Research and Application on Multi-Layer Matter-Element Extension Synthesis Evaluation Method for Software Quality

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***Abstract*—According to the requirements and characteristics of software quality comprehensive evaluation, a matter-element extension synthesis evaluation method is introduced, and its shortcomings and problems are also discussed in the practical evaluation process. Especially, the matter-element model, correlation function, matter-element value space and multilevel metrics data transmission in the original method that can't adapt for multi-level evaluation index system are analyzed. Moreover, the all elements and algorithm caused these shortcomings and problems have been studied and improved. Then a new multi-layer matter-element extension synthesis evaluation method is created. The metrics results and conclusion obtained by this new evaluation method are more objective, accurate and reliable than the original.**

***Index Terms*—software quality, matter-element model, extension algorithm, evaluation index system, evaluation grade**

I. INTRODUCTION

Software quality is the basic guarantee and the lifeline for the development of the software industry. The fundamental goal of software engineering is to produce high-quality software products under the premise of controlling funds and pace. However, after decades of software engineering research, development and application, software quality assurance has not fundamentally improved. Even now, due to frequent accidents caused by software quality, especially such heavy casualties and damages in the military, economic, financial and national security applications, software quality situation remains worrying. Into the twenty-first century, the development of human society has entered the networking and the information age. The growing scale and high risk of investment, the complexity and difficulty of production are the basic characteristics of modern software industry production and now it is troubled by the bottleneck of the difficulty to ensure software quality. Decades of practice has proved that due to the particularity of software production, the problem of software quality assurance will not be solved completely overnight but requires developing constantly new techniques and methods to improve software quality gradually through long-term software engineering research and practice. Thus, software quality assurance is still the current difficulty and hot issue in the software engineering research and study [1-3].

II. THE PROBLEMS OF SOFTWARE QUALITY METRICS

A. *The Evaluation Algorithm Model*

The standardized software quality model puts forward various factors and the structure reflecting software products' quality [4-5], but the key is how to determine a scientific and accurate method to achieve a quantitative measurement of software quality and the impartiality of evaluation. Objectively speaking, up to now, due to the logic, abstraction, complexity, and large-scale of software products, there is still no a general algorithm of quantitative metrics and evaluation methods of software quality which is recognized and accepted by software engineering. Quantitative evaluation methods of software quality in current research and application, such as weighted average method, are probable statistics method, hierarchy analytic process, fuzzy comprehensive evaluation method, not only have their own advantages, but also have their own flaws [6-9].

Matter-element model and its extension theory represented by Tsai Wen of China had studied for several decades is a scientific theory, technique and method aiming at solving problems of engineering contradictions [10]. Among them, the quality measurement and evaluation of things is a typical application of matter-element model and the extension evaluation method in the field of engineering. In the process of software quality metrics and evaluation, the single-

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level/layer software quality evaluation index system and the matter-element extension evaluation method are designed and used, which results satisfactorily. However, in the meantime, limitations and shortcomings of the single-level/layer evaluation index system and matter-element extension evaluation method are also founded.

When using the extension algorithm of matter-element model for the implementation of the quantitative measurement and evaluation of software quality, the key is to build a variety of matter-element models of software quality evaluation. That is, classical domain, section domain and matter-element model. However due to the logic of software products and the complexity of quality measures, software quality comprehensive evaluation index system generally consists of three or more levels. When matter-element model extension algorithm is used to implement the evaluation of multi-level complex quality index system, the difficulties directly encountered are: How is a multi-level matter-element model created? What is the calculation process of multi-level extension evaluation? How should the weight distribution matched with the process, the selection of correlation function, the division of evaluation grades and the determination of value range be considered and quantified? With the increasing levels of evaluation index system, these problems seem to be extremely complex and difficult. If they can not be quantified and handled, they will inevitably lead to a larger deviation of software quality evaluation result.

Matter-element extension evaluation method of software quality applicable to multi-level evaluation index system will be created based on the three-level software quality evaluation index system in this paper.

