



GPSS STUDIO: Synergy of modelling power and research complexity

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Abstract

The article analyzes and formulates pre-requisites of creation, conceptual framework and main functions of new GPSS Studio simulation environment for research of complex discrete-event systems. GPSS World simulation language is used as a simulation environment kernel. A number of new notions were introduced during the creation of simulation environment: shared research space, a simulation project, model dynamic monitoring, a simulation application and a virtual report. The article shows features of integrated application of simulation environment at all simulation phases with the use of model hierarchy diagrams, a text editor, automatic model code generation, a model debugger, an interactive standard simulation report, model source and simulation results databases, online analytical processing means of model measures change dynamics, conducting an optimization experiment. The main environment tools for creating simple and available for mass user simulation applications are described with due regard to the aspects of the domain of the system under study.

Keywords: DES, GPSS Studio modelling environment, a shared research space, model hierarchy diagrams

1. Introduction

Every simulation modeling (hereinafter “S&M”) professional should be well aware of the previous success story of GPSS group of languages and names of their developers and popularizers: Geoffrey Gordon (Gordon, 1961), Thomas J. Schriber (Schriber, 1974), Springer Cox (Cox, 2001), etc. Last decade saw the appearance of more state-of-the-art and technologically advanced S&M languages and systems such as: AnyLogic (AnyLogic.com, 2021), Extend (Extendsim.com, 2021), Simio (Simio.com, 2021), Simul8 (Simul8.com, 2021), etc. At the same time popularity and pragmatic use of GPSS, language went down a lot. Even so, many GPSS users still have a feeling of understatement and incompleteness in implementation of the full potential of this wonderful

language. Today GPSS modeling power is still as good as that of present-day leading languages and by some characteristics, it even outperforms them (by adequacy and response of discrete-event models, by dimension and complexity of simulated systems, etc.). It was not the language that was non-competitive, but the outdated technology of its use. An indirect proof of this fact is, that GPSS is still intensively used in learning process at many world universities and there are many successful practical applications of the language where other simulators fail.

It was these facts and dissatisfaction with features and practical application of existing S&M tools that initiated GPSS Studio simulation environment development, which was the first step in GPSS “recovery”.

Before starting the development of simulation



environment, the authors of the article have been making a years-long fundamental research that included analysis and improvement of S&M methodology, implementation technology and practical application (Devyatkov, 2018). One of the results of this research was proving the truth of Shannon's (Shannon, 1975) statement that, "simulation is both an art and a science" which is still true for the present stage of development as well as stating the fact that S&M have not become an all-round tool of engineers, economists and managers. This is despite the manifold increase of computer performance, extensive use of modern IT technologies and implementation of a number of new theoretical methods and approaches when conducting a simulation research. In fact, the level of S&M practical use has not substantially increased, S&M done by professionals and has been staying at the same level for decades. This is inconsistent with S&M application potential, the scope of which is huge and numbers into hundreds of thousands applications and its potential cumulative effect amounting to billions of US dollars. According to our research, only a little over 1% of this potential implemented in Russia.

Moreover, this poses a serious problem. The use of a model may improve any system at all phases of its life cycle: one can find and eliminate a number of erroneous project solutions when creating a system, find and eliminate bottlenecks during system operation and check efficiency of various development scenarios and system modernization. The obtained results may significantly increase labor productivity and system efficiency. In addition, implementation of this potential for a great number of complex systems on a national scale is one of possible ways of increasing national GDP.

2. The conceptual principles of GPSS STUDIO

Classical approach to organization and conducting of simulation research formulated by N.P. Buslenko (Buslenko, 1978), T. Naylor (Naylor, 1971) and R. Shannon is a methodological basis of all existing S&M languages and systems. All research process is divided in a number of methodologically related but functionally and informational separated phases (S_1, S_2, \dots, S_n): system description and setting research objectives, statistical data collection and processing, model development, etc. ending with results formulation and making recommendations for the system owner.

