Software for Animation and Graphic Visualization of Mechatronic Elements and Control Process of FMS

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Abstract: The issue of graphical visualization of the simulation, animation and design of mechatronic elements and control process in the example of the mechanical assembly shop of the flexible manufacture system (FMS), which is considered a complex technical system, is set. The purpose of the work is the development of graphics-mode software that provides computer experiments of 2D, 3D designer-modeling, animation and graphic visualization of the interface for evaluating the feasibility of the design process of the flexible mechanical assembly cell (FMAC) As the main research issues, the construction of the 2D and 3D grouping scheme of the static and dynamic elements of the research object, the development of 3D software for the animation models of the activities of its active elements, and the development of the generalized software for the graphic visualization of the interface for the design of the management system were set.

Based on the issues raised, the 3D grouping scheme of static and dynamic elements of the FMAC was established, the positioning coordinates of the 2D static and dynamic elements of the FMAC were determined in the PROOF Animation system, the analysis of the technological process of the FMS was carried out to build an animation model, and the animation movements of technological operations were MOVE (management unguided movement) or PATH (guided movement) operators. An animation model of the static and dynamic active elements of the FMAC was built, experiments were conducted, and as a result, it was possible to calculate a technological cycle in the research object and determine the productivity of the workshop. The software for the graphic visualization of the design of the control system of the FMAC was developed, and the procedures and operations of each software module of the interface were planned.

Keywords**:** flexible manufacture system, management system, animation, PROOF Animation, interface, graphic visualization, 2D, 3D, software modules.

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1. Introduction

Computer experiments, simulation method, graphic mode, 2- and 3-dimensional visualization, animation and in order to ensure the very interconnectedness of the design process of complex technical systems, features, complexity of technological and functional research issues, implementation of projects by individual designers in an uncertain way. application of multimedia technologies is required [1, 2]. In this regard, graphical modeling based on new information technologies and automation systems, the use of intellectually oriented algorithmic and graphical software tools for the automation and efficient management of complex and highly connected technological operations at hierarchical levels [3], mathematical, informational, management standard software using various project procedures and operations of tools is considered one of the important issues.

The specified requirements are of particular relevance in the design of flexible manufacture systems belonging to the category of complex systems. This is due to the fact that, as well as being a complex object, the FMAC consists of a set of mechatronic devices [4], equipment and other components with different properties , interacting with each other, operating in a real-time interval, and operating in common working zones to achieve the main goal . is a system that shows. As it can be seen, the main components of FMAC are mechanical devices controlled by electronics-based systems of the design of the FMAC is revealed in the experiments of their complex activities in the stages of processing the sketch design documents and application in the real object, and the costs and design periods required for the repeated elimination of design errors increase. In order to solve this problem, it is necessary to evaluate the appropriateness of the creation and verification of the operation of the FMAC and its management system in a complex way , with the use of modern constructor-modeling methods [5, 6], information technologies, and graphic mode computer experiments of the designers ' ideas at the stages of technical proposal and sketch design . it can be shown that it is relevant.

2. Setting the issue, the purpose of the work

Based on the analysis of the complex design issues of the FMAC, which is the object of the study, it was determined that the selection of the types of mechatronic elements, their assembly according to the sequence of technological operations, their organization by dividing them into production modules and joint working zones, the automation scheme of the FMAC for the automation and control of the technological process issues of establishing, connecting with SCADA are more important scientific and research works [7]. As it can be seen, each step of the complex design process of FMS is characterized by procedures and operations with a schedule [8]. For the effective implementation of these works, it is more appropriate to use constructor-modeling tools and to conduct experiments with separate 2D and 3D mode design functions according to the specifications of the application object, and based on the received constructor and animation models, a more accurate, reliable and safe working FMAC and it is possible to create its management system. In this regard, the main purpose of the article is defined. Thus, the goal is to develop a graphics-mode software that provides computer experiments of 2D, 3D designer-modeling, animation and graphical visualization of the interface for the evaluation of the feasibility of the design process of the control system of a flexible mechanical assembly shop. The research questions arising from the objective are as follows:

1. Construction of a 2D and 3D grouping scheme of static and dynamic elements of the research object;
2. Development of 3D software of animation models of the activities of its active elements in the example of the FMAC;
3. Development of generalized software for graphic visualization of the interface for the design of the control system of the FMAC.

