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Conceptual Resource-Saving Design of Real-Time Socio-Technical Systems

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Abstract. The article discusses the methodological resource-saving approach to the System design of socio-technical systems for real-time managing (STS RTM). The definition of STS RTM from the point of view of computer systems architecture is introduced. This approach made it possible to classify the main paradigms of using computer systems, including the modern stage, corresponding to STS RTM. For such complex systems, it is important to ensure their energy efficiency, which is ensured by the use of resource-saving models and methods for optimizing structural solutions. This is ensured by minimizing the total length of communications at the enterprise, saving computing and financial resources during system migration from a centralized structure to a functionally distributed hierarchical multi-microcontroller system. STS is a human a real-time machine system, therefore, the system's response time to the processing of requests related to the issuance of messages to the system's operating personnel is determined. The complex of formulated tasks and their solution on a common information and analytical base is extremely difficult without a unified system design methodology and automation tools for solving problems. Such a Framework is described in this article.

1. Introduction

For more than 40 years we have been developing and implementing of automated control systems for railway transport [1]: by tracing the development trends of such systems, we observe not only changes in the architecture of automation systems, but also the emergence of new users' needs based on expanding information resources for decision-making.

1.1. Architecture CS as a multistructure for the description of STS

In the work, developing the concept of CS architecture [5], a new definition of the architecture as an object-oriented multi-structure, which can be described STS in the form of the following expression, is introduced:

$$ASTS = Gs \cap Os \cap (Hs \cup Ss \cup Ms \cup Is \cup Ls \cup Ps \cup Ds \cup MLs), \quad (1)$$

where Gs is the business goals of creating a system; Os - the set of objects or the environment to which the system operates, raising the functions of control and management to achieve business goals; Hs is hardware, technical support (a set of technical means of the system); Ss is software (general and special); Ms is mathematical support (complex of mathematical models, methods and algorithms); Is is



information support (description of signals, principles of classification and coding of information, description of arrays, forms, reference information and information on regulations and other types of information); Ls is linguistic support (a set of language means of communication with the system for personnel); Ps is people support, organizational support (organizational structure and instructions to operational people).

All these types of support are characterized by a set of interrelated static and dynamic structures that are formed in the process of system design and are combined by a common conceptual scheme to achieve the creation goals while minimizing total costs [4, 5].

1.2. The development of computerization paradigms

The development of paradigms or trends in computerization in the world took place in the form of the following stages. The first stage is the stage of computing systems (CS). These were hardware-centric systems, in which the main goal was to get maximum performance; the dominant features in the ASTS are Hs , Ss (1950-80s). After this comes the network-centric stage of creating information systems that provide access to information “here and now”, the dominants are Is , Hs (net) (1990s - 2010). The third stage is human-centric, associated with the creation of systems with artificial intelligence, the dominants are integrated $Hs \cup Ss \cup Ms \cup Is \cup Ls \cup Ds$. The current stage is being formed in the context of the globalization of socio-economic and production processes. It will be called the sociocentric paradigm associated with the construction of STS with HYBRID TNELECT (STS GI). The dominant in this case are Gs , Ps , Os , Is , Hs .

2. STS conceptual design framework CoDeCS-2020

The variety and complexity of systems architectures makes it very important to create a methodology and develop frameworks and tools based on it.

The architectural scheme of the conceptual design is related to the preliminary research, optimization and selection of rational structures and characteristics: topology of technical facilities at the company, the technical structure, the structure of information flows and the databases organization, processor performance requirements for the modes of their operation in real time and priority processing of applications, indicators of reliability, power consumption and cost of the projected STS. All these studies and calculations are carried out, as a rule, in the conditions of incompleteness of the initial data and their uncertainty. In addition, many modern STS go into the category of complex (large) systems, described by a large number of parameters. For example, the control system of a modern nuclear power plant is connected with the input and processing of up to 10.000 signals. For complex systems, an essential characteristic that determines its effectiveness is the structure [7]. In this paper we are talking about a multistructure [8].

Effective implementation of a large volume of analytical work, the use of various models and methods of research, modeling and design, including artificial intelligence (fuzzy sets, genetic algorithms, neural networks, ontologies) is impossible without the methodology of their integration into a single conceptual framework (CF) with software tools for automation of design and research works [4, 6].

The authors developed a methodology for the conceptual (system) design of complex STS based on the scientific-methodical framework for conceptual design (CF), the general algorithm of which is shown in figure 1.

The methodology is based on the following statements.

1. The process of research and design of complex systems is presented in the form of a sequential iterative scheme for the step-by-step search for rational design solutions using heuristic optimization methods that can be tuned to the sequence of early stages, phases and tasks of STS information technology design in accordance with [3]. But the structure of CF can be adapted to any methodology of conceptual design.

