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Algebraic models of subsystems of abstract system with the user interface

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Abstract

Informatics abstractive system decomposition with its user interface into subsystems, taking into account the subsystems functions, is presented in the paper. There are three levels of decomposition. The first level contains functional subsystems of the user interface and functional subsystems. At the second level graphic-visual subsystems are decomposed into multi-level visual elements and multi-level property subsystems of visual elements. Functional subsystems on the second level are decomposed into variables, structures and procedures. Structural subsystems are decomposed into components of different designations. Procedures may contain variables, relations, operations and other components. Models of subsystems at all levels are described by the use the modified algorithm algebra, and the modified system of algorithmic algebras. The results of the comparison of models by different component numbers there are shown.

Keywords: algorithm algebra, algorithm formula, system decomposition, informatics system model.

Modele algebraiczne podsystemów systemu abstrakcyjnego z interfejsem użytkownika

Streszczenie

W artykule przedstawiono dekompozycję abstrakcyjnego systemu informatycznego z interfejsem użytkownika na podsystemy, przy uwzględnieniu funkcji podsystemów. Są trzy poziomy dekompozycji. Pierwszy poziom zawiera podsystemy interfejsu użytkownika z przypisanymi im funkcjonalnościami (podsystemy graficzno-funkcjonalne) oraz podsystemy funkcjonalne. Na drugim poziomie są podsystemy graficzno-funkcjonalne dekomponowane na elementy wizualne (podsystemy wizualno-elementowe) oraz podsystemy właściwości tych elementów wizualnych (podsystemy właściwościowe). Podsystemy wizualno-elementowe oraz właściwościowe mogą zawierać wiele poziomów dekompozycji. Podsystemy funkcjonalne na drugim poziomie są dekomponowane na zmienne, struktury i procedury. Podsystemy strukturne są dekomponowane na składowe o różnym przeznaczeniu. Procedury mogą zawierać zmienne, relacje, operacje oraz inne składowe. Modele podsystemów wszystkich poziomów opisano przy użyciu zmodyfikowanej algebry algorytmów oraz zmodyfikowanego systemu algebr algorytmicznych. Przedstawiono porównanie tych modeli przy uwzględnieniu kryterium liczby składowych.

Słowa kluczowe: algebra algorytmów, formuła algorytmu, dekompozycja systemu, model systemu informatycznego.

1. Introduction

Modern systems of automation, measurement and control are complex, containing information systems and technologies. In order to reduce the complexity of system, the design method of decomposition is introduced. Complex systems are decomposed according to selected criteria to define less complex subsystems. Subsystems can be still decomposed into smaller components. Decomposition level number depends on the complexity of the system and the available means of design automation as well as the functionality, feasibility, and other criteria.

Modern technologies and complex systems usually contain hardware and software components, which are implemented by algorithms. In order to describe the algorithm of complex system functioning can be applied intuitive or algebraic methods.

In the paper [6] there are discussed different methods of algorithm descriptions, and advantages of algebraic methods are pointed out.

In order to facilitate the choice of the most appropriate method of synthesis of optimal algorithms of automation, control, measurement and information systems and technologies it is appropriate to perform a comparative analysis of known algebraic methods of algorithms representation. By the use of the method the optimal synthesis of a system will realized.

2. Subsystem models

In order to construct the model of any specified informatics system a decomposition method of modified algebra of algorithms and modified system of algorithmic algebras is used. Decomposition is performed taking into account the functionality of the subsystems. The subsystem is next decomposed into smaller components. In the case of system with a user interface the components are functional and graphic-functional subsystems. Visual-element and element-property components are the result of decomposition of graphic-functional subsystems. Visual-element subsystem essentially is composed of interface elements of various designations and can has many levels of nested elements, one into another. Property subsystem establishes the properties of visual-element subsystem. Combination of visual-element and element-property subsystems form the functional subsystem. It is composed of variables, structures, properties, procedures, etc. Procedures are established by variables, relations, operations and other components. The general scheme of decomposition of system into subsystems is shown in Fig. 1.

