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Complexity Based Analysis of the Correlation between External Stimuli and Bio Signals

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Abstract: *Analysis of human reaction to different types of external stimuli is one of the major issues in physiological research. The reactions of human body has a broad range of categories such as brain and heart reactions. In this way, besides investigating about the human reaction, linking between characteristics of external stimuli and human reaction is a very important issue. Besides employing all developed methods for analysis of external stimuli and human reaction, none of them could make the relation between the characteristics of external stimuli and human reaction. Fractal theory is a new mathematical approach that defines the complexity of processes. Since external stimuli (in major) and human bio signals can be quantified using fractal theory, in this editorial paper, we discuss about employing fractal theory to make links between the external stimuli and human bio signals. In order words, we discuss about an approach that can correlate the complexity of external stimuli and the complexity of different bio signals. In fact, this investigation is quite important as it not only analyzes the human reaction to external stimuli, but also correlates the characteristics of human reactions to external stimuli. The application of this analysis could be widely considered in different areas of research works related to biomedical engineering.*

Keywords: *Human reaction, External stimuli, Bio signal, Fractal, Complexity.*

In order to correlate different bio signals to external stimuli we can benefit from complexity concept. The complexity can be defined in case of different phenomena in different forms. Therefore, we should be able to quantify different external stimuli using complexity concept. On the other hand, we can also apply complexity concept to different bio signals [1]. In this research, we employ fractal theory to quantify the complexity in case external stimuli (signals or patterns) and different bio signals. Fractals are self-similar objects that show repeating patterns [2] at every scale inside themselves. The self-similarity is quantified using fractal exponent. Fractals can be simple or complex. The computed fractal dimension for a fractal process changes based on the nature of process. In case of simple fractals, the computed value for fractal dimension is integer, whereas the computed value for complex fractal systems is non-integer [3].

Fractal theory has been applied widely to different types of bio signals and patterns to investigate their complex structures. The reported works that analyzed Electroencephalogram (EEG) signal [4-10], respiration signal [11-12], s-ABR signal [13-14], human face pattern [15], heart rate signal [16], eye movement [17-19], human DNA time series [20-23], human gait [24], Magneto encephalography (MEG) [25], spider brain signal [26-27], and animal movement behavior in foraging [28] using fractal theory can be called as some examples in this area.

In case that we deal with signal or pattern as external stimuli, we can apply fractal theory to quantify its complexity. For instance, auditory stimuli in the form of music are time series (signals) that can be quantified using fractal dimension. As another example, the complexity of images as visual stimuli can be quantified using fractal dimension. However, we have different types of external stimuli, and not all of them are defined in the form of signal (such as music) or pattern (such as image). In this case, we can employ other types of complexity. For instance, in case of olfactory stimuli, we can use molecular complexity concept to define the complexity of molecular structure of olfactory stimulus. Therefore, by referring to different concepts, we are able to define the complexity of external stimuli.

Therefore, we can quantify the complexity of different types of external stimuli and bio signals (human reaction). For instance, in case of application of auditory stimuli on human, we can compute the fractal exponents of EEG signal (as indicator of human reaction) and music (as external stimulus) in case of different music, and then investigate how the variations of fractal dimension of EEG signal in case of different auditory stimuli is correlated with the variations of fractal dimension of auditory stimuli themselves. In another example, we can investigate the correlation between the variations of molecular complexity of odorants (as external stimulus) and fractal dimension of EEG and ECG signals, when subject sniffs the odorant and accordingly the odorant affects his brain and heart activity. For instance, in case that we find out that fractal dimension of bio signal (human reaction) is increased with the increment of fractal dimension of external stimuli (as illustrated in Figure 1), we can indicate that variations of complexity of bio signal is correlated with the variations of complexity of external stimuli.

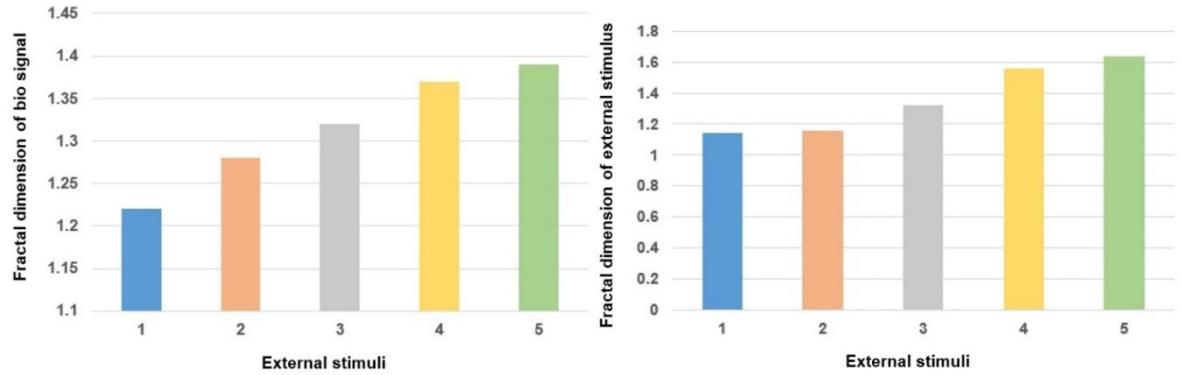

Figure1: *A sample illustration that shows the correlation between the variations of fractal dimension (complexity) of bio signal (left figure) and the variations of fractal dimension of external stimuli (right figure)in case of different external stimuli*

An important result of investigation about the correlation between external stimuli and bio signals is that the analysis could potentially leads us to make the models that relate bio signal (human reaction) to external stimuli. In fact, different mathematical models can be applied in this area [29-34], however the fractal-based models [35] have the advantage over other mathematical models due to their predictability. The predictability of fractal models can be well justified by introducing the Hurst exponent to the model. In fact, the Hurst exponent that is the indicator of long term memory a system is used in fractal based models in order to give predictability to the models. Therefore, the generated fractal models could potentially lead us to predict the characteristics of bio signals (human reaction) in response to different external stimuli. For further reading about the application of Hurst exponent for quantifying the memory of system (predictability) please refer to [36]. It is noteworthy that generated models also can be potentially applied to other branches of science and engineering [37-40], where the prediction of system response is important.

In conclusion we can indicate that since bio signals and a great category of external stimuli have non-linear complex structures, fractal theory is the outstanding approach for investigating about their non-linear complex structures. In this way, fractal theory could help us to overcome the current limitations, where the major developed methods do not consider the complex structure of external stimuli and bio signals.

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