2. The knowledge base of the methodology is presented in the form of a set of ontologies describing the automatized company and the complex of software and hardware of industrial computers

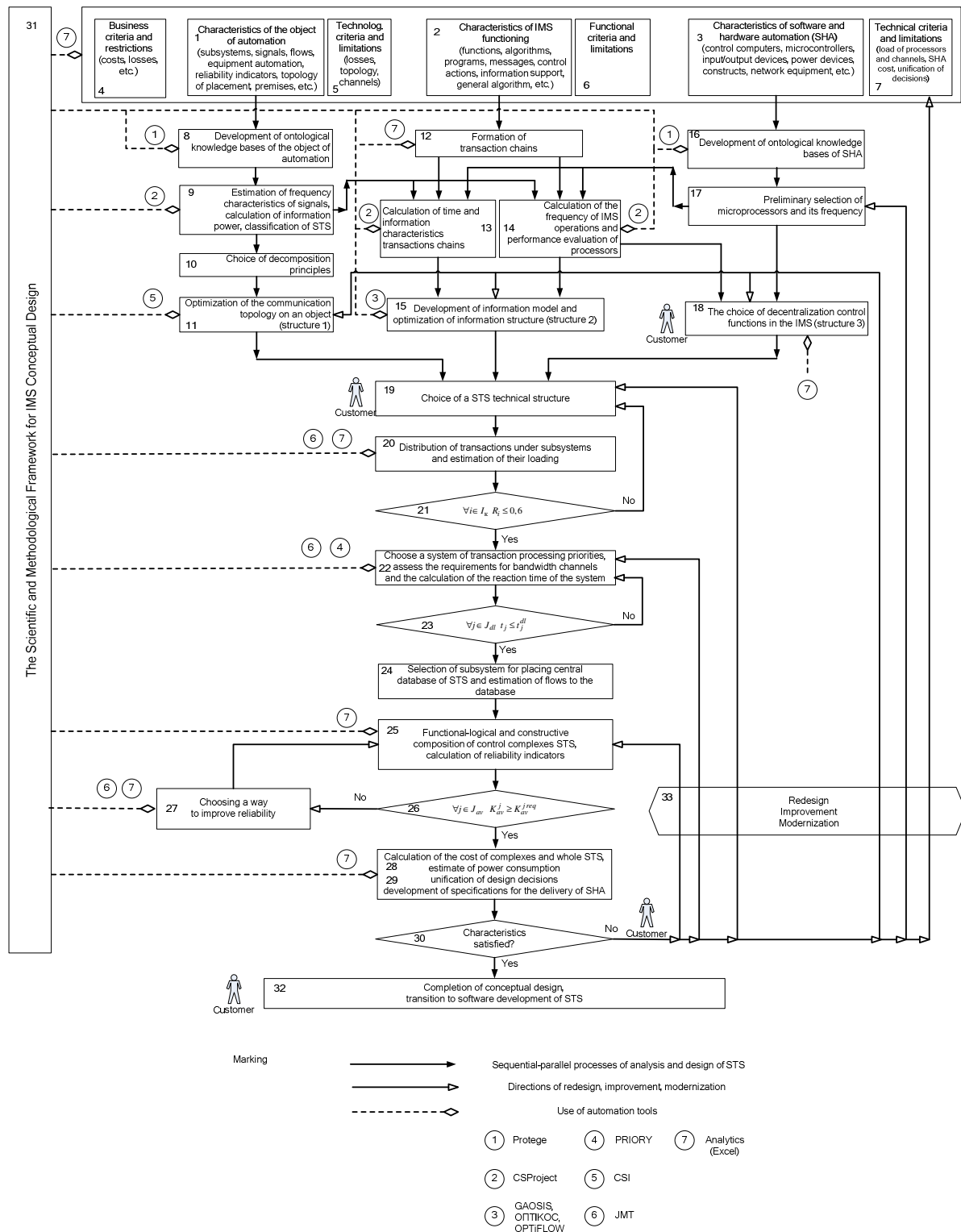


Figure 1. STS conceptual design framework.

(HSA). For example, HSA Advantech [9] is described to which development of automated systems in Germany, Russia and Ukraine is oriented.

3. The methodology is adaptive to the set of initial data available to the developer when analyzing and designing a particular system. This means that in the knowledge base, the sequence of design stages and procedures for which there is all the necessary data (either in the knowledge base or entered by the designer in the dialogue mode) is activated.

4. The methodology includes software tools to automate the work performed. The program CSI (complex system integrator), the program CSProject for the construction and calculation of information-time characteristics of real-time computer systems' transactions, the program OPTiFLOW for distribution of information flows in real-time systems, the program OPTICOS for optimization of information control systems, the program GAOSIS (based on the genetic algorithm) to optimize the structures of information systems and the program PRIORY to select priorities of application flows in STS. In addition, tools have been developed to automate the selection of design solutions under uncertainty. To create and edit ontologies in the form of OWL databases, a special program has been developed that makes it possible to use Cyrillic.

