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Regression Analysis and Optimization of Teletraffic Models for Parameters Forecasting

Ivelina Balabanova[1,*], Stela Kostadinova[2] and Georgi Georgiev[1]

[1]*Department of Communications Equipment and Technologies, Technical University of Gabrovo, 4 Hadji Dimirat Str., Gabrovo, Bulgaria*

[2]*Department Communications Engineering and Technologies, Technical University of Varna, 1 Studentska Str., Varna, Bulgaria*

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Abstract

One of the main aspects of quality of service provisioning in teletraffic systems is the ability to predict the moments in which the calls are received and served at optimal input parameters. For this purpose, in the report an approach for synthesis and optimization of mathematical Markov M/M/1 systems models based on design of experiment, regression analysis, Interior point and Genetic algorithms is presented. Non-symmetric quasi-D-optimal plan for second-order polynomials and the Symmetric Quasi-D-optimal plan for linear prognostic models based on the R^2 coefficient are selected. The impact of mean arrival rate and mean service time for the predicted incoming and outgoing traffic flow times are analyzed. Optimization procedures for constant non-linear minimization are applied in searching for potential minimum of the mean arrival rate of calls in the system through Interior point and Genetic algorithms. Achieved optimal solutions have a certain degree of similarity. The better results are achieved with the intelligent optimization approach, illustrated by a set of generated numerical and graphical experimental results.

Keywords: teletraffic system; design of experiment; regression analysis; optimization; interior point method; genetic algorithm.

1. Introduction

The probability planning and optimization approach is the basis for increasing productivity for modeling and management of the traffic processes in modern telecommunication systems.

A successful technique for parametric correlation analysis in processing results related to the evaluation of the efficiency of traffic management systems about blocking events, overflows and losses in telecommunications, synthesis of signals in electronic circuits, management of the data transmission in the optical communications, moand etc., is the regression apparatus [1-4].

The increasing the efficiency of wireless services through the maximization of the ergodic capacity of a Coordinated Multi-Point system with statistical Channel State Information is based on Convex optimization [5]. The problem of improving performance in accordance with physical phenomena of atmospheric channels and wave propagation is another aspect related to optimization in Free-Space Optical Multi-Input Multi-Output (FSO-MIMO) communication systems addresses [6]. To improve the system performance of Unmanned aerial vehicle (UAV) relay technology for long-distance wireless communications the path-optimization method for the relay UAV is investigated [7]. The application of the Gaussian pointing loss factor and the classical quadratic augmented Lagrange algorithm are the basis for successful optimal models for wireless optical communication systems [8]. The use of optimal CPS planning models for distribution networks leads to the optimization of network topology as provides the reliability of data transmission [9]. A major problem about the high nonlinearity and discrete design variables for small satellite communication systems has been solved by means of the genetic algorithm for the optimal design variable, allowing for the maximized downloaded data amount and minimizing the power requirements [10].

In this paper is presented an innovative approach for the synthesis of optimal models for predicting the times of receipt and release of customer service queries in teletraffic processes from M/M/1 type by Design of experiment, Regression analysis, Interior point and Genetic optimization algorithms.

2. Experiment and methods

2.1 Design of experiment for teletraffic modeling of Markov chain M/M/1

One of the main aspects of provision the quality of service in teletraffic systems is the ability to predict the potential moments in which the calls are received and predict the moments in which already served by the system calls are released. This can be done using appropriate mathematical models, based on experimental planning and regression analysis. In connection with this, simulation procedures have been performed, using Java Modeling Tool (JMT) associated

*E-mail address: ivstoeva@abv.bg
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with Markov M/M/1 queue, according to the previously prepared scenarios of different experimental plans with two manageable factors:

- the Average Arrival Rate (AAR) of incoming in the system calls, cust./s - (factor x_1);
- the Average Service Time (AST) for the system calls, s - (factor x_2),
-

in three granted levels of their variation - minimum, mean and maximum values, respectively 0.15, 0.35 and 0.55 cust./s for x_1 and 0.24, 0.48 and 0.78 s for x_2.

It is investigated, their influence on the output traffic parameters, respectively:

- Arrival Time (AT) for calls in the system, s - (parameter y1);
- Exit System Time (EST) for an already served by the system, calls, s - (parameter y2).
-

At design of experiment the data for a customer Cust. ID = 300 was used as follows:

- Symmetric composition plan (Table 1);
- Hartley composition plan (Table 2);
- Unsymmetrical quasi-D-optimal plan (Table 3);
- Optimal composition plan (Table 4);
- Symmetric quasi-D-optimal plan (Table 5).

Table 1. Symmetric composition plan for M/M/1 chain

№	**Factors**		**Parameters**	
	x_1, cust./s	**x_2, s**	**y_1, s**	**y_2, s**
1.	+1	+1	613.98	614.55
2.	-1	+1	2000.63	2001.49
3.	+1	-1	525.33	525.52
4.	-1	-1	1828.74	1829.86
5.	+1	0	655.51	655.71
6.	-1	0	2031.87	2032.66
7.	0	+1	872.44	873.60
8.	0	-1	953.81	954.32
9.	0	0	857.35	857.86

Table 2. Hartley composition plan for M/M/1 chain

№	**Factors**		**Parameters**	
	x_1, cust./s	**x_2, s**	**y_1, s**	**y_2, s**
1.	-1	-1	1828.74	1829.86
2.	+1	+1	613.98	614.55
3.	-1	0	2031.87	2032.66
4.	+1	0	655.51	655.71
5.	0	-1	953.81	954.32
6.	0	+1	872.44	873.60
7.	0	0	857.35	857.86

Table 3. Unsymmetrical quasi-D-optimal plan for M/M/1 chain

№	**Factors**		**Parameters**	
	x_1, cust./s	**x_2, s**	**y_1, s**	**y_2, s**
1.	-1	-1	1828.74	1829.86
2.	+1	-1	525.33	525.52
3.	-1	+1	2000.63	2001.49
4.	+1	+1	613.98	614.55
5.	+1	0	655.51	655.71
6.	0	+1	872.44	873.60
7.	0	0	857.35	857.86

