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ALGORITHMICALLY AND PROGRAMMING MANAGEMENT OF DESIGNING PROCESS OF FLEXIBLE MANUFACTURE SYSTEM

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Abstract. On an example of flexible manufacture system (FMS), it was set out analysis of the existing design systems for development of FMS and determined that there are no such systems that include multi-purpose software design functions. In this regard, the task of the article is to develop a complex automated design system of FMS for high-performance, flexible, versatile and accurate operations of project procedures performed in stages within a single system interface. With using of enjeneering, constructing and technological design procedures of FMS, program structure of computing design management system (CDMS) of FMS is proposed. For realisation of computing design process at one management system, algorithmic support for the management of the automated design process of FMS is developed. For project management database, the specialized system for graphical data has been established. The structure of software menu procedures for the creation of 2- and 3-dimensional graphical representations of the technical system in CDMS is proposed. Programming support for realisation of CDMS interface on the stages designing of FMS with presentation the main stages of designing like menu diagrams is proffered.

Key words: flexible manufacturing system; computing design management system; 2- and 3-dimensional graphical; the generalized drawing.

INTRODUCTION

As known flexible manufacturing systems (FMS) is complex technical enterprise system with multi-quantity active elements of automaticaly supporting and control systems. In order to provide automation procedures with flexible, fast and efficient principles in the system-technical design stages of, it is necessary to create interfaces with operational functions, local and global networks, computer graphics, multimedia, intelligent systems. However, by analyzing the existing design systems for development of FMS [1, 2], it was determined that there are no such systems that include multi-purpose software design functions. In this regard, the task of the article is to develop a complex automated design system for high-performance, flexible, versatile and accurate operations of project procedures performed in stages within a single system interface.

As it is known, computed design procedures of FMS are formed from the following important operations [3]:

– computing search, analysis, intuitive selection of prototype project data;

– forming the database management system of selected similar projects;

– selection of a model project option according to special criteria and its improvement;

– carrying out design, functional, technological and economic reports of the sketch project and development of 2D, 3D drawings;

– preparation, approval and application of working documents on the basis of sketch project;

– development of a working model of the project and its application in production.

ALGORİTHM FOR MANAGEMENT OF COMPUTER DESİGNİNG PROCESS OF FMS

To control the automated design of the FMS, the software interface of the control panel of the system is set up in accordance with the design stages. Automation of the process of working with the logical sequence of design procedures and their operations at standard stages for different areas of application is provided [4, 5]. Based on the terms of reference, prototype projects are selected, stored in the created database, a more efficient project is proposed for the field of application, its improvement and reconstruction is carried out. At that CDMS provides the process of design reports, 2D, 3D, animation, virtual design, computer experiments and calculation of economic efficiency of the proposed project.

At the technical task stage of the automated design of the FMS, the subsystem of the "Terms of Reference" 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 name and project purpose can write as follows [6].

In the second stage of CDMS, the main engineering parameters of the project proposal, which is cost-effective, equipped with new information and computer technology, are studied, checked and economic evaluation is carried out. At this stage, preference is given to the project option, which is equipped with progressive automation systems and works on the principle of artificial intelligence. Equipped with operating system and database management system software, the base subsystem includes technical parameters of active elements, 2-dimensional engineering drawings, algorithmic reports of kinematic and dynamic parameters of active elements. Management operations of the library of standard active elements are provided in the menus of data collection, structuring, editing, search in the form of queries to the database and selection menu commands [7]. 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. Design of non-standard elements is provided in AutoCAD 2D, 3D system.

At the stage of technical proposal, after the selection and design of standard and non-standard elements, the assembly of these elements, ie the process of constructive combination is performed. Due to this, at this stage the project menu operation of the project is activated. Depending on the requirements and principles of construction of automated design tools, the basis for the development of the layout scheme of the project object at the stage of system technical design is the selection and construction of layout schemes of the structure, creation and storage, archiving and extracting graphic descriptions of the project; issues such as mathematical, algorithmic and software tool development.

Project procedures such as coordinating algorithmic and software subsystems, geometric modeling and design reports, search and selection of ready-made layout schemes are used in the construction of the layout of the proposed project object [8].

Functional, technological and structural research is required within the development of non-standard elements of the proposed project object. In this regard, the design, search and selection subsystem, software subsystem, database subsystem of graphics software systems and modules of processed information software, graphics software packages are used.

