Simulation Modeling of a Queuing System in the MATLAB Environment

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Abstract - The paper dwells on the use of simulation modeling of a queuing system (QS) by the example of the trading facility. On the basis statistical analysis of numerical indicators obtained as a result of simulation modeling, there has been established the model adequacy and correctness. Also, the paper proposes various ways of improving a simulation model of a queuing system. Simulation modeling was carried out by using the MatLab/Simulink tools package.

Key words - simulation modeling, queuing system (QS), statistical characteristics

I. Introduction

Simulation modeling is a widely used method for modeling the business processes in diverse fields and areas of the activities. The method of simulation modeling allows for solving the problems of outstanding complexity, providing simulation of any complex and various processes with a large number of elements, and the separate functional dependences can be described by lengthy mathematical correlations. Thus, simulation modeling is effectively used in the objectives of studying the systems with a complex structure with the purpose of solving specific problems [1].

The methodology of simulation modeling is used most extensively when studying the queuing systems, which are difficult for studying analytically, but are well studied by methods of statistical modeling.

The analytical solutions of queuing problems, which are widely used in applied practice, describe the stationary period of working of system and they are constructed with use of a Poisson stream of events. At the same time, in too time the analysis of duration of transition periods in many cases is characterized by fact that they can constitute an essential part of the working period of system, thus by ignoring the instability period, it is impossible to optimize the system's performance data in general that is very characteristic for the mass services in trade enterprises.

Relevance of this subject of research is motivated by the necessity of developing the formalized means of the device of modeling, the analysis and optimization of QS for the purpose of increasing the efficiency of their functioning in non-stationary conditions.

A queuing system (QS) provides service of ongoing requirements, or, in a different way, a system of a special type that realizes the multiple solving of one-type problems. Similar systems play an important role in many fields of the economy, finance, production and household activities [2].

There exists a common approach to studying a QS. It consists in simulating the random moments of emergence of requests and time of their service in channels, to process and count characteristics of QS. The most popular among them are as follows: probability of providing client services by a system; average number of requests, standing in a queue; average waiting time for request in a queue; average service time of request; average standing time of request in a system, etc.

The parameters of QS could be as follows: request flow intensity; service flow intensity; average time, during which the request is ready to wait for service in a queue; number of service channels; service procedure and so on [3].

II. Problem statement

The paper dwells on simulation modeling of a queuing system by the example of a trading-production system – the client servicing system for product sales.

As a serviced facility we present the order or request. The role of orders or requests is taken by clients-customers. The means of servicing the orders

(requests) are called servicing channels. The role of servicing channels is taken by cashiers.

The random nature of the request flow and servicing time lead to fact that the QS turns out to be loaded non-uniformly: during some periods of time, very large number of requests are accumulated (either they stand in a queue or leave the QS unserved), but during the other periods, a QS works with a light load or stands idle. A graphic presentation of system is shown in Fig. 1 [2].
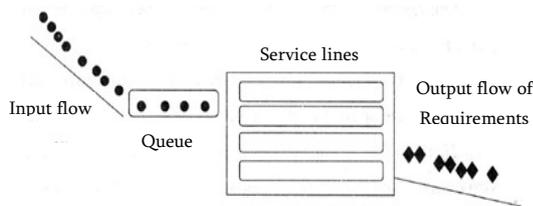

Fig. 1. Graphic presentation of a queuing system

The main objective of the research is to study the operating modes of a queuing system and investigate phenomena arising in servicing process.

The aim of the QS analysis is - to reach a reasonable compromise between requirements of "clients" and capacity of the system served. For this purpose, there are calculated the indicators of efficiency of QS through its characteristics. As the indicators of QS overall performance there are used as follows: average number of requests; queue length; average number of requests in the system, etc [3].

III. A QS Simulation Model Development in the MATLAB / SIMULINK Environment

One of the most convenient tools of discrete and eventful simulation modeling, in which the modeling of QS was carried out, is a MATLab/Simulink package, which has a big set of the blocks providing when modeling the influences with different functional and temporary dependences, as well as the blocks of recipients of information [4].

The analysis of QS by means of simulation models allows for studying the complex systems. Thus, study of QS is not reduced only to the construction of a model of its functioning processes. It is important, by analyzing the work of QS, to make proposals for increasing its efficiency. It is necessary to model the operation of a site during time. It is also necessary to define the statistical characteristics, such as: number of customers, average lengths of queues and operating time.

