Modeling and Simulating the Work of Robotics Technologic Modules

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Abstract: In the conditions of the market economy and restructuring of the economy, the Robotics Technologic Modules (RTM) and systems are an appropriate decision for automation of the small and middle businesses and companies. The pre-modeling and exploration of their work lets to be received preliminary idea for the functions of the system as a whole. The simulation modeling is in effective method exploration of RTM without risks, it makes possible to reveal the simultaneous factors and to determine their places.

Some schematic decisions are revealed, regarding to the work cycles. For the most used typical decisions, is proposed simulation model for exploring the work state and the effectiveness of RTM. The state of the structural nuits are defined and model scenaria for are revealed.

Key words: robotics technologic module (RTM), structure of RTM, structural elements, simulating, examining.

I..INTRODUCTION

There is a big diversification of the objects and the tasks for their automation. For their solution we have to approach from a point of view of their special features as well as giving an account of the fraternity and the unified methodology for their realization. All this requires certain investment so before their implementation it is good to perform a computer research with time for different variants. As a result of this research we get the whole notion about how RTM function as well as their structural components (experimenting without risk).

The purpose of their development on the basis of existing structures of RTM is, through modeling and simulating, to examine the working of RTM with an eye to the choice of an effective solution.

II. STRUCTURES OF RTM

The Robotics Technologic Modules represent a totality of technologic unit (TU), an industrial robot (IR) and a pallete trolley (automating devices), unified by a general system for automated control.

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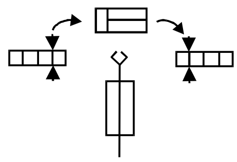
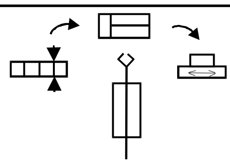
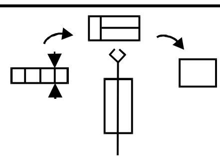
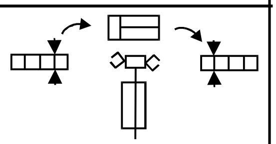
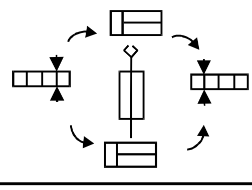
In the flexible automated manufacturing TU has a compulsory digital program control. In general the type of the station defies the difference in the structures. Sort, type size and models can distinguish the structural components.

When setting up the RTM structure attention should be paid to the technical features of the components which construct it and to the cultivating objects. The analysis of the details allows the determination of the working space and the determination of the structural units of the RTM considering the type of the working space, the loading capacity and the type of the IR grip as well as the type of the storage devices.

TABLE I.
TYPES OF STRUCTURAL SCHEMES OF RTM

№	Simptoms	Structure
1	TU = 1 IR = 1 MA = 1 CM-C CM-C	
2	TU = 1 IR = 1 MA = 1 CM-C TD	
3	TU = 1 IR = 1 MA = 1 CM-C SP	
4	TU = 1 IR = 1 MA = 2 CM-C CM-C	
5	TU = 2 IR = 1 MA = 1 CM-C CM-C	

Explanation: MA – mechanic arm (a grip); CM-C – charging magazine collector; CM-C – conveying magazine collector; TD – time device; SP – specialized

Structures of RTM can be built by using the following **basic variation indications:**

- Number of TU

- Number of IR
- Number of grips
- Type of charging magazine devices
- Type of conveying magazine devices
- Position of the structural units
- Type of technologic operations

Additional indications:

- Class of automating device
- Reciprocal disposition of the components; a possibility for connection to other similar RTM;

A structural RTM should be built in the form of a relatively independent system, that has an opportunity for unlimited growing.

In Table.I are shown some of the characteristic structural solutions for RTM.

An important factor when choosing the RTM structure is its productiveness. The cycling productiveness of RTM depends on the cycling time and it does not count the out-of-cycle losses in the time through the fault of instruments, devices, organizing causes and so on. The cycling productiveness Q is determined by this formula:

$$Q_{Ц} = \frac{1}{T_c} = \frac{1}{T_M + T_{s.n..}}$$

(1)

Where: T_c - is the time in a cycle;

$T_м$ – mechanic time;

$T_{s.n.}$- Subsidiary non-recovering time, when the machine stops so it can be served by the IR;

It is necessary: $T_{s.n..} \leq T_м$

Through analyzing the productiveness of different structural RTM solutions it can be choose a robotics module with high efficiency and minimal continuance of the subsidiary non-recovering time.

