Archaeology and the application of artificial intelligence : case-studies on use-wear analysis of prehistoric flint tools

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2 The application of artificial intelligence in archaeology

2.1 Introduction

In the early 1960's, archaeologists started using computers. Initially, they were only used as facilities for the storage and statistical analysis of large data sets (*e.g*. Kendall 1963), but in the 1970's the 'New Archaeology' clearly affected the way in which quantitative methods and computers were applied. Gradually their use became more differentiated: they evolved from a mere aid for plain data description into sophisticated tools for process modelling, simulation and hypotheses generation (see for instance Hodson *et al*. 1970; Doran & Hodson 1975; Hodder & Orton 1976). Nonetheless, it took quite a while before artificial intelligence methods became involved in archaeology as well. It was not until the 1980's that, for instance, the first operational expert systems were presented. Only then, this approach had developed enough to enable the first archaeologists to build their own applications. This development was part of the process of computing techniques becoming integrated in all kinds of archaeological research. A process which was enabled by the introduction of the personal computer and the subsequent explosive growth of the amount of software.

This chapter focuses on the role that artificial intelligence applications have hitherto been able to play in archaeology. In this, I have confined myself to the *knowledge based methods*, especially *expert systems* and to a lesser extent *intelligent databases* and *neural networks*. Methods like *pattern recognition*, *natural language processing* or *robotics* have been left out of consideration. This does not mean, however, that the latter have never been applied for archeological purposes. On the contrary, pattern recognition has been employed repeatedly. Examples of this will be discussed in chapter 4. In fact, it is an area archaeologists are still highly interested in because it may have much potential for archaeology.

In outline, in the first paragraph some historical and contextual developments will be traced that have stimulated the use of quantitative methods in archaeological research and the subsequent introduction of artificial intelligence methods (paragraph 2.2). This will be followed by a review of knowledge-based applications that have been developed since the 1980's on archaeological subjects (paragraph 2.3). It probably does not comprise all applications that have hitherto been developed, but it gives an impression of the divergency of the issues for which they can been deployed. It illustrates the way in which knowledge-based computing can be applied in archaeology. Finally, in paragraph 2.4, the attitude of archaeologists towards the use of artificial intelligence methods in archaeology shall be discussed. It will be tried to recover the reasons for the lack of popularity that knowledge based approaches suffer from.

2.2 Historical and contextual background

2.2.1 The emergence of quantitative methods

From the beginning of the twentieth century, mathematical and related quantitative methods have been employed in archaeological context, although in exceptional cases. Flinders Petrie was one of a few pioneers. In 1904 he already stated that the use of statistical methods might prove to be the "*necessary foundation of systematic knowledge and exact theory*" (Flinders Petrie 1904: 123). The prime aim of the first quantitative approaches was to obtain chronological sequences by means of artefact classifications. It took quite a long time and a combination of methodical, theoretical, ideological and technological developments before quantitative methods became more widely dispersed aids for archaeological studies and the research subject of a group of specialists. Three concrete developments have been of major influence on the development of quantitative methods as a research topic: the discovery of the potential of 'hard sciences' for archeological studies, the birth of the New Archaeology and subsequent systems theory, and the introduction of the personal computer. The role of these events will be looked at in more detail.

Throughout the second part of the twentieth century the physical and biological sciences influenced archaeologists. But especially the introduction in the 1950's of innovations like radiocarbon dating and pollen analysis showed archaeologists the importance and potential of these 'hard sciences'. Furthermore, when related social sciences like geography evolved towards a more quantitative approach, some archaeologists felt a desire to turn their discipline into a 'real' and objective science as well (see for instance Trigger 1988). Gradually, they realized that besides the intuitive theoretical studies they needed a more objective consideration of the existing concepts and of their rudimentary data. Illustrative for this changing attitude is, for example, that several books were written to show archaeologists the benefit of scientific methods (*e.g.* Brothwell and Higgs 1963). No longer the application of 'scientific backing' remained confined to chronological issues, but it became also employed to study the behaviour of prehistoric man himself, his environment and his material culture. The attempts to incorporate less subjective methods of archaeological research inaugurated a new era, that of *explanation*, *i.e*., explanation through testing hypotheses (Willey & Sabloff 1974).