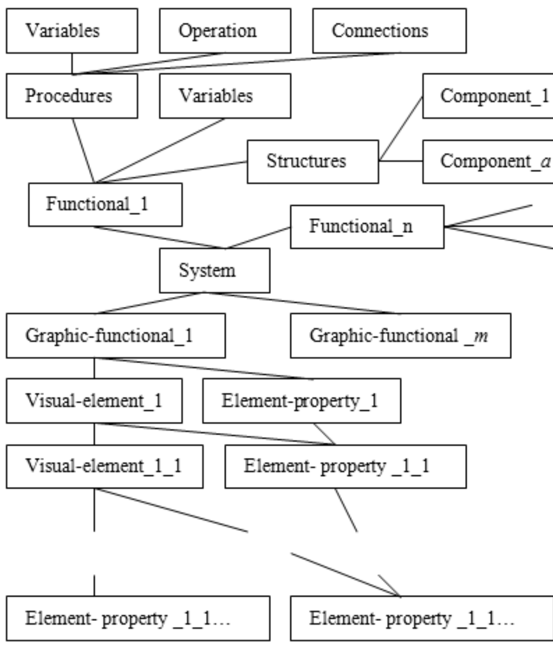

Fig. 1. General scheme of the system decomposition
Rys. 1. Schemat ogólny dekompozycji systemu

2.1. Components of decomposition

In the first level of decomposition the system is shared into subsystems functional and graphic-functional.

In the second level of decomposition the graphic-functional subsystems are shared into smaller subsystems of type visual-element and element-property.

Visual-element subsystems formed by interface elements of different designations are usually multi-leveled.

Property subsystems contain a text description of visual-element.

Combination of visual-elements and element- properties forms the functional subsystem. It contains variables, structures, properties, procedures, and other components.

Procedures are established by variables, connections, operations, and properties.

2.2. Decomposition into subsystems

Any informatics system can be decomposed into subsystems on many levels. The decomposition into four levels is described by the following formula of modified algorithm algebra:

$$S = \O i P_i = \O i \O j_i Q_{j,i} = \O i \O j_i \O t_{j,i} F_{t,j,i} = \O i \O j_i \O t_{j,i} \O x_{t,j,i} H_{x,t,j,i}, \quad (1)$$

where:

$$i \in \overset{\frown}{0, 1, \dots p\text{-}1};\ j \in \overset{\frown}{0, 1, \dots q\text{-}1};\ t \in \overset{\frown}{0, 1, \dots s\text{-}1};\ x \in \overset{\frown}{0, 1, \dots h\text{-}1};$$

i, j, t i x – variables of first, second, third and fourth levels of decomposition,

p, q, s, h – maximum values of variables of first, second, third and fourth levels;

S – system;

P_i – subsystem of the first level of decomposition;

$Q_{j,i}$ – subsystem of the second level of decomposition;

$F_{t,j,i}$ – subsystem of the third level of decomposition;

$H_{x,t,j,i}$ – subsystem of the fourth level of decomposition.

Model (1) is described by 59 characters.

The equivalent decomposition according to model described by modified algorithmic algebra system Zeitlin [2] is as follows:

