Virtual Research Laboratory – Conceptual Model and Preliminary Stochastic Investigation

Radi Romansky

Abstract: *The virtual laboratories unite different e-learning resources, knowledge and research technologies in common environment in order to obtain new knowledge and carry out experimental work. There are different virtual laboratories in the web world, but our idea is to build international environment for scientific research and e-learning in the field of modern electronic and computer technologies. In this reason the purpose of the paper is to introduce the initial phase of the development of a Virtual Research Laboratory (VRL) that will unite specialized sub-systems for research in the fields of circuit design and digital tests generation, fault tolerance investigation, 3D simulation and virtual scenarios realization, support of e-communications, etc. The realization of a VRL is object of new two-year research project started in April, 2010. In this reason, the paper discuses the development of the conceptual model, that is formalized by using graph describing. On this base a general structure could be determined and a stochastic model for preliminary investigation is defined. Some stochastic assessments are presented and discussed.*

Key words: *Virtual Environment, Distributed Servicing, Formalization, Stochastic Modelling.*

1. INTRODUCTION

The purpose of the virtual laboratory is to give a distributed platform for collaborative learning, cooperation between different scientists and online realization of scientific research in specialized fields – for example, in the field of medical research [3], computing and communication technology [2], electronic circuit simulation [7], etc. It presents a model of interactive tools for supporting lectures, hands-on training, homework assignments and research. There is a variety of virtual laboratories in the world. For example, three-layer architecture as networked applications to support research in mathematics and natural science is proposed in [5]. The architectural problem is discussed in [1] too. A web-based virtual laboratory that improves the automatic control teaching of undergraduate courses is presented in [4]. This is achieved by optimizing the time the students spend in the real laboratory.

The general object of discussion in this article is a Virtual Research Laboratory (VRL) that will support the scientific work, education, knowledge exchange and intelligent searching in the field of electronics and computer technologies, and particularly for circuit design and digital tests generation, fault tolerance investigation, 3D simulation and virtual scenarios realization, support of e-communications (e-meetings), etc. The main goal of the project is to create a virtual environment of different territorial subsystems, united in a common international research laboratory. The realization of this distributed environment is the object of a new two-year research project started in April, 2010. In this reason, a survey of some popular Web-based virtual laboratories and used means and tools is made by members of the project team which is presented in [8].

The purpose of this article is to present the first phase of the VRL architectural design. It is known that the initial steps of software development are conceptual analysis and formalization [9], components modelling [10] and processes evaluation [6]. In this reason, the paper discuses the general conceptual model of the joint virtual environment, based on the main idea to unite different sub-systems for specialized scientific research. A graph formalization of the expected information processes in the future VRL is made and preliminary investigation by using developed Markov chain model is carried out. Some stochastic assessments are presented.

2. GENERAL IDEA

The virtual laboratory is an alternative of the real laboratory work. Embedded software in such a laboratory could replace a significant investment for real equipment. It

has the advantage of flexible access (e-access), as safety permits remote users who use the Internet to carry out experiments.

The main idea is to build **V**irtual **R**esearch **L**aboratory on the field of **E**lectronic and **C**omputer **T**echnologies (VRL-ECT) as a multi-nationality virtual environment which could be extended by new modules, starting at the beginning with one of the several basic modules. Timeliness is associated with the growing interest in scientific and applied aspects of the creation of three-dimensional models of real world objects and their simulation using the capabilities of 3D modelling, computer graphics, virtual reality and communication. Applicability of the results can be sought in science and engineering, as well as the development of electronic learning, using three-dimensional technology for learning different objects.

Thus, creating an international virtual laboratory will expand the scope of research with the opportunity to combine knowledge, skills and content in different directions. This is a useful solution for global IT development which would allow future integration into the team from the Department of Electronics, Computer Systems and Technologies (Bulgaria) and new partners from other countries (Informatics and Management Dept. – Slovakia and Computing and Telecommunication Dept. – Greece) – Fig. 1.

