

A Metrics Method for Software Architecture Adaptability

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Abstract—Based on GQM(Goal Question Metric) approach, this paper presents a new process-oriented metrics for software architecture adaptability. This method extends and improves the GQM method. It develops process-oriented processes for metrics modeling, introduces data and validation levels, adds structured description of metrics, and defines new indexes of metrics.

Index Terms—Goal Question Metric, software architecture, adaptability, metrics, Interval Analytic Hierarchy Process, Data Envelopment Analysis

I. INTRODUCTION

Metrics is a process that assigns numbers or symbols to the attributes of entities in the real world based on clearly defined rules. Software quality measurement technique is a quantitative reflection, and its fundamental purpose is to assess the individual and the system or to predict the future development. Only through metrics, software engineering can enter the scientific stage.

Because software architecture development is the first phase in the design process, therefore, the measure of the quality of architecture will help us determine the quality of the final software. As an aspect of architecture quality characteristics, adaptability has a certain degree of specificity. The current research on the adaptability is still imperfect, lacks qualitative and quantitative metrics index and systemic evaluation method.

The current architecture analysis and evaluation methods are mostly based on the scene technology. In order to analyze the quality attributes of architecture more accurately, the majority of researchers believe that the use of metrics in the architecture stage to evaluate attribute is one of more precise technology. It includes metrics options for the quality attributes, the scale of metrics and a set of metrics methods. We can do this in two ways: first, adapting the existing measurement techniques, such as the dynamic complexity and dynamic coupling used in the design and code level validated effective object-oriented indexes. Object-oriented adaptability metrics for software maintainability prediction is very effective, because the required data

must be collected from the source code. But in the architecture phase, the prototype system has not been developed, and there is no source code. Therefore the second method is that definition and validation new measurement indexes in accordance with the characteristics of architecture, improving the metrics process. At present, some scholars are doing in this area. GQM (goal question metric) is a good technology used to define new metrics process. Based on GQM approach, integrating the research status, this paper presents a new process-oriented metrics for software architecture adaptability.

II. GQM

GQM (Goal Question Metric) is a widely used metrics modeling method. GQM is a goal-oriented (goal-oriented) method for software products and process metrics from Professor Victor Basisli of Maryland University. GQM refined goal to metrics by stepwise refinement approach, summarized and decomposed the objectives of the organization to metrics indexes, and refined these indexes to the value which can be measured. It is a goal-oriented metrics methods and a scientific and logical way of thinking for managers too.

The principle of the GQM approach is providing a model to help software managers to design a set of software metrics system for the management objectives, reduce and integrate the various objectives of software process and product model by systematic approach. GQM approach has strong flexibility and maneuverability. Implementation process is top-down analysis and bottom-up implementation process. First metrics target G (Goal) is putted forward, refining the goal to specific issue of Q (Question) of the process or product, and these questions can be answered in the way of measure M (Metric). So these vague and abstract goals are broken down into specific and measurable problems. Generally it is divided into three phases: the establishment of GQM metrics plan, the implementation of metrics and summarization of experiences. Each stage is divided into a number of activities. GQM measurement plan includes the early

development research, the definition of GQM (goal, question, metric) and the establishment of metrics plan (including strategies and technology). Metrics implementation phase includes data collection, analysis and interpretation. Summarization of experiences includes the submission of final report and collection of experiences.

GQM approach has three levels ^[1]: conceptual level(Goal), operational level (Question), quantitative level (Metric). GQM provides a top-down metrics definition approach and bottom-up data collection and interpretation approach, as shown in Figure 1.

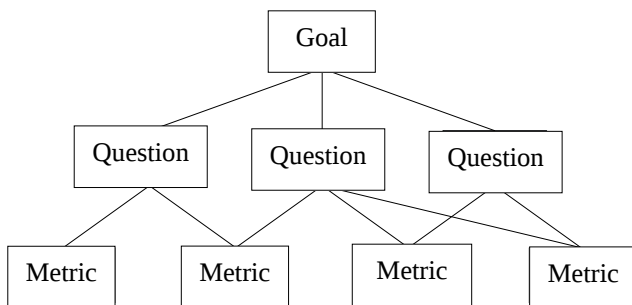


Figure 1 GQM model

- Conceptual level(Goal): A goal is defined for an object, for a variety of reasons, with respect to various models of quality, from various points of view, relative to a particular environment.
- Operational level (Question): A set of questions is used to characterize the way the assessment/achievement of a specific goal is going to be performed based on some characterizing model. Questions try to characterize the object of measurement with respect to a selected quality issue and to determine its quality from the selected viewpoint.
- Quantitative level(Metric): A set of data is associated with every question in order to answer it in a quantitative way.

