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Design Framework and Intelligent In-Vehicle Information System for Sensor-Cloud Platform and Applications

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ABSTRACT The sensor-cloud system (SCS) integrates sensors, sensor networks, and the cloud for managing sensors, collecting data, and decision-making. Smart transportation based on the sensor-cloud approach is constantly improving. The sensor cloud has promoted the industrialization of the Internet of Vehicles and has also brought it to a new research stage. SCS permits users to utilize its platform as a service, and providers offer several environments to users for the development of applications, which enhances the user driving experience. However, many users have concerns with the sensor-cloud platform (SCP) and the environment. Furthermore, to save sensor resources, we propose a novel design model and method for in-vehicle information systems (IVIS) in the framework of SCS, which can optimize the SCP user experience. Our contribution has three main aspects: first, we extract the new features presented by the IVIS under the sensor-cloud environment; second, we establish a mapping between the IVIS and user needs and innovatively propose the SCP-oriented experience element-level scheme; finally, an IVIS design method based on the experience element is proposed. Furthermore, this research establishes a mapping between user experience elements and intelligent IVIS design features in the SCS environment and proposes an innovative IVIS model.

INDEX TERMS Intelligent in-vehicle information system, sensor cloud, sensor resources, user experience.

I. INTRODUCTION

With the rapid development and integration of cloud computing technology and Internet of Things (IoT) applications, the sensor cloud has become an emerging cloud computing platform that supports the interaction of interconnected sensor devices with cloud applications and other devices. The intelligent data analysis of the Internet of Vehicles (IoV) in the sensor-cloud center has become a supporting platform for smart cities, smart transportation, smart manufacturing, and smart homes [1]–[5]. Sensors are widely used in various aspects of society such as environmental protection, measurement and control, and health. Among them, smart transportation based on the sensor cloud is constantly improving. The sensor cloud has promoted the industrialization of the IoV and has also brought it to a new research stage [6], [7]. As an important carrier for the realization of intelligent transportation systems, the IoV refers to the use of advanced information and communication technology [8]–[10], based on the in-vehicle network, the intervehicle network, and the vehicle cloud network, in accordance with the agreed system architecture and its communication protocol and data interaction standards, a cyber-physical fusion system for communication and data exchange between

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vehicles' (X: vehicles, roads, pedestrians and mobile Internet, etc.). The IoV not only provides important conditions and basic guarantees for the development of intelligent transportation systems, it is also one of the important vertical industries of the 5th Generation Mobile Communication Technology (5G), and it has been used by industry and academia [11]–[13]. The development of the IoV focuses on networking and intelligence and gradually shifts from single-vehicle intelligence to multivehicle collaboration. The sensor cloud can organically integrate vehicles with other vehicles, Road Side Unit, and other traffic elements to compensate for the shortcomings of insufficient computing power of a single vehicle terminal and tight communication resources of the IoV network. At the same time, the high reliability and low latency of 5G technology has also improved the feasibility of the sensor cloud in the IoV arena. The combination of a mobile sensor-cloud system and IoV further enriches and expands the application scenarios of IoV and promotes the gradual development of IoV [14]–[16]. The development from in-vehicle intelligence and bicycle intelligence to collaborative intelligence of ''people, vehicles, roads, and clouds'' provides a solid technical foundation for the connected, intelligent, and coordinated development of IoV and promotes the industrialization of new IoV technologies in recognition of the coordinated development of the ''smart car'' and ''smart road.'' However, with the rapid development of the Internet industry and wireless communication technology, users are not satisfied with the in-vehicle information system (IVIS), which can only provide safety warnings and assisted driving, and are increasingly eager to bring Internet applications into the IoV field [17]. This would enhance the riding experience. According to the related application scenarios and requirements of the IoV, its application types can be divided into three categories: traffic safety, traffic efficiency, and infotainment/telematics. Traffic safety applications mainly use vehicle sensors to perceive the surrounding environment during driving, collect data, identify dynamic and static conditions, while simultaneously, the communication unit can broadcast special events (such as road congestion and vehicle failure) to the rear vehicles, so that the driver has enough events to make React to avoid traffic accidents. Traffic safety applications are mainly based on safety warning applications, including forward collision warnings, emergency vehicle warnings, and intersection collision warnings [18]–[20]. Traffic efficiency applications mainly use the communication unit of the vehicle to carry out vehicle–vehicle and vehicle–road information interaction, to achieve intelligent collaboration between vehicles and road infrastructure, to obtain and implement road condition information, and to achieve rational traffic scheduling to relieve traffic congestion and improve traffic operation efficiency. Traffic efficiency applications are mainly assisted driving applications, including slowdown reminders, Electronic Toll Collection, and intelligent traffic lights at intersections. Information service applications mainly use onboard computer modules and communication units to implement a series of applications including in-vehicle entertainment, in-vehicle office, navigation, and consulting to enhance the driving experience. In addition, with the continuous popularization of smart terminals, Internet applications such as virtual reality and online games have also been brought into the IoV fold.

