ENTERPRISE PETRI NET BASED CAM SOFTWARE OPERA-TOPAZ

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ABSTRACT

Features of enterprise Petri nets based CAM software Opera-Topaz are studied. The successful usage of Opera-Topaz during more than ten years at military plants of Ukraine in production of radar station Kolchuga and aeroplane motors confirms the practical value of ideas embodied in this tool.

INTRODUCTION

Scheduling of the production processes is one of the classical fields of Petri net application (Sleptsov and Jurasov 1986). Massive production requires stochastic nets usage whereas individual or small series production may be represented adequately with deterministic nets.

Individual or drop series production is specific and is used for creation of large-scale complex manufactured articles. For example, such military articles as aeroplanes, radar stations etc.

The process of the article production may be considered as a set of interconnected jobs on a set of resources. There are a lot of various relations on a joint set including both jobs and resources. In the simple case jobs are interconnected with a following relation and either consumable or recoverable types of resources are considered.

Complex production requires extended types of relations that cannot be represented with standard PERT models. It is the first reason for Petri net usage. Another one consists in asynchronous character of the production processes. There are several units of the same article in the production. And the same equipment is used in the production of several articles.

Petri nets allow the representation of various relations among jobs and resources required in the practice. Timed nets are adequate models of production processes (Sleptsov and Zaitsev 1988). Complete formal description of behaviour of timed Petri nets was presented in (Zaitsev and Sleptsov 1997). And dynamic priority rules usage allows the generation of timetables enough close to optimal.

Above-mentioned ideas have being successfully applied during more than ten years at the military plants of Ukraine. CAM software system Opera-Topaz (Zaitsev and Sleptsov 1990), (Sleptsov and Zaitsev 1991) was developed for Topaz Corporation wide known in the world with Kolchuga (chain mail) radar stations. Then this system was used also in Motorsich Corporation, which is a major aeroplane motors producer in Ukraine.

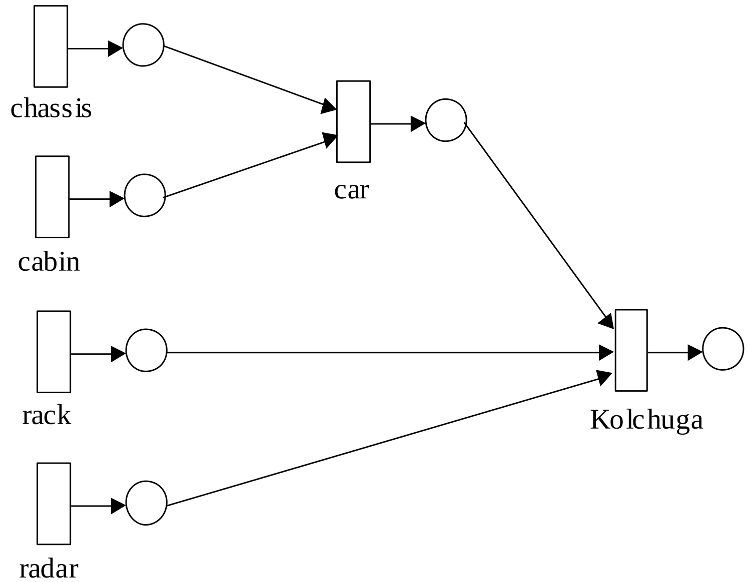
PETRI NET MODEL OF THE DISCRETE PRODUCTION

The process of the article manufacture in the discrete individual or small series production may be represented with timed Petri net (Sleptsev and Zaitsev 1988). Described in (Zaitsev and Sleptsev 1997) nets use integer values of time associated with transitions. Moreover repeated and simultaneous firing of the same active transition is allowed. So these nets was named also nets with multichannel transitions.

In (Zaitsev and Sleptsev 1997) the state equation of timed Petri nets with multichannel transitions was constructed. This equation is a complete formal description of net behaviour. On the base of this equation supplied with priority rules an ad-hoc algorithm for timetables generation was developed.

Now we consider separately a variety of processes' types and resources' relations used in the practice. Further at the figures for the convenience the places used for the description of processes have a small size whereas resources' places are lager.

