

# МАТЕМАТИЧНІ МЕТОДИ, МОДЕЛІ ТА ІНФОРМАЦІЙНІ ТЕХНОЛОГІЇ В ЕКОНОМІЦІ

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## MODELLING OF THE TEACHING PROCESS IN LOGISTIC SYSTEMS BY USING OF NESTED PETRI NETS

**Minakova S.M. Modelling of the teaching process in logistic systems by using of Nested Petri Nets.** Nested Petri nets (Nested Petri Nets – NPN) is one of the modern tools of modeling and research of parallel working systems that have certain independence and own activity. These features make attractive their use when modeling educational process, conducted by a group of students both in traditional educational process and interactive computer training. In this article we first offered two-level teaching model, consisting of a central system and a set of systems – satellites, which model the individual behavior of students. Interactive, in other words, largely, independent training with the use of modern information technologies is one of the main directions of improvement of the education system. Rapid development of telecommunications and, in particular, the Internet has created a technological basis for the exchange of information between agencies and individuals, regardless of their social status, nationality, geographical position, and became a powerful incentive for the development of distance education. Petri nets are, essentially, one of the forms of imitation of discrete processes. They were very popular 20 years ago, when with their help they hoped to count the above processes (without imitation). In the majority of applications, from usual imitation models they differ only by broad science variety and specific terminology.

**Keywords:** Petri nets, the two-level teaching model, interactive training, processes, distributed systems.

**Мінакова С.М. Моделювання процесу навчання в логістичних системах з використанням мереж Р NPN.** Вкладені мережі Петрі (Nested Petri Nets – NPN) – один із сучасних інструментів моделювання і дослідження паралельно працюючих систем, що володіють певною незалежністю і власною активністю. Ці риси роблять привабливим їх використання при моделюванні навчального процесу, проведеного групою учнів як у традиційному навчальному процесі, так і при інтерактивному комп'ютерному навчанні. У роботі вперше пропонується дворівнева модель навчання, яка складається з центральної системи і набору систем-сателітів, моделюючих індивідуальну поведінку учнів. Інтерактивне, тобто значною мірою самостійне навчання з використанням сучасних інформаційних технологій, – одне із найважливіших напрямів удосконалення системи освіти. Швидкий розвиток телекомунікацій, і особливо мережі Інтернет, створив технологічну основу для обміну інформацією між організаціями та окремими особами, незалежно від їхнього соціального статусу, державної приналежності, географічного положення, і став потужним стимулом розвитку дистанційної освіти. Мережі Петрі, по суті, є однією із форм імітації дискретних процесів. Вони були дуже модними років 20 тому, коли з їх допомогою сподівалися розраховувати згадані процеси (без імітації). У переважній більшості застосувань від звичайних імітаційних моделей вони відрізняються лише великим наукоманіттям і специфічною термінологією.

**Ключові слова:** мережі Петрі, дворівнева модель навчання, інтерактивне навчання, процеси, розподілені системи.

**Минакова С.М. Моделирование процесса обучения в логистических системах с использованием сетей P NPN.** Вложенные сети Петри (Nested Petri Nets – NPN) – один из современных инструментов моделирования и исследования параллельно работающих систем, обладающих определенной независимостью и собственной активностью. Эти черты делают привлекательным их использование при моделировании учебного процесса, проводимого группой обучаемых как в традиционном учебном процессе, так и при интерактивном компьютерном обучении. В работе впервые предлагается двухуровневая модель обучения, состоящая из центральной системы и набора систем-сателлитов, моделирующих индивидуальное поведение учащихся. Интерактивное, то есть в значительной мере самостоятельное обучение с использованием современных информационных технологий, – одно из важнейших направлений совершенствования системы образования. Быстрое развитие телекоммуникаций, и в особенности сети Интернет, создало технологическую основу для обмена информацией между организациями и отдельными лицами, вне зависимости от их социального статуса, государственной принадлежности, географического положения, и явилось мощным стимулом развития дистанционного образования. Сети Петри, по существу, являются одной из форм имитации дискретных процессов. Они были очень модными лет 20 назад, когда с их помощью надеялись рассчитывать упомянутые процессы (без имитации). В подавляющем большинстве применений от обычных имитационных моделей они отличаются лишь большим наукообразием и специфической терминологией.

