Optimal Design of Information Elements in Virtual Reality System Based on TOPSIS

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Abstract. Aiming at the problems of heavy cognitive load of users and uncoordinated allocation of design resources in virtual environment, this paper comprehensively analyzes the explicit expression of information in user interaction activities, builds SMCR model, and proposes an optimization model of virtual reality interface interaction system based on TOPSIS. Through the computer sensing of user actions, behaviors, tasks and other information in the virtual environment, the mapping relationship between resources and information is determined according to the resource allocation scheme based on SMCR mode, and encoded in the form of information representation; Based on TOPSIS, the importance of design resource elements is sorted. Through further refining the information representation, the sorting results are used as precipitated knowledge for scheme design to realize the optimal layout of interactive interface visual elements. The results show that the virtual reality interface system based on this model mobilizes the enthusiasm of users to actively interact and improves the usability and timeliness of human-computer interaction.

1. Introduction

With the rapid development of the digital era, people pay more and more attention to the design of human-computer interaction experience in virtual reality. Information representation methods characterized by information perception, resource matching and explicit expression of information have been widely studied and applied in design related fields. Information representation gradually transits from two-dimensional screen to three-dimensional virtual reality. Virtual reality technology is applied in industrial simulation, medicine, future virtual, etc. The research focuses on user interface, perceived information, user experience and software system design. Lin Yi et al. [1] proposed a set of hybrid mobile navigation system of virtual reality and augmented reality based on mental model. Sun Hui et al. [2] proposed an information visualization resource model based on distributed cognition. Virtual reality interface information visualization is a multi-disciplinary integration field, focusing on the visual presentation of non-numerical information resources. In the process of transforming coded data objects into visual forms, users need to transform abstract data into visual forms. This process is a representation of the mapping relationship between information from abstract forms to visual forms. Liu Hui et al. [3] put forward the concept of virtual interface. The cognitive basis of virtual interface is established by statistical analysis method, and a virtual interface construction algorithm based on cognitive behavior model is proposed to realize demonstration application based on virtual interface.

The dissemination of information can adopt Bello mode. Wang Yongqi et al. [4, 5] based on Bello mode as the research object, focus on analyzing the source part of Bello mode, focus on studying the various components of information source, find new ways of advertisement creation from the...
elements, and dig out the expression and combination of advertisement innovation. Yu Yue [6] Starting from the relationship between communication and ideological and political education in colleges and universities, based on SMCR's communication mode, analyzed the four factors that affect ideological and political education in colleges and universities and their current situation: information source, information, channel and information destination. Zhang Daqing [7] Based on SMCR's communication mode, he analyzed the current situation of honesty education for college students from four factors: information source, information, channel and information destination, and optimized and adjusted the teaching system.

TOPSIS model is a sort method that approximates the ideal solution. This method is based on the positive and negative ideal solutions in the evaluation system, and obtains the advantages and disadvantages of each evaluation object by calculating the distance and closeness between each evaluation object and the positive and negative ideal solutions and sorting them. Topsis Fu Xinwei et al. [8] combined grey correlation analysis with ranking of approximate ideal solutions to establish an evaluation model of safety guarantee capability of air traffic control operation units. In the experimental part, NASA Cognitive Load Scale was used to record the user values. Lu Nengchao et al. [9] used NASA Cognitive Load Scale to analyze the influence law of traffic signs with different information amounts on drivers' cognitive load through experiments, and verified the effectiveness of traffic sign information amount on load loading.

Based on this, the research framework of this paper is as follows: Firstly, the image space of virtual reality information transmission is built according to SMCR mode, starting from the sources, deconstruct the components and structural elements of virtual reality information, process the information through users' cognitive channels such as vision, hearing, touch, smell and taste, then sort the design elements according to topsis, then use the sorting results as precipitated knowledge to design the scheme, and measure the cognitive load to compare the data before and after.

