www.jpis.az

About one approach for determining the sensitivity of mathematical models

Azer Kerimov

Institute of Control Systems, B.Vahabzadeh Street, 68, AZ1141, Baku Azerbaijan

a.k.etn00001@gmail.com

orcid.org/0000-0002-1732-2474

ARTICLE INFO

http://doi.org/10.25045/jpis.v16.i2.11

Article history:
Received 16 February 2025
Received in revised form
18 April 2025
Accepted 19 June 2025

Keywords:

Criteria
Experimental confirmation
Best sensitivity
Monte Carlo
Sensitivity analysis of mathematical model
Sensitivity measurement

ABSTRACT

The article presents a new alternative approach for determining the sensitivity of mathematical models. Mathematical models (MM) operate on the basis of input and output, which are transmitted to and extracted from embedded mathematical algorithms. These algorithms, which have parameters, change when these sensitivity parameters of mathematical models change. This change in sensitivity can lead for the better, or maybe for the worse. The construction of a mathematical model is usually accompanied by problems in calculating the influence of inputs (other names: argument or factor). These problems are solved in the field of mathematics, which is called sensitivity analysis of mathematical models. To solve the problem of finding the sensitivity of mathematical models, the author proposes to find a criterion that allows not directly, but indirectly to determine the sensitivity. This criterion is derived on the basis of mathematical logic, and its experimental confirmation is also carried out. Further in the article, using a new criterion, one example is the best sensitivity of computer systems. In the article there is a proof of the criterion using the Monte Carlo method.

1. Introduction

The problem of this article can be formed as follows: how to find a simple criterion that determines the sensitivity of mathematical models, so that the computational costs are as minimal as possible, at the same time determines the sensitivity of mathematical models.

Currently there are several the following methods of sensitivity analysis:

- one-time analysis: this means one variable ($x_1, x_2, \ldots, x_n$) change; the disadvantage is the fact that the influence between variables is lost;
- differential analysis: variable derivatives are calculated and these derivatives are used to find the sensitivity value;
- scenario analysis: under different scenarios, to construct a spectrum of possible values, enter many variables into the model at the same time, find the worst and best sensitivity values;
- Monte Carlo analysis: the Monte Carlo method is used to generate random inputs that are examined output values;
- tornado chart (tornado chart): this is a type of column chart that visualizes sensitivity by changing input. The tornado pattern determines which inputs have the greatest impact on the result; the higher the input bars, the greater the degree of sensitivity;
- variational methods: this is a class of probabilistic approaches that measures the

uncertainties of input and output through their probabilistic distributions and decomposes the variation of the output corresponding to both individual inputs and a combination of inputs; thus, the sensitivity of the output to the input variable is measured by the variation in the output of the input variable caused by this; these measurements are achieved using Sobol indices (Sobol, 2001);

- Fourier amplitude sensitivity test: Fourier amplitude sensitivity test uses Fourier series to represent many variable functions in the frequency domain, using one variable.

2. Related work

Much research is being done in this part of mathematics and important results have been obtained by prominent scientists. The paper (Saltelli et al., 2008) examines how input uncertainties act on output uncertainties. In the work (Saltelli et al., 2000), Saltelli proposes that all approaches will be divided into two groups: local and global approaches.

Other work is devoted to global sensitivity analysis (Sanchez et al., 2001), (Lamboni et al., 2021), (Borgonovo et al., 2012), (Rana et al., 2018). Every year, the mathematical discipline of sensitivity analysis plays an increasingly important role in the study of applied programs. It should be noted medicine, where important results have been obtained for the correct diagnosis of human organs. In (Gul et al., 2016), parametric local sensitivity analysis was considered, in (Zhang et al., 2021), Sobol indices were applied to simulate COVID-19. Sensitivity analysis is also used in such a vital area as the environment. Each of the above methods has its own areas of application.

This work by the author can be considered as a continuation of previous works devoted to real computational aspects of application programs such as signal recognition (Kerimov, 2022), the recognition methods comparison (Kerimov, 2024).

3. Materials and methods

3.1. Problem solution

Typically, mathematical models are described as follows:

$$y = f(x_1, x_2, \ldots, x_n) = f(X). \quad (1)$$

where $X = (x_1, x_2, \ldots, x_n)$ are input arguments, and $f(X)$ represents the black box.

