A CONTRACT-STRUCTURE MODEL OF SOCIOCULTURAL CHANGE

Jim Doran

Department of Computer Science
University of Essex
Colchester CO4 3SQ
United Kingdom

ABSTRACT

This paper reports initial experiments with a computer program which embodies an abstract model of a sociocultural system. The model displays a form of spontaneous collapse. Central to the model is the adoption and discard of mutually beneficial and cumulative contracts between the component actors of the system.

INTRODUCTION

It is apparent that archaeologists, indeed social scientists generally, lack effective sociocultural theory. We cannot explain in any deep, systematic and agreed way the longterm dynamics of sociocultural systems as we observe them. Although a wide range of theoretical approaches has been attempted (Wenke, 1981) the climate is more one of debate and disagreement than of progress.

It is widely felt that progress in the effective deployment of formal methods in archaeology is being prevented, or at least made much more uncertain, by this lack of rigorous sociocultural theory. In spite of several attempts in recent years to establish some kind of mathematical or computational basis for theory (briefly reviewed in Doran, 1986), the archaeological record is still necessarily interpreted by reference to at worst unreliable common sense, at best the unformalised insights of cultural anthropology.

If archaeology is to become a more exact science this must change. The program and initial experiments which I shall describe in this paper illustrate a long term approach to the development of sociocultural theory which emphasises (a) a particular view of sociocultural systems as distributed problem-solvers, and (b) the role of the computer as a tool for establishing the implications of sociocultural hypotheses

THE ORIGINS OF THE MODEL

In the present state of sociocultural theory it seems premature and perhaps even counter-productive to try to model specific sociocultural systems. What seems to be needed is the exploration of processes that may be capable of generating observed sociocultural behaviour in general. If this exploration proves productive, it should then be possible to look into the archaeological record for evidence of particular processes at work. It is a

truism that if you have some idea of what you are looking for, it is much easier to find it.

In this paper I follow Renfrew in focussing attention on sudden sociocultural collapse without apparent external cause. Thus:

"Many writers in different areas have described, quite independently, the archaeological evidence in their region which clearly documents the sudden collapse of an early state society." (Renfrew, 1979, p 481).

and

"The culture trajectory can be analysed in terms of continuous systemic change, without any necessary appeal to external factors or diffusionist explanations. For processual archaeologists, sudden change, discontinuous change, remains a problem." (Renfrew, 1978, p 203).

Renfrew looked to catastrophe theory for insights into the origins of discontinuous change, but without claiming major advance in understanding by so doing. In related work, Allen(1982) has argued the relevance of 'dissipative structures' and multiactor system concepts to the emergence of modern urban structure including global and local fluctuations. The CONTRACT model I describe here has a number of aspects in common with Allen's work.

The CONTRACT model is based on three main assumptions. The first is simply that a sociocultural system may usefully be modelled in abstract computational terms. The second assumption is that a sociocultural system may be regarded as a distributed problem-solver, that is, it is solving the problem of how best to manipulate its environment in order to maximise its own 'wellbeing'. The system is distributed in that there are multiple loci of decision, actors, each of which has only partial knowledge, and in that the criterion of success, 'wellbeing', is itself distributed over the decision making loci and locally defined. The third assumption is that the knowledge which the problem- solver necessarily uses to solve its problem is to be identified with cumulative technological knowledge cooperatively deployed.

The model's more specific origins lie in:

-- Flannery's (1972) cybernetic 'control hierarchies', associated with specific 'evolutionary mechanisms' such as 'promotion' and 'linearisation', and (following Rappoport) the concept of 'pathologies' such as 'hypercoherence'.

-- my own previous work (Doran 1982) on the computational modelling of sociocultural systems and in particular the EXCHANGE model (Doran and Corcoran, 1985) of which the CONTRACT model is in some respects an abstraction.

THE CONTRACT MODEL

The essentials of the CONTRACT model are as follows:

-- There is a 'spatially' distributed set of actors. Two actors may or may not be neighbours.

-- Two or more neighboring actors can form 'contracts' to their mutual quantified 'benefit'.

