23

Second generation expert systems, explanations, arguments and archaeology

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In this paper I present a new approach to the design of expert systems in archaeology. An attempt is made to respond to the criticisms voiced by the potential users of such expert systems with a system which is flexible, natural and non-intrusive. This is achieved by using stylized argument exchange as the central paradigm for the system. The approach is illustrated in terms of a design for a program—the Argument Support Program for Archaeology (ASPA).

In recent years workers such as Huggett, Baker and Reilly at the Research Centre for Computer Archaeology have eloquently voiced concerns about the use of expert systems by archaeologists (Huggett 1985, Huggett & Baker 1985, Baker 1986, Baker 1988, Reilly 1985).

These researchers mention several problems they have encountered or foresee with the introduction of expert systems in archaeology. The problems range from lack of awareness on the part of the potential user, through the inadequacy of present expert systems, to the possible theoretical changes which may be brought about by the use of expert systems. In the past many expert system researchers have attempted to solve the problem of user resistance to expert systems by extending the explanation capabilities of these systems in order to give the user a more perspicuous view of the system's reasoning. This solution is woefully inadequate if only because it fails to take account of what is perhaps the predominant difficulty raised by the criticisms of Huggett and others *i.e.* the possibility that users fail to make use of expert systems not because they cannot adequately assess the reasoning used by the system but because they feel that the use of such systems is detrimental at a theoretical level to the proper operation of their discipline. I will concentrate on three problems here:

1. The *formalization* problem *i.e.* an inadequate model of an area of archaeological expertise may be used.

> ...the degree of formalization necessary to construct an expert system is a form of reductionism, in that the translation of knowledge from the

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> implicit to the explicit will inevitably involve the loss of elements in the process [Huggett 1985, p. 135]

2. The *fossilization* problem *i.e.* the domain knowledge contained in the expert system may come to be regarded as fixed and complete.

> ... expert systems potentially present the additional hazard of fossilising the 'particular conceptual framework' that was current at the time of the abstraction... Archaeological knowledge is in a state of constant flux: systematising that knowledge could have serious implications for its future development. [ibid]

3. The problem of the *partially non-deductive* nature of archaeological reasoning.

> The formal, fundamentally deductive reasoning of an expert system may be inapplicable when dealing with some types of archaeological problem... [ibid]

I suggest in this paper that one possible solution to these worries lies in the introduction of what has been called *second generation expert systems* (Steels 1987). Such systems can be distinguished from earlier expert systems in three ways (a) in their mode of interaction with the user (b) in the sorts of knowledge representation formalisms they use and (c) in their capacity to learn. In what follows I will concentrate on the mode of interaction which, in my opinion, determines both how knowledge is represented and what is learnt.

Recently a paradigm has begun to emerge which promises a more integrated framework for the design of interfaces for expert systems. In this paradigm there is as much symmetry as possible between the operations that the user and system can perform. I shall introduce two main types of second generation expert system interaction—the *critiquing* model and the *cooperative* model. As an extension of these I propose the notion of *arguing* expert systems (AES). The AES approach incorporates a more natural framework than either of its immediate precursors in that explanation is integrated into the stylized argument exchanges which can occur between the user and the system. Thus, in the AES approach, both user and system can be called upon to give explanations or justifications during an exchange.

The Argument Support Program for Archaeology (ASPA)—which is described in this paper and is currently being implemented as part of my PhD research—is particularly suited to non-formalized domains such as archaeology and other areas of the humanities. This is because it embodies a model of a means of acquiring knowledge through argument which, while it is pervasive throughout our academic and, indeed, non-academic culture, has greatest application in the humanities. *ASPA, in brief, attempts to model the colleague in the office next door on whom you try out your ideas and from whom you expect useful, informed and sustained criticism and suggestions.* Since the humanities lack the hard scientific evidence provided by experiment in the physical sciences, these sorts of exchanges are important. Archaeology itself falls somewhere between a science and a humanity. However, given the paucity of the physical remains of our forebears, archaeology requires argumentation if it is to give structure and meaning to the facts unearthed in excavation.

