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Specific Features of Modeling and Developing the Mathematical and Program Software for Designing Intranet-Interfaces during Competitive Development of Information Systems

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Abstract: This paper analyzes the specific features of creation of mathematical and program software for designing intranet-interfaces during competitive development of information systems. An optimization model has been constructed in the frameworks of solution of the problem on redistribution of the available resources between projects of the created software. Seeking an optimal solution is the NP-full task. Therefore, a part of requirements is classified as “stringent” ones, the violation of which is unacceptable and some requirements are classified as “desirable” (criteria), i.e., violation of these requirements is possible, but entails penalties. Development of Intranet-interfaces of human-machine systems was modeled on the basis of project group technology. An active interface user can take multiple parts in working, role and system groups. It is shown that the system of demarcation of users’ rights can be represented in the form of oriented, weighted multigraph. The problem on determining the user’s rights with respect to the object of special program interface (a set of rights in the context of a certain role) on the graph is reduced to seeking a set of oriented paths. We designed a special software for components of specialized system of studying the efficiency of information systems, including control system for modeling user load; sub-system of interaction with the user; statistical information storage; sub-system for managing of modeling.

Key words: Competitive development . information system . redistribution of recourses . NP-full task . penalties . active user . modeling of development

INTRODUCTION

The problem on competitive development of software systems with the use of intermodular interaction of Intranet-oriented components virtually exists since the latter had appeared [1]. At the same time, continuously upgrading the hardware facilities, software and means of telecommunication leads to the permanent appearance of new very complex information-computation systems, for which familiar methods of study often render inapplicable [2, 3].

Therefore, the urgency is dictated by the need to improve the processes of competitive elaboration of information systems on the basis of Intranet-interfaces through upgrading the technologies and tools for their development.

Theoretical basics for creating the mathematical and program software for designing the Intranet-interfaces during competitive development of information systems: In the framework of solution of the problem on redistribution of the available resources between projects of the created software, we will construct a theoretic-multiple model [4]. Let Φ be a set of projects; I is a set of resources; J^S is a set of works on sth project, s = 1,…, $|\Phi|$; $J = \bigcup_s J^s$ is a set of works on all projects; $K(J^S)$ is a set of works, immediately preceding the work j^S, $K(j^S) \subset J^S$; K is the number of types of recourses, $1 \le K \le |I|$; $R_1^k, \ldots, R_l^k$ are the classes of resources in each type k, being interchangeable, $R_s^k \subseteq I$, s = 1,…,l, $R_{s_1}^k \cap R_{s_2}^k = \varnothing$ for $s_1 \ne s_2$; $R^k = \bigcup_s R_s^k$ are all recourses of the type k, $1 \le k \le K$; m_{ij} and M_{ij} are the minimally and maximally permissible amounts of the resource i, consumed by the project j, $0 \le m_{ij} \le M_{ij} < +\infty$, $i \in I$, $j \in J$; t_j^-, t_j^+ are minimal and maximal times of implementation of the project j, $0 < t_j^- \le t_j^+ < +\infty$, $j \in J$; x_j, y_j are the times of start and finish of the work j; x_j, y_j are integers.

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The volume of work j, performed until the time t, will be denoted through W_{jt}, $j\in J$. The value W_{jt} is a characteristic for the state of work at time t. Formally, the accomplishment of work involves a change of W_{jt} from 0 to W_j, where W_j is the total volume of work j. Let r_{ij} be the productivity of the recourse i with respect to work j, i.e., the volume of work, performed by recourse j per the unit of time with respect to work j, $0\le r_{ij}<+\infty$, $i\in I$, $j\in J$.

Certain works with respect to every object have directive terms of completion, violation of which entails financial loses:

J_d^s is a set of works with respect to the sth project, having directive terms of completion, $J_d^s \subseteq J^s$; $J_d = \bigcup_s J_d^s$, $J_d\subseteq J$ is a set of all works of the complex, having directive terms; and D_j is the directive term of completion of work j, $j\in J_d$.

Since all resources are available in a limited volume, we will introduce the variables V_i, defined as the amount of the recourse i, available to the system at any time, $V_i>0$, $i\in I$. We will denote through c_{ij} the costs paid to use the resource i during the work j, $0\le c_{ij}<+\infty$, $i\in I$, $j\in J$. We will denote through u_{ijt} the intensity of consuming the recourse, i.e., the amount of the resource i consumed by the work j at time t.

