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The Analysis Method of Visual Information Searching in the Human-Computer Interactive Process of Intelligent Control System

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Abstract. As the back-end of system operation, visual information presentation of intelligent control system has become an important means and operation basis for people (operators) to obtain information, make inference and evaluate decision. The rational design of intelligent control system plays an important role in maintaining the safety and stability of production and operation in large enterprises. This paper presents the analysis method of visual information searching in intelligent control system. On the premise of visualization structure analysis of complex network information, taking reliability analysis of operator information searching as key point and main line, through studying characterization of information graphic elements relationship, information multi-dimensional attributes, information layouts and coding rules in information interactive interface, this paper establishes visual cognitive model of information structure which made information interaction more efficiently.

Keywords: Intelligent control system · Human computer interaction
Visual information searching · Visual cognition process

1 Introduce

With the rapid development of computer technology and information control theory, the control system becomes more complex and intelligent. In particular, major system areas such as large-scale production real-time scheduling, real-time monitoring of the entire process of manufacture, transportation hub monitoring, nuclear power control, environmental monitoring, aviation control which rely on computer technology totally are operated, supervised and decided by digital and intelligent industrial control system, as shown in Fig. 1. Especially in the background of large data, intelligent control system such as process monitoring of production line, intelligent traffic, police monitoring, satellite GPS, terrestrial geographic information system and other complex information display are characterized by a large quantity of information carrying capacity, complex information structure and task execution entering complex cognition. When the operator executes task such as producing or dispatching, the complicated human computer interactive process increases the cognitive load of the operator.

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Meanwhile, the execution task is difficult and the execution environment is complicated in the complex information system, which also brings the system unpredictability. The system is at high risk, so minor errors can lead to failure of the mission and cause major accidents easily. As the back-end of system operation, visual information presentation of intelligent control system has become an important means and operation basis for people (operators) to obtain information, make inference and evaluate decision.

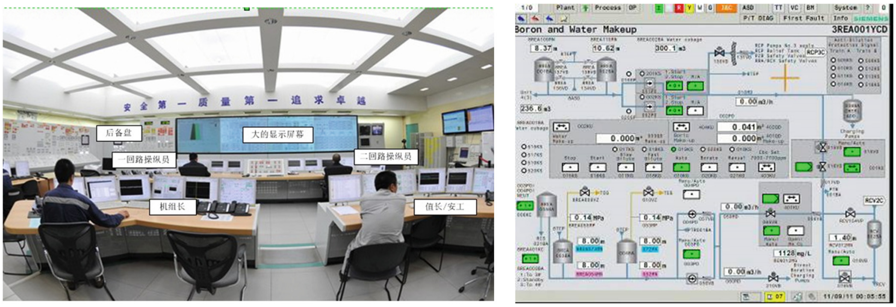

Fig. 1. Human computer interactive process of intelligent control system (Left) and displays of complex information (Right)

2 Background

2.1 Visual Information Interactive Research of Intelligent Control System

In recent years of visual information interactive research in intelligent control system, Burns [1] and Carvalho [2] established evaluation model and design method for the human-computer interactive interface controlled by nuclear power plant. Yim et al. [3] found the way to present interface design of complex information in limited screen space by information hierarchy visualization. Rydström [4] and Lee [5] studied in depth on the contrast method of digital interface, visualization representation method, experimental model and simulation environment of interface elements respectively for car navigation. Paul [6] studied the overload of information complexity in complex digital interface and established the pattern decision-making model from the perspective of time pressure to analyze the execution time required by different amounts of information. Zhang [7–11], Dai [10] and Li et al. [11] conducted a series study of analysis methods of reliability in digital industrial system, human cognitive behavior in large-scale digital control system and reliability of situational awareness of digital control room operator in nuclear power plant. That helped them put forward influence of human-computer interactive complexity, cognitive control mode of operator and identification method of human error. Besides, they studied evaluation method of digital human-computer interface by using mental load evaluation and eye-tracking technology. Li et al. [12] studied the human-computer interaction of the digital industrial system from the perspective of human-computer interaction, complexity and error and the diagnosis of task performance. Xue et al. [13–15] proposed scientific theory and design method for human-computer interactive interface design from the perspectives of cognitive load (CL) and situational awareness (SA) equilibrium, visual cognition brain mechanism and large data information visualization; Guo [16] studied the support technology of human-computer interactive interface design from the perspective of emotional needs, which provides a scientific method for interface design. Wu [17–22] put forward the corresponding relationship between error and cognition based on error-cognition correspondence model of human-computer interactive interface in complex system and carried out a series of experiments on visual searching. The above studies on digital control system and human-computer interactive interface provided scientific theoretical basis and technical means, but it ignored the study on association effect in cognitive behaviors, information characteristics and design factors.