In line with the rise of the 'hard science' approach a second important development emerged, *i.e.* that of the New Archaeology. Throughout the 1960's the traditional culture-historical approach was heavily criticized by anthropologically oriented archaeologists in the United States. Alternatively, they preferred to explain the archaeological phenomenon of cultural divergence in terms of *laws* of cultural dynamics (*e.g.* Binford & Binford 1968; Flannery 1968). They argued that culture change had to be explained in terms of internal cultural processes of adaptation rather than by external influences like migration and diffusion. Furthermore they believed that the archaeological record comprised fossilized behavior which could be retrieved if this record was fully and minutely recorded and analysed. In order to gain the right archaeological insight, they proposed a *holistic approach* of research and to retrieve objective, calculable evidence. Intrinsic to the holistic approach was the incorporation of a wide range of (scientific) information sources instead of purely artefactual data only. However, this holistic approach of the New Archaeologists caused a growing complexity of research questions that could only be answered by means of more sophisticated data sampling methods. In their turn, these yielded an increased amount and more complex data. The data no longer concerned artefacts only, but features, contexts and environments as well. In order to enable analyses on their data, the New Archaeologists employed mathematical and statistical methods that were borrowed from disciplines like economics, geography, sociology and anthropology.

A similar development coincided in Europe, in particular in England. But in comparison with the American approach, in England the emphasis was lying on the systems theory (Clarke 1968). This offered a practical means to model the mechanisms of cultural change. For instance in the second edition of Clarke's *Analytical Archaeology* (1978) it was shown how computer-based simulation models could be powerful methods for testing system models and for validating hypotheses.

The impact of this changing attitude towards archaeological research was that it gradually encouraged archaeologists to be open minded with regard to the application of quantitative methods. According to Sabloff "*...it appears natural that archaeologists should have turned to systems theory as a means of coping with the increasing complexity of their data*." (1981: 4). It was for instance in this period (1973) that the first congres on *Computer Applications and Quantitative Methods in Archaeology* was held. Especially spatial analysis and simulation became popular issues within the field of quantitative research (*cf* Doran 1970; Clarke 1972; Hodder & Orton 1976, Hodder 1978; Sabloff 1981). Due to the increasing complexity of the data it was believed that simulation methods "*...offered an exciting and rewarding new line of enquiry – a way out*." (Hodder 1978: viii).

A third development that influenced the incorporation of quantitative approaches in archaeology was the introduction of the personal computer in the early 1970's. Since only electronic data processing enabled the complex analyses of the vast quantities of data that the novel approaches required, their employment depended on the availability of computers. With the introduction of micro computers they came within the (financial) reach of more researchers. Simultaneously the software industry evolved as well. Due to the special-purpose packages like simulation programs all kinds of ready-made quantitative methods became available, and thus also accessible to a larger group of archaeologists than the mathematically grounded. As a consequence, quantitatively based studies and the application of complex statistics further increased.

Due to the changes in archaeological theory and model building, quantitative methods could gain importance during the seventies and eighties. Several books, and even international conferences, were dedicated to quantitative issues in an attempt to fill the gaps in the education of archaeology students and to stimulate professional archaeologists in using (at least) basic quantitative methods[1]. Even research projects were adjusted to the available methods, which were borrowed from other scientific disciplines, to the specific research questions of archaeologists. This new approach blossomed and started to acquire a firm position in our discipline.

2.2.2 A NEW APPROACH: ARTIFICIAL INTELLIGENCE

Despite the new possibilities that the quantitative approaches offered, their limitations were encountered as well. Not in all cases statistics and simulations sufficiently matched with the non-numerical nature of most archaeological data. Surely, the more processual approach of simulations had compensated part of the limitations of plain numerical analyses, but it remained essentially a numerical approach. It could, for instance, not approximate *heuristic reasoning strategies* such as rules-of-thumb which some aspects of the study of human behaviour simply required. According to Doran (1974), it was apparent that "*...the techniques of multivariate analysis [...] 'know' virtually nothing about archaeology. Therefore,* *they can never be more than very limited aids to the archaeologist. Agreement that knowledge utilization by the computer is fundamental in archaeological data analysis would, for example, prevent vain efforts to find the 'best' clustering method, and might go far to reassure the many archaeologists who [...] feel that all the computer can do for them is to simplify their problems to the point of absurdity."* (*ibid.*: 70). He was convinced that archaeological analyses were susceptible for artificial inferencing processes and expected the utilization of knowledge-based approaches eventually to become fundamental in archaeological data analysis.

