Analysis hierarchical model for discrete event systems

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Abstract. This paper presents the hierarchical model based on discrete event network for robotic systems. Based on the hierarchical approach, Petri network is analysed as a network of the highest conceptual level and the lowest level of local control. For modelling and control of complex robotic systems using extended Petri nets.

Such a system is structured, controlled and analysed in this paper by using Visual Object Net ++ package that is relatively simple and easy to use, and the results are shown as representations easy to interpret. The hierarchical structure of the robotic system is implemented on computers analysed using specialized programs.

Implementation of hierarchical model discrete event systems, as a real-time operating system on a computer network connected via a serial bus is possible, where each computer is dedicated to local and Petri model of a subsystem global robotic system. Since Petri models are simplified to apply general computers, analysis, modelling, complex manufacturing systems control can be achieved using Petri nets. Discrete event systems is a pragmatic tool for modelling industrial systems. For system modelling using Petri nets because we have our system where discrete event. To highlight the auxiliary time Petri model using transport stream divided into hierarchical levels and sections are analysed successively. Proposed robotic system simulation using timed Petri, offers the opportunity to view the robotic time. Application of goods or robotic and transmission times obtained by measuring spot is obtained graphics showing the average time for transport activity, using the parameters sets of finished products.

1. Introduction

When using Petri nets, events are associated with transitions. Activities are associated to the firing of transitions and to the marking of places which represents the state of the system. In addition to its graphic representation differentiating events and states, Petri nets allows the modelling of true parallelism and the possibility of progressive modelling by using stepwise refinements or modular composition. Libraries of well-tested subnets allow components reusability leading to significant reductions in the modelling effort. The possibility of progressive modelling is absolutely necessary for flexible manufacturing systems because they are usually large and complex systems. The refinement mechanism allows the building of hierarchically structured net models which leads to the implementation of hierarchical and distributed control [3].

Formally, a Petri net has two types of nodes, called places and transitions. A place is represented by a circle and a transition by a bar. The places and transitions are connected by arcs. The number of places and transitions are finite and not zero. An arc is connected directly from one place to a
transition or a transition to a place. In other words a Petri net is a bipartite graph, i.e. places and
transitions alternate on a path made up of consecutive arcs. [3]

An ordinary Petri net is represented by the 5-tuple $G = \{P, T, F, W, M_0\}$ such that:

- $P = \{p_1, p_2, \ldots, p_n\}$ is a finite, not empty, set of places;
- $T = \{t_1, t_2, \ldots, t_m\}$ is a finite, not empty, set of transitions;
- $F \subseteq (P \times T) \cup (T \times P)$ is the set of arcs;
- $P \cap T = \emptyset$, i.e. the sets $P$ and $T$ are disjointed;
- $W : F \rightarrow \{1, 2, 3, \ldots\}$ is the weighting function arcs;
- $M_0 : P \rightarrow \{0, 1, 2, 3\}$ is the initial marking.

Presentation formalization is:

1. Crowds $T$ and $P$ are disjoint, $P \cap T = \emptyset$
2. To ensure the definition, crowds $T$ and $P$ satisfy the condition $P \cup T = \emptyset$
3. Define the weighting function can extend the set of all ordered pairs of
   $$(P \times T) \cup (T \times P), \quad W : (P \times T) \cup (T \times P) \rightarrow \{0, 1, 2, 3, \ldots\},$$
   pairs that are not in the set $F$, function value $W$ is 0 and those pairs are not graphically represented. As the crowd $F$ corresponding to non-zero pairs that share only this plot a graph.
4. The network capacity is infinite, because the definition of Petri network believes that all network positions may contain any element.
5. They follow the notation of topology which specifies that a general Petri net structure $N = \{P, T, F, W\}$, that is without any specification related to the marking is denoted by $N$.
6. A Petri net with initial marking $M_0$ is denoted $(N, M_0)$.
7. A Petri net with some marking $M$ is denoted $(N, M)$.

In modelling system conditions and transitions positions represent events. Event have a number of entry and exit positions for the event. Items in position to be understood as logical values true condition associated with the position.

2. Description of the process

The analysis is an advantage for industrial systems, so using production cell consists of 6 components: 2 conveyors, 1 robot arm, 1 elevator, machine tool, a crane transport.

The system analysed in its initial form, the classic is relatively simple, but hierarchical system leads to a complex system, and graphical representations which can be obtained after the simulation provides useful information for any system.

The whole system forms a closed circuit. The production cycle is continuous and dynamic. Robot with two arms is to take the elevator blank, submit it to the machine tool and the second arm picks a work piece and deposited in the warehouse. The elevator rotating charged with material from the conveyor belt and positioned to the robotic arm.

Conveying and storage are powered by electric motor that can be turned on or off depending on the program of monitoring and control. A photoelectric cell mounted at the end of each band serves as a flow tracking.

Elevator rotary role performs vertical and rotational movement of the table depending on the robot arm. Robot arm is unable to work vertically. Electromagnets, attachments are not rotating and can not work at varying angles. The advantage is that there is placed an analogue potentiometer which indicates the angle of rotation of the table. Boolean switches are activated when the weight reaches the upper or lower position.