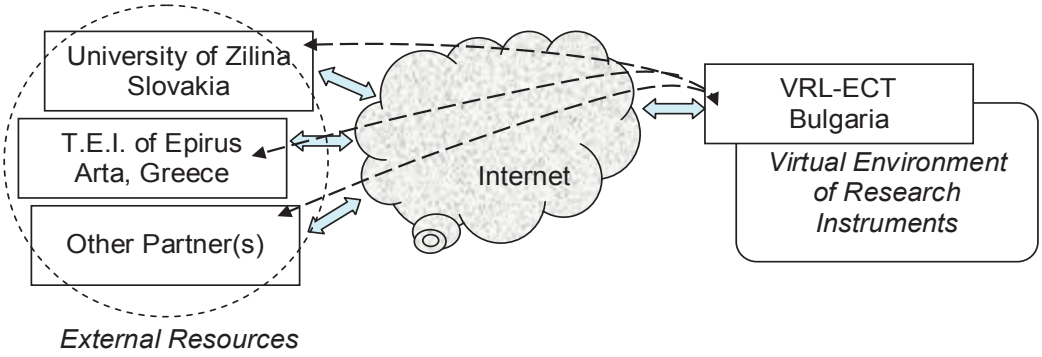


Fig.1. General idea of the VRL-ECT

3. CONCEPTUAL MODEL AND FORMALIZATION

The VRL development project is associated with modern IT (e-access, e-society, e-servicing, e-learning) and will allow to create a web-space for product support and stimulate research and innovation. For the construction of a virtual space, the following steps should be undertaken:

✓ Design and testing of the virtual space and the processes for implementation of the research laboratory as a medium for exchange of knowledge and ideas realized by web-based interactive multimedia and distributed technologies;

✓ Development of individual sub-systems (environments) for the realization of specialized research in several areas of computer technology in which partners are working;

✓ Development of systems for dynamic access management, result publishing and virtual presentation (e-meetings);

✓ Implementation and embedding of intelligent search engine;

✓ Experimental verification of the possibilities for using intelligent and semantic technologies in order to achieve high quality training, planning of the experiment and the search for scientific information;

✓ Design, implementation and testing of virtual laboratory.

A general conceptual model for the structure organization and processes realization is defined (Fig.2). Two main sub-systems of the VRL are planed: front office (as a web-

based interface for communication between users and virtual components) and back office (intelligent search machine and collection of specialized virtual mediums for research supporting in the planed fields with a possibility for extension).