B. *The Multi-Level Evaluation Index System*

In order to achieve software quality comprehensive evaluation of matter-element extension, software quality evaluation index system compatible with matter-element extension model and in line with standard model of software quality metrics needs to be established. Here, following the product-centric quality view, software quality metrics model and the system of quality characteristics put forward by McCall and others are selected. Furthermore, this system is in the abstract composed by three levels in accordance with the composition and affiliation constituting the three-level evaluation index system, the index on the lower level is the refinement and decomposition of the index on the upper level, as shown in Table 1. The first level indexes (quality characteristics) abstracted and decomposed from the entire software product quality-related attributes are divided into product operation, product changes and product modifications, which numbered as C_1, C_2 and C_3. The three indexes not only reflect the different composition constituting software quality attributes independently of each other, but also include and summarize all the factors and scope described in software quality. The second level indexes (sub-feature) are the refinement and decomposition of the first one, and include 11 indexes, numbered as $C_{11}, C_{12},\ldots, C_{32}, C_{33}$. The third level indexes (metric element), respectively, are the refinement and decomposition of the second level indexes and atomicity indexes directly used for measurement, a total of 41, numbered as $C_{111}, C_{112},\ldots, C_{332}, C_{333}$. With regard to the weighted calculation of indexes at all levels, AHP or expert evaluation method and other methods can be used to calculate level by level in accordance with the degree of impact that various indexes have on software quality or superior index, and should be marked in the brackets after indexes. Thus, the entire software quality evaluation index system has been established.

TABLE 1. SOFTWARE QUALITY VALUATION INDEX SYSTEM

Software	First level index	Second level index	Third level index
Software Products Quality	Product Operation c_1 (0.4)	correctness c_{11} (0.25)	traceability c_{111}(0.3) completeness c_{112}(0.35) consistency c_{113}(0.35)
		integrity c_{12} (0.2)	access control c_{121}(0.5) access audit c_{122}(0.5)
		efficiency c_{13}(0.15)	execution efficiency c_{131}(0.6) storage efficiency c_{132} (0.4)
		usability c_{14} (0.2)	operability c_{141}(0.3) training c_{142}(0.2) communicativeness c143(0.2) i/o capacity c_{145}(0.15) i/o speed c_{146}(0.15)
		reliability c_{15} (0.2)	error-tolerance c_{151}(0.35) consistency c_{152}(0.3) accuracy c_{153}(0.2) simplicity c_{154}(0.15)
	product revision c_2 (0.3)	maintainability c_{21} (0.4)	consistency c_{211}(0.25) conciseness c_{212}(0.15) modularity c_{213}(0.25) self-descriptiveness c_{214}(0.2)
		flexibility c_{22} (0.25)	modularity c_{221}(0.3) consistency c_{222}(0.25) expandability c_{223}(0.25) self-descriptiveness c_{224}(0.2)
		testabilityX_{23} (0.35)	simplicity c_{231}(0.2) modularity c_{232}(0.3) self-testability c_{233}(0.3) self-descriptiveness c_{234}(0.2)
	Product transition c_3 (0.3)	portability c_{31} (0.4)	modularity c_{311}(0.2) self-descriptiveness c_{312}(0.2) device-independency c_{313}(0.3) soft-independency c_{314}(0.3)
		reusability c_{32} (0.3)	generality c_{321}(0.15) modularity c_{322}(0.3) self-descriptiveness c_{323}(0.15) device-independency c_{324}(0.2) soft-independency c_{325}(0.2)
		interoperability c_{33} (0.3)	modularity c_{331}(0.3) communication commonality c_{332}(0.35) data commonality c_{333}(0.35)

III. MATTER-ELEMENT EXTENSION EVALUATION METHOD

Matter-element extension evaluation method is a new mean to realize a comprehensive evaluation of software quality with its novel theoretical system and measurement method [11-13]. This method will be discussed as below.

