IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received November 24, 2021, accepted December 12, 2021, date of publication December 14, 2021, date of current version January 10, 2022.

Digital Object Identifier 10.1109/ACCESS.2021.3135660

Internet of Things Intelligent Interaction Technology Using Deep Learning in Public Interaction Design

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This work was supported in part by the Scientific Research Fund of Yunnan Education Department, China, under Grant 2021J0733; and in part by the University-Level Talent Introduction Project, China, under Grant XJ20210031.

ABSTRACT In order to improve the intelligence and humanization of the home environment, smart air conditioners are used as the research objects. User needs using the theory of Human–Computer Interaction (HCI) are investigated and researched, and smart air conditioners are researched and practiced on human interaction design. Firstly, in order to establish a user model, the questions and needs of the target users are explored through the questionnaire survey method. Secondly, from the perspective of ergonomics, the hardware and software interaction interface of the smart air conditioner is analyzed. Finally, the intelligent air conditioner is designed for HCI according to user needs, and the unsupervised feature value extraction of the vibration measurement signal of the outdoor unit of the household air conditioner is carried out by using the stacked autoencoder neural network. Three preliminary options for the design of remote controllers for air conditioners are proposed, and the fuzzy evaluation method is utilized to analyze and evaluate the three options. The research results show that the comprehensive evaluation results of the three preliminary options of the remote-control design are 0.78, 0.77, and 0.8 respectively. Compared with Option 1 and Option 2, Option 3 has obvious advantages. The design of Option 3 is more prominent in terms of comfort, aesthetics, and rationality. Therefore, Option 3 is selected as the final design solution. Under different hidden layer numbers and node numbers, the classification accuracy rate changes in a convex function. When the number of layers is 3 and the number of nodes is 100, the classification accuracy rate is the highest. According to the needs of users, a specific interactive design analysis is carried out on the hardware design of home appliances from the perspective of ergonomics.

INDEX TERMS Internet of Things, human–computer interaction, smart air conditioning, user survey, deep learning.

I. INTRODUCTION

Today, the technological revolution is booming. As an important driving force of the current industrial revolution, deep learning, and Internet of Things (IoT) application technologies are constantly changing people's daily life production methods. IoT technology will further develop human society into a new era of human-machine integration, co-creation and sharing, and intelligence [1]–[4]. As the core technology of the current technological revolution, deep learning algorithms and IoT technology have also been widely used in the smart home appliance industry [5]. Data shows that in the next few years, the market demand for smart home appliances will rise sharply, and the product penetration rate will continue to increase.

The rapid development of IoT technology has promoted the transformation of human production and lifestyle. The development of 5G technology and the popularization of smart phones have enabled smart home appliances to be used in the daily life of ordinary people. Major internet and home appliance companies continue to increase the industrial layout of smart home appliances [6], [7]. At present, China's smart home appliance industry is still in its infancy stage, and there are still certain differences between the

The associate editor coordinating the review of this manuscript and approving it for publication was Dongxiao Yu.

convenience of product operation and developed countries, and the products of major leading companies lack unified management. However, with people's emphasis on smart home appliances, the smart lifestyle of household products has been further improved [8]–[10]. The automation of the production line of home appliances is continuously improving, and the detection and cause analysis of vibration and noise of home appliances also need to be automated and intelligent. The vibration detection of home appliances generally uses vibration detection sensors to detect its vibration data under various operating conditions in real time, and analyze the vibration source, vibration factors, and whether there are faults and failure factors using the vibration data.

However, the following problems still exist in the current home appliance smart field: smart devices are too single.

Manufacturers mainly focus on the system technology and functional design of smart products, while ignoring the interaction between people and products and the interconnection design between products. When controlling smart products, it is necessary to intervene manpower to trigger the network, which cannot be directly dealt with the current needs of users. Through the analysis of the target user's needs and the Human-Computer Interaction (HCI) relationship of smart home appliance systems, in the context of the IoT era, the HCI design strategy for smart home appliances has been proposed. The design strategy is verified through practice, making the home environment more humane.

II. DESIGN RESEARCH METHODS OF SMART HOME APPLIANCES

A. RESEARCH ON USERS OF SMART HOME APPLIANCES

In order to understand the needs of users, a questionnaire method is used to investigate the user's satisfaction with the smart home. The specific design of the questionnaire is shown in Figure 1:

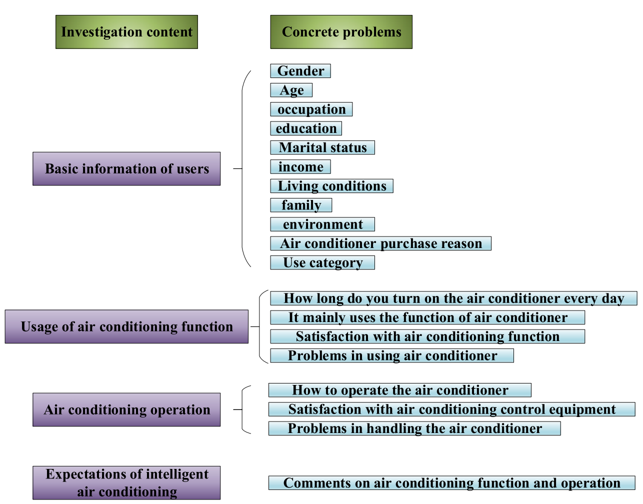

FIGURE 1. The design of questionnaire.