Smart vehicles adopt new interactive technologies to provide users with more choices and meet diverse user needs. However, during driving, users need to operate the IVIS system in the vehicle to handle different types of information tasks [21]. This makes the user unable to concentrate on completing the driving behavior, which leads to a negative driving experience. We have proposed a design framework and method for IVIS based on user experience, which is of great significance for optimizing the design of smart vehicle information systems and promoting the development of the smart vehicle industry [22].

The structure of our paper is as follows. Section 2 introduces some works related to our proposed method. Section 3 is focused on research into sensor-cloud platform (SCP) user experience elements. The IVIS design method is proposed in Section 4. Section 5 offers conclusions and direction for future works.

II. RELATED WORKS

In this section, we mainly introduce some research related to our proposed method.

A. RESEARCH ON INTELLIGENT IVIS

The rapid growth of smart vehicle system data, internal and external information interaction data, and user status data has led to a rapid increase in the amount of displayed information. At the same time, the dimensions of the displayed information have also become more complicated. Natural display based on the road conditions ahead, assisted driving display, multiscreen display in the vehicle, display of information inside and outside the vehicle, integrated display of mobile devices and vehicles, and so on will all become multidimensional display content. The complexity of the quantity and dimensions of information calls for sufficient space for the display in the vehicle's interior. In the future, the displays in smart vehicles will no longer be limited to areas such as traditional dashboards, center consoles, and rearview mirrors [23], [24]. Any physical equipment and environment may be embedded in the display device and become a medium for information display. With the application of multiple physical media devices represented by flexible screens and transparent screens, the information display of smart vehicles can appear in almost all areas inside and outside the vehicle. For example, Active-Matrix Organic Light-Emitting Diode (AMOLED), as a new generation of display panels, breaks the limitations of traditional rectangular screens, can realize specially shaped screen cutting, and meets different design requirements [25]–[27]. At the same time, AMOLED has flexible characteristics, which may subvert the current design concept of onboard display screens, so that it can appear in smart vehicles in a broader range and more forms. The most prominent feature of the ubiquitous display is the diversification of display positions and display methods [28]–[30]. The original driving-centric information architecture will be decomposed according to the levels of entertainment, interaction, and personalized settings. From the perspective of the vehicle display system, the display of the vehicle's human–computer interaction (HCI) interface in different areas will be systematically designed. Design dimensions, such as information distribution, information transmission in different display areas, and visualization of different information dimensions, will be introduced. Among many display technologies, the most likely major breakthrough is the head-up display (HUD).

From the perspective of HCI, the most significant advantage of the HUD is that the driver can obtain all kinds of information without leaving the road ahead, effectively improving driving safety, and it is considered the safest display method in the future one [31]. The HUD system visually processes navigation, road conditions, vehicle speed, and other data to the position near the front windshield of the vehicle, helping the driver to obtain driving information, driving assistance information, and even entertainment information. For example, BMW's HUD system has been used in many of its vehicles. Driving behavior will still be a vital issue in automotive HCI design in the next few years [32]–[35]. Therefore, the HUD has the advantages of improving driving safety and reducing the cognitive load of the driver so that it has more application scenarios and space. Even if fully automated driving is realized in the future, users will still have many demands for obtaining information through the front windshield, and the HUD also has an extensive design space. In terms of display mode, the display mode of smart vehicles will no longer be limited to a single physical device but will integrate multiple locations and display forms. Environment-based display technologies such as augmented reality, HUD, and holographic display have gradually matured and will be applied to dashboards and center consoles to form a new display interface [36]–[40].

