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INTRODUCTION TO COMBINED DYNAMIC SYSTEMS

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ABSTRACT: The main of this paper is to draw attention to the new potential hidden in the combined discrete dynamic systems, which could represent new type of distributed systems for the industrial automation and could contribute to the faster design and development of the control system.
KEYWORDS: distributed control system, IEC, combined systems, real-time, events

❖ INTRODUCTION

The interest in the new technologies and architectures for creating next generation distributed system for the industrial automation is rapidly increasing. For developing the competitive and advanced products the companies have to be able to rapidly design and create new types of progressive automated production. The key characteristic of this new systems would be the ability of the quick reaction to change the manufacturing system and manufacturing type and the application of the new processes required by the conditions and the market, eventually global standards, as for example standards IEC 61131 and IEC 61499, which together with the new technologies would have and they have enormous effect on the design and implementation control system.

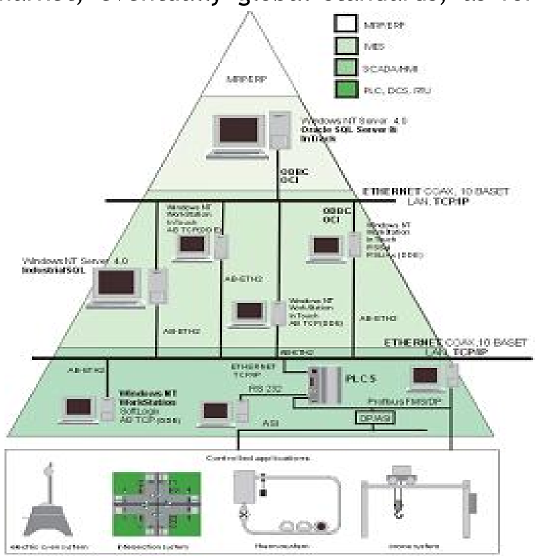

Fig.1. The Complex of information and control system

❖ STRUCTURE OF THE DISTRIBUTED CONTROL SYSTEM

The core of the automation and automated production is the control system, and all functions in the system, including the control functions, are realizing by the automatic instrumentation and automatic controllers. The control system intelligence through the instrumentation penetrates directly to the control process. The instrumentation represents the actuators and sensors, which are communicating with the major control systems (e.g. programmable logical controllers, PC, microcomputers, SCADA/HMI systems) through the serial communication channel or can be even equipped with the microcontroller for the signal processing and the realization of the control and regulation algorithms (fig. 1). This system can be one of the components of the information and control system and presents the distributed and automated control system.

One of the problem of the distributed control system is the optimal task distribution in the distributed control - what should keep at the technological level and what should be transferred to the visualization level, or how optimal distribute the performance between more control computers at the visualization and control level(fig. 2).

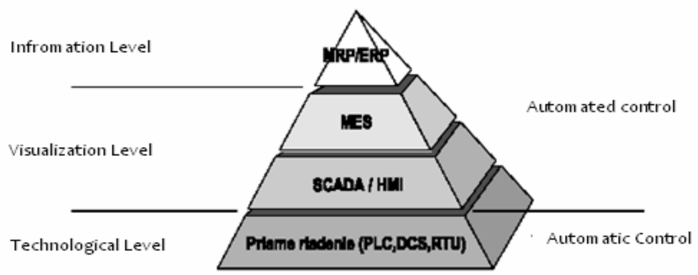

Fig.2. The Layers in the Distributed control system

For the automated control system developing is used its abstraction in the shape of the discrete (eventually hybrid) dynamic systems designed and developed by the methods of

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the discrete dynamic system analysis and synthesis. The processes in the discrete dynamic systems can run and be activated according to the events (discrete event dynamic systems), which appear in the particular systems, or according to the time (discrete dynamic real-time system) (Halenár, 2011). The difference between these discrete dynamic systems consists in the prediction – while the prediction in the discrete event dynamic systems (DEDS) is impossible, in the discrete dynamic real-time systems is the prediction possible.

The cooperation of these two systems offers us the new possibilities of the utilization –that means development of such control discrete dynamic system, which would optimally use the abilities of the real-time control system and the event-activated system. Therefore is needed to specify the dynamic properties of the control and visualization of this combined discrete system, including the signals discretization, their spectrum analysis, filtration a interpolation [2], the design of the applicable control structure, which would effectively use the benefits of both systems and minimize their output negatives, and design, development and optimalization of the control algorithms according to dynamic properties.