For clarity, the author uses formula (1) as follows:

$$\mathrm{Output} = \mathrm{SYSTEM}(\mathrm{Parameter}, \mathrm{Input}), \quad (2)$$

where each of Parameter, Input, Output is a multidimensional vector. Input sensitivity means that the ratio of percentage changes in output to input. If two inputs are taken $Input_1$, $Input_2$, then the following expressions indicate the percentage change in input

$$\mathrm{PInput}_{\mathrm{Input}} = \frac{||\mathrm{Input1} - \mathrm{Input2}||}{||\mathrm{Input1}||}, \quad (3)$$

For outputs

$$\mathrm{Output}_{\mathrm{Input1}} = \mathrm{SYSTEM}(\mathrm{Parameter}, \mathrm{Input1}), \quad (4)$$

$$\mathrm{Output}_{\mathrm{Input2}} = \mathrm{SYSTEM}(\mathrm{Parameter}, \mathrm{Input2}), \quad (5)$$

the percentage changes

$$\mathrm{POutput}_{\mathrm{Input}} = \frac{||\mathrm{Output}_{\mathrm{Input1}} - \mathrm{Output}_{\mathrm{Input2}}||}{||\mathrm{Output}_{\mathrm{Input1}}||}. \quad (6)$$

The sensitivity of mathematical models can be determined by the following expression:

$$\mathrm{Sensivity}_{\mathrm{Input}} = \frac{\mathrm{PInput}_{\mathrm{Input}}}{\mathrm{POutput}_{\mathrm{Input}}}. \quad (7)$$

Similarly, the sensitivity of mathematical models by parameters can be determined by the expression:

$$\mathrm{PInput}_{\mathrm{parameter}} = \frac{||\mathrm{Parameter1} - \mathrm{Parameter2}||}{||\mathrm{parameter1}||}, \quad (8)$$

$$\mathrm{Output}_{\mathrm{Parameter1}} = \mathrm{SYSTEM}(\mathrm{Parameter1}, \mathrm{Input1}) \quad (9)$$

$$\mathrm{Output}_{\mathrm{Parameter2}} = \mathrm{SYSTEM}(\mathrm{Parameter2}, \mathrm{Input1}), \quad (10)$$

$$\mathrm{POutput}_{\mathrm{parameter}} = \frac{||\mathrm{Output}_{\mathrm{Parameter1}} - \mathrm{Output}_{\mathrm{Parameter2}}||}{||\mathrm{Output}_{\mathrm{Parameter1}}||}, \quad (11)$$

$$\mathrm{Sensivity}_{\mathrm{parameter}} = \frac{\mathrm{PInput}_{\mathrm{parameter}}}{\mathrm{POutput}_{\mathrm{parameter}}}. \quad (12)$$

In general, finding the sensitivities of mathematical models using formulas (7) and (12) presents certain difficulties. An alternative approach is proposed in this article. The first question minimum quantities input has the answer three inputs must be. The next question is the relative position of these inputs. We find the answer using mathematical logic: in the relationship of the first two inputs, the third input must be located remotely, that is, for input $Input_1$, $Input_2$, $Input_3$ the conditions must be met:

$$||Output_3 - Output_1|| \gg ||Output_2 - Output_1|| \quad (13)$$

which is automatically executed for the following condition:

$$||Output_3 - Output_2|| \gg ||Output_2 - Output_1||\,, \quad (14)$$

To solve the above problem of finding the sensitivity of computer systems, Azer Bayaz Kerimov offers the following criterion:

Criterion (about the sensitivity of mathematical models): as the sensitivity of computer systems improves, the ratio expressing how many times less than one another, the distance of remote input from the other two decreases, and the ratio meaning how many times the distance of remote input from the first (the same and from the second) than the distance between the first and second inputs.

This criterion can be mathematically expressed as follows:

if we denote the distance between the elements in the input space with d_{ij} :

$$d_{ij} = ||Output_i - Output_j||, \quad (15)$$

then the matrix contains the entire distance between the three inputs:

$$\begin{pmatrix} d_{11} & d_{12} & d_{13} \\ d_{21} & d_{22} & d_{23} \\ d_{31} & d_{32} & d_{33} \end{pmatrix}, \quad (16)$$

From this matrix both relations of the criterion are found c_1, c_2:

$$c_1 = \begin{cases} \frac{d_{23}}{d_{31}}, & if.\ d_{23} \le d_{31} \\ \frac{d_{31}}{d_{23}}, & if.\ d_{23} \ge d_{31} \end{cases}, \quad (17)$$

$$c_2 = \frac{d_{13}}{d_{12}}\,, \quad (18)$$

As the sensitivity of mathematical models increases, c_1 and c_2 decrease.

