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A METHOD FOR EXPANDING THE REFERENCE MODEL OF OPEN SYSTEMS INTERACTION

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Introduction

Recent events have once again reminded designers and manufacturers of serial computer engineering objects intended to provide the aerospace segment with "one-off" unmanned aerial systems (UAS), of the difficulties associated with precisely following the requirements standardized by the classic Reference Model of Open Systems Interoperability. (RM OSI) [1]. The model primarily focuses the developer on finding options for implementing functions and services specified at each (separately) of its levels and sublevels, at which the best values of system parameters are achieved, which are not directly related to the cost of implementing the selected option, and above all, the cost of production and operation of the corresponding software and hardware. The sequential (non-network) structure of RM OSI significantly complicates the determination of connections between non-adjacent levels, which provokes designers and researchers to make a simplified assessment of the effectiveness (in particular, by cost) of the option chosen at a specific level. This simplification occurs by modeling a significantly reduced set of actually existing connections, for example, between a variant (technology) of data encoding at the representational level and a variant of the hardware and software implementation of the modem at the physical (and lower, at the "level" of the data transmission medium) level.

Such a (forced) reduction of the possible connection options set can lead to finding not a globally optimal option, but a locally optimal one, which, given the serial (mass) production of these computer engineering objects in the aerospace segment of "one-off" UASs, can lead to significant economic losses.

It should be said that the connections between levels are correctly introduced in RM OSI, but taking them into account in a practical attempt to determine the impact of changing the implementation option of a function, say, a lower level, on the efficiency indicators of a higher one, in order to achieve an improvement in the global indicator, is a difficult task for two reasons: 1. he lower level "influences" the upper one indirectly, through a number of intermediate levels and sublevels; 2. the set of intermediate layer options is limited by the requirements of RM OSI itself.

Regarding the first circumstance, increasing the probability of obtaining a global variant that is as close as possible to the optimum by reducing the number of levels is not a realistic way: the rapid development of new information and telecommunication technologies, on the contrary, provoked an increase in levels - sublevels were introduced at different times: MAC, LLC, PLCP, etc.

The second circumstance that can cause trouble is natural for real-world problems of designing computer engineering objects due to their exceptional complexity. Indeed, assuming that at each of the k levels and sublevels we have m functions and services (specified in the standard), and for each function and service, in turn, there are n variants of implementing functions and services, then the set of complete ones, that is, those that fully represent the system being created, is formed by the product k·m·n.

It is difficult for a designer to work with a problem of such dimensions even at a separate level, which leads to the aggregation of m·n options of a specific level (sublevel) into separate local technologies, which actually narrows the field of search for effective, even local, options.

For example, in the 802.11 standards at the physical layer, for use at the channel layer, aggregation of options in the form of FHSS, DSSS, OFDM, HR-DSSS, ERP-OFDM, ERP-PBCC, DSSS-OFDM technologies for ISM and U-NII bands is proposed. Another example, albeit heuristically determined, of a way out of the "embrace" of local search is to increase the efficiency of the physical layer function at the expense of a higher layer, as was done in Bluetooth [2].

Directly following the relevant recommendations (and in fact, the requirements) laid down in RM OSI regarding the number of levels and sublevels, the distribution of functions and services across them, as well as the perception of heuristically aggregated options in the form of (local) technologies, leads to the fact that the choice of a specific effective option, from the standpoint of global criteria, occurs on a significantly reduced set.

This also applies to the choice of the method to form the appropriate protocol data unit (PDU) formats, where a truly effective set of PDU formats at all levels may be lost, in terms of global efficiency.

Thus, we have a non-zero probability of losing a truly effective, by global criteria, variant of (information and telecommunications) technology, which is caused by the (artificial) relaxation of the variants set for solving the ascending problem.

Note that the described situation is not a defect of RM OSI specifically: it is a universal modeling problem when a set of isolated (almost autonomous) structures (in our case, levels) are synthesized, which allows simplifying the procedures for analyzing and synthesizing an object (information technologies of open systems interaction) in a specific structure (at a specific level). But on the other hand, a complication arises, as always with decomposition, associated with establishing real relationships between local solution options (local information technologies) of different structures (different levels).

