GLOBAL MODELING AND REASONING SUPPORT TOOLS

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Contents

Summary

This article deals with philosophical and methodological aspects of analyzing global systems, focusing on policy formulation and analysis. A reasoning support system, GLOBESIGHT was described as exhibiting the philosophy of blending science with vision. Some case studies using GLOBESIGHT are described.

1. Introduction

Globalization is an undeniable aspect of present and future development. Accounting for such a phenomenon in the formulation and analysis of policy at the local (state/province and national), regional, and even global levels requires an understanding of the interrelationships among various social, political, environmental and technological aspects. It has been obviously recognized by many that such development should be sustainable. It has also been recognized that mankind has embarked on an unprecedented experiment with nature, and some of the undesirable effects of development has been at the cost of the environment. An often mistaken notion is that human and environment are different.

A gnawing problem is the lack of understanding of various phenomena and forces that shape the future of the globe. This becomes particularly important when formulating policies for the future. More often than not future policies are made based on political and economic consideration with little or no effort to consider science. A good example is the policy (or lack of it) to combat the perceived threat of global warming, the decline in biodiversity, improper use or overuse of water, and so on.

Issues that are of concern to humankind are what we define as *Global Issues*. One way of classifying global issues is the following:

(a) Sustenance of Global Commons: climate, oceans, Arctic, Antarctic, and so on.
(b) Stewardships of Global Resources: oil, tropical forests, food, and so on.
(c) Global Interdependence problems, population, stratification, food, financial markets, and so on.
(d) Universal Problems: urbanization, and so on.

In this paper we discuss a methodology to understand the relationship among various entities that make up the global system under consideration for any global issue of interest. A complementary task is to describe the use of reasoning support tools to formulate policies for global issues. A precursor to the use of the tool is representation of the system—essentially through models—both conceptually and through the use of algorithms. These models when constructed properly will mimic system behavior.

1.2. Organization

The next section describes the view of the world as a cybernetic system. Section 3 delineates the philosophy of our approach. Section 4 describes the reasoning support tool GLOBESIGHT. Scenario analysis and visioning is described in Section 5. Use of GLOBESIGHT in real-life case studies is described in Section 6.

2. The World as a Complex Cybernetic System

2.1. Characteristics of Global Issues: Complexity and Uncertainty

The global system is characterized by both complexity and uncertainty. Often these characteristics are confused with one another. For instance, a simple system defined by a single equation could be highly uncertain. On the other hand, a complex system could be completely certain. To study global issues we require models that are representative of real phenomenon. Here we discuss the definitions and the consequent representations (models) of the complexity pertaining to global systems.

2.2. State Transition versus Goal-Seeking Paradigm

A common paradigm used for representation is the input/output or state transition paradigm. In this paradigm, which originated in the physical sciences, the evolution of the system is completely describable using the current state (or the preparation of the system thus far) and the current input. Models using this paradigm are developed in terms of differential or difference equations. Practical limitations of such models for applications in global issues are: short time horizons, inability to account for uncertainties in a satisfactory manner, and, limited "domain" of the extent of change for which the models are accurate (such as for ranges and rates of inputs, parameters, and so on).

The goal-seeking, or decisionmaking, paradigm addresses certain shortcomings of the state transition paradigm. Rooted in biology and the study of human behavior as opposed to physics, the goal-seeking paradigm is characterized by system goal or goals, and, the various procedures the system has access to, to pursue these goals. This paradigm accommodates concepts of "satisfactory human behavior" as opposed to the "optimization" view commonly used in economic theory, and explicitly accounts for uncertainty—both uncertainty under risk (usually accounted for using probability) and true uncertainty using tolerance (acceptability, survival, and so on).

2.3. Complexity

We define a complex system to be a system that is composed of systems called subsystems. (There are other ways to describe a complex system, such as Gell-Mann's, where systems exhibiting surprise behavior such as chaos are termed complex.) Each of the subsystems could in turn be a complex system or can be represented by simple relationships. The representation each of these subsystems in their most fundamental form uses is a simple methodology to "put under one roof" a multitude of items. Two categories are used: *transformations* (mappings in formal terms, processes in mathematical terms, functors in logical terms, and so on), and *indicators* which denote the items being transformed (inputs and outputs of the transformations).