And if you use the product $c = c_1 * c_2$, then naturally it also decreases.

3.2. Experimental validation of the criterion

To experimentally confirm the criterion, take as a mathematical model the continuous wavelet transform (Yakovlev, 1998) to recognize a discrete signal that has as a parameter the number of frequency bands). As inputs, we select discrete signals (Kerimov, 2024) obtained from the following analog signal:

$$A\sin(2\pi f0t) + A\sin(4\pi f0t)\,. \quad (19)$$

By selecting different A and f0, different discrete signals are obtained so that the condition is satisfied (13).

Example 1:

First signal A=1;f0= 0.5;

Second signal A=A+A/2; f0= f0+f0/2;

Third signal A=A+3; f0= f0+4;(fig.1)

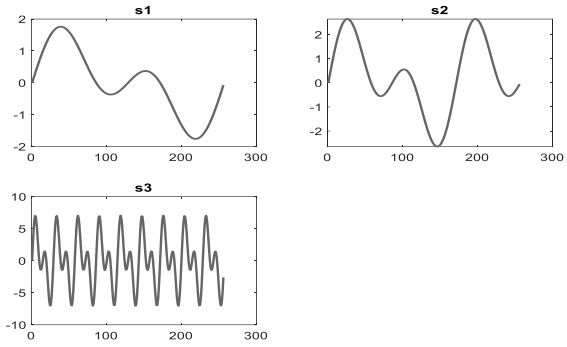

Fig.1. Signals: 1) A=1;f0= 0.5 ;
2) A=A+A/2; f0= f0+f0/2;
3) A=A+3; f0= f0+4.

If we take the parameter number of frequency bands 16; 32; 64; 128, we get the following table for each of them:

Table 1. Distances between terminals with the number of frequency bands equal to 16

	$Input_1$	$Input_2$	$Input_3$
$Input_1$	0.00000	0.19646	16.31725
$Input_2$	0.19646	0.00000	16.31622
$Input_3$	16.31725	16.31622	0.00000

Table 2. Distances between terminals with the number of frequency bands equal to 32

	$Input_1$	$Input_2$	$Input_3$
$Input_1$	0.00000	2.33436	23.85908
$Input_2$	2.33436	0.00000	23.80661
$Input_3$	23.85908	23.80661	0.00000

Table 3. Distances between terminals with the number of frequency bands equal to 64

	$Input_1$	$Input_2$	$Input_3$
$Input_1$	0.00000	13.38403	24.02374
$Input_2$	13.38403	0.00000	24.54319
$Input_3$	24.02374	24.54319	0.00000

Table 4. Distances between terminals with the number of frequency bands equal to 128

	$Input_1$	$Input_2$	$Input_3$
$Input_1$	0.00000	22.08033	24.44452
$Input_2$	22.08033	0.00000	29.20133
$Input_3$	24.44452	29.20133	0.00000

The following table shows that conditions (13) are met.

Table 5. Distances from the first to the other two signals

	$Input_1$	$Input_2$	$Input_3$
$Input_1$	0.00000	0.19646	16.31725
$Input_1$	0.00000	2.33436	23.85908
$Input_1$	0.00000	13.38403	24.02374
$Input_1$	0.00000	22.08033	24.44452

The following table shows that the criterion value for frequency bands 16, 32, 64, 128 decreases.

Table 6. Criterion value for frequency bands 16; 32; 64; 128

	c_1	c_2	c
16	0.99994	83.05443	83.04917
32	0.99780	10.22081	10.19833
64	0.97884	1.79496	1.75697
128	0.83710	1.10707	0.92673

Example 2
First signal A=1;f0= 0.5;
Second signal A=A+A/4; f0= f0+f0/4;
Third signal A=A+3; f0= f0+4; **(Fig.2).**

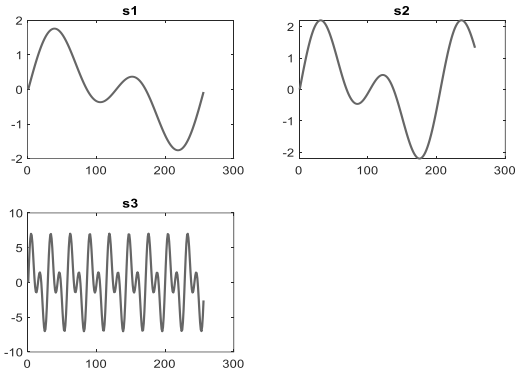

Fig.2 Signals 1) A=1;f0= 0.5
2) A=A+A/4; f0= f0+f0/4
3) A=A+3; f0= f0+4.

