Design of human-computer interaction display terminal system for intelligent home products based on colour vision analysis

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Abstract: Aiming at the traditional smart home product display terminal system ignoring the analysis of home colour vision, resulting in the display terminal system having low human-computer interaction adaptability, long running time, and experience satisfaction checking, the paper designs a smart home product based on colour vision analysis. Human-computer interaction display terminal system uses the Internet of Things (IoT) platform to design the overall architecture of the smart home system, and design the IoT wireless communication chip to optimise the system hardware functions. It uses the colour vision analysis method to extract the visual element characteristics of the smart home product display interface to complete the human-computer interactive display terminal system software design. Experimental results show that the human-computer interaction adaptability of the designed system is higher than 0.8, and the shortest response time is 0.25 s and the experience satisfaction is as high as 75%, which has good application advantages.

Keywords: colour vision; smart home; human-computer interaction; display terminal; internet of things; colour sequence.

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1 Introduction

Smart home is a residential platform, using integrated wiring technology, network communication technology, security technology, automatic control technology, audio and video technology to integrate facilities related to home life to build an efficient management system for residential facilities and family schedule affairs (Nadhiva and Mulyono, 2020). Smart home can effectively improve home safety, convenience, comfort and artistry, and realise an environmentally friendly and energy-saving living environment. Human-Computer Interaction (Human-Computer Interaction, abbreviated HCI) refers to the process of information exchange between humans and computers to complete certain tasks in a certain interactive manner using a certain dialogue language between humans and computers (Oyeleke et al., 2020). The smart home product display terminal introduces human-computer interaction technology, which can transform the internal information of the product into a form acceptable to humans, and realise the interactive intelligence of home products. However, the display terminal system of traditional smart home products ignores the analysis of home colour vision, resulting in low human-computer interaction adaptability, long running time and poor experience satisfaction in the display terminal system. In order to further improve the human-computer interaction performance of smart home products, designing and optimising the smart home human-computer interaction display terminal system has important research significance (Mashal and Shuhaiber, 2019).

In the research results on the human-computer interaction display terminal system of smart home products, Wang et al. (2020) proposed a multi-terminal controlled smart home product human-computer interaction display terminal system, which uses a private protocol to design against the vulnerabilities of wireless network intrusion The mining program uses a consensus mechanism to record and verify the security status of the access device, and accurately authenticate the control terminal to ensure the security of the home smart home system. The system can meet the cost and computing power requirements of establishing a security system structure. However, the design of the system does not consider the user's experience, and there is a problem of low-experience satisfaction. Sowmya et al. (2020) proposed a human-computer interaction display terminal system for smart home products based on the Internet of Things. The system uses the CC2430 chip produced by Texas Instruments as the basic hardware chip of the system sensor network. According to the characteristics of sensor data transmission in the home network and Development cost and difficulty. Zigbee was selected as the networking protocol of the smart home communication network to complete the optimisation of the human-computer interaction display terminal system. However, the system ignores the analysis of the visual elements of the product display interface, thereby reducing the adaptability of human-computer interaction. Huu et al. (2021) proposed a smart home product human-computer interaction display terminal system that combines infrared remote control and mobile devices. Since infrared extended control is an interactive way of infrared extended control, it is necessary to consider both when using smart home products Smart product users must also consider the inconvenient use of certain groups or scenarios. The disadvantage of this system is that the control distance of the infrared control terminal is limited, especially in non-line-of-sight application scenarios where the system runs for a long time.

Because the colour vision is not considered as the key point in the design process of the human-computer interaction display terminal system of the above smart home products, it leads to the problems of poor adaptability of human-computer interaction, long running time of the system and low-experience satisfaction. A human-computer interactive display terminal system for smart home products based on colour vision analysis is proposed. The overall design scheme of the system is as follows:

1) In order to improve the use effect of the human-computer interactive display terminal system of smart home products, the wireless communication chip is designed based on the Internet of Things platform, the infrared terminal control

range is expanded, the system hardware function optimisation design is completed and the non-line-of-sight application scenario is reduced. System running time.

2) Based on the realisation of the system hardware design, in order to improve the user satisfaction rate, the colour sequence of the image is used to generate the smart home visual panorama, the colour vision analysis method is used to extract the visual element characteristics of the human-computer interaction display interface and the back projection algorithm is used Carrying out panoramic map mapping improves the user's human-computer interactive display recognition, and realises the software design of the human-computer interactive display terminal system of smart home products.

