Andrzej PASZKIEWICZ, Marek BOLANOWSKI
DEPARTMENT OF DISTRIBUTED SYSTEMS RZESZOW UNIVERSITY OF TECHNOLOGY
Al. Powstańców Warszawy 12, 35-959 Rzeszów

The method for taking into account the indeterminacy in designing distributed connection systems

Ph.D., eng. Andrzej PASZKIEWICZ

He received a Ph.D. degree in Computer Science from Lodz University of Technology in 2009. His current research interests focus on widely under-stood processes in computer networks. He works at the Department of Distributed Systems Rzeszow University Of Technology as an assistant professor.

e-mail: andrzejp@prz.edu.pl

Ph.D., eng. Marek BOLANOWSKI

He received a Ph.D. degree in Computer Science from Lodz University of Technology in 2009. His current research interests focus on computer network design and interconnection network performance. He works at the Department of Distributed Systems Rzeszow University Of Technology as an assistant professor.

e-mail: marekb@prz.edu.pl

Abstract

Designing distributed systems requires consideration of many, usually conflicting parameters. The problem of selection and adaptation of solutions for the set of possible tasks, including evaluation of ambiguity and variability characteristics also contributes to the indeterminacy. Since part of the parameters taken into account in the design process changes its meaning, during the exploitation, the project created before cannot meet the requirements posed in front of him. Therefore it becomes necessary to include variability in time of the selected characteristics in the design [1]. In this paper, the way of taking indeterminacy into account with evaluation of the solution quality is presented.

Keywords: computer networks, distributed system, indeterminacy.

Uwzględnienie nieokreśloności w projektowaniu połączeniowych systemów rozproszonych

Streszczenie

Projektowanie systemów rozproszonych, tak jak wiele innych procesów projektowych, wymaga uwzględnienia licznych, zwykle sprzecznych ze sobą parametrów opisujących charakterystyki techniczne, ekonomiczne, uwarunkowania społeczne itp. projektowanych (modelowanych) obiektów. Próba odwzorowania złożonych relacji pomiędzy tymi charakterystykami prowadzi w większości przypadków do zadań NP-zupełnych. Z drugiej zaś strony, próby uproszczenia w tym zakresie modeli projektowanych obiektów, bazując na wybranych kryteriach (pojedynczych obszarach parametrów opisujących obiekt) nie pozwalają uzyskać pożądanych rezultatów. Problem wyboru i dostosowania dostępnych rozwiązań do zbioru potencjalnych zadań, z uwzględnieniem niejednoznaczności oceny oraz zmiennością charakterystyk opisujących obiekty przyczynia się do powstania nieokreśloności. Ponieważ w trakcie eksploatacji systemów rozproszonych część parametrów uwzględnianych w procesie projektowania zmienia swoje znaczenie, stworzony wcześniej projekt może nie spełniać stawianych przed nim wymagań. Konieczne staje się zatem uwzględnienie w projektowaniu zmienności w czasie wybranych charakterystyk systemu czy sieci komputerowej [1]. W artykule zaprezentowano sposób uwzględniania nieokreśloności w procesie projektowania systemów rozproszonych, a szczególnie systemów połączeniowych. Zaprezentowane własności uwzględniania nieokreśloności pozwalają na szerokie zastosowanie ich w przypadku projektowania systemów charakteryzujących się złożonością modeli ich opisujących oraz zmiennością warunków funkcjonowania.

Słowa kluczowe: sieci komputerowe, systemy rozproszone, nieokreśloność.

1. Introduction

Designing the distributed systems requires taking numerous, inconsistent parameters into consideration. These parameters describe the technical and economical characteristics, social conditions, etc. of the designed projects [1, 3]. The attempt of mapping complex relations among those characteristics leads to NP-complete tasks [2]. On the other hand, attempts of reduction of the designed object models based on chosen criterions (unit area of parameters describing object) do not allow obtaining the required results [4].

One of the problems in this area is selection of communication means that are used to connect components creating distributed systems. It is the fundamental element for designing teleinformatic systems [3]. The appropriate selection of technology, transmission protocol, etc. allows maximizing the efficiency of complete system utilization. Each of available communication methods has important working constraints resulting from technical characteristic, which restrict the range of their uses indeed. We observe mutual covering the areas of the uses of communication technologies what causes the ambiguity of the choice of a concrete solution and the same contributes to inception of the area of indeterminacy in the designing process.

Therefore, the above problem is common for a lot of solutions, which should be adapted to the set of potential tasks, taking an ambiguous evaluation and variability of characteristics describing objects into consideration, and contributes to creating an indeterminacy. This problem is described in the paper [2].

Let us consider a distributed communication system, where X is the set of tasks $\left(x \in X \subset R_n\right)$, and Y is the set of possible solutions $(y \in Y \subset R_p)$. In the next step a zone of attainable tasks $d\left(y_i\right), i=\overline{1,m}$ of the examined system is built [5]. This procedure reduces to an approximate building of these zone borders in the characteristics space of tasks taking limitation for the function conditions.

