Dynamical networks characterization of natural data: space weather events and the human brain response to surprise

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Dynamical networks are in widespread use in quantifying societal data. Here, we consider the possibilities of this approach in real world observations of natural systems where multipoint (in space) observations are available of multiscale systems that exhibit an emergent nonlinear response to an impulse or change in driving. Two examples will be discussed in detail. Magnetoencephalography (MEG) is a noninvasive human brain diagnostic in which the magnetic field at the scalp surface is measured at typically 100 equally spaced points. It can be used to infer how the functional network of the human brain dynamically emerges in response to stimuli, here, repeated and unexpected or surprising auditory tones [1,2]. Differences in this response between healthy subjects and those with a neurological condition such as schizophrenia may offer the potential for early diagnosis. The plasma and magnetic field of earths near-space environment is highly dynamic, with its own space weather which is an emergent response to the highly variable suns expanding atmosphere, the solar wind. Space weather effects on the ground are monitored by 100+ magnetometer stations in the auroral region as well as by a constellation of satellites. Spatio-temporal patterns of correlation between the magnetometer time series can be used to form a dynamical network [3,4]. Space weather impacts include power loss, aviation disruption, communication loss, and disturbance to or loss of satellite systems, on some of which a range of technologies depend for navigation or timing.

A dynamical networks approach to these datasets offers the possibility of capturing the time variation in emergent spatial pattern with a few time-varying network parameters. It could in principle be used to compare across many subjects or events and to obtain an averaged or typical system response if this is meaningful, and its dependence on system parameters. Whilst networks are in widespread use in the data analytics of societal and commercial data, there are additional challenges in their application to physical timeseries. Determining whether two nodes (here, ground based magnetometer stations or MEG sensors) are connected in a network (seeing the same dynamics) requires normalization w.r.t. the detailed sensitivities and dynamical responses of specific observations and instrumentation. The spatial sampling points may be signal integrating and may not be uniformly spatially distributed. In the case of ground based observations of space weather, the stations are moving w.r.t. the plasma-current system under observation. In the case of MEG human brain measurements, the background is highly variable both within and across subjects. In both the human brain and in space weather the observed current system itself is non-linear and highly dynamic. As well as presenting some of the first dynamical network analysis of these natural systems, this talk will focus on the challenges of natural data and some potential approaches.

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