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Identification of Collectible Items in the Rancor Microworld Simulator Compared to Full-Scope Studies

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Abstract. Most studies on collecting reliability data in human reliability analysis (HRA) have concentrated on research using full-scope simulators and actual operators. However, researchers have discovered challenges in collecting various items and amount of data needed to support HRA. As an opposite and complementing approach to a full-scope study, Idaho National Laboratory (INL) developed Rancor Microworld, a simplified simulator, to generate HRA data from student subjects. This paper aims to identify collectible items in Rancor Microworld versus those in full-scope simulators. In this paper, collectible items and their varying analysis levels in Rancor Microworld are identified in comparison with full-scope simulators. The appropriate method for treating the items is suggested through experiment directions for the future.

Keywords: Human reliability analysis · Data collection · Simulator study · Simplified simulator · Microworld

1 Introduction

Most studies on collecting reliability data in human reliability analysis (HRA) have concentrated on research using full-scope simulators and actual licensed operators [1-4]. This is primarily because these simulators largely replicate conditions in actual reactors. The biggest, most recent efforts in this regard are led by the U.S. Nuclear Regulatory Commission and the Korea Atomic Energy Research Institute (KAERI), which collect data from full-scope simulators using the Scenario Authoring, Characterization, and Debriefing

Application (SACADA) database [3] and the Human Reliability data Extraction (HuREX) [2] framework, respectively.

However, researchers discovered challenges in collecting various items and gathering a large enough sample to support HRA. In general, testing differences generated by design factors in the human-system interface can cause difficulties for the full-scope simulator, since changing a design already configured and programmed into the simulator is no easy task. Furthermore, projecting a full-scope study is relatively resource-intensive and time-consuming, and presupposes utilities' cooperation in partially releasing collected data. Therefore, it is strictly limited to those few organizations that can satisfy such conditions.

As a complementary approach to a full-scope study, Idaho National Laboratory (INL) developed Rancor Microworld, a simplified simulator, to generate HRA data from student subjects. The simulator was developed to reproduce the important characteristics of real nuclear operations and evaluate theoretical and practical design concepts [5]. This paper aims to identify collectible items within Rancor Microworld versus those in full-scope simulators. In the paper, collectible items and their varying analysis levels within Rancor Microworld are identified in comparison with full-scope simulators. The approach for treating the items is then suggested, along with experiment directions for the future.

2 Characteristics of Different Analysis Levels in Rancor Microworld

Rancor Microworld is a simplified simulation environment that reproduces the important characteristics of real operations at nuclear power plants (NPPs) [5]. Fig. 1 shows the interface for Rancor Microworld. As opposed to a full-scope simulator, it is equipped with alarms, indicators, a piping and instrumentation diagram, and controllable components (i.e., pumps and valves) representing at least the minimum components required to implement the system.

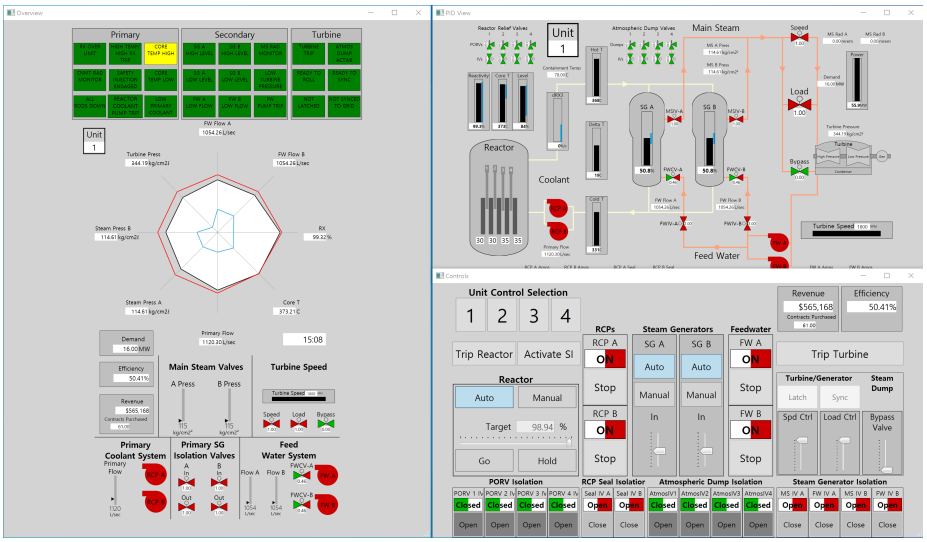

Fig. 1. Rancor Microworld interface.

