A FLEXIBLE AND GRAPHICAL OPERATIONAL EFFECTIVENESS EVALUATION TOOL

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ABSTRACT
To solve the reusability of evaluation information and extensibility of evaluation algorithms, and improve the efficiency of operational effectiveness evaluation of weapons, a flexible, graphical and simulation-based evaluation tool is developed. The problem analysis of effectiveness evaluation and solutions are given firstly. A process model for effectiveness evaluation is presented, which is flexible and suitable for different evaluation tasks and objects and a primitive-based graphical interface is designed to improve the usability of this tool. And the reusability mechanism of evaluation information and extensibility interface of evaluation algorithms are designed. Then, the design and implementation of the evaluation tool are described and an example of simulation-based operational effectiveness evaluation of an air-defense system is illustrated how to use the tool. Finally, the conclusion and future work are summarized.

Keywords: operational effectiveness, simulation-based evaluation, flexible evaluation, graphical interface

1. INTRODUCTION

Operational effectiveness is used to describe the degree of weapon system accomplishing the missions in the specific operational environment. It is an important comprehensive index for evaluating the quality of weapons and the basic reference for developing, equipping and using the weapons. Through evaluating operational effectiveness of weapons, the periods and cost of design and manufacture of weapons can be reduced and the comprehensive performance of weapons can be improved. The simulation-based evaluation method of weapon operational effectiveness gains the operational effectiveness value by performing simulation experiments and processing the simulation result data. Because the simulation-based method has the advantages of safety and economical and many different operational conditions can be simulated, it is more popular for evaluating the weapon operational effectiveness (Jiao 2013).

With the development of the weapon technology and more and more complex situation of warfare, the simulation-based effectiveness evaluation for weapon system has been raised new requirements, which involve multiple scenario schemes, large amount simulation experiments and data, complex data management and analysis. So the auxiliary tool needs to be developed to support the simulation-based evaluation process for operational effectiveness of weapons. For assisting the operational effectiveness evaluation, some researchers have provided the effectiveness evaluation frames and tools. U.S. RAND gave a mixed interactive evaluation frame based on multi-attribute decision-making and exploratory modeling (Pinder 2000). Li and Matthew proposed an effectiveness evaluation framework of the automatic target recognition and classification system (Li 2014, Matthew 2015). According to the characters of Anti-torpedo Torpedo Weapon System (ATTWS), the effectiveness evaluation system of ATTWS is established, and then a method based on the cloud model is proposed to achieve the effectiveness evaluation for ATTWS (Xu 2015). A distributed denial of service (DDoS) protection effectiveness evaluation system (DPEES) in Linux system is proposed (Qu 2012). An effectiveness evaluation system (EES) is proposed to eliminate the possible risk existing in the development of automatic test systems (ATS) (Wang 2010). The specific evaluation tools for the operational effectiveness of electronic warfare system (Lancon 2011, Qi 2014) and the ship system (Akyuz 2014) are also developed. In addition an integrated software environment of simulation experiment design, analysis and evaluation is researched in our previous work (Li 2016).

The existing effectiveness evaluation frames and tools are not applicable for the general evaluation objects and their complex evaluation procedures are only suitable for the professional, not easy to learn and apply for general users. Besides, the practicality and human-computer interaction (HCI) characteristic of these tools need to be strengthened further. So a flexible and graphical operational effectiveness evaluation tool, HIT-OEET (Harbin Institute of Technology Operational Effectiveness Evaluation Tool), is designed and implemented, which can be applied to various evaluation objects and has good reusability and extensibility. The remainder of this paper is organized as follows. The existing problems of effectiveness evaluation and solutions are analyzed in Section 2. Section 3 describes design and implementation of HIT-

OEET. And an example of simulation-based operational effectiveness evaluation is used to illustrate the efficiency and usage of HIT-OEET in Section 4. Finally, the conclusion and the future work are summarized.

