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Petri Nets Android application as a mobile aid for students' mastering modelling

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Abstract. Building models of various processes and their further investigation has been always in focus of different specialists' training. There are some quite well known mechanisms and tools of modelling. However, Petri nets theory has found its wide application to the real-life parallel processes modelling. Petri nets give powerful facilities for dynamic models building and enable comprehensive learning of the process peculiarities. Hence, it is important to have relevant tools which allow to apply Petri nets potential to educational practice on purpose of earning by students skills of models building and investigation. The aim of the paper is to depict the functionality of the authors' mobile Android application "Petri Nets Tool-Kit", and to specify facilities and examples of its using for mastering modelling by students. Developed and represented in the paper mobile application provides students with the set of tools which enables to create, edit, save their own Petri nets as well as to change their parameters, visualize changing and play various scenarios of the modelled process. The "Petri Nets Tool-Kit" also contains relevant theoretical materials and the set of ready-made Petri nets examples, which makes the application attractive for mobile learning both in classroom activity and in students' independent work in the context of their vocational training in terms of different specialties. The proper stages of learning activity for step-by-step mastering by students the basics of modelling and simulation are disclosed. It is shown that "Petri Nets Tool-Kit" is available exactly in its portable form for Android OS, which encourages students to mobile learning and arms them with a convenient simulation tool provoking them to improve their modelling and investigative skills anywhere during the day. The prospects of the work are outlined in terms of the empirical research as for validating the impact of modelling activity in the elaborated application on the trainees' level of modelling skills.

1. Introduction

Models and simulations have always been in focus of different specialists' training, and have become integral part of an advanced learning environment. According to studies, modeling activities must be incorporated into training process due to their high didactic potential. In particular, authors ([6], [7], [12] and others) point out that including students in the models creating and providing opportunities for them to experiment with it enables to increase students' comprehension of the modeled process (phenomena).



It is also emphasized the essential role of computer models building and simulation as a process of executing of the mathematical model which enables representation of the real system (process) and its behavior in real time by means of computer. The computer simulation provides facilities of dynamic visualization and modification of the model which allow students understand deeper the basic features of the modeled processes and develop their investigative intuition ([4], [6]). Computer simulations are also seen as an opportunity to explore complex processes without having access to their real prototypes, and to understand the peculiarities of interaction of its different elements.

In the context of computer models building and simulation, nowadays priorities tend to shift in favor of mobile aids using on learning purposes. It is explained by the rapid growth of across-the-curriculum mobile gadgets use, BYOD strategy spreading in all levels of education, current needs for integration of different educational technologies, flexible forms of learning and tools for students' personal independent work. In the studies it is pointed out some common features of mobile learning which seem to be beneficial for computer simulation mastering by the students: opportunity to study always and everywhere provoking trainees to generate and test your ideas instantly; portability of devices and immediate availability of learning mobile aids; facilities of easy content renewing and sharing the results of your work within the mobile applications etc.

There are some quite well known mechanisms and tools of modeling and simulation that has been used effectively for relevant investigation practice. Among them there is Petri nets theory which has found its wide application to the real-life parallel processes modeling. Petri nets give powerful facilities for dynamic models building and enable comprehensive learning of the process peculiarities. Hence, it is important to have relevant computer tools which allow to apply Petri nets potential to educational practice on purpose of developing students' skills of models building and investigation. In addition, regarding the contemporary tendencies in favor of mobile learning, it seems to be essential to develop and implement a mobile application with necessary tools and content.

However, the analysis of the available software (given, in particular, in [11]) testifies the lack of proper aids which could satisfy the needs of Petri nets using on educational purpose of modelling skills earning by students, and exactly in terms of mobile learning. In particular, the existed environments are mostly web-oriented software which are Internet-dependent and cannot be equally used by all the students everywhere. Some of the current applications are desktop ones and hence, are not usable on the purpose of mobile learning. Besides, all of the said Petri nets available software provides a user with necessary tools for Petri net design and analysis, but without proper didactic support (e.g. short theory, examples, instructions, tasks for independent modelling etc.), which decreases their educational value. It is also important to point out, that according to studies, Petri nets potential is currently applied to solving of urgent educational tasks (e.g. modelling educational processes in the learning management systems [2]; modelling students' learning paths [3]; students' scoring and evaluation at e-courses doing [1]; inclusive education IT-support [10] and others). However, there is a lack of studies describing the Petri nets using on purpose of developing students' computer modelling skills.