Issues related to the development of the architecture of automated design tools, automated design subsystems of the layout scheme and non-standard elements are the basic tools for the development of the project management system.

The internal interface of the automated design architecture allows selecting the active elements of the project object from the database, using the layout scheme and control system database and their 2, 3-dimensional image, animation data. To ensure the mutual exchange of electronic documents with the designer, technologist, programmer and other specialists in the internal corporate network of the designer, also to carry out designing and economic activities, hyperlinks are used of the internal interface of the automated design system [9, 10]. Interfaces with other special programs are also implemented in the generalized menu bar. These procedures make it possible to use the work panels, fields, and program commands of various systems during project development. For example, a set of subsystems of special software for designing, mathematical, informational and intellectual purposes is used to solve individual design problems, depending on the characteristics of the projected object.

The hardware subsystem ensures flexible, reliable and productive operation of CDMS special software packages, intelligent software systems, algorithmic reports and accurate modeling results [11].

The block of construction, configuration, creation of functional-technological schemes of technical systems, which are considered to be the basic subsystem of CDMS, covers the following areas:

– library of ready-made configuration schemes;

– database reflecting technical indicators, functional-technological characteristics and positions of active elements;

– database query block. In the architecture of automated design, the design and selection of the layout scheme is provided through a special file menu.

Algorithm for development of the structure of software menu procedures for the creation of 2- and 3-dimensional graphic representations of the technical system based on the interface of CDMS. To ensure the effective implementation of design work, procedures for drawing sketch documents through a computer graphics system should be automated. In this regard, the structure of drawing and animation of 2, 3-dimensional images [12] is proposed to automate the graphical mode procedures of the design process of FMS and its active elements (Fig. 1). For the designer, the process of designing FMS within the software interface of automated design is one of the important stages, because at this stage, along with all the mechanical reports of the project object, its design appearance and materials must be selected what are substantiated and accurately described in [13]. Graphical programming procedures of automated design architecture consist of the stages of drawing with 2, 3-dimensional images and animation operations. The design section selected in the control panel of the automated design architecture is formed from the following menu procedures:

1. Activation of AutoCAD system and proper naming of the drawing object.

2. Drawing a generalized drawing of the project object. Depending on the field of application, a 2-dimensional coordinate system is selected for the drawing of the proposed project object, and boundary lines, corner stamp in A1 format are drawn and the appropriate drawing scale is determined.

3. The prototype selected at the stage of technical proposal of the project object is placed in the working drawing area of the 2-dimensional generalized descriptive system of the project, on which changes of geometric shape, size, material type of construction.

4. Depending on the degree of complexity, the 2-dimensional generalized description provides additional views so that the process of preparing the project object can be carried out more accurately.

5. Depending on the actual dimensions of the project object, the main dimensions of the image are set according to the standard scale dimensions, and each mechanical or electronic part is assigned a serial number.

6. A specification table is constructed according to the serial numbers of the project object. According to the names of the included parts, their quantity and material are stored in memory.

7. The data included in the corner stamp of the project includes the name of the designer, information about the head, time of approval, name of the project, specially encrypted code, field of application and other standard information.