The following table shows that conditions (13) are met.

Table 7. Distances from the first to the other two signals

	$Input_1$	$Input_2$	$Input_3$
$Input_1$	0.00000	0.28647	16.31725
$Input_1$	0.00000	1.11657	23.85908
$Input_1$	0.00000	9.23679	24.02374
$Input_1$	0.00000	15.86048	24.44452

Criterion values for frequency bands 16; 32; 64; 128 are reduced.

Table 8. Criterion values for frequency bands 16; 32; 64; 128

	c_1	c_2	c
16	0.99985	56.95962	56.95105
32	0.99934	21.36815	21.35414
64	0.99402	2.60088	2.58532
128	0.92322	1.54122	1.42289

First signal A=1;f0= 0.5;
Second signal A=A+A/2; f0= f0+f0/2;
Third signal A=A+5; f0= f0+6; **(Fig.3)**

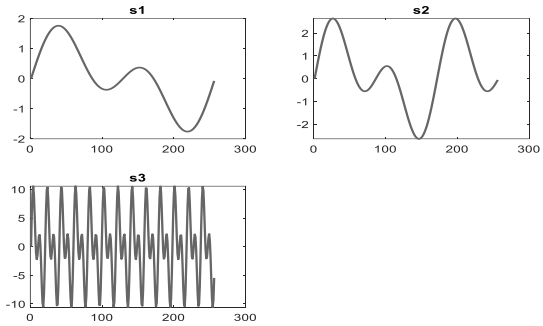

Fig.3 Signals: 1) A=1;f0= 0.5
2) A=A+A/2; f0= f0+f0/4;
3) A=A+5; f0= f0+6.

The following table shows that conditions (3) are met.

Table 9. Distances from the first to the other two signals

	$Input_1$	$Input_2$	$Input_3$
$Input_1$	0.00000	0.19646	24.58765
$Input_1$	0.00000	2.33436	27.46245
$Input_1$	0.00000	13.38403	27.46859
$Input_1$	0.00000	22.08033	27.75693

Criterion values for frequency bands 16; 32; 64; 128 are reduced.

Table 10. Criterion values for frequency bands 16; 32; 64; 128

	c_1	c_2	c
16	0.99997	125.15054	125.14724
32	0.99977	11.76443	11.76167
64	0.98518	2.05234	2.02193
128	0.88456	1.25709	1.11197

First signal A=1;f0= 0.5;
Second signal A=A+7; f0= f0+8;
Third signal A=A+5; f0=f0+6; **(fig.4).**

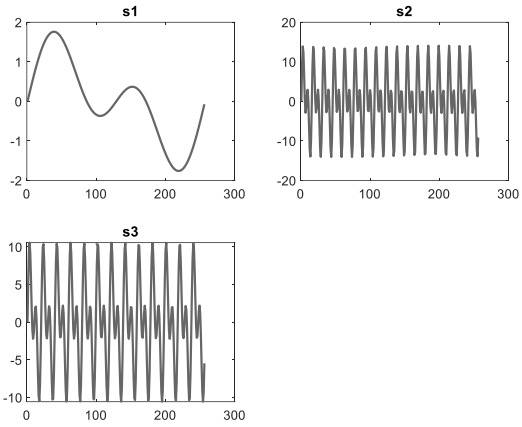

Fig.4 Signals: 1) A=1;f0= 0.5
2) A=A+7; f0= f0+8
3) A=A+5; f0= f0+6.

The following table shows that condition (13) is not met.

Table 11. Distances from the first to the other two signals

	$Input_1$	$Input_2$	$Input_3$
$Input_1$	0.00000	29.63827	24.58765
$Input_1$	0.00000	29.93054	27.46245
$Input_1$	0.00000	29.93644	27.46859
$Input_1$	0.00000	30.16021	27.75693

Criterion values c_2 for frequency bands 16; 32; 64; 128 not decrease .

