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Credibility Assessment of Modeling and Simulation Requirement

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***Abstract*—Credibility assessment of modeling and simulation(M&S) requirement was studied in this paper. Firstly, the shortcomings of the present credibility assessment methods in M&S requirement were analyzed. Then, the indicators of M&S requirement credibility assessment were put forward. Based on that, the M&S requirement credibility assessment method was studied, the integrated Subject Matter Experts(SMEs) weighting assignment algorithm based on specialty was brought forward. Finally, the study of this paper was used in the requirement credibility assessment of operational M&S system. The application result shows that the method which was brought forward in this paper preferably integrated the objective and subjective factors of the SMEs' weighting in the requirement credibility assessment.**

Keywords—M&S requirement; credibility assessment; weighting

I. INTRODUCTION

Whether or not the M&S system is credible and to what extent is credible is the most concerned issue of simulation users. Simulation without sufficient credibility is useless[1]. Whether the credibility of the combat M&S system meets the requirements of users depends on the correctness of the requirements of the M&S system. Requirement is important because it plays a decisive, directional and strategic role in the development process of M&S system. The requirement of combat simulation is the basis of the development of combat M&S system and the root of the establishment of combat M&S system. For a long time, people have been devoting themselves to the credibility assessment of simulation models, but neglected the credibility assessment of M&S requirements. According to statistics, the failure of M&S system development caused by M&S requirements accounts for a large proportion, and the longer the errors in the requirements exist, the higher the cost of correcting these errors.

This paper mainly studies the assessment of M&S requirement credibility. Firstly, the assessment indicators of M&S requirement credibility are established. Then, the assessment method of M&S requirement credibility is put forward. Aiming at the rationality of expert weight distribution, a weighting distribution algorithm is proposed. According to the specialty level, specialty correlation degree and the correlation degree of assessment content, the experts' specialty level, specialty correlation degree and assessment content are considered. Finally, the content of this paper is applied to the requirement credibility assessment of a M&S system.

II. SHORTCOMINGS OF EXISTING CREDIBILITY ASSESSMENT METHODS

The requirement credibility assessment of M&S system needs multi-domain knowledge, especially in domain field. The following shortcomings were existed in evaluating the requirement credibility assessment of M&S system.

- The credibility assessment of M&S requirement mainly depends on the subjective assessment results of subject experts, and simulation technicians can't effectively evaluate them due to lack of professional knowledge, while experts lack knowledge in simulation field, it is difficult to evaluate the credibility of M&S requirement comprehensively and effectively. Therefore, the existing credibility assessment methods can't meet the needs of simulation.
- Since the subject experts knowledge structure and experience level are different, if they all use the same expert weight while evaluating the credibility of M&S requirements, it will inevitably lead to the lack of accuracy and objectivity of credibility assessment results. Therefore, the weights of subject experts must be calculated. In the existing assessment methods, the static distribution method is usually used to assign the weight of the subject experts. However, since the knowledge structure and experience level of the subject experts are different when evaluating different contents, the accuracy and objectivity of the assessment results of the same expert are different even when evaluating different indicators.

III. REQUIREMENT CREDIBILITY ASSESSMENT INDICATOR

To evaluate the credibility of M&S requirement, the appropriate credibility assessment indicators system must be firstly established. The assessment indicators of M&S requirement credibility mainly include correctness, clarity, completeness, consistency, feasibility, modifiability, stability, testability and traceability [2-4].

A. Correctness

Correctness refers to the degree of accuracy of functions, behaviors and performances expected to be achieved by the M&S system to be developed as described in the requirements specification. The correctness of requirements is assessed by performing M&S requirement checks and M&S requirement validation. The main purpose of the correctness assessment is

to check "Do we have the right needs?" and verify "Are the requirements we created correct?" Whether the requirement meets the user's needs is the basis for judging its correctness.

B. Clarity

Clarity includes unambiguity and comprehensibility, which refers to the comprehensibility and clarity of requirement description. Ambiguity refers to whether there is only one clear and unified explanation for each requirement statement. Comprehensibility refers to whether the meaning of each requirement statement is easy to understand for all its users.