The advantages of the method are as follows:

- It ensures the adequacy, consistency and integrity of metrics plan and data collection. The designer of metrics program (that is metrics analyst) must get a lot of information and the dependence between them. To ensure the metrics collection is adequate, consistent and integrated, the analyst should understand why to metrics these properties accurately, what is the underlying assumption, and what the model will be applied to the use of metrics data.
- It can help manage the complexity of metrics plan. When a large number of measurable attributes exist and the number of metrics for the attributes increases accordingly, the degree of complexity of the metrics plan will undoubtedly increase. In addition, the approach selected in order to adequately metrics an attribute also

depends on the goal of metrics. If you do not have a goal-driven framework, the metrics plan will soon be out of control. No one mechanism capturing the dependence between attributes, the metrics plan is very easy to introduce inconsistency to any changes.

- In addition, it can also help software organizations to discuss the metrics and improvements of the goal based on the structure of a common understanding and eventually form a consensus. In turn, this also enabled the organizations to define the metrics and models accepted widely in the organizations.

GQM approach has been widely used in the software industry, and many companies have published the application experience. In addition, there are quite a few people has improved or added GQM approach based on the practical experience, some of them have also developed metrics tools to support the implementation of GQM approach.

Although GQM have pointed out the process of metrics, but it is still too abstract for the user. For this reason, many scholars propose the point of view to combine the metrics and process model.

III. A METRICS METHOD FOR SOFTWARE ARCHITECTURE ADAPTABILITY BASED ON GQM

Based on GQM approach, integrating the research status, this paper presents a new process-oriented metrics for software architecture adaptability. The expansion and improvement for GQM include the following aspects.

A. Process-oriented modeling process steps

This method is used to quantitative metrics for software architecture adaptability. Metrics modeling process is divided into the following four steps:

1) Determining the goal

Goal is a standard software metrics goals, it has a standard format. It should include five parts: metrics service objects, the aims, metrics objects, the attributes of the objects and metrics environment.

- Determining business goal: The metrics goals must be derived from business goals and maintained their traceability. Business goals are the highest purpose of the enterprise, and they must be determined together with the enterprise's manager to determine the correct priority and guarantee not to miss the important goals.
- Determining the obtainment needed: The process will produce a series of questions lists. They do not needed to be classified accurately, but list all the important questions.
- Determining the sub-goals: We group the relevant questions, which results in a series of sub-goals related to management or the implementation of activities.
- Determining the entities and attributes related to sub-goals: This process provides the information

of entities and attributes obtained to achieve sub-goals.

- Formatting metrics goals: The metrics goal formatted should include four elements: the object, the purpose, the focus group concerned and the environment for metrics.
- Determining the measurable problems and related indicators helping achieve targets: We must use metrics goals formatted to achieve quantified questions and indicators (including the various types of chart).

2) Data collection and analysis

Data collection is a process, which includes data acquisition, data validation, data preservation and other activities. Software organizations should monitor the data collection process to ensure that the data collected is timely, integrated, correct and reliable. If the result is reliable, the collection process is certainly stable and under control. When another organization or software process involves in it, the complexity of data collection process will increase. We must use standard metrics tools or protocols to ensure the consistency of data collected by different organizations or individuals using the same methods of data acquisition.

Data collection and analysis primarily concern about how to make data visible and be captured appropriately, how to ensure the quality of data and how to save and manage data to be analyzed. Data access can be manual methods, can also use automatic data capture tools.

Before data analysis, we must inspect and assess the data recorded to enhance the credibility of the process analysis. In the process of data selection and definition, collection, recording and preservation of metrics results, the following criteria shall be complied with.

