Computer Simulation as a Tool for Analyzing and Optimizing Real-Life Processes

Tomáš Domonkos

Article Info:

Management Information Systems,
Vol. 5 (2010), No. 1,
pp. 013-018

Received 25 April 2010
Accepted 28 May 2010

UDC 005.311.12:519.876.5

Summary

In some real-life situations, the analysis of complicated systems using standard analytical methods of operational research represents a particularly difficult endeavor, due to the system's complicated structure or the impossibility of reaching a mathematical solution. In cases when we are not able to use the standard methods of operational research, we can use simulation modeling. Sometimes simulation modeling as a tool for supporting practical decision-making offers a possible solution for this problem. The aim of this paper is to characterize briefly the development of discrete-event simulation methodology over the past 50 years on the grounds of the evolution of various simulation programs, describe the essentials of the simulation program tool Simul8 and present, on the basis of a case study, how we can analyze and optimize complicated real-life systems.

Key words

Computer simulation, discrete event simulation (DES), simulation methodology.

Introduction

Simulation modeling represents a useful tool for analyzing complicated systems where we cannot use standard methods of operational research. This is due to the fact that standard methods of operational research can mostly solve tasks with exactly given structure. On the one hand, this represents a disadvantage of these methods, while on the other they often give an optimal solution to the problems analyzed. In such complicated systems, when we are not able to optimize processes with the aforementioned standard methods of operational research, we need to use some other approaches. As we mentioned above, the simulation modeling methodology might be of use in these cases. On the one hand, the robustness of the proposed methodology is a major advantage, yet it must be admitted that sometimes we cannot reach an optimal solution, only the best one from a certain subset of alternatives.

We define simulation modeling as an approach analyzing and modeling an existing or nonexistent system on a computer through experimenting with them. Banks (1998, p. 3) defines simulation as an imitation of the operation of a real-world process or system over time. Simulation involves the generation of an artificial history of the system and the observation of that artificial history to draw interferences concerning the operating characteristics of the real system that is represented. Law (2007, p. 1) remarks that in simulation we use a computer to evaluate a model numerically, and data gathered in order to estimate the desired true characteristics of the model. Simulation modeling synthesizes methods and approaches from mathematics, statistics, the theory of probability, computer science and the theory of systems.

We can distinguish between two types of systems, discrete and continuous. In a discrete system, the state variables change instantaneously at separate moments of time. In a continuous system the state variables change continuously over time. Furthermore, we will deal with discrete event simulation in which the time is continuous, but the events are discrete.

The aim of this paper is to characterize briefly the development of discrete-event simulation methodology over the past 50 years on the grounds of the evolution of various simulation programs, describe the essentials of the simulation program tool Simul8 and present, on the basis of a case study, how we can analyze and optimize complicated real-life systems using simulation methodology.

1. A brief history of simulation

The practical use of simulation modeling is closely associated with the development of computer technology, without which it would be very difficult to apply, and which gradually expands its limits. This was due to the fact that the simulation model is a computer program which realizes a huge number of computational operations. We can say that the development of computers and simulation programs help advance the field of simulation modeling methodology and its practical applications. Therefore, the following characterization of the historical development simulation modeling over the past 50 years will be made on the basis of the development of simulation software and general programming languages.

The need for simulation modeling, driven by the demands of a world at war, arguably motivated the development of computer technology in the 1940s (Jenkins & Rice, 2009, p.755). These basic models were programs created in general programming languages which were previously the only available, such as FORTRAN. In the sixties, the gradual development of computer technology and the development of new specialized software tools, such as SIMCRIPT or GPSS caused that simulation modeling has become increasingly popular in the manufacturing industry and finance (Harrington & Tumay, 2000, p. 8). It is important to note that in 1967, the first object-oriented programming language was discovered. Its name was SIMULA and it supported simulation modeling. All this happened two decades before the introduction of the first general object-oriented programming language (Dlouhý, Fábry, Kuncová, & Hladík, 2007, p. 8). The development of personal computers and advanced simulation programs such as SLAM or SIMAN in the 1980s caused that simulation modeling started to be used more intensively in production, management, planning, project management etc. However, only the expansion and development of the computers in the last 25 years enabled a substantial shift of various simulation techniques from theoretical concepts to practical applications. At this time, various simulation programs offering the possibility of graphic representation of the system modeled started to appear on the market. Animation has gradually become a standard tool in simulation modeling software. This has led to programs supporting simulation model creation in a user-friendly graphical environment.

