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Modeling of Communication in a Computational Situation Assessment Model

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1. Introduction

Operators in nuclear power plants have to acquire information from human system interfaces (HSIs) and the environment in order to create, update, and confirm their understanding of a plant state, or situation awareness, because failures of situation assessment may result in wrong decisions for process control and finally errors of commission in nuclear power plants. Quantitative or prescriptive models to predict operator's situation assessment in a situation, the results of situation assessment, provide many benefits such as HSI design solutions, human performance data, and human reliability.

Unfortunately, a few computational situation assessment models for NPP operators have been proposed and those insufficiently embed human cognitive characteristics [1]. Thus we proposed a new computational situation assessment model of nuclear power plant operators. The proposed model incorporating significant cognitive factors uses a Bayesian belief network (BBN) as model architecture [2].

It is believed that communication between nuclear power plant operators affects operators' situation assessment and its result, situation awareness. We tried to verify that the proposed model represent the effects of communication on situation assessment. As the result, the proposed model succeeded in representing the operators' behavior and this paper shows the details.

2. New Computational SA Model and Communication

There are a few computational models that can be used to predict and quantify the situation awareness of operators have been suggested: MC Kim's model [3], Miao's Model [4], A-SA model [5]. However, these models do not sufficiently consider human characteristics for nuclear power plant operators. The proposed model incorporates human factors significantly affecting operators' situation assessment, such as attention, working memory decay, and mental model.

Contributions of the proposed model are as follows:

(1) The proposed model considers more human characteristics

While the existing models do not consider attention and working memory decay, the proposed model takes into account factors affecting situation assessment, such as attention, mental models, and working memory decay.

(2) The proposed model provides a more flexible modeling capability for mental models

We think that according to the level of training or expertise operators' rules should be upgrade from probabilistic to deterministic one. Mental models of operators in the proposed model can be defined as any form of deterministic (experts) or probabilistic (less skilled operators).

(3)The proposed model can be used to predict errors of commission

For a given operational environment, the proposed model confirms whether operators can reach a correct diagnosis. The information on a diagnosis is important in human reliability analysis because the failure in situation awareness implies high possibilities for commission errors.

(4) The proposed model can be used to design and evaluate HSIs

The proposed model generates all possible diagnostic paths for given HSIs and HSIs design alternatives. These diagnostic paths can be used to evaluate HSIs and recommend a HSIs design alternative.

2.1 The proposed Model

As BBN is used as the basic modeling structure, the inference mechanism of the proposed model is the Bayesian process: propagation and projection.

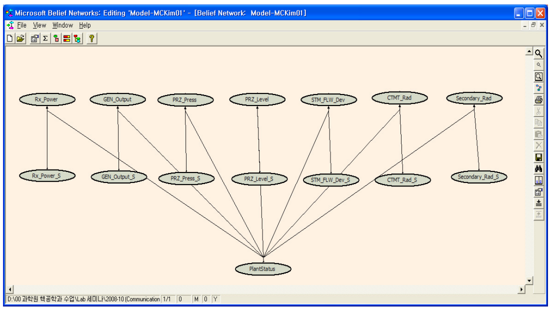
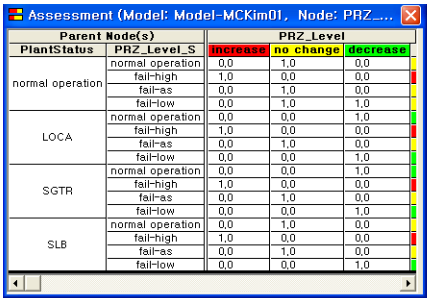


Fig. 1. BBN of the proposed model (Seven indicators and sensors are used to establish situation awareness in this model. MSBNx is used to construct and manage BBN)

Mental model of the proposed model is encoded in conditional probability tables (CPTs) in the BBN. Fig. 2 shows an example of the CPT for well trained and experienced operators have.