3. 2D and 3D grouping scheme of static and dynamic elements of the research object

As the object of research, the FMAC, which belongs to the machine-building industry, is chosen. FMAC belongs to the class of complex technical systems, because it contains standard and non-standard elements, the static and dynamic nature of the elements of the workshop during technological operations, one of the main issues for studying the productivity of automated operations is the animation-simulation model of the dynamics of the technological process. is to analyze. The construction of the animation model of the FMAC allows the researcher to study the issues of management, control, and planning of the product development process in more accurate ways [9, 10]. Specifically, the animation model provides solutions to the following issues:
- to check the suitability and adequacy of the model to the object in detail and in general;

- identify individual errors in simulation modeling;
- to prove to the client that the simulation model works correctly.

Recently, professional software tools are used for the simulation of automated production processes. Of these programs, GPSS\H specialized simulation complex and PROOF Animation computer animation language are more widely used. To create animation models of automated production systems, it is more appropriate to use Proof Animation computer animation language [11].

Proof Animation vector based with files management which is animation is a system. Proof Animation language to the structure Based on the production of FMAC of modules geometric fields and their coordinates which is of the benches types, descriptions and their geometric their dimensions _ operation types and coordinates of the crane-manipulator geometric form , operations and coordinates certain is done and to the system included is done. Proof Animation system tool with the technological operations instead of don't give duration and their final positions coordinate points included is done .

The mnemonic of FMAC static and dynamic graph of the elements from the combination consists of Static elements animation during does not change. They are lines, arcs, rectangles, circles use is established by doing Research in the facility static information to the base lathe, mill, radial drill and bender of the benches descriptions included is done. Their coordinates in advance certain done in positions is selected. The dynamic of FMAC object crane-manipulator is chosen because it is to the benches consistently technological transactions sequence with movement does and each one bench layout loading that ultimately layout ready to the product becomes (Fig . 1).

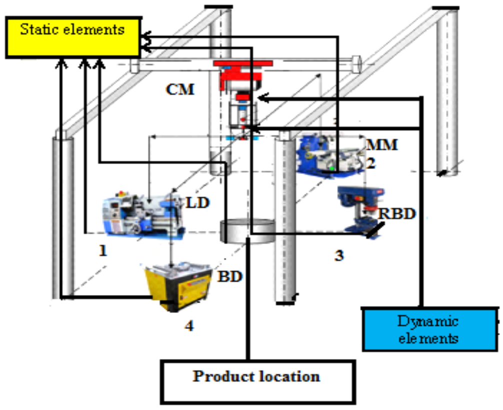


Fig . 1. Statics of FMAC and dynamic 3D grouping of elements scheme

In the Class Mode mode, selecting the "New class" option, the crane manipulator (CM) is drawn as a dynamic element, and the lathe machine (LM), milling machine (MM), radial boring machine (RBM), bending machine (BD), as static elements. area for layout and stored in MODAPS.lay (Fig. 2).

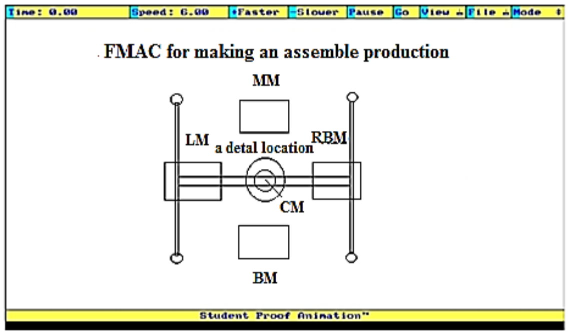


Fig. 2. Positioning locations of the 2D static and dynamic elements of the FMAC in the PROOF Animation system

The FMAC.exe file is activated to simulate the technological operations of the crane – manipulator. As a result, a tracing file is created. A fragment of this file is given in the following sample program:

TIME 0.0 CREATE KM 1 PLACE 1 AT 75 30
MOVE R 3 75 36 TIME 9 MOVE R 3 27 36 TIME 9
PL ACE 1 AT 18 36 ROTATE M1 TO -70
TIME 36.9
END

When the KM.EXE file is selected, the animation function is activated. To ensure the output of the animation model to the screen, the CM file is selected, and the "Open Layout & Trace" sub-item is managed in the horizontal menu, and the animation program is connected with the "Go" command.

