Modelling Dynamic Systems Using STELLA II

Dynamic Modeling (Mac Version). Bruce Hannon and Matthias Ruth. 1994. Springer-Verlag, New York, 248 pp. US$59.95, ISBN 0-387-94309-9 (Mac), ISBN 3-540-94287-4 (Window), Two $3^{1/2}$" diskettes.

One of the most fundamental characteristics of the world is its being dynamic. At any organizational level or any spatial and temporal scale, one thing is always certain - changes of various sorts occur in systems of concern. As we all live in a dynamic world, our ability to understand and predict the behavior of dynamic systems is ostensibly essential to the ultimate success of our scientific or non-scientific endeavors. This ability may slowly emerge *a priori* as a result of accumulation of knowledge and experience, but unaided human mind has inherent limitations to such ability as it is only as good as one's memory and idiosyncratic interpretation. Alternatively, we can gain such ability much faster with the aid of mathematical models. However, modelling has not been an effective tool for the majority of scientists in such fields as biology, ecology, and several other natural and social sciences because of the mathematical and computer programming skills involved. Fortunately, this situation is changing as advanced computer technology and high-level simulation packages become readily available, making modelling more and more a practical matter to many who never thought that they would be able to model the systems of interest on their own.

Hannon and Ruth's book, Dynamic Modeling, is an excellent example of how one can model a variety of dynamic systems with minimal mathematical sophistication and little programming effort. Models presented in this book are based primarily on the *system dynamics* (SD) modelling methodology, and are implemented exclusively using a simulation package called STELLA II™. System dynamics, founded by Jay Forrester and his associates at MIT in the 1950s, is based on general systems theory, cybernetics, and information theory. SD emphasizes the interactions among the various parts that constitute a system and applies feedback principles to model and analyze dynamic problems. Initially developed for industrial systems, SD has found applications in such diverse fields as business, economics, psychology, medicine, ecology, resource management, and environmental science. A unique feature of the SD modelling approach is the integration of

mathematics and computer simulation. Since its inception, the simulation language, DYNAMO, has bee associated with the development of the methodology.

STELLA (acronym for Structural Thinking Experiential Learning Laboratory with Animation) was developed by High Performance Systems, Inc., Hanover, New Hampshire in August 1985 to facilitate system dynamics modelling and to make it available for even those lacking computer experience and mathematical expertise. STELLA is icon-oriented and thus brings model conceptualization and formulation much closer than they would otherwise be. The 1989 Jay Wright Forrester Award was given to the software developer at High Performance Systems for "the best published piece of work in the field between 1984 and 1989". STELLA used to be run only on Macintosh computers, but the latest release (STELLA II 3.0) has both Macintosh and PC versions. Although the STELLA software was developed based on system dynamics, it can also be used without reference to the particular modelling methodology (e.g., as a convenient differential equation solver). In their book, Hannon and Ruth have shown a number of different ways to model dynamic phenomena using STELLA II.

Hannon and Ruth's book starts with the foreword by one of the leading system analysts, Donella Meadows, who co-authored the books, *The Limits to Growth* (1972) and *Beyond the Limits* (1992), among several others. She shares with the reader four Great Learnings in her life, among which dynamic modelling happens to be the third. The book contains 32 chapters that are grouped into 8 parts, with an appendix containing information on system requirements, installation procedure, and a quick help guide for using STELLA II. In Chapter 1 (the only chapter in Part 1), the authors introduce the reader to some basic concepts and principles in modelling, and demonstrate, through a simple population growth model, the basic elements and process of modelling with STELLA II. In Part 2 (Chapters 2-7), Hannon and Ruth present some general methods for dynamic modelling, which lay the ground for the development of the rest of the book. They begin with identifying four basic model forms: stimulus-response, self-referencing, goal seeking, and goal setting models (Chapter 2), and then through an industrialization model, theyt show how a more complex model may be built from basic model forms by gradually adding the complexity (Chapter 3). In the following four chapters, Hannon and Ruth illustrate how to use STELLA II to handle time and space as two independent variables, how to model positive and negative feedback, and how to obtain derivatives for finding extreme values for state variables.

From Part 3 to Part 7 (24 chapters), Hannon and Ruth present a number of simple and yet interesting models selected from several different fields, including chemistry (Chapters 8-10),

genetics (Chapter 11-12), ecology (Chapter 13-18), economy (Chapter 19-28), and engineering (Chapter 29-31). Most chapters are short, containing only one model each, while several others include two to four. These models are presented in a fairly consistent format: introduction to the problem, model structure (structural diagrams and graphical functions), sample outputs, and STELLA II equations. Suggestions for model modifications are also discussed in some chapters. While choosing a few examples from each of many diverse fields perceivably is rather difficult in terms of representativeness, the selected models seem to represent a good coverage of the variety of systems and processes that should be of interest to modellers. For chemical processes, the authors demonstrate how to use STELLA II to model the Law of Mass Action, enzyme-substrate interaction, and chemical oscillators. As examples of genetic models, the Hardy-Weinberg Law and simple natural selection and mutation processes are modelled. The category of ecological models includes age-structured population dynamics, predator-prey interactions, and epidemics. While the 9-patch spatial predator-prey model is interesting, it also shows that modelling with STELLA II may become awkward when a system consisting of many spatial units is modeled explicitly. Ten chapters are devoted to economics, including models of competitive and monopolistic firms, profit-maximizing, opportunity cost, and competitive scarcity. The apparent emphasis on economic models reflects, to some extent, the authors' background and professional expertise.

The title of Part 7, "Engineering Models", seems a little peculiar in that the three chapters it contains discuss models that are not necessarily engineering-oriented. In Chapter 29, Hannon and Ruth briefly gives a simple example of an assembly line and discuss how to model discrete events using STELLA II (i.e., the use of conveyors, queues, and ovens, instead of reservoirs). The following chapter focuses on how to model some physical phenomena that involve gravity and acceleration, which are fine little examples of demonstrating ways of translating differential equations into STELLA II models. Chapter 31 provides some intriguing ways of modelling chaos in STELLA II for both discrete and continuous systems. As examples, Jenson chaos, Lorenz chaos, and two-well chaos are nicely illustrated. The last chapter of the book (Part 8), with only several short paragraphs, highlights some aspects of the book and calls for exchange of ideas and experience between people who are interested in dynamic modelling and the authors.

Overall, the book well demonstrates the versatility and ease of using STELLA II to model a diversity of dynamic systems. It is a valuable reference book to those who are interested in simulation modelling, but always afraid that they do not have enough mathematical and computer programming knowledge to do so. For those who thought that STELLA II was too inflexible to

model the systems of their interest, this book may help change their perception. The two diskettes accompanying the book contain all the STELLA II models presented with a run-time version of the software, and should be very helpful to the reader. Because the book is written rather succinctly, for starters it is best used together with the well-written documentation that comes with the STELLA II software. I wish that the authors had written out the corresponding differential equations for most if not all STELLA II models as they did for a few. Explicit mathematical formulations would help the reader better understand model structure and underlying mathematics, and also more easily appreciate how this simulation approach can simplity and facilitate modelling processes. After all, modelling is, in its essence, the mathematics at work.

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