Proceedings of the Korean Nuclear Society Spring Meeting
Kwangju, Korea, May 2002

A Quantitative Approach to Modeling the Information Processing of NPP Operators under Input Information Overload

Jong Hyun Kim and Poong Hyun Seong
Korea Advanced Institute of Science and Technology
Department of Nuclear Engineering
373-1 Kusong-dong, Yusong-gu
Taejon, Korea 305-701
jh2@cais.kaist.ac.kr, phseong@mail.kaist.ac.kr

Abstract

This paper proposes a quantitative approach to modeling the information processing of NPP operators. The aim of this work is to derive the amount of the information processed during a certain control task under input information overlaod. We primarily develop the information processing model having multiple stages, which contains information flow. Then the uncertainty of the information is quantified using the Conant's model, a kind of information theory. We also investigate the applicability of this approach to quantifying the information reduction of operators under the input information overload.

I. Introduction

This paper proposes a quantitative approach to modeling the information processing for NPP operators under input information overload (IIO). The focus in the early part of the present paper will be on i) developing a model for information processing of NPP operators, and ii) quantifying the model. To resolve the problems of the previous approaches based on information theory, i.e. the problems of single channel approaches, we primarily develop an information processing model having multiple stages, which contains information flows. The uncertainty of the information is then quantified using Conant's model, a kind of information theory. This paper attempts to combine the qualitative information processing model with a quantitative approach. Then, the applicability of the proposed model to analyzing operators' information processing under input information overload is investigated.

II. Quantification of the Information Processing Model for NPP Operators

II.1 Development of the Information Processing Model for NPP operators in MCR

After reviewing qualitative models for human cognitive behavior and observing/interviewing the trainees in the Retraining Center for Gori 3&4 units in Korea, we developed an information processing model for NPP operators. In this work, the information processing model for NPP operators is developed as a channel which consists of multiple processing stages. In addition, according to the knowledge they are containing, the eight categories of the transformed information are defined. The definitions are shown in Table 1.

Figure 1 shows the overview of the information processing model for NPP operators. In the proposed model, an operator is represented as an information processing channel which consists of multiple stages, as mentioned above. The information processing stages are depicted by the
rectangle boxes in the figure. The circles depict the input and the output information of the stages. The arrows represent the flows of the stages and the information.

II.2 Quantification of the Information Processing Model

Conant considered a system S as an ordered set of variables $S = \{X_1, X_2, \cdots, X_n\}$ [1],[2]. Those variables in S that can be directly observed from its environment constitute output variables. The set of these output variables is denoted $S_o = \{X_1, X_2, \cdots, X_k\}$, with $1 \le k \le n$. the remaining variables within S are internal variables, denoted as S_{int}. Hence, $S = \{S_{int}, S_o\}$. Let E denote all relevant variables outside S. Next he obtained an expression for the total information rate F (in bits/s) as a measure of the total processing activity within S

$$F = F_t + F_b + F_c + F_n \qquad (1)$$

The different constitutes of F can be defined as follows:

$F_t = T(E : S_O)$	Relatedness (transmission) between the environment and the output
$F_b = T_{S_O}(E : S_{int})$	Transmission between the environment and the internal variables when the output is known
$F_c = T(X_1 : X_2 : \cdots : X_n)$	Transmission between the variables of S
$F_n = H_E(S)$	Information in S when E is known

(2)

The term F_t is the thruput rate and is a measure of the relatedness between input and output. The thruput rate represents the amount of the output information that is matched with input information in each process and then transferred to the next stage.

The second term is the blockage rate and represents the effort needed by S in order to block nonrelevant information. The blockage rate represents the amount of the information that is not transferred to the next process. This means that the irrelevant information is received from the previous stage and the information is blocked in this stage. The blockage rate is related to the fact that an MMI provides the operator with the unnecessary information in cognitive process.

The coordination rate F_c represents a measure of the total coordination between all the variables in *S*. The coordination rate represents the amount of information processing needed to obtain a coordinated action among the system variables (i.e., subsystems) of *S*.

The noise rate represents the amount of internally-generated information in the process. As mentioned above, the noise rate is the rate of "free will," since it corresponds to behavior which has no apparent cause. Considering operators don't create any information independent of the input during the operation, we can assume that the noise rate is zero

Therefore, we can redefine the information flow in each process as follows.

$$F = F_t + F_b + F_c \qquad (3)$$

The total information flow for a system is expressed as

$$F = \sum_{i=1}^{N} F^i . \qquad (4)$$

The total information flow is represented by the sum of the total rate for subsystems.

