

Practical Research on Smart Home Interactive Interface Design Based on Heuristics

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Abstract. The development of IoT, AI and sensor communication technology has led to the emergence of diverse interactive scenarios, with intelligent natural interactive interfaces becoming a common feature of smart home interactive interface design. However, the influence of traditional design methods and systems limits the ability of current designers to fully absorb new technological elements, preventing them from optimising product functions. In order to address this issue, this study has initiated an exploration of smart home interactive interface design methods. The researchers extracted 21 heuristics for smart home interactive interface design (DHS) from exemplary design cases and employed these in practice to assess their efficacy. They then summarised the model of the DHS for smart home interactive interface design.

Keywords: Design heuristics; smart home; interactive interface design.

1. Introduction

The concept of the smart home represents an innovative approach to family living that integrates household appliances, computer technology and the Internet of Things (IoT) into a unified system. The objective is to create a convenient, comfortable, healthy and energy-saving environment for family members by optimising the management of household appliances and computer equipment[1]. The rapid iteration of technology has brought both development and challenges to the smart home. The integration of new technologies into smart homes and the ability to meet the growing needs of users in a rapidly evolving field represent urgent problems[2, 3]. In this context, some companies and experts are engaged in technology research and development with the objective of meeting user needs and compensating for experience deficiencies through the incorporation of additional functions. The intelligent control of the home is primarily reflected in the intelligent interactive interface of the device as the principal control method. Consequently, some companies and experts are focusing their efforts on the research of smart home interactive interface design, with the goal of designing functions that better align with user needs[4]. Nevertheless, the smart home interactive interface design exhibits a number of distinctive characteristics, including the use of diverse interaction methods, integration of information and data, flexibility of system equipment, and an all-weather working status[5]. Additionally, it displays a tendency towards the weakening of scene boundaries, insensitivity to interaction, and a lack of entrance to connections[6]. Furthermore, the emergence of a new trend towards the provision of more personalised services and experiences has led to the original design methods and strategies becoming inadequate in meeting the current needs of smart home interactive interface design[7, 8].

Heuristics are typically regarded as a problem-solving strategy that employs straightforward and expedient "rules of thumb" to address specific issues and furnishes processes and methodologies for resolving problems[9]. A substantial body of research has demonstrated that design heuristics play a pivotal role in assisting designers in generating a greater number of solutions and enhancing the creativity of those solutions[10-12]. Consequently, this study will be based on design heuristics, propose new methods that can assist designers in program innovation, and promote the development of design heuristics and smart home interactive interface design.

2. Smart Home Interactive Interface Design Heuristic Tool

2.1 Design Heuristic Extraction

The extraction methods of design heuristics can be broadly categorised into three types: those based on literature and case studies, those based on expert and user research, and those based on the transformation of heuristic tools in other fields[13]. Among these methods, the approach based on literature and case studies involves the collection of cases, analysis, identification of design strategies, categorisation and construction of heuristics. The method based on expert and user research involves the extraction of design heuristics through observation and analysis of expert design activities or user feedback. The method of transforming heuristic tools in other fields involves the acquisition of new heuristics through the analysis of the core differences between fields and the targeted improvement of source tools to meet the needs of the target field. In contrast, the use of literature/case study-based methods for the extraction of design heuristics is more conducive to the discovery of new heuristics and is more efficient. In light of this, the researchers conducted research into the extraction of design heuristics, as illustrated in Figure 1.