3) Design experiments to verify the application performance of the system designed in this paper, using human-computer interaction adaptability, system running time and experience satisfaction as the experimental comparison indicators, comparing this system with Wang et al. (2020); Sowmya et al. (2020) and Huu et al. (2021). The system conducts comparative verification.

2 Design of human computer interactive display terminal system for smart home products

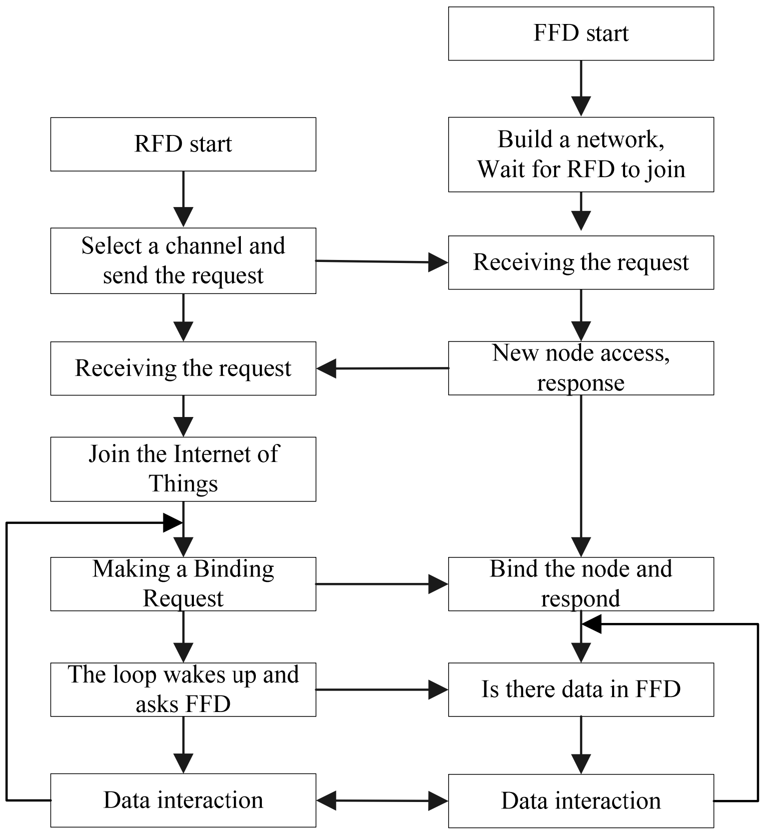
In order to enhance the user experience of human-computer interaction and enhance the experience satisfaction of smart home products, the Visual DSP + +4.5 multi-threaded embedded method (Mohapatra, 2020) is used to design the overall architecture of the human-computer interaction display terminal system for smart home products. The overall architecture of the computer interactive display terminal system is shown in Figure 1.

The human-computer interaction display terminal system designed in this paper starts from the terminal node (RFD) and the sensor node (FFD), and completes the node response according to the user service request content (Lds and Lb, 2019), binds the node with the Internet of Things platform, smart home Product users wake up and inquire the sensor nodes of smart home products through cyclic requests, which realises the data interaction between terminal nodes and sensor nodes and realises the human-computer interaction of smart home products.

