28th SUMMER SCHOOL-CONFERENCE ON DYNAMICAL SYSTEMS
AND COMPLEXITY, CHANIA, CRETE, 18 - 26 JULY 2022

Complex Networks Estimation from Multivariate Time Series

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In the study of complex dynamical systems, such as brain dynamics and financial market dynamics, from multivariate time series, a main objective is the estimation of the connectivity structure of the observed variables (or subsystems), where connectivity is also referred to as inter-dependence, coupling, information flow or Granger causality. Having selected a connectivity measure to estimate the driving-response connections among the observed variables, the complex network is then formed, called also connectivity or causality network, where the nodes are the observed variables and the connections are the estimated inter-dependencies. For a network with binary connections the inter-dependencies are discretized to zero (not significant) and one (significant) by applying a criterion for the significance, e.g. arbitrary threshold or statistical testing. There is a main and practical issue in the connectivity analysis: estimation of direct inter-dependence in the presence of many observed variables, where direct inter-dependence between two variables excludes the inter-dependence mediated by the presence of the other observed variables. To address this issue, inevitably one has to involve a dimension reduction scheme in the estimation of direct connectivity.

I will present the framework of connectivity analysis of multivariate time series and focus on direct connections and many observed variables. In our research group, we have developed appropriate methodology for this scope and in the last part I will attempt to introduce causality measures that apply dimension reduction. I will illustrate on simulated data the ability of causality measures using dimension reduction to identify the underlying complex network (connectivity structure of the underlying complex system) solely on the basis of the observed multivariate times series. I will then move to real-world applications and estimate changes of the connectivity structure in time series records of epileptic electroencephalograms and world financial markets.