When are nonlinear measures needed to detect pairwise spike-train couplings?

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We investigate the utility of non-linear statistical measures in identifying unidirectional couplings between neuronal spike trains modeled with binary data as compared to standard linear methods. Specifically, we explore the performance of an information-theoretic directional measure (directed information, DI) in detecting existing spike-train couplings and examine how detection sensibility and specificity are influenced by biological variables such as the firing rate. Using synthetic binary data sequences, we compare the performance of linear measures and DI considering pairwise couplings with up to memory two dependencies. Our results validate that one-to-one sample (memory 0) non-linear couplings cannot be built between binary sequences. However, when considering spike-train dependencies with memory, several biologically plausible models arise that are not detectable by linear methods, but can be instead identified by the DI. Overall, our results highlight the importance of using non-linear statistical measures to avoid missing functionally relevant spike-train interactions. Furthermore, our study helps characterize the impact of firing rate on statistical coupling detection performance, which may be considered in analyzing spike-train data from biological studies.