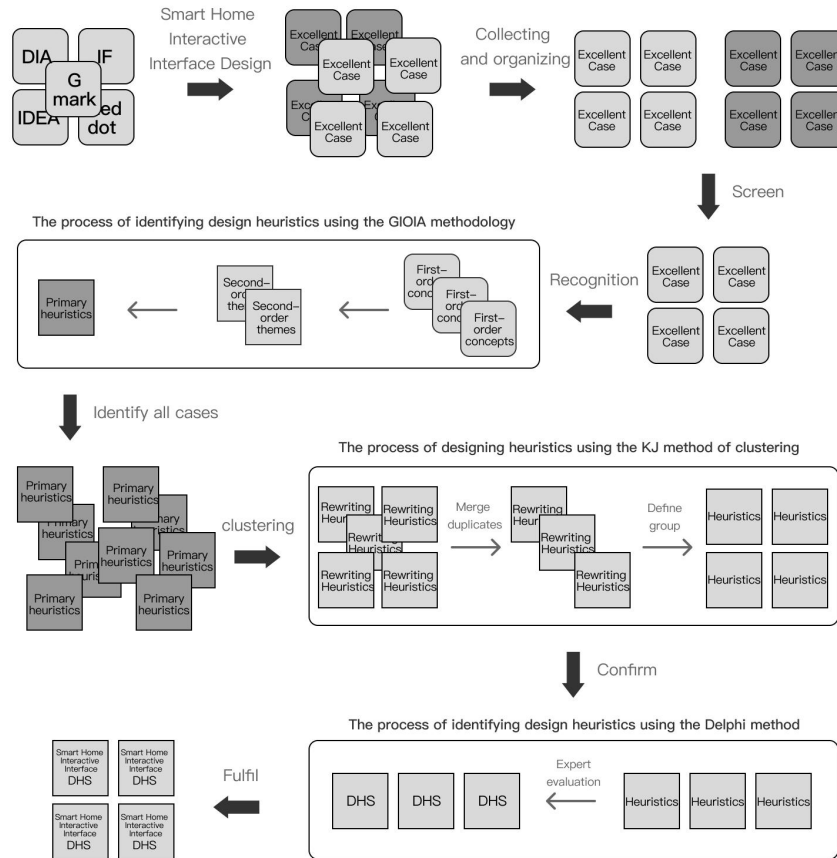


Fig. 1 Case-based design heuristic extraction process

2.2 Design Inspiration Cards

Following the aforementioned process, the researcher successfully extracted the smart home interaction interface, DHS, as illustrated in Table 1. In the field of design heuristic research, some researchers employ diagrams to summarise design heuristics, whereas others opt for a visual approach in the form of cards[14]. These cards often comprise basic elements, including inspiring titles, explanations, and examples. Some cards also include images of the examples, which serve to enhance understanding. Some cards are categorised for user convenience, while others provide detailed usage notes for better application of the heuristics[15]. In addition, in the digital age, some scholars have established specialised design heuristics and design strategy tool platforms, providing

designers with rich learning resources and efficient learning pathways[16]. Compared with charts and platforms, card formats are not only more efficient in communication and easier to use, but also easier to create. Consequently, this study employed the card format to visually represent the smart home interactive interface DHS, resulting in the generation of a pair of smart home interactive interface design heuristic cards (DHSC), as illustrated in Figure 2. The card comprises case images, heuristic titles, explanations, and cases. It also includes a description, source, and other pertinent information. The complete smart home interactive interface DHS can be accessed at <https://liuqi.my.canvasite.cn/d-hs>.

