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MODELING OF INTELLECTUAL LOGISTIC NET

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Introduction

Now gradual leaving from methodology MPR II (focused on a large-lot production and as a rule long life cycles of products) and transition to development of techniques and the technologies of management incorporated by term Supply Chain Management (SCM) is observed. The purpose of management of a logistical chain - to connect all participants in the uniform integrated system. Transaction character of modern commodity and monetary streams is causes of application of models which could take into account parallelism, non synchronous and transaction character of management process by a logistical chain.

The logistical chain unites both the companies having the general management, and independent subcontractors, the transport organizations, distributors and so forth which, nevertheless, should cooperate according to the common logic of business (the term - collaborative business). The set of logistical chains forms more complex structure - a logistical network. That is why, the task of optimization of a logistical network is actual. The dynamical character of business processes make it necessary to construct the adaptive system, capable to be adjust according to changing conditions. In essence, the question is an intellectual logistical network capable to "adjustment" for the current problem and to "expedient" change according to new conditions. Problems of construction of adaptive systems are rather actual and are considered in various areas, in particular, at construction animats and intellectual agents. Principles of construction animats can be, in our opinion, are applied for creation of an intellectual logistical network.

Formalization of logistic nets by Petry nets

Petri nets often used as formal model of logistic nets. Formal definition of a network can be found, for example, in [2]. In the same place some expansions of Petri nets are considered, allowing increasing their expressive capacity. Some examples of application of the Petri nets and their expansions for the analysis of business processes are resulted in [3,4,5].

Presence of tops of different type and corresponding rules of work of a network (rules of operation of transitions) allows analyzing dynamic parallel asynchronous processes. There is a set of updating (expansions) of classical networks Петри. For example, it is possible to apply time nets to an estimation of time of transaction [6,7]. In this case, time intervals are corresponded to transitions. Fuzzy Petri nets are based on the concepts of fuzzy logic entered by L.Zade. In [8] fuzzy Petri nets are used for modeling hybrid system. Other expansions - colored nets [9], stochastic nets, predicate nets, etc. are used also.

Opportunities of application Petri nets as imitation model can be illustrated with the help of simple model "Manufacture - Advertising -selling" represented on fig. 1. The model is prepared by the help of means of a portal [10].

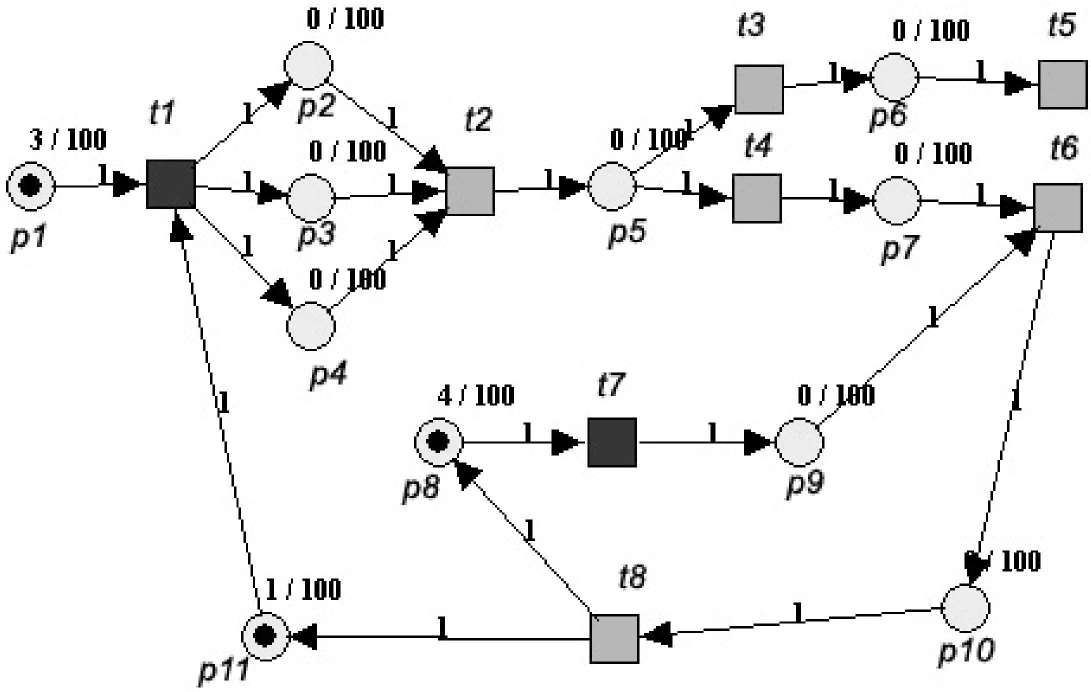


Figure 1. Model "Manufacture - Advertising -Selling"

