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A Review of Quantitative Situation Assessment Models for Nuclear Power Plant Operators

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1. Introduction

Situation assessment is the process of developing situation awareness and situation awareness is defined as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future."[1] Situation awareness is an important element influencing human actions because human decision making is based on the result of situation assessment or situation awareness.

There are many models for situation awareness and those models can be categorized into qualitative or quantitative. As the effects of some input factors on situation awareness can be investigated through the quantitative models, the quantitative models are more useful for the design of operator interfaces, automation strategies, training program, and so on, than the qualitative models.

This study presents the review of two quantitative models of situation assessment (SA) for nuclear power plant operators.

2. Qualitative SA Models

Most accepted definition and qualitative model of situation awareness is developed by Endsley[1]. Endsley's model can be briefly depicted as shown in Fig 1.

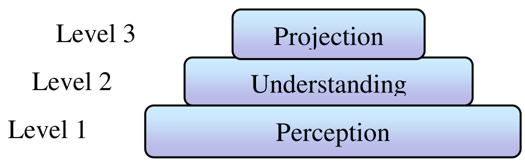

Fig. 1. Endsley Model of SA

Level 1 SA-Perception: it is the fundamental level of SA. In this level, human gets information from various information sources through system interfaces, direct channels, and team members.

Level 2 SA-Understanding: human processes the information obtained in the level 1 SA to comprehend the current situation. Acquired information is integrated and evaluated in aspect of goal.

Level 3 SA-Projection: It is the highest level of SA. Human forecasts future events and development of current situation in this level. It is known that experts have the ability to project from current situation and to anticipate future events.

According to Endsley model, SA is affected by task/system factors and individual factors. Task/system factors are system capability, interface design, stress and workload, complexity, automation and individual factors are goals and objectives, preconceptions (expectancy), ability, experience, training, long-term memory stores, automaticity, information processing mechanism. In addition, SA affects human decision making and action performance. Endsley said that it is possible to make good decisions even with poor SA, if only by luck [2].

Other qualitative and descriptive models of SA are proposed by Bendy and Meister [3], and Adams et. al [4].

3. Quantitative SA Models

2.1 Miao's Model

Miao and his colleagues proposed a computational SA model for NPP operators [5]. The model is based on SAMPLE (Situation Awareness Model for Pilot-in-the-Loop Evaluation) developed to evaluate subsystems and develop tactics in enhancing pilot SA.

Miao and his colleagues intended to apply his model to develop or evaluate operator decision aid systems. As a mechanism of situation assessment, the SA centered decision making process composed of five steps is assumed in the Miao model.

1) Monitor the environment.
2) Determine the need for situation assessment.
3) Propagate event cues
4) Project events
5) Assess Situation.

Miao model uses Bayesian Belief Networks (BBN) to represent operator mental models and inference. The model has complex node relationship. They assumed that

1) A situation is independent so several situation can be occurred at a time
2) Situations can be modeled in a hierarchical structure.
3) Situation-event links are probabilistic
4) Event-event links are also probabilistic

The SA model provides with a result of situation assessment of the true situation facing an operator. Miao and his colleagues proposed the *situation disparity (SD)*, given by the difference between the actual and the perceived situation beliefs as a SA metric. The SD is a time-dependant and its history gives an individual account of how each information cue contributes to overall SA.

2.2 MC Kim's Model

Kim and Seong [6] proposed an analytic and quantitative model of SA for NPP operators. The model postulates the situation assessment as followings;

1) Abnormal or accident situation occurs.
2) Operators recognize it by onset of alarms.
3) Operators read the relevant indicators.
4) Operators try to establish their situation models. At this point, operators usually also consider the possibility of sensor or indicator failures.
5) If operators receive other alarms, operators will read the relevant indicators. Even if operators do not receive other alarms, operators will probably decide to monitor other indicators to confirm their situation models.
6) Regardless of why they monitor other indicators, the observations they make will alter their situation models accordingly.

MC Kim model is also developed by using a BBN which is composed of three types of nodes: plant states (X), indicators (Y_i), and sensors (Z_i).

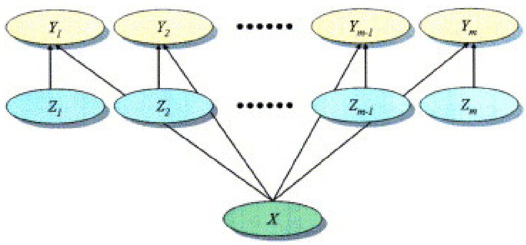

Fig. 2. BBN of MC Kim model

MC Kim model assumes that if operators observe the indicator Y_i, the probability of a state of the plant X can be revised by means of Bayes theory. MC Kim model has a simpler structure (no situation-situation links and no event-event links) than the Miao model. MC Kim model assumes that operators have deterministic knowledge and situation-event links have deterministic belief, 0 or 1.

2.3 Review Results

(1) BBN based modeling

Two models use BBNs to model operator mental models and diagnostic processes. Situations, events, and relations are coded into nodes and arcs, and conditional probability tables (CPTs). Graph representation in BBNs is very intuitive so easily understood and developed.

Two models assume that operators observe information sources and then update their situation awareness. This process can be most easily simulated in BBNs because BBNs automatically update higher level nodes whenever the state or value of a lower level node is changed.

(2) Human characteristics

As Endsley insists, SA is affected by many human cognitive characteristics such as attention, mental model, memory, bias, workload, and etc. However two models do not consider or explicitly implement human cognitive features. 100% perception, perfect knowledge, and no memory limit are assumed in two models.

3. Conclusions

Some researchers argue that human does not follow Bayesian inference process [6], however, the assumption that NPP operators follow a probabilistic inference mechanism seems to be practical and unavoidable as operators are likely to update their situation awareness when they observe critical alarms and indicators. Thus BBNs could be an efficient tool for developing a computational operator SA model because it provides a Bayesian inference process.

The SA model should have channels for user input such as design variables or operator characteristics in order to investigate the effects of variables and human cognitive characteristics on operator SA. However, two quantitative models do not provide various input channels. As the Miao model is mainly intended to evaluate decision aid systems, user input channels are not considered. MC Kim model uses the MSBNx BBN software [7] to encode operator mental models, however, the software does not provide a convenient user input function.

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