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INFORMATION SPACE MODEL IN TASKS OF DISTRIBUTED MOBILE OBJECTS MANAGING

V. O. Filatov, A. L. Yerokhin, O. V. Zolotukhin, M. S. Kudryavtseva

Kharkiv National University of Radio Electronics

e-mail: andriy.yerokhin@nure.ua, oleg.zolotukhin@nure.ua

A model of information systems of interaction "user–information environment", as well as a model of information space of distributed information and communication system with serial and arbitrary serial-parallel decision process is investigated. The basic components of the information and communication system are distinguished. The adaptive choice methods are analyzed. The algebraic system of information space is represented, which allows us to form a common approach to solving problems of distributed mobile objects control under conditions of uncertainty, finding more simple solutions to solve complex problems in the different fields of activity.

Keywords: *distributed mobile object, uncertainty conditions, information space, task flow, adaptive choice method, information and communication system*

МОДЕЛЬ ІНФОРМАЦІЙНОГО ПРОСТОРУ В ЗАДАЧАХ УПРАВЛІННЯ РОЗПОДІЛЕНИМИ МОБІЛЬНИМИ ОБ'ЄКТАМИ

В. О. Філатов, А. Л. Єрохін, О. В. Золотухін, М. С. Кудрявцева

Харківський національний університет радіоелектроніки

Досліджено модель інформаційного простору розподіленої інформаційно-комунікаційної системи з послідовним та довільним послідовно-паралельним процесом прийняття рішень. Проаналізовано методи адаптивного вибору та запропоновано алгебраїчну систему інформаційного простору для вирішення задачі управління розподіленими рухомими об'єктами в умовах невизначеності, забезпечення простіших рішень для складних задач у різних сферах діяльності. Запропонований підхід базується на використанні поточної інформації, отриманої в результаті підбору окремих дій, які можуть компенсувати відсутність попередньої інформації та реалізувати оптимальну стратегію управління в класі систем. Розглянуте формулювання адаптивного вибору рішень забезпечує формальну модель інформаційного простору, як середовища управління об'єктом та системою управління. Сформульовано загальні принципи формального підходу до побудови компонентів таких інформаційних систем, на основі чого обґрунтовано використання алгебраїчного підходу. Такий підхід дає можливість визначити новий тип даних, який характеризується набором операцій. Це дозволяє будувати такі операції не тільки розробникам мови, але й програмістам створювати власні. Запропоновану модель інформаційно-комунікаційного простору можна використовувати в різних системах, де існує вимога щодо розподіленого управління мобільними об'єктами, в тому числі можливість управління в режимі реального часу. Одночасно з використанням режиму реального часу можна вивчати та керувати автономними мобільними об'єктами як у послідовному, так і у багатопотоковому паралельному режимах.

Ключові слова: *розподілений мобільний об'єкт, умови невизначеності, інформаційний простір, потік завдань, метод адаптивного вибору, інформаційно-комунікаційна система.*

Introduction. Autonomous intelligent systems based on mobile objects are widely distributed in the most important spheres of human activity, such as space, industrial production, nuclear power, petrochemical and natural gas industry, construction, warfare and others.

A specific feature of the functioning of these classes of systems is the high level of uncertainty, which is caused by the unpredictability of the environment, large dimension of the state space, the lack of accurate mathematical models and decision hierarchy. For example, currently a perspective direction is to create universal mobile robots based on multi-modular design. That allows us to create a robot composed of identical modules, configured in various types of configurations, depending on the assigned tasks.

When the mobile robot moves to the target in a known or unknown environment, it must overcome various kinds of obstacles; avoid collisions with stationary and moving objects. To solve such problems in the offline mode a robot control system must be able to interpret, plan and carry out the received task without external interference, using on-board computer system.

Such complex technical tasks can be solved using only an intelligent control system based on information and communication technology, allowing making management decisions based on both accumulated knowledge and experience in the operation and handling of large information flows in real time, as well as the methods and algorithms of artificial intelligence theory.

Information and communication technology includes information processes and methods using computer hardware and telecommunications means [1].

On the basis of these technologies an information and communication system, or network, for example Internet, are created. The advantage of information and communication technologies used in various fields, is the ability to combine various types of resources with computational algorithms [2, 3]. This allows finding more simple solution complex problems.