The model displays parallelism and asynchronous the processes occurring in a logistical chain. Places are designated by circles and transitions by squares. Frequency rate of arches is designated by number (in this case all arches unitary). Places and transitions are interpreted as follows (Table 1,2)

Table 1. Interpreting of transactions of Model "Manufacture - Advertising -Selling"

T1	The order of parts
T2	assembling of products
T3,T4	Transportation to shop
T5,T6	Transportation to consumer
T8	Reception of money for sale
T7	Advertising of the goods

Table 2. Interpreting of places of Model "Manufacture - Advertising -Selling"

P1	Orders
P2,P3,P4	Parts
P5	Warehouse
P6,P7	Shops
P8	The account of Advertising agency
P9	Advertising
P10	Goods for consumer
P11	Bank account

The model illustrates process of the order of parts, assembly of products, and their transportation to a warehouse and selling to a consumer. This process is displayed by operation of transitions $t_1..t_6$. To illustrate process of advertising of the goods, transition t_7 is entered. As well as in a reality, occuring processes can be asynchronous. Well-known base properties of Petri nets [2], in our case it is possible to interpret, for example, as follows,

Safety and limitation - adequacy material and financial resources.

Keeping - resources will renew or will be exhausted.

Activity - can characterize amount of starts of separate transactions.

Approachability and coverability - achievable or not some condition of a net.

As a rule, graph of achievable markings apply to the analysis of properties of nets. Simulation technique uses for the analysis of nets with the big expressive capacity.

Petri nets weakness

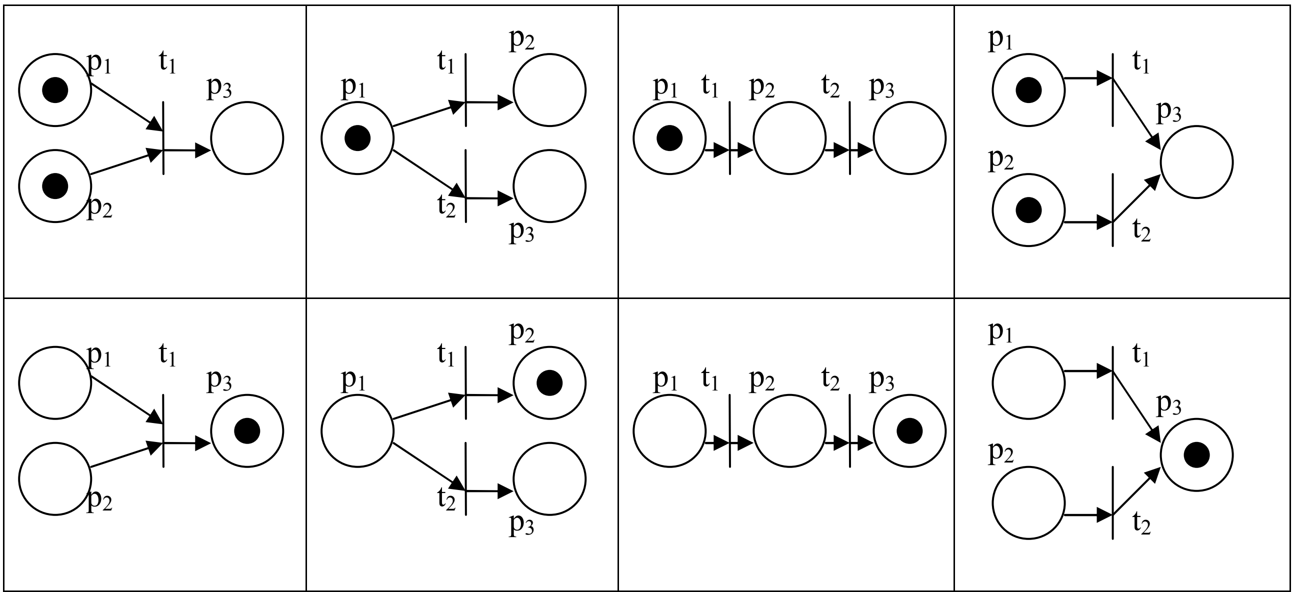
Standard Petri nets have the limited expressive capacity. Introduction a plus - minus of labels (PM nets), the structured nets, nets with switches and disjunctive rules, inhibitory, colored nets (CPM) , raises expressive capacity up to a level of Tjuring machine. However, in this case, some tasks of the analysis become algorithmically difficult.