B. THE DESIGN OF SMART HOME APPLIANCE HARDWARE INTERACTIVE INTERFACE

1) DESIGN REQUIREMENTS FOR AIR CONDITIONER REMOTE CONTROL

At present, the main tool used by air conditioner users to control the air conditioner is the remote control. Researchers have not paid much attention to the design of the air conditioner remote control, and the interface design of the remote control has not changed with the advancement of science and technology. The main problems in the current remote-control design are shown in Figure 2:

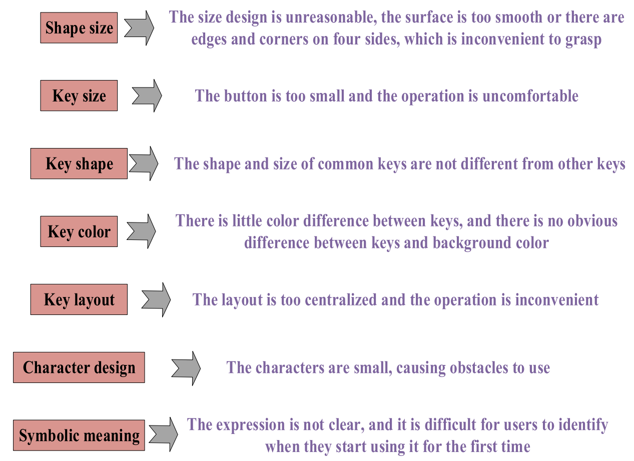

FIGURE 2. Description of the remote-control problem.

When designing the size of the remote-control buttons, the spacing and shape between the buttons and the buttons, the area of the user's thumb needs to be considered [11]. Using anthropometry, the average hand length and hand width of Chinese men are 183mm and 82mm, respectively. Women's average hand length and hand width are 171mm and 76mm, respectively. Since the remote control is universal for men and women, after the above data is compromised, the hand length and hand width are 177mm and 79mm [12]–[14].

The color design of air conditioning remote controller is relatively simple, and the color is generally black, white, and gray. Related studies have shown that users prefer neutral colors [15], [16]. However, if the color between the key and the contour of the remote control is too close, it may cause users to use obstacles. Thus, the color between the key, character and contour on the remote control needs to be compared. At present, the color matching of the remote control is commonly used as shown in Figure 3:

Figure 3 shows that, in order to improve the recognition speed of the remote-control function keys, the key color of the remote control needs to be contrasted with the background color and character color. Most of the buttons on the air conditioner remote control are used by users in the process of using the air conditioner, such as the temperature adjustment button, the wind speed button, and the mode button. But there are some keys that are not often used, such as the timer key, dehumidification key, energy saving key, and mute key.

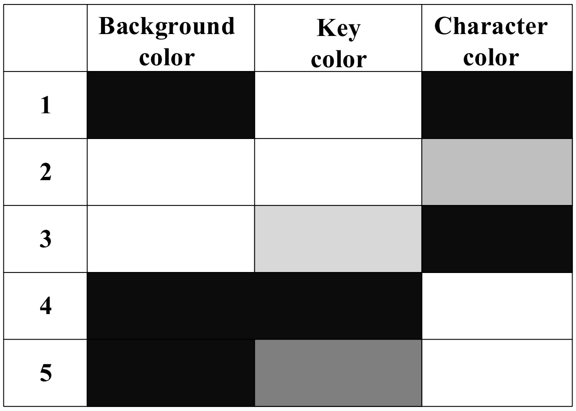

FIGURE 3. Common color matching of remote control.

The layout of the remote-control buttons should also be arranged according to the frequency of use of the buttons [17].

2) THE DESIGN REQUIREMENTS OF AIR CONDITIONING CONTROL PANEL

With the development of science and technology, the control panel of the air conditioner is no longer a simple physical control, but using wireless technology to control it through the display and buttons of the air conditioner. When performing HCI, the use of wireless technology has become more and more routine. Because of its simple operation, it has been widely used in various households [18], [19]. Meanwhile, as the window of HCI and the bridge of information transmission, the design of the control panel is particularly important. The main problems existing in the user operation process are shown in Figure 4:

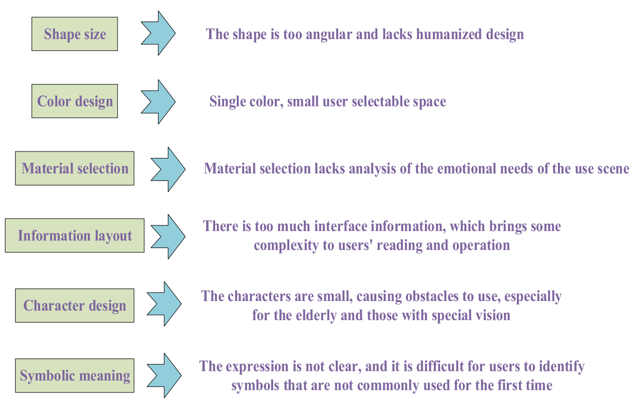

FIGURE 4. Control panel problem.

When the user uses the control panel of the air conditioner, the index finger is used the most. Most of the area of the control panel is occupied by the display screen. Therefore, when designing the size of the control panel, it is necessary to consider the human visual characteristics. During the operation, the user maintains a standing posture and the body is in a relaxed state, so the person's line of sight does not remain level, but is about 30° below the horizontal line [20]–[22]. According to the range of movement of the human arm, the user's viewing distance range when operating the control panel is 500mm-700mm, and the minimum viewing distance 500mm is used to calculate the size of the control panel. The specific calculation method is shown in the following equations (1)-(3):

$$\begin{aligned} visual\ angle &= (180/\pi)\ Object\ size/Sight\ dis\tan ce \\ &= 57.3\ Object\ size/Sight\ dis\ \tan\ ce \end{aligned} \tag{1}$$

$$\begin{aligned} Object\ (height)\ \dim\ ension &= (visual\ angle/57.3) \\ &\quad Sight\ dis\ \tan\ ce \end{aligned} \tag{2}$$

$$\begin{aligned} Screen\ (height)\ size &= (\alpha/57.3)\ Sight\ dis\ \tan\ ce \\ &= (10/57.3)500mm = 87.26mm \end{aligned} \tag{3}$$

According to equations (1)-(3), the height of the control panel is calculated to be at least 83mm.

