ISSN 1991-346X

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ

ХАБАРЛАРЫ

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН

NEWS

OF THE NATIONAL ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN

ФИЗИКА-МАТЕМАТИКА СЕРИЯСЫ

◆

СЕРИЯ ФИЗИКО-МАТЕМАТИЧЕСКАЯ

◆

PHYSICO-MATHEMATICAL SERIES

2 (300)

НАУРЫЗ – СӘУІР 2015 ж.
МАРТ – АПРЕЛЬ 2015 г.
MARCH – APRIL 2015

1963 ЖЫЛДЫҢ ҚАҢТАР АЙЫНАН ШЫҒА БАСТАҒАН
ИЗДАЕТСЯ С ЯНВАРЯ 1963 ГОДА
PUBLISHED SINCE JANUARY 1963

ЖЫЛЫНА 6 РЕТ ШЫҒАДЫ
ВЫХОДИТ 6 РАЗ В ГОД
PUBLISHED 6 TIMES A YEAR

АЛМАТЫ, ҚР ҰҒА
АЛМАТЫ, НАН РК
ALMATY, NAS RK

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«Известия НАН РК. Серия физико-математическая». ISSN 1991-346X
Собственник: РОО «Национальная академия наук Республики Казахстан» (г. Алматы)
Свидетельство о постановке на учет периодического печатного издания в Комитете информации и архивов Министерства культуры и информации Республики Казахстан **№5543-Ж**, выданное 01.06.2006 г.

Периодичность: 6 раз в год.
Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, ком. 219, 220, тел.: 272-13-19, 272-13-18,
www:nauka-nanrk.kz / physics-mathematics.kz

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Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75.

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News of the National Academy of Sciences of the Republic of Kazakhstan. Physical-mathematical series.
ISSN 1991-346X
Owner: RPA "National Academy of Sciences of the Republic of Kazakhstan" (Almaty)
The certificate of registration of a periodic printed publication in the Committee of information and archives of the Ministry of culture and information of the Republic of Kazakhstan N 5543-Ж, issued 01.06.2006

Periodicity: 6 times a year
Circulation: 300 copies

Editorial address: 28, Shevchenko str., of. 219, 220, Almaty, 050010, tel. 272-13-19, 272-13-18,
www:nauka-nanrk.kz / physics-mathematics.kz

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Address of printing house: ST "Aruna", 75, Muratbayev str, Almaty

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
PHYSICO-MATHEMATICAL SERIES
ISSN 1991-346X
Volume 2, Number 300 (2015), 104 – 109

HURST EXPONENT AND FRACTAL DIMENSION OF A TIME SERIES ESTIMATE IN A SINGLE PARALLEL ALGORITHM

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Key words: Hurst exponent, fractal dimension, self-affinity, parallel, series, neutron.

Abstract. Using C++ programming language we implemented an algorithm for simultaneous parallel calculation of the Hurst exponent Hand the fractal dimension D for the time series of interest. Parallel programming environment was provided by Open MPI package installed on three machines networked in the virtual cluster and operated by *64* bit *Debian Wheeze 7.4* operating system. We applied our program for a comparative analysis of week and a half long, one minute resolution, six channels data from neutron monitor. To ensure a faultless functioning of the written code we compared these results with the similar data analysis of the random Gaussian noise signal and time series with manually introduced self-affinity features. Both of them expected to have the well-known values of *H* and *D*. All results are in good correspondence to each other and supported by the modern theories on signal processing thus confirming the validity of the implemented algorithms. Our code could be used as a standalone tool for the different time series data analysis as well as for the further work on development and optimization of the parallel algorithms for the time series parameters calculations.

УДК 004.942

ОЦЕНКА ЗНАЧЕНИЙ ЭКСПОНЕНТЫ ХЕРСТА И ФРАКТАЛЬНОЙ РАЗМЕРНОСТИ ВРЕМЕННОГО РЯДА В ОДНОМ ПАРАЛЛЕЛЬНОМ АЛГОРИТМЕ

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Ключевые слова: экспонента Херста, фрактальная размерность, самоподобие, параллельные, ряд, нейтронный.