During the first decade of their development most phases of complex systems simulation research (hereinafter CSSR), except program model development and experimentation, were performed manually. Gradual automation of separate phases of CSSR, mostly in relation to separate software components of different developers, encountered

natural problems (information and language compatibility) during integration of the phases in the framework of one research. These problems arise due to use of third party programs in simulation research (e.g. OptQuest optimization engine), absence of integrated information and language space in CSSR process and manual performance of phases of research objectives setting and recommendations making. Despite the substantial progress of S&M languages, actually, this approach is still being used today.

All this prevents S&M from becoming an all-round engineering tool. For this reason, the creation of the new GPSS Studio (Devyatkov, 2013) simulation environment based on the following conceptual principles:

- **Research process automation.** Maximum possible of researcher's actions in CSSR process in one integrated software system.
- **Data unification and standardization.** Developing a uniform format for input and output data on each research phase, integration of all source data, files and simulation result in single database.
- **Research promptness and mobility.** Creating interactive tools of team and remote development, cloud computing, etc.
- **Making model development easier.** Using modern model design methods: graphical design, patterns, prototyping, automatic generation, etc.
- **Adapting the model-interaction language to the domain.** Providing the researcher with an easy to use, domain-adaptable model-interaction interface system.

As a result, it was possible to shift from "Phases and States" classical concept to "Shared Research Space" concept during CSSR process (Figure 1).

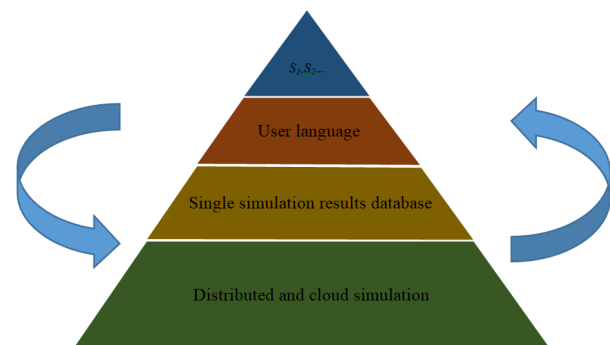


Figure 1. Shared research space in GPSS Studio

Though, now, not everything has been implemented in the environment as originally designed, still there is a stable foundation for the future development of GPSS Studio.

3. The basic features and tools of the simulation environment

GPSS Studio simulation environment is a set of tools

(subsystems) that enable a user to conduct an integrated research. It should be noted that subdivision of systems is rather a logical than physical division of the research process.

Simulation research “Project” is one of fundamental GPSS Studio concepts. The Project allows organizing the research and grouping all relevant information – model text, graphic block diagram, data input and results output forms, designing forms of series of experiments, results of experiments and series of experiments, simulation application files, etc. This structure is user-friendly and can be easily adapted to the research needs and features (preferences) of an individual researcher. Besides the user can manage folder and file structure in the project, open them for work, save, move, copy, delete, etc.

For ease of representation of GPSS Studio environment features two subsystems are singled out from Project information representation: “Model Input Database” and “Simulation Results Database”. GPSS Studio “Model Input Database” ensures saving of all data and files related to model and application creation: block diagram, model text, input, output and designing forms, files used for dialog styling, initial parameters, etc. As an option, all model history can be saved to the database. There may be more than one model, and any unnecessary model and all related data can be deleted at any moment.

“Simulation Results Database” ensures generating and saving experiment (or series of experiments) results. The user may always go back to the results of previous experiments. After results are analyzed, they may be saved or deleted.

Let us briefly run through other main subsystems in relation to simulation research phases where they are used (Figure 2).

