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A study on the development of a novel task complexity measure: TACOM

Jinkyun Park and Wondea Jung,

Integrated Safety Assessment Division, Korea Atomic Energy Research Institute,
P.O.Box 105, Duckjin-Dong, Yusong-Ku, Taejon, 305-353, Republic of Korea.

1. Introduction

It is well perceived that human performance related problems would occur due to complicated procedures [1, 2]. Unfortunately a serviceable framework that can be used to systematically evaluate the complexity of procedures is relatively scant. For this reason, in this study, a complexity measure called the TACOM (Task Complexity) measure is suggested to quantify the complexity of emergency tasks that are prescribed in emergency operating procedures (EOPs) of nuclear power plants (NPPs).

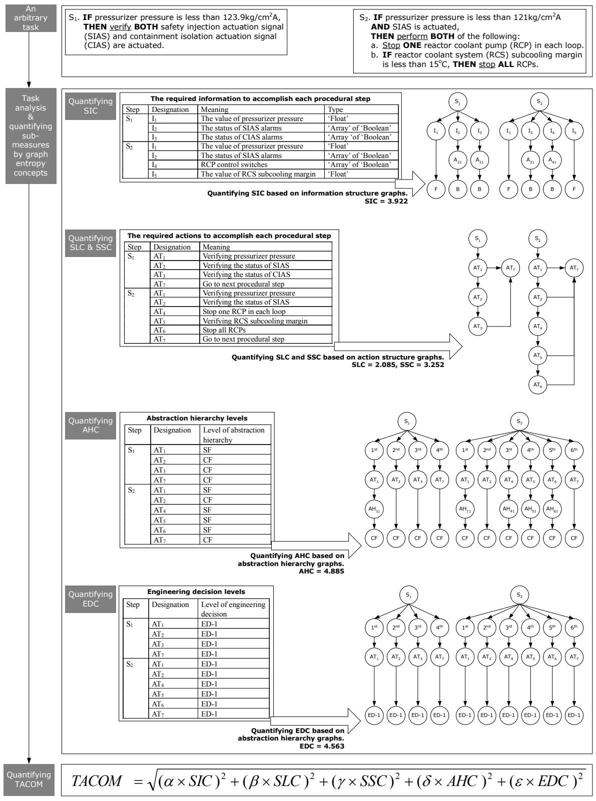
2. The development of the TACOM measure

The TACOM measure is composed of five sub-measures that cover five kinds of distinctive decisive factors making the performance of emergency tasks complicated. Table 1 summarizes the definition of the TACOM measure with all the five sub-measures.

< Table 1. TACOM with the associated sub-measures >

	Definition/Meaning
TACOM	$\left[\begin{aligned} &(\alpha \times SIC)^2 + (\beta \times SLC)^2 + (\gamma \times SSC)^2 \\ &+ (\delta \times AHC)^2 + (\varepsilon \times EDC)^2 \end{aligned} \right]^{\frac{1}{2}}$
SIC	Representing the complexity due to the amount of information to be processed by operators.
SLC	Representing the complexity due to the execution logic of the required actions to be sequenced by operators.
SSC	Representing the complexity due to the amount of the required actions to be performed by operators.
AHC	Representing the complexity due to the amount of system knowledge that is necessary to identify the problem space of the required actions.
EDC	Representing the complexity due to the amount of cognitive resources that is necessary to establish proper decision criteria of the required actions.
$\alpha, \beta, \gamma, \delta, \varepsilon$	Weighting factors for SIC, SLC, SSC, AHC and EDC.

Each sub-measure is quantified by graph entropy concepts that have been widely used to measure the complexity of software (i.e., source codes) [3]. Fig. 1 delineates three phases for quantifying the complexity of an emergency task that consists of two procedural steps (i.e., S_1 and S_2).



< Figure 1. The quantification scheme of TACOM >

3. Measure validation

The appropriateness of the TACOM measure is briefly verified by comparing the estimated TACOM scores with averaged task performance time data. The task performance times denote an elapsed time to accomplish the required tasks, and these data are extracted from OPERA database developed by KAERI [4].