2. THE PROBLEM ANALYSIS AND SOLUTIONS

In the simulation-based operational effectiveness evaluation applications, many difficulties are faced, such as the different evaluation tasks and objects, complex components of weapon system, plenty of operational scenarios and simulation experiments, a large quantity of complex simulation data, and many evaluation algorithms. So the main problems of the effectiveness evaluation to be solved are summarized below:

- **Flexible evaluation (FE)**. The evaluation tool could apply for different effectiveness evaluation objects, which include signal equipment, the weapon system and system-of-systems (SoS), in different operational scenarios. At this point, the evaluation process is not constant and could be constructed flexibly according to the different evaluation requirements.
- **Human-computer interaction (HCI)**. Recent researches indicate that HCI techniques can contribute much to an efficient fulfillment of the evaluation task. So a suitable evaluation tool must provide a good interface of HCI for users from different fields and assist to accomplish evaluation tasks effectively.
- **Reusability and extensibility (R&E)**. In different evaluation tasks and objects, much evaluation information is overlapped such as, evaluation index system, data extraction methods, evaluation index arithmetic, integration evaluation methods. So the practicality and efficiency of the evaluation tool can be further improved through the storage and reuse of the evaluation information. Besides, more and more evaluation algorithms are developed and applied newly in different evaluation tasks and the evaluation tool must integrate these new and existing evaluation algorithms.

Based on the problem analysis, relevant solutions are developed. First, a process model of different evaluation tasks and objects is presented to implement the flexible evaluation. Considering the HCI characteristic of this tool, the primitive-based graphical interface is designed. Besides, the reusability of evaluation information and the extensible interface of evaluation methods are researched. The detailed solutions are given as follows.

2.1. The Process Model of Effectiveness Evaluation

According to the problems analysis above, the general procedures of operational effectiveness evaluation need to be researched. So we extract the common points of different evaluation tasks and construct a process model of effectiveness evaluation in form of IDEF0 (see figure 1). This model contains the primary and detailed selection of evaluation indexes, simulation experiment execution, value and ranking evaluation of operational effectiveness. The detailed illustration of each procedure is given below:

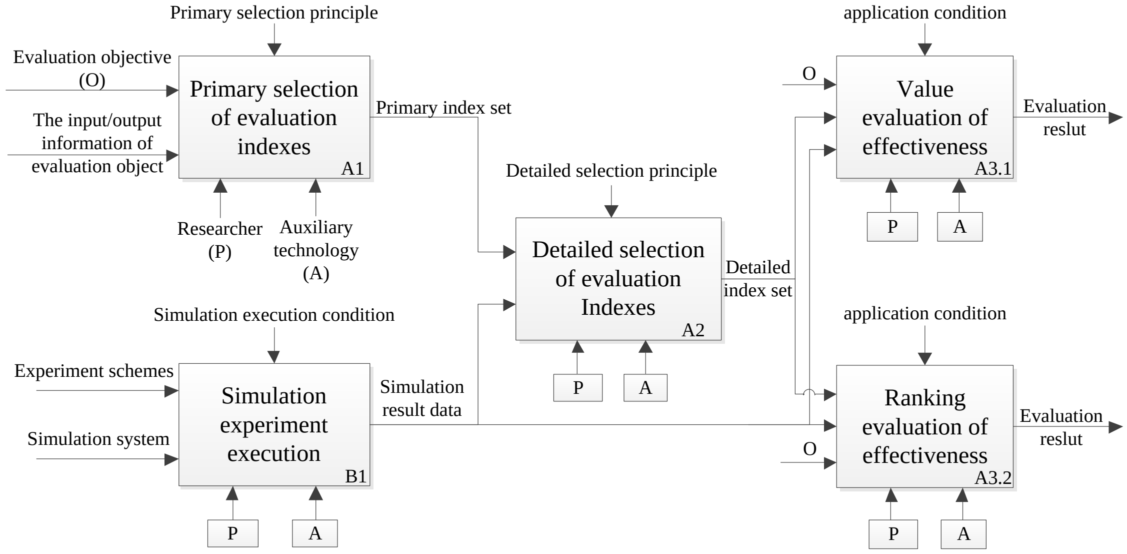


Figure 1: Process Model of Effectiveness Evaluation

I) **Primary selection of evaluation indexes (A1)**: According to evaluation purposes and objects information, researchers could select the available evaluation indexes from the evaluation index model library. With respect to the indexes without extraction model, we need to construct them based on the input and output data information of evaluation object, and then, the primary indexes set are obtained.

II) **Detailed selection of evaluation indexes (A2)**: Multiple sample values of primary indexes could be achieved via the simulation result data from B1 and the primary index set from A1. After that, the sample values would be conducted through the detailed selection method to acquire the detailed index set.