The survey found that the panel buttons and the remote-control layout problems are basically the same. Research shows that the user's frequency of use of each button on the control panel is shown in Figure 5:

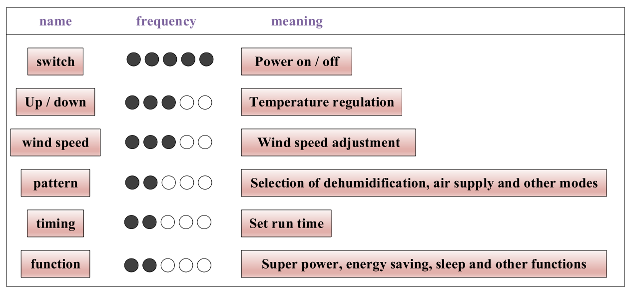

FIGURE 5. Buttons on the control panel.

In Figure 5, the user's frequency of use of each button on the control panel can be seen. According to the user's gaze patrol characteristics, the patrol mode that the user is most accustomed to is from left to right. Compared with the vertical direction, the patrol speed in the horizontal direction will be faster. Therefore, when sorting the buttons on the control panel, they should be arranged horizontally according to the importance of the buttons.

C. RESEARCH ON THE INTERACTIVE DESIGN OF THE SOFTWARE INTERFACE OF SMART HOME APPLIANCES

As a platform for HCI, the software design of smart home appliances should consider the usability of human-computers and the comfort of users, and adhere to the user-centric principle. Using the above principles, the software interface is specifically designed, focusing on improving the convenience and operability of the interface, and achieving user needs to the greatest extent.

1) SOFTWARE INTERACTIVE INTERFACE INFORMATION ARCHITECTURE DESIGN

As the mental framework of the software interactive interface, the information framework needs to be using the behavior

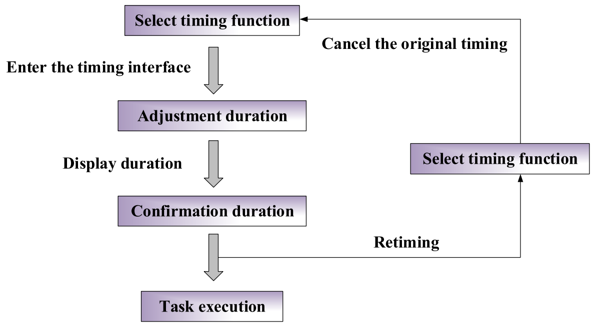

FIGURE 6. User behavior flow chart of air conditioning timing.

and needs of the users when it is constructed. First, analyze the user's behavior. Then, design the interface function so that the interface information architecture of the software interaction can meet the actual needs of the user and improve the user's satisfaction. The specific design strategy includes matching the information structure with the behavior logic and constructing the information structure of the interactive interface.

The user's behavior logic refers to the user's thinking and planning logic for the generated behavior in the process of using the smart air conditioner. In order to reasonably allocate the user's behavior path and operation process, so that the user can get a better interactive experience, the above behavior logic needs to be followed when designing the structure of the software interactive interface information [23], [24]. When the user performs the air conditioning timing behavior, the specific process is as shown in Figure 6:

2) VISUAL DESIGN ANALYSIS OF SOFTWARE INTERACTIVE INTERFACE

Related research shows that the main way for humans to obtain information is vision. Vision also plays a particularly important role in the design of software interfaces. In order to improve the rationality of the software interaction interface, reduce the difficulty of operation, and enable users to feel relaxed and happy, this paper conducts a specific visual design of the intelligent air conditioning interface using the information architecture and interaction design [25].

When users are faced with complex interface elements, first, they will make corresponding guesses about the icons on the interface using their daily life experience and personal intuition. This behavior can be used in the visual design process of the software interactive interface to design icons that have the same semantics as specific functions, so that users can familiarize themselves with the icon elements on the interface in a short time, and reduce the user's memory burden [26]–[29]. In addition, the scientific nature of the interface layout can make the operation interface appear more coordinated, thereby enhancing the user experience. The commonly used software interface layout is shown in Figure 7:

In order to meet the needs of different users, the software design includes a variety of design patterns in Figure 7.

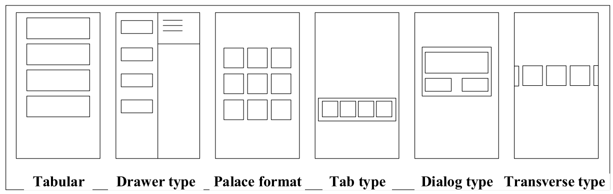

FIGURE 7. Common layout of the software interface.

The characteristics of different design patterns are different. The software interface involves a single or multiple layout method. In order to improve the intuitiveness of the interface information, the layout methods of tabbed, drawer and list are selected [30].