In this paper I will look briefly at the history of explanation and the nature of critiquing and cooperative expert systems. I will then delineate the main features of ASPA and end with a discussion of archaeological reasoning and archaeological theory and the relevance to these of the approach represented by ASPA.

23.1 Explanation, argument, critiquing and cooperation.

The attempt to add 'explanation' capabilities to expert systems has been pursued since at least the mid-seventies. The Mycin expert system (Buchanan & Shortliffe 1984) for the diagnosis of bacterial infections incorporated facilities for answering *Why?* and *How?* questions about the system's reasoning. Basically a *Why?* question allows the user to query why a particular request has been made by the system whereas a *How?* question is a request for the chain of reasoning leading to some conclusion by the system. These facilities were incorporated into the Emycin shell which is a domain-independent version of Mycin and which is the prototype for many of the expert system shells currently available. Since these systems only provide a trace of the inferences the system makes, they remain largely unintelligible to the majority of users. There are also problems in suiting the explanations given to the abilities and knowledge of the particular user. Explanation facilities have improved only slightly over the past ten years although there has been much research on different approaches to the problem. These can be divided into those which concentrate on the development of new forms of representation of the target domain and the system's reasoning (Clancey 1983, Hasling *et al.* 1984, Swartout 1983) and those which focus on producing a more human like exchange between the system and the user (Weiner 1980, Goguen *et al.* 1983) although inevitably there is a great deal of overlap between them. The following two sections briefly describe examples of the latter which were influential in the development of the AES approach to the problem.

23.1.1 The critiquing approach

In simple terms an expert system designed in terms of the critiquing approach is one which, instead of offering a decision or piece of advice to the user, accepts the user's decision or plan and subjects it to *critical evaluation.* (Langlotz & Shortliffe 1983, Miller 1983) The program will usually do this by comparing the user's decision or plan with its own and commenting on and/or explaining the significant differences between them. This goes some way towards obviating the second inadequacy mentioned in the previous paragraph since it is rendered more likely that the program will produce explanations which are relevant to the needs of the particular user.

The critiquing approach does not *on its own* represent a solution to the problems of explanation. However, it is obvious that adequate explanations will not be forthcoming from an expert system unless this includes elements from the critiquing approach. This is because the critiquing approach at least renders the explanations it provides more suitable by focusing on the user's own plan, solution or diagnosis. One possible development would be a system where both the user and the system can provide and criticise plans or other recommendations and pursue lines of reasoning stemming from these. This is the underlying idea behind the cooperative approach.

23.1.2 The cooperative approach

The cooperative approach embodies a shift in emphasis from a model of expert systems as Delphic oracles toward a more democratic model in which the system and the user act together to solve a problem. (Rector *et al.* 1985, Kidd 1985, Wordern *et al.* 1986, Knight 1986) This may involve, as in the suggestions of Kidd (Kidd 1985), a system which is capable of a process of negotiation in order to produce the best explanation in answering the user's query.

The basic reason for the introduction of the cooperative model is the extreme reluctance of users to accept expert systems. One possible means of overcoming this reluctance is to have a system which does not provide a once and for all answer but which *cooperates* with the user in performing some task. As part of the model, the decisions of the system can be overridden by the user in such a way that the system will take account of this in subsequent reasoning. In one sense the cooperative model can be seen as an extension of the critiquing model in that it is one function of an assistant to criticise the decisions of the person being assisted. A full assistant will however need to have knowledge not only about the domain but also about how this domain knowledge is organized as well as about the sorts of actions appropriate for an assistant.

The chief interest of this research is in the alternative model of explanation it suggests. The explanation is situated in an ongoing cooperative exchange. During user and system cooperation in a task, the system provides explanations of its decisions and expects explanations of the user's decisions.

The cooperative approach overcomes problems raised by inadequate explanations by allowing a two way exchange. Thus the focus of the exchange can be provided by either the system or the user. Unlike the critiquing approach the system can thus acquire as well as display knowledge and aid the user in articulating his or her reasons for some statement. As we shall see, the AES paradigm not only allows mixed initiative dialogues but also conducts these in terms of the sort of informal logic we make use of every day in forming and attacking arguments.

