Synergetic and redundant information flow in dynamical systems: an operative definition based on prediction

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Information theoretic treatment of groups of correlated degrees of freedom can reveal their functional roles as memory structures or information processing units. Furthermore, by looking at the common amount of information shared in a group of variables we can tell whether they are mutually redundant or synergetic. The application of these insights to identify functional connectivity structure is a promising line of research. Another topic of general interest is the understanding of couplings between dynamical systems and their parts. Transfer entropy and Granger causality are popular approaches used to distinguish effectively driving and responding elements and to detect asymmetry in the interaction of subsystems. These two methods can be unified under some conditions, opening new computational and methodological perspectives. Several techniques can evidence sets of variables which provide information for the future state of the target. This information can be synergetic or redundant, with important implication on our understanding of the functioning of the dynamical system under analysis.
Importantly, not taking into account the joint dynamical influence of two or more variables can lead to bias and wrong estimations of links (false positive and false negatives).
In the field of information theory these concepts are often defined and studied by means of axioms. Here we will instead use an operative definition based on reduction in variance, using the unnormalized version of Granger causality. We will present an application to simulated datasets and neuroimaging data, such as the one depicted in figure 1, where average redundant and synergetic contributions, computed on 116 brain regions from 90 subjects from the Human Connectome Project dataset are depicted.

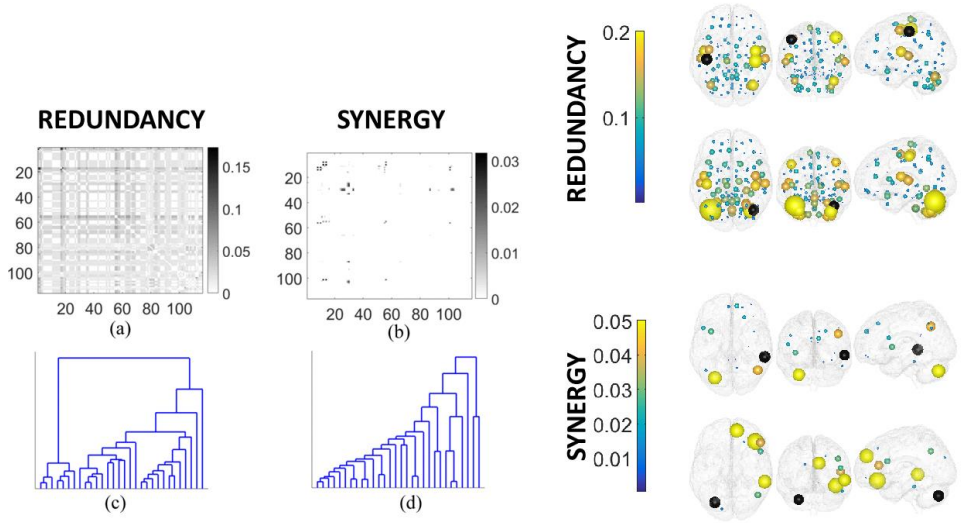

Figure 1. Synergetic and redundant influences between 116 brain regions from the AAL template, averaged over 90 subjects from the HCP dataset. Left: matrix of synergetic/redundant contributions (a/b) and dendrograms (c/d).
Right: Redundant (top) and synergetic (bottom) contributions for two representative regions, a cortical and a cerebellar one.

References

1. 1. Stramaglia S, Angelini L, Wu G, Cortes J, Faes L, Marinazzo D: **Synergetic and redundant information flow detected by unnormalized Granger causality: application to resting state fMRI.** *IEEE Trans. Biomed. Eng.* 2016, **63 (12):**2518-2524.