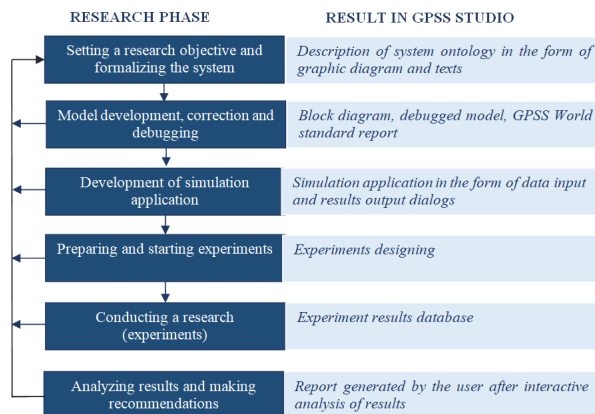


Figure 2. CSSR integrated process

4. Setting a research objective and formalizing the system

It is of the utmost importance to set properly and describe accurately the simulation research goal and objectives, as well as to give the research model and process the most accurate description of the system.

All this will enable the user to speed up the creation of an adequate working model, define the right direction of the research and make the estimate of research results more accurate and efficient. Most of S&M systems do not allow formalizing and computerizing researcher’s actions in this phase. GPSS Studio provides an opportunity of making an incomplete but still sufficient for use ontology of the studied system in the form of a set of interrelated textual descriptions, elements and links as part of “Block Diagram Graphics Editor” subsystem. Generally, speaking the process of making ontology may be shown as follows (Figure 3).



Figure 3. Formation of ontology of the system

The graphics editor provides new principles of setting goals and objectives and developing a model by means of a user-made hierarchy graphic block diagram. The editor enables the user to give a detailed description, including textual description, of diagram elements, links between the elements, state parameters and indicators and to develop a GPSS World (Minuteman Software, 2021) model for finite (indivisible) diagram elements. Additional texts are interrelated by model logic and generally are a part of the ontology of the studied model. Despite the fact that so far this description can only help the user to develop a model and does not influence its logic, we get a hierarchy of descriptions that allow a detailed documentation of the model. Descriptions will allow you to document and save all your knowledge and ideas, clarify subtle aspects and identify names used. When after a while you go back again to this model, all this will help you to quickly recollect the things you meant when developing it.

5. Model development and debugging

Creating a system model is the next step in GPSS Studio. There are two variants of this phase implementation:

- If you used “Graphics Editor” subsystem, then the model built automatically from the set of indivisible elements models and you can start its debugging.
- If you prefer to create a model in a traditional way then before debugging you have to use “Graphics Editor” subsystem and create the entire model.

Model development and debugging diagram, is shown in Figure 4.

The debugging process is starting partially in “Block Diagram Graphics Editor” and “Text Editor” subsystems, for in case of model generation failure the system gives diagnostic messages that let the user detect the error and fix it on the spot.

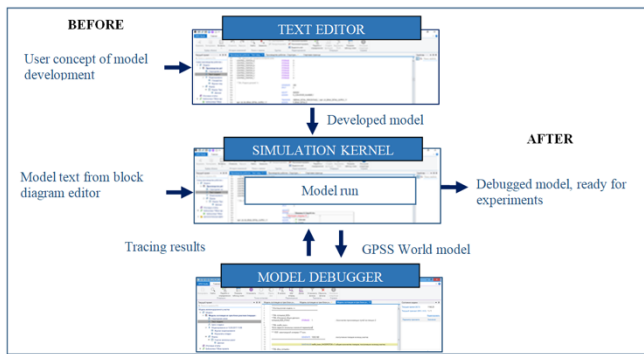


Figure 4. The process of model development and debugging

There are several hundreds of such diagnostic messages and this helps to find the error and fix it immediately.

“Text Editor” subsystem enables the user to write the model text directly in GPSS World language (without making a block diagram). It is also used to describe logic of standard elementary model blocks (SEMB models) when making a graphic diagram. Software technologies of modern programming system (tabs, automatic generation of text elements, tooltips on the fly, highlighting, alignment, etc.), are used for work with the text editor. GPSS World model text is the text editor output.

