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Improving Predicting Accuracy by the Method of Least Squares

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Abstract

Several predicting methods are analyzed in this paper, including: least squares method, extrapolation method, exponential smoothing method, adaptive smoothing method, mathematical modeling method, band method, matrix method, simulation method. One of these methods is aimed at solving the given problem using the methods of least squares linear regression and second order parabola method (quadratic regression). Currently, issues related to the approximation of points in the plane for calculating the coefficients of the function are relevant. Technologists, designers, and mathematicians use various approximation methods to average any number of measurements. Also in this paper, the analysis and programming of the above methods are aimed at finding the optimal function coefficients and helping the future application of these methods in the analysis of experimental data. In addition, a statistical approach aimed at modeling and predicting the level of fire risk based on the data coming from devices and environmental factors using the method of least squares has been developed.

Keywords: Least squares method, prediction, approximation, true values, linear function model, error, linear regression, quadratic parabola method.

Introduction

Currently, issues related to the approximation of points on the plane for calculating function coefficients are relevant. Technologists, designers and mathematicians use various approximation methods to average any measurements. The purpose of the work is to deeply analyze and program these methods, find optimal function coefficients and use these methods in the analysis of experimental data in the future to predict fire hazard. In this article, the methods of linear regression of the least squares method and the method of the second order parabola (quadratic regression) are considered to solve the problem posed [1].

Predicting fires that will occur in various objects, residential buildings and settlements is one of the methods of fire prevention. Today, there are a lot of computer programs and mathematical models designed to predict any trends in the selected field. This article will consider methods for predicting values obtained from devices using regression analysis [2].

Methods

As is known, there are several forecasting methods, which include:

- least squares method;
- extrapolation method;
- exponential smoothing method;
- adaptive smoothing method;
- mathematical modeling method;
- network method;
- matrix method;
- simulation method.

The method of least squares is used to approximate a given function through simpler functions, to build a simple mathematical model [3].

The construction of a linear model using the least squares method is carried out in the following order:

$$\hat{y}_i = \widehat{\beta_0} + \widehat{\beta_1} x_i \tag{1}$$

here, we first need to find the coefficients, $\widehat{\beta_0}$ and $\widehat{\beta_1}$.

$$\widehat{\beta_0} = \bar{y} - \widehat{\beta_1}\,\bar{x}$$

$$\widehat{\beta_1} = \frac{\sum(y_i - \bar{y})(x_i - \bar{x})}{\sum(x_i - \bar{x})^2} \tag{2}$$

Research results

To perform the calculation, a table of 44 values of the methane gas sensor obtained from the experiment is taken [12, 13].

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Table 1. Table of 44 values of the methane sensor obtained from the experiment

x_i - time	y_i - methane value	y_i-y_average	x_i-x_average	(yi-y_average)*(xi-x_average)	(xi-x_average)*(xi-x_average)
120	0	-3,5136	42,5227	-149,4094	1808
119	0,5	-3,0136	41,5227	-125,1344	1724
116	0	-3,5136	38,5227	-135,3549	1484
114	0	-3,5136	36,5227	-128,3276	1334
113	0	-3,5136	35,5227	-124,8139	1262
110	0	-3,5136	32,5227	-114,2730	1058
109	0	-3,5136	31,5227	-110,7594	994
106	0,2	-3,3136	28,5227	-94,5139	814
104	0	-3,5136	26,5227	-93,1912	703
103	0	-3,5136	25,5227	-89,6776	651
100	0,1	-3,4136	22,5227	-76,8844	507
99	0,5	-3,0136	21,5227	-64,8617	463
96	1,2	-2,3136	18,5227	-42,8549	343
95	2,6	-0,9136	17,5227	-16,0094	307
92	4,4	0,8864	14,5227	12,8724	211
91	5,7	2,1864	13,5227	29,5656	183
89	7,4	3,8864	11,5227	44,7815	133
86	10	6,4864	8,5227	55,2815	73
84	10	6,4864	6,5227	42,3088	43
83	10	6,4864	5,5227	35,8224	31
80	10	6,4864	2,5227	16,3633	6
79	10	6,4864	1,5227	9,8770	2
76	10	6,4864	-1,4773	-9,5821	2
75	10	6,4864	-2,4773	-16,0685	6
72	10	6,4864	-5,4773	-35,5276	30
71	9,6	6,0864	-6,4773	-39,4230	42
69	10	6,4864	-8,4773	-54,9867	72
66	10	6,4864	-11,4773	-74,4458	132
64	10	6,4864	-13,4773	-87,4185	182
63	9,3	5,7864	-14,4773	-83,7708	210
60	2,9	-0,6136	-17,4773	10,7247	305
59	0	-3,5136	-18,4773	64,9224	341
56	0	-3,5136	-21,4773	75,4633	461
54	0	-3,5136	-23,4773	82,4906	551
53	0	-3,5136	-24,4773	86,0042	599
50	0	-3,5136	-27,4773	96,5451	755
49	0	-3,5136	-28,4773	100,0588	811
46	0	-3,5136	-31,4773	110,5997	991
45	0	-3,5136	-32,4773	114,1133	1055
43	0	-3,5136	-34,4773	121,1406	1189
40	0	-3,5136	-37,4773	131,6815	1405
39	0	-3,5136	-38,4773	135,1951	1481
36	0,2	-3,3136	-41,4773	137,4406	1720
35	0	-3,5136	-42,4773	149,2497	1804
77,477272727	3,513636364			-104,786363636	28277
		B1^=	-0,003705713		
		B0^=	3,800744904		