C. Completeness

Completeness means that all aspects of M&S requirements are described in detail without missing any information, that is to say, each requirement is complete and independent, so that developers can get all the necessary information needed to design and implement the M&S system. Completeness can be evaluated by the function, performance, input/output, condition limitation and application scope of the system described by requirements. The wider the coverage and completeness of requirement description, the more complete and detailed the requirement specification, the easier the design and development of M&S system.

For example: "Vehicle speed is 45 in normal condition" is an incomplete requirement, because it omits the "kilometer/hour" part.

D. Consistency

Consistency means that there is no difference or contradiction between the requirements of different parts and the requirements of different fields in the requirement statement, and uniform symbols, terms and symbols are used according to the regulations. Requirement consistency assessment is a quantitative expression and calculation of the degree of consistency of requirements. Requirement consistency assessment includes two aspects: grammatical consistency assessment and semantic consistency assessment. Among them, the grammatical consistency assessment mainly evaluates whether unified symbols, symbols and terminology standards are used in requirements, whether the functions and behavioral characteristics of requirements description are consistent, and the semantic consistency assessment mainly evaluates whether the meanings of requirements described in user domain, problem domain and simulation domain are consistent, and whether there are contradictions and conflicts among them.

E. Feasibility

Feasibility refers to the degree of difficulty in realizing a requirement within the known capabilities and constraints of the M&S system and its operating environment, as well as a number of potentially conflicting requirements at the same time. Sometimes there may be conflicting situations between multiple requirements. It may be easy to complete a certain requirement, but it may not be able to complete a series of requirements at the same time. Feasibility is also important for M&S requirement. If the formulated requirement is not feasible and operable under the conditions of existing technology and funds, such requirement is not feasible, which will bring unnecessary trouble to the development of the system.

F. Modibility

Modibility refers to whether the requirement analysis report is easy to modify, that is, whether the requirement analysis report can easily accept the operation of adding, deleting and modifying. In the process of requirement verification and validation, a series of problems existing in the requirement may be found. At this time, it is necessary to constantly modify the requirement to meet the requirement of requirement confirmation.

G. Stability

Stability refers to the situation in the development of M&S software that needs to be modified, and the impact of changing requirements on project schedule, cost, risk, quality, function, design, integration and testing.

H. Testability

Testability refers to the existence of technically, methodologically and economically feasible methods for testing any requirement. If the requirements are not tesTable, the developed product cannot be validated for availability.

I. Traceability

Traceability means that all requirements related to each requirement obtained after requirement analysis must be easy to find. Traceability of requirements can facilitate subsequent system development, testing and validation, and document reference. Traceability checking of requirements can ensure that each requirement source is clear, and is easy to modify and refer to. When a requirement needs to be modified, the related requirements affected by the requirement modification can be tracked and searched for consistency verification.

IV. REQUIREMENT CREDIBILITY ASSESSMENT METHOD

Whether the construction of M&S system can meet the needs of users depends on the correctness of the requirements of M&S system. It is difficult to find an objective method to assessment the credibility of M&S requirements because of the strong dependence on subject experts in the assessment process. Therefore, relevant subject experts in domain field and simulation field should be employed to make subjective credibility assessment of M&S requirements.

A. Credibility Assessment Method of M&S requirements

The experience and knowledge of subject experts are fully utilized to evaluate the credibility of needs. Firstly, subject experts are organized to evaluate the credibility of assessment indicators. Then, according to the personal information and assessment results of subject experts, the weight of subject experts in assessment indicators is calculated. Based on that, the credibility of each assessment indicator is calculated. Finally, the requirement credibility of the M&S system is evaluated through synthesis.

The main steps of M&S requirements credibility assessment are as follows:

Step1: The M&S requirement credibility assessment indicators are determined.

Step2: The indicators of M&S requirement are evaluated by experts.

Step3: The weights of subject matter experts in different assessment indicators are calculated.

Step4: The credibility of the evaluated indicators is calculated.

Step5: The M&S requirement credibility is assessed by processing the credibility of the indicators synthetically.