Introduced variables, in accordance with conditions of the problem, should satisfy the following constraints.

Any work for every project can be started only after finishing the preceding works within a given project (the condition of canonicity); therefore, the times of beginning and end of work should satisfy the inequality:

$$x_{j^s} \ge \max_{l\in K(j)} y_l, j^s \in J^s, s=1,...,|\Phi| \quad (1)$$

Any work should last within acceptable limits:

$$t^-_{j^s} \le y_{j^s} - x_{j^s} \le t^+_{j^s}, j^s \in J^s, s=1,...,|\Phi| \quad (2)$$

Next, during its implementation, work uses only chosen resources and, at the same time, the amount of consumed resources should be within acceptable limits; therefore, we obtain the following constraints

$$e_{ij^s} m_{ij^s} \le u_{ij^st} \le e_{ij^s} M_{ij^s} \ ??? \ t\in [x_{j^s}, y_{j^s}], i\in I, j^s \in J^s \quad (3)$$

where

$$e_{ij^s} = \begin{cases} 0, \text{if resource i is consumed by work } j^s \\ 1, \text{otherwise} \end{cases}$$

During the remaining time, work consumes no resource:

$$u_{ij^st} = 0 \ \text{for} \ t\notin [x_{j^s}, y_{j^s}], i\in I, j^s \in J^s \quad (4)$$

The total amount of resources of each type R^k should ensure accomplishing the entire volume of work j^S. Since u_{ij^st} are integers in the problem considered here, the constraint may not hold as equality. Therefore, we obtain:

$$\sum_{t=x_{j^s}}^{y_{j^s}} \sum_{i\in R^k} r_{ij^s} u_{ij^st} \ge W_{j^s}, \ j^s \in J^s, s=1,...,|\Phi| \quad (5)$$

The non-violation of directive terms is specified by the inequalities

$$y_{j^s} \le D_{j^s}, j^s \in J^s \quad (6)$$

Moreover, the resource conditions should be satisfied: the amount of resources of every type with respect to all current works within all projects should not exceed the available inventory of resource:

$$\sum_{s=1}^{|\Phi|} \sum_{j^s\in J^s} u_{ij^st} \le V_i, i\in I, t\ge 0 \quad (7)$$

We add natural conditions on variables:

$$u_{ijt}, x_j, y_j \ge 0 \quad (8)$$

$$u_{ijt}, x_j, y_j \text{ are integers} \quad (9)$$

Total costs paid to use the resources are

$$\sum_{j\in J} \sum_{i\in I} \sum_{t=0}^{t_{max}} c_{ij} u_{ijt}, \text{ where } t_{max} = \max_{j\in J} y_j \quad (10)$$

Thus, to reduce the variable expenses, it is necessary to minimize function (10) taking into account constraints (1)-(9). However, seeking this solution is the NP-full task [5]. Therefore, a part of requirements should be considered as “stringent”, violation of which is unacceptable; and some of them can be regarded as “desirable” (criteria), i.e., these requirements can be violated, but this will entail penalties.

In accordance with the studied problem of minimization of cost, conditions of compliance with directive terms (6) will be considered as these criteria. For this, instead of (6), we introduce functions of penalties for violation of terms:

$$q_j(y_j) = \gamma_j(y_j - D_j), j \in J_d \quad (11)$$

where γ_j is the coefficient of penalty for one-day violation of terms with respect to work j. Then, the total penalty will be

$$\sum_{j \in J_d} q_j(y_j) \quad (12)$$

Thus, the total cost paid to use the recourses, taking into account penalties for violation of directive terms, represents the function

$$\sum_{j \in J} \sum_{i \in I} \sum_{t=0}^{t_{max}} c_{ij} u_{ijt} + \sum_{j \in J_d} q_j(y_j) \quad (13)$$

Therefore, we get the problem of minimization of the function (13) under the conditions (1)-(5), (7)-(9).

Thus, we created the models of competitive development of programs and program systems, notably capable of redistributing resources, taking into account the penalties for violation of terms in the process of design and ensuring an optimization of the parallel creation of program systems.

