FRACTAL ANALYSIS ISSUES OF THE ELECTROCARDIOGRAM

Myangad Tungalag (Phd Scholar)

Mongolian University of Science and Technology

tungalag@must.edu.mn

Abstract: The paper presents you mathematics fractal methods for calculation of the electrocardiogram data. Use of fractal analysis on the electrocardiogram, CT scans of the brain and other nonlinear diagnostics makes conditions of the accurate diagnosis. We took purpose to execute mathematical procedure on electrocardiogram signal data of healthy Mongolian people and we studied it using by fractal analysis which accesses fractal characteristics of data on biomedical signal.

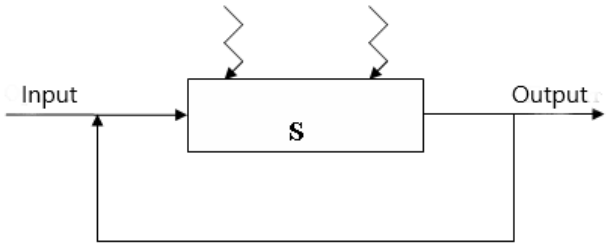
Keywords: * Electrocardiogram, *Fractal dimension, *Hurst index, *Correlation integral.

INTRODUCTION

Sector of first priority which is considered as important is health sector. Core part of modern medical service and diagnosis are reliable and high quality health technology and medical equipments.

For the Mongolia, it is not manufacturing country of medical equipment devices and it imports necessary healthcare technology and medical devices which have different specifications from foreign countries especially Russia, America, Japan, China, Korea and Italy etc. Thus, there is needed to build a mechanism of security control for medical devises which are used by Mongolian medical organizations. The ECG from the medical equipment involved in the diagnosis and treatment is used widely in Mongolian medical service. For this device, its specification must be inspected by unified method of inspection in order to satisfy measurement uniformity. There to, there is need to use the device which fits with feature of Mongolia and shows normal cardiac index of healthy Mongolian person. We took purpose to execute mathematical procedure on electrocardiogram signal data of healthy Mongolian people and we studied it using by fractal analysis which accesses fractal characteristics of data on biomedical signal.

The classification of nonlinear waves and the introduction of mathematical analysis methods in the field of medicine and health technology are very interesting trend in the modern research. Currently using of mathematical method of statistics, spectral and correlation analysis in bioelectric cardiogram and brain tomogram is considered inadequate because they cannot fully determine the entire process. So it is important in the current nonlinear diagnosis. Because the nonlinear process (biological and technical) in any environment (picture1) leaves the trace that has a fractal structure. The bio-electrocardiogram and CT scans of the brain are nonlinear process depending on many factors with complex structure. In this process the same signs of a whole with the parts and the parts with the whole confirmed the fractal structure of bioelectric cardiogram and brain tomogram. Based on this study and using fractal program, a fractal analysis of a bio-electrocardiogram has been executed and used to select the data for relatively healthy heart.
Considering of a biological process in terms of the fractal structure with the aim of its study and analysis of diagnosis is considered one of the latest innovative techniques.
In some textbooks [1] write that linear processes are completely absent in the world.



Picture1. Nonlinear process

Process with an uncertain decision of the black box of the system, which has a definite entrance, an indefinite output, the random effects from the outside and effects of feedback, is called nonlinear. Because the processes in the cardiac and cerebral systems are without doubt, non-linear, then the electrical recording /left traces/ are also nonlinear.

The records clearly show that the processes in the cardiac system are subject to non-linear law (picture2) [2]. The fractal test has been investigating based on two methods: Correlation integral and Hurst. Therefore, the fractal method has been used for analysis of the registered analog electric recording by its transferring into the digital form.

CORRELATION INTEGRATION METHOD

$x_1, x_2, \ldots\ldots\ldots, x_n$ are the amplitude digital values of the analog electrocardiogram. Total length of the recording is marked N[3].

$$C(\varepsilon)=\frac{1}{n}\sum_{I-1}^{N}\sum_{j-1}^{N}\theta(\varepsilon-(x_i-x_j)) \qquad (1)$$

C(ε)- correlation integral, ε- an average amplitude

$$\Theta(y)=\begin{cases}0, y\prec 0\\ 1, y\geq 0\end{cases} \qquad (2)$$

It is to calculate the fractal.

