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MODEL OF COMPONENT TRANSPORT BEHAVIORAL TESTS

In the article the model of determining the set of component transportation by extended automata behavioral tests is presented. The modified verification graph for the initial extended automata and special subautomata without the loss of information for extended automata based on its modified verification graph is built. Subautomata model without the loss of information determines the conditions of component transportation of network behavioral tests.

Keywords: *test, detection of input behavior, transportation, automata without loss of information, screening graph.*

Introduction. The efficiency of today's complex distributed information systems (DIS) is usually provided by different systems of diagnostics, carrying out work, and test control. The high complexity of DIS, abstract, incomplete, unclear and multi-level specifications [1] along with the inability to directly monitor and control the majority of the components of DIS involves the development of formal models and methods of the test analysis, based in particular on integrated approaches to structural, functional, information DIS representation [2].

NP-complexity of the synthesis of behavioral tests, often generating combinatorial enumeration [3], determines the feasibility of the development of decomposition models and methods [4]. However, structural-behavioral approach to the synthesis of the tests, taking into account the natural structure of DIS expands tasks needed to ensure controllability and observability test analysis to reach the direct impact of the components of DIS [5]. The controllability is feasibility of impacts from DIS inputs, observability – the transportability of the results to DIS outputs.

However, the analysis of behavior observability for automata extension performed based on automata without the loss of information [6] and input identifiers [7], suggests additional research component transport model that makes it relevant to the construction of a formal model of transportation expanded automata.

Formulation of the problem. The development of models of behavioral testing modern DIS, based on network test experiments, may involve the use of the network, advanced models of automata class – networks of extended automata (NA). Realized and transported in the NA test fragments – special input-output words of external behavior of component automates NA – form a set of objects in manage and monitor behavioral tests.

The aim is a constructive description of transportable advanced automata input-output words as building special subautomata without the loss of information. To achieve the goal it is necessary to solve the following problems:

a) the construction of modified verification graph g_a for the initial extended automata a;

b) the building of special subautomata without the loss of information gTr_a for extended automata a based on its modified screening graph g_a.

Determined on the basis of g_a, component test fragments in NA can be used as transportable objects combined model testing representing DIS. Verification graph g_a is a part of the test model to determine the conditions of transport functional testing DIS.

Used as a part of NA temporary nondeterministic Mealy automata a (hereinafter – just automata a), which give an opportunity to present the main behavioral, time, often incompletely specified mechanisms DIS components are defined as:

$$a=(S, X, Y, T, Pb, \delta_T, \lambda_T, S_0), \qquad (1)$$

where

– S, X, Y – a set of states, input and output alphabets;

– $T \subset N$ – a set of discrete time intervals, measured in cycles of automata and appropriate intervals, after which it switches to the next states, and during which the action takes place output signals Mealy automata;

– $Pb \subset [0;1] \subset D$ – a set of odds ratios range [0;1];

– $\delta_T: S \times X \times T \times Pb \rightarrow S$ – temporary non-deterministic transition function;

– $\lambda_T: S \times X \times T \times Pb \times S \rightarrow Y$ – temporary non-deterministic output function for transitions;

– $S_0 \subseteq S$ – a subset of initial states.

In automata *a* for some four $(s, x, t, pb) \in S \times X \times T \times Pb$ it may be true with some probability $pb \in Pb_{s,x,t}$, that

$$\exists s' \in S(s' = \delta_T(s, x, t, pb) \text{ or } s' \in \delta_T(s, x, T_{s,x,t}, Pb_{s,x,t})),$$

where $Pb_{s,x,t} = \Sigma_{pb \in Pbs,x,t} pb = 1$ and $T_{s,x,t} = \cup_{t \in Ts,x,t}\ t$, that can be imagined as the existence with probability pb some non-deterministic transition – five (s, x, t, pb, s') duration $t \in T$.

