Causality Analysis: Identifying the Leading Element in a Coupled Dynamical System

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Abstract

Physical systems with time-varying internal couplings are abundant in nature. While the full governing equations of these systems are typically unknown due to insufficient understanding of their internal mechanisms, there is often interest in determining the leading element. Here, the leading element is defined as the sub-system with the largest coupling coefficient averaged over a selected time span. Previously, the Convergent Cross Mapping (CCM) method has been employed to determine causality and dominant component in weakly coupled systems with constant coupling coefficients. In this study, CCM is applied to a pair of coupled Lorenz systems with time-varying coupling coefficients, exhibiting switching between dominant sub-systems in different periods. Four sets of numerical experiments are carried out. The first three cases consist of different coupling coefficient schemes: I) Periodic–constant, II) Normal, and III) Mixed Normal/Non-normal. In case IV, numerical experiment of cases II and III are repeated with imposed temporal uncertainties as well as additive normal noise. Our results show that, through detecting directional interactions, CCM identifies the leading sub-system in all cases except when the average coupling coefficients are approximately equal, i.e., when the dominant sub-system is not well defined.

Read the full article in *PLoS ONE* [1].

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