Scientific Report: CIDNET - Causality, information transfer and dynamical networks

Inferring cause-effect relationships from observations is one of the fundamental challenges in natural sciences and beyond. Due to the technological advances over the last decade, the amount of observations and data available to characterize complex systems and their dynamics has increased substantially, making scientists face this challenge in many different areas. One specific example is the brain for which one can make multivariate recordings of its activity on many different levels, ranging from single neurons to extended brain regions. Another important example is the identification of genes that interact to control cellular processes by transcriptional activation of a set of target genes – identifying their interactions is an essential task for network reverse engineering in modern systems biology. Several analysis techniques from information theory, statistics and related disciplines exist to estimate causal influences, interactions and connectivity from general multivariate recordings under certain assumptions. The connectivity is often of particular importance since it allows one to describe the dynamics of a given system in the modern language of complex network theory and to tackle questions related to structure and functionality.

CIDNET targeted various fundamental issues and open questions that remained. These included but are not restricted to: 1. Suitable choice of a network definition in terms of nodes for a given system. 2. Scale-dependent properties of the networks. 3. Role of nonlinearities in extracting causal influences and interactions. 4. Distinguishing between direct and indirect interactions. 5. Feedback between dynamics and interactions. 6. Unobserved processes. 7. Observational noise and non-stationarities.

CIDNET invited 32 outstanding experts in this area of research from all over the world. To name only a few of the key attendees, who contributed to the big success of CIDNET by triggering and facilitating discussions and new collaborations, we list: (a) Celso Grebogi (University of Aberdeen): Multi-layered networks and emergence of spatiotemporal order in ecological systems, (b) Klaus Lehnertz (University of Bonn): Measuring directed interactions in the human brain, (c) Dante Chialvo (University of the Balearic Islands & UCLA): Emergent complex neural dynamics, neuronal avalanches and the critical brain, and (d) Michal Zochowski (University of Michigan): From network structure to brain function and back. Key contributions from local participants - Holger Kantz (MPI-PKS): Direction of coupling from phases of interacting oscillators: A permutation information approach and Stefan Kiebel (TU Dresden and MPI for Human Cognitive and Brain Sciences): Dynamic models for brain function and neuroimaging data analysis - completed the CIDNET seminar and workshop programme.

In particular, young investigators and researcher from related disciplines were given the chance to present their work during the seminar programme and additionally posters during the workshop phase. Several discussions and new collaboration were facilitated through this. Overview talks in the various areas were given by experts that led to extremely fruitful discussions during which scientific newcomers could gain and increase their knowledge in the important research field of CIDNET.

The key scientific result of CIDNET in most certainly the various novel collaborations that emerged from the in depth discussions during the seminar and workshop phase of the CIDNET programme. These collaborations will result in various publications and research grant triggered by CIDNET. Already during the seminar phase, researchers that hadn’t worked together joint forces to tackle some of the challenges mentioned above.