Plan of Research

The goal of the Open Model for Climate Behaviors is to identify drivers and leverage points in the social system surrounding climate change, by developing new approaches in system modeling and analysis. The project combines system dynamics with spatial and network methods, uniquely building on the strengths of each, and synthesizing a wide range of models and data. This framework has wide applicability, and the first case study will focus on passenger transportation behaviors in the United States. By identifying underlying forces in coupled social, economic, and political systems, this research can help focus research and facilitate effective policymaking. The spatially explicit and institutionally specific results are simultaneously accessible to scientists and the public, helping bridge divisions between these groups.

Anthropomorphic climate change and environmental degradation are among the most pressing issues of our time, and despite a recent explosion of green technologies and strategies, the social behaviors that drive climate change remain intractable. Politicians, businesses, and consumers may individually favor changes, but mutually reinforcing incentives make action difficult or costly. This kind of overdetermined homeostasis is typical of complex systems. While the feedback loops that support the status quo reduce the effectiveness of some actions, whether they are new laws, citizen movements, or business decisions, other changes can be reinforced and amplified. These “leverage points” are places where small changes can make pervasive differences. Due to the structural nature of complex systems, from ecosystems to economies, leverage points are ubiquitous, if difficult to identify (Meadows, 1997). To better understand the social realities that affect behaviors surrounding climate change, this research aims to develop a high-dimensional numerical model, along with the tools to elucidate it.

The Open Model provides the greatest advantage for problems that are currently intractable due to systemic forces, and that are spatially heterogeneous. A wide range of environmental and public health issues fit this description, including emissions from passenger transportation, environmental degradation, obesity, substance abuse, groundwater use, and fishery management, as well as situations fraught with rebound effects and environmental standards that shift activity across borders (e.g., carbon leakage).

The Open Model for Climate Behaviors combines five fundamental components to better identify leverage points: (1) a system dynamics framework, (2) support for multiple network maps and conditional self-similarity, (3) integration of time series data, (4) computational tools for model evaluation, and (5) an open interface for contributions and communication. Each component builds on a variety of prior work, but their combination is one this project’s significant contributions.

The system dynamics approach (see Forrester, 1991) has been applied to many sectors relevant to this project, including urban growth and decline, energy policy, environment modeling, public health, and social change initiatives. One weakness of system dynamics is that it is hugely aggregative, both demographically and spatially. Ahmad et al. (2004) addresses the spatial aggregation by integrating geographic information system modeling (GIS) and system dynamics, calling the approach spatial system. This technique has been used for flood management, water resource modeling, and invasive species spread.

This project extends spatial system dynamics into a powerful network-based approach with models that can vary between regions. This provides three advantages. First, it allows different networks to represent the different ways stocks flow between nodes (e.g. across land or along roads), different demographic groups, and relationships between institutions. Second, the use of networks helps capture network properties common to social systems like the small-world property, scale-free behavior, and hierarchical modularity. Third, the networks can be used to form a hierarchy of scales, and combined with techniques from climate downscaling, this supports efficient modeling with the potential to “drill down” to arbitrary levels of detail.

In traditional system models, time series data are only used for parameter tuning and model verification (Forrester, 1991). In this framework, data has a more complementary role, driving the downscaling process, defining the pattern of spatial heterogeneity, and supporting the computational identification of missing or contradictory relationships. A variety of techniques exist to validate system dynamical models (Barlas, 1996), and this project adapts them to larger a computation framework. However, like many economic and traditional system dynamic models and unlike climate models, the purpose of the Open Model is to capture the dynamics implicit in institutional relationships and not to predict future states.

In additional to developing tools to validate dynamics, the project involves the creation of a variety of new tools necessary to run experiments and discover the underlying drivers of the results. In particular, these tools will identify key elements, relationships, and loops which can significantly effect the dynamics of the whole system. Following Meadows (1997), the system will analyze changes in parameters, buffer sizes and flow speeds, the strength of feedback loops, and the structure of information flows to seek potential points of leverage.

Finally, the Open Model will be open: it will include an online interface for other researchers to make contributions and analyze the results. By connecting with other scientists on the Internet, the project becomes both more manageable and more useful. As a platform for researches to run their partial models within a larger context, this framework can help to identify both strengths and contradictions between existing models. Different researchers can also identify drivers for different outcome variables, such as CO2 emissions, the well-being populations, and the biodiversity of ecosystems.

The process for pursuing this research follows five overlapping phases: literature research, framework implementation, model development, analysis, and policy recommendations. Many of the core framework elements are already complete and in use for the author’s current research on flooding and self-organized economies. These elements include a basic synthesis of system dynamics and multiple network maps, some integration with time series data, and a growing set of tools for analysis.

The Open Model project envisions an evolving dialogue with policymakers and institutional actors, as a boundary-bridging knowledge system. The first step of this process is to conduct interviews with the relevant stakeholders and institutions, to supplement a literature review in understanding the interconnections behind current behaviors. These actors will be invited to maintain an active role in reviewing and advising the model as it develops.

The complexity of the social, political, and economic system surrounding climate change requires new tools, drawing on the strengths of many fields. With the support of the NSF, this new model can provide considerable benefits to both researchers and policymakers.

References

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