B. Subject Expert's Weight Calculation Method

The weight of the subject expert is the quantitative representation of the proportion of the assessment results. In the process of requirement credibility assessment, how to scientifically and reasonably distribute the weights of the subject experts involved in the assessment is related to the credibility and correctness of the results of requirement credibility assessment. While calculating the weights of subject experts, both objective and subjective factors should be taken into account. This paper considers both subjective and objective effects when calculating the weights of subject experts, and proposes an algorithm for empowering subject experts based on expertise.

The basic steps of the weighting distribution algorithm based on the expertise of the subject matter expert groups are as follows.

Step1: The requirements credibility assessment indicators are established.

Step2: Expert's personal information database is established, including expert profiles, expert assessment indicators, etc.

Step3: Requirements credibility are evaluated by experts based on credibility assessment indicators.

Step4: The objective weight distribution of subject experts for all assessment indicators is calculated.

In order to objectively distribute the weight of subject experts, this paper proposes a feedback-based objective weight distribution method for subject experts when calculating the objective weight of subject experts.

The assessment results of experts and non-experts are considered separately. Firstly, all experts who do not have the expertise described in the assessment index are regarded as an expert (hereinafter referred to as non-expert expert) and participate in the weight distribution together with other experts who have the expertise described in the assessment index. Assuming that there are n experts, including non-experts, to evaluate an assessment index, the distance between the credibility assessment value of the first expert and the average value of the credibility assessment value of other experts is calculated according to formula (1).

$$DI_i = \left| P_i - \left(\sum_{i=1}^{n} P_i \Big/ n \right) \right| \tag{1}$$

The above distances are normalized according to formula (2).

$$R_i = \frac{DI_i}{\sum_{i=1}^{n} DI_i} \tag{2}$$

The weights of experts are calculated according to formula (3).

$$K_i = \frac{1 - R_i}{\sum_{i=1}^{n} \left(1 - R_i\right)} \tag{3}$$

K_i means the weight of the ith subject matter expert, $\sum_{i=1}^{n} K_{ij} = 1$.

For all experts who do not have the expertise mentioned in the assessment indicators, the objective weight distribution method based on feedback is used to calculate the weight of experts who do not have the expertise, and then the weight of experts who do not have the expertise mentioned in the assessment indicator is calculated according to the weight of non-expertise experts.

Step5: Subjective weight distribution of subject experts is calculated for all assessment indicators in turn. The subjective weights of subject matter experts are calculated as shown in Table I.

TABLE I. COMPARISONS OF EXPERT PROFILE AND PROFESSIONAL WEIGHT COEFFICIENT

Overview of experts	**Expertise Weight Coefficient**
Non-expert	1
Junior expert	2
General expert	3
Senior expert	4

For assessment indictor j, if the assessment indictor belongs to the expertise of the subject expert i, the corresponding weight coefficient Wsi_{ij} is assigned to the subject expert according to the comparison Table between the general situation of the subject expert and the weight coefficients of the expertise. Otherwise, if the assessment index does not belong to the expertise of the subject expert, the weight coefficient value of the subject expert in evaluating the assessment item is the weight coefficient value of the non-expertise expert, Wsi_{ij}=1. Finally, according to formula (4), the weights of subject experts in assessment items are obtained by normalizing the weights.

$$Ws_{ij} = \frac{Wsi_{ij}}{\sum_{i=1}^{n} Wsi_{ij}} \tag{4}$$

n denotes the number of experts.

Step6: The combination weight distribution of subject experts for all assessment indicators are calculated in turn.

In this paper, the subjective and objective effects are taken into account when calculating the weights of subject experts. The weights of subject experts are distributed according to formula (5).

$$W_{ij} = Wo_{ij} \times 50\% + Ws_{ij} \times 50\% \tag{5}$$

W_{ij} means the weight of subject matter expert *i* while evaluating item *j*.

Wo_{ij} means the objective weight of subject matter expert *i* while evaluating item *j*.

Ws_{ij} means the subjective weight of subject matter expert *i* while evaluating item *j*.