2.1 System hardware design

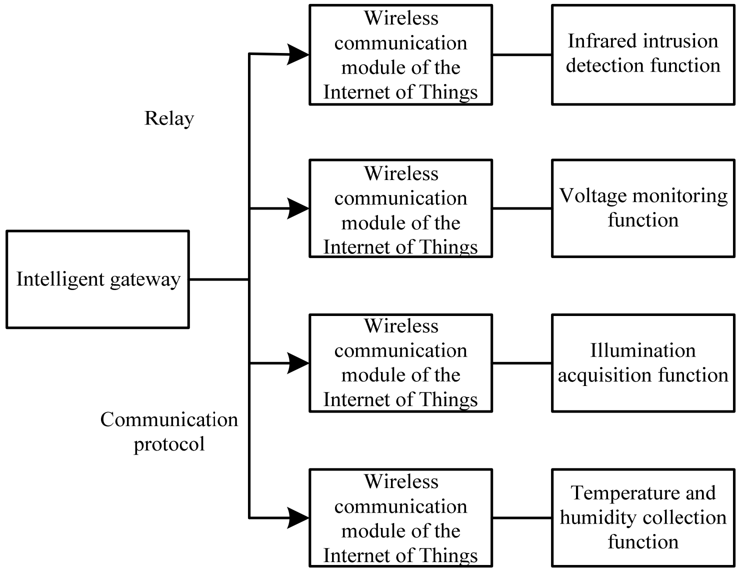
In order to improve the human-computer interaction intelligent household products display terminal application performance of the system, the system hardware design, in the process of hardware design, you need to follow to ensure that the hardware generality, scalable, between each module to do matching, low-power consumption, high ratio of performance and guarantees the convenience of smart home equipment such as original (Toylan and Cetin, 2019). Based on the intelligent gateway platform and combined with the relay and communication protocol to complete the design of the IoT network wireless communication chip, the design is carried out for other functional modules of the system hardware, which mainly includes the temperature and humidity acquisition function, illumination acquisition function, voltage monitoring function and infrared intrusion detection function. The functions of infrared intrusion detection, voltage monitoring, illumination acquisition and temperature and humidity acquisition in the human-computer interactive display terminal system of smart home products are realised (Chhikara et al., 2020). The schematic diagram of system hardware function is shown as in Figure 2.

Figure 1 The overall architecture of the human-computer interaction display terminal system



It can be seen from Figure 2, the realisation of system hardware functions is mainly through the wireless communication module of the Internet of Things, so it is necessary to optimise the wireless communication chip of the Internet of Things. The main function of the chip is to transmit data through the differential method and reduce the signal generation by combining with the balanced circuit. The radiation and noise interference, etc., ensure that the entire system has a strong anti-interference ability (Przybyo, 2019).

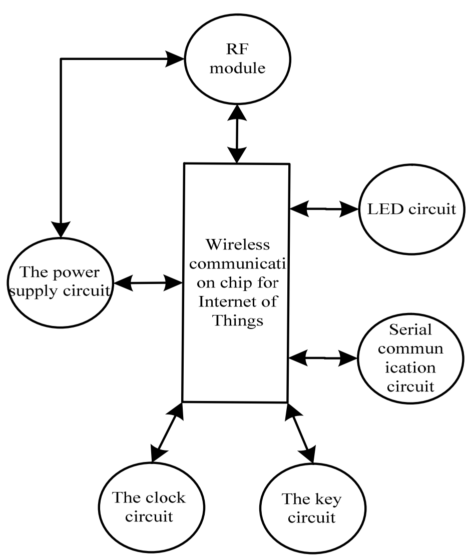
Figure 2 Schematic diagram of system hardware function



2.1.1 IoT wireless communication chip design

Based on the above process, when selecting a wireless communication chip for the Internet of Things, the selection of the chip must not only have the characteristics of high integration and high-work efficiency (Li et al., 2019), but also meet the technical requirements of the system. The structure of the wireless communication chip for the Internet of Things is shown in Figure 3.

Figure 3 The structure diagram of the wireless communication chip of the IoT



The structure of the wireless communication chip of the Internet of Things is mainly composed of a communication chip, a power supply circuit, etc., among which the main function of the power supply circuit in the system is to realise the voltage stabilisation of the system and provide the working voltage for the chip (Petrick, 2020).

2.1.2 System hardware function module design

After completing the design of the wireless communication chip for the Internet of Things network, the design of other functional modules of the system hardware is carried out, mainly including the temperature and humidity acquisition function, the illumination acquisition function, the voltage monitoring function and the infrared intrusion detection function. The above corresponding function modules and the Internet of Things The chip pin connection in the wireless communication module (Wang, 2019) completes the system hardware function design.

1) *Temperature and humidity collection function*: The temperature and humidity collection function is an important manifestation of home comfort, mainly through the temperature and humidity composite sensor to achieve data collection (Dominguez et al., 2019). The temperature and humidity collection process is shown in Figure 4.