D. SMART AIR CONDITIONING INTERACTIVE DESIGN

1) PRELIMINARY PLAN DESIGN OF AIR CONDITIONER REMOTE CONTROL- OPTION 1

According to the human hand size calculated in section 2.3, the first dimension of the air conditioner remote control is: the overall length is 140mm, the maximum width and thickness are 46mm and 16mm, respectively, and the screen length and width are 40mm and 36mm, respectively. The user can operate flexibly with one hand. The specific design plan is shown in Figure 8:

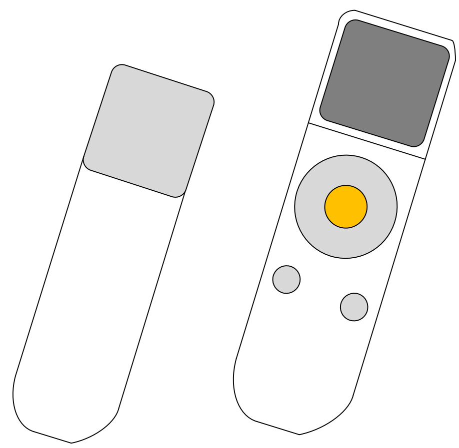

FIGURE 8. Option 1: schematic diagram of the size design of the air conditioner remote control.

Figure 8 shows that in order to facilitate the user's grasp and improve the user's comfort, the edges and corners of the designed air conditioner remote control are all arc-shaped. The remote control uses white and gray as the main color, which is stylish and atmospheric. Set the most frequently used switch key to orange to increase the visibility of the switch key and prevent users from pressing it by mistake. The rest of the buttons are gray. The materials of the remote-control shell and buttons are plastic and rubber respectively. The battery is no longer used for charging, and the charging method is changed to the data interface. The two circular buttons are the mode button and the voice button, with a diameter of 10mm. The four sector buttons on the ring outside the orange switch

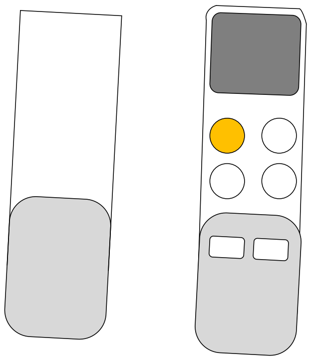

FIGURE 9. Option 2: schematic diagram of air conditioner remote control design.

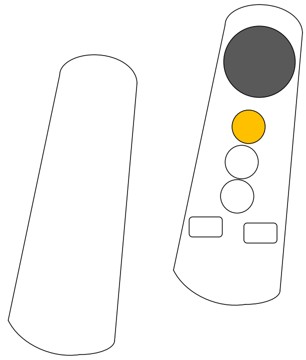

FIGURE 10. Option 3: Schematic diagram of air conditioner remote control design.

button are the up and down adjustment buttons, the up and down, left, and right air outlet buttons, with a diameter of 30mm. In order to distinguish this key from the rest of the keys, the ring key is set to have a slightly concave touch to distinguish it from the slightly convex touch of the other keys. The difference between this solution and the original remote control is the addition of a voice key to facilitate the user's voice control [31].

2) PRE-PLAN DESIGN OF AIR CONDITIONER REMOTE CONTROL- OPTION 2

The size of the air conditioner remote control program two is: the overall length is 135mm, the maximum width and thickness are 42mm and 8mm respectively, and the screen length and width are 38mm and 30mm respectively. The specific design plan is shown in Figure 9:

Figure 9 shows that the main colors of the remote-control design of Option 2 are still white and gray. The orange button is still the most frequently used switch. The other buttons are designed as white, and the information on the buttons is designed as grey. The four circular buttons with a diameter of 12mm on the upper part are the switch button, the mode button, and the up and down adjustment buttons. The two long rectangular buttons in the lower part of 12mm and 8mm are the wind speed and direction buttons. The biggest difference between Option 2 and Option 1 is that its overall layout is more concise and generous [32], [33].

3) PRELIMINARY PLAN DESIGN OF AIR CONDITIONER REMOTE CONTROL- OPTION 3

Compared with the first two options, Option 3 is more innovative. The three dimensions of the air conditioner remote control option are: the overall length is 130mm, the maximum width and thickness are 48mm and 18mm, respectively, and the screen diameter is 30mm. The specific design plan is shown in Figure 10:

The upper part of the Option 3 consists of three circular keys with a diameter of 10mm, which are respectively the switch key and the up and down adjustment keys. The rectangular buttons with a length of 12mm and 8mm in the lower part are the mode button and the timer button, respectively. The main color of the remote control is the same as the previous two option.

4) VIBRATION DETECTION METHOD OF AIR CONDITIONER OUTDOOR UNIT

The main vibration sources of the outdoor unit of the air conditioner are compressors, fans, and motors. The He-Na laser vibrometer acquisition card is used to detect and sample the vibration data of 6 working conditions that are normal outside the air conditioner, lack of sound insulation cotton, fan blade cracks, fan blade imbalance, lack of damping blocks, and loose fan brackets. The sampling rate is 1000, and the sampling duration is 2s. Normalize the signal input network to 0, 1. Experimental analysis shows that the number of layers and nodes of the first hidden layer have a greater impact on the classification accuracy. In order to determine the appropriate number of layers and nodes, a SAE network with several layers of N ($N = 1, 2, 3, 4, 5$) is constructed, and the number of nodes is 400, 300, 200, and 100 for experiments (the learning rate is 0.5, and the attenuation factor is 1. The L2 norm regularization coefficient is 0, the number of batch processing samples is 800, the dropout factor is 0, the number of pre-trainings is 100, and the number of fine-tuning is 1000).

E. FEATURE EXTRACTION USING DEEP LEARNING

In order to monitor and analyze the vibration and noise of household appliances, the neural network of the stacked autoencoder is used to extract the characteristic quantity of the vibration measurement signal of the outdoor unit of the household air conditioner. Due to the limited ability of a single Auto Encoder (AE) constructor, in order to construct a more expressive function, multiple AEs are stacked to form a stacked auto encoder (SAE). The hidden layer of the first AE is used as the input layer of the second AE, and the hidden layer of the second AE is used as the input layer of the third AE. Stack multiple AEs to realize a deep neural network. The 3-layer SAE model is shown in Figure 11:

The fuzzy comprehensive evaluation method proposed since integrating objective cognition and fuzzy mathematics is a combination of qualitative and quantitative methods.