III) Value evaluation of effectiveness (A3.1): The evaluation result of each detailed index can be obtained through computing the simulation result and scenario data with evaluation index arithmetic and evaluation integration methods.

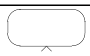
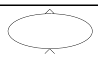
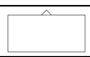
IV) Ranking evaluation of effectiveness (A3.2): The sequential effectiveness evaluation results of different operational scenarios can be obtained by conducting the simulation result and scenario data with integration evaluation methods.

V) Simulation experiment execution (B1): The simulation result data could be acquired through executing experiments schemes on the simulation system and these data is used to stored and analyzed.

2.2. The Graphical Interface Design of HIT-OEET

HIT-OEET is developed to assist users from different fields to accomplish evaluation tasks better, then a suitable HCI interface needs to be designed and applied. So a primitive-based graphical interface is proposed in the effectiveness evaluation process. Some relevant primitives are defined based on the evaluation activities from the process model (Section 2.1) and three kinds of primitives are designed (see table 1) which include index system establishment, basic data extraction and evaluation algorithms setting. The primitives of index system establishment are used to build the index system of effectiveness evaluation, including root index, middle index and bottom index. The primitives of basic data extraction are used to construct the condition and attribute of interested data and these data would be extracted from the scenario and experiment result database. The primitives of evaluation algorithms setting involve the evaluation arithmetic of bottom indexes and integration evaluation methods and the evaluation results could be obtained via these algorithms.

Table 1: Primitives Definition in Effectiveness Evaluation Process

Primitive type	Primitive form	Primitive description
Index system establishment		Root index
		Middle index
		Bottom index
Basic data extraction	C	Condition expression described the experiment data attribute
	&	"And" expression between conditions
	||	"Or" expression between conditions
	~	"Not" expression of condition
	1*1	1*1 dimension data
	n*1	n*1 dimension data
	Basic data	Output basic data
Evaluation algorithms setting	Basic data	Input basic data
	Evaluation index	Output evaluation index
	Index evaluation algorithm	Evaluation algorithm
	Customer algorithm	Extended evaluation algorithm

2.3. The Reusability and Extensibility Design of HIT-OEET

For solving the repeated construction of much overlapped evaluation information for different evaluation objects and improving the evaluation efficiency, the information of each evaluation object should be stored and reused. Due to large amount of data to be stored and diverse data formats, we select relational database as the container of evaluation information and the storage format of data tables and the interaction interface between HIT-OEET and database needs to be designed. The database design will be given in Section 3.2. Here, we will take the information of evaluation algorithms as an example to illustrate the interface design (see figure 2). The evaluation algorithm interface contains index information and algorithm information. The index information describes the attribute of evaluation indexes such as index name, index type and primitive position etc. and the algorithm information is used to record the parameter information of algorithms and evaluation value of indexes. The evaluation results of bottom indexes could be either equal to the basic data directly or obtained via the evaluation arithmetic and the evaluation results of integrated indexes (middle and root indexes) could be achieved through integration evaluation methods.

Besides, more and more evaluation algorithms are being developed and applied for different evaluation tasks and objects and these new and existing algorithms all need to be integrated in evaluation tool. If we update the tool repeatedly with the fast development of these evaluation algorithms and this will generate high cost and lead to the worse practicability of the tool. So we design and implement the extended interface of evaluation algorithms based on Dynamic Link Library in HIT-OEET. It consists of three parts including algorithm description, parameter configuration and algorithm execution (see figure 3) and the detailed description of each procedure is given as follows.

I) **Algorithm description (A1)**: This procedure is used to give the information description of extended algorithms including algorithm usage, input/output variable attribute and application condition.

II) **Parameter configuration (A2)**: Based on the algorithm description and actual input/output variables, the parameter information such as parameter name, parameter type and description could be given. Then, users could set the parameter value for the extended algorithm.

III) **Algorithm execution (A3)**: Based on the input variable and parameter setting, the calculation results could be achieved through the algorithm execution.