Modeling the design of Intranet-interfaces of human-machine systems on the basis of project group technology: Relying upon the set theory and group theory, we will describe the model of project groups [6]. We introduce the following sets:

Ω is the set of all interface users,
Ω_R is the set of reserve interface users,
Ω_E is the set of active interface users.
For the above-mentioned sets, it is true that:

$$\Omega_R \subset \Omega \quad (14)$$

$$\Omega_E \subset \Omega \quad (15)$$

$$\Omega_R \cup \Omega_E = \Omega \quad (16)$$

$$\Omega_R \cap \Omega_E = \varnothing \quad (17)$$

We introduce into consideration the project groups on the set Ω: K is the root group of interface users, S_i, $i \in N$ (from here on, N is the set of natural numbers) are structural groups of interface users, C_j, $j \in N$ are structural-working groups of interface users, W_k, $k \in N$ are working groups of interface users, R_m, $m \in N$ are the role groups of interface users and T_p, $p \in N$ are system groups of interface users. For the above-mentioned groups, it is true that:

$$K \subset \Omega_R \quad (18)$$

$$|K| = |\Omega_R| \quad (19)$$

$$\forall i \in N: S_i \subset \Omega_E \quad (20)$$

$$\forall j \in N: C_j \subset \Omega_E \quad (21)$$

$$\forall k, m \in N, k \neq m: S_k \cap S_m = \varnothing, C_k \cap C_m = \varnothing \quad (22)$$

$$\bigcup_i S_i + \bigcup_j C_j = \Omega_E \quad (23)$$

$$\forall k \in N: W_k \subset \Omega_E \quad (24)$$

$$\forall m \in N: R_m \subset \Omega_E \quad (25)$$

$$\forall p \in N: T_p \subset \Omega_E \quad (26)$$

Group K includes reserve interface users. Groups S_i, C_j ($i, j \in N$) are subsets of Ω_E; an active user take a unique part in structural and structural-working groups; moreover, if the user participates in any of the groups S_i ($i \in N$), he participates in neither of groups C_j ($j \in N$) and vice versa; active users of interface surely participate in any of groups S_i or C_j ($i,j \in N$). Groups W_k, R_m, T_p are the subsets of Ω_E.

Let, on Ω_E, there exist the sets α, β, γ of interface users, belonging to any of the groups W_k, R_m, T_p ($k, m, p \in N$), such that:

$$\alpha = \bigcup_k W_k \quad (27)$$

$$\beta = \bigcup_m R_m \quad (28)$$

$$\gamma = \bigcup_p T_p \quad (29)$$

Then, it is true that:

$$\sum_k |W_k| \geq |\alpha| \quad (30)$$

$$\sum_m |R_m| \geq |\beta| \quad (31)$$

$$\sum_p |T_p| \geq |\gamma| \quad (32)$$

That is, an active interface user can take the multiple parts in working, role and system groups.

Table 1: The hierarchy of groups

		Descendant group				
No.	Ancestor group	Structural group	Structural-working group	Working group	Role group	System group
1	Root group	*				
2	Structural group	*	*	*	*	*
3	Structural-working group	*	*	*	*	*
4	Working group			*	*	*
5	Role group				*	*
6	System group					*

Next, we will consider the communication model of hierarchical relation of different types of groups. In Table 1, possible variants of hierarchical subordination between types of groups of the information-managing interface [7] are indicated with asterisks.

We will describe the graph model of the system of demarcation of users' rights. We represent the model of the system of demarcation of rights in the form of graph $G=(X,U,\Phi)$, where X is the finite set of vertices; U is the finite set of edges (arches); Φ is the incidence relation; $X \cap U = \varnothing$, the vertices of which will be users, groups, objects and roles and the edges will be the relations between them. Let Y be the set of vertices corresponding to the users and groups, O be the set of vertices corresponding to objects and P be the set of vertices corresponding to roles:

$$Y \subset X, O \subset X, P \subset X \quad (33)$$

Graph G is an oriented and weighted multigraph, with the weights of edges being defined as follows. Let the relation W(x, y) be the relation, determining the weight of the edge between adjacent vertices x and y; then we have:

$$\forall x, y \in Y, W(x, y) = 1 \quad (34)$$

$$\forall x, y \in O, W(x, y) = 1 \quad (35)$$

$$\forall x, y \in P, W(x, y) = 1 \quad (36)$$

Let us define the set of resolution relations M in the context of system of demarcation of users' rights, such that m_i ($i \in N$) is the relation tying the vertices y, o, p, where $y \in Y$, $o \in O$, $p \in P$. $\forall$ y, o, p, for which there exists a resolution relation and it is unique.

