WORKSHOPS

INTRODUCTORY WORKSHOP ON COMPUTER SIMULATION TECHNIQUES FOR STUDYING NATURAL SYSTEMS.
Preliminary Notes

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THE PURPOSE OF SIMULATION

There are many reasons why it is inconvenient or impossible to study natural systems in the field. In the case of karst, as for many other dynamic systems, the time scales are too long and changes are unobservable. In order to test hypotheses, processes can be greatly sped up by simulation using dynamic models. In the field of engineering, models are very frequently used when it is too costly or dangerous to experiment with the actual hardware.

A TAXONOMY OF MODELS AND SYSTEMS

Models can be classified in four ways, as follows (Shannon, 1975, p.7).

a. Static or dynamic models.
b. Deterministic or stochastic models.
c. Continuous or discrete models.
d. Iconic, analogue or symbolic models.

The first three ways, a, b, c, of classifying models can also be applied to systems. This gives eight possible types of system to be modeled. The final classification applies to models only.

Any one of the eight types of system may not necessarily be simulated by the same type of model. For instance, the distinction between static and dynamic systems depends on whether any of the independent variables in the system is time. Often, however one of the variables in a static system can be transformed into time for the purpose of, say, plotting curves on a chart recorder or oscilloscope. A real-time model can be made analogous to a static system.

Deterministic systems are ones where all the variables have particular values, governed by the state of the system. If one or more variables are governed by a probability distribution the system is stochastic. Stochastic systems are often run as deterministic models, by replacing a probabilistic variable by its mean value.

Continuous systems have variables which are continuously differentiable, whereas discrete systems are governed by events. When continuous systems are simulated on digital computers continuous variables have to be represented by series of numbers. Digital computer models are sampled data models which are discrete, whereas analogue computer models are themselves continuous. Sadly, analogue computers are now unfashionable, even though they run very much faster than comparable digital ones.

Shannon recognizes a continuous spectrum of model types. One end of the spectrum represents models which are very similar to the real system, and are dubbed ISOMORPHIC. Models which differ from the real system are called HOMOMORPHIC. The other end of the spectrum represents totally abstract or conceptual mathematical models. Most workers in the field are content to divide the spectrum into three groups:

Iconic models - those which are created in the same or a similar medium to the original, such as architects' models or working scale models.

Analogue models - those which are mathematically comparable models created in an essentially quite different medium from the original. In a way, computer software models usually fit into this category.

Symbolic models - which are mathematical models in the form of concepts and equations.

EXAMPLES OF SOME NATURAL SYSTEMS

Most natural systems are dynamic, continuous and stochastic, and this certainly applies to geomorphology. The karst model that I have been working on fits into this category. The system is dynamic since all the variables change with time. The system is continuous since none of the variables change instantaneously. It might be thought that the start of rain is an event, thus making the system discrete, but the smallest value of rainfall rate can always be smaller, so it is continuous. There is often an element of chance, or more correctly, probability, about many of the variables, for example the incidence of joints and bedding planes in the rock, and so the system is stochastic.

Traditional geomorphology has often taken systems to be discrete, which, in my view has been a mistake. For example "the plateau was uplifted, and then the rivers carved gorges....". In fact the uplifting is usually slow and the action of the rivers continues all the while.

Ecological systems or evolutionary systems can be modeled as discrete, if the birth of an individual is used as an event - which it is, since there cannot normally be half a birth, or part of an individual.

PREPARING A MODEL

Often the system simulation is part of learning about the system. The researcher starts with a fragmentary knowledge. An early model based on that knowledge will usually reveal information, or at least, raise some questions which may prompt a line of experiment.

A model consists of three parts:

a. An operation section or process. This part has a whole variety of names depending on the academic discipline or the techniques. With some discrete systems it is called a transition matrix. The process IS the system, or at least, the system behaviour. It is an information modifier, taking input information and generating output information.

b. The input information. This can often be the initial state of the system, but may incorporate other information. It very often incorporates feedback, or information derived from the output of the process.

c. The output information. This is often the new state of the system, or may embody other derived information.

It is important, when creating a model, not only to classify the model and the variables correctly, particularly if they are of mixed type, but to identify the input information, the process and the output information.

With stochastic systems a very useful technique is the Monte Carlo technique. Where an input signal (a trigger, or driving function) is made to be random. The random signal is fed into the process for a length of time to see if the output stabilizes.

I am using the Monte Carlo method to simulate random rainfall, rock jointing, and other variables to see if my ideas about how tower karst develops will generate a stable tower shape. The resulting shape is checked against some typical samples such as Mount Etna at Rockhampton or the Royal Arch at Chillagoe.

A WORD ABOUT PROGRAMMING LANGUAGES

Choice of programming language can get quite emotional as most people have their favourites. This a personal view only. FORTRAN is a traditional medium, since it has very powerful mathematical routines, although I have never used it. BASIC is often used, but I believe that its value is extremely limited, because of slowness and lack of structure. Many people are using C now but it is not really designed for simulation. MODULA 2 is probably the best option, but I use PASCAL, and Borland TurboPASCAL is undoubtedly the best package for PC's. There are also many proprietary software simulation packages on the market.

REFERENCE

SHANNON, R. E. (1975). **Systems Simulation: The Art and Science.** Prentice-Hall.

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