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Formation of Balanced System of Program Project Characteristics

Vladimir Gvozdev
dept. Computer Science and Robotics
Ufa State Aviation Technical University
Ufa, Russia
wega55@mail.ru

Oksana Bezhaeva*
dept. Computer Science and Robotics
Ufa State Aviation Technical University
Ufa, Russia
obezhaeva@gmail.com

Dinara Akhmetova
dept. Computer Science and Robotics
Ufa State Aviation Technical University
Ufa, Russia
dinara.akhmetova.92@gmail.com

Gulnur Safina
dept. Computer Science and Robotics
Ufa State Aviation Technical University
Ufa, Russia
lafleur300997@gmail.com

***Abstract*—Formation of characteristic balanced system of program project is a critical factor in the successful implementation of the project. This paper describes the formal procedure for evaluating the budget and project duration values, that provide the best correlation between customer satisfaction of project results and project actors. The project is presented as a multivariable control object. Empirical functional dependencies correspond to direct and cross-linking of multivariable object. The feature of empirical models constructing is the need to share actual (historical) data about budgets and the previously implemented projects duration, and subjective estimates (determined by experience) of consumers and developers. An original approach is used to build the empirical models that correspond to direct and cross-links of multivariable object based on the joint use of expert estimates and historical measurement data of various volumes corresponding to previously implemented projects. The proposed approach makes it possible to increase the validity of decisions about the reasonableness of project implementation, taking into account the potential of the implementing organization, budget restrictions and project duration. The proposed procedure is formalized, this allows us to get stable estimates of the project characteristics.**

Keywords— program project, measured data, expert estimates, multivariable control object, budget restrictions, project duration, projects implementation, metric characteristics

I. Introduction

The information presented in the reports of Standish Group [1, 2] allows to make the conclusion that despite the progress in the field of project development, technologies and tools, the effectiveness of the projects implementation is poor. In [3-9] and others, it is noted that one of the reason of incidents that occur in subject-centric systems (projects also belong to this class of systems) are organizational system errors.

One of the reasons of system errors occurrence is the imbalance in the main characteristics of the project (project budget, project duration, satisfaction of project participants) [2, 8].

It is normal practice for implementing projects to specialize implementing organizations in creating certain types of products. This also gives reason to postulate the provision on the stable state of the implementing organization, as well as its specialization in the implementation of projects of a certain type, and provides the basis for descriptive models constructing that establish a relationship between the characteristics of the project (and having a scope only for this organization).

This paper describes a formal procedure for evaluating budget values and the duration of a project, which provides the best balance between customer satisfaction with project results and project actors.

II. Assumptions Underlying the Procedure Development

The scientific idea of the development is to present the organization's experience in projects implementation of a certain direction in the form of an empirical mathematical model.

The essential parameters of the program project, according to the system model "project triangle" [8] are: budget, duration of implementation, customer satisfaction with the project results, satisfaction of performers with the project terms.

In this paper, it is postulated, that customer satisfaction with project results, and performers with project progress, is a latent characteristic of the quality of the organization of the project, including the balance of project characteristics. This means that the objective quality characteristics of the management at different stages of the project life cycle are, firstly, customer satisfaction with the implementation results of the stage, secondly, the satisfaction of performers with the conditions in which they worked.

The program project is presented in the form of a multivariable control object [10], the input parameters of which are the budget and the project duration, output parameters - the satisfaction of users and performers. According to these assumptions the project could be associated with the model presented in Figure 1.

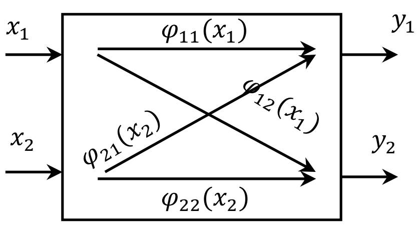

Fig. 1. Presentation of the project in the form of a multivariable control object

On the figure 1 $f_{ij}(\cdot)(i,j=\overline{1;2})$ is marked the functional dependencies, characterizing the direct and cross-link connections between input and output parameters.

- x_1 and x_2 - are the budget and the duration of the project, respectively.
- y_1 and y_2 – are metric characteristics of satisfaction of project consumers and performers with the project progress.

Empirical functional dependencies, corresponding to direct and cross-links of a multivariable object are:

$$y_j = \varphi_{ij}(x_i),\ \ (i,j=1,2) \tag{1}$$

Functional dependencies are strict on the intervals of possible argument values $x_i \in [0, x_i^*]$, where x_i^* are the maximum permissible values of the *i* input parameter, above which the implementation of the project is impractical.

