Automation of Reliability Assessment of Functional Elements of Flexible Automated Production Based on Functional Network Methodology

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Abstract. In the article, we propose to consider the reliability of flexible automated production and justify the need for functional decomposition of automated systems, followed by the description of processes in the form of functional networks. We have developed the principles of variant modeling for flexible production systems, the structure, and information and software of information technology for reliable design of automated production. The test proved the effectiveness of the proposed toolkit.

Keywords: Reliability, Flexible Manufacturing System, Ergonomics, Computer Modeling, Man-Machine, Algorithm of Functioning, Functional Network.

1 Introduction

Computerization and flexible control systems are becoming a trend of the modern stage of society development [1-4]. Flexible manufacturing radically changes the traditional, years-old approaches to production organization. Current technology, which is based on the differentiation of the process of machining parts for numerous operations and transitions performed on various machines, has lost its economic advantages, because production became much more complex and its range began to change more often. The essence of the concept of flexible automated production is that it allows you to switch from the release of one product to the release of another without reconfiguring the equipment or with the reconfiguration performed in parallel without stopping the release of the current product [5-8]. Unfortunately, the efficiency and reliability of flexible production systems (GPS) do not always meet current requirements in practice [1, 8].

2 Statement of the task

Unfortunately, the classical theory of reliability [10-14], methods of estimation and optimization of production systems [10, 15, 16], methods of estimation of reliability of operational personnel [17-19], do not have in their arsenal a complete library of models necessary for operative obtaining assessing the functional reliability of the processes occurring in the GPS.

In this regard, we aim to provide the possibility of prompt automated analysis of options (from the point of view of reliability) for organizing the operation processes in flexible manufacturing systems (FMS), taking into account the reliability of all structural elements and features of functional elements [6-9].

3 Results

3.1 Analysis of the functional structure of the FMS

For the normal operation of the FMS, a number of functional subsystems must be included in its composition. Among them:

- Warehouse module is an automatic warehouse, i.e. dispenser with an automatic search and transfer system to and from the warehouse, pallets, trays, etc. on vehicles.
- A transport module is a complex of automatic vehicles together with a system for automatically controlling the movement of these vehicles along a route.
- The installation module includes a set of equipment for the installation of workpieces into fixtures and pallets. (These three modules are combined into a transport and storage module).
- A tool module is an entire tool economy integrated into a tool management subsystem.
- The production module is the technological equipment that forms the FMS machine tool system.
- The test module consists of a quality control section, including CNC control and measuring machines, test benches, etc.
- ACS module is a complex of a central computer, intermediate mini-computers and microprocessors in conjunction with all the mathematical and software.

3.2 Development of principles for modeling the implementation of GPS function

Modeling and optimizing the operation of FMS becomes possible if you develop a technology based on the principles of:

- Functional decomposition (division of the process into separate functions - according to subsystems, as described above).

- A formalized description of all processes in the form of functional networks (FN) [8, 20-22] (unlike other network methods, for example [23, 24], they allow not only describing, but also evaluating and optimizing processes).
- Consideration of possible failures, malfunction of hardware and software, human operator errors, as well as modeling diagnostic processes, identifying errors and problem situations and restoring normal operation processes.
- Maintaining databases on the reliability of all structural elements (hardware, software, human operator).
- Maintaining databases of typical options for the implementation of functional structures (as in Fig. 1).
- Automatic analysis and calculation of the probability of error-free and the probability of timely implementation of alternative options for the organization of functioning.
- Taking into account the influence of individual characteristics of operators on the reliability of processes (including qualifications, motivation, workload, intensity of activity, category of work severity, etc.).
- Etc.

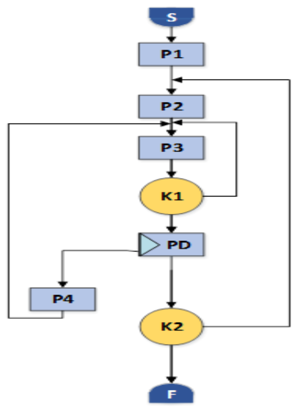


Fig. 1. A fragment of the description of the operation of the transport and storage system (symbols and composition of operations - see [20])

3.3 Description of information technology

Information technology (Fig. 2-7) provides:

- The accumulation of models necessary to obtain estimates of the probability of error-free and timely execution (for typical functional units (TFU) and typical functional structures (TFS);
- Accumulation of models of typical processes;
- Accumulation of input data for calculations;
- Automatic analysis of operational options;
- Automatic selection of the best option.

