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Discrete Simulation of the Remote Access to the Resources of a Virtual Research Laboratory

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***Abstract*—This article discusses the problem of an evaluation of the remote access to the resources of a Virtual Research Lab (VRL) and information servicing investigation by using queuing model and program simulation. The results presented here are the final part of general investigation of proposed architecture of the VRL developed in the frame of two years scientific project. Some results from the initial phases of the investigation (functional, deterministic and stochastic modeling) are discussed in other publications of the author. The purpose of this article is to present a simulation organization and performance factors evaluation of the remote access and information servicing in the VRL. In this connection formalization and an abstract model are made. An extension of this formalization based on the queuing theory is made and a general queuing model for the simulation organization is developed. The program realization of the simulation experiments is made by using the system WebGPSS. Object of investigation is the user access to the resources and some variants are evaluated, for example 'single-user access to a single resource' and 'multiple-user access to multiple resources'. Some experimental results are discussed. Different assessments for the components that take part in the remote access are calculated and presented (utilization, workload, waiting time, etc.)**

***Index Terms*—remote access, processes evaluation, queuing model, simulation, assessments**

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1. Introduction

The need for collaborative using of different information, knowledge and learning resources increases and defines new requirements to the global Information Society for creating distributed systems for effective information servicing and e-learning [1] [2].

It is known that each virtual environment is a distributed system and proposes different possibilities for organization of on-line work in a special area of knowledge. The design of such environment as a virtual space for scientific research and intelligent searching (virtual lab) should be based on an architectural concept for the structural organization of the system components (as an initial step) [3]. A part of this concept is the allocation of the system resources. These resources could be organized on the base of the centralized model (located in a host station) or on the base of the distributed model (located in different nodes of the global network). The architecture should be determined on the base of a defined preliminary conceptual model by using any formal apparatus and should be investigated for validation of the main processes and parameters. The goal is to find answers of the questions about adequacy of the conceptual model and structure organization of the system components, realization of the main purpose for information servicing, allocation of the resources in the distributed environment, etc. In this

reason, the architectural design should be conformed to the contemporary concepts for semantic Web as ontology in the e-learning and research scenarios [4] and personalization of the access to the distributed information resources and organization of the virtual collection of mediums [5].

The object of this paper is the using of some approaches for investigation to decide some problems of the architectural design of a Virtual Research Laboratory (VRL). The development of VRL in the area of electronic and computer technologies has been the goal of two year scientific project [6]. The conceptual model of this VRL consists of two main subsystems [7] – front office and back office. The back office subsystem unites some relatively independent mediums for intelligent searching of the information and knowledge and for scientific research (for an organization and carried out experiments in the fields of circuits design and testing, system diagnostics, virtual reality and 3D simulation, etc). The background for VRL development is made and some basic issues (architecture, structural organization, preliminary investigation, etc.) are decided.

The purpose of this article is to present a simulation organization and performance indexes evaluation of the remote access and information servicing (utilization, waiting time, etc.) in the modules of the VRL by using the queuing theory and simulation system WebGPSS [8]. Formalization by using the set theory and graph tools is made to develop a suitable abstract model of the remote access to the distributed resources in the VRL. The functionality of the components is discussed. General queuing model for the purpose of the simulation is developed. The program realization and the simulation experiments permit to obtain different assessments for VRL components, users and communication resources that take part in the remote access and information servicing.

The remainder of this paper is organized as follows: Section 2 defines the main problem of the investigation and discuses related works. Section 3 presents a preliminary formalization and abstract model of the remote access to the resources and describes the queuing model built based on this formalization. Section 4 presents the program organization of the simulation and some experimental results and assessments. Conclusion and future work are given in the final section.

2. Problem Definition and Related Work

The problems with the virtualization of research and learning resources are discussed in some surveys made by members of the project team and different papers [9] [10]. Particularly, some of the problems with the allocation of informational resources in global network and a specialized VRL building and investigation are discussed in [7] [11] [12]. In this reason, this paper discusses the final part of general investigation to obtain assessments for some important factors of the remote access such the utilization, transportation, workload, waiting time, etc.