HURST METHOD

$x_1, x_2, \ldots\ldots\ldots, x_n$ are the amplitude digital values of the analog electrocardiogram. In picture2 the total length of the recording is marked N.

Physics measure unit dimension to do the statistics operation of exploration use arithmetic average by using this formula.

$$X=\frac{1}{N}\sum_{i=1}^{N}X_i \quad (3)$$

Average quadrate deflection:

$$S=\sqrt{\frac{1}{N}\sum_{i=1}^{N}(X_i-\bar{X})^2} \quad (4)$$

Accumulation of slewed deflection from average:

$$Z_U=\sum_{i=1}^{U}(X_i-\bar{X}) \quad (5)$$

Calculated average variance W step as ΔN :

$$V(\Delta N)=\frac{1}{N-\Delta N}\sum_{i=1}^{N-\Delta N}(X_{i+\Delta N}-X_i)^2 \quad (6)$$

Name max deflection value R_0 as coast, max finds this formula.

$$R_0=\max_{1\le i\le N}|X_i-\bar{X}| \quad (7)$$

If overall line coast R_p :

$$R_p=\max_{1\le i\le N}(X_i-\bar{X})-\min_{1\le i\le N}(X_i-\bar{X}) \quad (8)$$

U is odds function total line :

$$U_i=X_i-X_{i-1}\quad 2\le i\le N \quad (9)$$

R $_x$ - odds coast:

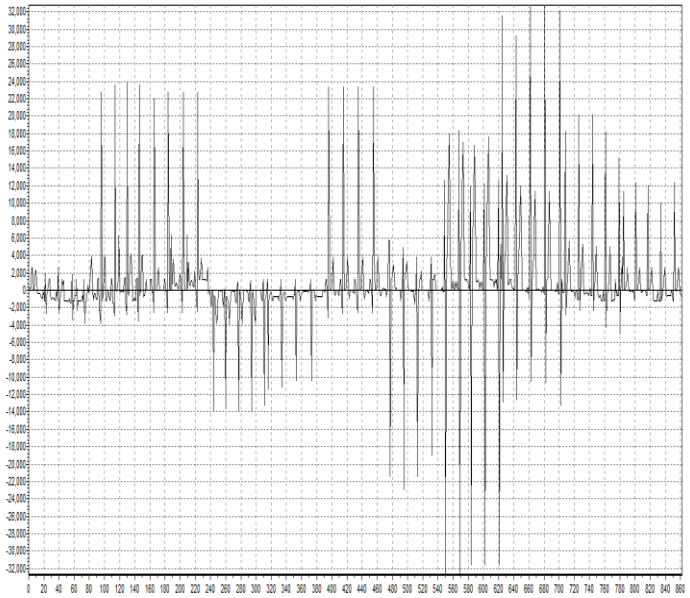
$$R_x=\max_{2\le i\le N}(U_i)-\min_{2\le i\le N}(U_i) \quad (10)$$

The Hurst index R/S shows accumulative deflection coast quadrate average deflection.

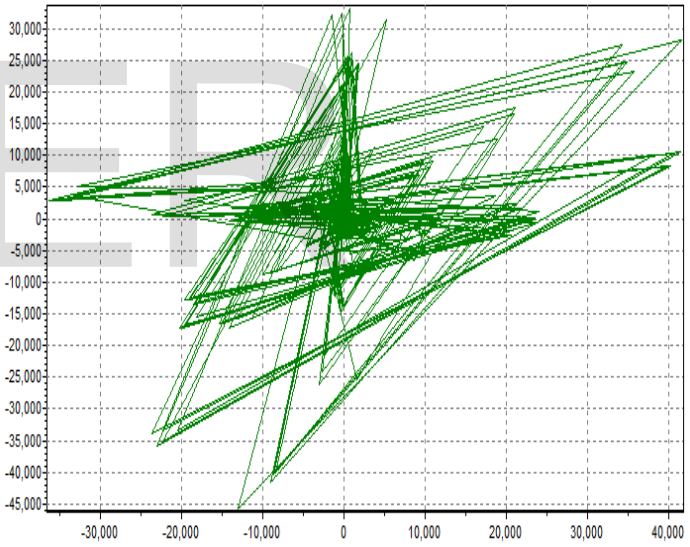
$$R/S=(AN)^H \quad (11)$$

A - Constant of the current process:

$O\le H\le 1$ - the Hurst index to determine the fractal of the process.