3.4 Testing

The developed system was used to design the functioning processes of flexible manufacturing sections of machining, as well as several other automated systems [8, 25-29].

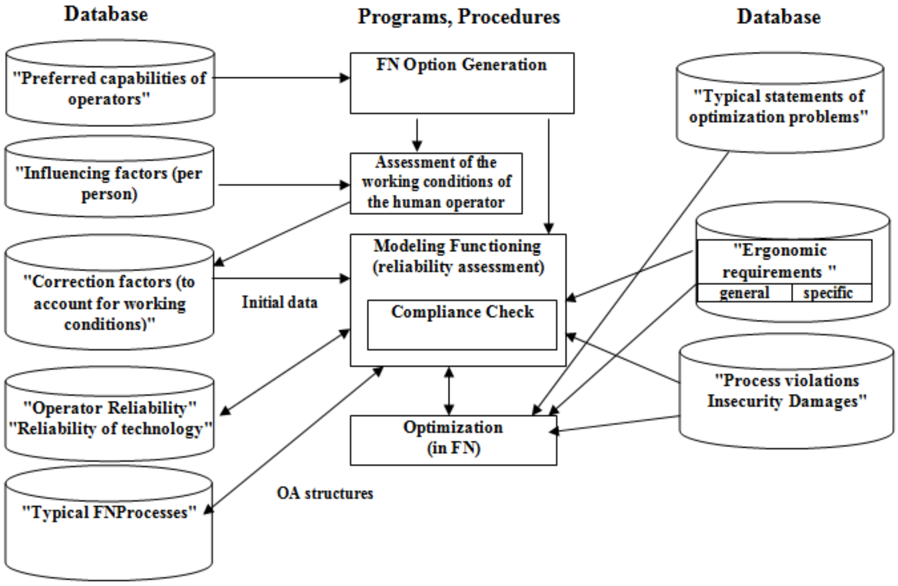


Fig. 2. A set of information and software automation tools for a reliable design of FMS