Table 4. Optimal composition plan for M/M/1 chain

№	**Factors**		**Parameters**	
	x_1, cust./s	**x_2, s**	**y_1, s**	**y_2, s**
1.	-1	-1	1828.74	1829.86
2.	+1	-1	525.33	525.52
3.	-1	+1	2000.63	2001.49
4.	+1	+1	613.98	614.55
5.	-1	0	2031.87	2032.66
6.	+1	0	655.51	655.71
7.	0	-1	953.81	954.32
8.	0	+1	872.44	873.60
9.	0	0	857.35	857.86

Table 5. Symmetric quasi-D-optimal plan for M/M/1 chain

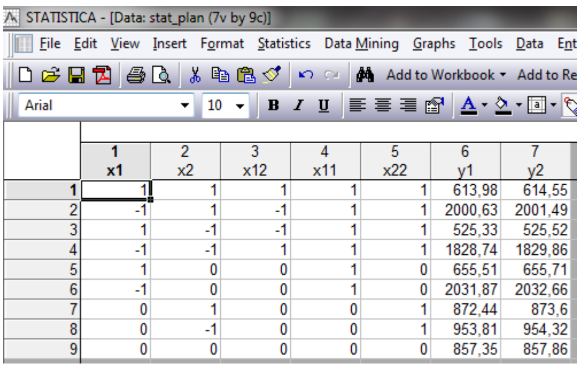
№	**Factors**		**Parameters**	
	x_1, cust./s	**x_2, s**	**y_1, s**	**y_2, s**
1.	-1	-1	1828.74	1829.86
2.	+1	-1	525.33	525.52
3.	-1	+1	2000.63	2001.49
4.	+1	+1	613.98	614.55
5.	-1	-1	1828.74	1829.86
6.	+1	-1	525.33	525.52
7.	-1	+1	2000.63	2001.49
8.	+1	+1	613.98	614.55
9.	0	+1	872.44	873.60
10.	0	-1	953.81	954.32
11.	+1	0	655.51	655.71
12.	-1	0	2031.87	2032.66
13.	0	0	857.35	857.86

The demand of predictive mathematical models is based on an examination of the suitability of analytical equations, reflecting interaction between the factors of zero (1), first (2) and second order (3), and formed on their basis expanded matrices of the experiment from Fig. 1.

$$y = b_o + b_1x_1 + b_2x_2 \tag{1}$$

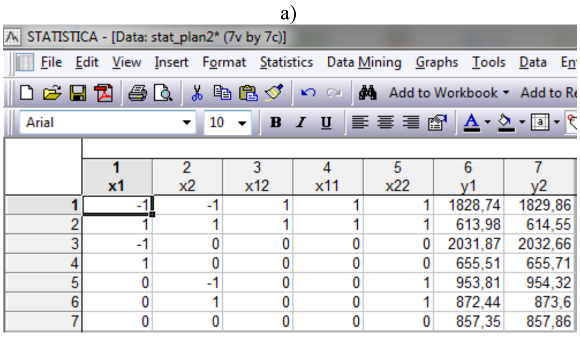
$$y = b_o + b_1x_1 + b_2x_2 + b_{12}x_1x_2 \tag{2}$$

$$y = b_o + b_1x_1 + b_2x_2 + b_{12}x_1x_2 + b_{11}x_1^2 + b_{22}x_2^2 \tag{3}$$



	1 x1	2 x2	3 x12	4 x11	5 x22	6 y1	7 y2
1	1	1	1	1	1	613,98	614,55
2	-1	1	-1	1	1	2000,63	2001,49
3	1	-1	-1	1	1	525,33	525,52
4	-1	-1	1	1	1	1828,74	1829,86
5	1	0	0	1	0	655,51	655,71
6	-1	0	0	1	0	2031,87	2032,66
7	0	1	0	0	1	872,44	873,6
8	0	-1	0	0	1	953,81	954,32
9	0	0	0	0	0	857,35	857,86

a)



	1 x1	2 x2	3 x12	4 x11	5 x22	6 y1	7 y2
1	-1	-1	1	1	1	1828,74	1829,86
2	1	1	1	1	1	613,98	614,55
3	-1	0	0	0	0	2031,87	2032,66
4	1	0	0	0	0	655,51	655,71
5	0	-1	0	0	1	953,81	954,32
6	0	1	0	0	1	872,44	873,6
7	0	0	0	0	0	857,35	857,86

b)

STATISTICA - [Data: stat_plan3* (7v by 7c)]

	1 x1	2 x2	3 x12	4 x11	5 x22	6 y1	7 y2
1	-1	-1	1	1	1	1828,74	1829,86
2	1	-1	-1	1	1	525,33	525,52
3	-1	1	-1	1	1	2000,63	2001,49
4	1	1	1	1	1	613,98	614,55
5	1	0	0	1	0	655,51	655,71
6	0	1	0	0	1	872,44	873,6
7	0	0	0	0	0	857,35	857,86

c)

STATISTICA - [Data: stat_plan4 (7v by 9c)]

	1 x1	2 x2	3 x12	4 x11	5 x22	6 y1	7 y2
1	-1	-1	1	1	1	1828,74	1829,86
2	1	-1	-1	1	1	525,33	525,52
3	-1	1	-1	1	1	2000,63	2001,49
4	1	1	1	1	1	613,98	614,55
5	-1	0	0	1	0	2031,87	2032,66
6	1	0	0	1	0	655,51	655,71
7	0	-1	0	0	1	953,81	954,32
8	0	1	0	0	1	872,44	873,6
9	0	0	0	0	0	857,35	857,86

d)

STATISTICA - [Data: stat_plan5 (7v by 13c)]

