

## **A refinement of recurrence analysis to determine the time delay of causality in presence of external perturbations**

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### Abstract

This article describes a refinement of recurrence analysis to determine the delay in the causal influence between a driver and a target, in the presence of additional perturbations affecting the time series of the response observable. The methodology is based on the definition of a new type of recurrence plots, the Conditional Joint Recurrence plot. The potential of the proposed approach resides in the great flexibility of recurrence plots themselves, which allows extending the technique to more than three quantities. Autoregressive time series, both linear and nonlinear, with different couplings and percentage of additive Gaussian noise have been investigated in detail, with and without outliers. The approach has also been applied to the case of synthetic periodic signals, representing realistic situations of synchronization experiments in thermonuclear fusion. The results obtained have been very positive; the proposed Conditional Joint Recurrence plots have always managed to identify the right interval of the causal influences and are very competitive with alternative techniques such as the Conditional Transfer Entropy.