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GERT-MODEL OF PROCESSES OF ACTIVE ANALYSIS OF THE SYSTEM RESOURCE MANAGEMENT AND IMPLEMENTATION IN THE COMPUTER SYSTEM

One of the main and complex stages of the algorithm allocation process from binary code is presented - optimization stage. The main feature of the developed method is the adaptation to the requirements of the task of allocating a set of attractors with common features. Furthermore, the use of optimization algorithm, which eliminates unnecessary loads and unloads, will significantly reduce the complexity of the developed graph.

Key words: binary code, optimization, allocation of algorithm.

Introduction

The experience of conducting computer safety testing shows that the time of active analysis of the resource management system and the introduction into the computer system can take more than 45% of the total testing time.

From the literature [2, 3, 5] it is known that one of the features of the process of active analysis of the resource management system is not specificity of the test methods in the course of solving the tasks posed. This is shown by the fact that the tester most often plays the role of a hacker and begins to manipulate the resources of the computer system in different ways. access control system for Dos attack security, purposeful implementation of errors with further penetration into the system during recovery, viewing unclassified data in the hope of finding the key for logging on to the system, etc. It is these, non-specific techniques, in conjunction with the experience of the main types of vulnerability of computer systems, that put test cases in an unclear correspondence with the existing specification for the system under investigation.

It is known that one of the most important stages of development and research of processes in technical systems is the stage of mathematical formalization. Therefore, the task of developing a mathematical model for the processes of active analysis of the resource management system and introduction into the computer system is crucial.

Formulation of the problem.

When posing the problem of mathematical formalization of the algorithm for active analysis of the resource management system, a number of factors should be taken into account. Te be exact:

1. Security testing is conducted with access (at least approximate) to the system, while its implementation, although it exists, is not known.

2. The interaction of the tester with the computer system should be safe for the latter (not lead to complete failure).

3. Interacting with the computer system, we get data on its capabilities.

4. Specification, semantics, realization of the functional are final.

5. Repetition of the same test exposure at this stage of testing can cause different behaviors (the condition of non-determinism).

For completeness of carrying out of a described stage it is necessary to check up all transitions of realization specified in the specification. For this, the mathematical model must satisfy a number of conditions:

- presence of the condition of mathematical formalization of the procedure for restarting the implementation of the active control system analysis algorithm;

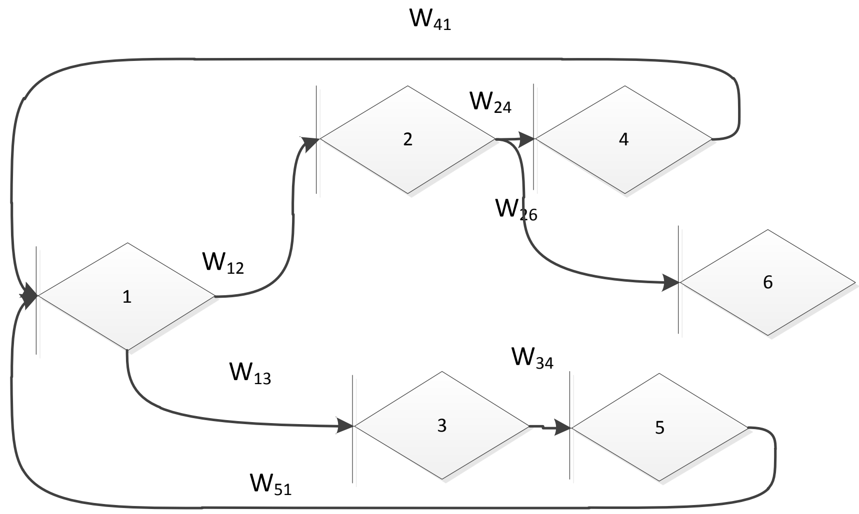
- stabilization of the initial state of implementation or at least the formalization of one state achievable along the safe route of the specification;

- separation of full and partial testing in the process of active control system analysis.

It should be noted that a whole phase of "implementation into the computer system" is deliberately introduced into the model being developed. This will simplify the mathematical model being developed. In further studies, it is possible to analyze this stage with the corresponding development of a separate mathematical model.

Tochastic GERT model

In Pic. 1 presents a generalized stochastic GERT-model of processes of active analysis of the resource management system and implementation of it into the computer system.



Pic.1. Generalized stochastic GERT-model of processes of active analysis of the resource management system and implementation of it into the computer system.