In graphical representation, transformations are shown as blocks while the indicators are shown as arrows (the so-called block diagrams, see Figures 14 and 15). One way of understanding complexity is by the process we call "deconstruction" or multilevel approach and consequent hierarchical representation.

2.4. Deconstruction of a System and Hierarchical Representation

An example of hierarchical representation of a complex system that can be deconstructed into subsystems is given in Figure 1. Starting at the top left hand corner and proceeding counterclockwise, a gradual deconstruction process is given. A simple representation of the globe in the top left hand corner divides it into living (biosphere) and nonliving spheres. Below this is the representation wherein the biosphere is further divided into the nonhuman species sphere and the nonliving sphere. Together this is called the nature sphere. In the final representation in the right hand portion of Figure 1 the human sphere is further deconstructed into representation with hierarchies. In general the subsystems at the top in a hierarchical representation provide constraints through the downward directed arrows, whereas the upward arrows from the subsystems at the lower levels provide performance specification to their upper level. A more explicit and detailed hierarchical representation of the globe with focus on water studies is given in Figure 2. Other examples of such hierarchical stratification are given in Figure 3.

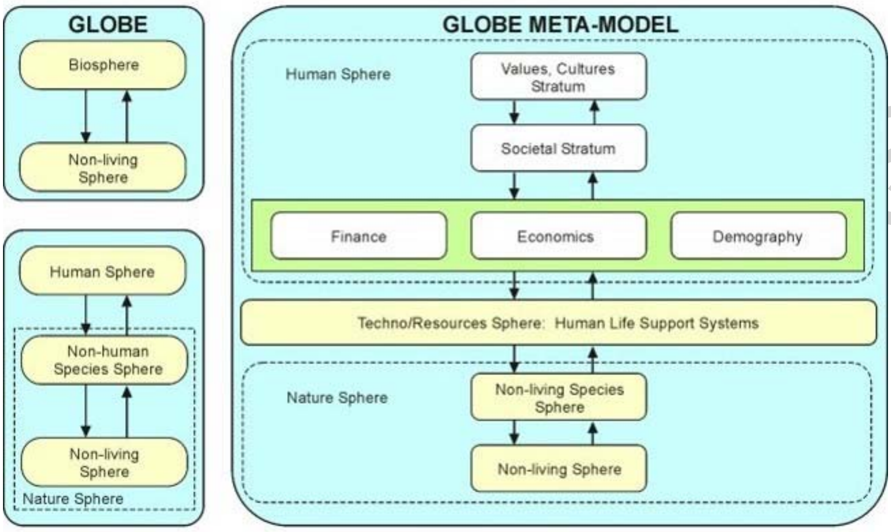

Figure 1. Deconstruction of the global system

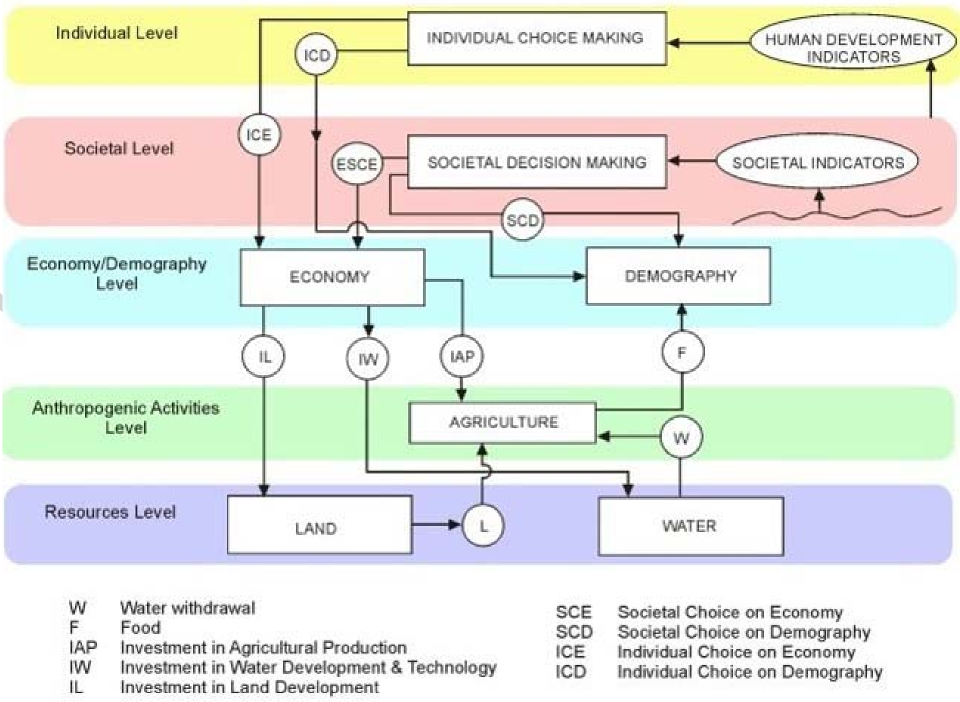

Figure 2. A more detailed representation of the global system with focus on water studies

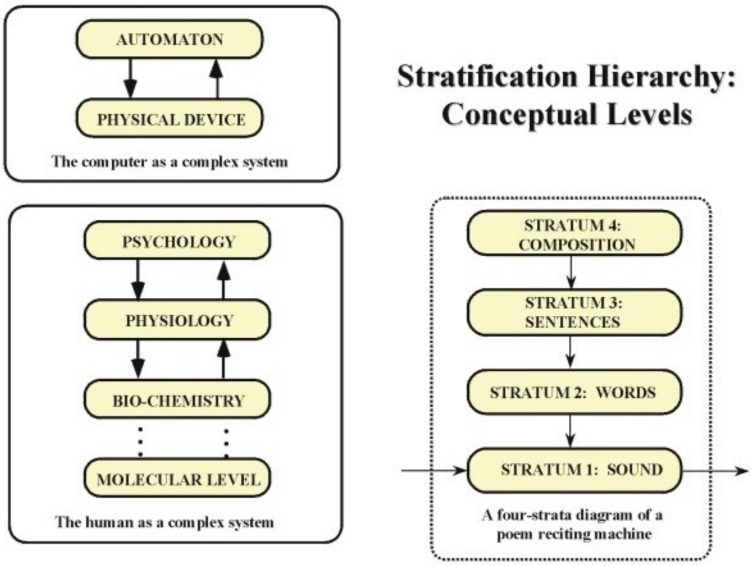

Figure 3. Other examples of hierarchical representation

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Biographical Sketch

