Archaeology and the application of artificial intelligence : case-studies on use-wear analysis of prehistoric flint tools
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1 introduction[1]

One of the most dynamic research disciplines is that of computer science. Only just in the 1940's the first 'computers' were devised, but nowadays we even apply them to gain a better understanding of the human brain. The research discipline dedicated to this particular field of study, *artificial intelligence*, emerged in the 1950's. It arises from cognitive psychology and computer sciences and its main interest is to simulate human speech, reasoning and behaviour. This discipline has hitherto yielded several methods, such as robotics, (visual) pattern recognition, natural language processing, speech recognition, expert systems, and neural networks that have proved to be practical instruments for all kinds of tasks.

In many fields of research and in our daily life these instruments have already been incorporated. In archaeology, however, they do not (yet) play an important role. In the past twenty years several archaeologists have discussed the potentials of, in particular, expert systems. Important contributions to this debate have for instance been made by *computer archaeologists* like Jim Doran and Jean-Claude Gardin. Others, however, seemed to be indecisive on the value of knowledge-based systems for our discipline. The overall impression was that archaeology was not a suitable host discipline.

This discussion was still going on when this study started in 1990. In fact, this thesis is more or less a reaction to this debate. I wondered whether archaeology was indeed an unsuitable area for knowledge-based applications, especially because it was hardly possible to draw this radical conclusion from the few prototypes that had been built up till that moment. Moreover, there were no objective test results to base such conclusions on. It was believed that the best way to validate the arguments would be to develop an application ourselves. Since many of the existing case-studies were theoretically oriented, *i.e.* they concerned an assessment of the possibilities of a knowledge-based approach, the primary objective of the present study, therefore, was to test the practical applicability of a system which had been built by means of a knowledge-based approach.

The selection of the domain for which an application would be build is based on several considerations. First of all, the application had to be of practical use. Nobody was waiting for another useless prototype. Moreover, the selected domain or method would have to benefit from the results of the study as well. If an expert was going to invest a considerable amount of his or her time in this project, something had to be delivered in return. Secondly, it had to allow for an objective test in practice. Thirdly, sufficient domain knowledge had to be available and — last but not least — an expert had to be willing to provide the required knowledge.

At the Faculty of Pre- and Protohistory of the Leiden University, the place where this project has been carried out, the application area of *use-wear analysis* was believed to be eligible most because it could benefit from this project in various ways. First of all since there was only one expert on this method in the Netherlands[2], some assistance was welcome. Teaching use-wear analysis is a very time-consuming task, because it involves an intensive practical training that is supervised by an expert. It was thought that a knowledge-based application could simultaneously support the expert in this task and offer students a practical training tool. Secondly, use-wear analysis was not yet a formalised and standardized method.[3]

A final, though not less important reason for selecting wear-trace analysis as the subject of this study, was that the expert was amenable to the application of artificial intelligence techniques and willing to share her knowledge and data for this purpose. Based on the most important needs of this field of research, it was decided that the application's main task would be *computer-assisted-instruction*.

While the expert system application was being developed, the neural network technology was introduced into the archaeological world. Neural networks were launched as a 'superior alternative' to expert systems that would overcome the latter's major functional shortcomings (Gibson 1992: 263). In order to verify this statement and to make a comparison of the achievements of both methods, it was decided to develop such a system for use-wear analysis as well. Since both systems could employ the same knowledge source, this offered a unique opportunity to make a comparison of their performance. Moreover, it was a challenge to subject use-wear analysis to a neural network approach: it had never been done before.

I expected it to be possible to develop a neural network that would suit a comparability study in a relatively short period, because the knowledge source that was used for the expert system would be fairly easily adapted and employed for this new purpose. Due to time-constraints, however, this second application had to be confined to a prototype.
This thesis is written from the point of view of an archaeologist rather than a computer technician. Not only because it is written by an archaeologist, not a computer scientist, but primarily because it addresses archaeologists. It is intended to illustrate my colleagues *how* they can deploy knowledge-based systems and *what* benefit this may have. Since most archaeologists are not experienced with knowledge technology, I want to spare them the unnecessary technical details and complicated discourses on computing.
In outline, the project and its results will be discussed in the following order. First, I will go into the role that computer applications in general and knowledge-based approaches in particular have hitherto played in archaeology (chapter 2). Ever since the emergence of the New Archaeology, quantitative methods, computers and finally knowledge-based approaches have been applied in archaeological research, however with various results. Moreover, a brief review will be given of the knowledge-baed applications that have hitherto been developed on archaeological issues.
Next, the fundamentals of expert systems will be described (chapter 3). Regarding the fact that many good books cover this area already, this chapter does not give a comprehensive overview of the field of expert systems, but only an introduction of the most important aspects concerning knowledge elicitation, representation and inferencing processes, as far as they are relevant to this thesis. I consider this useful because it has been almost ten years since in archaeology the last comprehensive reflection on this issue was given (Gardin *et al*. 1988). The domain has been developing quickly and some of the recent developments are surely of interest for archaeologists.
Since use-wear analysis is the domain that the case-studies in this dissertation deal with, I will give some background information on the theoretical and methodical aspects of this method in chapter 4. Additionally, I will address the difficulties that this method faces and the subsequent research on standardization and quantification that has been done to accommodate some of them.
Chapter 5 addresses the main part of this study: the expert system application (WAVES)[4] that was developed for the analysis of use-wear traces on flint implements. It gives a glimpse into the kitchen of the building process and a guided tour through the application. First an explanation and justification will be given of the development process, the knowledge analysis and subsequent design and composition of the application. Secondly, it will be shown how the application operates. In chapter 6 the same shall be discussed in relation to the second case study, the neural network approach that resulted in the prototype called WARP.[5]
Both the expert system application and the neural network prototype have been exposed to a test. The aim of this test was to compare their qualities under equal circumstances. Since WAVES is meant to function in practice it has also been subjected to a second test, in which its functioning was evaluated by four analysts. The outcome of this trial has been compared with other 'blind tests' on use-wear analysis. All test results are presented in chapter 7.
Chapter 8 addresses the principle question of this study: the potential of artificial intelligence techniques, especially knowledge-based systems, for archaeology. The questions I will answer are *why* we should want to go through the effort of developing them and *how* we could do this.
Finally, an assessment of WAVES is given by two expert analysts (addendum). Since the goal of this study was to build a practical application, it is important to present a second opinion on its functionality. The two human use-wear experts that have been asked for this purpose are A.L. van Gijn (see note 2), who has provided most of the knowledge for WAVES, and R. Fullagar[6]. The latter comes from a different (and distant) methodical school and can give an impartial evaluation of the application. He has participated in the blind test and, therefore, experienced WAVES as a user.

notes

1 Some parts of this study have been published previously (Van den Dries 1993, 1994; Van den Dries & Van Gijn, in press).

2 Dr. A.L. van Gijn, Faculty of Pre- and Protohistory, P.O. Box 9515, Leiden, The Netherlands.

3 Grace had already developed a knowledge-based system for the functional analysis of stone tools (Grace 1989), but the kind of knowledge he had incorporated and the emphasis of his approach deviated considerably from what we had in mind to justify the development of a second application (see chapter 5.9).

4 WAVES stands for Wear Analysing and Visualizing Expert System.

5 WARP stands for Wear Analysing and Recognizing neural network Prototype.

6 Australian Museum, Sydney, Australia.