21th International Conference on Renewable Energies and Power Quality (ICREPQ'23)
Madrid (Spain), 24th to 26th May 2023
Renewable Energy and Power Quality Journal (RE&PQJ)
ISSN 2172-038 X, Volume No. 21, July 2023

Research on the Application of Virtual Reality Technology in the Design and Evaluation of Interactive Interfaces for Renewable Energy Systems

Xingqi Cao[1] and Minjung Song[2]

[1]College of Design
Hanyang University
15577-Ansan-si, (Korea)
Email: caoxingqi1@163.com

[2]College of Design
Hanyang University
15577-Ansan-si, (Korea)
Email: mjung111@hanmail.net

Abstract.

In this investigation, we delve deeply into the visual interaction design of electric vehicle power management systems, particularly how we can integrate sustainable development principles to enhance the user experience and promote environmentally friendly travel. Initially, we take a look at the present situation and challenges faced by electric vehicle power management systems. We identify shortcomings in traditional design approaches that fail to prioritize sustainability, such as low energy efficiency and challenges in accessing user-friendly information. To validate the effectiveness of our proposed method, we conduct case studies and user tests. The results reveal that incorporating sustainable development elements into the visual interaction design not only significantly boosts user satisfaction and trust in the power management system but also helps reduce energy consumption and environmental pollution.

Key words. Environmental protection materials and technologies, elements of sustainable development, visual interaction design, user behavior analysis.

1. Introduction

Electrification is the energy revolution, networking represents the interconnection revolution, intelligence is the goal, and sharing brings about consumption changes [1]. The rapid evolution of the "new four modernizations" within the automotive sector has injected fresh momentum and direction into established automotive enterprises, while concurrently posing unprecedented business opportunities and challenges across various industries [2].

Domestic major car companies have used a lot of space to describe their own "new four modernizations" strategies, and the tide has been flourishing for a while. At the "China Electric Vehicle Committee of 100 Forum" in 2019, Chen Zhixin, president of Shanghai Automotive Group Co., Ltd., said that "SAIC puts electrification at the top of the basic position in the process of promoting the 'New Four Modernizations' strategy". Chen Zhixin specifically mentioned the electrification of automobiles [3].

"Electrification will profoundly change the value chain of automobiles. Through the integration with intelligence, it will create conditions for the realization of smart transportation, and gradually transform automobiles from a single means of transportation driven by fossil energy to clean. Mobile intelligent terminals provide important opportunities for the development of mobile travel services such as shared travel."

Moreover, they have high power conversion efficiency, fast start acceleration and low noise, and also bring an unprecedented sense of operation and driving experience to users. In 2017, almost all mainstream car companies in the world announced a transformation plan for electric vehicles, and Audi's board of directors also announced a strategic plan called "Audi. Vorsprong.2025", which will achieve annual sales of about 800,000 pure electric vehicles and plug-in hybrid vehicles in 2025, and invest 40 billion euros in the fields of electrification, autonomous driving and digitalization. China has occupied the first place in the global production of electric vehicles for three consecutive years [4]. If the invention of the internal combustion engine reshaped the transportation and business picture of the whole world in the past century or so, the ever-changing energy technology and design trend will soon subvert the automobile industry, making electric vehicles more in line with people's minds. With the rapid development of new energy vehicles, doubts have followed. For example, the so-called "virtual standard" problem reflected by the short endurance range and difficult charging of electric vehicles has been mentioned constantly [5]. I dare not run long distances, turn on the air conditioner at will, accelerate too hard, display inaccurate power information, and seriously attenuate power... All kinds of unimaginable sufferings in the era of fuel vehicles have been accustomed to by the first batch of private users of new energy vehicles in China. Electric vehicle users need to spend a lot of energy doing homework to understand vehicle performance, and technical indicators, plan charging and discharging time nodes so as to arrange travel reasonably and so on.

"Mileage anxiety" refers to the mental unease and psychological stress that users experience when they fret over the possibility that the current vehicle's energy reserve may fall short of supporting them in reaching their intended destination or completing the anticipated journey. This term is mainly used to refer to electric vehicles (EV), and "mileage anxiety" is also considered as one of the main obstacles to the large-scale adoption of all-electric vehicles [6]. The concept of "mileage anxiety" was first introduced by Richard Acello in the San Diego Business Journal on September 1, 1997. On July 6, 2010, GM registered a trademark for the term, stating that its purpose was to "raise public awareness of the performance of electric vehicles." Admittedly, the development of the electric vehicle industry is not mature enough. For example, lithium battery technology needs to be developed, charging mode is single, charging space is restricted, charging equipment is imperfect, etc., which restricts the promotion of electric vehicles, and the transportation system conforming to electric travel lacks layout.

At present, many automobile manufacturers and potential electric vehicle users think that the performance of electric vehicles needs to be developed, and the industrialization of electric vehicles is still far away [7]. Compared with traditional vehicles, there is still a gap in performance, even in the future for a long time. Because electric vehicles are different from the power forms of traditional fuel vehicles, the usage habits of tram users have not yet been developed. At present, the man-machine interface of electric vehicles is not friendly, which not only lacks function indication, but also easily leads to misoperation of users, and the system functions are not complete enough to fully meet the needs of users. For the sake of commercial interests, traditional car companies still iterate in modeling design to complete the innovation of products. As an automobile is closer to "electronic products" rather than "industrial products", the communication between electric vehicles and users is particularly prominent and close. There is a dynamic relationship between the flush and discharge of electricity and the travel planning of users [8]. In addition to solving the problem of battery life range on the technical level, from the design level, we can systematically optimize the travel planning scheme based on the existing electricity from the perspective of users and human-computer interaction.