This need for less numerically oriented methods slightly opened the door for the knowledge-based approaches from the field of artificial intelligence. Since the application of simulations had already introduced a more processual approach of data analysis, the step towards the employment of knowledge-based methods was not very large. It was more or less a logical continuation, which coincided with developments in artificial intelligence research. At that time, in the early 1970's, this discipline had just yielded some major advances with the development of the famous expert systems DENDRAL and MYCIN (see chapter 3). Commercially and scientifically, this provoked quite some attention for this kind of applications and made some archaeologists curious as well.

Probably Borillo was one of the first scholars who attempted to translate archaeological reasoning into an explicit quantitative format, although this did not yet lead to computerized inferencing. In the early 1970's, he described mathematically the lines of reasoning a specialist employs in interpreting and classifying Greek statues and amphorae (Borillo 1971). Subsequently, his attempts were followed by various other studies on all kinds of subjects and eventually operational applications were built. Especially Doran, who is originally a computer scientist, has been an important pioneer in applying these methods to archaeological purposes. He developed the SOLCEM program, in which he combined elements of seriation, classification, simulation, and heuristic reasoning for the purpose of interpreting La Tène cemetery data (*cf.* Doran & Hodson 1975: 309-316). Subsequently he deployed the knowledge-based approach for the purpose of automatic generation and evaluation of explanatory hypotheses (*e.g.* Doran 1977).

It was not until the 1980's, however, that several computer archaeologists started to jump on this new bandwagon.

For instance the programs of the annual conferences on *Computer Applications and Quantitative Methods in Archaeology* mirrored this raising interest. For a long time, Doran had been the only one who gave papers on artificial intelligence, but from 1984 onwards several other people started to present knowledge-based applications (fig. 1).

From the beginning of the 1990's the interest in knowledge-based applications subsided. They had been presented as tools applicable to a wide range of issues and knowledge domains, but soon their restrictions were encountered. Obviously, they could not provide a suitable solution to every research question and after a while expert systems became an exceptional item on conference programs. It was only occasionally that determined researchers persisted in building new applications.

2.3 Review of knowledge-based applications in archaeology

Archaeologists that were interested in artificial intelligence methods focused their attention primarily on the knowledge-based approaches, especially *expert systems*. In general, expert systems are a means to formalize and model knowledge on methods and theories (see chapter 3). In archaeology they can, for instance, be utilized for the evaluation of hypotheses, the classification of artefacts, the prediction of site locations, the standardization of find analyses, the simulation of reasoning processes, etc. Moreover, they can be used for the purpose of communicating knowledge, for instance amongst experts, but also between experts and laymen (Ennals & Brough 1982). Experts may employ or develop such systems to pass or discuss expertise, while laymen can use them for consultation. Hence, expert systems are useful for computer-assisted instruction as well.

From the beginning of the 1980's and throughout the 90's various archaeological applications have been developed for methodical and a theoretical research topics (fig. 1). Usually, the goal of the methodical applications was to standardize a particular specialistic data-analysis procedure and to preserve and surpass the knowledge that this requires. In many cases these applications are designed for practical purposes, which often includes that they are involved in educational tasks. The application that will be discussed in chapter 5 (WAVES) is also an example of this approach.