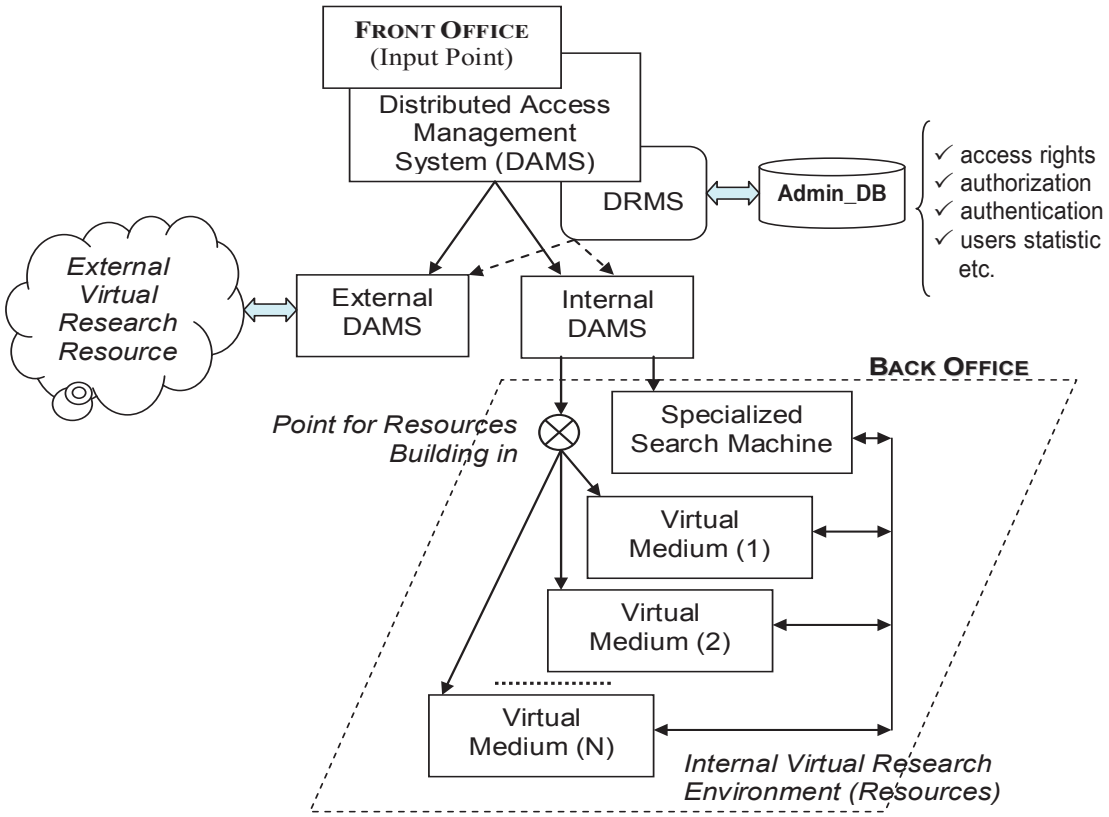


Fig.2. General conceptual model of the VRL-ECT

Two very important management systems should be developed to connect the front office and back office processes:

✓ Digital Rights Management System (DRMS) to support the high level of information security and to manage the access to the resource;

✓ Distributed Access Management Systems (DAMS) consists of two modules for management of the user's access to internal and to external resources.

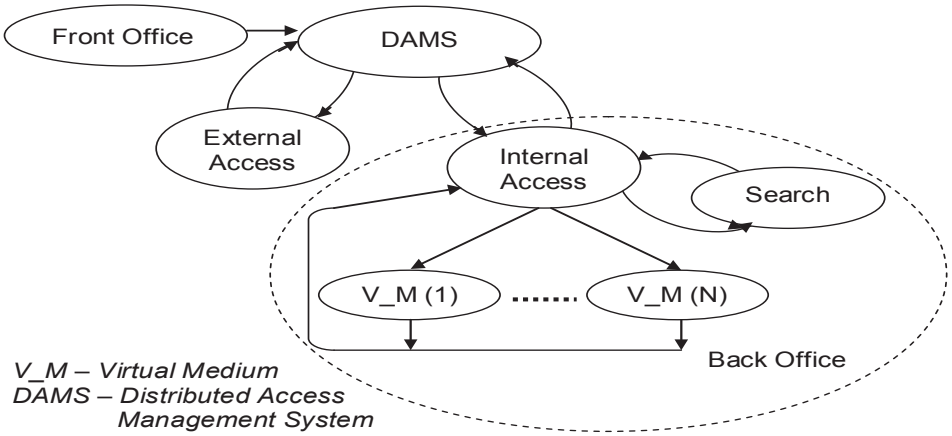


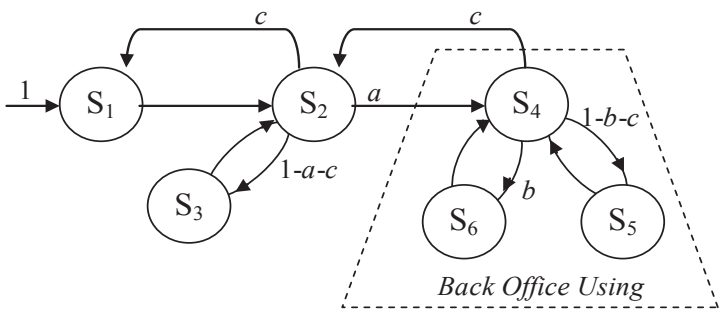
Fig.3. Graph formalization of the information processes in the VRL-ECET

A graph formalization of the functionality and information processes in the VRL is shown in Fig.3 that the basic functional processes are presented as separate states. This

formalization permits to determine a suitable structural organization of the VRL components and to make a model of information servicing for preliminary investigation. As the nature of the processes is stochastic the apparatus of Markov's chains is selected to carry out this investigation in the next section.