A. Time simulation of QS

As an example there is considered the solution of a problem of QS:

At the self-service store it is established that the flow of buyers is the elementary with intensity of 2 buyers per minute. At the store, there is placed one cash register allowing for achieving intensity of a flow of service of 2 buyers per minute. We shall define the characteristics of QS, assuming that a queue is limited by five buyers at an entrance to the self-service hall.

There is used the method of implementation of mechanism of simulated time – at a regular interval.

When using this method countdown of system time is carried out through time the fixed intervals, chosen by the researcher. The events in a model are considered occurred at the time of the termination of this interval.

Then, to model the simplest flow of customers and services, it is necessary to make use of Poisson distribution which models a number of events per unit of time (as a unit of time 1 min.).

B. The construction of a model

There is constructed in this research a computer model, Fig. 2, in the MATLAB Fcn block we shall put the poissrnd(2) function for modeling of a flow of customers with intensity of 2 persons per minute. Since the cash desk works with the same intensity, then in the second MATLAB Fcn block we shall also put the the poissrnd (2) .

We will subtract quantity from a number of the coming buyers served by the cashier in the Sum block, but the rest of them we shall accumulate in the Discrete-Time Integrator block. But, in order not to accumulate a "negative" queue, adjust the Discrete-Time Integrator block: We shall put a tag in a window "Restriction of output signals", then we shall put 0 in the parameter "the lower limit value". All other Discrete-Time Integrator blocks simply summarize the input signals, and they don't need to be adjusted.

In order to organize restriction in a queue, some blocks are working. The Relational Operator block compares the extent of a queue with the restriction in 5 buyers, and if a queue is more than 5, sends the operating signal to the Switch block – the switch, which limits an entrance of buyers, without passing a signal from the MATLAB Fcn block, but passing 0. We shall adjust the switch block, by setting a threshold value 1 in it. In Fcn and Fcn1 blocks we shall bring the specified functions of user [5].

By means of Display blocks, we shall find the system's service characteristics, by which there are calculated: the total number of buyers; probability of service; the number of completely met demands; average number of buyers standing in a; queue average

length; probability of how many buyers will be served by a cash register.

The MATLAB Fcn blocks with the random numbers have no the initial values, just each launching of a model will generate the different, nonrecurring sequences. Thus, we just conduct 6-10 runs for each time value.
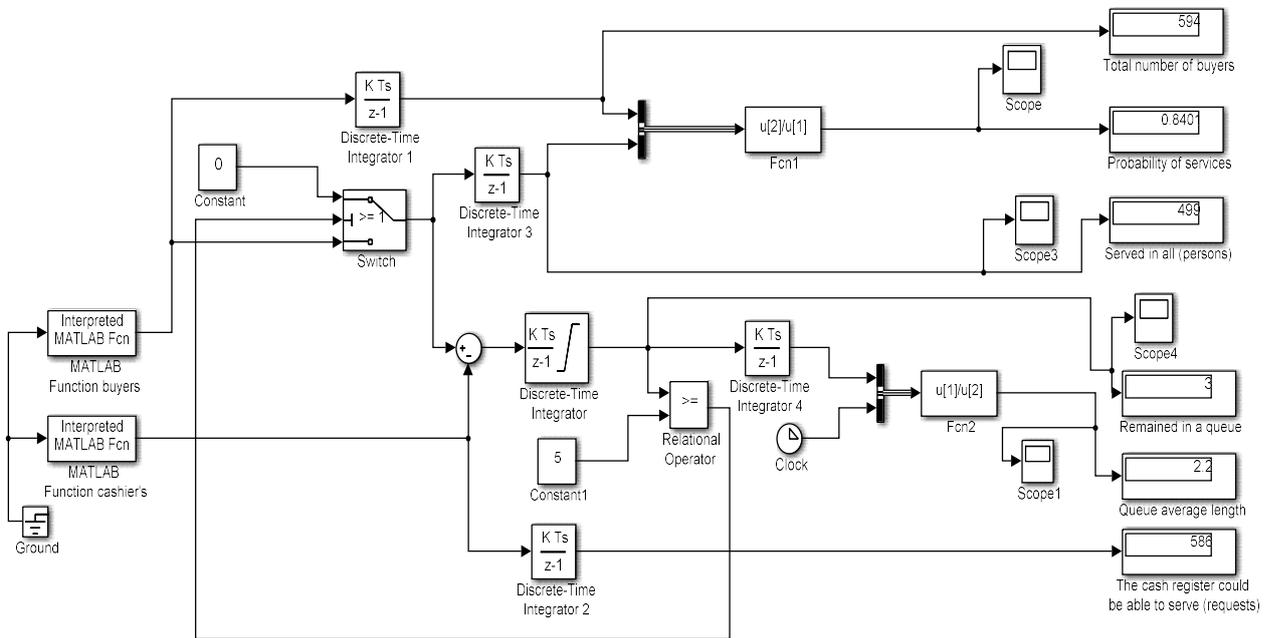