B. RESEARCH ON SCP USER EXPERIENCE

User-centered design (UCD) emphasizes starting from the needs of users, placing users at the center of product development, developing products that meet user needs, and achieving the best user experience. UCD provides the foundation and methods for research into smart vehicle user experience [28], [41]–[46]. With the improvement of the automation level of smart vehicles, users are freed from arduous driving tasks, but at the same time they have less control over the vehicle. In the unmanned stage, there may even be a loss of control. The reduction or loss of control will have a negative impact on users' sense of security and emotions [47]–[51]. At present, many researchers use computer technology to give full play to the value advantages of massive data by analyzing data characteristics, exploring user characteristics, and mining user needs to build a portrait of user groups. Jansen *et al.* used data on nearly 35,000 users of social media platforms to cluster and represent driving users based on how they share business information.

C. REAL-TIME MEDIA INTERACTIVE EXPERIENCE-RELATED RESEARCH

In the application of IoV smart vehicles, the physical devices in the vehicle may become interactive media and be given new interactive functions [52], [53]. In addition, physical media interaction will present information in a physical form, and users will interact and perceive dynamic interactive information on the physical interface through new interaction methods (such as tactile interaction). With the development of intelligent technology and material science, the physical control equipment of automobiles has gradually surpassed its fixed physical attributes and has begun to be given dynamic interactive content, forming a physical display control interface and a communication medium for information and data. In terms of media materials, its properties such as material, flexibility, and curvature realize diversified entities; at the same time, by controlling the linearity, sensitivity, repeatability, and other conditions of the interactive sensor, a new interactive form is constructed. Relevant technologies include hand-held/hands-off steering wheel detection, lane departure, and accident state warning. The new interaction method of physical materials constructs flexible entity interaction and further replaces mechanized traditional entity interaction [54]–[57]. The driver completes the operation and obtains feedback through more natural touch or button behavior, which is more in line with the driver's operating habits. The physical media interaction method provides interactive, tangible and physical spatial data, enabling users to master and manipulate complex three-dimensional data, thereby supporting more effective and natural learning [58]–[61]. If fully automated driving can be achieved, users' main driving concerns will shift to the interior of the smart vehicle system, and significant changes will occur in the interior of the vehicle, creating future scenarios for self-driving vehicles in terms of mobile entertainment, mobile rest, and mobile office. In such a scenario, traditional control equipment may be hidden or disappeared and replaced by other methods. In the new technological environment, the design of physical interaction media is not only the design of the physical interface but also the design of virtual information, breaking through the traditional form of control equipment and forming a new physical interaction medium [62]–[65].

D. RESEARCH ON EMOTIONAL INTERACTIVE EXPERIENCE IN-VEHICLE

On the basis of intelligent driving, future intelligent vehicles will be able to ''understand and think'' and thereby realize intelligent, emotional interaction. Perception and cognitive capabilities are the two critical aspects of the core capabilities of artificial intelligence [66]. The perception and cognitive capabilities of artificial intelligence-powered vehicles are the prerequisites for intelligent, emotional interaction. In the future era of autonomous driving, smart vehicles should not only be tools for responding to people's commands but should also communicate and collaborate with users [67]–[69]. The ability to ''understand and think'' enables smart vehicles to perform complex tasks that usually require human intelligence to complete, helps users complete driving tasks in a more efficient manner, and meets various needs raised by users through communication and interaction [47]. As an intelligent body, an intelligent vehicle will interact not only with users in the vehicle but also with external traffic entities such as pedestrians, other smart vehicles, and transportation infrastructure [70]. As the main body of communication, the smart driving vehicle interacts with the surrounding individuals through various forms and establishes an emotional interaction relationship. When pedestrians are about to cross the street, they need to be able to know the impending behavior of the smart vehicle: that is, the intention of the smart vehicle.

III. SCP USER EXPERIENCE ELEMENTS

The elements of SCP user experience are defined by the physical layer, cognitive layer, and perceptual layer, as shown in Figure 1. The physical layer involves design issues related to the user's physiological attributes. For example, according to anthropometric data, determine the touch, field of view, size, press, rotation, click, and other related design aspects of the in-vehicle information interaction interface. The cognitive layer involves design issues at the user's cognition and understanding level, including recognizability, understandability, learnability, and ease of use. The perceptual level involves design issues at the emotional level, including the quality of user emotion, aesthetics, and experience.