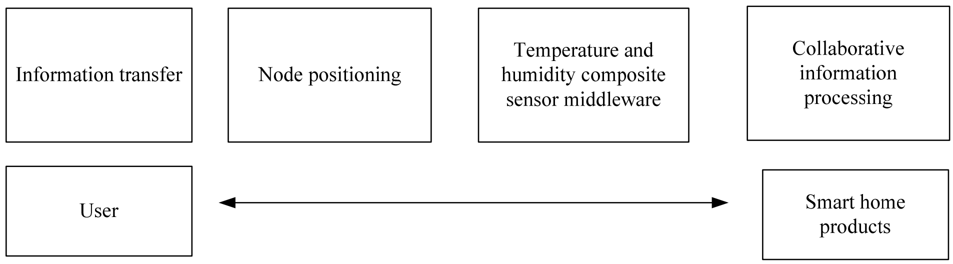
2) *Illumination acquisition function*: Illumination collection is an important manifestation of the intelligence of home life, mainly through high-resolution detection of illuminance in a larger range (Choi et al., 2018), while providing certain parameter data for lighting brightness.

3) *Voltage monitoring function*: Motor voltage monitoring is the most basic function for monitoring abnormal voltage of the motor. By setting the infrared structure diode as a sensitive element, the running status of the motor voltage is collected in real-time to complete the monitoring. When the motor voltage is too high in the living area, the system detects a certain intensity of infrared signal and the resistance decreases; as the infrared intensity continues to increase, the resistance becomes lower and lower. If the system does not receive an infrared signal, the resistance of the diode is higher.

4) *Infrared intrusion detection function*: In order to effectively solve the problem of long system running time in non-line-of-sight application scenarios in traditional human-computer interactive display terminal systems, the infrared intrusion detection function is optimised in the system hardware design and infrared sensor equipment is introduced to effectively expand the control of infrared intrusion detection. The distance range improves the operating efficiency of the system in non-line-of-sight application scenarios. Infrared intrusion detection function has very important development significance for preventing intrusion (Mazhar et al., 2019).

In summary, the hardware design of the human-computer interactive display terminal system for smart home products is completed, and the long running time problem of the traditional computer interactive display terminal system is effectively solved by optimising the wireless communication module of the Internet of Things in the system hardware.

Figure 4 Temperature and humidity collection process



2.2 System software design based on colour vision analysis

On the basis of realising the hardware design of the system, in order to solve the problem of poor application effect of the traditional system due to the lack of colour vision analysis, this paper takes solving this problem as the research objective and introduces colour vision analysis into the software process of human-computer interaction display terminal system of smart home products. The main process is as follows: Use the colour of the image sequence to generate intelligent household panorama vision, colour vision analysis method to extract visual elements characteristics of man-machine interactive display interface, use the panoramic map projection algorithm, improves the human-computer interaction of user display recognition, human-computer interaction to realise the intelligent household products display terminal system software design. Therefore, this system software design method has the characteristics of high human-computer interaction adaptability, low-system running time and high-experience satisfaction and can be further popularised in practice.

Smart home products are highly intelligent, and intelligently integrate and innovate the home space through the use of advanced interactive concepts and technologies. Therefore, it is necessary to use the image sequence to generate the visual panorama of the human-computer interaction display interface of the smart home product. The generation process is:

1) *Implement cylindrical colour projection on the local visual image of the smart home vision*: In the process of implementing cylindrical colour projection of the local visual image of the smart home, it is necessary to map the local visual image of the smart home to a standard cylinder without image distortion, so that the coordinate changes of each pixel point are all Can be observed. Including cylindrical colour projection on the side, bottom and top (Chavarría et al., 2020).

In the process of cylindrical colour projection, it is first necessary to establish a coordinate system $O-XYZ$, where the image is the projected local visual image of the smart home, $P(x, y)$ represents a pixel on the image, O represents the camera position and f represents the image to the camera Focal length. Map point $P(x, y)$ and map it on a cylinder. The mapped point is point Q. The coordinates of point Q are obtained. The specific coordinate calculation formula is as follows:

$$\begin{cases} x_1 = f \cdot \arctan\left(\dfrac{x-L}{f}\right) \\ y_1 = \dfrac{f \cdot \left(\dfrac{y-L}{3}\right)}{\sqrt{\left(x-\dfrac{H}{2}\right)}} \end{cases} \tag{1}$$

In the above formula, L represents the overall width of the image; H represents the overall height of the image; X represents the centre of the image block; f represents the grey value of the image; y represents the smooth value of the image. Use the above formula to project all the pixels on the local visual image of the smart home, and combine all the mapping points to obtain a cylindrical colour panorama of the local visual image of the smart home.

