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FORMALIZATION OF THE INFOCOMMUNICATION NETWORK ADAPTATION TASK WITHIN THE LIFE CYCLE AND THE GENERAL APPROACH TO ITS SOLUTION BASED ON GENETIC ALGORITHMS

Nikityuk L.A.

O.S. Popov Odessa national academy of telecommunications,
1 Kuznechna St., Odessa, 65029, Ukraine.
lesyanikityuk579@gmail.com

ФОРМАЛІЗАЦІЯ ЗАДАЧІ АДАПТАЦІЇ ІНФОКОМУНІКАЦІЙНОЇ МЕРЕЖІ В МЕЖАХ ЖИТТЄВОГО ЦИКЛУ І ЗАГАЛЬНИЙ ПІДХІД ДО ЇЇ РОЗВ’ЯЗАННЯ НА ОСНОВІ ГЕНЕТИЧНИХ АЛГОРИТМІВ

Нікітюк Л.А.

Одеська національна академія зв’язку ім. О.С. Попова,
65029, Україна, м. Одеса, вул. Кузнечна, 1.
lesyanikityuk579@gmail.com

ФОРМАЛИЗАЦИЯ ЗАДАЧИ АДАПТАЦИИ ИНФОКОММУНИКАЦИОННОЙ СЕТИ В ПРЕДЕЛАХ ЖИЗНЕННОГО ЦИКЛА И ОБЩИЙ ПОДХОД К ЕЕ РЕШЕНИЮ НА ОСНОВЕ ГЕНЕТИЧЕСКИХ АЛГОРИТМОВ

Никитюк Л.А.

Одесская национальная академия связи им. А.С. Попова,
65029, Украина, г. Одесса, ул. Кузнечная,1.
lesyanikityuk579@gmail.com

Abstract. Infocommunication network on formal grounds is a complex system that functions in a disturbing environment, evolves over time and is characterized by non-stationary fault flow of its subsystems and elements. In this paper the infocommunication network is considered as an object of adaptation within its life cycle including optimal planning, management, reconstruction and development forecast. A generalized architecture of the infocommunication network is presented reflecting the hierarchy of epistemological levels of its model representation. A generalized characteristic of system tasks in infocommunications and the role of adaptation in their solution are presented. The general description of the adaptation problem for the infocommunication network is formulated and a dynamic model of the formalization of the adaptation process of the object is considered. Specific features of the construction of genetic algorithms for solving the problem of adaptation of the infocommunication network are indicated.

Key words: infocommunication network, planning, control, reconstruction, system approach, adaptation model, genetic algorithms.

Анотація. Інфокомунікаційна мережа за формальними ознаками є складною системою, яка функціонує у збурюючому зовнішньому середовищі, еволюціонує в часі і характеризується нестаціонарністю потоку несправностей її підсистем і елементів. У даній статті інфокомунікаційна мережа розглядається як об'єкт адаптації в рамках її життєвого циклу, що включає оптимальне проектування, керування, реконструкцію та прогноз розвитку. Представлена узагальнена архітектура інфокомунікаційної мережі, яка відображає ієрархію епістемологічних рівнів її модельного уявлення. Надана узагальнена характеристика системних задач в інфокомунікаціях і роль адаптації в їх розв’язанні. Сформульована загальна постановка задачі адаптації для інфокомунікаційної мережі та запропонована динамічна модель формалізації адаптаційного процесу об'єкта. Названі особливості побудови генетичних алгоритмів для розв’язання задачі адаптації інфокомунікаційної мережі.

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Ключеві слова: інфокомунікаційна мережа, планування, керування, реконструкція, системний підхід, адапційна модель, генетичні алгоритми.

Аннотация. Инфокоммуникационная сеть по формальным признакам представляет собой сложную систему, которая функционирует в возмущающей внешней среде, эволюционирует во времени и характеризуется нестационарностью потока неисправностей ее подсистем и элементов. В данной работе инфокоммуикационная сеть рассматривается как объект адаптации в рамках ее жизненного цикла, включающего оптимальное проектирование, управление, реконструкцию и прогноз развития. Представлена обобщенная архитектура инфокоммуникационной сети, отражающая иерархию эпистемологических уровней ее модельного представления. Представлена обобщенная характеристика системных задач в инфокоммуникациях и роль адаптации в их решении. Сформулирована общая постановка задачи адаптации для инфокоммуникационной сети и предложена динамическая модель формализации адаптационного процесса объекта. Указаны особенности построения генетических алгоритмов для решения задачи адаптации инфокоммуникационной сети.