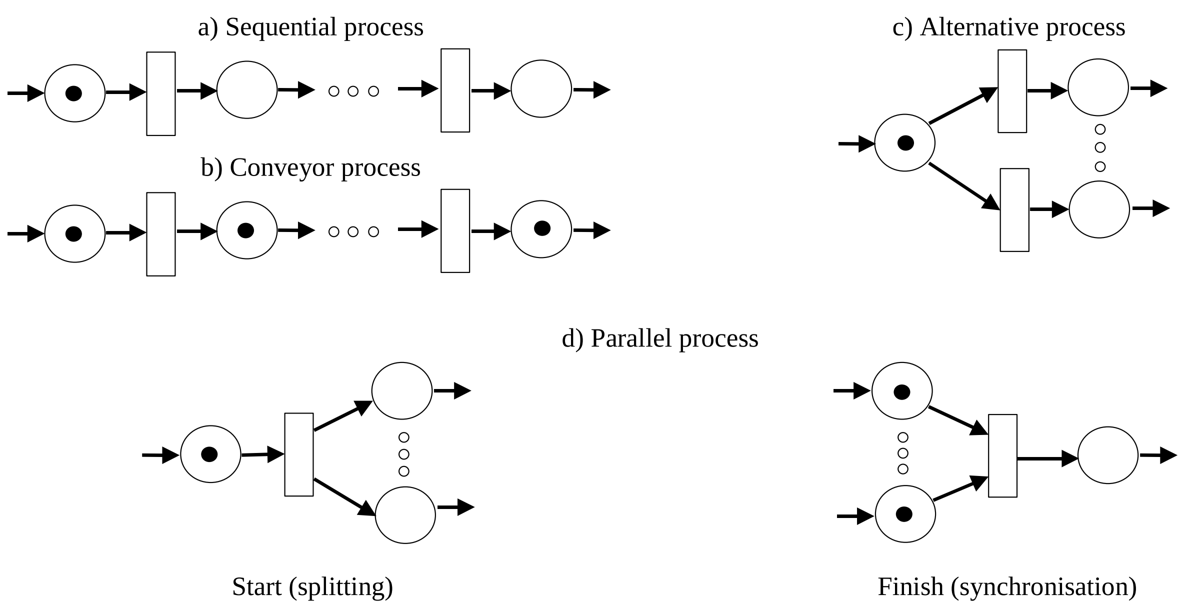
Petri net that has a tree structure describes a typical process of an article production. Article consists of units, units consist of lesser units and at least units consist of details. A tree represents this obvious hierarchy. An example of such tree is presented in Fig. 1. Only synchronisation relation is used in this model. For example, to manufacture unit "car" such units as "chassis" and "cabin" are required.



Figures 1: Technological scheme

It should be noted that even such hierarchical Petri net is more powerful than PERT net, as it represents a conveyor character of production that is reflected with marking and state of transitions. The flow of tokens moving through the net models the processes of production for a few units of the article.