2. Related Works

2.1 Analysis of the Causes of Mileage Anxiety and User Experience

Over the past century, cars driven by internal combustion engines have been running on the earth for more than 100 years. Thanks to its outstanding achievements and functions, people's ways and forms of life have been improved unprecedentedly. The word "mileage anxiety" seems to have slowly entered people's field of vision with the emergence of electric vehicles. Isn't there "mileage anxiety" in the era of the internal combustion engine? In fact, there are some. In fact, both traditional fuel vehicles and electric vehicles have their mileage limits, and the cruising mileage will fluctuate under different road conditions [9]. Only after sufficient technical accumulation, the thermal efficiency of internal combustion engines has been greatly improved, and the cruising range of fuel vehicles has been relatively stable and controlled within a certain range, exceeding people's psychological expectations. Unfortunately, electric vehicle technology is still in its nascent stage of development, resulting in significant variations in the cruising range of these vehicles. Consequently, consumers lack a stable and objective understanding of their capabilities, which often leads to the prominent emergence of the "mileage anxiety" phenomenon. According to the chart data compiled by the Research and Consulting Department of China Electric Vehicle Committee of 100 in 2019, we can clearly see that there is still a gap between the mileage limit of electric vehicles and fuel vehicles, and the fluctuation range is also large.

Table 1. Functional Requirements Table of Electric Vehicle Power Management System

Functional Requirements	Importance	User Group	Expected Effect
Electricity display	High	All users	Intuitively display the electric quantity, which is convenient for users to judge
Charging tips	Medium	All users	Avoid power exhaustion and remind you to charge in time

Functional Requirements	Importance	User Group	Expected Effect
Energy saving mode	High	Users with strong environmental awareness	Reduce energy consumption and extend cruising range
Electricity statistics	Medium	Users who need data analysis	Statistics of electricity usage and optimization of electricity consumption habits

Table 1 shows the functional requirements table of the electric vehicle power management system. Another reason is that there is a gap between the cruising range understood by users and the actual vehicle condition [10]. At present, the cruising range advertised in the market is mostly the result of constant speed cruising tests, which cannot truly reflect the actual driving of electric vehicles under complex working conditions. Some businesses still have false standards and excessive publicity, which further aggravates the psychological gap among consumers. The so-called constant speed cruising is the cruising range of a vehicle at a constant speed of 60km/h. In real life, due to the complex traffic environment and road conditions, it is difficult for users to meet the driving standards of the test, which is also the main reason why many users cannot run the officially announced maximum cruising range. However, the test standards of the Ministry of Industry and Information Technology, such as energy consumption and emission regulations, refer to the previous European NEDC test system, which is inconsistent with the driving conditions of pure electric vehicles in China. Many of them are also measured data under ideal conditions such as no air conditioning at normal temperatures and test road sections, so the conclusions can not fully reflect the actual driving range [11]

2.2 Battery Performance is Greatly Affected by the Environment

In addition to the limitations of the performance and battery capacity of electric vehicles, the mileage of different types of electric vehicles decays to varying degrees with the changes of seasons, road conditions and service life of vehicles, and becomes a common phenomenon in automobile products.

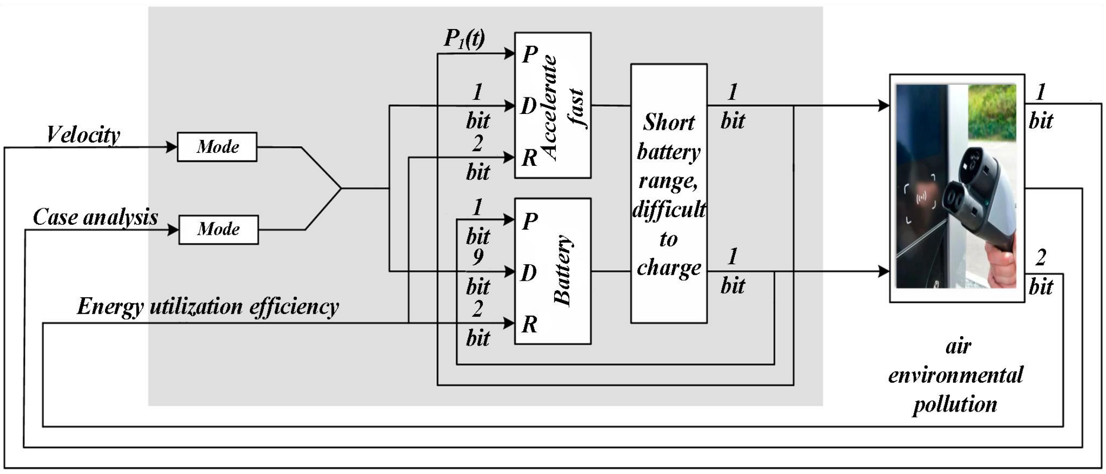

Figure 1. The Energy Efficiency Optimization Process of the Electric Vehicle Power Management System

