Human-Computer Interaction*, Vol. 35, No. 3, pp.2210–2223.

Brivio, E., Serino, S. and Cousa, E.N. et al. (2020) 'Virtual reality and 360° panorama technology: a media comparison to study changes in sense of presence, anxiety, and positive emotions', *Virtual Reality*, Vol. 36, No. 3, pp.1154–1169.

Gabriele, P. and Lamberti, F. (2021) 'Towards the adoption of virtual reality training systems for the self-tuition of industrial robot operators: a case study at KUKA', *Computers in Industry*, Vol. 129, No. 5, pp.103446–103457.

Guo, Z., Zhou, D. and Zhou, Q. et al. (2020) 'A hybrid method for evaluation of maintainability towards a design process using virtual reality', *Computers and Industrial Engineering*, Vol. 140, No. 5, pp.106227.1–106227.14.

Guzsvinecz, T., Orbán-Mihálykó, V. and Sik-Lányi, C. et al. (2021) 'Investigation of spatial ability test completion times in virtual reality using a desktop display and the Gear VR', *Virtual Reality*, Vol. 21, No. 3, pp.25–39.

Hantao, Z., Tyler, T. and Mubbasir, K. et al. (2020) 'Assessing crowd management strategies for the 2010 Love Parade disaster using computer simulations and virtual reality', *Journal of the Royal Society Interface*, Vol. 167, No. 17, pp.105–116.

Hazer-Rau, D., Meudt, S. and Daucher, A. et al. (2020) 'The uulmMAC database-a multimodal affective corpus for affective computing in human-computer interaction', *Sensors*, Vol. 20, No. 8, pp.2308–2319.

Klumpp, M., Hesenius, M. and Meyer, O. et al. (2019) 'Production logistics and human-computer interaction-state-of-the-art, challenges and requirements for the future', *The International Journal of Advanced Manufacturing Technology*, Vol. 26, No. 9, pp.1154–1168.

Li, S., Yang, J. and Zhang, Z. (2020) 'Research on 3D international river visualization simulation based on human-computer interaction', *Wireless Communications and Mobile Computing*, Vol. 21, No. 2, pp.1–12.

Liu, S. and Xia, C.W. (2019) 'Interactive 3D virtual exhibition on web environment', *Journal of Engineering Graphics*, Vol. 30, No. 4, pp.20–25.

Maloca, P.M., Faludi, B. and Zelechowski, M. et al. (2020) 'Validation of virtual reality orbitometry bridges digital and physical worlds', *Scientific Reports*, Vol. 10, No. 1, pp.11815–11826.

Mou, Y.H. (2018) 'Design method of intelligent human-computer interaction product virtual display system based on gesture recognition', *Electronic Design Engineering*, Vol. 26, No. 20, pp.169–173.

Petrick, E. (2020) 'A historiography of human-computer interaction', *IEEE Annals of the History of Computing*, Vol. 78, No. 9, pp.158–169.

Wu, F.S., Pan, Z.G. and Chen, T. et al. (2018) 'Distributed prototype system of furniture's 3D displaying and customization', *Computer Applications*, Vol. 23, No. 3, pp.80–83.

Zibrek, K., Niay, B. and Olivier, A.H. et al. (2020) 'The effect of gender and attractiveness of motion on proximity in virtual reality', *ACM Transactions on Applied Perception*, Vol. 17, No. 4, pp.754–763.