- Authenticity: Strict data must have passed inspection, be guaranteed to be collected in accordance with specifications and no error.
- Synchronization: When the values of two or more attributes associate with each other in the event of time, it should ensure that their producing time is synchronous.
- Consistency: Ensuring the definition for the record values of the same type is same.
- Effectiveness: Metrics should be clearly defined to ensure that the value used to describe an attribute can be a true reflection of the property.

Data collection provides the data flow from data collection point to the evaluation of metrics, determine the conditions of data collection, give the instructions of tools for use and data storage protocols.

3) Metrics structure

Metrics concept can be formalized as a metrics structure, which strictly designates metrics objects and

how to combine data to generate a result needed. We can divide metrics tasks into multi-level.

- Metrics Definition: The organization clearly defines the metric formula and the meaning of metrics data, uses a structured approach to ensure that no important metrics is missed.
- Determining the activities of metrics: It mainly includes the identification of data sources, the determination of the method, frequency, executor of data collection, the determination of the users, the definition of these data analysis reports, the definition for the tools of auxiliary process automation and process management and the determination of data collection process.

4) Metrics scheme

The plan prepared to achieve metrics should include: the purposes, the background, the range of metrics, the relation of other process improvement activities, the task, activities, human resources, metrics progress, measurement functions and supported activities achieving metrics.

Each metrics goal corresponds to a metrics scheme. It breaks a goal into a set of problems, and then breaks each problem into a set of metrics process descriptions. It is a necessary process, which defines specific attributes to achieve the goals. With the metrics scheme, we can make specific metrics and achieve the objective evaluation by analyzing the metrics data sequentially.

Metrics scheme provides a consistent way to identify, select and specify the information needed by software architecture adaptation. And it integrates them into the analysis and evaluation of software architecture. The result of metrics scheme is the achievement of metrics plan.

Step (1) produces the goal G of the method by the analysis and decomposition for the business goals. Step (2), step (3) and step (4) map the goals to the corresponding metrics. Throughout the process, must be kept track of two: one is the goal G to go back to business goals, and the other is Measure M to the target G, so we can ensure that the measure will not deviate from the organizational goals and avoid unnecessary data collection, waste of manpower.

B. Introducing data level D and validation level V

After the decompositions, the calculation mode and the data used will generate a new change. Data item D (Data) is used to provide measurement data level for relational metrics. When the metrics itself is direct measurement data, D and M are the same.

Introducing validation level V (Validation) aims at analyzing the metrics method after data collection. Thereby in the metrics process, we can more clearly abnegate excrescent or impossible collections to improve the collection efficiency and reduce costs. As shown in Figure 2.

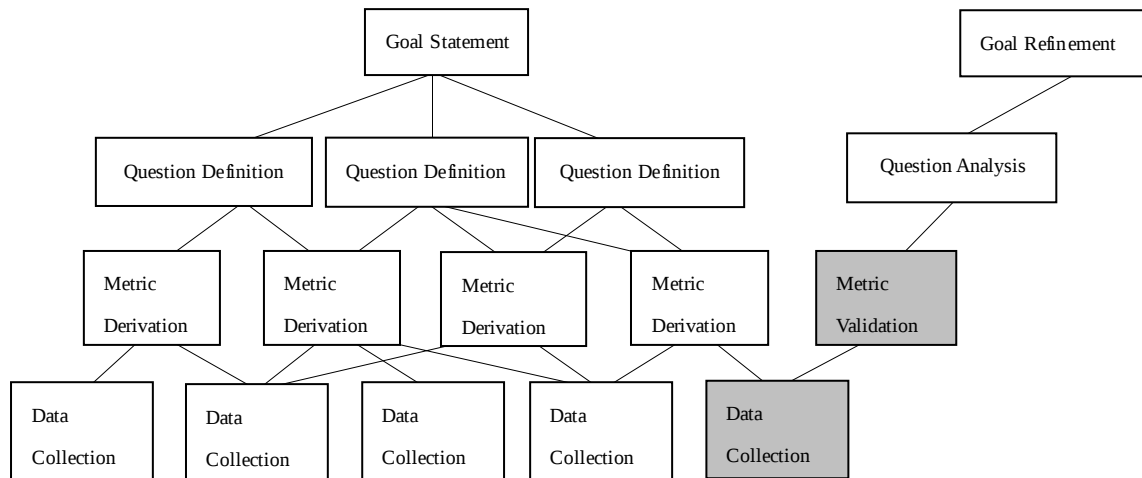


Figure 2 Extended Metrics

C. Adding structured description of metrics

The purpose of structured description for metrics, data items and validation items is to help us to make the metrics, define the data and ensure consistency of understanding.

