



Presentation Abstract

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Presentation Title: Non-linear dynamical classification of short time series of the Rossler system in high noise regimes

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Topic: ++D.17.b. Finger and grasp control: Age, pathology, and physiology

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Abstract: Time series analysis with delay differential equations (DDEs) reveals non-linear properties of the underlying dynamical system and can serve as a non-linear time-domain classification tool. In a companion paper, we apply the DDE model developed here to classify short segments of encephalographic (EEG) data recorded from patients with Parkinson's disease and healthy subjects. Here global DDE models were used to analyze short segments of surrogate time series from a known dynamical system, the Rossler system, in high noise regimes. Nine simulated subjects in each of two distinct classes were generated by varying the bifurcation parameter  $b$  and keeping the other two parameters ( $a$  and  $c$ ) of the Rossler system fixed. Data segments of 512 samples were used. All choices of  $b$  were in the chaotic parameter range. We diluted the simulated data using white noise ranging from 10 dB to -20 dB signal-to-noise ratios (SNR). Structure selection was supervised by selecting the number of terms, delays, and order of nonlinearity of the model DDE model that best linearly separated the two classes of data. The distances  $d$  from the linear dividing hyperplane was then used to assess the classification performance by computing the area under the receiver operating characteristic (ROC) curve,  $A'$ . The selected model was tested on untrained data using 3-fold cross-validation.

DDEs were able to accurately distinguish the two dynamical conditions, and moreover, to quantify the changes in the dynamics. There was a significant correlation between the dynamical bifurcation parameter  $b$  of the simulated data and the classification parameter  $d$  from our analysis. This correlation still held for new simulated subjects with new dynamical parameters selected from each of the two dynamical regimes. Furthermore, the correlation was robust to added noise, being significant even when the noise was greater than the signal (SNR = -10 dB for single trials  $A' = 0.6$  and for means over 50 trials  $A' = 0.9$ ; SNR = -15 dB for means of 50 trials,  $A' = 0.75$ ).

We conclude that DDE models may be used as a generalizable and reliable classification tool for even small segments of noisy data, if the data have an underlying nonlinear dynamical structure.

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