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Nonlinear technics for biomedical signals analysis

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Abstract – **Chaos theory and other nonlinear signal processing techniques are mathematical apparatus, describing the behavior of certain nonlinear dynamical systems which fall under certain conditions into the phenomenon known as chaos. The application of approximate entropy, Lyapunov exponent and Hurst exponent calculation techniques to the *real and simulated* EEG are presented, showing potential applicability of the methods to diagnostics.**
Keywords – **EEG analysis, nonlinear analysis, approximate entropy, Lyapunov exponent, Hurst exponent.**

I. INTRODUCTION

Human brain produces electric waves which can be detected and analyzed. These waves create an electroencephalographic picture of brain activity. Electroencephalogram (EEG) is often considered as a set of nonlinear chaotic signals, therefore it can be possible to apply the nonlinear techniques of signal processing to it. Some of them, such as approximate entropy, largest Lyapunov exponent, Hurst exponent are presented in this paper. The aim of this work is to compare rates of these methods and identify the one that most accurately shows the difference between healthy and diseased EEG.

II. MAIN PART

Approximate entropy (*ApEn*) measures the predictability of future amplitude values of the EEG based on the knowledge of previous amplitude values. In a perfectly regular data series, knowledge of the previous value enables prediction of the subsequent value. A deterministic signal with high regularity has a very small *ApEn* value [1].

Largest Lyapunov exponent [2] reflects the sensitivity of the system to the initial conditions. The time-domain signal is embedded in the phase space, and examined in there. If the attractor, during its orbit, passes closely to a state it was previously in and diverges, λ_{max} provides a measure of the rate of this divergence. This number, called the Lyapunov exponent, is useful for distinguishing among the various types of orbits.

In fractal geometry, the generalized Hurst exponent (*H*) is referred to as the "index of dependence" and is the relative tendency of a time series to either strongly regress to the mean or 'cluster' in a direction. The Hurst exponent [2] is used as a measure of the long term memory of time series, i.e. as autocorrelation of the time series. Where a value of $0 < H < 0.5$ indicates a time series with negative autocorrelation (e.g. a decrease between values will probably be followed by an increase), and a value of $0.5 < H < 1$ indicates a time series with positive autocorrelation (e.g. an increase between values will probably be followed by another increase). A value of $H = 0.5$ indicates a true random walk, where it is equally likely that a decrease or an increase will follow from any particular value.

In this work were used real and simulated [3] signals from sick and conditionally healthy persons. We wanted to show the application of nonlinear technics for this type of signals analysis.

III. CONCLUSION

This paper utilizes approximate entropy, Lyapunov exponent and Hurst exponent as a nonlinear signal processing methods for EEG analysis. The simulated and real EEG signals from epileptic and conditionally healthy persons were analyzed by these methods. Different rates of *ApEn*, *H* and Lyapunov exponent were gained for various types of signals. For example values of ApEn for sick and healthy persons are 0,5436 and 0,5331 appropriately.

TABLE I. AVERAGED APPROXIMATE ENTROPY

Signal	Entropy value
Real signal from conditionally healthy person	0,2113 ± 0,1250
Simulated signal from conditionally healthy person	0,1844 ± 0,0276
Real signal from sick person	0,5436 ± 0,2266
Simulated signal from sick person	0,1129 ± 0,0235

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