“Simulation Kernel in GPSS Studio Environment” subsystem runs the developed models and implements all features of GPSS World language. The only difference is the possibility of simultaneous execution of a number of models by several simulation kernels. Only one kernel is selected for execution of a particular model. There are no any changes in the language functional, syntax or semantics. Model text automatically created from the block diagram or developed manually in the text editor passed to the system input.

In addition to simulation kernel, there are also “GPSS Studio Cloud Services”. They designed to organize remote and team work with simulation kernel and project database. The model is started from the user’s work computer. Simulation and database services may be located at any available point in the virtual space. GPSS Studio services control the process of transferring the model and data from the user’s computer to any computer within the local network or the Internet where simulation kernel is located. Besides, they start model execution in one of the available simulation kernels and then return the results to the user’s computer or to a remote project database.

“Model Debugger” subsystem represents a new level of debugging power, interactivity and depth. It carries out step visual control of transactions passing through GPSS model blocks, analyzing any system numeric attribute (hereinafter SNA) and parameter values of this transaction.

It is common knowledge that GPSS World has a unique, tried and true, comprehensive standard simulation report. The same kind of report used in GPSS Studio with interactive features added to it.

Thus upon completion of this phase we get a fully debugged model which can then be turned into an easy to use simulation application.

6. Development of simulation application

Even a well-documented and debugged model is rather difficult to use in a research, since you have to memorize a lot of names, assignment of parameters and SNA and to make changes. Especially it is difficult for users who have not been engaged in the development of the model and do not know the simulation language. It is a usual situation when a model developer has to transfer the model to a domain expert for further research. As for example, if provided by the contract terms and access to model source data is limited or the model is used as a training simulator, etc. Even for the user it is difficult after a while to recall the model in detail and all its aspects.

For this reason, GPSS Studio simulation environment has a number of subsystems allowing making from a usual GPSS model a simulation application, which is easy to use for domain experts. Implementation of application development phase, shown generally in Figure 5.

“Entry Form Designer” enables the user to create easy to use, model text-based, domain-relevant dialogs (forms) for input of source data into the model. Any dialog connects experiment-modified operands of corresponding operators and model blocks with dialog sections.

The number of created dialogs and ways of their presentation depend on developer’s ideas, research Customer’s requests and domain. The dialog designing and styling features are rather diversified: multi-layer tabs, tab groups, captions, images, color management, selection of fonts and styling, etc.

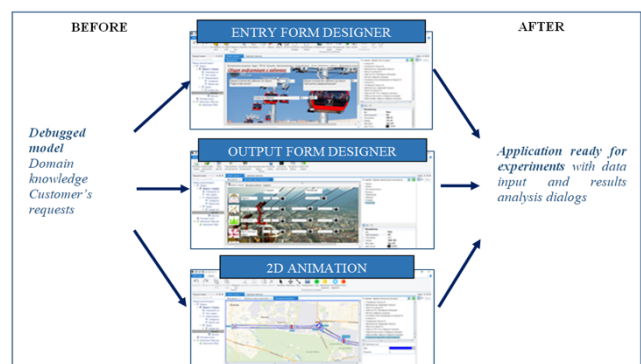


Figure 5. Simulation application creation process

The way simulation results presented is the most important and sometimes governing factor of research

quality. The available standard report just documents the result of the experiment. A new user feature added to GPSS Studio: possibility of analyzing any SNA change dynamics during the execution of every experiment. For this purpose a model measures output designer has been created. It enables the user to create a wide variety of representation forms of simulation results. Firstly, in the form of a combination of diagrams, pictures and other objects with windows dynamically changing during the experiment. Moreover, the variation range can be both numerical and color (e.g. green in comfort zone, yellow for deviations and red when the system is in danger). Secondly, in the form of dynamically changing tables and SNA value graphs.