Table 12. Criterion values for frequency bands 16; 32; 64; 128

	c_1	c_2	c
16	0.74742	0.82959	0.62005
32	0.77793	0.91754	0.71378
64	0.77779	0.91756	0.71367
128	0.76971	**0.92032**	0.70837

First signal A=1;f0= 0.5;
Second signal A=A+7; f0= f0+8;
Third signal A=A+9; f0= f0+10; (fig.5)

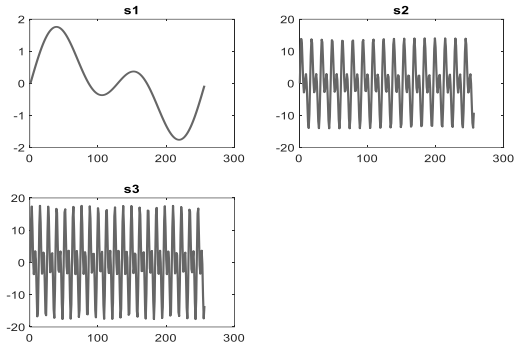

Fig.5 Signals: 1) A=1;f0= 0.5
2) A=A+7; f0= f0+8
3) A=A+9; f0= f0+10.

The following table shows that condition (13) is not met.

Table 13. Distances from the first to the other two signals

	$Input_1$	$Input_2$	$Input_3$
$Input_1$	0.00000	29.63827	31.82863
$Input_1$	0.00000	29.93054	31.83427
$Input_1$	0.00000	29.93644	31.83918
$Input_1$	0.00000	30.16021	32.0270

Criterion values for frequency bands 16; 32; 64; 128 decrease very slightly.

Table 14. Criterion values for frequency bands 16; 32; 64; 128

	c_1	c_2	c
16	**0.62559**	**1.07390**	**0.67183**
32	0.64726	1.06361	0.68843
64	0.64720	1.06356	0.68833
128	**0.64340**	**1.06190**	**0.6832**

First signal A=1;f0= 0.5;
Second signal A=A+1; f0= f0+2;
Third signal A=A+15; f0= f0+20; **(fig.6)**

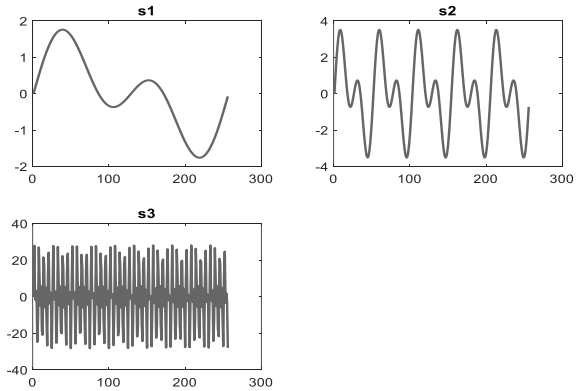

Fig.6 Signals: 1) A=1;f0= 0.5;
2) A=A+1; f0= f0+2;
3) A=A+15; f0= f0+20.

It can be seen from the following table that condition (13) is satisfied.

Table 15. Distances from the first to the other two signals

	$Input_1$	$Input_2$	$Input_3$
$Input_1$	0.00000	6.58075	29.69025
$Input_1$	0.00000	13.19904	29.69112
$Input_1$	0.00000	17.95198	29.69809
$Input_1$	0.00000	18.86144	29.9617

Criterion values for frequency bands 16; 32; 64; 128 they are decreasing.

Table 16. Criterion values for frequency bands 16; 32; 64; 128

	c_1	c_2	c
16	0.99958	4.51168	4.50980
32	0.99148	2.24949	2.23032
64	0.96932	1.65431	1.60355
128	0.97763	1.58852	1.5530

3.3 Finding the best sensitivity of mathematical models using a confirmed criterion

From the point of view. mathematics, if a computational circuit gives the best sensitivity, then the value is equal to one. In practice, sensitivity values greater or less than one are obtained.

For example, in theory, the greater the number of frequency bands (BLATTER, 2006), the more accurate the continuous wavelet transform. In practice, due to the accumulation of errors in computers, large values of frequency bands can lead to inaccuracies.

By gradually increasing the number of frequency bands, we will monitor how the criterion reflects this increase.