23.1.3 The arguing expert systems approach

The AES approach is an organic development of the critiquing and cooperative approaches. An expert system exemplifying this approach can be seen as one which allows either the system or user to put forward explanations, plans or decisions in the form of arguments and expects the other to criticise these by finding weaknesses or alternative arguments. The system can acquire new knowledge by changing its knowledge base in the face of strong user arguments. The main differences between it and the cooperative approach are i) that a system based on this paradigm is constrained to being an assistant in one task—the production of arguments; ii) the exchange of beliefs and their rationales between the system and the user is *sustained* in an exchange which simulates as closely as possible an argument between human participants.

Explanation is thus viewed as having its rightful place within an ongoing argument exchange. Either side in the exchange can be expected to produce an explanation. Conversely, either side can use this explanation as a means of acquiring new knowledge. The AES approach thus integrates knowledge acquisition and the display of expertise. This integration in itself goes some way towards the solution of the formalization and fossilization problems mentioned above since the archaeologist user of the system can convince the system that it must integrate new knowledge into its knowledge base.

23.2 Argument support programs

An argument support program (based on the AES approach) is a system which combines many of the ideas from the critiquing and cooperative models with notions from informal logic (Toulmin *et al.* 1979), studies of dialogue (Reichman-Adar 1984) and work on the computational modelling of argumentation (Flowers *et al.* 1982, Alvarado *et al.* 1986, Cohen 1987). In designing ASPA, I have also been influenced by the work of J-C Gardin and his colleagues (Gardin 1980, Gardin *et al.* 1987). The result is a model of a system in which there is greater symmetry between the operations possible for the user and the system. For instance, as in the critiquing model, either the user or the system can put forward a point of view with its accompanying rationale. Unlike the critiquing model a sustained debate can then ensue in which either side can provide supporting, attacking or alternative arguments or make requests for clarification of grounds, explanations or factual information. ASPA, while acting as an assistant in the development of an argument, will nonetheless make every attempt to overturn the user's argument. This is because: (a) the system must have good reasons for changing its mind and (b) the best way to develop an argument is to have an opponent who adopts the opposing point of view.

In the remainder of this section I will present (i) a general model for an argument support program and (ii) a sketch of the design for a particular program which embodies the model.

23.2.1 The model

If an exchange between two participants is to be regarded as an argument it must have at least the following components. Human argument exchanges will include other components some of which, such as common sense knowledge, are not easily captured on a computer.

- Argument is an *exchange* between two or more participants. As such it must have a *symbolic medium* capable of sustaining at least an approximation to natural language interchanges.

- An argument, like other conversations, is composed of *moves* (cf. Reichman-Adar 1984). A move being a description of a chunk of the interchange which is described in terms of the purpose of the agent instigating the move. For instance, during the course of an argument, a participant will attempt to defend a claim s/he has made by means of a *support* move.

- These moves have *rules* which govern whether or not they are regarded as legal by the participants.

- Participants take *turns*. In any well ordered debate an implicit mechanism for turn taking will be in operation.