A. Matter-Element Model of Software Quality Metrics

As shown in Table 1, once software quality evaluation index system is established, you can proceed with the establishment of matter-element model of quality characteristics (first level indices) to meet the need of software quality extension evaluation method. In order to discuss conveniently and without loss of generality, set m quality characteristics (for example, in Table 1, m=3), respectively C_1, C_2,…, C_m. According to the requirements of comprehensive evaluation of software quality, software quality evaluation criterion can be quantitatively divided into n-level (such as excellent, good, qualified, unqualified) by an expert or through a statistical analysis method, and the value range of the evaluation index C_1, C_2,…, C_m is also determined when software quality evaluation achieve a different grade, thus matter-element model of software quality evaluation (also known as "classical domain") is established as follows:

$$R_{0j} = \begin{bmatrix} N_{0j} & c_1 & V_{0j1} \\ & c_2 & V_{0j2} \\ & \cdots & \cdots \\ & c_m & V_{0jm} \end{bmatrix} = \begin{bmatrix} N_{0j} & c_1 & <a_{0j1}, b_{0j1>} \\ & c_2 & <a_{0j2}, b_{0j2>} \\ & \cdots & \cdots \\ & c_m & <a_{0jm}, b_{0jm>} \end{bmatrix}$$

Where: j = 1, 2, ..., n; R_{0j} means matter-element model of the j-level software quality, N_{0j} refers to the j-level software quality, $V_{0jk} =< a_{0jk}, b_{0jk} >$ (k = 1, 2, ..., m) indicates the value range of c_k, the k-level evaluation index, when software quality achieves the j-level.

In addition, the matter-element model constituted by the allowed value range of each index (the entire value range of each index) of software quality comprehensive evaluation (known as the "section domain ") can be expressed as:

$$R_p = \begin{bmatrix} N_p & c_1 & V_{p1} \\ & c_2 & V_{p2} \\ & \cdots & \cdots \\ & c_m & V_{pm} \end{bmatrix} = \begin{bmatrix} N_p & c_1 & <a_{p1}, b_{p1>} \\ & c_2 & <a_{p2}, b_{p2>} \\ & \cdots & \cdots \\ & c_m & <a_{pm}, b_{pm>} \end{bmatrix},$$

Where R_p means section domain of matter-element model of software quality comprehensive evaluation, N_p refers to all the grades of software quality evaluation results. $V_{pk} =< a_{pk}, b_{pk} >$ indicates the value range of the index ck in N_p, $V_{0jk} \subset V_{pk}$, j=1, 2, …, n; k=1, 2, … , m.

For evaluating software, all indicators of the actual data or analysis results get through the actual measurement (measurement) can be expressed using the following matter-element model:

$$R = \begin{bmatrix} N & c_1 & v_1 \\ & c_2 & v_2 \\ & \cdots & \cdots \\ & c_m & v_m \end{bmatrix}$$

, where k=1, 2, … , m; N refers to the quality of software to be evaluated, v_k indicates the first k-index measurement of software to be evaluated.

B. Single-Level Extended Evaluation Method

After the establishment of matter-element model of software quality comprehensive evaluation, it is necessary to evaluate software quality in accordance with evaluation grade. Therefore, the "proximity" between matter-element model to be evaluated and the classical domain of matter-element model needs to be calculated. In practice, different methods of calculation of the "proximity" should be selected according to characteristics of indexes. Here elementary correlation function of extenics can be used. Order:

$$\rho(v_k, V_{0jk}) = \left| v_k - \frac{a_{0jk} + b_{0jk}}{2} \right| - \frac{1}{2}(b_{0jk} - a_{0jk}),$$

where k=1, 2, … , m; j=1, 2, … , n.

$$\rho(v_k, V_{pk}) = \left| v_k - \frac{a_{pk} + b_{pk}}{2} \right| - \frac{1}{2}(b_{pk} - a_{pk}),$$

where k=1, 2, … , m.