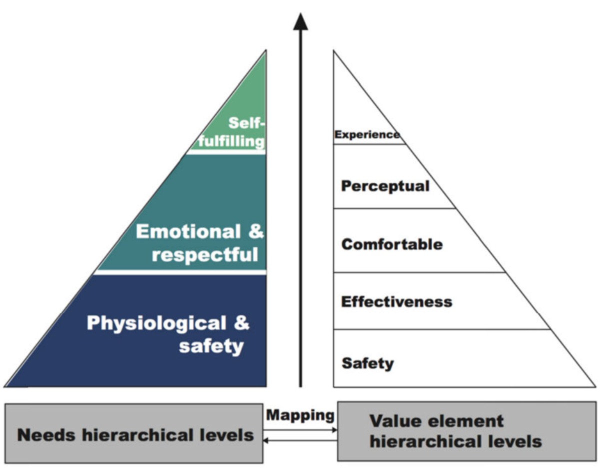

FIGURE 1. The elements of SCP user experience.

The proportions, spaces, colors, materials, lighting, sound effects, processes, services, and so on conveyed by the interface are the themes expressed by the perceptual layer. The value element is the design objectification of the user demand level, and the value elements level maps the user needs. Figure 2 shows the mapping relationship between the value elements of design and evaluation decisions and user needs.

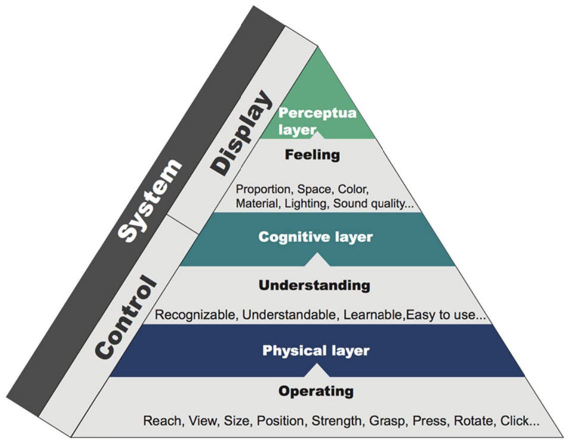

FIGURE 2. Value elements level and user needs.

In our paper we describe user needs with the help of behavioral needs hierarchy theory [71]. Although the safety problem has been solved to the maximum at the technical level, the interactive tasks are becoming increasingly complex, and the driving tasks are competing for driving resources. The situation is turning into what Norman called ''how to manage complexity through vehicle fuel design.'' Besides, in the context of intelligent driving, ''safety'' will be elevated from basic needs to experience because in terms of personal subjective safety, people trust humans to control vehicles, so safety is embodied as ''controllable.'' Here ''controllability'' is not just a technical problem but a solution integrated with a series of products, services, and public social facilities, which is an experience problem. Efficiency, in the human–vehicle relationship, is not only about the efficiency of human–machine operations but also reflects the adaptability of machines to humans in the system. Multichannel interaction expands the information output bandwidth, and the adaptability of the machine is reflected in the natural matching of the most suitable output channel of the human in different interactive situations, thereby reducing the driving load [65]. The user's emotional and respectful needs endow the interface with comfortable and perceptual value. From the perspective of ergonomics, respect is embodied in the view that ''machines adapt to people.'' Comfort is the ''just right'' performance of the physical and psychological state. Comfort means no discomfort. This can be understood as the limit of people in terms of not just physical strength but also mental load and so on. For example, the ''mileage anxiety'' caused by electric vehicles reflects the design's respect for people by providing functional solutions. Respect can produce emotion; of course, emotion also includes richer perceptual content, such as reliability, trust, and a sense of belonging.

IV. IVIS DESIGN METHOD BASED ON SCP USER EXPERIENCE ELEMENTS

Design tasks and design objects are the most important part of our proposed system (Figure 3). In this part, we will show our recommended solution as an IVIS design (Figure 4). The design tasks of design definition include: user research, demand analysis, task analysis, and interface benchmarking analysis; design objects include: user portraits and design definition books.

