Sunburst Hierarchical Visualization Technique-based Navigation Support Interface for Information Processing System (IPS) in Nuclear Power Plants

Seung Min LEE[1], Gwi Sook JANG[2], and Gee Yong PARK[3]

1. Korea Atomic Energy Research Institute, 989-111, Daedeok-daero, Yuseong-gu, Daejeon, Korea (jewellee@kaeri.re.kr)

2. Nuclear ICT Research Division, Korea Atomic Energy Research Institute, 989-111, Daedeok-daero, Yuseong-gu, Daejeon, Korea (gsjang@kaeri.re.kr)

3. Nuclear ICT Research Division, Korea Atomic Energy Research Institute, 989-111, Daedeok-daero, Yuseong-gu, Daejeon, Korea (gypark@kaeri.re.kr)

Abstract: Analogue-based information display panels in Main Control Room (MCR) have been changed to digitalized visual display units (VDUs). The VDU provides enormous amount of information and digital-based various functions to support human operators' monitoring and control tasks. However, to display lots of information on the limited VDU screen generates a major secondary task, that is a navigating, and it induces the degradation of human performance. To support the navigating tasks for layered display systems, the sunburst visualization technique, which is proven that it is useful for conducting navigating tasks, is applied to describe the whole hierarchical structure in small space. In this work, Sunburst hierarchy visualization technique-based navigating support system (SUNNI) is suggested. It is expected that the suggested system helps human operators to get rapid understanding and the formation of a mental model for the information display structure, to support page movement function, to decrease working time, and finally to improve the human performance.

Keyword: Hierarchical visualization, Monitoring system, Human performance

1 Introduction

By adopting new human-system interfaces (HSIs) based on computer-based technologies, the operation environment of main control rooms (MCRs) in nuclear power plants (NPPs) has changed. The digitalized MCR coupled with digital instrumentation and control (I&C) systems and includes various sizes of visual display units (VDUs), soft controls such as mice, trackballs, and joysticks, and computerized procedures[1]. Digital-based MCR provide much more real-time information than is found in conventional MCRs. While the volume of information increases considerably, it is available through a limited viewing area provided by VDUs[8]. In order to provide information that is simple and easy to access, display designers layered the screen up to four levels. When the operators perform their work using this layered display, they need to obtain the desired information quickly and accurately. Therefore, operators must know where the desired information is, and how to navigate and retrieve it [8].

The navigating refers to the access and retrieval of a specific aspect of the HSIs. It involves developing and following a path to the desired information based on an understanding of one's current location, or the location of the desired information within the display, or accessing specific information from within a display page [8]. In digitalized MCRs, navigating tasks are considered to be the cause of human errors. In a study that derives human errors that are expected to appear in digitalized MCR, the navigating task is considered as the second highest human error factor[1]. These human errors create workload and may divert attention away from primary tasks in MCRs such as monitoring, situation awareness,

planning and implementation tasks, and make operators difficult to perform. It increases working time, interrupts accurate and rapid operation, and decreases human performance. Thus, navigating tasks are important and need to be carefully addressed and designed in display designing process[9].

The hierarchical visualization technique is proven to be useful for navigating tasks, and the sunburst visualization technique is applied to describe the whole hierarchical structure of display systems in MCRs in limited space.

The sunburst visualization technique provides the overview of display system, and it helps human operators to obtain an intuitive understanding with better cognition. Besides, they are not required to follow the decided path to move to the different pages[2].

Human operators' rapid understanding and the formation of a mental model for information structure can decrease working time and improve the human performance, and supporting page movement function also helps to rapid and accurate monitoring tasks.

2 Information Processing System in NPPs (IPS)

Information processing system (IPS) is a computer based display system to provide plant data and status information to the operators[11]. The information is derived from plant sensors and self-contained algorithms called application programs. The IPS makes the information available to the plant operator staffs both on a real-time and historical basis. The major functions of IPS includes plant data acquisition, validation of sensed parameters, the execution of Nuclear Steam Supply System(NSSS) application programs and Balance of Plant (BOP) performance calculations, the monitoring of general plant status and of plant safety status, the presentation of status and calculation results, the generation of logs, and the determination of alarm condition. In order to perform these various functions, IPS is designed as a hierarchical structure as shown in Fig. 1.

