Petrii Net as a Tool for Modelling the Microprocessor Measurement-Control System Used in Critical Applications

Ryszard MIELNIK

Department of Electrical and Computer Engineering, Cracow University of Technology, 24 Warszawska St., 31-155 Cracow, Poland

ABSTRACT.

The paper presents assumption for a microprocessor measurement-control system (MMCS). For synthesis this system the Petri net was used. On the basis of the analysis of the operation of MMCS there were formed sets of elementary events and conditions defining when particular events could take place, or conditions resulting from a given event. On this basis a Petri net for MMCS was worked out. Using formally prepared specification of the task, a general idea of software was worked out. For application idea of software is used of the SFC language for PLC controllers.

Keywords. Petrii net, microprocessors control system, critical applications.

1. INTRODUCTION.

The design of modern microprocessor measurement-control systems applied in such fields as nuclear and power, chemical, metallurgical industries, air, sea and rail transport, military and telecommunications applications requires a special approach to the philosophy of design, manufacture and use of such systems. This follows from the fact that in case of damage or failure of the system the object or its surroundings might be exposed to danger, which could cause life loss and material waste. Therefore attention should be focused on safeguarding the required level of reliability and safety of working conditions of such systems. These two terms when referred to the applications mentioned above lead to the definition of reliability of computer systems in critical applications [12]. Such systems are designed and produced after certain specifications [11], [12] which can be divided into four phases according the cycle of microprocessor systems design: specification of tasks, software production, manufacture of hardware as well as verification and conformity confirmation of the whole system on an example of a microprocessor system for an automatic railway crossing signaling.

2. PETRI NET.

The Petri net [4], [11] is usually used to denote a triple

$$PN = <P, T, S> \tag{1}$$

in which:
P - *non-void set of places,*
T - *a non-void set of transitions,*
S - *a non-void set of arcs connecting places with transitions and transitions with places.*

Function:

$$M : P \rightarrow K \tag{2}$$

where:
K = *{0, 1, 2, ...}*

serves as M marking for PN net, which assigns to each place P a non-negative integer determining the number K of indicators in the given place.
The marked net MPN refers to pair

$$MPN = < PN, M_o > \tag{3}$$

in which:
PN - *denotes Petri net,*
M_o - *initial marking.*

Each marking can be presented by means of vector

$$M = [m_1, m_2, ... m_n] \tag{4}$$

where:
n = *card(P),*
$m_1, m_2, ... m_n$ - *represent the number of indicators in places $p_1, p_2, ..., p_n$, respectively.*

The basic essential event that can take place in the marked net is transition excitation. The only transition that can be excited is a prepared one. Transition t of MPN net is prepared by marking M only when each input place of transition t has at least one indicator. Each transition prepared by marking M determines new marking of the net. In a given marking process the number of prepared transitions is larger than one, we have the case of conflicting transition. In such case the choice of transition to excitation is of random character. Marking M_j is directly attainable from marking M_i only when in marking M_j there a prepared transition t such that its excitation transforms marking M_j into M_j . Marking M_j is attainable from marking M_j if there is a sequence of markings $M_0, M_2, ..., M_n$ such that:

$$M_{i0} = M_i \ and \ M_{ik} = M_j \ and \ \underset{1<l<k}{\forall} M_{il\,-1} \xrightarrow{\ til\ } M_{il} \tag{5}$$

The set of all markings attainable from initial marking M_o is a set of markings attainable M of marked net MPN = <PN,M>.

The graph directed:

$$G = \langle \vec{M}_0 , F \rangle \qquad (6)$$

where:

F - *a set of directed edges* $F \leq \vec{M}_0 \, x, \vec{M}_0$.

Following the definition, graph represents all the states in which net can appear (M_0) all the ways of variations of these states. Due to an analysis of such a graph of any constrained net it is possible to examine the following properties of the given net: its liveliness, sticking, stability, invariance and incompatibility.

