COMPLEX PROCESS MODELS AND THE UNDERSTANDING OF PREHISTORIC CHANGE

James Doran
Computing Centre
University of Essex
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Introduction

The use of the digital computer in archaeological work is now widespread. A wide variety of computer-based techniques of data capture, data handling and data analysis have been applied or even developed in archaeological contexts, and some of these are now virtually in standard use. A number of introductory texts on computer archaeology have either appeared (for example, Doran and Hodson 1975) or are on the point of appearing.

But it is at least arguable that archaeology has as yet learned very little from computing science itself: all that has happened is that archaeologists have found it useful or interesting to use techniques (mathematical, statistical or non-numerical) which happen to require a computer to be fully effective. The conceptual content of computing science has remained largely unexplored.

But what can computing science, a highly technical subject covering the theory, design and use of computing systems, possibly have to offer to archaeology concerned as it is with people and societies as they existed and developed in the past? In this paper I shall suggest that one link between the two disciplines is, or should be, the abstract but powerful notion of a process.

The explanation of prehistoric change

Before discussing what is meant by a process in computing science, I shall introduce a subsidiary theme: that of the crucial importance in any problem-solving or understanding activity of using the "right" conceptual framework. By a "conceptual framework" I mean a relatively coherent collection of concepts, and of facts or beliefs expressed in terms of those concepts. No doubt most would accept the need to approach a problem in the right way and with the right intellectual background. It may be less obvious that one's conceptual "kit" is significant at a much more mundane everyday level. However computing science experiments demonstrate that even the most apparently elementary acts of observation are conditioned by conceptual repertoire (see, for example, Winston 1975) and sociologists have explored the dependence of this repertoire on social environment. In archaeology the development of the "new archaeology" is a recent and dramatic example of a conceptual framework being propagated through a specialised social group, and then having a practical impact by guiding and shaping research activity.

It is instructive to look from this standpoint at a problem which is fundamental to archaeological research: the understanding and explanation of prehistoric change. To quote Plog (1974, p.8) "Archaeologists can fruitfully focus research upon this question: Why do cultures change as they do? In other words, explaining change should be our primary undertaking." The general exhoratation to explain change naturally takes a variety of particular

forms: questions of urbanisation, plant domestication, site abandonment and so on. But what is striking is the range of relatively distinct intellectual stances which have been taken by prehistorians trying to answer such questions. Perhaps the most important are those which variously emphasise:

(a) the actions and characteristics of individuals and peoples -- especially migrations. Much earlier work was couched in these terms.

(b) ideas of innovation, diffusion and evolution. Again the basis of much traditional study, but with the emphasis on the development and transmission of ideas.

(c) social behaviour and social organisation. Childe (1958), for example, puts social and economic organisation at the heart of his discussion of urbanisation and the development of metal working around the Mediterranean and in temperate Europe.

(d) ecological approaches -- studies of man in his environment, sometimes as an application of systems analysis.

(e) general systemic approaches -- identification of subsystems and their interactions, sometimes coupled with the establishment of mathematical relationships between key indices (for example, Plog, 1974).

Of course, these differing approaches to the study of change are by no means entirely distinct. For example, advocates of systemic approaches would certainly try to take account of social organisation and ecological environment. Nevertheless the conceptual repertoire mobilised certainly varies greatly from one orientation to another. However I suspect that, in anything like their present form, none of these orientations will prove adequate to answer the questions we would like to ask. Admittedly this pessimism is little more than a specialisation of the widely held view that social science as a whole is in considerable conceptual difficulty. More concretely, none of the intellectual orientations listed above has given rise in archaeology to convincing formal models: in particular the mathematical models based on the systemic approach have so far been distinctly primitive. It is arguable that what is needed in the study of culture change is some flexible and yet rigorous way of capturing in thought and in formal models the extremely complex developments and interactions that occur in society. This brings me back to the notion of a process.

Processes and process models

By a process I mean the temporally extended equivalent of an entity. It is something changing relatively autonomously: for example, the time-trajectory of a star, or of a person, or of a population. Two or more processes may interact and one process may be a sub-process of another.

By a process description I mean a set of statements about the behaviour of a process. A comprehensive process description might reasonably be called a process specification.

By a process model I mean a model which is itself structured as a set of interacting processes: perhaps a "working model" in the usual sense, perhaps a set of processes within a computing system. Naturally one would expect process models to be used to model systems of processes.

