ARC Journal of Neuroscience
Volume 3, Issue 2 2018, PP 10-12
ISSN 2456-057X
DOI: http://dx.doi.org/10.20431/2456-057X.0302003
www.arcjournals.org

Can we Mathematically Correlate Brain Memory and Complexity?

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Abstract: *Investigating about different features of brain activity always has been a major issue in studies related to neuroscience. Memory and complexity are two important issues that discussed widely in related studies. However, no study has yet linked between these two important issues. In this editorial paper for the first time, we talk about the tools that can be used to mathematically link between brain's memory and complexity. The employed tools are fractal dimension, Hurst exponent and approximate entropy. Using the concepts of complexity and randomness which are the characteristics of fractal dimension, Hurst exponent and approximate entropy respectively, we make the link between these measures for the brain. The obtained investigations from this study can be widely used by researchers in order to talk about human memory and complexity in different conditions.*

Keywords: *Brain, Memory, Complexity, Randomness, Fractal dimension, Hurst exponent, Approximate entropy.*

1. Fractal Theory And Complexity

Fractal is a wide growing concept that is used to quantify the complexity of a process. The process that is quantified by fractal theory can be time series or pattern. A fractal is a natural phenomenon or a mathematical set that exhibits a repeating pattern that displays at every scale (self-similar). The scaling rules are characterized by "scaling exponents" (dimension). "Simple" regular fractals have integer-scaling dimensions [1]. Complex self-similar objects have non-integer dimension. In fact, fractal is the measure of complexity of the process where its greater value stands for a more-complex process. Fractal dimension is the scaling exponent to quantify the complexity of process. It should be noted here that fractal dimension is a form of power law exponent.

During years, many works reported in literatures that employed fractal theory for their analysis. More works be satisfied with the analysis, and less works proceeded with the fractal modelling. The reported works on analysis of DNA [2-4], EEG signal [5-8], s-ABR signal [9], heart rate signal [10], human respiration time series [11-12], eye movement time series [13], human stride time series [14], human face pattern [15], spider brain signal [16-17] are noteworthy to be mentioned. In all reported studies, the variation of complexity of time series or pattern analyzed in different conditions. The fractal dimension can be computed using different methods that all of them are based on entropy concept [18].

2. Hurst Exponent, Approximate Entropy And Randomness

Hurst exponent is another exponent that is defined under fractal theory. Hurst exponent that is the measure of randomness of signal, is used to quantify the memory concept of process. Hurst exponent can vary in the range of 0 to 1. The value of 0.5 indicates the Brownian motion that is complete chaotic condition. The system that has Hurst exponent closer to 0.5, contains greater level of randomness. For instance, a signal with the Hurst exponent of 0.6 is more random than a signal with the Hurst exponent of 0.8. There are very limited works in literature that employed Hurst exponent to discuss about the randomness and its memory feature. In [19], Namazi et al. showed that memory of EEG signal, which is quantified with the Hurst exponent, is correlated with the memory of applied music to subjects.

Approximate entropy is another exponent that can quantify the randomness of system. In general, the system that is less random, has smaller value of approximate entropy.

Approximate entropy as the measure of system randomness also received less attention by researchers. There are limited works that employed approximate entropy to talk about randomness of bio-signals [10-11].

Since both Hurst exponent and approximate entropy defines the randomness of time series, therefore we can link them together. In other words, the time series that has greater randomness should have greater approximate entropy and also the Hurst exponent closer to 0.5.

3. Brain Memory, Randomness And Complexity

Now, the question that rises here is that can we make a link between complexity, randomness and memory? The link between complexity and randomness can be made by relating the fractal dimension and the Hurst exponent. For a time series, the Hurst exponent has a direct relation with fractal dimension by H=2-F, where H and F stand for the Hurst exponent and fractal dimension respectively. On the other hand, in the last section we mentioned that the Hurst exponent and approximate entropy are linked together using randomness concept. Therefore, it can be said that we can correlate complexity, randomness and memory to each other. In order to this jobwe can use mathematics.

Since brain is a complex system that contains memory [20-22], we can investigate about the relation between memory, complexity and randomness in the brain. For this purpose, we can apply the mathematics to EEG signal. EEG signal as a random time series has complex structure. On the other hand, we can define the memory for EEG signal using the Hurst exponent. Therefore, we can say that by making the relation between the Hurst exponent, fractal dimension and approximate entropy, we make a link between EEG signal's memory, complexity and randomness. In further steps, we can link between EEG signal and human memories to see is there any direct relation between them. If so, the complexity, randomness and memory of the brain are linked to each other that is a great achievement in human neuroscience. In further steps, we can employ the mathematical equations [23] to develop a model for this relation. The developed model can be linked to other mathematical models in human body [24] to solve the big questions about the interacting between human brain and other organisms. On the hand, the developed model can be applied to other branch of engineering and science [25], where relating the memory and complexity of system is the important concept.

References

[1] Namazi, H. R. Fractal Based Analysis of Movement Behavior in Animal Foraging. ARC Journal of Neuroscience. 2 (3), 1-3; DOI: 10.20431/2456-057X.0203001 (2017).

[2] Namazi, H. & Kiminezhadmalaie, M. Diagnosis of Lung Cancer by Fractal Analysis of Damaged DNA. Comput. Math. Methods Med. 2015, DOI:10.1155/2015/242695 (2015).

[3] Namazi, H., Kulish, V. V., Delaviz, F. & Delaviz, A. Diagnosis of skin cancer by correlation and complexity analyses of damaged DNA. Oncotarget; 6 (40), 42623-31; DOI: 10.18632/oncotarget.6003 (2015).