Thus, due to the urgency of the problems mentioned above, the elaboration of the aids which are able to provide mobile learning for students' modelling and simulation based on Petri nets seem to be of current importance.

The aim of the paper is to depict the functionality of the mobile Android application "Petri Nets Tool-Kit" developed by the authors, and to specify means and examples of its using for mastering modelling by students.

2. Petri nets as a modelling instrument

Developing the application, we addressed to the fundamentals of Petri nets theory which provided us the mathematical basics of the nets building and their application to the processes modeling. Petri nets make a modeling formalism with a graphical representation and a precise syntax and semantics.

According to the theory ([8], [9], [3], [10]), a Petri net can be defined as a two-partite oriented graph $N = \langle P, T, R \rangle$, where $P = \{p_i\}$, $T = \{t_i\}$ are finite nonempty sets of a graph vertices among

which there are distinguished two types of vertices: places (P) and transitions (T). R -component determines a relationship between the vertices corresponding to the arcs. In a graphical representation of a Petri net, places are indicated with circles, whereas transitions are denoted with bars. Due to the rules of Petri nets theory, vertices of the same type cannot be connected. The places (circles) can accommodate tokens that can move around the net via transitions (bars). Disposition of tokens in places is determined by the marking set M which assigns an integer number to each place: $M = \langle M(p_1), \dots, M(p_i) \rangle$, where i is a number of places of the net, and $M(p_i)$ is the number of tokens in the place p_i . Thus, the number of tokens and their disposition around the net control the net execution.

Various markings of the Petri net characterize the states of the corresponding dynamic system, and the dynamics of state changes is modelled by the movement of the tokens around places. Net marking may be changed as its transitions are triggered. When a transition is triggered, one token is deleted from each input place and is added to each output place.

The main features of Petri nets briefly covered above, demonstrate their core advantages to be effectively used for modelling of parallel and consequent processes to solve real-life practical tasks. In the educational context, we would like to emphasize some essential Petri nets benefits. The formalism has intuitively clear facilities which correspond to real objects (process elements), events and their interaction, which encourages building of the real process model. In addition, Petri nets enable to demonstrate the interaction of the process components in its dynamics that can be visualized in computer interpretation of the net. Finally, facilities of manipulation with the nets parameters and changing its state with immediate visualization make them really powerful instrument for students' learning to model and simulate various processes during their vocational training in terms of different specialties.

3. Authors' mobile application "Petri nets tool-kit" and modelling activities within its environment

The basics of Petri nets theory were applied by the authors to the development of the mobile application "Petri Nets Tool-Kit". The requirements to the application which determined its functionality were formulated due to didactic needs as for incorporation of modelling activity into the students' training with the aim of the forming of their modelling skills. So, the application has to provide a trainee with (1) necessary tools to build a Petri net as a model of a process, to validate its functionality, to manipulate with its parameters, to edit, and save the built Petri net; (2) a set of ready-made examples of Petri nets with the learning tasks to explore the nets behavior and use as a base for trainee's own models; (3) concise theoretical materials on Petri nets formalism. In terms of technical needs, the application must be running on all Android OS since version 5, and the net overload should not exceed 300ms.

3.1. Main stages of the application development

Coming from the formulated requirements, the main phases of the application development were outlined which can be characterized as follows.

At the first stage the didactic functions of the application were specified due to the requirements, which made the basis for interface specifications.

At the next stage the general architecture of the application was developed. It defined the core structure of the application, links between the components which were determined by the basic application functions. In particular, the general architecture is represented by two main components: data (Petri net) component and graphical support. Data component includes four subcomponents, which respectively provide (1) internal net representation, (2) its storing, (3) execution, and (4) utilities for users' nets manipulation respectively. The data component makes a basis for graphical support component that realizes proper visual representation of the said data component parts.

Then object-oriented analysis and design were provided. In the process of the analysis the technical functions of the application were determined in terms of concepts and objects of the subject area, based on the depicted concepts and revealed links between them.