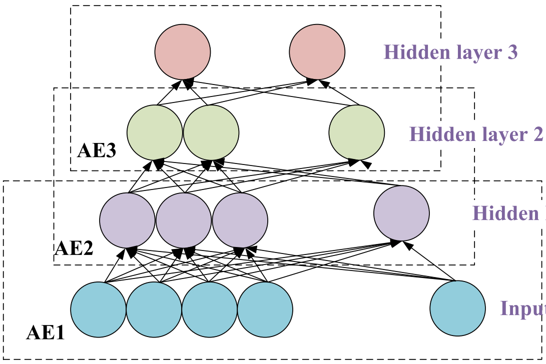

FIGURE 11. 3-layer SAE model.

It has great advantages when dealing with some non-deterministic problems. Because there are some soft evaluation aspects when evaluating interactive products of smart air conditioners, such as appearance and quickness of operation.

Therefore, first choose the fuzzy evaluation method to make a preliminary grade evaluation of related issues. After the grade evaluation, the information is quantitatively analyzed and evaluated using fuzzy mathematics. The specific steps are as follows: the first step is to determine the index level of the evaluation object. Level 1 $U = \{U_1, U_2, U_3, U_4\}$. Level two $U_1 = \{U_{11}, U_{12}, U_{13}, U_{14}\}$, $U_2 = \{U_{21}, U_{22}, U_{23}, U_{24}\}$, $U_3 = \{U_{31}, U_{32}, U_{33}\}$, $U_4 = \{U_{41}, U_{42}, U_{43}, U_{44}, U_{45}\}$, The second step is to divide the comments of the design plan from worst to best into five grades, corresponding to scores of 1 to 5; the third step is to assign the weights of evaluation factors. Finally, the single-factor fuzzy evaluation and multi-index evaluation are combined to select the scheme with the highest evaluation value.

III. EVALUATION OF HCI DESIGN OF SMART AIR CONDITIONERS

A. RESULTS OF THE QUESTIONNAIRE SURVEY

A total of 93 valid questionnaires are collected in this questionnaire survey, of which 38 are males and the rest are females. The basic situation of the surveyed population is shown in Figure 12:

Figure 12 shows that the number of people aged 25-35 in the survey population is the largest, accounting for 68.82%. Office workers account for more than half. Most of the people surveyed have a bachelor degree or above. There is no big difference in the proportions of the areas of residence, but the number of people living in the sliding areas is slightly larger, accounting for 27.37%. In terms of family status, the proportion of people surveyed who are married and have children accounted for the largest proportion, reaching 43.88%. Nearly half of the households have monthly incomes of 12000-18000, and most of the households are two-bedroom and one-living room, three-bedroom and one-living room, and three-bedroom and two-living room. The types of air conditioners used in homes are mostly suspended

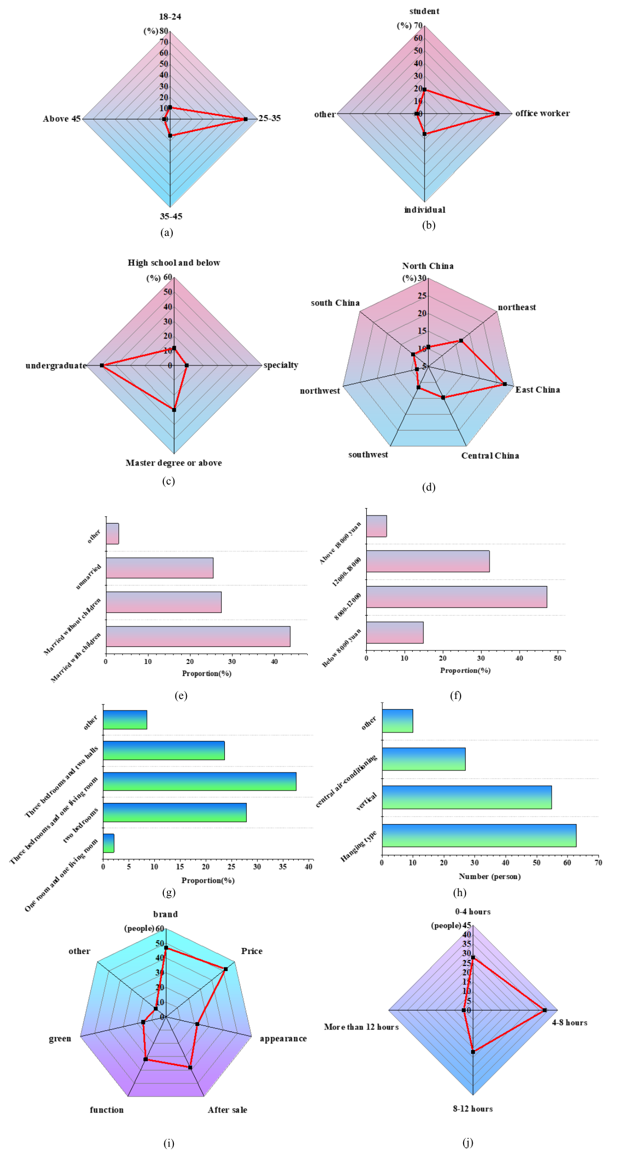

FIGURE 12. The basic situation of the survey population. (a: age ratio; b: occupation ratio; c: education ratio; d: residence area ratio; e: marital status; f: family monthly income; g: household type; h: household air conditioner type; i: purchase air conditioner factors; j: duration of using air conditioner).

air conditioners and vertical air conditioners. Regarding the purchase of air conditioners, the main factors for the surveyed users to purchase air conditioners are brand, price, after-sales service, and air-conditioning function. Most of these families use air conditioning for 0-8 hours a day.

