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MODEL FOR DESIGN SYNTHESIS OF ADAPTIVE INFORMATION SYSTEMS

Abstract

It is suggested a model for synthesis of effective design decisions where a generalized space graph notion are used. The properties of this graph are examined. Engineering interpretation and CAD- application of receiving results are given.

1. Introduction.

Adaptivity is a property characterizing the ability of information systems (IS) to adapt quickly (often at on-line) and without essential expenditure to new requiements and working environment [1]. At present in connection with often alterations of production-technological and administrative structures, the problem of IS adaptivity is very sharply. There are cases when the adaptivity of IS determines not only profitability and also the survivance of an enterprise [2].

To solve the problem by means of "open systems" technology is far from being justified, and compromises considered the specifics and traditions of particular enterprises are needed.

Acceptance of compromise decisions requires to create a whole complex of mathematical models adequately describing problems and procedures of project synthesis in accordance with adopted engineering conception [3].

2. Engineering conception.

A wide use of module principle is the distinctive in modern practice of IS design. Host- computer, workstations, server, local area networks, SCADA systems, specialized measuring complexes, local regulation systems and others may be presented as "modules". Modules are completed from such autonomous "components" as: computers. controllers, operating systems, database management systems, software packages, communication channels and so on.

Adaptivity estimation of various modules in design synthesis process in realized on criteria that characterize: (1) variability and adjustment of modules (for instance, adjustment of WS Report Writer to the forms of output documents, variability of structure of DB information massif, variability of topology, channel protocols, routiring algorithms and throughput of LAN); (2) possibility to use values from some enumeration and nomenclature (for instance, possibility to use service discipline from enumeration <PRTY, ORDEREED, FIFO>, possibility to choice DB access method from enumeration <HSAM, HISAM, HDAM, HIDAM>); (3) possibility to accomplish some direct reguarements to components, modules and IS (for instance, transferability and reenterability of software). Very important project limitations as cost, interface with other modules, resources (time, financial expenditure, specialists) necessary for readjustment and others are used along with adaptivity criteria.

Variety of design solutions of IS obtained from modules (M) to within isomorphism may be represented by means of directed tree $D(M,F)$, where B is a set of vertices corresponding to functional structure of IS; $F: B \to B$ are maps indicating the incidence of directed tree vertices. We can obtain from $D(M,F)$ various types directed trees completing the components of M, for instance, directed tree of technical supplying $D(T,F_t)$ directed tree of software $D(P,F_p)$, information supplying directed tree $D(I,F_i)$. Directed trees of separated components of M are isomorphism of directed graphs [4,5].

Principal problem of a design choice is the search for of directed tree route (configuration) on $D(M,F)$ with optimal value of integral criteria adaptivity combining the above mentioned indices.

Due to the additive utility theory, integral criterion ϖ may be presented as

$$\varpi = \sum \lambda_i f_i(\mathrm{v}), \tag{1}$$

where λ_i is the weight of a local criterium, $\lambda_i = [0,1]$, $\sum \lambda_i = 1$; $f_i(\mathrm{v}_i)$ is a utility function of the i-th local criterium.

Such a convolution method is equivalent to the ranking of utility functions. The values of λ_i show how much integral criterium ϖ varies, by varying of the i-th local criterium.

Let a module component $t_i \in T_i$ contained in configuration be characterized by integral criterium $\varpi_i \in W_i$; where W_i is the set of integral criteria corresponding to the subset of component $T_i \subseteq T$.

With each directed tree $D(T,F_T)$, $D(P,F_p)$, $D(I,F_I)$ we can associated the directed tree of integral criteria $D(W,Q)$, and with each configuration on directed tree $D(W,Q)$ we can associate a total value of integral criterium $x_T = \sum_{i=1}^{k} \omega_i$, where $\omega_1 \in W_1, \omega_2 \in W_2, \ldots, \omega_k \in W_k$. For the definition of the set of configurations effective by x_T and to the definition of module components generalized graph notion [4] are used.

3. Mathematical model of a design synthesis.

A generalized graph (GG) $G(X,F)$ is Bergh's graph with a set of vertices and maps F, referring to each vertex $x \in X$ the subset X (possibly empty), i.e.

$$F_x = \{x_j \mid x_j \in X \wedge \vec{g}(x_i, x_j)\}, \tag{2}$$

where $\vec{g}(x_i, x_j)$ is an arc directed from the vertex from the vertex $x_i \in X$ to the vertex $x_j \in X$.