Theoretical applications, on the other hand, aim to model and formalize a conceptual framework or to validate hypotheses and to simulate reasoning processes according to a particular paradigm. Their development contemplates predominantly research rather than the construction of an application that can be employed by laymen on the issue. For instance one of the aims of the theory-directed approach is to show the possible impacts that different theories or explanatory models can have when applied to a certain phenomenon. Doran's simulation programs (*e.g.* 1986a) are examples of this approach. Other examples of applications used for theoretical issues are given by Lagrange & Renaud (1985) and Gardin *et al.* (1988). They utilized the expert system approach for the purpose of *logicist analyses*, by which they aimed to express and schematize the reasoning that underlies archeological explanations in written texts, by means of explicitly defined chains of operations (see also

Application	Type of application/Subject	Reference
—	Expert system translation of an archaeological guide book	Ennals & Brough 1982
BEAKER	Expert system for the identification and classification of ceramic beakers	Bishop & Thomas 1984
—	Expert system for ageing horse remains on the basis of tooth characteristics	Brough & Parfitt 1984
EXCHANGE	Simulation program for studying sociocultural changes in a multi-actor exchange environment	Doran & Corcoran 1985; Doran 1987
—	Expert system for simulating the interpretation of Seljukid and Greek iconography	*cf*. Lagrange & Renaud 1985
CONTRACT	Simulation program to demonstrate a mechanism of discontinuous socio-cultural collapse as provoked by internal change	Doran 1986a
RHAPSODE	Classification system for Bronze Age axes	Ganascia *et al*. 1986
—	Example programs (6) that reproduce complex reasoning processes as reflected in archaeological texts	Gardin *et al*. 1988
—	Expert system shell for the identification of finds from excavations	Rugg 1986
ARCHAEOPTEREX	Expert system for the analysis of bird bones	Baker 1987
ASPA	Design for an argument support program	Stutt 1988
FAST	Expert system for functional analyses of stone tools, using metrical and use-wear information	Grace 1989
KIVA	System emulating the reasoning processes of archaeologists in interpreting hypothetical archaeological sites, based on the findings from American Pueblo cultures	Patel & Stutt 1989
VANDAL	Expert system for the provenance determination of archaeological ceramics, based on instrumental neutron activation analysis	Vitali & Lagrange 1988; Vitali 1989
RAPS	Rule-based system for dating Japanese keyhole tombs	Ozawa 1989
—	Expert system prototype for the classification of Bronze Age burials	Gegerun *et al*. 1990
PALAMEDE	Expert system evaluating urbanization evidence for early state societies	Francfort 1991
ESTELAS	Intelligent database prototype for confirming the existance of social differentation in the late Bronze Age in the southwestern Iberian Peninsula, based on warrior decorated stelae	Barceló 1991
—	Simulation program for testing contrasting models for the emergence of Upper Paleolithic social complexity	Palmer & Doran 1992
—	Hybrid neural network for archaeofaunal ageing and interpretation	Gibson 1992; 1996
WAVES	Expert system for analyzing and teaching use-wear analysis	Van den Dries 1993; 1994
PYGMALION	Expert system for the classification of Phoenician pottery (800-550 BC), by means of pattern recognition	Barceló 1996

Fig. 1. Examples of archaeological applications which handle knowledge by means of artificial intelligence.[2] [3]

Gardin 1980, 1990). By means of various case studies they demonstrated the benefits and limitations of the expert system approach as a means to analyse, understand and represent archaeological reasoning and as an alternative for communicating knowledge (Gardin *et al*. 1988).

The majority of the system developers, however, designed their applications to simulate a methodical issue which were directed towards the classification, dating or (functional) analysis of artefacts. Usually, these are issues which are more practically applicable. They have often reached a more stable phase of development than theoretical issues and the knowledge and procedures that they require are straightforward and well-defined. Moreover, they may suffer less from archaeological controversy as compared with theoretical issues and this consensus conduces their acceptance.

From figure 1 it can be seen that archaeologists not only deployed expert systems for the purpose of handling knowledge, but also the so-called *intelligent databases* (Barceló

1991) and *neural networks* (Gibson 1992, 1996). Intelligent databases are storage facilities with sophisticated communication and control facilities. They are meant to improve the internal consistency of databases. They provide facilities to verify incoming data on mistakes before it is entered into the database. But the most interesting facility of these databases is the automatic deduction of new facts from known facts. Intelligent databases can be utilized to control and retrieve factual knowledge, but their applicability for computational problem solving is limited because they do not contain inferencing processes such as used in expert systems. The main advantage of this approach, however, is that it employs some useful aspects of artificial intelligence without having to suffer from the burden of high expectations (see paragraph 2.4). Despite their virtues, they are not employed on a large scale in archaeology.

