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КОМП'ЮТЕРНІ НАУКИ ТА ІНФОРМАЦІЙНІ ТЕХНОЛОГІЇ

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Content

The Method of Software Architecture Design Accounting the Quality Requirements Change

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Abstract* – The adaptive method for selecting of architecture project of software system is discussed in the article under changeable quality requirements. The method includes the calculation of comparative assessment for alternatives and operative correction of assessments for taking into account the change of quality requirements. Comparative assessments for the alternatives are obtained with modified Analytical Hierarchic Process. The method of pairwise substitution of V.V. Podinovskiy is used for the correction of assessments which consists in the compensation by the priority of the criteria changes.

Key words – architecture of software system, multicriteria optimization, compensation by the priority, comparability by the substitution.

I. Introduction

During the software system (SWS) exploitation the changes of the domain happen what causes the necessity to change the SWS, and this as a rule makes quality characteristics of SWS worse. Therefore, the necessity of system reengineering or even complete change of existing SWS is required. In first turn the software architecture (SWA) should be changed since it decisively influences on the SWS quality. The change of quality requirements can occur as well during the process of SWS design, what causes necessity of correction in made design decisions.

Making changes in the SWA for taking into account the changes of quality requirements can be done by means of evaluation of existing architecture and comparison of its quality characteristics with alternatives. Besides that standard architecture decisions with requisite corrections can be used as alternatives.

The problem of assessment of alternative architectures for the SWS on the set of criteria was discussed in some papers [1], [2] where the Analytical Hierarchic Process (AHP) [3] was applied. Appling of AHP allows to obtain comparative assessments of alternative architectures for each quality criterion and to range the alternatives according to the values of assessments. However, it is possible to acquire reliable assessments for the decision-making on selecting of the SWA only for small quantity of alternatives ($n \leq 9$), what is caused of the specificity of the comparative expert environment. This was remarked both by Saaty [3] and it was discussed in the works of other authors [4], [10].

In the article [2] it is offered to normalize the relative estimates for the alternatives obtained with AHP on use cases and criteria to identify and decrease inconsistency in the experts' assessments. If there are differences in the normalized assessments that exceed some threshold, the experts are proposed to repeat the process of AHP completely. However, it makes the procedure expensive enough and without the guaranty to acquire the acceptable result.

In the papers [6], [7] the modified AHP (MAHP) was applied to solve this problem what gave the possibility to expand the frames of its applicability on greater quantity of alternatives ($n \leq 45$).

For the evaluation of alternatives on the set of criteria it is possible to apply linear convolution of obtained assessments on single criteria [7] but it is needed to define the priorities of criteria what is enough complicated process and it is an additional source of inconsistencies because it is connected with acquiring and processing of great amount of expert data.

In this article, the approach to obtain the solution of multicriteria architecture selection is discussed on the base of the information about comparability of criteria by importance and making of requisite corrections of the assessments for taking into account change of quality requirements to SWS.

The Podinovskiy's method of pairwise substitution [8] is applied to solve mentioned problem. Since the problem of substitution can have many solutions the optimization model [9] offered by Pavlov O.A. is applied to choose the best one.

II. The method of multicriteria selection of software architecture on the base of the information about criteria comparability

The scheme of the problem of multicriteria selection for the best variant of architecture of the SWS among the set of alternatives relatively the set of quality criteria of the SWS is presented on the Fig. 1.

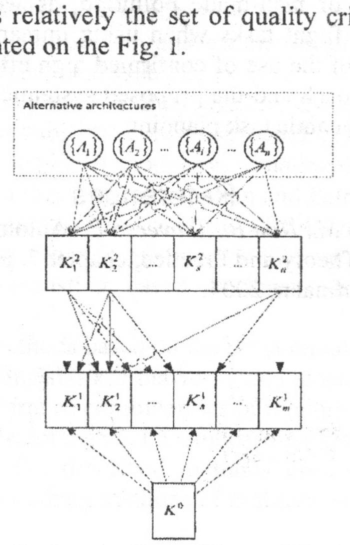

Fig.1 Multicriteria selection of the architecture for SWS

Here $\{A_i\}$ – alternative architectures of SWS;

$\{K_i^2\}$ – quality characteristics of the architecture;

$\{K_i^1\}$ – quality characteristics of the SWS;

K_0 – integral quality of the system.

For obtaining of the assessments of the alternatives $\{A_i\}$ for each criterion $\{K_i^2\}, i=\overline{1,n}$ the Analytical Hierarchic Process (AHP) or modified AHP can be applied, which discussed in details in [5], [6], [10]. For obtaining of the assessments of the alternatives $\{A_i\}$ for the set of criteria, the method of scalar convolution is applied most often, where the vector criterion $\{K_j^2\}, j=\overline{1,n}$ is replaced with scalar one as the sum:

$$\overline{K} = \sum_{j-1}^{n} p_j \cdot K_j . \quad (1)$$

where p_j is the coefficient of the priority of j^{th} criterion.