It respectively indicates the "proximity" of point v_k and interval V_{0jk}, V_{pk}. For example, when $\rho(v_k, V_{pk}) \ge 0$, it shows that v_k is within the range of V_{pk}. while $\rho(v_k, V_{pk}) \le 0$, it shows that v_k is not within the range of V_{pk}. And various negative values express v_k is in different locations within the range of V_{pk}.

Order: $D(v_k, V_{pk}, V_{0jk}) = \rho(v_k, V_{pk}) - \rho(v_k, V_{0jk})$, it indicates the "bit value" of point of v_k and interval V_{0jk}, V_{pk}.

Order: $$K_j(v_k) = \frac{\rho(v_k, V_{0jk})}{D(v_k, V_{pk}, V_{0jk})}$$, where: k=1, 2, …, m, j=1, 2, …, n. It means the correlation between C_k, the evaluation index k of matter-element to be evaluated with the j-grade evaluation results, and $-\infty< (v_k) <+\infty$. If $K_j(v_k)\ge 0$, it means that v_k belongs to V_{0jk} and the larger $K_j(v_k)$ is, the more properties of V_{0jk} v_k has. If $K_j(v_k)\le 0$, it means that v_k does not belong to V_{0jk} and the smaller $K_j(v_k)$ is, the farther v_k is from the interval V_{0jk}.

Thereby the correlation matrix between various evaluation indexes of software to be evaluated and various evaluation grades can be calculated as $K=[K_j(v_k)_{m\times n}]$. According to the correlation matrix $K=[K_j(v_k)_{m\times n}]$, calculated as follows:

$$K^*(v_k) = K_{i_0}(v_k) = \max_{1 \le j \le n} K_j(v_k)$$, k=1, 2, …, m.

Then $K_{i_0}(v_k)$ refers to the i-grade evaluation of the k evaluation index and comprehensive evaluation of software quality can be decided by $K_{i_0}(v_k)$ As follows:

If $\alpha_i(\sum_{i=1}^{m}\alpha_i = 1)$ is the weight coefficient of software quality evaluation index, then the correlation between software to be evaluated and the first j-grade evaluation results are:

$$K_j(R) = \sum_{i=1}^{m}\alpha_i K_j(v_{i)})$$, Where: j = 1, 2, ..., n; then calculated as follows: $K_{j_0}(R) = \max_{1 \le j \le n} K_j(R)$. Thus j_0, the comprehensive evaluation rating result of software quality being assessed, can be available.

IV. Establishing a New Multi-Layer Matter-Element Extension Evaluation Method

A new multi-layer matter-element extension evaluation method is created as follows:

1) Establish Software Quality Evaluation Index System

For the implementation of comprehensive assessment of software quality, first, the quality evaluation index system of software is going to being assessed, as well as the weight distribution of various indexes should be built. Here, the three evaluation index systems taking product quality as the center are introduced, as shown in Table 1. The weights of various indexes can be calculated through AHP or DELPH the polling method and the values in parentheses after indexes in Table 1 are the weight values of corresponding indexes [14-15].

2) Establish Software Quality Evaluation Grades

According to the requirements and specifications of software quality evaluation, the reasonable comprehensive evaluation grades of software quality should be given, namely reviews collection. In general, comprehensive assessment grades of software quality taking product quality as the center of software quality are: excellent, good, qualified, unqualified.

3) Calculate The Classical Domain Matter- Element Model of Indexes at All Levels

According to the established software quality evaluation index system, under the guidance of experts in the field of evaluation, each index's matter-element model of classical domain and section domain can be established level by level from the beginning of the first level indexes to the end of the third level indexes using either software statistical analysis tools or some kind of mathematical-statistical algorithm.