The use case diagram was built at this stage to describe in details a potential user's behavior. In particular, it was determined that the user is expected to initiate such use cases as: (1) to run the application; (2) to get familiar with Petri nets basics; (3) to work with ready-made examples of the nets (to choose them from the library, to obtain their graphical image, to solve modelling problems from the library upon the chosen net, to change the net states to solve the problem, to see the visualized graphical image of the changed net etc.); (4) to design their own Petri net (to locate on the screen places, transitions, and to join them with arcs, to set up marking allocating tokens in the proper places, to test and check the net correctness, to trigger fired transitions, to manipulate the net parameters and monitor the changes, to save the net and later download it, to edit the net via adding/deleting vertices, changing links and the net marking); (5) to simulate various processes (to work with their own net or the net from the library, to play different scenarios, to solve problems, to fill up the examples library with their own nets). Apparently, all the use cases are connected with each other, which is also reflected at the diagram (that is not included into the paper for the sake of conciseness). As a result, the conceptual model of the subject area "Process modeling by the means of Petri nets" was created. On the stage of object-oriented design the obtained conceptual model was used to determine application classes, objects, and proper links between them.

Next phase was devoted to the application interface design coming from the requirements and the use case diagram. Design of all application screens was developed in accordance with all use cases and links between them. All of the elements of graphical interface were tested as for their usability to make sure that the design solutions are ergonomical ones and enable a user to solve their tasks efficiently. Then the program realization of the application "Petri Nets Tool-Kit" was undertaken in Java within Android Studio platform: class diagram (figure 1) was built, and the class and methods description was done along with their program implementation.

Then necessary didactic content for the aid was created and proper components were filled in with the theoretical material, Petri nets examples, learning tasks, instructions etc.

At the final stage the application was tested, according to the didactic and technical requirements formulated above. Then the application was introduced into practice of students' classroom and independent learning activities.

3.2. Didactic potential of "Petri Nets Tool-Kit" as for students' modelling learning

As a result, the Android mobile application "Petri Nets Tool-Kit" allows a trainee to work in three main modes which determine basic functions of the application. The first core mode (Petri nets design) enables to design your own Petri net in order to model a process in order to solve a suggested modelling problem. A trainee is provided with necessary tools to create proper places, transitions and arcs, and to set initial marking of the net. Afterwards the application allows to test created net's execution, to verify its correctness via comparing with the state matrixes, and to edit the net (if necessary).

Then the student can modify the net parameters with the aim of simulation of various scenarios of the process evolution, and to explore their peculiarities. There is a possibility to save the designed net and then to restore it in order to go on working upon it later.

Besides, a trainee can work with ready-made Petri nets which are available in the library of examples of our application (the second mode). Working in this mode (Examples Library), students can simulate various processes and solve simple tasks on learning the basics of Petri nets theory. The examples from the Library can be also used as a base for trainee's own models. In addition, there is a realized facility to fill up the Library with student's own nets, created during their work in the design mode of the application.

Students are also provided with the third mode of learning fundamentals of Petri nets theory where they are supported by the concise theoretical materials on the topic and the facility to implement them on simple examples.

Characterizing the didactic potential of the developed application, we would like to recommend some stages of learning activity for step-by-step mastering by students the basics of modelling and

simulation based on Petri nets formalism. Below we are illustrating the learning activity on some examples of modelling problems within the environment of the “Petri Nets Tool-Kit” that were offered to the students within their classroom or independent mobile learning.