-- Each contract can itself participate in higher contracts, so that multiple hierarchies of contracts are possible

-- In each time unit each contract receives benefit from the higher contracts in which it participates, and itself yields a benefit. The sum of these is distributed amongst its own participating contracts or actors. The benefit accumulates with the actors at the base of the contract structure.

-- In each time unit contracts may be added wherever an addition is possible but the probability of this happening on any particular occasion is low. Each actor and contract has a total workload limit and no contract may be added which causes any actor's or contract's workload limit to be exceeded. The workload is determined by all the contracts in which the actor or contract directly or indirectly participates.

-- Contracts are discarded when a participating actor or contract decides that its return from the contract is no longer sufficient. This decision is made on the basis of only LOCAL information. This 'limited horizon' effect (an aspect of the broader notion of cognitive economy -- see Doran, 1982) is a central feature of the model. When a contract is discarded, all contracts which it directly or indirectly supports are necessarily also discarded. This is the immediate mechanism by which collapse phenomena arise.

The basic cycle of the model is thus

```
REPEAT

      add some new possible contracts;

      remove some existing contracts which are no longer locally
        acceptable
UNTIL

      experimental trial ended
```

Recall that interest is primarily in the behaviour which such a contract structure can display and, in particular, in possible mechanisms of spontaneous collapse. The most obvious association with actual sociocultural systems is obtained by identifying actors with settlements and contracts with specific forms of technological cooperation.

THE PROGRAM

A program has been written in PASCAL which implements a particular version of the CONTRACT model. Although relatively simple, this program necessarily contains much detail additional to the basic structure of the model given above.

In the existing program:

-- a uniform spatial array of actors is implemented

-- two contracts are neighbouring when they have neighbouring supporting contracts or actors.

-- only contracts involving exactly two participants are implemented, and benefit is shared equally between the participants. The benefit derived from a

contract depends only upon its level in the contract hierarchy: the higher the level, the greater the benefit. The benefits do NOT vary with location or time.

-- a contract is deleted, along with those in which it directly or indirectly participates, when the benefit which it provides is less than the average provided by its neighbours, provided that a minimum number of neighbouring contracts exist (currently 4) and that the participants of the contract have a relatively high workload.

For each basic cycle of the model, the program provides full and/or summary information about the contracts in existence and the benefits reaching the individual actors.

EXPERIMENTAL RESULTS

Initial experiments have been conducted for a range of spatial layouts, workload limits, new contract probability settings and time durations.

Figure 1 and Table 1 show results obtained in a typical experimental trial. In this experiment a uniform 9 x 3 array of actors was employed, with a 0.1 chance of a contract being inserted (in each situation where a contract could be inserted) on a particular cycle, and a loadlimit for each actor/contract of 10. Figure 1 shows total benefit reaching the actors plotted against time over a period of about 25 cycles. A drop from an initial plateau is followed by an erratic climb to higher and higher total benefit which is in turn followed by a major sustained decline. Table 1 shows the actual 'spatial' distribution of benefit at the benefit peak and at the following trough. Notice that the 'collapse' is uneven being less severe on the left than on the right. During this period approximately 100 contracts were in existence at any one time distributed over about 6 levels.

The experiments so far performed demonstrate the following behaviour of the contract structure:

--- trend upwards in the total benefit reaching the actors

--- spatial variation in the benefit reaching the actors

--- tendency to low benefit at spatial boundary

--- sudden global collapses in the contract structure and consequently in the total benefit to the actors

--- localised collapses including cases where the collapse has proved irreversible

--- a 'domino' effect whereby a collapse in one part of the structure leads to successive partial collapses elsewhere.

These phenomena emerge from the precise mechanisms by which contract hierarchies are built and then dismantled in the light of local factors. They occur even though the 'environmental' context of the actor system is constant in time and space.

DISCUSSION

The experiments demonstrate a mechanism of sudden, discontinuous collapse not provoked by change external to the system but brought about entirely by processes within it.