Let's analyze the technological process of FMAC to build an animation model in the PROOF Animation system. Thus, the sequence of technological operations of FMAC is performed as follows: the crane-manipulator in position 1 (the center of the production module) moves in a straight line to the left and down, loads the assembly on the lathe (LM-1 position) and to the upper safe position moves. A shaft-shaped mechanical part is made as a result of machining the arrangement in LM. When the operation is finished, the crane-manipulator moves down and grabs it, moves up, moves to the initial slot (the center of the production module). From this position, the crane-manipulator shaft-type assembly moves the line back and down and loads the part into the milling machine (MM-2 position) and moves to the upper safety position. At this time, the operations of cutting the parts of the shaft and opening the key are performed in the MM. After the operations are finished, the crane-manipulator moves down to pick up the finished product, grabs it, moves up and back to the center of the production module. From this position, the crane-manipulator moves the shaft-type arrangement linearly to the right and down and loads the part into the radial boring machine (RBM-3 position) and moves to the upper safety position. At this time, the shaft piercing operation is performed in the RBM. After the operation is finished, the crane-manipulator moves down to pick up the finished product, grabs it, moves up and back to the center of the production module. From this position, the crane-manipulator moves the shaft-type assembly forward and down the line and loads the part into the bending machine (BM-4 position) and moves to the upper safety position. At this time, the shaft bending operation is performed in the PC. After the operation is finished, the crane-manipulator moves down to pick up the finished product, grabs it, moves up and back to the center of the production module, and loads the finished product into the finished product slot in the center of the production module.

4. 3D software development of animation models of the activities elements on the example of the FMAC

Animation movements of the above technological operations are performed with the help of MOVE (uncontrolled movement) or PATH (controlled movement) operators. Since the displacement of the layout in FMAC is provided by linear movement, "Time" (time), "Speed" (speed), "Faster" (acceleration) or "Slower" (reduce the speed of animation), "View" (sizes, positions and selection of production area), "File " (selection of technological processes), "Mode" (selection of animation modes), "Go" (connection of image movement) commands are applied, which allows to adjust the planning, management and overall productivity of the production process [12].

Proof Animation commands are applied to the GPSS/H model to study the animation process with a simulation model. In this case, the PUTPIC operator and the BPUTPIC block are used.

Format used:

PUTPIC opt, ... , (list)

BPUTPIC opt, ... , (list)

where opt is an option; and list - is a list of numerical expressions, variables, standard numerical attributes written by GPSS/H to an external file (.atf).

FILE=log

LINES=unt

where log is the logical name of the external file; unt – is the number of lines of numbers reflected after the BPUTPIC block.

logical name is given using FILEDEF to control the animation of the CSIMS:

LOG FILEDEF 'NAME'

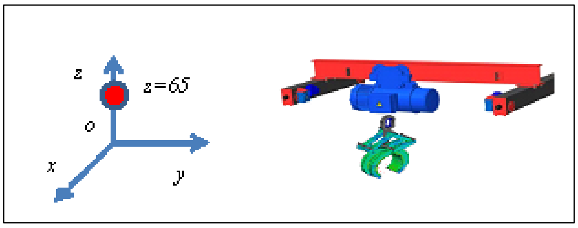
where NAME is the name of the atf file , LOG is the logical name of the file. .

For the research object

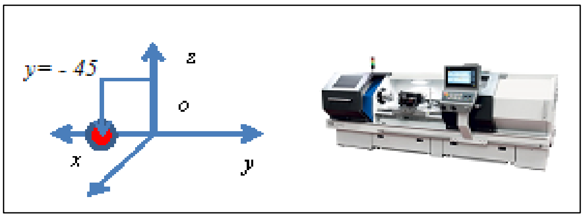
ATF FILEDEF "MODAPS.ATF"

*BPUTPIC FILE=ATF1, LINES=1, AC 1 TIME *.***

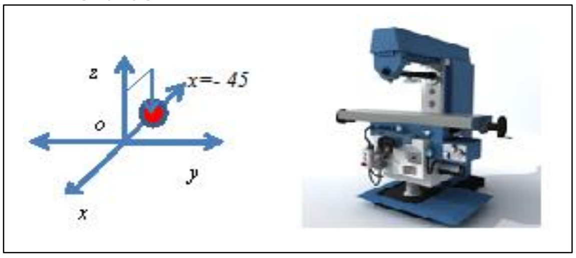
CREATE FAUCET -MANIPULATOR PLACE D AT 0 0 65



