Suppleness and Open-Endedness for Social Sustainability[1]

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Abstract

One of the research questions in ALife that could contribute greatly to social sustainability issues is how dynamic meta-states of a complex system may be sustained through continual adaptive changes, or *suppleness* (Bedau, 1998). The idea of sustainability by suppleness is fundamentally different from conventional ideas of sustainability by robustness or resilience, and it is directly linked to *open-endedness*, a topic that has recently attracted significant attention in the ALife community (Taylor et al., 2016). Understanding and implementing mechanisms of suppleness and open-endedness may provide novel perspectives of many of today's socio-economic, socio-ecological and socio-technological problems that call for new strategies to cope with inevitable environmental/contextual changes. This short essay provides a non-exhaustive list of research questions on this topic and encourages ALife researchers to play a leading role in this interdisciplinary collaboration endeavor.

Sustainability of a dynamical system is often conceptualized and characterized as either robustness or resilience in the literature. Robustness implies persistent stability, rigidness and outright tolerance of a system against perturbations. A robust system's state remains at or near a stable fixed point without much deviation from it (Fig. 1(a)). The mechanism that realizes sustainability of a robust system is a strong, quick negative feedback which eliminates any small perturbation before it grows and takes the system away from its normal state. There is little room for adaptation in a robust system.

Resilience implies a more elastic, longer-term stability than that implied by robustness. A resilient system's state may undergo large drifts from the normal one occasionally, but temporary accommodation and gradual recovery eventually bring the system back to normal (Fig. 1(b)). The mechanism that realizes sustainability of a resilient system is elasticity (i.e., capability of temporary accommodation) and restoration (i.e., capability of gradual recovery). Like robustness, resilience is based on goal-oriented negative feedback, which is much slower and more moderate than those of robust systems.

As seen above, robustness and resilience are, in a sense, similar – robust systems may show resilience at a finer scale, while resilient systems may show robustness at a coarser scale. The distinction between the two is partly based on the scale of observation and control being used.

The sustainability of real biological or ecological systems, however, is not necessarily based on either robustness or resilience. Although those systems can definitely be robust and resilient, their states never remain at a single place in a long term. Instead, they continue to change dynamically due to complex interaction and evolutionary adaptation of system components. What is sustained over a long period of time in those systems is not a specific normal state, but the ability to demonstrate a unique, dynamic, emergent meta-state, such as "alive", "active", "productive", and so on. Some of those meta-states may be readily quantifiable and measurable, while others are more qualitative and may be hard to quantify.

By shifting our focus from the system's specific desired

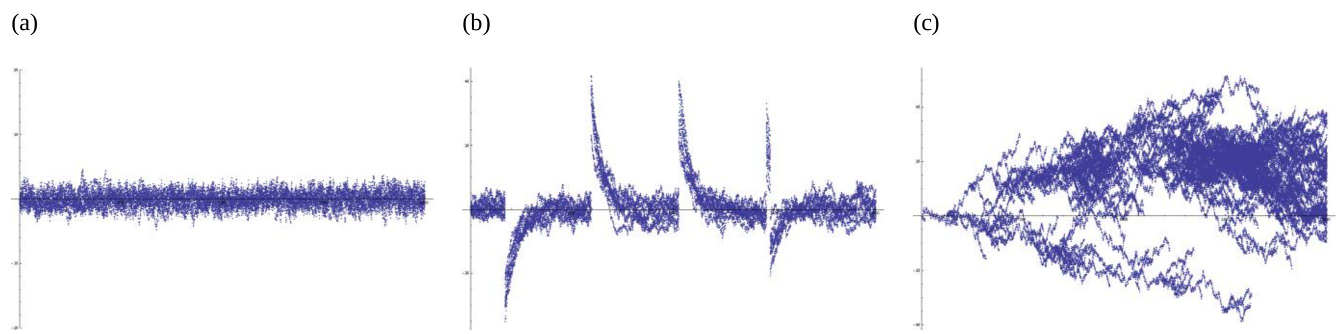

Figure 1: Illustrative visualizations of three different forms of sustainability. (a) Robustness. (b) Resilience. (c) Suppleness. Horizontal axes show the progress of time, while vertical axes show the system's states represented by the aggregate states of its components.