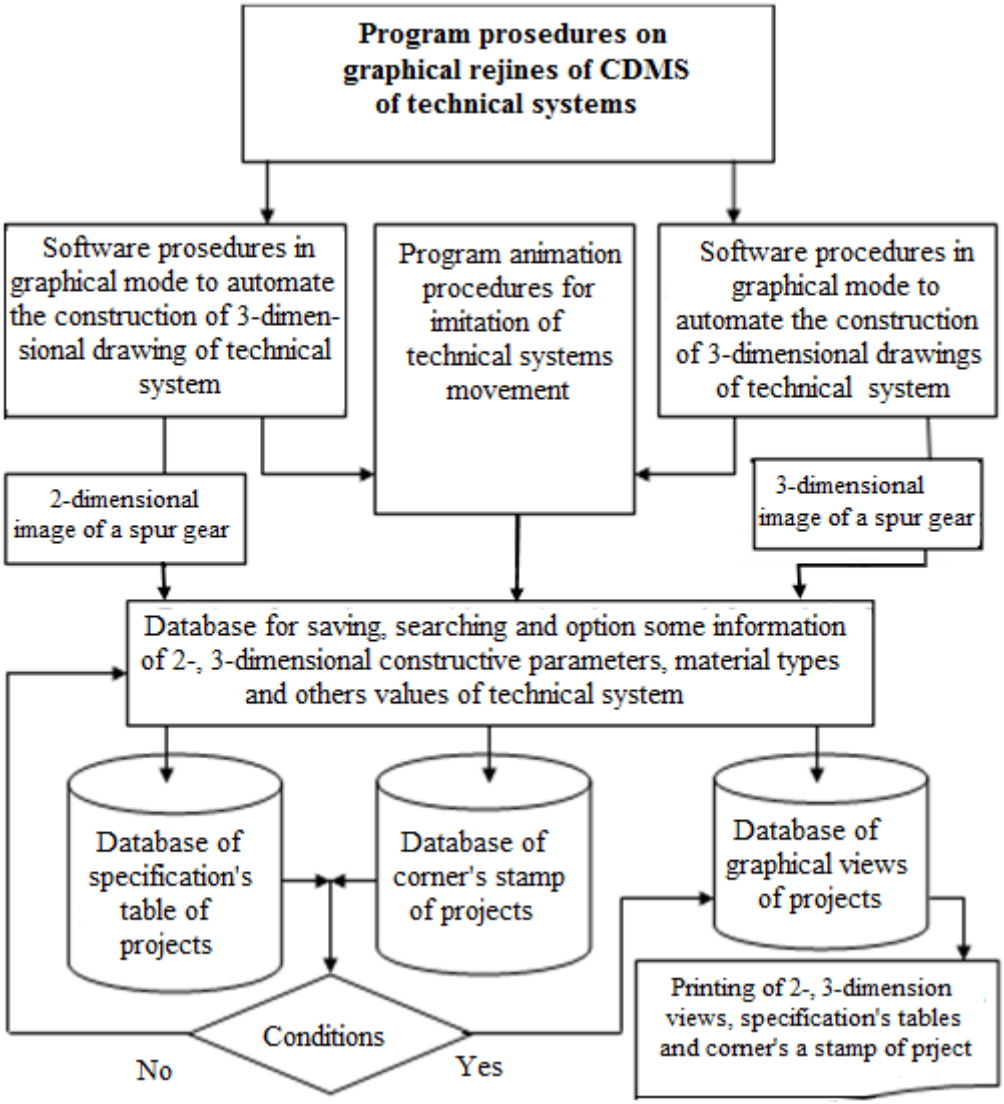

Fig. 1. Structure of graphical mode software procedures of the design process

Procedures for the selection of standard elements and the development of non-standard elements are carried out in accordance with different areas of application. For example, the mechanical (technological equipment, machines) and electronics (automated control systems, their elements) parts of a complex process automated production plant are selected on the basis of a request from the mechanical and electronic database, respectively. By analogy, the mechanical and control electronics parts of an industrial robot are selected and the generalized design is placed in the required coordinate positions.

The Generalized Project Database (GPDB) is formed from the separate databases of PDDMS. In addition, the kinematic schemes, structure, technological and functional schemes of the project are stored in the GPDB. A generalized drawing of industrial robot of FMS is formed on the basis of combining standard elements selected from the database of mechanical and electronic parts of PDDMS. İn this case, to perform the merge logic operation, the Zade operator is used [14]:

$$\mu A \cup B = MAX(\mu A, \mu B) \quad (1)$$

Process of choising mechanical parts of IR from the mechanical database (MDB) is executed as follows:

$$\begin{gathered} MDB \rightarrow \text{IR body (B)}; \\ \text{IR hand (H)}; \\ \text{IR gripper (G)}. \end{gathered} \quad (2)$$

By means of $MB \cup H \cup G = MAX(\mu B, \mu H, \mu G,)$ operator, IR frontal view is created.

The selection of the electronic parts of the IR from the electron database (EDB) and its addition to the frontal view of the IR is described by the following expression:

EDB → IR control block (CB); IR sensor (S).
([IR body (B); IR hand (H); IR gripper (G)] →M (mechanical)) ∪
([IR control block (CB); IR sensor (S)] →E (electronic))

By means of above written logical expression and MM∪ E = MAX (μM, μE) operator, the IR control parts are added to the IR frontal view.