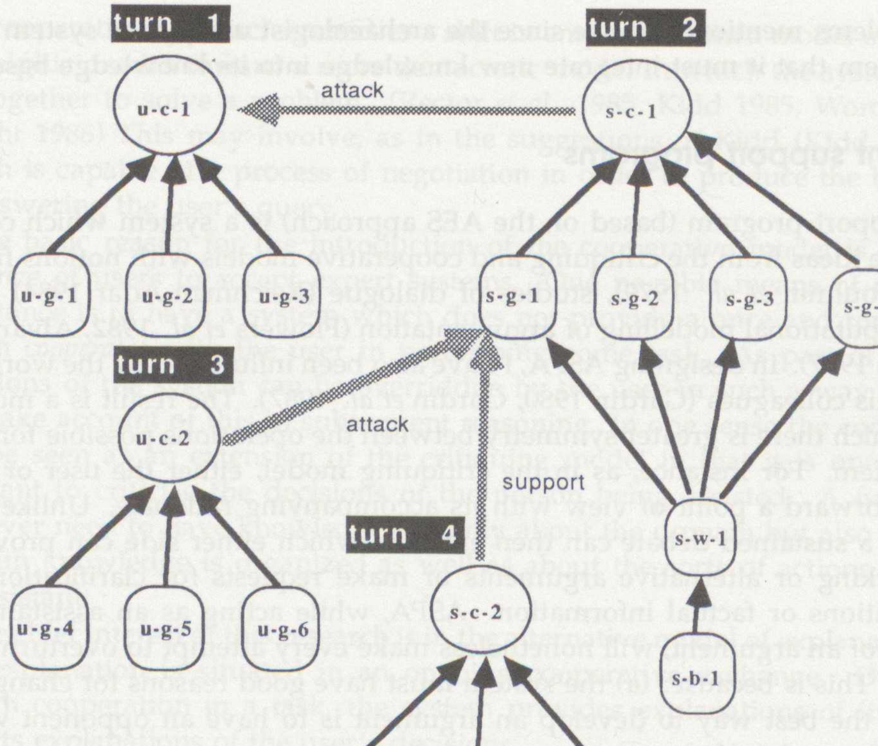

Figure 23.1: An argument network

- During a move an *argument step* is produced. By argument step I mean the set of related propositions which make up the contents of a move in an argument exchange. An argument step is composed of a claim with supporting grounds. Grounds can be related to claims by warrants or derivation rules drawn from common sense or accepted as conventional in the particular domain. The warrant can be given a backing or statement of provenance or authority (Toulmin *et al.* 1979).

  An *argument exchange* or debate is composed of a sequence of these steps which may be spread over several turns in the argument. There are relations of *support* or *attack* between the claims of previous and subsequent steps. The exchange can be represented diagrammatically as in Fig. 23.1 (in which 'u-c-1' stands for user-claim-1, 'u-g-1' for user-ground-1 and so on). Here an exchange is represented in which the user puts forward and justifies a claim which is attacked by the system with an argument fully supported by reasons and with a warrant and backing.

  The user responds by attacking one of the system's grounds, whereupon the system retaliates by finding further support for this ground.

- One of the participants can *win* the argument. This should result in a change in the beliefs of the loser. Since we are not ideal reasoners it is rarely the case that human/human arguments have this result.
- If a participant can win/lose, s/he can also have *strategies* or plans which represent a means to the goal of winning. Conversely the other participant can have counter-plans which attempt to subvert those of his or her antagonist.
- Again, if there are to be winners and losers, there must be a means of *assessing* the strength of the overall argument.
- Arguments can be said to represent the *viewpoint* of the arguer. They are also frequently argued from some other point of view adopted for some specific occasion or in responding to a particular antagonist.
- It is possible to distinguish different *types of argument* depending on the type of reasoning involved. Thus we have deductive, causal and analogical arguments. Most arguments, however, are composed of mixtures of the different types of reasoning.
- Humans commit to *memory* at least the gist of arguments, standard patterns of argument for a discipline and good arguments.

While the above are necessary components for an arguer, various compromises and elaborations have had to be made when designing a viable system, as we shall see in the next section.

23.2.2 The program—ASPA

ASPA (see Fig. 23.2) is being implemented in Prolog on a Macintosh Plus microcomputer and is composed of two main modules: (a) the argument module and (b) the underlying knowledge base. An earlier version of the design is described in Stutt 1987.

23.2.2.1 *The argument module*

This is made up of a series of procedural components, which realize the model mentioned above, and an associated knowledge base. The principal procedural components are for control, user argument parsing, user argument checking, system argument generation and overall argument assessment. At the heart of the system is the reasoner which can draw upon an inference engine to produce or assess arguments which can be either deductive or analogical (using a version of Gentner's structure mapping theory (Gentner 1983)). The system also includes system and user viewpoints and a means of switching between them (cf. Weiner 1980). Each separate user has a user viewpoint which is stored in a file. The system knowledge base consists of knowledge about general and domain-dependent argument strategies (cf. Alvarado *et al.* 1986, Reichman-Adar 1984), previously successful arguments and knowledge of how to assess an argument. The system also contains an argument net composed of frame-like nodes for storing the argument as it proceeds (cf. Flowers *et al.* 1982) which can be used to display the current state of the argument (textually or graphically).