Though various subsets of Petri nets are capable to model PERT diagrams and WorkFlow systems, nevertheless, given approach have lacks, also. Most essential of them is bulkiness. Nets of real processes, as a rule, are complex. It is possible to note also, that though the network allows to model asynchronous and parallelism of processes, but from the point of view of change of the model, it nevertheless is static. Classical networks and their expansions have no the algorithms adjusting structure of a network. Hence, classical nets quite approach for modeling stable chains. For example, for systems with the settled structure in which we further can apply algorithms of optimization, including, the algorithms of a weak artificial intellect [11] that optimize a network by criterion of reduction of expenses or time.

Intellectual logistical net we shall name logistical system containing the block of intellectual management. As against classical algorithms of optimization, intellectual management assumes self-training and development of new strategy of behavior. If process of self-training, basically, is possible at repeated passage of a circuit the task of development of new strategy assumes not only change of characteristics of separate elements of a network, but also possible change of its structure. Such problem is considered as one of most of difficult. As a rule, we have the restriction of the time and the resources for decision of this problem, and the purpose can be formulated indistinctly. In such kind the problem of development of strategy of behavior like a problem of an alive organism or its model - animate [12,13].

Formalization of intellectual logistic network

Let's consider models of elements of a logistical network (fig. 2). Above in figure elementary models with initial marks are represented. The final marks are pointed below. These achievable after operating of transitions. Final marks we shall name "target marks" according to semantics of nets.



a. Assembling	b. Distribution	c. Delivery canal	d. Alternative delivery canal

Figure 2. Models of elements of logistical network

Tops of a network can be interpreted as follows

a. p_1, p_2 - warehouses, t_1 - process of assembly, p_3 - a warehouse of finished goods
b. p_1 - a warehouse of production, t_1, t_2 - delivery, p_2, p_3 - the consumers
c. p_1 - a warehouse, p_2 - the intermediary, p_3 - the consumer, t_1, t_2 - delivery
d. p_1, p_2 - warehouses, t_1, t_2 - delivery, p_3 - the consumer

The logistical network constructed with use of described elementary components can be optimized. Thus

- In a time net it is possible to optimize speed of passage of labels from one tops of a net to another (speed of transactions), choosing a way with the least value of total time.
- If transitions correspond to weights (expenses for operation) optimization can consist in minimization of total expenses of a network.
- If transitions correspond to probabilities of operation (a variant of a stochastic network) optimization can consist in maximization of probability of delivery.

The various combined variants of optimization are possible, of course.

In the elementary case, when rates of arches of a network and/or time of operation of transitions is known the problem of optimization is reduced to a task of arrangement of labels.

What to do, if rate of arches or time (probabilities, weights) of operations of transitions are unknown? One of decisions is to try various variants, choosing the best by the criterion of optimization. Actually it means some strategy of self-training of a network. Process of self-training can simulate natural strategy of training which, according to [13], include the following:

- Generating new tactics of behaviour
- Conformity of tactics to physical laws of environment
- Presence nonlinear oscilator
- A predicative functioning
- Considering history of work

In case of use of Petri nets as a formalism describing logistical circuits, the predicative functioning is provided with rules of operation of transitions.

An approach to taking into account of "physical" laws of environment

To taking into account of physical laws of environment means that from all of set of variants of behavior are excluded obviously unsuitable (it is impossible to deliver faster the plane speed, it is impossible to have a unlimited source of the finance, etc.)

In our case, the "physical" environment for work of a control system of a logistical network is the subset of Petri nets (time nets). Hence, from all set of initial marks it is necessary to consider only "expedient" that provide set of target marks. There is no necessity to consider obviously impasses.

Let x is any positive integer and 0, w is the positive greater 0. m (p_i) – marks of a place p_i, on an any step of work of a net. Then the set of marks m (p_1)=x, m (p_2)= x , m (p_3)=w is target marks of subnet on fig. 2a . or in the vector form g_a=(xxw). The target marks of subnets are resulted in tab. 3

Table 3. Target marks of elementary subnets (fig.2)

Subnet on fig.2	Vector of set of target mark (g)
a	xxw
b	xww
c	xxw
d	xxw

Definition 1. We shall name initial mark of a net m_0 as "expedient" if one of target marks g can be achieved from m_0 at the defined rule of operation.