Definition 1. *A subset of integral criteria*

$$\begin{aligned} W_0 &= \{\omega_0^0\}, \\ W_1 &= \{\omega_0^1, \omega_1^1, \ldots \omega_{n_1-1}^1\}, \\ W_2 &= \{\omega_0^2, \omega_1^2, \ldots \omega_{n_2-1}^2\}, \\ &\ldots\ldots\ldots\ldots\ldots\ldots \\ W_k &= \{\omega_0^k, \omega_1^k, \ldots \omega_{n_k-1}^k\} \end{aligned}$$

we call a basis set of GG. Amount of basis elements corresponds to the amount of elements of the subset $T_i \subseteq T$ of the directed tree $D(T,F_T)$ and they equal to

$$|W_0| = 1;\ |W_1| = n_1,\ |W_2| = n_2;\ \ldots;\ |W_k| = n_k.$$

Definition 2. *GG* $G(X,F)$ *we call a directed graph and for it the following statement is valid:*

a) $X=\bigcup_{i=0}^{k}X_i$ *and* $X_i \cap X_{i-1}=\varnothing$, *i.e. the subset of various level vertices have no general vertices;*

b) $\exists!\, x_0 \in \left[F_{x_0}=X_1 \wedge X_1=W_1 \wedge F_0^{-1}=\varnothing\right]$, *i.e. there is a unique vertex* $x_0 \in X_0$ *for which (b) is faithful and the vertex* $x_0 \in X_0$ *is the root of the graph* $G(X,F)$;

c) $\forall x_T \in X_{i-1}\left[F_{x_T} \subseteq X_i \rightarrow F_{x_T}=\left\{x_T+\omega_0^i, x_T+\omega_1^i, x_T+\omega_2^i,\ldots,x_T+\omega_{n_i-1}^i\right\}\right]$, *i.e. exactly* $|W_i|$ *arcs start from the vertex* $x_T \in X_{i-1}$;

d) $\forall x_T \in X_k\left[F_{x_T}=\varnothing\right]$, *vertices* $x_T \in X_k$ *of k-th level are terminal and the subset* X_k *are the subset of terminal vertices.*

By means of *GG* $G(X,F)$ we can determine the set of routes connecting the root $x_0 \in X_0$ with the vertex $x_T \in X_k$, corresponding to extremal value of integral criterium.

On the given definition of *GG* we can also determine effective module components.

With each type of module component we associate own *GG*: $G_T(W_T,F_T)$; $G_p(W_p,F_p)$; $G_l(W_l,F_l)$ and so on.

A generalized of adaptivity of M can be derived on the base of the space model of *GG*. It is represented as:

$$G_M(X,F)=\bigcup_{i=1}^{m}G_i\,, \tag{3}$$

where G_i is the i-th type *GG* constituting the component of M.

Choice of effective structure of M in IS brings to selection of sure space points G_M, whose total integral exponents satisfy specific project restrictions. Space module of *OG* to within isomorphism is presented by means of its module-graph.

Module-graph is the graph indicating the constituent components of M. Each arc of this graph indicates the specific components forming M for the realization of the p-th function of IS.

Definition 3. *Module- graph of the space GG is the graph* $G_{x_p}(X',F')$, *satisfying the following statements:*

a) $X'=X_0' \cup X_1'$ *and* $X_0' \cap X_1'=\varnothing$, *where* $X_0'=\{x_p\}$,

$X_1\{x_p+\omega^0, x_p+\omega_1;\ldots;x_p+\omega_{n-1}\}$;

b) $\exists!\, x_p \in X_0'\left[F_{x_p}=x_1' \wedge (F')_{x_p}^{-1}=\varnothing\right]$, *i.e. the vertex* $x_p \in X_0$ *is the root of the graph* $G_{x_p}(X',F')$;

c) $\forall x_T \in X_1'\left[F_{x_T}'=\varnothing\right]$.

From the definition of the module- graph it follows that

$$G_{x_p}(x',F')\subseteq G_M(X,F).$$

The directed graph notion in a graph theory, in a general case doesn't restrict the graph elements (arc and vertex), i.e. arcs may have any geometric length and direction without breaking of incidence and connectedness properties [5].

In connection with this fact without breaking Definition 3 at the graph $G_{x_p}(X',F')$ we can:

1) combine the root $x_p \in X_0$, with the point of origin of n - dimensional space;
2) give to each arc $\vec{g}(x_p,x_i)$, where $x_i \in X_i$ corresponding direction and measures of unit vectors $\vec{\ell}_0,\vec{\ell}_1,...,\vec{\ell}_{n-1}$ of n - dimension space.

By fulfilling these conditions we obtain a space representation of the module-graph $G_{x_p}(X',F')$ coinciding to within isomorphism with the basis of n - dimensional space and the origin $x_p \in X'_0$ and also with the set of unit vectors $\vec{\ell}_0,\vec{\ell}_1,...,\vec{\ell}_{m-1}$.