However, the experiments so far performed do not constitute a systematic exploration of the properties of these processes and this kind of structure. For example, the effects of variation in the decision rule by which contracts are discarded is both central to the study and yet to be assessed.

In general, the properties of the model cannot be predicted in any detail in advance of experimentation. However, if the growth of the contract structure is regarded as a distributed search for the optimal contract structure, meaning that contract structure which yields the maximum possible total benefit to the actors, then the tendency of the structure to stick for a time in suboptimal configurations before 'backtracking' and doing better is no great surprise. Indeed, what the contract adding and deleting mechanisms do is to provide an effective locally driven backtracking mechanism. The conditions under which the search procedure will converge to a stable optimum are not known -- and, as concerns sociocultural systems, probably irrelevant.

Of course, there can be no proof that this model and the processes which it contains reflect actual sociocultural phenomena. Nevertheless, they do seem at least as plausible as alternative formulations and, for example, offer a relatively concrete interpretation of Flannery's concept of 'hypercoherence' as a 'pathology' which can afflict sociocultural systems: too great integration, so that the collapse of the part brings down much of the whole.

The relationship of the CONTRACT model to, for example, catastrophe theory and to established models of settlement patterning is yet to be examined in any detail. When this latter connection is made, it should indicate how best to relate considerations at this level of abstraction to the data of the archaeological record.

CONCLUSIONS

The initial experiments reported in this paper indicate that variants of the CONTRACT model may be able to contribute to our understanding of the processes of sociocultural change. They also support the contention that using a computer to explore the consequences of sociocultural assumptions is a viable way to build longterm sociocultural theory and one which complements direct examination of the archaeological record.

ACKNOWLEDGEMENTS

This paper has been written during a visit to the Institute for Pre- and Protohistory of the University of Amsterdam. I an most grateful to the members of the Institute, especially Bert Vooripps and the TIA group, for their hospitality.

REFERENCES CITED

Allen, P.M.
1982 The Genesis of Structure in Social Systems: the Paradigm of Self-Organisation. In Theory and Explanation in Archaeology eds. A.C.Renfrew, M.J.Rowlands and B.A. Seagraves. New York: Academic Press. pp. 347-374.

Doran, J.
1982 A Computational Model of Sociocultural Systems and their Dynamics. In Theory and Explanation in Archaeology, ed. A.C. Renfrew, M.J. Rowlands, and B. Seagraves, pp 375-388. Academic Press, New York.

Doran, J.
1986 Formal Methods and Archaeological Theory: a Perspective. To appear in World Archaeology, 18(1).

Doran, J. and G. Corcoran
1985 A Computational Model of Production, Exchange and Trade. In To Pattern the Past, ed. A. Voorrips and S.H.Loving, pp 349-359. Journal of the European Study Group on Physical, Chemical and Mathematical Techniques Applied to Archaeology, 11.

Flannery, K.V.
1972 The Cultural Evolution of Civilisations. Annual Review of Ecology and Systematics 3:399-426.

Renfrew, A.C.
1978 Trajectory discontinuity and morphogenesis, the implications of catastrophe theory for archaeology. American Antiquity, 43:203-244.

Renfrew, A.C.
1979 Systems Collapse as Social Transformation: Catastrophe and Anastrophe in Early State Societies. In Transformations: Mathematical Approaches to Culture Change eds. A.C.Renfrew and K.L. Cooke. New York: Academic Press. pp. 481-506.

Wenke, R.J.
1981 Explaining the Evolution of Cultural Complexity: A Review. In Advances in Archaeological Method and Theory, vol. 4, ed. Michael B. Schiffer, pp. 79-127. Academic Press, New York.