$$\begin{aligned} S = (P_0 = (Q_{0,0} = (F_{0,0,0} = (H_{0,0,0,0} \| \dots H_{h\text{-}1,0,0,0})\| \dots F_{s\text{-}1,0,0} = \\ =(H_{0,s\text{-}1,0,0} \| \dots H_{h\text{-}1,s\text{-}1,0,0}))\| \dots \\ Q_{q\text{-}1,0} = (F_{0,q\text{-}1,0} = (H_{0,0,q\text{-}1,0} \| \dots H_{h\text{-}1,0,q\text{-}1,0})\| \dots F_{s\text{-}1,q\text{-}1,0} = \\ =(H_{0,s\text{-}1,q\text{-}1,0} \| \dots H_{h\text{-}1,s\text{-}1,q\text{-}1,0})))\| \dots \\ (P_{p\text{-}1} = (Q_{0,p\text{-}1} = (F_{0,0,p\text{-}1} = (H_{0,0,0,p\text{-}1} \| \dots H_{h\text{-}1,0,0,p\text{-}1})\| \dots F_{s\text{-}1,0,p\text{-}1} = \\ =(H_{0,s\text{-}1,0,p\text{-}1} \| \dots H_{h\text{-}1,s\text{-}1,0,p\text{-}1}))\| \dots \\ Q_{q\text{-}1,p\text{-}1} = (F_{0,q\text{-}1,p\text{-}1} = (H_{0,0,q\text{-}1,p\text{-}1} \| \dots H_{h\text{-}1,0,q\text{-}1,p\text{-}1})\| \dots F_{s\text{-}1,q\text{-}1,p\text{-}1} = \\ =(H_{0,s\text{-}1,q\text{-}1,p\text{-}1} \| \dots H_{h\text{-}1,s\text{-}1,q\text{-}1,p\text{-}1})))). \end{aligned} \quad (2)$$

Model has $\{2+[4+(6+8\times h)\times s]\times q\}\times p$ characters.

Formula of modified algebra of algorithms has $\{2+[4+(6+8h)\times s]\times q\}\times p/59$ times less characters. For example, for 4 subsystems on each level one gets more than 42 times less characters.

2.3. Models of graphic-functional subsystem

Model of graphic-functional subsystem ($\%P_k$), shared into visual-element (W_k) and element-property (E_k) components, and described by modified algebra of algorithms is as follows:

$$\%P_k = \overline{W_k ; E_k}, \quad (3)$$

where: k – number of graphic-functional subsystems, $k \in \overset{\frown}{0, 1, \dots K\text{-}1}$; % – identifier of graphic-functional subsystem.

The model (3) is written by 10 characters.

The same decomposition of graphic-functional subsystem ($\%P_k$), shared into visual-element (W_k) and element-property (E_k) components and described by modified algorithmic algebra system is as follows

$$\%P_k = W_k \| E_k. \quad (4)$$

Model (4) is written by 9 characters.

Thus, formula (3) of modified algorithm algebra is written by more characters then formula (4) for graphic-functional subsystem.

2.4. Models of visual-element subsystem

Visual-element subsystem model is written by the following formula of modified algebra of algorithms:

$$\overline{W_k; \O i_k \overline{R_{i,k}; \O j_{i,k} \overline{Q_{j,i,k}; \O t_{j,i,k} S_{t,j,i,k}}}}, \quad (5)$$

where:

i_k – variable $R_{i,k}$ elements of nested into element W_k; $i \in \overset{\frown}{0, 1, \dots I_k\text{-}1}$;

$j_{i,k}$ – variable $Q_{j,i,k}$ elements of nested into element $R_{i,k}$; $j_{i,k} \in \overset{\frown}{0, 1, \dots J_{i,k}\text{-}1}$;

$t_{j,i,k}$ – variable $S_{t,j,i,k}$ elements of nested into element $Q_{j,i,k}$; $t \in \overset{\frown}{0, 1, \dots T\text{-}1}$.

The model (5) is written by 41 characters.

The model of the same decomposition of visual-element subsystem is written by the following formula of modified algorithmic algebras system:

$$\begin{aligned} W_k{*}R_{0,k}{*}Q_{0,i,k}{*}\ S_{0,j,i,k} \| \dots S_{T\text{-}1,j,i,k} \| \dots Q_{J\text{-}1,i,k}{*}S_{0,j,i,k} \| \dots S_{T\text{-}1,j,i,k} \| \\ \dots\ R_{I\text{-}1,k}{*}Q_{0,i,k}{*}\ S_{0,j,i,k} \| \dots S_{T\text{-}1,j,i,k} \| \dots Q_{J\text{-}1,i,k}{*}S_{0,j,i,k} \| \dots S_{T\text{-}1,j,i,k}. \end{aligned} \quad (6)$$

The model is written by $2+5\times I–1+7\times J–1+9\times T–1$ characters.