Design Framework	Design Tasks	Design Objects
Design Definition	▪ User research ▪ Needs analysis ▪ Task analysis ▪ Interface benchmarking	▪ User portrait ▪ Design brief
Concept & System Construction	▪ Concept theme ▪ Interaction paradigm ▪ System architecture ▪ General layout ▪ Visual style	▪ General layout design ▪ System interface ▪ Style demonstration (Renderings, animation) ▪ Integrated system architec ▪ Integrate conceptual thematic representation
Detailed Design	▪ Styling and functional design of hardware HMI components ▪ Software system GUI design ▪ Flow & interaction design	▪ Interior digital model ▪ Graphic UI renderings ▪ Multi-channel display & ▪ Control design (prototype)

FIGURE 3. IVIS design framework.

The design tasks of concept and system construction mainly include: system architecture, interaction paradigm exploration, conceptual theme divergence, and visual style exploration; design objects include: system interface general layout, system interface style presentation, system architecture, and conceptual theme performance.

The design tasks of detailed design include: system hardware interface modeling and functional design, software system graphical user interface design, process and interaction design, and multichannel user interface design; design objects include: system hardware interface digital models, system graphical user interface renderings, and more channel interface display, and control design.

A. DESIGN DEFINITION

1) SCP USER DRIVING TASK RESEARCH

Driving task research, using situational exploration methods to conduct on-site investigations, involves observing the user's tasks and operations in the actual driving situation, dividing the user's driving situation into the main situation and the sub-situation, and listing the key events (Figure 5). The research is divided into two methods: vehicle-following observation and parking interview. The vehicle-following observation records the "key events" or problems that occur during driving; the parking interview involves conducting an in-depth exploration of the "key events" recorded in the vehicle-following observations. For example, when a user observes a traffic jam while following a vehicle, he frequently refreshes the behavior of checking Weibo messages, which is recorded as a key event, and the user's needs are discovered through interviews: "I hope to learn the latest traffic information from social platforms." Research is conducted to obtain the operating frequency of the communication, navigation, music, and other functions of the user's driving. In this way, the main and sub-situations of the user's driving are defined.

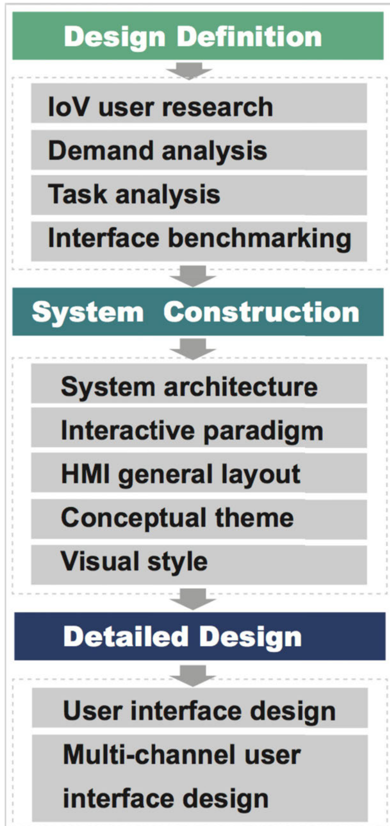

FIGURE 4. IVIS design method.

Driving task analysis is an important part of design definition. The researcher constructs the main scenarios, including normal driving scenarios, driving micro-situations, assisted driving while on the move, and information and entertainment, and enumerates key events related to the scenarios. The main and sub-scenarios correspond to the main and sub-tasks of driving. As a homogeneous element of the integrated design, the driving task is the key to user definition and the starting point of the design concept [72].

2) MODELING OF USER PORTRAIT

User role is an abstract description of a user group through a typical user image. It is a visualization process of survey data and a way to understand and user needs. The creation of user roles includes information classification

Main situation	Sub-situation
Normal driving situation	Commute Tourism Business ......
Driving micro-situation	Parking Traffic jam overtake Follow the car......
Assisted driving & intelligent driving	Cruise control Adaptive cruise Autopilot......
Information & Entertainmen	Phone Dial number Receive information Music Weibo WeChat Other social media......

FIGURE 5. Driving situation.

TABLE 1. Proportion and degree of IVIS.