	1 x1	2 x2	3 x12	4 x11	5 x22	6 y1	7 y2
1	-1	-1	1	1	1	1828,74	1829,86
2	1	-1	-1	1	1	525,33	525,52
3	-1	1	-1	1	1	2000,63	2001,49
4	1	1	1	1	1	613,98	614,55
5	-1	-1	1	1	1	1828,74	1829,86
6	1	-1	-1	1	1	525,33	525,52
7	-1	1	-1	1	1	2000,63	2001,49
8	1	1	1	1	1	613,98	614,55
9	0	1	0	0	1	872,44	873,6
10	0	-1	0	0	1	953,81	954,32
11	1	0	0	1	0	655,51	655,71
12	-1	0	0	1	0	2031,87	2032,66
13	0	0	0	0	0	857,35	857,86

e)

Fig 1. Expanded experimental matrices at a) Symmetric compositional plan, b) Hartley composite plan, c) Unsymmetrical quasi-D-optimal plan, d) Optimal compositional plan and e) Symmetric quasi-D-optimal plan.

2.2 Optimization procedures

An unaltered part in providing better quality of service in the teletraffic systems is the process of optimization of certain traffic parameters. Therefore, the next stage after defining the final forecasting models is to be determined an optimal values of the mean speed of the incoming calls (AAR factor) which be satisfying about the condition of achieving a global extreme minimum of the target functions.

It is foreseen, the search processes of optimums in MATLAB environment to be implemented by applying Interior point and Genetic algorithms for constant non-linear minimization in GUI Optimtool. The process of reaching a global minimum using Genetic Algorithms (GA) goes through the following sequence:

- creating an initial set of individuals (a set of points), named another generation;
- evaluation of the values of the fitness function for each point in the optimization space;
- determining the best estimate of the fitness function (the point at which the target function has a local minimum);
- generating a new population in the vicinity of the best estimate and repetition of the previous two steps;
- creating a new generation, etc. until the moment of finding the optimum.

3. Results and discussion

3.1 Results from Regression analysis of experimental data

The achieved results of the regression analysis performed from evaluating the Symmetric composition plan are shown in Fig. 2 to Fig. 4. The main criteria, subject of the rating is the coefficient of determination (denoted by R^2). In evaluation analysis of the linear and the model, which reflects the combined influence of factors, the levels for y_1 and y_2 parameters above "0.89" are registered. For the second-order polynomial model the values of the coefficient are better, slightly above "0.991".

Regression Summary for Dependent Variable: y1 (stat_plan)
R= ,94605948 R?= ,89502854 Adjusted R?= ,86003805
F(2,6)=25,579 p<,00116 Std.Error of estimate: 232,33

N=9	b*	Std.Err. of b*	b	Std.Err. of b	t(6)	p-value
Intercept			1148,851	77,44227	14,83494	0,000006
x1	-0,945142	0,132270	-677,737	94,84702	-7,14558	0,000379
x2	0,041644	0,132270	29,862	94,84702	0,31484	0,763544

a)

Regression Summary for Dependent Variable: y2 (stat_plan)
R= ,94614997 R?= ,89519977 Adjusted R?= ,86026636
F(2,6)=25,626 p<,00115 Std.Error of estimate: 232,22

N=9	b*	Std.Err. of b*	b	Std.Err. of b	t(6)	p-value
Intercept			1149,508	77,40670	14,85024	0,000006
x1	-0,945226	0,132162	-678,038	94,80346	-7,15204	0,000377
x2	0,041808	0,132162	29,990	94,80346	0,31634	0,762462

b)

Fig 2. Regression results with respect to Symmetrical composition plan, concerning model (1) for parameters a) y_1 and b) y_2.

Regression Summary for Dependent Variable: y1 (stat_plan)
R= ,94635617 R?= ,89559001 Adjusted R?= ,83294401
F(3,5)=14,296 p<,00690 Std.Error of estimate: 253,82

N=9	b*	Std.Err. of b*	b	Std.Err. of b	t(5)	p-value
Intercept			1148,851	84,6066	13,57875	0,000039
x1	-0,945142	0,144506	-677,737	103,6215	-6,54050	0,001251
x2	0,041644	0,144506	29,862	103,6215	0,28818	0,784773
x12	-0,023695	0,144506	-20,810	126,9099	-0,16397	0,876173

a)

Regression Summary for Dependent Variable: y2 (stat_plan)
R= ,94644188 R?= ,89575224 Adjusted R?= ,83320358
F(3,5)=14,321 p<,00688 Std.Error of estimate: 253,71

N=9	b*	Std.Err. of b*	b	Std.Err. of b	t(5)	p-value
Intercept			1149,508	84,5710	13,59222	0,000039
x1	-0,945226	0,144394	-678,038	103,5779	-6,54617	0,001246
x2	0,041808	0,144394	29,990	103,5779	0,28954	0,783790
x12	-0,023505	0,144394	-20,650	126,8565	-0,16278	0,877064

b)

Fig 3. Regression results with respect to the Symmetric Composition Plan regarding model (2) for parameters a) y_1 and b) y_2.

Regression Summary for Dependent Variable: y1 (stat_plan)
R= ,99573603 R?= ,99149025 Adjusted R?= ,97730733
F(5,3)=69,907 p<,00264 Std.Error of estimate: 93,549

N=9	b*	Std.Err. of b*	b	Std.Err. of b	t(3)	p-value
Intercept			927,259	69,72699	13,2984	0,000919
x1	-0,945142	0,053260	-677,737	38,19104	-17,7460	0,000390
x2	0,041644	0,053260	29,862	38,19104	0,7819	0,491308
x12	-0,023695	0,053260	-20,810	46,77428	-0,4449	0,686532
x11	0,307145	0,053260	381,477	66,14883	5,7669	0,010364
x22	-0,039523	0,053260	-49,088	66,14883	-0,7421	0,511852

a)

Regression Summary for Dependent Variable: y2 (stat_plan)
R= ,99574960 R?= ,99151726 Adjusted R?= ,97737937
F(5,3)=70,132 p<,00263 Std.Error of estimate: 93,433

N=9	b*	Std.Err. of b*	b	Std.Err. of b	t(3)	p-value
Intercept			927,829	69,64107	13,3230	0,000914
x1	-0,945226	0,053175	-678,038	38,14398	-17,7758	0,000388
x2	0,041808	0,053175	29,990	38,14398	0,7862	0,489116
x12	-0,023505	0,053175	-20,650	46,71665	-0,4420	0,688394
x11	0,306951	0,053175	381,372	66,06732	5,7725	0,010336
x22	-0,039320	0,053175	-48,853	66,06732	-0,7394	0,513240

b)

Fig 4. Regression results with respect to the Symmetric Composition Plan regarding model (3) for parameters a) y_1 and b) y_2.