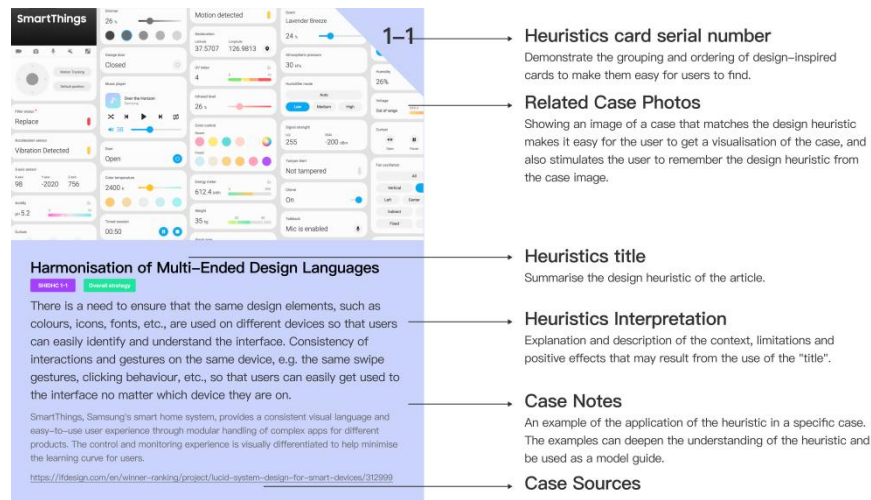


Fig. 2 Smart home interface design heuristic card example

3. Smart Home Interactive Interface Design Practice

3.1 Design Practice analysis

3.1.1 Requirements analysis

The smart home IoT system encompasses all intelligent connected devices in a household, such as cameras, door locks, floor-cleaning robots, routers, and various other IoT-enabled devices. Currently, the Lechange APP aims to integrate a new bulb device, enabling users to conveniently operate the device within the APP. Specifically, the objective is to achieve control over the bulb's on/off status, timed on/off, color adjustment, and the ability to set and switch between different scene modes through the APP. This requires a thoughtful arrangement of the bulb's switch, timer, color adjustment, and scene switching functionalities within the newly integrated bulb device's control interface, taking into account the various states and interactions of these functions. A detailed list of specific issues and requirements can be found in Table 1.

Table 1. List of questions and requirements

Page/function module	Requirements/Features List
Home-Light Bulb Information Card	Switch button; Basic information of the light bulb (such as switch status, energy consumption status, timing status, etc.)
Light bulb control center	switch button; Basic information about the light bulb; Different light bulb color modes and scene mode setting trigger buttons; Timing and countdown setting trigger button
Light bulb scene settings	scene theme; Supports modification of bulb cover image, color, contrast, and brightness; light bulb display

Bulb timing function	<p>Scheduled task list; List open/close button; Add, delete and modify scheduled task list buttons; When adding a new task, time selection and task selection functions are included</p>
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3.1.2 User research

Based on previous user research reports of the Lechange APP, the target user group for this design can be positioned as young adults residing in major cities. However, given the vast size of this population and their diverse demands for smart home devices, designers have further segmented the target users into three categories: trendsetters, busy professionals, and quality-seekers. Detailed user personas are illustrated in Figure 3.

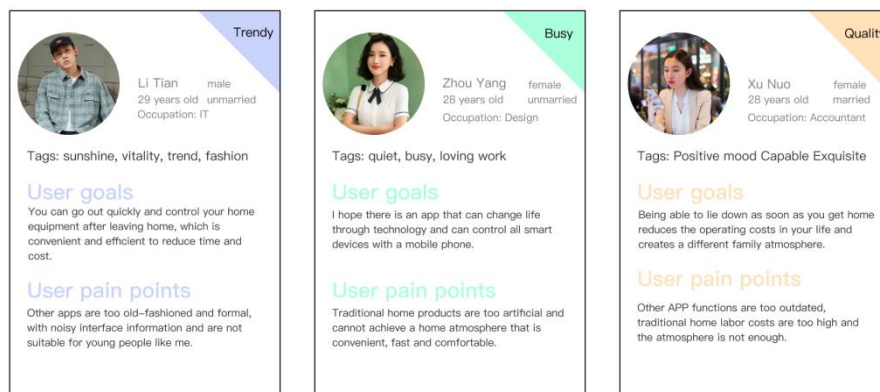


Fig. 3 User profile

Despite the varying demands of these three user groups towards smart home devices, an in-depth analysis reveals that in the context of smart bulb control, they all seek effectiveness in lighting control to enhance their daily lives and quality of experience. Designers have summarized the main objectives of these users as pursuing convenience and intelligence in lighting control devices, thereby reducing living costs and enhancing living comfort. Their behavioral motivations and target needs are illustrated in Figure 4. Most users' initial motivation is to pursue an effective and user-friendly lighting control device. Therefore, the interface of the control device needs to be simple yet comprehensive. Only on this basis will users further pursue convenience, comfort, and ultimately satisfy their aspirations for a quality lifestyle.