Definition 1 (Metrics Model): Metric Model (recorded as T) is a 5-tuple.

$$T = (G, Q, M, D, V)$$

The sign G denotes the goals. Q denotes the problems achieving from G. M denotes quantitative answers to the Q and the decomposition of the entity. D denotes data items of the calculation supporting M. V denotes the analysis and confirmation after D.

Definition 2 (metrics set): each metrics of metrics set (recorded as M-Set) is an 8-tuple.

$$M_i = (N, C, Q, T, D, F, E, M')$$

The sign N denotes the name of metrics, which is unique. C denotes the cost. Q denotes the relational problems. T denotes relational tools such as data storage tools, collection tools and analysis tools. D denotes the data items required. F denotes calculation formula or steps. E denotes the expectations. When the metrics has the decomposition of entities, we denote it by M' .

Definition 3 (data item): each data item of data item set (recorded as D-Set) is a 9-tuple.

$$Di = (N, M, De, T, C, W, P, S, V)$$

The sign N denotes the name of data item, which is unique. M denotes the relevant metrics. De denotes the definition of the data item. T denotes data collection time. C denotes the person making data collection. W denotes data collection methods. P denotes data storage locations. S denotes data type. V denotes validation item associated with the data item.

Definition 4 (validation item): each validation item of validation item set (recorded as V-Set) is a 7-tuples.

$$Vi = (N, M, Ve, T, C, W, D)$$

The sign N denotes the name of validation item, which is unique. M denotes the relevant metrics. Ve denotes the definition of the validation item. T denotes metrics validation time. C denotes the person making the metrics. W denotes metrics validation methods. D denotes data item associated with the metrics.

D. New indexes of metrics

As an aspect of the quality attributes, the current research for adaptability is still very imperfect. Metrics indexes for adaptability putted forward by many literatures are useful in the stage of software products, but the metrics for early phase of software products, software architecture phase more effectively forecast the final software products. At present there is a lack of qualitative and quantitative indexes of metrics.

Referring to software performance evaluation model [2] and survival environment elements of software, this paper presents a quantitative software architecture adaptability metrics indexes model from three dimensions and seven environment elements. As shown in Figure 3. The three dimensions are as follows: Economic dimension (referred to as E), Social dimension (referred to as S) and Technical dimension (referred to as T). In this model, we take into account the three dimensions by using a taper tetrahedron. The three dimensions respectively denote as the ox, oy and oz axes. Through measuring the volume of the tetrahedron, we can achieve the quantitative metrics of software architecture adaptability.

Economic dimension stands for the point of view of managers, and mainly considers cost elements and market elements. Social dimension stands for the point of view of users, and mainly considers customers and end-users elements. Technical dimension stands for the point of view of developers, and mainly considers the metrics of technical quality: requirement elements, structural elements, technical elements and the elements of operating environment.

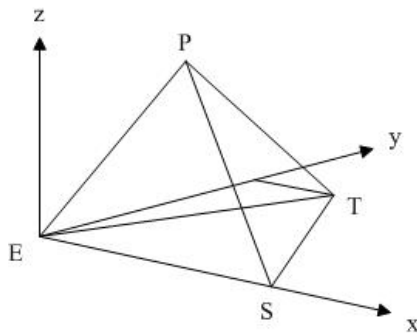


Figure 3 three-dimension metrics indexes model for software architecture adaptability