Ключевые слова: инфокоммуникационная сеть, планирование, управление, реконструкция, системный подход, адаптационная модель, генетические алгоритмы.

The process of building the Global Information Infrastructure is realized through the continuous integration of telecommunication and information technologies. Thanks to this, by the beginning of the 21st century, a new communication paradigm was finally formed – infocommunications [1, 2].

Today the term infocommunications is quite popular and understood as a set of means for information processing, accumulation, storage and transferring through the space, as well as subscriber terminal units, implemented into the common network structure, providing public access to informational, software*,* computing resources and information exchange is ensured [3].

One of the main research objects, in accordance with the new paradigm, is the infocommunication network which should be considered as a system set of information, computing, and software resources interacting and accessed by means of a telecommunication network.

It is out of question that, by formal attributes, we deal with a complex system which functions in noisy environment and is evolving through time. It is also characterized by non-stationary flow of failures of its elements and subsystems. Changes in state characteristics of such complex system are hardly predictable; it is highly difficult to obtain adequate models for research object, to formalize and search for optimal solutions for main system tasks such as optimal planning, management, reconstruction, development prognosis [4].

This work offers to examine general approach to solution of the mentioned system tasks considering the adaptation of complex systems [5, 6].

Adaptation can be broadly defined as a process of purposeful changes in parameters and structure of the system. The process determines the criteria for system functioning and achieving fulfillment of these criteria. There is no clearly defined requirements for a given optimization criterion and complex systems, as a rule, do not have the sole criterion of functioning. The system matching an infocommunication network operates in a multicriteria environment; these criteria may be not only extreme, but they have restrictions. This results in the need to specify multiple criteria and vary their choice depending on the task set. Thus, the very choice of criteria in a changing external environment and the internal needs of the system is an adaptive process.

The procedure for selecting the optimal criterion in the process of adaptation extends the notion of adaptation and brings it to the interpretation of biology and sociology. This is a very important factor that the technique is still not operating effectively in adaptive systems.

The aim of this work is to formulate and formalize the task of adaptation for the infocommunication network within its life cycle on the basis of a dynamic model of formalization of the adaptation process of the object.

Infocommunication network as an adaptation object Infocommunication network is a complex system with multiple adaptation tasks at different levels of its organization. Infocommunication network is characterized by:

– the lack of the necessary mathematical description, i.e. the lack of the F algorithm for obtaining object states Y depending on states of inputs (controlled U and uncontrolled X) that is $Y = F(X,U)$;

– non-stationary nature results in system characteristics drift, unpredictability of failures flow, evolution through time. All these make adaptation an essential measure for keeping the object in an optimum state with environment;

– unpredictability of environment which results in varying range of subscribers needs, in unpredictability of probabilistic properties, in unpredictable nature of service requests flow, in changes of user requirements to resources involved in service;

– necessity to vary parameters and structure. Notable structure variations have much greater effect compared to parametric.

Thus, infocommunication network as an adaptation object is an extremely complex object and implementation of adaptation is a least-evil solution. It is not an exaggeration to state that mentioned systems can not exist in their optimum state under conditions when environment and systems themselves change without adaptation algorithms – genetic algorithms.

Hierarchy of epistemological levels of the infocommunication network model representation Hierarchy of epistemological levels creates taxonomy mainframe of any system [6]. It is based on the representation of a system as a model of research object and rather depicts multilevel interaction between a scientist and object than the object itself. Such a hierarchy methodologically simplifies a set of methods for solving system tasks. The methods involve computing technique.

At the lowest epistemological level (level 0) system is defined with the help of a set of variables representing researched characteristics of an object, its elements and states. This set can be divided into subsets according to different criteria: for example, input and output, internal and external variables. Input and internal variables are independent variables because they are considered to be determined by some factor (environment, variation of internal states) residing outside the examined system.

At the first epistemological level system is added with values achievable by variables. Depending on a task values can be obtained through measurement, statistically or directly set (in tasks of planning). If there is knowledge about some invariant characteristics of relations between variables, then data can be generated by means of simulation.

At the second epistemological level invariant nature of variables is represented by a general characteristic setting restriction for the given multitude. The task of parametric invariant restriction is description of process of variables' values generation.

Structure of a system model is described at higher epistemological levels. The structure is represented by interconnected structured elements and subsystems with connectivity provided by some common variables or in other way.

General characteristic of system tasks architecture in infocommunications and a role of adaptation for their solution Multitude of system tasks is huge and diverse. However, for a certain artificial object (infocommunication network in this case) it can be fully represented by a finite set of system tasks. Extent of systems tasks specification can be researched using the hierarchy of epistemological levels shown above.

