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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

DEVELOPMENT OF INTELLIGENT INTERFACE OF AUTOMATED DESIGN OF TECHNICAL SYSTEMS

Specialty: **3338.01 - System analysis, management and information processing**

Field of science**: Technical sciences**

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GENERAL CHARACTERISTICS

The actuality of the subject: Since the 70s of the XX century, high development of computer science has been observed in various fields of industry on the basis of automated design and application of new information technologies. Automated design systems are one of the intellectual directions formed on the basis of classical applied mechanics, material resistance, reverse geometry and machine parts and modern information, multimedia technologies, computer technology. Technical, software, information and mathematical tools of computer aided design (CAD) provide automation of design procedures and operations of technical objects in various fields. Analysis of modern ALS shows that such information systems do not have the properties of universality, flexibility and transparency, such as text editing, spreadsheets and mathematical programs, and do not adequately meet these principles, but are limited to solving design and engineering problems. is used.

European, US and Asian manufacturing corporations use CAD systems of automated design, intellectual and corporate software, technical and information support tools for various purposes, depending on the initial technical task, in solving individual design problems. Combining engineering and design functions, these tools specifically provide the selection of geometric shapes and materials, the determination of exact dimensions and strength calculations, the drawing of 2- and 3-dimensional lines, animation and other issues. However, the large number of software tools, constructors, media, networking and communication tools used does not fully ensure the overall efficiency of project work, as these tools are special-purpose and are used only to solve specific design problems in the field of application. In many cases, the principles of flexibility, universality and transparency of the system are not fully taken into account in the existing automated design work.

In this sense, the creation of a corporate-managed design-computing system that combines intellectual design-engineering and engineering-computational issues is a scientifically relevant issue.

Analysis of research on the creation of automated design systems for various industries shows that there are unresolved issues and their solution is of scientific and practical interest. It was determined that the technical, software, information and mathematical support tools of the developed automated design are the basis for future development for the effective conduct and practical application of research. Thus, it is necessary to conduct research on complex automation of all design stages of the technical facility.

The purpose of the dissertation work: Development of algorithmic, mathematical and software tools of a flexible design interface that provides automation of complex design of technical objects in various fields of application. In order to achieve this goal, the following key issues are addressed:

1. Construction of the architecture of technical, information, algorithmic and mathematical tools that provide automation of the complex design process according to the stages of development of the technical system;
2. Development of information support database management system that provides automation of the flexible design process of the technical system;
3. Development of functional and planning schemes of the interface, providing automation of the flexible design process of the technical system;
4. Development of algorithmic and software tools to automate the design and technological design process of the technical system;
5. Development of economic calculation algorithm for search and selection of efficient project options based on the management interface of automated design;

6. Development of intelligent software structure for flexible management of automated design process;
7. Development of a generalized management scheme of the designer to automate the flexible design process.

Research methods. Modern modeling methods, the concept and methods of artificial intelligence, automated control methods were used to solve the problems.

The main provisions for scientific protection are:

- Setting the general purpose of the work and defining research issues on the basis of comparative analysis of the automated design tools of the technical system in the areas of application;
- Development of flexible automated design tools based on standard design stages of various project objects;
- Development of a general-purpose control interface to automate the design of a technical facility based on the principles of universality, flexibility, openness and mobility;
- Development of algorithmic software that provides flexible automation of design stages;
- Development of algorithmic and mathematical support tools for the preparation of sketches and working projects that provide flexibility and intelligence of the design process;
- Development of algorithmic and mathematical models that provide automation of the intelligent design process;
- Development of an economic reporting algorithm for the selection of an efficient project option based on the management interface of the design process automation;
- Development of an intelligent software interface that provides automation of design procedures

Scientific innovations. The following can be mentioned as scientific innovations of the dissertation:

- An interface planning algorithm has been developed that provides automation of the flexible design process of the technical system;
- Data and knowledge base management system for information support of automation of the flexible design process of the technical system has been developed;

- Algorithmic and mathematical support tools have been developed to automate information retrieval and selection of standard and non-standard elements;
- An algorithm for selecting a cost-effective project option based on the management interface of the automated design of the technical system has been developed;
- Information and algorithmic support tools have been developed to manage the intelligent interface of the flexible design of the technical system

Practical significance of the work and application o fresults.

Development of an intelligent automated design system that provides the principles of universality, flexibility, openness and mobility, and implements complex design procedures and operations with computer experiments. Development of a flexible managed software interface that provides automation of step-by-step functions of the designer according to different areas of application.

Approbation of the dissertation work.

The results of scientific research performed in the dissertation were reported and discussed at international and national conferences and symposiums: International Conference on Mathematics and ICT Applications and New Educational Technologies (Ganja, June 5-6, 2014); Scientific and technical conference. Informatics, Mathematics, Automation (Sumy, Ukraine, April 18-22, 2016); III Republican Scientific Conference on Applied Mathematics and New Information Technologies (Sumgayit, December 15-16, 2016); XX Republican Scientific Conference of Doctoral Students and Young Researchers (Baku, May 24-25, 2016); Ufa State Petroleum Technical University. International scientific-technical conference of graduate students and young scientists "Science. Technology.Production "(2017, May 10-12, Salavat); Actual scientific-practical problems of software engineering I republican conference (Baku, May 17, 2017); International scientific-practical conference on the possibilities and prospects of application of information technologies and systems in construction (Baku, July 5-7, 2018); Information systems and technologies: achievements and prospects Materials of the international scientific conference. (Sumgayit: SSU 2018, November 15-16); Developing Flexible Manufacture Cell in University Industrial Park and its Modeling. Proceedings 2019 International Russian Automation Conference (RusAutoCon) (Sochi, Russia September 8-14,2019); Information Systems and Technologies, Achievements and Prospects II International Scientific Conference (Sumgayit: SSU July 9-10, 2020)

Name of the organization where the dissertation work is performed. The dissertation work was carried out at the Department of Information Technology and Programming of Sumgayit State University.

Personal presence of the author. The author indicated the main objectives of the research and the tasks set to achieve them, identified areas of research. A comparative analysis of the automated design tools of the technical system was conducted, flexible automated design tools were developed. A general-purpose control interface has been developed to automate the design of the technical facility. Algorithmic and mathematical support tools have been developed for the development of algorithmic support that provides flexible automation of design stages and sketches and working projects that provide flexibility and intelligence of the design process. An economic reporting algorithm has been developed to select an efficient design option based on the design process automation management interface. An intelligent software interface has been developed to automate design procedures.