Table 17. Criterion values for frequency bands 16; 32; 64; 128

	c_1	c_2	c
16	0.97884	1.79496	1.75697
32	0.93577	1.45904	1.36532
64	0.89261	1.28922	1.15077
128	0.83710	1.10707	0.92673

Table 18. Criterion values for frequency bands 170; 230; 250; 300

	c_1	c_2	c
170	0.77280	0.95551	**0.73842**
230	0.77567	0.97490	0.75620
250	0.78841	0.99159	0.78179
300	0.82243	1.01377	0.8338

Table 19. Criterion values for frequency bands 320; 340; 360; 400

	c_1	c_2	c
320	0.83455	1.01594	0.84785
340	0.84537	1.01616	0.85903
360	0.85487	1.01538	0.86802
400	0.87025	1.01302	0.8816

Table 20. Criterion values for frequency bands 150; 160; 170; 175

	c_1	c_2	c
150	0.79510	0.99796	0.79348
160	0.78207	0.97127	0.75960
170	0.77280	0.95551	0.73842
175	0.76948	0.95093	0.7317

Table 21. Criterion values for frequency bands 180; 185; 190; 195

	c_1	c_2	c
180	0.76697	0.94817	0.72722
185	0.76525	0.94701	0.72469
190	0.76424	0.94720	0.72389
195	0.76392	0.94854	0.7246

Table 22. Criterion values for frequency bands 188;189; 190; 191

	c_1	c_2	c
188	0.76456	0.94697	0.72402
189	0.76439	0.94706	0.72393
190	0.76424	0.94720	**0.72389**
191	0.76413	0.94739	0.7239

These results show that the best values for the number of frequency bands are around the value 190. Calculating from 185 to 195 in steps of 1, we clarify this value.

Example 1:

First signal A=1;f0= 0.5;

Second signal A=A+ A/2; f0= f0/2;
Third signal A=A+3; f0= f0+4; (**fig.7**):

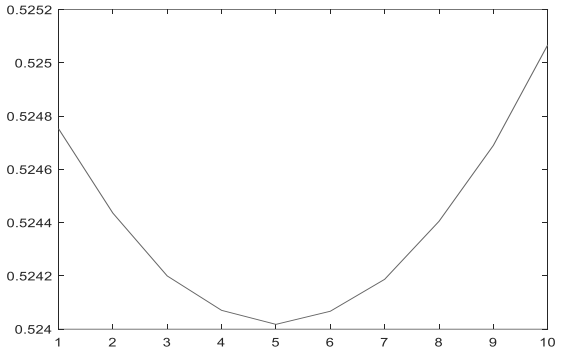

Fig.7 Best sensitivity point for example 1

Example 2:
First signal A=1;f0= 0.5;
Second signal A=A+ A/2; f0=f0/2;
Third signal A=A+5; f0=f0+6;
If you calculate from 185 to 205 in steps 2, you get the final value (fig.8):

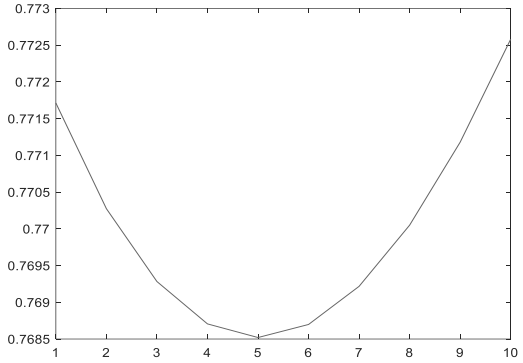

Fig.8 Best sensitivity point for example 2

Example 3:
First signal A=1;f0=0.5;
Second signal A=A+ A/2; f0=f0/2;
Third signal A=A+7; f0=f0+9;

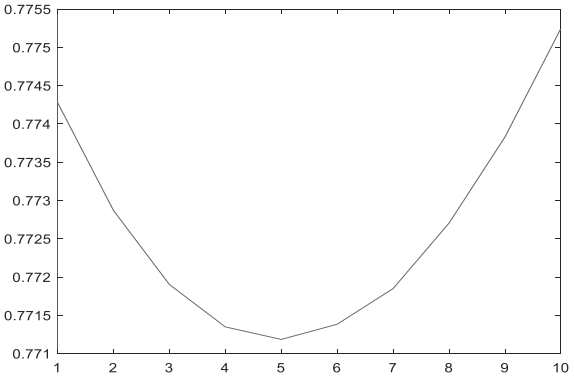

Fig.9. Best sensitivity point for example 3

Example 4:
First signal A=1;f0= 0.5;
Second signal A=A+ A/2; f0=f0/2;
Third signal A=A+15; f0=f0+20;