Banks, Carson, Nelson, & Nicol, (2005, p. 96) provides the following way of dividing the historical development of simulation programs based on papers by Richard Nancy and information from the panel discussion from the Winter Simulation Conference 1992:

- 1955 - 1960 - In this period, simulation models were mainly created in general programming languages (e.g. FORTRAN).
- 1961 - 1965 - In this period, the predecessors of today's simulation programming languages appeared on the market (e.g., GPSS or SIMSCRIPT and GASP based on FORTRAN).
- 1966 - 1970 - Concepts from the previous periods were tested, tuned and gradually renovated and became widespread among professionals (e.g. GPSS/360, SIMSCRIPT II and SIMU).
- 1971 - 1978 – in this period, the development in the field of simulation programs continued and the first GPSS/Norden program was created, through which it was possible to form a model in an interactive visual environment.
- 1979 - 1986 – the period represents the beginning of the production of simulation programs for desktop computers and microcomputers. Most existing simulation programs were adjusted to be applicable on desktop computers and microprocessors (e.g. Siman, GASP IV, SLAM II, GPSS).
- since 1987 – The development of simulation programs for personal computers and the development of graphical user interface for the creation of simulation models in 2D or 3D graphics environment is characteristic for this period. Most of the software already includes modules for statistical analysis of input and output data and/or for optimization. Simulation through the internet, the so-called web-based simulation, is the most recent advancement in the field.

2. Currently used programs for simulation

Choosing an appropriate simulation program is an important stage in the process of reaching a sound simulation project or study. Our choice might have a crucial importance for the success of our analysis. Generally, this decision depends on the nature of the specific simulation project. The program chosen should be flexible enough to cover all requirements, but using it should not be too difficult, because then the creation of the model can be too complicated. Currently, there are many different simulation software tools, which can be divided into three groups:

- General Programming Languages – e.g. Visual Basic for Application (VBA), C, C++, C#, Java. It is time-consuming to create a simulation model using a general programming language, but these languages provide the widest possibilities to adapt the model to the reality. Such approach is appropriate even if it is necessary to reduce the computing time. The costs of the general programming languages are often lower than the costs of specialized simulation programs, but the total costs of the projects in the first case can be sometimes much higher. The possibility of creating a simulation model in a general programming language is not popular among professionals, because of the existence of a wide range of specialized simulation programs, which allow more efficient modeling.

- Specialized Simulation Software Tools – these are programs specifically developed for simulation modeling. These software tools allow the modeler to use graphical interface, integrated programming languages and other built-in tools that facilitate the creating of simulation models and simulation analysis. Such software often contains tools for error detection, which helps to shorten the time needed for the production of the model. These programs provide built-in tools for input data analysis and output data analysis and support their presentation. Some of them provide the option of exporting the outputs of programs into MSWord or MS PowerPoint directly and thus facilitate the processing of results for further use. These software tools can be divided into two main groups, namely simulation programming languages and the application-oriented programs. In simulation programming languages, the model is generated by writing code. Their main advantage is flexibility, but the creation of the model is time- consuming. In the case of the application-oriented software, the model formulation proceeds by using graphical interface, dialog boxes and various other built-in tools. On the one hand, their advantage is shorter time needed to develop the model, yet the lack of flexibility is one of their major disadvantages. Currently, there are also programs, which are a combination of these two types of software. These allow the users to simultaneously use simulation programming languages and application-oriented simulation software, and to create models of complex and large systems in a clear form in a relatively short time. Another way of dividing these programs is into universal simulation software and application-oriented packages. Application orientation means that they are intended to solve certain specific types of tasks. Universal simulation programs have general application. At present, the best known specialized simulation software tools are ARENA (www.arenasimulation.com),

AUTOMOD (www.automod.com),
EXTEND (www.imaginethatinc.com)
FLEXSIM (www.flexsim.com),
MICROSAINT
(www.maad.com/index.pl/micro_saint),
PROMODEL (www.promodel.com),
SIMUL8 (www.simul8.com),
SIMPROCESS (www.simprocess.com),
WITNESS (www.lanner.com),
GPSS/H www.wolverinesoftware.com),
SIMSCRIPT II.5 (www.simprocess.com), etc.

