



A data mining framework within the Chinese NPPs operating experience feedback system for identifying intrinsic correlations among human factors



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ABSTRACT

With the continuous increase in the number of operating nuclear power plants (NPPs) in China, the amount of operating experience feedback (OEF) increases significantly. On the other hand, the safe operation of NPPs has become an urgent problem that the National Nuclear Safety Administration (NNSA) must solve. To this end, NNSA established a nationwide OEF system to improve the safety level of NPPs and strengthen the exchange of operating experience. Analyzing the human factors events (HFEs) is an important part of OEF and it is significant to improve human performance and prevent human error. Data mining has been recognized as an effective way to analyze data. With the continuous increase in operating event reports, data mining related to nuclear safety becomes a new domain of study. In this paper, we propose a data mining framework in support of the OEF system. The framework combines three statistical approaches (i.e., correlation analysis, cluster analysis and association rule mining) for identifying intrinsic correlations among human factors: correlation analysis measures the strength of linear relationship between human factors; cluster analysis classifies human factors into relevant groups; association rule mining identifies associations and causalities among human factors. For illustration, we apply the proposed framework to 162 human factors events (screened out from 313 events collected from the OEF system), and the results reflect the feasibility and effectiveness of the framework in identifying the intrinsic correlations among human factors. Besides, further suggestions for improving human performance and preventing human errors in NPPs are also discussed.

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1. Introduction

Up to January 31, 2018, there were 38 operating units of nuclear power plants (NPPs) and 20 units under construction in mainland China (World Nuclear Association, 2017). With the continuous increase in the number of operating NPPs, the amount of information from operating experience feedback (OEF) rises significantly. OEF is important for maintaining and improving safety in NPPs (Simic et al., 2015). How to ensure safety in the operation of NPPs has become an urgent problem that the National Nuclear Safety Administration (NNSA) must address. In this respect, one of the most important tasks of the Nuclear Safety Center (NSC) is to col-

lect, screen and analyze operating event reports from various domestic NPPs, providing regulatory suggestions to the NNSA.

The collection of information on operating experience (OE) is the responsibility of the NPP operator (Nuclear Energy Agency, 2011). Operating experience with respect to events, incidents and accidents are very important for nuclear safety (International Atomic Energy Agency, 2010). Lessons from operating experience can improve emergency procedures and operator training, and focus more attention on safety culture and human factors (Preischl and Hellmich, 2013). The practice of collecting and analyzing operating experience information has grown over the years, all over the world. Some international agencies and organizations have their own programme and systems of operating experience, such as the operating experience information exchange programme of the World Association of Nuclear Operators (WANO) (Revuelta, 2004), the experience feedback system and incident

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reporting system of the International Atomic Energy Agency (IAEA) (International Atomic Energy Agency, 2015), and the operating experience programme of the Organisation for Economic Co-operation and Development (OECD) (Nuclear Energy Agency, 2008).

NNSA has established a nationwide NPPs operating experience feedback system, to improve the safety level of NPPs and strengthen the exchange of operating experience. This system, organized and managed by NNSA, is a communication platform for national experience feedback between nuclear power plants and related organizations. The members in the system include NNSA, NPPs, NSC, Regional Nuclear Safety Supervision Station (RSS) and other Technical Support Organizations (TSOs). The role of each member is shown in Fig. 1. NNSA is mainly responsible for organizing event reactive inspection, informing generic event and applying significant OE into inspection activities. The department of event assessment of experience feedback in NSC, as TSO, performs technical analysis of significant events and generic event, then provide recommendation to NNSA. Besides, NSC will participate to reactive inspection when NNSA needs. RSS is in charge of local-site OE inspection based on order from NNSA and involvement of reactive inspection.

The experience feedback platform of NNSA, which is an important part of the operating experience feedback system, was online in November 2014. This platform is mainly used for the collection and release of operating experience feedback of NPPs, with the functions of information summary and query, correct action tracking, evaluation of safety status, and judgment of abnormal importance. The members of OEF system can analyze the events which are reported by the NPPs through the experience feedback platform. The platform enables all NPPs to learn from the operating experience of other plants. In particular, the platform informs and alerts NPPs on events that have occurred at other plants.