A naive top-level *strategy* for dealing with another participant's argument can be illustrated by the following:

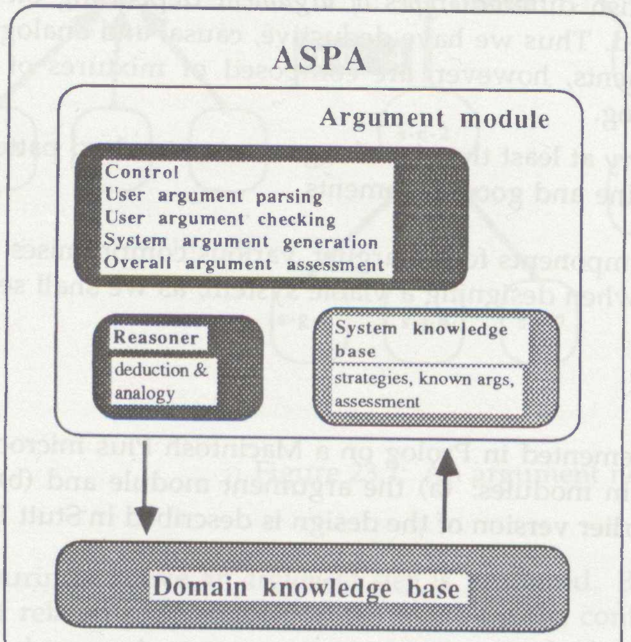

Figure 23.2: ASPA—the system

Attack the other's claim *or* Attack the other's grounds *or* Defend your own claim *or* Defend your own grounds *or* Attack the other's reasoning *or* Find another argument.

However, one of the main data structures in the system, argument *scripts*, can be used to focus the system's reasoning. A script is here taken as a stereotypical sequence of possible steps in an argument exchange. There are three main sorts of script: strategy scripts, responses-to-argument-type scripts and known-argument scripts. These scripts are used by the system as short-cuts in understanding user arguments and as a means of selecting an appropriate response (cf. the 'argument units' of Alvarado *et al.* 1986). Strategy scripts are used as a means of high-level control, response-to-argument-type scripts provide responses to tokens from the broad classes of argument which the system knows about, and known-argument scripts store previously successful arguments.

At the end of the argument, if the system loses, the system view will need to be revised resulting in possible changes to the domain knowledge base and the knowledge base of scripts. During the exchange the system may decide, on the basis of subsequent user arguments, that its reconstruction of the user's viewpoint has been erroneous. This will necessitate changes to the user view and concomitant changes to the argument-net.

The central operations performed by the system are argument generation, argument step checking and overall argument evaluation:

- Argument generation is performed by transforming the proof traces provided by a rule interpreter which makes derivations using facts and rules about the domain or assumptions derived from knowledge of what the user believes. These are further reduced by a set of operations which (a) extract sub-arguments which have been used previously in exchanges with a particular user and (b) produce the best ordering for the argument step. The notion of argument as tree transformation using knowledge of the structure of actual arguments is based on Weiner's work on similar transformations of tree structures for explanation in BLAH (Weiner 1980, Goguen *et al.* 1983).

- Argument step checking involves a process whereby the system must attempt to bridge any gap between the user's conclusion and his or her grounds. As Cohen (Cohen 1987) has pointed out, most arguments fail to explicitly state all of the arguer's premises. The system must therefore reconstruct the user's argument using the domain knowledge base or again by derivations from what the user can be held to believe.

- The assessment of the overall argument is governed by a notion of the 'strength of an argument'. The strength of the overall argument depends on the strength of each individual step. In turn this depends on: a) the plausibility and relevance of the relation between claim and evidence or grounds (cf. Cohen 1987) and b) the pertinence of the current claim to the overall argument. The current version of the program depends on a simple point-scoring method for successful supporting and attacking argument steps.

23.2.2.2 *The archaeological knowledge base*

This is a fairly standard fact and rule knowledge base which can contain knowledge about any domain either within or without archaeology. In the current version the system knows about the modern Cree Indian site written about by Bonnichsen (Bonnichsen 1973) in his paper 'Millie's Camp: an experiment in archaeology'. The user can: consult a graphical display of the camp and then engage the system in an argument about the interpretation of the site at various levels ranging from the identification and use of the various activity areas to an overall interpretation of the site use.

