

Steering a Complex Adaptive System: A Complexity Science Design Methodology Applied to an Industrial Ecosystem in the Humber Region, UK

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Many important challenges facing society today involve the management of interlinked complex adaptive systems (CAS): coupled socio-economic and ecological systems composed of many interacting elements which have been created or partially created by human actions. As we explicitly wish to manage and transform these systems, engineering and design approaches have much to offer us, however they must be fundamentally modified to deal with CAS. These systems are not static artifacts, but dynamic, evolving and reflexive *processes* the behaviour of which is not straightforwardly predictable and which may respond in unexpected ways in response to our interventions. Additionally many of the complex systems which we would most like to influence have significant social components. Objective choices about design goals cannot be made and the integration of participatory or political processes may be required.

In order to manage complex adaptive systems, we suggest a “steering” approach; an action or series of actions applied to a complex system and/or its environment for achieving a specific purpose. Steering combines tools from complexity science with whole systems design philosophy and is a continuous process which involves interacting with, monitoring and learning from the system in question. The techniques required for effective steering fall into two categories. Firstly we wish to understand, and indeed exploit, the systems’ structure and dynamics in order to intervene efficaciously with them. Hence we need techniques to uncover this structure and to choose points of intervention: system “levers” through which the system as a whole could be manipulated with system interventions designed accordingly. Secondly we frame those techniques within a participatory “adaptive management” structure (Waltner-Toews and Kay, 2005), which explicitly takes into account the adaptive nature of these systems and our limited capacity to fully model real world complex systems, by building in monitoring and feedback processes with which to modify our interventions as systems respond.

We are currently applying this process to a case study aiming to facilitate regional decision making in an industrial ecosystem in the Humber region, UK. The region represents a significant proportion of UK infrastructure, energy generation capacity and CO₂ production. However, there is a strong desire to develop the “Humber Gateway” as a renewable energy hub using the extensive agricultural hinterland and offshore and port facilities to support bio-based energy production and offshore wind and tidal generation. We have

undertaken participatory modelling exercises in which stakeholders collaboratively constructed simple systems models of the development of their regional bio-based economy, the key factors of influence, drivers and their perceived interdependencies (Penn *et al.*, 2013). Building on this approach we used a “control nodes” methodology from network theory (Liu *et al.*, 2011) to determine the specific subsets of these factors which could theoretically be used to drive the system into any given state. This technique is combined with an evaluation of the practical controllability of each factor from the perspectives of the actors present to allow its use in real world contexts in which policy makers and industrial stakeholders must make decisions (Penn *et al.*, In press.).

Applying this hybrid approach in the real world context of the Humber allowed stakeholders to uncover and discuss possible novel points of intervention in their regional system, based both on its structure and their own differing abilities to influence different factors within it. This proved to be a useful starting point for debate on policy ideas and the importance of considering not just *where* to intervene, but *who* is able to intervene with a given factor. However this approach, like all network-based methods, is limited by its sensitivity to the network structure described. Additionally by the fact that once suitable control configurations are discovered, the method as yet gives us no indication of how to construct the time variable control inputs required to steer the system to a given state. Instead we must use such modelling as a “thinking tool” to provide principled starting points, to be combined with stakeholder expertise, for the participatory design of complex social systems.

References

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