COSSplay: Validating a Computerized Operator Support System Using a Microworld Simulator

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Abstract. Our computerized operator support system microworld simulator with student operators approach is called COSSplay. COSSplay allows testing of specific interface elements such as alarm visualizations without the constraints of the surrounding nuclear control room elements typically associated with full-scope simulation studies. Approaches like COSSplay are ideal for first principles research in human factors and human-computer interaction. This paper highlights the uses of COSSplay as a complimentary approach to full-scope simulation studies for complex interface design.

Keywords: Microworld · Simulation · Process control · Interface design

1 Introduction

Computerized operator support systems (COSS) exist in numerous complex work environments in aviation, maritime navigation, space exploration, medicine, and nuclear process control [1]. Within the context of nuclear process control, a COSS consists of automatic plant control features and a decision support system to aid operators while they monitor and control the plant. A prototype COSS was developed to demonstrate and empirically evaluate added capabilities afforded by automating operator actions for plant transients as described in [2]. The report recognized that managing certain plant upsets is sometimes limited by the operator's ability to quickly diagnose the fault and to take the needed actions in the time available. The COSS provides rapid assessments, computations, and recommendations to reduce workload and augment operator judgment and decision-making during these fast-moving, complex events.

The prototype COSS also provides advanced visualizations to aid the operator in understanding the current state of the plant. Furthermore, the automated prognostic system intelligently detects faults and prescribes procedures, which reduces the cognitive burden placed on the operator. Automating these tasks can lead to an overall improvement in system performance by reducing human error and allowing cognitive

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resources to be dedicated to other supervisory tasks. However, adding automation can lead to decreased system performance as evidenced by the operator out-of-the-loop performance problem [3], in which the automation precludes the operator from maintaining situation awareness. Prior to implementation in an actual nuclear power plant control room, the human-computer interactions with the COSS must be carefully evaluated. Any issues associated with the human-computer interactions must be eliminated through an iterative design process in order to create a useful operator support system. Furthermore, a COSS must undergo a verification and validation process as required by NUREG-0711 for any significant control room modification [4].

Two separate simulation approaches will continue to be used to support COSS development. Specifically, a microworld simulation has been used to support COSS development during the iterative design stages to vet and identify usability issues with novel interface display and control schemes. A full-scope simulation has also been extensively used to test and develop the COSS system within the context of a nuclear control room. The full-scope simulation will also be used to perform the verification and validation process required to approve the COSS system prior to its implementation in an actual nuclear control room. Advantages and disadvantages associated with each type of simulation will be discussed in the subsequent sections.

2 Full-Scope Simulations

Simulations serve as a primary method to generate and gather performance data needed for iterative design [5]. Nuclear utilities could potentially use their control room simulators to explore design changes proposed for their control rooms, but plant simulators are ill-suited for these activities. Significant demands for simulator time to conduct operator training and requirements to maintain an exact replica of the actual plant control room preclude plant simulators from much use for design purposes. Dedicated research simulators, such as the Human Systems Simulation Laboratory (HSSL) at Idaho National Laboratory, provide a simulation platform to develop and test complex interface designs for control rooms [6]. The HSSL is a full-scope, fully reconfigurable simulator capable of displaying various virtual nuclear power plant control rooms across its bays of large glasstop touch screen displays. The HSSL has been used extensively to evaluate digital control room upgrades. As control rooms age, obsolete analog components require digital replacements. The digital interface replacements largely embody the original functionality of the analog system being replaced. The resulting “digital islands” replace only a small subset of the original analog indicators and controls found across the control room; therefore, they require the extensive use of neighboring analog indicators and controls for operators to perform their duties. As such, a full-scope simulation is required to test and evaluate the digital replacement within the context of the surrounding control room.

Dedicated research simulators, like the HSSL, circumvent issues associated with the inability to modify plant simulators to test designs. The HSSL is also sufficiently flexible that designs and modifications can be rapidly mocked-up and tested within a virtual representation of a nuclear control room. Dedicated research simulators also alleviate the availability issue with plant simulators due to their extensive use for training; however, there are only a handful of research simulators across the world and their use still poses a significant financial and time investment. There are many instances in which a full-scope research simulator is the most appropriate tool to generate performance data needed for iterative design, but there are also instances in which another simplified approach is more appropriate.

When performing simulations, the amount of the real world elements included in the simulation must be addressed based upon the intended goals of the simulation. For example, simulators used by nuclear utilities are intended for training purposes and therefore require a high level of fidelity to provide learner engagement, suspension of disbelief, and transferable skill acquisition from operator training to the actual real world operation of the plant [7]. In research, the goal of a simulator is fundamentally different because the aim is to acquire human-computer interaction data to better understand how an operator performs the nuclear process control task and translate that understanding into effective interface designs that improve performance. As such, a high level of fidelity is not necessarily required to capture the underlying human-computer interactions needed for the design and testing of new digital interfaces.