Figure 1 shows the energy efficiency optimization process of the electric vehicle power management system. Due to the chemical characteristics of the power battery itself, the activity of the battery decreases obviously in low-temperature environments, especially in winter and spring, the cruising range of electric vehicles changes most obviously. According to the test data statistics of the EV-TSET project of China Automobile Center, when "whether to use air conditioner" is set as a single variable in other situations, it is found that the cruising range will decrease by 25%-33% when using air conditioner. In summer, the air conditioning energy consumption of electric vehicles accounts for about 30% of the driving energy consumption, which is not significantly different from that of fuel vehicles [12]. Nevertheless, in winter, electric vehicles require increased energy consumption to maintain a comfortable cabin temperature. Additionally, the battery itself necessitates temperature adjustments to ensure optimal performance. Furthermore, when driving at high speeds, the substantial increase in wind resistance becomes a significant factor that affects battery lifespan. According to the test data statistics of the EV-TSET project of China Automobile Center, the battery life of electric vehicles will generally decrease by 28%-45% when driving over 100-120km/h.

The battery capacity itself is limited, and the energy density of the battery is definitely not as good as gasoline [13]. The specific energy of gasoline is 11kWh/kg, and that of a ternary lithium battery is 150Wh/kg. With the current technical support, if the cruising range of an electric vehicle is 300 kilometers, the battery weight alone will exceed 500kg, and the battery weight of a pure electric vehicle with a cruising range of more than 500 kilometers will be close to 1 ton. It can be said that the improvement of the cruising range is at the expense of the increase in battery weight.

2.3 Unreasonable Allocation of Charging Resources

The above two reasons for mileage anxiety are the technical barriers of batteries and environmental restrictions. Many car companies have invested considerable research and development to improve the cruising range and battery performance of electric vehicles. However, there are still restrictive factors, that is, there is no balanced match between the cruising range performance of electric vehicles and the design of the charging facilities system. First, the distribution of charging facilities in cities with different levels of development is uneven, and the infrastructure construction of charging piles in China's vast third-and fourth-tier cities or township areas is not perfect [14]. This undoubtedly aggravates the difficulty and psychological pressure of users. Even many users need to plan their trips, navigate and calculate the electricity quantity in advance in order to realize the inter-city journey with confidence. Secondly, the cooperation between many car companies and charging pile suppliers is not close, and the matching degree between the on-board system and the charging pile search system is not high. Users need to download additional apps to search for charging points, and often encounter the phenomenon of full parking spaces or queuing after arriving at the charging area. The effectiveness of this information is not enough, and the matching degree between people, vehicles and charging piles is not high. In "2019 China Electric Vehicle Committee of 100 Research Briefing", it is pointed out that the government and car companies should "improve the layout of charging infrastructure and rationally promote infrastructure construction [15]. Accelerate the construction of charging infrastructure, rationally plan and optimize the layout of charging infrastructure, and promote the interconnection of charging infrastructure." In the "2019 China Electric Vehicle Committee of 100 Research Briefing", it is also mentioned that "the research on related standard tests and test methods such as instruments should be strengthened to ensure the authenticity and reliability of driving range and reduce anchor and safety problems caused by display problems." Because the working principle of an electric vehicle is different from that of a fuel vehicle, its electric quantity decays with mileage, and its gradient varies with temperature, environment and speed, and the behavior habits of electric vehicle users have not yet been fully formed. In this stage of plasticity, there is still a lot of design space for meters that can reflect the vehicle condition in real-time, reduce the learning of users and transmit information efficiently. With the development of concepts such as 5G and smart cars, a large amount of information and screens full of cabins are pouring in. How to reasonably plan, sort out and transmit this information to users and help users relieve mileage anxiety is also worth thinking about. Shi Xuesong, CEO of Zebra Network, spoke at the "2017 Auto Internet Conference" and pointed out that "the scene planning for new energy vehicles. Today, new energy vehicles have several very big pain points, the first is mileage anxiety, and the second is charging, which is a very big problem. When we make a real Internet car charging map, we can make an intelligent plan for all the links in the process of travel, charging, leisure and driving. This is what we are doing and can do in the future." It can be seen that interactive design still has its indispensable design space in the system optimization for "mileage anxiety".

3. Methodology

3.1 Optimization Conception of Interactive Design of Electric Vehicle Electricity Management System

In the field of automobile design, the proper term for vehicle interactive system is HMI in English, and HMI teams or R&D teams are specially set up in the design departments of major OEMs. HMI is the abbreviation of Human Machine Interface, which is also called "man-machine interface" [16]. The man-machine interface (also known as user interface) is a medium for interaction and information exchange between systems and users, which realizes the transformation between the internal form of information and the acceptable form of human beings. Man-machine interface exists in all fields involved in man-machine information exchange.

Table 2. Visual Interactive Design Elements of Electric Vehicle Power Management System

Design Element	**Describe**	**Design Purpose**	**Application Scenario**
Icons	Concise and clear, representing specific functions	Simplify the interface and improve the recognition	Electricity display, charging prompt, etc.
Color	Use contrasting colors or soft colors to provide visual comfort	Improve the visual experience of users	Overall interface design
Font	Choose clear and legible fonts to ensure accurate communication	Improve the readability of information	All text information
Animation effect	Appropriate animation effect to increase user interaction experience	Enhance user participation	Function switching, operation feedback, etc.

