A Network Approach to Calculate the Entropy of Social Organisations

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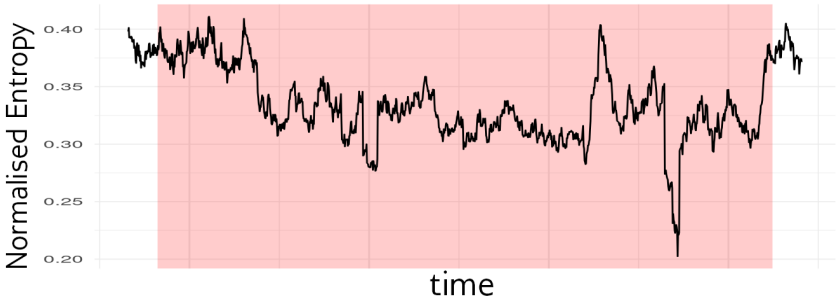
Social organisations are ubiquitous in our everyday life, ranging from the project team we are working in to the special interest group we are contributing to, online. Network science allows to study such systems in terms of networks, where nodes represent individuals and edges their interactions. Our experience tells us that social organisations and consequently their network representations are highly dynamic. In addition to a continuous entry and exit dynamics of nodes, there are dynamics of links, like addition, deletion and rewiring. We can study all these processes from a "microscopic" perspective, focusing on single events. But we aim at a *macroscopic* perspective that allows us to understand to what extent such events are within the expected dynamics of the organisation, or beyond what should be expected. This will allow us to define the dynamic stability, or resilience, of the social organisation in a completely new way.

The key element of our approach is a measure of the **potentiality** of the organisation. This expresses the ability to recover from any kind of perturbation, or shock, that the organisation experiences (individuals leaving, interactions interrupted, etc.). To calculate the potentiality, we use a representation of the organisation as an **ensemble of networks**. Suppose that at time t we observe a network $\mathcal{G}(t)$. In principle, we can treat $\mathcal{G}(t)$ as a random realization, sampled from the set of all possible configurations of the organisation that could have been observed under the constraints given. The lower the number of configurations, or the more similar the possible configurations, the lower the potentiality of the organisation, because fewer options are available for the system to operate. The higher the number of possible configurations and the more diverse they are, the higher the potential of the organisation to recover from a shock as more and more alternative ways of interacting are available for its elements.

By appropriately fitting a generalised hypergeometric ensemble of random graphs (gHypEG) to the observed interactions, we study the probability distribution of the possible configurations of the system. We thus estimate potentiality in terms of the probability distribution underlying the ensemble. A system has high potentiality if the distribution is broad and possible configurations are heterogeneous, and low potentiality if the distribution is narrow and possible configurations tend to be homogeneous. By computing the **Shannon entropy** of the gHypEG, we quantify precisely this property. Thus, the *potentiality of a social organisation* is the Shannon entropy of the network ensemble characterising the current state of the system.



Time-series showing potentiality in the Gentoo Linux developers community.
The dynamics can be mapped to known critical transitions in the system behaviour.