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Instrumental Methods of Analysis of Quality of Automated Control Systems

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Abstract:

The article reveals the problem of analysis of automated control systems in oil refineries was addressed through creation of models, techniques and tools for analyzing and evaluation the quality of automated control systems.

These models can help refiners in the creation, operation and development of Information Systems.

The scientific novelty of the research is the development of methodological and instrumental support for the analysis and evaluation of the quality of automated control systems of oil refineries.

Keywords: *analysis of quality, evaluation of quality, automated control systems, oil refinery, classification of the components, quality characteristics, refinery model, method of integral quality assessment, visual UML models, instrumental system.*

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1. Introduction

1.1 Classification of the components of ACS refinery, including classification characteristics, reflecting the specifics of the oil refining industry

New classification features of the components of IP are proposed, among them: the level of management, the stage of the technological process, the authorship of the component. A fragment of this classification is given in Table 1, which shows the classification characteristics and possible variants of the values of these characteristics.

Table 1. *Calculation table for the method of analyzing hierarchies.*

№	Classification characteristic	Variants of realization of the classification feature
1	Level of management	- management of production equipment - management of the production process - enterprise resource management - Business Analytics and Strategic Management
2	The authorship of the component	- a component developed by the forces of the enterprise - component is made to order of the enterprise - the component is expanded and adapted for the needs of the enterprise - the production component - part of a comprehensive software solution
3	Localization	- production of the local country - production of the countries of the EU - joint development with foreign participation - production of foreign countries
4	Integration	- is a fully autonomous component - manual interaction with other components - manual upload of data - a format for exchanging information with other applications - service for interaction - a single information base

This classification defines the basis for building a model of an automated information system of a large manufacturing enterprise in the field of oil refining and can be used to create instrumental methods for assessing the quality of information systems in the field of oil refining.

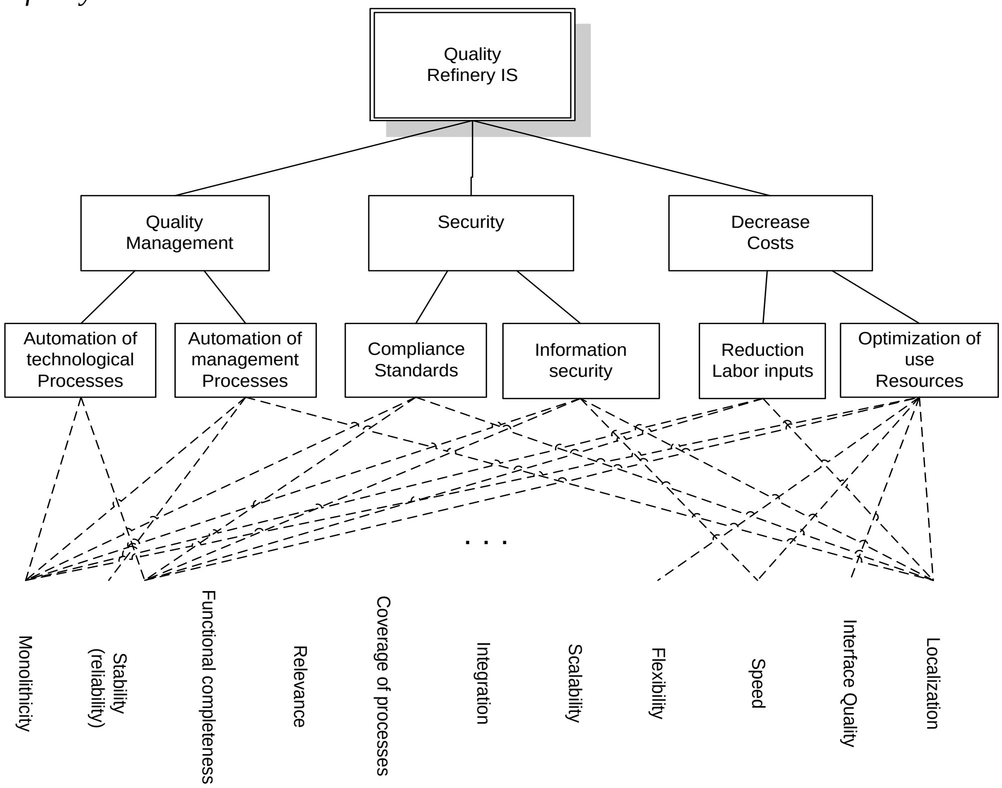
1.2 Ranked set of quality characteristics of the automated control systems (ACS) of oil refineries, considering the refinery functional requirements