Analyzing human factors events (HFEs) is an important part of OEF, as it is significant to improving human performance, such as improving human error prevention activities and increasing system safety (Zheng et al., 2017). Data mining has been recognized as an effective way to analyze data in the last few years, and it can be used to reveal the hidden information behind the data (Han et al., 2011). With the continuous increase in operating event

reports, an important application area of data mining techniques is in nuclear power plants and related data (Toshniwal, 2013). For example, Park et al. (2017) applied a big data mining technique to extract the relative importance of performance shaping factors (PSFs) from NPPs event reports. Although there were some attempts to introduce data mining techniques to help human reliability analysis (HRA), none of them studied the intrinsic linkages and interactions among influencing factors, which exist in the human factors events. Considering the patterns in the data, they can be represented in many different forms, in this study, in support of OEF system, we propose a data mining framework combining with correlation analysis, cluster analysis, and association rule mining for identifying intrinsic correlations among human factors. Data mining are conducted for the 162 human factors events and the results reflect the feasibility and effectiveness of the framework in identifying the intrinsic correlations among human factors. On the other hand, this data mining framework can help to analyze human factors events, further it can provide a basis for the study of the relevance of PSFs in HRA and help to develop a systematic framework of human performance improvement.

The rest of this paper is structured as follow. In Section 2, we introduce the coding system of WANO and present the screening criteria of human factors event. In Section 3, we first analyze 313 operating event reports during 2008–2017, which were collected from the experience feedback platform, and the 162 HFEs that were screened out based on the screening criteria. Then, based on the proposed data mining framework, the software of statistical product and service solutions (SPSS) and SPSS Modeler are used to conduct the data mining, including correlation analysis, cluster analysis, and association rule mining. In Section 4, we summarize the results of Section 3 and compare these results with OE of WANO. We conclude with a discussion of the importance of intrinsic correlations among human factors for analyzing human factors events and propose some suggestions for improving human performance and preventing human errors.

2. Screening criteria of human factors events

Since the beginning of 1998, a codification system has been set up for all the event reports provided by the NPPs, and the WANO

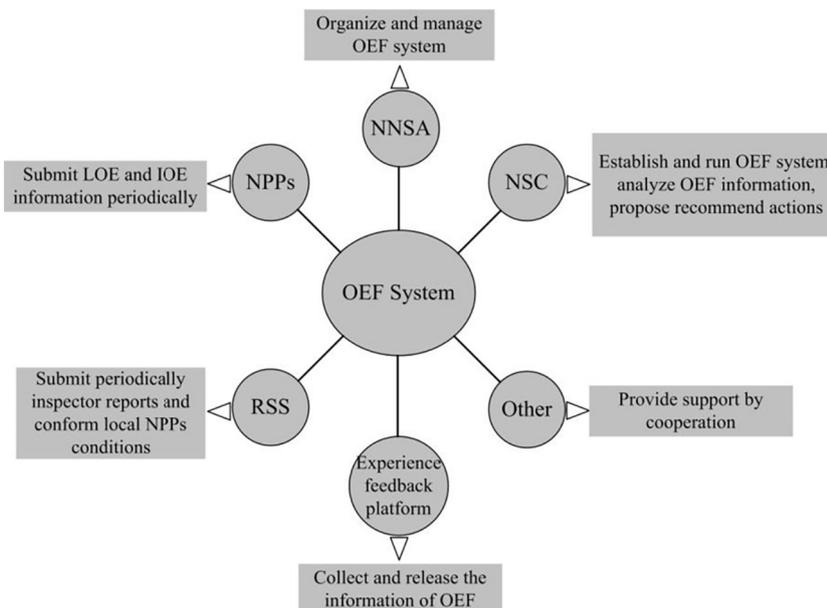


Fig. 1. OEF system.

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