The VRL is planned as a multi-user and interactive environment for knowledge presentation, intelligent searching and laboratory work organization. The access to the resources is realized from different remote nodes by communication tools of the global network. The general formalization of this access is shown in fig.1 and it permits to use the apparatus of the set theory and the graph theory to define the abstract model of the remote access. In this reason, the communication processes could be described by an oriented graph **G**(*V*, *A*) with two discrete finite sets – set *V* for describing the objects of the remote access (users, system modules, information and knowledge resources, etc.) and set A for presentation of the relations between them.

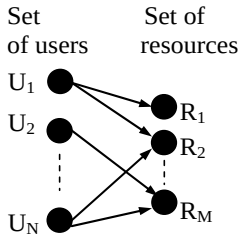


Fig. 1. Preliminary graph formalization of the remote access

The real location of the nodes is very important for the realization of the remote access. It could be assumed that $U \cap R = \varnothing$, where $U=\{U_1, \ldots, U_N\}$ and $R=\{R_1, \ldots, R_M\}$, but one or more nodes could be allocated together in common place [11]. This assumption defines two types of relations (fig.2):

(1) $\exists V_k \in V \Rightarrow (V_k \in U) \,\&\, (V_k \in R)$;

(2) $\exists V_k \in V \Rightarrow [(V_k \in U) \,\&\, (V_k \notin R)] \vee [(V_k \notin U) \,\&\, (V_k \in R)]$;

for $\forall k \in \{1, 2, \ldots, |U|+|R|\}$ and $V = U \cup R$.

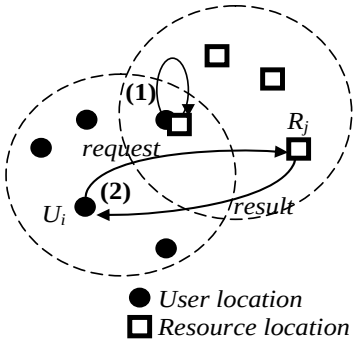


Fig. 2. Two types of relations

The first type could be realized in the case of user allocation in the node of any resource. The second type of relations presents the real transfer via network medium and this situation corresponds to the fig.1. Analyzing the second type of access it is possible to extend the formal description of the information servicing and to regard the remote access as a stochastic input flow of users' demands (requests) to different distributed or centralized scientific and educational resources. The participants of the information servicing (users and resources) are situated in different places with logical connections between them via network.

A variant of this concept is presented in [11] where the information servicing is formalized as a sequence of events and each of them could be realized if a set of conditions is executed. This approach permits to use the asynchronous discrete apparatus of the Petri Nets to made formal description and analytical investigation of the servicing.

The VRL is designed as a collection of two main subsystems – front office (input requests flow processing with authentication and authorization) and back office (management of the access to different external and internal resources). The internal resources are organized as separate modules of the back office accessed by using administrative components of the front office. In this reason, the paper discusses an investigation carried out by using the approach of discrete simulation.

3. Formalization and Abstract Model

The preliminary formalization is based on the abstract model shown in fig.3. It is assumed that each user U_i realizes a remote access to the lab's resources (information content, knowledge, instruments, etc.) and all resources (virtual modules) permit (in general) multi-user access by requests directed trough the transmitter T_q (communication tools of the network) with the assistance of any distributor D (it describes the protocols and tools for routing the requests and answers).

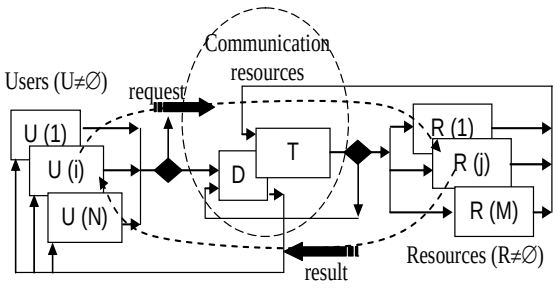


Fig. 3. Abstract model of the remote access to the resources

The functionality of the VRL could be described on the base of the following discrete sets:

✓ Set of users $U = \{Ui \;/i=1 \div N\}$, $U \neq \varnothing$, that generates a stochastic flow of requests to R;

✓ Set of resources $R = \{Rj /j=1\div N\}$, $R\neq\varnothing$, $R\cap U=\varnothing$, presenting the knowledge contents of the VRL's virtual modules (VM) as separate objects;

✓ Set of communication resources $CR=D\cup T$, that unites different technical and technological tools for routing and transmission of user requests and results through the communication medium.

