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LABVIEW IN THE RESEARCH OF FRACTAL PROPERTIES OF THE TOPOLOGY OF NETWORKS AND STOCHASTIC PROCESSES

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ABSTRACT

The advancement and utilization of computer technologies for studying and diagnosing the technical state of dynamic systems are closely linked to scientific and technological progress. Among these technologies, fractal technologies hold a prominent position [1]. Time series data, which record changes in controlled parameters over time, are commonly used for diagnosing technical objects and systems. The use of fractals will also be of interest in assessing the resonant frequency characteristics of oscillatory systems [3]. The informational characteristics of topologically distributed networks (e.g., computer, cellular) significantly depend on their geometry, node placement, and inter-node distances. The fractal dimension, a fundamental characteristic of networks, plays a crucial role in this context [2].

The research paper presents a methodology for modeling and synthesizing large networks using the node density function, which follows a power function with a fractal dimension. This characteristic aligns with Zipf's law of population distribution around urban centers. The paper also provides fractality degree indices for the network diagram. Software tools such as LabVIEW play a significant role in scientific research and experiment automation.

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Introduction.

The effectiveness of LabVIEW in scientific research lies in its ability to develop mathematical models of objects and integrate experimental data from real objects using input-output hardware. LabVIEW can be utilized both as a programming tool that does not require high-level programming language knowledge and as a toolkit for automating scientific and technical experiments. The objective of this study was to calculate the fractal dimension based on the correlation function for modeling the topology of distributed object sets and analyzing time series. Furthermore, the study aimed to describe the utilization of GA\ME\M/ as a programming environment by showcasing the analysis of fractal properties of distributed networks and random processes.

Materials and Methods.

Fractal structures are prevalent in numerous real processes, often used to describe non-linear dynamic systems where the fractional dimension signifies fractality, specifically a strange attractor. A strange attractor represents the ultimate destination of motion in a chaotic system [2, 4].
In general, a smooth n-dimensional manifold within an n-dimensional Euclidean space has an integer dimension of ne. Conversely, the fractal dimension, distinct from the integer dimension, characterizes geometric objects with a more intricate structure. Various methods for estimating the fractal dimension are known [5]. However, practical calculations of the fractal dimension rely on the correlation dimension.

$$D_c = \lim_{\varepsilon \to 0} \frac{\ln C(\varepsilon)}{\ln \varepsilon}$$

where $C(\varepsilon)$ — correlation function.

$C(\varepsilon)$ is calculated, as a rule, as the ratio of the number of points n. pairwise distances between which are less than ε, to the square of the total number of points N.

$$C(\varepsilon) = \frac{n}{N^2}$$

ε - the size of the geometric structure that covers the set of points.

The distance between the points $P_1(x_1, y_1)$ and $P_2(x_2, y_2)$ is usually defined as

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

Therefore, at the beginning it is necessary to count the number of points n, the distance between which is not $d \leq \varepsilon$ exceeds ε is given. For example: ε:=0.1,0.2 ,0.3...

To calculate the fractal dimension of a point set, we simulated the process by generating sequences of uniformly and normally distributed values within the LabVIEW environment. The calculation was performed using a virtual instrument (VI) with the following controls on its front panel: N - the number of randomly generated points within the square area, ε – initial dimension value, $\Delta\varepsilon$ - increment value for the dimension, and n - number of increment steps. Figure 1 illustrates the block diagram for calculating the dimension of uniformly distributed points.

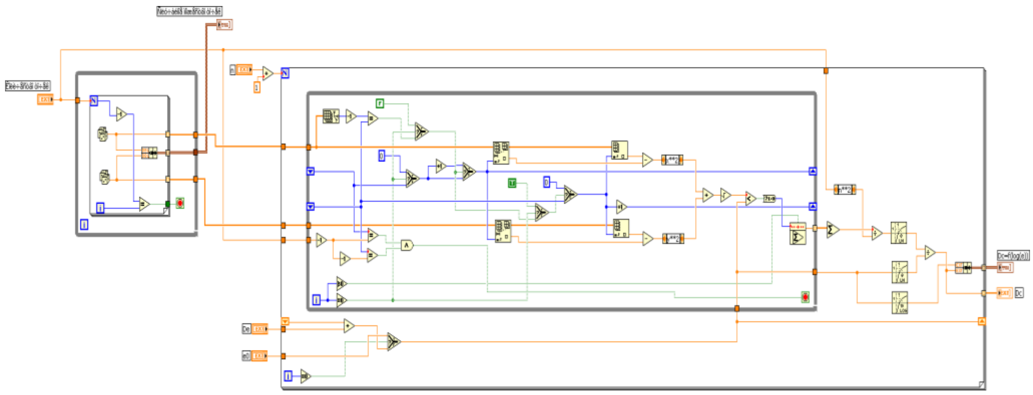
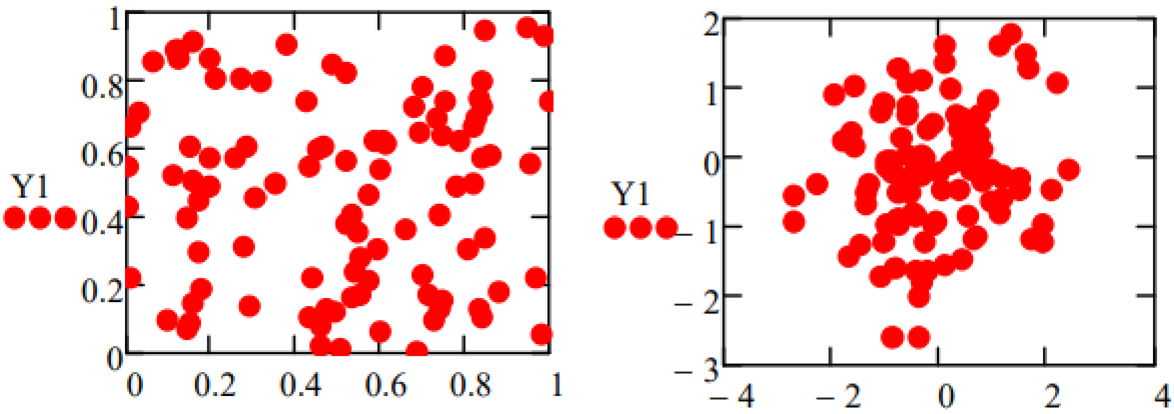