Empirical functional dependencies are based on joint use of expert estimates and historical measurement data of various volumes corresponding to previously implemented projects. Description of the technology for constructing empirical functional dependencies is beyond the scope of this paper. This method is described in detail in [11].

Formations of generalized characteristics of the joint influence x_i on y_j based on functional dependences $y_j = \varphi_{ij}(x_i)$:

$$A^{(j)}: \{y_j = \varphi_{ij}(x_i)\} \to y_j = \Phi_j(x_1, x_2), i, l = 1,2 \tag{2}$$

Range of possible values of satisfaction characteristics y_j is the interval [0,1], the lower bound of the interval corresponds to the absolute dissatisfaction subjects, and vice versa, the higher, than closer to the upper boundary of interval - absolute satisfaction. Zero corresponds to the absolute dissatisfaction; one corresponds to the absolute satisfaction.

Accordingly, dissatisfaction is characterized by the value:

$$\varepsilon_j = 1 - y_j \tag{3}$$

The basis of the formation $\Phi_j(x_1, x_2)$ are the following. Customer satisfaction decreases as both the budget x_1 and the project duration x_2 increase. Therefore, the functional dependence $y_j = \varphi_{ij}(x_i)$ are inverse and defined in intervals $x_i \in [0, x_i^*]$.

It is considered, that it is possible to compensate the changes in the project duration due to changes in the project budget and vice versa (this question is discussed, for example in [12].

At the same time, from the consumer's point of view, it is possible to implement a zero-duration project (purchase of turnkey solution). These facts allow us to claim that $\Phi_1(x_1, x_2)$ is an additive function, i.e.

$$y_1 = \varphi_{11}(x_1) + \varphi_{12}(x_2) \tag{4}$$

In turn, the satisfaction of performers grows with an increasing in the budget x_1 and the duration of project implementation x_2. It is considered that the performer refuses the project if at least one of the project characteristics x_i (i=1,2) is equal to zero. Also, based on the uniqueness property of the project [9], it is assumed that the performer cannot have a solution ready for sale to the consumer.

Based on these considerations, we can conclude that:

$$y_2 = \varphi_{12}(x_1) * \varphi_{22}(x_2) \tag{5}$$

i.e., $\Phi_2(x_1, x_2)$ is a multiplicative function.

III. FORMULATION OF THE PROBLEM

A. Problem 1

Required to evaluate the values of the project parameters $x_i^{(OUT)}$ (*i*=1,2), at which is reached the smallest length of the vector $\vec{\varepsilon}$, i.e.

$$|\vec{\varepsilon}| \xrightarrow[x_i^{(OUT)}]{} min \tag{6}$$

under restrictions:

$$x_i \in [0, x_i^*] \tag{7}$$

Given the fact that:

$$y_j = \Phi_{ij}(x_1, x_2) \tag{8}$$

the length of the vector is a generalized characteristic of the satisfaction of consumers y_1 and performers y_2 and is determined as:

$$|\vec{\varepsilon}| = \sqrt{(1-y_1)^2 + (1-y_2)^2} \tag{9}$$

B. Problem 2

Required to evaluate the values of the project parameters $x_i^{(OUT)}$ (i=1,2), at which is reached the smallest difference in satisfaction with the project results of consumers y_1 and performers y_2:

$$\sqrt{(y_1 - y_2)^2} \xrightarrow[x_i^{(OUT)}]{} min \qquad (10)$$

under restrictions:

$$x_i \in [0, x_i^*] \qquad (11)$$

$$0 \le \varphi_{11}(x_1) + \varphi_{21}(x_2) \le 1 \qquad (12)$$

$$0 \le \varphi_{12}(x_1) * \varphi_{22}(x_2) \le 1 \qquad (13)$$

Given the fact that:

$$y_j = \Phi_{ij}(x_1, x_2) \qquad (14)$$

Restrictions (12) and (13) are due to $y_j \in [0, 1]$, j=1,2.

Note that in the formulation of problem 1, solution (6), taking into account (7) - (9), coincides with the solution obtained in approach “Ideal Point Method” [13].

IV. Formal scheme for solving optimization problems

As formal scheme for solving optimization problems identified as problem 1 and problem 2, is used known optimization method without determination of the derivatives [14].

As a tool for finding the optimal solution we use the method of deformable polyhedron. The deformable polyhedron method is used as a tool for finding the optimal solution of the problem. The deformable polyhedron method shows positive results in cases when there is no analytical dependence between optimized indicator and input parameters. The method stands out among others due to:

- simplicity of the method, it allows to optimize functions without calculating the gradient and derivative;
- efficiency of the method, opportunity to cycle through the steps of the algorithm until it reaches a certain stop condition.

During the solving the optimization problem restrictions (11)-(13) were taking into account.