Animation of results is an additional feature to make simulation results even more realistic. “Subsystem of 2D Animation” of the results of a separate GPSS Studio experiment animates the system dynamics in realistic virtual space. Animation has a special effect for the developer when debugging a model or while training. It can be very effective in presentations or a graphic demonstration of conclusions and recommendations when submitting the research results to the Customer. The development of the 3D animation subsystem using the UNITY platform is being completed.

Thus, when conducting experiments in a simulation application it is possible to organize model source data input and simulation results analysis in any research domain terminology. These dialogs are integrated in the model automatically. As a result, even non-professional users from research domain can use them.

7. Preparing and running experiments

“Experimental Designs Form Designer” is a special subsystem for designing and running series of experiments in GPSS Studio simulation environment. The process of experiments and series of experiments preparation and running shown generally in Figure 6.

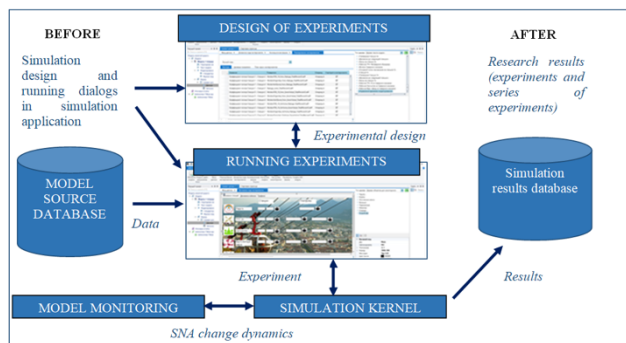


Figure 6. The process of preparing the experiments

“Experiment Design” subsystem enables the user to make an experiment design form for each series of experiments. Experiment design procedure consists of three steps:

- Factor selection. Determination of user-significant model factors influencing the main system performance indicators. Factor selection is done through use of model text tree formed by the environment.

- Indicator selection. Main performance indicators, which the user wants to observe during execution of this series of experiments, are selected from the set of all model SNAs based on another tree created by the environment – “model-monitoring tree”.

- Series of experiments design making. One of two possible ways of experiment designing (automatic or stepped) selected and series of experiments is being made. Besides the user may always create or correct the design manually.

After preparation of series of experiments design and using start dialog the user starts running of the design. After running of the series of experiments is completed, the results of the series summarized in tables and graphs.

“Simulation Kernel” subsystem provides execution of experiments.

“Dynamic monitoring” subsystem provides observation of the model during the experiment with an option of saving any model SNA value. The user defines a list of SNAs to be collected during simulation process. The user also defines monitoring and SNA values recording interval. Monitoring results saved in project database, in the section of this particular experiment or a series of experiments. The user may use these results to analyze the model measures change dynamics during the experiment.

If necessary the user may run other experiments or series of experiments with the model until he decides that the entire quantity of experiments have been executed, all objectives set have been tackled, and the research is to be finished.

8. Experiment result analysis and making recommendation

After every experiment or series of experiments the user makes an on-line analysis of results to which he may go back later, e.g., during next session in the application, as all experiment results are saved in results database.

Simulation results analysis process shown in a simplified form in Figure 7.

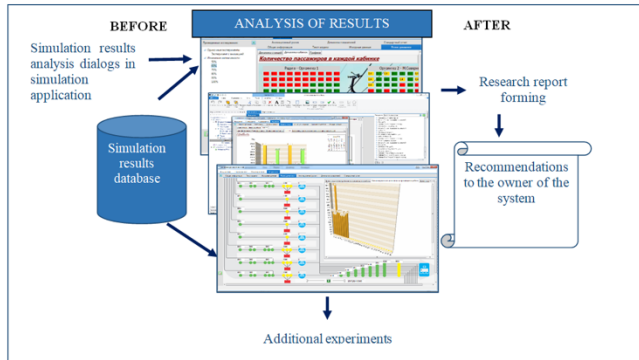


Figure 7. The process of results analysis in the application

“Analysis of Results” interactive subsystem controls review of experiments and series of experiments results. It enables the user to make on-line review and analysis of results of experiments or series of experiments in user-developed forms, as well as in the form of standard reports automatically created by simulation environment. The user can interactively select and review any part of results he wants.