A third artificial intelligence method that is used in archaeology for the purpose of handling knowledge is the *neural network*. This method was introduced in the 1990's, but has not often been applied yet (see for instance Gibson 1992, 1996; Van den Dries 1993). It is based on quite a different principle of knowledge handling (see chapter 6), of which the benefits and limitations have not yet been fully explored in the context of our profession. In chapter 6, I will return to this method and discuss my experience with the development of a neural network prototype for use-wear analysis on flint tools (WARP).

2.4 Attitudes towards the application of knowledge-based methods

2.4.1 From high expectations to cautiousness

Due to the successful development in the 1970's of industrial and medical expert systems, like DENDRAL and MYCIN, the expectations of newly developed applications were very high, not just in archaeology, but in all kinds of disciplines. Especially the business world portrayed expert systems as tools that were useful for handling whatever problem-solving task: the sky was the limit. When in the 1980's the first prototypes were developed for archaeology, however, it became clear that the expectations had been too high and that the expert system approach had its limitations as well. Hence, all kinds of critical notes could be heard (*e.g.* Huggett 1985; Lagrange & Renaud 1985; Baker 1986, 1987; Wilcock 1986). The discussion that followed consisted of a technical and a principle component.

A major technical point of discussion concerned the knowledge representational abilities of these systems. For instance, they were said to be 'narrow minded' because they are not as flexible and adaptive as the human mind and because they contain knowledge of a limited area only. Moreover, the process of formalizing and translating human knowledge into a computational language was found to be extremely difficult. It was not only hard to elicit the appropriate knowledge, but also laborious to fit it into the formal representation method of an expert system. Often the regulations of the language formats felt like an oppressive corset. Frequently, it caused the delay of development processes and, therefore, increasing costs or even project cancellations.

Another worry was the reliability or 'safety' of an expert system. Since most systems were *black boxes*, which on request simply appeared with a solution to a problem or an answer to a question, but which never gave a justification or an explanation, it was feared that if it made a mistake this could not be detected. Moreover, who would be the one to blame for a mistake of the system? Would that be the user, the expert, the system developer, or the system itself?

The main concern of most authors was, however, of a principle nature. It was argued that formalizing knowledge within an expert system, would fossilize knowledge in the conceptual framework that is current at the time the knowledge is encapsulated (*cf* Huggett 1985; Baker 1987). One of the disadvantages would be that once the theoretical background would loose its currency, the expert system would become useless as well. Moreover, once knowledge had been encapsulated, the need would disappear to adjust and expand it. Stagnation would be the result. In chapter 5 we will return to this aspect in relation to the development of WAVES.

The discussion on knowledge formalization was not primarily conducted in the context of applying expert systems. In general, there was a considerable disagreement concerning the necessity or possibility to formalize archaeological knowledge in the first place (see for instance Djindjian 1986; Doran 1986b). Not all archaeologists felt the need or were willing to accept the 'hard scientific' approach of the new systemic archaeology and the methods accompanying it. Additionally, field archaeologists were (or were said to be) afraid that the standardization and automation of methods would transform them from decision making archaeologists into button pushing technicians (Richards 1985). This, however, was a principle discussion that took place in all kinds of disciplines as well as in the non-academic world. It mirrored the fear of many people to become overruled by artificially intelligent machines.

2.4.2 Lessons

None the less, the discussions have yielded a positive and constructive contribution to the research on the use of knowledge-based methods and in particular of expert systems. We have, for example, learned about the demands archaeologists pose on knowledge-based tools and for which purposes they are applied best. To start with, the answer of an application should not be presented as definite and absolute. Instead, a user and a system should cooperate and 'discuss' a case (Stutt 1988). Moreover, such a system should be able to reason while allowing some uncertainty (Doran 1987). Regarding the application areas, it has been acknowledged that the expert system approach suits well-defined methodical tasks best. Compared with theoretical issues they are more easy to formalize and the required knowledge may be more easily retrieved. These conditions facilitate the development process and may withhold a system developer from a disappointing experience.