**Ключевые слова:** сети Петри, двухуровневая модель обучения, интерактивное обучение, процессы, распределенные системы.

**Statement of a problem.** Nowadays, despite considerable success of interactive studying, there are many problems that are not decided. To them, first of all, can be added development of engineering methods of creation computer teaching systems as a type of information systems using modern development methodologies and technologies, in particular, CASE-technologies. In addition, it is actual the creation of methods of apriori evaluation of didactic and operational characteristics of the developed training systems.

Solving of the given problems requires the existence of models that adequately describe all the sides of the teaching process – functional, information, dynamic. To describe the dynamics of the teaching process were proposed models based on Petri formalism nets and on closely related with it theory of Markov chains. However, the proposed earlier models described only interaction of a separate student with a teaching system.

At the same time, in modern education an important role plays the ability of students to work in a team interact while making projects. One of the possible ways to model the processes of teamwork of students is associated

with the use of a comparatively new class of network models – Petri nets.

**Review of recent studies and publications.** Among home researches according to Petri nets and specification and analysis of distributed systems are marked works of N.A. Anisimov, O.L. Bandman, I.B. Virbitskajte, V.V. Voevodin, N.V. Yevtushenko, U.G. Karpov, V.E. Kotov, I.A. Lomazovoj, V.A. Nepomnyashiy, R. L. Smelanskiy, V.A. Sokolov, L.A. Cherkasova.

In works of V.E. Kotov [1] were identified the formalisms of regular and hierarchical Petri nets which have convenient algebraic representation, N.S. Pisarenkova, G.G. Garbuz [4] were studying the equivalent conversion in automatics theory, a theory of program schemes, to compare the behavior of parallel systems V.A. Vasilyev and others [3] introduced the concept of bisimulative equivalent.

**Tasks of a research.** Nowadays, despite the considerable success of interactive studying, there are a lot of outstanding problems. To them, first of all, is included the development of engineer methods of creation of computer teaching systems as a kind of information systems using modern methodologies and tech-

nologies of development, in particular, CASE-technologies.

In addition, the actual is the creation of a priori evaluation of didactic and operational characteristics of the developed training systems. Solving of these problems requires existence of models that adequately describe all the sides of studying process – functional, information, dynamic.

To describe the dynamics of the teaching process were proposed models based on Petri formalism nets and on closely related with it theory of Markov chains.

There are a lot of classes of formal models built on the base of Petri nets. Some of them are an extension of ordinary Petri nets and by their expressiveness are close to Turing machines, some of them – narrowing (sometimes up to final systems). There are Petri nets with inhibitory arcs, with invisible transitions, networks with time and probability, object-oriented Petri nets.

But, the proposed earlier models described only the interaction of a separate student with a teaching system. At the same time, in modern education an important role plays the ability of students to work in a team, interact in making of projects. One of the possible ways to model the processes of teamwork of students is associated with the use of a relatively new class of network models – Nested Petri nets.

**Basic material of a research.** Let's look through the extension of Petri nets, which is useful while modeling of the teaching process. We speak about so-called Nested Petri networks (Nested Petri Nets-NPN).

The appearance of a given variety of Petri nets is connected with the desire of researchers to have a tool for adequate and convenient representation of complex systems with difficult hierarchical and multi-agent structure.

Nested Petri Nets are an extension of standard Petri net formalism in which chips that represent local resources in positions of the system network, can themselves be complex objects with network structure and be modeled by low-level Petri networks -they will be called – satellite networks.

Structurally, this network consists from system network SN and set of network-chips (satellites)  $EN_i$ ,  $i= 1, \dots, n$ . Among some of transi-

tions of the system network and transitions of network-chips can be established the correlation, allowing their joint operation only. Such transitions are called labeled.

Functioning of networks that form a part of NPN largely coincides with the functioning of traditional Petri Nets. Differences make the mechanisms of synchronization of different levels Petri Nets working. In this regard, in NPN they distinguish the following four types of step operation:

- System-offline step which corresponds to the operation of an unlabeled transition in the system network;

- Satellite-offline step which corresponds to the operation of an unlabeled transition in network-chip  $EN_i$ ;

- Step of the horizontal synchronization, at which both operate transitions in networks-chips  $EN_i$ , marked with the same labels;

- Step of the vertical synchronization, at which simultaneously operate transitions in the system network SN and networks -chips  $EN_i$ , that have the same labels.