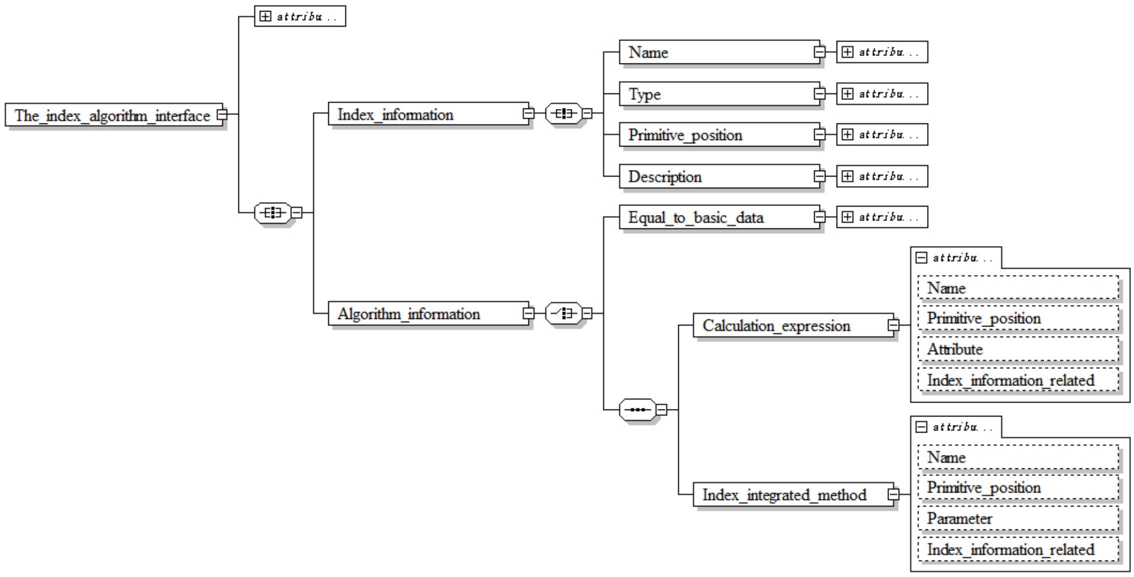


Figure 2: Interaction Interface of Evaluation algorithms

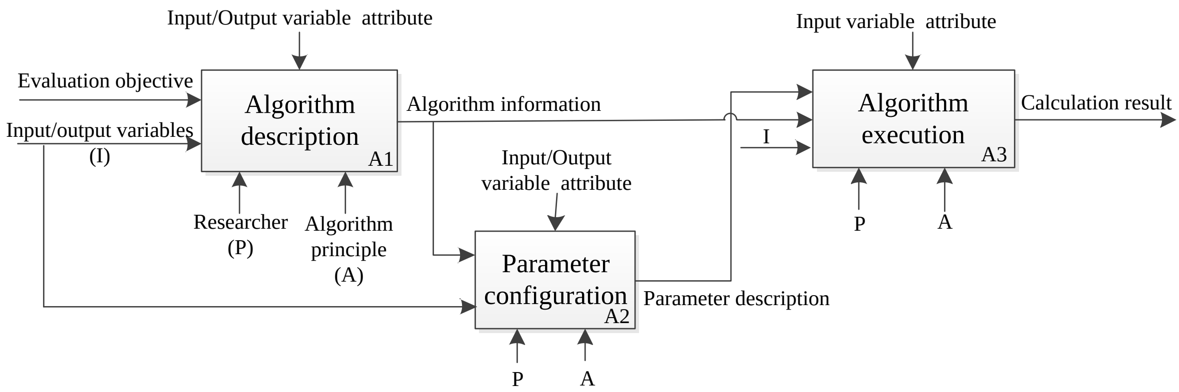


Figure 3: Execution Procedures of Extended Algorithm

3. THE DESIGN AND IMPLEMENTATION OF HIT-OEET

According to the researched content above, the functions of HIT-OEET would be conceived as below: establishing evaluation project, setting evaluation content, evaluating weapon operational effectiveness, analyzing evaluation result and generating evaluation report. This tool can also assist the users to set the information of data extraction methods, evaluation index arithmetic and indexes integration methods. Based on the described functions above, HIT-OEET is designed and implemented including component and structure design, database design and software implementation.

