Georgian Scientists
ქართველი მეცნიერები
Vol. 6 Issue 2, 2024
https://doi.org/10.52340/gs.2024.06.02.27

კატეგორია: 3.3.1. კომპიუტერული მეცნიერება: კომპიუტერული ქსელები და კომუნიკაციები

Analysis of time series using the fractal method

Eka Akhlouri
Georgian Technical University, PHD Student

ABSTRACT

The article introduces a method for diagnosing the stability of large-scale processes, centered around analyzing the fractal structure of time series. This method comprises several stages, such as data preparation, calculating fractal characteristics, and constructing a stability model based on the acquired data. Application of this method to real data demonstrated its effectiveness in both anomaly detection and predicting process stability.

KEYWORDS: Fractal analysis, time series, stability

1. INTRODUCTION

Ensuring the stability of measurement results is vital in areas requiring accurate and reliable measurement of large-scale process parameters. Large-scale processes, such as production, transportation, energy, and the environment, are often characterized by complex dynamic changes in both time and space. Under such conditions, minor fluctuations or unforeseen effects can significantly impact the measurement results, leading to a loss of measurement stability and accuracy.

One of the primary challenges faced by researchers and engineers is the myriad sources of disturbances (errors) and external influences that can affect the measurement process. These sources may include environmental changes, electromagnetic interference, mechanical vibrations, and other factors that are challenging to control or account for.

Utilizing fractal analysis to diagnose the stability of measurement results offers several significant advantages. Fractal analysis considers the complex, large-scale structure of time series data, enabling the detection of dynamic changes and fractal regularities that classical methods of analysis may overlook [1-3].

Fractal analysis enables the discovery of long-term relationships and structures in data that may be overlooked by traditional methods. This capability is particularly crucial for diagnosing measurement result stability in large-scale processes characterized by extended changes and trends.

Through fractal analysis, even minor alterations in system dynamics can be detected, rendering it a sensitive tool for diagnosing measurement result stability. This ensures prompt identification of potential issues and precludes their further development.

Furthermore, fractal analysis facilitates the examination of structural features within time series at intricate levels. This capability unveils fractal structures and patterns across various time scales. Most fractal analysis methods offer relatively straightforward interpretations of results, making them accessible to a broad spectrum of specialists.

Hence, leveraging fractal analysis for diagnosing measurement result stability proves to be a potent tool for effectively analyzing and interpreting complex dynamic systems and time series. Consequently, it enhances the reliability and precision of measurements [4], [5].

2. Main

Consider employing the fractal analysis method to diagnose the results of monitoring a real process, specifically the temperature values measured by the internal space sensor of one of the boilers within the existing complex monitoring system of Vardzia spanning from 2017 to 2023. Data were collected at three-hour intervals in December, resulting in a total of 168 observations (N=168). We will segment the data into fragments corresponding to each year of observation, with each fragment comprising 240 data points. The average temperature values for each year are presented in Table 1.

Table 1. average temperature values for the month of December

years of observation	2017	2018	2019	2020	2021	2022	2023
mean value	5,265	5,84	6,142	6,19	6,202	6,23	6,95

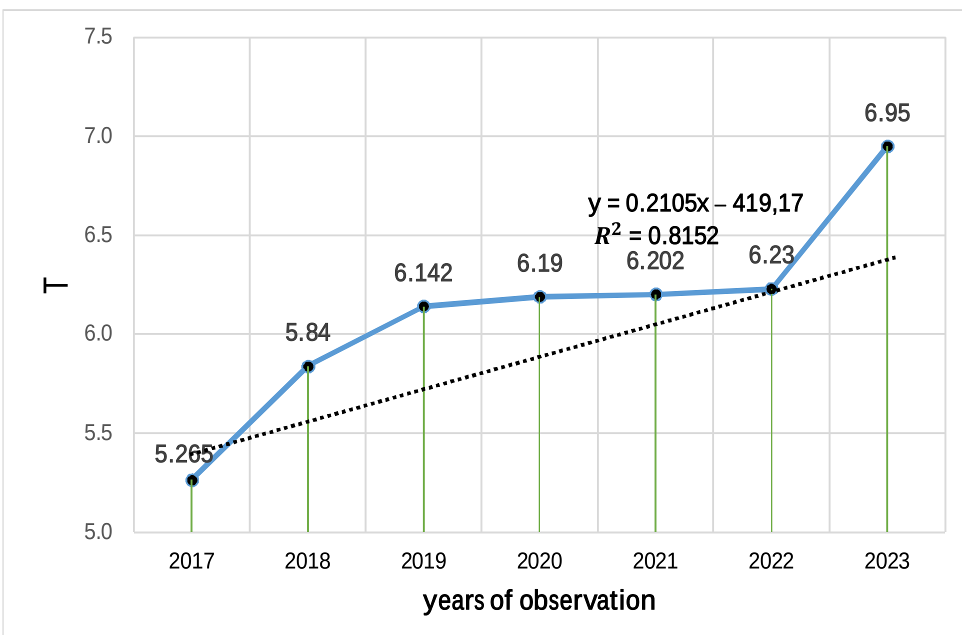

Figure 1. Regression analysis of the average temperature change in the boiler.