The OPERA database contains many kinds of plant-specific and domain-specific operators' performance data obtained under simulated emergencies. To collect operators' performance data under simulated emergencies, a full scope simulator installed in the training center of the reference NPP was used. This simulator was designed based on a 1,000MWe pressurized water reactor (PWR), and it has conventional control interfaces, such as switches, indicators, and alarm tiles, etc. Using this simulator, for over a period of three years (from 1999 to 2001), more than 100 audio-visual records were gathered from the re-training sessions of emergency operations. Then both a time-line analysis and a verbal protocol analysis were carried out to extract useful information. As a result, various kinds of operators' performance data were successfully secured.

For this comparison, as epitomized in Table 2, performance time data for 38 tasks are extracted from the OPERA database.

< Table 2. Averaged task performance time data >

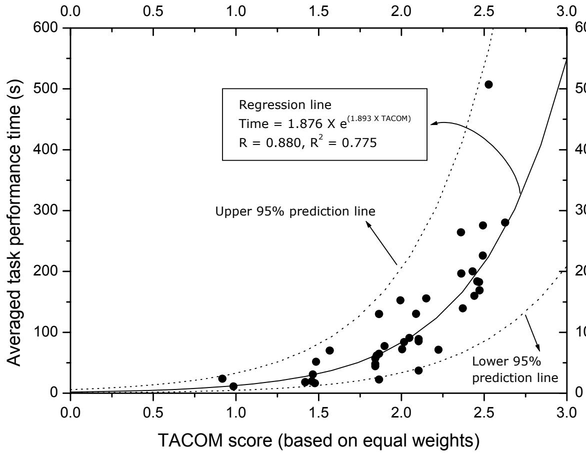
ID	TACOM[1]	Time[2]	ID	TACOM	Time
1	1.842	57.0	20	2.005	72.2
2	2.627	280.3	21	2.430	200.1
3	2.104	85.4	22	1.898	77.3
4	2.224	71.2	23	2.441	159.9
5	2.048	90.7	24	2.492	226.0
6	2.362	196.5	25	1.865	64.8
7	2.458	183.7	26	2.360	264.3
8	2.371	139.3	27	1.851	61.9
9	1.842	44.1	28	2.150	155.6
10	2.104	89.0	29	1.419	18.0
11	2.472	169.0	30	0.918	23.7
12	2.528	507.0	31	1.865	130
13	1.842	47.9	32	1.567	69.9
14	2.104	37.1	33	1.477	16.4
15	2.089	130.3	34	1.865	22.4
16	2.493	275.5	35	0.985	11.1
17	2.469	182.5	36	1.459	19.5
18	1.994	152.5	37	1.465	30.7
19	2.016	83.9	38	1.484	51.6

[1]All the weighting factors used in quantifying TACOM scores are equivalent.
[2]Averaged task performance time (s).

From these comparisons, it was observed that the TACOM measure seems to be meaningful for explaining the change of operators' performance because there is a significant statistical correlation between the averaged task performance time data and the estimated TACOM scores (see Fig. 2, $R^2 = 0.775$ with $p < 0.001$).

4. Conclusion

In this study, the TACOM measure that can systematically evaluate the complexity of emergency tasks is developed based on the five sub-measures. These sub-measures cover five kinds of distinctive factors that can affect the complexity of tasks, and each sub-measure is quantified by a graph entropy concept. In order to demonstrate the appropriateness of the TACOM measure, the estimated TACOM scores are compared with operators' performance time data obtained from the OPERA database.



< Figure 2. The result of comparisons between averaged task performance time data with the associated TACOM scores>

As a result, it was observed that the change of task performance time data is susceptible to the change of TACOM scores. Subsequently, although more detailed verification activities are decisive to assure the appropriateness of the TACOM measure, the following conclusion could be drawn without an irrationality – "The TACOM measure can be used to quantify the complexity of tasks stipulated in EOPs."

References

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