Table 2 shows visual interactive design elements of the electric vehicle power management system. In the traditional sense, vehicle-mounted HMI is generally composed of the instrument, central control and steering wheel, which are mostly physical interactions of entities, accompanied by abundant physical buttons and mechanical displays [17]. The instrument part displays real-time vehicle condition information such as vehicle speed, remaining fuel, cruising range and temperature; The interactive tasks in the steering wheel area are mostly operated quickly and conveniently with the information displayed by the instrument; Central control mainly includes temperature control, entertainment and other information. In recent years, the replacement of physical keys by LCD smart screens has gradually become the evolution trend of vehicle-mounted interactive terminals. With the development of intelligent and networked vehicles, the scope and design boundary of HMI is constantly expanding. All the interactive relationships between people and vehicles, including but not limited to the interior and exterior decorations of automobiles and the interactive relationships between people derived from automobiles in the future [18]. The design of an automobile interaction system necessitates a thorough discussion of various aspects, ranging from the intricate details of interface icon design and screen layout to the intricate nuances of voice interaction design and user behavior patterns. The crucial question of how to present information within the vehicle efficiently, and how to establish a reasonable, efficient, and natural interaction between the user and other intelligent terminals within the car's intelligent ecosystem, are paramount considerations. With the advancement of experience design, service design methodologies, and the integration of technologies like 5G, speech recognition, and vehicular large screens, the trend towards a multimodal, multisensory, and immersive full-cabin interactive experience is emerging as the forefront of future HMI design. Traditional vehicle interactive system design includes the design of interactive mode and interface of instrument system, navigation system, entertainment system, air conditioning system, voice system and communication system. Due to the change in energy structure, the display mode of traditional fuel vehicle instruments, vehicle conditions and other information interfaces has changed. Users need to judge and expect the vehicle's real-time driving condition according to the relevant information on battery power [19]. Therefore, the concept of the power management system is put forward. From the perspective of user experience, a good design should make "things" better adapt to "people", instead of making people spend a lot of learning costs to adapt to "things". A set of information transmission systems for electric vehicle power, vehicle condition, navigation, etc., which can be read and understood by users quickly and has high information transmission efficiency, is particularly necessary.

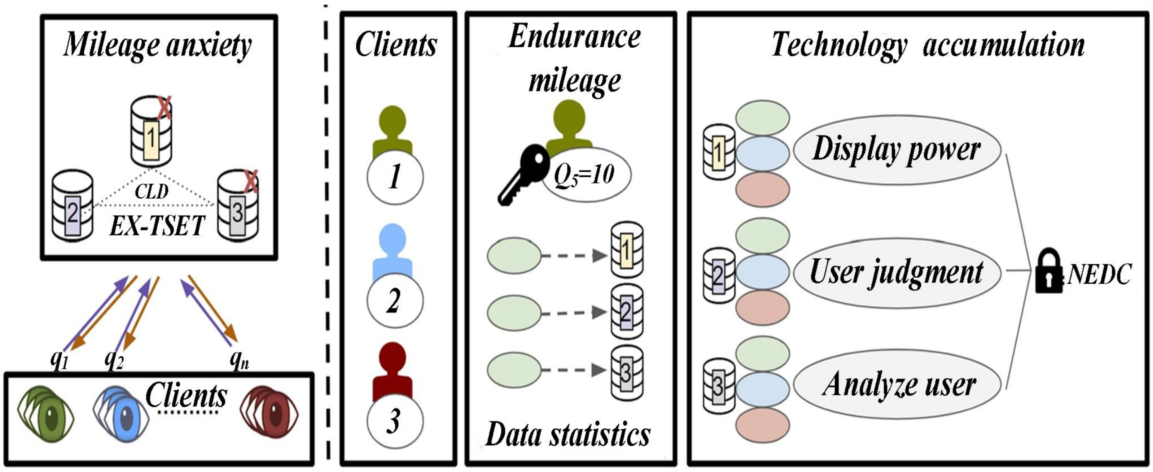

Figure 2. The Application Process of the Visual Interaction Design in the Electric Vehicle Power Management System

Figure 2 shows the application process of the visual interaction design in the electric vehicle power management system. This paper does not discuss too much about the complete framework and interface design of all parts of the whole vehicle-mounted interactive system, but only starts from the user pain point of "mileage anxiety", and designs the interactive process and interface around the information of battery power, cruising mileage, navigation and power distribution of electric vehicles. Through measurement, the working state of the battery is obtained, and this state is displayed visually through design [20].

3.2 Optimization of Interaction Mode Under the Guidance of System Theory Thinking

In the 1980s, system theory developed with the new technological revolution, and at the same time, cybernetics and information theory flourished. Nowadays, the development of human society has entered a comprehensive era of multidisciplinary integration and cross-border. Because of the complexity and variability of social forms, it is impossible to fully understand and solve complex practical problems with the thinking mode of putting forward and solving problems in isolation in different sciences and fields in the past. The role of the automobile has changed from transportation to personal space, from mechanization to intelligence, from individuation to networking, from focusing on design modeling to focusing on design experience, and its design boundary is constantly being expanded and defined. This brings more space for automobile design, and at the same time puts forward higher requirements for it. Focusing on the user pain point of "mileage anxiety", the concept of "system theory" is introduced here to help optimize the concept definition, design boundary and design object of the whole system of "electricity management system" [21]. System thinking has a long history. The word "system" comes from ancient Greece and means that parts constitute a whole. But as a scientific theory, it is recognized that Ludwig Von Bertalanffy, a theoretical biologist and Austrian, founded it. He put forward the principle of general system theory in 1937, which laid the theoretical foundation of this science. However, his theory didn't get the attention of academic circles until 1948 when he taught General System Theory in America. The academic status of this science was established by Bertalanfei's book "General System: Foundations, Development, Applications" published in 1968, which is the representative work of this discipline.