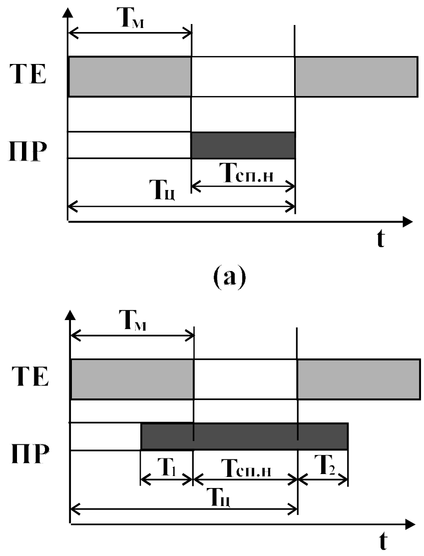


Fig.1. Cyclorama of RTM
a-RTM with IR with a single grip; b – with two grips;
$T_1 + T_2 = T_{s.n}$ subsidiary non-recovering time;

Figure.1. Shows cycloramas for structural variants which were represented in Table.1: (a) - variants of RTM with IR with a single grip; (b) – IR with two grips

In the first case (a) – the time for serving the TU by IR ($T_{t)}$ is equal to the subsidiary non-recovering time: $T_t = T_{s.n.}$

In the case (b) the subsidiary non-recovering time is obligatory decreased which leads to a higher cycling productiveness: $T_t = T_{s.n.} + T_{s.p.}$

Thus a minimum stay of TU is achieved with maximum load of IR

III. STIMULATING THE RTM WORK

The development of the computer technologies has created opportune preconditions for projecting and examining RTM and systems with the help of simultaneous modeling.

The simultaneous modeling is a creative method for examining the accidental operative process and factors in the time. It allows the discovery of accidental operative factors on the work of the robotics system so the results are very close to the actual ones.

The result of the simultaneous modeling is the simultaneous model that serves for the examining of RTM behavior in different situations of work and different disturbances from the outside which can change stochastically. In the simultaneous model more of the dependencies between the parameters are in a vague aspect which makes very difficult their analyzing and the search for the solution.

The mathematic models for simultaneous modeling can be determined and stochastic. More interesting are the stochastic ones. The examinations is made with time when in an arbitrary intervals of time, in the frames of the time for modeling, the state of all structural elements and the system as a whole can be followed. Two types of algorythms are typical for the simultaneous modeling:

- Algorhythms with a constant (determined) step – there is a possibility to follow the condition in a desired interval of every structural element. It is simpler and requires more computer time for completing the examination.
- Algorhythms with an inconstant step – only the intervals of time, where the change is expected to set in the condition of a specific structural component, are examinated.

The robotics systems are determined on the basis of two different multitudes – a multitude of elements and a multitude of the relations between them. Elements of RTM are: TU, IR, PT and more.

For exploring the complex of questions on the examination of RTM and systems the theory of mass servicing (TMS) is used. TMS gives the methods for analyzing the processes of functioning of the manufacturing systems when the time for servicing the applications is a casual quantity and the applications come in accidental moments of time.

The more of the simulation models use casual quantities so they compensate detailed information about what is going to happen in the process of real life. The occurrences, which are modeled in such, ways include: choice, quantities, frequencies, intervals and continuance. Suitable probable apportionment is chosen and the computer is programmed to generate casual quantities from this apportionment.

The following probable apportionments are used: constant, exponential normal, triangular, apportionment of Poisson.

In the mechanical engineering the most broad application find the exponential and the normal (Gauss's) apportionment as in some cases it is possible the application of the constant one.

The stages and the relations between them, when working out the simulation model, are illustrated on Fig.2.

