Preface

Is it possible to build a machine to do archaeology?
Will this machine be capable of acting like a scientist?
Will this machine be able to understand the way humans acted, or how humans think they acted in the past?

This book tries to offer some possible answers to these questions and to investigate what it means to solve "automatically" archaeological problems.
Don't panic! Even if those questions would have a positive answer, I am not arguing that an artificial archaeologist will replace human archaeologists, because it will work better and cheaper than we will. We all know that artificial intelligence will eventually produce robots whose behavior may seem dazzling, but it will not produce robotic persons. Automatic archaeologists will DO a lot, but they will not BE a lot. Computational mechanisms cannot carry by themselves the weight of a scientific explanation.
I have tried to create an analogy with an "intelligent" machine, in order to understand the way we think. We should imagine an automated or artificial archaeologist as a machine able to act as any of us, human archaeologists, learning through experience to associate archaeological observations to explanations, and using those associations to solve archaeological problems. It should have its own "cognitive core" and should interact with the world to make changes or to sense what is happening. In so saying, I am not arguing that machines run as human brains or that computer representations should be isomorphic to "mental" states. Rather, I want to understand reasoning processes by understanding the underlying abstract causal nature behind what archaeologists do. If a computer can be programmed to perform human-like tasks, it will offer a "model" of the human activity that is less open to argument than the verbalized explanations that are normal in philosophy. The purpose is then to understand how intelligent behavior is possible in archaeology.

I am just arguing that the activity of machine and human automata can be described and analyzed in the same terms. The idea of an intelligent robot should be seen as a model of archaeologist's behavior rather than an explanation of his or her mind. Computer hardware and programming techniques enable the model builder to construct virtual creatures that behave in intelligent and flexible ways under natural conditions. They provide powerful (and perhaps indispensable) tools for building such creatures, but they can play no role as explanatory kinds by themselves.

In some way, computational intelligence provides social scientists with a set of tools with the same degree of finesse as those used in current qualitative studies and with the same mobility, the same capacities of aggregation and synthesis, as those used in quantitative studies by other social sciences. The limitations of these tools and methods are the same as those of any instrument from any scientific discipline. Instead of being restricted to the usual representational schemes based on formal logic and ordinary language, computational approaches to the structure of archaeological reasoning can include many useful representations such as prototypical concepts, concept hierarchies, conceptual spaces, production rules, associative memories, causal networks, mental images, and so on. Researchers concerned with the growth of scientific knowledge from a computational perspective can go beyond the narrow resources of inductive logic to consider algorithms for generating quantitative laws, discovering causal relationships, forming concepts and hypotheses, and evaluating competing explanatory theories. This book presents tools and methods that liberate us from the narrow constraints of words by enforcing rigor in a non-classical way, namely via the constraint of computational realizability.

Maybe some of you will say that we do "not yet" have automatic archaeologists, but we should hurry up to the engineering department and build them for having someone able to substitute us in the tedious task of studying ourselves and our past. Other readers will claim: "fortunately, such a machine will never exist!" "Why we need such an awful junk? Computers cannot emulate humans." These critics seem to think that computer programs are guilty of excessive simplification, of forcing knowledge, or distorting it, and of failing to exploit fully the knowledge of the expert, but it seems to me that it is archaeology, and not computer programs, what is "narrow minded." The saddest thing is that archaeologists do not know how they know archaeological matters.

The so called "intelligent" machines incite instinctive fear and anger by resembling ancestral threats, a rival for our social position as more or less respected specialists. But robots are here, around us. I have never heard of a claim against washing machines selecting "intelligently" the best way to wash a specific tissue, or a photo camera with an "intelligent" device measuring luminance and deciding by itself the parameters to take the picture. So, why have fear of a machine classifying a prehistoric tool and deciding "intelligently" its origin, function and/or chronology? Rather than arguing whether a particular behavior should be called intelligent or not,a point that is always debatable, I try to provide answers to the following question: Given some behavior that we find interesting in some ways, how does the behavior come about? Rather than use intuition as the sole guide for formulating explanations of past human behavior, we need a theory of why a specific computation or a group of related computations should be performed by a system that has certain abilities.