3. MICROPROCESSOR MEASUREMENT-CONTROL SYSTEM.

3.1. Automatic railway crossing signaling.

Level railway crossings belong to a group of engineering solutions of particular hazard to road safety. Road safety can be improved by installing warning devices or such that close the danger area of the crossing. Such devices can be switched on by the railway staff or automatically by an approaching train. Most devices used by the Polish and foreign railway companies are based on relay tectonics, which are of low functional and in-service flexibility. The microprocessor systems of automatic crossing control, introduced by some rail companies abroad, have produced favorable results [5], [6]. What is characteristic of these systems is that a point criterion of train movement was adopted, which was realized by various types of track sensors. The basic aim of crossing control devices is to achieve maximum efficiency of the crossing, which minimum working period. To keep the warning period constant, depending on traffic and technical conditions, it is advantageous to measure the basic parameters of train movement, i.e. its speed and acceleration. The train movement parameters can be measured in three variants: single at the beginning of the approach section, several times along the approach section, continuously along the whole approach section. The train movement parameters can be obtained indirectly by measuring the module and/or input impedance argument of track circuit or impedance of specially arranged loop circuit [13] followed by calculations. The calculation algorithm for continuous and point measurements of train movement parameters were given in [7], [9].

3.2. Functional model.

The MMCS functions formed on the basis of technical and movement assumptions could be classified as discrete events (processes). To design a model of discrete events

system, which is a formal form of specification of real system tasks, special attention should be paid to the possibility of modeling events occurring simultaneously. On the basis of the analysis of the operation of MMCS there were formed sets of elementary events and conditions defining when particular events could take place, or conditions resulting from a given event [13]. On this basis a Petri net for MMCS was worked out [13]. Applying the rules of net reduction [4] a reduced net for the system was worked out [8] - fig. 1.
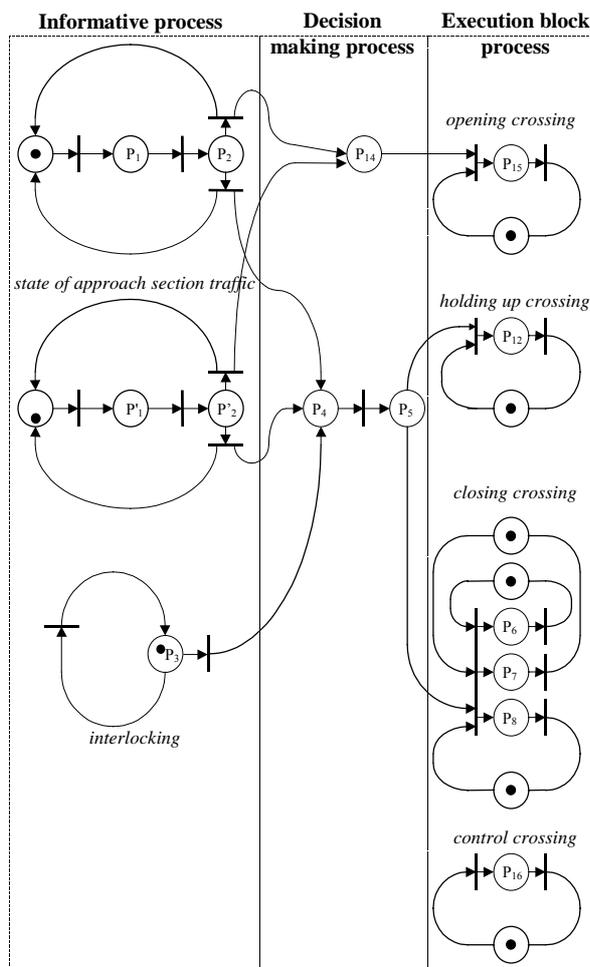

Fig. 1 Reduced Petrii net for MMCS.

An analysis of this net made it possible to separate three basic processes taking place in MMCS:

- informative process which transfers information to the process making decisions on: approach sections traffic and crossing section as well as signals of crossing closing or lifting coming from devices,

- decision making process which chooses input signals of crossing closing, holding up or lifting for the execution process,
- execution block process, which comprises execution sub processes.

