CONFERENCE REPORT

Developing New Concepts in System Dynamics:

A Review of the 7th International System Dynamics Conference at Brussels

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The 7th International Conference on System Dynamics, held at the Universite´Libre de Bruxelles, Brussels, Belgium between June 16 and 18, 1982 witnessed the assembly of 100 plus researchers. In all, 44 papers were presented that discussed recent applications in the field, presented new concepts and theoretical developments, and surveyed recent trends in system dynamics. Papers were presented either in plenary sessions or in parallel sessions, two sessions meeting simultaneously. Sponsored by F.N.R.S. (Fonds National de la Recherche Scientifique – Belgique), Ministère de l'Education National et de la Culture Française, A.F.C.E.T. (Association Française pour la Cybernétique Economique et Technique), and SOGESCI (Société Belge pour l'Application des Méthodes Scientifiques de Gestion), the conference drew heavily on the research efforts of the French and Belgian groups with researchers from throughout Western Europe and North America present. As with other similar conferences, there was little representation from the far east, most notably a lack of researchers from Japan.

The conference was held in simultaneous translation in French and English and the published pre-proceedings reflected about an equal split of papers presented in both languages. Copies of these papers may be available from Professor Peter Allen, the conference organizer in Brussels. As of this writing it is still not clear if the full proceedings will be published as they were for the 1980 conference in Paris.

The papers presented at the conference treated applications and reviewed trends in the field. This review however looks primarily at those papers that discussed new concepts and techniques that have been under development for the past several years, mostly but not exclusively in Belgian and French research centers. Much of the vocabulary used at the Brussels conference has an unfamiliar ring to practitioners trained in the United States. In fact, a recurring theme at the Brussels conference appeared to be the redefinition of the field in light of recent results in basic research. Often reference was made to "classical" system dynamics with the emphasis being on new developments within the field to update this classical view.

Without a doubt, interesting and important new concepts are in the process of development. However, it would also appear that familiar concepts are also being rediscovered and renamed with a resultant semantic confusion. As new jargon proliferates, researchers and practitioners may begin to lose an ability to communicate effectively and the possibility exists that the field may needlessly segment itself into groups that treat the same concepts and phenomena with different names.

The discussion below presents one observer's efforts to distinguish new concepts from renamed concepts from concepts that probably do not yet apply in a precise fashion to the dynamic modeling of social systems. These efforts are based on attendance at the Brussels conference and reading of the papers. Further and, obviously, they reflect the author's peculiar bias in training and experience. This review concludes by drawing several tentative inferences from these remarks concerning the sociology of system dynamics.

Evolving Concepts and Vocabulary

Although many concepts, techniques, and applications were presented at the Brussels conference, attention will be directed here primarily to the following notions receiving some attention at Brussels. Each of these notions will no doubt be more or less familiar to various researchers in the field.

The theme of the conference, "From the Simple to the Complex", reflects an interest on the part of Prigogine and his followers in a class of low order system that exhibit surprisingly complex behavior. *Bifurcated structures* or system structures with non-linear structures allowing them to transition sharply and suddenly between different behavior modes or equilibrium end states received both theoretical and applied attention in the papers of Aracil,[1] Gumowski & Mira,[2] Couvreur & Van Snick,[3] and Braunschweig.[4] The dynamics of *chaotic systems* were touched upon by Day,[5] Gumowski & Mira,[6] Day,[7] and Nicolis.[8] These systems (usually of order not greater than second or third for the cases presented) can generate unpredictable behavior, behavior that might be mistaken for random, from a totally deterministic and endogenously driven system. Closely tied to the study of *chaos* was the study of *attractors* or *strange attractors*. Apparently although chaotic systems cannot be predicted when plotted over time, when their trajectories are plotted in state space (parameterized by time) these plots often conform to stable topological formations or attractors. Apparently, some systems do not trace out neat or stable topological forms in state space and hence these systems are said to possess strange attractors. The talks of Day[9] and Nicolis[10] referred to systems that had *strange attractors*.

Some attention was paid to *deterministic vs. probabilistic* solutions to a system, notably those of Couvreur & Van Snick,[11] Mosekilde, et. al.,[12] and Prigogine's closing lecture. Here the point was made that deterministic solutions (apparently even deterministic solutions driven by stochastic terms in a brand of Monte Carlo simulation) can produce qualitatively different results than probabilistically-based solutions of the same system. These results were not claimed to be general.