Based on the frontal view of the created 2-dimensional IR, the top view is drawn. AutoCAD software commands are used to draw the most commonly used circle and rectangular geometric shapes. Performing this design procedure is required to maintain symmetry with the frontal view. The broken lines are directed to the second projection area. The broken lines intersecting the central axis of the top view define the top-view boundary dimensions of the IR arm, handle, body, and control unit. Other intersecting geometric figures are placed in the drawing area of the top symmetricaly. As a result of drawing the second projection in the form of a specification table and a corner stamp, its information support is added to the generalized line obtained.

PROGRAM FOR EXECUTİNG CDMS İNTERFACE ON STAGES OF FMS DEVELOPMENT

For management of comlex computing design procedures of FMS by means of one program interface diagram with intellectual design operations of a professional designer is proposed in fig. 2.

The interface of the developer's complex intellectual-operating system includes menu blocks, such as design stages, design programs, service-operational functions [15].

$$P_{pr\_ij} = \left\| \begin{matrix} L_{task1}, L_{task2}, \ldots, L_{taskn} \\ L_{prop1}, L_{prop2}, \ldots, L_{propm} \\ L_{sketch1}, L_{sketch2}, \ldots, L_{sketchl} \\ L_{working\ dr1}, L_{working\ dr2}, \ldots, L_{working\ drc} \end{matrix} \right\|,$$

where L_{taski} – set of technical task stage; L_{propi} – set of technical proposal stage; L_{scetch} –-set of scetch design stage; $L_{working\ des}$ – set of working draft stage.

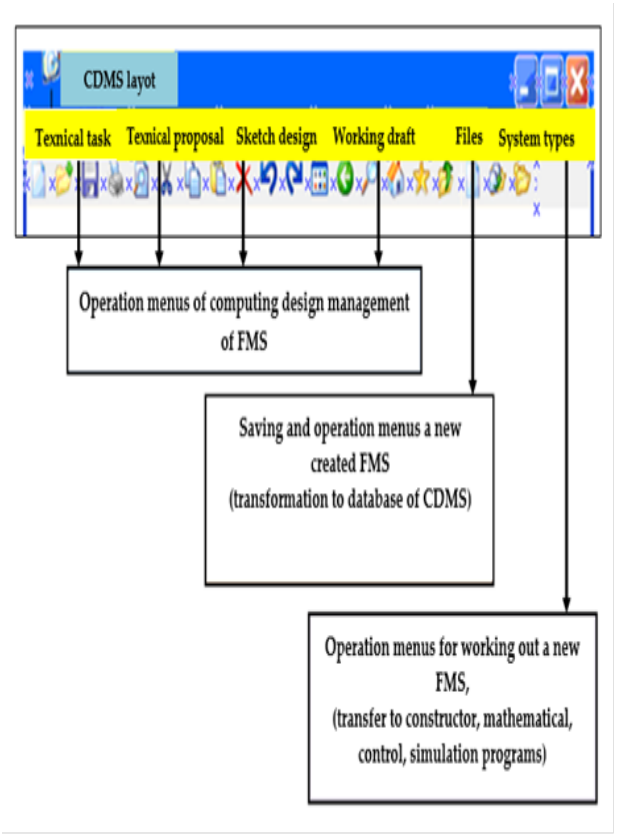

Fig. 2. Program interface scheme with intellectual design operations of a professional designer

To ensure the automation of the design process of FMS, the operating menu of CDMS, Windows and special software packages is set. The following set of operations is used to provide FMS design automation procedures:

Project-based research often consists of long-term, unsystematic procedures. It takes a lot of time to search for prototype projects and select effective options.

However, by performing information retrieval operations within a system, it is possible to study the issues raised with high productivity and develop a new improved project option. In this regard, in contrast to the traditional functions of the project object, it is scientifically relevant to systematize the initial research – registration of ideas, comparative analysis, selection and evaluation of projects within a single interface.

The following procedures should be followed to work more productively, flexibly and accurately during the project stages:

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.

Computing design works consist 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:

Stage 1 – drawing of the sketch form of the project object with non-scale dimensions, selection of the number of projections, determination of additional views and drawing of a complex generalized 2-dimensional image, selection of the main dimensions and marking on the image; drawing of 2-dimensional drawings of separate parts of the project;

Stage 2 – drawing a generalized 3-dimensional description of the project; drawing 3D drawings of separate parts of the project; selection of types of main parts of the project and creation of a database;

Stage 3 – project animation; determination of the dimensions of the main parts of the project; selection of materials for the main parts of the project;

Stage 4 – development of a small-scale model of the project and development of a trial version in FMS.