From the analysis of this data, we can delineate a temperature range corridor of ±0.5°C. This corridor indicates where a change is likely to occur with high probability, and deviations from it can be viewed as anomalous events.

It is established that Hurst's empirical law holds true for a significant number of data sets and natural processes [2]:

$$\left(\frac{n}{2}\right)^H = \frac{R(n)}{S_n}$$

Table 2 displays all the intermediate values obtained through the fractal analysis method for analyzing the observation results.

Table 2 results of the fractal analysis method

№	years	$R(n)$	S_n	$R(n)/S_n$	$log\, R(n)/S_n$	$\left(\frac{n}{2}\right)^H$	$H = log\, n/2$
1	2017	12,63	1,33	9,49	0,97	$(30/2)^H$	1,176
2	2018	11,45	0.62	18,46	1.267	$(60/2)^H$	1,47
3	2019	11,17	0,64	17,45	1,24	$(90/2)^H$	1,95
4	2020	12,12	0,602	20,13	1,29	$(120/2)^H$	1,78
5	2021	13,07	1,05	12,44	1,11	$(150/2)^H$	1,87
6	2022	12,67	0,746	17,12	1,23	$(180/2)^H$	1,95
7	2023	13,21	0,686	19,25	1,28	$(210/2)^H$	2,02

Using the method of least squares, we derived the regression equation, yielding: y=0.121x+1.26, with a correlation coefficient of 0.721. The significance of both the coefficients and the equation itself was evaluated using Student's criterion, confirming the model's adequacy for analyzing the data. Consequently, the Hurst coefficient for the studied process is determined to be 0.121, indicating process stability and the absence of extreme deviations.

The coefficients of the resultant equation underwent adequacy testing based on the t-Student's criterion, confirming their suitability. Subsequently, the equation was scrutinized for adequacy, with the high correlation coefficient and a P-value below 0.5 indicating its validity for prediction purposes. Thus, the Hurst coefficient is established as 0.122, affirming process stability and the absence of extreme deviations.

3. CONCLUSION

The fault deformation and structural change diagnosis algorithm completes quite rapidly, even when utilizing computing equipment with limited resources. This capability enabled the creation of a unified core for both collecting and processing measurement data within the automated monitoring system. The adequacy of the procedure increases with the number of analytical variables utilized.

This developed approach holds promise for the preliminary diagnosis of long-term process monitoring results

References

Kenneth Falconer. (2013), “Fractals: A Very Short Introduction”, Published By Oxford University Press, 138-152 Pages, Paperback.

N. Otkhozoria, Z. Azmaiparashvili, L. Petriashvili, V. Otkhozoria, & E. Akhlouri. (2023). Labview In The Research Of Fractal Properties Of The Topology Of Networks And Stochastic Processes. World Science, (3(81). https://Doi.Org/10.31435/Rsglobal_Ws/30092023/8020

N. Otkhozoria, V. Otkhozoria, M.Narchemashvili, Fractality Of Measurements Of Quantities And Real Processes. International Trends In Science And Technology, Engineering Sciences June 2021 Doi: https://doi.org/10.31435/rsglobal_conf/30062021/7620

Z Azmaiparashvili, N Otkhozoria (2021) “Mathematical Model for Studying the Accuracy Characteristics of Devices for Measuring the Resonant Frequency of Oscillatory Systems New Approaches in Engineering Research” 121-131 https://doi.org/10.9734/bpi/naer/v5/10242D.

Chkheidze Irina, Otkhozoria Nona, Narchemashvili Medea (2023) “Evaluation Of Measurement Quality Using The Monte-Carlo Method” // Universum: Technical Science №3-4 (84). Url: Https://Cyberleninka.Ru/Article/N/Evaluation-Of-Measurement-Quality-Using-The-Monte-Carlo-Method.

დროითი სერიების ანალიზი ფრაქტალური მეთოდით

ეკა ახლოური

საქართველოს ტექნიკური უნივერსიტეტის დოქტორანტი

რეზიუმე

სტატიაში აღწერილია მასშტაბური პროცესების სტაბილურობის დიაგნოსტიკის მეთოდი, რომელიც ორიენტირებულია დროითი სერიების ფრაქტალური სტრუქტურის ანალიზზე. ეს მეთოდი მოიცავს რამდენიმე ეტაპს, როგორიცაა მონაცემთა მომზადება, ფრაქტალის მახასიათებლების გამოთვლა და შეგროვებული მონაცემების საფუძველზე სტაბილურობის მოდელის აგება. ამ მეთოდის რეალურ მონაცემებზე გამოყენებამ აჩვენა მისი ეფექტურობა როგორც ანომალიების გამოვლენაში, ასევე პროცესის სტაბილურობის პროგნოზირებაში.

საკვანძო სიტყვები: ფრაქტალური ანალიზი, დროითი სერიები, სტაბილურობა