Formula of modified algebra of algorithms has $(2+5\times I–1+7\times J–1+9\times T–1)/41$ times less characters. For example, for 4 nests ($I=J=T=4$) one gets about 2 times less characters.

2.5. Model of element-property subsystem

Model of element-property subsystem is described by modified algebra of algorithms:

$$E_k = \left(\not\subset e_k E_{e,k} \ ; \ \left(\O x_{e,k} \overset{\frown}{H_{x,e,k}; \not\subset h_{e,x,k} H_{h,x,e,k}} \ ; \ \O y_{x,e,k} \overset{\frown}{G_{y,x,e,k}; \not\subset g_{y,x,e,k} G_{g,y,x,e,k}} \right) \right),$$

where:

e_k – variable of properties of an element E_k, $e_k \in \overset{\frown}{0, 1, \dots A_{e,k}\text{-}1}$;

$E_{e,k}$ – properties of an element E_k;

$x_{e,k}$ – variable of element properties $H_{x,e,k}$ of nested into element description E_k; $x_{e,k} \in \overset{\frown}{0, 1, \dots X_{e,k}\text{-}1}$;

$h_{e,x,k}$ – variable of element properties $H_{x,e,k}$;

$y_{x,e,k}$ – variable of element properties description $G_{y,x,e,k}$ of nested into element $H_{x,e,k}$; $y_{x,w,k} \in \overset{\frown}{0, 1, \dots Y_{x,e,k}\text{-}1}$;

$g_{y,x,e,k}$ –variable of properties of an element $G_{y,x,e,k}$, $g_{y,x,e,k} \in \overset{\frown}{0, 1, \dots G_{y,x,e,k}\text{-}1}$.

The quantity of model characters is 78.

The model is described by a modified system of algorithmic algebras:

$$E_k = \{[e_k]\, E_{e,k}\}*(H_{0,e,k}*\{[\, h_{x,e,k}\,]\, H_{h,x,e,k}*(G_{0,x,e,k}*\{[g_{0,x,e,k}]\, G_{g,0,x,e,k}\} \| \dots G_{Y\text{-}1,x,e,k}*\{[g_{Y\text{-}1,x,e,k}]\, G_{g,Y\text{-}1,x,e,k}\}) \| \dots H_{X\text{-}1,e,k}*\{[\, h_{X\text{-}1,e,k}\,]\, H_{h,X\text{-}1,e,k}*(G_{0,X\text{-}1,e,k}*\{[g_{0,x,e,k}]\, G_{g,0,X\text{-}1,e,k}\} \| \dots G_{Y\text{-}1,X\text{-}1,e,k}*\{[g_{Y\text{-}1,X\text{-}1,e,k}]\, G_{g,Y\text{-}1,X\text{-}1,e,k}\})) \tag{8}$$

Quantity of model characters is $14+23\times X+29\times Y$.

Model of modified algebra of algorithms has $(14+23\times X+29\times Y)/78$ times less characters. For example, for 4 nested elements ($X=Y=4$), one gets 2,8 times less characters.

