Interface Design Technology and Verification of Intelligent Manufacturing Oriented CNC System

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Abstract. Objective With the proposal of German Industry 4.0, intelligent manufacturing has become the main direction of manufacturing technology development. In recent years, CNC technology industry for intelligent manufacturing has developed rapidly in China, and it has been widely used in various fields of manufacturing industry. Among them, the design of man-machine interface for system appearance is closely related to the operation mechanism of internal functions with high specialization and complexity, which has attracted more and more attention from the industry and designers. Therefore, the design method and key points of the human-machine interface of NC system will be discussed for intelligent manufacturing, and the technical verification will be made. Method The interface design requirements of intelligent manufacturing oriented CNC system were systematically analyzed, and the corresponding design techniques and key points were given. The specific design scheme and verification of Huazhong 9 interface design of Huazhong CNC were discussed based on a specific design case. Conclusion It is hoped that the design of man-machine interaction interface of intelligent manufacturing CNC system can be optimized and improved, and that a little contribution can be made to the CNC technology industry in China. Keywords. Intelligent manufacturing; CNC system interface; human-computer interaction design.

1. General Introduction on the CNC System Interface of Intelligent Manufacturing

Intelligent manufacturing, IM, is a type of integrated human-computer system composed of intelligent machinery and human experts. It is able to implement intelligent activities in the process of manufacturing like analysis, reasoning, judgment, conception, decision-making and so on. When the smart machinery works with human being, it can partly replace the human experts’ brainwork in production process [1]. “Intelligence” is the core element of “Made in China 2025”. CNC system is the top priority for the manufacturing equipment to become smart. Therefore, the interface design of intelligent CNC system is one of the critical factors to realize intelligent manufacturing in China [2].

CNC system interface, i.e., human-machine interface, refers to the operation mode of human-machine interaction. It is a medium for the users and the machinery to communicate each other. That medium includes information input and output. In a broad sense, the human-machine interface works as a medium between human being and the machinery. Through eyes, ears and else sensory organs, human receives information from the machine. After that, the brain processes the information, makes decisions and then reacts. Accordingly, it achieves the human-machine information transmission. The human-machine interface design aims at endowing the machinery with an effective mechanism to assist human’s work, thus realizing friendly human-machine interaction [3].
2. Requirements of Intelligent Manufacturing on Interface Design

The interface of CNC system for intelligent manufacturing establishes a communication platform between manual operation and CNC. It requires optimizing the pages on the basis of realizing basic functions. In addition to promising the users’ normal and safe interactive operation, it must provide them with pleasant operating experience. Under the background of intelligent manufacturing, the design of CNC system interface is required to be organized, friendly, simple and interactive by touch. It aims at reaching a high quality standard to match with the CNC system in a smart and high-speed way.

2.1. Unitization

Unitization, just as its name implies, refers that the things are classified as per certain principle. The same group of things is processed in the same method. When designing the interface of CNC system, with the improving of CNC technology, its system contains more and more functional items. Reflected in the CNC interface, it means increasing amount of functional information. Therefore, various models may exist in CNC system interface. The information becomes more complicated as the functional divisions increase. Consequently, it becomes more difficult for user identification. To relieve users’ visual fatigue and increase the efficiency of operation, the CNC system interface requires that all functional information subjects in the interface to be classified in accordance with respective function. Consolidate the same category of functions together; then classify them as per specific principles. Let the interface possess fine layout, frame structure and logical organization. In addition, such design enables a distinct interface level, coordinated layout as well as consistent hue and style.

2.2. User-Friendly

The CNC system interface in operation is constantly implementing and feeding back users’ commands. As an object to serve users every day, the interface plays an extremely role in affecting users’ emotions and moods, even their working efficiency. It is indispensable to design a user-friendly CNC system interface for good interaction between the users and the interface. It is also necessary for such an interface to satisfy users’ psychological needs and reduce their fatigue.

User-friendly design of the CNC interface will be reflected in the high efficiency and pleasant operation experience. The interface design is required to provide a logical layout to the users, so that each interface has clear levels and properly functional divisions which are both relatively independent and organically integrated. It enables users to grasp the characteristics of interface and to master the function of each division directly and accurately, so as to enter an efficient operative mode quickly. Different function divisions are classified with different colors. Even for the same button, it will display various colors in accordance with current function, so as to let users know the status of present interface function. This will greatly improve the operator’s efficiency and affinity.

2.3. Simplicity

A successful interface design must follow this principle. The core task is transmitting information smoothly and displaying the information contents before the users completely and vividly. And in CNC system interface, there is a huge amount of information waiting for display. It is full of various figures, icons, texts and other types of information. There are various data including important and less important data, primary and secondary data and else data. In real work, the interface content design must be simple so that the operators can capture the target information quickly and accurately; meanwhile they can avoid wrong selection or operation. In particular, when abundant information needs to be displayed on a limited size of screen, reasonable organization and simple design can reduce occupied space, thus expressing the information clearly and completely, further improving the efficiency of each page at the same time.