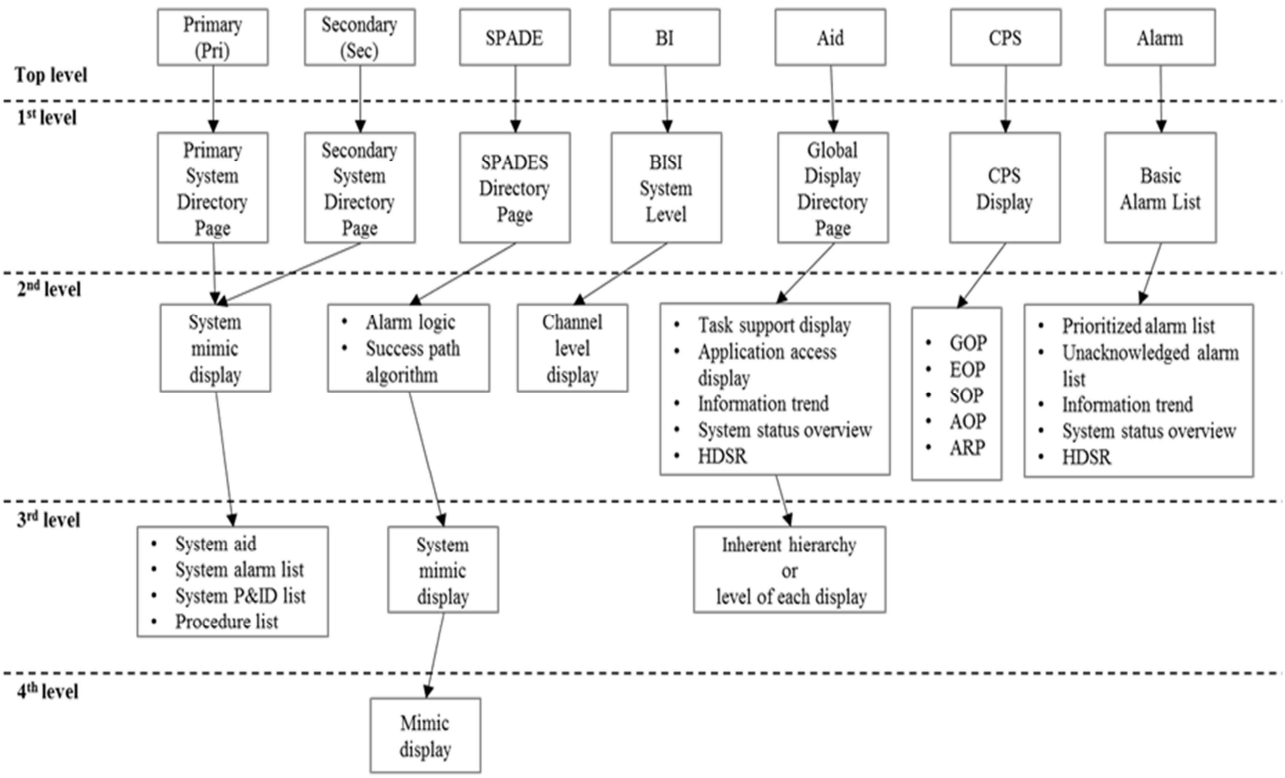

Fig. 1 Hierarchy structure of IPS

Top level is categorized into seven parts. General information, trend and system mimic for NSSS is provided in Primary category. If operators click Primary tab using their soft controller, they go to 1st level and open Primary System Directory Page as shown in Fig. 2.