Fig. 2 Time simulation scheme of QS

A. Model setting

We shall set this model as follows: an interval fixed by a size 1, switch the logic signals off. We shall launch the constructed model for checking, by indicating, for example, time 100 that means 100 buyers.

D. Statistical experiment preparation

Since in statements of the problem about shop hours it is told nothing, you can assume different options: for example, 10, 12, 16 hours, and besides, we shall take into account that the time interval is equal to 1 minute, and therefore in settings we shall set the operating time of a model at 600, 720, 1060 minutes.

Table 1 shows the results of statistical experiment, for the so-called experimental design.

Real intensity of an input flow of the trading facility is changeable, and it changes during the day, week and month. These changes are associated with an employment rate of the working population, with the frequency cash inflow. In this work, for studying the intensity of an input flow, there has been gathered the statistical information reflecting change of intensity of buyers flow during the day. On the basis of collected data, there has been constructed the time dependence of change of the intensity of an input flow, Fig. 3. The line in this picture, reflecting the average value represents the equivalent theoretical stationary approach to the description of an input flow, but the line reflecting statistics, reproduces the simulation approach.

Table 1

Numerical results of modelling

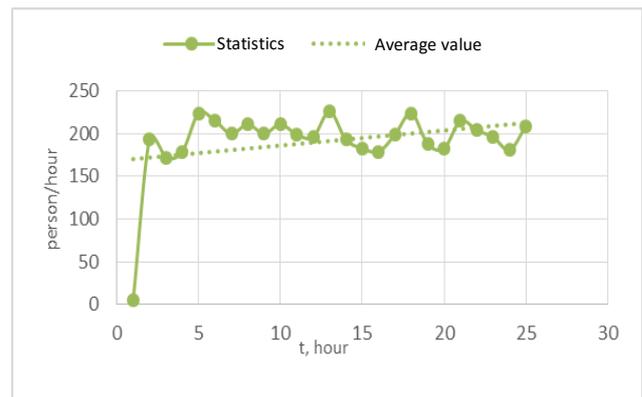| Display Blocks	1	2	3	4	5	6
Total number of buyers	195	188	198	191	200	197
Probability of services	0.85	0.87	0.83	0.84	0.91	0.86
Served in all	167	164	166	162	183	170
Remained in a queue	0	1	1	0	0	3
Queue average length	2,31	2,03	1,75	2,16	1,76	1,85
The cash register could be able to serve (requests)	200	211	199	196	226	193

Fig. 3 Change of an input flow intensity

Approximation of the dependence of an input flow intensity of on the basis of statistical data is presented graphically in Fig. 4, apparently from it, the most part of computational points practically merges with the basic data.
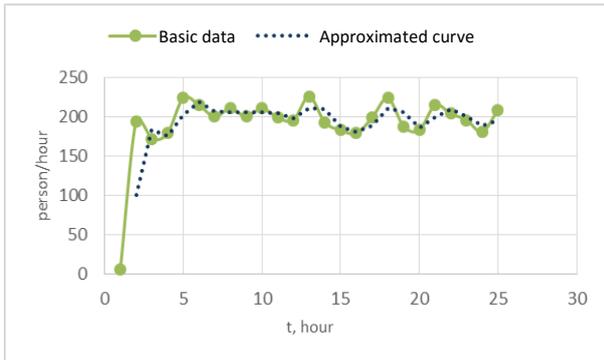