2.4. Touch Control Interaction

Touch control interaction (also known as gesture interaction), refers that using hands to realize direct manipulation on the system, so as to formulate human-computer interactive experience integrated by
user’s hearing, vision and touch [4]. In the interface of CNC system, the information agent contains high-density contents. It possesses highly complex structure and changes in real time. The users have to deal with a number of similar interfaces. When they attempt close monitoring and precise operation, it is out of their abilities by clicking the interface with mouse. Instead, this will enhance users’ cognitive difficulty, cause psychological pressure and influence their working efficiency. It is urgent for present intelligent CNC system to equip touch interactive functions because it can bring direct, simple, flexible and effective operation experience. After equipping with touch control function, the users can have fewer cognitive burdens, less visual interruption and shorter operation hours, thus increasing their working efficiency.

3. Technical Methods and Key Points of CNC System Interface Design

3.1. Layout and Arrangement
To meet the demands of “unitization” interface design, reasonable layout and arrangement are the precondition and key of unitization interface design [5]. Not like normal electronic interaction interface, the CNC machine system comprises many interfaces of complex functions and structures. Each interface contains a large deal of data, diagrams, texts, figures, icons, models and other information. It demands elaborate arrangement and design. The interface design requires clear structural logic and proper allocation of functional divisions, so that it has friendly visual guidance; With regard to the division and change of interface space, the effect of “blanking” should be properly considered. To avoid the large amount of information contents flooding in the interface and colliding with one another, an ingenious blanking at proper location can produce a well-structured interface. It shows more space comfort. Meanwhile, the information subject is extraordinarily highlighted and emphasized. It gives prominence to the functions, thus bringing convenient for corresponding operations.

3.2. Figures and Texts
In the interface of CNC system, the figures and texts are the main subject of information task. They are also the main contents of interface design. To ensure the users to acquire the essential information precisely and clearly, the figures must be designed as simple as possible and the texts must be arranged in a friendly and intimate way [6]. Firstly, for the figure partition, it includes the functional subjects like icons, buttons, etc. and additional contents like background picture, frame and else. It requires the designers of attempting to use simple elements after they can well control the design targets. The design subjects need to be concentrated, simplified and abstracted as much as possible. Additionally, the features of functions and figure recognition should be maintained and simplified. By doing so, it appears that figures are simple and real, beautiful and neat. Accordingly, the information subject will not be interrupted. Next, for the text part, it is one of the most significant and most direct transmitting information subjects. In CNC system, the task information is reflected in large amount of texts. Therefore, it requires the interface to be simple and clear, so that users will focus on the information subject with fewer visual burdens.

3.3. Hue and Transparency
In the interface design, although the processing of hue and transparency is not the main task, coordinated control on hues and appropriate use of transparency are essential “additives” in an excellent, simple and intelligent interface design. As is known to all, the interfaces of past CNC system are so monotonous that there’re hardly any vital pages or hues. Like most industrial design interfaces, users will be tired of watching for a long period. Conversely, highly saturated elements are selected in simple interface; unified hues are used in relatively more diversified interface to bring integral impression. A couple of colors with identical series coordinate to improve the springy and clear identified level of the interface. In addition, it can also reinforce the interface affinity; the cognitive properties of various colors in users’ mind are fully used to strengthen the technology and inheritance of interface design.
4. Design of Huazhong Nine Type Interface

The Huazhong CNC system, i.e. Huazhong Nine type touch display is a reformatory and upgrade product on the basis of Huazhong Eight type series. It represents an innovative design for improving the corporation’s product image. Huazhong Nine type CNC system interface is required to be as novel as its product appearance; compared with the traditional and regular design style in previous generation, it needs a higher grade of style. Take the APP Store interface and touch interactive interface design, one of Huazhong Nine type interface design as example, it is elaborated as below.

4.1. Interface Design of APP Store

The APP Store interface is a newly added functional interface of Huazhong Nine type display. It works to manage the APP. The layout of interface is divided into a top-level main page and many secondary information detail pages. The design style among interfaces is required to be consistent. Moreover, the design elements in every interface must be coordinated in colors, sizes, proportions, styles, materials and other aspects. The layout of module information in sub-interfaces should be in accordance with the main page. It is separated into “interface description column, APP classification column and detail information area”. The interface of debug tool in Huazhong Nine type APP Store is shown in figure 1.