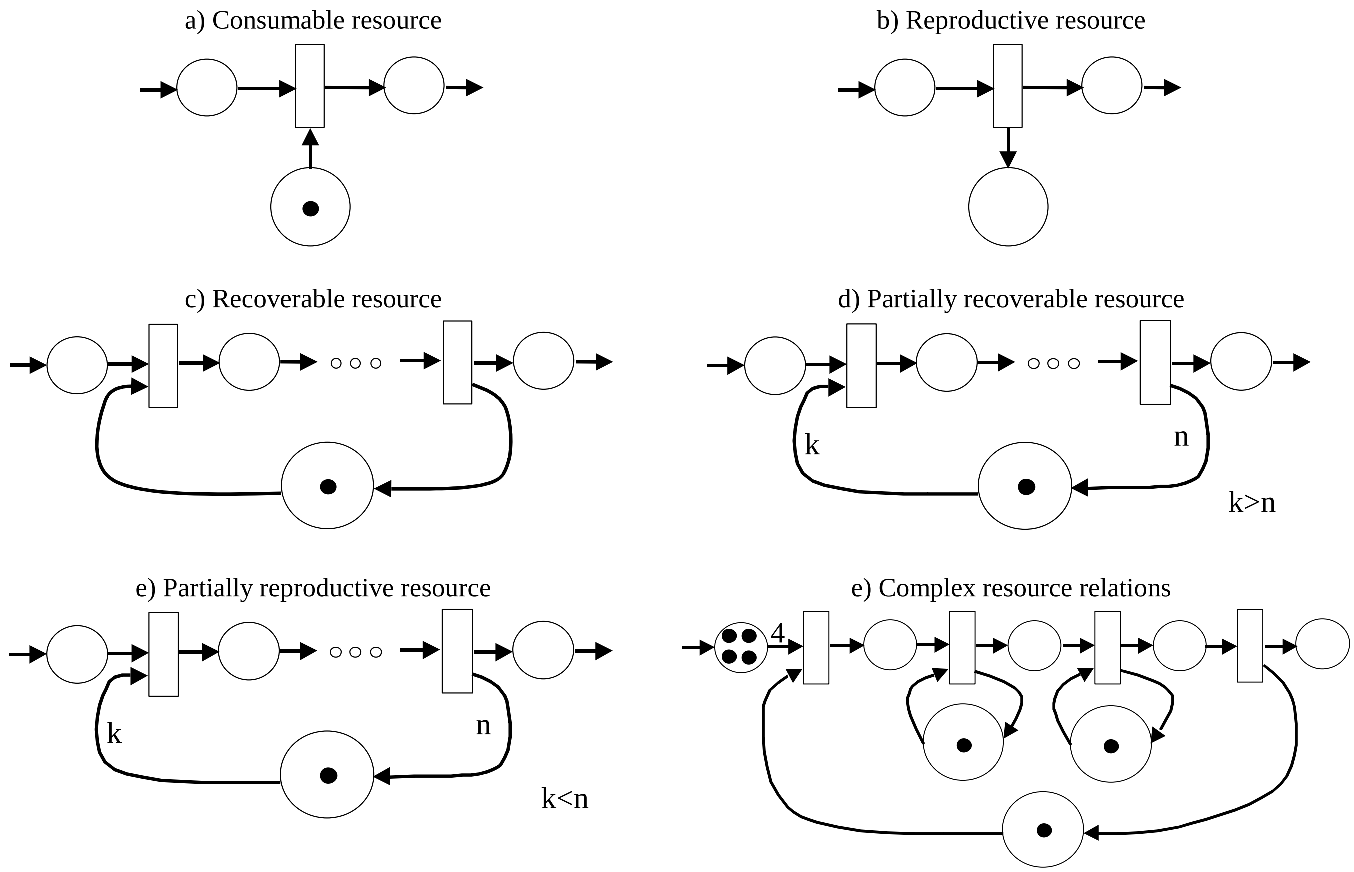
In Fig. 2 the basic types of processes represented by Petri nets are shown. The simplest is a sequential process a); a conveyor process b) is obtained from a) with marking of all places; an alternative process c) describes mutual replaceable units; a parallel process d) describes a constructive hierarchy of the manufacturing.



Figures 2: Types of processes

Parallel processes representation consists of the splitting of process, processes' descriptions and synchronisation. In most cases the splitting operation is not considered and we have a set of synchronisations of initially asynchronous branches. For example, Petri net with a tree structure (Fig. 1) is a set of synchronised jobs.

In Fig. 3 the basic types of resources' relations represented by Petri nets are shown. Consumable a), reproductive b) and recoverable c) resources are the most widespread. Consumable resources represent materials that will have been used to produce details. Reproductive resources correspond to manufactured units. Recoverable resources represent equipment, for example, machine tools.



Figures 3: Types of resources

More rarely such types of resources as partially recoverable d) or partially reproductive e) are used. In the case d) we can represent the wear of tools. The case e) is rather more sophisticated; it describes tools that are used for production of the same type tools. For example, lathe is used in the manufacturing of new lathes.

Moreover, Petri nets allow the representation of the complex multilevel resource relations also. So the net in Fig. 3 f) may be considered as the description of production with the usage of cassette with capacity of four details. Details are located in cassette for two next operations' execution: degreasing and dying.

Therefore, Petri nets are adequate models of discrete production processes.