Published scientific works.

21 scientific works on the topic of the dissertation, including articles in 10 prestigious scientific-practical journals, materials of 11 International and Republican conferences and symposiums were published.

The published scientific works.

The dissertation consists of an introduction, four chapters, a conclusion, a list of 165 titles and appendices. The volume of the main content of the work consists of 164,143 characters without tables, figures and bibliography. In particular, Introduction -17305 signs, Chapter I - 57524 signs, Chapter II-31752, Chapter III-33357 signs, Chapter IV -22707 signs, Conclusion-1498 signs.

MAIN CONTENT OF THE WORK

The introduction The relevance of the topic of the dissertation is substantiated, the purpose of the research is formed, the main issues that need to be addressed are identified, the main provisions for defense are indicated, the scientific innovations and practical significance of the obtained results are indicated.

The first chapter the current state of the literature on the technology of software development for automated design of technical systems is studied, research issues are identified on the basis of comparative analysis of existing methods and tools, and the general purpose of the work is set.

The second chapter the general structure of the interaction of project procedures used in the system-technical design stages is given, with the task of developing a step-by-step procedures and operations research model for automation of the flexible system design process. Based on the designer's automated design procedures, the task was to develop an algorithm for planning interface menu operations. As a result of the analysis, it was determined that in practice, different design, multimedia, information-search, virtual design and expert systems of ALS are used in the design stages of the project object. However, tools designed to automate the design process are used in an unsystematic way in the design stages based on the intuitive decisions of the designer, which ultimately reduces the efficiency and productivity of the design and does not adequately meet the standard quality indicators of the project. In this regard, an intelligent operating system interface scheme (Figure 1) [1] is proposed to ensure the management and flexibility of design automation procedures.

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1. Mamedov J.F., Tagiyeva T.A., Akhmedova S.M., Aliyeva A. Interface for intelligence computing design and option of technical systems. Intelligent Control and Automation, China,Impact factor-1.09, Vol.6 No.4, 2015, pg. 289-294.

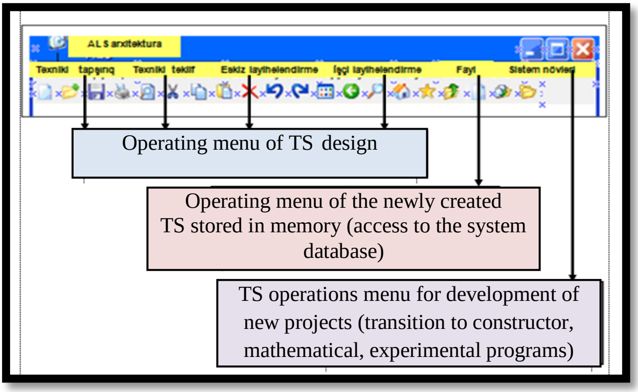

Fig. 1. Interface scheme of intellectual - operations of design procedures

Software procedures of automated design of technical system are carried out in 4 stages (technical task, technical proposal, sketch design, working design).

The following procedures are performed to work more productively, flexibly and accurately during project phases:

1. Comparative analysis of project prototypes (technical, environmental, economic information is included in the created database in the prepared annotation about the project).
2. Selection of existing project options (selection of options based on technological, environmental and economic criteria).
3. Development of a new project (improvement of the selected existing project - selection of a simpler, improved design; selection of lightweight and quality material; environmental friendliness of the fuel used and calculation of economic efficiency).
4. Tests of the project (tests of the object of the new project made by computer experimental, model and real dimensions) are carried out.

Automated project work consists of a complex of intellectual functions such as scientific research and engineering solution of the problem. Design procedures are implemented in stages in different areas of application. Based on these procedures, the initial intellectual research interface is built on the basis of the scheme of search-analysis-selection procedures of the designer.

The following algorithm is built to describe the procedures in the project task:

1.1. Procedure_1 (Pr1) → Data entry:

$$\forall Pr1 \in \{ 〚Əm〛\_(1.1.i) \}, i=1,5$$

1.1.1. 〚Əm〛 _1.1.1 → Name of the projected object;

1.1.2. 〚Am〛 -1.1.2 → Application area;

1.1.3. 〚Em〛 _1.1.3 → Manufactured product;

1.1.4. 〚Em〛 _1.1.4 → Product model;

1.1.5. 〚Em〛 _1.1.5 → Productivity.

1.2. Procedure_2 (Pr2) → Design of standard form of terms of reference:

$$\forall Pr2 \in \{ 〚Əm〛\_(1.2.j) \}, j=1,4$$

1.2.1. 〚Əm〛 _1.2.1→ Procedure_1 data;

1.2.2. 〚Əm〛 _1.2.2→ Customer's name;

1.2.3. 〚Əm〛 _1.2.3→ Designer;

1.2.4. 〚Əm〛 _1.2.4→ Project enterprise.

1.3. Prosedura_3 (Pr3) →Memorization of the technical task in the form of a standard form.

1.4. Prosedura_4 (Pr4) → Adjustment of terms of reference as required.

1.5. Prosedura_5 (Pr5) → Printing a standard terms of reference.

1.6. Prosedura_6 (*Pr6*) → Transition to the second stage (technical proposal stage).

. In accordance with the initial project data included in the Terms of Reference and stored in memory, the next stage is the search, selection, structuring of prototype projects according to priority and temporary storage of project proposals in the database and submission of new proposals on these options.

An algorithmic support is established to automate the technical proposal procedures of the technical system design process.

Step 1: In the Designer Registration ("Designer Registration") process, the author enters his / her personal data and information about his / her project into the system (project name, purpose, short idea and annotation). All this information is stored in the "Annotation" section;
Step 2: The "Project Prototype" panel is selected to select prototype projects that match the project name and purpose. Prototype projects stored in the database management system are analyzed by qualified experts and selected project options based on economic, technological, design and standardization conditions;
Step 3: Designer-user registration data and project annotation are checked. The following formula is used to select an effective project:

$$L_{opt\_seç}=\{L^j|max_j[(1-\infty)*min_i S_{ij}+\alpha*max_i S_{ij}]\} \qquad (1)$$

where the coefficient of the α-optimal project is rated from 0 to 1; S_{ij} - the main characteristics of the project.
If α = 1, then the selection of the alternative project is performed according to the maxima rule, and if α = 0, it is provided according to the maxima rule. J is the mathematical expectation value of the alternative project. The choice is made based on this price. The optimal version of the project is determined by the following formula:

$$L_{opt\_seç}=\{L^j|max_j \sum_{i=1}^{n} S_{ij}*P_i\} \qquad (2)$$

where burada P_i – i– is the probability of the state of the external environment.

