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Dedicated to the memory of Academician Mitrofan M. Cioban (1942-2021)

Petri nets for e-learning. Case study

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Abstract. The internet technology induces a new style of learning by the rapid development of it. This one is different from the traditional and comes to complete it with new opportunities. The study described in this article has researched the management process of the learning progress and collaborative issues in distance learning by means of Petri nets. A case study is presented.

Keywords: e-learning, collaborative learning, Petri nets, efficiency of learning.

Reţele Petri pentru e-learning. Studiu de caz

Rezumat. Dezvoltarea rapidă a tehnologiilor informaţionale induce un nou stil de învăţare. Acesta este diferit de cel tradiţional şi vine să îl completeze cu noi oportunităţi. Prin studiul descris în acest articol s-a cercetat managementul procesului de progres al învăţării instruiţilor şi probleme de colaborare în învăţământul la distanţă prin intermediul reţelelor Petri. Este prezentat un studiu de caz.

Cuvinte cheie: e-learning, învăţare prin colaborare, reţele Petri, eficienţa învăţării.

1. Introduction

Educational system in the Republic of Moldova faces a lot of problems that, especially in the Covid 19 pandemic situation, have intensified even more, generating a series of difficulties at the level of organization and management of learning, both from a methodological point of view and from a technical and psycho-emotional one of all educational actors involved. Thus, a priority of all education systems, including the education system in the Republic of Moldova, in this period of forced reorganization of the system, radically different from the traditional one, is to ensure continuity and avoid educational disruptions. Distance learning comes to solve these problems, but generates new ones related to the adaptation to this way of training, ensuring the supervision of the learning process so that it brings efficient results. The opportunities offered by information and communication technologies are increasing the efficiency of the educational system, extending and diversifying the educational offers, and continuous training. Until recently, in many countries, distance learning has not been widely used for several objective reasons - mainly due to the insufficient development of technical means of training. Currently,

the technical premises for the widespread use of distance learning in education have been created, and the COVID-19 pandemic has energized and accentuated their urgent need.

That's why, it is essential to identify the users needs and to integrate into the used tool the functionalities that allow them to be satisfied. The emphasis on distance learning shifts from teacher to student and it is necessary to obtain information about student's progress and the level of collaboration with other students. For this purpose it is proposed to use Petri nets [4] as a tool in modelling the management of these processes.

2. Distance education

The learner has flexibility in time and location in distance education [6]. This one, according to the facility used, can be categorized into two styles: *synchronous* and *asynchronous*. Thus, being geographically dispersed, in a synchronous way, they have opportunities to collaborate and to develop even in crisis situations.

Definition 2.1 ([7])**.** Collaborative learning is the educational approach of using groups to enhance learning through working together. Groups of two or more learners work together to solve problems, complete tasks, or learn new concepts.

Collaborative learning involves new opportunities for learners and new approaches for teachers, their role being no less necessary as a mentor, thus optimizing the teaching process by distributing the resources to the trainees and organizing activities through new technologies.

In order to increase the efficiency of group learning, information and communication technologies in education are coming. Learning Management Systems (LMS) are one of them. They are able to provide on-line content, member accounts, discussion board, assessment and other facilities. The motivation of each member of the group, the number of members, their skills are other important issues in increasing the effectiveness and efficiency of collaborative learning [5].

For the proposed it will be applied approach of modelling the individual and group route management through Petri nets, the MAETIC learning method (from the French: Pedagogical Method with ICT tools), which is based on project-based development.

3. High-Level Petri Nets

Ordinary Petri nets are a formal method of describing real distributed systems that have the following characteristics:

(1) Graphical Representation - a Petri net is represented by a directed bipartite graph in which nodes are either places (represent conditions) or transitions (represent activities);
(2) Formal Analysis - formal analysis techniques allow determining properties and verifying the workflow of information;
(3) Software tool - a tool developed to facilitate the process of verifying the system properties.

In the description of complex systems explosions of the number of elements can occur, which lead to a difficulty in properties verification. To avoid these problems High-Level Petri Nets were developed by introducing higher-level concepts, such as the use of complex structured data as tokens, and using algebraic expressions to annotate net elements.

High Level Petri-nets (HLPNs) asset:

(1) Have an intuitive graphical representation and a well-defined semantics that unambiguously define the behaviour of each HLPN;
(2) They are very general and can be used to describe a large variety of different systems;
(3) HLPNs have very few, but powerful, primitive, and an explicit description of both states and actions;
(4) HLPNs are stable towards minor changes of the modelled system;
(5) A formal analysis methods allow proving the properties of HLPNs;
(6) The two most important analysis methods are known as occurrence graphs and invariant technique. There are computer tools [8] supporting their drawing, simulation and formal analysis.

