# Automatic classification of sleep stages from one EEG measurement using nonlinear DDEs

Claudia Lainscsek[1,2], Dounia Bounoiare[3,4], Adriana Portmann[3], Antoine Cuvelier[3], Jean-François Muir[3], & Christophe Letellier[4]

[1] Institute for Theoretical Physics, University of Technology, Graz, Austria
[2] INC, University of California at San Diego, La Jolla, CA, USA
[3] GRHV EA 3830, Rouen Universitary Hospital, France
[4] CORIA UMR 6614, University of Rouen, France
clainscsek@ucsd.edu

Quantifying sleep fragmentation is central in assessment of sleep quality. The graphic representation of sleep-stage sequences across the night is called a hypnogram and derived by visual scoring of 20–30 s pieces of EEG (electroencephalogram), EOG (electrooculogram), and EMG (electromyogram) recordings. Visual scoring is labor intensive, time consuming, and subject to errors between different scorers of around 20 %. Therefore a tool to automatically produce a hypnogram would be very helpful.

Here a method for automatic classification of sleep stages from one single EEG measurement using nonlinear delay differential equations (DDEs) is presented. The so obtained hypnograms are then compared to visual scorings by a neurologist.

Our novel method is based on nonlinear DDE analysis. A DDE is an equation

$$\dot{x} = f(x_{\tau_1}, x_{\tau_2}, \dots) \tag{1}$$

where $x_{\tau_j} = x(x - \tau_j)$ and that relates the derivative at a data point to previous data points of the signal. The linear terms of such a DDE correspond to the main frequencies of the treated signal while the nonlinear terms are related to the phase couplings between its harmonic parts. This framework therefore can be seen as a time-domain analysis equivalent to a Fourier analysis that is very robust against noise contamination and fast.

In this study, 35 polysomnographies were extracted from our data base. They were recorded in patients who received noninvasive mechanical ventilation. In this work, the manually scored hypnograms were compared to scorings automatically obtained from the single time series of EEGs from the C3/A2 area. This was done by using the coefficients of the nonlinear term of a three-term DDE. The correlation between the manual and automatic scorings was around 80% for all patients.