2.2 Complex Information Structure and Information Presentation Research

In the research field of information structure in large data environment, there are some research achievements at home and abroad from aspects of information visualization, information complexity, information structure, information network analysis and information presentation. Reda et al. [23] studied how to realize extensible data visualization of the heterogeneous data set in a complex real environment, allowing users to collocate 2D and 3D data sets simultaneously and create information space from 2D to 3D. Cheshire et al [24]. illustrated the significance of large data and showed how to describe the data flow in different time scales based on London public transport system. Basole et al. [25] discussed the way to visualize large data with multiple associations through a variety of view methods based on node. Mueller et al [26] studied the visualization analysis of the data which using visual similarity matrix through graphic sorting algorithm. Kaushik et al. [27] studied the complexity of space from the perspective of information theory, and queried optimization through corresponding table. Wang et al. [28] showed the degree of regularity of images through the complexity of image space and located the calculation area of space complexity so as to extract information from complicated situation. Wang et al. [29] and Liu [30] explored network structure and node center of intelligent control system interface with the method of complex network. They also analyzed the distribution of network, the average path length and clustering coefficient. Kim et al. [31] put forward that it is better to simulate a system of connecting buyers and suppliers in a mesh way rather than linearity. They also established theory structure of social network analysis and key indicators of network structure construction. Ahn et al. [32] proposed a combination between interactive visualization and personalized search. Qi [33] designed the information management, information presentation and information dissemination in digital cultural heritage by adopting information visualization model and design principle. Anuar et al. [34] used the visual analysis tool kit to break through the traditional analysis methods of eye-movement data and proposed analysis method of space measurement of eye-movement data innovatively to summarize the searching strategy when users search for information in the map. Molnár et al. [35] compared the advantages and efficiencies of different scanning strategies by analyzing the horizontal and vertical eye-movement trajectories. Schreudera et al. [36] used eye-movement technique to test the degree of drivers' drowsiness during driving so as to improving the alarm system. Aloisea et al. [37] analyzed how to control the visual focus of the interface and how to adjust the interface element to cause the user's visual attention through eye-movement. Wang et al. [38] evaluated and analyzed the design plan experiment of interface layout by using eye-movement tracker. They chose reasonable optimized plan of space layout based on the evaluation of eye-movement data indicators. In the field of information structure and information presentation, scholars have accumulated research achievements on information visualization technology and information complexity analysis. In particular, mature complex network analysis method and information visualization model play important roles in establishing information interactive design method.

3 Analysis of the Human Computer Interactive Process of Visual Information

3.1 Human-Computer Interactive Process of Intelligent Control System

The complicated information in the system is analyzed and processed by the computer and finally presented to the operator to observe, analyze, judge the situation and make decision as visual information sources and bases. This information will be feedback from sensory channels through attention, perception, memory, and decision. Different from ordinary information system, it carries a huge amount of information. Its information structure is complex and it is presented to user (operator) in a dynamic and changeable way. The visual information interface of the intelligent control system includes multi-module information structure and multi-variate information unit. The interface expresses the complicated and changeable information in the form of character, text, image, icon, color and dimension through the navigation design and the structure of the information hierarchy; the operation of the system will show the dynamic of the interface and replace multi-hierarchy information content constantly; In the process of human-computer interactive monitoring mission, the operator needs to deal with large scale information and real-time monitoring at the same time.

All aspects of the control system information are gathered here. The internal operation of the system is presented in the form of information. So the system can interact with the outside world intuitively. Specifically, the information interactive interface takes responsibility for interactive tasks of whole system. It must present slight changes of the system. It is the only channel for users to communicate with the system, as shown in Fig. 2.