4. PRELIMINARY STOCHASTIC INVESTIGATION

The stochastic model (Fig.4) is based on the following analytical formalization of the states from Fig.3: s_1 – work with the front office; s_2 – activity of the DAMS; s_3 – management of the access to the external resources; s_4 – management of the access to the internal resources; s_5 – search machine usage; s_6 – work in selected virtual medium V_M(j) / j=1,2,…,N.



Graph of states

$$1)\ p_1 = c.p_2$$
$$2)\ p_2 = p_1 + p_3 + c.p_4$$
$$3)\ p_3 = (1-a-c).p_2$$
$$4)\ p_4 = a.p_2 + p_5 + p_6$$
$$5)\ p_5 = (1-b-c).p_4$$
$$6)\ p_6 = b.p_4$$
$$7)\ p_1 + p_2 + p_3 + p_4 + p_5 + p_6 = 1$$

Analytical model

Fig.4. Stochastic model of the VRL processes

The analytical solution of the stochastic model permits to determine the assessments for all final probabilities – the substitution $\pi = 2(a + c - a.c)$ is made:

$$p_1 = \frac{c^2}{\pi};\ p_2 = \frac{c}{\pi};\ p_3 = \frac{c.(1-a-c)}{\pi};\ p_4 = \frac{a}{\pi};\ p_5 = \frac{a.(1-b-c)}{\pi};\ p_6 = \frac{a.b}{\pi}.$$

Two steps of the investigation are realized based on the model solution and some results are presented below.

4.1. Single random plan

A random plan for selected combination of values for the model parameters (a = 0,6; b = 0,7; c = 0,1) is realized. The numerical assessments of all final probabilities are as follows: $p_1 \approx 0{,}008; p_2 \approx 0{,}078; p_3 \approx 0{,}023; p_4 \approx 0{,}469; p_5 \approx 0{,}094; p_6 \approx 0{,}328$ (Fig.5).