Function	Proportion	Mean functional requirements	Mean Interaction Time
Navigation	90%	2.2	4.5
Music	60%	2.8	4.3
Telephone	45%	3.8	1.9
Social media	43%	3.7	5.0
Other functions	8%	3.4	1.4

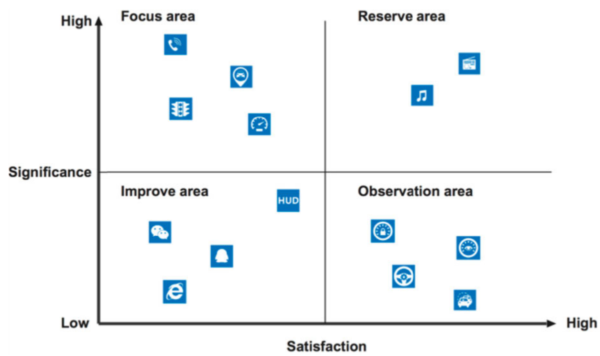

FIGURE 6. Four-quadrant analysis of the priority of user needs.

and information visualization [73]. Information classification involves summarizing the information obtained from field investigations and photo diaries and dividing it into basic user information, lifestyle information, and driving situation information to form corresponding information modules; meanwhile, information visualization entails using photos and charts to abstract and analyze information modules [74]–[76]. For example, the driving situation information module is further divided into a "task operation" information module, a "behavior description" information module, and a "requirement suggestion" information module, and the user's feelings are emphasized through graphical representation (photos, icons, charts) special information needs.

3) SCP USER DEMAND ANALYSIS

Based on the "requirements suggestion" module of the user role model, the user needs analysis adopts the priority four-quadrant analysis method (Table 1): the horizontal coordinate represents the degree of user satisfaction, and the vertical coordinate represents the degree of user demand. The results of a survey of 30 users aged 22–32 show the following (Figure 6):

Focus area: functions that are of high importance to users but relatively low in operating satisfaction, including phone functions, navigation, vehicle information, and real-time road conditions.

Improved area: features with low user demand and satisfaction. There is much room for design improvement. Although it is not the most critical requirement, it is conducive to improving overall satisfaction, including social applications represented by WeChat and Weibo.

Reserve area: a function with relatively high user demand and satisfaction. Vehicle system functions, including radio and music, can be improved by design to enhance user satisfaction.

Observation area: features with low user demand but high satisfaction, including interconnected driving and autonomous driving. The functions are forward-looking, and most users look forward to them but adopt a wait-and-see attitude. The four-quadrant analysis of demand shows that electric vehicle users' information needs include three categories:

1) Driving information, such as vehicle speed and power
2) Assisted driving information, such as navigation
3) Interconnection and entertainment information, such as real-time road conditions and social applications

Among them, assisted driving and connected entertainment to improve the quadrant of the district are opportunities for design, which is also the most frequently mentioned problem in the "demand suggestion" module.

4) INFORMATION INTERFACE BENCHMARKING ANALYSIS

The contents of the desktop survey include vehicle interior (hardware): overall modeling, parts modeling; information system interface (software): display interface, control and interaction methods. The survey scope includes two latitudes: first, the existing electric vehicles, concept electric vehicles, and their related HCI systems. The survey data come from two well-known automotive design websites, *Car Design News* and *Car Body Design*, and authoritative magazines such as *Auto Design*. Among them, the keywords "SCP" and "intelligent car design" were searched to obtain more than 2,240 items related to the interaction of IVIS. By querying

38 volumes of *Auto Design* issued from 2018 to 2020, 73 related articles were obtained. Second, we researched 60 vehicle brands' concept vehicles and mass-produced electric vehicles. Research data include text, pictures, and videos.

Through desktop research, it is proposed that the benchmark interface is the HCI interface of Tesla (Tesla Model S) and BMW (BMW i3) vehicles. The main reasons are: 1) The software and hardware integration interface have a rich user experience and describe the new characteristics of electric vehicle information systems and service modes; 2) Mass production of vehicles has the feasibility of interactive technologies such as display and control.

The interface benchmarking analysis mainly includes: functional architecture benchmarking, information architecture benchmarking, interactive mode benchmarking, and visual style benchmarking. Figure N shows part of the interface benchmarking analysis.

Through desktop research and benchmarking analysis and research, we define the design innovation points of the electric vehicle HCI interface:

1) The design of the distributed information display centered on the main driver, including the innovation of display position, display content, and display mode;

2) Multichannel interaction design, including the exploration of multichannel display and control interface of automobile HCI.

The interface benchmarking analysis reflects the straightforward process of product goals in the design definition stage, provides technical support and design reference for the integration of information system and interfaces, and ensures the effectiveness and reasonableness of the design ideas.