III. Application: Quantifying the Information Reduction under Input Information Overload

In complex automatic systems such as a NPP, mismatch of information between the operators' demand and systems' supply can occur. Too much or too little information may reduce the quality of information. A straightforward distinction can therefore be made between situations where information is in abundance and situations where it is lacking. Experience from system failure analysis and study of human recognition indicates that at least the following three categories must be considered: incomplete information, insufficient information, and input information overload (IIO) [3]. Incomplete information means that the information is missing or ill-defined. In the case of insufficient information, additional information potentially exists, but a separate and specific effort is required to bring it out. Input information overload is the situation where operators are provided with too much information and don't have enough time to process the input information. More information is usually provided to operators in the MCR of NPPs than they need, since it is thought that missing information is more dangerous than information overload.

Due to limits of capacity in an operator's information processing, limit of attention, and time pressure under a situation of input information overload, operators may (1) fail to respond to (i.e., omit) some inputs, (2) respond less accurately, (3) give occasional incorrect responses, (4) store the inputs and respond to them as time permits, (5) systematically ignore (i.e., filter) some features of the input, (6) recode the inputs in a more compact or effective form, or in an extreme case, (7) quit [4]. Hollnagel has also identified operators' coping strategies for information input overload [5].

The responding characteristics can be summarized into three categories: 1) reducing the amount of the information, 2) controlling the response time, and 3) giving up the control process. Among the three ways, the first seems to be a more practical way than the others, if it is carried out accurately. The second and the third may cause loss of control of the plant.

Information reduction mainly occurs in the early stages of the proposed model, including information acquisition, identification, and diagnosis. Figure 2 shows quantification of information reduction of an example under IIO. The information reduction of the operators starts at locating their attention. Operators do visual sampling by using their mental model, which may be thought of as a set of expectancies of how frequently and when events will occur on each channel and of correlation between events on pairs of channels [6]. Then the information reduction in the operator is carried out. We categorize the information reduction in the operators' information processing into the reduction of irrelevant information and the reduction of relevant information.

The reduction of irrelevant information means that operators block information that is considered unnecessary for responding to the situation. The reduction of irrelevant information can also be divided into shallow and deep recognition. In shallow recognition operators block and ignore the information in the stage of information processing just after they read (or hear) it. Deep recognition represents blocking the information after processing it to the stages of identification or diagnosis. As shown in the figure, the amounts of blocked information by shallow and deep recognition are 1 bit and 2 bits, respectively. The values in the parentheses show the total amount of processed information related to the blocked information. These mean how much unnecessary information processing the operator has done until the information is blocked.

The reduction of relevant information is the desirable information processing, which is a reduction of the amount of information occurring due to information integration. Through this processing, the inputs are mapped to higher abstract information in situation awareness. The amount of information reduced in this way is 2.73 bits in the example.

IV. Conclusions

We have quantified the amount of information in information processing, using information theory. To model the complicated information processing of NPP operators, a human operator was defined as an information processing channel having multiple stages. By defining the transformation of the information in stages, we can quantify the proposed model. The total information flow *F* quantified is the amount of the information processed in the operator. Each term (thruput, blockage, and coordination) can be also considered as the workload that is made to do the respective works. We also investigated the applicability of the proposed approach to an analytic and quantitative analysis of operators' information reduction under input information overload.

This proposed approach focuses on how much information the operator processes rather than on how much information is provided to an operator, even though the former can be affected by the latter. Therefore it is expected that this approach can be used as a quantitative measure for human centered evaluations in the development of MMIs. It was known that response time for transmission tasks is proportional to the amount of transmitted information. As a future work, we also have a need to experimentally find out the relation of the information flow to the response time and performance of operators.

References

[1] R. C. Conant, “ Laws of information which governs systems,” IEEE transactions on System, Man, and Cybernetics, vol. 6, NO.4, 240-255, 1976

[2] C. J. Koomen, “ The entropy of design: a study on the meaning of creativity,” IEEE transactions on System, Man, and Cybernetics, vol. 15, NO.1, 16-30, 1985

[3] E. Hollnagel, “Information and reasoning in intelligent decision support systems,” Cognitive Engineering in Complex Dynamic Worlds, Ed. E. Hollnagel, G. Mancini, and D. Wood, Academic Express, 1988

[4] J. Rasmussen, “Diagnostic reasoning in action,” IEEE transactions on System, Man, and Cybernetics, vol. 23, NO.4, 981-992, 1993