This opus is dedicated to building, based on RM OSI, a more detailed model of open systems interaction that takes into account a wider set of implementation options for a computer and telecommunications system and reduces the likelihood of losing the globally optimal (efficient) option.

The statement of the problem

The objective of this work is to provide a tool for establishing a multi-valued mapping on sets of implementation options for level functions, a kind of "higher level - lower level" chains. Each chain is a sequence of interaction technology options that are acceptable for use at specific levels; the sought-after tool should allow to form the (most) complete set, with the subsequent selection of such a chain that ends at the physical level. The technology variant of this level determines the technical and economic parameters of the software and hardware complex being built, in particular, the complexity of the radio frequency path equipment, which directly affects the value of the present value of the production, operation, and modernization of UAV systems.

Problem solving

To expand the set of "allowable" options for implementing the system of computer components interaction of open unmanned aircraft single-use systems, there is proposed an adaptation of the morphological analysis method [3, 4]. The method of applying the morphological analysis method is to perform the following sequence of actions.

1. Structuring, according to the requirements of the morphological analysis method, the object of computer engineering. A two-level structure is proposed, defined by RM OSI in terms of the levels and sub-levels

number, as well as the division of functions and services into them.

2. Generation for each component ("function", in terms of the classical morphological analysis method) of the structure of the local options to the corresponding problem, that is, ways of implementing functions and services of the current level. The options are combined into a set that does not take into account its "natural binding" to the current level and sublevel of the reference model; It is proposed, in contrast to the requirements of classical morphological analysis, to include in this set such methods that do not correspond to the modern level of computer engineering, including those that were once rejected as "outdated" and unpromising (an example is the long-standing rejection of information and telecommunication technologies related to analog computing [5]).

3. Generation of a set of "complete solutions" to the ascending problem. It is proposed, in contrast to the requirements of classical morphological analysis, to include in this set such complete solutions that consist of duplicate local solutions or are quasi-unrealizable due to the "autonomous" search for local solutions for each level ("morphological table function") (an example would be the ASCII encoding method as a local solution to the problem at the upper levels and comma encoding at the lower ones).

This set is the Cartesian product of the sets, each of which was obtained in step 2; This will lead to the fact that the cardinality of this set will be even greater than that obtained after eliminating, according to the requirements of classical morphological analysis, duplicate and clearly contradictory local solutions. And this circumstance (the very high complexity of the construction of admissible solutions) is the main one that makes it difficult to use the tools of classical morphological analysis to solve arbitrary problems, and in our case it is even more burdensome, because it falls even more under the "curse of high dimensionality" [6].

The authors, explaining this circumstance, propose to use for analysis the new, for today, apparatus of artificial intelligence (AI), the numerous tools of which are very well suited to such tasks: we need to analyze essentially "vectors" (of the same dimension) of the parameters of global solutions [7-10].

4. Solving an optimization problem, for example, by the hardware and software complexity criterion (cost of production and operation of a computer engineering object), on the set obtained at stage 3.

And again, as we just said, it is appropriate to use the brute force method, which modern AI tools are very well suited to implement.

Example

The resulting extended RMOSI allowed us to determine the truly optimal (obtained by exhaustive search) by the simplicity criterion, and therefore, indirectly, the cost of software and hardware, a tuple of local solutions, with the initial element of solution local variants chains of which is one of the classes of languages, according to Noam Chomsky's classification. The grammar chosen here is a grammar adequate to the simple language of an aviation computer system components interaction in the process of mutual positioning. This reduced the likelihood of losing the globally optimal (efficient) hardware and software organization option.

This example illustrates a method for minimizing the complexity of hardware and software support for performing open systems interaction functions in a swarm of low-power UAVs, as a criterion for the "effectiveness of the lower (physical) level function implementation option". At the same time, we assume that this indicator most accurately, albeit indirectly, characterizes the final efficiency indicator on which this opus is focused - the (reduced) cost of production, operation, and modernization of hardware and software.