Therefore, as the back-end of system operation, visual information presentation of intelligent control system has become an important means and operation basis for human (operator) to obtain information, make inference and evaluate decision. In the large data environment, rational analysis and evaluation of visual information plays an important role in playing performance and precise implementation, also in maintaining the safety and stability of intelligent control system.

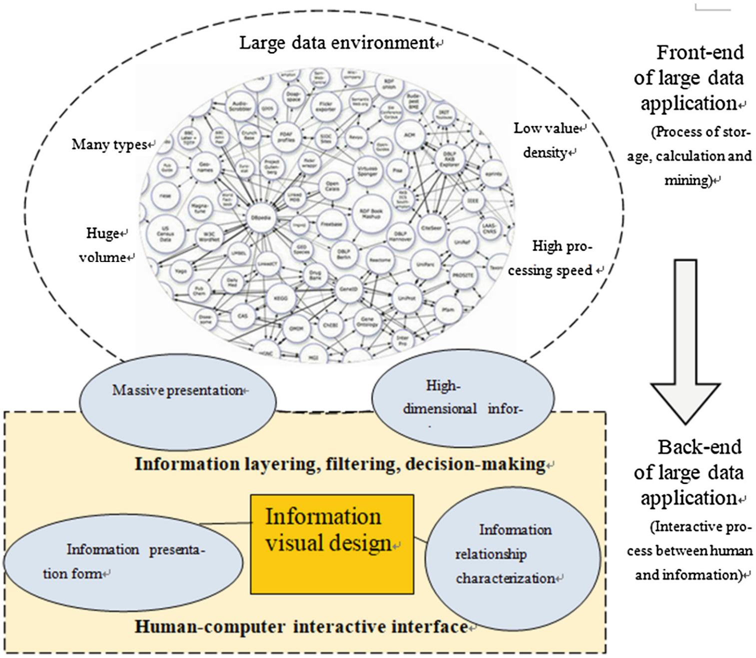

Fig. 2. Information interactive interface of intelligent control system

3.2 Cognitive Behavior Process of Visual Information

A system that hosts large data operations should use information for interaction and decision-making efficiently, which requires the information interactive interface to show "information exchange and communication, information circulating, updating and sharing among each other." For example, Trina Solar Technology Company established MES manufacture information management system for real-time monitoring of the entire process of production line, which is a typical intelligent control system. Figure 3 shows photovoltaic modules production line. The monitoring system involves a full set of technological process such as cell separation, welding, laminating, frame-making, curing, testing, and packaging. The monitoring system needs to record process parameters from the source of production process. The production presentation interface of each process can monitor the information in real time to response and adjust to abnormal condition.

The visual information presentation of the system can be visualized as monitoring, searching, response and execution based on information from the operator's records on visualized production process parameter, real-time process production status information and emergency decision, as shown in Fig. 4. The complicated information in the system is analyzed and processed by the computer and finally presented to the operator to observe, analyze, judge the situation and make decision as visual information sources and bases. This information will be feedback from sensory channels through attention, perception, memory, and decision. Therefore, it is necessary to classify,