V. REQUIREMENT CREDIBILITY ASSESSMENT OF M&S SYSTEM

The requirement credibility assessment of an M&S system was given in this paper as an example. In the M&S requirement assessment process, the assessment team invited nine subject experts in related fields, including one senior expert, two Vice-Senior experts, three general experts and three junior experts. In the process of assessment, the assessment indictor of requirement credibility proposed in this paper was adopt, that is, the correctness, clarity, completeness, consistency, feasibility, modifiability, stability, testability and traceability.

A. Expert Assessment

The assessment results of subject matter experts on requirements credibility assessment indicators are shown in Table II.

TABLE II. THEMATIC EXPERT ASSESSMENT RESULT TABLE

	1	2	3	4	5	6	7	8	9
1	0.88	0.91	0.89	0.90	0.70	0.92	0.87	0.96	0.89
2	0.84	0.90	0.86	0.92	0.89	0.88	0.82	0.93	0.87
3	0.86	0.87	0.89	0.92	0.87	0.85	0.90	0.94	0.90
4	0.85	0.90	0.88	0.91	0.85	0.89	0.85	0.97	0.89
5	0.72	0.88	0.87	0.90	0.83	0.87	0.89	0.95	0.86
6	0.90	0.93	0.91	0.94	0.89	0.91	0.86	0.95	0.73
7	0.86	0.89	0.87	0.89	0.85	0.89	0.89	0.93	0.88
8	0.87	0.86	0.90	0.95	0.90	0.86	0.86	0.98	0.87
9	0.86	0.88	0.89	0.91	0.87	0.90	0.85	0.96	0.89

Note: The assessment results of different indicators by experts on the same subject in the Table.

B. Calculation of Expert Weight

1) The calculation of subjective weight distribution

According to the established expert personal information database, the indicators of the requirements credibility assessment are obtained as shown in Table III.

TABLE III. EXPERT INFORMATION TABLE

Assessment Indicator	1	2	3	4	5	6	7	8	9
Correctness	Y	Y	N	Y	N	N	Y	Y	N
clarity	Y	N	N	Y	N	Y	Y	Y	N
completeness	N	Y	N	Y	N	Y	Y	Y	N
consistency	Y	Y	N	Y	Y	Y	N	Y	N
feasibility	Y	N	Y	N	Y	Y	N	N	Y
modifiability	N	Y	Y	Y	Y	N	N	Y	Y
stability	N	N	Y	N	Y	N	Y	N	Y
testability	Y	N	Y	N	Y	Y	N	N	Y
traceability	N	Y	Y	N	Y	N	Y	N	Y
Expert Overview	4	4	4	3	3	3	2	2	2

Note: "Y" means that subject matter experts have the expertise required for the assessment index, while "N" means that subject matter experts do not have the expertise required for the assessment index.

Firstly, the weight coefficients of subject experts Wsi_{ij} are calculated. According to the subjective weight calculation method proposed in this paper, the weight coefficients of subject experts are calculated. The results are as follows.

$$Wsi = \begin{bmatrix} 4 & 4 & 1 & 4 & 4 & 1 & 1 & 4 & 1 \\ 4 & 1 & 4 & 4 & 1 & 4 & 1 & 1 & 4 \\ 1 & 1 & 1 & 1 & 4 & 4 & 4 & 4 & 4 \\ 3 & 3 & 3 & 3 & 1 & 3 & 1 & 1 & 1 \\ 1 & 1 & 1 & 3 & 3 & 3 & 3 & 3 & 3 \\ 1 & 3 & 3 & 3 & 3 & 1 & 1 & 3 & 1 \\ 2 & 2 & 2 & 1 & 1 & 1 & 2 & 1 & 2 \\ 2 & 2 & 2 & 2 & 1 & 2 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 2 & 2 & 2 & 2 & 2 \end{bmatrix}$$

The weight coefficient values are normalized and the weight of each item evaluated by subject experts Ws_{ij} is calculated according to formula (4).