[5] E. Hollnagel, et al., “Coping with complexity-strategies for information input overload,” Proceedings of CSEPC 2000, 264-268, 2000, Taejon, Korea

[6] C. D. Wickens, “Engineering psychology and human performance,” Harper Lollins Publishers, 1992

Information	Definition
Signal	The information that exits in the environments or is provided by the environments
Sign	A certain feature in the environment and the connected condition
Alert	A warning information notifying the occurrence of some changes in NPP
Symptom	A perceived state of the plant
Cause	The information about the location of the anomalies and the root of the cause
Goal	An ultimate objective of actions which are carried out in response of the anomalies
Procedure	The steps to follow for problem solving
Scheduled Action	A series of actions chosen and scheduled according to the procedure

Table 1. The definitions of the transformed information

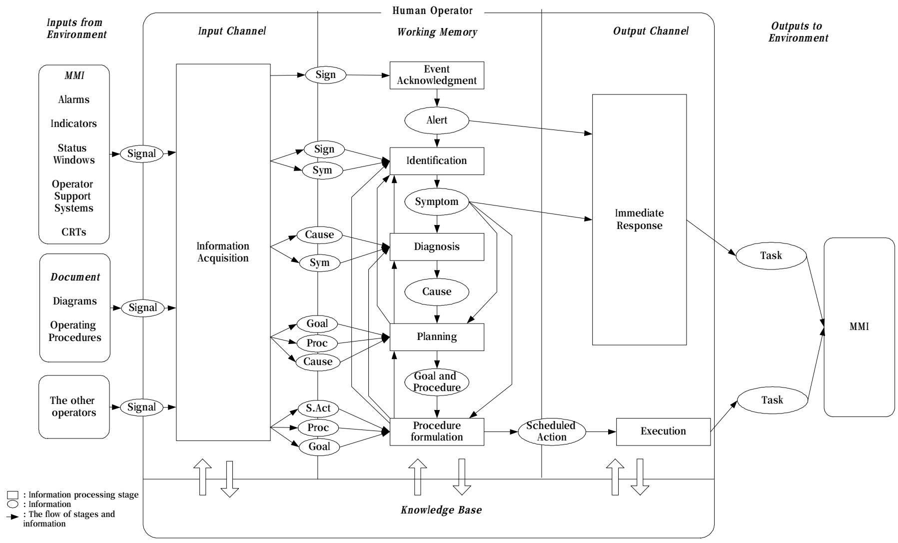

Figure 1. The overview of the suggested model for the information process in NPP operators

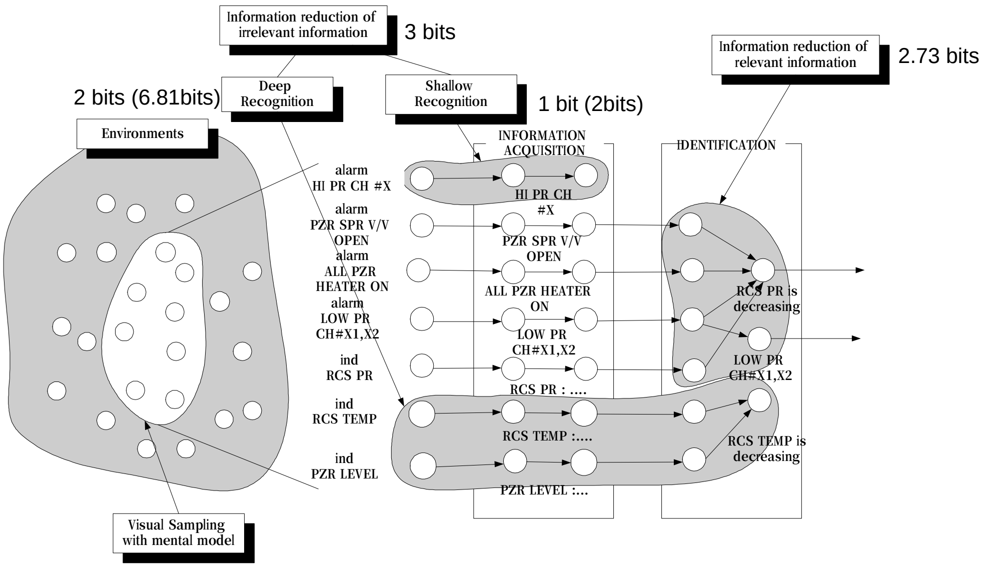

Figure 2. Quantifying the information reduction under the IIO