Another topic under discussion by Allen,[13] De Greene,[14] and indirectly March[15] was that of *evolving structures*. Here the implication was that real systems possess structures that can and do evolve over time. Models of social systems should strive to capture this process of *structural evolution*.

Finally, the opening and closing lectures of Prigogine laid out a conceptual vocabulary that seemed to permeate all facets of

discussion at the conference. Based on his pioneering work in chemical thermo dynamics, Prigogine suggested that non-linear chemical reactions when operating far from equilibrium (that is, when treated as *open systems experiencing energy flows*) can exhibit *self-organizing structures.* The existence of such *dissipative structures* in the field of chemical thermal dynamics has been linked to several profoundly important theoretical and practical conclusions. Specifically for such systems classic concepts of entropy may not apply. A *new view of entropy* not linked by definition to the *arrow of time* emerges. In fact, for certain locally defined, open, and non-linear chemical systems, the *arrow of time may be reversed.*

In an attempt to make sense of this flurry of new discoveries, they have been grouped below into several broad sets. This grouping is based on the belief that several of these terms treat various aspects of broadly similar phenomena.

Set I: Bifurcated Systems, Probabilistic Analysis, Structural Evolution, Multiple Attractors

These terms are grouped out of a belief that they all treat an important and seminal observation. Namely — highly non-linear (bifurcated) systems when operating in a stochastic environment exhibit surprisingly complex, multi-equilibrium responses. The final pattern of system response may depend on initial conditions and stochastic elements as well as on the system's structure of equations. Failure to recognise these facts may produce analyses that are wrong.

For sure, the "classical" literature on system dynamics has not paid much attention to these very interesting phenomena. For example, two researchers in the field, Richmond[16] and Braunschweig,[17] report having "discovered" real world and important applications of these principles just by beginning to think in terms of bifurcations and stochastic simulations.

However, the enveloping of this new phenomena by new or redefined terms creates the impression that a new class of systems are under investigation — not just an interesting special case of non-linear dynamic systems. For example, Couvreur and Van Snick discuss the existence of "multiple attractors" in their one level example. A more "classical" view would have characterized the system as having "multiple equilibria." Allen discussed the "structural evolution" of an urban area simulated by his spatial model of urban growth. However, what actually appeared to evolve in his presented results was the model's behavior, *not* its structure. In fact, in spite of much abstract discussion, all concrete examples of "structural evolution" reduced to examples of "behavioral evolution." Granted, the word "structure" is a complicated one, but still it is one that is well defined in the field of system dynamics. What is gained, aside from semantic confusion, by ignoring old conventions and inventing new ones?

Laying aside quibbles over semantics, the research over stochastic bifurcated response presented at Brussels raises many interesting questions. For example, in bifurcated systems is purely deterministic simulation (perhaps with noise inputs) ever appropriate? If so, do rules of thumb exist to guide modelers concerning how much randomness can be tolerated? How many runs under what conditions would be needed to adequately explore the full ensemble of system responses? Can pedagogues suggest a catalog of bifurcations to be studied by our students? In general, do "rules of thumb" exist for helping applied modelers deal with this class of bifurcated systems?

Set II: Chaotic Systems, System Attractors, Structural Evolution

These concepts also appear to be grouped around a core of several seminal observations. Specifically, deterministic sets of low order difference (and differential) equations can produce "chaotic" behavior. Such chaotic structures may be essential to understanding economic behaviour (see Day's article in this current issue).[18]

This set of ideas as well as the previous set reinforces the classical wisdom in the field that non-linear feedback systems are extremely complex and most always more tricky to deal with than expected. Basic research into chaotic systems raises a series of challenging questions that certainly are worthy of further investigation. For example, Karsky has suggested that the addition of exponential smoothing to chaotic structures may reduce the complexity of the system's responses.[19] What happens when chaotic structures appear embedded in higher order, multiple loop feedback systems, especially when many of the loops are characterized by negative feedback? The classic wisdom states that such higher order multi-loop systems are in general insensitive to minor random shocks and changes in parameters. If chaotic structures retain their sensitivity to minor perturbation when embedded in larger systems, this conventional wisdom will need to be re-examined.