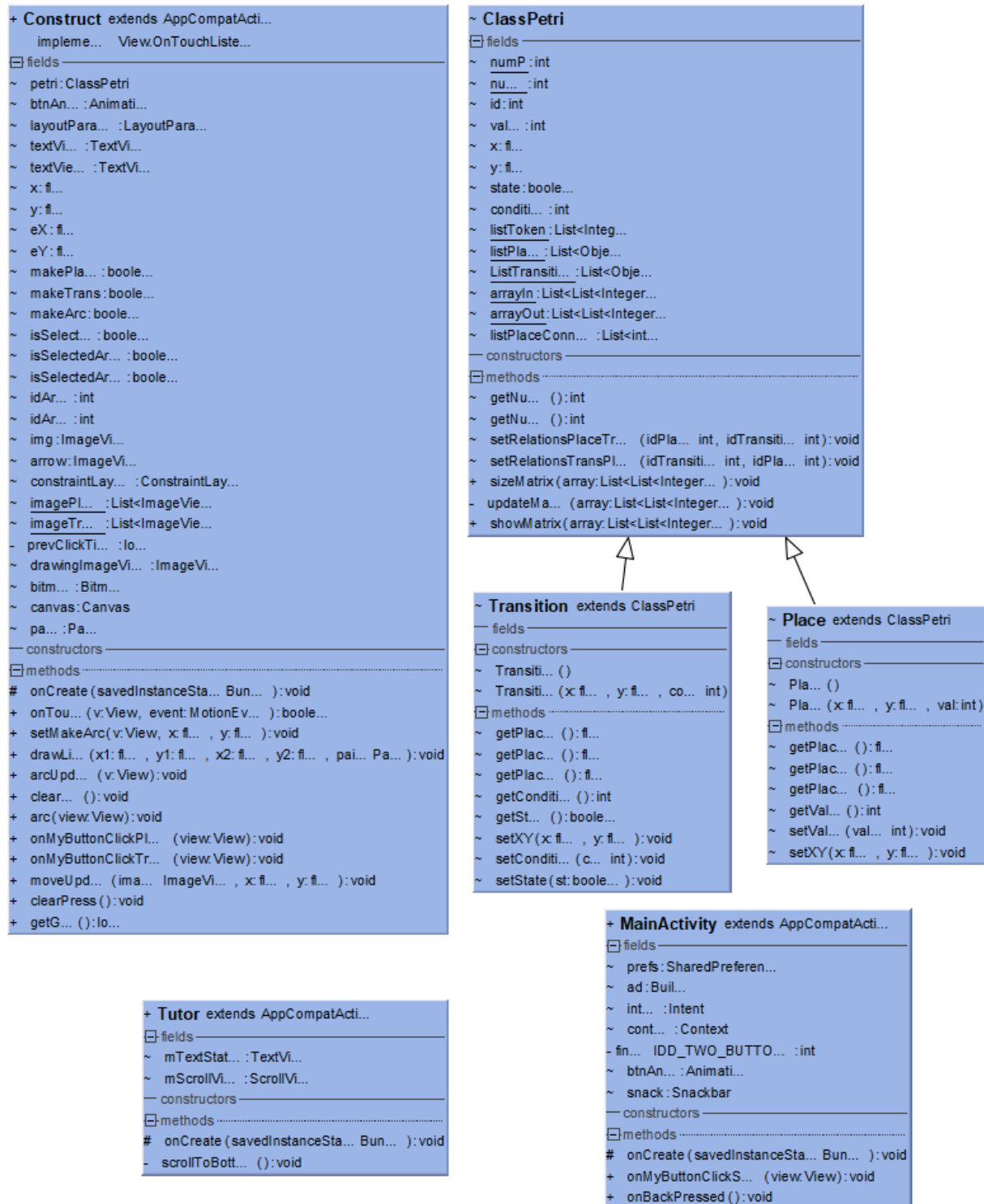


Figure 1. Class diagram for the program realization of the application “Petri Nets Tool-Kit”.

In particular, we would recommend to start with the work in the third mode within “Petri Nets Tool-Kit” and master the formalism as a main tool for processes modelling. Theory learning is enhanced here with the work upon simple samples provided by the Examples Library along with modeling tasks for students.

For instance, at this stage a trainee can be proposed to model the traffic control with the traffic lights using simple net from the Library. Here students are asked to determine which places refer to the traffic lights, what functions of transitions are etc. Then students are encouraged to add independently proper places and transitions in order to simulate triggering of traffic movement, to set up initial marking, and execute the net. In figure 2 the episodes of the students’ learning activity upon the sample are shown, where places 1-3 refer to red, yellow and green lights of the traffic lights, places 4-5 refer to traffic movement, transition 1 corresponds the green light arriving, and transition 4 triggers the traffic movement. Using the slider students can change initial marking of the net and explore the states of the net.