2.6. Model of functional subsystem

Model of functional subsystem described by modified algebra of algorithms:

$$F_r = \overbrace{\text{Ø}q_r x_{q,r}\,;\, \overbrace{\text{Ø}v_r V_{v,r}\,;\, \overbrace{\text{Ø}p_r M_{p,r}(h,\ \dots g),\ \dots \not\subset l_r L_{l,r}}}}\,, \tag{9}$$

where:
F_r – r-th functional subsystem;
q_r – number of variables of functional subsystem F_r, $q_r \in \overbrace{0, \overbrace{1, \dots \overbrace{Q_k-1}}}$;
$x_{q,,r}$ – variables;
v_r – number of properties, $v_r \in \overbrace{0, \overbrace{1, \dots \overbrace{N_k-1}}}$;
$V_{v,r}$ – property;
p_r – quantity of procedures, variable of cycle $p_r \in \overbrace{0, \overbrace{1, \dots \overbrace{P_k-1}}}$;
$M_{p,r}(h,\dots g)$ – procedure that depends on variables $h,\ \dots g$;
l_r – number of other elements, variable of cycle,
$L_{l,r}$ – other elements of functional subsystem.
The quantity of model characters is 42.

Model of modified system of algorithmic algebras (Zeitlin):

$$F_r = (x_{0,,r} \| \dots x_{Q,,r})^*\ (V_{0,r} \| \dots V_{N,r})^*(M_{0,r}(h,\ \dots g) \| \dots M_{P,r}(h,\ \dots g))^* \ \dots\ \{[l_r]\, L_{l,r}\} \tag{10}$$

Model has $5\times(Q+N)+10\times P+10$ characters.

Formula of modified algebra of algorithms has $(5\times(Q+N)+10\times P+10)/42$ less characters. For example, for 4 elements ($N=Q=P=4$), one gets 2,1 times less characters in comparison with the formula of modified system of algorithmic algebras.

2.7. Procedure models with eliminations

The procedure description by modified algebra of algorithms:

$$M_{p,r}(h,\ \dots g) = \overbrace{\not\subset d_{p,r} n_{d,p,r}\,,\, \overbrace{\not\supset b_{p,r} C_{b,p,r}\,,\ \dots \not\subset x_{p,r} S_{x,p,r}}}\,, \tag{11}$$

where:
$M_{p,r}(h,\dots g)$ – procedure that depends on variables $h,\ \dots g$;
$d_{p,r}$ – number of variables of procedure, variable of cycle, $d_{p,r} \in \overbrace{0, \overbrace{1, \dots \overbrace{D_{p,r}-1}}}$;
$n_{d,p,r}$ – variables of procedure;
v_r – number of properties, variable of cycle,
$C_{b,p,,r}$ – element of exception;
$b_{p,r}$ – number of exceptions, variable of cycle; $b_{p,r} \in \overbrace{0, \overbrace{1, \dots \overbrace{B_{b,p,r}-1}}}$;
$x_{p,r}$ – number of other elements, variable of cycle;
$S_{x,p,r}$ – other elements of functional subsystem.
Quantity of characters is 45.

Formula of modified system of algorithmic algebras:

$$M_{p,r}(h,\ \dots g) = \{[d_{p,r}]\, n_{d,p,r}\}*([b=0]\, C_{0,p,r},\ ([b=1]\, C_{1,p,r},\dots ([b=B_{p,r}-1]\, C_{0,p,r},\ )\dots))^* \dots\ \{[x_{p,r}]\, S_{x,p,r}\} \tag{12}$$

Quantity of characters is $37+14\times B_{b,p,r}$.

Formula of modified algebra of algorithms has $(40+14\times B_{b,p,r})/45$ times less characters. For example, for 4 procedures ($B_{b,p,r}=4$) one gets about 2 times less characters.