[4] Namazi, H. et al. Mathematical Modelling and Prediction of the Effect of Chemotherapy on Cancer Cells. Sci. Rep. 5, 13583; DOI: 10.103 8/srep13583 (2015).

[5] Staudinger, T. &Polikar, R. Analysis of complexity based EEG features for the diagnosis of Alzheimer's disease. Conf. Proc. IEEE Eng. Med. Biol Soc. 2011, 2033-6; DOI: 10.1109/IEMBS.2011.6090374 (2011).

[6] Namazi, H. &Jafari, S. Age-based variations of fractal structure of EEG signal in patients with epilepsy. Fractals; DOI: 10.1142/S0218348X1 8500512 (2018).

[7] Namazi, H. & Kulish, V. V. Fractional Diffusion Based Modelling and Prediction of Human Brain Response to External Stimuli. Comput. Math. Methods Med. 2015, 148534; DOI:10.1155/2015/148534 (2015).

[8] Namazi, H., Akrami, A., Nazeri, S. & Kulish, V. V. Analysis of the Influence of Complexity and Entropy of Odorant on Fractal Dynamics and Entropy of EEG Signal. BioMed. Res. Int. 2016, 5469587, DOI: 10.1155/2016/5469587 (2016).

[9] Mozaffarilegha, M., Namazi, H. R., Ahadi, M. &Jafari, S. Complexity based analysis of the difference in speech-evoked Auditory Brainstem Responses (s-ABR) between binaural and monaural listening conditions. Fractals; DOI: 10.1142/S0218348X18500524 (2018).

[10] Namazi, H. & Kulish, V.V. Fractal Based Analysis of the Influence of Odorants on Heart Activity. Sci. Rep. 6, 38555; DOI: 10.1038/srep38555 (2016).

[11] Namazi, H., Akrami, A. & Kulish, V. V. The Analysis of the Influence of Odorant's Complexity on Fractal Dynamics of Human Respiration. Sci. Rep. 6: 26948, 1-8; DOI: 10.1038/srep26948 (2016).

[12] Namazi, R. H. Fractal-based analysis of the influence of music on human respiration.

Fractals, 25. DOI: 10.1142/S0218348X175005 91 (2017).

[13] Namazi, H., Daneshi, A., Azarnoush, H., Jafari, S. &Towhidkhah, F. Fractal based analysis of the influence of auditory stimuli on eye movements. Fractals. DOI: 10.1142/S0218348 X185004 08 (2018).

[14] Namazi, H. & Kulish, V. V. Mathematical-based modeling and prediction of the effect of external stimuli on human gait. Int. J. Numer. Method Biomed. Eng. 32; DOI: 10.1002/cnm. 2805 (2016).

[15] Namazi, H. et al. The fractal based analysis of human face and DNA variations during aging. Biosci. Trends. 10 (6), 477-481; DOI: 10.5582/bst.2016.011 82 (2016).

[16] Namazi, R. H. The Complexity Based Analysis of the Correlation between Spider's Brain Signal and Web. ARC Journal of Neuroscience. 2 (4), 38-44; DOI: 10.20431/24 56-057X.0 203006 (2017).

[17] Namazi, H. Can We Correlate the Spider's Brain Activity to it Spinning Web Activity. ARC Journal of Neuroscience. 2 (1): 17-18; DOI: 10.20431/2456-057X (2017).

[18] Namazi, H., Akrami, A., Haghighi, R., Delaviz, A. & Kulish, V.V. Analysis of the Influence of Element's Entropy on the Bulk Metallic Glass (BMG) Entropy, Complexity and Strength. Metallurgical and Materials Transactions A. 48 (2); DOI: 10.1007/s11661-016-3870-3 (2016).

[19] Namazi, H. et al. Analysis of the influence of memory content of auditory stimuli on the memory content of EEG signal. Oncotarget, 7, 56120-56128; DOI: 10.18632/oncotarget.11234 (2016).

[20] Namazi, et al. A signal processing based analysis and prediction of seizure onset in patients with epilepsy. Oncotarget 7, 342-350; DOI: 10.18632/oncotarget.6341 (2016).

[21] Namazi, H. & Kulish, V. V. A mathematical based calculation of a myelinated segment in axons. Comput. Biol. Med. 2013 Jul; 43(6):693-8. DOI: 10.1016/j.compbiomed.201 3.03.005

[22] Seetharaman, K., Namazi, H. &Kulsih, V. V. Phase lagging model of brain response to external stimuli—modeling of single action potential. Comput. Biol. Med. 42, 857-862 (2012).

[23] Namazi, H. & Kulish, V. V. Mathematical Modeling of Human Brain Neuronal Activity in the Absence of External Stimuli. Journal of Medical Imaging and Health Informatics. 2 (4), 400-407 (2012).

[24] Namazi, H., Kulish, V. V., Wong, A. &Nazeri, S. Mathematical Based Calculation of Drug Penetration Depth in Solid Tumors. Biomed Res Int. 2016: 8437247; DOI: 10.1155/2016/8 437247 (2016).

[25] AkhavanFarid, A., Sharif, S. &Namazi, H. Effect of Machining Parameters and Cutting Edge Geometry on Surface Integrity when Drilling and Hole Making in Inconel 718. SAE International Journal of Materials and Manufacturing; DOI10.4271/2009-01-1412 (2009).

Citation: *Hamidreza Namazi. Can we Mathematically Correlate Brain Memory and Complexity?. ARC Journal of Neuroscience. 2018; 3(2):10-12. doi:dx.doi.org/10.20431/2456-057X.0302003.*