Use Likert scale to score the questions in the questionnaire, with a score of 1-5 points. The score from low to high indicates that users are more affected by air conditioning, that is, their satisfaction with air conditioning is lower. Use this method to analyze the user's use of air conditioners, operating methods, and follow-up suggestions for improvement.

1) AIR CONDITIONING FUNCTION

The scoring result of the air conditioning function is shown in Figure 13:

In Figure 13, serial numbers 1-12 are all sentences about the use of air-conditioning functions. Frequently adjust the air-conditioning humidity and temperature; often adjust the air-conditioning wind direction and speed; often forget to turn off the air-conditioning; often choose energy-saving or power-saving mode; often choose sleep and silent mode; often use timing mode; often clean the air conditioner; often put forward different opinions on the air conditioner settings; often do not know the operating status of the air conditioner; are not very satisfied with the appearance of the air conditioner; and are not satisfied with the operation control of the air conditioner. Figure 13 shows that most users will adjust the temperature, humidity and wind speed and direction of the air conditioner. In the choice of the air conditioner sleep and energy saving modes, users have shown a two-level differentiation phenomenon. The main reason is: some users ignore these two functions because they are not clear about the functions of the above two modes. Users who know the sleep mode and energy-saving mode functions often use these two modes. They are not clear about the operating status of the air conditioner. The average score of is as high as 3.25, indicating that most air-conditioning users do not know the operating status of the air-conditioning, so it is necessary to improve the intuitiveness of the air-conditioning operating status.

2) AIR CONDITIONING OPERATION

The scoring result of air conditioning operation is shown in Figure 14:

In Figure 14, serial numbers 1-10 are statements about the operation of the air conditioner. The remote control is often used to control the air conditioner; the remote control is often not found; the wrong remote control buttons are often pressed; most of the buttons on the remote control have not been used; it is difficult to use the remote control; the buttons on the remote control are too small; the display screen is too small to see clearly; the response is slow when controlling the air conditioner; the mobile phone software air conditioner is often used; the panel is often used to control the air conditioner. Figure 14 shows that the highest average score is that most of the buttons on the remote control of the air conditioner have not been used, indicating that the current design of the remote control of the air conditioner lacks a certain degree of rationality. Many users are not familiar with the functions on the air conditioner remote control. The average score of users using the air conditioner remote control to control the air conditioner is also as high as 3.85, indicating that most users still think that it is more convenient to use the remote control to control the air conditioner than the mobile phone software and panels. Therefore, the reasonable design of the air conditioner remote control is very important.

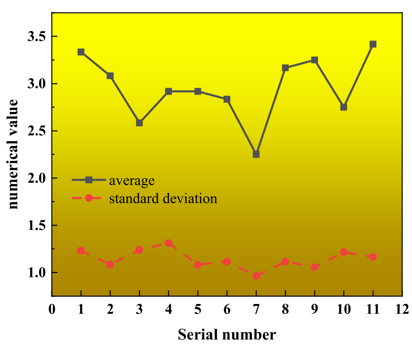

FIGURE 13. Score results of air-conditioning function.

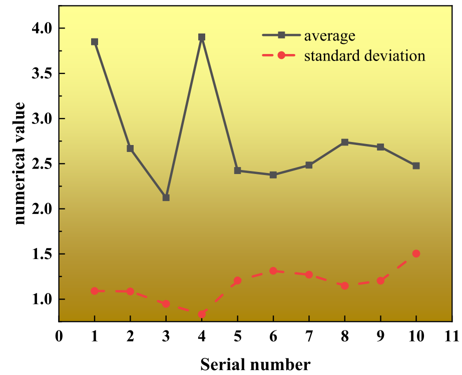

FIGURE 14. Scoring results of air-conditioning operation.

3) SUGGESTIONS FOR FOLLOW-UP IMPROVEMENT

The user's subsequent improvement opinions on the use of air conditioners are shown in Figure 15:

The serial numbers 1-9 in Figure 15 respectively represent: need to operate interface buttons simple and clear; need remote control to control air conditioner; need mobile phone software to control air conditioner; need panel control air conditioner; need air conditioner to automatically control and adjust according to the environment; need air conditioner to record user habits; the setting of the air conditioner is required; a tailor-made healthy air environment plan is required; the air conditioner is required to monitor the human body to adjust the appropriate temperature, humidity, and wind direction and speed; the air conditioner is required to have different user modes. Figure 15 shows that compared to mobile phone software and panel control, the average score of the remote control required to control the air conditioner is higher, indicating that the user prefers to use the remote control to control, and the user prefers the simple and clear operation interface air-conditioner remote. In addition, the investigation found that users hope that smart air conditioners can automatically adjust and control according to the indoor and outdoor environments, record user habits, and customize healthy air environment solutions for users.

B. ANALYSIS OF REMOTE CONTROL USING FUZZY EVALUATION METHOD

Using the previous investigation and analysis, the establishment of the secondary model of the air conditioner remote control design and the weights of indicators at all levels are shown in Figure 16:

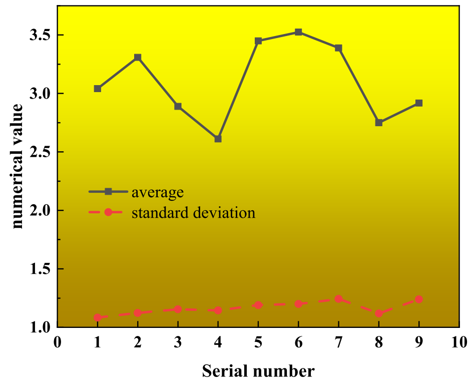

FIGURE 15. Rating results of subsequent improvement suggestions for air conditioners.