If for transition (s, x, t, pb, s') is true with some probability $pb' \in Pb_{s,x,t}'$, that

$$\exists y \in Y(y = \lambda_T(s, x, t, pb, s', t', pb') \text{ or } y \in \lambda_T(s, x, t, pb, s', T'_{s,x,t}, Pb'_{s,x,t})),$$

where $Pb'_{s,x,t} = \Sigma_{pb' \in Pb's,x,t} pb' = 1$ and $T'_{s,x,t} = \cup_{t' \in T's,x,t}\ t'$, including the output transition marks $(s, x, t, pb, s', t', pb')$ present output y duration $t' \in T$. Moreover, the interval t' of action of the output y fits into the interval t of the transition (s, x, t, pb, s'), i.e. there $t'', t''' \in T \cup \{e\}$ such as $t = t''t't'''$. This, in turn, can be represented as the existence with probability $pb \cdot pb'$ of combined indeterminate transition – eight $(s, x, t, pb, s', t''t't''', pb', y)$.

Definition of a formal model of transportation. For a constructive description of recognizable (transported) input words Tr_i – so called input identifiers –different "verification" graphs g_a are commonly used [1]. Ambiguity functions δ_T, λ_T and δ_T^{-1}, λ_T^{-1} automata *a*, however, permit the use of special verification graph g_a. For the used in a paper automata *a* modified verification graph is of the form:

$$g_a = (B(S), (T \times Pb \times Y) \times (X \times T \times Pb \times S^2), \Delta_{ga}, S), \quad (2)$$

where

– B(S) – a set of nodes, defined as the boolean of the set of states S of initial automata *a*;

– $(T \times Pb \times Y) \times (X \times T \times Pb \times S^2)$ – a set of graph arcs g_a, marked:

– identifying output marks from the output alphabet Y of automata *a*, intervals T of their actions and probability Pb of occurrence;

– identifiable incoming marks from the input alphabet X of automata *a*, intervals T of their actions and probability Pb of occurrence;

– retains the ability to identify input marks by pairs of states in a Cartesian degree S^2 a set of states S of automata *a*;

– Δ_{ga} – partial mapping transitions species $\Delta_{ga}: (B(S) \times (B((T \times Pb \times Y) \times (X \times T \times Pb) \times S^2))) \rightarrow B(S)$;

– $S_0 = S$ – starting, initial node of the verification graph g_a, partial function marked adjacency of the graph g_a, as the initial state, it takes the set of all states S of automata *a*.

Verification graph g_a can be generated from the state S_0 by function definition Δ_{ga}, which has the following form:

$$\Delta_{ga}(S_0, ((t', pb', y), (x, t, pb), (s, s')) = \begin{cases} S', & \text{if } ((t',pb',y),(x,t,pb),(s,s')) \in \\ & \in ((T \times Pb \times Y) \times (X \times T \times Pb) \times S^2) \& \\ & \& \forall s' \in S'[\exists((x,t,pb),s) \in (X \times T \times Pb) \times \\ & \times S[(t,pb,s') \in \delta(s,x,t,pb) \& \\ & \& (t',pb',y) \in \lambda(s,x,t',pb')]] \& \\ & \& \ \overline{\exists} s'' \in S \backslash S'[\ \overline{\exists}(x,t,pb,s) \in X \times T \times \\ & \times Pb \times S[(t,pb,s'') \in \delta(s,x,t,pb) \& \\ & \& (t',pb',y) \in \lambda(s,x,t',pb')]]; \\ \varnothing & \text{– otherwise} \end{cases} \quad (3)$$

Getting of the graph g_a by the original automata *a* may be the corresponding map $g_a = \gamma(a)$. Recognized in the graph g_a transition is a transition, consisting of many species strictly parallel arcs $((t', pb', y), (x, t, pb), s, s')$, that for each pair of arcs marcs are different by components:

a) the first (difficult), the third (simple), the fourth (simple) components – $((\boldsymbol{t_1}', \boldsymbol{pb_1}', \boldsymbol{y_1}), (x, t, pb), \boldsymbol{s_1}, \boldsymbol{s_1}')$ and $((\boldsymbol{t_2}', \boldsymbol{pb_2}', \boldsymbol{y_2}), (x, t, pb), \boldsymbol{s_2}, \boldsymbol{s_2}')$;

b) the first, the third components – $((\boldsymbol{t_1}', \boldsymbol{pb_1}', \boldsymbol{y_1}), (x, t, pb), \boldsymbol{s_1}, s')$ and $((\boldsymbol{t_2}', \boldsymbol{pb_2}', \boldsymbol{y_2}), (x, t, pb), \boldsymbol{s_2}, s')$;

