Characterization of event-related directional couplings

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The framework of nonlinear time series analysis comprises a variety of measures that allow extracting different characteristic features from complex dynamical systems. In particular, nonlinear interdependence measures estimate the strength and direction of couplings between two dynamical systems from pairs of signals derived from them (e.g. [1, 2]). This aspect is of high relevance for neuroscience because often signals are measured from different brain areas, and a reliable detection of directional couplings between these areas can contribute to the understanding of physiological or pathological processes. In particular, neuronal activity is often measured time-locked to multiple repetitions of a task, and it can be hypothesized that such paradigms result in transient event-related directional couplings between the involved brain areas. We here present a novel technique which can detect such transient event-related directional couplings from multiple realizations of a measurement. For this purpose, we have introduced the general concept of time-resolved causal statistics derived from embeddings across multiple realizations of time-dependent dynamics [3]. We have adapted a conventional nonlinear interdependence measure to serve as a time-resolved causal statistic and construct surrogates by permuting the order of realizations. In applications to mathematical model systems we demonstrate that our approach allows one to detect event-related directional couplings based on only a few tens of realizations. Couplings as short as one oscillation period of the dynamics can be detected. We show that the performance of this approach degrades smoothly with increasing noise levels. Furthermore, we show results of first applications to event-related neuronal recordings.

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[1] J. Arnhold et al., *Phys. D* **134**, 419 (1999).

[2] M.G. Rosenblum and A.S. Pikovsky, *Phys. Rev. E* **64**, 045202 (2001).

[3] R.G. Andrzejak et al., *New J. Phys.* **8**, 6 (2006).