For example, for net (fig. 2a) "expedient" marks is (110), (120)..., (ww0). The task of approachability of mark is the NP-full [14]. Therefore, the algorithm or a method of calculation of set of "expedient" marks is necessary.

Let's not strictly define net R as "reverse" of net N if places and transitions of these networks coincide, however, the direction of arches of network N is changed on opposite in comparison with network M.

Formally,

Let M (X) is a rectangular matrix of connections of net X, in which element

x_{ij} = 1 if the arch from a place p_i to transition t_j exist;

x_{ij} =-1 if the arch from transition t_j to place p_i exist;

x_{ij} = 0 if the place p_i is not connected to transition t_j.

E (X) set of "expedient" marks of net X.

Definition 2. Net R = (P_r, T_r, M (R)) is reverse for net N=(P_n,T_n,M_n(N)), if $P_r = P_n$, $T_r = T_n$, and M (R) = j * M (N), where the scalar j =-1.

For calculation of set E (N) it is enough to calculate set of marks of net R. Elementary nets that is reverse for nets of fig.2 are represented on fig.3. **It is easy to see** that after operation of transitions the marks of networks on fig. 3 and fig. 2 will coincide.

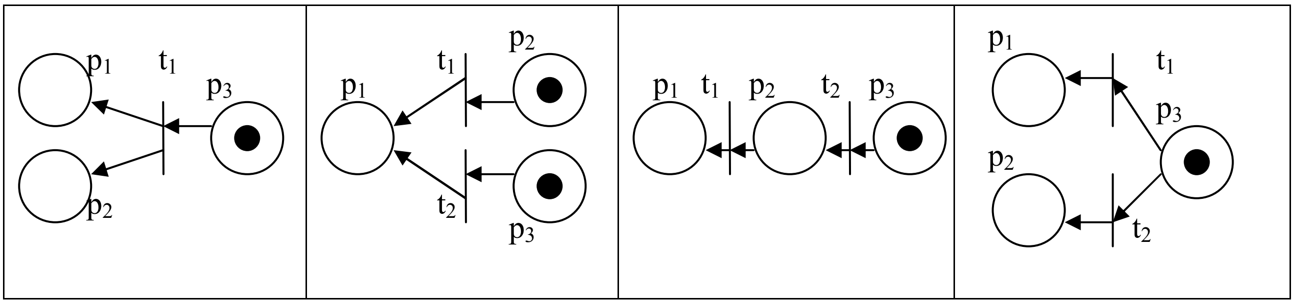


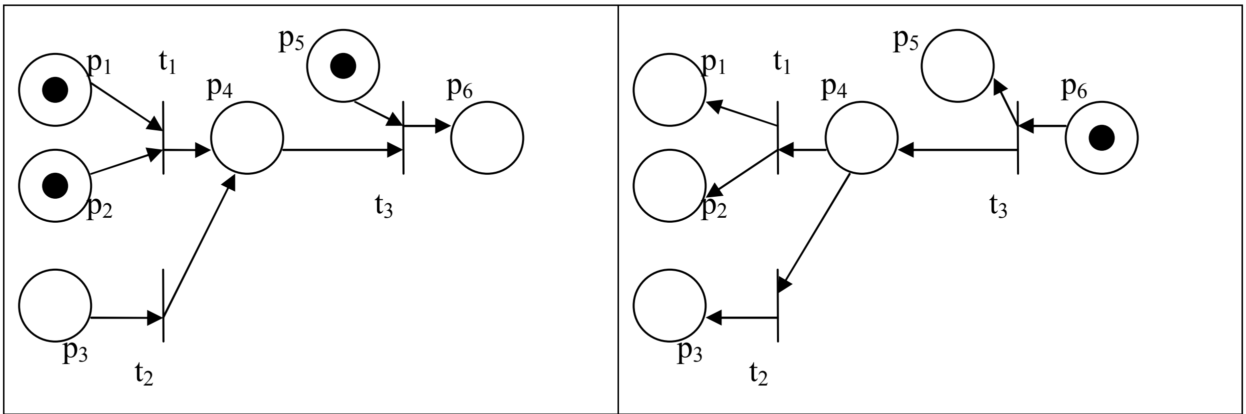
Figure 3. Reverse nets

Let's consider an example for an illustration of the described approach.

Let we have a nets N_1 and R_1 (fig.4). The tab.4 represent matrix of connection of net N_1 - M(N_1). For calculation of a matrix of connections of a reverse net it is enough to execute

M(R_1) = -1* M(N_1)

The result is represent in tab.5.



a. Net N_1. b. Net R_1.