Picture2. Electrocardiogram in the fractan program



Picture3. 3D electrocardiogram

By logarithm scale the H-Hurst index is

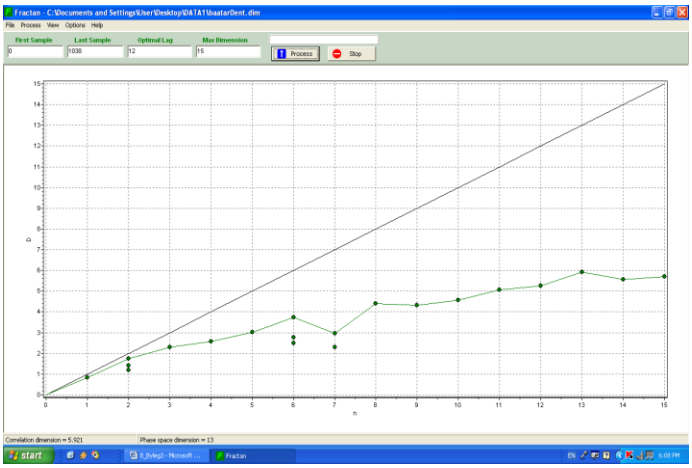
$$\lg(R/S)=H\lg(AN) \quad (12)$$

Or

$$H=\frac{\lg(R/S)}{\lg(AN)} \quad (13)$$

The bioelectric cardiogram by Fractan program as formula data in picture2 is shown graphically in picture4 and

picture5 under calculation of Correlation and Hurst indexes through Fractan program.



Picture4. Correlation studies

Hurst index H is the angle tangent created by action of fractal function linear approach with a horizontal axle.

Picture5. Hurst index

CONCLUSION

Studies have shown that the Hurst index in bio-electrocardiogram of healthy people is bigger than of the sick one. Use of fractal analysis on bio-electrocardiogram, CT scans of the brain and other nonlinear diagnostics makes conditions to diagnose the disease accurately. Today we do not use any mathematic processing for electrocardiogram and CT scans of the brain in our country. Therefore, in future they should use and apply methods of signal processing. Today, fractal analysis method is one of the many innovative methods of analysis widely used in medical treatment and diagnostic practice.

REFERENCES:

[1] PITAS I., Venetsanooulos A.N. Nonlinear order statistics filters for image filtering and edge detection. // North Holland. Signal processing. -1986. -N 10. -P. 395-413

[2] Ulziihutug.A., Electrocardiogram physiology, echocardiogram. Ulanbator. 1994.

[3] EVALUATING Arrhythmias in ECG signals using wave let transforms. Real time analysis of the Ventricular Fibrillation Waveform Can Reveal Hidden Structures. IEEE Engineering in medicine and biology. 2000. ADD2000

[4] HIDEKI I. et al. An efficient encoding method for electrocardiography using spline functions // System and Computers in Japan. -1985. –V.16. –N3. –P.85-94

[5] M. Abadi and E. Grandchamp, 2006 Texture features and segmentation based on multifractal approach. The 11th Iberoamerican Congress on Pattern Recognition, 4225 (2006), pp. 297–305

[6] A. Bhatti, S. Nahavandi, Y. Frayman. 3D depth estimation for visual inspection using wavelet transform modulus maxima. Computers and Electrical Engineering, 33 (1) (2007), pp. 48–57