![Figure 1. Huazhong nine type APP Store—debugging tool interface.](image)

APP classification column

Interface description column

Detail information area

The interface description column mainly consists of the Huazhong NC LOGO, the interface name, the search bar and the off button. This column is placed in the top of interface to remind and navigate the users. The APP category column is designed in the left of interface. It accords with human engineering. As per the top-down and left-to-right observation customs of human eyes, users can have an easy access to corresponding APP name when browsing the APP buttons in the left, thus bringing convenient operation. Firstly, in the interface of APP icons, every APP image is made up of relevant icon overlaying on the same translucent rounded rectangle. Below each rectangle writes corresponding APP name. Glow effect is designed on the outline of the little background to underline the intelligence and sense of technology; Semi-transparent effect of the outline ensures the icons to arrange in more reasonable and standard way. Besides, the interface looks more unified and regular. This kind of consistent design is convenient for users to browse quickly and search the needed APP. It also brings users convenience to comprehend and operate the interface. Next, the secondary information detail interface corresponding to each APP, Huazhong Nine type APP Store-HNCLadder interface is shown in figure 2. This interface consists of three little parts: APP brief introduction and download block, software introduction block and new version features block. Among them, the APP brief introduction and download block is highlighted through translucent background padding and the striking design of download buttons. It helps users to acquire quick details of the APP information and to complete their download tasks. The same APP icon owns the same style of interface. Three information blocks in this
interface are subdivided as simple polygons. It looks outstandingly simple and user-friendly. The primary and secondary partitions are clear and reasonable, consequently greatly reducing users’ operation hours.

![Huazhong nine type APP Store—HNC ladder interface.](image)

**Figure 2.** Huazhong nine type APP Store—HNC ladder interface.

4.2. **Touch Interactive Interface Design**

To satisfy the demands of product upgrading and innovation, the appearance of Huazhong Nine type has applied brand new modeling design: upper-lower double touch screen; the angle of host computer and slave computer can be fine-tuned. Huazhong Nine type touch control interface is shown in figure 3. The upper screen is touch display and the lower screen is touch operation console. The users only need to gently touch the icon or words on the display to realize human-machine interactive operation. It’s rather direct way of interaction; the upper-lower double touch screen design simplifies users’ operation and therefore obtains more timely information feedback. In this design, the upper touch control display is an improved host computer display. The direct touch design allows users to tap directly with their fingers on the screen. By saving mouse and keyboard, the manipulating path and total hours are greatly reduced. That is convenient and fast. The lower touch control panel removes the solid mechanical buttons on before panel (only reserves some important physical buttons; other keys are replaced with touch control soft interlace. The hidden menu in the interface is an excellent design. It allows the MCP interface, the PC keyboard interface and the simulation interface to switch freely in real time. It aims at making the best of the touch screen functions, reasonably allocating the interface, reducing the operation steps and enhancing the display functions. The upper-lower touch control panel is connected by a large movable stand with an angle-adjustable rotating shaft. This design establishes a perfect balance of the display and the operation. Meanwhile, it accords with the user-friendly principle. The information can be displayed and fed back in time. It also realizes the handiest operation for different heights of users.

5. **Experiment Validation**

In the section of experimental verification, eight NC operators with equivalent working ability were picked out and evenly divided into two teams. In one team, the four operators use Huazhong Eight type intelligent CNC system that is not improved by design; The Huazhong Eight intelligent CNC system is shown in figure 4. The other four operators use Huazhong Nine type intelligent CNC system which is improved by design. The Huazhong Nine type intelligent CNC system is shown in figure 5. Two teams complete the same operation task (two interface contains the same information content). Then four operational indexes are recorded as “total period of operation”, “error rate of operation”, “comfort level of operation” and “efficiency of operation”. After analysis and calculation, the mean values of these indexes are worked out to get the experimental results in table 1 below (The mean value comparison of
operational indexes between Huazhong Eight type CNC system and Huazhong Nine type intelligent CNC system is shown in table 1).

![Huazhong nine type touch interface.](image)

**Figure 3. Huazhong nine type touch interface.**

|                  | Total period of operation | Error rate of operation | Comfort level of operation | Efficiency of operation |
|------------------|----------------------------|-------------------------|---------------------------|-------------------------|
| Huazhong Eight Type Interface | 10 (min)                  | 30%                     | Relatively inferior        | 75%                     |
| Huazhong Nine Type Interface   | 7 (min)                   | 10%                     | Quite good                 | 98%                     |

The experiment shows that, Huazhong Nine type interface is better than Huazhong Eight type interface. The former is more competent in complicated CNC system human-machine interactive environment. Moreover, it is more user-friendly and smart. Therefore, Huazhong Nine type interface fits the cutting-edge design trends.

![Huazhong eight type intelligent CNC system.](image)

**Figure 4. Huazhong eight type intelligent CNC system.**

![Huazhong nine type intelligent CNC system.](image)

**Figure 5. Huazhong nine type intelligent CNC system.**

6. **Conclusion and Expectation**

Human society is developing and design is also stepping forward. In this thesis, the research shows that, the study on optimal design of human-machine interface is highly valuable in promoting the development of CNC system industry, improving the users’ experience as well as increasing the security and efficiency of work. Adhered by the user-oriented design idea, the CNC system interface
must be innovated and optimized constantly. The interface design of CNC system under the intelligent manufacturing environment must fulfill the concept of simplicity, efficiency, easy identification and easy operation. This is inevitably stylistic trends in today and tomorrow. Therefore, the designers need to pay closely attention to the developmental dynamics of CNC industry. In accordance with the functions, markets and else relevant factors, designers should improve and optimize the flat-style design of CNC interface steadily, so that the principal information is highlighted in a coordinated and elegant interface.

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