Actual user needs, purpose and practical principles of system organization are determined at the highest level of abstraction. In this case we refer to *planning*. Tasks of planning in infocommunications include optimum synthesis of a network in general, its segments and synthesis of different service platforms (distributed computing, cloud services). Distinctive feature of system planning is the fact that parametric invariant restrictions for variables are mainly defined by a user. It is known that complexity of computation for planning tasks increases rapidly with increase of number of variables involved. The way to decrease planning complexity is to drive down objective criteria. Instead of optimum approach “good” or “satisfying” one is implemented. Such an approach to system planning assumes usage of heuristic methods, which actualizes application of adaptation in planning. Adaptation in this case is equivalent to search optimization under interference associated with uncertainty of environment and an object. It replaces compensation requiring adequate model of an object.

Effective operation of the system is impossible without solving the task of *control* since any complex system operates in changing environment and a system changes itself.

Control is a process of dedicated influence on an object that shifts the object to the required (purpose) state. Control requires solutions for the following tasks: monitoring of states of system elements and environment, specification of control purposes, structural synthesis of a control model, parametric synthesis of a control model, synthesis of control (algorithm of controlled parameters behavior in time) and its implementation. Peculiarity of the examined object requires adding a task of adaptation (correction of control while its precise model is absent). It is convenient to classify adaptation in this case as well as control according to the ways the object changes. If its parameters change, then it is parametric adaptation; if their structure changes, then it is parametric adaptation.

The task of *identification* as a rule supplements the task of system *reconstruction* (rebuilding according to new principals). The task of identification is to select from a reconstruction multitude of systems a system that is the best hypothetical reconstruction for the initial system. Solution assumes generation of a reconstruction multitude for a given system under reconstruction. The multitude is formed according to intuitively selected criteria, which means it may not include the best variant of a system. The latter fact makes identification questionable because it involves information obtained solely on the basis of the generated reconstruction multitude. In the case of lacking full information the task of adaptation is risen allowing us to identify the weakest possible restriction for variables or the most imprecise subset of all states of variables for the given structured system.

Forecast of a complex system development is also associated with adaptation because it simulates the process of system *evolution* and is reduced to an algorithm of its structure variations in the form of random mutations changing performance effectiveness of an adapted object.

Thus, it is possible to conclude that system tasks in infocommunications are content subtasks of a general adaptation process arising at different stages of infocommunications life cycle. They can be described operationally; however, general methodology for solving them must be based on adaptation methods that involve the use of genetic algorithms.

General tasks statement of adaptation The task of adapting the infocommunication network should be considered as a sequential chain of steps performed at different stages of its life cycle in the absence of sufficient information to clearly formalize the goal, due to the uncertainty of the environment and the complexity of the object itself. Thus, it can be stated that the formalization of such a task is a dynamic model of the life cycle of the study object.

Herewith, adaptation is not considered as the task of compensation requiring adequate model of an object with known state of environment.

Let us consider adaptation as particular case of control consisting in changes of controlled factor in the way of maintaining some preset functionality of the object in required state despite internal and external influences.

Let object G be down-dropped in environment with state X affecting the state Y of the object. Moreover, the state Y of the object can be changed with the help of adaptive factors:
$U = (u_1, \ldots, u_g)$ – object parameters.

The purpose of adaptation determines requirements to criteria set for the Y state of object. These requirements may have different structure.

Criteria of inequality:

$$H(U) = (h_1(U), \ldots, h_n(U)) \geq 0. \quad (1)$$

Criteria of equality:

$$Q(U) = (q_1(U), \ldots, q_m(U)) = 0. \quad (2)$$

Minimized criteria:

$$W(U) = (w_1(U), \ldots, w_p(U)) \to \min, \quad (3)$$

where:

$$h_i(U) = M_r h'_i(Y) = M_r h'_i(G(X, U)) \quad i = 1,...,n; \quad (4)$$

$$q_j(U) = M_r q'_j(Y) = M_r q'_j(G(X, U)) \quad j = 1,\ldots,m; \quad (5)$$

$$w_k(U) = M_r w'_k(Y) = M_r w'_k(G(X, U) \quad k = 1,\ldots,p, \quad (6)$$

where M_r – operator of averaging over X.

Criteria of adaptation are represented by functionality defined over Y states of the object as averaged values of the $h'_j(G(X, U))$, $q'_i(G(X, U)$, $w'_k(G(X, U))$ functions that must be set.