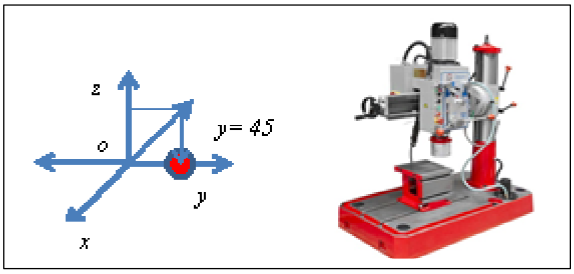
*BPUTPIC FILE=ATF2, LINES=2, AC 2 TIME *.***
CREATE LATHE PLACED AT 0 - 45 65



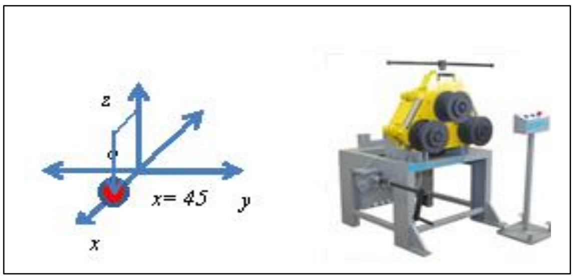
*BPUTPIC FILE=ATF3, LINES=3, AC 3 TIME *.***
CREATE MILLING MACHINE PLACED AT -45 0 65



*BPUTPIC FILE=ATF4, LINES=4, AC 4 TIME *.***
CREATE RADIAL BORRING MACHINE PLACED AT 0 45 65



*BPUTPIC FILE=ATF5, LINES=5, AC 5 TIME *.***
CREATE BENDER MACHINE PLACED AT 45 0 65



During the animation, it can be seen that at the initial stage, the position of the crane-manipulator at the current time is $x = 0$, $y = 0$, If it is defined in $z=0$ *coordinates, the coordinates of its subsequent movements correspond to the following parameters:*
$x = 0, y = 0, z=65$, *where* $t_0 = 5$ *sec;*
$x = 0, -y = -45, z=65$, *where* $t_{-y} = 9$ *sec;*
$-x = -45, y = 0, z=65$, *where* $t_{-x} = 11$ *sec;*
$x = 0, y = 45, z=65$, *where* $t_y = 10$ *sec;*
$x = 45, y = 0, z=65$, *where* $t_{-y} = 12$ *sec.*

Productivity of production is determined based on the process transformation of a design into a product in FMAC. Thus, 1 product is made in one production period, on the base of the following expression $\sum_{i=1}^{5} t_i$, where as a result we are got 47 seconds.

The result of the animation representation of the FMS is shown in figure 3a and 3b. Enter PUTPIC: PUTPIC FILE=ATF END with the END command in the control file to terminate the animation process.

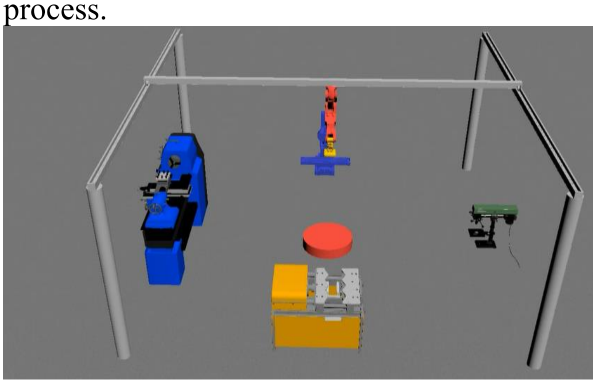


Fig. 3a. Animated representation of active elements of FMAC

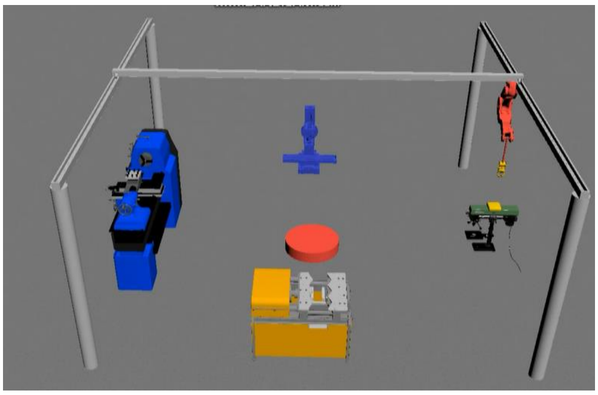


Fig. 3b Animated representation of active elements of FMAC

The used method allows for effective design of the composition and automation schemes of the of FMAC.