Based on these procedures, the initial intellectual research interface is built and the scheme of search-analysis-selection procedures of the designer. The initial data of the new project is registered in the “Project Assignment” program template (Fig. 3).

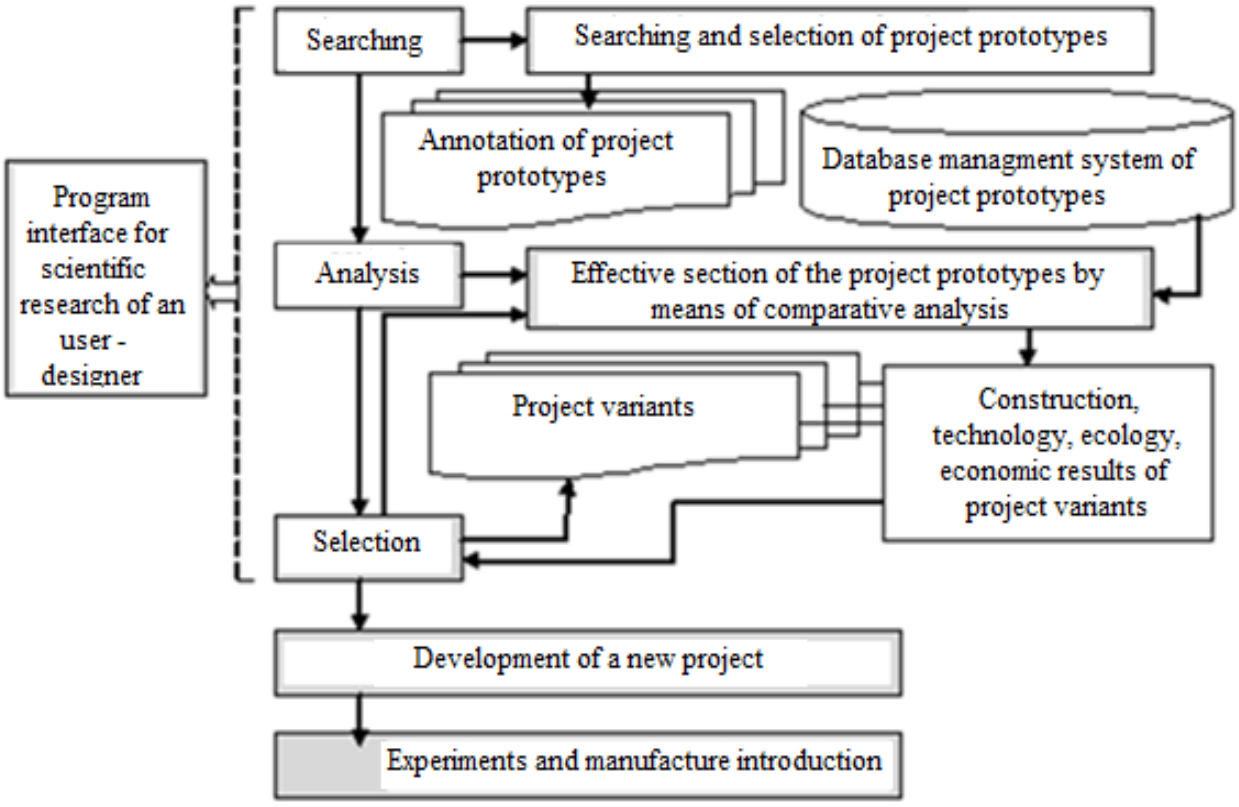

Fig. 3. Scheme of information-search-analysis-selection procedures of the designer