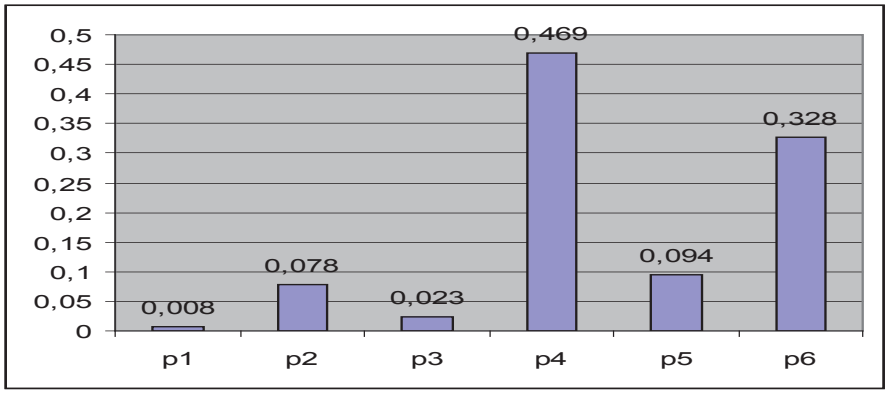


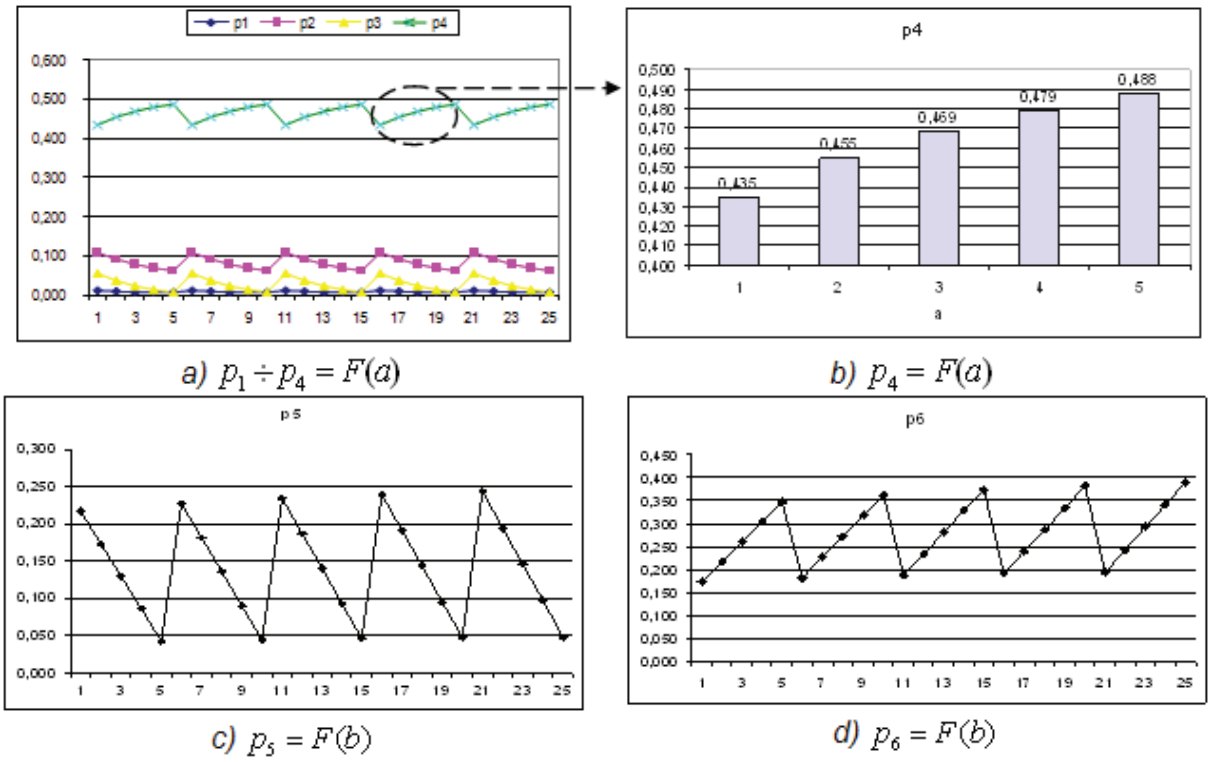
Fig.5. Graphical interpretation of the assessments

The results permit to make the following conclusions: ✓ The module for management of the access to the internal resources is the most loaded resource; ✓ High level of using

for each Virtual Medium in the VRL-ECT; ✓ Front Office system is used for input-output communications only.

4.2. Multiple full factors plan

The full factors plan gives more precise assessment. A work space defined by the values $a,b \in \{0,4;\ 0,5;\ 0,6;\ 0,7;\ 0,8\}$ *и* $c \in \{0,1;\ 0,2;\ 0,3\}$ is selected for experiments realization based on the hypotheses: ✓ probability c for refusal is relatively low; ✓ parameters a and b are related to the outputs of the states s_2 and s_4 and the sum of all probabilities should be 1. Some results are shown in Fig.6. The assessments determine that the probabilities p_1, p_2, p_3 and p_4 depend on the parameter a only (Fig.6a) and identical groups are formed periodically (Fig.6b). The parameter b influences to the probabilities p_5 (Fig.6c) and p_6 (Fig.6d).