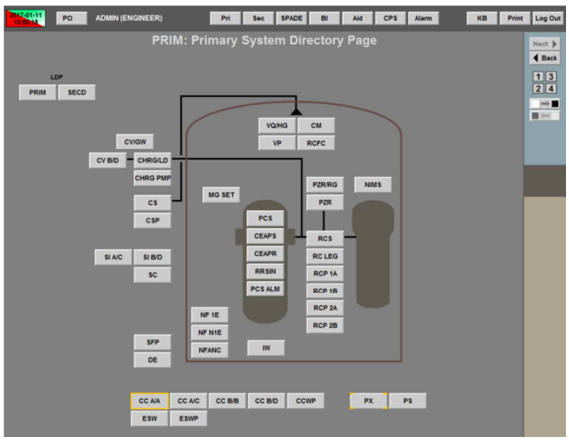

Fig. 2 Primary System Directory Page

Primary System Directory Page provides lots of tabs named with various parts of the primary system. If operators click one of tabs, they go to 2nd level and open the system mimic displays as shown in Fig. 3.

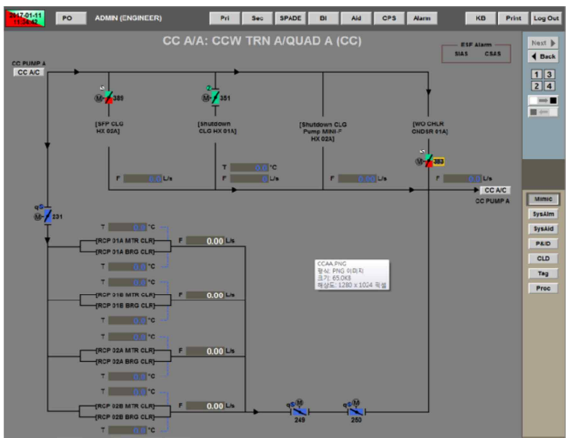

Fig. 3 Core cooling water(CCW) Train(TRN) A mimic display

On the right side of Fig. 3, there are seven tabs named with system mimic, system aid, system alarm list, P&ID (Piping and Instrumentation Diagram) list, CLD (Control Login Diagram), tagging, and procedure list. If operators click one of six tabs except for system mimic, they go to 3rd level. If they click system mimic, then the can go back to 2nd level and open the mimic display (Fig. 3) from 3rd level display pages.

The remaining six top level categories work the same as above. Secondary category provides BOP-related information. SPADE (Safety Parameter Display and valuation System) category provides continuously monitored information about the plants' essential functions and success paths including safety function. BI (Bypassed & Inoperable Status Indication; BISI) category provides the information that the safety channel or ESFAS (Engineered Safety Features Actuation System) train is inoperable in the event of a communication failure due to the safety channel or the ESFAS train. CPS (Computerized Procedure System) categorization provides General operating procedure (GOP), emergency operating procedure (EOP), standard operating procedures (SOP), abnormal operating procedure (AOP), alarm response procedure (ARP). Alarm categorization provides various alarm list, status overview, and supports to enter the HDSR (Historical Data Storage and Retrieval system) pages to access historical data.

The IPS contains various functions for monitoring the status of the plant and performing control tasks as mentioned above. It, therefore, consists of a very large number of pages. There are tabs for moving between levels, top level categorization tabs for moving to other categories, and buttons for moving to a previous page. However, there is no systematic support interface for reducing human errors related to navigating tasks through cognitive load reduction.

3 Information Hierarchy Visualization

Information visualization is the visual representation of complex information in ways that enhance understanding[8]. Since the 1980s, many researchers establish the information visualization field by developing the various techniques to present information hierarchy[2]. The purpose of information visualization is to provide a compact representation of the information, which is the notion of overview, in order to assist users in navigating the information. In other words, it functions as to leverage the

functioning of the human visual system in an effort to provide insight, to help human resolve logical problems, to think and reason, and to provide help in understanding data[2,3,4,5,8].
Especially from the human factor engineering point of view, it is conjectured that well-designed visualizations must engage and promote high-level cognitive functions, such as gaining insight, reasoning, and understanding. The well-designed visualization also improves chunking and shapes encoding[8].
The various types of information hierarchy visualization techniques are shown in Fig. 4[7].