Table 3. Customer Satisfaction Survey of Visual Interaction Design of Electric Vehicle Power Management System

User Satisfaction Index	Very Satisfied	Satisfied	General	Dissatisfied
Interface design	40%	35%	20%	5%
Functional practicability	50%	30%	15%	5%
Convenience of operation	45%	35%	18%	2%
Visual comfort	42%	38%	17%	3%
Overall satisfaction	43%	37%	17%	3%

Table 3 shows a customer satisfaction survey of visual interaction design of the electric vehicle power management system. The core idea of system theory is the holistic concept of the system. Bertalanfei emphasized that any system is an organic whole, not a mechanical combination or simple addition of various parts, and the overall function of the system is a property that each element does not have in an isolated state [22]. He used Aristotle's "the whole is greater than the sum of parts" to explain the integrity of the system, and opposed the mechanistic view that the good performance of a single element can improve the performance of the whole, and the part represents the whole. There are no isolated and useless elements in the system, and each element is in a specific position and plays a specific role. The elements are interrelated and constitute an inseparable whole. Elements, being integral parts of a system, relinquish their defining characteristics when detached from their systematic context. The fundamental premise of system theory lies in treating the subject matter of inquiry as a cohesive system, meticulously examining its underlying structure and functionality. It involves delving into the intricate relationships and interaction patterns among the system, its constituent elements, and the surrounding environment. Moreover, it strives to refine the perspective and elevate the vantage point from which problems are viewed, thereby optimizing the approach to addressing them [23]. It is necessary to comprehensively analyze the relationship between elements, elements and systems, systems and environments, and between this system and other systems, comprehensively consider problems, and deeply understand the dynamic relationship among various elements of the system, so as to comprehensively obtain the solution with optimal effect. The application of system theory should follow the following basic principles: the principle of integrity and synthesis, the principle of connection, the principle of dynamics and the principle of optimization. Below, combined with the specific design problem of "electricity management system design", this principle is expounded.

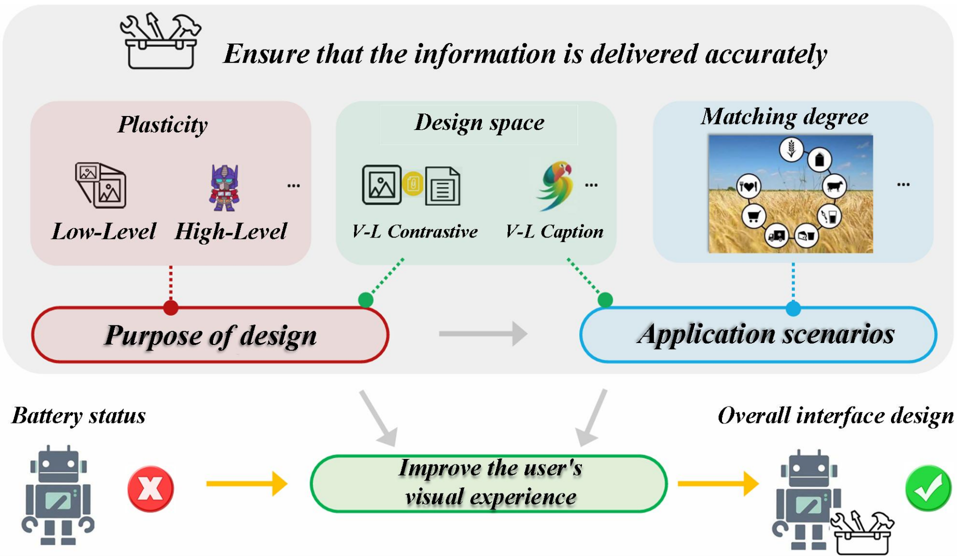

Figure 3. Sustainable Development Element Integration Process of Electric Vehicle Power Management System

Figure 3 shows the sustainable development element integration process of the electric vehicle power management system. The principle of integrity is an important principle of system theory. When studying problems, we should have a global concept and always regard the object to be studied as an organic system and whole [24]. Analyze which parts or elements of the whole are composed of, but at the same time realize that the function of the whole is not equal to the sum of the functions of each part. The whole characteristic should be the "chemical reaction" produced by the organic collocation and connection of various elements. In the design scheme of the electric power management system, it is undoubtedly limited and narrow to focus on the instrument in the interior space or the electric power display in the central control. The display of information in the interior is only a link in the whole user experience process, so it is more appropriate to treat it as an element of the system. For electric vehicle users, there is the possibility of experience and interaction before, during and after travel, so in the design of this system, "whole" should be the sum of users' experiences covering different scenes, different stages and different regions [25]. To be exact, charging piles, mobile apps, intelligent mobile terminals, vehicle-mounted central controls, instruments, and head-up display screens are all part of this system. Only by considering these scenes and terminals comprehensively can we create an enclosed, immersive and ubiquitous interactive experience.