The activities of oil refineries have several features relevant to the operation of information system, which stipulate certain requirements for information systems of oil refineries, such as:

- large scale of the enterprise;
-working in the key strategic area for the economy;
- continuous production cycle;
- significant environmental and man-caused risks of production processes;
- a high degree of automation of basic technological processes and their integration into the comprehensive information system of the oil refineries;
- state control of the enterprise;
- functioning as part of holdings and corporations, requiring the organization of interaction with the information systems of the parent organization.

To rank the quality indicators of the information system that considers the features of the refinery, we will use expert methods and an analytic hierarchy process. Figure 1 shows the tree of objectives of this method, which includes the top-level goal, two intermediate levels and compared alternatives, which are IS quality characteristics.

Figure 1. *Hierarchy of the objectives and characteristics of the quality of the IS refinery*



At each stage of the application of the hierarchy analysis method, the experts conducted a paired comparison of alternatives according to the scale proposed by Saati (1993). One of the advantages of the method is the use of the experts' abilities to pair comparison of two objects, instead of a much more complicated ranking problem or even more difficult for a person to estimate the weight coefficients.

Based on the obtained back-symmetric matrix of pairwise congruences A, the maximal value $\lambda_{\max}$ and the corresponding eigenvector w of the matrix A were calculated and selected, such that: $Aw=\lambda_{\max}w$. After normalizing the elements of the eigenvector w, we obtained the weight coefficients of the compared nodes:

$$wn_i = \frac{w_i}{\sum_{j=1}^{n} w_j}$$

To assess the consistency of the matrix of paired comparisons, standard methods for calculating the consistency index and the consistency relation were used, considering the random consistency index:

$$CI = \frac{\lambda_{\max} - n}{n-1}, \quad CR = \frac{CI}{RCI(n)}$$

At the last stage, for each of the goals of the third level, the weight coefficients for each of the alternatives were calculated. The final estimate was obtained by multiplying the weights of each node by the weighting factor of the parent node.

Based on the results of the analysis, a ranked list of characteristics of the quality of information systems are:

"Stability" (v = 0.28);
"Integration" (v = 0.19);
"Coverage of processes" (v = 0.12);
"Functional completeness" (v = 0.7), etc.

1.3 The ACS refinery model, implemented with the help of the theory of sets and reflecting the types and levels of the components of the automated system, their interaction and their use within production and technological processes

Information system of refinery:

$$IS = < C, F, X, BP, BPoC, Y, U, R, RoC >,$$

$C = \{C_i, i = \overline{1,n}\}$ - a lot of software components of the information system.

$F = \{F_i, i = 1, m\}$ - dictionary functions of the information system of the enterprise. X - the matrix of the implementation of functions, the elements of which determine the implementation of functions by software components:

$$x_j^i = \begin{cases} 1 \text{ If the component } C_i \text{ implements the function } F_j \\ 0 \qquad \text{otherwise} \end{cases}$$

$BP = \{BP_i, i = 1, u\}$ - a lot of technological and managerial processes of the enterprise.

$$BP_i = \langle \{O_{ij}, j = 1, NO_i\}, \{SEQ_j^i\} \rangle$$

Where Oij-operations of process BPi, and SEQij - the matrix defining a sequence of operations.

The set $BPoC = \{BPoC_{jk}^i\}$ determines whether the i-th software component is involved in the k-th operation of the j-th process.

The matrix $C = \{C_j^i, i = 1, n, j = 1, n\}$ determines the integration of software components among themselves. The set U defines the parts of the enterprise, and the set R - the jobs.

1.4 The method of integral quality assessment of ACS refinery based on the selected set of quality indicators

The information system of a modern large enterprise cannot be regarded as monolithic. This is an environment consisting of heterogeneous elements that are constantly changing. Therefore, the task of assessing the quality of the information system of the refinery consists of an analysis of the state, interaction and dynamics of its many components.