A viable version of the system would have to contain many such individual knowledge bases so that arguments can be conducted not only within and across viewpoints on one domain but within and across different domains. My next step will be to add, for example, a knowledge base about a mesolithic hunter gatherer site so that the system can cope with arguments by analogy between the two domains.

By means of these components the system functions as a tool which can

- store a user's argument over time
- check it for internal consistency and with prior user arguments
- allow the user to mix reasoning types
- provide good arguments
- act as a tutor for what counts as a good argument generally and in a particular domain

One final use of the system implicit in the above is as a means of testing the effect on a pattern of argumentation of certain changes in knowledge. This will often happen in archaeology where new discoveries are happening all the time.

In the next section I will briefly consider the nature of archaeological reasoning and theory and how a system of the sort described above could, in practice, begin to answer the objections mentioned in the introduction.

23.3 Archaeological reasoning and archaeological theory.

It seems reasonable to take the view that (a) archaeology is a semi-formal discipline in which the form of reasoning used is plausible rather than deductive and (b) theory in such a discipline is not fixed. This section will i) discuss the analogical nature of archaeological reasoning and how ASPA copes with it and ii) suggest that archaeology at present makes use of more than one one body of theory and show how ASPA may accommodate this aspect of the discipline.

23.3.1 Analogy

Archaeology makes extensive use of analogical argument. Other domains also make use of analogical reasoning in the production of hypotheses. However, given the paucity of the data available to the archaeologist, analogy perhaps plays a larger part here than in most domains.

While analogy is used frequently in archaeology, because of the bad press it gets from philosophers, archaeologists have always been uneasy about this use. Thus on the one hand we have the sub-field of ethnoarchaeology (Stiles 1977) which is concerned to make use of analogies between the culture of living peoples and those of prehistoric date. On the other hand Gould (Gould & Watson 1982) argues strongly that such analogies are suspect:

> Ethnographic analogies may be plausible and potentially testable, but they are often unscientific and are sometimes hard to distinguish from wishful thinking.

Wylie (Wylie 1987) has put forward suggestions which attempt (a) to make the use of analogy in archaeology more viable and thus (b) overcome the fears of writers like Gould. She argues that analogy is given its viability by being *grounded in deductive reasoning*:

> The conclusion I draw concerning these general arguments is that although analogical inference certainly comprises a loosely defined type of inference strategy, it does not seem plausible that its warrant is as analogical. Its warrant is that it approximates, to one degree or another, a valid inference from general knowledge of determining structures that link known and inferred properties. [Wylie 1987, p. 5]

In this view analogical argument derives its validity from possible corresponding deductive arguments which make use of 'determining structures'. I take these to be much the same as the second order relations mentioned by Gentner (Gentner 1983) (and Hodder's 'relational analogies' (Hodder 1982)). These structure or constrain the first order relations of potential analogues. An example would be a second order attribute such as *leads_to[has_wealth(person), has_expensive_burial(person)]* which expresses the notion, true of some societies, that the having of great wealth leads to the displaying of it after death. An analogy between two cases would be more powerful if it could be shown that the first level relations or attributes (such as 'has_wealth') were generally constrained by second level relations (such as 'leads_to'). Thus it could be argued, by analogy with a contemporary culture in which the *leads_to* relation is true, that since the prehistoric culture shows evidence for expensive funeral rites therefore this culture contained individuals with large amounts of accumulated wealth which was expressed in their funerary monuments. If this is what Wylie means, then it seems unlikely that such general constraints will be found. We could easily imagine occasions where wealth is not expressed in the above manner and, on the other hand, where expensive funeral rites are carried out for poor individuals (e.g. Gandhi).

Nonetheless, although analogies may not have a deductive grounding it is still possible, using Gentner's approach, to render them computationally tractable. The process of creating the rules for 'good' analogies explicit should be of interest to archaeologists.

23.3.2 Archaeological theory

> Leaps of faith are necessarily made since much of what archaeologists reconstruct is unobservable (Hodder 1984).