Based on this formalization the abstract model of the remote access to each VM∈VRL could be described as an ordered couple (V, CR) for $V=U\cup R$ and with two types of relations – *request*: $\{U\}\rightarrow\{R\}$ and *result*: $\{R\}\rightarrow\{U\}$.

4. Queuing Model Development

The structural and functional formalization of the discussed VRL as a collection of different web-based components is presented in [6]. The access to the VRL resources and their utilization having a stochastic nature and it is suitable to use the theory of the random processes and the queuing theory to describe the processes of the communication and servicing. This approach permits to organize a discrete simulation on the base of a program environment and collect experimental data for statistical evaluation.

The first step of the simulation organization is queuing model development and a generalized version is shown in Fig.4. The purpose of this model is to simulate different types of remote access to the VRL to design a program model for investigation of some performance indexes (intensity of the input flow and the servicing flow, waiting time, servicing time, utilization, etc.).

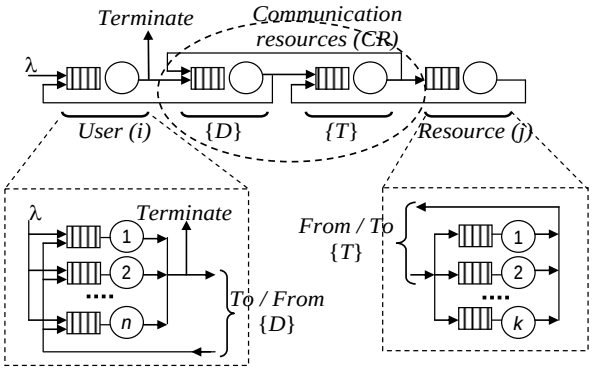


Fig. 4. General queuing model for remote access simulation

5. Discrete Simulation and Assessments

The discrete simulation is organized by using the program environment WebGPSS [8]. Two parts of this simulation are realized – for information servicing investigation (part 1) and remote access investigation (part 2). The first part simulation has been an object of another paper but some assessments are shown in fig.5.

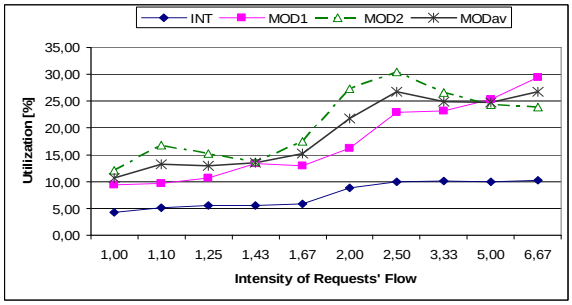


Fig. 5. Assessments for the utilization

The figure illustrates the dependency of the utilization of the administrative components of the front office (INT) and virtual modules (MOD) of the back office (MOD_{AV} is average value) from the intensity of the stochastic flow of user's requests.

The experimental work of the second part is object of this section. In this reason, some separate program models for investigation of different types of remote access are developed: single-user access to single resource; multi-user access to single resource; multi-user access to multiple resources. The simulation is carried out on the base of the one factor experiment plan by variety of the input intensity λ of the users' request flow. Each generated request for information access is formed

as a package by user U and is directed trough the communication space by the router D and transmitter T. In the model the transmitter T processes the request before being analyzed for access permission. The request could be terminated only by the user after returning the needed information (after realized access to the required resource in the virtual medium).

5.1. Single-user access to single resource

The next figure 6 illustrates some experimental results obtained after a single execution of the program model for selected levels of the controlled parameters.