In Hartley's compositional plan according to the target teletraffic times, the levels of the regression coefficient R^2 for models (2) and (3) are with a few tenths lower around "0.85" and "0.87" than in a previous one – the models described in a relatively small degree the experimental data (Fig. 5 and Fig. 6). In an attempt to analyze the model from the highest degree an impossibility for its application was established because the input data was established.

The applying an Usymmetrical quasi-D-optimal plan of the experiment with respect to zero and first order equations are obtained values close to R^2 in the Symmetric composition plan of the experiment - levels around "0.89" (Fig. 7 and Fig. 8). The regression procedures about of model (3) in Fig. 9 gets a positive minimum increase for the criteria - R^2 = 0.99984455 at y_1 and R^2 = 0.999844084 for y_2 (values, ideally approaching to theoretical by definition "1").

Regression Summary for Dependent Variable: y1 (stat_plan2)
R= ,92459425 R?= ,85487452 Adjusted R?= ,78231178
F(2,4)=11,781 p<,02106 Std.Error of estimate: 266,90

N=7	b*	Std.Err. of b*	b	Std.Err. of b	t(4)	p-value
Intercept			1116,243	100,8786	11,06521	0,000379
x1	-0,924459	0,219944	-647,685	154,0947	-4,20316	0,013661
x2	-0,000271	0,219944	-0,190	154,0947	-0,00123	0,999075

a)

Regression Summary for Dependent Variable: y2 (stat_plan2)
R= ,92469701 R?= ,85506456 Adjusted R?= ,78259684
F(2,4)=11,799 p<,02101 Std.Error of estimate: 266,81

N=7	b*	Std.Err. of b*	b	Std.Err. of b	t(4)	p-value
Intercept			1116,937	100,8457	11,07570	0,000378
x1	-0,924721	0,219799	-648,082	154,0444	-4,20711	0,013618
x2	0,000048	0,219799	0,033	154,0444	0,00022	0,999838

b)

Fig 5. Regression results with respect to the Hartley compositional plan for model (1) for parameters a) y_1 and b) y_2.

Nearly identical levels of R^2 in a study of Markov chain M/M/1 with an Optimal composition plan as the achieved in the Symmetrical composition plan were observed when checking the suitability of all models. It can be said that the analyzed experimental data are described equally by the two experimental plans. The results from analysis are given in Fig. 10 to Fig. 12.

Regression Summary for Dependent Variable: y1 (stat_plan2)
R= ,93307674 R?= ,87063221 Adjusted R?= ,74126441
F(3,3)=6,7299 p<,07585 Std.Error of estimate: 290,98

N=7	b*	Std.Err. of b*	b	Std.Err. of b	t(3)	p-value
Intercept			1074,196	130,1289	8,25486	0,003723
x1	-0,924459	0,239785	-647,685	167,9957	-3,85537	0,030829
x2	-0,000271	0,239785	-0,190	167,9957	-0,00113	0,999169
x12	0,125530	0,207660	147,164	243,4489	0,60450	0,588170

a)

Regression Summary for Dependent Variable: y2 (stat_plan2)
R= ,93319723 R?= ,87085708 Adjusted R?= ,74171415
F(3,3)=6,7434 p<,07566 Std.Error of estimate: 290,82

N=7	b*	Std.Err. of b*	b	Std.Err. of b	t(3)	p-value
Intercept			1074,830	130,0585	8,26420	0,003711
x1	-0,924721	0,239576	-648,082	167,9048	-3,85982	0,030737
x2	0,000048	0,239576	0,033	167,9048	0,00020	0,999854
x12	0,125668	0,207479	147,375	243,3172	0,60569	0,587473

b)

Fig 6. Regression results with respect to the Hartley compositional plan for model (2) for parameters a) y_1 and b) y_2.

Regression Summary for Dependent Variable: y1 (stat_plan3)
R= ,94382761 R?= ,89081056 Adjusted R?= ,83621584
F(2,4)=16,317 p<,01192 Std.Error of estimate: 245,05

N=7	b*	Std.Err. of b*	b	Std.Err. of b	t(4)	p-value
Intercept			1141,560	95,3847	11,96796	0,000279
x1	-0,943899	0,165291	-635,222	111,2367	-5,71054	0,004650
x2	-0,002550	0,165291	-1,716	111,2367	-0,01543	0,988431

a)

Regression Summary for Dependent Variable: y2 (stat_plan3)
R= ,94393044 R?= ,89100467 Adjusted R?= ,83650700
F(2,4)=16,349 p<,01188 Std.Error of estimate: 244,94

N=7	b*	Std.Err. of b*	b	Std.Err. of b	t(4)	p-value
Intercept			1142,250	95,3413	11,98065	0,000278
x1	-0,943997	0,165144	-635,564	111,1861	-5,71622	0,004634
x2	-0,002374	0,165144	-1,598	111,1861	-0,01437	0,989221

b)

Fig 7. Regression results with respect to the Unsymmetrical quasi-D-optimal plan regarding model (1) for parameters a) y_1 and b) y_2.