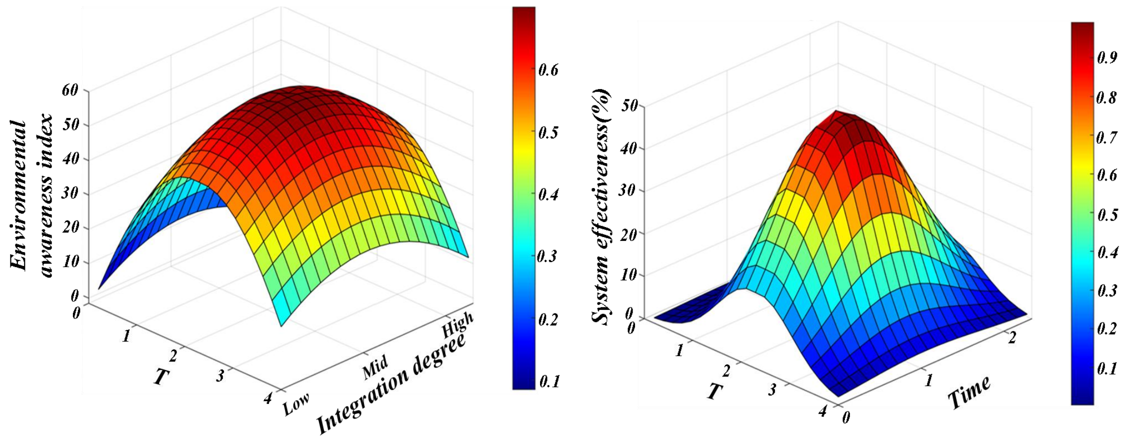

Figure 4. The Integration of Environmental Protection Elements of Electric Vehicle Power Management System on Users' Environmental Awareness

Figure 4 shows the integration of environmental protection elements of the electric vehicle power management system on users' environmental awareness. The principle of relevance requires researchers not only to pay attention to the interrelation and restriction between various elements in the system, but also to the connection and restriction between the system and the external environment. Although it is important to pay attention to the characteristics of each element of the system, the effects of the connection between each element are different for the whole, and the elements can be transformed into each other through connection [26]. Often, the problem of element A can't be solved in element A itself, but if A is placed in the system and other elements have the possibility of complementarity, there will be more solutions. Focus on the specific problem of power management, and the information it covers should be shared and transmitted among terminals to help users adapt to the feedback of real-time information in different situations. For example, can users remotely monitor and perform operations on car conditions through smartphones without leaving home? Can you assign the nearest charging station according to the current vehicle condition and location? If battery performance is affected by temperature and wind resistance, can this correlation be balanced to maximize system efficiency? Can seemingly charging-related problems be transformed into navigation problems to be solved? Will driving behaviors and habits also affect energy consumption, and can guiding driving specifications by optimizing navigation routes also help users save energy? Studying the correlation between these elements can find more design foothold for alleviating the psychological problem of "mileage anxiety" [27].

A system ought to remain open, eschewing absolute stagnation and closure. Its stability derives from maintaining a particular dynamic equilibrium, constantly exchanging energy, matter, and information with the exterior world within a specific environmental context. The electric quantity of an electric vehicle is a dynamic variable, exhibiting diverse states in response to varying working conditions, road situations, and driving modes. In the design of the man-machine interface, users should also know the current state and get timely feedback of information, without making wrong decisions because of information asymmetry [28]. For example, users should be able to know the location allocation and availability of current charging resources to avoid doing useless work; Users should be able to clarify the impact of current temperature, speed and road conditions on power consumption and make adjustments; Users can freely choose energy saving and sport modes, and the dashboard status presented by the two modes should also be distinguished. The interface of ECO mode should be quiet and soothing, and the interface of Sport should express a sense of speed and passion. If a car and its users are an independent human-computer interaction system, this system is only one element in the torrent of car networking. Every car exchanges information with the whole system all the time, and every car owner can interact with other car owners to complete tasks, allocate resources and share information together to create a dynamic balance of the whole system.

3.3 Design Principles Based on User Experience

In the User Experience Elements, Jesse James Garret breaks down the process of building a clear purposeful user-centric product design into five components. These five elements can also be understood as five levels of decision-making, which are strategic level, scope level, structure level, framework level and presentation level from bottom to top. These five levels provide the basic framework and process of design research based on user experience. This framework can help designers discuss what tools to use to solve problems and the manifestation of solutions. From the strategic level to the presentation level is a bottom-up reasoning process, and it is a decision-making process from abstraction to concreteness [29].

In fact, the exploration of design problems and reasons and the possibility analysis of optimizing the system have already covered some contents of the strategic layer and scope layer. User experience products can be divided into functional products and information products. The strategic layer of the two products pays attention to the same content, that is, the goals of products developed within the enterprise and the external user needs.