Definition 3.1 ([2])**.** A **High-level Petri Nets** is a structure $HLPN = (P; T; D; Type; Pre; Post; M_0)$, where

- P is a finite set of elements called Places.
- T is a finite set of elements called Transitions disjoint from $P(P \bigcap T = \emptyset;)$.
- D is a non-empty finite set of non-empty domains, where each element of D is called a *type*.
- $Type : P \bigcup T \rightarrow D$ is a function used to assign types to places and to determine transition modes.
- $Pre; Post : TRANS \rightarrow \mu PLACE$ are the pre and post mappings with
  $TRANS = \{(t; m) | t \in T; m \in Type(t)\};$
  $PLACE = \{(p; g) | p \in P; g \in Type(p)\}.$
- $M_0 \in \mu PLACE$ is a multiset called the initial marking of the net.

A *Marking* of the HLPN is a multiset, $M \in \mu PLACE$.

A transition is enabled with respect to a *net marking* or in a particular *transition mode*. A transition mode is an assignment of values to the transition variables, that satisfies the transition condition (i.e., the transition condition is true). The transition variables are all those variables that occur in the expressions associated with the transition. These are the transition condition and the annotations of arcs involving the transition.

A finite multiset of transition modes, $T \in \mu TRANS$, is enabled at a marking M iff $Pre(T_\mu) \leq M$.

A step may occur resulting in a new marking M' given by $M' = M - Pre(T_\mu) + Post(T_\mu)$.

4. Mapping High-Level Petri Nets for collaborative learning

In this section, we use HLPNs [3] to construct various sequence control in distance learning. Depending on the behavior of the learners we can have different learning paths. In order to identify these paths, we will specify several control sequences that may occur. Based on the same course content, we can have different instructional strategies: *linear, choice*, and *arbitrary* traces that combines the first two.

For linear learning path, the learner progress is in a pre-determined order (Figure 1). In Figure 1, the learner can go to the next topic only after finishing the previous one and so on.

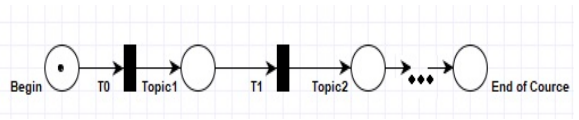

Figure 1. Linear Learning Path by Petri Nets

Linear choice path allows jumping and selecting the next content in the arbitrary order (Figure 2). The learner in Figure 2 can access arbitrarily any topic he wants from n existing ones.

The collaborative learning is an effective method in distance education, thus we propose to model this process for better understanding.

The goal of collaborative learning is to form a group with heterogeneity even if they have different background, various learning paths and diverse instruction styles. In order to achieve this goal, it is necessary that each learner has the opportunity to make a break point (jump) to obtain additional information from the outside (a sub-net), so that, on return, he/she can ensure the homogeneity of the group.

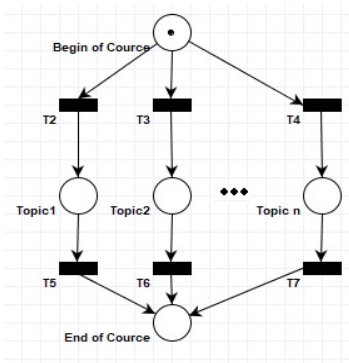

Figure 2. Choice Learning Path by Petri Nets

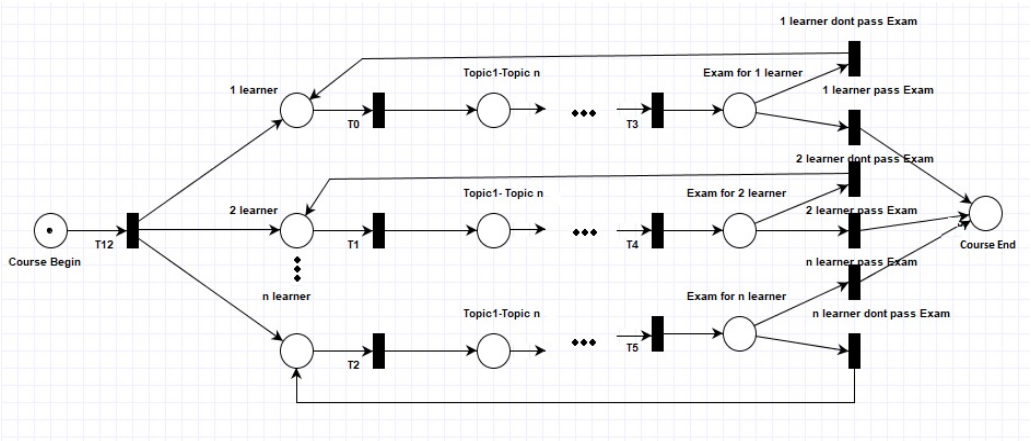

Figure 3. Collaboration modelled by H-L Petri Nets

5. Case study

For the case study we will model the system with two learners which can collaborate for completing the course.