c) the first, the second (difficult), the third components – $((\boldsymbol{t_1}', \boldsymbol{pb_1}', \boldsymbol{y_1}), (\boldsymbol{x_1}, \boldsymbol{t_1}, \boldsymbol{pb_1}), \boldsymbol{s_1}, s')$ and $((\boldsymbol{t_2}', \boldsymbol{pb_2}', \boldsymbol{y_2}), (\boldsymbol{x_2}, \boldsymbol{t_2}, \boldsymbol{pb_2}), \boldsymbol{s_2}, s')$;

d) the first and the second components – $((t_1', pb_1', y_1), (x_1, t_1, pb_1), s, s')$ and $((t_2', pb_2', y_2), (x_2, t_2, pb_2), s, s')$.

Defining in the graph g_a unrecognized (lost for recognizing) by automata *a* the second complex components of type (x, t, pb) of its transitions $((t', pb', y), (x, t, pb), s, s')$ involves identifying the set of beginning in states from *S* strictly parallel arcs whose marks differ only in the second component. Definition in g_a unrecognized input words of the second complex component involves identifying beginning in the states of *S* final paths in the graph g_a, for which both of the conditions:

– each not the last word transition consists of a set strictly parallel arcs in which for each pair of arcs marks are different by:

a) third and fourth components – $((t', pb', y), (x, t, pb), s_1, s_1')$ and $((t', pb', y), (x, t, pb), s_2, s_2')$;

b) second and fourth components – $((t', pb', y), (x_1, t_1, pb_1), s, s_1')$ and $((t', pb', y), (x_2, t_2, pb_2), s, s_2')$;

c) second, third and fourth components – $((t', pb', y), (x_1, t_1, pb_1), s_1, s_1')$ and $((t', pb', y), (x_2, t_2, pb_2), s_2, s_2')$;

– last transition consists from the set strictly parallel arcs in which for each pair of arcs marks are different by:

a) a third component – $((t', pb', y), (x, t, pb), s_1, s')$ and $((t', pb', y), (x, t, pb), s_2, s')$;

b) second and third components – $((t', pb', y), (x_1, t_1, pb_1), s_1, s')$ and $((t', pb', y), (x_2, t_2, pb_2), s_2, s')$.

Defining in the graph g_a unrecognized by automata *a* input words involves identifying beginning in the states of *S* endless paths ending simple cycles for which each transition consists from the set strictly parallel arcs in which for each pair of arcs marks are different by:

a) third and fourth components – $((t', pb', y), (x, t, pb), s_1, s_1')$ and $((t', pb', y), (x, t, pb), s_2, s_2')$;

b) second and fourth components – $((t', pb', y), (x_1, t_1, pb_1), s, s_1')$ and $((t', pb', y), (x_2, t_2, pb_2), s, s_2')$;

c) second, third and fourth components – $((t', pb', y), (x_1, t_1, pb_1), s_1, s_1')$ and $((t', pb', y), (x_2, t_2, pb_2), s_2, s_2')$.

Statement 1. Defining in the graph g_a path – is path with the transfer from a set of strictly parallel arcs that do not include unrecognized components, ending the recognized transition.

Selection from the graph g_a a subgraph gTr_a, giving the regular representation of a set of recognizable by automata *a* own input words $Tr^{X''}$, is to remove from the graph g_a sets starting at *S* strictly parallel arcs that have one of the conditions:

a) marks differ only in the second component – $((t', pb', y), (x_1, t_1, pb_1), s, s')$ and $((t', pb', y), (x_2, t_2, pb_2), s, s')$;

b) marks differ only in the third component – $((t', pb', y), (x, t, pb), s_1, s')$ and $((t', pb', y), (x, t, pb), s_2, s')$;

c) marks differ only in the second and third components – $((t', pb', y), (x_1, t_1, pb_1), s_1, s')$ and $((t', pb', y), (x_2, t_2, pb_2), s_2, s')$.

Statement 2. Subgraph gTr_a of the graph g_a, in accordance with the conditions of recognition, includes a set of detected by automata *a* input words $Tr^{X''}$.