5) IVIS DESIGN DEFINITION

Based on user research, task analysis, demand analysis, and benchmark interface analysis, we advance a design definition book for the HCI interface of electric vehicles. The main contents include:

User role positioning: young (22–32 years old), follows technology, hopes to be online anytime, anywhere (always online).

Group characteristics: young people who have just graduated, have been in the workplace for a short time, and have limited income but are eager for free and convenient travel, are willing to try new things, and grow with the Internet.

Modeling definition: lightweight, new materials, new interactions. Lightweight and new materials reflect the styling design characteristics of electric vehicles that differ from traditional vehicles. The new interaction reflects the need for interaction as the center, reflecting the needs of users for related information and rich interactive experiences.

Model platform: The length of the electric vehicle is 2513mm, the wheelbase is 1700mm, the width of the vehicle is 1495mm, the front track is 1300mm, the rear track is 1265mm, and the height is 1475mm.

B. SYSTEM CONSTRUCTION: INFORMATION SYSTEM ARCHITECTURE

In the case of IVIS interface design, the architecture of the interactive system and the overall layout design of the interior are simultaneous. The main design tasks include functional architecture, information architecture, and interactive processes (Figure 7).

First, based on the integrated input of driving tasks, demand analysis, and design opportunities, the system function structure is carried out. The main functions of the defined system include navigation, music, radio, and telephone.

Second is the information architecture and gesture interaction process. In the design process, three sets of interface information frameworks—horizontal, vertical, and vertical—were developed, and three corresponding gesture sets were proposed. The main feature of the horizontal information structure is to organize the menu list information in the horizontal direction, and the dynamic horizontal direction dominates the corresponding gesture set. The horizontal information structure and the gesture interaction process are shown in the main feature of the vertical information structure as the vertical organization of the menu list information, and vertical dynamics dominate the corresponding gestures. Figure 7 shows the vertical information structure and gesture interaction process.

Functional module	Function description	Interactive mode	User experience
Navigation	Destination input Address list Destination favorites Points of interest Route preview View switching View zoom in(out)	Button Gesture Screen click Intelligent voice HUD/VR	Natural interaction Personalized recommend Emotional experience
Music	Music search Switch up and down tracks Volume up Volume down Music pause Music collection Delete	Intelligent voice HUD/VR Gesture	Comfortable low-load intera experience: Distributed visual informati which converts part of the v information into voice intera information, and some into visual interactive informatio
Phone	Contact list Call history, Dialing Hanging up Rejecting calls	Button Gesture Screen click Intelligent voice	Simple and convenient nat interaction mode that confo to user habits
Others	System settings Function selection Return to the previous level Return to thehomepage	Button Screen click Intelligent voice	Personalized recommenda Emotional experience

FIGURE 7. Function module and description of IVIS.

The vertical and horizontal interface information structure is characterized by the vertical organization of the home page list and the horizontal list organization of the sub-page information. The corresponding gestures have dynamic characteristics of crossing the vertical and horizontal directions.

C. DETAILED DESIGN: INFORMATION SYSTEM INTERFACE VISUAL DESIGN

The main design tasks of hardware interface modeling and software interface visual exploration are based on the general layout and system architecture of the HCI interface, the core