4) Calculate the Matter-element Model to Be Evaluated of The Third-Level Indexes

After establishing each index's matter-element model of classical domain and section domain, evaluating the measurement and analysis of software should be implemented through software test and assessing analysis tools and matter-element model of the third level indexes (metric element) should be calculated according to measured values. Here the algorithm of evaluation factors and their corresponding measurement and analysis tools for software metrics elements, which are studied by U.S. Air Force RADC (Rome Air Development Center), are adopted to find the third level indexes of the actual measured values. [16]. Due to space limitations, here only taking "C_{111} = the number of traceable requirements / the total number of needs, C_{112} = the sum of marks to meet the terms of completeness / the total terms, C_{113} = 1 – the number of module violating rules / module total number" as a calculation example, the measurement of the remaining third level indexes will not be repeated here. Please refer to the data definitions of RADC. Note that this step is only to measure and calculate matter-element model to be evaluated of the third level indexes, the first and second level indexes can be achieved in the evaluation process.

5) Calculate The Extension Measurement of the Second-Level Indexes

After the establishment of a variety of matter-element models of third level indexes, the evaluation and measurement of second level indexes can be carried out using matter-element extension evaluation method. In order to maintain the consistency of evaluation values and the classical domain values range of matter-element model the evaluation values should be adjusted according to second level indexes' corresponding value range of classical domain. Suppose the evaluation value of second level index, C_{ij} is X_{0jik}, where $0j$ indicates the assessment grade, ik refers to second level index C_{ik}. If classical domain values range of $0j$-grade evaluation corresponding with C_{ik} is $<a_{0jik}, b_{0jik}>$, when $X_{0jik}<0$, results in $X_{0jik}=a_{0jik}$. when $0 \le X_{0jik} \le 1$, results in $X_{0jik}=a_{0jik}+(b_{0jik}-a_{0jik})*X_{0jik}$. when $X_{0jik}>1$, results in $X_{0jik}=b_{0jik}$. Thus calculated X_{0jik}, adjusted value, can be used as the actual measure value of second level index C_{ik}, which constitutes matter-element model to be evaluated of second level indexes.

6) Extension Measurement of the First Level Indexes

When the evaluated matter-element model of the second level indexes of the previous step is established, the evaluation and measurement of the first level indexes can be implemented in accordance with matter-element extension evaluation method. The measure values should also be adjusted according to the classical domain value range of matter-element model corresponding with the first level indexes. The adjustment method is similar to the previous step (step 5). After the adjustment of the measure values of the first level indexes, matter-element model of the first level indexes will be created with such adjusted measure values for the implementation of software quality comprehensive evaluation.

7) Software Quality Comprehensive Evaluation

When the first level indexes matter-element model is established, software quality comprehensive measurement could be implemented based on matter-element extension evaluation method. Then assessed software quality is analyzed and evaluated objectively and according to the result of software quality comprehensive measurement impartially. If necessary, software quality evaluation reports can also be formed based on the evaluation conclusions. Thus, the introduction to multi-level matter-element extension comprehensive evaluation method of software quality has been completed.

V. APPLICATION OF THE NEW EVALUATION METHOD

1) Determine software quality evaluation index system and evaluation grade

The assessed software quality evaluation index system is as shown in Table 1. Each weight of index has also been given. Assessment grades are divided into five: excellent, good, medium (general), poor, very poor.

2) Establish the Matter-Element Model of Indexes at All Levels

In order to facilitate understanding, and also due to limit space, matter-element models of the first level indexes and part of the second, third level indexes are established to demonstrate the process of multi-level extension evaluation algorithm.

TABLE 2. FIRST LEVEL INDEXES MATTER ELEMENT MODEL

Index	Excellent	Good	Medium	Poor	Very poor
C_1	(0.82,1)	(0.62,0.82)	(0.45,0.62)	(0.35,0.45)	(0,0.35)
C_2	(0.83,1)	(0.70,0.83)	(0.50,0.70)	(0.36,0.50)	(0,0.36)
C_3	(0.82,1)	(0.60,0.82)	(0.46,0.60)	(0.35,0.46)	(0,0.35)

The classical domain matter-element model of the first level indexes, C_1, C_2 and C_3, through the evaluation of experts and evaluation statistical analysis is shown in Table 2.