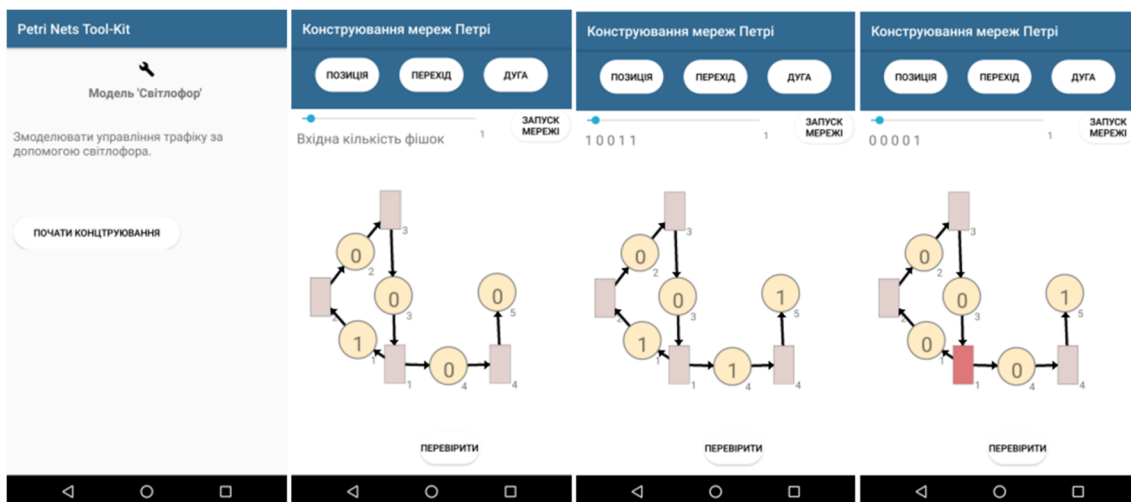


Figure 2. The episodes of the students’ learning activity upon the modelling of traffic control with the traffic lights.

At the next stage of learning activity students can be offered to solve independently some simple modeling problems on Petri nets design within our application with their consequent exploring. In particular, for students of different specialties it might be beneficial to learn how to model the processes of mass service on the example of colloquial exam passing. The problem may be formulated in such a way [12]: to build a model of passing an exam by four students to a teacher. In order to solve such a problem and to design proper net, the trainees have to detect themselves how many places and transitions they will need, how to join them, what the role of the initial marking is etc. Students design the net using the instruments of our tool-kit. Afterwards, trainees are asked to imitate different scenarios of the given process, for example, when (1) all four students are waiting for their turn, (2) two students are waiting, one student is passing his exam (the teacher is busy and unavailable to other students), and one student has already passed it, (3) three students are ready to pass the exam and one student is queuing etc. (see figure 3 below).

At the next stage, in order to advance students’ modeling skills we would recommend them to solve more complicated real-life problems. For instance, it might be the problem [12] as for simulation of safe one-way movement on the railway segment of given configuration (see figure 3 below) that consists of railway drives with semaphores and indicators of occupation. To provide effective modeling and simulation activity, it is relevant to encourage trainees to analyze the given configuration and to determine the purpose of places and transitions they need, how to join them to

obtain the necessary shape of the road, what kind of initial marking to assign etc. The results of the model building on its different stages are given in the figure 4.

