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Contents

The Method of Assessment Correction for Software Architectures when Quality Requirements are Changed

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Abstract — **Abstract. In the paper the adaptive method for choosing of software system architecture is discussed with accounting of quality indices. The method includes the calculation of comparative assessments of alternatives and operative correction of the assessments for taking to the account changes of quality requirements. Comparative assessments of the alternatives are estimated by the modified Analytical Hierarchic Process, and for the correction of assessments the V. Podinovsky's method of pairwise substitution is applied, which content is to compensate changes of criteria by the priority. For the optimization of substitution models of linear programing are used.**

Keywords — **software architecture, multicriteria optimization, substitution by the priority, comparability by substitution.**

I. Introduction

During exploitation of a software system the changes of the domain happen, what causes necessity to make changes in the software system. And this, as rule, degrades quality characteristics of the software system. Thus, the necessity of system reengineering appears or system should be changed completely. The architecture of the system is the first what will be changed because it dominantly influences on the quality of the system. Quality requirements can be changed during the system design too.

Changing of the software architecture for accounting of quality requirements is performed by means of assessment of existing architecture and its comparison with alternatives. Since this is the problem of multicriteria hierarchic optimization so to find its solution the analytical hierarchic process (AHP) is used [1]. In the papers [2], [3] the modified AHP (MAHP) is used, what gave possibility to expand considerably the limits of applying of this method. To consider additional factors when choosing software architecture among the set of evaluated alternatives one of the trade-off schema should be used [4].

The correction of assessments for prioritized alternative with goal to make it better is one of the way to obtain compromise decision. The V. Podinovsky's method of pairwise substitution is used for this [5]. Since the problem of substitution can have few solutions so to select the best one the model of optimization, offered by O.Pavlov, is used [6].

II. The Method of Comparative Assessment with Applying of Modified AHP (MAHP)

For the assessment of alternate architectures $\{A_i\}$ the following sets of quality indices are used [3]: $K_i^1, i=\overline{1,m1}$ – quality indices for software system; $K_i^2, i=\overline{1,m2}$ – quality indices for architecture.

The assessments of alternative architectures w_i^s (here i is a number of the alternative and s is a number of criterion) with applying of AHP for the realization of each quality criteria for small quantity of alternatives (n<9) can be found as a components of eigenvector of pairwise comparisons matrix. These components correspond with maximum characteristic number of the matrix. The indices of the matrix of pairwise comparisons $B\{b_{ij}\}$ (here b_{ij} defines the supremacy of i^{th} alternative over j^{th}) must be consistent, i.e. $b_{ij}=w_i/w_j \quad \forall b_{ij}\in B$. But for considerable quantity of alternatives and because of influence on the experts different negative factors the inconsistences of the matrix $B\{b_{ij}\}$ appear, i.e. its range will not be equal to 1 and the matrix will have some eigenvalues. I.e. applying of AHP for this case will be incorrect because obtained solutions will contain considerable errors.

A. Pavlov in the article [6] proposed the modification of AHP for solving of this problem when quantity of alternatives are great. The essence of the modification is calculating of alternatives' weights on the base of condition of inconsistency minimization for the matrix $B\{b_{ij}\}$. And in the papers [2], [3] of authors of this article this method was used in the problem of selection of software architecture with taking to the account of quality indices.

The model of optimization is defined by chosen form of the measure of inconsistency, which can be chosen on the base of additional conditions. For the case of integral measure of consistency $\sum\sum_{i,j\in L}\left|w_i^*-\beta_{ij}w_j^*\right|$, so the correspondent problem of optimization will be as follows:

$$\min \sum_{i,j \in L} \left(y_{ij}^{+} + y_{ij}^{-}\right) \tag{1}$$

$$w_i - \beta_{ij} w_j = y_{ij}^{+} + y_{ij}^{-}, \quad y_{ij}^{+} \geq 0, y_{ij}^{-} \geq 0,$$

where w_i, y_{ij}^{+} are variables of the optimization problem.