$$Ws = \begin{bmatrix} 0.2105 & 0.2222 & 0.0556 & 0.1817 & 0.2000 & 0.0476 & 0.0625 & 0.2000 & 0.0526 \\ 0.2105 & 0.0556 & 0.2222 & 0.1817 & 0.0500 & 0.1905 & 0.0625 & 0.0500 & 0.2105 \\ 0.0526 & 0.0556 & 0.0556 & 0.0455 & 0.2000 & 0.1905 & 0.2500 & 0.2000 & 0.2105 \\ 0.1580 & 0.1666 & 0.1666 & 0.1364 & 0.0500 & 0.1429 & 0.0625 & 0.0500 & 0.0526 \\ 0.0526 & 0.0556 & 0.0556 & 0.1364 & 0.1500 & 0.1429 & 0.1875 & 0.1500 & 0.1580 \\ 0.0526 & 0.1666 & 0.1666 & 0.1364 & 0.1500 & 0.0476 & 0.0625 & 0.1500 & 0.0526 \\ 0.1053 & 0.1111 & 0.1111 & 0.0455 & 0.0500 & 0.0476 & 0.1250 & 0.0500 & 0.1053 \\ 0.1053 & 0.1111 & 0.1111 & 0.0909 & 0.0500 & 0.0952 & 0.0625 & 0.0500 & 0.0526 \\ 0.0526 & 0.0556 & 0.0556 & 0.0455 & 0.1000 & 0.0952 & 0.1250 & 0.1000 & 0.1053 \end{bmatrix}$$

Ws_{ij} denotes the subjective weights when subject matter expert *i* evaluates the *j*th assessment indicator.

2) The calculation of objective weight distribution

This paper illustrates the calculation process of objective weight distribution by taking the calculation of weight

distribution in evaluating correctness indicator by subject experts as an example. In the process of correctness assessment, the first, second, fourth, seventh and eighth subject matter experts can be obtained through Table III. The third, fifth, sixth and ninth expert are not experts in correctness assessment. Therefore, subject experts third, fifth, sixth and ninth are involved in the calculation as non-specialist experts.

Firstly, the assessment values of non-specialist experts are calculated.

The assessment results of the third, fifth, sixth and ninth thematic experts were as follows:

VF=[0.86 0.72 0.90 0.86]

The average of the assessment results of the four subject experts.

EV = 0.835

The distance between the assessment results of the four subject experts and their assessment mean.

DIF=[0.0250 0.1150 0.0650 0.0250]

The weights of the four subject experts in the assessment results of non-specialist experts were calculated by normalizing the distance mentioned above.

KF=[0.2971 0.1667 0.2391 0.2971]

According to the weights and assessments of the four subject experts, the assessment values of non-specialist experts are calculated.

$$VF = \sum_{i=1}^{4} KF_i \times V_i = 0.8462$$

The assessment results of all experts involved in the distribution of experts' weights, namely, the assessment results of the first, second, fourth, seventh and eighth experts and non-experts, are obtained.

V=[0.88 0.84 0.85 0.86 0.87 0.8462]

Calculate the average assessment results of the six experts.

EV = 0.8577

Calculate the distance between the assessment results of the six subject experts and their assessment mean.

DI=[0.0223 0.0177 0.0077 0.0023 0.0123 0.0115]

The weights of these six experts in the assessment results were calculated by normalizing the distance mentioned above.

KZ=[0.1396 0.1520 0.1791 0.1938 0.1667 0.1688]

According to the weights of non-specialist experts, the weights of four non-specialist experts are calculated.

KFR=*KF***K*(6)=[0.2971 0.1667 0.2391 0.2971]*0.1688

=[0.0502 0.0281 0.0404 0.0502]

The weights of all experts are obtained.

K=[0.1396 0.1520 0.0502 0.1791 0.0281 0.0404 0.1938 0.1667 0.0502]

By analogy, the weights of all experts in evaluating other items are calculated.