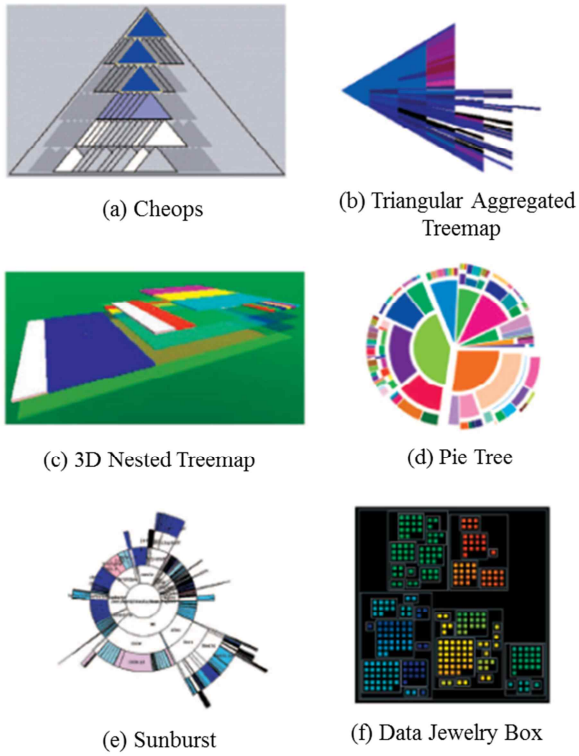

Fig. 4 Examples of implicit information hierarchy visualizations

Various types of presentation techniques can be used depending on the purpose, the characteristics of users and contents of information visualization.

4 Sunburst Hierarchicy Visualization Method based Navigation Support Interface for Monitoring Systems in NPPs (SUNNI)

Treemap hierarchy visualization techniques are the most frequently used. This technique is very appropriate to connect different attributes, such as size and type in hierarchy. However, it is vulnerable to convey structure. Thus, the radial space-filling techniques have been emerged to help convey structure better as an alternative to the treemap techniques[6].
In order to suggest a display interface that supports understanding the structure in IPS and navigating lots of display pages, one of the radial space-filling techniques, called the sunburst hierarchy visualization technique, is applied in this work.
An example of Sunburst Hierarchicy Visualization Method based Navigation Support Interface (SUNNI) is shown in Fig. 5.

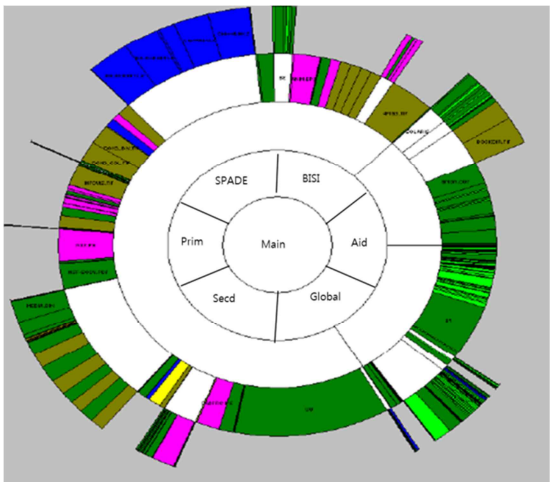

Fig. 5 An example of SUNNI for IPS

The core space is allocated for main page. The very outer of the core is allocated for 1st level tabs for each category. The very outer of the 1st level radial expression is allocated for 2nd level tabs for each 1st level tabs. In this way, the hierarchy structure of IPS shown in Fig. 1 is able to be visualized in sunburst form.
In the sunburst visualization form, operators can intuitively aware and understand the IPS structure. It helps operators to reduce the cognitive load by decreasing working load and assisting establishment of mental model (long term memory), thus, it is expected to improve the human performance with accurate and rapid operators'

response. They also can click and reach any display pages by using the sunburst visualized IPS structure regardless of categories or levels. It helps operators by allowing them to reach any display pages, thus, it is expected to decrease working time by being available to ignore the moving steps between display pages.