The purpose of adaptation is to solve tasks of the following kind:

$$W(U) \to \min \Rightarrow U^*;$$
$$U \in C, \quad (7)$$

where C: $H(U) \geq 0$; $Q(U) = 0$.

Simplification of the task (7) is the single-criterion task for adapted parameters of object in discrete time instants while states of environment create a random process in time similar to white noise.

We illustrate this with the example of constructing a model of structural adaptation for the infocommunication network

Let the structure St be described by the graph G (N, B), where N is the set of vertices of the graph, the power of n, and B is the set of arcs of power m with the parameters $\| b_{i,j} \|$, where $b_{i,j}$ is the parameter of the arc connecting the vertex i with vertex j (i, j = 1,2, ...,n). On the graph G a functional is specified, which must be minimized:

$$W(G) \to \min;$$
$$G \in S,$$

where S is the constraint that the adapted graph G must satisfy in accordance with conditions of the task (7).

We describe the set Ξ of possible variations of the graph G. It can consist, for example, of the following changes:

$$\Xi = (\xi_1, \xi_2, \xi_3, \xi_4, \xi_5, \xi_6, \ldots, \xi_p),$$

where ξ_1 – is union of two randomly selected vertices of the graph into one;

ξ_2 – is the introduction of a new (m + 1)-th vertex with random constraints $b_{i+1,i}$ ($i=i_1,...,i_k$) and $b_{j,,n+1}$ ($j=j_1,...,j_q$);

ξ_3 – is elimination of a randomly selected vertex together with its connections;

ξ_4– is introduction of a new connection of two randomly selected vertices;

ξ_5 – is elimination of a randomly selected edge;

ξ_6 – is accidental switching of a randomly selected arc, etc.

As can be seen the spectrum of possible random mutations of the graph can be sufficiently large, which ensures the evolution of the great variety needed to find the optimal graph.

The values of the parameters of the arcs of the graph can be purposefully changed, at the stage of parametric adaptation, preceding the selection of the best structures. This can be done for each discrete time point based on the simulation results.

Peculiarities of the constructions of genetic algorithms for solving the adaptation problem for the infocommunication network When constructing genetic algorithms for solving the problem of adaptation for an infocommunication network, one should take into account the hierarchical nature of the adaptation itself for such an object. At the upper level the structure of the St object is adapted and at the bottom - its parameters U. It is obvious that these two adaptation levels work in different time modes, namely: the rate of parametric adaptation is much higher than the rate of structural adaptation. So, for every step of structural changes in the object the entire cycle of parametric adaptation must occur, since otherwise the effectiveness of the changed structure can not be fully appreciated.

Obviously, the methods for solving the problems of structural and parametric adaptation are different which makes them differentiate. In turn, structural adaptation is conveniently divided into alternative and evolutionary.

The *alternative adaptation* is characterized by the fact that the set of admissible structures $\{St\}$ is small and contains some alternative structures.

Evolutionary adaptation models a process analogous to biological evolution. Such an algorithm is distinguished by the introduction of insignificant variations of the St structure modeling random mutations which also slightly change the Q efficiency of the adaptive object. There is a relation of the type of the Lipschitz inequality:

$$\left| Q\,(St + \Delta St) - Q\,(St) \right| \le \mu \left\| \Delta St \right\|, \tag{8}$$

where μ = const, and the norm of the variation of the structure $\left\| \Delta St \right\|$ should be understood as the number characterizing the degree of structure change with this variation ΔSt.

Modifications ("mutation") of the structure ΔSt and the rule of selection of the most suitable variations form a mechanism of evolution, allowing to construct a sequence of improving structures:

$$St(1) \to St(2) \to St(3) \to St(n) \to \tag{9}$$

having the property:

$$Q(St(n-1)) < Q(St(n)). \tag{10}$$

In the development of the algorithm, the violation of the relation (10) is permissible, for example, in the case when the structure is not changed by its change. In this case, the best of the "mutated" structures is selected, which violates (10), but provides the evolutionary procedure with global properties most valuable in structural adjustment problems.

In conclusion, we can note the following.

If object's changes in adaptation process are conveniently performed with the $U = (u_1, \ldots, u_n)$ parameters, then we dial with parametric adaptation. Notable every u_i parameter may take on a finite or infinite value.

Frequently it is convenient to perform adaptation of object not by changing its parameters but modifying its structure. In this case we have structure adaptation and control factor is represented by the $U = (S, P)$ pair; where S denotes structure parameters while P denotes multitude of adapted during structural changes parameters allowing, at the same time, parametric adaptation as well.