E. Decision-making method based on IAHP and DEA

AHP put forward by a famous expert of operational research in America is a practical and multi-properties decision making method. This method combines qualitative and quantitative analysis to deal with various decision-making elements. It is systemic, flexible and terse and applied in the social and economic fields quickly and widely. The traditional AHP uses an exact number to show the judgment that the expert make when they compare the two projects. But it is difficult for a decision-making expert to do this in the practical situation. The problem we meet is more complicated and sensitive and the known information is not all-sided and assured enough. Therefore, there is uncertainty and subjectivity when the expert makes a comparison between the two projects. In order to solve these problems, IAHP comes into being. It uses interval number instead of point value to form judgment matrix and then get the interval weight vector. The original data and result are also expressed by interval numbers so that the flexible decision realizes. In the interval AHP, decision-making expert can ascertain the importance of various elements but there is disaccord in judgment matrix. While DEA is a new method of evaluating efficiency based on the idea of relative efficiency. It is one of the effective ways of dealing with multi-goals decision-making problems. CCR model of DEA adopts variation weights to evaluate the decision-making item on the base of input and output data. It just focuses on the status value of the considered elements corresponding to the decision-made objects. Therefore, the combining of the both can give a reasonable decision-making method to solve the above problems.

The traditional combining of AHP and DEA are most often adopted. Either point weights^[14-17] or interval weights^[18] are regarded as constraints. Based on this, this paper improves the method given by literature^[14-17], uses interval number to express the original data and result, makes the interval weight vector constraints, emphasizes on the differences between AHP and DEA and their own advantages. It provides a new thought for multi-goals

decision-making problems and uses an example of practical application to show its effectiveness.

1) Algorithm

Suppose the number of the objects of the same type is n . The objects are arranged according to the status value that each object has in the m aspects. The bigger the status value of these elements is, the better it is.

The first step: use IAHP^[19-20] to get the right weights of these S kinds of elements.

For the influence of various uncertain elements, it is difficult for the decision-making experts to use an exact number to show the judgment they make after the comparison between the two projects. The experts can only give a range in the form of interval. That is $a_{ij} =$

$\left[\underline{a}_{ij}, \overline{a}_{ij} \right]$. It denotes the judgment the experts make after comparing the importance of the project I and J . Here, $\underline{a}_{ij}, \overline{a}_{ij}$ separately refers to the upper limit and lower limit. Thereupon, the comparison judgment matrix of these n elements goes like this:

$$A = \begin{bmatrix} 1 & \left[\underline{a}_{12}, \overline{a}_{12} \right] & \cdots & \left[\underline{a}_{1n}, \overline{a}_{1n} \right] \\ & 1 & \cdots & \left[\underline{a}_{2n}, \overline{a}_{2n} \right] \\ & & 1 & \cdots \\ & & & 1 \end{bmatrix} \quad (1)$$

In the formula $\underline{a}_{ij} = \frac{1}{\overline{a}_{ji}} > 0$, $\underline{a}_{ii} = \overline{a}_{ii} = 1$, $\frac{1}{9} \leq \underline{a}_{ij} \leq \overline{a}_{ij} \leq 9$, $i, j=1, 2, \dots, n$, A is called the interval judgment matrix. The interval judgment matrix A is a reciprocal. If to all $i, j=1, 2, \dots, n$, $\underline{a}_{ij} = \overline{a}_{ji}$, A contracts to the traditional point judgment matrix.

Suppose the interval weight is $W_i = [\underline{\omega}_i, \overline{\omega}_i]$ ($i=1, 2, \dots, n$). According to the operation

$$\frac{W_i}{W_j} = \left[\frac{\underline{\omega}_i}{\underline{\omega}_j}, \frac{\overline{\omega}_i}{\overline{\omega}_j} \right]$$

principle of interval number, there is Thus it can be seen when getting the interval weight vector of the judgment matrix, the distance between

$\frac{\underline{\omega}_i}{\underline{\omega}_j}$ and $\frac{\overline{\omega}_i}{\overline{\omega}_j}$, $\underline{a}_{ij}$ and $\overline{a}_{ij}$ should be as short as possible in order to make the uncertainty degree of the vector as small as possible. For the mutual-opposite of the judgment matrix, only upper triangular matrix can be

taken into account when considering the judgment matrix. Using external approximation computation, that is, if to all i and j , w_{ij} includes the judgment interval a_{ij} , then

$$\frac{\omega_i}{\omega_j} \leq \overline{a_{ij}}, \quad \overline{a_{ij}} \leq \frac{\overline{\omega_i}}{\omega_j}, \quad 1 \leq i < j \leq n \quad (2)$$