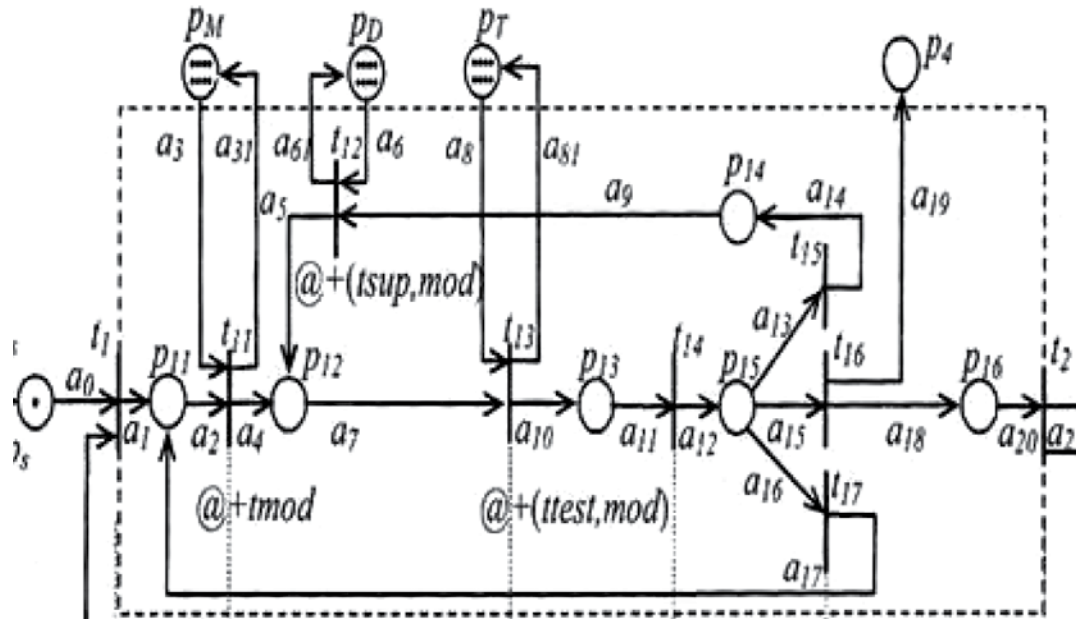
Of course, this suggests that in all networks all the transitions that take a part and are active, i.e., their input positions have the necessary resources to operate.

Let's study the use of Nested Petri nets on example.

Process model of interactive teaching by using of nested Petri networks. We illustrate the possibilities of Nested Petri nets for getting the model of the teaching process with the subsystems of different levels. Let's see a model of a process of interactive teaching shown in Fig. 1. In this model, each student is modeled by one chip, marked as variable  $var\ s$ : STUDENT that corresponds to the integer code of a student. While the information about the passing of a course by a concrete student is lost after the training process is completed.

In addition, in the model in Figure 1 there is no possibility of a differentiated evaluation of the success of learning. Also is not foreseen the possibility of failure of a course, since the number of attempts to study the material and the test is not limited. And finally, there is no possibility to model the interaction of students.

Functioning of the system can be improved if to make a model of the behavior of each student



Preparing Teaching Testing Evaluation Taking a decision  
 Fig. 1. System network SN-painted Petri network with part-time and probable mechanisms, modeling coming through the training course in logistics systems