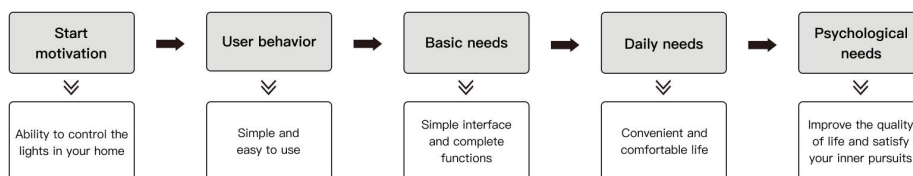


Fig. 4 User behavioural motivations and target needs

3.1.3 User research

In alignment with the business objectives and user goals of this task, the design objective can be summarized as developing a simple yet comprehensive smart bulb control system. This system aims to achieve comprehensive control over smart bulbs, encompassing functionalities such as on/off switching, color adjustment, mode settings, and timing configurations. Additionally, it strives to meet users' demands for a smart lighting control interface that enhances their quality of life. To achieve this objective, it can be further decomposed into interactive and visual layer goals. At the interactive layer, the goals are to establish a clear information hierarchy, develop a comprehensive functional framework, and ensure effective user interactions. On the visual layer, the objectives are

to create a minimal yet effective design, maintain consistency and standardization, and incorporate emotional elements to pursue a visual style that aligns with the brand's tone. The evolution and decomposition of these goals are illustrated in Figure 5.

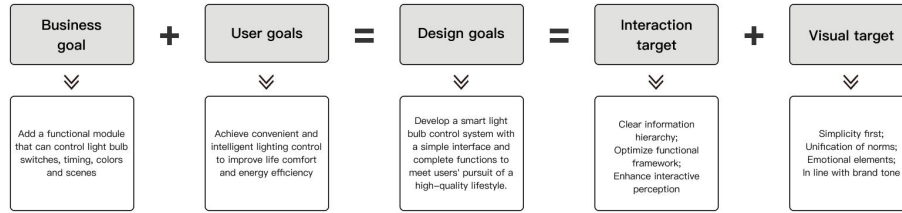


Fig. 5 Goal evolution and dismantling process

Based on the aforementioned design objectives, researchers have proposed a target hierarchy and corresponding design strategies as illustrated in Figure 6. At the business level, considering the need for a unified interface style, privacy protection, and energy efficiency, the designer aims to integrate smart bulb functionality into the Lechange APP, ensuring interface consistency while addressing energy conservation and family privacy concerns. At the user level, by borrowing the concept of multi-level task settings with one-touch access, scene settings and one-click switching functions are introduced to enhance the convenience of users controlling smart devices. At the interaction level, to strengthen user feedback perception, multimodal feedback methods such as visual and auditory cues are employed, combining sound effects with lighting effects to enhance the interactive experience. At the visual level, a combination of simulation and high-tech visual elements is utilized to provide a fashionable and user-friendly interface, while supporting user customization of interface elements to satisfy individual preferences.

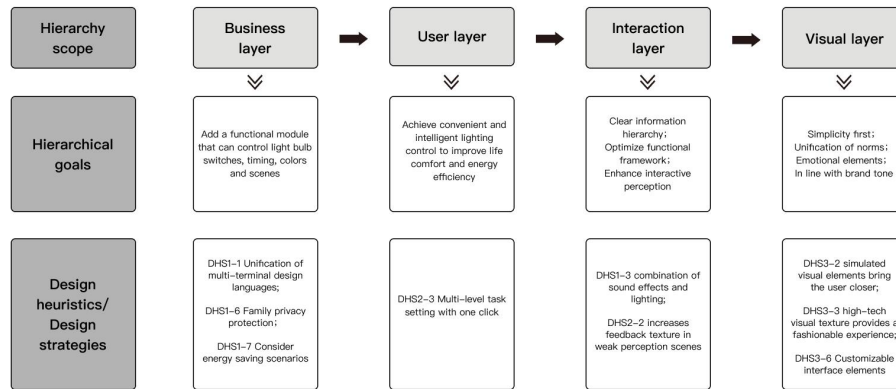


Fig. 6 Target Hierarchy and Corresponding Design Strategies

3.2 Design Practice Scheme

3.2.1 Front page

On the homepage, users can add rooms and devices, but as this design primarily focuses on the addition of smart bulbs, the process of adding room scenarios will not be elaborated. During the design process, the designer adhered to the principles of clear information hierarchy and optimized functional frameworks, thus refraining from incorporating excessive functional controls and interactive gestures on the homepage's information cards. Users can simply tap on a device card on the homepage to expand and view all cards of that particular device type. Tapping the card again leads to a page displaying all devices located in the same room. Additionally, long-pressing a card allows for the deletion of that device. Specific interactive operations can be referenced in Figures 7.