In order to make the interval weight vector satisfy the standard as the traditional point weight vector, the theorem of the standard interval vector proposed by the reference can be adopted:

$$\omega_j + \sum_{\substack{i=1 \\ i \neq j}}^n \overline{\omega_i} \geq 1, \quad \overline{\omega_j} + \sum_{\substack{i=1 \\ i \neq j}}^n \omega_i \leq 1, \quad j=1,2,\dots,n \quad (3)$$

The interval weight computation is the core of IAHP. The present computation methods are mainly iterative method、stochastic simulation method、interval eigenvalue method、mutual-complement matrix method and linear programming method etc. This article adapts LP to get the interval weight by combining formula (2) and (3). LP model is just the following:

$$\begin{aligned} & \min \sum_{i=1}^n \overline{\omega_i} - \omega_i \\ & \text{s.t.} \quad \frac{\omega_i}{\omega_j} \leq \overline{a_{ij}}, \quad \overline{a_{ij}} \leq \frac{\overline{\omega_i}}{\omega_j}, \quad i=1,2,\dots,n-1; \\ & \quad \quad \quad j=i+1,i+2,\dots,n \quad (4) \\ & \omega_j + \sum_{\substack{i=1 \\ i \neq j}}^n \overline{\omega_i} \geq 1, \quad \overline{\omega_j} + \sum_{\substack{i=1 \\ i \neq j}}^n \omega_i \leq 1, \quad j=1,2,\dots,n \\ & \overline{\omega_i} \geq \omega_i \quad i=1,2,\dots,n \end{aligned}$$

The second step: the second consideration on the weight of $m_i (i=1,2,\dots,s)$ items are transferred to the one on the sequence of status value of these decision-made objects by using CCR model of DEA^[18].

DMU is used to refer to the objects of the same type. The bigger the status value of these items is, the better it is. status value is regarded as the output index. Suppose there is an input index in which all the objects meet one requirement, and all the input data is 1.

Suppose the efficiency evaluation of DMU_{jo} is made. The weight of input index V and the weight of output

index $u_r = (u_1, u_2, \dots, u_{k_i})$ are variables. The efficiency index of jo DMU is the target. The efficiency

$$h_j = \frac{\sum_{r=1}^s u_r y_{rj}}{v x_j}$$

of all DMU ≤ 1 ($j=1,2,\dots,n; r=1,2,\dots,k_i$) is

the constraint. Then the most optimized model is formed. After the change of C2 (Charnes-Cooper), the following linear programming model is set up:

$$\begin{aligned} \theta_{jo}^* = \max \quad & u y_o \\ \text{s.t.} \quad & v x_o = 1 \\ & -vX + uY \leq 0 \\ & v \geq 0, u \geq 0 \end{aligned} \quad (5)$$

In this formula,

$X = (x_1, x_2, \dots, x_n) = (1, 1, \dots, 1)$ represents input index, x_j is the input result that can be obtained when the j DMU corresponds to this input index.

$$Y = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ y_{s1} & y_{s2} & \cdots & y_{sn} \end{bmatrix}$$

represents output index, y_{rj} is the output result when the J DMU corresponds to R output index; v and u represents input weight and output weight respectively.

After canonicity transforms the output data through y_{rj}/y_{ro} , we can get

$$\hat{Y} = \begin{bmatrix} \hat{y}_{11} & \cdots & 1 & \cdots & \hat{y}_{1n} \\ \hat{y}_{21} & \cdots & 1 & \cdots & \hat{y}_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \hat{y}_{s1} & \cdots & 1 & \cdots & \hat{y}_{sn} \end{bmatrix}$$

Then:

$$\hat{\theta}_{ij}^* = \hat{u}_1 + \hat{u}_2 + \cdots + \hat{u}_r \quad \begin{matrix} i=1,2,\dots,s; j=1,2,\dots,n; \\ r=1,2,\dots,k_i \end{matrix} \quad (6)$$

$\hat{\theta}_{ij}^*$ can be regarded as the sequence weights of the j th object in n items according to the status value of this kind of elements. The interval weight of this class can also be considered.