Subgraph gTr_a on the basis of its own transitions kind $((t', pb', y), (x, t, pb), s, s')$, as well as on the partition, and the identification states of own complex tops allows to build the inverse mapping $aTr=\gamma^{-1}(gTr_a)$ to the corresponding subautomata *aTr* recognized input words $Tr^{X''}$ automata *a* with the usual kind transitions $(s, ((t', pb', y), (x, t, pb)), s')$. Subautomata $aTr \subseteq a$ gives for $Tr^{X''}$ regular representation, that is *aTr* is subautomata without loss of information.

When implementing recognition elements for an information test technology DIS based on the proposed model transportation test fragments the procedure is proposed for constructing special subautomata without loss of information gTr_a for extended automata *a* based on its modified screening graph g_a. As a part of the procedure – the sequence of tasks:

– building a complete modified verification graph g_a for the initial extended automata *a*;

– definition of not transporting check subgraph $g_a^{nTr} \subseteq \subseteq g_a$ based on the selection in g_a unrecognized transition, simple and endless unrecognized ways;

– selection transporting screening subgraph $g_a^{Tr} = =g_a \backslash g_a^{nTr}$;

– build subautomata without the loss of information gTr_a based on transporting screening subgraph g_a^{Tr}.

An approximate upper bound for the main task a behavioral recognition of complexity cg_a modified screening graph g_a, reduced to the cardinality of the set of vertices can be represented by the formula $cg_a=2^{2^n}ml$, where n – power of the set of states, m – power of input alphabet, l – power of output alphabet original automata a. Show scores relate behavioral recognition problem to *NP*-complex, that can determine the boundaries of the immediate applicability of the model at the component level DIS medium difficulty (1000 automata states), as well as to assume its decomposition for possible approximation of complexity to an acceptable level.

Conclusions. Transport model representing the recognition of input behavior of the expanded automata by its output behavior based on building subautomata without the loss of information is considered in the work to determine:

– conditions component transport network behavioral tests in NA, representing DIS;

– the level of decomposition in NA, to provide reasonable computational *NP*-complexity of solving component observability test fragments in a network environment of DIS;

– the procedure of a network construction of transported test behavior from arbitrary of the NA node to its common outputs.

The ability to limit resource model transport – the number of nodes and arcs of screening graph, in particular, the minimum necessary multiplicity for the recognition of the of non-deterministic transitions/outputs of the original automata, and the ability to stop the screening branch of the graph in depth and width when certain current indicators of completeness recognition provides completion of construction of the partial subautomata without loss of information.

The advantages of the proposed approach are the following: in addition to ensuring acceptable computational NP-complexity of solving component observability test fragments can be attributed parallelism computing organizations build subautomata without the loss of information. The disadvantages are the membership of the proposed solution the construction of the screening graph to NP-complexity, as well as the uncertainty of the necessary multiplicity of recognition for non-deterministic transitions/outputs of the original automata.

Experimental software and algorithmic implementation of the model, made with the use of object-component programming for the network service level of DIS, has confirmed the feasibility of the development and implementation of research in this area.

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MODEL OF COMPONENT TRANSPORT BEHAVIORAL TESTS

Decomposition approach to the synthesis of tests, taking into account the structure of information systems extends the testing tasks needed to ensure controllability and observability analysis cannot be directly exposed to the components. The aim is a constructive description of transportable advanced automata input-output words as building special subautomata without the loss of information. A formal model of transport for a set of behavioral tests transported by extended automata is defined. The modified verification graph for the initial extended automata, allowing to get for the extended automata special subautomata without the loss of information on the basis of a modified screening graph is built. Subautomata`s model without the loss of information determines the conditions of the component transportation of network behavioral tests. The advantages and disadvantages of the proposed approach are considered. Continuing in the transport model NP-complexity of the problem a behavioral recognition requires the expediency of its decomposition in order to bring to the attainable level of implementation.

Experimental software and algorithmic implementation of the model, made with the use of object-component programming for the network service level of DIS, has confirmed the feasibility of the development and implementation of research in this area.

Keywords: *test, detection of input behavior, transportation, automata without loss of information, screening graph.*

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