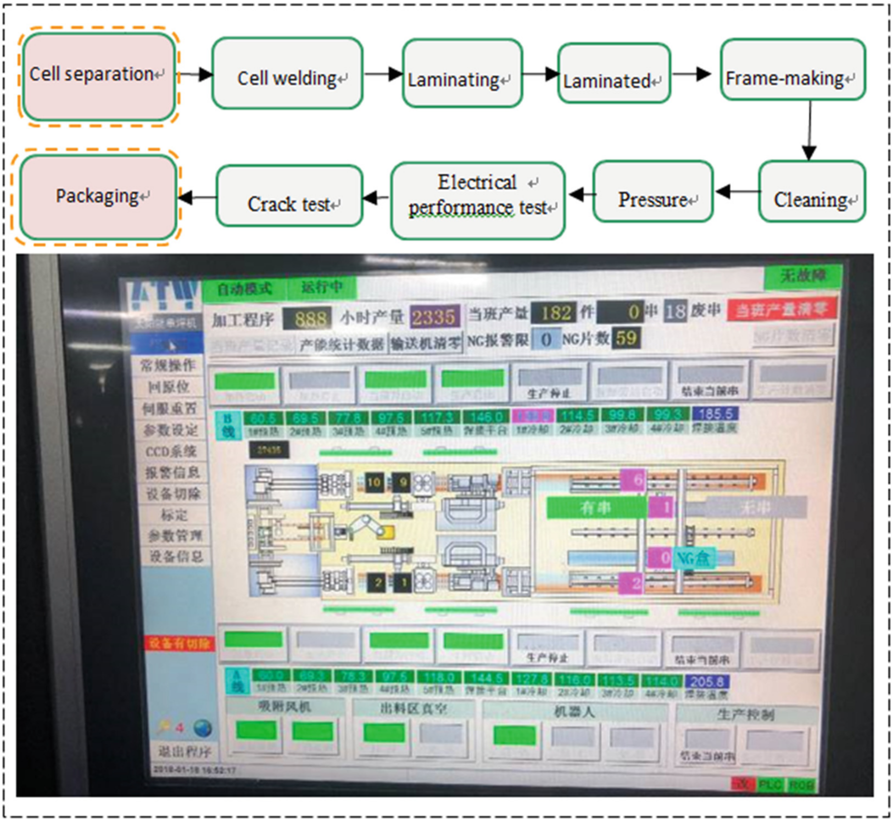

Fig. 3. Control process (above) and visual information interface (following) of photovoltaic modules production line

cluster and explore the reliability analysis method of visual information searching in intelligent control system. That should start with the cognitive behavior of visual information searching in the human-computer interactive process. Then we can establish a physiological evaluation model of visual information which is the premise of the interface design of information interaction.

4 The Analysis Method of Visual Information Searching

This paper presents the analysis method of visual information searching in intelligent control system. On the premise of visualization structure analysis of complex network information, starting with the cognitive behavior of visual information searching in the human computer interactive process, taking reliability analysis of operator information searching as key point and main line, classifying and clustering huge amount of information, this paper studies characterization of information graphic elements relationship, information multi-dimensional attributes, information layouts and coding

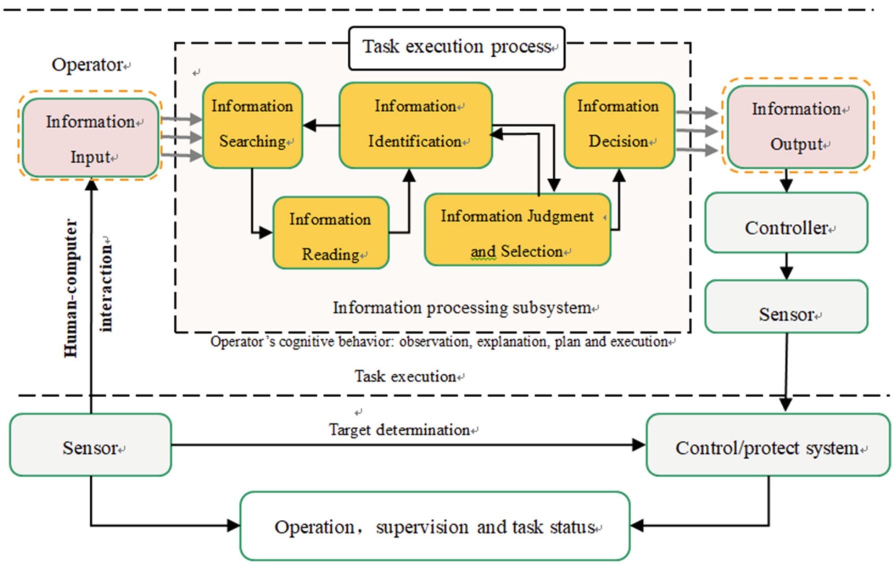

Fig. 4. Visual information cognitive behavior process of control system for real-time monitoring

rules in information interactive interface and establishes information structure model of visual cognition. Thus, operator can interact with control system efficiently.