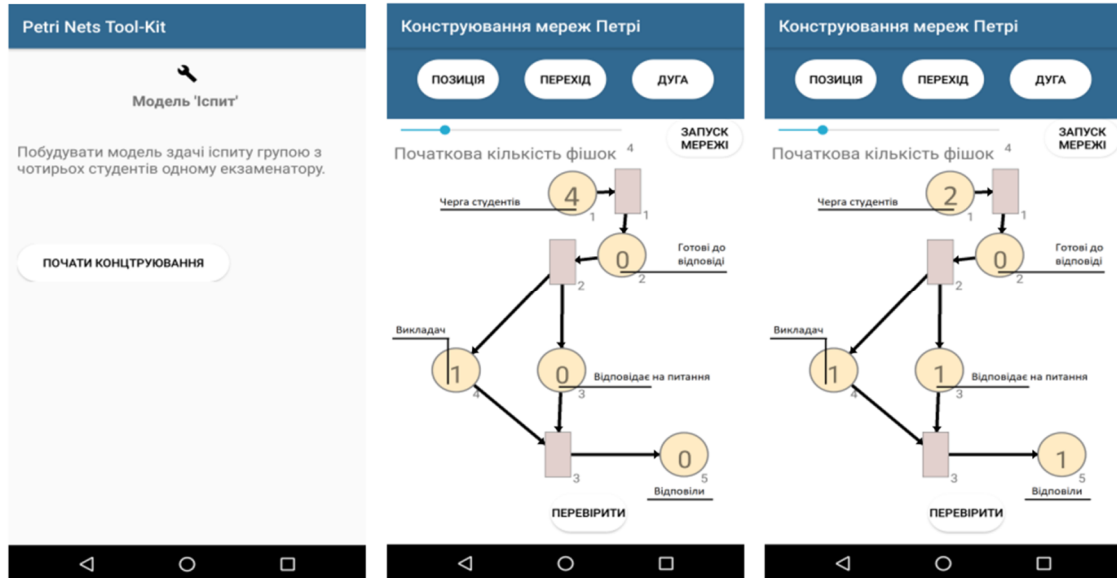


Figure 3. Various scenarios of the evolution of the process of passing an exam within the environment “Petri nets tool-kit”.

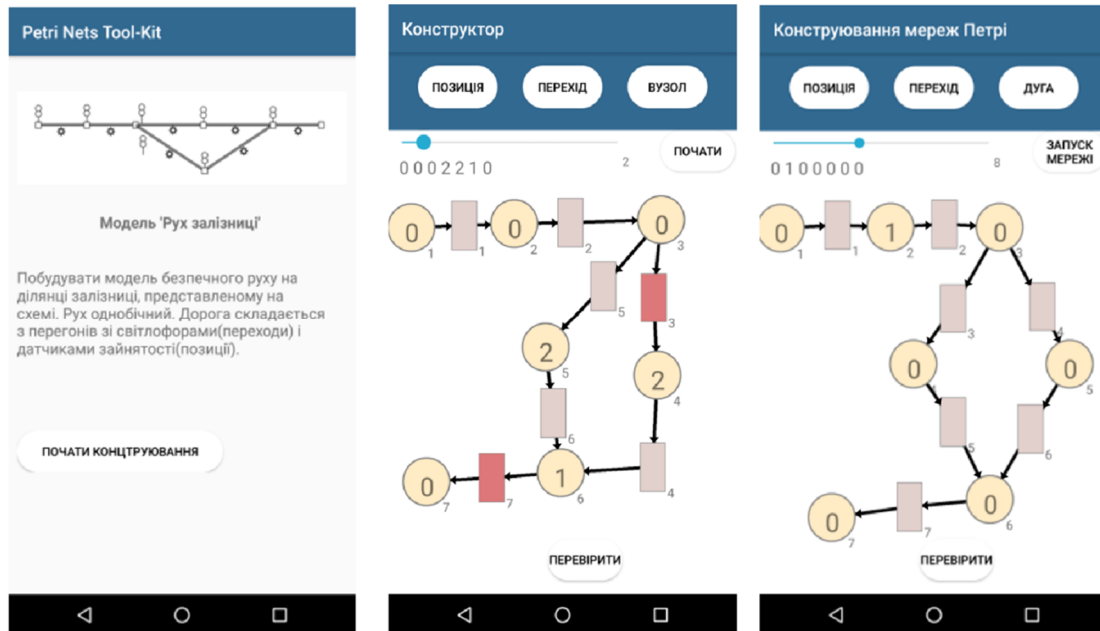


Figure 4. Various stages of students’ design of the Petri net which models safe one way movement on the railway segment of given configuration.

After the model building it is recommended to offer students to imitate and investigate various scenarios of the process, emphasizing the conditions of safe movement for this exact segment of railway.

At the level of advanced modelling in pre-service IT specialists' training, special tasks can include algorithmic problems solving. The Examples Library of the application provides students with the primitives of basic algorithmic constructions (sequence, selection, repetition) in the form of ready-made Petri nets which can be used by trainees to design themselves and investigate various real-life algorithms including parallel ones.

In fact, the didactic components of the developed application contain variety of examples and modeling problems which can be changed and renewed due to the needs of proper specialists' training.