During the evaluation process, five corporate designers and professional teachers A, B, C, D, and E are invited. The research directions of the five experts are slightly different. The specific weight distribution is shown in Figure 17.

The three proposed remote-control design options are scored since the evaluation level. Since the number of experts is less than 30, the calculation adopts the weighted average method. The final evaluation results are shown in Figure 18:

According to the data in Figure 18, the single factor evaluation matrix R1, R2, R3, R4 is transformed, as shown in equations (4)-(7):

$$R_1 = \begin{Bmatrix} 0.75 & 0.68 & 0.85 \\ 0.72 & 0.85 & 0.92 \\ 0.85 & 0.78 & 0.73 \\ 0.68 & 0.64 & 0.83 \end{Bmatrix} \tag{4}$$

$$R_2 = \begin{Bmatrix} 0.89 & 0.83 & 0.85 \\ 0.80 & 0.72 & 0.79 \\ 0.69 & 0.78 & 0.63 \\ 0.76 & 0.91 & 0.73 \end{Bmatrix} \tag{5}$$

$$R_3 = \begin{Bmatrix} 0.73 & 0.90 & 0.70 \\ 0.73 & 0.82 & 0.71 \\ 0.86 & 0.81 & 0.85 \end{Bmatrix} \tag{6}$$

$$R_4 = \begin{Bmatrix} 0.78 & 0.71 & 0.92 \\ 0.86 & 0.74 & 0.76 \\ 0.86 & 0.75 & 0.75 \\ 0.81 & 0.77 & 0.91 \\ 0.82 & 0.79 & 0.87 \end{Bmatrix} \tag{7}$$

The low-level comprehensive evaluation is using the fuzzy composite matrix. And the results obtained are shown in equations (8)— (11):

$$\begin{aligned} B_1 &= U_1 \times R_1 = (0.300.250.200.25) \\ &\quad \times \begin{pmatrix} 0.75 & 0.68 & 0.85 \\ 0.72 & 0.72 & 0.92 \\ 0.85 & 0.78 & 0.73 \\ 0.68 & 0.64 & 0.83 \end{pmatrix} \\ &= (\,0.75 \quad 0.70 \quad 0.84\,) \end{aligned} \tag{8}$$

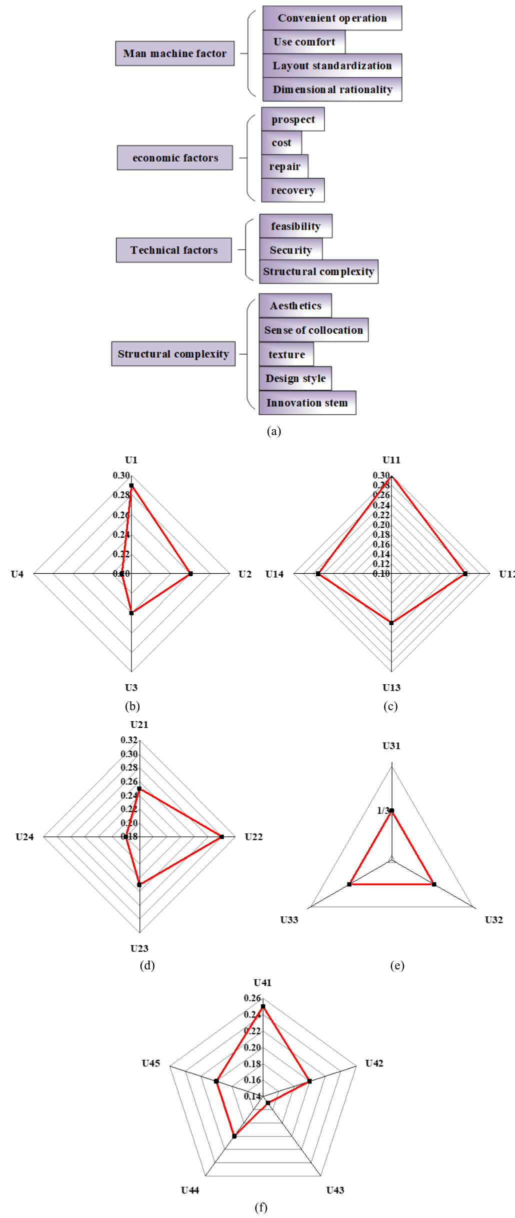

FIGURE 16. The secondary model of the remote-control design. (a: model design; b: first-level index; c: man-machine factor; d: economic factor; e: technical factor; f: aesthetic factor).

$$\begin{aligned} B_2 &= U_2 \times R_2 = (0.250.300.250.20) \\ &\quad \times \begin{pmatrix} 0.89 & 0.83 & 0.85 \\ 0.80 & 0.72 & 0.79 \\ 0.69 & 0.78 & 0.63 \\ 0.76 & 0.91 & 0.73 \end{pmatrix} \\ &= (\,0.79 \quad 0.80 \quad 0.75\,) \end{aligned} \tag{9}$$

$$\begin{aligned} B_3 &= U_3 \times R_3 = (\,1/3 \quad 1/3 \quad 1/3\,) \\ &\quad \times \begin{pmatrix} 0.73 & 0.90 & 0.70 \\ 0.73 & 0.82 & 0.71 \\ 0.86 & 0.81 & 0.85 \end{pmatrix} \\ &= (\,0.77 \quad 0.84 \quad 0.75\,) \end{aligned} \tag{10}$$

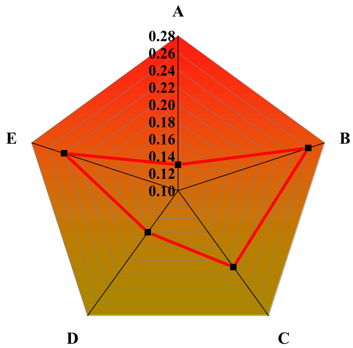

FIGURE 17. Weight distribution.