4.1 Establishment of Graphic Elements Relationship of Visual Information

Liking a network, characterization of graphic elements relationship in information interface is nonlinear and complex. As optimized strategies of information visualization, solving network relationship characterization of information elements and establishing relationship efficiently among information nodes are helpful for reasonable information layouts and coding. When studying typical intelligent control system, we should analyze the structure of the massive and dynamic huge amount of information through visual cognition such as information searching, information recognition, information identification, information judgment and decision-making. Information visualization is a process to visualize the abstract information network. A huge amount of high-dimensional data information interface is characterized by irregularity, fuzziness and external "space complexity". When analyzing the complexity among graphic elements, we extract design factor of interface element, consider the problem of perfect matching, point set coverage and graph is not isomorphic and apply the theory of space complexity analysis, especially NP complete theory of complexity. The graphic element coding and layout in information interface should be designed according to the complexity of the graphic element which is analyzed by Pajek complex nonlinear network and the visual behavior relationship. That is benefit to establishing information adjacency matrix, breaking down the large data into several small internets and establishing characterization of visual graphic elements relationship.

The steps to establish an information space network are shown below (as shown in Fig. 5.):

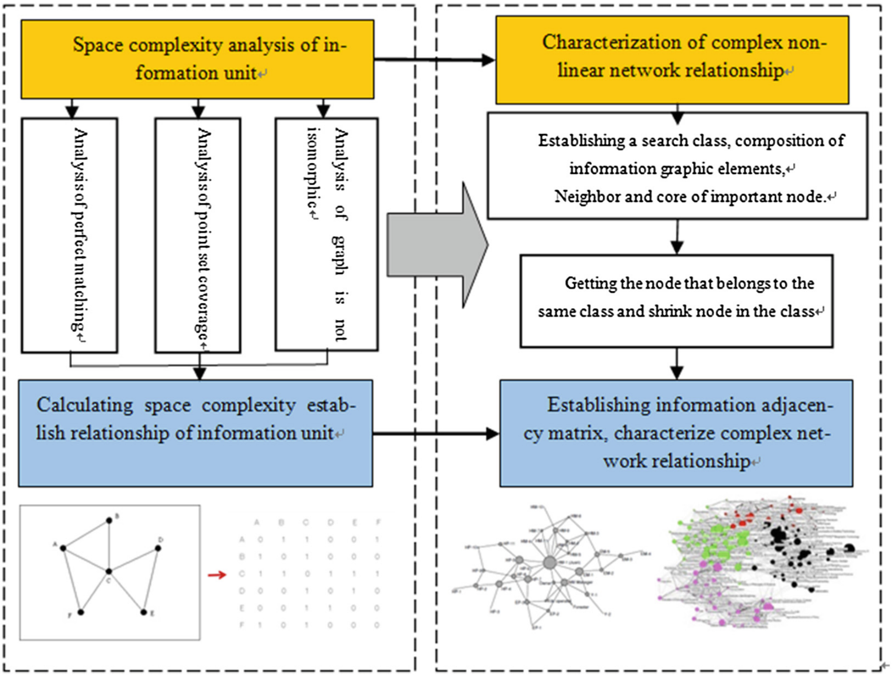

Fig. 5. Space complex network research of information interface in large data environment

The main research content is (as shown in Fig. 2.):

① Space complexity analysis of information unit in large data
② Establishing information node in the information graphic elements network
③ Characterization of complex non-linear network relationship based on information node

4.2 Establishment of Visual Information Structure of Human-Computer Interactive Process

It is an effective way to control cognitive load and ensure information perception advantage by adjusting information network structure and increasing information flow channel among information cluster. Through the method of increasing information dimension such as motion dimension, time dimension, image dimension, index dimension and constructing interactive system such as juxtaposition, covering, nesting, contrast and transition among information clusters vividly, this paper assembles static association information of complex network relationship into many dynamic organic wholes so as to regulate horizontal and vertical depth of information network. It needs us to study decompression form of high-dimensional information to express the high-dimensional data in low-dimensional space in different information clusters. In the visual interactive interface, the user's vision is just a small portion of the whole information presented while the user expects to "decompress" a lot of information from the small amount of data. Decompression form of high-dimensional information needs the study of implicit central manifold in high-dimensional or large data. Feature of high-dimensional information is characterized by low-dimensional variable. This paper mainly studies low-dimensional nonlinear approximation model of high-dimensional linear problem and changes high-dimensional linear problem into low-dimensional nonlinear problem. That is helpful for new research of Ultra-high dimensional data to reduce the dimension.