After the modelling of collaboration learning trace, by analysing the HLPNs, we can estimate the block, deadlock of the system and learning path in order to improve the process. In our case study we obtain that each learner must complete the course alone by following the red path (for the first learner) and the green path (for the second learner) (Figure 4). Also, they can take the course by collaborating in Figure 5. In order to successfully course completion, achieving state S16, they follow red path - blue path for the first choice, green path-blue path for the second choice.

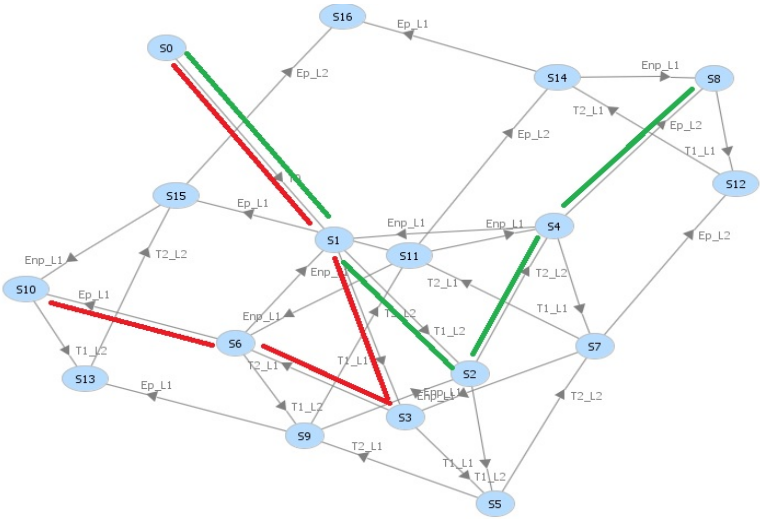

Figure 4. The occurrence graph of the modelled system

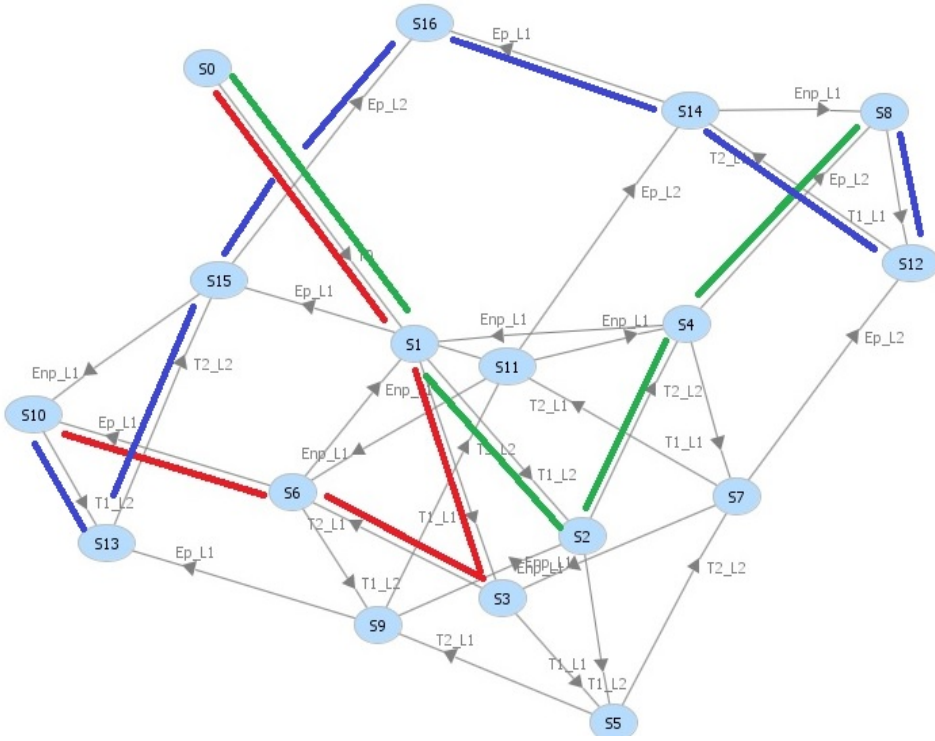

Figure 5. The occurrence graph, highlighting the collaboration of learners

6. Conclusion

By HLPNs it is possible to model large systems in a manageable and modular way. In particular, Petri nets is a convenient formal method for modelling the management of the learning progress and collaborative issues. Thus, it was shown how to identify the needs of users and integrate the functionalities into the system for better understanding of these processes.

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