On the set M, we define a function B(m), $m \in M$ such that:

$$\forall m \in M, B(m) > 1, B(m) \in N \quad (37)$$

$$\forall i, j \in N (i \neq j), B(m_i) \neq B(m_j) \quad (38)$$

Then $\forall$ y, o, p, for which there is the resolution relation $m \in M$, we have the following conditions: edges y and o, as well as o and p, are adjacent, with:

$$W(y,o) = W(o,p) = B(m) \quad (39)$$

Thus, the system of demarcation of users' rights can be represented in the form of oriented weighted multigraph.

The problem on determining the user's rights with respect to the object of special program interface (a set of rights in the context of a certain role) on the graph is reduced to seeking a set of oriented paths. It is noteworthy that there are the following restrictions on the oriented paths:

- The start of oriented path is vertex, corresponding to a given user;
- Oriented path must include exactly 2 edges, the weight of which is greater than unity and the weights of these edges must be equal.

To solve the problem on searching for the set of oriented paths, it is reasonable to search for into depth and the algorithm for searching into depth on oriented multigraph should be modified to include restrictions imposed on oriented paths.

Next, we will consider an object model of infrastructure of the special program interface [8]. The diagram of classes of the corresponding component is presented in Fig. 1.

As a result of the call, reload of the page of the working environment is initiated on the page of the working environment of interface of module out of the list of available modules. Infological model of the database of infrastructure of the special program interface is presented in Fig. 2.

Special mathematical and program software: Special program software for components of specialized system of studying the productivity of information system was designed; this software includes a control system for