However, as it was remarked above the defining of the values p_j is a complicated problem, which requires the processing of large amount of expert data, and it is as well a source of new inconsistencies.

The assessments of the quality criteria for selection of the SWA obtained from different groups of stakeholders are given in the Table 1 [1].

TABLE 1

PRIORITIES OF QUALITY CRITERIA

Quality attributes	Stakeholders			Aggregate value
	designers	users	customers	
Modifiability	0,216	0,294	0,184	0,280
Scalability	0,087	0,092	0,038	0,082
Effectiveness	0,052	0,117	0,087	0,097
Cost	0,245	0,019	0,272	0,135
Dev. effort	0,245	0,019	0,272	0,135
Portability	0,050	0,155	0,053	0,094
Ease to install	0,106	0,304	0,093	0,177

Represented data show that the assessments of priorities for some criteria obtained from different groups of stakeholders differ more than twice. In this case the average value of priorities does not ensure the trade-off and the application of linear convolution for the SWA alternatives assessment and for selection of the best one can be not proper way.

Therefore it is important to apply methods of acquiring of multicriteria solutions, which are not based on the linear convolution. One of such methods is the method of multicriteria selection of software architecture on the base of the information about criteria comparability [11]. On the first step of this method the relation S of criteria comparability by importance is constructed based on additional information about superiorities on the set of criteria $K=\{K_i\}, i=\overline{1,n}$. Then the rule T is deduced based on reasonable concept of comparability that allows to build the relation of the supremacy $R(P, T)$ on the concrete structure on the base of assessments of criteria E^m and further its narrowing.

The result relation includes introduced relations of pairwise comparability and belongs to the class of rational transitive relations. The final structure of the result relation of the supremacy R in the space of the assessments of criteria is defined by the structure of relation of comparability.

There are worked out some realizations of this method [14]. Let us discuss one of them. This is the comparability by substitution.

The relation of the supremacy are based on the local information about the importance. To construct these relations the axiomatic approach proposed by Podinovskyj V.V. is applied. [12]

The concept of the comparability by substitution is not reduced to any structuration of supremacies on entire set of alternatives $\{A^n\}$, but only shows the possibility for any alternative the compensation (by supremacy) of arbitrary change of the criterion K_r, by some change of criterion K_s. I.e. if for arbitrary alternative A_i then for any Δr exists equivalent alternative A_j.

The concept of comparability by substitution of criteria K_r and K_s defines that for any alternative A_i the compensation by supremacy is possible for any change of the criterion K_r by some change of the criterion K_s. The size of possible changes of the criteria K_r and K_s is defined by the essence of these criteria.

In the article [13] the following definition of the comparability by substitution is represented. If for the alternative A_i and for any Δs exists equivalent to it alternative A_{ic} such that $\overline{K}_r^{ic} = \overline{K}_r^{i} - \Delta r$, $\overline{K}_s^{ic} = \overline{K}_s^{i} + \Delta rs$, $\Delta rs = f(r, s, \overline{K}, \Delta r)$, $\dfrac{\Delta r}{\Delta rs} > 0$,

then criteria K_r and K_s are comparable by substitution ($K_r\, C\, K_s$). Here $\overline{K}_i$ – are values of criteria. There is the assumption that when $\Delta r \neq 0$, $\Delta rs \neq 0$, but for $\Delta r = 0$ it is true that $\Delta rs = 0$, $A_{ic} = A_i$. Let us to emphasize that the relation of comparability by substitution is symmetrical but in general is not transitive. I.e. $K_r\, C\, K_s$, $K_s\, C\, K_r$, but $K_r\, \bar{C}\, K_s$.

III. Case study of the proposed approach

Let assume that we have some alternative A_i from the set $\{A_i\}$. Let K_r and K_s r^{th} and s^{th} components of quality for the alternative. The relationship between the changes of the criteria in this problem can be represented as Δr, $\Delta rs = f(r, s, K, \Delta r)$. The problem is that to make the alternative A_i better than A_j ($i \neq j$) by substitution of the its components according the rule that each component of A_i is not worse than component of A_j ($i \neq j$).

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

$$\overline{K}_r^{ip} = \overline{K}_r^i - \Delta_r,$$
$$\overline{K}_s^{ip} = \overline{K}_s^i + \Delta_{si}, \qquad (1)$$
$$\Delta_{si} = f(r, s, \overline{K}, \Delta_r).$$

Here $\overline{K}$ is the vector of criteria values.