2) *Seamless splicing and matching the overlapping part of the cylindrical colour projection map in the smart home display interface*: According to the obtained cylindrical colour panorama data, the image data can be processed according to the terminal data parameters, and the linear normalisation function is selected to process the communication data (Blott, 2019), which is used to express the linear normalisation function, and then the cylindrical colour projection is obtained. The information filtering formula is:

$$\sigma = \frac{\sum_{-\infty}^{+\infty} c_1 + c_2}{\sqrt{B} \times S(u)} \tag{2}$$

In the above formula, $c_n, n = 1, 2, ..., n$ represents the perceived local visual image information set of the smart home; B represents the local visual image sequence of the smart home.

According to the obtained cylindrical colour projection information results, the determinant detection is performed on the interest points of the image through the Hessian matrix. The detection formula is:

$$H = \sqrt{\sigma + d} + \delta \tag{3}$$

In the above formula, d represents the grey-scale pixel information of the local visual component of the smart home; δ represents the edge value of the local visual image parameter distribution sequence of the smart home.

According to the determinant detection result, the cylindrical colour projection map in the display interface is spliced and matched, which is expressed by the following formula:

$$g^i = H \times d + \frac{\sqrt{\sigma + d}}{B} + y(x) \tag{4}$$

In the above formula, $y(x)$ represents the grey value of the sparsity feature decomposition of the local visual image of the smart home.

3) *Implement mapping of partial smart home cylindrical colour projection images and convert them into plane images*: Based on the matching of the smart home display interface, Haar wavelet is used to respond to the points of interest to generate sub-vectors of feature points to the image (Alilou et al., 2019), which is described by the following formula:

$$sim\left(H, g^i\right) = \frac{\Delta B}{y(x)} \tag{5}$$

According to the image sub-vector and the geometric image transformation model, the coordinate relationship of the cylindrical panorama of each smart home partial visual image is determined and the visual element characteristics of the smart home product display interface are extracted:

$$K^i = i\left(nc_1 + c_2\right) + j \cdot sim\left(H, g^i\right) \tag{6}$$

In the above formula, i represents the joint information entropy of feature extraction; j represents the resolution of local visual feature extraction of smart homes.

The cylindrical panorama of the visual image of the smart home is mapped through the back-projection algorithm of the image, and the plane image corresponding to the cylindrical colour panorama is obtained. At the same time, in order to facilitate user identification, in the visual design of the display interface of the smart home human-computer interaction display terminal, it is necessary to emphasise the textual expression of the display interface and standardise the design of the display interface icon. So far, the software design of the human-computer interaction display terminal system for smart home products based on colour vision analysis has been completed, which improves the adaptability of human-computer interaction while taking into account the user's experience. The computer interactive display terminal system lays the foundation.

In summary, the design of the smart home human-computer interactive display terminal system is completed. Through the conversion and projection of colour visual images, the overall quality of the visual elements of the smart home human-computer interactive display terminal interface is improved and the application of the system is reliable. It needs to design experiments for further verification.

3 Experimental research

A comparison experiment is designed for the proposed colour vision-based smart home human-computer interaction display terminal system to verify the practical application performance of the proposed system.

3.1 Experimental plan design

Use the C# language to design the experimental platform, load the smart home human-computer interactive display terminal on the experimental platform and obtain the experimental data. The smart home product specific product data configured in the smart home human-computer interactive display terminal experimental platform is shown in Table 1.

Table 1 Intelligent home products configured in the platform

The serial number	*The product type*	*The product name*	*Product features*
1	Access control products	Smart door lock	APP control and biometrics
2	Electric control products	Intelligent electrical outlet	Socket remote control and current break as well as socket switch timing setting
3	Electric control products	Intelligent switch	Statistics power, reservation switch and intelligent power-off
4	Network control product	Intelligent Router	Online time, web browsing, online number, bandwidth, application control
5	Water control products	Intelligent faucet	Purification function and water-saving function
6	Lighting control products	Smart bulb	Setting of lighting effect and lighting situation
7	Temperature and humidity control products	Smart thermostat	Humidity detection control and temperature detection control

The optimal simulation parameters are taken as the initial parameters, use the built experimental platform to test the human-computer interaction performance of the smart home human-computer interaction display terminal. In order to ensure the reliability of the experimental results, the experimental plan is designed as follows: The colour vision-based smart home human-computer interaction display terminal system designed in this paper and the Wang et al. (2020); Sowmya et al. (2020) and Huu et al. (2021) proposed the smart home human-computer interaction display terminal system for comparison experiments.