Furthermore, it became clear that knowledge-based systems must be equipped with a user-friendly communication interface in order to stimulate the acceptability of their user: laymen should be able to use them. This can mean, for instance, that an application must be provided with explanatory facilities concerning the domain jargon and that the communication with the user must be in ordinary language (see also Ennals & Brough 1982).

Apart from the above propositions concerning the 'internal' improvements of the expert system, some proposals to deal with the problems addressed completely different directions. For instance, Doran did not think that concentrating on the improvement of one specific technique would, in general, yield the solution (Doran 1987: 84). Since he was convinced that the character of the archaeological data set in combination with a lack of reliable sociocultural theory was the main cause for the backward benefits of formal methods, he alternatively suggested to take this more into account and to tune the applications better to these restrictions (*e.g*. Doran 1988). Others seemed to be willing to adjust the way in which expert systems were utilized. Cheetham and Haigh (1991), for instance, proposed to employ expert systems simply as intelligent interfaces to databases. They argued that this would allow a multi-expert interpretation of a particular data set and it would not lead to a fossilization of knowledge. Baker even proposed to use intelligent data-bases as temporary solutions for as long as at least some of the major problems with expert systems had not been overcome (1986: 16). As an alternative, Baker proposed to accept the limitations of the expert system approach and to exploit only the best developed parts, while in the meantime one could work on the development of standards for assessment, testing, validation and acceptance (Baker 1988: 235). Subsequently, Barceló (1992) made an attempt to bridge the gap between archaeology and the computational representation means by showing how different expert system representation methods accommodate the different aspects of archaeological knowledge.

2.4.3 DISCUSSION

The changing attitude towards knowledge-based systems has probably been part of a natural development. It seems that in scientific disciplines, novel topics, either theories or methods, have to go through an evolutionary trajectory. For instance Aldenderfer (1987) gave a clear description of such a trajectory. He argues that in archaeology, as in other disciplines, similar ideological and social processes may influence the breakthrough and acceptance of innovations.

It is thought that, in general, a novelty will follow a course of four stages: early exploration, discovery, consolidation and accommodation (Aldenderfer 1987: 12). The first phase, the early exploration, means that the initial idea is presented. This happens in isolated occasions dispersed over several scientific disciplines, without a substantial follow-up. It is only after a while that the ideas are discovered and recognized as scientifically important by a larger group. The subject then receives a lot of attention. The next phase, that of the consolidation, consists of a counter-action. It is characterized by scepticism and criticism, and the subsequent appearance of reviews and theoretical works which put the novel method in its place. Finally, a phase of accommodation may be reached: the discipline accepts the topic as a recognized and beneficial approach.

Regarding the use of knowledge-based systems, I am inclined to think that we have just left the phase of consolidation and are heading for accommodation. The first stage started in the 1970's with the publications of Doran (*cf*. 1974, 1976) and of a few others. These were isolated attempts that initiated the discussion on this issue. It was not until the 1980's that the method was discovered by a larger group. Numerous publications appeared in which enthusiasm and optimism predominated. Subsequently, we saw a series of critical contemplations and reviews of achievements together with a theoretical validation.

After some twenty years since its introduction, the issue stopped being a hot topic of discussion again. The smoke cleared and the situation more or less turned towards stabilization. The aims of the applications that were presented afterwards were more realistic and less ambitious. These applications have mainly been built for the purpose of more straightforward methodical and practical applications, such as classifications, data analysis, and education. Meanwhile the expert system technique developed as well. Especially its knowledge representational facilities expanded. Consequently, this obviated part of the above mentioned critiques (paragraph 2.4.1) and slightly improved their academic acceptance.

This does not mean, however, that knowledge-based systems are at present widely distributed in archaeology. Despite the fact that several successful expert systems have been developed (*cf*. Bishop & Thomas 1984; Brough & Parfitt 1984; Francfort 1991; Lagrange & Vitali 1992) and that their potential value for archaeological research has been stressed repeatedly (*cf*. Huggett 1985; Wilcock 1986; Doran 1987, 1988, and 1990; Baker 1988; Gardin *et al*. 1988; Vitali 1989; Voorrips 1990), they are not as much employed as for instance Geographical Information Systems. In fact, some archaeologists are still reluctant to use expert systems (see also Stutt 1988).

