The Research of Implementing SC to Evaluate Complexity in Flight

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Abstract. In aviation, the Standard Operating procedures (SOPs) provides typically a list of action items that allowing the pilots to complete tasks in flight environment. Therefore, the complexity of SOPs should be appropriate to guarantee the flight safety. In this paper, step complexity (SC) from nuclear power plant is introduced to evaluate complexity in flight in nine tasks selected from SOPs. The verification measurement of SC is difference of heart rate (HR-D) of pilots. From experiment result, SC is correlative to HR-D. However, the correlation is not significant enough. Thus, to evaluate complexity in flight efficiently, the SC measure should be modified.

Keywords: SC, HR-D, complexity.

1 Introduction

Task is defined as activities or actions that need to be accomplished within a defined period of time or by a deadline. It is ubiquity in daily life. The performance of a certain task not only influences the context circumstances, but also closely relates to the safety of the whole system. Especially, the omission of procedural steps in task is a forms of human error with serious consequences in many complex work settings (Reason 2002, Hobbs and Williamson 2003). For instance, several fatal crashes resulted from inadvertently omitting of the crew to set the flaps prior to takeoff and the warning horn malfunctioned (Degani and Wiener 1993). Therefore, to accomplish a task ideally, certain procedures should be followed step by step. The Standard Operating Procedures (SOPs) are designed as a series of step operations for pilot to deal with normal or abnormal conditions of the aircraft. However, how to evaluate step operations in SOPs is still controversial.

Step Complexity (SC) was supposed to be implemented in nuclear industry (Park, Jung, and Ha 2001, Park and Jung 2007), and (Xu et al. 2009) studied the influence of SC and presentation style on step performance in aerospace field. In both industries, SC shows an acceptable capability of complexity. In our study, we implement SC in flight circumstances to evaluate complexity in SOPs.

In order to verify the effectiveness of SC in flight circumstances, workload measurement has been used. As with increasing of complexity, the workload of operator

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increases simultaneously. It has been suggested that increase HR could be related with an increased workload (Mulder 1989). Therefore, we select difference of HR as an indicator.

In this paper, firstly, the method of SC is briefly described in section 2. The implementation results of SC in flight conditions and verification HR-D are compared in section 3. In Section 4 discussion of the study is shown.

2 SC Measure

2.1 SC Overview

SC introduces entropy concept into complexity measure in nuclear power plants (NPPs). SC includes two type of complexities which are logic complexity and size complexity from two graphs that are action control graph (ACG) and information structure graph (ISG). Action control graph contains step logic complexity (SLC) and step size complexity (SSC), which represent logical sequence of the required actions and the amount of required actions respectively, and information structure graph includes step information complexity (SIC), which indicates the amount of information to be managed. Two kinds of order entropy were used to describe the complexity. The first-order entropy is used to evaluate the regularity of the program control logic, and the second-order entropy can evaluate the number of hierarchical levels of the graph (Davis and LeBlanc 1988). A simple example graph of two kinds of order entropy is shown as following in Fig. 1. Considering first-order entropy of the graph, Node 4, 5 and 3 have same In and Out numbers (1 In with 1 Out), and same as Node 6 and 8 (1 In without Out) as shown in Table 1. Therefore, the first-order entropy G_1 of the graph is calculated as:

$$G_1 = -\sum_{i=1}^{6} p(A_i)log_2 p(A_i) = 2.156$$

On the other hand, second-order entropy is calculated through considering neighbor nodes of each nodes. If the neighbors are same, then the nodes are organized as one class, the classes for second-order entropy is in Table 2. Thus the second-order entropy G_2 of the following graph is:

$$G_2 = -\sum_{i=1}^{6} p(A_i)log_2 p(A_i) = 2.750$$

According to different contents of complexities, SSC and SIC are obtained from second-order entropy, and SLC is from first-order entropy. In sum, SC is calculated by a weighted Euclidean norm as shown:

$$\mathrm{SC} = \sqrt{(\alpha * SIC)^2 + (\beta * SLC)^2 + (\gamma * SSC)^2} \quad (1)$$

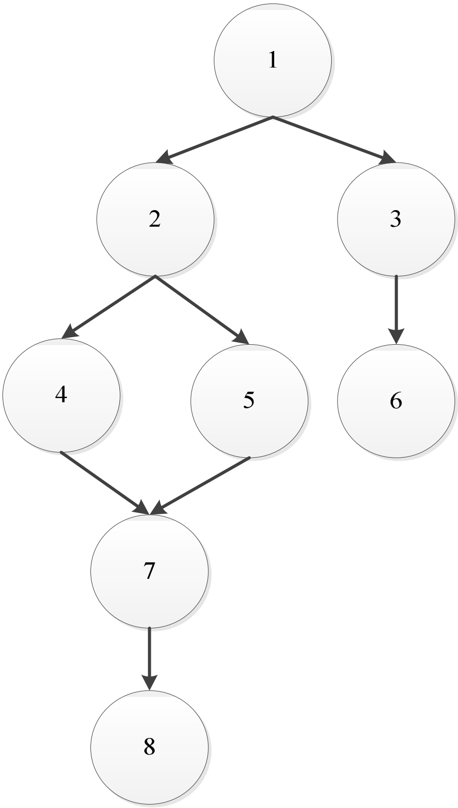

Fig. 1. An example graph for two kinds of order entropy

Table 1. Classes for first-order entropy

In	Out	Nodes	Class
0	1	1	1
1	2	2	2
1	1	4,5,3	3
2	1	7	4
1	0	6,8	5

Table 2. Classes for second-order entropy

Nodes	Neighbor Nodes	Class
1	2	1
2	1,4,5	2
3	1,6	3
4,5	2,7	4
6	3	5
7	4,5,8	6
8	7	7