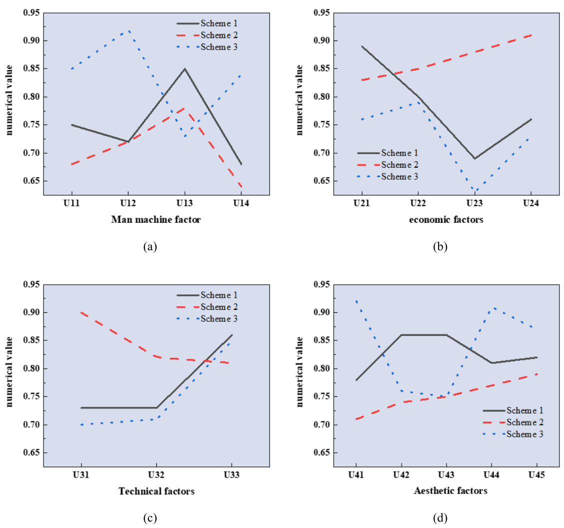

FIGURE 18. Evaluation result graph. (a: man-machine factor; b: economic factor; c: technical factor; d: aesthetic factor).

$$B_4 = U_4 \times R_4 = (0.25 \quad 0.20 \quad 0.15 \quad 0.20 \quad 0.20) \times \begin{pmatrix} 0.78 & 0.71 & 0.92 \\ 0.86 & 0.74 & 0.76 \\ 0.86 & 0.75 & 0.75 \\ 0.81 & 0.77 & 0.91 \\ 0.82 & 0.79 & 0.87 \end{pmatrix} = (0.82 \quad 0.75 \quad 0.86) \tag{11}$$

The high-level comprehensive evaluation is using the fuzzy matrix compound calculation method, as shown in equations (12)-(14):

$$U = \{U_1, U_2, U_3, U_4\} \tag{12}$$

$$R = \{B_1, B_2, B_3, B_4, B_5\} \tag{13}$$

$$B = U \times R = A \times \begin{pmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \end{pmatrix} = (0.29 \quad 0.24 \quad 0.26 \quad 0.21) \times \begin{pmatrix} 0.75 & 0.70 & 0.84 \\ 0.79 & 0.80 & 0.75 \\ 0.77 & 0.84 & 0.75 \\ 0.82 & 0.75 & 0.86 \end{pmatrix} = (0.78 \; 0.77 \; 0.80) \tag{14}$$

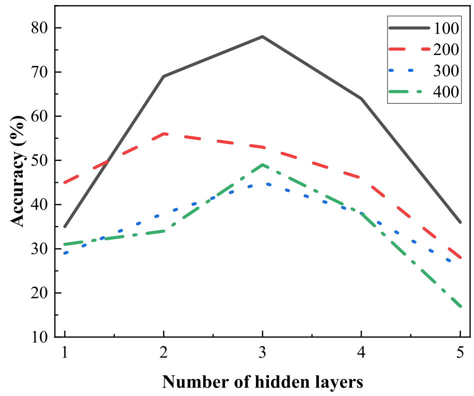

FIGURE 19. The relationship between the classification accuracy and the number of hidden layers.

According to the evaluation results, the pros, and cons of the three options are in the order of Option 3> Option 1> Option 3. Five experts evaluated the three options and found that, compared with Options 1 and 2, Option 3 has significant advantages in terms of comfort and aesthetics. Therefore, Option 3 is selected.

C. VIBRATION DETECTION AND ANALYSIS OF THE EXTERNAL AIR CONDITIONER

The relationship between the classification accuracy and the number of hidden layers is shown in Figure 19:

Figure 19 shows that under the number of layers and nodes of different hidden layers, the classification accuracy rate presents a convex function change, that is, the classification accuracy rate first increases and then decreases as the number of hidden layers increases. When the number of hidden layers is greater than 2, compared with the number of other three types of nodes in the graph, when the number of nodes is 100, the classification accuracy is significantly improved. When the number of layers is 3 and the number of nodes is 100, the classification accuracy rate is the highest. Therefore, in the experiment, the number of nodes in the deep learning diagnosis network is 100, and the number of layers is 3.

IV. CONCLUSION

With the popularization of smart home appliances in people's lives, problems in their use have gradually emerged, such as the unreasonable design of the remote control and the overly complex symbol information on the control panel. These problems have seriously affected the user experience. Smart air conditioners are used as research objects, and user needs are investigated and studied using the theory of HCI. Smart air conditioners have been researched and practiced on HCI design. Firstly, in order to establish a user model, the questions and needs of the target users are explored through the questionnaire survey method. Then, from the perspective of ergonomics, the hardware and software interaction interface of the smart air conditioner is analyzed. Finally, the smart air conditioner is designed for HCI according to user needs. Three preliminary options for the design of remote controllers for air conditioners are proposed. Fuzzy evaluation method is used to analyze and evaluate the three schemes. In the end, the final plan is selected using the evaluation results. The unsupervised feature value extraction of the vibration measurement signal of the outdoor unit of the household air conditioner is carried out using the stacked autoencoder neural network, and the number of nodes in the deep learning diagnosis network is determined to be 100 and the number of layers is 3. The design option stays at the theoretical stage, without actual production design, and no final user operation feedback can be obtained.

Therefore, in the case of unlimited time, the design plan will carry out the production of the actual model. Put the design plan into actual use, to get actual feedback.

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