The formalized approach of building a network controller for the information handling automated process control system of the technological control cycle

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Abstract. The article discusses the use of a formalized approach to building a network controller which bases on a graph of Mealy machine. This approach can be applied in modern automated control systems (ACS), since ACS can be considered as network systems, intended for transportation (transmission) and distribution of flows, including energy and information. A comparison of a fragment of the graph of Mealy machine and a fragment of the flowchart of the algorithm and basic interpretations of their elements is presented. The technological process of applying protective coatings is considered, as well as basic operations that are deterministic. Considered minimization of the state of the graph automaton and the transformation into the flowchart of the technological process operations is obtained. The proposed approach allows obtaining the deterministic characteristics of the information handling automated process control system of the technological control cycle.

1. Theoretical aspects

The modern automated control systems are considered as a network systems intended for transportation and distribution of the energy and information flows. So since each of the subsystems automated control system, in this case there is a need for effective using of the existing technical means and in the rational design of new means. The methods of network analysis are essential in designing and improving of large and complex systems, as well as in the search for ways of their most rational using. Thus, the task of applying the network analysis methods becomes relevant in order that to obtain and evaluate the deterministic characteristics of information processing in the information handling automated process control system.

We consider the application of the formalized approach for building a network controller for information processing an automated process control system of the technological control cycle for solving the problem of obtaining and evaluating the deterministic characteristics of information exchange by components of the heterogeneous environment of the automated process control system [1].
Comparing the fragments of the graph of Mealy machine and the fragment of the algorithm scheme shown in figure 1, you can see that it is equivalent. Here, X and Z are binary vectors belonging to sets of sets of input \{x_i\} and output \{z_i\} signals; Q is the set of states of the projected automaton; and \(Q_i\) and \(Z_i\) are functions of \(Q_{i-1}\) and \(X_i\). The operator rectangles in the block diagram of the algorithm can be interpreted as vertices ("stable" states of \(Q_i\)) in the graph of the machine and conditional operators as arcs of the graph \(X_i / Z_i\), i.e., the transitions to a different state. In this case, the operator rectangle, or the "stable" state of \(Q_i\), is a linear unbranched fragment of the network controller program, in which a monotonically increment command counter (CC) addresses each subsequent instruction. During the \(Q_i\) period, which is uniquely determined by the start and end addresses, the contents of the CC in each instruction cycle take a value increases by one. For these addresses in the memory of the network controller are data, data exchange commands and data transformation commands. During the entire period of the "stable" state \(Q_i\), the input \(X_i\) and the output \(Z_i\) vectors remain unchanged. However, the conditional operators of the algorithm select the changes of the input vector \(X_i\) if it occurs in the \(Q_i\) state under the influence of external events relative to the network controller. As a result of such selection, the network controller pass to another "stable" state \(Q_{i+K}\) which is determined by the scheme of the algorithm [2].

**Figure 1.** Graph machine (a) and algorithm scheme (b).

Since any operator of the algorithm scheme shown in Fig. 1 can be represented by the sequence of machine instructions. The further procedure of projection is a translation, as a result, a sequence of processor instructions is formed and location addresses in the memory cells are determined network controller.

2. Formalization of the technological control cycle the automated process control system of the technological control cycle

The automated control system for the technological process of applying protective coatings to products is considered [3]. The process regulation is a sequence of predefined technological operations:
- Coating application 10 nM (1);
- Coating of 15 nM (2);
- Coating 20 nM (3);
- Coating with 25 nM (4);
- Task Manager (5).
Figure 2. A graph of the technological control cycle of the automated control system for the technological process.

The processes (vertices 1-4) are determined deterministically and the specified value of the coating is applied to the products at each stage, the total value of which is 70 nM (figure 2) [4]. After finish a process the coated detail is moved to a warehouse and control is transferred to the job manager this is a graph vertex 5, which makes decision to transfer of graph vertex control from 1 to 4, respectively, some details with coating from 25 to 70 nM can be obtained.

3. Construction of the graph machine with a transition table
Table 1 shows the formalized description of the system.

| Coating thickness, nM | Coating thickness, nM (binary) | Time of application, second |
|----------------------|--------------------------------|-----------------------------|
| 10                   | $X_1 = 01010$                  | 100                         |
| 15                   | $X_2 = 01111$                  | 150                         |
| 20                   | $X_3 = 10100$                  | 200                         |
| 25                   | $X_4 = 11001$                  | 250                         |

In accordance with a technology, ensuring the given amount of coverage is provided by the specified duration of the operation, the input of graph vertex 5 corresponds to the number $X_5 = 11111$.

We developed the specification of the output control actions (table 2).

Table 2. Specification of output controls control actions.

| $Z_4$ | $B_6$ | $B_7$ | $B_8$ | $B_9$ | $B_1$ |
|-------|-------|-------|-------|-------|-------|
| 0     | 1     | 1     | 0     | 0     | 0     |
| 1     | 0     | 0     | 1     | 0     | 0     |
| 1     | 1     | 0     | 0     | 1     | 0     |
| 1     | 1     | 1     | 1     | 1     | 0     |

Specification of output controls control actions is made by converting the value of the coating time to binary code (8 digits). The vertex output 5 corresponds to the number $Z_5 = 11111111$. 
Figure 3. Machine graph.