2. Relevant Theories

2.1. Information Resource Transmission Theory of Virtual Reality Interface System Based on SMCR

Human-computer interaction is an important supporting technology of MR. It is also a hot research topic at home and abroad in recent years. Human-computer interaction has experienced command line interface, graphical user interface, GUI has entered the stage of natural human-computer interaction represented by multi-touch interface, tangible user interface (TUI), 3D user interface (3DUI) and multi-channel user interface. This paper combines the information resource circulation mode of virtual reality interface system with SMCR theory to discuss the relationship between resource information structure and users. As shown in the figure.

![Figure 1 Deconstruction Map of Virtual Reality Information Resources under Bello Mode](image)

In the research of virtual reality information transmission and user behavior perception layer, SMCR communication mode is one of the very representative communication modes. David K Berlo put forward SMCR's communication model in 1960 by using relevant sociological theories. Bello
propagation mode divides the propagation process into four dimensions: information source, information, channel and receiver. Each dimension is composed of several basic elements, of which S represents information source, M represents information, C represents channel and R represents receiver. Therefore, this mode is also called SMCR mode. Bello’s mode of communication accurately describe that characteristics of various element in the process of communication, It integrates new theories such as philosophy, psychology, linguistics, anthropology, mass communication and behavioral science. It clearly and vividly explains that the virtual reality interface is based on different elements in the process of communication and explains that information communication can be carried out through different ways and channels. The factors that affect and determine the efficiency and effect of information dissemination in virtual reality interface are various and complicated. It is determined not only by a certain part of the transmission process, However, it is determined by the four dimensions of information source, information, channel and receiver that make up the communication process and their mutual relations, and each dimension in the communication process is limited by its own factors, thus vividly explaining the conditions that affect the information source, receiver and information to realize their communication functions.

2.2. Optimization of Information Resources in Virtual Reality Interface System Based on TOPSIS

TOPSIS method is adopted to sort the importance of design resource elements in virtual reality design interface information system. TOPSIS (Technology for Order Preference by Simularity to an Ideal Solution) method was first proposed by C. L. Hwang and K. Yoon in 1981. TOPSIS method is a method to rank a finite number of evaluation objects according to their proximity to the idealized goal, and evaluates the relative advantages and disadvantages of the existing objects. TOPSIS method is a sort method that approximates to ideal solution. This method only requires that each utility function has monotone increasing (or decreasing) property. TOPSIS method is a common and effective method in multi-objective decision analysis, also known as the distance method of good and bad solutions. The calculation steps are as follows

1. The normalized decision matrix is obtained by using the normalized vector. The decision matrix of multi-attribute decision problems is $A = (a_{ij})_{m \times n}$, and the normalized decision matrix $B = (b_{ij})_{m \times n}$, In which

$$b_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{n} a_{ij}^2}}, \quad i = 1,2,\cdots, m; \quad j = 1,2,\cdots, n$$

2. Composition of Weighted Standard Shares $C = (c_{ij})_{m \times n}$. Let the weight vector of each attribute given by the decision maker be $w = [w_1, w_2, \cdots, w_n]^T$, $c_{ij} = w_j \cdot b_{ij}, i = 1,2,\cdots, m; \quad j = 1,2,\cdots, n$

3. Determine positive ideal solution $C^*$ and negative ideal solution $C^0$. Let positive ideal solution $C^*$, The j th attribute value of the is $c_j^*$, Negative ideal solution $C^0$,The j th attribute value of the is $c_j^0$. Positive ideal solution $c^*_j = \left\{ \max_i c_{ij} \right\}$; Negative ideal solution $c^0_j = \left\{ \min_i c_{ij} \right\}$.