It is worth noting that from this standpoint a mathematical model (one or more equations) involving time is a process description, not a process model. It has the useful property that it can be used as the basis for inferences about the properties of the process it describes.

Finally, there is the rather uncertain notion of a process concept, that is, a concept which is itself a process. The suggestion is that the primitive elements of our thought are often more like processes than time-independent entities. Whatever the details, it is surely the case that we often think in terms of processes: the way a pit fills, or a pot shatters, or a building collapses. All the conceptual frameworks for social change listed earlier certainly utilise many process concepts. Thus the issue here is whether computing science can offer more.

Processes in computing science

The concept of a process is prominent in a several branches of computing science, but is handled rather differently in each. For example, a computer operating system, the extremely elaborate program system which organises and controls the flow of work through the machine, is commonly conceptualised as a set of interacting processes each with its own requirements and resources. Operating system theory covers strategies for the design and analysis of operating systems in process times, together with rudimentary formalisms within which system validations may be attempted (see, for example, Horning and Randell, 1973).

Probably more immediately relevant to archaeological needs, however, are process oriented ideas associated with computer simulation studies (for a good introduction to computer simulation see Fishman, 1973). The following quotation will give something of a flavour of these ideas:

> "An ALGOL program (block) specifies a sequence of operations on data local to the program, as well as the structure of the data themselves. SIMULA extends ALGOL to include the notion of a collection of such programs, called processes, conceptually operating in parallel ..... The process concept is intended as an aid for decomposing a discrete event system into components, which are separately describable. In general a process has two aspects: it is a data carrier and it will execute actions." (Dahl and Nygaard, 1966).

Ofcourse, there have already been some substantial archaeological simulation studies (for example, Zubrow, 1975), but the concepts which underlie the design of simulation programming languages like SIMULA (and its successor, SIMULA-67) are a good deal more sophisticated than those which archaeologists seem so far to have assimilated. Thus if archaeologists press on with computer simulation work there is a potential double benefit: a conceptual benefit, centering on the notion of a process, which looks particularly relevant to the study of cultural change, together with the practical "know-how" needed to design and exploit rigorous process models. The benefit is potential not guaranteed. It is to be seen just how far and how often cultural systems can be conceptualised in strict process terms.

The final branch of computing science I shall mention is artificial intelligence: the theory and design of systems which can reason using ordinary everyday knowledge and understanding (see, for example, Jackson, 1974; Winston, 1975). The goal of a typical artificial intelligence project might well be a computer program capable of answering intellectually non-trivial questions about some particular data base posed in some substantial subset of natural language. For an example of just such a project concerning a corpus of archaeological material -- graeco-roman amphorae -- see Borillo, 1978. Other typical artificial intelligence projects are concerned with the interpretation of visual data as indicated earlier.

Artificial intelligence programs are intended, obviously, to display at least primitive forms of such abstract cognitive capabilities as planning, learning, hypothesis generation, and understanding. Typically they turn out in practice to be both complex and highly sophisticated in computing science terms. Many have been explicitly written as sets of interacting and cooperating processes each of which has its own capabilities and knowledge. In such a system the control regime within which the processes exist is of great importance. The properties of the system as a whole emerge from the process components and the way in which they are integrated.

Artificial intelligence studies lend powerful support to the proposition that process models are extremely useful tools. But at first sight it seems absurd to suggest that reasoning systems could themselves be used as models of social systems. Yet the suggestion may have some merit in it: after all, we all often talk as if groups and organisation took decisions in some corporate sence. It might seem reasonable to model them accordingly. In fact the qualities which it is legitimate to attribute to organisations are a major source of debate in the sociology of organisations. For an archaeologist the illuminating observation may be that there is no real demarcation between the systems and system properties studied by general systems theorists, and the reasoning systems and properties which are the subject of artificial intelligence research. If general systems theory has something to offer of value to archaeology, as is widely accepted, then so also must have artificial intelligence. Just how far reasoning system concepts and models can be generally useful remains to be established.

Concluding remarks

In this paper I have presented in outline an argument leading to the conclusion that process models as understood among computing scientists, are likely to prove useful in the study of prehistoric change both conceptually and in practical computer simulation studies. I am well aware that to gain more than a preliminary hearing such an argument must be supported by detailed case studies. I am sure that detailed studies will be forthcoming, if only as a natural extension of existing computer simulation work. In the meantime, if any archaeological reader is led to probe a little more deeply into the conceptual content of computing science I shall be well satisfied.

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