Section domain matter-element model is as follows:

$$R_p = \begin{bmatrix} N_p & C_1 & <0,1> \\ & C_2 & <0,1> \\ & C_3 & <0,1> \end{bmatrix}$$

Classical domain matter-element model of the second level indexes, C_{11}, C_{12}, C_{13}, C_{14}, C_{15}, associated with the first level index, C_1, is shown in Table 3. Section domain matter-element model is R_{p1}.

TABLE 3. SECOND LEVEL INDEXES MATTER ELEMENT MODEL

Index	Excellent	Good	Medium	Poor	Very poor
C_{11}	(0.83,1)	(0.71,0.83)	(0.55,0.71)	(0.40,0.55)	(0.20,0.40)
C_{12}	(0.86,1)	(0.74,0.86)	(0.57,0.74)	(0.35,0.57)	(0.15,0.35)
C_{13}	(0.82,1)	(0.70,0.82)	(0.58,0.70)	(0.42,0.58)	(0.18,0.42)
C_{14}	(0.85,1)	(0.72,0.85)	(0.60,0.72)	(0.46,0.60	(0.20,0.46)
C_{15}	(0.84,1)	(0.75,0.84)	(0.60,0.75)	(0.40,0.60)	(0.19,0.40)

$$R_{p1} = \begin{bmatrix} N_{p1} & C_{11} & <0,1> \\ & C_{12} & <0,1> \\ & C_{13} & <0,1> \\ & C_{14} & <0,1> \\ & C_{15} & <0,1> \end{bmatrix}$$

Classical domain matter-element model of the third level indexes, C_{111}, C_{112} and C_{113}, associated with the second level index, C_{11}, is shown in Table 4. Section domain matter-element model is R_{p11}.

TABLE 4. THIRD LEVEL INDEXES MATTER ELEMENT MODEL

Index	Excellent	Good	Medium	Poor	Very poor
C_{111}	(0.85,1)	(0.75,0.85)	(0.55,0.75)	(0.40,0.55)	(0,0.40)
C_{112}	(0.86,1)	(0.74,0.86)	(0.57,0.74)	(0.35,0.57)	(0,0.35)
C_{113}	(0.84,1)	(0.75,0.84)	(0.60,0.75)	(0.40,0.60)	(0,0.40)

$$R_{p11} = \begin{bmatrix} N_p & C_{111} & <0,1> \\ & C_{112} & <0,1> \\ & C_{113} & <0,1> \end{bmatrix}$$

3) Calculate the Third-Level Indexes Matter-element Model to Be Evaluated

For complex software products to be evaluated, the measurement of third level indexes (metric element) and the creation of matter-element model to be evaluated must rely on software testing and measure tools. Here the author adopts evaluation factors measurement algorithm studied by the U.S. Air Force RADC (Rome Air Development Center), measures and derives the actual measure values of third level indexes. In order to facilitate understanding and discussion, the third level indexes C_{111} = 0.73, C_{112} = 0.81, C_{113} = 0.65 associated with the second level index, C_{11} , can be obtained through the above-mentioned RADC metric element formulas. Thus the established matter-element model to be evaluated of index, C_{11} is as follows:

$$R_{11} = \begin{bmatrix} N_{11} & C_{111} & 0.73 \\ & C_{112} & 0.81 \\ & C_{113} & 0.65 \end{bmatrix}$$