Аннотация. Нами был реализован, на языке программирования *C++*, алгоритм для одновременного параллельного вычисления значений экспоненты Херста *H*и фрактальной размерности *D*для анализируемого временного ряда. Среда параллельного программирования *Open MPI* была развернута на виртуальном кластере из трех *Linux* машин под управлением *64* разрядной операционной системы *Debian Wheeze 7.4*. Используя полученную программу, мы провели сравнительный анализ данных нейтронного монитора зарегистрированных за полторы недели по шести каналам с минутным разрешением. Для тестирования корректной работы алгоритма полученные результаты сравниваются с результатами обработки случайного сигнала, а также с временным рядом с искусственно внедрёнными элементами самоподобия. Оба обладают хорошо известными свойствами и заранее предсказуемыми результатами вычисления *H* и*D*. Полученные результаты хорошо согласуются друг с другом и общепринятыми теориями, подтверждая правильность реализованного алгоритма. Написанная программа может быть использована как конечный инструмент для анализа данных временных рядов различной природы, так и для дальнейшего развития и оптимизации параллельных алгоритмов вычисления характеристик временных рядов.

Introduction. The applications of the Hurst exponent *H* and fractal dimension *D* calculations are ranging from stock market analysis [1] to electron gas modeling[2]addressing data statistics and system's fractal properties [3].Multiple studies have been done, including the studies of abundant data on cosmic rays variations. For example, Sankar et al [4]analyzed 36 years long data series on cosmic rays density covering almost three solar cycles and came to conclusion that "the present data is anti-persistent in behavior and the process is a short memory process" with the *H* value of 0.15. Flynn and Pereira, on the contrary, studied extra short, hundred points and less, data sequences [5] and extracted vital information from a data sample on population dynamics. Hurst exponent estimates are known to be strongly dependent on the length of data sample and the nature of data type taken into analysis.

A fractal dimension *D* is a quantity reflecting how frequently and to what extent the self-affine patterns appear with the change of scale in picture. For self-affine processes we expect the local properties to be observable at the level of the global ones leading, in limited number of cases, to the relationship $D+H=n+1$ between *D* and Hurst exponent *H* in *n*-dimensional space [6].More often, in real experimental data, local and global behaviors are decoupled without any linear relation.

Our primary goal in this work is to offer effective parsing of original data text file, to identify similar steps in *H* and *D* calculations algorithms, and to provide reliability of results of the Hurst exponent *H* and fractal dimension *D* data calculations. We also demonstrate a quick self-affinity test for the data of interest using our program.

Methods. Conventional algorithm for the Hurst exponent calculation runs as follows:

Original time series of length *N* is divided into the sets of shorter partial series $\{X_i\}$ with length $n = N, N/2, N/4, \ldots, 4, 3,$ and 2 points. The upper, $n=N$, and lower, $n=2$, cutoff limits differ from study to study and depend on data availability and studied phenomena.

For each set with particular *n* value, and for every partial series $\{X_i\}$ within this set we calculate the mean-adjusted series derived from $\{X_i\}$ using its mean value *m*

$$Y_t = X_t - m\,; \qquad t = 1, 2, \ldots, n; \qquad m = \frac{1}{n}\sum_{i=1}^{n} X_i \tag{1}$$

We define the rescaled range *R(n)*for a given subseries $\{X_i\}$ as follows

$$R(n) = \max(Z_1, Z_1, \ldots Z_n) - \min(Z_1, Z_1, \ldots, Z_n) \tag{2}$$

where the cumulative deviate series Z_n are given by the following expression

$$Z_t = \sum_{1=1}^{t} Y_t\,; \qquad t = 1, 2, \ldots, n. \tag{3}$$

Now, we can built the tabulated power law function *E(n)*for all possible values of *n* such as