The purpose of the research. Consider a general statement of the problem of adaptive choices shown in Fig. 1. The achievement of the target in uncertainty conditions is possible on the basis of application of the adaptive approach, the meaning of which is to use the current information obtained as a result of the selection of individual actions that can compensate the lack of prior information and implement optimal management strategy in the class of systems.

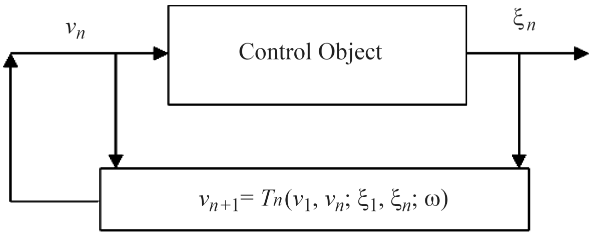

Fig. 1. Adaptive selection scheme.

As a result of choice made by control the system loss control ξ_n represents random variable outcome elementary function ω and depends on ν_n and possibly on states of the system. Variants $\{\nu_n\}$ realized in this sequence must be such to achieve a predetermined goal, formulated in terms of the limits of the current secondary losses.

Having a priori uncertainty, consisting in the absence of accurate information about the losses of the system and its characteristics, leads to the fact that the formation sequence variants $\{\nu_n\}$ ensuring the achievement of the target conditions of the problem, should be carried out in accordance with the adaptive approach.

The choice of the next option ν_{n+1} is made based on the information received at a given moment of time on loss sequence $\xi_1, \xi_2,\ldots,\xi_n$, corresponding to the implemented sequence of options $\nu_1, \nu_2,\ldots,\nu_n$.

It means that ν_{n+1} is a function $\nu_1, \nu_2,\ldots,\nu_n$ of $\xi_1, \xi_2,\ldots,\xi_n$ and possibly of time n and elementary outcome ω.

In this way

$$\nu_{n+1} = T_n(\nu_1, \nu_2, ..., \nu_n; \xi_1, \xi_2, ..., \xi_n; \omega), \quad n = 1, 2, ...,$$

here ξ_n depending on the task is a scalar or a vector.

Function T_n, called the rule of option, select an ν_{n+1}. This function may be either deterministic or random (randomized). Sequence of selection rules $\{T_n\}$ defines choices of strategy or management strategy.

Deterministic selection strategy is the subject of study of the deterministic behavior theory of automata in random environments.

The finite-state machine is a calculation model, containing a finite number of object states [4]. Scheme of finite-state machine is shown in Fig. 2.

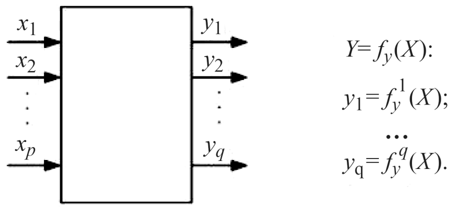

Fig. 2. Scheme of finite-state machine.

Finite state machines are used to organize and present the tasks flow and are ideally suited for implementing artificial intelligence in distributed mobile objects.

These strategies allow a simple implementation using a deterministic finite-state machine. They are mainly targeted at binary loss tasks. Under complete information, optimal strategy always belongs to the class of deterministic strategies

$$\nu_{n+1} = T_n(\omega) , \quad n = 1, 2, \ldots .$$

Availability of a priori uncertainty makes it necessary to use more complicated randomized strategy. In the behavior of machines theory such strategies correspond to stochastic machines with variable structure. Most of them realize the randomized selection rule of the following form

$$p_{n+1} = R_n(\nu_1, \nu_2, \ldots, \nu_n;\ p_1, p_2, \ldots, p_n;\ \xi_1, \xi_2, \ldots, \xi_n) , \quad n = 1, 2, \ldots ,$$

where R_n is vector function with values in simplex S_n; p_n is vector of conditional probabilities of choices $\nu(1)$, $\nu(2)$,…, $\nu(N)$ at time t_n.

A randomized strategy defined by the sequence of the rules of the type belongs to a class of recurrent algorithms of adaptive choices. These algorithms can be easily implemented, as they at every step n use minimal information about the prehistory of the process.

Considered statement of the task of the solutions adaptive choice provides a formal model of information space as a management environment of the control object and the control system.

Material and methods. General principles of a formal approach to the construction of information systems components are described.