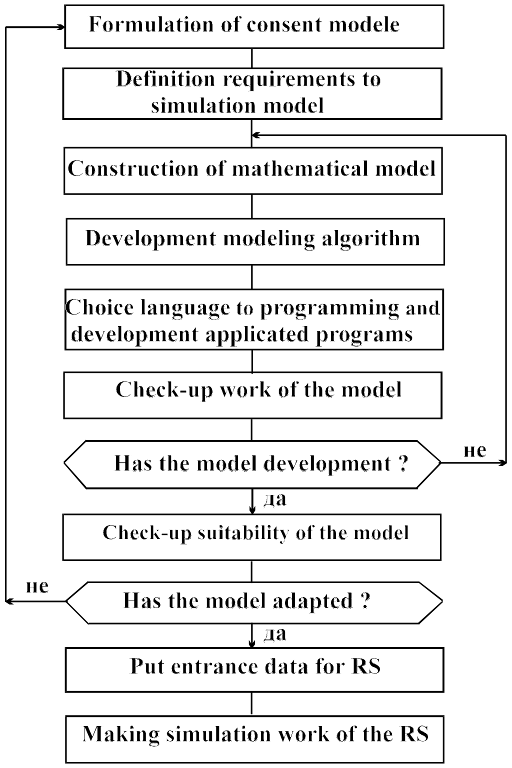


Fig. 2. Block-scheme – stages of working out the simultaneous model

The RTM functioning is considered for an exact interval of time. It can be represented as accidental sequence of discreet moments of time t_i (i = 1 ÷ n), while in every one of these moments changes occur in the state of a single one or some structural elements and in the gaps of time no changes in the state occur. It is necessary to follow the rule: the event that occurs in the t_i can be modeled only after modeling all the events, which have occurred in the moment t_{i-1} . Otherwise the result of modeling can turn out to be false. The mechanism of RTM modeling with determinate step is as follows:

- At the i-step of moment of time t_i all he elements of RTM are examined and it is determined which one of them can change their state in this time.
- All the changes in the state, which can occur in a given moment of time t_i, are modeled
- A transition towards the moment of time is completed $t_{i+1} = t_i + \Delta t$, while the step Δt is performed until the time for modeling is over.

The continuance of the process is interpreted as a casual quantity, put with the function of F (d) or the function of the density of the possibility f (d). For rating the continuance of the process d we use the mathematic expectancy m (d):

$$m(d) = \int_a^b f(d)dd \qquad (2)$$

Where: **a** – is the shortest possible continuance of the process; b – the longest possible continuance of the process.
In general terms the simultaneous model can be represented mathematically in this way:

$$F = f (X_i , Y_i) \qquad (3)$$

Where: F – is the result of the operation of the system; X_i – dirigible changeable parameters; Y_i – non- dirigible changeable parameters, which determine the value of F.

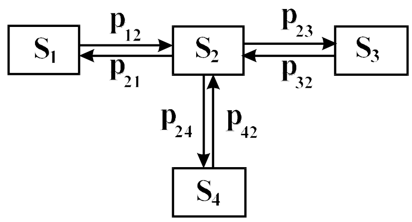


Fig. 3 Similar Markovsky chain for the states of TU

TABLE II.
STATES OF TU

State	Description of the state	Code
S_1	Stops because of lack of blanx	0
S_2	Works	1
S_3	Stops because its own unreliability	2
S_4	Stops for a change of the grip	3

For TU of RTM are determined the following four characteristic conditions, which are shown in the table.II.

The four listed conditions of TU can be described through Markovsky chain - Fig.3.
The matrix of the previous probability for technological unit is:

$$\left\| p_{ij} \right\| = \left\| \begin{matrix} p_{11} & p_{12} & 0 & 0 \\ p_{21} & p_{22} & p_{23} & p_{24} \\ 0 & p_{32} & p_{33} & 0 \\ 0 & p_{42} & 0 & p_{44} \end{matrix} \right\| \qquad (4)$$

The elements of the matrix of the previous probability, when there is no change of the state are defined by the following dependencies:

$$\begin{aligned} p_{11} &= 1 - p_{12} \\ p_{22} &= 1 - (p_{21} + p_{23} + p_{24}) \\ p_{33} &= 1 - p_{32} \\ p_{44} &= 1 - p_{42} \end{aligned} \qquad (5)$$

TABLE.III.
IR STATES

State	Description of the state	Code
S_5	Stops because of lack of blanx	0
S_6	Brings blanx towards TU	0
S_7	Carries worked details towards the palletes	2
S_8	Stops because its own unreliability	3
S_9	Stops for a change of the grip	4

For IR are delimited five conditions – TableIII.