Table 4. Trend Analysis of Visual Interaction Design of Electric Vehicle Power Management System

Design Trend	Expected Impact	Possible Challenges	Implementation Recommendations
Concise design	Improve the efficiency of information recognition	Avoid information loss caused by oversimplification	Moderate simplification according to user needs
Personalized customization	Meet the personalized needs of users	Meet the design challenges of different user groups	Provide customizable interfaces and themes
Intelligent interaction	Improve user experience and convenience	Difficulty and cost of technical implementation	Combine AI and machine learning technology to continuously optimize the interactive experience
Environmental theme	Respond to the concept of sustainable development	Maintain the balance between design aesthetics and environmental protection theme	Use environmentally friendly materials and technologies to convey the concept of environmental protection

Table 4 shows a trend analysis of visual interaction design of the electric vehicle power management system. In the summary of the introduction, the problems existing in the current automobile "electrification" transformation are roughly clarified, and the research results made by all sectors of society to alleviate "mileage anxiety" are determined, and the feasibility and development space of the research direction are determined. In the first chapter, by analyzing the related factors of "mileage anxiety" and users' psychology, and summarizing the results of user investigation, the model of user role and user experience journey diagram is established, and the typical user experience process and pain points are visualized to help us find user needs and potential design opportunities. In the second chapter, under the guidance of system theory, the possibility of optimizing user experience by optimizing system structure is put forward. In fact, the above analysis has included part of the strategic layer and scope layer, that is, defining the functions and contents of the system on the basis of clear user needs and design goals. Although the concept of system theory has helped to build a structural model of a system, the elements and composition relations in these structures are still somewhat loose. This part will further concretize these concepts and composition forms through the design of the structural layer and framework layer.

The structure layer is the third of the five layers and the upper layer of the scope layer. At this level, the dividing line between abstraction and concreteness will become blurred, but the decisions made at this time will still have a visible and sensible impact on the final user experience. The decision made by the structure layer includes two parts: interaction design and information architecture [30]. The book "User Experience Elements" mentioned that "in the traditional software development industry, the method involving 'Designing Structured Experience for Users' is called interaction design", while "Information Architecture" builds user experience through content construction. Both interaction design and information architecture emphasize a key point: determining the "pattern" and "order" of elements to be presented to users. Interaction design focuses on the elements that affect users' execution and completion of tasks, while information architecture focuses on how these elements are passed to users.

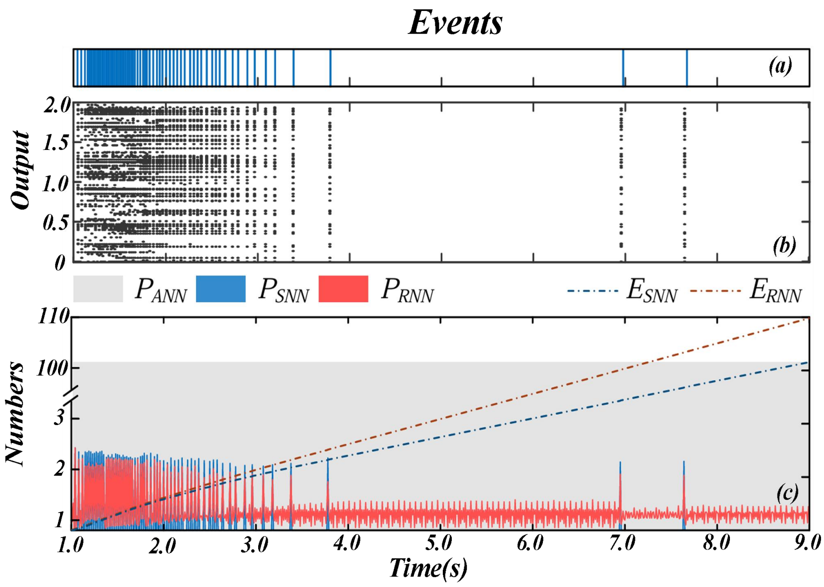

Figure 5. The Relationship Diagram between Power Consumption and the Range of Electric Vehicles

Figure 5 shows the relationship diagram between power consumption and range of electric vehicles. The structure layer is full of conceptual elements and forms a large number of requirements, while the framework layer needs to refine these requirements, describe information in more detail, and determine detailed interface appearance, navigation and so on. The three elements of the structure layer are interface design, navigation design and information design. Among them, interface design is mostly suitable for functional products, while navigation design is mostly used for information products, but information design is a part that both products need to take into account.

Although the method of "user experience elements" is mostly applicable to Internet software development companies, the "habits" and "metaphors" proposed in the framework layer are still universal interaction design methods. "Habit" means that the logic and process of interaction should conform to the basic habits of users and give effective feedback, while "metaphor" means using and referring to the characteristics and movements of objects in real life in a specific interface design, so as to reduce the learning cost of users. Finally, I mentioned the use of "wireframe", which is the most effective and intuitive tool to knead information, interface and navigation design together and display them on the page.

Table 5. Comparison of Visual Interaction Design of Electric Vehicle Power Management System with Other Fields

Domain	Design Features	Advantages	Disadvantages
Mobile APP	Simple interface and smooth interaction	Good user experience and convenient operation	Visual elements may be too single
Smart home	Emphasize the integration of overall home style	Coordinate with the home environment to enhance the overall aesthetic feeling	Functionality and user experience may be ignored
Electric vehicle dashboard	Rich in information and updated in real- time	Provide comprehensive vehicle information	Too much information may lead to user confusion
Electric vehicle electricity management system	Emphasize intuition, practicality and sustainability	Users can quickly understand the electricity information, which is easy to operate and conforms to the concept of environmental protection	Design innovation may be limited and needs to be continuously optimized in combination with technological development

Table 5 shows a comparison of visual interaction design of electric vehicle power management system with other fields.