Facility	Average utilization	Number of entries	Average time/trans		
USER	98.61	164	30.06		
DISP	33.48	174	9.62		
TRANS	68.08	175	19.45		
RES	50.06	88	28.44		
AD set	Maximum contents	Average contents	Total entries	Zero entries	Percent zeros
BUSER	22	10.91	184	3	1.63
BDISP	2	0.04	174	142	81.61
BTRAN	3	0.30	175	87	49.71
BRES	1	0.04	88	71	80.68

Fig. 6. Experimental assessments from single model execution

The important experimental results and obtained assessments for the observed parameters are summarized in table 1 (assessments for the work-load) and table 2 (assessments for the waiting time).

Table 1. Assessments for work-load (WL)

$\lambda.10^{-2}$	U	D	T	R
1,00	57,27	17,80	41,19	28,47
1,10	64,30	22,05	44,70	34,18
1,25	74,78	23,31	51,02	37,25
1,43	83,87	28,50	58,33	42,59
1,67	92,80	32,67	63,82	44,91
2,00	98,61	33,48	68,08	50,06
2,50	98,74	34,93	75,10	58,31
3,33	99,04	39,60	76,98	55,19
5,00	99,69	46,29	90,67	68,56
6,67	99,79	49,93	95,97	80,04

Table 2. Assessments for waiting time (WT)

$\lambda.10^{-2}$	U	D	T	R
1,00	5,68	0,69	1,29	0,00
1,10	5,48	0,93	1,63	0,00
1,25	8,62	0,97	3,11	0,89
1,43	13,17	1,06	3,98	1,59
1,67	23,12	1,21	5,77	1,57
2,00	296,55	1,01	8,65	2,12
2,50	588,72	1,94	9,75	4,24
3,33	995,58	1,24	13,01	4,96
5,00	5,68	1,51	31,19	10,05
6,67	5,48	1,81	47,01	16,17

Some of them are graphically interpreted in the next figures. The input intensity λ varies in the diapason [0,01 ; 0,1]. Fig. 7 shows the work-load (assessments for average utilization [%]) of the participants in the remote access to the virtual medium. The user work-load increases to the maximum in the first half of the intensity diapason. The level of the resource's utilization is between 30% and 80%.

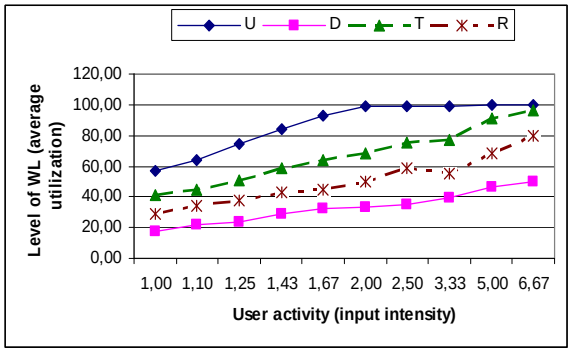


Fig. 7. Average assessments of the work-load (WL)

Fig. 8 shows the assessments of the waiting time (WT) for user tasks before service in the VRL modules. The right part of the figure shows great increasing of the WT for the high values of the intensity.

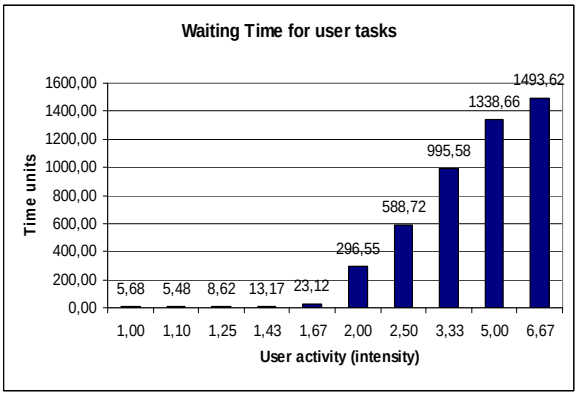


Fig. 8. Waiting Time (WT) for user tasks– average assessments

Fig. 9 shows the average assessments for the waiting time (WT) during the transportation via communication resources and servicing by the resources of the VRL. The diagram shows that the waiting before request servicing by VRL resources is permanent.