3.1. Component and Structure Design of HIT-OEET

On the basis of the necessary functions of HIT-OEET and modular design principle, the structure framework and components of HIT-OEET are designed firstly. This tool consists of six modules including interface of HCI, evaluation project information management, evaluation execution, database management, evaluation process information management and evaluation process monitoring (see figure 4). The functions and interaction relation of these components are designed as follows.

a) The HCI interface provides the operation panel for users to implement evaluation tasks and the graphical operation manner is integrated in it.

b) The module of evaluation project information management is used to manage and set the related information, which includes personal information of estimators, evaluation project information and evaluation phase information.
c) The evaluation execution module is used to execute the evaluation operations and set the information of evaluation index system, data extraction methods, evaluation index arithmetic and integration evaluation methods. The evaluation results can be obtained via this module.
d) The module of evaluation process information management is used to provide the interface for storing and extracting the evaluation information including evaluation project and evaluation execution. This information will be packed and transmitted to database management module, and also displayed by the module of evaluation process monitoring.
e) The evaluation process monitoring module is used to monitor the user operation and evaluation process information. All evaluation information is all displayed in this module, if some errors such as user operation and setting information appear and then the tool would give the caution signal.
f) The database management module consists of scenario database, evaluation database and experiment result database, and is used to store the information, which contains scenario data, simulation data and evaluation process in a certain format. The storage format of data is designed in Section 3.2.

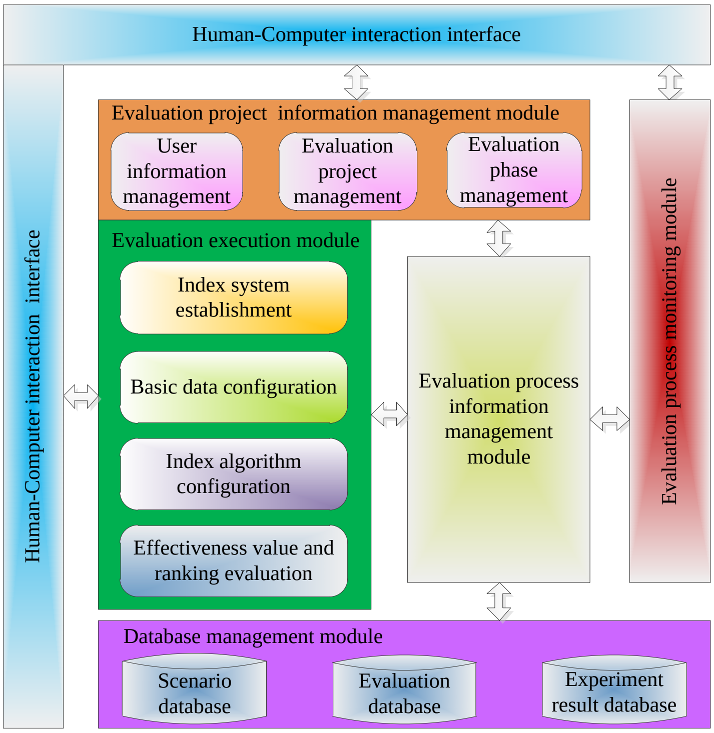


Figure 4: Component and Structure design of HIT-OEET

3.2. The Database Design of HIT-OEET

The simulation-based operational effectiveness evaluation of weapons is a data-intensive work, which involves large amount of operations of evaluation information, scenarios and simulation data. So a data container needs to be provided in evaluation tool. Relational database could be used to store the data due to the support of superior data size and different storage formats. According to the different sources of data, there are three databases are provided in HIT-OEET: scenario database, evaluation database and experiment result database. The scenario and experiment result database are used to store the scenario and simulation result data respectively, and provide the data source for effectiveness evaluation. The evaluation database is responsible for the storage and management of evaluation information and closely related to evaluation process. So this paper mainly introduces the design of evaluation database.

According to the structure design of HIT-OEET above, there are six kinds of evaluation information need to be stored, which includes evaluation project information, user information, index system information, data extraction information, evaluation index arithmetic and evaluation indexes integration, evaluation result information (see figure 5).

3.3. Implementation of HIT-OEET

Based on the design thought and functions description above, HIT-OEET is implemented based on C++ language, Matlab and ACCESS through utilizing the technologies of ADO, ActiveX. The main interface and each function component of HIT-OEET are shown in Figure 6, which contains user and project management, index system setting, data extraction configuration, evaluation index arithmetic, evaluation indexes integration, evaluation results display and extended algorithm interface etc.