The scheme of the numerical algorithm for finding the optimal solution based on the method of a deformable polyhedron is shown on the figure 2.

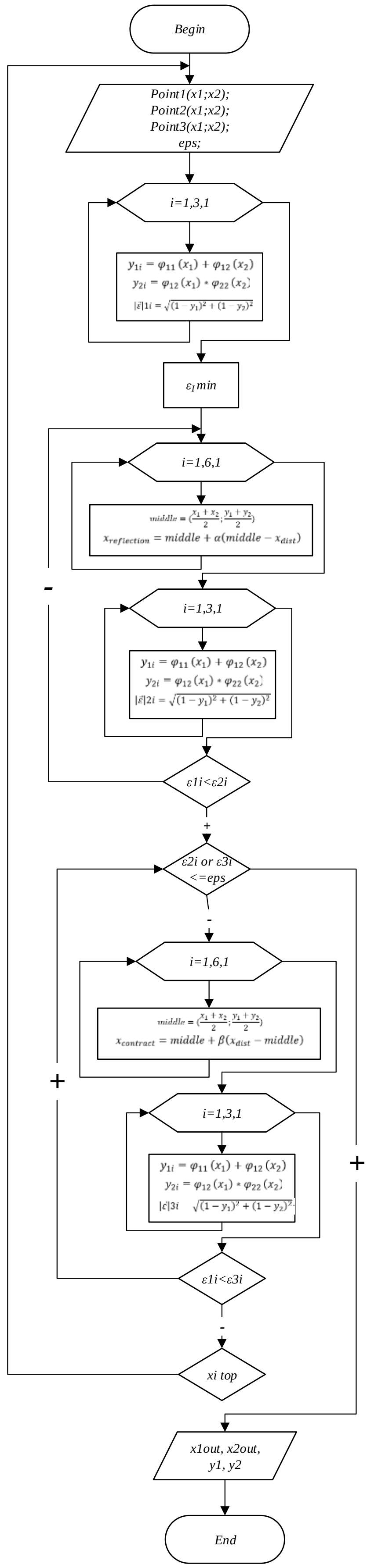

Fig. 2. The scheme of the algorithm

V. EXAMPLES OF SOLVING THE PROBLEM OF FORMATION OF BALANCED SYSTEM OF PROGRAM PROJECT CHARACTERISTICS

Let's first consider the case, when direct and cross-links are represented as linear dependencies, i.e. $y_j = a_{0i} + a_{ji}(x_i)$. In this case, the cumulative effect of x_1, x_2 on y_1, y_2 is determined by the relations:

$$y_1 = (a_{01} - a_{11} x_1) + (a_{02} - a_{12} x_2) \quad (15)$$

$$y_2 = b_{12} x_1 * b_{22} x_2 \quad (16)$$

Given the linear nature of the dependencies $\Phi_{ij}(x_i)$, restrictions (12), (13) take the form:

$$y_1 = (a_{01} - a_{11} x_1) + (a_{02} - a_{12} x_2) = A - a_{11} x_1 - a_{12} x_2 \quad (17)$$

$$y_2 = b_{12} x_1 * b_{22} x_2 = B x_1 x_2 \quad (18)$$

Given that $y_j \leq 1$, from (17) we get the following:

$$x_2 \geq \frac{A - a_{11} x_1}{a_{12}} = \mathrm{C} - \mathrm{e}\, x_1 \quad (19)$$

where $C = \frac{A}{a_{12}}; e = \frac{a_{11}}{a_{12}}$.

From (18) we get the following:

$$x_2 \leq \frac{k}{x_1} \quad (20)$$

where $k = \frac{1}{B}$.

The relations (19) and (20) define the area in which can be searched the parameters $x_1^{(OUT)}$ and $x_2^{(OUT)}$. This area is shown on the figure 3 and is indicated by hatching.