An alternative ranking method can be used to address the selection of a new set of projects. In this case, each project is evaluated independently, taking into account different selection criteria. The set of technical (T_l) and economic ($İ_l$) indicators of the project and their requirements ($Təl_l$) are determined:

$$T_l=\{T_{l\_1},\ T_{l\_2},\dots,T_{l\_n}\}.$$

$$İ_l=\{İ_{l\_1},\ İ_{l\_2},\dots,İ_{l\_m}\}.$$

$$Təl_l=\{Təl_{l\_1},\ Təl_{l\_2},\dots,Təl_{l\_n}\}.$$

Each technical and economic indicator of the project is associated with a set of requirements for them:

$Təl_{l\_i} \in$ Təl$_l$, burada i ∈ N = $\{1, \dots, n\}$,

The task of selecting the optimal economic indicator (based on the project cost) for the implementation of the requirements is as follows:

$$F_{təl1}(x) = \sum_{j=1}^{n} \mathrm{T}_{ili} x_j \to min \quad (3)$$

conditions:

$$\sum_{j=1}^{n} a_{1j} x_j \geq 1, \ \ here \ \ i = m \quad (4)$$

$$x \in 0{,}1, here \ \ j = n \quad (5)$$

In this case, the problem of structural synthesis is aimed at determining the extreme value of the objective function (3).

If we interpret Samj as the efficiency of the project, then the value of the objective function ensures the determination of the most effective options for the projects. (4) and (5) are used to establish a system that meets the requirements at all boundaries:

$$F_{təl1}(x) = \sum_{j=1}^{n} Səm_j x_j \to max \quad (6)$$

Let's enter the data in the mathematical model about the technical parameters of the solved R problem. For this purpose, the following matrix is constructed:

$B = (b_{ij}), \ i \in m, j \in n$:

$$b_{ij} = \begin{cases} b, əgər \ a_{ij} = 1 \ and \ r_i \\ j \ objekt \ ilə \ b = 0..1 \ parametr, \\ 0, otherwise \end{cases} \quad (7)$$

Due to the fact that the projects have specific price characteristics, the quantitative and qualitative parameters that reflect them are performed by standard negotiation and normalization procedures (in the range [0..1] (1 - good, 0 - bad)) to perform the rj demand function. In this case, it is possible to compare the parameters with quality indicators.

The expert's procedures are performed in the "*Expertise*" panel and stored in memory. In order to prepare a comprehensive presentation of the project, its novelty, modernity, high engineering solutions and economic efficiency are theoretically and practically substantiated, and experiments are conducted in the laboratory in accordance with various scientific profiles. The best design selected in the experimental laboratory is prepared as a test sample, its technological, design and functional characteristics are tested. At this stage, unlike the existing prototype projects, the quality level of the project, the main technological characteristics are determined. All the information of the designer is stored in the database ("*Project Database*").

The main normative rules and requirements used in the domestic and foreign markets for the economic analysis and commercialization of the project are determined, the economic efficiency of the project is calculated.

The “*Sketch Design*” menu operations of the control unit of the CLS are used to develop the algorithmic support of intelligent procedures in the sketch and working design stages. The process of drawing 2-dimensional drawings at the sketch design stage of TS consists of the following design-design procedures:

1. Selection of generalized and separate technical line drawing formats.
2. Determining the number of projections and selecting additional views depending on the level of complexity of the project object.
3. Creation of information support of the project: drawing and filling of a corner stamp; drawing up and filling in the specification table.

In order to increase the efficiency of project procedures, prototype drawings of generalized and separate technical parts are selected from the expert graphic database (GDB) based on the project name and scope. The initial search and selection procedure is provided by the corner stamp of the expert working base according to the name of the project. The search and selection of the lines of the technical parts of the project is carried out in the database of the table of specifications of the generalized line. Procedures define the element name, material, dimensions, and area of application as the main conditions for searching for element parts. Based on this principle, the algorithm of the design process is described as follows:

Konstruktor_Prosedur 1ij:

[Constructor_Procedure 1ij

(Summary of the project) → A0 ∧

(Corner stamp of the generalized line of the project) → A0 ∧
(Specification of the generalized project line) → A0];
[Constructor_Procedure 11j
(Drawing of the outer part of the project) → A1 ∧
(Corner stamp of the outer part of the project) → A1];
[Constructor_Procedure 121
(Drawing of the interior of the project) → A2 ∧
(Corner stamp of the interior of the project) → A1];
[Constructor_Procedure 122
(Drawing of the interior of the project) → A2 ∧
(Corner stamp of the interior of the project) → A2]. . . [Konstruktor_Prosedur 12n (Drawing of the inner part of the project) → (A2 ∨ A3 ∨ A4) ∧ (Corner stamp of the inner part of the project) → (A2 ∨ A3 ∨ A4)].

In the Constructor Procedure procedure, the database of the project object is formed from the generalized line, the database of descriptions of separate parts and the table structured database in the form of a corner stamp and specification of each line.

The third chapter the issue of developing information support subsystems based on the interface of flexible design of technical system was raised. In order to effectively implement the automated design procedures of the technical system, it is required to establish a general data management system (GDMS), which is part of the information support. In this regard, at the design stage (Lmi), the functional scheme of this process is determined by the following algorithm:

$$L_{mi} \rightarrow \left\{ \begin{array}{c} 1 - ci, onda\ VB_{tx_i}, \\ 2 - ci, onda\ VB_{tx_i} \wedge QVB_{2t_i} \wedge QVB_{3t_i}, \\ 3 - cü, onda\ QVB_{2t_i} \wedge QVB_{3t_i} \wedge AVB_{2t_i} \wedge AVB_{3t_i}, \\ 4 - cü, onda\ VB_{tx_i} \wedge QVB_{2t_i} \wedge QVB_{3t_i} \wedge AVB_{2t_i} \wedge AVB_{3t_i} \wedge (VVB_{2d_i} \vee QVB_{3d_i}) \end{array} \right\}, \qquad (8)$$

where L_{mi} is the serial number of the design stages (Stage 1: Terms of Reference; Stage 2: Technical Proposal; Stage 3: Sketch Design; *Stage 4:* Working Design.