Sree N. Sreenath received his Bachelor’s Degree from Bangalore University, India, in 1980, his Master’s in Engineering Degree (M.E.) from the Indian Institute of Science, Bangalore, India, in 1982, and a Ph.D. from University of Maryland, College Park, MD, in 1987. Currently he is a faculty member at the Systems Engineering Department of Case Western Reserve University (CWRU), Cleveland, Ohio, where he has been employed since 1988, first as an Assistant Professor, and from 1994 onward as an Associate Professor.

For the past seven years he has been interested in the broad topic of global issues. His area of specialty is in the application of systems science techniques to the problem of understanding the interaction of economic policies and the environment. In addition to many research papers, he has published a book *Systems Representation of Global Climate Change Models*, by Springer-Verlag, Berlin/New York/Tokyo, 1993. His present work has focused on the design of regional and international economic policies, and the impact of development in regions with shared water resources over long time horizons of years to decades. The case study of the Nile River Basin has been one such.

He is a member of the Scenario Panel advising the *World Commission on Water for the 21st Century*. He is a Co-Director of the Global-Problematique Education Network Initiative (GENIe) program sponsored by United Nations Education Scientific and Cultural Organization (UNESCO). He has held many honors: Center for Professional Ethics Fellowship, Lilly Teaching Fellow, NASA-OAI Summer Faculty Fellowship; the NASA-USRA Fellowship, Systems Research Center Fellow, National Merit Scholarship, founding chairman of the IEEE Control Systems Society, Cleveland Chapter, and, member of Tau Beta Pi Honor Society. He has been recognized by Case Western Reserve University with an Undergraduate Teaching Excellence Award for 1995–1996. He has lectured in more than a dozen countries.