❖ COMBINED SYSTEMS

Combined systems include two parts of discrete systems: discrete time-dynamic-activated systems, as well as discrete events systems. This system consists of a combination of cyclically recurring processes in each period of processing and the stochastically emerging events. The fusion result of time-driven and event activated systems are combined dynamic systems, called also hybrid systems. In case that notion "Hybrid system" is used in connection perhaps between distributed control system and programmable logical controllers, neural networks, genetic algorithms and fuzzy logics, or combination of electric and mechanical power units, for better prediction and better identification was introduced the concept of "Combined dynamic system".

These events affect the management and substantially influence the selection of a suitable sampling period. Sampling period must be designed so all necessary control instructions and utilities, which are responding to emerging events are processed Given the sampling period, combined dynamical system are classified into 2 groups:

a. with the constant sampling period - when setting its value, it is necessary to determine the ratio of ingredient event TP and the component of a time-driven system, TR
b. with changing sampling period in which it is necessary to determine the impact, respectively the relationship between the constant component (time-controlled system) and random event component (various depending on emerging events).

Event component of the sampling period significantly affects the behavior of the entire system. It affects controllability, stability and overall dynamic properties of the combined systems that are designed by ratio of events and time-controlled discrete systems. Time-controlled part of the combined discrete systems is realized by a constant cyclic monitoring, processing and evaluation of inputs and states of the system. Event part is in automated control systems implemented by service interruptions, called upon the occurrence of any of the events. A particular problem in such systems appears to be how to determine the impact of stochastically changing event component of their dynamic properties and quality control. [3]

❖ THE SYNTHESIS AND ANALYSIS OF THE DISCRETE EVENT DYNAMIC SYSTEMS

The methods of the synthesis and analysis of discrete event dynamic system are primarily depend on its character. DEDS are characterized by the set of states, to which the system is able to get, and by the state of events, which are responding to the transitions between the states in the discrete time moments. The main purpose is to have the common model describing the dynamic of DEDS and then to create a control insuring that by the activity of different factors to the system required parameters and behavior of the system is keeping.

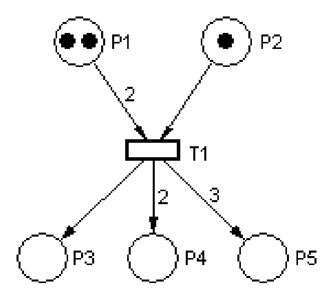
For the specification and analysis of the DEDS are using the tools, which are also the starting-point for the design of the system automated control and are able to express the properties of the discrete system and help by the control designing with the ability of the real-time system reactivity.

The basic tools can be distributed in three main groups:[1]

a) graphic tools – mainly useful with respect to the ability of the ease reading and the offering of the rich graphic information. Here belongs e.g.:
   - the finite automatons
   - the reactive flow diagrams
   - the Petri-nets
   - Grafcet
   - the state diagrams
   - the ladder diagrams
b) algebraic tools - e. g. :
   - the Boolean algebra
   - algebraic expression in the relevant state space
   - the Max-plus algebra

c) tools developed by the formal languages:
- the formal-language models
- the standard programming languages with the support of the real-time operation systems
- the real-time programming languages

The most complex and the most variable tool from the reflected tools using for the DEDS designing are standard Petri-nets(fig. 3), eventually their modifications created by the reduction or extension of the standard Petri-nets. The reduced representation is always able to transfer itself to the standard Petri-net, even if the created model can be larger and not so transparent as before. The Petri-net extensions contain the additional function rules to the defined basic rules. The extensions are creating for example with adding the new edges called inhibitors or with the adding other firing conditions to the transitions. The added conditions can be deterministic, stochastic, time etc. In this case the firing of the transitions can be coupled with external internal states, or events. The extensions are able to present the reactive control function, and therefore this class is known as Petri-nets interpreted for control.



after firing:

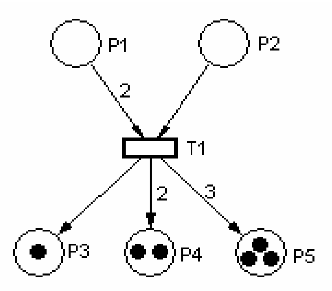


Fig.3. The Petri Nets Example

According to this analysis of DEDS we are able to create its description. It exists several possibilities of the DEDS description. The most efficient, with respect to the Petri-nets as the primary analysis tool, is the system developed by Mannu and Pneuli, especially effective in the transformation of the each correctly model, developed by the means of the tools, to the basic transition system. This basic transition system if defined as:

$$SYST=(\Pi, \Phi, \Sigma, \Theta)$$

Π – is the final set of the state parameters,
Φ – is the set of the states, where each state is given with the concrete value of parameters of set Π,
Σ – is the set of the transitions,
Θ – is the set of the initial conditions, which are important for specification of the states, in which the events can be applicated.