Figure 1. Block Diagram of Dimension Calculation for Uniformly Distributed Points.

Results.

In the simulation, the coordinates of the points were generated using random number generators that followed the specified distribution laws. These points were positioned along the axes of a square, with the maximum side length determined by the maximum value of the generated random numbers.

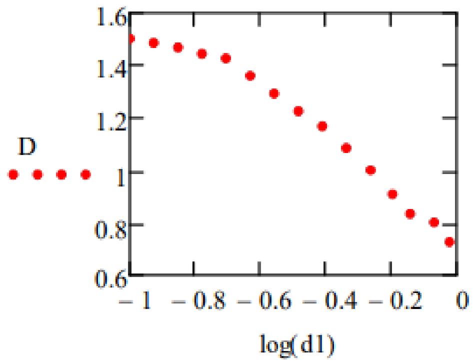


A

B

Figure 2. Topology of a set of points: A - for uniformly distributed points,

B for normally distributed points.



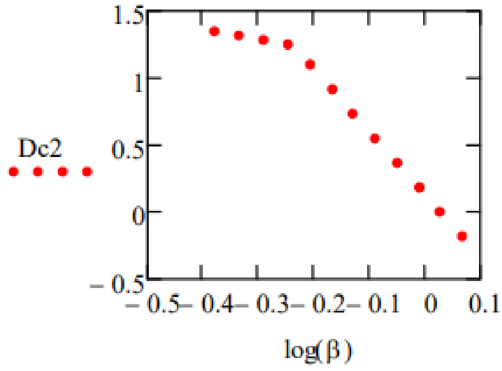


Figure3. Distribution of fractal dimension: A – uniform distribution, B – normal distribution.

The method described above for estimating the correlation dimension is obvious when there is a network of nodes.

However, when dealing with time series that contain thousands of data points, the aforementioned method becomes ineffective for determining the dimension. In such cases, studying time series using the correlation function provides a satisfactory geometric understanding of the system's behavior [4]. This approach involves using delay vectors, denoted as q, instead of the original variables of the system: $z_i = \{x_i, x_{i+1}, \dots, x_{i+m-1}\}$. The mathematical foundation for this analysis of time series was initially established by F. Takens [2, 3].

Discussion.

It is important to note that the fractal dimension, which represents the complexity and intricacy of the process, may vary across different sections of the process. Consequently, this variation affects the values of the correlation function. In this study, we considered a signal that simulates Brownian motion. As known [4], this model serves as an indicator of process persistence and anti-persistence. For a Brownian process, D = 1.5. When D < 1.5, the random process exhibits persistence and possesses a deterministic component (memory). On the other hand, when D > 1.5, the process is anti-persistent and completely unpredictable.

In the LabVIEW software environment, correlation can be determined using pre-built correlation functions. It is also recognized that the behavior of a dynamic system can be described using a sequence of process values with a delay [4]. Consequently, it is possible to establish the relationship between the logarithm of the correlation function and the delay in a straightforward manner (Figure 4).

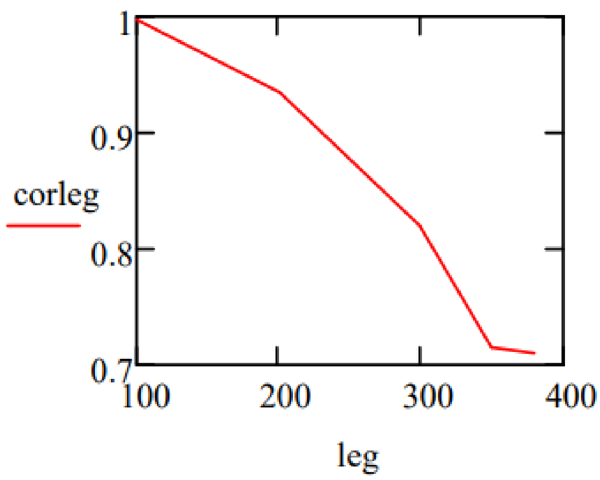


Figure 4. dependence of the logarithm of the correlation function on the delay.