- Other Programs – these are suitable for modeling simpler processes, such as those that do not capture the dynamics of the system, i.e. static models with a less complicated structure. Examples for programs are MSExcel and other programs for optimization, such as MATLAB, which are not specialized simulation software, but allow the user to create essential simulation models with certain limitations.

3. Ski resort simulation modeling (case study)

In this part of our work, we would like to describe an actual simulation model with its main properties and possible areas of use. This simulation analysis is based on information from a real ski resort in Slovakia. We use the discrete-event simulation methodology and the SIMUL8 software tool because they allow us to analyze and model complicated discrete-event systems, such as the ski resort discussed in the present paper.

Currently, SIMUL8 represents one of the most widely used simulation packages. SIMUL8 supports discrete-event simulation methodology and is not based on programming or statistical data, but on drawing one's own organization (with the computer mouse) on the screen, and only filling in numerical information where it is needed. However, it is possible to use SIMUL8 for traditional hard number crunching simulation. It is built with the expectation that this is the likely finale of most simulation studies. The users can build their SIMUL8 simulation by drawing it on the screen and, additionally, they can improve the simulation model by an integrated programming language called Visual-Logic. There is a wide range of additional tools which support the simulation model creation process, such as OptQuest for Simul8 or StatFit for Simul8. OptQuest is a specialized optimization module which provides the ability to optimize various systems modeled in SIMUL8. StatFit for SIMUL8 is a specialized statistical tool which can be useful during input data analysis.

During the preparation of the ski resort simulation model, we follow eight steps which are helpful in creating a sound simulation study. This procedure is based on the progresses of Dlouhý et al.,

(2007) and Law (2007). Our approach is a combination of the modified versions of the aforementioned approaches. It is not a universal procedure, but it can help us reach a sound simulation study. The steps are (Domonkos, 2010):

- Analyzing the problem and formulating our goals – at this stage, we identify the problem and outline the goals, and we must decide whether the simulation modeling methodology is an appropriate approach;
- Creating a conceptual model – at this step, it is recommended to collect as much information about the nature of the simulated system as possible. It is also useful to create a conceptual model which can help us to learn more about the system that is being studied;
- Collecting data and constructing the model – at this step, we must learn what kind of data are available and whether these data can be used for the simulation study. The construction of the actual model includes programming the simulation model;
- Verification and validation of the model – verification is done by comparing the conceptual model and the computer simulation model. Validation is done by comparing the computer model with the real system;
- Designing experiments and realizing experiments – at this step, we define the circumstances relevant to the simulation experiments and, subsequently, we run the experiments;
- Analyzing output data – Correct documentation is highly needed if we want to work with the model later. It is important to present the results to the submitter of the analysis with correct and exact interpretation;
- Implementation of results.

Our model was programmed in the software tool Simul8 and the methodology used was discrete event simulation. In the ski resort modeled, four sky lifts are run. Three of them are ski-tows which are able to pull one skier or snowboarder uphill. One of them is a six-seat chairlift. The skiers might sometimes miss the tow even when they are in the queue. We determined that ninety-five percent of the skiers waiting in the queue catch the tow and five percent of them miss it. Modeling the number of skiers transported in one passenger ropeway cabin is somewhat more complicated. We use a special probability profile distribution which was created directly in the software Simul8. Specifically, we use six different discrete probability profile distributions depending on the number of the skiers waiting in the queue. These distributions are:

Table 1 Characteristics of the probability profile distributions used for the number of passengers in the ropeway cabin depending on the number of skiers in the queue

Probability in percentage		Number of skiers in the cabin						
		0	1	2	3	4	5	6
Number of skiers in the queue	0	100%	0%	0%	0%	0%	0%	0%
	1	5%	95%	0%	0%	0%	0%	0%
	2	5%	15%	80%	0%	0%	0%	0%
	3	4%	11%	30%	55%	0%	0%	0%
	4	3%	7%	20%	30%	40%	0%	0%
	5	2%	5%	13%	25%	30%	25%	0%
	6 and more	0,3%	0,7%	4%	5%	20%	40%	30%