Let us write down the correlation for the compensation under substitution for the set of vector's components $\overline{K}^i$ of the alternative A_i, which we want to make better than A_j:

$$\Delta\overline{K}_r^{ir_z} = C_r^{ir_z} \cdot \Delta K_r^i,\ r_z \in R_i^2(r),\ r \in R_i^1, \qquad (2)$$

where $\Delta\overline{K}_r^{ir_z}$ – possible increment of the component $\overline{K}_r^i$ aiming to increase $\overline{K}_{r_z}^i$;

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

$R_i^2(r)$ – the given for R_i^1 set of indexes such that the components $\overline{K}_r^i, r \in R_i^1$ can take part in substitution of components $\overline{K}_s^i, s \in R_i^2(r)$;

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

After the substitution the components of the vector $\overline{K}^i$ are determined by following expression:

$$\overline{K}_r^{ip} = \overline{K}_r^i - \sum_{r_z \in R_i^2(r)} C_r^{ir_z} \cdot \Delta\overline{K}_{r_z}^i,\ r \in R_i^1;$$
$$\overline{K}_r^{ip} = \overline{K}_{r_z}^i + \sum_{r \in R_i^1} \sum_{r_z \in R_i^2(r)} \Delta\overline{K}_{r_z},\ r_z \in s,\ s \overline{\in} R_i^1,\ r_z \in R_i^2(r). \qquad (3)$$

Let us to discuss the procedure of optimization of the substitution. We will introduce the restriction on the procedure of the change of criteria's values:

$$\overline{K}_s^{ic} > C_s^i, \left(s = \overline{1,m},\ i = \overline{1,n}\right), \qquad (4)$$

where the vector C^i defines minimum possible components' values of the criterion K^i of the alternative A_i.

The optimization of the procedure of the substitution is executed by means of maximization of following index:

$$\max \sum_{s=1}^{p} \beta_s K_s^i, \qquad (5)$$

where β_s are weight coefficients.

So as a result we will get the following problem of linear programming:

$$\max \left\{ \begin{array}{l} \sum_{l \in L_i^1} \beta_l \left(K_l^i - \sum_{l_m \in L_i^2(l)} \Delta K_l^{ilm} \right) + \\ + \sum_{\substack{l_m \cup L_i^2(l) \\ \forall l \in L_i^1}} \beta_{lm} \left(K_{l_m}^i + \sum_{l_m \in L_i^2(l)} \Delta K_l^{ilm} \right) \end{array} \right\} \qquad (6)$$

Now we will discuss the application of the given models for the practical problem of substitution. We have three alternatives of the architecture. Quality of which are rated by five quality indices. The problem is to correct the characteristics of one alternative in order to make it the best.

Values of the assessments of the architectures, obtained with MAHP, are given on the table 2

TABLE 2

VALUES OF THE QUALITY CHARACTERISTICS FOR ARCHITECTURE ALTERNATIVES

Criteria	Architecture		
	A_1	A_2	A_3
K_1	5	2	2
K_2	4	4	4
K_3	3	5	6
K_4	2	4	3
K_5	4	1	2

It is necessary to correct the assessments of the alternative A_1 so that for each criteria it will be not worse than for other two.

Here the set $L_i^1 \to \left(\forall l \in L_i^l, \overline{K}_l^i > \overline{K}_l^j, i \neq j\right) \in \{1;5\}$, and respectively $L_i^2 = \{3;4\}$. So the problem is to increase the assessments for 3[rd] and 4[th] criteria by decreasing of assessments for 1[st] and 5[th] criteria. However, they must be still not worse than for two other alternatives. Since maximum assessment of the 1[st] criterion for 2[nd] and 3[rd] alternatives is 2 and for 5[th] criterion is 2 too so these restrictions look as following:

$$5 - \left(\Delta\overline{K}_{13} + \Delta\overline{K}_{14}\right) \geq 2 \pm 1 \cdot y;$$
$$4 - \left(\Delta\overline{K}_{53} + \Delta\overline{K}_{54}\right) \geq 2 \pm 0{,}8 \cdot y.$$

Restrictions that the assessments for 3[rd] and 4[th] criteria, for which the correction is carried out, were not worse than for two other alternatives look like follows:

$$3 + \left(1{,}6 \cdot \Delta\overline{K}_{13} + 1{,}3 \cdot \Delta\overline{K}_{53}\right) \geq 6 + 0{,}5 \cdot y;$$
$$2 + \left(2{,}5 \cdot \Delta\overline{K}_{14} + 2 \cdot \Delta\overline{K}_{54}\right) \geq 4 + 0{,}6 \cdot y.$$

The coefficients of the substitution C_l^{ilm} – are introduced by experts on the base of the criteria's importance.

The restrictions on the maximum change of the assessments for 1[st] and 5[th] criteria look like follows:

$$\Delta\overline{K}_{13} + \Delta\overline{K}_{14} \leq 3;$$
$$\Delta\overline{K}_{53} + \Delta\overline{K}_{54} \leq 2.$$

As the result of the solution of this optimization problem with introduced restrictions we will obtain:

$$\Delta K_{13} = 1{,}1; \Delta K_{14} = 1{,}01;$$

$$\Delta K_{53} = 1{,}29; \Delta K_{54} = 0; y = 0{,}89.$$

Conclusion

In the article the problem of operative correction of the assessments for software architecture is examined. The substitution by priority is proposed as the method for correction.

The usage of given approach gives the possibility to change, within certain limitations, the values of the quality attributes of the alternative which is preferred taking into consideration additional factors. Such correction does not require solving the problem of assessments repeatedly. After the correction desire architecture decision become the best with values of quality characteristics which are not worse than for other alternatives.

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