$$\widehat{\beta_0} = \overline{y} - \widehat{\beta_1}\,\overline{x} \qquad \widehat{\beta_1} = \frac{\sum(y_i-\overline{y})(x_i-\overline{x})}{\sum(x_i-\overline{x})^2} \quad (3)$$

$$\widehat{\beta_1} = -0{,}004$$

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$$\widehat{\beta_0} = 3{,}514 - 0{,}004 \cdot 77{,}477 = 3{,}801$$

$$\widehat{y_i} = 3{,}801 - 0{,}004x_i.$$

The graph of actual values coming from the device looks like this (Figure 1).

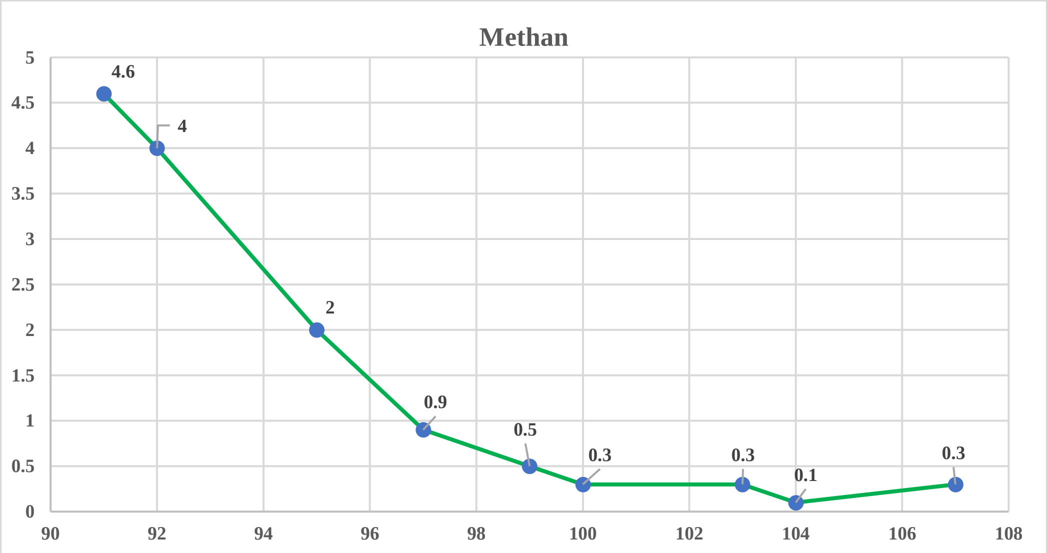

Figure 1. Graph of actual values obtained from the device

Based on the above calculations, the error in the linear function model of the least squares method can be seen in this table (Figure 2).

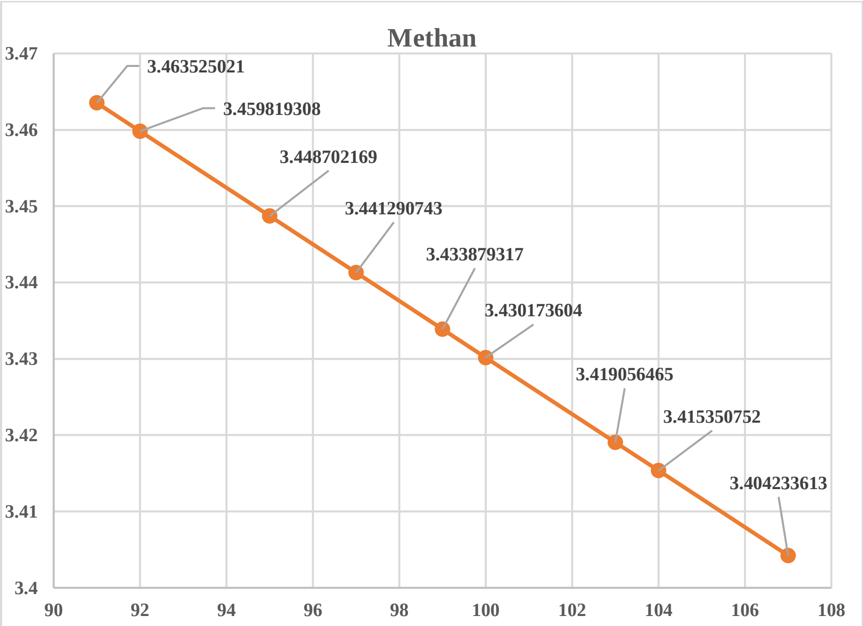

Figure 2. Graph of the linear function model of the least squares method

To reduce the error, the second-order parabola method (quadratic regression) is used [4, 5, 6, 11].