$$E\left[\frac{R(n)}{S(n)}\right] = Cn^H \tag{4}$$

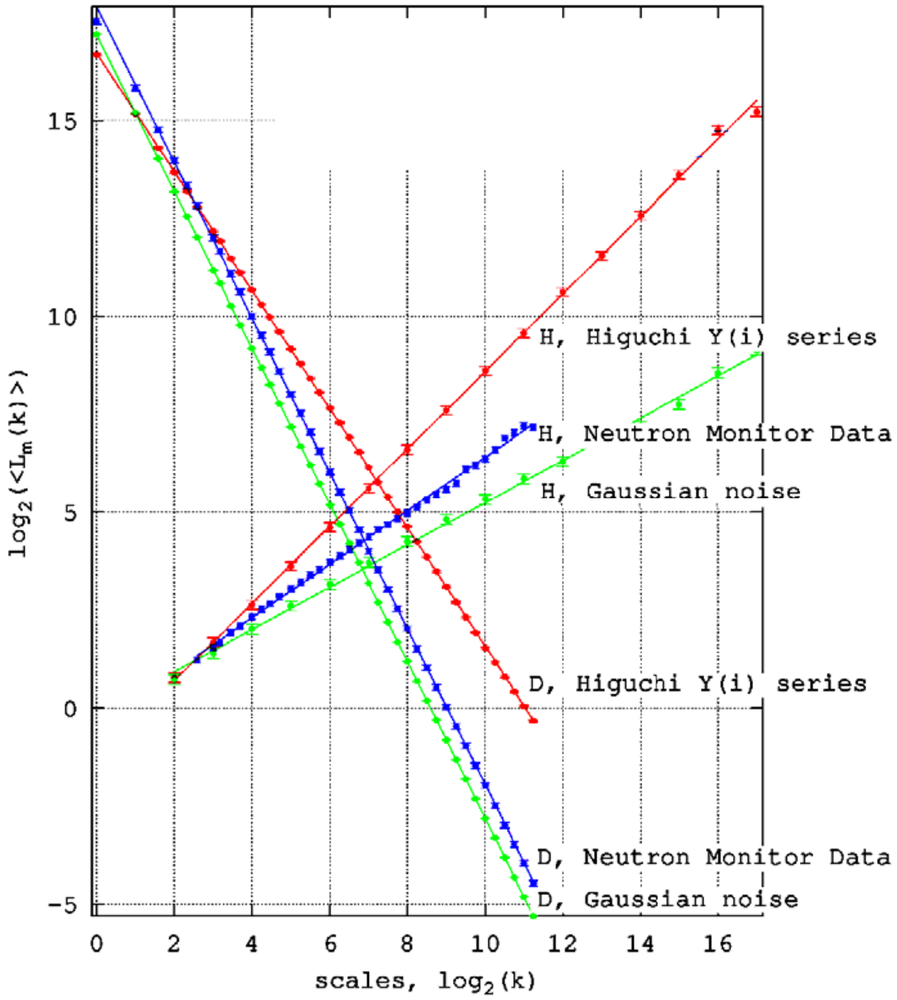
where $S(n) = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(X_i - m)^2}$ is a standard deviation. The value of *H* then could be estimated from the slope of the line $log(E)=log(C)+H*log(n)$[7].

Figure shows our *H* estimate for the first out of six registration channels of the nuclear monitor, see the blue line with the negative slope. Each data time series contains 10 days long data, taken with one minute resolution. Operator makes the choice of registration channel within the program.

Fractal dimension *D* is closely related to the Hurst exponent and could be calculated, according to Higuchi cornerstone paper [3], by constructing the following sets of subseries X_k^m

$$\begin{gathered} X(m), X(m+k), X(m+2k), \ldots, X\left(m + \left[\frac{N-m}{k}\right]k\right); \\ m = 1, 2, \ldots, k; \;\; k = 1, 2, \ldots, \left[2^{(j-1)/4}\right]\,; \; j = 11, 12, 13, \ldots \end{gathered} \tag{5}$$

where the square brackets are used to denote the closest integer after rounding the fraction to zero.