Regression Summary for Dependent Variable: y1 (stat_plan3)
R= ,94424468 R?= ,89159801 Adjusted R?= ,78319603
F(3,3)=8,2249 p<,05858 Std.Error of estimate: 281,93

N=7	b*	Std.Err. of b*	b	Std.Err. of b	t(3)	p-value
Intercept			1141,560	109,7429	10,40213	0,001896
x1	-0,943899	0,190172	-635,222	127,9811	-4,96340	0,015705
x2	-0,002550	0,190172	-1,716	127,9811	-0,01341	0,990144
x12	-0,028062	0,190089	-20,810	140,9673	-0,14762	0,892004

a)

Regression Summary for Dependent Variable: y2 (stat_plan3)
R= ,94434071 R?= ,89177938 Adjusted R?= ,78355877
F(3,3)=8,2404 p<,05844 Std.Error of estimate: 281,82

N=7	b*	Std.Err. of b*	b	Std.Err. of b	t(3)	p-value
Intercept			1142,250	109,6987	10,41262	0,001890
x1	-0,943997	0,190013	-635,564	127,9296	-4,96808	0,015665
x2	-0,002374	0,190013	-1,598	127,9296	-0,01249	0,990818
x12	-0,027834	0,189930	-20,650	140,9105	-0,14655	0,892783

b)

Fig 8. Regression results with respect to the Unsymmetric quasi-D-optimal plan regarding model (2) for parameters a) y_1 and b) y_2.

According to the results of Fig. 13 and Fig. 14 for the Symmetric quasi-D-optimal plan, 92.855026% and 92.925198% of the change of AT and 92.867189% and 92.936232% for EST parameters are due to the influence of the x_1 and x_2 factors. The remaining percentages to 100.00% are a consequence by the action of other factors of the experimental environment. About the model (3), the coefficient of determination varies around "0.993" (Fig. 15)

- higher than the Symmetric and Optimal Composition Plans.

Regression Summary for Dependent Variable: y1 (stat_plan3)
R= ,99992227 R?= ,99984455 Adjusted R?= ,99906729
F(5,1)=1286,4 p<,02116 Std.Error of estimate: 18,492

N=7	b*	Std.Err. of b*	b	Std.Err. of b	t(1)	p-value
Intercept			866,899	15,83578	54,7431	0,011628
x1	-0,995767	0,013273	-670,128	8,93258	-75,0206	0,008485
x2	0,100334	0,013273	67,522	8,93258	7,5591	0,083733
x12	-0,028062	0,012468	-20,810	9,24610	-2,2507	0,266179
x11	0,361984	0,014137	449,189	17,54325	25,6047	0,024851
x22	-0,057644	0,014137	-71,531	17,54325	-4,0774	0,153111

a)

Regression Summary for Dependent Variable: y2 (stat_plan3)
R= ,99992042 R?= ,99984084 Adjusted R?= ,99904506
F(5,1)=1256,4 p<,02142 Std.Error of estimate: 18,719

N=7	b*	Std.Err. of b*	b	Std.Err. of b	t(1)	p-value
Intercept			867,527	16,03035	54,1178	0,011762
x1	-0,995744	0,013430	-670,403	9,04234	-74,1405	0,008586
x2	0,100378	0,013430	67,582	9,04234	7,4739	0,084676
x12	-0,027834	0,012616	-20,650	9,35971	-2,2063	0,270918
x11	0,361610	0,014305	448,920	17,75880	25,2787	0,025171
x22	-0,057332	0,014305	-71,175	17,75880	-4,0079	0,155664

b)

Fig 9. Regression results with respect to the Unsymmetrical quasi-D-optimal plan regarding model (3) for parameters a) y_1 and b) y_2.

Regression Summary for Dependent Variable: y1 (stat_plan4)
R= ,94605948 R?= ,89502854 Adjusted R?= ,86003805
F(2,6)=25,579 p<,00116 Std.Error of estimate: 232,33

N=9	b*	Std.Err. of b*	b	Std.Err. of b	t(6)	p-value
Intercept			1148,851	77,44227	14,83494	0,000006
x1	-0,945142	0,132270	-677,737	94,84702	-7,14558	0,000379
x2	0,041644	0,132270	29,862	94,84702	0,31484	0,763544

a)

Regression Summary for Dependent Variable: y2 (stat_plan4)
R= ,94614997 R?= ,89519977 Adjusted R?= ,86026636
F(2,6)=25,626 p<,00115 Std.Error of estimate: 232,22

N=9	b*	Std.Err. of b*	b	Std.Err. of b	t(6)	p-value
Intercept			1149,508	77,40670	14,85024	0,000006
x1	-0,945226	0,132162	-678,038	94,80346	-7,15204	0,000377
x2	0,041808	0,132162	29,990	94,80346	0,31634	0,762462

b)

Fig 10. Regression results with respect to the Optimal composition plan regarding model (1) for parameters a) y_1 and b) y_2.

Regression Summary for Dependent Variable: y1 (stat_plan4)
R= ,94635617 R?= ,89559001 Adjusted R?= ,83294401
F(3,5)=14,296 p<,00690 Std.Error of estimate: 253,82

N=9	b*	Std.Err. of b*	b	Std.Err. of b	t(5)	p-value
Intercept			1148,851	84,6066	13,57875	0,000039
x1	-0,945142	0,144506	-677,737	103,6215	-6,54050	0,001251
x2	0,041644	0,144506	29,862	103,6215	0,28818	0,784773
x12	-0,023695	0,144506	-20,810	126,9099	-0,16397	0,876173

a)

Regression Summary for Dependent Variable: y2 (stat_plan4)
R= ,94644188 R?= ,89575224 Adjusted R?= ,83320358
F(3,5)=14,321 p<,00688 Std.Error of estimate: 253,71

N=9	b*	Std.Err. of b*	b	Std.Err. of b	t(5)	p-value
Intercept			1149,508	84,5710	13,59222	0,000039
x1	-0,945226	0,144394	-678,038	103,5779	-6,54617	0,001246
x2	0,041808	0,144394	29,990	103,5779	0,28954	0,783790
x12	-0,023505	0,144394	-20,650	126,8565	-0,16278	0,877064

b)

Fig 11. Regression results with respect to an Optimal composition plan on model (2) for parameters a) y_1 and b) y_2.