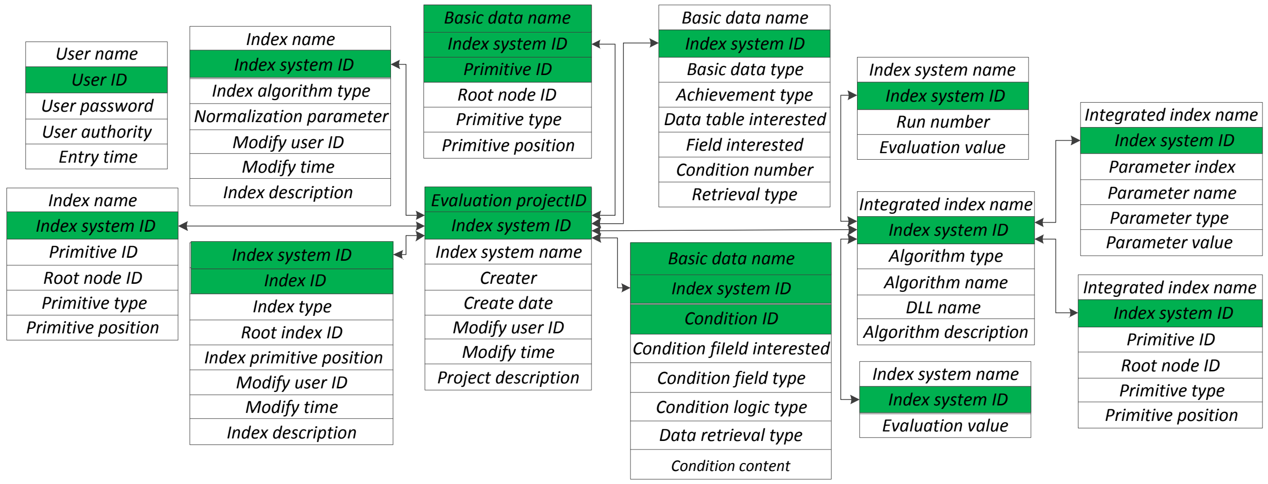


Figure 5: Structure of The Evaluation Database

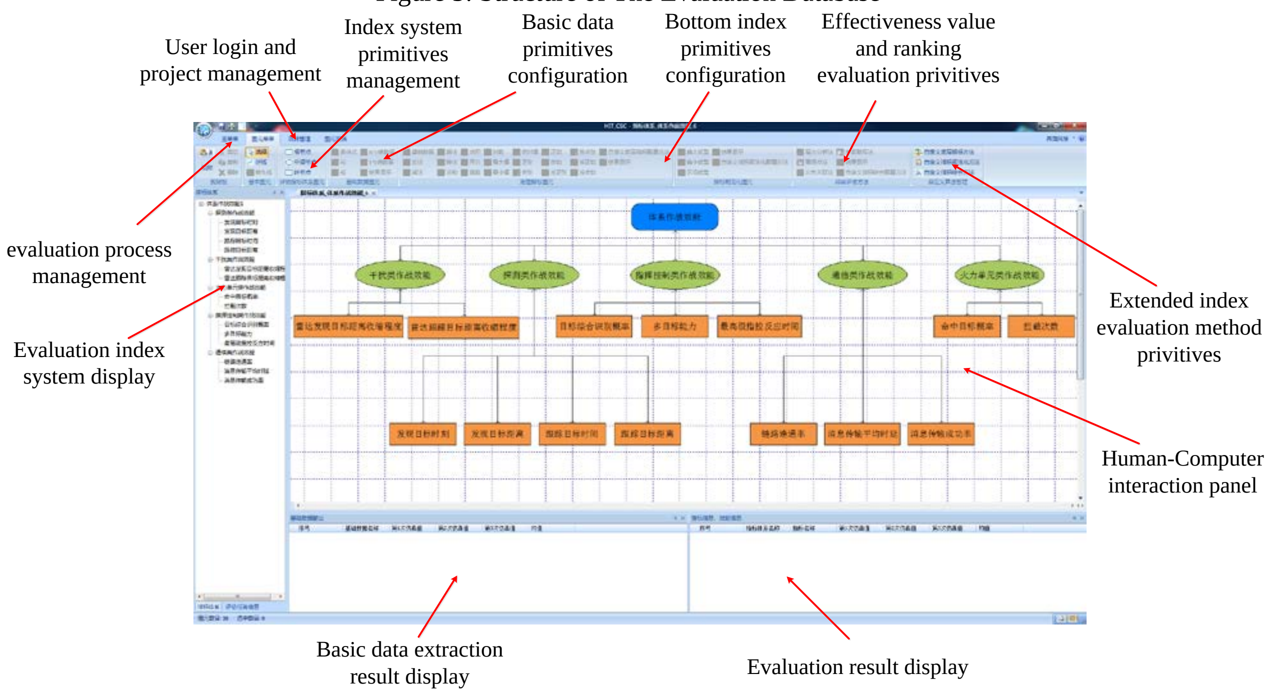


Figure 6: Main Interface of HIT-OEET

4. APPLICATION

In order to demonstrate the efficiency and usage of HIT-OEET, an example of simulation-based operational effectiveness evaluation of an air-defense system is given. The system consists of many entities, including aircrafts, missiles, radars, regional command and control system, etc. The operational scenario is that blue aircrafts violate the red area and the blue planes will be intercepted by red aircrafts and missiles when the objects are found by red radar. Our goal is to evaluate the operational effectiveness of rad air-defense system.

According to the process model proposed in Section 2.1, we need to establish the indexes system of effectiveness evaluation firstly. Considering application domain of the air-defense system, we construct the evaluation indexes system which consists of four middle indexes and eight bottom indexes, including investigation ability, command and control capability, communication ability, Interception ratio, hitting ratio, etc. (see figure 7).

Second, we need to configure the bottom and middle indexes based on the basic data. Take the interception ratio as an example and it's computation formula is given as follows.