In the discovered zones group $d\left(y_i\right), i=\overline{1,m}$, the resource requirements of making tasks set X by system means are checked. They are modelled as X covered by the zones $d\left(y_i\right), i=\overline{1,m}$:

$$\bigcup_{i=1}^{m} d\left(y_i\right) \supset X. \tag{1}$$

There is a zone of optimal using means of communication (specialization zones $D_i, i=\overline{1,m}$) determined on the stage of the optimal selection of set X. This is necessary for evaluating a needful series number and parameters $s_i, i=\overline{1,m}$ for any type of the means of communication.

$$D\left(y_i\right) \subset d\left(y_i\right), i=\overline{1,m}, \quad D\left(y_i\right) \cap D\left(y_k\right) = \varnothing, i \neq k, \quad \bigcup_{i=1}^{m} D\left(y_i\right) = X. \tag{2}$$

The essence of a problem is the solution evaluation as a form of the elements set $D(y_i) = X_A$ (means of communication) taking the indeterminacy into consideration [4].

2. Indeterminacy involving methods

The indeterminacy involving method will be called as the rule that unambiguously attributes a number $F(X_A)$ to any subset $X_A \subset X$ with the determined function $f(x)$ on it. The set *S* will be the permissible value set of an indeterminacy involving. All known indeterminacy methods presented in the authors' studies fulfils the above definition [1, 4, 5]. It results from the fact that the methods are determined for any subsets of an indeterminacy set (specifying the rules of normalize weight factors on the set *X* is necessary). However, this definition is wider than a general meaning where there is necessary to determine one number that corresponds to values $f(x)$ directly in the whole X set. This relationship is a special case of the determined definition, when $X_A = X$. The definition assumes that there is a possibility of estimating the influence of the indeterminacy set both entirely and partly. Thus, the way of indeterminacy consideration is both the functional and function of this set. With the constant X_A, it is the functional over the function set $f(x)$ defined on X but with the constant on X of the function $f(x)$ - it is the function from subsets of X.

In conformity with above, $f(x)$ will be called as the generalized costs $F(X_A)$ – *n*-the generalized costs and $f(x)$ will be considered as a normalized one: $0 \le f(x) \le 1, \quad x \in X$ [3].

If the generalized costs are considered as a possible relative (in relation to the highest one) level of *y* solution quality in conditions *x*, then *n* – generalized costs [4] are an averaging level of *y* solution quality on the whole set X_A, but the averaging rule is determined by the method of the indeterminacy consideration [5].

3. Calculation of n-generalized costs

The indeterminacy is directly connected with the selection criteria. The problem consists in the efficiency evaluation of many of alternative technical solutions is common in the real world. In this case, we are dealing with different, often conflicting technical and economic criteria of evaluation [3]. Any available and acceptable solution can be described by multiple criteria with different coefficients for each of them.

Because the efficiency of the solution y cannot be sufficiently exactly characterized by one coefficient of efficiency f_y, the vector of the coefficients of efficiency $f = (f_1, \ldots, f_n)$ was introduced, where f_i – *i*-th the partial coefficient of efficiency, $i = 1, \ldots, n$. We can receive the value of the coefficient of local efficiency on the basis of the expression:

$$\varphi(f_1, \ldots, f_n), \tag{3}$$

where: φ - the convolution principle of the partial coefficients of efficiency. Commonly, the above expression is called the principle of defining the efficiency on the basis of partial coefficients [1, 4]. From the point of view of the convolution principles, φ has to belong to the set of evenly useful principles Φ $(\varphi \in \Phi)$, from which any can be preferred, because unique premises do not exist.

We will consider two types of the set of indeterminacy *X*: consisting of the finite set of elements *N* and closed, limited *n*-dimensions area of Euclid's space.

Let *X* consist of finite number of elements $X(x_i), i = 1, \ldots, N$. When we consider this set as a result of sequential linking its elements and use monotonicity and stability features [2] we can write:

$$F(X) = \Phi\left(f(x_1), \Phi\left(f(x_2, \Phi\left(\ldots, \Phi\left(f(x_{N-1}), f(x_N)\right), \ldots\right)\right.\right. . \tag{4}$$

Then we can use the given generating continuous function $G(t)$ [6] in the methods taking indeterminacy into account [3]. Therefore, we get:

$$\begin{aligned} G(F(x)) &= G\Big(\Phi\big(f(x_1), \Phi\big(f(x_2), \Phi\big(\ldots, \Phi\big(f(x_{N-1}), f(x_N)\big), \ldots\big)\big)\big)\Big) = \\ &= G\big(f(x_1)\big) + G\Big(\Phi(x_2), \Phi\big(\ldots, \Phi\big(f(x_{N-1}), f(x_N)\big), \ldots\big)\Big) - G(l) = \\ &= \ldots = G\big(f(x_1)\big) + G\big(f(x_2)\big) + \ldots + G\big(f(x_N)\big) - (N-1)G(l) = \\ &\sum_{i=1}^{N} G(f(x_i, A)) - (N-1)G(l). \end{aligned} \tag{5}$$