FEATURES OF OPERA-TOPAZ

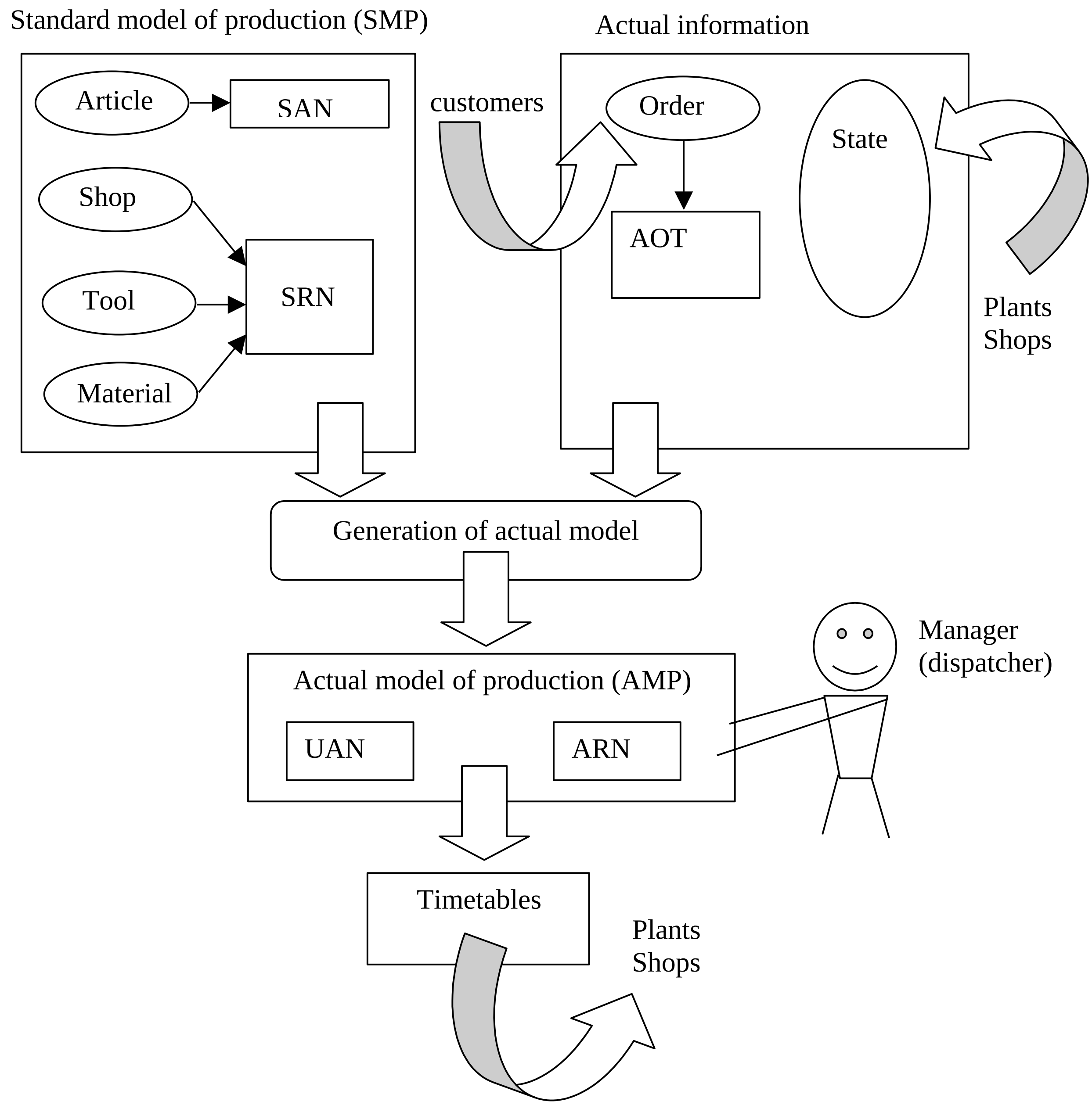
Enterprise CAM software system Opera-Topaz was described in details in (Sleptsov and Zaitsev 1991). It is based on R-technology of the modelling (Sleptsov and Zaitsev 1988) and timed Petri net (Zaitsev and Sleptsov 1997) model of production. The model is applied for a clear visual presentation of the current state of the production and for automatic and automated generation of timetables. Timetables may be represented in the standard form used in the usual process of shops' management.

The basic features of Opera-Topaz are:

- automatic and automated construction of Standard Article production Net (SAN);
- description of the resources of the plant (shops, equipment, tools, materials) with Standard Resource Net (SRN);
- maintenance of Article Orders Table (AOT) with the dates of the pass;
- automatic construction of the general actual model of production consisting of Unit of Article production Nets (UAN) connected with Actual Resource Net (ARN);
- automatic generation of quasi-optimal timetables of production;
- visual tools for presentation of current state of production and special tools for automated editing of timetables.