2.8. Procedure models with cyclic paralleling

Model of modified algebra of algorithms:

$$M_{p,r}(h,\ \dots g) = \overbrace{\not\subset d_{p,r} n_{d,p,r}\,,\, \overbrace{\text{Ø}b_{p,r} C_{b,p,r}\,,\ \dots \not\subset x_{p,r} S_{x,p,r}}}\,, \tag{13}$$

where:
$M_{p,r}(h,\dots g)$ – procedure that depends on variables $h,\ \dots g$;
$d_{p,r}$ – number of procedures, variable of cycle, $d_{p,r} \in \overbrace{0, \overbrace{1, \dots \overbrace{D_{p,r}-1}}}$;
$n_{d,p,r}$ – variables of procedure;
v_r – number of properties, variable of cycle;
$C_{b,p,,r}$ – element parallelled;
$b_{p,r}$ – number of parallelled elements, variable of cycle, $b_{p,r} \in \overbrace{0, \overbrace{1, \dots \overbrace{B_{b,p,r}-1}}}$;
$x_{p,r}$ – number of other elements, variable of cycle;
$S_{x,p,r}$ – other elements of functional subsystem.
Quantity of characters is 45.

Description by modified system of algorithmic algebras:

$$M_{p,r}(h,\ \dots g) = \{[d_{p,r}]\, n_{d,p,r}\}*(C_{0,p,r} \| C_{1,p,r} \| \dots C_{B\text{-}1,p,r})^* \dots \{[x_{p,r}]\, S_{x,p,r}\} \tag{14}$$

Quantity of characters is $37+7\times B_{b,p,r}$.

Formula of modified algebra of algorithms has $(37+7\times B_{b,p,r})/45$ times less characters. For example, for 4 elements ($D=C=B=4$) one gets 1,5 times less characters.

The table below presents for all types of subsystems the number of characters for models of modified algebra of algorithms and modified system of algorithmic algebras.

Tab. 1. Comparison of models of subsystems described by modified system of algorithmic algebras and modified algebra of algorithms
Tab. 1. Porównanie modeli podsystemów opisanych przez zmodyfikowany system algebr algorytmicznych i zmodyfikowaną algebrę algorytmów

Model	Modified system of algorithmic algebras (number of characters)	Modified algebra of algorithms (number of characters)	The reduction coefficient of number of characters
Subsystem	$\{2+[4+(6+8\times h)\times s]\times q\}\times p$	6+10+17+26	$\{2+[4+(6+8\times h)\times s]\times q\}\times p/59$
Graphic-functional	9	10	9/10
Visual-element	$5I+7J+9T-1$	7+11+15	$(5I+7J+9T-1)/33$
Element-property	$23X+29Y$	26+34	$(23X+29Y)/60$
Functional	$5(Q+N)+10P$	7+7+12	$(5(Q+N)+10P)/26$
Procedures of elimination	$37+14\times B_{b,p,r}$	45	$(37+14\times B_{b,p,r})/45$
Procedures of paralleling	$37+7\times B_{b,p,r}$	45	$(37+7\times B_{b,p,r})/45$

Note. The system of algorithmic algebras and its modification descript sequences using the operator of composition (multiplication) [1, 2]. But the operation of composition has associative property [1]. Therefore, the above constructed models of subsystems that use operation of composition ignore the associativity, however, in general, the algorithms are non-associative.

In algebra of algorithms and its modification description of sequences is performed by operation of sequencing [3, 4, 5]. If the separator in operation of sequencing is a comma, the operation is associative, and if - the semicolon, then the operation of sequencing is non-associative. In this regard, algebra of algorithms and its modification describe both classes, the associative and non-associative algorithm classes.

3. Conclusions

With the help of decomposition of complex systems into subsystems it is achieved reduction of design complexity by reducing the size of subsystems.

Any complex system with the user interface, at criterion of functionality on the first level, is shared into subsystems of functional and graphic-functional.

At the second level graphic-functional subsystems, at criterion of functional purpose, are shared into visual-element and element-property components. Visual-element subsystems are formed by interface elements, and the elements can be multi-level nested. Element-property subsystems are formed by properties of visual-element subsystems.

Functional subsystems are formed by variables, structures, properties, and procedures. Procedures contain variables, relations, and operations.

Generalized model of subsystems is described by modified algebra of algorithms and a modified system of algorithmic algebras. Models of modified algebra of algorithms have fewer characters in comparison with the models of modified system of algorithmic algebras.

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