Also, are chaotic structures sensitive to discrete versus continuous formulations and does the method of numerical integration used (including the selection of step size) influence the final behavioral pattern? Does there exist a catalog of "generic structures" that typically generate chaotic behavior? Can the notion of evolving structure be operationalized in terms of the shifts in "strange attractors" within chaotic structures?

If research into questions such as these yields insights, then those involved in such basic research should be prepared to provide guidelines or rules of thumb for helping applied modelers to recognize and deal with chaotic systems. In all, the results presented in Brussels concerning chaos seem most interesting and worthy of further investigation.

Set III: Reversible Time, the Arrow of Time, Self Organizing Systems, and New Thoughts on Entropy

As discussed above, this set of concepts emerged from the pioneering work of Prigogine and his followers in the field of chemical thermodynamics. In fact, investigations of bifurcations, stochastic responses, and chaotic structures are also linked intimately to the work of Prigogine and his followers.

The seminal observation connected with this set of concepts could be roughly stated as follows: for certain low-order thermodynamic systems operating far from equilibrium and in the presence of non-linear reaction equations, classic views of entropy and time may not apply. For these open systems driven by exogenous energy flows, self organizing structures emerge. During these non-equilibrium, local and open system reactions, the second law of thermodynamics may not apply.

Certainly these observations have profound practical and philosophical implications in the physical and perhaps the biological sciences. The possibility that entropy may be reversed in local chemical reactions provides a new way of thinking about chemical and perhaps more broadly bio-chemical reactions. Such research provides the first small steps toward operationalizing the concept of living organisms as entities ultimately capable of reversing what had hitherto been theorized to be an inexorable increase of entropy throughout the universe.

However important these ideas may be to chemists and at a more broad level philosophers, the precise application of these notions to system dynamics modeling is not at all clear. Although much discussion centering on self-organizing systems and entropy occurred at Brussels, no one appeared willing to speculate on what any notion of entropy meant within the context of a systems dynamics model. Specifically has any-one ever computed the entropy of a model and what would such a computation mean?

Apparently, this third set of concepts are meant to be invoked as a "philosophical paradigm" or set of broad metaphors for reinterpreting the field of system dynamics. Of course the problem with recasting a field in metaphoric terms is that two researchers may differ over how to interpret the metaphor and scientific progress may be blocked rather than enhanced in needless semantic controversy. The real possibility exists that the field may fracture into sociological subgroups defined more by metaphoric than by substantive distinctions.

This problem is not new to the field of system dynamics. In the early 1970s (continuing to some extent on through today) the substantive field of system dynamics — an interesting and useful way of thinking about and solving problems in social systems —) became confused with the set of environmental and social beliefs that motivated much of the work centering on books such as *World Dynamics* and *Limits to Growth*. To the casual observer of the field, the basic tenets of the field could be confused with the conclusions of several studies completed within the field. This fuzzy co-mingling of the field's basic tenets with a particular set of philosophical or metaphoric orientations was confusing in the 1970s when system dynamics was aligned with ecological awareness and is confusing now when system dynamics becomes aligned with chemical and bio-chemical thermodynamics.

On the Sociology of System Dynamics
Since the Brussels conference also passed a resolution designed to establish an international system dynamics society by circa 1984, it seems appropriate to close by suggesting that the remarks above do have interesting implications for the emergence of system dynamics as a field.

First, the deliberate or inadvertent redefinition or reinvention of technical terms and concepts can and does lead to semantic confusion. Researchers who live and work in homogeneous technical communities are not troubled by the invention of new terms (in fact the coining of new jargon helps to build a sense of a research community). However when dealing with interested researchers outside such homogeneous communities, semantic confusion can impede progress in the field by slowing down the diffusion of new ideas.

Second, the field should seek a sense of "conceptual parsimony" when describing basic technical research results. Without a doubt philosophies and metaphors are important determinants of one's research agenda, but when technical discussions (such as discussions of the importance of bifur-cated and chaotic structures) become engulfed in metaphors that reflect personal beliefs more than technical results scientific progress is impeded. The field can produce fissures that are more metaphoric than substantive in nature (but nonetheless very real) and sub-groups increasingly defined by the sociology of metaphors find it increasingly difficult to communicate.

In sum, the 1982 Brussels conference provided a rich and stimulating new set of basic ideas in the field of system dynamics. However, unless problems with semantic confusion and a lack of conceptual parsimony can be attacked (realizing that problems exist on both sides of the Atlantic) rapid diffusion of new ideas and development of the field will be impeded.