Regression Summary for Dependent Variable: y1 (stat_plan4)
R= ,99573603 R?= ,99149025 Adjusted R?= ,97730733
F(5,3)=69,907 p<,00264 Std.Error of estimate: 93,549

N=9	b*	Std.Err. of b*	b	Std.Err. of b	t(3)	p-value
Intercept			927,259	69,72699	13,2984	0,000919
x1	-0,945142	0,053260	-677,737	38,19104	-17,7460	0,000390
x2	0,041644	0,053260	29,862	38,19104	0,7819	0,491308
x12	-0,023695	0,053260	-20,810	46,77428	-0,4449	0,686532
x11	0,307145	0,053260	381,477	66,14883	5,7669	0,010364
x22	-0,039523	0,053260	-49,088	66,14883	-0,7421	0,511852

a)

Regression Summary for Dependent Variable: y2 (stat_plan4)
R= ,99574960 R?= ,99151726 Adjusted R?= ,97737937
F(5,3)=70,132 p<,00263 Std.Error of estimate: 93,433

N=9	b*	Std.Err. of b*	b	Std.Err. of b	t(3)	p-value
Intercept			927,829	69,64107	13,3230	0,000914
x1	-0,945226	0,053175	-678,038	38,14398	-17,7758	0,000388
x2	0,041808	0,053175	29,990	38,14398	0,7862	0,489116
x12	-0,023505	0,053175	-20,650	46,71665	-0,4420	0,688394
x11	0,306951	0,053175	381,372	66,06732	5,7725	0,010336
x22	-0,039320	0,053175	-48,853	66,06732	-0,7394	0,513240

b)

Fig 12. Regression results with respect to the Optimal composition plan on model (3) for parameters a) y_1 and b) y_2.

Regression Summary for Dependent Variable: y1 (stat_plan5)
R= ,96361313 R?= ,92855026 Adjusted R?= ,91426031
F(2,10)=64,979 p<,00000 Std.Error of estimate: 187,82

N=13	b*	Std.Err. of b*	b	Std.Err. of b	t(10)	p-value
Intercept			1177,565	52,09118	22,6058	0,000000
x1	-0,961579	0,084528	-675,648	59,39308	-11,3759	0,000000
x2	0,062579	0,084528	43,971	59,39308	0,7403	0,476117

a)

Regression Summary for Dependent Variable: y2 (stat_plan5)
R= ,96367624 R?= ,92867189 Adjusted R?= ,91440626
F(2,10)=65,099 p<,00000 Std.Error of estimate: 187,73

N=13	b*	Std.Err. of b*	b	Std.Err. of b	t(10)	p-value
Intercept			1178,230	52,06710	22,6291	0,000000
x1	-0,961636	0,084456	-675,951	59,36563	-11,3862	0,000000
x2	0,062682	0,084456	44,060	59,36563	0,7422	0,475049

b)

Fig 13. Regression results with respect to the Symmetric quasi-D-optimal plan for model (1) for parameters a) y_1 and b) y_2.

Regression Summary for Dependent Variable: y1 (stat_plan5)
R= ,96397717 R?= ,92925198 Adjusted R?= ,90566931
F(3,9)=39,404 p<,00002 Std.Error of estimate: 197,00

N=13	b*	Std.Err. of b*	b	Std.Err. of b	t(9)	p-value
Intercept			1177,565	54,63862	21,5519	0,000000
x1	-0,961579	0,088662	-675,648	62,29762	-10,8455	0,000002
x2	0,062579	0,088662	43,971	62,29762	0,7058	0,498161
x12	-0,026490	0,088662	-20,810	69,65085	-0,2988	0,771895

a)

Regression Summary for Dependent Variable: y2 (stat_plan5)
R= ,96403440 R?= ,92936232 Adjusted R?= ,90581642
F(3,9)=39,470 p<,00002 Std.Error of estimate: 196,93

N=13	b*	Std.Err. of b*	b	Std.Err. of b	t(9)	p-value
Intercept			1178,230	54,61727	21,5725	0,000000
x1	-0,961636	0,088593	-675,951	62,27327	-10,8546	0,000002
x2	0,062682	0,088593	44,060	62,27327	0,7075	0,497150
x12	-0,026276	0,088593	-20,650	69,62363	-0,2966	0,773507

b)

Fig 14. Regression results with respect to the Symmetric quasi-D-optimal plan regarding model (2) for parameters a) y_1 and b) y_2.

Regression Summary for Dependent Variable: y1 (stat_plan5)
R= ,99696198 R?= ,99393319 Adjusted R?= ,98959976
F(5,7)=229,36 p<,00000 Std.Error of estimate: 65,413

N=13	b*	Std.Err. of b*	b	Std.Err. of b	t(7)	p-value
Intercept			931,371	47,59523	19,5686	0,000000
x1	-0,961579	0,029440	-675,648	20,68553	-32,6628	0,000000
x2	0,062579	0,029440	43,971	20,68553	2,1257	0,071122
x12	-0,026490	0,029440	-20,810	23,12713	-0,8998	0,398118
x11	0,256591	0,029705	375,308	43,44831	8,6380	0,000056
x22	-0,037778	0,029705	-55,257	43,44831	-1,2718	0,244071

a)

Regression Summary for Dependent Variable: y2 (stat_plan5)
R= ,99697250 R?= ,99395416 Adjusted R?= ,98963570
F(5,7)=230,16 p<,00000 Std.Error of estimate: 65,326

N=13	b*	Std.Err. of b*	b	Std.Err. of b	t(7)	p-value
Intercept			931,945	47,53142	19,6069	0,000000
x1	-0,961636	0,029389	-675,951	20,65780	-32,7213	0,000000
x2	0,062682	0,029389	44,060	20,65780	2,1329	0,070373
x12	-0,026276	0,029389	-20,650	23,09612	-0,8941	0,400968
x11	0,256416	0,029653	375,198	43,39005	8,6471	0,000055
x22	-0,037606	0,029653	-55,027	43,39005	-1,2682	0,245276

b)

Fig 15. Regression results with respect to the Symmetric quasi-D-optimal plan for model (3) for parameters a) y_1 and b) y_2.