2.2 Case Study

We selected final approaching phase from SOPs of Boeing 777 as an example. In final approach, in order to maintain descend as glide slope, pilot flying should establish approaching configuration of the aircraft above 1000 feet by controlling altitude, airspeed, heading and throttle. Meanwhile, he/she should confirm landing order from ATC. As operating procedures descriptions in SOPs, the first-order entropy equals to 2.807, and the second-order entropy is 2.522. In order to get SIC, more detailed analysis should be carried out on final approach. To settle correct configuration, the pilot should obtain information from prime flight display including altitude, airspeed and heading information. Moreover, he/she operates properly by manipulating control wheel, throttle and flight mode panel (FCP). At the same time, the pilot needs to communicate with ATC by setting frequency. Therefore, SIC is 3.322. From equation (1), SC equals to 2.903, where $\alpha = \beta = \gamma = 1/3$.

3 Validation Tests

3.1 SC Result

Nine tasks were chosen from SOPs including one engine failure, traffic collision avoidance system warning, the hydraulic system failure, etc. The results of SSC, SLC, SIC and SC of these nine tasks are shown in Table 3.

Table 3. The results of SSC, SLC, SIC and SC

Task	SSC	SLC	SIC	SC
Task 1	2.322	1.922	3.700	1.591
Task 2	2.000	2.000	3.000	1.374
Task 3	1.628	3.322	1.922	1.390
Task 4	4.437	1.928	4.858	2.285
Task 5	3.807	1.149	4.459	1.992
Task 6	2.322	1.371	1.685	1.060
Task 7	3.000	2.156	2.585	1.503
Task 8	3.700	3.085	3.459	1.978
Task 9	2.807	2.522	3.322	1.6758

3.2 HR-D Results

In order to obtain HR-D, same experiments as nine tasks were carried out in a Boeing 777 flight simulator as Fig. 2, and the participants of the experiments including 8 experienced pilots (mean=1965 flight hours, SD=932). Average HR-D were deduced from the difference of HR value in tasks conditions and relaxation condition of pilots by a physiological parameters monitoring equipment (Bio Harness, Zephry Technology, Annapolis, U.S.A.). The results of HR-D is shown in Table 4.

Fig. 2. Boeing 777 Flight Simulator

Table 4. HR-D reults

Task	HR-D	Task	HR-D
1	5.15	6	4.16
2	8.23	7	9.22
3	3.53	8	12.18
4	18.71	9	23.42
5	15.12		

3.3 Comparison of SC and HR-D

As calculation and recording results of SC and HR-D, the correlation coefficient of these two value by Pearson correlation shown as Table 5. That means SC could somehow represent complexity in flight.

Table 5. The correlation coefficient of SC and HR-D

		HR-D
SC	correlation coefficient	.689*
	Significance	.040

Besides Pearson correlation, the exponential regression curve of SC with HR-D is displayed in Fig. 3.

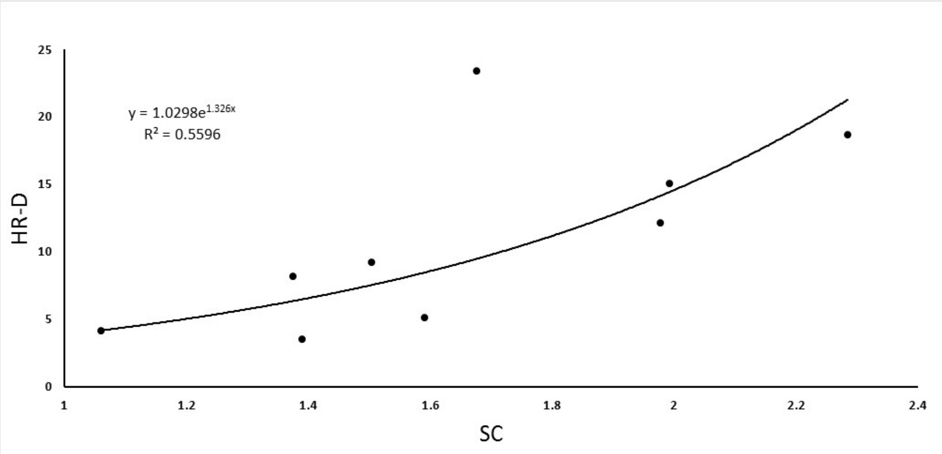

Fig. 3. The exponential regression of SC with HR-D

4 Discussion

In this paper, the preliminary study of quantitative indication of complexity in flight is carried out. This is important to aviation safety. Because excessive workload might result in disasters (Reason 2002). SC measurement from nuclear industry was introduced to represent the complexity.

From the experiment result, SC measurement is correlative to heart rate change. It could be considered related to complexity. However, the correlation is not significant enough. Although similar with nuclear plant, in flight much more operations are required to maintain the aircraft flying, not only surveillance tasks. Considering in real flight conditions, the real world operations might perturb and disrupt the executions (Greeno 1989), and these disruptions might cause the attention shift from the current task of the pilot. Therefore, more significant representation of complexity in flight is necessary.

According to the specific environment of flight, pilots might have much information exchange with the aircraft current configuration. Meanwhile, the operations are more complicated than in nuclear plant, different actions might yield the same results, or same device might have multiple functions. In further study, the above factors should be considered to form a more significant indication of complexity in flight.

5 Conclusion

In our study, we implemented SC from nuclear planet to evaluate nine flight tasks, and the verification method is difference of heart rate. The results of the experiments shows SC could indicate complexity in some extent. Nevertheless, the correlation might be improved by considering flight circumstance in further study.

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