Higuchi time series (red lines), neutron monitor data (blue lines) and Gaussian noise (green lines) calculations of *H* and *D* values

Next, we calculate the normalized lengths $L_m(k)$ of the constructed subseries

$$L_m(k) = \left\{ \frac{N-1}{\left[\frac{N-m}{k}\right]k} \sum_{i=1}^{\left[\frac{N-m}{k}\right]} |X(m+ik) - X(m+(i-1)k)| \right\} k^{-1} \tag{6}$$

These are expected to follow the power law in the form of $\langle L_m(k)\rangle \propto k^{-D}$ after averaging within all sets of *k* values for different *m* = 1,2, … ,*k*.

To test the validity of the program we reproduced the exact same time series *Y(i)* which were used by Higuchi in his derivations [3] and plotted the results on the same figure, see Figure 1 and the red line with the negative slope.

Here $(i) = \sum_{j=1}^{1000+i} Z(j)$, where *Z(j)* is a Gaussian noise with mean zero and standard deviation equals to 1.The set of $L_m(k)$ subseries is again expected to produce data following the power law $\langle L(k)\rangle \propto k^{-D}$ and the value of *D* could be extracted following the same procedure as described above for the Hurst exponent. The same code can be applied to this procedure. We get *D* value equals precisely -1.5341 for a Higuchi's time series, see Table 1.Separate test run of the code for the Gaussian time series *Z(j)* produced another set of values *H* and *D* equal -1.9999 and 0.54000 correspondingly, as expected for the highly uncorrelated times series, see Table I. The *Y(j)* data are plotted with the green color on Figure.

The *n* length of subseries, in case of the Hurst exponent calculations, and *k* value for the fractal dimension calculation have been treated equally in our code, that is as a single variable $k=n$ in one of the outer parent loops. Two separate arrays of size *k* were allocated for both types of calculations. In case of the Hurst exponent calculations the array's values have been filled sequentially by the data file readout. For fractal dimension calculations, each array's element contained the value $<L_m(k)>$ assembled through the data readout according to the scheme described in Eq.6. The number of processes was equal to the number of virtual machines and kept equal to three.

The original neutron monitor data were retrieved from the Nikolay Pushkov's Institute of Earth Magnetism, Ionosphere and Radiowaves Propagation of the Russian Academy of Sciences (IZMIRAN) mobile 6NM64 super monitor database [8]. Neutron counts were acquired at one minute interval from June the 31st, 2014 till August the 8th, 2014 in the vicinity of Moscow city. Neutron monitor time series data additionally underwent simple exponential smoothing filtration procedure as described in [9].

To address a persistent need for the effective parallel algorithms in data processing we designed our piece of C/C++ code compatible with available on *Debian* distribution *Open Message Passing Interface* (Open MPI) parallel computations environment. We have configured our virtual cluster using the *Oracle VM Virtual Box*. The host is 64 bit *Windows 8.1* operating system running on *Intel Core i3-3220 CPU* with *4 Gb* of *RAM*. The guest operating systems are the three *Linux* machines with 64 bit *Debian GNU/Linux 7.4* (*Wheezy*) with 512 Mb of *RAM* per each server and two nodes.

Results. Calculated slopes for all three sets of data are given in the Table. These are the Higuchi time series, Gaussian noise and neutron monitor data *H* and *D* values.

Curve's slope estimates in D and H calculations

Time series name	Number of points in time series, *N*	Fractal dimension, *D*	Hurst exponent, *H*
Higuchi time series	2^{17}	-1.5143	0.98758
Gaussian noise	$1000+2^{17}$	-1.9999	0.54000
Neutron monitor data, 1st channel	14703	-1.9973	0.68353
2nd channel	14703	-1.9984	0.66275
3rd channel	14703	-1.9985	0.63786
4th channel	14703	-1.9982	0.67716
5th channel	14703	-1.9994	0.64220
6th channel	14703	-1.9973	0.65107

The $\pm\Delta y_i$ error bars were plotted on the figure around the experimental data points (x_i,y_i) using *polyfit*, *polyval* and *errobar* functions available in *Matlab/Octave* in such a way that then $y_i\pm\Delta y_i$ contains at least 50% of the predictions of future observations at x_i, see *Matalb/Octave* help notes on the selected functions.