The results, as depicted in Figure 4, demonstrate that as the delay increases, the correlation function decreases, and consequently, the fractal dimension also decreases. Figure 5 illustrates a block diagram of the Correlation Function Calculation VI, utilizing LabVIEW VI templates as a starting point.

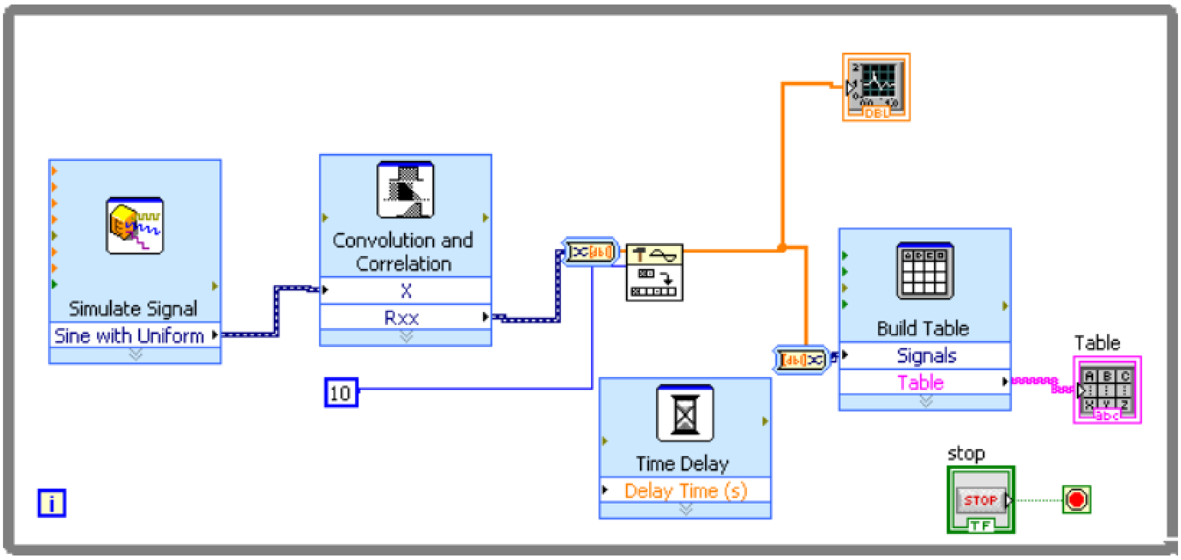


Figure 5. Block Diagram of the Correlation Function Computation VI.

Conclusions:

The conducted research yielded the following conclusions:

1) Numerical experiments and calculations of the fractal dimension of a set of points arranged on a plane and representing nodes in an information network revealed the following:

- The fractal dimension is lower than the Euclidean dimension $D_c < D_E$, where D_E is the Euclidean dimension ($D_E = 2$).
- The distribution of the correlation dimension with respect to ε demonstrated that as ε increases, the fractal dimension $(D_c \rightarrow 0)$ of the point set decreases. This implies a sort of contraction of the points into a single, larger point. Conversely, as ε decreases $(\varepsilon \rightarrow 0)$, the dimension of the point set increases, approaching the value of D_E.

These experiments encompassed various distribution laws for random numbers.

The implementation of the compiled algorithms and modeling within the LabVIEW environment significantly facilitated the calculation of the fractal dimension for time series. Fractal dimension estimation results were obtained through the simulation of Brownian motion.

REFERENCES

1. Kenneth Falconer. (2013), "Fractals: A Very Short Introduction", Published by Oxford University Press, 138-152 pages, Paperback.
2. V. Butakov, A. Grakovsky (2005), "Estimation of the level of stochasticity of time series of an arbitrary origin using the Hurst exponent". Computer Modeling and New Technologies, vol 9, #2, 27-32.
3. 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 doi.org/10.9734/bpi/naer/v5/10242D.
4. Chkheidze Irina, Otkhozoria Nona, Narchemashvili Medea (2023) "EVALUATION OF MEASUREMENT QUALITY USING THE MONTE-CARLO METHOD" // Universum: технические науки №3-4 (84). URL: https://cyberleninka.ru/article/n/evaluation-of-measurement-quality-using-the-monte-carlo-method.
5. G. Doborjginidze, L. Petriashvili (2020) "Improving efficiency of inventory identification system" EUROPEAN SCIENCE REVIEW, Premier Publishing ISSN: 2310-5577. 84-88 DOI: 10.29013/ESR-20-1.2-84-88.