Fig. 4 The result of specified approximation

By introducing additional graphic objects in a model, there is provided the control of calculations. The Scope and Scope1 blocks show fcn1 and fcn2 functions with a time dependence of changes in values. The Scope3 block describe the dynamics in a system of served requests. From diagram of Scope4, it is seen that all the coming requests arrive at service immediately, and there are some requests, which are accumulated in a queue. The Scope1 represents time of a full cycle of simulation.
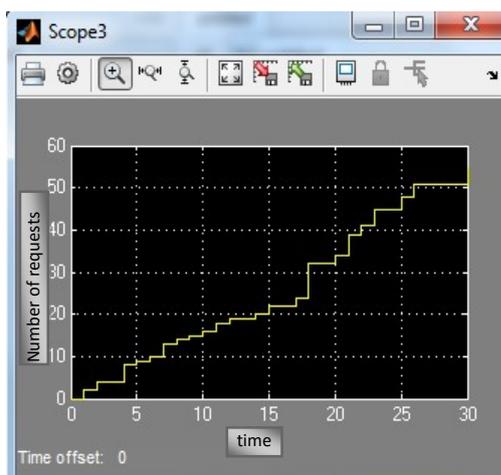

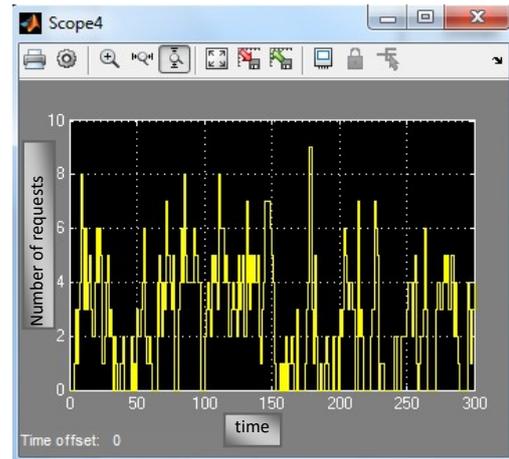Fig. 5 The dynamics in a system of served requests
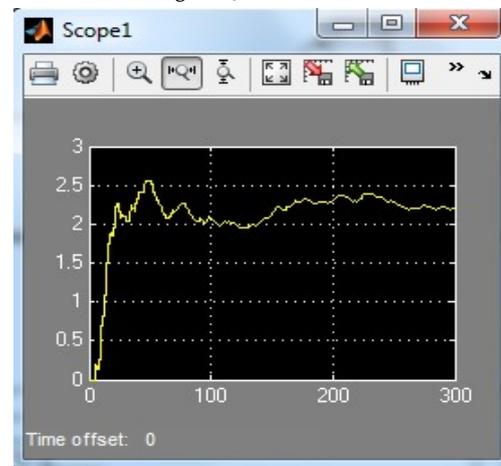

Fig. 6 Queue content

Fig. 7 The dynamics of the process occurring in a QS

The numerical values of the Display blocks used in a model reflect the servicing procedures of the demands existing in a system. As a result of the experiment conducted on their basis, there have been obtained the system's service indicators, on the basis of the statistical analysis of which there have been obtained the curves (Fig. 3), which confirm adequacy of system's simulation modeling and the correctness of a simulation model, see the Scope 1.

Conclusions

The Display blocks used in a simulation model of a queuing system there is used the numerical indicators reflect the serving procedures of demands existing in a system. As a result of the experiment carried out on their basis, there have been obtained the system serving indicators, on the basis of statistical analysis of which there have been obtained the curves, which confirm adequacy of system's simulation modeling and the correctness of a simulation model. The results obtained from simulation modeling describe the general dynamics of the process occurring in a system.

By taking into account the chosen ideology for constructing a model on the basis of simulation modeling of a queuing system presented and considered in a given paper and by using the MatLab/ Simulink tools, it is possible to improve a simulkation model of the reviewed queuing system in various directions, such as: In a modeling system: Increasing the number of servicing channels; Change of a queue intensity; Change of the intensity distribution of flows of requests; Change of the service procedures in a queue; Limitation of time of the presence of requests in a system; Awarding additional parameter properties to the requests – by introducing additional attributes of requests.

A model can be also improved on other indicators, but this would require too much efforts in comparison with the above listed changes. The developed model, with due testing and adjustment, may serve as irreplaceable means for solving specific queuing problems.

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