Consider the following set of standard functions of a typical information and communication system:

1. The ability to describe and to form the required data structures, to manipulate, store, and protect inside the system.

2. Providing opportunity of efficient data exchange inside the system between its elements and with other information and communication systems.

3. A wide range of intelligent processing and data access for solution of the tasks.

4. Availability of the information analysis apparatus and communication system itself.

5. The ability to adapt the system to different conditions during the period of the task solution.

Several methods of formal specification of information and communication software systems, models and data types in particular are proposed [5–7].

Algebraic approach is the most popular as a formal justification and types specification tool received [8].

In general the algebraic system can be represented as

$$U_a =< A, \Omega_f, \Omega_p >, . \quad (1)$$

where A is a set of the basics; $\Omega_f = \{F_1,\ldots,F_k\}$ is a plurality of operations names on a predetermined set A; $\Omega_p = \{\pi_1,\ldots,\pi_m\}$ is a plurality of predicates defined on the set of A. System U_a can be written in a short form $U_a = < A, \Omega >$if the union of sets $\Omega = \Omega_f \cup \Omega_p$.

Set of A is called the carrier or fundamental set; the operation F_k and predicates π_m unlike other operations and predicates are called primary or main.

Research in the field of data models of information systems, shows that at the present time the type of data has become a central concept. The problems of creating a new programming language and the introduction of modern technologies to organize data associate with it.

Of the variety of approaches to the definition of a data type the following one looks like the most constructive–data type specification by the set of values by a plurality of operations [9].

In connection with the special role of operations in the definition of data structures and the functioning of the systems, consider this concept in more detail.

For a formal data type definitions the concept of signature Σ as the pairs consisting of a plurality of names of operations F_k and many descriptions of operations Ω_0 is introduced. Then, the signature can be defined as $\Sigma = < F_f, \Omega_0 >$. Data type T of signature Σ – is a pair: the data type specification signatures Σ and the corresponding implementation of the data type.

This approach allows us to define a new data type, which is characterized by a set of operations. This enables to construct operations for creators of the language and of their own programs.

Because the data type as the object is composed of two main components: the specification and implementation, the operations on the types are the compounds of these components. These actions may include an increase or decrease of the number of operations, replacement of all or some implementations of operations, changes in the type of representation and related operations.

Development of a model of information space of distributed information and communication system. The computing environment of the modern corporation, institution or office, as a rule, presents a server, network equipment, local computers, office equipment for various purposes application, system and special software.

All the resources of the computer system, user files, databases structures, application programs, system components are stored in files, and files are stored in named directories. Such computer system technology is conceptual and does not depend on the class of solvable by the user problems, or the type of interaction between the server and the local computer.

Thus, the computing environment is an invariant component of any information system and forms an information area.

Information space can be represented as an abstract algebraic system

$$E =< O, S, \Omega > \quad , \quad (2)$$

where O is the information space objects; S is relationships between objects; Ω is objects manipulating operations in space E.

As an object, model (2) can simulate components of a modern computer system (all types of files, directories, logical and physical drives, personal computers)

$O=\{o_n \mid n=\overline{1,N_1}\}$. Relation $S=\{s_n \mid n=\overline{1,N_2}\}$ between the objects of information area defines a specific configuration of the computing environment E, focused on a specific user or users from the set $G=\{g_n \mid n=\overline{1,N_3}\}$.

Depending on the goals set by the user and the computing environment, all actions are performed on the basis of operations $\Omega=\{q_n \mid n=\overline{1,N_4}\}$. As an example a set of elementary operations $\Omega=\{q_1, q_2, ..., q_n\}$ can be such operations as file manipulation in the information space {<run>, <copy__from__to>, ...<delete>}. All operations on objects at arbitrary points in times $t_1, t_2, \ldots, t_m$. $t_{m+1} > t_m$ the user g_n of information space initiates on the basis of a formalized action plan $z^*_{n1}(t_1), z^*_{n2}(t_2), \ldots z^*_{nm}(t_m)$ or unitary action $z^*_1(t)$.

In this way, the formalized problem z_1= <Copy file from_*b*_> can be solved with the help of operation q_1=<copy_from_to>.

Scheme of the user interaction with information space is shown in Fig. 3.