Information unit and characterization of graphic elements relationship based on multi-hierarchy structure need the visual structure model of information multi-dimensional attributes. Information is divided into three forms based on complex network theory, at the same time, the attributes of information are summarized as entity attributes, association attributes and time attributes. According to the attributes division

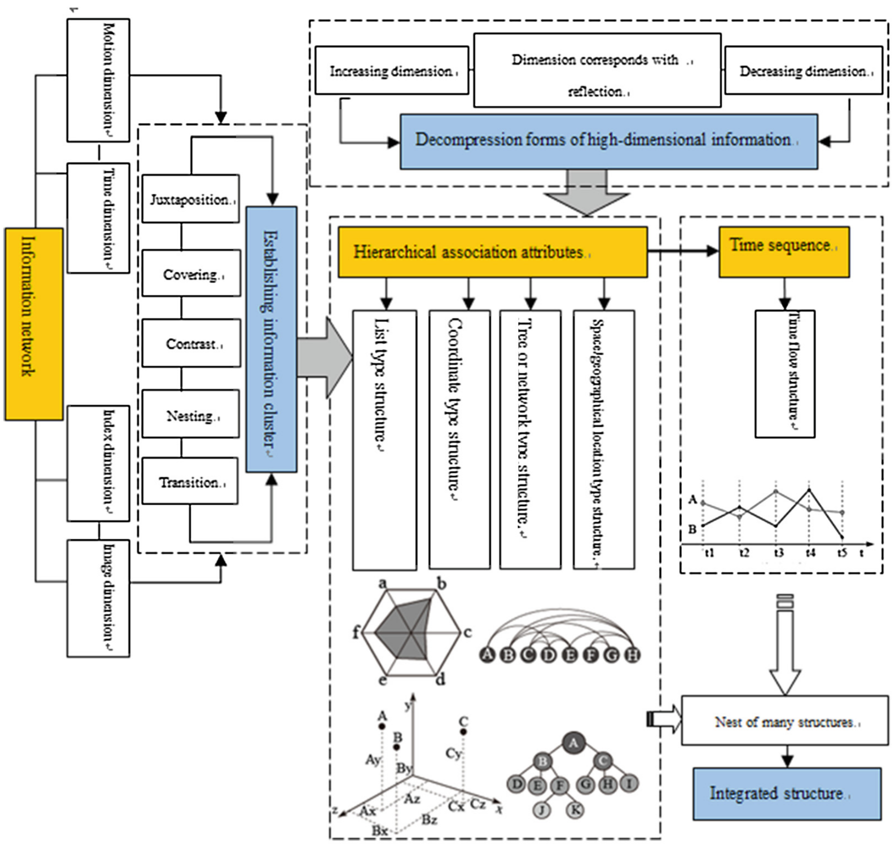

Fig. 6. Visual structure model of high-dimensional information

of information, this paper puts forward the mapping relationship between entity attributes and visual graphic, the mapping relationship between association attributes, time attributes and visual structure. We establish a visual structure mapping model through analysis of various association attributes, as shown in Fig. 6.

5 Conclusion

(1) This paper analyzes human-computer interactive process of intelligent control system and puts forward that visual information presentation of intelligent control system has become an important means and operation basis for people (operators) to obtain information, make inference and evaluate decision;
(2) This paper presents the analysis method of visual information searching in intelligent control system. On the premise of visualization structure analysis of complex network information, starting with the cognitive behavior of visual information searching in the human computer interactive process, taking reliability analysis of operator information searching as key point and main line, classifying and clustering a huge amount of information, through studying characterization of information graphic elements relationship, information multi-dimensional attributes, information layouts and coding rules in information interactive interface, this paper establishes visual cognitive model of information structure so as to make information interaction between operators and control system more efficiently.

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