The skiers can use each of the ski lifts and ski sloops in the center. There are four different ski slopes. The choices of the individual skiers are stochastic and based on a set of complicated probability rules when selecting one of the ski slopes or ski lifts. One of the important features of the model is that skier waiting for too long in one queue will next time choose another ski lift with higher probability. The intensity of the changes in probabilities depends on the skier's last queuing time. The length of skiing down a ski slope was set from 5 minutes to 10 minutes. The discipline in each queue is based on the principles of FIFO (first in first out). The maximum number of skiers pulled uphill in each ski tow is approximately nine hundred per one hour. The maximum number of people transported uphill with the six-seat chairlift is approximately two thousand and four hundred per hour.

The skiers can arrive at the ski center by cars before midday from eight a.m. to midday. Eighty percent of visitors come to the center from eight a.m. to ten a.m. and twenty percent of skiers arrive at the centre from ten a.m. to twelve a.m. The inter-arrival time of vehicles is modeled by exponential distribution. The number of visitors who arrived in one car is modeled with a discrete probability profile distribution. A car contains one skier with the probability of ten percent; a car contains two skiers with the probability of twenty-five percent; a car contains three skiers with the probability of thirty-five percent; finally, a car contains four skiers with the probability of twenty-five percent. The skiers can leave the ski center from one p.m. to four p.m. The intensity of leaving the ski center rises in time.