3.2 Experimental index design

In order to ensure the validity of the experimental results, the following experimental indicators are designed and the values of the indicator results are the average values after multiple experiments.

1) *Human-computer interaction adaptability*: Test the human-computer interaction adaptability under different systems. The higher the fitness index, the better the human-computer interaction display effect of the system. The calculation formula of fitness index is:

$$\omega_k = p\left(X_k, Y_k\right) \tag{7}$$

In the above formula, p represents the sensor coefficient of the human-computer interactive display interface; X_k represents the feedback parameter of the X coordinate direction of the cylindrical colour projection of the visual image of the system display interface; Y_k represents the feedback parameter of the Y coordinate direction of the cylindrical colour projection of the visual image of the system display interface parameter.

2) *System running time*: Use different methods to compare running time. The shorter the running time, the higher the efficiency of the system for human-computer interaction display.

3) *Experience satisfaction*: Use different methods to conduct experience satisfaction tests. The higher the experience satisfaction, the better the actual application performance of the system. The specific calculation formula is:

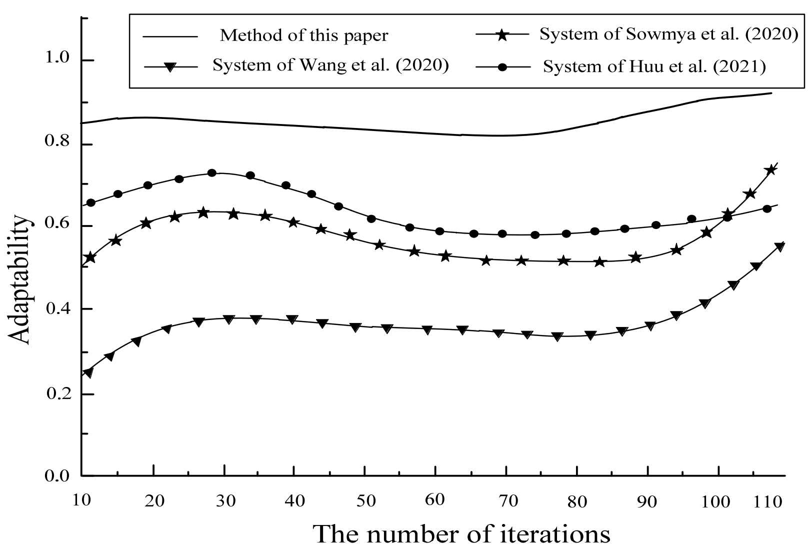
$$W(i) = X(i) / \left(x(1) + x(2) + x(3) + \ldots + x(n)\right) \tag{8}$$

In the above formula, $X(i)$ represents the influence coefficient of original satisfaction and $x(1) + x(2) + x(3) + \ldots + x(n)$ represents the weight of experience satisfaction after normalisation.

3.3 Comparison of human-computer interaction adaptability

Test the system of this article and the traditional system, take the human-computer interaction adaptability of the smart home product human-computer interaction display terminal as the test index and obtain the comparison result of human-computer interaction adaptability as shown in Figure 5.

Figure 5 Comparison of human-computer interaction adaptability



It can be seen from Figure 5 that the human-computer interaction adaptability of the system in the Wang et al. (2020) is the lowest, generally lower than 0.6, the human-computer interaction adaptability of the system in the Sowmya et al. (2020) and the system in the Huu et al. (2021) is generally lower than 0.8, and the system in this paper has the lowest human-computer interaction adaptability. The human-computer interaction adaptability is the highest, generally above 0.8. It can be seen that the human-computer interaction display terminal system of the smart home product designed in this article can improve the human-computer interaction adaptability. This is because the system in this article has carried out the visual elements of the product display interface. Effective analysis shows good application value.

3.4 Comparison of system running time

The running time of three different systems is tested and compared. The results of comparison are shown in Table 2.