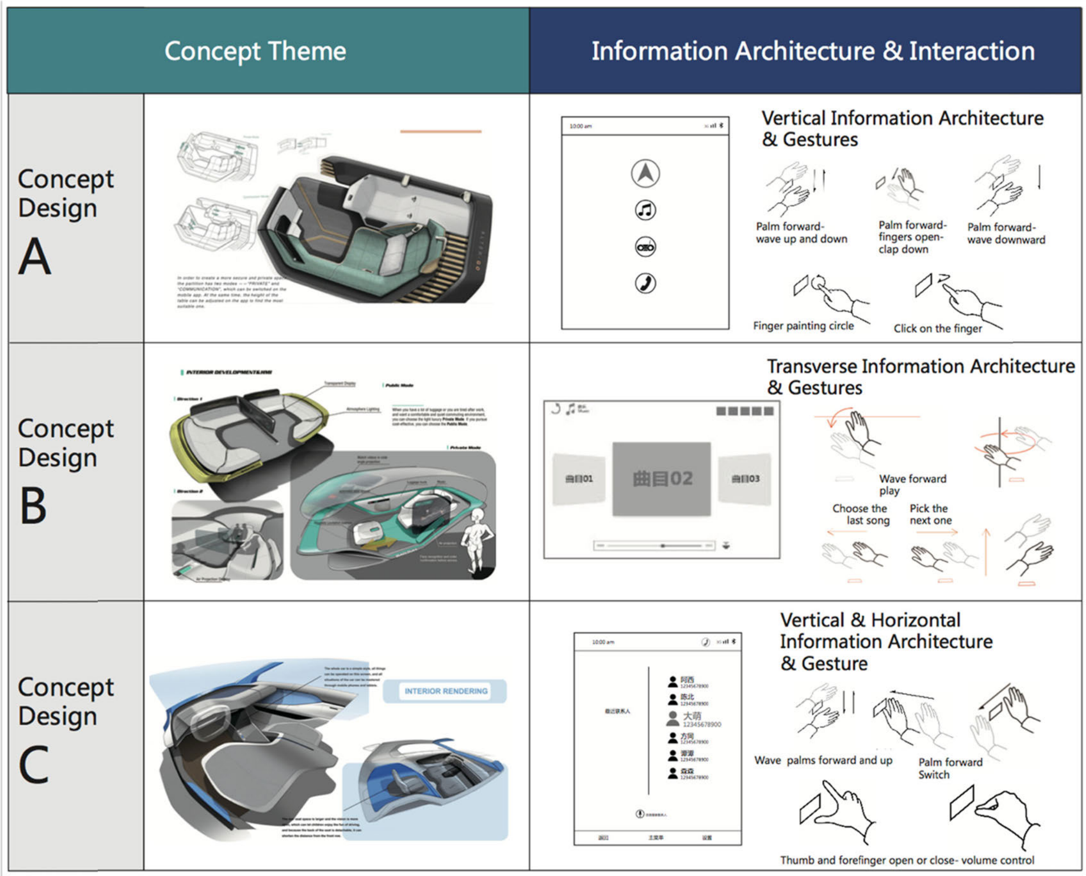

FIGURE 8. Conceptual design.

semantics of ''simplicity: smart, agile'' and ''technology: smart, elegant'' as the design theme, the soft and hard interface, and the uniform visual style design.

In the process of concept divergence, the hardware interface modeling design screens out three sets of solutions, corresponding to the three sets of information architectures. The first solution is to adopt the vertical layout of the central control tablet computer, corresponding to the vertical information frame gesture set, and to convey the ''simple'' and ''smart'' style image through the full curved shape of the main dashboard. The second solution is to adopt the horizontal layout of the central control tablet computer, corresponding to the horizontal information frame gesture set, and to convey the ''intelligent'' and ''elegant'' style image through organic style lines. The third solution is to adopt the vertical layout of the central control tablet computer, corresponding to the vertical and horizontal information frame gesture set, and to convey the ''agile'' and ''intelligent'' style image through the nested shapes and smooth lines of the primary and auxiliary dashboards.

The conceptual design of the software graphical user interface is based on three sets of information architectures, which echo the semantic features of the hardware interface modeling in the design style, extract visual symbols from the interior modeling elements (feature lines, feature surfaces) of electric vehicles, and implement interface icons for design creation (Figure 8).

The practice of interface visual design shows that the integrated conceptual theme and system architecture promote the consistency of IVIS and car interior design styles. Through the echoing relationship of lines, shapes, colors, graphics, and other visual elements, the unified visual effect of IVIS and interior interfaces is expressed.

V. CONCLUSION

In this paper, we focused on an IVIS design method that enhances the driving experience of SCP users. We studied SCP driving requirements and innovatively proposed user experience elements, including the physical layer, cognitive layer, and perceptual layer. Consequently, we proposed a design method for an IVIS based on the aforementioned research, which consists of the design decision, concept and system architecture, and detailed design. Finally, we combined the design case application to illustrate that our research is of great significance for optimizing the design of smart car information systems and promoting the development of the smart car industry.

In future work, we are planning to focus on the following issues: 1. Exploring the distributed information interaction process and characteristics of IVIS to improve the safety experience of users' driving operations; 2. Examining the multichannel information interaction system in the car to enhance the user's credibility experience design; 3. Investigating information interaction system between IVIS and the IoT outside the car design facilities.

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