Parent Node(s)		PRZ_Level		
PlantStatus	PRZ_Level_S	increase	no change	decrease
normal operation	normal operation	0,0	1,0	0,0
	fail-high	1,0	0,0	0,0
	fail-as	0,0	1,0	0,0
	fail-low	0,0	1,0	1,0
LOCA	normal operation	0,0	0,0	1,0
	fail-high	1,0	0,0	0,0
	fail-as	0,0	1,0	0,0
	fail-low	0,0	0,0	1,0
SGTR	normal operation	0,0	0,0	1,0
	fail-high	1,0	0,0	0,0
	fail-as	0,0	1,0	0,0
	fail-low	0,0	0,0	1,0
SLB	normal operation	0,0	1,0	0,0
	fail-high	1,0	0,0	0,0
	fail-as	0,0	1,0	0,0
	fail-low	0,0	0,0	1,0

Fig. 2. A CPT for experts in the proposed model (Indicator's behavior for plant status is deterministic)

Indicators that operators attend are determined by the salience of the indicators and value (worth) of the information that gained by attending the indicators.

2.2 Communication between Operators

It is assumed in the proposed model that

1. (1) Local operators perfectly diagnose the sensor failure and report
2. (2) Local operators always report the sensor failure information to MCR operators
3. (3) MCR operators are well aware of information from local operators

Thus a local operator and an MCR operator communicate and the MCR operator is responsible for achieving situation awareness in the situation.

We tried to model the effect of communication and mental model (or expertise) on situation assessment by means of the proposed model and verify the situation awareness produced by the proposed model.

2.3 Verification of Communication Modeling

The scenario used in the model verification is a SGTR accident with a CTMT radiation sensor failure (Fail-high).

Table I shows the results of situation assessment produced by the proposed model. Experts succeeds in finding the true accident and the sensor failure without communication (refer to (a) of Table I). Less-skilled operators also find the correct accident, however the confidence level is low (refer to (b) of Table I) and they fail to identify the sensor failure. In case that a local operator communicates correct sensor information to MCR operators, they do diagnose the accident correctly and with higher confidence (0.75->0.90) .

3. Conclusions

It is believed that additional correct information from other sources can improve the diagnosis performance of operators who have an incomplete mental model

In this model, it is postulated that, through communication, information on the sensor failure is transferred to MCR operators.

The results from the proposed model show that, when correct and valuable information is given to operators, they diagnose correctly with higher level of belief.

Through this result, we can conclude that communication among operators can be incorporated in the proposed model and the proposed model produces reasonable results of situation assessment for nuclear power plant operators,

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Table I: the results of situation assessment for each combination of communication and mental model

(a) No communication and complete mental model

No.	**Observation**	**X**	**Normal**	**LOCA**	**SGTR**	**SLB**
0	Initial		0.9997	0.0001	0.0001	0.0001
1	CTMT Rad Inc		0.5001	0.4998	0.0001	0.0001
2	PZR Level Dec		0.0001	0.9998	0.0001	0
3	2nd Rad Inc		0	0.5	0.5	0
4	STM/FW dev. Inc		0	0.0001	0.9999	0

(b) No communication and incomplete mental model

Normal	**LOCA**	**SGTR**	**Normal**	**LOCA**	**SGTR**	**SLB**
0	Initial		0.9997	0.0001	0.0001	0.0001
1	CTMT Rad Inc		0.5001	0.2999	0.1	0.1
2	Rx Power Dec		0.0002	0.7497	0.25	0
3	2nd Rad Inc		0	0.5	0.5	0
4	STM/FW Dev Inc		0	0.25	0.7499	0

(c) Communication after observation of Rx power indicator and incomplete mental model

No.	**Observation**	**X**	**Normal**	**LOCA**	**SGTR**	**SLB**
0	Initial		0.9997	0.0001	0.0001	0.0001
1	CTMT Rad Inc		0.5001	0.2999	0.1	0.1
2	Rx Power Dec		0.0002	0.7497	0.25	0
3	Communication		0	0.4547	0.2726	0.2726
4	2nd Rad Inc		0.0002	0.25	0.7497	0
5	STM/FW Dev Inc		0	0.1001	0.8999	0

(d) Communication after observation of 2nd radiation indicator and incomplete mental

No.	**Observation**	**X**	**Normal**	**LOCA**	**SGTR**	**SLB**
0	Initial		0.9997	0.0001	0.0001	0.0001
1	CTMT Rad Inc		0.5001	0.2999	0.1	0.1
2	Rx Power Dec		0.0002	0.7497	0.25	0
3	2nd Rad Inc		0	0.5	0.5	0
4	Communication		0	0.25	0.7497	0
5	STM/FW Dev Inc		0	0.1001	0.8999	0