Visualizing the characteristics of a work process being observed from the main control room of nuclear power plants – identifying underlying requirements

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1. Introduction

In the operation of large process control systems, such as nuclear power plants (NPPs), it is very important to emphasize that a human performance related problem (e.g., human error) is one of the determinants resulting in significant events. For example, Pasquale et al. pointed out that human error is attributable to 60-90% of the significant events that have occurred in diverse industrial sectors such as an automobile, heavy truck, maritime vessel, and road transportation [1]. In addition, Kim et al. argued that the influence of human error on the occurrence of the significant events in NPPs (i.e., unexpected reactor trips) is remarkable [2].

Accordingly, huge amount of effort has been spent to reduce the likelihood of human error. One of the disseminated approaches is to identify and manage vulnerable tasks (i.e., error-prone tasks) by applying many kinds of human reliability assessment (HRA) techniques. That is, if HRA practitioners are able to identify plausible error forcing factors (e.g., performance shaping factors; PSFs) under a given task context, effective countermeasures that are helpful for reducing the possibility of human error can be drawn by deducing how to eliminate the associated PSFs. Typical PSFs include: (1) Experience level, (2) Procedure quality, (3) Environment, (4) Ergonomics and HMI (Human Machine Interface), (5) Available time, (6) Task complexity, (7) Stress level, (8) Team dynamics, (9) Work process, and (10) Communication characteristics [3-5].

Unfortunately, there are times when HRA practitioners are not able to clarify the nature of a situation due to the ambiguity and/or subjectivity of a certain PSF. For example, Podofillini et al. pointed out that [6]: "Indeed, the application of current HRA methods is largely based on subjective evaluations (coming in at different stages of the analysis and to different extents, depending on the specific method and analyst knowledge/experience)." Subsequently, in order to reduce the variability of HRA results, the development of an objective criterion for determining the level of each PSF could be the most plausible countermeasure.

In order to address this issue, this paper applied a process mining technique to the analysis of communication logs gathered from main control room (MCR) crews in NPPs, which could be useful for visualizing their characteristics in terms of the Work process.

2. Observable instances with respect to the Work process

As mentioned in Section 1, one of the important PSFs to be carefully considered in conducting HRA is the Work process because the performance of MCR crews could be significantly degraded if they followed a wrong or inappropriate Work process. However, the definition of the Work process seems to be still equivocal. For example, Lois et al. and Hallbert et al. give the following working definitions on the Work process [3, 5].

- "Work processes refer to the way of working and the mechanics of work, such as the care taken in reading procedures, and, more generally, in performing individual work [3]."
- "Work processes refer to aspects of doing work, including inter-organizational, safety culture, work planning, communication, and management support and policies [5]."

The challenge is that, to some extent, these definitions seem to be so vague that it is not easy for HRA practitioners to properly state the quality of the Work process (e.g., *Good, Neutral,* and *Poor*) in a consistent way. Here, it is very interesting to point out that a couple of positive and negative instances with respect to the Work process [5]. Table I shows several instances.

Table I: Positive and negative instances

Dimension	Instance
Positive	Quick identification of key information
	Determining appropriate procedure to use in unique situation
	Complex system interactions identified and resolved
	Difficult or potentially confusing situation well understood
Negative	Self-check less than adequate (LTA)
	Procedural adherence LTA
	Recognition of adverse condition/questioning LTA
	Poor understanding of the situation/problem

For example, one of the positive instances shown in Table 2 is *Quick identification of key information*. This instance indicates that the quality of the Work process will move to a positive direction (i.e., *Good*), if MCR crews quickly identified key information in the course of conducting a required task. In contrast, the quality of the Work process will go to a negative direction (i.e., *Poor*), if they misunderstood a situation and/or problem at hand (i.e., the last negative instance in Table I). Therefore, it is possible to assume that the variability of HRA practitioners can be reduced by providing additional information that is helpful for elucidating the observable instances listed in Table I.

3. Information requirements

Before providing additional information, it is necessary to specify what kind of information is supportive for HRA practitioners. In other words, HRA practitioners may want to know how to elucidate whether or not the positive and/or negative instances are observable from an MCR crew which is exposed to a certain situation. In this regard, it would be helpful to compare working definitions on the Work process being adopted in diverse industrial sectors (refer to Table II).

Table II. Working definitions on the Work process

Working definition	Reference
"A work process is defined as the way in which organizations create products, services or policies. It is a succession of structured and interconnected activities across time and space which, starting from one or more identifiable inputs, result in one or a set of defined outputs in the form of products or services."	[7]
"A work process comprises a set of activities through which information and knowledge are transferred, converted and generated, many times tacitly, among group members."	[8]
"[…] a work process is a collection of interrelated actions in response to an event that achieves a specific result."	[9]
"Formally, a work process is defined as a standardized sequence of tasks designed within the operational environment of an organization to achieve a specific goal."	[10]

From Table II, it is possible to identify at least three kinds of underlying requirements. The first one is the ability to describe the flow of a work to be conducted by MCR crews. This is because, as can be seen from Table II, most of working definitions on the Work process emphasize the sequence of actions (or activities), which clarify how to achieve a specific goal or result.

The second requirement is that time and spatial information should be incorporated into the flow of a work because Vandenbroucke et al. pointed out that the Work process is the succession of structured and interconnected activities across time and space [7].

The last requirement is that the flow of symptoms and/or knowledge being incorporated in an MCR crew should be extracted. This requirement is crucial for characterizing the Work process, because MCR crew members need to collaborate with each other in the course of conducting the sequence of actions through high level cognitive activities, such as generating, transferring, converting, and sharing various kinds of observable symptoms including alarms and parameter indications.

4. Discussion and general conclusion

In this study, before providing additional information that is helpful for HRA practitioners in determining the quality of the Work process, three kinds of underlying requirements are identified. They are: (1) an ability to describe the flow of a work, (2) an ability to incorporate time and spatial information into the flow of a work, and (3) an ability to identify the flow of symptoms and/or knowledge being employed by an MCR crew.

In order to satisfy these requirements, a couple of techniques can be used. One of the promising techniques is to analyze communication logs collected from MCR crews by using a process mining technique because Kelly stated that: " […] it is potentially useful to examine the logs for each crew to determine how crews are similar and different in their response. This might allow partial pooling of log information according to how the information can be clustered [11]." In other words, the process mining technique is very useful for discovering the flow of a work being involved in a given situation, it is strongly expected that the analysis of communication logs that allow us to understand what and how they did in order to cope with a situation at hand. If so, it is possible to visualize necessary information that is essential for minimizing the variability of HRA practitioners who have to determine the quality of the Work process.

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