This section compares the different analysis levels between Rancor Microworld and existing full-scope studies. The four levels considered in this comparison are 1) task level, 2) step level, 3) instruction level, and 4) execution level. The task level corresponds to a strategy such as "feed and bleed," an important long-term cooling strategy for maintaining core safety in emergency situations at NPPs. This level normally consists of several steps within NPP operational procedures. The step level is a procedure step level composed of several actions. Controlling reactor coolant temperature, such as by opening the atmospheric dump valve, is an example of a procedure step level. The instruction level matches the action level included in each procedure step. Lastly, the execution level, the simplest task unit, consists of actions such as looking at or reaching for an object.

Fig. 2 summarizes the various analysis levels in different simulators. Full-scope studies collect data in the task, step, and instruction levels. In the recent studies mentioned in the Introduction, the SACADA database [3] focuses on the task and step levels, whereas the HuREX framework [2] concentrates on the instruction level. The execution level is rarely considered in full-scope studies, since they already focus on so many items in the larger task units; therefore, information from items in small task units may be missed or ignored.

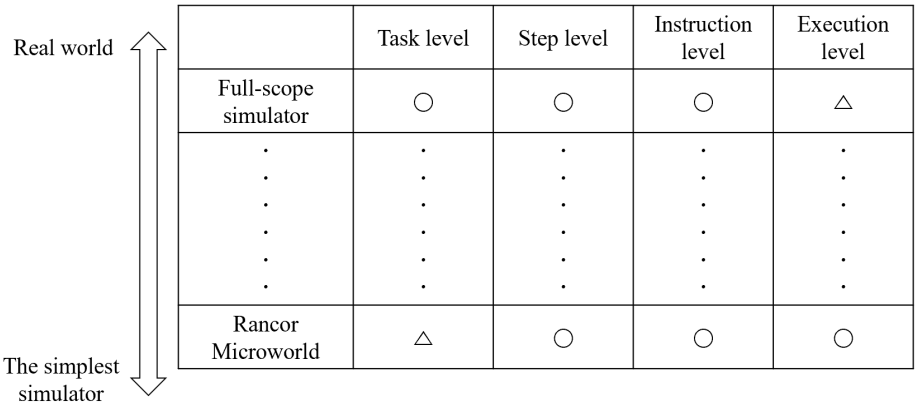

Fig. 2. Spectrum of different analysis levels in different simulators.

On the other hand, for reasons of fidelity (i.e., the degree to which a simulated environment corresponds to the real world), Rancor Microworld focuses on relatively low item levels (i.e., the step, instruction, and execution levels) compared to full-scope simulators. This makes Rancor Microworld advantageous in allowing research focused on the execution level, such as how operators use perception to gather information and make decisions of confounding complexity for full-scope studies.

3 Collectible Items in Rancor Versus Full-Scope Simulators

To investigate collectible items in Rancor Microworld, this study defines a relationship for collectible items between Rancor Microworld and full-scope simulators. The Venn diagram in Fig. 3 indicates this relationship and encompasses four sections: 1) Section A (items only collectible in full-scope simulators), 2) Section B (items collectible in both Rancor Microworld and full-scope simulators), 3) Section C (items only collectible in Rancor Microworld), and 4) Section D (items not collectible in either Rancor Microworld or full-scope simulators). The study described in this paper focuses on Sections B and C.

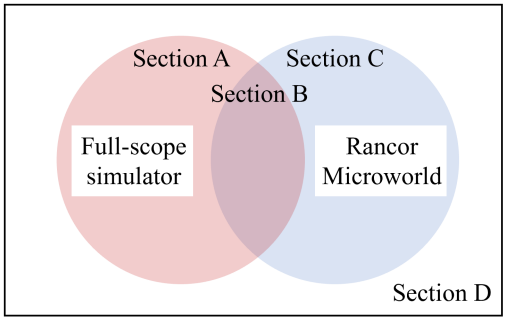

Fig. 3. A relationship of collectible items between Rancor Microworld and full-scope simulators.

A technical report from KAERI [6] suggests a catalog of generic HRA data items collected from documents issued from the perspective of HRA practitioners and human factors engineers. It includes a total of 89 generic HRA data items in seven different categories: 1) environment, 2) human-system interface, 3) organization, 4) procedure, 5) task, 6) evaluation/success criteria, 7) and performance context. The details are shown in [6], including measurable instances for each data item.

For this paper, the catalog of generic HRA data items was used to evaluate collectible items in the Rancor Microworld and full-scope simulators, then categorize the ones that correspond to Sections B or C. Table 1 gives example evaluation results for collectible items in full-scope simulators and Rancor Microworld. Certain data items—for example, "adverse environment associated with the accident sequence"—are collectible using Rancor Microworld, but not collectible using full-scope simulators. In fact, Rancor Microworld is portable and can be installed on a laptop; therefore, the data-collecting experiment can be performed wherever a desk, chair, and power source are available. For this reason, data can be collected in a facility equipped with a specific adverse environment, such as seismic experimentation equipment.