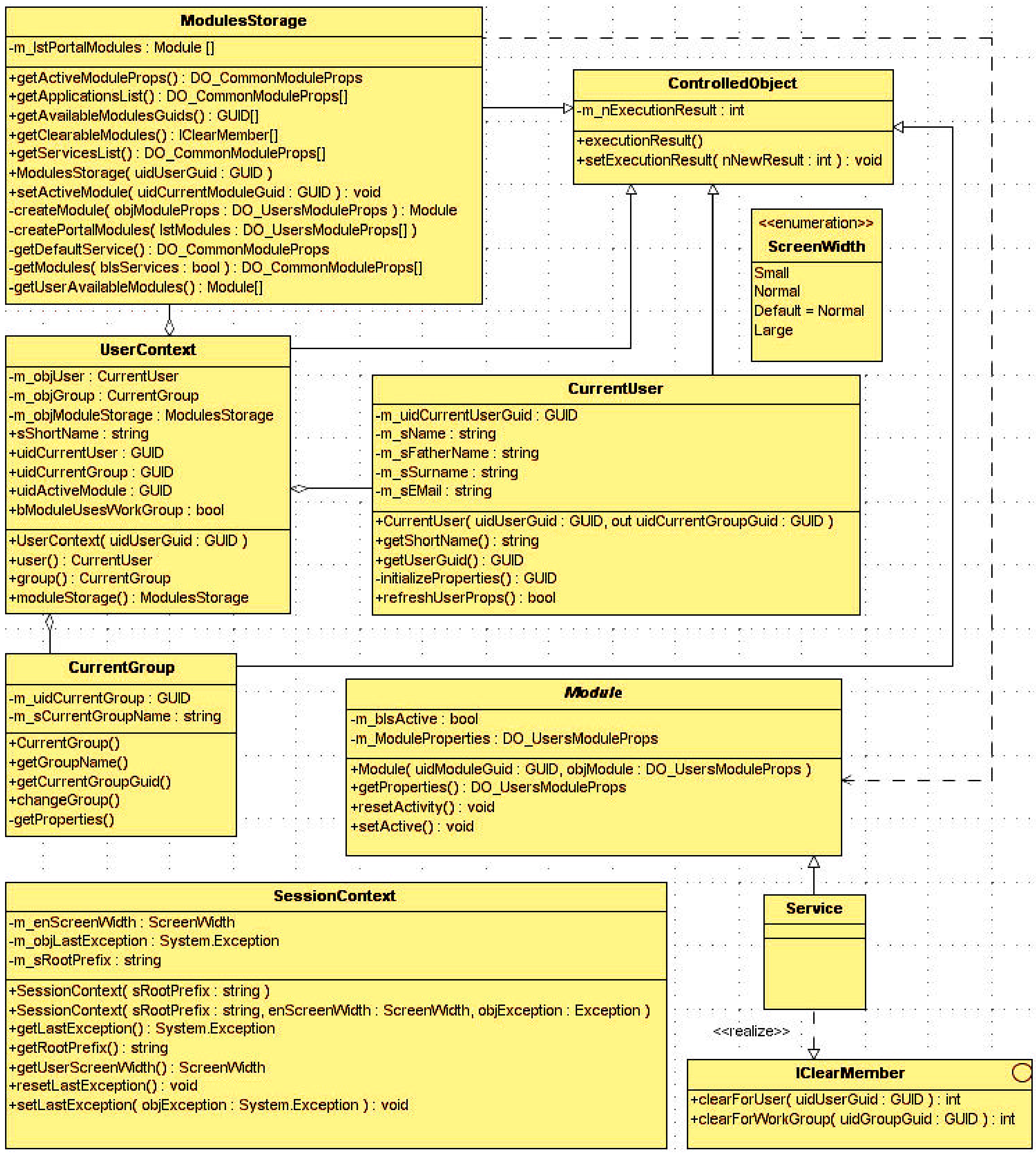

Fig. 1: The diagram of classes

modeling the user load; sub-system for interaction with the user; storage of statistic information; sub-system for interaction with the storage of statistical information; and sub-system for managing of modeling.

To satisfy these requirements, we propose the following structure of the program complex for studying the productivity of information systems. The program complex includes:

1. The managing system for modeling the user load. Two elements can be singled out in the system composition:
   - An application, which implements the necessary functionality;
   - The storage of statistical information.
2. The system for generating the user load. This component represents a set of test applications for modeling the user load. Load capacity of the system is estimated as the dynamics of the time of system response to increase in the load.
3. Studied information system or a component of information system. In this work, the studied component of the information system is the database management system (DBMS).