4. Calculate the distance of each scheme to the positive ideal solution and the negative ideal solution. Options $d_i$ The distance to the positive ideal solution is: $s_i^* = \sqrt{\sum_{j=1}^{n} (c_{ij} - c_j^*)^2}, \quad i = 1,2,\cdots, m$ , The distance from the alternative $d_i$ to the negative ideal solution is: $s_i^0 = \sqrt{\sum_{j=1}^{n} (c_{ij} - c_j^0)^2}, \quad i = 1,2,\cdots, m$

5. Calculate the queuing index value of each scheme (i.e. Comprehensive evaluation index): $f_i^* = \frac{s_i^0}{s_i^0 + s_i^*}, \quad i = 1,2,\cdots, m$

6. According to the order of $f_i^*$ from large to small, the following figure is the overall flow chart.
3. Instance Validation

3.1. Decoding Resource Elements of Virtual Reality Information Interface in Intelligent City

The interactive development of VR system in this paper is completed by Unreal Engine 4 and 3DS MAX software. Unreal Engine 4, as VR development environment, supports blueprint and C++ language to edit two-dimensional or three-dimensional objects in virtual situations, and realizes interface interaction, situation construction, operation behavior definition, etc. in virtual situations. In the VR system interface of a smart city, users need to know the general situation of city layout and various index information due to cognitive intention needs and behavioral perception needs. Because the information in the smart city system interface is complicated and the users who carry out interactive experience are mostly unfamiliar with VR system operation, and are prone to confusion and obstruction of experience emotions, improving the efficiency of users in completing tasks in VR system is an urgent problem to be solved in VR interface task scenarios. The following table deconstructs and codes according to the information elements of the virtual reality interface.

| Project                | Category    | Category Definition                                                                 |
|------------------------|-------------|-------------------------------------------------------------------------------------|
| Function Operation Area| Aggregation C11 | The layout of functional operation areas is relatively concentrated.               |
| Layout X1              | Discrete C12 | The layout of the functional operation area is relatively discrete.                  |
| Visual browsing order  | Less browsing interruptions C21 | The number of interruptions of household visual browsing is small.                |
| X2                     | Many browsing interruptions C22 | The user's visual browsing is interrupted many times.                             |
3.2. Priority Ranking of Virtual Reality Resource Elements Based on TOPSIS

The data set of virtual reality resource elements based on TOPSIS comes from experiments. In the formal experiment, 18 personnel were recruited to carry out the virtual reality interface system operation experiment test. The age distribution was between 20 and 28 years old, including 10 boys and 7 girls. All the subjects had normal vision or corrected vision, no defects in visual, auditory and tactile perception, and were right-handed. 10 subjects had experience in using VR system and 7 subjects had no previous experience in using VR. There are two experimental tasks, one is to read the interface data information, the other is to click on the "Enter the System" selection area, and the data
measurement is calculated by NASA Cognitive Load Scale. After data collection, the sample interface is designed with element structure and then goes through TOPSIS calculation steps. The specific results are shown in the following table.

| Numbers | Indicators                  | Positive   | Negative ideal solution | Sort |
|---------|-----------------------------|------------|-------------------------|------|
| 1       | Layout                      | 0.09951    | 7.66914                 | 1    |
| 2       | Distributed information     | 0.08778    | 5.37907                 | 10   |
| 3       | Function Orientation        | 0.06041    | 4.14645                 | 2    |
| 4       | Shape chamfering            | 0.03167    | 2.29853                 | 18   |
| 5       | Font                        | 0.02921    | 2.67585                 | 14   |
| 6       | Shape semantics             | 0.06135    | 4.32056                 | 7    |
| 7       | Wireframe                   | 0.03354    | 2.26741                 | 15   |
| 8       | Total Tone                  | 0.03680    | 2.36864                 | 8    |
| 9       | Brightness                  | 0.03125    | 2.29110                 | 16   |
| 10      | Saturation                  | 0.03183    | 2.03339                 | 17   |
| 11      | Transparency                | 0.04136    | 2.74302                 | 9    |
| 12      | Contrasting color           | 0.04060    | 3.89301                 | 5    |
| 13      | Environmental contrast      | 0.04007    | 2.83918                 | 6    |
| 14      | Browse Order Jump           | 0.09540    | 8.29246                 | 4    |
| 15      | Module matrix arrangement   | 0.05979    | 5.53469                 | 13   |
| 16      | Prompt Tone                 | 0.05185    | 3.38856                 | 3    |
| 17      | Background music            | 0.02828    | 2.45448                 | 19   |
| 18      | Voice Wizard                | 0.05634    | 8.77720                 | 11   |
| 19      | Vibration frequency         | 0.02820    | 8.80575                 | 12   |