Within the system, a functional block diagram of the design procedures of the technical facility is established to ensure the automation of the L_{MI} design stages (Figure 2). The algorithm, based on the principle of interaction with different types of databases, is implemented in the scheme of query - search - comparative analysis - selection - decision making - results.

After entering the initial data D_{tt_i} in the standard program template issued in the terms of reference, according to these indicators, the prototype projects stored in the database DBtx_i with technological, design (simplicity of construction, few mechanical parts, simple installation and operation of electronics) and economic characteristics. (project cost) are compared. In the final selection process, the project must meet ISO standards and meet environmental requirements.

Based on the analysis of the data, a selection is made for the design of the project sketch. For this purpose, the following requirements of the projected technical system are identified:

1. Demand for the projected product in the world market - (M_t → {there is a great demand (μ = 1), demand is high (μ = 0.8), there is demand (μ = 0.5), demand is low (μ = 0.3), there is no demand (μ = 0.1)}.

2. Level of project automation - (AS_l → {fully automated (μ = 1), main technical indicators are automated (μ = 0.7), auxiliary technical indicators are automated (μ = 0.4), a small number of technical indicators are automated (μ = 0.2), the automation system is outdated (μ = 0.1)}.

3. The degree of complexity of the structure - (MD_k → {very complex (μ = 0.9), complex (μ = 0.7), medium complex (μ = 0.5), simple (μ = 0.3), very simple (μ = 0.1)}.

Based on the above requirements, the generalized selection algorithm is based on the following logic scheme:

$$S_l = \left\{ \begin{matrix} M_t \in \mu_i[1, 0.8, 0.5, 0.3, 0.1] \\ AS_l \in \mu_i[1, 0.7, 0.4, 0.2, 0.1] \\ MD_k \in \mu_i[0.9, 0.7, 0.5, 0.3, 0.1] \end{matrix} \right\}, \qquad (9)$$

where μ_i is the coefficient used to select the project.

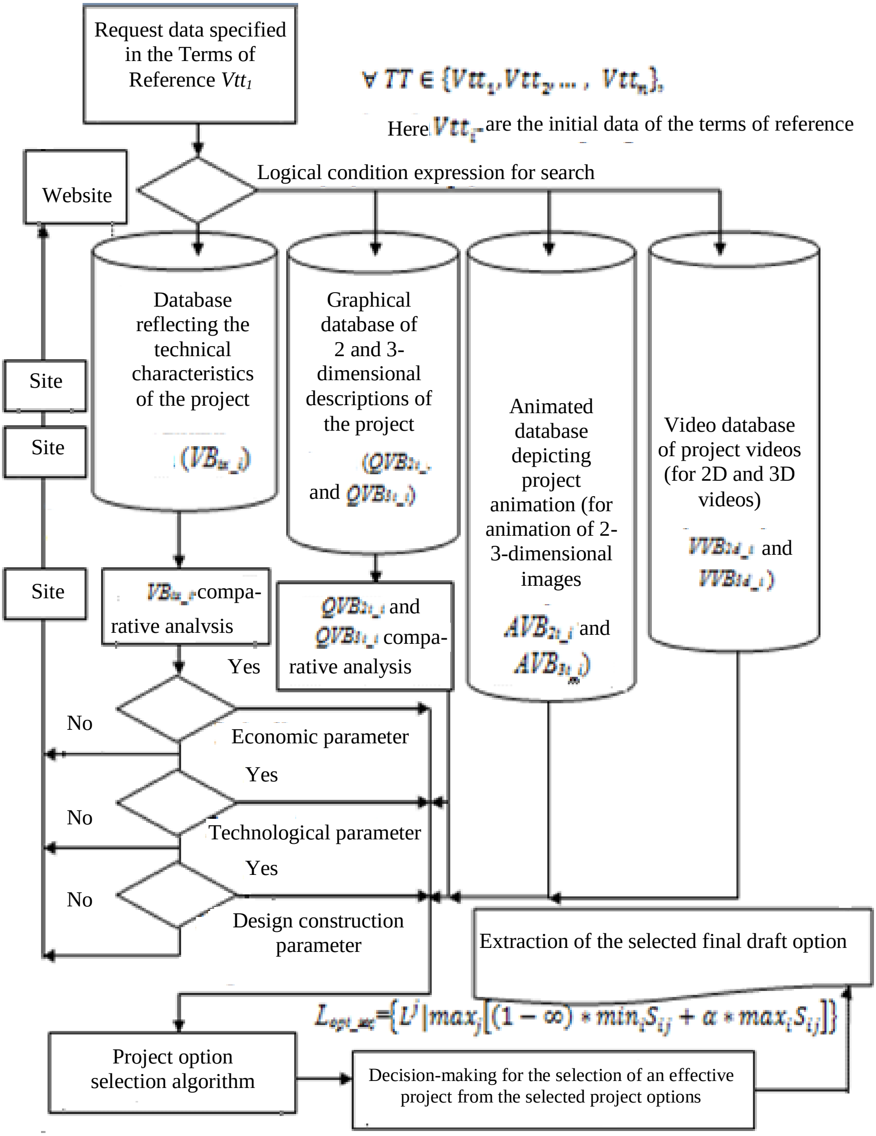

Fig. 2. Functional block diagram of technical facility design procedures

In summary, the formula μ_{ij} is written in the form of a matrix as follows:

$$\mu_{ij} = \begin{bmatrix} 1 & 0.8 & 0.5 & 0.3 & 0.1 \\ 1 & 0.7 & 0.4 & 0.2 & 0.1 \\ 0.9 & 0.7 & 0.5 & 0.3 & 0.1 \end{bmatrix} \quad (10)$$

The selection criteria M_t, AS_l, MD_k of the technical system for the selection of an effective project ideally correspond to the following coefficients:

$$S_{lj1} \rightarrow \mu_{ij} = \begin{bmatrix} 1 & 0.8 \\ 1 & 0.7 \\ 0.5 & 0.3 \end{bmatrix} \quad (11)$$

As can be seen from equation (11), the favorable project selection factors are:

$$S_{l11} \rightarrow \mu_{11} \wedge \mu_{12} = 1 \vee 0.8);$$
$$S_{l21} \rightarrow \mu_{21} \wedge \mu_{22} = 1 \vee 0.7$$
$$S_{l31} \rightarrow \mu_{33} \wedge \mu_{34} = 0.5 \vee 0.3$$

It is also necessary to determine the economic indicators of the most suitable project option selected with the help of a flexible design system, so that the final project meets the international standards and is launched on the world market. One of the important indicators in the project selection process is the economic parameters. The selection of an economically viable project option is based on the following limitations: social norms and standards; environmental requirements; implementation period; application of advanced technologies (should exceed the best world achievements).