Concerning to on the regression results, the most suitable for performing predictive processes on the target teletraffic times are found in:

- Symmetric quasi-D-optimal plan for linear models (4) at y_1 and (5) at y_2 with coefficients R^2 about "0.929" in the adequacy checking model (2):

$$y_1 = 1177.565 - 675.648x_1 \quad (4)$$

$$y_2 = 1178.230 - 675.95_1x_1 \quad (5)$$

- Non-symmetric quasi-D-optimal plan for second order polynomial models (6) at y_1 and (7) in response to y_2 with slightly above "0.999" levels of R^2 in the applicability study model (3):

$$y_1 = 866.899 - 670.128x_1 + 449.189x_1^2 \quad (6)$$
$$y_2 = 867.527 - 670.403x_1 + 448.920x_1^2 \quad (7)$$

It is suggest, the final forecasting models related to the target parameters of incoming and outgoing traffic processes with the best applicability, confirmed on the basis of R^2 values, to be models (6) and (7).

3.2 Optimization of models for predict of parameters traffic flow at analysis of Markov chain M/M/1

Target functions and function limits (do not allow of factor reaching of reaching of a maximum threshold) were defined as script files on Fig. 16.

Figure 17 presents a set of results obtained by minimizing models in graphical form in optimization by Interior point algorithm. The optimization occurs within 6 iterations during as the minimized functions are evaluated eighteen times to moment to find the optimal parametric values of the variable x_1 with respect to the y_1 and y_2 target values. The output null value of the Maximum Constant Violation and the positive values of "exitflag" indicator on Fig. 18 confirms the propriety of the optimization process.

Editor - C:\Users\Iva\Documents\MATLAB\telsys1.m

telsys1.m | telsys2.m

```
function f = telsys1(x)
f = 866.899 - (670.128*x(1)) + (449.189*x(1)^2);
```

a)

Editor - C:\Users\Iva\Documents\MATLAB\telsys2.m

telsys1.m | telsys2.m

```
function f = telsys2(x)
f = 867.527 - (670.403*x(1)) + (448.920*x(1)^2);
```

b)

Editor - C:\Users\Iva\Documents\MATLAB\ogrtelsys12.m

telsys1.m | telsys2.m | ogrtelsys12.m

```
function [c,ceq] = ogrtelsys12(x)
c = x(1)^2 - 1;
ceq = [ ];
```

c)

Fig 16. Defining a) model (6), b) model (7) and c) function limits regarding the predictive models.

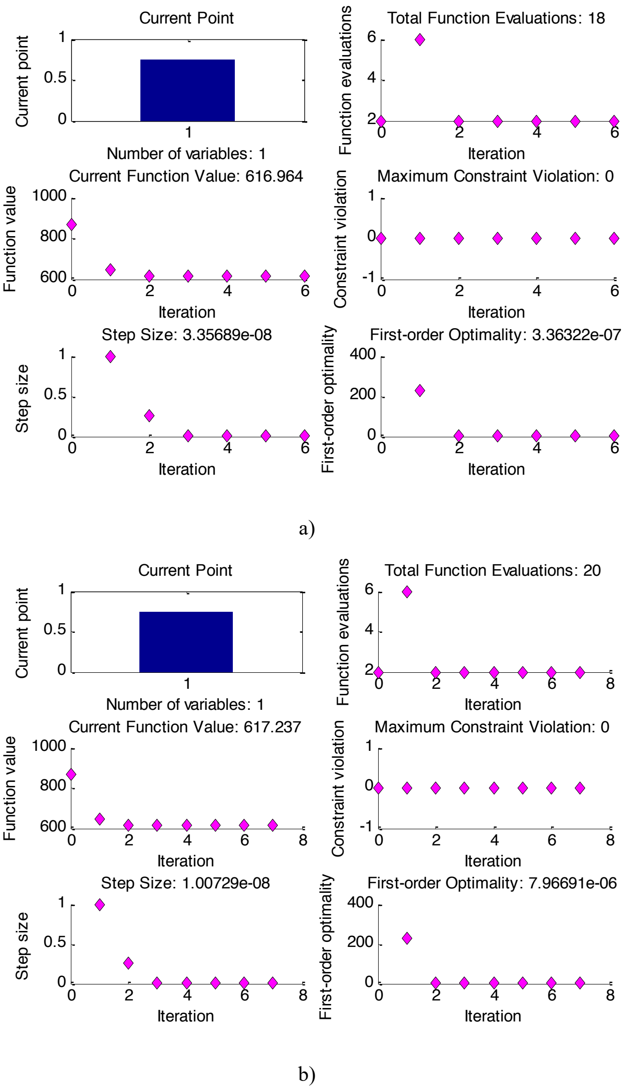
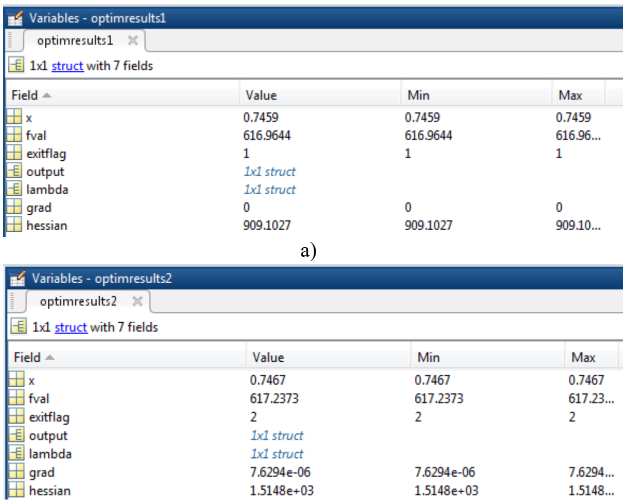


Fig. 17. Graphic results in searching of optimum by Internal point algorithm about predictive models a) 6) and b) (7).