Based on TOPSIS ranking, it can be seen that the virtual reality digital interface is divided into navigation, interaction, selection, input, etc. The navigation function digital interface focuses more on user satisfaction. As the navigation interface requires users to browse more information, the navigation interface with lower cognitive load has higher usability. The interactive function, selection function and input function are more inclined to digital interfaces with short interactive time, and there are few interface elements such as virtual reality. Reducing the user's interactive time through reasonable layout and element size design can more effectively improve the usability of the interface. The design of virtual reality interface focuses on interface layout, function orientation, prompt tone, browsing sequence jump, contrast color and environment contrast, shape semantics, total tone, interface transparency, distributed information, voice guide, vibration frequency, module matrix arrangement, font, wireframe, lightness, saturation, shape chamfer and background music. The following design scheme is obtained through the guidance of sequence importance, with a cognitive load of 65.2, which belongs to a lower cognitive load value.

Figure 3 Design Scheme
4. Summary
Based on SMCR model, the image space of virtual reality information transmission is built. Deconstruct the components and structural elements of virtual reality information, The virtual reality information resources are processed through user cognitive channels such as vision, hearing, touch, smell and taste. Secondly, according to TOPSIS, It is found that the interface layout, function orientation, voice prompt and browsing sequence jump have a large influence on the user's cognitive load. Therefore, the optimization analysis of the virtual reality system interface is carried out from these design elements. The results show that the user's cognitive load value of the optimized design interface is relatively low. The established virtual reality SMCR model carries out TOPSIS calculation on the cognitive load score of VR digital interface, and then carries out strength verification, which reduces the time for evaluating virtual reality digital interface and provides an effective auxiliary tool for relevant designers to design virtual digital interface.

References
[1] Lin Yi, Chen Jing, Liu Yue, et al. User Experience Design of Virtual Reality and Augmented Reality Hybrid Mobile Navigation System Based on Mental Model [J]. Journal of Computer Science. 2015, 38(02): 408-422.
[2] Sun Hui, Lu Jian, Cun Wenzhe. Information visualization model of VR system [J]. Acta Graphicae Sinica. 2018, 39(02): 317-326.
[3] Liu Hui, Feng Zhiquan, Liang Liwei, et al. Natural Interaction Model and Algorithm of Virtual Interface [J]. Journal of Zhejiang University (Engineering Edition). 2016, 50(06): 1167-1175.
[4] Wang Yongqi, Qian Hangyuan, Zhang Peicheng. Application of Bello's Communication Model in Advertising [J]. Contemporary Communication. 2006(1): 68-70.
[5] Wang Yongqi, Zhang Peicheng. Bello's Communication Model and Its Application in Advertising Design [J]. Press. 2006(02): 107-108.
[6] Yu Yue. Research on the Application of Bello's Communication Model in Ideological and Political Education in Colleges and Universities [J]. Journal of Higher Education. 2018(09): 75-77.
[7] Zhang Daqing. Construction of "Four in One" Honest Education Model for College Students Based on Bello Communication Model [J]. Journal of Jilin Institute of Agricultural Science and Technology. 2019, 28(01): 18-21.
[8] Fu Xinwei, Yang Changqi, Xiao Qi. GRA-TOPSIS Evaluation Model of Air Traffic Control Operation Unit Safety Guarantee Capability Based on Game Theory [J]. Journal of Civil Aviation. 2020, 4(04): 44-48.
[9] Lu Nechao, Cao Yue, Qin Ling, et al. Study on the Effectiveness of Driving Load Loading Based on Traffic Signs Information [J]. China Journal of Highway. 2018, 31(08): 165-172.