Depending on the dynamics of development, the costs and economic benefits of each selected project option are determined. A project with maximum economic efficiency and minimal costs is considered more efficient.

The economic efficiency of the project is determined in the following sequence:

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2. Mamedov J.F., Guliyev H.B., Farkhadov Z.I. System of automation regulation of reactive power by means of fuzzy logic. American Journal Reliability: Theory and applications. San Diego, Impact factor-0.45, Vol. 10 № 2 (37), June 2015, pg. 50-58.

1. Economic efficiency is calculated for the years of the reporting period:

$$\dot{I}S_l = N_l - S_l, \quad (12)$$

where $\dot{I}S_l$ - economic efficiency of the project for the reporting period; N_l - estimate the value of the results for the reporting period; S_l - estimate of project costs for the reporting period.

The economic efficiency report is made at different times according to the ratio of costs and results to the reporting year. The reporting year is usually the period before the initial production of the project (calendar year) or the period of use of new technology in production. The evaluation of results for the entire reporting period is determined by the following formula:

$$N_T = \sum_{t=t_b}^{t_s} N_t * \alpha_t \quad (13)$$

where N_t – is the value of the results in year t of the reporting period; t_b – - starting year of the reporting period; t_s – is the last year of the reporting period.

In the first year of the reporting period, research begins, along with project financing. In the last year of the reporting period, the entire life of the project is expected to expire.

Additional labor and tool costs are required to be assessed during project development. To this end, the evaluation of the observed project work depends on additional economic outcomes (social and environmental). Therefore, the following formula is used to assess social and environmental values in year *t*:

$$N_t^{se} = \sum_{j=1}^{n} N_{jt} * a_{jt}, \quad (14)$$

where N_{jt} – is the value of individual outcomes depending on the scope of application in year t; a_{jt} - is the unit of measurement of a separate outcome in year t; *n* is the amount of indicators to determine the impact of work on the environment and the social sphere.

Expenditures for the implementation of *NTP* works during the reporting period consist of the costs of production and operation of the project and are determined using the following formula:

$$S_T = S_{L\dot{I}} + S_{L\dot{I}st}, \quad (15)$$

burada $S_{Lİ}$ – hesabat periodunda layihənin istehsal sərfləri; $S_{Lİst}$ – hesabat periodunda layihənin istifadə sərfləri; where $S_{Lİ}$ – production costs of the project during the reporting period; $S_{Lİst}$ - project operating costs during the reporting period;

The production and use of the project are calculated identically by the following formula:

$$S_T^{İ(İst)} = \sum_n^{t_i}(G_t + E_t - Q_t) * \alpha_t \qquad (16)$$

where G_t - current delays in the production (operation) of the project, without depreciation transfers to the renovation in the year t; Simultaneous production E_t – costs of the project in the year t; Q_t - Residual values of fixed assets issued in t.

If at the end of the reporting period there are fixed assets that can be used for several years, then Qt is calculated as the residual value of these funds.

According to this method, in the process of determining the annual economic benefit, the project's production and operating costs are determined by comparing the base and new production options.

These costs are calculated by the following formula as the total normative income and total related to a single project or service:

$$S_l = Q + KQ_{nə}*KQ_{if}, \qquad (17)$$

where Q – is the value of the project unit (man); $KQ_{nə}$ - normative coefficient of efficiency of capital investments; KQ_{if} - capital investment in production funds per project unit.

The annual economic efficiency report of the new project, technology and organization of production is made according to the following formula:

$$İS_{il} = a_t * [(M_1 + KQ_{nə}K_1) - (M_2 + KQ_{nə}K_2)] \times A_2 \quad (18)$$

where a_t – the coefficient of performance of work according to time; M_1 və M_2 – - profit (cost) of a single project, performed with the base and new equipment; K_1 and K_2 - capital investments for base and new equipment; A_2 –the annual volume of the project implemented with new equipment in the reporting year.

Due to the creation of a new project, formula (18) can be modified in various ways. An important indicator is the determination of the return period of capital investments planned for the introduction of new equipment, depending on the situation. The return on planned and additional capital investments in new technology is determined by the following formula:

$$T = \frac{K_p}{PG_t} \quad T = \frac{K_p}{\Delta M_t} \qquad (19)$$

where ΔM_t- gəlirin artmasının planlaşdırılmış yenisi . where K_P and $K_Ə$ - planned and additional capital investments in new equipment; PG_t - t is the planned annual income from the sale of new equipment; ΔM_t - t- planned new increase in revenue.

The parameter of the remaining income within the enterprise is generally determined by the following formula:

$$G_t = Q_t - M_t - V_t , \qquad (20)$$

where G_t – is the income remaining in the enterprise in t; Q_t – profit from the product sold at the enterprise in year t; M_t – project profit in t year; V_t – total tax calculated from balance income.

When comparing the current performance of the enterprise, the income for the project is determined before and after the implementation of the project (remaining from the total income):

$$G_l = G_t – G_{üm} \qquad (21)$$

where $G_{üm}$, G_t - the cost of total revenue remaining in the enterprise before and after the implementation of the project.

Implementation of the project is based on the return on investment capital, budget efficiency of the project, net current cost, return on investment, annual volume of tax revenues to budgets at all levels, the cost of construction and reconstruction of 1 m2. Indicators of investment analysis and efficiency of business plan implementation are determined.

Return on investment capital (*ROIC*) - the ratio of net operating income calculated for the development of the selected project option to the average annual sum of investment capital:

$$ROIC = \frac{NOPLAT}{INV} \times 100\%, \qquad (22)$$

where, *NOPLAT* - the company's net operating income (excluding adjusted taxes); *INV* is the average annual sum of investment capital.

Project budget efficiency (LS_b) is the difference between budget revenues and expenditures:

$$LS_b = G_b - S_b, \qquad (23)$$

where, G_b – budget revenues; S_b - budget expenditures.