In this model, the node S1 characterizes the current state of the system before the impact (launching the algorithms for analyzing the resource management system and implementing it into the computer system). The node S2 describes a positive for the hacker (negative for the system) situation of inability to intercept system management resources. The node S3 characterizes the reverse node S2 of the situation of an unsuccessful for the hacker (successful for the computer system) passage of the algorithm of active analysis of the resource management system. The node S4 describes the error recovery situation. The node S5 characterizes the state of incomplete execution of the algorithm. The node S6 characterizes the state of full verification and implementation in the computer system.

Connections between nodes in the model of Pic. 1. Can be interpreted as follows: Transition (1-2) formalizes the procedure for analyzing the effect on the element of the system in accordance with the given algorithm and a positive outcome for the tester. Transition (2-4) - describes the process of eliminating errors. Transition (4-1) - corresponds to the return to the state before the start of the test, to ensure the completeness of the execution of the algorithms. The transition (2-6) formalizes the process of introducing malicious elements into the computer system. Transition (1-3) describes the procedures for influencing the system in accordance with the algorithm of active analysis of the resource management system and negative for the tester (positive for the computer system) result. The transition (3-5) corresponds to the procedures for assessing the completeness of coverage by the analyzed impact of the elements.

The characteristics of the branches of the model are presented in Table 1.

Table 1 – Characteristics of the branches of the GERT model of the processes of active analysis of the resource management system and iimplementation into the computer system

№	Branch	*W*-function	Probability	The generating function of the moments
1.	(1,2)	W_{12}	p_1	$\lambda_1/(\lambda_1-s)$
2.	(2,4)	W_{24}	p_2	$\lambda_2/(\lambda_2-s)$
3.	(2,6)	W_{26}	$1 - p_2\ (q_1)$	$\lambda_3/(\lambda_3-s)$
4.	(4,1)	W_{41}	p_3	$\lambda_4/(\lambda_4-s)$
5.	(1,3)	W_{13}	p_4	$\lambda_1/(\lambda_1-s)$
6.	(3,5)	W_{35}	p_4	$\lambda_5/(\lambda_5-s)$
7.	(5,1)	W_{51}	$1 - p_4\ (q_2)$	$\lambda_6/(\lambda_6-s)$

The equivalent W-function of the execution time of the active analysis algorithms of the resource management system and the implementation into the computer system equals to:

$$W_E(s)=\frac{W_{12}W_{26}+W_{12}W_{24}W_{41}W_{12}W_{26}+W_{13}W_{35}W_{51}W_{12}W_{26}}{1-W_{12}W_{24}W_{41}W_{45}W_{51}-W_{13}W_{35}W_{51}}=$$

$$=\left(\frac{\dfrac{\begin{pmatrix}\left(p_1q_1\lambda_1\lambda_3(\lambda_1-s)(\lambda_2-s)(\lambda_4-s)(\lambda_5-s)(\lambda_6-s)\right)+\\+\left(p_1^2p_2p_3q_1\lambda_1^2\lambda_2\lambda_3\lambda_4(\lambda_5-s)(\lambda_6-s)\right)+\\+\left(p_1p_4^2q_1q_2\lambda_1^2\lambda_3\lambda_5\lambda_6(\lambda_2-s)(\lambda_4-s)\right)\end{pmatrix}}{(\lambda_1-s)^2(\lambda_2-s)(\lambda_3-s)(\lambda_4-s)(\lambda_5-s)(\lambda_6-s)}}{1-\left(\dfrac{\begin{matrix}p_1p_2p_3\lambda_1\lambda_2\lambda_4(\lambda_5-s)(\lambda_6-s)+\\+p_4^2q_2\lambda_1\lambda_5\lambda_6(\lambda_2-s)(\lambda_4-s)\end{matrix}}{(\lambda_1-s)(\lambda_2-s)(\lambda_4-s)(\lambda_5-s)(\lambda_6-s)}\right)}\right).$$

By performing simple mathematical transformations, we obtain

$$W_E(s)=\frac{a+bs+cs^2+ds^3+gs^4-s^5}{(\lambda_1-s)(\lambda_3-s)\left(k+ms+ns^2+hs^3+rs^4-s^5\right)},\qquad (1)$$