Unit vectors $\vec{\ell}_0,\vec{\ell}_1,...,\vec{\ell}_{m-1}$ correspond to arcs $\vec{g}(x_p,x_p+\omega_0)$, $\vec{g}(x_p,x_p+\omega_1)$, ..., $\vec{g}(x_p,x_p+\omega_{n-1})$.

Lemma. *A generalized $n-GG$ graph $G_M(X,F)$ for the estimation of adaptivity of M may be presented by means of own module- graph at the space, i.e.*

$$G_M(X,F)=\bigcup_{x_p} G_{x_p}(X',F'), \tag{4}$$

Definition 4. *The graph obtained by combination of module- graphs by means of expression (4) we call a space representation of the generalized $n-GG$ on the basis $\langle\omega_0,\omega_1,...,\omega_{n-1}\rangle$ or a space generalized $n-GG$ on the basis $\langle\omega_0,\omega_1,...,\omega_{n-1}\rangle$ and denote it by $G_{M_n}(X,F)$.*

Theorem. *The space graph $G_{M_n}(X,F)$ is isomorphic to the generalized $G_{M_n}(X,F)$ graph $G_M(X,F)$ on the basis $\langle\omega_0,\omega_1,...,\omega_{n-1}\rangle$.*

4. Applications.

The use of the space generalized graph notion allows to solve project synthesis problems of adaptive IS, in particular, to realize estimation and choice of effective configuration of M and their constituents (computers, controllers, operating systems, database management systems and their encirclement, software packages and so on), to carry out generation and estimation on integral criteria of grouping variants of different level IS subsystems.

On this model prototype of CAD- system has been developed for designing adaptive IS.

Appendix.

Proof of lemma.

Proof of lemma is easily proved for $k=1$, i.e.

$$G_M(X,F)=\bigcup_{x_p} G_{x_p}(X,F)=G_{x_0}(X',F'),$$

where $X_0=X'_0=\{x_0\}$ and $X_1=X_1$, $F=F'$ is fulfilled for mappings F and F'.

Hence, it follows that for $k=1$, a generalized n- graph $G_M(X,F)$ on the basis $\langle\omega_0,\omega_1,...,\omega_{n-1}\rangle$ to within isomorphism coincide with own module- graph.

Let lemma be fulfilled for the generalized n- graph of the effective M on the basis $\langle\omega_0,\omega_1,...,\omega_{n-1}\rangle$ with a set of vertices $X''=X_0\cup X_1\cup\cdots\cup X_{k-1}$, i.e. with length equal to $k-1$. Denote this graph by $G_{k-1}(X'',F'')$.

For this graph expression (4) has the form:

$$G_{k-1}(X'',F'')=\bigcup_{x_p} G_{x_p}(X',F'), \tag{5}$$

where $x_p \in X_0 \cup X_1 \cup \ldots \cup X_{k-2}$.

Then, from lemma it follows that for the graph $G_M(X,F)$ it holds

$$G_M(X,F)=G_{k-1}(X'',F'')\cup G_{x_p}(X',F'). \tag{6}$$

From definition 2 of the graph $G_M(X,F)$ and definition 3 follows

$$\forall x_p \in X_{k-1}\left[F_{x_p}=\{x_p+\omega_0, x_p+\omega_1,\ldots,x_p+\omega_{n-1}\}\wedge F'_{x_p}=F_{x_p}\right].$$

For the subsets of vertices X_k of graph $G_M(X,F)$ is fulfilled

$$X_k=\bigcup_{x_p\in X_{k-1}} F'_{x_p}.$$

From this fact it follows that if $G_{k-1}(X'',F'')$ may be represented by means of module- graph, then for a generalized n- graph on the basis $\langle\omega_0,\omega_1,\ldots,\omega_{n-1}\rangle$ from expression (6) it follows:

$$G_M(X,F)=\bigcup_{x_p\in X_0\cup X_1\cup\cdots\cup X_{k-1}} G_{x_p}(X',F')\cup G_{x_p}(X',F')=\bigcup_{x_p} G_{x_p}(X',F'),$$

where $x_p \in X_0 \cup \cdots \cup X_{k-1}$.

The lemma has been proved.

The space graph G_{M_n} has been obtained by combination of the module-graph $G_{x_p}(X',F')$ whose arcs have definite directions coinciding with direction and measure of unit vectors $\bar{\ell}_0,\bar{\ell}_1,\ldots,\bar{\ell}_{n-1}$. The latters do not break incidence and connectedness properties of generalized n- graph vertices on the basis $\langle\omega_0,\omega_1,\ldots,\omega_{n-1}\rangle$, and that is the necessary and sufficient condition for isomorphism of graphs [5] $G_M(X,F)$ and $G_{M_n}(X,F)$.

The theorem has been proved.

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