The robot consists of extendable arms placed at different levels and pivot rotation. The position of each arm must be withdrawn when the robot rotates or perform the duties of an arm, that processing or
submission blank piece. Robot arm extensions and rotation angles are indicated by means of potentiometers. In the processing, because it is a different placement level of the robot arm, there are two loading positions of the blank on each machine tool and a work piece discharge from the machine tool. Adjust the positions corresponding to switches the signal. The role of the crane is to provide a continuous supply of semi-finished goods storage conveyor without involving other additional external component. The set of sensors of the crane comprises switches that are activated if the retainer is positioned above the belt and a potentiometer that determines the height of the grip.

3. Modelling with hierarchical Petri Net
To be able to express security requirements relating to physical devices, the model must be designed to contain a description of the working environment to adapt their behaviour to situations that may occur (not provided).

Planning complex processes face the problem of describing the workload characteristics and their interactions in a concise and easy to understand. One of the basic strategies for achieving this function is a hierarchical approach.

Within the complex processes by analysing the characteristics of the system according to the blank transported considering the general case. A particular case where it can be studied in future work in the system is to be used for the transport of hot blanks, that is, in the steel rolling system. [4]

![Petri Net Diagram](image)

**Figure 1.** The hierarchical levels with Petri Nets [4].

In level 1 Petri Net is presented to the highest level network, a hierarchical transition and is used for level 2 Petri network. At level 2 transition Petri Net is a lower level hierarchical Petri Net. This mechanism can be used to achieve hierarchical decomposition of a complex system.

Under this system could be divided into different levels of detail from top to bottom. The concept of hierarchical structure information can be used effectively. The upper level offers a higher level of abstraction and detail a complete plan without extensive and complex hierarchical system. At the lowest level it offers a high level of detail on Petri Nets modelling form and is working at the complex tasks of system. [4]

The concept of transition hierarchical modularity provides features programming technique using Petri net based systems. Many repetitive technology components can be found and adapted to complex systems. These units can be combined repetitive work in "mock" and referenced a "hierarchical transition". This "transition hierarchical" network can be specified as a number system based on repetitive components in the system. The modularity can be adopted for the benefit schemes involving repeat modules workplaces.
4. System modelling

Figure 2 presents the classical structure modelled with Petri nets, from which depart in order to analyse hierarchical system. The classic is the representation of Petri Nets model with factors indicated in the first chapter.

![Figure 2. Classical structure modelled with Petri nets.](image)

![Figure 3. Increased flow after initial processing.](image)

![Figure 4. Transport blank in the classical system.](image)

Shaped structure of the system under analysis is provided below and is presented analysis system.

![Figure 5. Model built with Petri Nets.](image)
The modelling used to describe a manufacturing system consisting of a set of sorting or selection of material and then using the appropriate conveyor belt six work stations or components which interfere with the flexible robot arm with a role of charging the material to be processed and after processing requires the use of robot arm for depositing. Ready processed material is transported in mobile storage where the process continues, but not shown in the model. Real time processing times are selected from the specifications of processes and transport times were selected after changing the location of the equipment system to optimize transport times, but without interfering calling strings.

![Figure 6](image1.png)  
**Figure 6.** Graphical representation of the average for the first conveyor transport.

![Figure 8](image2.png)  
**Figure 8.** Graphical representation of average flux through the semi finished products elevator.

![Figure 7](image3.png)  
**Figure 7.** Graphical representation of the average occupancy of the machine.

![Figure 9](image4.png)  
**Figure 9.** Graphical representation the system for monitoring the first robot arm.

For the analysis of variance monitoring and control of production flow are considered only nodes and transitions without extensions. Monitoring and control system was developed and analysed step by step, as described in the literature. The model of cooperation is described abstractly in sync aspect cell components.

The bottom is made up of the following steps:
- Analysis of reusable models on communication,
- Communication between devices, identified and modelled as Petri nets,
- Complete model is built by composing courts by merging communication places.

The description has led process control with Petri nets.
Figure 5 shows the basic relationship between neighbourhoods. The entry and exit restrictions are modelled. According to the requirement of mutually exclusive, should be run to ensure a good flow in order to avoid errors in the manufacturing system.

Robot arms are held separately to increase the degree of parallelism in the production cell. To avoid collisions shared regions are set to be used exclusively. In this study, are problems that disappear in a constructive way so the robot arms and crane are allowed to move only when the arms are retracted and the crane is raised.

For analysis, figure 6, figure 7, figure 8, figure 9 are considered three types of communication model regions in the order of input, output, control and release.

5. Conclusions
Analysis with Petri nets in this type of hierarchical control system is applied after each step. Analysis of a successful model at a given hierarchical level is considered a prerequisite for the next stage of modelling. Thus, faults and design errors can be detected early.

To date models based on Petri nets to control cell production, analysed the hierarchical levels have developed valuable qualitative properties, which can be used successfully for production systems. The paper has not been described Petri net model, but used to delimit restrictions and management analysis tools.

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