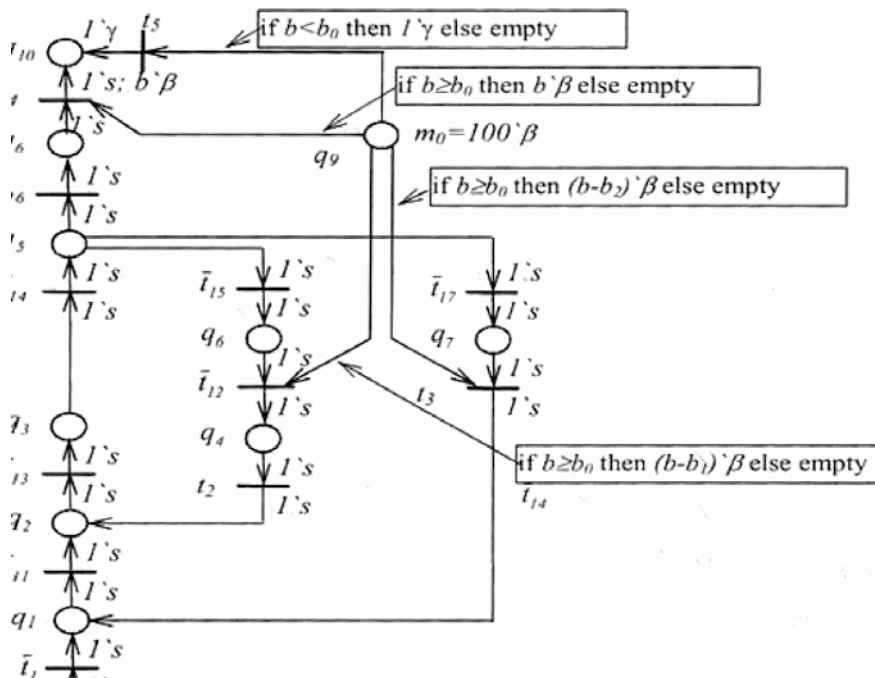


Fig. 2. Nested network Es

with a separate Petri net. Then chip, marked by the variable  $s$  will be the network of ENs, where  $s$  is the code of a student, as in Figure 1.

Taking this, will be the Nested Petri network which consists of the system network SN (it is shown in Fig. 2) and the set the satellite networks  $EN_s$ , ( $s=1,2, \dots$ ). One of the possible variants of network ENs is presented in Figure 2.

We'll describe briefly the work of the nested network. In figure 2 positions are marked with the letters  $q_i$ ,  $i = 1, \dots, 10$ . The meaning of positions  $q_1, \dots, q_6$  coincides with the meaning of  $p_{11}, \dots, p_{16}$  in Figure 2, the rest positions relate to the evaluation of success of the training. Transitions  $t_1, t_{11}, \dots, t_{17}$  on both pictures have one and the same meaning.

The line above the marking of transition in figure 2 means an existence of vertical synchronization: the same transitions can work only simultaneously. This means synchronization the following actions:

- arrival of a student into the system (working of a transition  $t_1$ ), creation in the system network SN of a satellite network  $EN_s$ , as a chip  $s$ ; in turn, in the satellite network variable  $s$  refers to the color set of STUDENT;

- choice of a training module and the beginning of the studying process, working of passing  $t_{11}$ ;

- completion of the training process and selection of tests, working of transition  $t_{13}$ ;

- completion of the testing process and transition to the evaluation- working of transition  $t_{14}$ ;

- taking of a decision according to the testing results – working of transitions:  $t_{15}$ -studying of additional material,  $t_{16}$ -completion of module studying,  $t_{17}$ -re-studying of all material.

Besides the described events,  $EN_s$  network allows us to estimate the number of goals got by students in the process of module studying. For this purpose were put additional resources, given by color varieties:

- Color BALL = integer;

- Color FAILURE = Boolean;

and appropriate variables:

var  $\beta$ : BALL, var  $\gamma$ : FAILURE.

Variable  $\beta$  means the number of goals got by students while making of a module. Ini-

tially, in the position  $q_9$ , there are 100 goals, and then at every fail, the marking of this position decreases: if necessary to study additional material – on  $b_1$  goals and if necessary to re-study the whole course –  $b_2$  goals. In case of successful passing of studying process is working transition  $t_5$  and to the position  $c$  is given the got by a student number of goals – number  $b$ .

The minimum number of goals, at which positive mark is possible, is  $b_0$  goals. If the current meaning for  $\beta$  is less than  $b_0$ , the learning process is unsuccessful and the variable  $\gamma$  takes the meaning – *true*, which is passed to the position  $q_{10}$  when works transition  $t_5$ . All other transitions here are blocked.

In this example, that was looked through, is shown only vertical synchronization, which is in the requirement of simultaneous activation of transitions in SN and  $E_s$  networks. It is possible to foresee and horizontal synchronization also between  $E_s$  networks, which would allow to model a joint work of students, such as when you perform a collective project.

Of course, the practical use of the proposed model is possible only at presence of the proper program providing, which is currently being developed.

**Conclusions.** The final result of this work became mathematical models with use of Petri nets, building of dynamic models on the base of Petri nets, using of network models with the help of Petri nets. Petri nets are an effective tool for discrete processes in logistic systems, in particular, the functioning of the machine-tool systems. Are developed theories of modeling with the help of Petri nets. In this work are given the examples of models, the program.

Looking out of a network planning, as management method based on using of mathematical apparatus of graph's theory and system approach for reflecting and algorithmization of complexes of interrelated works, actions or activities to achieve this aim, shows that the use of nested Petri nets expands the possibility of training logistics systems modeling and enables to make previously unavailable researches.

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