Applying the described procedure for forming a set of "allowable" solutions based on the presented method of extending RM OSI, adapted for the conditions of wireless networks standardized by documents IEEE 802.11 - IEEE 802.16 with modifications, we have a set (realizable and not yet realizable) of complete solutions to the given problem (chains), which are the Cartesian product of nine solutions options sets to partial problems.

Fixing the most effective ("cheapest") version of the physical level, which, as follows from the rules of morphological analysis, is searched without taking into account its connections with the adjacent (in our case, this is a sublevel of the MAC) level, based on the assumption given above, made it possible to determine the chains that are feasible (in modern conditions).

The initial vertex of the implemented chain is a super-high-level PDU, which corresponds to a variant of a regular language (from the set of 4 communication languages types according to Chomsky). It is assumed that this type of language allows organizing communication between subjects of a swarm of UAVs in the process of mutual positioning.

The intermediate vertex, which corresponds to the variant of the representational level technology, is the technology of encoding information about the distance between subjects with a comma code; the vertex - the lower-level variant is a finite state machine built on a classical element base.

Conclusions

1. The decomposition parameters, i.e. the number of levels and the proposed distribution of functions and services by levels, adopted in the reference model of open systems interaction, meet the classical requirements of design analysis, allowing to generate a sufficiently powerful (in the mathematical sense!) set of implementation options for functions and services, effective according to certain criteria that are not related to performance, in particular, cost ones that are not included in the QoS list.

2. It is advisable to expand the set of options for implementing functions and services, thereby reducing the likelihood of losing a truly effective option for organizing a computer system, adapting the significantly increasing complexity of checking (feasibility study) numerous options using a relatively new method of implementing this formal search procedure - AI tools.

3. It is proposed to expand the set by generating local, at the levels of the reference model, variants – components of the global variant using the technology of multilevel morphological analysis.

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A METHOD FOR EXPANDING THE REFERENCE MODEL OF OPEN SYSTEMS INTERACTION

One type of aviation computer systems formed by a complex of interacting components placed on unmanned aircraft of light and ultralight classes is considered. A method is proposed to reduce the probability of loss of effective, in terms of the cost of production and operation, software and hardware support of the entire system, which can occur with the conscientious use of a multi-level reference model of open systems interaction . The method is based on the use of the morphological analysis method, for which the number of local components is proposed to be equal to the number of levels and sublevels, the search field is expanded for each level autonomously, without taking into account the relationships between levels, and the set of complete solutions of morphological analysis is formed by the classical operation of direct product. The resulting design allows you to determine, for example, by direct search using artificial intelligence tools, those elements (chains) of the display in which each variant of the implementation of the function for the higher levels corresponds to the variants of the implementation of functions and services for the lower levels, which determines the efficiency of the entire system.

Keywords: *UAV; reference model; component interaction.*

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СПОСІБ РОЗШИРЕННЯ ЕТАЛОННОЇ МОДЕЛІ ВЗАЄМОДІЇ ВІДКРИТИХ СИСТЕМ

Розглядається один тип авіаційних комп’ютерних систем, утворених комплексом взаємодіючих компонентів, розміщених на безпілотних літальних апаратах легкого та надлегкого класів. Пропонується спосіб зменщення ймовірності втрати ефективного, за показником вартості виробництва і експлуатації програмно - апаратного забезпечення всієї системи, що може трапитись при сумлінному використанні багаторівневої еталонної моделі взаємодії відкритих систем. Спосіб оснований на використанні методу морфологічного аналізу, для якого кількість локальних складових пропонується прирівняти кількості рівнів і підрівнів, поле пошуку розширювати по кожному рівню автономно, без урахування взаємозв’язків між рівнями, а множину повних рішень морфологічного аналізу формувати за класичною операцією прямого добутку. Отримана конструкція дозволяє визначити, наприклад – прямим перебором за допомогою інструментарія штучного інтелекту, ті елементи (ланцюжки) відображення, в яких кожному варіанту реалізації функції вищих рівнів відповідають варіанти реалізації функцій і сервісів нижніх рівнів, що обумовлює ефективність всієї системи.

Ключові слова: *БпЛА; еталонна модель; взаємодія компонентів.*