We will require that couple $G(t), l$ [2, 6] describing permissible method taking indeterminacy into account, fulfill condition of the averaging. So, the following condition has to be fulfilled for: $f(x_i) = F(X)$

$$G(F(X)) = \sum_{i=1}^{N} G(F_A(X)) - (N-1)G(l) \tag{6}$$

therefore, $l = F(X)$ because of strictly monotonicity $G(t)$ [4]. Finally, it is obtained:

$$G(F(X)) = \frac{1}{N} \sum_{i=1}^{N} G(f(x_i, A)), \tag{7}$$

it allows forming the following functional:

$$F(X) = G^{-1}\left(\frac{1}{N} \sum_{i=1}^{N} G(f(x_i, A))\right) \tag{8}$$

Let X be the closed and limited area of measure of Euclid's space Ω. That set will be divided into *N* areas with the same measure $\Delta_i = \Delta = \Omega / N,\ i = 1, \ldots, N$. Any point is chosen $x_i \in X$ from them in the next step. The whole set *X* is characterized by the given set of points X_N with known closeness. The value F_N of effective coefficients of the solution, calculated with X_N instead of X, fulfills the equation:

$$\begin{aligned} G(F_N) &= \frac{1}{N} \sum_{ii=1}^{N} G(f(x_i, A)) = \frac{1}{\Omega} \sum_{i=1}^{N} G(f(x_i, A)) \frac{\Omega}{N} = \\ &= \frac{1}{\Omega} \sum_{i=1}^{N} G(f(x_1, A))\Delta \end{aligned} \tag{9}$$

When *N* increases then X_N characterizes *X* better, thus basing on the continuity of $G(t)$ [4], it is possible to note:

$$F(X, y) = G^{-1}\left(\frac{1}{S_X} \int_{x \in X} G(f(x, y))dx\right), \tag{10}$$

where S_X - measure of space *X*.

Therefore, the n-generalized costs can be defined by the following formulas for $X=\{x_i\}_{i=1,...,N}$ [5]:

$$F(X,y)=G^{-1}(\frac{1}{N}\sum_{i=1}^{N}G(f(x_i,y))) \cdot \quad (11)$$

for X – the Euclid's space area with the finite measure:

$$F(X,y)=G^{-1}(\frac{1}{S_X}\int_{x\in X}G(f(x,y))dx). \quad (12)$$

In this case the reduced n-generalized costs are calculated as an average value of the reduced generalized costs for the indeterminacy set X, but the rule of converting generalized and n-generalized costs into the reduced ones is determined by the indeterminacy consideration (by the generating function $G(t)$) [7].

Aggregated indeterminacy consideration supposes a necessity of enumerating multidimensional integrals on the indeterminacy set X for the reduced generalized costs which are calculated for the constant generating function from a typical set. For enumerating these integrals in the computer there are standard programs. However, when different indeterminacy forms influence the generalized costs independently (i.e. the set X can be shown as a direct product of the value set of indeterminate factors with different type) then it is advisable to pass from simultaneous consideration of all the indeterminacy type to the sequent one.

The above n-generalized costs expression allow them to be widely used in the design of distributed systems. The partial functions can express different criteria for the operation of those systems, such as economic or technical. Therefore, the amount and type of specific functions depends only on the knowledge and experience of the designer.

In the particular case of distributed communication systems it may be e.g. minimizing the maximum load of the communication channel, measure bandwidth utilization, a life cycle cost of links, etc. So, one of the basic technical coefficient, determining the applicability of the solution is a maximum load of the communication channel, which aims at minimizing the maximum load of the communication channel, according to the expression:

$$\min \rho_{\max} = \min\left(\max_{y_i} \rho_{y_i}\right) = \min\left(\max_{y_i} \sum_{w=1}^{|W|} \lambda_w\right), \quad (13)$$

where: ρ_{y_i} describes traffic on a given link by using the i-th communication mean; w is a given communication channel from the set of available channels.

On the other hand, the basic and commonly used coefficient of the technical systems efficiency is a life cycle cost called LCC (Life Cycle Cost):

$$LCC = K_C + K_E + K_U \cdot \quad (14)$$

where: K_C is the cost of construction (design, implementation, testing, etc.); K_E is operating expenses; K_U describes loss on disposal.

The above coefficients are only examples. When designing real connection structures there should be considered much more various functions.

4. Summary

In this paper the way of indeterminacy consideration in the distributed system designing process, particularly teleinformatic systems, is presented. A lot of acceptable solutions and more than one criterion of evaluation cause indeterminacy. This approach will make extensive use of it in the case of the designing systems characterized by a complexity that describes topologies and a variability of function conditions. For example, the presented solution can be used by the selection communication means in the designing of distributed interconnection structures, where the set of task X and the set of communication means Y are defined. Moreover, the considered partial functions of evaluation, i.e. technical and economical, can be contradictory.

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