5. The initial data and results of system analysis and design are given in table-graphical forms. The initial data for creating STS are (Figure 1):

block 1 - the characteristic of the object of automation: a description of the organizational and technological characteristics of the system that is designed, including the technological subsystems, their structures, sections, flows and characteristics of signals in the sections, mechanization tools and equipment of the bottom automation, the layout of their location, buildings and premises in the company, reliability of devices, the sequence of technological operations, which is performed by the operational staff of the system (flows, location, time); peripheral equipment, which should be serviced by STS;

block 2 - the characteristic of STS functioning (in terms of the customer): functions, tasks, algorithms or programs that the projected system should perform; for new systems, this description will be at the level of functions and tasks; for systems that are being improved or modernized are developed algorithms or programs for estimating the frequency composition of operations (commands); for all levels with different layers of completeness and accuracy, the components of information support (variables, arrays) are specified; For each signal (application), the control actions or messages transmitted to personnel are indicated; the description is made in the form of transactions in the dialogue with the CSI program;

block 3 - description of software and hardware automation tools SHA: control computers, micro-controllers, input-output, normalization and switching of signals, power supplies, network equipment, software, reliability and cost indicators of devices and modules;

blocks 4, 5, 6, 7 - describe the criteria and limitations in business: resource saving, costs, losses, system costs, reliability indicators that must be provided, technological constraints (topology elements, channels), functional and technical indicators (workload of processors and channels, cost of software and hardware, unification of solutions);

The design of the system begins with three interrelated directions. The first - blocks 8, 9, 10, 11: optimization of the communication structure at the automation object by the minimization criterion for the total length of communications with fixed channels (the construction of a minimum spanning tree). The second - blocks 12, 13, 14, 15: optimization of the STS information structure by the minimization criterion for the growth of the total information flow with decreasing the number of information links in the structure). The third direction - blocks 16, 17, 18: the choice of variants for the decentralization of functions in a hierarchical structure by the minimization criteria for the total losses and the cost of STS.

Within the framework of the first and third directions, the respective ontologies of the company are formed (the ontology for the automation object and the ontology for complex of SHA software and hardware).

The first ontology is used in blocks 9, 10, 11, 19, 24, 25, 29. The second ontology is used in blocks 17, 18, 24, 25, 29.

On the basis of the formed three variants of the structure, a variant of the technical structure (block 19) is chosen with the participation of the customer, which represents the current business interests (priorities) for the preselected type of microprocessor (block 17).

In the second direction, transactions (block 12) are generated on the basis of the initial data (block 2) and their time and information characteristics (block 13) are calculated to optimize the information structure (block 15). In addition, the frequency composition of the operations solved in the system of tasks is calculated, and the performance of the processors in the MIPS and in transactions/s for finding optimal hierarchical structures (block 18).

For the chosen variant of the technical structure, the transactions are distributed among the subsystems and their load is estimated (blocks 20, 21). If this restriction is performed for a distributed STS, then the system response time is calculated for each transaction, the optimal priority is selected and channel bandwidth requirements are calculated (block 22). Further, when the time constraints are satisfied (block 23), based on the data of block 13, a subsystem is selected to place the central database in the decentralized STS (block 24).

At the next phase (block 25) for each subsystem, the functional-logical and constructive composition of the corresponding computer complex is done using the SHA ontology (block 16). Besides, technology and communication facilities are selected in the system in the same ontology. These means must match the requirements for the channel capacity (block 22). Estimation of availability factors is carried out for the obtained technical structure. If availability factors are not provided (block 26), a weak element reservation scheme is selected (block 27).

If the required reliability is achieved, the unification of the designed hardware-software decisions is carried out for the STS and the specifications for the SHA purchase are prepared, the cost of the complexes and the whole system, the power consumption and system performance are calculated (block 29). The design results are considered by the customer (block 30) and, if they suit it, the system design is completed and the development of the software for STS begins (block 32). If "No", the direction of redesign is selected (block 32). Improvements or modernization of the system begins from the same place. Figure 1 shows the names of the tools used for the research and conceptual design of STS.

3. Conclusion

The conceptual design of real-time information management systems (IMRTS, now STS RT) in the conditions of increasing their dimensionality and multi-structural complexity is a necessary stage of any development. In the process of system (conceptual) design, it is important to represent the STS architecture as a set of interrelated types of support that are oriented towards the achievement of specific business goals. The proposed CoDeCS-2020 methodology is complemented by a set of tool programs for solving practical engineering tasks that can be used autonomously and can be adapted to other design standards.

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