The above given five states of the industrial robot can be represented with the Markovsky chain that is shown on Fug.4.

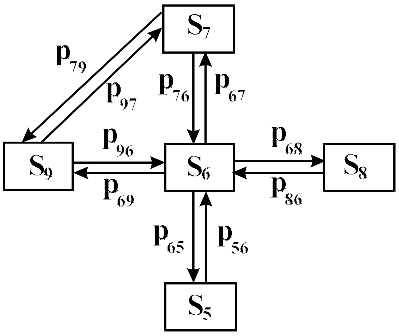


Fig.4. A uniform Markovsky chain of IR states

The matrix of the previous possibility for the industrial robot will look this way:

$$\left\| p_{ij} \right\| = \left\| \begin{matrix} p_{55} & p_{56} & 0 & 0 & 0 \\ p_{65} & p_{66} & p_{67} & p_{68} & p_{69} \\ 0 & p_{76} & p_{77} & 0 & p_{79} \\ 0 & p_{86} & 0 & p_{88} & 0 \\ 0 & p_{96} & p_{97} & 0 & p_{99} \end{matrix} \right\| \quad (6)$$

The element of the previous matrix, when they do not change their states, is determined by the following dependencies:

$$\begin{aligned} p_{55} &= 1 - p_{56} \\ p_{66} &= 1 - (p_{65} + p_{67} + p_{68} + p_{69}) \\ p_{77} &= 1 - (p_{76} + p_{79}) \\ p_{88} &= 1 - p_{86} \\ p_{99} &= 1 - (p_{96} + p_{97}) \end{aligned} \quad (7)$$

Modeling the work of RTM is based on the construction of the Petrie's nets, which gives the connections between TU and IR.

On Fig.5. Is shown an exemplary scheme of a Petrie's net for RTM.

In TableIV.are represented some of the results when simulating the mechanic of RTM with the help of computer technology while achieving minimal stops of the TU at maximum load of the IR (the highest coefficient of loading).

TABLE IV.
RESULTS

Stop	Without blax	Dead load	A change in the grip	Summary	Coefficient of loading
TE	61	240	0	301	0,218
TE	181	0	0	181	0,887
TE	301	0	0	301	0,812
ПР	220	60	0	280	0,825
ПР	220	50	0	270	0,815
ПР	220	60	0	280	0,825

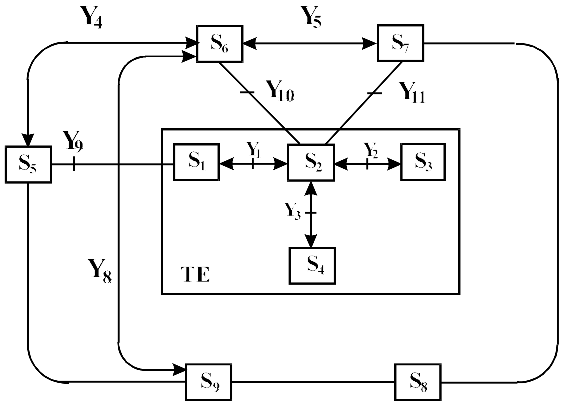


Fig.5. Petrie's net for RTM.
$S_1 \div S_4$ - states of TU; $S_5 \div S_9$ – states of IR; $Y_1 \div Y_3$ - conditions for a change in the state of TU; $Y_4 \div Y_8$ – conditions for a change in the state of IR; $Y_9 \div Y_{11}$ - conditions for a change in the interaction Between TU and IR;

IV. CONCLUSION

When realizing the development the following results were achieved:

- Type-structures of RTM on the basis of the various indications were developed
- The stages and the relations when developing the simultaneous model for RTM were observed.
- A simultaneous model for examining the work of a certain structure of RTM was developed while scrutinizing the states of the structural units and the relations between them were represented using Markovsky chains and Petrie's nets.
- Some of the results completed when simulating RTM were given. They can serve when choosing the effective decision.

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