The proposed formation of an internationally based system dynamics society may well provide an institutional base for attacking these two problems.

REFERENCES

1. ARACIL, J., "Order through Fluctuations and System Dynamics Models," (1982), *From the Physical Sciences to the Social Sciences: Proceedings of the 7th International Conference on System Dynamics,* June 16-18, Université Libre de Bruxelles, Brussels, Belgium.

2. GUMOWSKI, C., and C. MIRA, "Sur la description de régimes dynamiques non constants et leurs bifurcations," (1982), *From the Physical Sciences to the Social Sciences: Proceedings of the 7th International Conference on System Dynamics,* June 16-18, Université Libre de Bruxelles, Brussels, Belgium.

3. COUVREUR, P., and J.C. VAN SNICK, "Comparaison de approaches probabiliste et déterministe en présence des bifurcations," (1982), *From the Physical Sciences to the Social Sciences: Proceedings of the 7th International Conference on System Dynamics,* June 16-18, Université Libre de Bruxelles, Brussels, Belgium.

4. BRAUNSCHWEIG, B., "Structures dissipatives, dynamique des systèmes,et exploration pétrolière," (1982), *From the Physical Sciences to the Social Sciences: Proceedings of the 7th International Conference on System Dynamics,* June 16-18, Université Libre de Bruxelles, Brussels, Belgium.

5. DAY, R.H., "New Developments in Dynamical Systems Theory (Implications for the System Dynamicist)," (1982),*Paper presented at the 7th International Conference on System Dynamics,* June 16-18, Université Libre de Bruxelles, Brussels, Belgium.

6. GUMOWSKI and MIRA, Op. Cit.

7. DAY, R.H., "Complex Dynamics in the Macroeconomy," (1982), *Paper presented at the 7th International Conference on System Dynamics*, June 16-18, Université Libre de Bruxelles, Brussels, Belgium.

8. NICOLIS, J.S., "The Role of Chaos in Reliable Information Processing," (1982), June 16-18, Université Libre de Bruxelles, Brussels, Belgium.

9. DAY, "New Developments in Dynamical Systems Theory" Op. Cit.

10. NICOLIS, Op. Cit.

11. COUVREUR and VAN SNICK, Op. Cit.

12. MOSEKILDE, E., F. JACOBSEN, A. POULSEN, and S. POULSEN, "Stochastic Simulation with Dynamo," (1982), *From the Physical Sciences to the Social Sciences: Proceedings of the 7th International Conference on System Dynamics*, June 16-18, Université Libre de Bruxelles, Brussels, Belgium.

13. ALLEN, P.M., "Dynamic Modelling in Evolving Complex Systems: Towards a New Synthesis," (1982), *From the Physical Sciences to the Social Sciences: Proceedings of the 7th International Conference on System Dynamics*, June 16-18, Université Libre de Bruxelles, Brussels, Belgium.

14. DE GREENE, K.B., "Toward an Integrated Theory of Societal Macrosystems with Special Reference to the Evolution of War or Peace," (1982), *From the Physical Sciences to the Social Sciences: Proceedings of the 7th International Conference on System Dynamics*, June 16-18, Université Libre de Bruxelles, Brussels, Belgium.

15. MARCH, L. "Design, Machines and Languages," (1982), *From the Physical Sciences to the Social Sciences: Proceedings of the 7th International Conference on System Dynamics*, June 16-18, Université Libre de Bruxelles, Brussels, Belgium.

16. RICHMOND, B., "Endogenous Generation of Structural Change in System Dynamics Models: An Illustration from Corporate Context," (1981), *Proceedings of the 1981 System Dynamics Research Conference* (Andersen and Morecroft Eds.), Institute for Government and Policy Studies, State University of New York at Albany, Albany, New York.

17. BRAUNSCHWEIG, Op. Cit.

18. DAY, R.H., "Complex Behaviour in System Dynamics Models," (1981), *Proceedings of the 1981 System Dynamics Research Conference* (Andersen and Morecroft, Eds.), Institute for Government and Policy Studies, State University of New York at Albany, Albany, New York, and also DYNAMICA Vol. 8, Part 2, pp 82-89.

19. KARSKY, M., Comments at the 7th International Conference on System Dynamics, June 16-18, (1982), Brussels, Belgium.