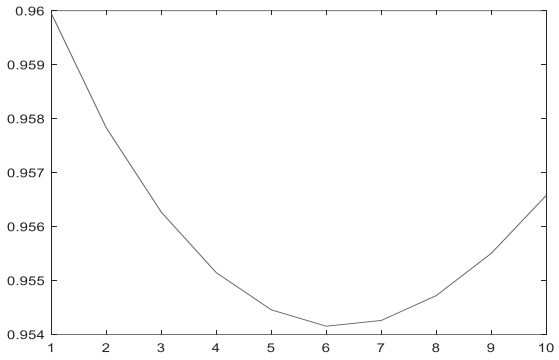

Fig.10. Best sensitivity point for example 4

The above calculations find the value of the number for frequency bands equal to 195 for the best sensitivity of mathematical models, only the last example shows the value for frequency bands 197. The final quantity value for the frequency bands must be selected 197, because only the last example, than other examples, satisfies the distance condition (13) for the third input more.

So, the best sensitivity of mathematical models is achieved when the number of frequency bands is 197.

3.4. Application of Monte Carlo's method to prove a new criterion for assessing the sensitivity of mathematical models

If the result obtained using a new criterion is obtained using another method, we can say about the full proof.

Using the Monte Carlo method with the selected multiplication factor, we obtain the signal $Input_*$.Then adding it to the input $Input_1$we get:

$$Input_2 = Input_1 + Input_*. \qquad (20)$$

By applying formula (7) to $Input_1$ and $Input_2$ to find the sensitivity of mathematical models, we obtain that the best sensitivity for the mathematical model under study is when the value of the number of frequency bands changes close to 197. This result coincides with the result obtained using a new criterion on the sensitivity of mathematical models.

If the number of frequency bands is from 185 to 195, and the multiplication factor is 0.5, then the range of sensitivity changes is 25.6:26.6.

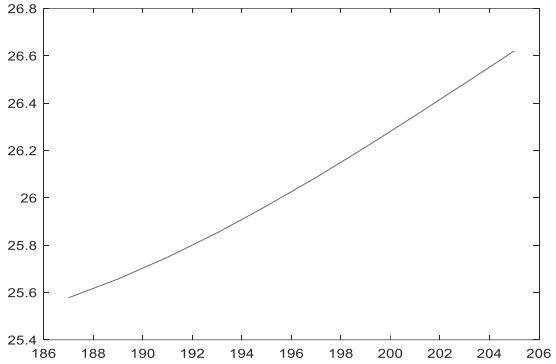

Fig.11. The range of best sensitivity according to the Monte Carlo method with a multiplication factor of 0.5, for frequency bands from 185 to 195

If the number of frequency bands is from 85 to 95, and the multiplication factor is 0.5, then the range of changes in sensitivity is 29.5: 32.5 (fig.12).

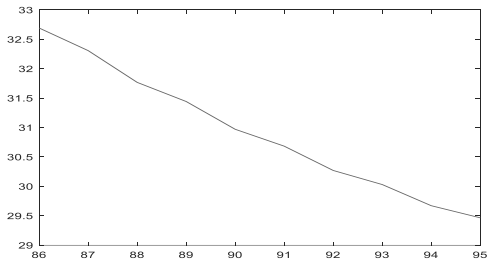

Fig.12. The range of best sensitivity according to the Monte Carlo method with a multiplication factor of 0.5, for frequency bands from 85 to 95

If the number of frequency bands is from 185 to 195, and the multiplication factor is 0.05, then the range of sensitivity changes is 3.05: 3.25 (fig.13).

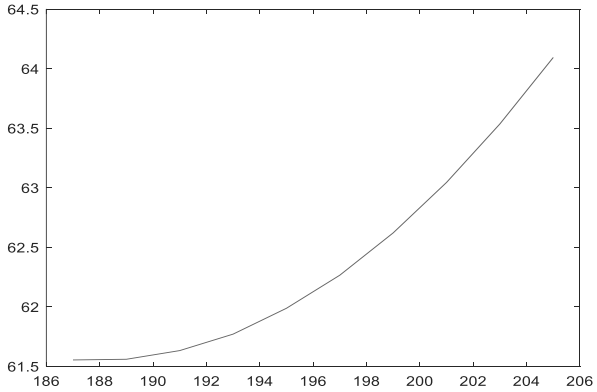

Fig.13. The range of best sensitivity according to the Monte Carlo method with a multiplication factor of 0.05, for frequency bands from 185 to 195

If the number of frequency bands is from 85 to 95, and the multiplication factor is 0.05, then the range of changes in sensitivity is 48.75: 52.75 (fig.14).