$$\hat{y} = ax^2 + bx + c, \qquad a \neq 0;$$

$$\begin{cases} a\sum x_i^2 + b\sum x_i + nc = \sum y_i \\ a\sum x_i^3 + b\sum x_i^2 + c\sum x_i = \sum x_i y_i \\ a\sum x_i^4 + b\sum x_i^3 + c\sum x_i^2 = \sum x_i^2 y_i \end{cases} \qquad (4)$$

The matrix equation looks like this:

$$\begin{bmatrix} x_i^4 & x_i^3 & x_i^2 \\ x_i^3 & x_i^2 & x_i \\ x_i^2 & x_i & n \end{bmatrix} \cdot \begin{bmatrix} a \\ b \\ c \end{bmatrix} = \begin{bmatrix} \sum x_i^2 y_i \\ \sum x_i y_i \\ \sum y_i \end{bmatrix} \quad (5)$$

$$a = \frac{(\sum x_i^2 y_i \sum x_i x_i) - (\sum x_i y_i \ \sum x_i^2)}{(\sum x_i x_i \sum x_i^2) - (\sum x_i^2)^2};$$

$$b = \frac{(\sum xy \sum x_i^2) - (\sum x_i^2 y_i \sum x_i^2)}{(\sum x_i x_i \sum x_i^2) - (\sum x_i^2)^2};$$

$$c = \frac{\sum y_i}{n} b \left(\frac{\sum x_i}{n}\right) - a \left(\frac{\sum x_i^2}{n}\right).$$

here, n - is the number of elements, $\sum x_i$ – the sum of the x_i values, $\sum y_i$ - the sum of the y_i values [7, 8, 9, 10].

The next step is to determine the correlation coefficient R.

$$R = \sqrt{1 - \frac{\sum(y_i - \hat{y}_i)^2}{\sum(y_i - \bar{y}_i)^2}} \quad (6)$$

here, $\bar{y} = \frac{1}{n}\sum y_i$.

R^2 – prediction reliability.

$y = 0{,}032x^2 - 6{,}496x + 334{,}830$ – quadratic regression equation.

The graph of the results obtained using the quadratic regression method looks like this (Figure 3).

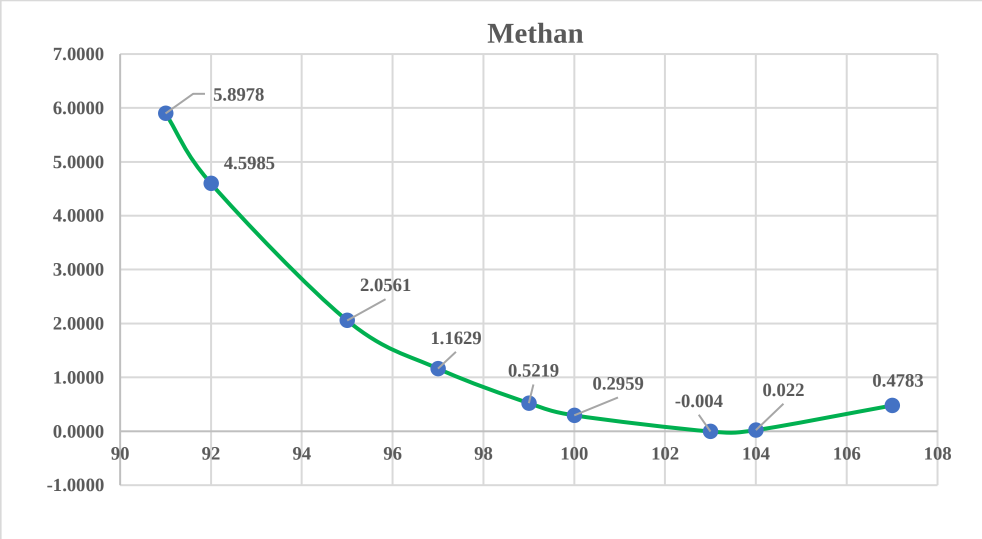

Figure 3. Graph of the results obtained using the quadratic regression method

As can be seen from the graph, the resulting graph is very similar to the graph of the actual values coming from the device (Figure 1).

Conclusion

Fire hazard prediction is an important aspect of rapid fire risk prevention using fire hazard prediction methods. In particular, this method is a statistical approach aimed at modeling and predicting the level of fire hazard based on data from devices and environmental factors. The method of least squares involves fitting a regression model to the available data points (values coming from the device) by minimizing the sum of squared differences between the observed and predicted values.

By analyzing fire data coming from devices, researchers can develop predictive models using the method of least squares. These models can then be used to predict the level of fire hazard in the future. This helps in the effective allocation of resources in emergency management, implementation of preventive measures, and emergency response planning.

In general, least squares methods provide a systematic and statistical approach to predicting fire risk, while also helping to make quick and effective decisions and improve fire prevention strategies in facilities with high fire and explosion risks.

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