Given the prevalence of non-deductive forms of reasoning in archaeology in its attempt to make what Hodder (Hodder 1984) calls 'leaps of faith' to the proper interpretation of the data available, it is obvious that archaeological theory will not correspond to the sets of propositions (or equations) with relations of logical or mathematical implication applicable to 'hard' sciences such as physics. Archaeology as an interpretive discipline will have theories which are more concerned with shedding light on some particular object or site than with general laws. Thus archaeology will make use of currently fashionable theories such as structuralism and marxism in order to provide a theoretical viewpoint on the data.

ASPA, through its mechanism for modelling several different points of view, could be used to model different interpretive theories as sets of facts plus their interpretive transformations and strategies for composing these.

23.4 Conclusion

In conclusion, there are four main reasons why such a program should be of interest to archaeologists:

1. In its knowledge acquisition role, ASPA answers, in part, the sorts of high level criticisms raised in the introductory section. The program has three principle features which enable it to obviate these difficulties:

   (a) The user can change the domain knowledge base by providing a convincing argument for any new claim whether this be about facts or the relations between facts contained in rules. This has the effect of modifying the theoretical viewpoint reflected in the knowledge base by modifying how the knowledge is structured and manipulated and allows the user to change the knowledge base in a principled manner.

   (b) The system can employ different viewpoints on the facts of the domain thus allowing the user to model the domain from various quasi-theoretical points of view.

   (c) The system can understand arguments which are based on non-deductive forms of inference, in particular, on analogical reasoning.

2. Archaeology is an argumentative discipline. Since material finds are so scarce, it is inevitable that if the archaeologist is to go beyond the mere cataloguing of finds then arguments pro and contra certain interpretations or theoretical positions will be rife. This can be illustrated by the work of a prehistorian like Richard Bradley (Bradley 1984) or the theoretical discussions of Ian Hodder (Hodder 1986). ASPA, as an argument generator as well as checker, can aid in the production and appraisal of arguments at many levels. Furthermore, ASPA has the ability to create and comprehend arguments which are either completely or partially non-deductive. At the moment this is confined to analogical reasoning but future versions will include other forms of plausible reasoning as well as causal reasoning. ASPA also includes the capacity to argue across differing viewpoints thus offering the possibility of the integration of multiple viewpoints.

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   (b) The system can employ different viewpoints on the facts of the domain thus allowing the user to model the domain from various quasi-theoretical points of view.
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3. Hodder (Hodder 1982) and others have discussed the importance of analogical reasoning in archaeology. Because of its non-deductive nature this sort of reasoning has been frowned upon by many philosophers and hence by many archaeologists. If Hodder is right, then archaeologists cannot avoid the use of analogical reasoning. What they must do, however, is to apply it in as strict and principled a fashion as possible. One means of imposing this strictness and discipline is by making the rules for analogical reasoning explicit in the form of pieces of Prolog code and utilizing these to generate and evaluate arguments.

4. In most expert systems used in archaeology the knowledge involved is confined to certain facts about some domain and heuristics for making use of these facts. ASPA, as it develops as a means of capturing and engaging in more theoretical arguments, will of necessity reveal certain characteristic patterns of reasoning which the archaeologist makes use of in interpreting sites and evaluating the theories of other archaeologists.

If nothing else, I hope to draw archaeologist's attention to the possibilities inherent in the sorts of ideas embodied in the currently proposed models for expert systems. I hope I have also supported the notion that an arguing expert system would be of value in an archaeological context. In particular I hope that I have shown that such a system could overcome the problems of formalization, fossilization and non-deductive reasoning mentioned in the introduction. It would hardly be surprising if a system which could really argue (and I recognise that ASPA only approximates to one) would be of help in the formulation of ideas in archaeology. Argument conceived as the critical interchange of ideas is something which underlies all of our academic discourse. A system which embodies an arguer will be one which does not deliver oracular pronouncements from some centre of excellence but which allows the individual archaeologist to express as forcibly as possible an individual view on the artifact assemblages and structures revealed during excavation.

In short, ASPA integrates expert system explanation and knowledge acquisition in a model for user/system interaction in archaeology which is natural (because archaeologists make extensive use of argumentation), non-intrusive (no theory of the domain is imposed by the AI program) and flexible (the knowledge base can be altered via argument exchanges). Thus, although ASPA remains a partially implemented research tool, it has much to interest the archaeologist.

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