A FREE-ENERGY PRINCIPLE METAMODEL FOR SOCIO-TECHNICAL SYSTEMS

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Statement of research interest

Socio-Technical System (from now on STS) is a framework that aims to modelling and analyzing complex systems by means of four interdependent component: tasks, people, physical system, and structure, where each of them influences the others (Leavitt, 1965). This perspective means that all the events studied under its framework affect both social subsystem (human and structure) and technical subsystem (technology and task). Thus, to know systems throughout the STS it is necessary to identify and describe each of these components, both alone and in the interaction with others. In the last decade, STS was increasingly studied under a complex system perspective. As an example, new methodologies for measuring complexity in STS were developed (Schöttl & Lindemann 2015), system dynamic (Oosthuizen & Pretorius 2015) and agent-based (Bergman 2008) techniques were applied. Moreover, there were presented network-based research works (Burger et al. 2013).

Lately, a new methodology to study complex systems was developed. It is called free-energy principle (Friston et al. 2005, Friston 2012). The idea behind it is simple but powerful. In physical systems entropy increases over time. Consider an open bottle of perfume in a room: after a certain amount of time, the perfume will spread throughout the whole room (van Es 2020). Nevertheless, there is a category of systems — living systems, or biological (Friston et al. 2005) — that constantly act to not disperse randomly (Friston & Stephan 2007). Variational free energy is the upper bound of entropy. The free-energy principle states that every biological system minimizes its free energy to survive. Or, in other words, each living system behaves to minimize the surprise (while lessening the upper bound of entropy, a biological system reduces the number of unlikely statuses it can be; this is a way to quantify surprise). Once in a state, a system has two modes to decrease its free energy: to move to another state or to update its expectation. The first is a process called active inference. It is an inference because it rests on a prevision of the future state of the system. Since it implies an action from a state to another, the inference is active. The second means that a system updates its probability distribution. Thus, previously surprising states are not so anymore.

Thus, the research proposal I would like to discuss is the following. Let's suppose that every STS (or at least a subclass of them, still to be defined) could be modeled by a bimodal and dynamic network in which the nodes stand for component of the physical system and humans. The nodes are related to each other by links that stands from the possibility of interaction. Under this perspective, the topology of the network (i.e. the distribution of the links) would represent the structure of the STS. The nature of the interactions relates to the creation, the assignation, the solution and the submission of tasks and to the creation of new links. Specific rules for these five operations have to be define in each specific application. In the model each of the two kinds of node is able to perform every operation related to tasks, while only humans could create new links. Furthermore, technology nodes are represented as reactive entities. Humans — that are by definition biological systems — are modelled as agents that act and interact to minimize their free energy, which would be defined and measured each time in function of the peculiar contest (i.e., in relationship with the other components of the STS). Thus, human agents would decide how to create, assign, solve and submit the task by the minimization of their free energy, minimizing the expected surprise. I sustain that this metamodel could be applied to model real-world STS as organizations or research networks and that through simulation it could be possible to assess the performance of an STS and to detect viable organization interventions.

Bibliography

1. Leavitt, H. J. (1965) ‘Applying Organizational Change in Industry: Structural, Technological and Humanistic Approaches’, in March, J. G. (ed.) Handbook Organizations. Ed. Chicago IL, USA: Rand McNally, pp. 1140–70. Available at: http://people.plan.aau.dk/~sh/SundTek2001/Tekster/Leavitt.pdf.
2. Bergman, N., Haxeltine, A., Whitmarsh, L., Köhler, J., Schilperoord, M., & Rotmans, J. (2008). Modelling socio-technical transition patterns and pathways. JASSS.
3. Burger, V., Hock, D., Scholtes, I., Hoßfeld, T., Garcia, D., & Seufert, M. (2014). Social Network Analysis in the Enterprise: Challenges and Opportunities. In K. Zweig, W. Neuser, V. Pipek, M. Rohde, & I. Scholtes (Eds.), Socioinformatics - The Social Impact of Interactions between Humans and IT (pp. 95–120). Cham: Springer International Publishing.
4. Friston, K. J., & Stephan, K. E. (2007). Free-energy and the brain. Synthese. https://doi.org/10.1007/s11229-007-9237-y
5. Friston, K., Kilner, J., & Harrison, L. (2006). A free energy principle for the brain. Journal of Physiology Paris. https://doi.org/10.1016/j.jphysparis.2006.10.001
6. Karl, F. (2012). A free energy principle for biological systems. Entropy. https://doi.org/10.3390/e14112100
7. Oosthuizen, R., & Pretorius, L. (2016). Assessing the impact of new technology on complex sociotechnical systems. South African Journal of Industrial Engineering. https://doi.org/10.7166/27-2-1144
8. Schöttl, F., & Lindemann, U. (2015). Quantifying the complexity of socio-technical systems-A generic, interdisciplinary approach. Procedia Computer Science. https://doi.org/10.1016/j.procs.2015.03.019
9. van Es, T. (2020). Living models or life modelled? On the use of models in the free energy principle. Adaptive Behavior. https://doi.org/10.1177/1059712320918678