Regarding the visual design, the entire page system employs a card-based segmentation approach to create a refreshing and transparent visual space. Through rational layout planning, the interface achieves a sense of transparency and comfort. Furthermore, the border design is simplified,

avoiding the use of excessive dividing lines or other line elements to maintain the integrity of the interface. Conversely, whitespace is skillfully utilized to showcase the hierarchical relationship of information, enhancing the aesthetics of the interface while highlighting crucial information on the cards for quick access by users. Finally, a consistent design style is applied across various component modules, and rounded corners are given to the cards, lending the overall design a more approachable appeal.

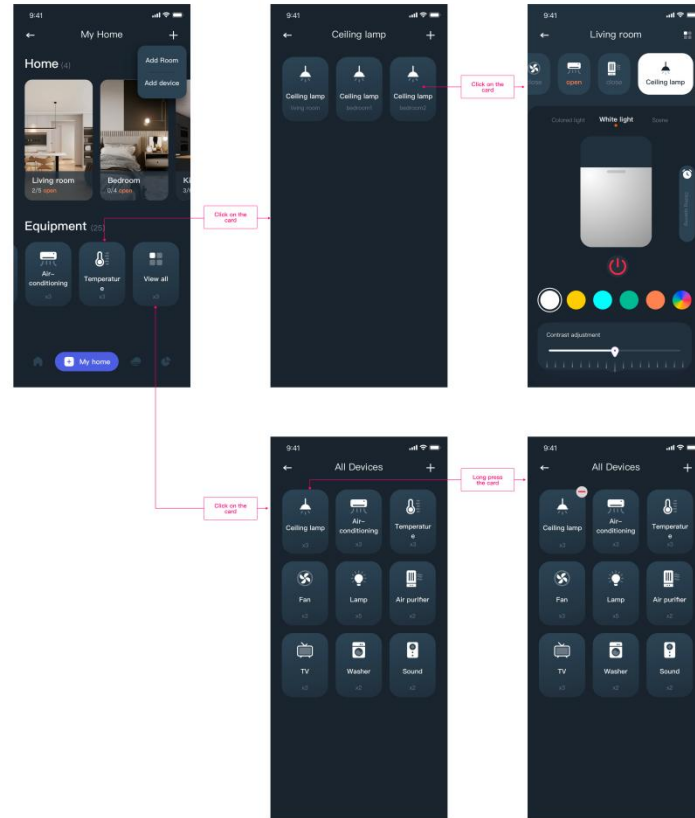


Fig. 7 Interaction flow of home page information card

3.2.2 Middle console control page

Centralized Control Page: Inspired by the DHS2-3 approach of "multi-level task settings with one-touch access," the designer has created two page view modes for the centralized control page. The first is a simple tiled view mode, where users can view all smart devices in a room and check basic device information, such as the timing of lamps and the temperature of air conditioners. These cards feature on/off buttons for convenient user control. The second is a deep control view, where users can switch modes, adjust light colors, preset scenes, and set timed scenes. Responding to the DHS2-2 approach of "enhancing feedback quality in weakly perceived scenarios," the designer has implemented a sliding bar interaction to adjust light contrast and brightness, enhancing the interactive feedback quality. Additionally, users can swipe up to activate the timed mode and swipe down to deactivate it, both actions accompanied by sound effects. The specific interaction flow can be referenced in Figure 8.

At the visual level, the designer primarily employed the DHS3-2 strategy of "using simulated visual elements to bring users closer" and the DHS3-3 strategy of "providing a fashionable experience through high-tech visual textures." By simulating real-life visual elements for icon design, specifically allowing users to upload real home photos as backgrounds in the regular view mode, the designer adds a sense of warmth to the home. The sliding bars in the deep control view also utilize pseudo-3D design, enhancing the authenticity of the visual elements and increasing user familiarity. Additionally, a dark color palette was chosen for the main interface, along with

enhanced light brightness, contrast, and color adjustment buttons, coupled with dynamic interaction effects, to highlight the high-tech texture of the interface.