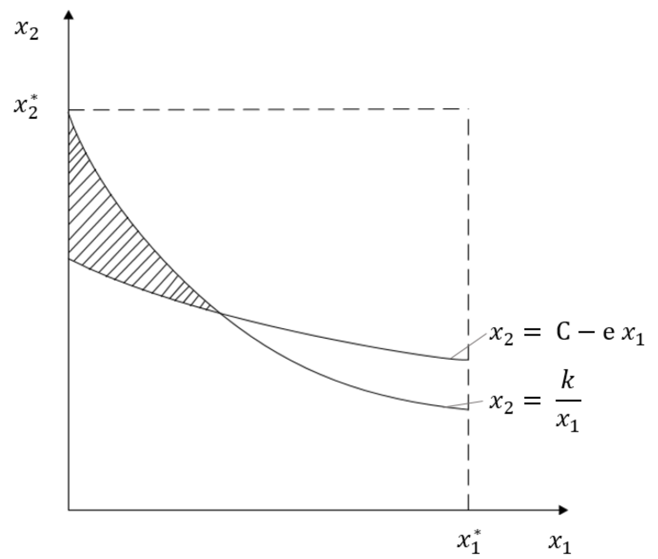

Fig. 3. Search area of $x_i^{(OUT)}, i = 1, 2$

Table 1 shows the values $x_1^{(OUT)}$ and the corresponding values $y_j = \Phi_{ij}(x_1^{(OUT)}, x_2^{(OUT)})$, for different values of linear dependencies coefficients obtained in the solution of problem 1.

TABLE I. VALUES $x_1^{(OUT)}$ AND VALUES $y_j = \Phi_{ij}(x_1^{(OUT)}, x_2^{(OUT)})$

a_{01}	a_{02}	a_{11}	a_{12}	b_{22}	b_{12}	$x_1^{(OUT)}$	$x_2^{(OUT)}$	y_1	y_2
0,5	0,5	1	1	1	1	0	0	1	0
0,5	0,5	2	1	2	1	0	0	1	0
0,5	0,5	3	1	3	1	0	0	1	0
0,5	0,5	1	2	1	2	0	0	1	0
0,5	0,5	1	3	1	3	0	0	1	0
0,5	0,5	2	2	2	2	0	0	1	0
0,5	0,5	3	3	3	3	0	0	1	0

Table 2 shows the values obtained under similar conditions in solving problem 2.

TABLE II. VALUES $x_1^{(OUT)}$ AND VALUES $y_j = \Phi_{ij}(x_1^{(OUT)}, x_2^{(OUT)})$

a_{01}	a_{02}	a_{11}	a_{12}	b_{11}	b_{12}	$x_1^{(OUT)}$	$x_2^{(OUT)}$	y_1	y_2
0,5	0,5	1	1	1	1	0,4	0,4	0,2	0,2
0,5	0,5	2	1	2	1	0	0	1	0
0,5	0,5	3	1	3	1	0	0	1	0
0,5	0,5	1	2	1	2	0	0	1	0
0,5	0,5	1	3	1	3	0	0	1	0
0,5	0,5	2	2	2	2	0,2	0,2	0,2	0,2
0,5	0,5	3	3	3	3	0,1	0,1	0,2	0,2

Table 3 shows the results of calculations when the value of coefficients a_{01} and a_{02} increases.

TABLE III. VALUES $x_1^{(OUT)}$ AND VALUES $y_j = \Phi_{ij}(x_1^{(OUT)}, x_2^{(OUT)})$

a_{01}	a_{02}	a_{11}	a_{12}	b_{11}	b_{12}	$x_1^{(OUT)}$	$x_2^{(OUT)}$	y_1	y_2
0,5	0,5	1	1	1	1	0.5	1	0.5	0.5
0,5	0,5	1	1	1	1	1	0.5	0.5	0.5
1	0.5	2	1	2	1	0.5	0.5	0.5	0.5
1	1	3	1	3	1	0.5	0.3 (3)	0.5	0.5
1	1	3	1	3	1	0.3 (3)	0.5 (5)	0.5	0.5
0.5	1	1	2	1	2	1	0.25	0.5	0.5
1	1	1	3	1	3	1.5	0.1 (1)	0.5	0.5
1	1	1	3	1	3	1	0.2	0.5	0.5
1.5	1	2	2	2	2	1	0.125	0.5	0.5
1.5	1	2	2	2	2	0.5	0.25	0.5	0.5
2	2	3	3	3	3	1	0.05	0.5	0.5
2	2	3	3	3	3	0.5	0.1 (1)	0.5	0.5

The tables show the values obtained in solving optimization problems formulated above.

Developed procedure works on the basis of the method of deformable polyhedron. Suggested method allows to estimate the possible satisfaction degree of customer and performer of the project at the pre-project stage, knowing the budget and project duration,

VI. Conclusion

The proposed approach allows to increase the validity of decisions on the feasibility of the project, taking into account the potential of the organization - the contractor, budget restrictions and project duration.

The main results of the research are:

- The program project model as multivariable control object is proposed.
- Formal procedure for formation of characteristics balanced system of program project is proposed. Also, the algorithm for finding optimal solution based on the method of a deformable polyhedron is proposed.
- Due to the proposed procedure of formation of balanced system of project characteristics is shown an example of solving the problem.

The proposed procedure is formalized, which, firstly, allows to obtain the stable estimates of the project characteristics. Secondly, it makes possible to present the procedure as a software component in project management information support systems.

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