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Applications of Signal Processing in Engineering, Life and Social Sciences

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Abstract

The ubiquity of cheap sensors and novel measurement techniques have created the ability to observe many processes that evolve over time and/or space. This talk will address a number of signal processing problems, motivated by real examples from nonlinear and spatio-temporal processes. First, the identification framework for data observed as time series and modelled as nonlinear autoregressive and moving average with exogenous (NARMAX) models are described along with its estimation methodology within a statistical signal processing framework. The applications of signal processing involving modelling of spatio-temporal systems is considered next. 2

The first application is an engineering problem in which the delimitation of composite plates, such as those in modern aircraft wings, is to be detected. Using the data collected from a non-destructive testing set-up where the vibration pattern is observed on an array of spatial locations, a spatio-temporal model based on the coupled map lattice model is used to represent the behaviour under normal and faulty conditions and to use the model difference to detect the fault. Data from an experimental rig was used to demonstrate the proof of principle.

The second application is a life science problem in which neutrophils (a type of white blood cells) behaviour following inflammation resolution is not very well understood. The neutrophils in normal conditions move away from the location of the inflammation after resolution and if they do not, they can damage the host tissue. Using time lapse in-vivo images of fluorescent cells from a transgenic zebrafish, the spatiotemporal movement of cell behaviour was modelled using drift-diffusion equation to identify that cells with receptor depletion and diffusion was the mechanism that is most likely supported by data. Real in-vivo data was used to arrive at this conclusion.

The third application is in the healthcare domain and is the detection of epilepsy from an array of electrodes placed on the surface of the brain, for severely affected patients, often prior to surgical treatment. The idea is to model the spatiotemporal signals using the integro-difference equation (IDE) which also fits in with an interpretable neural field biophysical model. The detection is based on the model parameters associated with the cortical connectivity kernel in which particular inhibitory pathways disappear during epilepsy episodes. Application to a real data from a patient demonstrates its applicability.

The final application is a social science problem based on the wikileaks data, and in particular, data referred to as the afghan war diary. The data consists of conflicts that took place during the period 2004 to 2005 and consists of spatial location and event information. The challenge is to model the dynamics of conflicts based on spatio-temporal data of events so that predictions can be made and appropriate actions can be taken. We developed a partial differential equation model for processing spatio-temporal events data and demonstrated its predictive powers. This work received the PNAS Cozzarelli Prize for its innovative contribution in Applied Science and Engineering.