Net present value (NPV) is the difference between the present value of cash on a project or investment and the cost of cash payments for the investment or the financing of the project at a discount:

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} - \sum_{t=0}^{n} \frac{I_t}{(1+r)^t} \qquad (24)$$

where CF_t - is the receipt of the company's cash during the period t; Total investments in I_t- t period; r - discount rate; n - investment period (t = 1,2,… n).

Return on investment - the time when the return on investment is equal to the initial investment:

$$\sum_{t=1}^{n} CF_t > I_0,\ T_{ok} = n, \qquad (25)$$

where n - is the month of the periods; CF_t - cash inflow to the company in period t; I_0- is the cost of initial investment in the zero period.

The annual amount of taxes included in the budgets at all levels is an indicator of the tax burden on income from the sale of products, works and services and residents working on the project

$$V_{нп} = В \times 14{,}4\%, \qquad (26)$$

where, 14.4% - the average level of the tax burden; B - income from the sale of products, works and services and residents working on the project.

The cost of construction and reconstruction of 1 m2 is the ratio of the total volume of investments in the construction of facilities to the total area of facilities.

$$C_c = \frac{V_{вс}}{P_O}, \qquad (27)$$

where, $V_{вс}$ - the total amount of investment in the construction of facilities (excluding the cost of high-tech equipment and external engineering networks); P_O - the total area of the enterprise producing the project.

One of the important requirements in the process of system design is the correct selection of such elements for the development of the type, mechanical design, layout, structure and functional schemes of electronic parts. In this regard, the logical methods of algorithmic support are widely used. In this case, implications, sets, symbols, expressions and logical extracts are used according to the structure of each model.

The objective function required to select the elements of the project object is defined:

$$W_i = extr\ (\{x^{ii}_1\}, \{x^{ii}_2\}, \{x^{ii}_3\}, \{x^{ii}_4\}, \{x^{ii}_5\}) \quad (28)$$

Logical procedures of the information-search subsystem of the "*technical proposal*" menu functions of the interface of the flexible design systems (FDS) are used to select the industrial robot, which provides automation of the technological process in accordance with the requirements of the production process. The knowledge base for these procedures is implemented using the following algorithm:

($\exists\ x^{ii}_j \in$ Selection of Flexible Production Module (FLE) Industrial Robot)

İF (min (Loading ability (akt _element 2_ tx) $\{x^{1i}_2\}$)

Then (is selected from the database $x^{11}_2 \wedge x^{12}_2$ ($IR_1 \wedge IR_2$)).

The logical selection algorithm by the production method is written as follows:

$(\min\{x^{1i}_2\}) \Rightarrow IR_1\ \&\ IR_2$

İf(min (degree of freedom (akt_element 2_tx) $\{x^{21}_2\}$)

Then(is selected from the database x^{21}_2 (IR_1))

$(\min\{x^{2i}_2\}) \Rightarrow IR_1$

İf (max (angle of rotation (akt_element 2_tx) $\{x^{3i}_2\}$)

Then (is selected from the database $x^{32}_2 \wedge x^{33}_2$ ($IR_2 \wedge IR_3$))

$(\max\{x^{3i}_2\}) \Rightarrow IR_2\ \&\ IR_3$…..

Thus, according to the developed intelligent selection algorithm, the generalized selection algorithm in the form of production is written as follows:

İf $((\min\{x^{1i}_2\}))$ then ($IR_1\ \&\ IR_2$);

İf $((\min\{x^{2i}_2\}))$ then (IR_1);

İf $((\max\{x^{3i}_2\}))$ then$(IR_2 \& IR_3)$;
İf $((\max \{x^{4i}_2\}))$ then (IR_2);
İf $((\max \{x^{5i}_2\}))$ then (IR_2);
İf $(\max(N_{IR1}, N_{IR2}, N_{IR3}, N_{IR4}))$
Then (is selected from the database IR_2).
where, N_{IRi} - is the number of industrial robot models selected according to the technical characteristics of the industrial robots.

The selection algorithm in the form of a product is written as follows:

$$(\min\{x^{1i}_2\}) \& (\min\{x^{2i}_2\}) \& (\max\{x^{3i}_2\}) \& (\max\{x^{4i}_2\}) \& (\max\{x^{5i}_2\}) \Rightarrow IR_2.$$

Other active elements in the CDM are selected in accordance with the requirements of the production (loading capacity of process equipment, positioning manipulator and automatic transport device, positioning errors up to 10 ¸15 kg, ± 0.02 ¸ ± 0.1 mm).

İn order to ensure the efficiency and reliability of the management and control system in an automated enterprise, it is necessary to create an algorithmic support for the selection and design of elements of information systems of active elements. In this regard, information systems are conventionally divided into internal (transmitters and finite automata) and external (execution mechanisms) information subsystems, depending on their functional responsibilities and the nature of the problems to be solved, to organize special automated design tools based on data and knowledge base. The transmitters provide registration of the actual position of the moving parts of the active elements at any time and positioning of the required displacement parameters, measurement of temperature, humidity, pressure and other production parameters in special modules.

Parameters such as positioning error and degree of freedom of these elements are used to select transmitters for industrial robots, manipulators and process equipment. If the degree of freedom of the industrial robot serving the techno logical equipment is Sd = 3, then the type of industrial robot is selected from the table-type database of industrial robots. The selection of transmitters that ensure the positioning of the industrial robot arm, angular displacements and technological operations of closing and opening the handle of the industrial robot must meet the following conditions:

$$S_İ * K / D \leq U \qquad (29)$$

where $S_İ = \{S_{İG}, S_{YA}, \varphi_B\}$- is the displacement of the degree of freedom; D is the number of pulses in discrete conversion; K- 1.5… 3- is the quality factor; U- is the positioning error of the industrial robot.

If we assume that according to the technical characteristics of the industrial robot "Brig-10" forward or reverse linear motion $S_{İG}$ = 600 mm, up or down linear motio S_{YA}= 100 mm n; If the angular displacement around the z axis is $\varphi_B = \pi /2$, the positioning error of the industrial robot is U = 0.3 mm, and the quality coefficient is K = 2, then using the intelligent information retrieval system and the expression dx($S_{İG}$), dy($S_{İG}$), dz(S_{YA}), $\varphi(\varphi_B)$ transmitters are selected to position the displacements as follows:

İf the forward or reverse linear motion of an industrial robot is $S_{İG}$ = 600 mm and the number of pulses in discrete conversion for type "BE51M" is D = 5400 pulses / min, $S_{İG} * K / D \leq U \Rightarrow 0.22 \leq 0.3$, then the type pulse transmitter type "BE51M" is selected to position the forward or backward movements of the robot arm.