The discussion is between what is considered an artificial way of reasoning (computer programs), and a natural way of reasoning (verbal narrative). Critics of computationalism insist that we should not confound scientific statements with predicate logic operations, since discursive practices or argumentations observed in a scientific text are not "formal." By that reason, they are tributary, to a certain extent, from the Natural Language and the narrative structure (literary) of which scientific texts derive. I take the opposite approach: scientific problem solving stems from the acquisition of knowledge from a specific environment, the manipulation of such knowledge, and the intervention in the real world with the manipulated knowledge. The more exhaustive and better structured the knowledge base, the more it emulates a scientific theory and the easier will be the solution to the scientific problem, and more adequate the interpretations we get.

My personal approach is based on a fact that archaeologists could not evaluate 15 years ago: computer programs do work in real science, not only in archaeology. Maybe they are more successful in other "harder" sciences, but we cannot deduce from this fact that archaeology is a different kind of science. We should instead rebuild archaeology. Simulating or reproducing the way archaeologists think today is not the guide to understand archaeology, because we are doing archaeology in the wrong way! Computable archaeology, if you do not like the expression "automatic archaeology," is the proper way of exploring new ways of thinking old concepts.

In other scientific domains the performance of humans at a particular task has been used to design a robot that can do the same task in the same manner (and as well). In many different domains it has been shown how 'robot scientists' can interpret experiments without any human help. Such robots generate a set of hypotheses from what it is known about a scientific domain, and then design experiments to test them. That is, a robot scientist can formulate theories, carry out experiments and interpret results. For instance, the robot biochemist developed by Ross King of the University of Wales at Aberystwyth, and his colleagues, does everything a flesh-and-blood scientist does—or, rather, it does what philosophers of science say that scientists ought to do. That is, it formulates hypotheses from observations, conducts experiments to test them, and then formulates new hypotheses from the results. And, it does so as effectively as a person. The intellectual input comes from deciding, on the basis of the results obtained, which experiments to do next until you have filled in all the blanks. The robot scientist was able to do this. It was fitted with artificial intelligence software that could perform the logical processes involved in making such decisions, and this software was given a representation of the pathway chosen (one of those by which amino acids, the building blocks of proteins, are made) from which to work. The robot scientist can infer hypotheses to explain observations, infer experiments that will discriminate between these hypotheses, actually do the experiments and understand the results.

Consequently, the design of an automated archaeologist should not be considered a mere science fiction tale. It is a technological reality. Research in cognitive robotics is concerned with endowing robots and software agents with higher level cognitive functions that enable them to reason, act and perceive in changing, incompletely known, and unpredictable environments. Such robots must, for example, be able to reason about goals, actions, when to perceive and what to look for, the cognitive states of other agents, time, collaborative task execution, and so forth. In short, cognitive robotics is concerned with integrating reasoning, perception and action within a uniform theoretical and implementation framework. The question of whether it is possible to such machines to automate the scientific process should be of both great theoretical interest and increasing practical importance because, in many scientific areas, data are being generated much faster than they can be effectively analyzed.

The book is divided into four parts. The first one introduces the subject of "artificial intelligence" within the apparently restricted domain of archaeology and historical sciences. This introductory part contains two chapters. The first one, "'Automatic'" Archaeology: A Useless Endeavor, an Impossible Dream, or Reality?" provides an overview of the approach. After discussing the basic concepts of automata theory, the first elements of a formalization of archaeological reasoning are presented. The very idea of archaeological problems is introduced from the point of view of cause-effect analysis and social activity theory. The relationship between archaeological, anthropological, and historical problems is studied in detail, to serve as a basis for a presentation of how a mechanical problem solving procedure would look like in those domains. The chapter ends with a very short presentation of the diversity in current Artificial Intelligence theory and techniques.

The second chapter, "Problem Solving in the Brain and by the Machine," presents the classical artificial intelligence approach to problem solving as search and planning. Rule-based systems are discussed, focusing in its philosophical foundations. Jean Claude Gardin's logicist analysis is used as a relevant archaeological example, together with some of the current expert systems used in practical archaeology. A final debate leads the reader to a discussion about "rationality" and the shortcomings of traditional artificial intelligence and expert systems.

The second section of the book is the most technical one and presents a detailed but understandable account of learning algorithms and neural networks. It has been divided into two chapters. The third chapter, "Computer Systems that Learn," develops the criticism of the classical approach to "intelligent robotics," presenting the way computer systems and "intelligent" robots may learn. Learning is here presented as a predictive task that can be simulated by computers. Many archaeological cases are used through this chapter to understand the algorithmic nature of experimentation and discovery tasks.