4) Extension Evaluation of the Second-Level Indexes

When matter-element models of classical domain and section domain of indexes at all levels, as well as matter-element to be evaluated of third level indexes are established, extension evaluation can be implemented from low-level to high level. First, the evaluation values of the second indexes should be obtained by matter-element model of the third level indexes. Now take the evaluation of C_{11} as an example. In order to facilitate understanding of the evaluation process, assume that the proximity between indexes at all levels and their classical domain interval is elementary correlation functions, then obtain the correlation matrix of three indexes, C_{111}, C_{112}, C_{113} associated with C_{11} as follows:

$$K = [K_j(v_k)]_{3\times 5} =$$

$$\begin{bmatrix} -0.31 & -0.07 & 0.08 & -0.40 & -0.55 \\ -0.21 & 0.36 & -0.27 & -0.56 & -0.71 \\ -0.35 & -0.22 & 0.17 & -0.13 & -0.42 \end{bmatrix}$$

From Table 1 the weight of the third level indexes, C_{111}, C_{112}, C_{113}, is A = (0.30, 0.35, 0.35), then $A \bullet K$ = (-0.29,0.03, -0.01, -0.36, -0.56), that is, the correlation degree of index to be evaluated, C_{11} is: $K_1(R)$ =- 0.29, $K_2(R)$ = 0.03, $K_3(R)$ =- 0.01, $K_4(R)$ =- 0.36, $K_5(R)$ =- 0.56. Take $K_2(R)=\max_{j=1,2,3,4,5} K_j(R)$ =0.03. Thus quantitatively measure the second level index, C_{11}, and obtain the comprehensive evaluation grade is 02. That is: evaluation is good, and its evaluation value is 0.03.

5) Calculate the Matter-Element Model to Be Evaluated of the Second Level Indexes

When the comprehensive evaluation value of the second level indexes is obtained, it is necessary to adjust the evaluation value of the second level indexes to ensure the validity and consistency of the multi-level extension matter-element evaluation algorithm data. C_{11}, for example, due to the evaluation of C_{11} level is 02, its corresponding review is good, X_{0211} = 0.03. In Table 3, the value range of C_{11} corresponding to good evaluation grade is<0.71, 0.83>, and then using the formula $X_{0jik} = a_{0jik} + \left(b_{0jik} - a_{0jik}\right) \times X_{oijk}$, the adjustment measure value of C_{11} can be obtained: X_{0211}=0.71+(0.83-0.71)*0.03=0.71+0.0036=0.7136. To demonstrate the calculation process of matter-element extension evaluation, the adjusted values of C_{12}, C_{13}, C_{14}, C_{15} can also be obtained based on similar methods and processes. They are as follows: 0.8245, 0.7305, 0.7636 and 0.8685. As a result, matter-element model to be evaluated of the second level indexes associated with the first level index, C_1, is as follows:

$$R_1 = \begin{bmatrix} N & C_{11} & 0.7136 \\ & C_{12} & 0.8245 \\ & C_{13} & 0.7305 \\ & C_{14} & 0.7636 \\ & C_{15} & 0.8685 \end{bmatrix}$$

Of course, the same method can be applied to construct all matter-element models to be evaluated of the second level indexes associated with the first level indexes, C_2, C_3, getting ready for the evaluation of each the first level index.

6) Extension Evaluation of the First Level Indexes

After matter-element models to be evaluated of the second level indexes are constructed, matter-element extension evaluation of the first level indexes can be respectively implemented. Take C_1 as an example to demonstrate the calculation process of evaluation. In order to facilitate the discussion, assume that the proximity between second level index's matter-element model to be evaluated and its classical domain is elementary correlation functions, the proximity of to be evaluated with the classical field of matter-element is still elementary correlation function. Thus, the correlation matrix of the second level indexes, C_{11}, C_{12}, C_{13}, C_{14}, C_{15}, associated with C_1 can be obtained.

$$K = [K_j(v_k)]_{5\times5} = \begin{bmatrix} -0.29 & -0.11 & 0.15 & -0.36 & -0.52 \\ -0.17 & 0.25 & -0.33 & -0.59 & -0.73 \\ -0.25 & 0.13 & -0.10 & -0.36 & -0.54 \\ -0.27 & 0.23 & -0.16 & -0.41 & -0.56 \\ 0.28 & -0.18 & -0.47 & -0.67 & -0.78 \end{bmatrix}$$