In both *H* and *D* calculations, different scales evaluations were distributed between three processes. The number of processes in our case is equal to the number of machines used for calculations.

Discussion. *H* and *D* values for Higuchi time series in our calculations were found to be equal to the *D* and *H* values in [3], where *H* value close to 1 (see Table 1)indicates long term positive autocorrelation, as expected from the *Y(i)* series. For the neutron monitor series, Hurst exponent estimates are matching the majority of the previously obtained results for geomagnetic indices [10] where *H* value is above *0.5*. In our previous studies [11] of the same data with the same algorithm, the*H* value was slightly bigger than 0.6. The single reason for this change in the first decimal place is the change in the spectrum of *k* values used for our calculation. These slight changes easily rotate the curve in *log(E) vs. log(k)* plane. Nevertheless, all values stay well above 0.5.Between all six channels, the *H* values are in 0.64-0.68 range, suggesting that at the chosen series duration, our time series do have some scalable order. However, possibility of a long-term positive autocorrelation requires further studies.

The Gaussian noise data *Z(i)*in its turn produces values of D=-1.9999 and H=0.54000 as expected from the highly uncorrelated data.

As we can see, for all sets of data the processes are not completely self-affine in the sense of $D+H=n+1$ relationship, and the dependence between D and H is not of linear nature.

It is also interesting to observe how the slope changed according to the changes in data structure. We can see this transition when we come from Higuchi time series down to the chaos in the Gaussian noise. Rotations happen to be around (2:0) point for the Hurst exponent and (2:14) points for Hurst exponent and fractal dimension data calculations. This may be due to the loss of differences between time series of different origin at the small scales.

Conclusion. Using *C++* programming language we implemented an algorithm for the simultaneous parallel calculations of Hurst exponent H and fractal dimension Dover specific time series. Parallel programming environment was provided by an *Open MPI* package installed on three machines networked in the virtual cluster and operated by a *64* bit *Debian Wheeze 7.4* operating systems. We used our program to perform a comparative analysis of the week and a half long, one minute resolution, six channels data file from neutron monitor. To verify the functionality of the written code, we compared these results with a similar data analysis of the random Gaussian noise signal and time series with manually introduced self-affinity features and known values of H and D. All results are in good correlation with each other and are supported by the modern theories on signal processing, thus confirming the validity of the implemented algorithms.

Besides the straightforward workload distribution between the parallel processes, performed by splitting the data on the channel or on the calculated scale basis, we also identified common features in the calculations of two variables of interest, and tracked them in a single common outer loop within a single thread, providing additional optimization for the code. Our data and algorithms have multiple applications such as quick data self-affinity [12] test and have great potentials for the future development. The code is compiled to run independently on different networked computers and could be used as a tool to study time series of different nature and origin. Timing and optimization in this study are the subjects of further studies.

Acknowledgements. *This research was supported by grant №2532/ГФ3 provided by the Science Committee at the Ministry of Science and Education of Republic of Kazakhstan to the principal investigator at the National Nanotechnology Open Laboratory.*

We also would like to thank Dr. Yelena White, from East Georgia State College, Swainsboro, GA, USA, for editing the manuscript.

REFERENCES

[1] Zhou J., Gu G.-F., Jiang Z.-Q., et al. Microscopic determinants of the weak-form efficiency of an artificial order-driven stock market. arXiv:1404.1051,**2014**,P.1-11.

[2] Hurst J., Morandi O., Manfredi G., Hervieux P.-A. Semiclassical Vlasov and fluid models for an electron gas with spin effects. The European Physical Journal D,**2014**,Vol.68,Issue 6,P. 176-179.