After this manner the confrontation through the basic transition system of two models developed by different tools can be realized. Transition can be assigned through the transition relation defined by the extended logic expression

$$\rho \in (\Pi , \Pi')$$

which contains the state parameters interpretation representing the state *s* and the state parameters interpretation representing the state *s´*.

❖ THE DISCRETE DYNAMIC REAL-TIME SYSTEMS

In the design of a real-time system, the designer requires flexible and configurable control over the execution rates of different parts of different parts of the program. Generally the different parts should execute at rates determined by the requisite responsiveness of the system and a need to optimise the use of the PLC processing capacity. Where there are multiple tasks declared, it is important to determine exact time of activation for all tasks used in the system, and also assigned a different interval and priority. The moment in time at which a particular task is executed depends on the type of sheduling regime, the priorities and intervals of the other tasks and how long each of the tasks has been ready and waiting to execute.

The elements of the control of the dynamic discrete systems are using two methods of scheduling: [2]
- Non-preemptive,
- Preemptive.

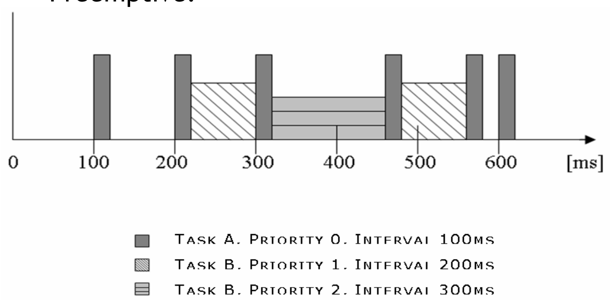


Fig.4. The non-preemptive scheduling

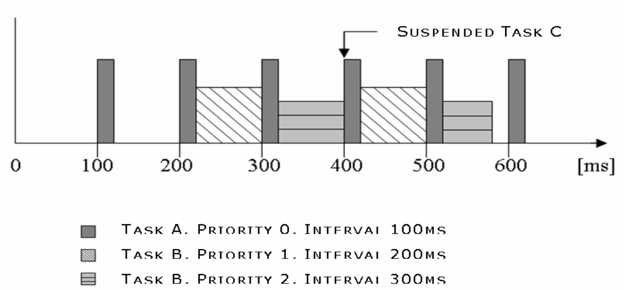


Fig.5. The preemptive scheduling

NON-PREEMTIVE SCHEDULING. In non-preemtive schediling regime, once a task is executing, it always continues until all the programs and function block instances assigned to it have been executed once. The task then terminates. The next execute is the waiting task with the highest priority, or if there are several tasks with the same priority, it is the task that has been waiting the longest (Fig.4). Once a task has executed, it is not considered for scheduling again until a period equal to the task interval has elapsed. The highest priority has the task with the lowest value of the priority.

The actual real-time interval between task executions may vary considerably as it depends on how long the other tasks take to complete. If one task occasionally takes significantly longer to execute, then all other tasks may be delayed. By this method it is not always possible to predict when certain tasks will execute, so such systems, which are using this type of scheduling, are said to be non-deterministic and generally should not be used for time critical applications.

PREEMPTIVE SCHEDULING. This method of scheduling is required for deterministic systems, i.e. control systems, that are required to have consistent timing relationships between events, for example where certain control algorithms are updated at precise and regular periods. With this regime, irrespective of what task is currently executing, when a higher priority task interval elapses it is immediately scheduled and the currently active task is suspended (Fig.5). When the higher priority task terminates, the suspended task of lower priority continues.

❖ CONCLUSIONS

The real control system usually contains both parts of discrete controlling – the discrete dynamic real-time system as well as the discrete event dynamic system. General dynamic properties of the combined discrete systems are assigned by the event factors of the discrete event dynamic systems and discrete dynamic real-time systems. The fluctuant scale of the sampling period for the real-time systems is assigned according to the static characteristics of the events processing. The structure of these types of the dynamic systems (with their methods of analysis and synthesis, such as Petri-nets or Taks scheduling) is the base of the analysis and synthesis of the combined dynamic systems and their sample period determining using different modern and also alternative tools and approaches (Queuing, Genethic Algoritms, Neuron Networks etc.).

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