In Table 1, most HRA data items fall under the human-system interface category and are evaluated as collectible via Rancor Microworld. For full-scope simulators, it may not be easy to change a design already configured and programmed into the simulator. On the other hand, the Rancor Microworld design can be easily changed, making it favorable for evaluating aspects of human factors engineering, such as information coding and visual representation.

4 Direction for Designing Empirical Studies Using Rancor

INL posited several empirical studies using Rancor Microworld. The goal of this research is to 1) infer actual-operator data collected from a full-scope simulator by using Microworld data from student subjects and 2) collect additional data potentially missed in full-scope research. The following sections detail these goals.

Table 1. Example evaluation results for collectible items in a full-scope simulator and Rancor Microworld

Category	Subcategory	Data item	Evaluation		Classification
			Full-scope simulator	Rancor Microworld	
Environment	Workplace	Appropriateness of ingress and egress paths	Not collectible	Collectible	Section C
		Appropriateness of workspace envelope	Partially collectible	Partially collectible	Section B
	Work environment	Adverse environment associated with the accident sequence	Not collectible	Collectible	Section C
Human-system interface	Ergonomics	Existence of barriers	Not collectible	Partially collectible	Section C
		Existence of buffers	Partially collectible	Partially collectible	Section B
		Provision of memory aids	Partially collectible	Partially collectible	Section B
	Panel design	Conformity of standards, conventions, and nomenclature	Not collectible	Collectible	Section C
		Availability of indications	Partially collectible	Collectible	Section B

	Availability of controls	Partially collectible	Collectible	Section B
Status indication	Existence of wrong or inadequate information	Not collectible	Collectible	Section C
	Appropriateness of task feedback	Partially collectible	Collectible	Section C
	Provision of clear decision criteria	Partially collectible	Collectible	Section C

4.1 Treatment of Items Collectible in Both Rancor Microworld and Full-Scope Simulators

Items collectible in both Rancor Microworld and full-scope simulators align with the first of the aforementioned goals. Fig. 4 outlines a method for inferring actual-operator data collected from a full-scope simulator by using student data from Rancor Microworld. To achieve this, the differences between actual operators and students first need investigated. In the author's previous study [7], an investigation into the differences in human performance between actual operators and students using Rancor Microworld was initiated. Secondly, the differences that occur when operators use different simulators with varying levels of complexity need to be understood. Lastly, based on the results of the first and second steps, actual-operator data from full-scope simulators can be approximately inferred through the student data from Rancor Microworld.

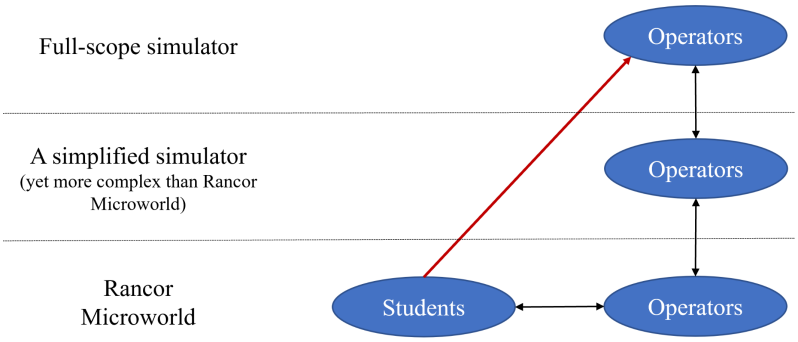

Fig. 4. Method for inferring actual-operator data from a full-scope simulator by using student data from Rancor Microworld.

4.2 Treatment of Items Only Collectible in Rancor Microworld

Items only collectible in Rancor Microworld would contribute to existing efforts to collect additional HRA data that are difficult to gather using a full-scope simulator. In HRA, the concept of a performance-shaping factor (i.e., any factor influencing human performance) has been used to highlight error contributors and adjust nominal human error probabilities [8]. Through empirical studies using Rancor Microworld and student subjects, it is possible to collect a variety of performance-shaping factor data not collected in the full-scope studies. Furthermore, when designing an interface, the results of this study could serve as a reference for selecting the best graphical design among various human factors engineering principles.

5 Conclusion

This paper suggests collectible items within Rancor Microworld compared to full-scope simulators. Collectible items and their levels in Rancor Microworld are identified in comparison with full-scope simulators. A method for treating the items is suggested with proposed experiment directions to be treated in the future. This study represents an ongoing effort to experimentally collect data using Rancor Microworld. Experiments introduced in this paper will be conducted at a future date. Results of experiments using Rancor Microworld are expected to foster a variety of HRA data items, with sufficient sample sizes to inform HRA.

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