Variables - optimresults1
optimresults1
1x1 struct with 7 fields

Field	Value	Min	Max
x	0.7459	0.7459	0.7459
fval	616.9644	616.9644	616.96...
exitflag	1	1	1
output	1x1 struct		
lambda	1x1 struct		
grad	0	0	0
hessian	909.1027	909.1027	909.10...

a)

Variables - optimresults2
optimresults2
1x1 struct with 7 fields

Field	Value	Min	Max
x	0.7467	0.7467	0.7467
fval	617.2373	617.2373	617.23...
exitflag	2	2	2
output	1x1 struct		
lambda	1x1 struct		
grad	7.6294e-06	7.6294e-06	7.6294...
hessian	1.5148e+03	1.5148e+03	1.5148...

b)

Fig. 18. Generated variables in applying the Internal point algorithm to optimize a) model (6) and b) model (7).

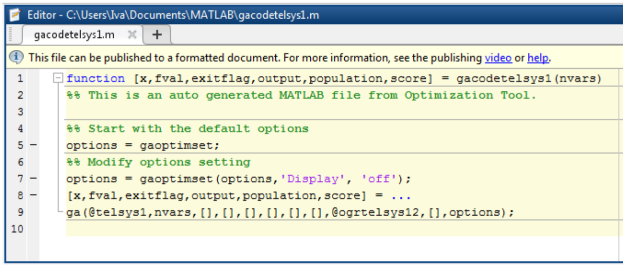
The extremums of target predictive functions for y_1 and y_2 are "x = 0.7459" and "x = 0.7467" achieved in the "fval = 616.9644" and "fval = 617.9644", respectively. The variables "output" and "lambda" contain a general information about the process of minimization and set of Lagrange multipliers in terms of optimal solutions. The values "0" and "909.1027", as well as "7.6294e-06" and "1.5148e + 03" represent the gradients and Hessian functions in the optimums.

The application of Genetic Algorithms is one of the best ways to realize of nonlinear optimization by unconventional (intelligent) methods. The target fitness functions as well as the function with limits are estimated for five in y_1 and four iterations in y_2. The source code in realizing of Genetic algorithm for optimization of the researched parameter of incoming traffic is shown on Fig. 19 - the type of code related to model (7) is identical.

Specificity of the Genetic algorithm is that for one iteration can be generated more than one generation.

The sets of output variables at GA non-constant minimization of models (6) and (7) are given in Fig. 20. The global minimums of AAR factor "616.9710" and "617.54" for found optimums "x = 0.7421" and "x = 0.7285" were achieved, respectively for the time parameters of the incoming and outgoing traffic processes. Estimates about the recent populations with the minimums of target functions have been included in the variables "score".

By comparing the optimal solutions obtained by Interior point and the Genetic algorithms, it can be concluded that they have a certain degree of similarity as better than both is the intelligent optimization approach.

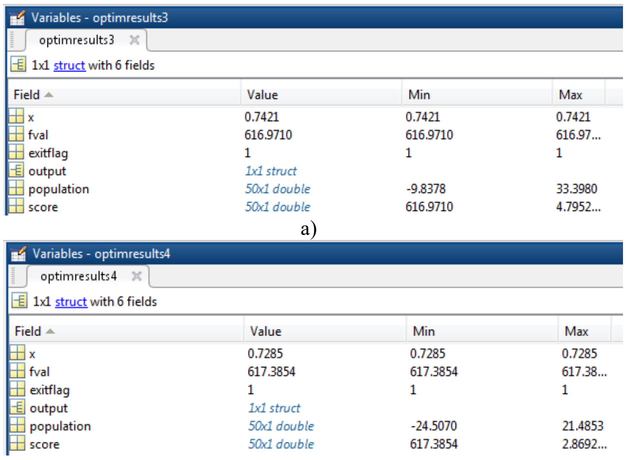


Editor - C:\Users\Iva\Documents\MATLAB\gacodetelsys1.m
gacodetelsys1.m
This file can be published to a formatted document. For more information, see the publishing video or help.

```
function [x,fval,exitflag,output,population,score] = gacodetelsys1(nvars)
%% This is an auto generated MATLAB file from Optimization Tool.

%% Start with the default options
options = gaoptimset;
%% Modify options setting
options = gaoptimset(options,'Display', 'off');
[x,fval,exitflag,output,population,score] = ...
ga(@telsys1,nvars,[],[],[],[],[],[],@ogrtelsys12,[],options);
```

Fig. 19. Generated code for Genetic algorithm in minimization of AAR factor about predictive model (6).



Variables - optimresults3
optimresults3
1x1 struct with 6 fields

Field	Value	Min	Max
x	0.7421	0.7421	0.7421
fval	616.9710	616.9710	616.97...
exitflag	1	1	1
output	1x1 struct		
population	50x1 double	-9.8378	33.3980
score	50x1 double	616.9710	4.7952...

a)

Variables - optimresults4
optimresults4
1x1 struct with 6 fields

Field	Value	Min	Max
x	0.7285	0.7285	0.7285
fval	617.3854	617.3854	617.38...
exitflag	1	1	1
output	1x1 struct		
population	50x1 double	-24.5070	21.4853
score	50x1 double	617.3854	2.8692...

b)

Fig. 20. Output variables at optimization of a) model (6) and b) model (7) via a Genetic algorithm.

4. Conclusions

Plan of experiment on the basis of mathematical statistics was successfully synthesized. Regression models for prediction of Arrival and Exit System Times in analysis of Markov chain M/M/1 with a high parameters correlation have been obtained.

Optimization procedures about the Average Arrival Rate of customer queries have been implemented for minimizing the target traffic times.

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