The integral quality score is a function of the indicators defined earlier, for example:

$$I = \sum_{i=1}^{n} \alpha_i \cdot I_i ,$$

Where $\alpha = (\alpha_1 \quad \alpha_2 \quad \ldots \quad \alpha_n)$ is the vector of weight coefficients obtained by expert means, for example, using the hierarchy analysis method. In this case, the individual quality indicators Ii should be reduced to dimensionless quantities. Therefore, the integral indicators of the quality of the information system, highlighted earlier: $(I_1 \quad I_2 \quad \ldots \quad I_n)$

Each of the enterprise IP quality indicators can be obtained on the basis of the calculation function:

$$I_i = \frac{\sum_{j=1}^{m} f^{i}(C_j, F_j, BP_j, P_j) \cdot b_j}{\sum_{j=1}^{m} b_j},$$

Where bj is the basis for calculating the integral quality score.

The choice of the base is very important. Suppose the information system includes two software components, imported and domestic production. What is the localization index in this case? The answer depends on the selected database. The proposed methodology for the integrated quality assessment of ACS refinery is presented in Figure 2.

The first step of the technique is to determine all the software components available in the enterprise, linking them using the appropriate model matrices to the sections and workstations. At the same time firm-software vendors are fixed.

The second step uses the technique of analyzing complex systems by the criterion of functional completeness, a list of functions is highlighted, and the initial implementation matrix of these functions is formed.

The third step establishes the interaction of components. This can be the use of a single database, either the use of a service, or the standard for the exchange of messages, or the unloading of information, or manual data transfer.

At the fourth step, the components are tied to the operations of the technological and managerial processes of the enterprise.

At the fifth step, the processes are ranked through expert methods and obtaining weight coefficients.

At the sixth step, the calculation of quality indicators is carried out.

At the seventh step, a profile of integrated quality indicators is formed for the information system of the refinery as a whole.

In Figure 3, as a radial diagram ("Windrose"), an example of the profile of integrated indicators of the quality of the information system of refinery, a forecast of the development of the system in accordance with the implementation schedule and two alternative projects for the development of this system is given.

Figure 2. *Steps of the methodology for estimating integrated quality indicators of IP*