The presentation layer is the top of the five-tier model and the first place the user will notice: perceptual design. "Here, content, function and aesthetics come together to produce a final design, which accomplishes all the goals of the other four levels and satisfies the sensory feelings of users at the same time." At the frame level, the placement of elements has been basically solved, and the logic of information arrangement and interaction has been basically established, but at this time, the wireframe is still unappealing to users. Therefore, the role of the presentation layer is to make up for the perceptual presentation of elements, so that users can intuitively and concretely receive information. At the heart of the presentation layer lies design perception, which typically originates from the five senses inherent in human beings: smell, taste, touch, hearing, and vision. Amongst these senses, visual design occupies a pivotal position as the focal area of design across diverse industries. This is due to the ubiquitous nature of visual perception, as virtually all products inevitably involve the comprehension of visual elements. To evaluate the design of the visual part, not only from the perspective of "aesthetic feeling" and "good-looking", but also the designer should pay attention to whether these beautiful forms strengthen the function. Is there any damage to the interface structure? Or, do colors and typesetting make the interface clearer? Or is it more disorganized? In an excellent interface design, the user's line of sight should not be free, but a smooth and traceable route. This needs to guide the user's line of sight through the reasonable presentation and typesetting of various elements in the interface. There are several principles for reference. The first is contrast, which can highlight and strengthen the main information that the page needs to convey most in a certain state. It can usually be reflected by means of light and shade of colors, the dense thickness of lines, etc. Making good use of contrast can effectively highlight key points.

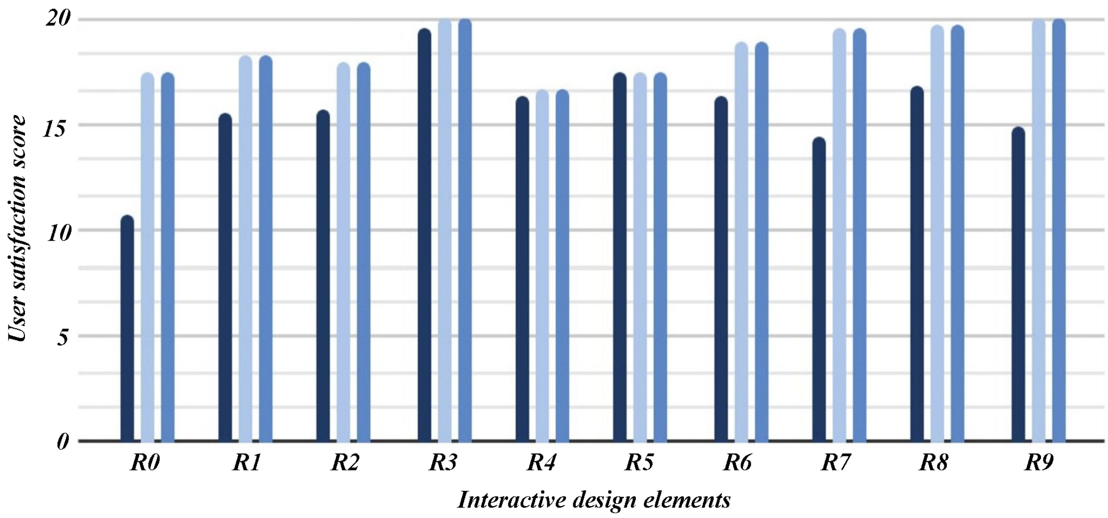

Figure 6. User Interface Interaction Design Satisfaction Survey

Figure 6 shows the user interface interaction design satisfaction survey. The second is the consistency principle, which includes the consistency of the design of each element in a single interface and the consistency of the design of each element in the interface with the same state, level and scope. Because users often jump between different interfaces, it is particularly important to keep consistency in order to prevent users from feeling confused and confused in frequent jumps. It is usually realized by the same font, color number, word spacing, line thickness, alignment and so on. The third is color and typesetting. People are emotional, and different colors can just cause different emotions. Warning colors such as red and orange can keep people alert to the current state of the page, while blue and green can cause people's comfort senses and let people know that the current state of the page is safe. Different colors should be selected according to different states and functions.

4. Results and Discussion

This research centers on the visual interactive design of electric vehicle power management systems, integrating sustainable development principles. It delves into enhancing both the efficiency and user experience of these systems through cutting-edge design methodologies and interactive technologies. Given the push for sustainable practices, optimizing the power management system of electric vehicles, as a clean energy alternative, holds immense significance.

In this study, we've crafted a visual interactive system for electricity management, drawing inspiration from sustainable development principles. This system, born from a blend of user research and data analysis, offers not just intuitive and comprehensible power displays and predictions but also optimized charging strategies, thanks to intelligent algorithms. This not only extends the lifespan and driving range of electric vehicles but also seamlessly incorporates environmental protection elements into its design. Our aim is to raise users' environmental awareness through visual cues and prompts, thereby fostering the widespread adoption and sustainable growth of electric vehicles.

5. Conclusion

This study delves into the future trajectory of visual interaction design for electric vehicle power management systems. With the constant advancements in technologies such as the Internet of Things, big data, and artificial intelligence, we foresee a transition towards increasingly intelligent and personalized power management systems. Future designs will prioritize user experience and emotional connections, leveraging advanced technologies to provide users with smoother, more efficient power management experiences. This study offers fresh perspectives and methodologies for the visual interaction design of electric vehicle power management systems. We aim to continue our exploration and refine our design approach to further propel the sustainable growth of the electric vehicle industry. Furthermore, we hope that our findings can serve as a valuable reference and inspiration for sustainable design practices across diverse fields.

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