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Application of Nonlinear Dynamics Methods for Measuring Characteristics of Biosignals and Quality of Materials' Surfaces in *SENSATION* Project

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Abstract: We present FP6. Integrated Project *SENSATION* and works done by our Group on application of nonlinear dynamics for analysis of biosignals measured by new nanosensors for vigilance monitoring and for biomedical applications..

Keywords: nanosensors, nonlinear dynamics, biosignals

1. BASIC INFORMATION

SENSATION is an FP6. Integrated Project co-funded by the European Commission under 'Information Society' (IST 507231, January 2004 - December 2007) [1]. Consortium consists of 46 partner institutions from 20 countries (Project Coordinator - Dr. E. Bekiaris, CERTH, Thessalonica; Technical Manager - Dr. G. Ruffini, STARLAB, Barcelona; Quality Assurance Manager - Dr. A. Amditis, ICCS, Athens; Principal Scientific Officer EC - Dr. T.J.Sommer, Brussels). The total project effort reaches the amount of 17 MEuro, of which about 10 MEuro are funded by EU.

SENSATION aims to explore a wide range of micro- and nano-sensor technologies, targeting at un-obtrusive, cost-effective, real-time monitoring, detection, and prediction of human physiological state in relation to wakefulness, fatigue, and stress, anytime, anywhere, and for everybody. The focus of this work targets the enhancement of health, safety, and quality of life, by reducing the number and scope of sleepiness-related accidents through the use of multi-sensorial medical and industrial applications. Three major research areas are: innovative sensors and technologies, health oriented applications, safety in transport and industrial applications.

Before any signal generated by human body or brain may be appropriately used, e.g. for monitoring of the brain state, that signal has to be received by an appropriate sensor, processed, and analysed. In most cases there is a necessity to apply special data-processing algorithms. Research needs to draw upon multiple disciplines to create novel algorithms and computational methods for biosignal registration and modelling, for extraction, fusion and visualization of multi-modal information, for representing and managing signal complexity. It is necessary to develop methods that are computationally effective, i.e. that enable to extract and apply useful information to specific tasks in a timely fashion; of particular interest is development of real-time methods. These advances may have relevance in all fields requiring human-machine interface.

In the ***Group of Biosignal Analysis Fundamentals (GBAF)*** [2] we develop such new methods, based on Nonlinear Dynamics and Symbolic Dynamics. In particular, we use two methods - Higuchi's fractal dimension method and our own symbolic method. Both methods measure what is called *signal complexity* - the former measures 'degree of chaoticity' of the signal, the latter - 'relative power' of the wave components with frequencies smaller than certain value depending on sampling rate.

2. RESULTS

Examples of applications of our new nonlinear methods:

- we demonstrated that each sleep stage can be characterized by a certain range of fractal dimension, D_f of EEG-signal; based on this principle we prepared *sleep stager FRAST*© that automatically constructs the hypnogram based on the whole-night EEG-signal (in only ca.2 min. on a PC with Pentium 2 GHz, cf. [3]);
- we have also demonstrated that based on similar principles it may be possible to make a sleep stager that constructs hypnogram from running D_f of the whole-night *HRV* (Heart Rate Variability) signal (cf. [4]);
- we demonstrated that D_f significantly diminishes when person falls asleep (transition from wakefulness to stage 1 sleep); based on this we have prepared *vigilance monitor FRAMON*© (cf. [5]);
- we demonstrated that D_f of EEG-signals as monitored during anaesthesia can serve as a good indicator (even better than widely used BIS) of the *depth of anaesthesia* (*monitoring system FRANES*© , Fig. 1, cf. [6}); patent pending [7]);
- our symbolic method may help to discriminate *insomniacs* from those with other sleep disorders (cf. [8]);
- our methods are also applicable to analysis of other biosignals, and last but not least for biofeedback.

The same methods may be used in solving problems quite far from biosignals processing, e.g. for quality control of nanosensors' surfaces (Fig. 2, cf. [8]), implant materials' surfaces [9], or even in *Econophysics* [10].