[1] This work is largely based on the author's earlier white paper submitted to the US National Science Foundation (https://bit.ly/2HmwWkz), with revisions and addition of discussions on the linkage to open-endedness.

state to its dynamic meta-state, we may consider yet another characterization of sustainability, which we call *suppleness*. Bedau (1998) defined supple adaptation as “an automatic and continually creative evolutionary process of adapting to changing environments”. We can conceptualize suppleness as a novel form of sustainability fundamentally different from robustness or resilience discussed above. It may inform us about the sustainability of our social systems from a different perspective.

Suppleness implies the maintenance of a dynamic meta-state of a system by continual adaptive changes of the system (and its components), where the system’s actual state drift greatly and may not even come back to the original place in its state space (Fig. 1(c)). There is no strong negative feedback to a normal state in action, while inputs are continuously provided to the system from an ever-fluctuating environment. Since there is no reference point to converge towards, the dynamics of a supple system are necessarily open-ended, which may result in divergent, exploratory, or even creative processes unless the environment is too selective. Understanding and creating such open-ended processes is now widely recognized as one of the major challenges in the ALife community and the AI community at large (Taylor et al, 2016; Stanley, 2018).

The concept of suppleness and its significance for the maintenance of dynamic meta-states of complex systems have already been discussed in various forms. The Red Queen principle discussed in evolutionary biology (Van Valen, 1973) is a classic example, which illustrated the need of continual adaptation for a dynamic evolutionary system to survive in co-evolutionary environments.

Many of today’s socio-economic, socio-ecological and socio-technological problems arise in rapid environmental/ contextual changes, such as global warming, economic volatility and political instability. In the presence of such large-scale changes, an attempt to bring the system back to its original state, which is the central idea of sustainability by robustness or resilience, may no longer be a viable option from a practical viewpoint. Instead, these problems call for new strategies to cope with inevitable environmental changes.

Here we argue that the concept of suppleness (and open-endedness) discussed above will have significant implications for today’s social problems that are all situated in rapidly changing environments. Meanwhile, applications of the concept of suppleness to social sustainability issues has not fully developed yet in either science or practice. There are a number of open questions to be investigated. Here are some examples:

1. How can suppleness be modeled theoretically/ mathematically? How to formally define sustainability by suppleness?
2. What are appropriate, meaningful, and/or useful ways of characterizing dynamic meta-states sustained in a supple system?
3. What are the environmental conditions for suppleness to be an effective strategy for the system’s sustainability? Does our current natural and social environment meet those conditions?
4. What are potential risks of being supple?
5. Are all biological systems supple, or are there exceptions?
6. Among a variety of different social, political and economic systems human being has developed in its history, which are suppler than others? Are/were they functioning effectively or not?
7. Can suppleness help improve creativity, decision making and problem solving by human individuals or groups?
8. Has the recent development of IT and social media made our society suppler or not?
9. Rapid concentration of resource and information in a small number of entities is ongoing in many scenes of our society. Is it for or against social suppleness?
10. Is there any fundamentally different form of social mechanisms (policies, technologies, customs, etc.) that could significantly enhance social suppleness?
11. How can we make the financial systems suppler to prevent further financial crises from happening?
12. How can we make the social infrastructure (e.g., power grid, water supply, transportation, the Internet) suppler?
13. What are the implications of suppleness for global climate change?
14. How can we improve the current political decision making mechanisms using the concept of suppleness?
15. Is the current form of science and engineering supple enough to promote new discovery and innovation? If not, what should be done?

These research questions are by no means intended to be exhaustive. Readers are encouraged to explore other directions of inquiry and come up with more questions and answers.

We believe ALife and other related disciplines have a lot to offer to the research on suppleness and open-endedness for social sustainability. Models and simulations of nonlinear dynamical systems, evolutionary systems and agent-based systems will likely play an essential role in driving this research. Equally important will be evolutionary biology and mathematical biology, where numerous models of evolutionary adaptation have already been developed and studied extensively. Moreover, insight into practical social applications will be obtained from management and organizational sciences that study innovation, creativity, decision making and social networks. ALife researchers can and should play a leading role in promoting such interdisciplinary collaboration endeavor.

References

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