Transmitters selected on the basis of information retrieval algorithm are used to build the control algorithm of the industrial robot "Brig-10", which is an active element of the flexible production module "BE51M" and "FEP-15". In order to design the control algorithm of the industrial robot "Brig-10", a set of transmitters is formed in accordance with its technological operations.

Chapter IV is devoted to the development of complex software for the automated intelligent design process of the technical system. The development of a complex software package is required to provide automation procedures at the stages of system design of the technical system, to create an interface with the operating, computer-network, computer-graphics, multimedia, intelligent systems. In this regard, the structure of the general software of the automated design system of the CLS is determined (Figure 3) [3].

As shown in the designer's generalized control block diagram for automated design, the ADS control panel software interface provides automation of the process of designing standard procedures and their operations in a logical sequence at different stages for different applications. DGCBDFAD consists of a control unit, a menu subsystem of procedures and operations.

In the task task of automated design, the sub-system of the "*Task*" procedure is activated. Based on the initial data of the "*Terms of Reference*" software procedure, the search, intuitive selection and structuring of similar project options in the global network system according to the priority of similarity is performed. The basis of this procedure is the initial data of the project (project area of application, project name and project purpose):

The first similarity priority(SP):

SP1: İf $\forall\ LV \in \{LTS_i\}$, Then $OLV^1\ \&\ OLV^2\ \&....\&\ OLV^n$;
SP2: İf $\forall\ LV \in \{LA_i\}$, Then $OLV^1\ \&\ OLV^2\ \&....\&\ OLV^m$;
SP3: İf $\forall\ LV \in \{LM_i\}$, Then $OLV^1\ \&\ OLV^2\ \&....\&\ OLV^k$.

At this stage, the technical parameters of the selected project options (constructive dimensions (CD), type of material (TOM), working principle (WP)) are checked:

The second similarity priority:

SP4: İf $\forall\ LV \in \{LA_i{:}K\ddot{O}_1, K\ddot{O}_2,..., K\ddot{O}_n\}$, Then $OLV^1\ \&\ OLV^2\ \&....\&\ OLV^n$;
SP5: İf $\forall\ LV \in \{LA_i{:}MN_1, MN_2, ..., MN_m\}$, Then $OLV^1\ \&\ OLV^2\ \&....\&\ OLV^m$;
SP6: İf $\forall\ LV \in \{LA_i{:}\dot{I}P_1, \dot{I}P_2, ..., \dot{I}P_k\}$, Then $OLV^1\ \&\ OLV^2\ \&....\&\ OLV^k$.

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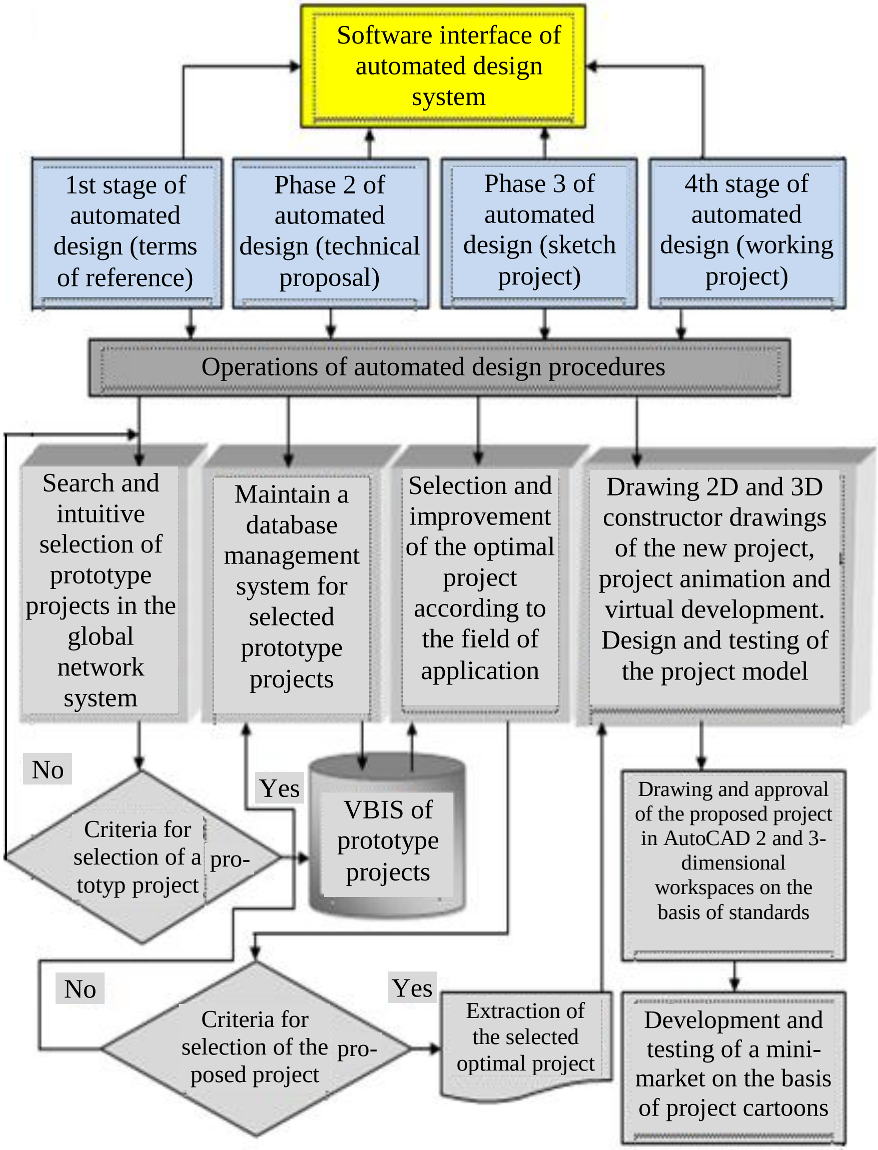

Fig. 3. The structure of the general software of the automated design system of FDS

In the second stage of the designer's generalized control block diagram for automated design, the main engineering parameters of the proposed project, equipped with cost-effective, new information and computer technology, are studied, checked and economic evaluation is carried out.