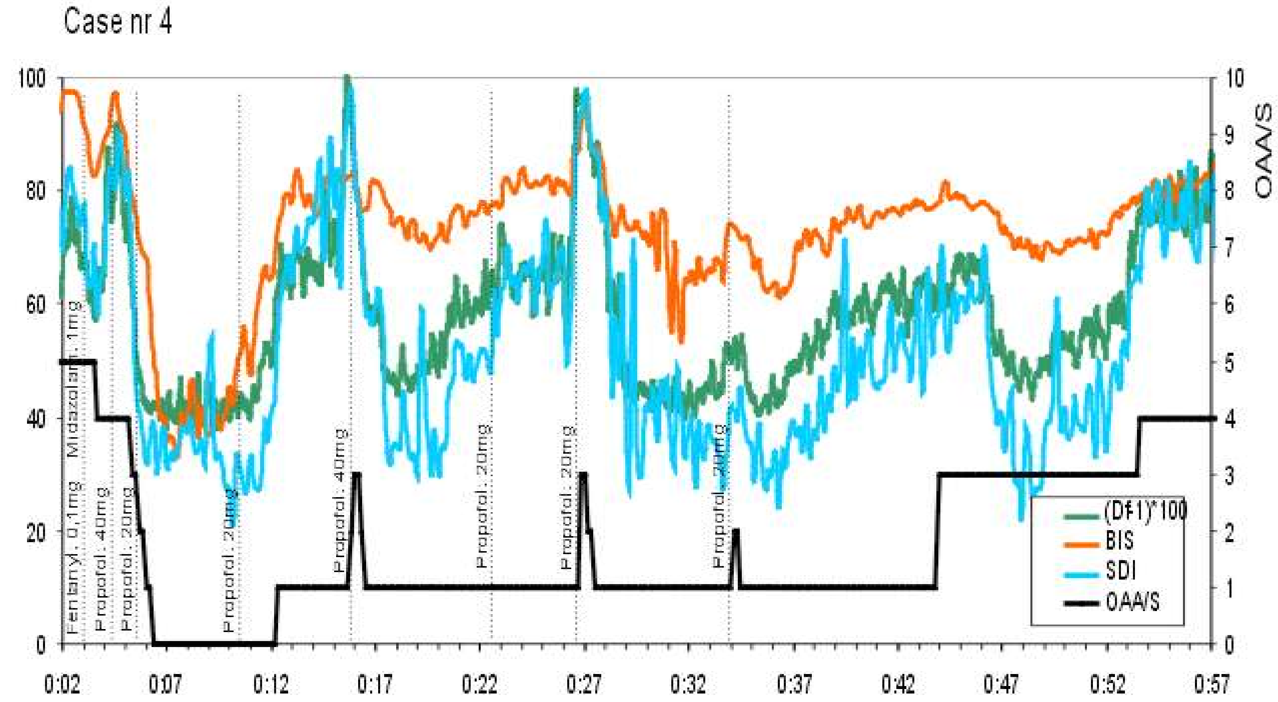

Fig. 1. Measuring the depth of anesthesia during surgical procedure using fractal dimension of a single-channel EEG-signal, (D_f -1)x100 (middle curve), symbolic dynamics method (SDI) (lower curve), compared with widely used bispectral index (BIS) (upper curve) and OAA/S (Observer's Assessment of Alertness and Sedation scale, bottom curve); changes in fractal dimension precede the changes in BIS.

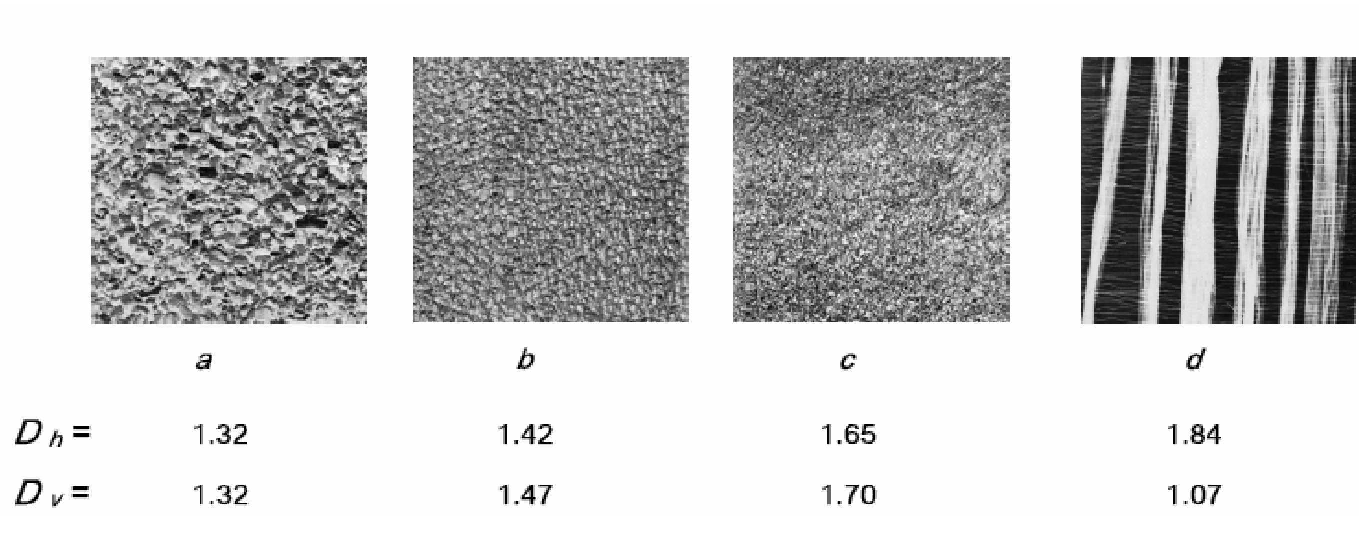

Fig. 2. Examples of surfaces with (nearly) isotropic and uniform roughness properties (a., b., c. - fractal dimensions in the horizontal direction, D_h, and in the vertical direction, D_v, are nearly equal) and of a surface with anisotropic roughness properties (texture) (d. - fractal dimension in horizontal direction, D_h, and in the vertical direction, D_v, differ considerably). 'Landscapes' [8] were constructed from these greyscale images of surfaces, each 644x644 pixels, and then analyzed using Higuchi's fractal dimension method (window of 128 points, moved each step 1 point to the right).

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