The lack of popularity of these programs in archaeology is a rather strange phenomenon. Since expert systems offer a means to model and formalize subjective expert knowledge and to make it accessible and applicable for non-experts, our profession certainly has an abundance of potential applications (see chapter 8). After all, much archaeological knowledge is subjective. Moreover, this reluctance is not common in other scientific disciplines. Numerous applications are operational in all kinds of scientific, industrial and commercial fields (see for instance Bonnet 1984).

According to Gibson, this lack of popularity "*...is due perhaps to the limited potential of expert systems in host disciplines.*" (1992: 263). This implies that since archaeology is one of these hosts for which expert systems were not explicitly developed, it is to be expected that they are of limited use for us. In my opinion this is not a valid argument. None of the computational methods that are being employed by archaeologists, like databases or geographical information systems were developed explicitly for our profession, but still they are useful tools. The success of any borrowed method or technique depends predominantly on the way the host deploys it.

In my opinion, the present lack of popularity of expert systems is primarily caused by other factors. First of all I believe that part of the critique towards expert systems has merely been a reaction on the extravagance of commercial presentations of expert systems as tools with infinite potential. It is true that the expectations had been far too high, and rightly it was stressed that "*one has to look before one leaps.*" (Baker 1986). Rightly, because it was experienced before (Richards 1986; Moffett 1989) that archaeologists were suffering from the 'Deep Thought Syndrome'[4], and again some started to believe that a novel method, this time expert systems, could provide *the* answer for all questions. Doran typified this as an illustration of the 'Law of the Hammer' (Doran 1988: 239): archaeologists had found a new tool with which they immediately tried to pound everything in reach with it. Hence, many of the critical notes were merely intended to warn experts and end-users not to have too high expectations, for a disillusionment would rob them of the real benefits of these systems (Baker 1986).

Still, part of the critique was not legitimate. The high expectations were not solely a matter of wishful thinking: they were certainly based on promising achievements. In fact, many of the optimistic expectations concerning the practical methodical applications have indeed been fulfilled. Therefore, I think that the critique has been somewhat exaggerated and that sceptics could have had a little more confidence in the results of the work of the pioneers.

I believe that the main cause for the lack of popularity of expert systems is that their potential for archaeology has not really been demonstrated. I do not think that archaeologists principally oppose to the use of knowledge-based systems. When they are asked about their opinion on employing these techniques, they are usually interested and curious, but not acquainted with their abilities or with operational applications. Many applications have hitherto been presented as designs, example programs or, when lucky, as prototypes and have never been developed into operational means. Despite the fact that they were said to be very promising, nothing was heard from many of them ever since. Consequently, hardly any test results were presented. Therefore, the lack of popularity of expert systems is something computer archaeologists should take to heart. When potential users are not enabled to assess the functionality of these systems, they are not encouraged to employ them either. Nevertheless, it must also be stressed that the role of knowledge-based systems in archaeology can of course not entirely be ascribed to their promotion. Compared with, for example, geographical information systems or databases their applicability is more limited: they are less easy developed and implemented by archaeologists who are not specialized or really interested in computing, each application covers only a limited and specialized area of knowledge which may not be of interest for a large group of users. Additionally, a limited applicability is partly inherent to the nature of specialized knowledge-based systems and prevents them from playing an equally important role as other more generally applicable methods. We should therefore try to develop applications with a more practical use, like for instance educational systems or other systems that are interesting for a larger group than scientific researchers or domain specialists only (see also chapter 8).

notes

1 Of these books the best known are Hodson, Kendall & Tăutu (1971), Doran & Hodson (1975), Hodder & Orton (1976), Thomas (1978), Sabloff (1981), and Shennan (1988).

2 The sequence of the applications as given here, does not represent the exact order of development: of several applications the first publication could not be retrieved.

3 The applications that are called *simulation* differ from other simulations by the fact that they are based on artificial intelligence techniques rather than on numerical data and statistics only.

4 What is meant by 'Deep Thought Syndrome' is that people believe that if you keep feeding your computer with huge amounts of data, it will eventually come up with *the* answer (see also Moffett 1989).