From Table 1 the weight of C_{11}, C_{12}, C_{13}, C_{14}, C_{15} is A = (0.30,0.35,0.35), then $A \bullet K$ =(-0.1, 0.05, -0.1, -0.4, -0.63), that is, the correlation degree of index to be evaluated, $C_1$is: $K_1(R)$=-0.1, $K_2(R)$=0.0, $K_3(R)$=-0.1, $K_4(R)$=-0.4, $K_5(R)$=-0.63. Take $K_2(R) = \max_{j=1,2,3,4,5} K_j(R)$ =0.05. Thus quantitatively measure the first level index, C_1, and obtain the comprehensive evaluation grade is 02. That is: evaluation is good, and its evaluation value is. X_{021}=0.05.

In Table 2, the value range of C_{11} corresponding to evaluation grade good is <0.71, 0.83>, and then adjust $X_{021} = 0.62 + \left(0.82 - 0.62\right) \times 0.05 = 0.63$. Similarly, the adjusted values corresponding to C_2, C_3 can be calculated. They are respectively X_{012} = 0.86, X_{033} = 0.67. Therefore, matter-element model to be evaluated of the first level indexes is as follows:

$$R = \begin{bmatrix} N & C_1 & 0.63 \\ & C_2 & 0.86 \\ & C_3 & 0.67 \end{bmatrix}$$

7) Comprehensive Evaluation of Software Quality

When R which is matter-element model to be evaluated of the first level indexes is determined, matter-element extension evaluation of the first level indexes can be respectively implemented. The proximity is still calculated through elementary correlation functions. According to matter-element extension evaluation method, the correlation matrix of the first level indexes of software quality to be evaluated can be obtained.

$$K = [K_j(v_k)]_{3\times5} = \begin{bmatrix} -0.34 & 0.03 & -0.03 & -0.33 & -0.43 \\ 0.27 & -0.18 & -0.53 & -0.72 & -0.78 \\ -0.31 & 0.27 & -0.18 & -0.18 & -0.49 \end{bmatrix}$$

Thus available: $K^*(v_1)=K_2(v_1)$=0.0, $K^*(v_2)=K1(v_2)$=0.2, $K^*(v_3)=K2(v_3)$=0.27. Therefore, the evaluation findings of various quality characteristics of the evaluated software can be obtained. They are as follows: operation and modification: second grade, that is, good; Transferability, third grade, that is, medium or general.

From Table 1 the weight of the first level indexes are respectively A=(0.40, 0.30, 0.30), then $A \bullet K$=(-0.16, 0.04, -0.26, -0.41, -0.57), that is, the correlation degree of software to be evaluated is: $K_1(R)$=-0.16, $K_2(R)$=0.04, $K_3(R)$=-0.25, $K_4(R)$=-0.41, $K_5(R)$=-0.57. Take $K_2(R)$

$= \max_{j=1,2,3,4,5} K_j(R)$ =0.04. Thus quantitatively measure that the comprehensive evaluation grade of software quality to be evaluated is 2, that is: the final evaluation is good.

VI. Conclusion

From the discussion above, it is through software quality multi-level extension matter-element comprehensive evaluation method that complex qualitative index system reflecting software quality is organically combined with objective qualitative measurement method and many other problems are satisfactorily resolved, such as the creation of multi-level matter-element model, the measurement and calculation of evaluation results (including intermediate results) and the consistent transfer of layer by layer, the weight distribution of matter-element, the determination of correlation function, the division of evaluation grades, and the determination of indexes value range, etc. Comparing with the current popular software quality assessment methods (such as the weighted statistical method, analytic hierarchy process method, fuzzy comprehensive evaluation method, etc.), the newly created multi-level extension matter-element comprehensive evaluation method may well be a better way. Moreover, to achieve the computability and automation of software quality comprehensive evaluation, it laid the basis for quantification [17].

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