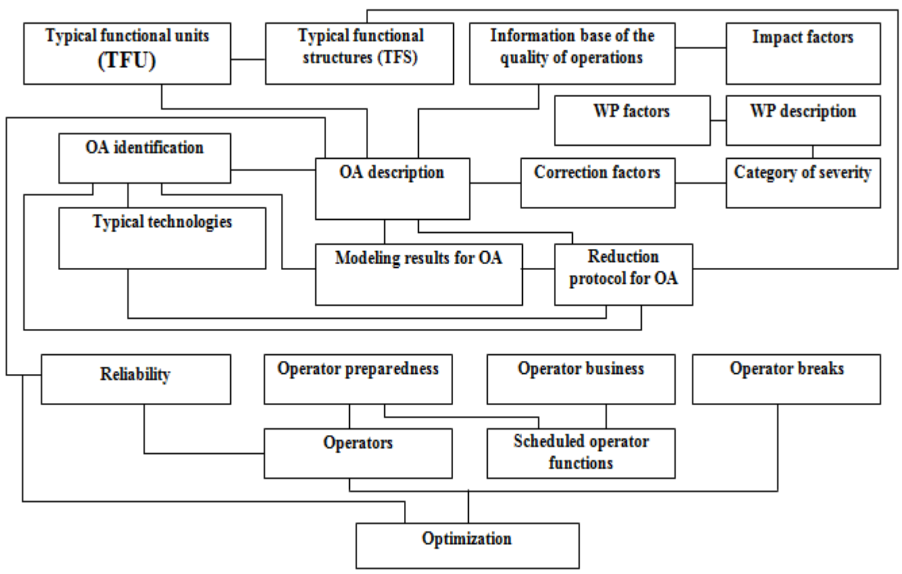


Fig. 3. Scheme of interconnections of tasks of the software package

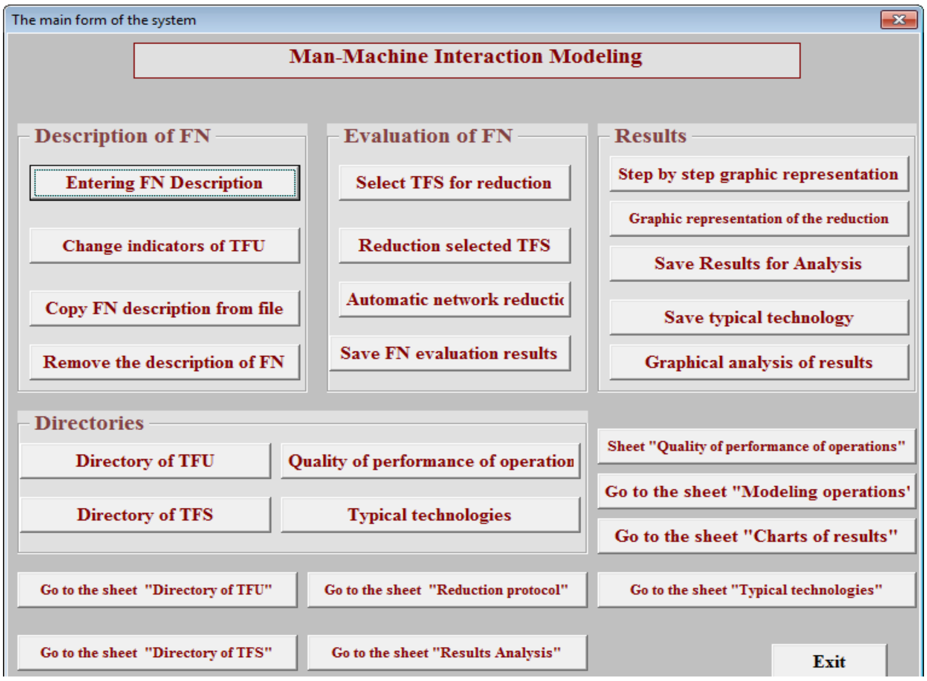


Fig. 4. The main form of the system

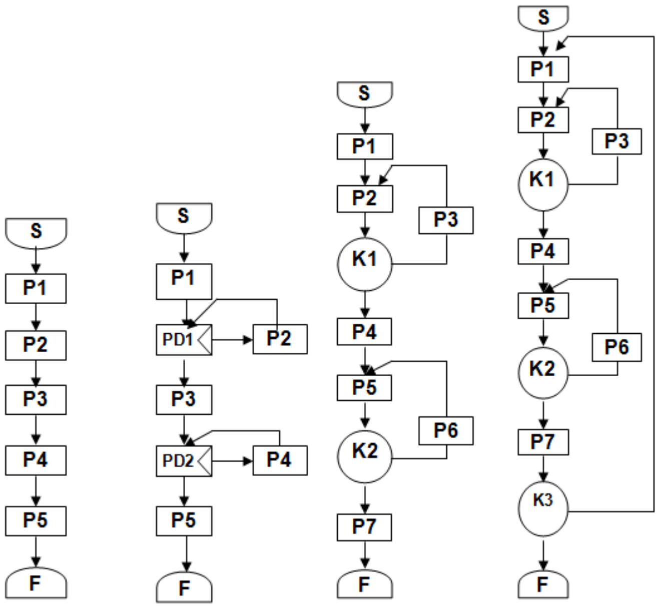


Fig. 5. Examples videogram of a computer program. Algorithm of the functioning of the robot manipulator. Variants of functional structures