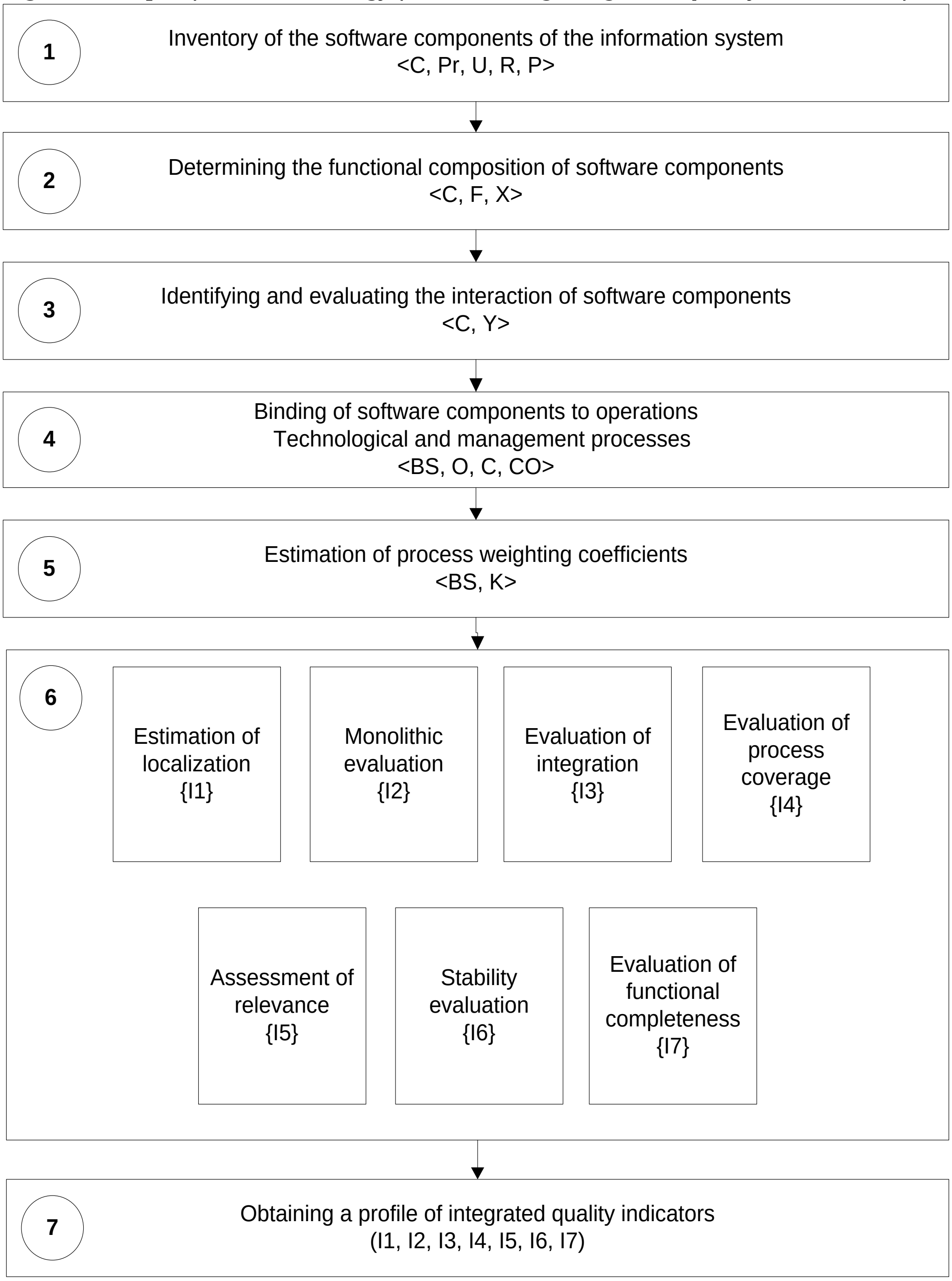
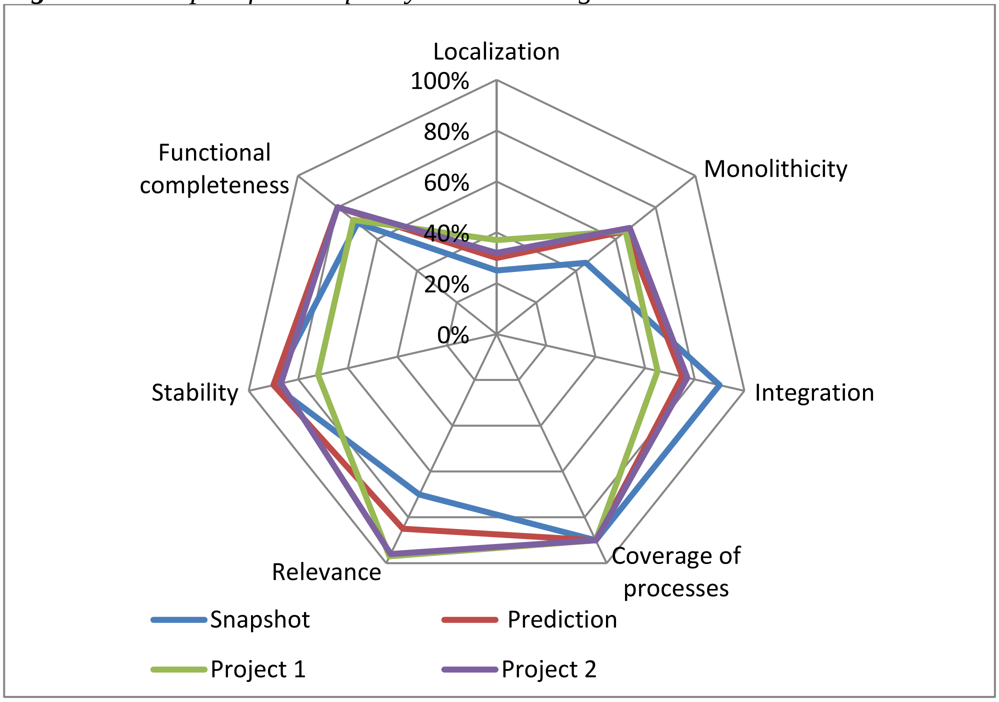


Figure 3. *Example of an IC quality indicator diagram*



1.4 A set of visual UML models of the processes of quality analysis of the ACS refinery, which allows to reflect the structure of the subject area and the dynamics of the analysis processes and to become the basis for the development of a tool system for the analysis of the quality of ACS refinery

To implement this model of the information system of the refinery and the developed methodology for assessing the quality of the information system, it is necessary to build a set of visual models that provide a representation of the dynamics of the quality assessment processes, the structure of the domain and lay the foundation for automation of IP quality assessment processes.