At this stage, preference is given to the project options selected on the principle of artificial intelligence, equipped with progressive automation systems. Technical parameters of active elements of the base subsystem provided with software tools of the operating system and database management system; AutoCAD 2D, 3D software system, their 2 and 3 dimensional engineering drawings; algorithmic reports of kinematic and dynamic parameters of active elements are included.

Procedures for selection of standard elements of the proposed project and processing of non-standard parts and relevant operations are carried out for the effective formation of the database of the technical proposal stage. At the stage of technical proposal, after the selection and design of standard and non-standard elements, the operation of assembling these elements, ie constructive combination, is performed.

The following logical formula describes the functional relationships of many application software packages used within the internal interface of an automated design architecture.

$$\forall M_{p\_ij} \in (\exists M_{os} \in \{M_{p\_os\_i}\}) \cup \left\{ \begin{matrix} M_{pk\_ij} \\ M_{pm\_ij} \\ M_{pi\_ij} \\ M_{ppy\_ij} \\ M_{ppv\_ij} \end{matrix} \right\}, \quad (30)$$

here $M_{p\_os\_i} \in \{M_{p\_os\_1}, M_{p\_os\_2}, \ldots, M_{p\_os\_n}\}$- a set of general-purpose programs that ensure the functional operation of the operating system; n - configuration, dispatch, service, etc. in accordance with the operating system. number of programs; M_{pk_ij} - a set of design programs based on AutoCAD; M_{pm_ij} - MathCAD, a set of mathematical programs based on MatLab; M_{pi_ij} - a set of information programs based on Microsoft Access; M_{ppy_ij} - a set of programs created on the basis of Delphi or C ++; M_{ppv_ij} - a set of programs that provide search and selection of project information.

Based on the interface of the flexible design system, it is proposed to develop the structure of software menu procedures for the creation of 2 and 3-dimensional graphics of the technical system, and to structure the drawing and recall of 2 and 3 images to automate the graphical procedures of the design process. Software procedures provide search, selection, and drawing functions with logical operations on the 2- and 3-dimensional design process.

The main user-constructor constructs editing operations on the proposed project object with a query-search-selection-edit logic scheme. Standard and non-standard elements of the project object are selected from separate databases of mechanical and electronic parts and shown in the example of the 2-dimensional drawing of an industrial robot.

A generalized line of the IR is formed on the basis of the combination of standard elements selected from the database of mechanical and electronic parts of the design. To do this, Z_{ade} operator to implement the combination logic operation

$$\mu_{A \cup B} = MAX\ (\mu_A, \mu_B) \qquad (31)$$

is used.

Selection of mechanical parts of industrial robot from MDB from logical database

MVB → IR body (B); Arm of IR (H); IR handle (T)

is described by the expression.

The frontal view of İR is created on the basis of the operator

$$M_{G \cup Q \cup T} = MAX\ (\mu_G, \mu_Q, \mu_T,).$$

The selection of the electronic parts of the industrial robot and their addition to the front view are described by the following expression.

Based on the frontal view of the created 2-dimensional İR, the outline of the upper view is drawn. AutoCAD software commands are used to draw the most commonly used circle and rectangular geometric shapes. The broken lines intersecting the central axis of the top view define the top view border dimensions of the İR's arm, handle, body, and control unit. Other intersecting geometric figures are placed on the drawing area of the top view, waiting for symmetry. The structure of software menu procedures for creating a technical system database based on the interface of a flexible design system is proposed. The project database software contains the name of the project, field of application, scientific direction, information about the author, annotations:

1. In order to form a database of project ideas, the "Project Idea" menu procedure is activated in, and the designer's idea is stored in the database in the form of text, description and animation. First, the author of the project enters his name, surname, patronymic into the system and remembers it. The designer is registered using the "*Project Author_Registration*" procedure.
2. Profile experts get acquainted with the topics and annotations of innovative projects. Preliminary expert opinions are stored in standard form in the memory of the "*Expert opinion*" section.
3. Detailed project presentations are prepared and maintained on the basis of “*Project presentation*” (relevance, innovation, purpose and idea, problem statement, application of modern technologies, projects with high engineering solutions and cost-effectiveness) and selected by an expert to obtain initial information about the project.
4. The project name or scientific direction is included in the survey for the selection and display of descriptions, animations ("*Project Selection*") of 2 and 3-dimensional lines of graphic annotations of the project in the software of the project database. At this stage, the engineering report of the main characteristics of the project, economic reporting documents, quality assessment and approval document, printed summary and line sheets of individual parts are approved.
5. In order to carry out the economic evaluation of the project, the menu procedure "*Economic indicators of the project*" is activated. Based on the design, functional and technological characteristics of

the project, the economic efficiency is calculated by the applied mathematical models and stored in the project database. According to the scope of the project, a business plan of the project is prepared and included in the. Technical specifications, presentation and business plan of the project are selected and demonstrated from to present the project to the customer.

6. Procedures for visual presentation of the finished project to experts, submission of project documents are carried out. At this stage, all the documents approved by the experts are sent to production, and the process of technological preparation of the project in the field of flexible production is carried out.

CONCLUSIONS

1. As a result of research and comparative analysis of the current state of technology development of software tools for automated design of technical systems, the purpose of the dissertation was formed and the issues that need to be addressed in order to achieve this goal were identified .

2. An algorithm for planning procedures and operations of the interface of a flexible design system that provides a complex of automated design procedures has been developed [15].

3. Algorithms for information retrieval, design, technological and virtual design, data and knowledge creation have been developed based on the step-by-step procedures of the flexible design system interface [14].
4. Within the framework of the flexible design system, an information support database and algorithms for the selection of standard and non-standard elements have been developed for the efficient development of the project object [11].
5. A mathematical model was developed to determine the economic performance of the selected project option with the help of the program interface of the flexible design system [19].
6. The structure of the menu procedures of the intelligent program has been developed for the management of the interface of the flexible design system [7].
7. The scheme of mobile creation of the generalized line of the industrial robot is developed on the basis of mechatronic elements selected from the constructive database management system [8].
8. Within the interface of the flexible design system, the structure of software menu procedures for the creation of 2 and 3-dimensional graphical representations of the technical system was proposed, the design algorithm was developed [20].

The main provisions of the dissertation are published in the following scientific works:

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