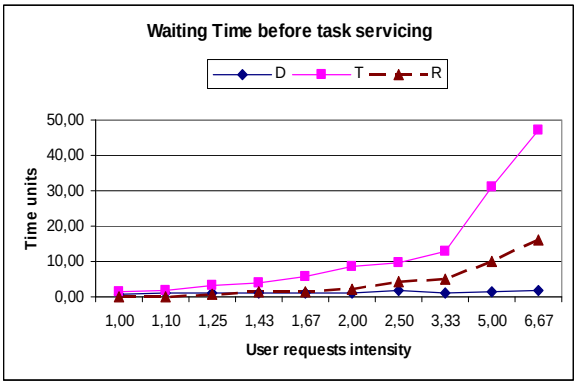


Fig. 9. WT of the transportation and servicing in VRL (average assessments)

The experimental results show that the problems with the remote access exist at a very large user's activity. In this case the work-load of the user's node and the waiting time for servicing have maximal values. This problem could be decided by input flow of user's request to be regulated.

5.2. Multi-user access to multiple resources

Table 3 summarizes the average assessments of the workload and waiting time. The average values for U_{av} and R_{av} are calculated on the base of the experimental results from the simulation for all users and resources. The parameter Net unites all communication tools take part in the remote access. A graphical interpretation is presented in fig. 10 & 11.

Table 3. Summarized assessments for multi-user access to multiple resources

$\lambda.10^{-2}$	WL – average assessments			WT – average assessments		
	U_{av}	R_{av}	Net	U_{av}	R_{av}	Net
1,00	29,19	15,36	20,00	2,87	0,12	0,00
1,10	32,99	16,56	22,06	3,81	0,05	0,16
1,25	36,37	18,54	24,58	4,32	0,18	0,46
1,43	42,95	21,61	27,50	5,95	0,33	0,66
1,67	48,44	24,73	32,22	5,60	0,69	0,70
2,00	59,87	27,80	38,46	18,64	1,69	1,44
2,50	74,60	36,87	52,67	77,29	3,51	3,13
3,33	81,09	43,70	59,30	472,25	6,04	4,06
5,00	99,45	55,47	73,69	854,97	12,17	7,42
6,67	99,66	60,10	79,05	816,25	17,92	7,93

Fig.10 shows the work-load of the user nodes as a function of the request flow intensity λ. The scheme determines some problems for the great levels of the intensity (see sector '1').

Fig.11 illustrates the connection of the WT(λ) for user nodes (a) and for resource nodes (b). The parameter WT_R (see R_{av} from fig.11b) has a maximal value that is some times more than the equivalent parameter R from the fig.9.

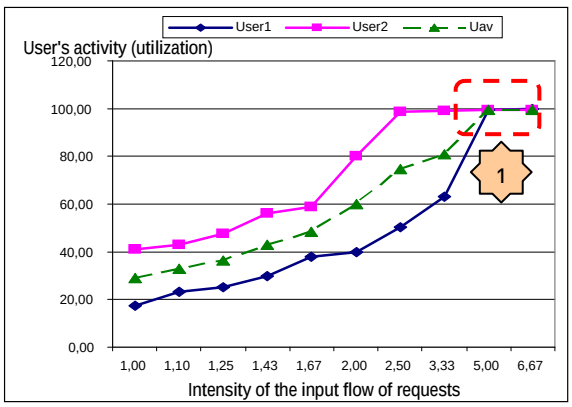
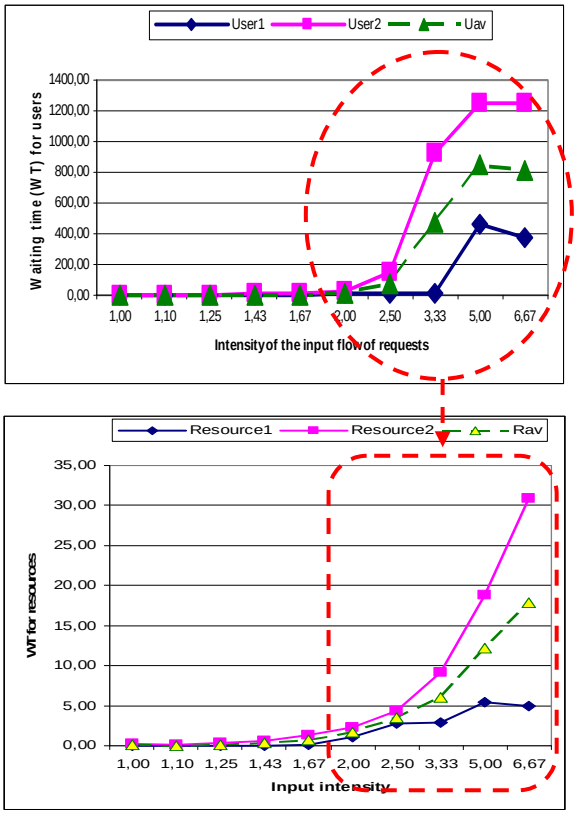