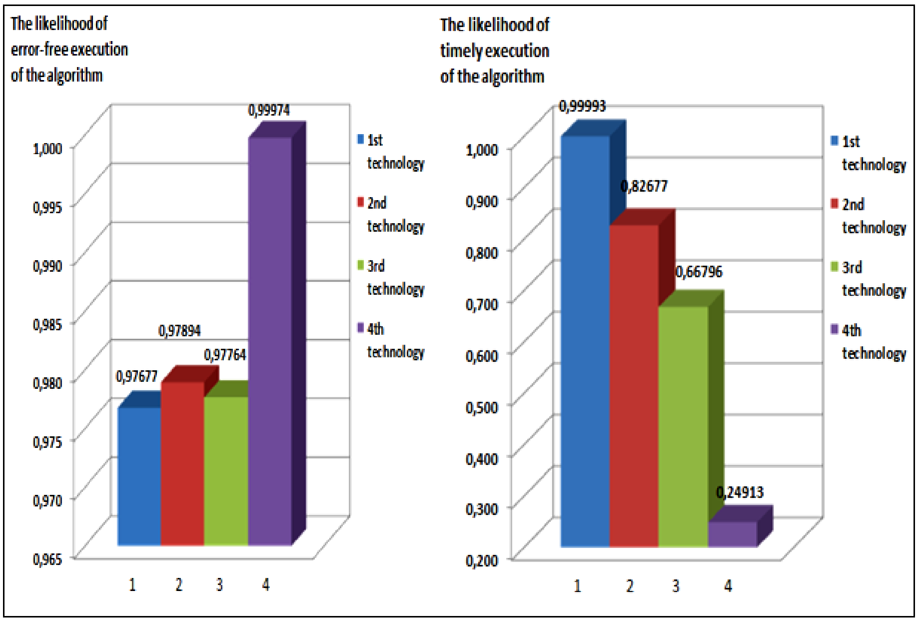
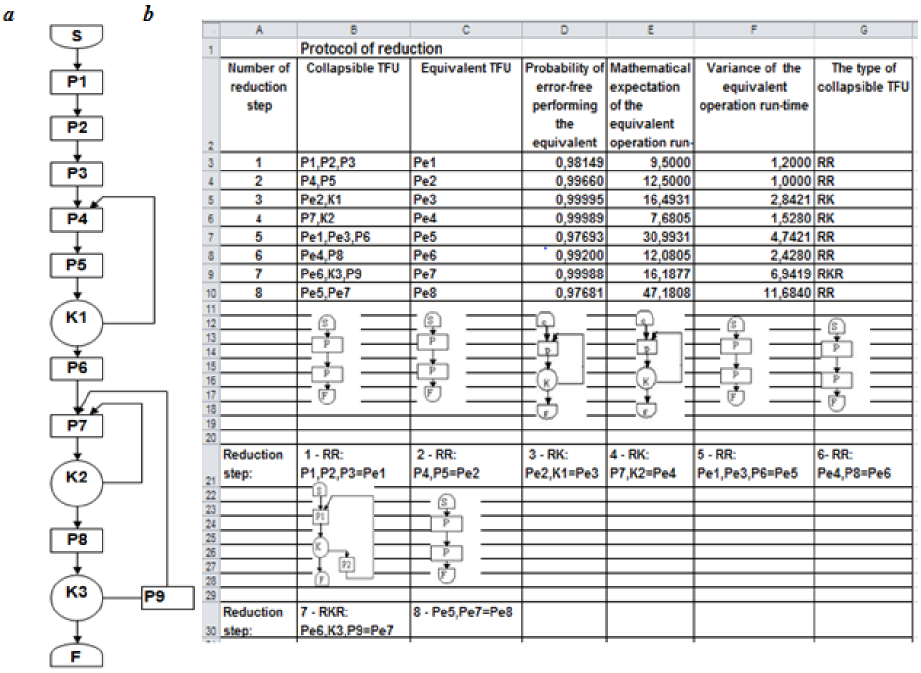


Fig. 6. Examples videogram of a computer program. Assessment results of the algorithms of the functioning of the robot manipulator



Protocol of reduction

Number of reduction step	Collapsible TFU	Equivalent TFU	Probability of error-free performing the equivalent	Mathematical expectation of the equivalent operation run-	Variance of the equivalent operation run-time	The type of collapsible TFU
1	P1,P2,P3	Pe1	0,98149	9,5000	1,2000	RR
2	P4,P5	Pe2	0,99660	12,5000	1,0000	RR
3	Pe2,K1	Pe3	0,99995	16,4931	2,8421	RK
4	P7,K2	Pe4	0,99989	7,6805	1,5280	RK
5	Pe1,Pe3,P6	Pe5	0,97693	30,9931	4,7421	RR
6	Pe4,P8	Pe6	0,99200	12,0805	2,4280	RR
7	Pe6,K3,P9	Pe7	0,99988	16,1877	6,9419	RKR
8	Pe5,Pe7	Pe8	0,97681	47,1808	11,6840	RR
Reduction step:	1 - RR: P1,P2,P3=Pe1	2 - RR: P4,P5=Pe2	3 - RK: Pe2,K1=Pe3	4 - RK: P7,K2=Pe4	5 - RR: Pe1,Pe3,P6=Pe5	6- RR: Pe4,P8=Pe6
Reduction step:	7 - RKR: Pe6,K3,P9=Pe7	8 - Pe5,Pe7=Pe8				

Fig. 7. Examples of videograms. Production module control algorithm: a - functional network; b - reduction report and evaluation result

4 Conclusion

The functional network provides modeling of production management processes, transport, warehouse operations, and preparation of control programs. It is a convenient tool for assessing the accuracy and timeliness of the implementation of FMS functions. The information technology developed on the principles of functional network reduction is a convenient tool for a variant analysis of automated control processes in FMS.

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