Study on Comprehensive Evaluation of Conflict Operations in Man-machine Interaction System

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Abstract. Conflict operations seriously affect the performance of man-machine interactionin time-critical domains. Evenconflict sometimes adversely impacts on safety operation. Based on collaboration task analysis, the hierarchy of comprehensive evaluation index system of conflict operations was established with Delphi method. And weight coefficient of indexes was calculated by G1 method. The result of evaluation of conflict operationswas calculated by fuzzy comprehensive evaluation method. The result indicates the validity and rationality of comprehensive evaluation method. And base on the method, the indexes and evaluation results of conflict operationsare provided guidance and assistancedesign of theman-machine interaction system.

1. Introduction

In the design of the man-machine interaction system, research generally focuses individual operator performance. However study of collaborative Operationshould focus on the collaboration operating performance, reduce or avoid conflict operations. With individualman-machine systemdesign, collaboration rely heavily on communication, a common overview of the situation and delegation of tasks so that members share the workload[1]. The conflict operations inevitably occur conflict in the process of team collaboration task. So that the effectiveness of team collaboration reduced, or even collaboration mission failed in time-critical domains. In the FAA report, conflict ranked fourth in the reasons of team operation failure, and 42% team operation failed because of conflicts[2]. Because of the serious consequences of collaborative task fail time pressure or psychological pressure, and sudden urgent tasks, the process of team operations conflict frequently occur, Such as aircraft operation, air the traffic control, nuclear power plant operation and diverse military operation. Therefore, the evaluation of conflict operationsarevery important for the design of man-machine interaction system.

In this paper, we analyzed the operation of collaboration tasksin bomber cockpit. Based the collaboration tasks analysis, the evaluation indexes were established. And the index system of conflict operations were established by the Delphi method. According to the evaluation index system and the weightcoefficient of indexes,conflict operations were analyzed and evaluated by fuzzy comprehensive evaluation method.

2.The Indexes of Conflict Operations

2.1 collaboration task analysis. In the paper, the task analysis model was established (table 1). In the model, collaboration operation was divided into two types of basic and support. The basic typewasthe based and important component in the process of collaboration operation, the support type was implementation and support of the basic tasks. The collaboration task included four elements: information exchange, communication, team task responsibilities and task operations.

Table 1Model of task analysis

Task element	Pilot A	PilotB	Task type
Information exchange	Providing information for collaboration task and situation awareness	Providing information for collaboration task and situation awareness	Basic
Communication	Communication for collaboration operation	Communication for collaboration operation	Support
Task responsibilities	Main responsibilities for collaboration task	Main responsibilities for collaboration task	Basic
Task operations	Actions of operation	Actions of operation	Support
Error correction			Support

In the paper, the main 8 collaboration tasks were analyzed in the bomber cockpit. And the 8 collaboration taskswere operated under the time pressure and psychological pressure. Therefor the conflict operation often occurred in the process of 8 collaboration tasks.By the collaboration task analysis model, the indexes of conflict operation were established.

2.2 Indexes of conflict operations. Based on the collaboration task analysis, the model of the index system for comprehensive evaluation was built, which was multi-index and multi-level (table 2). The model of index systemincluded five areas: information exchange, communication, cockpit layout, collaboration task operation, operation safe, which were first grade index. And the cockpit layout included two areas: layout of display and control, design dimension, which were second grade index. Collaboration task operation included display design and control design two areas, which were second grade index in the model.By the expert investigation, indexes of conflict operations were established.In the paper, 386 indexes of conflict operation were established based on the 8 collaboration tasks analysis.

Table 2 Model of the indexsystem for comprehensive evaluation

The index system	First grade index	Secondgrade index	Indexes
The index system of the conflict operations(I)	Information exchange(i_1)		Index(i_{101}~i_{10n})
	Communication(i_2)		Index(i_{201}~i_{20n})
	Cockpit layout(i_3)	Layout of display and control(i_{31})	Index(i_{311}~i_{31n})
		Design Dimension (i_{32})	Index(i_{321}~i_{32n})
	Collaborationtask operation(i_4)	Display design(i_{41})	Index(i_{411}~i_{42n})
		Control design(i_{42})	Index(i_{421}~i_{42n})
	Operation safe(i_5)		Index(i_{501}~i_{50n})

3. Comprehensive evaluation of conflict operations

In bomber cockpit, the conflict operations were impacted on many factors, including: assignments, display and control design, task assignment and sharing information. The relative factors of conflict operations need to analyze and trade-off in the cockpit design. Therefore, the indexes of conflict operationwere analyzed and evaluatedbyfuzzy comprehensive evaluation method.