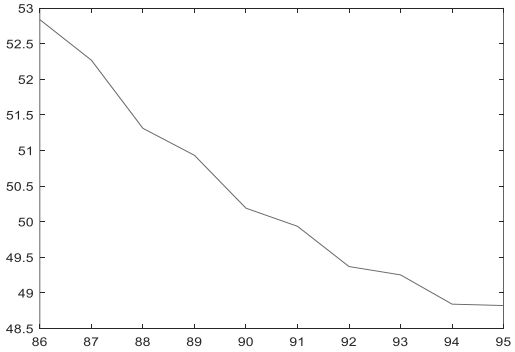

Fig.14. The range of best sensitivity according to the Monte Carlo method with a multiplication factor of 0.05, for frequency bands from 85 to 95

4. Discussion

The work on this topic aroused great interest in this part of mathematics among the author himself. Additional ideas emerged for studies of sensitivity analysis of mathematical models (SAMM). Among the ideas is to do more accurate calculations, as well as experiment with great examples. The author also plans to carry out the same calculations in the following works for application programs that use a discrete wavelet transform, and will compare the results obtained with the results of known methods in the field of sensitivity analysis of mathematical models (SAMM).

5. Conclusion

In all of the above calculations using the Monte Carlo method, the range of changes in the sensitivity of the mathematical model near 197, found using the new criterion, is less than in other remote intervals of changes in the number of frequency bands. Note that the result obtained in this article using a new criterion is the region of the best parameters of a continuous wavelet transform, then there is a region of change. The number of frequency bands is of great applied importance, since wavelet transform and continuous and discrete are used in many areas, for example, if wavelet transform is used in medicine, then using the established area of the best parameters, the application program will more accurately determine the patient's diagnosis.

References

Blatter, K. (2006) Wavelet Analysis. Basic Theory. Translated from English, Tekhnosfera, Moscow. (In Russian)

Borgonovo, E.; Castaings, W.; Tarantola, S. (2012). Model emulation and moment-independent sensitivity analysis: An application to environmental modelling. Environ. Model. Softw. 34, 105–115.

Gul, R.; Schütte, C.; Bernhard, S. (2016). Mathematical modeling and sensitivity analysis of arterial anastomosis in the arm. Appl. Math. Model., 40, 7724–7738.

Kerimov, A.B. (2024). An algorithm the sequence of artificial symmetric signals for comparison and creating new methods. Problems of Information Society 15(2), 24–29. http://doi.org/10.25045/jpis.v15.i2.03

Kerimov A.B. (2022). Comparison of some signal recognition methods for their adequacy, Proceedings of the 8-th International Conference on Control and optimization with industrial applications, I, 24-26 August, Baku, Azerbaijan.

Lamboni, M.; Kucherenko, S. (2021). Multivariate sensitivity analysis and derivative-based global sensitivity measures with dependent variables. Reliab. Eng. Syst. Saf., 212, 107519.

Yakovlev A.N. (1998). Introduction to wavelet transforms, Textbook, Novosibirsk, NSTU Publishing House, (in Russian)

Rana, S.; Ertekin, T.; King, G.R. (2018). An efficient assisted history matching and uncertainty quantification workflow using Gaussian processes proxy models and variogram based sensitivity analysis: GP-VARS. Comput. Geosci., 114, 73–83.

Saltelli, A.; Ratto, M.; Andres, T.; Campolongo, F.; Cariboni, J.; Gatelli, D.; Saisana, M.; Tarantola, S. (2008). Global Sensitivity Analysis: The Primer; John Wiley & Sons: Chichester, UK.

Sanchez, D.G.; Lacarriere, B.; Musy, M.; Bourges, B. (2001). Application of sensitivity analysis in building energy simulations: Combining first-and second-order elementary effects methods. Energy Build, 68, 741–750.

Sobol, I.M. (2001). Global sensitivity indices for nonlinear mathematical models and their Monte Carlo estimates. Math. Comput. Simul., 55, 271–280.

Zhang, Z.; Gul, R.; Zeb, A. (2021). Global sensitivity analysis of COVID-19 mathematical model. Alex. Eng. J., 60, 565–572.

How to cite: Azer Kerimov (2025). About one approach for determining the sensitivity of mathematical models. Problems of Information Society, 2, 98–106. http://doi.org/10.25045/jpis.v16.i2.11