Table 2 Comparison of operation time

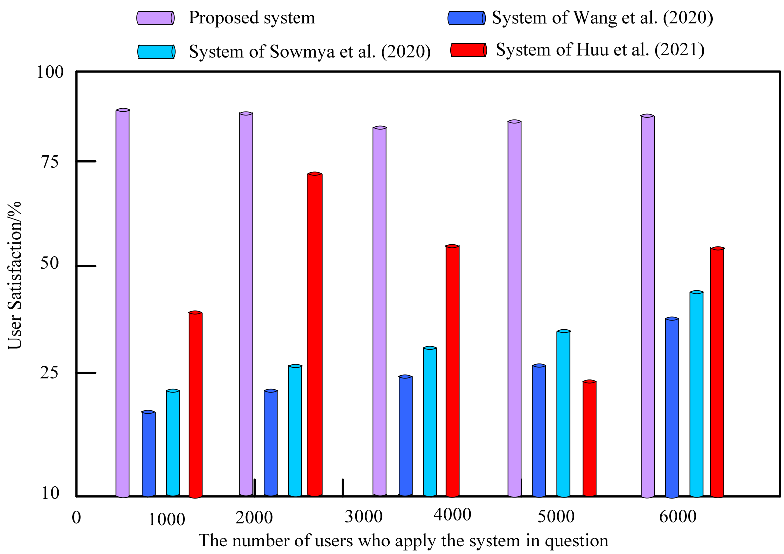
Number of times received data	*Number of times of data sent*	*Running time of the designed system/s*	*Wang et al. (2020) system running time/s*	*Sowmya et al. (2020) system running time//s*	*Huu et al. (2021) system running time//s*
1000	1000	0.25	0.48	0.70	0.89
1500	1500	0.32	0.53	0.76	0.90
2000	2000	0.33	0.60	0.83	0.93
2500	2500	0.37	0.67	0.89	0.95
3000	3000	0.40	0.74	0.97	1.10
3500	3500	0.41	0.80	1.105	1.109
4000	4000	0.43	0.85	1.116	1.110
4500	4500	0.45	0.92	1.123	1.128
5000	5000	0.47	1.10	1.129	1.135
5500	5500	0.50	1.11	1.134	1.140

A comprehensive analysis of the experimental data in the above table shows that the minimum running time of the system in Wang et al. (2020) is 0.48 s, the minimum running time of the system in Sowmya et al. (2020) is 0.7 s and the minimum running time of the system in Huu et al. (2021) is 0.89 s, and The minimum running time of the system in this paper is 0.25 s. According to the numerical comparison, the running time of the system in this paper is significantly lower. This is because the designed system adds the infrared control function in the design process, which expands the control distance range of the infrared control terminal, thereby improving the operating efficiency of the human-computer interactive display of smart home products and reducing the operating time of the system.

3.5 Comparison of experience satisfaction

In the process of system design, experience satisfaction is a key factor that needs to be considered in the design process. The following experimental tests focus on testing the experience satisfaction of different systems. The comparison of the experience satisfaction test results is shown in Figure 6.

Figure 6 Comparison of experience satisfaction test results of different systems



Analysis of the experimental data in Figure 6 shows that compared with the other two systems, the experience satisfaction of the system in this paper is significantly higher, generally above 75%. Explain that when designing smart home product human-computer interaction display terminal system, after considering colour vision, it can effectively enhance the user satisfaction rate of the entire system. This is because the system in this paper fully considers the 'human' experience in smart home product human-computer interaction. Demand, fundamentally optimised the human-computer interaction display terminal system for smart home products.

4 Conclusions

In order to solve the problem of colour vision element analysis that is ignored by traditional smart home product display terminal systems, this paper proposes and designs a smart home product human-computer interaction display terminal system based on colour vision analysis.

(1) This article analyses the feasibility of the application of human-computer interaction technology in smart homes and the elements of colour vision, designs the overall architecture of the smart home system and completes the cloud computing information processing of the smart home. The colour sequence of the image is used to generate the visual panorama of the smart home, complete the visual interactive roaming of the smart home and realise the design of the human-computer interaction display terminal system for the smart home product.

(2) Specifically, the human-computer interaction adaptability of the system in this paper is the highest, generally above 0.8 and the shortest running time is 0.25 s and the experience satisfaction is generally above 75%. The smart home product human-

computer interaction display terminal designed in this article. The system is significantly better than the traditional system.

(3) However, due to the limited experimental conditions, the colour eye tracking effect of the smart home terminal display interface cannot be verified. This indicator is also an important evaluation indicator for the human-computer interaction display terminal system of smart home products. In future studies, the designed system will be in-depth verified against this indicator.

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