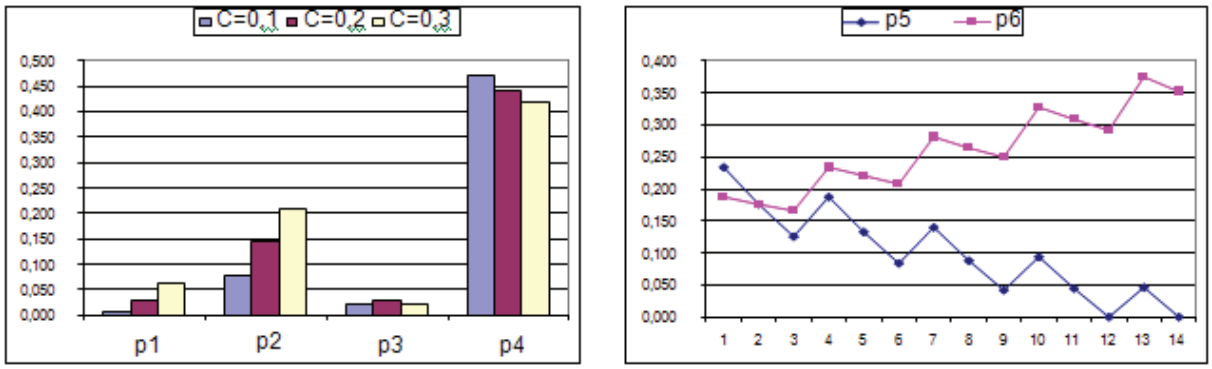


a) $p_1 \div p_4 = F(a)$ b) $p_4 = F(a)$

c) $p_5 = F(b)$ d) $p_6 = F(b)$

Fig.6. Assessments for p_i=F(a); i=1,2,3,4

The role of the parameter c is evaluated for different series of values for all parameters and assessments are shown in Fig.7.



a) $p_1 \div p_4 = F(c/a,b = fix)$ b) $p_5, p_6 = F(b,c/a = fix)$

Fig.7. Assessments for p_i=F(c)

5. CONCLUSION AND FUTURE WORK

The preliminary investigation gives some important conclusions. The back-office system will be the most loaded component in the VRL (82-92%), while the front office system using will be only 1%. The most used subsystems of the back office will be the system for internal access management (about 44-49% of the actions will be realized by them) and the complex of virtual mediums (about 35-40%). The assessments for the state s_2 (in the frame of 8-11%) show how important the role of the global DAMS is, and particularly the DRMS. All these assessments will permit to choose correct parameters and to build an effective virtual environment.

The future work includes the VRL architecture development (on the base of the conceptual model) and software design, implementation and verification of the separate components of the environment (after discussion of the obtained assessments from the preliminary investigation).

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REFERENCES

[1] Afsarmanesh, H. et al. Towards a Multi-layer Architecture for Scientific Virtual Laboratories. In book High Performance Computing and Network, 2010, pp. 163-176

[2] Balamuralithara, B., P. C. Woods. Virtual laboratories in engineering education: The simulation lab and remote lab. Computer Applications in Engineering Education, 2008, 1 (vol.17), pp.101-118.

[3] Funika, W. et al. Environment for Collaborative Development and Execution of Virtual Laboratory Applications, Lecture Notes in Computer Science,2008, vol.5103, pp.446-455.

[4] Granado, E. et al. A Web-based Virtual Laboratory for Teaching Automatic control. Computer Applications in Engineering Education, 2 (vol. 15), 2007, pp. 192-197.

[5] Jeschke, S., T. Richter, R. Seiler. VideoEasel: Architecture of Virtual Laboratories for Mathematics and Natural Sciences, 3rd Int'l Conf. on Multimedia and Information and Communication Technology in Education, 7-10 June 2005 (book Recent Research Developments in Learning Technologies), 2005 (ttp://www.formatex.org/micte2005)

[6] Liegle, P., P. N. Meso. Evaluation of a Virtual Lab Environment for Teaching Web Application Development. Information Systems Education Journal, 2007, 7,vol. 5, pp.3-11.

[7] Ouyang Yang et all. ECVlab: A Web-Based Virtual Laboratory System for Electronic Circuit Simulation, in book Computational Science, Springer Berlin, 2005, pp.1027-1034.

[8] Radojska, P., N. Spasova. Virtual research Laboratories in the Field of Electronic and Computer Technologies. Proceedings of the International Conference on Information Technologies (InfoTech-2010), ISSN 1314-1023, 2010, pp. 263-270.

[9] Xu Hong, Liu Yu, Wang Lin. Study on the Construction of Web-based Virtual Laboratory, Experiment Science and Technology, 2007, 4,

[10] Way, T. P. A Virtual Laboratory Model for Encouraging Undergraduate Research. ACM Conference SIGCSE'06, March 1–5, 2006, Houston, Texas, USA.

ABOUT THE AUTHOR

Prof. Radi Romansky, PhD, Head of Department "Electronics, Computer Systems and Technologies", College of Energy and Electronics at Technical University – Sofia, Phone: +359 2 965 32 95, e-mail: rrom@tu-sofia.bg