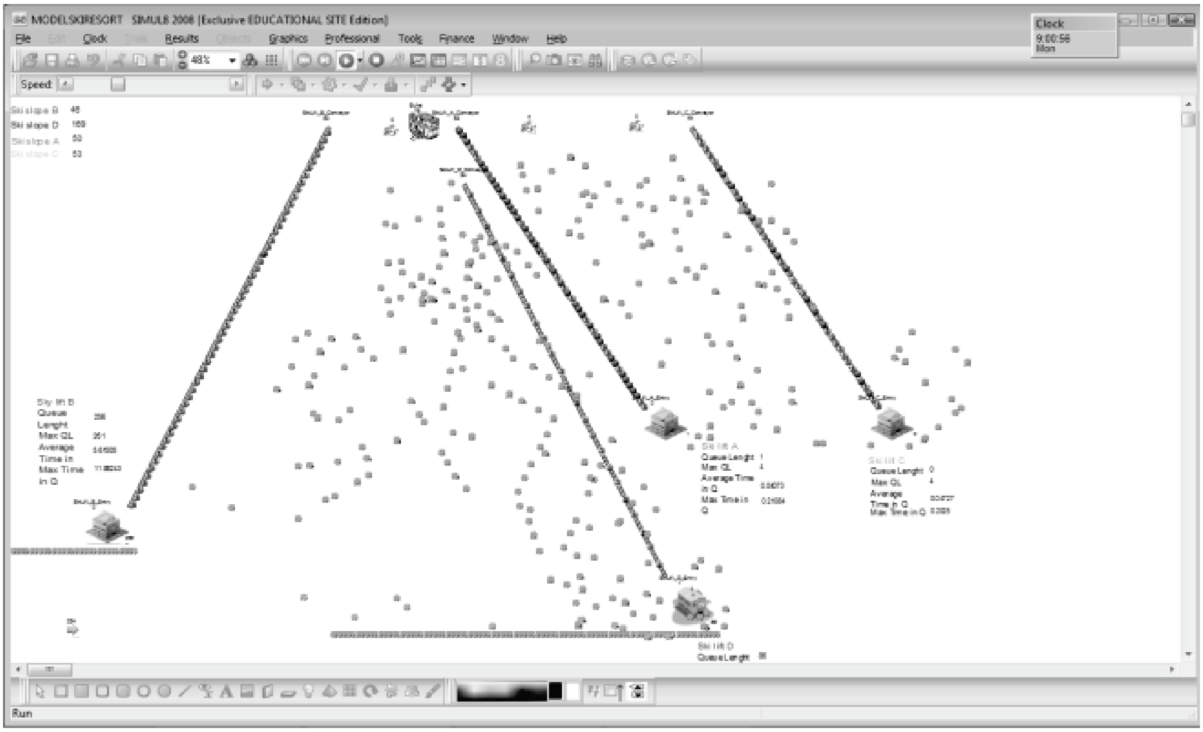

Figure 1 Ski resort simulation model in Simul8

This model provides us with the ability to analyze various system configurations, such as changing the intensity and/or the organization of the arrival discipline, the capacity of the ski tows, the capacity of the ski slopes, the queuing discipline etc. Furthermore, it is also possible to analyze and model the behavior of the system with respect to changing numbers of skiers in the center. We can analyze the average and maximum queuing time spent by the skiers in the queues and the average and maximum number of skiers in these queues up to the ski lifts in discrete moments of the day. The model in Simul8 is shown in Figure 1.

4. Conclusions

The objective of this paper was to briefly characterize the development of discrete-event simulation methodology over the past 50 years on the basis of the evolution of simulation programs, describe the essentials of the simulation program tool Simul8 and present a case study in which we analyze and optimize complicated real-life systems.

The practical use of simulation modeling is closely associated with the development of computer technology, without which it would be very difficult to apply, and which gradually expands its limits. After all, the simulation model is a computer program which realizes a high number of computational operations and thus requires robust hardware. The development of computers and simulation programs helps advance the field of simulation modeling methodology and its practical applications.

Choosing an appropriate simulation program is an important stage in the process of reaching a sound simulation project or study. Our choice might have a crucial importance for the success of our analysis. The program chosen should be flexible enough to cover all requirements, but using it should not be too difficult, because then the creation of the model can be too complicated. Currently, there are many different simulation software tools, which can be divided into three main groups: General Programming Languages; Specialized Simulation Software Tools; Other Programs.

To sum up, in the present paper, we described a relatively complicated simulation model, based on an actual ski resort situated in the Slovak Republic. The model was programmed in the software tool Simul8 and the methodology used was the aforementioned discrete event simulation. We followed eight steps during the preparation of the model, all of which can help us reach a sound simulation study. This model provides us with the ability to analyze various system configurations such as changing the intensity and/or the organization of the arrival discipline, the capacity of the ski tows, the capacity of the ski slopes, the queuing discipline etc. Finally, it can be stated that the analysis realized clearly demonstrates that the methodology of discrete event simulation is a useful tool for analyzing such complicated systems.

References

Banks, J. (1998). *Handbook of Simulation: Principles, Methodology, Advances, Applications, and Practice*. Hoboken: John Wiley & Sons.

Banks, J., Carson, S. J., Nelson, B. N. & Nicol, D. M. (2005). *Discrete-event system simulation* (4th ed.). New Jersey: Prentice-Hall, Inc.

Dlouhý, M., Fábry, J., Kuncová, M. & Hladík, T. (2007). *Simulace podnikových procesú.* Brno: Computer Press.

Domonkos, T. (2010). *Ski resort organization optimization with discrete event simulation*. Paper presented at the 15th International Scientiic Symposium SM 2010, Subotica.

Fishman, G. S. (2001). *Discrete-event simulation*. New York: Springer.

Goldsman, D., Nance, R. & Wilson, R. J. (2009). *A Brief History of Simulation from 1777 to 1981*. Paper presented at the 2009 Winter Simulation Conference, Austin.

Harrington, H. J. & Tumay, K. (2000). *Simulation Modeling Methods*. New York: McGraw-Hill.

Jenkins Ch. M. & Rice, S. V. (2009). *Resource Modeling in Discrete-Event Simulation Environments: A Fifty-Year Perspective*. Paper presented at the 2009 Winter Simulation Conference, Austin.

Law, A. M. (2007). *Simulation Modeling and Analysis*. (4th ed.). New York: McGraw-Hill.

Tomáš Domonkos
University of Economics in Bratislava
Faculty of Economic Informatics
Dolnozemská cesta 1/b
852 35 Bratislava
Slovak Republic
E-mail: tdomonkos@gmail.com