The results required for report documenting are saved by the user step by step with the help of “Virtual Report” subsystem. The virtual report provides an opportunity automatically form most of the report or recommendations (in MS Word format) from model source database and results database created during the research. At the end of the user can change the format of this virtual report to MS Word or MS Excel for further manual adjustment. After that, the user makes recommendations based on the research results using this report.

Besides, if it provided for when designing the application, the user can automatically form overall results of the experiment in domain terminology and export them in MS Excel file.

Creating an executable module of simulation application is a function of utmost importance. In other words, it is possible to create a development environment-independent, executable module in GPSS Studio simulation environment, which can be used for further research. It is extremely important when the developer has to submit the application to the customer. In this case it is impossible to make any changes in the application, one can only prepare different variants of experiments, execute them, accumulate the results in the project database, etc. GPSS World system available on the customer's computer or providing remote access to it is the only prerequisite for running experiment.

9. Conclusions

Thus, based on an advanced CSSR methodology a fundamentally new software tool of discrete systems simulation research – GPSS Studio simulation environment created (Elina-Computer Ltd, 2021). The environment operability and functionality was tested

during creation of dozens of simulation applications in Russia. The environment developers are planning to add functionality to the tool as well as to localize it into English in the earliest possible time.

References

- Cox, D. R. (1972). Regression models and life tables (with Discussion). *J. R. Statist. Soc. B*, 34:187–220.
- Gordon, Geoffrey. (1961). A General Purpose Simulation Systems Simulation Program / Geoffrey Gordon // Proc. EJCC. – Washington: D.C., Macmillan Publishing Co., Inc., New-York, pp. 87–104.
- Schriber, Thomas J. (1974). Simulation using GPSS: Wiley.
- S. Cox, Schriber, T.J., J.O. Henriksen, P. Lorenz, J. Reitman, & I. Stahl (2001). GPSS Turns 40: Selected perspectives. Proceedings of the 2001 Winter Simulation Conference, pp. 565–576.
- AnyLogic Company (2021). Official website of the company. Available at: <http://www.anylogic.ru/> [Accessed 04 May 2021]
- SIMIO LLC (2021). Official website of the company. Available at: <http://www.simio.com/index.php> [Accessed 09 March 2021]
- ExtendSim of Imagine That., Inc. (2021). Official site of product. Available at: <http://www.extendsim.com> [Accessed 04 May 2021]
- Devyatkov V.V., Devyatkov T.V., & Fedotov M.V. (2018). Imitatsionnye Issledovaniya V Srede Modelirovaniya GPSS STUDIO [Simulation Modelling In GPSS STUDIO Simulation Environment] Moscow, OOO “INFRA-M” Publ. 283 p.
- Shannon R.E., (1975). Systems Simulation–The Art and Science. 1 st: Prentice–Hall publisher.
- Buslenko N.P. (1978) Modelirovanie Slozhnykh Sistem [Modelling of Complex Systems] Moscow, Nauka Publ., 400 p.
- Naylor T.H., 1971. Computer Simulation Experiments with Models of Economic Systems: John Wiley & Sons.
- Devyatkov V.V. (2013) Metodologiya I Tekhnologiya Imitatsionnykh Issledovaniy Slozhnykh Sistem: Sovremennoye Sostoyaniye I Perspektivy Razvitiya [Methodology and Technology of Complex Systems Study: Current Status and Development Potential] Moscow, OOO “INFRA-M” Publ., 448 p.
- Minuteman Software (2021). Official website of the company. Available at: <http://minutemansoftware.com/> [Accessed 04 May 2021].
- Elina-Computer Ltd, (2021). Official site of product GPSS Studio. Available at: <http://www.elina-computer.ru> [Accessed 14 July 2021].