$$\eta = \left(NP + NM\right) / NE \qquad (1)$$

where η is the interception ratio of red side. NP is the number of intercepted planes. NM is the number of intercepted missiles. NE is the number of entities which need to be intercepted.

All necessary basic data could be determined from Eq. (1) and then extracted from experiment results (see figure 8). After that, the interception ratio could be configured based on these basic data and Eq. (1) in Figure 9.

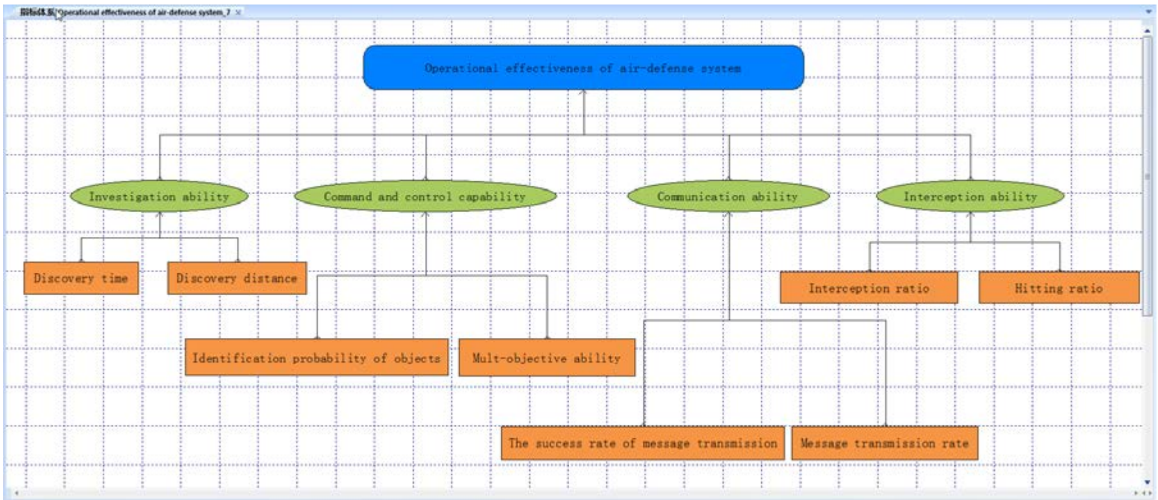


Figure 7: Evaluation Index System of Operational Effectiveness of an Air-defense System

So, the middle and root indexes could be configured layer by layer based on the indexes system. Finally, the configuration of root index, Operational effectiveness of air-defense system, is given in Figure 10. In the example, we adopt weighted average method to synthesize the middle indexes and each weight of four middle indexes is 0.25.

After accomplishing all configuration of basic data extraction information, evaluation index arithmetic and integration evaluation methods, the ultimate effectiveness results of an air-defense system could be computed via the information of indexes configuration.