Thus, depicted above functionality of mobile application "Petri Nets Tool-Kit" and examples of modelling activities in its environment, testify its significant facilities as for earning simulation habits and investigative skills for students of various (technical, engineering, IT) specialties within the set of curriculum subjects (such as Discrete Mathematics, Computer Modelling, Programming, Operations Investigation, Systems Modelling etc.). In fact, modelling and simulation activities provided by the application are able to awake students' interest as for processes exploring, imitating their different scenarios, their critical estimation, and revealing their weak points. In such a way these activities within the application encourage students to enquiry-based learning and develop their modelling and investigative skills. Obviously, it can be beneficial for their real professional activities.

We would like also to underline some special benefits of the application using in the training of pre-service teachers (especially Science, Math, and Informatics teachers). Modeling activities, based on Petri nets formalism within our mobile tool-kit, arm them with powerful tool of various processes simulation and exploring. In long run, it can be extended by the pre-service teachers in their own training activity with schoolchildren. In addition, using Petri nets tools, teachers can incorporate the elements of gamification into the learning process. Finally, Petri nets mechanism enables to model academic disciplines structure and build optimal individual students' paths, which can be applied by teachers in their professional activity, as it was offered in some of studies, in particular in [2], [3].

Special emphasis should be put on the advantages of exactly mobile learning of Petri nets modeling, provided by the aid "Petri Nets Tool-Kit". Obviously, it enables all the common benefits of mobile learning (mentioned in the Introduction). Besides, we could point out some special features of the application which are really beneficial from the standpoint of modelling skills developing within mobile learning. In particular, it supplies a trainee with all necessary theoretical, didactical and instrumental means to design and to explore a process model easily and in thought-provoking way. The application can be downloaded to Android device, so it is Internet-independent, and can be used completely everywhere and free. In addition, a student is enabled and encouraged to fill up the Examples Library with his own Petri nets models to use them for further elaboration and exploration. It makes the application an attractive instrument for individually-driven mobile learning which motivates a student to master modelling skills according to his personal interests and needs. On the whole, the Android mobile application "Petri Nets Tool-Kit" represents a portable convenient tool for instant and permanent model design, experimenting, hypothesis testing, provoking students to improve their modeling and investigative skills anywhere during the day.

4. Prospects of the research

The application has been developed in its pilot version with the set of functions presented above. It was implemented into the pre-service teachers' training within the classroom and independent work on the courses of "Computer modelling", "Discrete Mathematics", and "Programming". Our observations as for the students' mobile learning activity within the "Petri Nets Tool-Kit" and students' preliminary academic results allow to predict its positive impact on the trainees' level of modelling skills and cognitive eagerness.

Hence, it turns up necessity of the empirical research to validate our prediction which makes the prospects of our work. On the preparation stage, it is elaborated the indicators base for the research. In particular, it is developed the set of questionnaires (based on the work [5]) with proper scale of modeling skills measuring. In addition, the program of observation and assessment of students' cognitive eagerness during classroom and independent work is created. Thus, empirical research as for

the impact of modelling activity in the elaborated application “Petri Nets Tool-Kit” is ready to get started and will be covered in further papers. Due to the results of the future empirical research, the application will be elaborated.

5. Conclusions

According to the aim of the paper, it is depicted the functionality of the mobile application “Petri Nets Tool-Kit” developed by the authors resting on the Petri nets fundamentals and minding their advantages as for modelling of parallel and consequent processes. The basic stages of the application development are covered. The functionality and examples of the application using to provide modelling activities for students within their mobile learning are specified. The advantages and benefits of processes modelling based on Petri nets mechanism and provided by “Petri Nets Tool-Kit” are emphasized in the context of students’ vocational training in terms of different specialties. The proper stages of learning activity for step-by-step mastering by students the basics of modelling and simulation are disclosed.

In particular, “Petri Nets Tool-Kit” provides students with the set of tools which enable to solve modelling problems: to create, edit, save their own Petri nets as well as to change their parameters, visualize changing and play various scenarios of the modeled process. The application also contains the library of ready-made Petri nets examples and learning tasks for the models exploration, and relevant theoretical materials, which makes the application attractive both for classroom activity and for students’ independent work in terms of their mobile learning. It is also important to point out, that “Petri Nets Tool-Kit” is available exactly in its portable form for Android OS, which encourages students to mobile learning, and arms them with a convenient simulation tool provoking them to improve their modeling and investigative skills anywhere during the day.

The prospects of the work are outlined in terms of the empirical research as for validating the impact of modelling activity in the elaborated application on the trainees’ level of modelling skills.

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