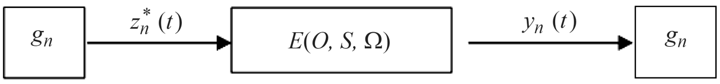

Fig. 3. Scheme of the user interaction with information space

The model of user interaction with the information space can be represented as

$$y_n(t) = e_n(z_n(t)), \quad i=\overline{1,N_3}, \tag{3}$$

where $z_n(t)$ is an input effect in the information space by the user $g_n \in G$; $y_n(t)$ is system response E, configured to the user g_n and having the form e_n.

In general $z_n(t)$ is an elementary task that a user $g_n \in G$ decides with the help of information system $E(O, S, \Omega)$.

An elementary problem can be combined into functional tasks by combining the elementary operations $q_1, q_2, \ldots, q_n$ in a series of interrelated operations of algorithm $a_k = \{q_1, q_2, \ldots, q_n\}$, $a_k \in \Lambda$, where Λ is a set of algorithms of solving functional tasks.

Depending on the structure and relationship problems solved by the user, they can be combined into a sequences or threads of tasks. The flow of user tasks $g_n \in G$ is called their sequence, $P(y_n) = \{y_{n_1}, y_{n_2}, \ldots, y_{nk}\}$ for which the following conditions are satisfied

$$y_{nj}(t) = e_{nj}(z_{nj}(t)), \quad n=\overline{1,N_3}, \; j=\overline{1,K}. \tag{4}$$

$$z_{nj}(t) = y_{nj+1}(t). \tag{5}$$

where j is the task order number of the n-th user.

Let us consider in detail the meaning of conditions (4)–(5). Restriction (4) comes down to the following. The user with the information system has plan for serial or parallel work (activities), for example, to copy unnecessary files into a certain the computer recycle bin, then to run an antivirus program, open the database file and execute SQL-query. The meaning of restriction (5) is the result of the previous job or task that is an essential condition for starting the next task or tasks.

Linear flow diagram of such tasks is shown in Fig. 4.

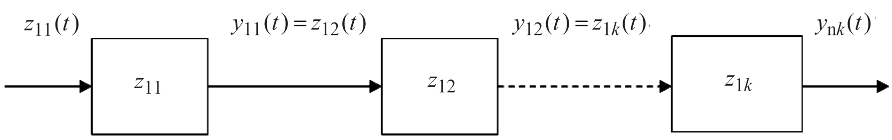

Fig. 4. Linear flow diagram of tasks.

Result. Specific feature of the task flow technology presented in Fig. 3, is that it may form both serial and arbitrary serial-parallel decision process. The basic condition of the group tasks in the flow is the coordination of the related problems for input/output, while at intermediate stages of a task in general it can be understable to the user whose action that does not require support tools of computing system [10–12].

Consider the particular case of the task flow, when for each task z_{nk} there is a tool software package or software module $m_k \in M$, where there is set of software modules that implement a variety of tasks Z. At the same time it must satisfy conditions for compatibility problems in the flow.

The first condition is the logical conclusion of the previous problem and the beginning of the subsequent task.

The second condition is the agreement of data at the intermediate stages of the decision: $y_{nj}(t) = z_{nj+1}(t)$ is the output of the previous problem and the input of the next. Then the general solution of tasks flow can be represented as a series of problem-solving $z_{n1}(t)$, $z_{n2}(t)$,…,$z_{nj}(t)$, $i = \overline{1, N_3}$, $j = \overline{1, K}$.

Discussion. The proposed model of information and communication space can be used in various systems in which a distributed control of mobile objects is necessary, including ability of control in real time. Simultaneously with the use of real-time mode, it becomes possible to learn and control autonomous mobile objects in both sequential and multi-threaded parallel mode.

For example, such a model can be used in the cleaning industry using the Internet of Things technology (smart house system); in military affairs in the field of defense (conducting reconnaissance operations using unmanned aerial vehicles); for logistics tasks in the transport sector (for managing transport facilities without human participation), solving problems of navigation and control of mobile robots.

All applications considered include the uncertainty of managing autonomous objects.

CONCLUSIONS

Based on the research of the basic processes the information systems of "user–information environment" are developed and a model of information space of the computer system is investigated. The basic components of the information and communication system are distinguished. The adaptive choice methods are analyzed. That allows the formation of a common approach to solving control problems of distributed mobile objects under conditions of uncertainty.

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