Figure 4. «Direct» and «reverse» nets

Table 4. Matrix of connection of N_1

p \ t	**1**	**2**	**3**
1	1	0	0
2	1	0	0

3	0	1	0
4	-1	-1	1
5	0	0	1
6	0	0	-1

Table 5. Matrix of connection of R_1

p \ t	**1**	**2**	**3**
1	-1	0	0
2	-1	0	0
3	0	-1	0
4	1	1	-1
5	0	0	-1
6	0	0	1

It's easy to calculate set of "expedient" marks of net - $E(N_1)$. There is enough to calculate graph of achievable markings (GAM) of R_1. For one of set of target marks $g_1(N_1)$=000001, GAM of net is represent on fig.5.

g_1: **000001**
↓
m_1: **000110**
↓
m_2: **111010**

Figure 5. GAM of net N_1

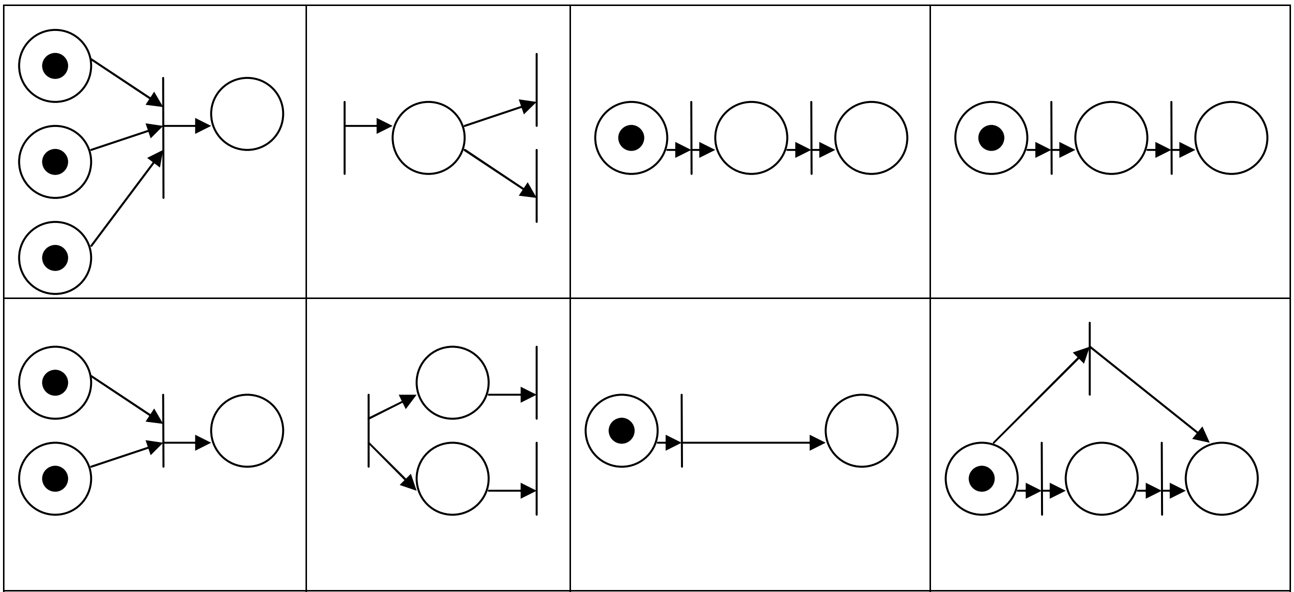
The set $E(N_1)$ includes m_1 and m_2. It is obvious that the mark m_1 for net N_1 is intermediate. It means, that m_1 always can be founded from m_2. Calculation of all set E in an any network can represent a uneasy problem. Let's introduce concept of final mark.

Definition 3. The set of final marks of reverse net *F (R)* will consist of marks $f_i \subset E(R)$ such at which any transition cannot work or which does not vary at operation of any transition (probably also, that it is zero marks).

In other words, the final mark includes set of deadlock marks of a net and set of marks which do not vary at operation of any transition. It is obvious, that $|F(R)| \leq |E(N)|$. Though it is possible to believe, that generally algorithmic complexity of calculation of sets *F (R)* and *E (N)* is equivalent, nevertheless, many cases quantity of elements in *F (R)* less than in *E (N)*, that allows to lower requirements for memory at the analysis of a network. In particular, in an example, $E(N_1)=(m_1, m_2)$, and $F(R_1)=(m_2)$.