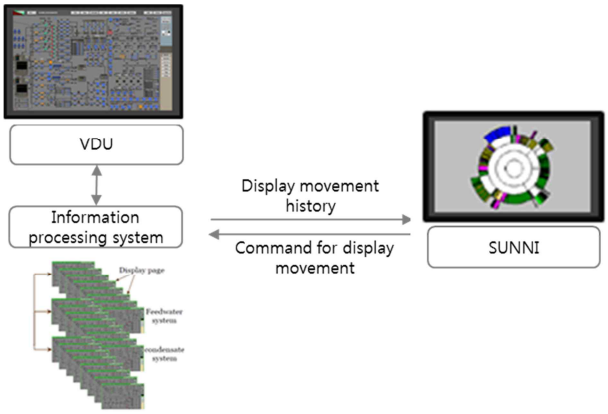

Fig. 6 SUNNI structure and interaction with IPS system

Fig. 6 shows the SUNNI structure and interaction with IPS system. The SUNNI is designed alone and it is used only for navigation purposes. In other words, SUNNI can be considered as an independent system so that it is detachable. The IPS server does not have excessive burden emerged by SUNNI, because SUNNI can only send and receive the page movement command with the IPS server.

Therefore, the SUNNI can be easily applied to not only new IPS systems, but also current IPS systems.

5 Conclusion

The VDU provides enormous amount of information and digital-based various functions to support human operators' monitoring and control tasks. It has been proven that the digital-based support functions reduce human errors and improve human performance. However, to display lots of information on the limited VDU screen generates a major secondary task, that is a navigating, and it induces the degradation of human performance. The IPS contains various functions for monitoring the status of the plant and performing control tasks, and it consists of a very large number of pages without any systematic navigation supporting tools.

By using the sunburst hierarchy visualization technique, which is proven that it is useful for describing the structure of system and assisting decrease of cognitive load and establishment of mental model, we suggest the navigating support display interface, SUNNI.

The positive effects of the sunburst hierarchy visualization technique have been widely studied and proven, and the effect of SUNNI can be also expectable. However, SUNNI will be considered more reliable and available if the verification of the effects of SUNNI itself is conducted.

References

[1] I. S. Jang, W. D. Jung, P. H. Seong, "Human Error and the Associated Recovery Probabilities for Soft Control being Used in the Advanced MCRs on NPPs," Annals of Nuclear Energy, Vol. 87, pp. 290-298, 2016.

[2] K. Hornbaek and M. Hertzum, "The notion of overview in information visualization," Internation Journal of Human-Computer Studies, Vol. 69, pp. 509-525, 2011.

[3] B. Bederson, a. Clamage, M. P. Czerwinski, G. G. Robertson, "DataLens: a fisheye calendar for PDAs," ACM Transactions on Computer-Human Interaction, Vol. 11, pp.90-119, 2004.

[4] N. Elmqvist, P. Tsigas, "CiteWiz: a tool for the visualization of scientific citation networks," Information Visualization, Vol. 6, pp. 215-232, 2007.

[5] K. Hornbaek, E. Frokjaer, "Reading electronic documents: the usability of linear, fisheye, and overview+detail interfaces," Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp.293-300, 2001.

[6] J. Stasko and E. Zhang, "Focus+Context and Navigation Techniques for Enhancing Radial, Space-Filling Hierarchy Visualizations," IEEE Symposium on Information Visualization, 2002.

[7] H. Schulz, S. Hadlak, H. Schumann, "The Design Space of Implicit Hierarchy Visualization: A Survey," IEEE Transactions on visualization and Computer Graphics, Vol. 17, No. 4, 393-411, 2011.

[8] R. E. Patterson et al., "A Human Cognition Framework for Information Visualization," Computers & Graphics, Vol. 42, pp. 42-58, 2014.

[9] NUREG/CR-6691, Vol. 2, "The effect of interface management tasks on crew performance & Safety in Complex, Computer-based System: Overview and Main Findings," 2002.

[10] NUREG/CR-6947, "Human Factors Consideration with Respect to Emerging Technology in Nuclear Power Plants," 2008.
[11] NPX80-IC-SD710, "System Description for the Data Processing System for Nuplex 80+."