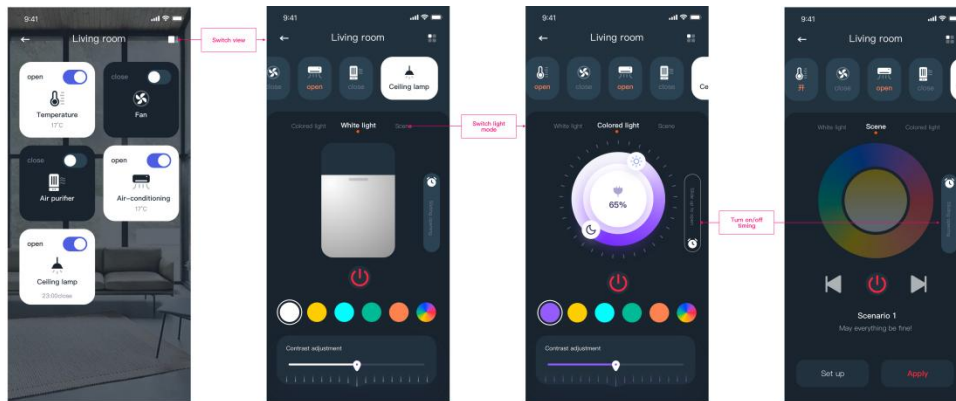


Fig. 8 Interactive interface of the centre console page

3.2.3 Bulb Scene Mode Settings

After switching to the scene mode on the centralized control page, users can navigate through different scenes (the system has preset 8 scenes, supporting up to 8) by clicking the left and right buttons or swiping. Clicking the "Set This Scene" button allows users to edit the scene, adjusting brightness, contrast, and color, and fixing these settings for that specific scene. Users can also name the scene for quick access in the future. Please refer to Figure 9 for detailed operation procedures. Furthermore, inspired by DHS3-6's approach of "customizable interface elements," the designer allows users to personalize scene images and captions according to their preferences and needs.

To enhance user experience, operational perception, and clarity of operation results, as well as to boost interface aesthetics and appeal, the designer optimized the interactive interface based on the principles of DHS2-2 ("enhancing feedback quality in weakly perceived scenarios") and DHS3-3 ("providing a fashionable experience through high-tech visual textures"). For instance, in the color light mode of the centralized control page, the designer transformed the brightness adjustment slider into a circular slider with accompanying audio feedback. The contrast adjustment was also presented in a card-based design, enhancing visual quality. To avoid monotony in swiping operations, color selection was changed to a click-based interaction. In terms of visual design, a more technological dark theme was adopted, with icons and cards ensuring a clear and effective layout.

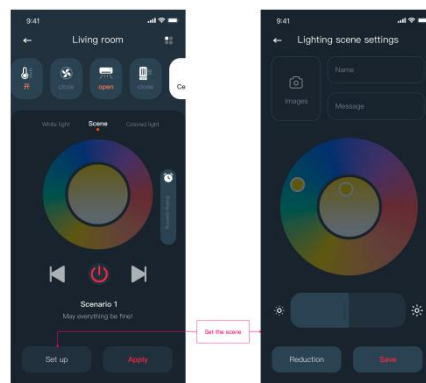


Fig. 9 Bulb Scene Mode Setting

3.2.4 Bulb Timer Mode Settings

On the centralized control page, users can manage timing configurations via a sliding switch on the right. Sliding down to turn off the timer settings will cancel all scheduled timers, while sliding up to activate will engage the topmost timer setting. Users can simply slide the clock icon to the middle to access the timer settings page. On this page, users can delete, add, and modify different

timing requirements. Specific operations include clicking the button next to a timer card to turn off or on a particular timing mode, swiping left to delete that timer setting, and long-pressing to rearrange the timer cards. Clicking on a timer card will lead to a popup window for timer configuration, where users can select the start and end times of the timer as well as the repetition frequency. Please refer to Figure 10 for detailed operation instructions.