Generating of new tactics of behaviour

Till now we considered nets with steady structure. So the quantity of places, transitions and arches are fixed as well as connections between tops of a net. New knowledge in our model is an occurrence of new tops and connections. Obvious, that first of all it is necessary to subject transformations those parts of a net which render the greatest influence on optimized parameters (time, cost). By analogy with PERT diagrams the given parts of a network we shall name critical. The concept of a critical part of a net is follows from the semantics of the processes simulated by model. In our case, at modeling logistical circuits it is possible to separate critical ways and critical nodes (fig. 6). Thus, 6a is critical node, 6b and 6c is critical ways. The critical parts before transformation are displayed on the top of fig.6. The results of transformation are displayed at the bottom.



a. Reduction of amount of suppliers	b.Exception of risk of non-delivery	c. Reduction of quantity of intermediaries	d. The alternative channel of delivery.

Figure 6. Critical parts and nodes.

"Reasonable" changing of a network

Generally, amount of possible updating of a net can't be restricted. Nevertheless, from the common reasons it is possible to offer the following sequence of steps of updating of a net.

1. Revealing critical nodes and ways.
2. Reasonable updating a network by optimization of critical nodes and ways. In other words, addition or removal of tops and arches with a question - « What will be if...? ». In case of a logistical network is, for example, finding a new channels of deliveries or commodity markets. Thus, "reasonable" updating consists in change of critical nodes and ways, calculation of "expedient" marks and the analysis of the received result for revealing optimum updating.
3. Updating a network.
4. Go to a step 1 if the parameters (time or transactions costs) are changed.
5. Go to a step 1 "spontaneously" even without change of parameters of net after casual interval of time dT

Note, that the efficient system of updating should reveal contradictions during updating a net, and also take into account the previous experience of changes and carry out selection of size dT.

Conclusion

The ways of the description of logistical circuits by Petri nets are considered . Various expansions of Petri nets are applied to the description of logistical networks. Generally, evident models can be used for calculation of some parameters and optimization of static logistical chains. The logistical net can be transformed depending on the purposes business of process in the real environment . The concept of an intellectual logistical network for modeling transformed circuits are proposed.

For modeling changeable circuits the concept of an intellectual logistical network is offered. Management of such network is carried out on the basis of principles of behaviour of artificial alive essences - animates, in particular self-training. A self-training net is a net which is capable to optimal changing according to changing conditions. For example, it must change in the case of change of cost of separate transactions or change of critical ways and nodes.

In some cases speed of change of a net and restriction of checking a variants of transformation can be critical. With the purpose of reduction of amount of possible initial marks of model, the algorithm of calculation of "expedient" set of initial marks is offered. It allow to reduce amount of variants and steps of "reasonable" changing of a network.

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R. Muhamedijevs. Intelektuālā loģistiskā tīkla modelēšana

Tiek piedāvāta Intelektuālā loģistiskā tīkla (ILT) koncepcija, lai modelētu maināmos tīklus. Aplūkoti ILT apraksta paņēmieni ar Petri tīklu palīdzību. Tādu tīklu vadīšanā par pamatu var ņemt mākslīgo dzīvo būtņu (“animate”) uzvedību, piemēram to pašapmācību. Lai samazinātu modeļa sākotnējo marķējumu skaitu, tiek piedāvāts algoritms “lietderīgo” sākotnējo marķējumu aprēķinam. Tiek piedāvāts arī “saprātīgs” paņemiens tīkla izmaiņām.

R. Muhamedyev. Modeling of intellectual logistic net

The concept of an intellectual logistical network (ILN) for modeling transformed circuits is proposed. The ways of the description of ILN by Petri nets are considered. Management of such network is carried out on the basis of principles of behavior of artificial alive essences - animates, in particular self-training. With the purpose of reduction of amount of possible initial marks of model, the algorithm of calculation of "expedient" set of initial marks is offered. The way to "reasonable" changing of a network is proposed also.

Р. Мухамедиев. Моделирование интеллектуальной логистической сети

Предложена концепция интеллектуальной логистической сети (ИЛС) для моделирования изменяемых сетей. Рассмотрены способы описания ИЛС с помощью сетей Петри. Управление такими сетями может базироваться на основных принципах поведения искусственных живых существ – аниматов, в частности, самообучении. С целью уменьшения количества начальных маркировок модели предложен алгоритм расчета «целесообразных» начальных маркировок модели. Также предложен способ «разумного» изменения сети.