3 Microworld Simulations

A microworld is a simplified part-task simulation of a real-world process. The educational value of microworld simulations has been established in a large volume of empirical work [8, 9]. The value of a microworld simulation in the context of complex interface design research is much less established, though a number of studies exist [10–13]. In terms of nuclear process control interface design, microworld simulation offers a complimentary approach to full-scope simulation. Microworld simulation offers a number of advantages particularly during the early design phase. The reduction in scope embodied by the microworld simulation adds experimental control to the evaluations of the interface design [14]. The interface can be evaluated alone without any potential confounds of the control room associated with full-scope research simulations. Specific interface design elements can also be examined in isolation. A detailed evaluation of specific interface elements, such as a new widget, can aid the design process by focusing the human-computer interaction evaluation on that interface element. Each new interface element can undergo this type of testing to determine its effectiveness before undergoing evaluation within the context of the overall new interface. From these detailed control level examinations, first principles for advanced visualization designs can be explored and evaluated under strict experimental control.

The microworld simulation's reduction in scope also expands the applicant pool of participants beyond experienced nuclear operators and condenses the scenario simulation timespans [14]. Individuals without extensive process control training and experience can serve as participants because the reduced scope of the simulation reduces the complexity of the simulated process control task. Inexpensive student participants or plant personnel in training can be quickly trained on the operation of the microworld *and* perform numerous scenario simulations, all within a relatively short timeframe, such as a single experimental session. With a larger participant pool and shorter time required to conduct the simulation scenarios, the central questions surrounding the human computer interaction can receive more focus. During any simulation there are periods of uninformative dead time between events containing useful diagnostic data. Simplified simulations that focus on upset conditions can eliminate some of this dead time, and the scenario simulation can focus on the key human-computer interactions for a particular task. For example, a subset of the system containing the interface element of interest can comprise the entire microworld scenario simulation and focus on that particular interface element to evaluate human-computer interaction dynamics.

Microworld simulations are particularly well suited for addressing research questions for novel designs. Unlike the digital interface replacements comprised of the same or similar functionality found within the original analog system, advanced digital interfaces contain novel design schemes that are outside the current concept of operations found at existing nuclear power plants. Since there is little similarity between the existing analog control room operations and operations proposed in the new advanced digital interface, there is less need to include peripheral components for design and testing. The advanced digital interfaces are also self-contained in the sense that all necessary information from the various sensors throughout the plant and the necessary controls to manipulate all aspects of plant components are present within the interface. There is little need to simulate surrounding analog indicators and controls because they are obsolete and redundant to those found within the advanced digital interface.

The manner in which information is presented in advanced digital interfaces follows a multi-window view scheme in which subsystems of related component information and associated controls are presented at a given time. The operator and the automation within the interface drive which system is presented based on the current plant status and operator task. As a result, the interface can be displayed in a much smaller space on as little as a single visual display unit. For evaluation purposes the relevant windows can be included in the microworld simulation in order to examine how particular visual elements convey information or support operator actions. Including only relevant portions of the system not only isolates the components, but as mentioned previously, it restricts the scope of the simulation to enable novice participants to perform short operator tasks without being overwhelmed by complexity. Since the perceptual capabilities of operators are comparable to that of students, novice participants can provide valid usability data given a sufficiently low-complexity task simulated in the microworld. Additionally, the novice participants are unbiased by prior operating experience and may reveal advantageous novel human-computer interactions that experienced operators may not exhibit. Enhancing aspects of the advanced digital interface to support or strengthen these novel interactions could improve operator performance.

Though microworlds provide a number of advantages, there are some limitations since they are simplified simulations and the novice participants are not nuclear operators. Aspects of the interface that work well in a microworld context may not scale to larger contexts found within a full-scope simulation or actual control room. Some aspects of the interface might prove advantageous with novice users, but those advantages may not translate to advantages for experienced nuclear operators. As a result, it is important to also use a full-scope simulation to ensure that the results and conclusions from the microworld scale to the full-scope simulation context with nuclear operators.

4 Continued COSS Development

In our approach the available pool of student operators for the microworld is extensive, allowing more statistically conclusive design studies to refine COSS. Our COSS microworld simulator with student operators is called *COSSplay*. COSSplay is a word play on cosplay, a term used to describe dressing up like famous characters. COSSplay in this sense is the microworld dressed up to perform key functions of the actual COSS. COSSplay allows testing of specific interface elements such as alarm visualizations without the confounds of the surrounding control room elements [15]. COSSplay therefore is ideal for first principles research in human factors and human-computer interaction. The limitation of this approach is that experimental tasks requiring the skill of professional reactor operators are not possible in COSSplay. Such tasks can, however, be performed by actual operators on the COSS implemented in the full-scope simulator. COSSplay complements COSS and serves as a useful testbed for research.

5 Conclusion

Full-scope and microworld simulations offer complementary approaches to design and evaluate interfaces for nuclear process control. Microworld simulations should be used for novel designs and during early design phases to leverage the expanded participant pool and small cost of operating a microworld simulation. The interface should then undergo testing in the full-scope simulator to ensure any lingering usability issues or context sensitive issues are addressed prior to installation of the new interface in the plant control room.

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