[3] Higuchi T. 1988. Approach to an irregular time series on the basis of the fractal theory. Phys. D., **1988**, V.31(2), P.277-283.

[4] Sankar N.P. et al. Scaling and Fractal Dimension Analysis of Daily Forbush Decrease Data, International Journal of Electronic Engineering Research, **2011**, V.3(2), P.237-246.

[5] Flynn M, Pereira W. Ecological studies from biotic data by Hurst exponent and the R/S analysis adaptation to short time series. Biomatematica, **2013**, Vol.23,P.1-14.

[6] Mandelbrot B.B., Passoja D.E., Paullay A.J. Nature, **1984**, V.308, P.721-724.

[7] Gorski A.Z. et al. Financial multifractality and its subtleties: an example of DAX, Physica, **2002**, V.316, P.496-510.

[8] The Shepetov's database in IZMIRAN at http://cr29.izmiran.ru/vardbaccess/frames-vari.html accessed on August 10, 2014.

[9] Brown R.G. Exponential smoothing for predicting demand.Cambridge,Massachusetts: Arthur D. Little Inc,**1956**,15 p.

[10] Pesnell W. D. Solar Cycle Predictions (Invited Review). Sol. Phys,**2012,** Vol.281, P.507–532.

[11] Kussainov A.S., Kussainov S.G. Hurst exponent estimation, verification, portability and parallelization.Vestnik KazNU (Physics Edition), **2014**, 4(47), in press.

[12] Tilmann Gneiting and Martin Schlather. Stochastic Models That Separate Fractal Dimension and the Hurst Effect,SIAM Review, **2004**, 46(2), P.269-282.

БІР ПАРАЛЛЕЛЬ АЛГОРИТМДЕГІ УАҚЫТТЫҚ ҚАТАРДЫҢ ХЕРСТ ЭКСПОНЕНТАСЫНЫҢ ЖӘНЕ ФРАКТАЛДЫ ӨЛШЕМДІЛІГІНІҢ МӘНДЕРІН БАҒАЛАУ

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Тірек сөздер: Херст экспонентасы, фракталды өлшемділік, өзіндік, параллельді, қатар, нейтрондық.

Аннотация. Біз талданатын уақыттық қатардың Херст экспонентасының H және оның фракталды өлшемділігінің D мәндерін *C++* бағдарламасында біруақытта параллель есептеу үшін алгоритм жаздық. OpenMPI параллельді программалау ортасы үш *Linux* машинасынан тұратын виртуалді кластерде жүзеге асырылды. Бұл үш машина *64* разрядты операциялық жүйе *Debian Wheeze 7.4* арқылы басқарылды. Алынған программаны қолданып, алты канал бойынша және минуттық айырумен бір жарым аптада тіркелген нейтрондық монитордың деректеріне салыстырмалы талдау жүргізілді. Алгоритмнің дұрыс жұмыс істеуін түсіндіру үшін алынған нәтижелер кездейсоқ сигналды және бұрыннан белгілі қасиеттер мен H пен D-ны есептеудегі болжамды нәтижелерге ие, элементтері жасанды еңгізілген уақыттық қатарды өңдеудің нәтижелерімен салыстырылады. Алынған нәтижелер бір-бірімен және теориямен жақсы үйлеседі. Бұл алгоритмнің дұрыстығын растайды.Жазылған программаны табиғаты әр түрлі уақыттық қатарлардың деректерін талдаудағы және уақыттық қатарлардың сипаттамаларын есептеудің параллельді алгоритмдерін әрі қарай дамыту және оптимизациялаудағы негізгі құрал ретінде қолдануға болады.

Поступила 17.03.2015 г.

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Редактор *М. С. Ахметова*
Верстка на компьютере *Д. Н. Калкабековой*

Подписано в печать 20.03.2015.
Формат 60х881/8. Бумага офсетная. Печать – ризограф.
10,5 п.л. Тираж 300. Заказ 2.

Национальная академия наук РК
050010, Алматы, ул. Шевченко, 28, т. 272-13-18, 272-13-19