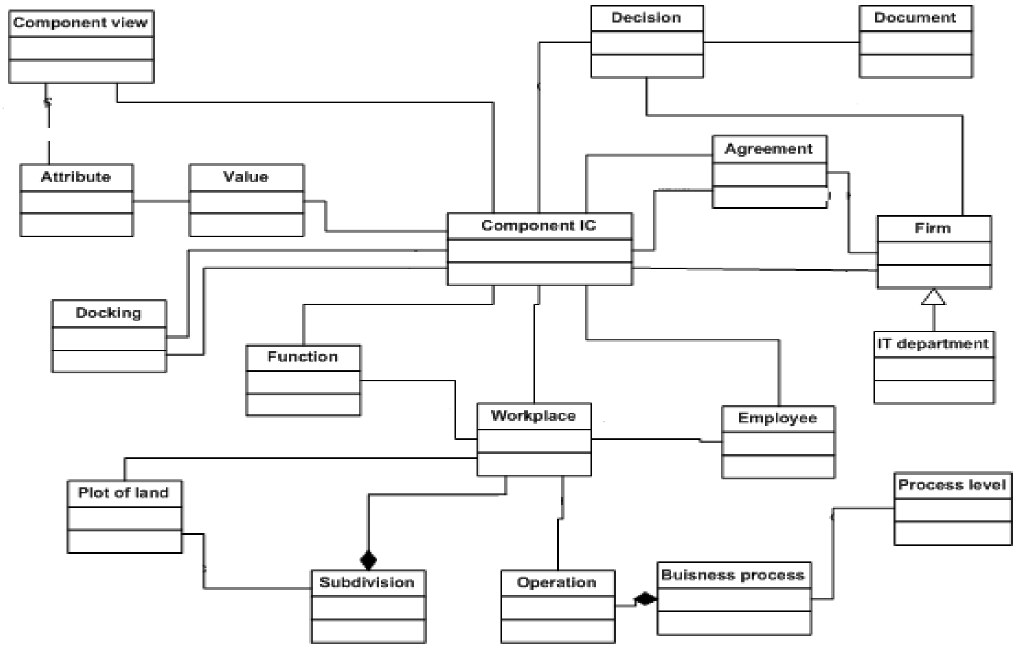
As a means of implementing a set of visual models, the unified UML is chosen. Within the framework of the dissertation research, a complex of UML-models was developed, including:

- a case diagram that describes the process of assessing quality in the most general form. The diagram defines the limits of the problem being solved, assigns actors (persons who are involved in the process of assessing the quality of the IP of the refinery), and determine the precedents (use cases) of the quality assessment system for each of these actors;
- diagrams of the activities of individual quality assessment processes. Among these processes are "Accounting for the components of the information system",

"Accounting for the interaction of the components of the information system", "Covering business processes", "Adjusting the information system quality indicators", "Monitoring the state of enterprise IP", "Analyzing the quality of enterprise IP based on the calculated indicators", "Forecast of the development of the information system", etc. The resulting set of diagrams reveals the sequence of operations of individual processes of assessing the quality of IP of the refinery;
- packet diagrams describing the main levels and subsystems in the IP quality assessment system, as well as their interrelationships;
- Class diagrams showing the static appearance of the quality system. The class diagram extends the ideas of the entity-relationship model and allows us to present a more complex and flexible nature of the relationships between entities, as well as the structure of the entities themselves. The class diagram represents the realization of the set-theoretical IP model of the oil refining enterprise.

A general view of the class diagram of the domains of the domain of assessing the quality of the IP of the oil refining enterprise is presented in Figure 4.

Figure 4. *Class diagram of IP quality assessment classes; sequence diagrams for describing the interaction between classes for implementing the assessment of the quality of information systems*



The proposed set of UML diagrams in aggregate offers a graphical model implemented with the standard common notation, which allows to describe the processes of assessing the quality of information systems of oil refining enterprises and lay the foundation for the creation of a tool system that allows automation of the processes of assessing the quality of IS refineries.

1.6 Instrumental system "Automation card", which allows to describe the current state of the ACS refinery, to receive an integral quality assessment, to identify the problem components, and to analyze the scenarios of the system development

Since the information systems of large industrial enterprises, including oil refineries, are characterized by a large scale, many different-level components and their interaction points, development inertia, etc., one can conclude that automation of the task of accounting for the components of the information system of a large industrial enterprise is necessary.