Now we explain features mentioned. For the scheduling purposes the Actual Model of Production (AMP) is used. This model is constructed by Opera-Topaz on the fly out of Standard Model of Production (SMP). The process of model generation is shown at Fig. 4.

SMP consists of SAN for each manufactured article and SRN that describes the structure of resources of the enterprise. There are two ways of SAN development: with the special visual graphical editor of Petri nets and via tools for automatic creation of Petri net. In the last case information about the jobs' following relation is extracted from the technological schemes.



Figures 4: Models generation and usage

In the simplest case SRN consists of the lists of shops and its resources. Moreover, it includes the information about variation of resources' amounts in time.

The major key for AMP generation is AOT. Information about actual amount of resources and actual state of processes is used also. On the base of this information the current state of the production is reflected in clear visual form.

Dispatcher disposes a set of forms for the reflection of current state of production. He may use such traditional forms as tables and Gant diagrams. Moreover, he may use Peri net on which the current state of production is represented in vivid form. Various colours reflect different states of jobs and resources. For the executing jobs the corresponding transition is filled with the part of rectangle equalling to the percentage of job's execution.

PECULIARITY OF TIMETABLES GENERATION

In the ideal case we have to generate an optimal timetable. Of course, we may describe the formal task of optimisation. Though this description is hard enough also. There are a lot of conditions that may be represented ether as criteria or as restriction.

For example, we have a list of the pass dates for units of articles. In any case we may consider the penalties for violation of the pass dates and include these penalties in the criteria that will be minimised. In other case, especially for military production, we have precise hard pass dates and have to consider them as the restrictions.

So, firstly, special tools for automated description of optimisation task is required. These tools have to process the standard list of conditions and extend this list with new required conditions. Each condition has to be represented either as restriction or be included in criteria with its own weight coefficient.

But unfortunately there are not known universal formal methods to solve described above optimisation task with the exception of the complete look over. But the complexity of the complete look over is exponential in time. It requires enormous amount of time even for small dimension tasks and, therefore, is not practically applicable.

The classical practical approach consists in the priority rules usage for the quasi-optimal timetables construction. We applied this approach to timed Petri net model. To generate a timetable we supply net with the priority rules, which allow solving conflicts among fireable transitions. From the formal point of view we extend state equation with the expressions that describe priority rules. Then we use this extended state equation to generate timetables.

It is enough nontrivial task to maintain a set of priority rules with correspondence to conditions that define optimisation task and may be included ether in criteria or in restrictions. Our goal is to extract from the practice and accumulate such a correspondence that allows generating quasi-optimal timetables enough close to optimal in a short time.

The best result was obtained in Opera-Topaz with criteria based on kan-ban technology (Sleptsov and Jurasov 1986) with the hard pass dates and soft bounds of accessible resources.

But the automatically generated plan is not a dogma because an alive dispatcher could not express in any criteria and priority rule all his skill. We give convenient tools to dispatcher for revision and correction of plans represented with Gant diagrams, tables or Petri nets. Petri net model defines the restrictions for manual adjustment of plans.

CONCLUSION

Therefore, the basic features of enterprise Petri net based CAM software Opera-Topaz were studied. The successful usage of Opera-Topaz during more than ten years at military plants of Ukraine confirms the practical value of ideas embodied in this tool.

REFERENCES

Sleptsov, A.I. and A.A. Jurasov. 1986. *Automated development of management and control systems for flexible manufactures*, Kiev, Tehnika, 160p. (in Russian).

Sleptsov, A.I. and D.A. Zaitsev. 1988. "R-technology of modeling for parallel structures and processes", Program-methodical and program-technical complexes for CAD and CAM: Proceedings of Scientific-technical conference, Izhevsk, 62-63. (In Russian).

Sleptsov, A.I. and D.A. Zaitsev. 1991. *CAM Software Opera-Topaz*, Donetsk, DPI, 68p. (in Russian).

Zaitsev, D.A. and A.I. Sleptsov. 1990. "Visualization of production processes in tool system of dispatcher in machine-building enterprise", Autometria, no. 4, 90-93.

Zaitsev, D.A. and A.I. Sleptsov. 1997. "State equations and equivalent transformations of timed Petri Nets", Cybernetics and System Analysis, vol 33, no. 5, 659-672.

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