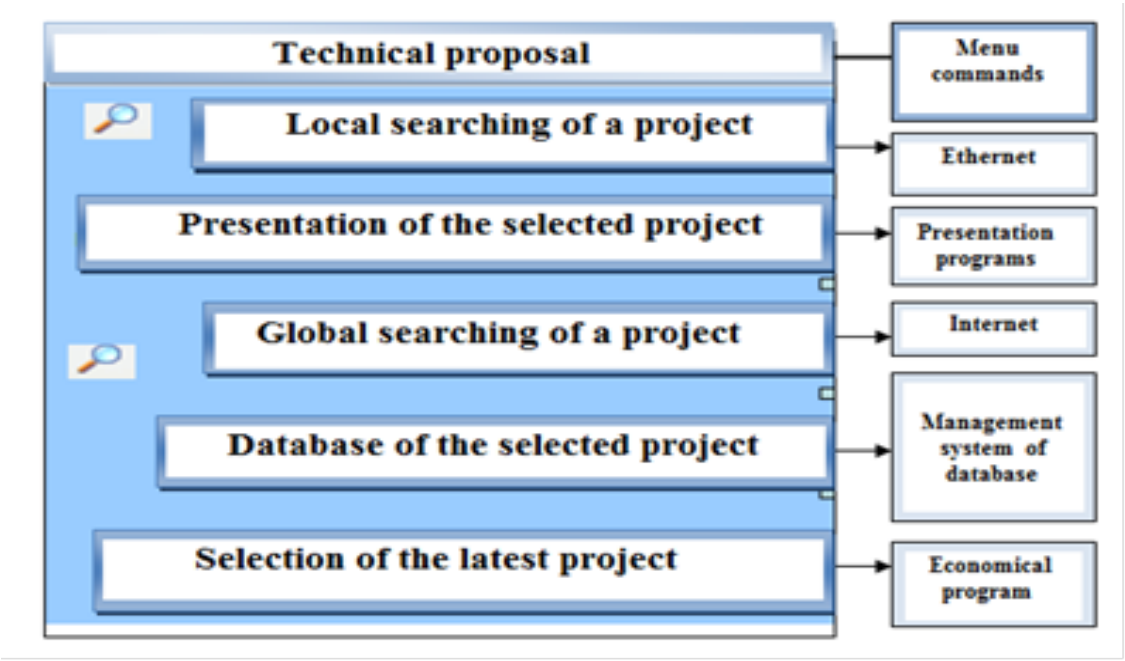

Fig. 4. Interface functions of the system of technical proposal stage in the design process

Depending on the scope, level of complexity and technical properties of the technical system, the search and selection of prototype project information, samples at the initial design stages increases the efficiency of project work, allows you to develop a better product, work on a project that meets modern requirements. Considered one of the initial design stages of the technical system, the technical proposal stage consists of a number of procedures and related operations. In the automated design interface, the technical proposal stage is provided by the following operations: activate the "Technical Proposal" software operation and enter the relevant data in the menu window. Schematic of the commands in the "Technical proposal" menu window is shown in fig. 4.

Preliminary search and selection of prototype projects is carried out in the existing database of the local and global network system.

1. In the designer's database (DB1);

2. In the database of ready projects of the corporate network of the research center (DB2);

3. Database of ready projects of the international global network (DB3);

4. Selection of a list of ready-made projects (RMPi) from DB1, DB2, DB3.

Project procedures are carried out to search and select ready-made projects from the designer's expert database. Iterative extraction of inappropriate data is provided by search and selection of projects.

The designer's corporate communication scheme with expert specialists is implemented in the following sequence:

1. Based on the data stored in the terms of reference of the technical task, a local search of ready-made project options is performed (technical proposal menu block of the program interface);

2. Demonstration of similar projects in the system according to their purpose;

2.1. Demonstration of 2-dimensional layout descriptions of projects;

2.2. Demonstration of 3-dimensional descriptions of projects;

2.3. Demonstration of 2-dimensional descriptions of technological operations of projects;

2.4. Demonstration of 2-dimensional descriptions of technological operations of projects;

3. Economic, construction, etc. preliminary selection of cost-effective project options:

3.1. The version of the project must meet the requirements of the world market. If these conditions and specifications meet ISO standards, then ready-made projects with more

efficient technical specifications are selected from the database.

CONCLUSİON

1. On a basis of raising of an issue of software development, to ensure the complex automation of the design process of the technical system, the structure of the menu procedures of the intelligent software interface was proffered.

2. Scheme of information-search-analysis-selection procedures of the designer is proffered.

3. Program interface scheme with intellectual design operations for a professional designer is developed.

REFERENCES

1. **Jefferson T. G., Benardos P.** and **Ratchev S**. Reconfigurable Assembly System Design Methodology: A Wing Assembly Case Study // SAE International Journal of Materials and Manufacturing. 2015, Vol. 9, no. 1. Pp. 31-42. **[** T. G. Jefferson, P. Benardos, S. Ratchev, "Reconfigurable Assembly System Design Methodology: A Wing Assembly Case Study", in *SAE International Journal of Materials and Manufacturing,* vol. 9, no. 1, Pp. 31-42, 2015. **]**

2. **Terkaj W., Tolio T., Valente A.** Designing Manufacturing Flexibility in Dynamic Production Contexts // Design of Flexible Production Systems Springer-Verlag Berlin Heidelberg, 2009. Pp. 11-61. DOI: 10.1007/978-3-540-85414-2_3.