$$Wo=\begin{bmatrix} 0.1396 & 0.1904 & 0.0534 & 0.1615 & 0.1703 & 0.0375 & 0.0345 & 0.1587 & 0.0414 \\ 0.1520 & 0.0291 & 0.1462 & 0.1436 & 0.0441 & 0.1667 & 0.0248 & 0.0251 & 0.1849 \\ 0.0502 & 0.0374 & 0.0534 & 0.0317 & 0.1022 & 0.1250 & 0.1923 & 0.1453 & 0.1425 \\ 0.1791 & 0.1912 & 0.1923 & 0.1539 & 0.0315 & 0.1528 & 0.0455 & 0.0502 & 0.0414 \\ 0.0281 & 0.0539 & 0.0321 & 0.1361 & 0.1978 & 0.1528 & 0.2163 & 0.1773 & 0.1607 \\ 0.0404 & 0.1360 & 0.1385 & 0.1436 & 0.1862 & 0.0563 & 0.0414 & 0.1773 & 0.0257 \\ 0.1937 & 0.1728 & 0.1692 & 0.0505 & 0.0592 & 0.0312 & 0.2163 & 0.0314 & 0.1909 \\ 0.1667 & 0.1353 & 0.1615 & 0.1346 & 0.0542 & 0.1388 & 0.0414 & 0.0440 & 0.0458 \\ 0.0502 & 0.0539 & 0.0534 & 0.0445 & 0.1545 & 0.1388 & 0.1875 & 0.1907 & 0.1667 \end{bmatrix}$$

3) The computation of Combination Weight

According to formula (5), the combination weight distribution of subject experts is calculated for all assessment indexes. The results are as follows.

$$W=\begin{bmatrix} 0.1750 & 0.2063 & 0.0545 & 0.1716 & 0.1852 & 0.0426 & 0.0485 & 0.1794 & 0.0470 \\ 0.1812 & 0.0423 & 0.1842 & 0.1627 & 0.0471 & 0.1786 & 0.0437 & 0.0376 & 0.1977 \\ 0.0514 & 0.0465 & 0.0545 & 0.0386 & 0.1511 & 0.1578 & 0.2212 & 0.1727 & 0.1765 \\ 0.1686 & 0.1789 & 0.1795 & 0.1452 & 0.0408 & 0.1478 & 0.0540 & 0.0501 & 0.0470 \\ 0.0403 & 0.0548 & 0.0439 & 0.1362 & 0.1739 & 0.1479 & 0.2019 & 0.1637 & 0.1593 \\ 0.0465 & 0.1513 & 0.1526 & 0.1400 & 0.1681 & 0.0520 & 0.0519 & 0.1637 & 0.0392 \\ 0.1495 & 0.1420 & 0.1402 & 0.0480 & 0.0546 & 0.0394 & 0.1707 & 0.0407 & 0.1481 \\ 0.1360 & 0.1232 & 0.1363 & 0.1127 & 0.0521 & 0.1170 & 0.0519 & 0.0470 & 0.0492 \\ 0.0514 & 0.0548 & 0.0545 & 0.0450 & 0.1273 & 0.1170 & 0.1563 & 0.1454 & 0.1360 \end{bmatrix}$$

It can be seen from the results that the weights of expert are generally higher than those of non-expert experts. By comparing the weights of expert experts in assessment indicators, we can find that the higher the level of expert, the greater the weight of subjective distribution and the more objective it is.

C. Calculating the Credibility of A Single Item to Be Evaluated

According to the assessment results of the subject experts and the weight value of the subject experts, the credibility of all the indicators in the requirement credibility assessment indicators is calculated according to formula (6).

$$C_j = \sum_{i=1}^{9} W_{ij} \times V_{ij} \tag{6}$$

C=[0.8558 0.8954 0.8834 0.8636 0.8848 0.8789 0.8767 0.8570 0.8743]

D. Overall Credibility of Computing Requirements

The overall credibility of the requirements is calculated according to formula (7).

$$C = \sum_{i=1}^{9} W_i \times C_i \tag{7}$$

W_i denotes the weight of the assessment item and C_i denotes the credibility of the assessment item.

The overall credibility of the M&S system requirements is 0.8734. The result shows that the overall credibility of the requirements meets the development needs of the M&S system.

VI. CONCLUSION

In this paper, the method of requirement credibility assessment for M&S is studied. Firstly, the shortcomings of existing methods in evaluating the requirement credibility of M&S system are analyzed. Then, the indicators of requirement credibility assessment are established. On the basis, the method of requirement credibility assessment is studied, and a weighting distribution algorithm based on specialty subject expert group is put forward. Finally, the paper presents the method of requirement credibility assessment. The method of requirement credibility assessment is applied to the requirement credibility assessment of an M&S system.

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