DORAN

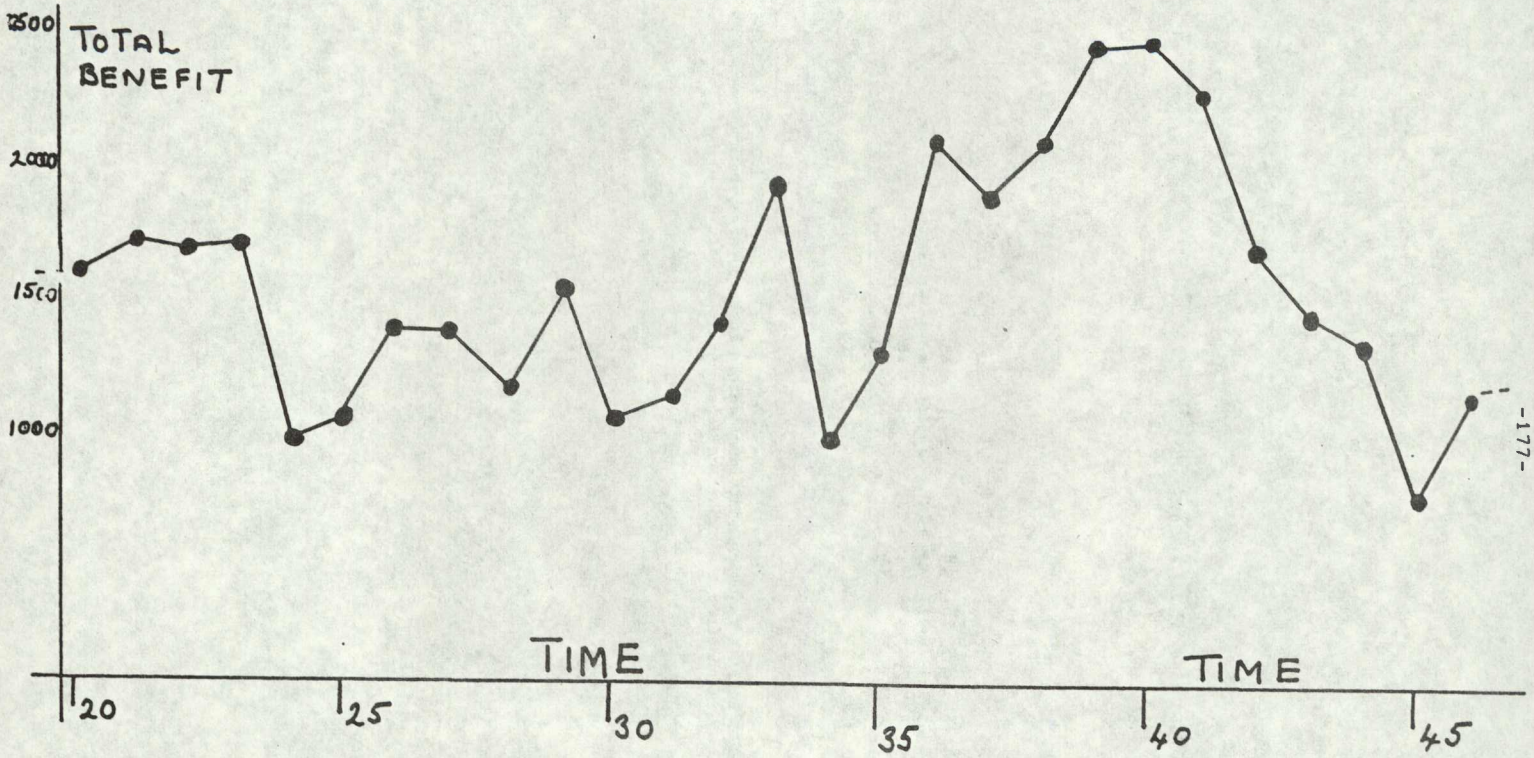

FIGURE 1 : TYPICAL GRAPH OF TOTAL BENEFIT AGAINST TIME

oran

TIME 40:

56	154	75	92	69	79	5	51	96
69	108	57	97	159	186	178	117	151
46	48	128	90	102	83	73	16	69

TIME 45:

19	60	40	19	14	11	11	43	41
35	58	32	12	28	23	23	27	39
24	29	43	21	23	16	19	26	28

Table 1: Benefit reaching individual actors in 9 x 3 array before and after the major 'collapse' shown in figure 1.