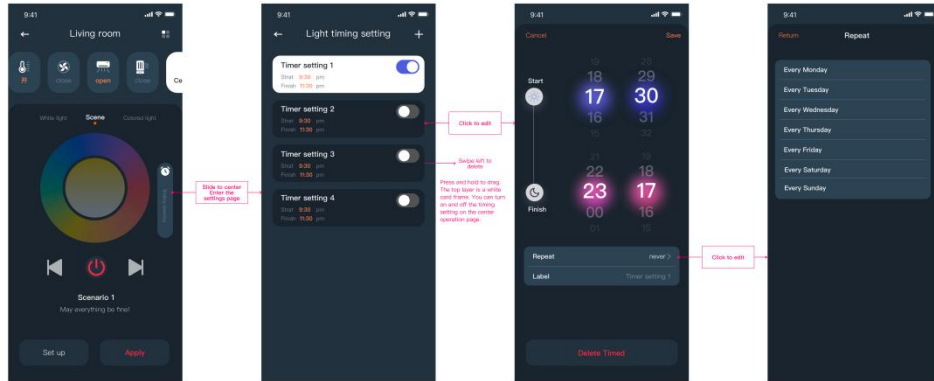


Fig. 10 Lamp Timing Mode Setting

3.2.5 Family Member Management

Drawing inspiration from DHS1-6's emphasis on "family privacy protection," the designer has implemented a fine-grained user authorization and permission management system to ensure effective control over personal data access. Consequently, a family member management feature has been added to the "My" page, enabling users to restrict other members' manipulation of smart home devices. Please refer to Figure 11 for a detailed page design overview.

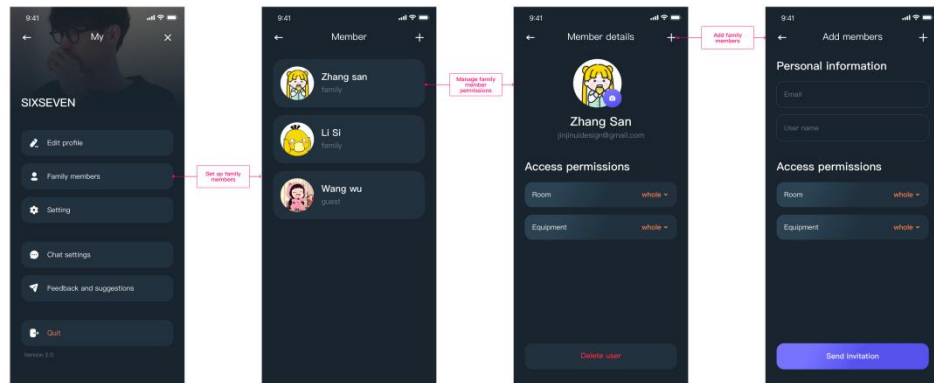


Fig. 11 Family Member Management Page

3.2.6 Front page

Energy Consumption Details: Inspired by DHS1-7's focus on "energy-saving scenarios," the designer has introduced a range of functionalities, including energy monitoring and management, intelligent scheduling and control, energy reminders and prompts, personalized settings and suggestions, data visualization and analysis, as well as intelligent linkage and collaboration. To this end, a new device data page has been added, where users can conveniently view the energy consumption of their devices and receive personalized energy-saving suggestions powered by big data and artificial intelligence technologies. The complete design can be viewed in Figure 12.