For the case of minimization for measure of consistency $\max\left|w_i^* - \beta_{ij} w_j^*\right|$ the solution w_i^* is found from the problem of linear programming:

$$\min \sum_{i,j \in L} \sum y_{ij} \tag{2}$$

$$w_i - \gamma_{ij} w_j \leq y_{ij}, \quad y_{ij} \geq 0,1 < w_i, i = \overline{1,n}.$$

After selection of the form of inconsistency and the solution of appropriate problem of minimization the weights w_i^s are found, and then the alternatives $\{A_i\}$ are ranged according to the values of weights $\{w_i^s, A_i\}$. To select the best alternative on the base of the set of quality indices for defined priorities of criteria the method of scalar convolution can be used [4]. But often the selection of criteria indices is unwarranted and requies a lot of additional expert information. So to obtain the solution in the conditions of undefined priorities of criteria the schema of compromises are used [2], [4].

The peculiarity of the discussed problem is that the architect on the base of the analysis of obtained ranging $\{w_i^s, A_i\}$ desided to choose the alternative A_j with the vector of the criteria assessments $\overline{K_j^2}$ but some components of the vector $\overline{K_j^2}$ are not the best in comparison with other alternatives. The problem is to increase assessments for components that are not the best by means of decreasing of other components. To do it the V. Podinovsky's method is used where the concepts of pairwise comparability, comparability by substitution are defined. For optimization of the procedure of substitution the method proposed by A. Pavlov is used where this problem is decreased to the problem of linear programming [7].

III. Operative Correction of the Alternatives with Applying of Substitution and Compensation

The problem of evaluation correction appears when experts and an architect prefer some alternative A_i, but it for some criteria has worse values. The problem is stated to increase the assessments for these criteria by means of decries others, but such that assessments of the alternative A_i for all criteria were not worse.

Such situation is typical during design of distributed systems when desired architecture is known and the correction of criteria can be done with selection of standard functional components [8].

To solve this problem the V. Podinovsky's axiomatic approach [5] can be applied, which concluded in pairwise criteria substitution. Criteria K_r and K_s are comparable by substitution if for some alternative A_i the compensation of any change of the criterion K_r by changing of the criterion K_s is possible.

That is if A_i^p is an alternative, which substitute A_i by means of correction K_r and compensation of K_s so their corrected values will be

$$\overline{K_r^{ip}} = \overline{K_r^i} - \delta_r, \overline{K_s^{ip}} = \overline{K_s^i} + \delta_{si}, \delta_{si} = f\left(r, s, \overline{K}, \delta_r\right), \tag{3}$$

where $\overline{K}$ – the vector of criteria values.

Let's write down the expression for compensation of the components set of the vector $\overline{K^i}$ for the alternative A_i, which we are doing better than A_j:

$$\delta\overline{K_r^{ir_z}} = C_r^{ir_z} \cdot \delta K_r^i, r_z \in R_i^2(r), r \in R_i^1, \tag{4}$$

where $\delta\overline{K_r^{ir_z}}$ – possible decreasing of the component $\overline{K_r^i}$ to increase $\overline{K_{r_z}^i}$;

R_i^1 – the set of indices r for which $\overline{K_r^{iz}} > \overline{K_r^j}$, $j = \overline{1,n}; i \neq j$;

$R_i^2(r)$ – given for R_i^1 set of indices, such that the components $\overline{K_r^i}, r \in R_i^1$ can be involved for substitution of the components $\overline{K_s^i}, s \in R_i^2(r)$;

$C_r^{ir_z}$ – given indices of proportionality.

The components of the vector $\overline{K^i}$ after substitution are defined as follows:

$$\overline{K_r^{ip}} = \overline{K_r^i} - \sum_{r_z \in R_i^2(r)} C_r^{ir_z} \cdot \delta K_{r_z}, \quad r \in R_i^1;$$

$$\overline{K_r^{ip}} = \overline{K_{r_z}^i} + \sum_{r \in R_i^1} \sum_{r_z \in R_i^2(r)} \delta \overline{K_{r_z}}, \quad r_z \in s, s \overline{\in} R_i^1, r_z \in R_i^2(r) \tag{5}$$

A. Pavlov in the article [7] the problems of substitution optimization (5) are defined which decreased to the problems of linear programming, and mathematical models of which depend on the strategy of decision-making. For the Pareto-optimal strategy, the model of optimization will be as follows:

$$\max\left\{\sum_{r \in R_r^1} d_r + \sum_{s \overline{\in} R_j^1} d_s\right\} = \max\{y\} \tag{6}$$

with constraints:

$$d_r, d_s \geq 0, r \in L_j^1, s \overline{\in} R_j^1;$$

$$\overline{K_r^j} - \sum_{r_z \in R_j^2(r)} \delta K_r^{jr_z} \geq \max_i \left(\delta \overline{K_r^i} \right) + d_r, i \in \overline{1,n}, i \neq j, r \in R_j^1$$