5. Development of software for graphic visualization of the design of the control system of FMAC

In the system engineering design phase of the of FMAC of mechanical processing flexible manufacture systems, consisting of a large number of information-measurement, control and regulation relationships, the development of graphic-visualization software is required for the establishment of their reliable, productive and efficient management system [13]. In the process of designing the control system of the of FMAC, the constructor design of its layout scheme, the visualization of the automation scheme divided into levels, the planning and simulation of the interrelationships of the information-measurement, management and control system elements of the information-measurement, management and control system at separate levels, the planning and simulation of the interactions of the management functions, to the industrial network since the solution of the integration issues is required, the structure of the generalized software, which ensures the realization of the above-mentioned issues in the example of a specific research object, is proposed (Fig. 4).

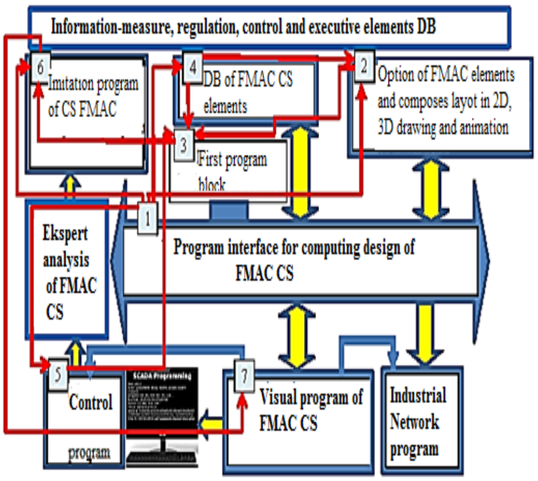


Fig. 4. The general structure of the software for the graphic visualization of the design of the management system of of FMAC

The design process is regulated by its software interface based on the structure of the software for the graphic visualization of the processing of the control system of the of FMAC (*program block 1*). The design procedures carried out in stages include the selection of active elements of the of FMAC, the selection of those elements according to the technological sequence of the production area (mechanical processing machines (lathe, mill, radial drill, bender), overhead crane-manipulator, means of transportation, tools for storing raw materials and finished products) composition and their animation is carried out by means of the *2nd program block in the program mode of the 2- and 3-dimensional coordinate computer graphics system.* The composition of the active elements of the of FMAC is analyzed with drawings, construction reports and animation in a 3-dimensional coordinate system. After checking layout dimensions, safety working zones and movement routes, the project is placed in the working area of the program (*program block 3*) and stored in memory [14].

The issue of development of the management system of the of FMAC is raised. At this stage*, the 4th program block* is applied to data base (DB) FMAC. In the working area *of the 1st program block (3rd program block*) 2- and 3-dimensional drawings of the FMS of the research object are placed. Information-measuring elements, their adjustment tools, general programmable logic controller (PLC) of production, execution mechanisms, their communication lines are selected from DB FMAC to each active element of of FMAC, and the automation scheme of of FMAC is established in the initial version. *In the 5th program block , the software is built, tested and interfaced to the* working area *of the 1st program block (3rd program block)* with the ZelioSoft visualization program of the PLC with implicative commands corresponding to the planned trajectory transitions of the crane-manipulator [5, 15].

A simulation program is activated to check the reliability, integrity and productivity of the management program of the of FMAC (*program block 6*). At this time, the software system of the Petri net is started, the transitions of the control process, based on the execution time and procedure types, and the control program placed *in the workspace from the 3rd program block It is transferred to the 6th program block* and the simulation process is carried out. As a result of simulating the management process of the research object with a Petri net, it is analyzed until the requirements set for the design of the management system are met. If the reliability, safety and high productivity of the operation of the control system of the of FMAC are ensured, then the connection of the control process of the research object to the industrial network and control with SCADA is carried out in *the 7th program block*.

6. Conclusions

1. 2D and 3D grouping scheme of static and dynamic elements of the research object (on the base of FMAC).
2. 3D software of animation models of the activities of its active elements in the example of FMAC.
3. Proposing the general structure of the graphic visualization software for the design of the control system of the of FMAC, the procedures and operations of each software block were explained.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.