3. **Terkaj W., Tolio T., Valente A.** Design of Focused Flexibility Manufacturing Systems (FFMSs). // Design of Flexible Production Systems. 2009. Pp. 137-190.

4. **Methodologies** and tools to design production systems with focused flexibility / M. Cantamessa**,** et al. // Proceedings of the 4th International Conference on Digital Enterprise Technology (Sept. 19–21. 2007). Bath, UK, 2007. Pp. 627-636.

5. **Contini P., Tolio T.** Computer aided setup planning for machining centers configuration // Int. J. Prod Res. 2004, Vol. 42 (17): Pp. 3473-3491.

6. **A. Matta, et al.** An integrated approach for the configuration of automated manufacturing systems. **[** A. Matta., et al**.** // Robotics Comput. Integr. Manuf. 2001. Vol.17. Pp. 19-26. **]**

7. **Matta A., Semeraro Q., Tolio T.** Configuration of AMSs – Stochastic models for performance evaluation of Automated Manufacturing Systems. 2005. № 4. Pp. 230-241.

8. **Chinnathai M. K., Ahmad M.** An Application of Physical Flexibility and Software Reconfigurability for the Automation of Battery Module Assembly, // Procedia CIRP 63. (Dec. 2017), Pp. 604-609.

9. **Gania I. P., Stachowiak A., Ole´ków-Szłapka J.** Flexible manufacturing systems: Industry 4.0 solution // Proceedings of the 24th International Conference on Production Research (ICPR), (30 July–3 August). Posnan, Poland, 2017. Pp. 124-129.

10. **Seebacher G., Herwig, W.** Evaluating flexibility in discrete manufacturing based on performance and efficiency // Int. J. Prod. Econ. 2014. 153. Pp. 340-351.

11. **Diaz J. L., Ocampo-Martinez C., Olaru S.** Dual mode control strategy for the energy efficiency of complex and flexible manufacturing systems // J. Manuf. Syst. 2020. 56. Pp. 104-116.

12. **Xiaomo H. J.** Three-dimensional mechanical parts reconstruction technology based on two-dimensional image // International Journal of Advanced Robotic Systems. 2020. Vol. 17(2). Pp. 66-75.

13. **A. R. Puerta et al.** Mobile: User-Centered Interface Building **[** Puerta A. R. et al. // CHI99: ACM Conference on Human Factors in Computing Sysems, May 2009 Pittsburgh. 2009. pp. 129-143. **]**

14. **Roubi S., Erramdani M. and Mbarki S.** Modeling and generating graphical user interface for mvc rich internet application using a model driven approach // Proceedings of the 2016 International Conference on Information. 2016.

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МЕТАДАННЫЕ

Название: Алгоритмическое и программное управление процессом проектирования гибкой производственной системы.

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Аннотация: На примере гибкой производственной системы (FMS) был проведен анализ существующих систем проектирования для разработки FMS и определено, что не существует таких систем, которые включают в себя многоцелевые функции проектирования программного обеспечения. В связи с этим задачей статьи является разработка комплексной системы автоматизированного проектирования FMS для высокопроизводительного, гибкого, универсального и точного выполнения проектных процедур поэтапно в рамках единого системного интерфейса. С использованием процедур проектирования, конструирования и технологического проектирования FMS предложена программная структура системы управления вычислительным проектированием (CDMS) FMS. Для

реализации процесса компьютерного проектирования в одной системе управления разработано алгоритмическое обеспечение управления процессом автоматизированного проектирования FMS. Для базы данных управления проектами создана специализированная система графических данных. Предложена структура процедур программного меню для создания 2-х и 3-х мерных графических представлений технической системы в CDMS. Предлагается программное обеспечение реализации интерфейса CDMS на этапах проектирования FMS с представлением основных этапов проектирования в виде диаграмм меню.

Ключевые слова: гибкая производственная система; вычислительная система управления проектированием; двух- и трехмерная графика, обобщенный чертеж.

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