Fig. 12 Device Data Page

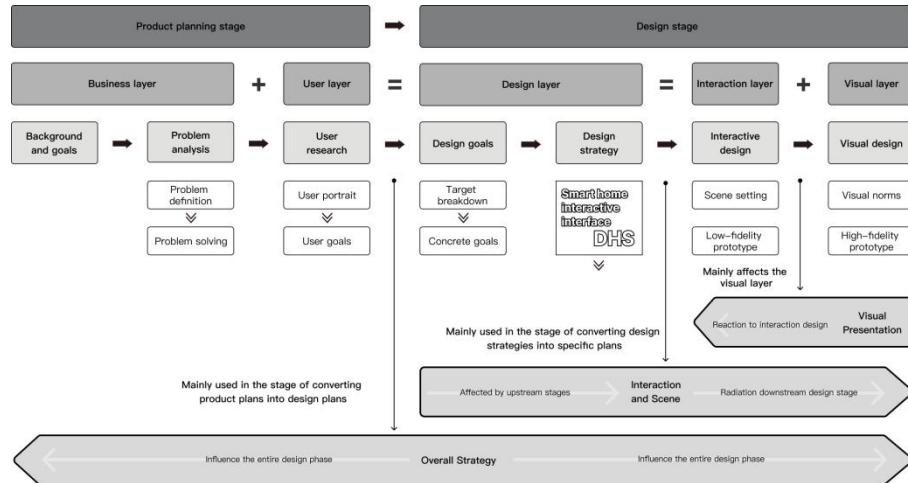
3.3 Design Practice Conclusion

Through extensive design practices, researchers and professional designers have discovered that the smart home interaction interface DHS not only provides additional inspiration for design, adding creative ideas that are not inherent in the original scheme, but also serves as a tool strategy, offering specific design implementation paths and methods for achieving program objectives. Among them, the inspirations provided by the "overall strategy" mostly contribute to enhancing the creative solutions, while the insights derived from "scenario and interaction" and "visual presentation" not only offer strategies for achieving program goals but also assess the original scheme. However, as the primary objective of this research stage is to obtain the overall usage method of the smart home interaction interface DHS, and considering the constraints of time and space, this study will not delve into the specific action paths of each design heuristic in detail.

Design objectives play a pivotal role in formulating design strategies as they represent a comprehensive consideration of business objectives and user needs. In this process, the "overall strategy" aspect of the smart home interaction interface DHS focuses primarily on the definition of functionalities, constituting a crucial component in the determination of design objectives. Therefore, the "overall strategy" should be leveraged effectively during the design objective phase to ensure the accuracy and completeness of the design objectives. In contrast, "scenario and interaction" and "visual presentation" are more focused on the implementation level of design. Among them, "scenario and interaction" primarily concerns itself with the interaction flow and experience between users and products, necessitating its involvement in the interaction design phase to optimize the interaction methods and processes between users and products. Meanwhile, "visual presentation" emphasizes the visual expression and aesthetic design of products, requiring its intervention in the visual design phase to ensure that the visual effects align with the design objectives and user expectations.

Through design practices, it has been observed that the "overall strategy" aspect of the smart home interaction interface DHS not only influences the revision of design solutions but also directly impacts the objectives at the business and user levels. For instance, in this design exercise, DHS1-1 (unified multi-platform design language), DHS1-6 (home privacy protection), and DHS1-7 (consideration of energy-saving scenarios) have served to inspire business-level objectives. Consequently, there is ample reason to believe that the "overall strategy" plays a significant role throughout the entire design process, particularly in the stage of transforming product concepts into design solutions. On the other hand, the DHS aspect of "scenario and interaction" is influenced by upstream stages and, in turn, impacts downstream visual design. For example, in this design practice, the objective of facilitating convenient light control led to the identification of the design heuristic DHS2-3 (multi-level task settings accessible with a single tap). Therefore, researchers argue that "scenario and interaction" is influenced by upstream design objectives and affects downstream visual design, primarily functioning during the transition from design strategy to design solution. In contrast, the role of the "visual presentation" aspect of DHS is relatively straightforward, primarily influencing visual design and, conversely, affecting interaction design.

Based on the aforementioned analysis, researchers have summarized a design heuristic usage model, as depicted in Figure 5-15. This model clearly illustrates the entry points and modes of action of the smart home interaction interface DHS throughout the design process, providing designers with clearer and more systematic guidance, thereby enhancing the quality and efficiency of design.



4. Summary

In recent years, as technology rapidly advances and user demands diversify, design tasks faced by designers have become increasingly complex. To assist smart home interface designers in tackling this challenge, researchers have extracted 21 distinct design heuristics from outstanding case studies and developed an assistive tool called DHSC. Subsequent design practices leveraging this tool have culminated in the formulation of a DHS utilization model. However, these studies also possess certain limitations. For instance, the process of design heuristic extraction is susceptible to the subjective biases and potential gaps in knowledge and experience of researchers, which may lead to an incomplete exploration of design heuristics in award-winning cases. Furthermore, design practices are often constrained by factors such as time, resources, and technological proficiency, thereby affecting the effectiveness and feasibility of design heuristics. Additionally, the exploration of design heuristic application methods lacks rigor, and the resulting utilization model may be insufficiently convincing due to its reliance solely on practical summaries. Future research could build upon these foundations to further exploit design heuristics in broader and more diverse smart home interface design practices. Simultaneously, subsequent studies could draw inspiration from this methodology to continuously refine design theories and practices in related fields.

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