где $a = p_1 q_1 \lambda_1 \lambda_3 \left(\lambda_1 \lambda_2 \lambda_4 \lambda_5 \lambda_6 \left(p_1 p_2 p_3 + p_4^2 q_2 + 1 \right) \right)$,

$$b = -p_1 q_1 \lambda_1 \lambda_3 \begin{pmatrix} \lambda_4 \lambda_5 \lambda_6 \left(\lambda_2 + \lambda_1 + p_4^2 q_2 \right) + \lambda_1 \lambda_2 \lambda_5 \lambda_6 \left(1 + p_4^2 q_2 \right) + \\ + \lambda_1 \lambda_2 \lambda_4 \left(\lambda_6 + \lambda_5 + p_1 p_2 p_3 \left(\lambda_6 + \lambda_5 \right) \right) \end{pmatrix},$$

$$c = p_1 q_1 \lambda_1 \lambda_3 \begin{pmatrix} \lambda_4 \lambda_5 \lambda_6 + \lambda_2 \lambda_5 \lambda_6 + \lambda_2 \lambda_4 \lambda_6 + \lambda_1 \lambda_5 \lambda_6 \left(1 + p_4^2 q_2 \right) + \\ + \lambda_2 \lambda_4 \lambda_5 + \lambda_1 \lambda_4 \lambda_6 + \lambda_1 \lambda_4 \lambda_5 + \lambda_1 \lambda_2 \lambda_5 + \\ + \lambda_1 \lambda_2 \lambda_4 \left(1 + p_1 p_2 p_3 \right) \end{pmatrix},$$

$$d = -p_1 q_1 \lambda_1 \lambda_3 \begin{pmatrix} \lambda_5 \lambda_6 + \lambda_4 \lambda_6 + \lambda_4 \lambda_5 + \lambda_2 \lambda_6 + \lambda_2 \lambda_5 + \\ + \lambda_2 \lambda_4 + \lambda_1 \lambda_6 + \lambda_1 \lambda_5 + \lambda_1 \lambda_4 + \lambda_1 \lambda_2 \end{pmatrix},$$

$$g = p_1 q_1 \lambda_1 \lambda_3 \left(\lambda_6 + \lambda_5 + \lambda_4 + \lambda_2 + \lambda_1 \right),$$

$$k = \lambda_1 \lambda_2 \lambda_4 \lambda_5 \lambda_6 \left(p_1 p_2 p_3 + p_4^2 q_2 - 1 \right),$$

$$m = -\begin{pmatrix} \lambda_1 \left(p_4^2 q_2 \lambda_5 \lambda_6 \left(\lambda_4 + \lambda_2 \right) + \lambda_2 \lambda_4 p_1 p_2 p_3 \left(\lambda_6 + \lambda_5 \right) \right) + \\ + \left(\lambda_4 \lambda_5 \lambda_6 \left(\lambda_2 + \lambda_1 \right) + \lambda_1 \lambda_2 \left(\lambda_5 \lambda_6 + \lambda_4 \lambda_6 + \lambda_4 \lambda_5 \right) \right) \end{pmatrix},$$

$$n = \left(\lambda_1 \left(p_4^2 q_2 \lambda_5 \lambda_6 + \lambda_2 \lambda_4 p_1 p_2 p_3 \right) - \begin{pmatrix} \lambda_5 \lambda_6 \left(\lambda_4 + \lambda_2 \right) + \lambda_2 \lambda_4 \left(\lambda_5 + \lambda_6 \right) + \\ + \lambda_1 \lambda_6 \left(\lambda_5 + \lambda_4 \right) + \lambda_1 \lambda_4 \left(\lambda_5 + \lambda_2 \right) + \\ + \lambda_1 \lambda_2 \left(\lambda_5 + \lambda_6 \right) \end{pmatrix} \right),$$

$$h = -\begin{pmatrix} \lambda_6 \left(\lambda_5 + \lambda_4 + \lambda_2 + \lambda_1 \right) + \lambda_5 \left(\lambda_4 + \lambda_2 + \lambda_1 \right) + \\ + \lambda_4 \left(\lambda_2 + \lambda_1 \right) + \lambda_2 \lambda_1 \end{pmatrix},$$

$$r = \lambda_6 + \lambda_5 + \lambda_4 + \lambda_2 + \lambda_1 .$$

Studies have shown that in complex GERT-networks with possible cycles there are no simple methods for finding singular points of the function $\Phi_E(z)$ which replaces real variables $(z = -i\varsigma)$, where ς – is a real variable. This is due to the fact that to find the singular points it is necessary to solve nonlinear equations, and the more complex the structure of the GERT-network, the more complex the initial equation Therefore, in the course of modeling, performing a complex transformation, we obtain:

$$\Phi(\mathrm{z}) = \frac{\mathrm{z}^5 - gz^4 - \mathrm{dz}^3 - cz^2 - bz - a}{\left(\left(\lambda_1 + z \right) \left(\lambda_3 + z \right) \left(\mathrm{z}^5 - rz^4 - \mathrm{hz}^3 - nz^2 - mz - k \right) \right)}, \qquad (2)$$