Figure 3 shows the machine graph, the arcs are marked with input and output vectors x1x2x3x4x5V ... Vx1 "x2" x3 "x4" x5 "V ... / Z1-5. . , the machine graph bases on tables 1 and 2 is constructed (figure 3). Tables 3-5 illustrate the method of minimizing the number of states of an automaton [5].

Table 3. Table of transitions / outputs.

| Condition | X1, X2, X3, X4, X5 |
|-----------|--------------------|
|           | 01010 01111 10100 11001 11111 |
| 1         | 2, Z2 - - - |
| 2         | - - 3, Z3 - - |
| 3         | - - - 4, Z4 - |
| 4         | - - - - 5, Z5 |
| 5         | 1, Z1 2, Z2 3, Z3 4, Z4 5, Z5 |

Table 4. State minimization table.

| Condition | X1, X2, X3, X4, X5 |
|-----------|--------------------|
|           | 01010 01111 10100 11001 11111 |
| 1,2       | Q1 - 2, Z2 3, Z3 - - |
| 3,4       | Q2 - - - 4, Z4 5, Z5 |
| 5         | Q3 1, Z1 2, Z2 3, Z3 4, Z4 - |

Table 5. Table of marked states.

| Condition | X1, X2, X3, X4, X5 |
|-----------|--------------------|
|           | 01010 01111 10100 11001 11111 |
| Q1        | - Q1 - - - |
| Q2        | - - Q2 Q3 - |
| Q3        | Q1 Q1 Q2 Q2 - |
Figure 4. Simplified machine graph.

4. Transformation of an machine graph into an algorithm scheme

According to the description of the transformation, each operator representing the graph vertex is defined by three parameters: the state Q, the input (X), and the output (Z) vectors. In consequence of absorption Q₁ and Q₂ have one local loop when minimizing the state. The equivalent scheme of an algorithm should reflect these features. For this algorithm constructs in such a way that the controller continuously tests the input actions and makes a decision about the formation of the output vector and the transition to another state [6]. The vertices with two local loops are denoted by indexed labels Q₁ = Q₁A V Q₁B for simplify the testing procedure. At the same time, the task of forming output vectors is simplified because the logical statement reduces to the simplest expression:

- if X = 01111, then Q₁A and Z₂ otherwise
- if X = 10100, then Q₁ and Z₃.

For Q₂ = Q₂A V Q₂B, the expression is as follows:
- if X = 11001, then Q₂A and Z₄ otherwise
- if X = 11111, then Q₂ and Z₅.

For Q₃ = Q₃A V Q₃B V Q₃C V Q₃D, the expression is as follows:
- if X = 10100, then Q₃A and Z₃ otherwise
- if X = 11001, then Q₃B and Z₄ otherwise
- if X = 01010, then Q₃C and Z₁ otherwise
- if X = 01111, then Q₃ and Z₂.

Figure 5 shows the network controller algorithm scheme; it is equivalent to the machine graph.
**Figure 5.** The schematic diagram of the network controller algorithm.
5. Conclusion
Receiving the formalized approach for building a network controller become possible when applying the deterministic characteristics of the information handling automated process control system of the technological control cycle [7]. The obtained results are focused on increasing the correctness (regulating) of the technological control cycle of the automated control system management. This result forms the complex approach in obtaining and evaluating the characteristics of the information processing process in the automated Control System of the technological control cycle.

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References
[1] Kovalev I V, Zelenkov P V, Losev V V, Efremova S V and Khrapunova V V 2016 The algorithmization of the deterministic models technological cycles of automated control systems Vestnik SibGAU 18(1) 58–61
[2] Kagan B and Stashin V V 1987 Osnovy proektirovaniya mikroprossornyh ustrojstv avtomatiki (EHnergoatomizdat)
[3] Kovalev I V, Zelenkov P V, Losev V V, Kovalev D I, Perantseva A V and Burdina E V 2016 IOP Conf. Ser.: Mater. Sci. Eng. 12 012033
[4] Gonzalez J M 1977 Deterministic Processor Scheduling Computing Surveys 9(3)
[5] Kuznetsov P A, Kovalev I V, Losev V V, Kalinin A O and Murygin A V 2016 IOP Conf. Ser.: Mater. Sci. Eng. 19 012020
[6] Kovalev I V, Semen'ko T I and Tsarev R Yu 2005 Metodologiya ocenki i povysheniya nadezhnosti programmnno-informacionnyh tekhnologij i struktur (Feder. agentstvo po obrazovaniiyu: Krasnoyar. gos. tekhn. un-t)
[7] Philips D T 1981 Fundamentals of network analysis (Prentice-Hall. Inc)