Following further analysis a general Petri net was obtained [2] -fig. 2.
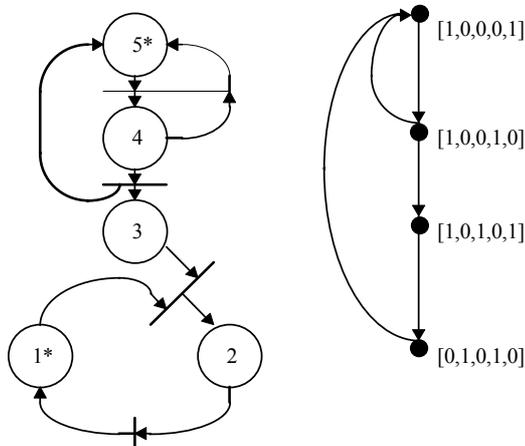
Fig. 2. The general Petrii net and the graph of attainable marking allows for MMCS.

The identified places are:
1 - end of one of the sub processes: closing, holding up, lifting, control or decision and transition to information receipt event (if there is one),
2 - end of information receipt,
3 - end of information transmission,
4, 5 - conditions allowing control of approach section states and transmission of information on the state.

Places 4 and 5 are markers generators; place 3 transfers them to places 1 and 2 where they are absorbed. This means that each piece of information on approach sections state reaches the decision-making - execution processes, is then interpreted and executed. The graph of attainable marking allows - fig. 2 - a statement that the net is lively, active, stable, 3-side constrained, safe and it is a net of conditions and events.

4. SOFTWARE

Using formally prepared specification of the task, a general idea of software was worked out – fig. 3. Since the informative and decision making processes are parallel, a proposition was made [13] to use two independent microprocessor systems one being supervisory (decision - control), the other subordinate (measurement) transmitting the measured and processed data on approach sections state. The measurements system actually comprises implementation of the algorithm of calculating access time [9] on the basis of track circuit measurement. The decision - executive program was implemented on the PLC controllers.
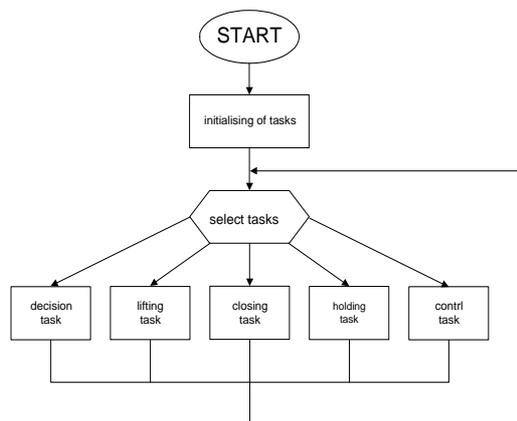
Fig. 3. The general block diagram of software for MMCS.

Block 3:

```
ACTION (P) :
      sydrog:=false;
      uklprz:=false;
      zamawar:=false;
      zamykanie:=false;
      kontrzap:=false;
      akust:=false;
      (*Sygnal1:=false;*)
END_ACTION;
```
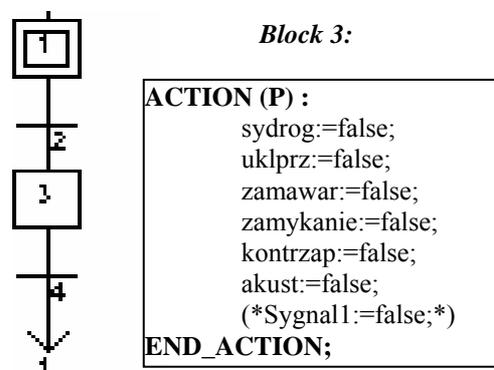
Fig. 4. Application lifting task in SFC language.

The latter one responds to data coming from subordinate informative systems and stores them all. The system program executes the tasks of decision making, device control, closing, holding and lifting. Software in the SFC language of PLC was worked out. For example application lifting task in SFC language is shown in fig. 4. When designing and starting the program it was helpful that it had been divided into the above-mentioned procedures, which made it easy to test or modify any of them. The software is open to new segments assuring the required level of reliability and safety of the system.

5. CONFORMITY CONFIRMATION AND VERIFICATION OF THE SYSTEM

The MMCS, being a measurement-control system working in critical applications, must be certified and verified before it is allowed in use. The tests must include at least those required for devices used by the Polish railway so far. The formal model, using Petri net, points out the elements of the system and their functions, which definitely meet the reliability and safety requirements. It also enables simulation test and proof of the system operation safety.

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