The third step: The weights of the decision-made items in all the considered items can be confirmed by combining the results gained by the first and second step, that is, by adding the interval weights constraints of the interval AHP in DEA evaluation model. Therefore, the decision-making experts can get the final sequence of all the items.

Suppose the interval weights of the output index gained by interval AHP is $[\omega_r, \overline{\omega}_r]$, then

$$w_r \leq \frac{\hat{u}_r}{\sum_{r=1}^{k_i} \hat{u}_r} \leq \bar{w}_r \quad r=1,2,\dots,k_i \quad (7)$$

Combining formula (5) and (7) can get

$$\begin{aligned} \hat{\theta}_{10}^* = \max & \sum_{r=1}^{k_i} \hat{u}_r \\ \text{s.t. } & \hat{u} \hat{Y} \leq 1 \\ w_r \leq & \frac{\hat{u}_r}{\sum_{r=1}^{k_i} \hat{u}_r} \leq \bar{w}_r \\ & \hat{u} \geq 0 \quad r=1,2,\dots,k_i \end{aligned} \quad (8)$$

The weights of the decision-made projects in all considered objects can be gained in accordance with status value of all the elements by formula (8).

2) Computation example

Suppose one decision-making problem. There is one input index, four output index and five decision-made objects. The judgment matrix of the output index given by decision-making experts after comparing each two is like the following:

$$A = \begin{matrix} & \begin{matrix} y_1 & y_2 & y_3 & y_4 \end{matrix} \\ \begin{matrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{matrix} & \begin{bmatrix} 1 & \left[\frac{1}{6}, \frac{1}{4}\right] & [3,6] & \left[\frac{1}{4}, \frac{1}{2}\right] \\ & 1 & [6,8] & [2,4] \\ & & 1 & \left[\frac{1}{8}, \frac{1}{6}\right] \\ & & & 1 \end{bmatrix} \end{matrix} \quad \begin{matrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{matrix}$$

The specific data of these five objects is like this:

	x ₁	y ₁	y ₂	y ₃	y ₄
A	1	1	8	1	3
B	1	2	3	4	4
C	1	2	6	6	1
D	1	3	3	5	5
E	1	3	7	4	2

The whole process is like this:

(1) The linear programming model can be set up by matrix A according to the formula (4) and the result can be obtained by software LINDO. The optimal value $z=0.3$.

Thus, the interval weights vector of A is [0.075,0.15], [0.6,0.6], [0.025,0.1], [0.15,0.3].

(2) The original linear programming model can be set up by the specific data of the objects according to the formula (5).

The evaluation index of the most superior efficiency is

$$\theta_{10}^*=1.00, \theta_{20}^*=0.85, \theta_{30}^*=1.00, \theta_{40}^*=1.00, \theta_{50}^*=1.00$$

(3) The object A is taken as an example. The data is gained like the following by making the output data canonicity transforms through y_{rj}/y_{or} .

	A	B	C	D	E
y ₁	1	2	2	3	3
y ₂	1	0.375	0.75	0.375	0.875
y ₃	1	4	6	5	4
y ₄	1	1.333	0.333	1.667	0.667

According to formula (8), the linear programming model can be set up. The evaluation index of the most

superior efficiency can be gained. That is $\hat{\theta}_{10}^*=0.930$. The weights of the index output are respectively [0.075, 0.6, 0.025, 0.3].

In the same way, the other evaluation indexes are $\hat{\theta}_{20}^*=0.552$, $\hat{\theta}_{30}^*=0.736$, $\hat{\theta}_{40}^*=0.568$, $\hat{\theta}_{50}^*=1.000$.

Therefore, the final sequence of these five objects is E, A, C, D, B.

IV. CONCLUSION

Based on GQM approach, integrating the research status, this paper presents a new process-oriented metrics for software architecture adaptability. This method extends and improves the GQM method. It develops process-oriented processes for metrics modeling, introduces data and validation levels, adds structured description of metrics, and defines new indexes of metrics. The method resolves the metrics for software architecture adaptability to some extent. However, it is still insufficient, needs further in-depth study.

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