Density distribution of the probabilities of the execution time of active analysis algorithms of the resource management system and the implementation into the computer system

$$\phi(\mathrm{x}) = \frac{1}{2\pi i}\int_{-i\infty}^{i\infty} e^{zx} \frac{\mathrm{z}^5 - gz^4 - \mathrm{dz}^3 - cz^2 - bz - a}{\left((\lambda_1 + \mathrm{z})(\lambda_3 + \mathrm{z})\left(\mathrm{z}^5 - rz^4 - \mathrm{hz}^3 - nz^2 - mz - k\right)\right)} dz, \qquad (3)$$

where the integration is performed along the Bromwich contour [6].

Expression (3), in accordance with [6, 7], can be represented as a fractional rational function with relative dependence to the degree of the denominator greater than the degree of the numerator; therefore, the conditions of the Jordan lemma. Function $\Phi(\mathrm{z})$ has poles in points $z_1 = -\lambda_1$, $z_2 = -\lambda_3$. Polynomial $\mathrm{z}^5 - rs^4 - \mathrm{hz}^3 - nz^2 - mz - k$ creates another 5 poles. The solution of equation

$$\mathrm{z}^5 - rz^4 - \mathrm{hz}^3 - nz^2 - mz - k \qquad (4)$$

can be found by any numerical method. Then we get five more singular points z_3, z_4, z_5, z_6, z_7.

Let's find the probability distribution density of the execution time of active analysis algorithms of the resource management system and implementation into the computer system $\phi(\mathrm{x})$ using the following parameters of the branch models: $\lambda_1 = 0{,}9$, $\lambda_2 = 0{,}9$, $\lambda_3 = 0{,}6$, $\lambda_4 = 0{,}3$, $\lambda_5 = 0{,}91$, $\lambda_6 = 0{,}9$ $p_1 = 0{,}9$, $p_2 = 0{,}9$, $p_3 = 0{,}6$, $p_4 = 0{,}8$.

With such values of the parameters of the branches of the model, having carried out simple mathematical calculations, we obtain the following results: $r = 0{,}07$, $h = 1{,}872$, $n = 3{,}705$, $m = 5{,}97$, $k = -3{,}91$.

Solving the equation in the denominator of expression 3 using the Vieta-Cardano method, the function $\Phi(\mathrm{z})$ has simple poles: $z_1 = -0{,}9$, $z_2 = -0{,}6$, $z_3 = 0{,}479$. In addition to real roots, there are four complex conjugate: $z_4 = -1{,}124 + i \cdot 0{,}963,$ $z_5 = -1{,}124 - i \cdot 0{,}963,$ $z_6 = 0{,}847 - i \cdot 1{,}741,$ $z_7 = 0{,}847 + i \cdot 1{,}741.$

Using the calculation methods presented in [7], as well as taking into account the numerical values of the variables, the probability distribution function of the execution time of active analysis algorithms of the resource management system and implementation into the computer system for root variants z_4, z_5, can be determined as

$$\phi(\mathrm{x}) = 2\frac{\mathrm{e}^{-1,124x}\left[\frac{\left(1,341\cos\left(0,963x\right)\right)}{10^{-3}} + \frac{-1,322\sin\left(-0,963x\right)}{10^{-3}}\right]}{8,348\times10^{5}}.$$

Similarly, it is possible to determine the probability distribution function of the execution time of algorithms for active analysis of the resource management system and implementation into the computer system for root variants z_6, z_7.

Conclusions

Thus, a mathematical GERT-model of the processes of active analysis of the resource management system and introduction into the computer system is developed. The proposed mathematical model differs from the known ones taking into account the factors of the completeness of the test methods and the finiteness of the specification when the algorithm is implemented in a computer system. The model can be used to study the main stages of testing the safety of computer systems in order to reduce its vulnerability, as well as in developing new methods, algorithms and ways to manage IT resources.

The use of GERT networks in the course of mathematical modeling will make it possible to use the results obtained in analytical form (functions, distribution densities) for carrying out comparative analysis and research, various stages and stages of testing computer systems.

Further studies may be related to the synthesis of a complex of mathematical models for the generation and sale of "ethical" cyberattacks, as well as the development of a security software testing method for peer-to-peer computer networks.

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