[7] HV Huikuri, TH Makikallio, C-K Peng, *et al.* Fractal correlation properties of R-R interval dynamics and mortality in patients with depressed left ventricular function after an acute myocardial infarction. Circulation, 101 (2000), pp. 47–53

[8] T. Koshino, Y. Kimura, Y. Kameyama, T. Takahashi, T. Yasui, H. Chisaka, *et al.* Fractal and periodic heart rate dynamics in fetal sheep: comparison of conventional and new measures based on fractal analysis. Am J Physiol Heart Circ Physiol, 284 (2002), pp. H1858–H1864

[9] D.T. Schmitt, P.C. Ivanov. Fractal scale-invariant and nonlinear properties of cardiac dynamics remain stable with advance age: a new mechanistic picture of cardiac control in healthy elderly. Am J Physiol Regul Integr Comp Physiol, 293 (2007), pp. R1923–R1937

[10] J. Fell, K. Mann, J. Roschke, M.S. Gopinathan. Nonlinear analysis of continuous ECG during sleep I. Reconstr. Biol. Cybern., 82 (2000), pp. 477–483

[11] M. Katz. Fractals and the analysis of waveforms. Comput. Biol. Med., 18 (3) (1988), pp. 145–156

[12] V.K. Yeragani, E. Sobolewski, V.C. Jampala, J. Kay. Fractal dimension and approximate entropy of heart period and heart rate: awake versus sleep differences and methodological issues. Clin. Sci., 95 (1998), pp. 295–301

[13] R.M. Rangayyan, F. Oloumi. Fractal analysis of knee-joint vibroarthrographic signals. Proc. 10th IEEE International Conference on Information Technology and Applications in Biomedicine (ITAB 2010), IEEE, Corfu, Greece, November, pp. 1–4 (2010)

[14] HV Huikuri, TH Makikallio, CK Peng, AL Goldberger, U Hintze, M Moller. Fractal correlation properties of R-R interval dynamics and mortality in patients with depressed left ventricular function after an acute myocardial infarction. Circulation, 101 (2000), pp. 47–53

[15] TH Makikallio, S Hoiber, L Kober, C Torp-Pedersen, CK Peng, AL Goldberger, *et al.* Fractal analysis of heart rate dynamics as a predictor of mortality in patients with depressed left ventricular function after acute myocardial infarction. TRACE investigators (TRAndolapril Cardiac Evaluation)
Am J Cardiol, 83 (1999), pp. 836–839

[16] JS Perkiomaki, W Zareba, J Ruta, S Dubner, C Madoery, P Deedwania, *et al.* Fractal and complexity measures of heart rate dynamics after acute myocardial infarction. for the IDEAL investigators Am J Cardiol, 88 (2001), pp. 777–781

[17] JM Tapanainen, PE Thomsen, L Kober, C Torp-Pedersen, TH Makikallio, AM Still, *et al.* Fractal analysis of heart rate variability and mortality after an acute myocardial infarction Am J Cardiol, 90 (2002), pp. 347–352

[18] TH Makikallio, HV Huikuri, U Hintze, J Videbaek, RD Mitrani, A Castellanos, *et al.* Fractal analysis and time- and frequency-domain measures of heart rate variability as predictors of mortality in patients with heart failure for the DIAMOND Study Group (Danish Investigations of Arrhythmia and Mortality ON Dofetilide) Am J Cardiol, 87 (2001), pp. 178–182

[19] A. Eke, P. Herman, L. Kocsis, L. Kozak. 2002. Fractal characterization of complexity in temporal physiological signals. Physiological Measurement, 23 (1) (2002), pp. 1–38

[20] H. Huikuri, T. Mäkikallio, C. Peng, A. Goldberger, U. Hintze, M. Moller. 2000. Fractal correlation properties of RR interval dynamics and mortality in patients with depressed left ventricular function after an acute myocardial infarction Circulation, 101 (1) (2000), pp. 47–53

[21] Khan M. Iftekharuddin, Jing Zheng, Mohammad A. Islam, Robert J. Ogg. 'Fractal-based brain tumour detection in multimodal MRI'. Applied Mathematics and Computation, 207 (1) (2009), pp. 23–41