3.1 The index system of conflict operations. Based on the model of the index system for comprehensive evaluation, the index system of conflict operations was established by the Delphi method in the 8 collaboration tasks of cockpit.For selecting the indexes that could cause more impact on conflict, 24 experienced pilots werereferred twice as the consultants upon preliminary index system.The degree of classification influence was used 5-point Likert-type scale.

386 indexes were chosen through the first survey. The result of the first survey showed that3 indexes didnot meet the consensus of experts ($p < 0.01$). The 3 indexes were inappropriate. In the second round of surveys, all indexes meet the consensus of experts ($p<0.001$). 383 indexes ultimately were determined in the system of index for comprehensive evaluation of conflict operations.

In index system, all indexes were qualitative. The indexes were quantifiedby using linguistic variables and fuzzy numbers. An irregular quadrilateral membership function of the fuzzy numberis

$$\mu_{A(x)} = \begin{cases} \frac{x-c}{a-c} & , c \le x < a \\ 1 & , x \in [a,b] \\ \frac{x-d}{b-d} & , b < x \le d \\ 0 & , others \end{cases} \quad (1)$$

In thepaper,the language variables of comprehensive evaluation was determined to be {excellent, good, fair, poor, bad}. The value Number of trapezoidal membership function of each fuzzy language variable: "excellent"is (0.7 , 1,1,1); "good" is (0.5,0.7,0.7,1); "medium" is (0.3,0.5,0.5,0.7); "poor" is (0.2,0.4,0.4,0.6) ; "bad" is (0,0,0,0.3) [3].

3.2 weight coefficient of indexes. Weight coefficient of the system of index was calculated by using G1 method, including first grade index, second grade index and indexes. In the paper, the 12 pilots were select to investigatethe weight coefficient of indexes. Results of Weight coefficient of first grade indexes are shown in table 3.

Table 3 Weight coefficient of first grade indexes

Indexes	Weightcoefficient
$\{w_{i1},w_{i2},w_{i3},w_{i4},w_{i5}\}$	{0.20,0.14,0.23,0.24,0.19}

3.3 comprehensive evaluation of conflict operations. In this paper, the evaluation grade was divided into five levels: excellent, good, moderate, poor, and bad. Theimplication is shown in Table 4.

Table 4 Evaluation level and implication

Evaluation level	Implication
Excellent	Not conflict，and notinfluence the cooperation performance and safe of man-machine interaction
Good	Occasionally conflict, andnegligiblyinfluence the performance of collaborative operations and safe of man-machine interaction
Moderate	Occasionally conflict, and seriouslyinfluence the performance of collaborative operation and safe of man-machine interaction
Poor	Often conflict, and higher severity of the influence on the performance of collaborative operation and safe of man-machine interaction
Bad	Often conflict, and highest severity of the influence on the performance of collaborative operation and safe of man-machine interaction

The impact of various factors was needed to fully consider in the process of collaborative operation. So comprehensive evaluation mathematical model is[4]

$$B = \sum_{i=1}^{n} w_i \circ u_i i = 1,2,\dots,n \quad (2)$$

In the formula, i is number of indexes, $w_i$is the weight coefficient of i, u_i is thesubordinate degree of i, "°" is fuzzy operator.

In this paper, the comprehensive evaluation results of conflict operations of radar bombing mission is 0.6645 (data shown in Table 5).

Table 5The partial data of evaluation indexes ofconflict operations

Total level	First grade index	Weight coefficient	Subordinate degree
The index system of conflict operationsof radar bombing	Information exchange	0.20	0.6217
	Communication	0.14	0.5734
	Cockpit layout	0.23	0.7304
	collaboration task operation	0.24	0.6127
	Operation safe	0.19	0.7624

The conflict operations of radar bombing were evaluated by 18 pilotsto verify the result. The evaluation results were divided into five grades: excellent, good, moderate, poor and bad (theimplication shown in Table 4). The result of evaluation is 16 good grade and 2 moderate grade. According to the principle of maximum membership degree of fuzzy set theory [5], the results of 18pilotssubjective evaluation is good grade.The subjective evaluation result is consistent with the comprehensive evaluation.

4. Conclusion

In the paper,taking multi-crew bomber cockpit for example, the method of comprehensive evaluation of conflict operations was proposed, including the model of collaboration task analysis, the model of index system, the Delphi method, G1 method and the fuzzy comprehensive evaluation method. The method can also be applied to analyze and evaluate other multi-crew machine interaction system.

The method of paper is used to analyze and evaluate thesystem design phase. But the method isnot considered to evaluate the multi-crew machine system setting phase andteam members selection and training. Therefore, the method of evaluation of conflict operations be established to further evaluate the entire life cycle of the multi-crew machine system.

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