When solving system problems in infocommunications, in contrast to applied mathematics, it is expedient to use adaptation as an integral part of the decision process itself. Adaptation of the decision search process occurs when the algorithm needs to be changed in the search process in order to maintain its effectiveness at the desired level.

This will allow us to realize the solution of problems in their natural formulation, without resorting to simplifying assumptions. A similar problem occurs when optimizing complex objects for which deterministic decision algorithms can not be created in advance.

It is obvious that methods for solving tasks of structural and parametric adaptations are different, which forces to use such a differentiation.

Conclusion Modern communication networks cannot be considered only at the level of telecommunications. Their functional capabilities in the 21st century reach a fundamentally new level which is defined as "infocommunication".

The main system tasks in infocommunications such as design, management, reconstruction, development forecast, should be considered as tasks of adaptation of complex systems within the life cycle of the infocommunication network.

The formalization of the tasks of adapting the infocommunication network is carried out using a model that allows us to take into account changes in the controlled factor in such a way as to maintain the given functional of the object in the required state regardless of the action of external and internal influences.

When constructing genetic algorithms for solving the adaptation problem of the infocommunication network it is necessary to take into account the hierarchical nature of the adaptation itself for such an object. Often the adaptation of an object is more convenient not by changing its parameters, but by modifying its structure.

The tasks of the adaptation of complex objects are connected, first of all, with the decision of tasks of increasing the efficiency of their functioning throughout the whole life cycle. Methods and algorithms for solving such problems are the main mechanisms of the processes of targeted improvement and optimal design of complex systems in the conditions of uncertainty of their subsequent functioning.

REFERENCES:

1. Nikityuk L. "Infocommunicatsii – novaya paradigma sviazi". Naukoemkie technologiy v infokommunikatsiah. Obrabotka i zashchita informatsii. Collektivnaya monographia / editing by V.M. Bezruk, V.M. Barannik. – X.: Comp.SMIT, 2013. – 398 p.
2. Kuzovkova T.A., Timoshenko L.S. "Analiz i prognozirovanie razvitia infocommunicatsiy". – M.: Goriachaia linia – Telecom, 2009. – 224 p.
3. Vorobienko P., Nikityuk L. "Terms and Definitions in the Area of Infocommunication" - Proceedings of the 11th International Conf. "Modern Problems of Radio Engineering, Telecommunications and Computer Science" (TCSET'2012). Lviv-Slavske, 21-24 feb 2012, pp. 275.
4. Nikityuk, L. "System tasks in information communications and a general approach to their solution" - Proceedings of the 22th Int. Crimean Conf. "Microwave & Telecommunication Technology" (CriMiCo'2014). Sevastopol, 2014, pp. 380-382.
5. L. Rastrigin "Adaptatsia slozhnikh sistem". – Riga: Znanie, 1981. – 375 p.
6. G.Klir "Architecture of Systems Problem Solving". – Plenum press, New York and London, 1990. – 544 p.

ЛІТЕРАТУРА:

1. Нікітюк Л.А. Інфокомунікації – нова парадигма зв'язку. Наукоємні технології в інфокомунікаціях. Обробка та захист інформації: колективна монографія; за ред. В.М. Безруки, В.В. Баранніка. – Харків: СМІТ, 2013. – 398 с.
2. Кузовкова Т.А. Аналіз і прогнозування розвитку інфокомунікацій / Т.А. Кузовкова, Т.С Тимошенко. –- М.: Горяча лінія – Телеком, 2009. – 224 с.
3. Воробієнко П.П. Інфокомунікації: терміни і визначення в галузі інфокомунікацій / П.П. Воробієнко, Л.А.Нікітюк // 11-та міжнародна конференція [«Сучасні проблеми радіоинженерії, телекомунікацій й комп'ютерних наук»] (TCSET'2012), (Львів, 21-25 лютого 2012), – Львів: Славське, 2012, – С. 275.
4. Нікітюк Л.А. Системні задачі в інфокомунікаціях і загальний підхід до їх вирішення / Л.А.Нікітюк // 22-га міжнародна конференція [«Мікрохвильові та телекомунікаційні технології»] (CriMiCo'2014). – Севостополь, 2014. – С. 380-382.
5. Растрігін Л.А. Адаптація складних систем / Л.А. Растрігін. – Рига: Знання, 1981. – 375 с.
6. Клір Дж. Системологія. Автоматизація розв'язання системних задач / Дж. Клір; пер. з англ. – М.: Радіо і зв'язок, 1990, – 544 с.