The developed software system "Automation card" is based on the following results obtained in the thesis research: the set-theoretic model of IP of a large industrial enterprise, the UML model of processes for analyzing the quality of information systems; Method of assessing the quality of information systems of large industrial enterprises. The proposed software system allows:

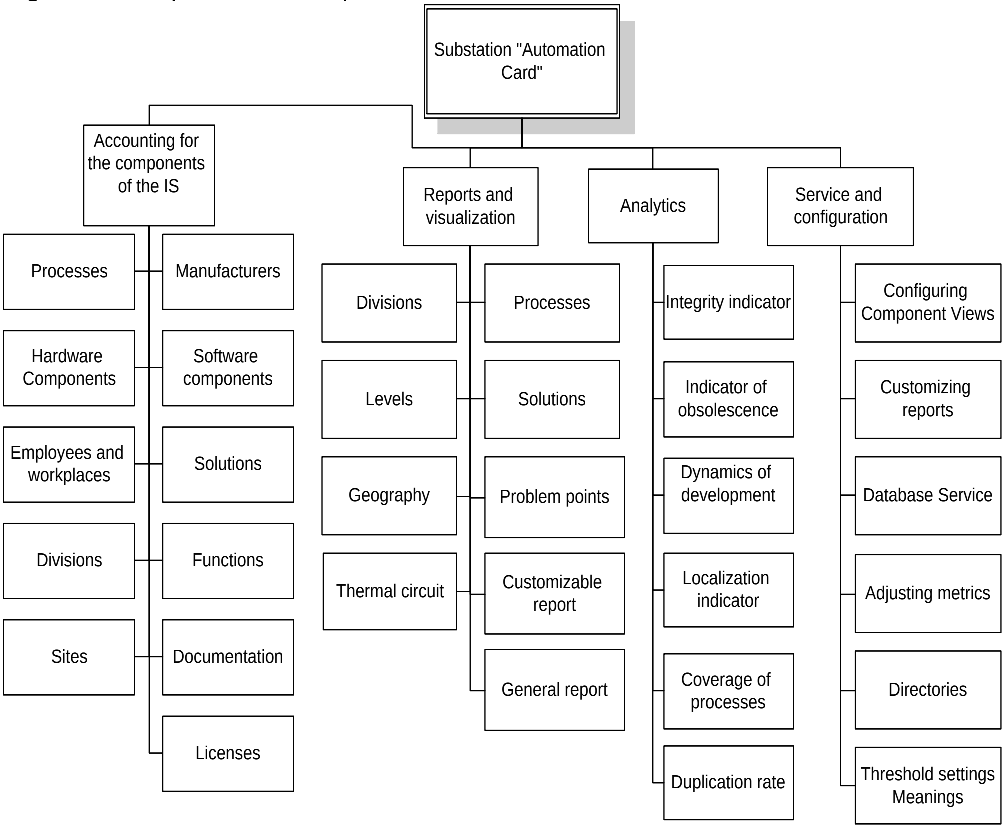
- to keep track of the implemented (as well as implemented and planned to be implemented) components of the enterprise information system (subsystems, software and hardware components, employees, departments, business processes);
- consider the relationship of components among themselves;
- visualize information in various projections: geographic, organizational, from the point of view of business processes;
- receive reports on the available components of the information system in different sections according to specified conditions;
- calculate the quality of automation, including the degree of coverage of business processes, the level of integration, the degree of heterogeneity, the level of import substitution, the index of duplication of functions;
- identify problem areas and components;
- explore scenarios for the development of the information system.

Figure 5 shows a diagram of the functions of the Automation Card tool system. The instrumental system "Automation Card" allows you to answer the questions:

- What are the software components, from which manufacturers and where are they installed?
- How much automation is "patchwork"?
- What technological and managerial processes are covered by automation and to what extent?
- To what extent does the software meet the requirements of today?

- What are the problem points (duplication of functions and the complex nature of the "interconnection" of components, insufficiently reliable or obsolete software)?
- What components will be affected when modifying an enterprise IP?

Figure 5. *The function tree of the PS "Automation card"*



The "Automation Card" software developed within the framework of the study can be used to solve problems of management and development of IP of large industrial enterprises, including in the sphere of oil refining, as well as in the activity of consulting firms in the field of business automation.

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