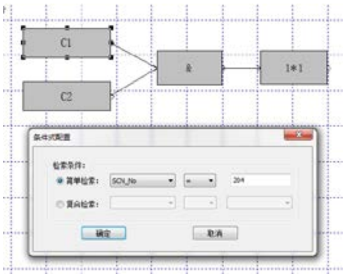


Figure 8:Condition expression setting

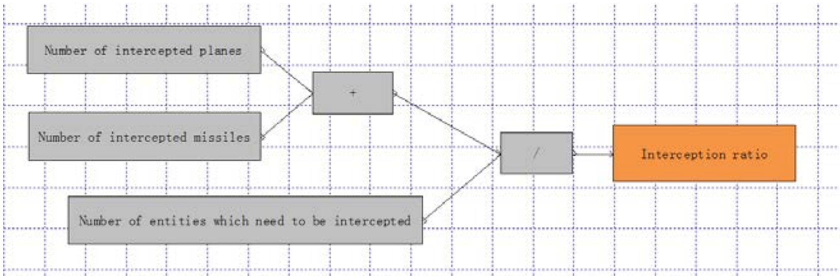


Figure 9: Setting information of interception ratio

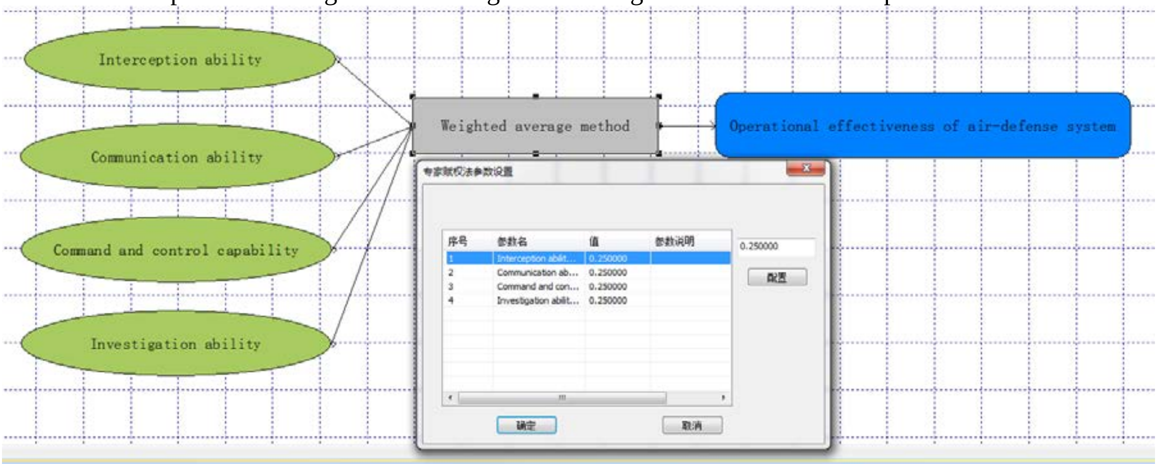


Figure 10: Setting information of indexes integration

5. CONCLUSION

This paper focuses on the development of a simulation-based operational effectiveness evaluation tool, HIT-OEET. In order to solve the existing problems of effectiveness evaluation and improve the evaluation efficiency, a process model of effectiveness evaluation is presented and reusability of evaluation information and extensibility of evaluation algorithms are clearly enhanced. Also a primitive-based graphical interface is designed to improve the HCI characteristic of the tool. The proposed process model is regarded as a guideline for the simulation effectiveness evaluation and the graphical interface based on primitives makes HIT-OEET suitable for users from different fields better.

Depending on the reusability design of evaluation information and the extensibility design of evaluation algorithms, the efficiency of the operational effectiveness evaluation is improved greatly. Based on the researched content above, HIT-OEET is designed and implemented.

In the example, HIT-OEET is validated to accomplish the operational effectiveness evaluation of weapons well and the usage of this tool is shown. In addition, the graphical interaction interface primitive-based makes the evaluation process more straightforward than existing evaluation tools.

Due to the more and more complex effectiveness evaluation objects in the future such as, Sos, multiple components of weapon system, etc. and the evaluation tasks may be accomplished by several users together in different places. So a networked, multi-node and simulation-based effectiveness evaluation tool for complicated weapon system needs to be developed in future work.

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