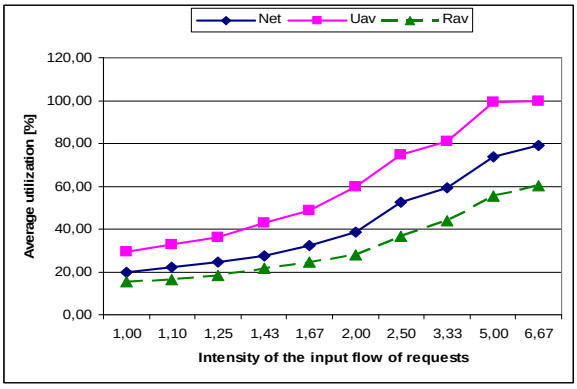
Fig. 10. Determination of average assessments for WL_U



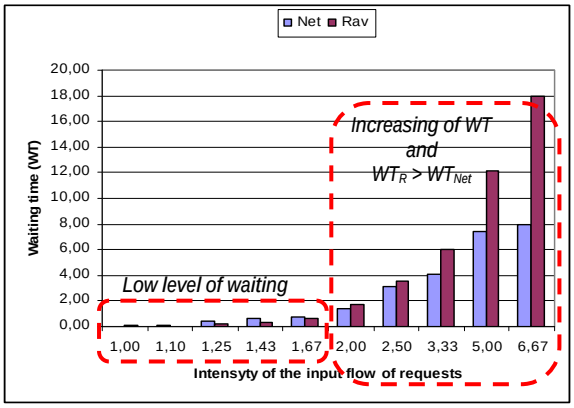
(b). Determination of average assessments for WT_R

Fig. 11

The graphical interpretation of the function WL(λ) presented in fig.12a shows that has no problem with the remote access to the multiple resources in the VRL (the work-load is about 60%), but the large user's activity will cause loading of the network infrastructure and increasing of the waiting tome (fig.12b).



a) graphical interpretation of the assessments for WL(λ)



b) graphical interpretation of the assessments for WT(λ)

Fig. 12. Assessments for remote access factors

5. Conclusion

The simulation experiments and obtained assessments permit to make some conclusions for the processes before realization of the VRL modules. The simulation of a single-user access permits to determine the value frames of the observed parameters and the dependence of the performance indexes from the intensity of the request flow. The multi-user case permits to define the average levels of utilization, average waiting times, number of served requests, average time for servicing, etc. Experimental results will help to define the buffers' capacity, the size of the information and educational objects, the number of 3D etalons, objects and scenarios and especially, the organization of the administrative support of the servicing in 3D virtual medium of the VRL.

This work is a part of an investigation of the processes for remote access to the knowledge and scientific resources and organization of the information servicing in a designed virtual environment to support scientific research and laboratory experiments. The simulation is organized on the base of preliminary conceptual modeling [7], formalization and functional description [11]. Some other investigations are carried out by using the apparatus of Petri nets [12], Markov's chains [7], data flow diagrams, etc. In this reason, the obtained simulation results could permit to compare the

assessments and to define the adequacy of the different model experiments in the phase of system design of the virtual research environment.

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