

MODELLING OF HYDRAULIC CONTROL SYSTEMS USING THE COLOURED PETRI NETS

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Abstract

This paper considers the class of Coloured Petri Nets. Their basic idea and formal definition is presented. Application possibilities for system modelling are shown in the example of one hydraulic control process. In that way, significantly simpler and more compact models are obtained. Specificities of these nets simplify the models of complex systems with identical subsystems.

Key words: Coloured Petri Nets, hydraulic control system, modelling, folding

1. INTRODUCTION

In the recent years, Petri Nets (PN) have experienced a very rapid development and wide application. They have become an efficient apparatus for analytical and simulation studies, for modelling the asynchronous, discrete and stochastic processes, for behaviour analysis, optimization and synthesis of various systems. In order for these tasks to be more successful and effectively implemented and considering the specificities of various fields, theoretical development of Petri Nets follows the direction of „enlargement” i.e., it comes to the formation of various kinds and types. A large number of authors adapted the basic idea to their own purpose, and thus the so-called „extensions” of Petri Nets, i.e. new forms were obtained. From „ordinary” Petri Nets of the first, lower level, the nets of the second, higher level, originated. Considering the purpose and characteristics, their number is very big. Some of them are: black and white PN, coloured PN, hierarchical PN, timed PN, signal interpreted PN, modular PN, stochastic PN etc. Some nets were named by their authors (e.g. Robert Esser's, Petri Net, Thomas Braun's Petri Net) and some by the specificities of purpose (e.g. communication, automated, simulation, etc). In this paper, the class of Coloured Petri Nets (CPN) is considered; their basic idea is presented, as well as formal definition and possibility of their application in modelling of the work dynamics of hydraulic control systems.

2. FORMAL DEFINITION OF ORDINARY AND COLOURED PETRI NETS

Ordinary Petri Net can be defined as a 5-tuple $PN = (P, T, I, O, M)$, where:

$P = (p_1, p_2, \dots, p_n)$ – finite set of places;

$T = (t_1, t_2, \dots, t_n)$ – finite set of transitions;

I – input function – directed arcs from transitions to places;

O – output function – directed arcs from places to transitions;

M – marking—defines the number and allocation of markers in the places of the net.

Coloured Petri Net can be defined as a 6-tuple $CPM = (P, T, U_o, I_o, M_o, C)$, where:

$P = (p_1, p_2, \dots, p_n)$ – finite set of places;

$T = (t_1, t_2, \dots, t_n)$ —finite set of transitions;

I_o – coloured input function – defines the directed arcs from coloured markers to places;

O_o —coloured output function – defines directed arcs from coloured markers to transitions;

M_o – initial marking – defines the number and allocation of the coloured markers;

$C = (c_1, c_2, \dots)$ – a set of colours.

3. SOME CHARACTERISTICS OF COLOURED PETRI NETS

As it is known, ordinary Petri Nets (PN) have only one type of marker that determines the state of the place. In case of the Coloured PNs, markers are associated with identifications

in the form of colour, i.e. markers are coloured dots. Using the Coloured PN (of a higher level), the state of the system can be more precisely described since each marker carries a more complex information. Two versions of Coloured Petri Nets were developed, where the second one is more advanced and sophisticated (2).

Transformation of ordinary PN into coloured PN is performed by the operation called the folding. (2).

Although the properties of Coloured Petri Nets are the same as the properties of ordinary Petri Nets, there are some specificities of the former ones, among which the following are the most important:

- Places are associated with a set of coloured firings;
- Transformation of colours occurs during the transition firing;
- Input and output branches of transition are marked by so-called associated functions;
- Functions of the output branch define the number and colour of the marker that will be removed from the input place at the time when the transition fires;
- Functions of the input branches define the number and colour of the marker that will be added to output places of the transition;
- A branch without a coloured transformation is associated with an identical function (Id) (which is often not written).

4. MODELLING THE DYNAMICS MODELIRANJE DINAMIKE RADA HIDRAULIČKOG UPRAVLJAČKOG SISTEMA

Hydraulic control system consists of two hydraulic cylinders A and B, and it is shown in the Figure 1. His work cycle, i.e. the order of cylinders activation is: [A+ B+ B- B+ B- A-]. Ordinary Petri Nets that describe the dynamics of movement of the cylinders A and B are shown in the Figure 2.

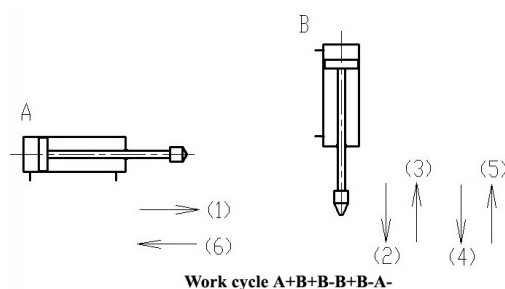


Figure 1. Hydraulic system

In the process of folding of Ordinary Petri Nets, two coloured markers were introduced (two

differently coloured dots). By the formation of Coloured Petri Net, a significantly reduced model of the dynamic work of the observed hydraulic system is obtained, as shown in the Figure 3.

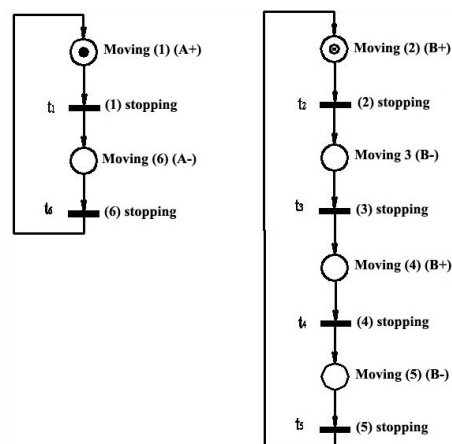


Figure 2. Ordinary Petri Nets for the movement of cylinders A and B

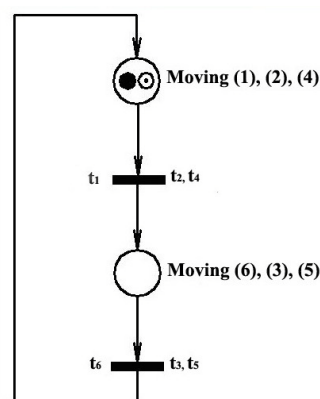


Figure 3. Coloured Petri Net

5. CONCLUSION

The application of the Coloured Petri Nets when modelling a system obviously provides complex, but simpler and more compact graphical models. For that reason, this class of nets is suitable for the application in case of the complex systems, especially if they contain identical subsystems. In this case, it is shown in the example of modelling the dynamics of functioning of the hydraulic control system.

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