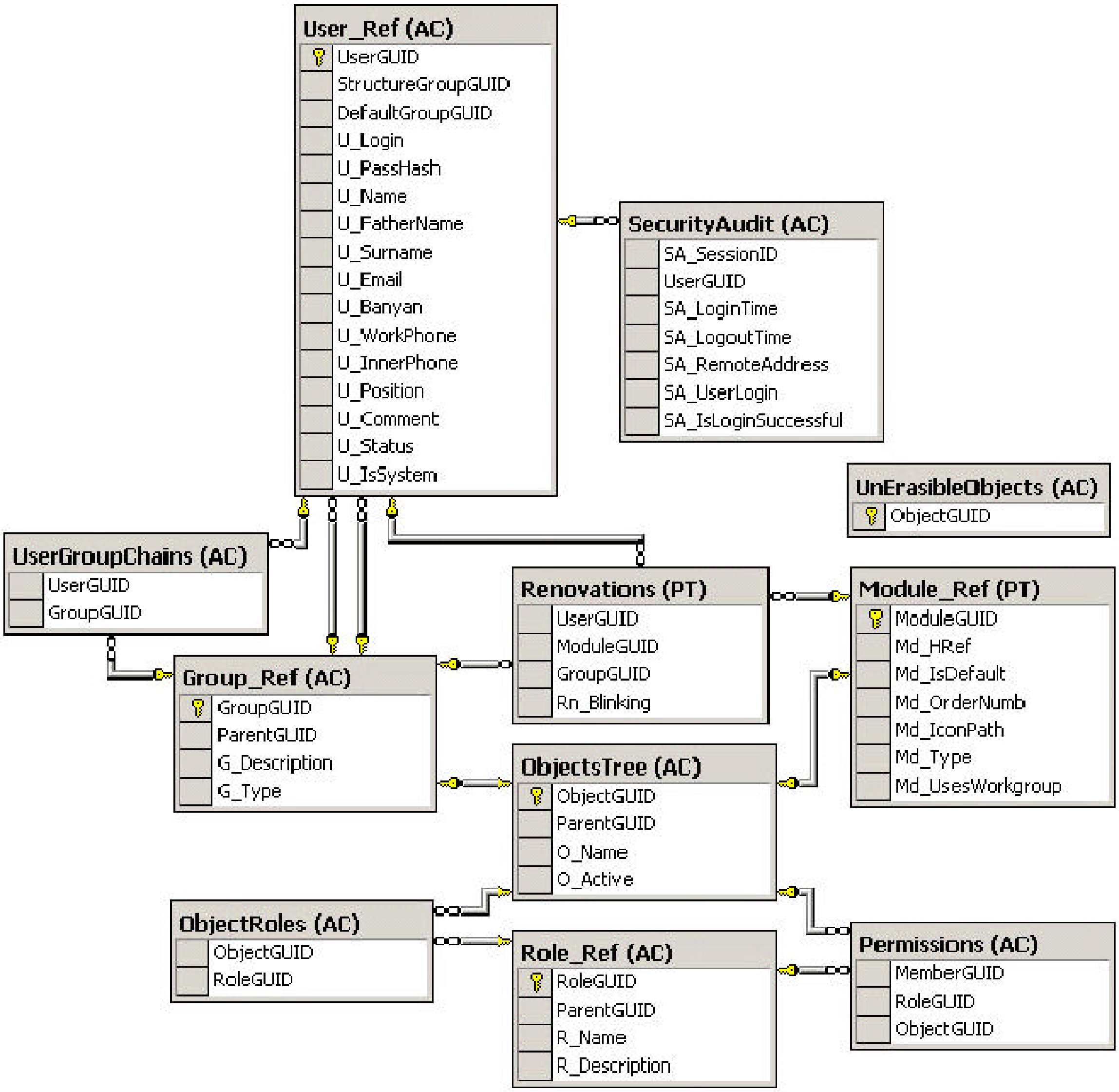

Fig. 2: Infological model of database of infrastructure of the special program interface

The subsystem of interaction with the user organizes graphic interface, providing an option to enter different parameters and make settings by the user. The general algorithm of interaction subsystem with the user consists of launching the interface elements and then processing of received information. Key concepts of the modeling process are the scenario of the user load, virtual user and test transaction.

- Test transaction is a typical query to DBMS of a certain type [9].
- Virtual user is a program, emulating the work of the human with the system; it produces the load on the system in the form of a set of test transactions. From the viewpoint of the studied system, no matter which (real or virtual) user is at work.
- Scenario of the user load is a set of rules, according to which the virtual users and test transactions are launched [10].

The developed database of the storage of the statistical information is presented in Fig. 3, which indicates relations between tables.

The program is written with the use of the library of classes Microsoft Foundation Classes (MFCs) in C++ language. The employed classes are grouped in accordance with their functions.

The structure of the program system for studying the productivity of information systems is developed, based on the use of the model of competitive development of programs and program systems and theoretically-multiple model of intranet-interfaces of

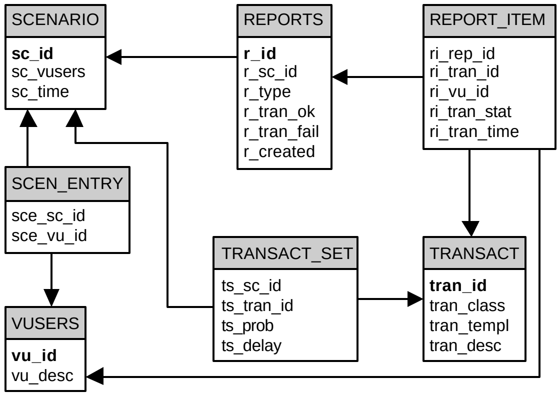

Fig. 3: The database of the storage of the statistical information

human-machine system and the technology of project groups, using an ideology of virtual users and test transactions and making it possible to estimate the load capability of intranet-interfaces during access to data storage.

RESULTS

We developed the models of the competitive development of programs and program systems, notably capable of redistributing the resources, taking into account the penalties for violation of terms in the process of design and ensuring the optimization of the parallel creation of program systems.

We developed theoretically-multiple models of intranet-interfaces of human-machine systems on the basis of technologies of project groups, providing a versatile mechanism of demarcation of rights on the basis of use of groups and roles.

We constructed an object model of infrastructure of the special program interface, making it possible to readily change the functionality of interface by means of plugging and unplugging the modules with the help of special algorithms of loading and call.

We created components of information and program software of a special human-machine interface, ensuring the necessary functionality and information support of the modules.

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