;

$$\overline{K_s} + \sum_{r \in R_j^1} \sum_{r_z \in R_j^2(r)} \frac{1}{d_r^{jr_z}} \delta \overline{K_r^{jr_z}} \geq \max_i \left(\overline{K_s} \right) + d_s, \quad i = \overline{1,n}, i \neq j, r \in \overline{R_j^1}, r_z = s,$$

$$\exists r, s \in R_j^2(r), \quad (7)$$

$$\sum_{r_z \in L_j^2(r)} \delta \overline{K_r^{jr_z}} \leq b_{K_j^i}, \quad j \neq i, r \in R_j^1, r_z = s$$

.

Here the variables are $\delta K_r^{jr_z}, d_r, d_s$.

After some transformations for the solving of this task the standard simplex-method is used.

To achieve a compromise for the final decision and for the situation when requirements for the software system are changed the priorities of quality criteria can be changed too. For this case to correct the priorities of the criteria the expression is used:

$$D'_{s,i,j} = \frac{|J_i - J_j|}{|w_i^s - w_j^s|} \cdot \frac{100}{P_s}. \quad (8)$$

Here $D'_{s,i,j} \left(s = \overline{1, m2}; i, j = \overline{1,n}; i \neq j \right)$ is minimal change of the priority value P_K for the quality criterion K_s which changes the order of adjacent alternatives A_i and A_j onto opposite. The minimal value of the $D'_{s,i,j}$ shows, that the priority P_s of the attribute K_s is critical for the changes of assessments in pairwise comparisons.

Applying the relation (8) for each criterion K_s the interval ΔP_s can be found, where experts can correct priorities P_s directly or by means of correction of values of pairwise comparisons without changes in ranged order of alternatives $D_s^* = \min_i D_{s,i,j} = \Delta P_s, i = \overline{1,n}, s = \overline{1,k_2}$.

IV. Practical Applying of the Method of Alternative Correction

For practical example let's discuss the assessments of alternative architectures from the article [3]. In the table 1 weights of alternatives regarding to quality criteria for such architectures:

1. Three-layered on the base of J2EE (TJEE).
2. Three-layered on the base of .NET (TNET).
3. Two-layered.
4. The platform with support of distributed agent (DAS).

TABLE 1.
ASSESSMENTS OF THE ALTERNATIVES REGARDING TO THE QUALITY CRITERIA

Quality criteria	Alternatives			
	TJEE	TNET	TWOL	DAS
Modifiability	0,521	0,172	0,106	0,210
Scalability	0,404	0,402	0,074	0,143
Performance	0,201	0,204	0,347	0,246
Cost	0,166	0,120	0,487	0,227
Development effort	0,152	0,110	0,515	0,223
Portability	0,450	0,050	0,050	0,400
Ease of installation	0,368	0,268	0,256	0,208

Let the decision to correct the alternative TJEE is made during the software design. As it seen from the table 1, the alternative TJEE dominates for first, second, sixth and seventh criteria. I.e. the set is {1,2,6,7}. And since for the rest criteria the alternative TJEE yields the set will be {3,4,5}. It is required to increase the indices of the alternative TJEE for vector components {3,4,5} by means of decreasing of indices for components {1,2,6,7}. The constraint in the optimization problem (6), (7) is the condition that after decreasing of the components {1,2,6,7} for the alternative TJEE they become not worse than for other alternatives. The constraint for maximum possible decreasing of the components {1,2,6,7} must be written. Then the problem of optimization (6), (7) can be solved.

V. Conclusion

The problem of optimal correction of quality indices for software architecture choosing on the base of the solution of Saaty's hierarchic optimization problem. For this the procedure of substitution, compensation is used and the model for the optimization of the substitution. Necessity in the correction of assessments is caused by the change of quality requirements which leads to necessity of software architecture change.

Applying of this approach allows to change the values of some quality indices for the alternative by means of decreasing of others, and so to make the alternative such, that it meets all changed requirements the best.

According to the changed assessments of the criteria changes are made in the architecture. Such correction does not require repeatable solution of the problem of multicriteria evaluation of alternatives. Applying of optimization model allows to make such substitution the best regardint to the minimization of required changes. This approach can be useful as well for creation of few architectures from standard patters.

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