The fourth chapter, "An introduction to Neurocomputing," offers a presentation of neural networks. After discussing in plain language what neural networks are, some algorithms are introduced with a minimum of mathematical jargon, here reduced to the basic arithmetic operations. Backpropagation networks are exhaustively analyzed, together with radial basis functions, self-organized maps, Hopfield networks, and other advanced architectures.

Section III constitutes the core of the book, and discusses different examples of computational intelligence in archaeology, with cases concerning rock-art, lithic tools, archeozoology, pottery analysis, remote sensing, ancient settlement investigation, funerary ritual, social organization in prehistoric societies, etc. It has been divided into six chapters.

In Chapter V, "Visual and Non-Visual Analysis in Archaeology," some of the elements introduced in chapter I are developed. A general approach towards an "intelligent" pattern recognition system is presented, discussing the differences between a true visually based system and another one, which uses identified previously—instead of visual—data. This chapter serves as an introduction to the following ones, where practical and relevant examples of archaeological neurocomputing are shown in the domains of shape, texture, composition, spatiotemporal and functional analysis.

Chapter VI, "Shape Analysis in Archaeology," defines the concept of "shape" and presents different approaches to shape representation, analysis, and interpretation. Emphasis has been placed on the analysis of three-dimensional objects and the study of complex shapes.

Chapter VII, "Texture and Compositional Analysis in Archaeology," defines the concepts of "texture" and "composition." It also presents many archaeological applications of neurocomputing in these domains.

Chapter VII, "Spatiotemporal Analysis," has been written in order to explain the way spatial and temporal data (frequencies and densities of archaeological findings, for instance) can be analyzed using neural networks and other similar technologies. The spatial interpolation problem is posed, and different methods for finding a solution are evaluated, showing many real examples. Remote sensing also finds its place in this chapter. Time series and chronological problems are also a form of interpolation problem. Neural networks can be used to solve it, but we also need specifically organized networks to deal with recursiveness and related questions. The focus is on spatiotemporal explanatory models, not only from a strictly archaeological point of view but with a more general social science and historical perspective.

In Chapter IX, "An Automated Approach to Historical and Social Explanation," visually based explanatory approaches are substituted by a more general account of simulation and modeling, which illustrates how social processes can be simulated as computational mechanisms to be understood. The idea of social classification is discussed, and many examples of simulating social interaction using "populations" of computer programs are finally presented.

To conclude our journey into the automatization of scientific reasoning, the book ends with a Section IV that presents a theoretical discussion on the philosophy of social sciences and the benefits of computers and nonlinear algorithmic approaches. This part is composed of a single chapter that explores the theoretical consequences that may arise when using computational intelligence technologies to study the human past. Here the "robot" analogy gives its place to a proper account of a Computational Philosophy of Archaeology and related sciences.

It is important to take into account that this is a book on "computational intelligence" in archaeology, and not on "computer applications in archaeology." I have focused the text on the very concept of "explanation," and what it really means to explain archaeological (and historical) data. Therefore, important and usual concepts that are not properly related to "explanation" have less relevance. The reader may ask why I have not included more references to fashionable and apparently modern issues like geographic information systems, visualization and virtual reality. The answer is that these subjects appear in the book, but in a different envelope, insisting in their contributions to archaeological explanation. Therefore, GIS techniques have been included in Chapter VIII on spatiotemporal explanation, and all the discussion on virtual reconstructions has a more logical place in Chapter VI on shape analysis, but it is also analyzed in Chapter X. The reader is referred to other books for the practical side of data bases, GIS, CAD and visualization software. This is a book on the interface between technique and theory. Although some "how-to" is presented, and many practical applications are referred, the book merely opens a door, encouraging the reader to begin a research along this line.

Do not look for a classic presentation of the archaeological practice. This is an unconventional book with very little respect for tradition. In a first reading, the text may seem highly skewed towards computational intelligence, with very little traditional archaeological stuff. Even the number of traditional archaeological references is surprisingly small. This is because my goal has been to open new grounds in archaeology and the social sciences. Technology is not the solution, but it is the way we have to follow if we want to rethink the way archaeology has been done. This emphasis on new ways to understand ancient times explains the apparently minor relevance of traditional aspects. However, they are not absent. They have acquired a new appearance, as a careful reading will prove.

This is not an encyclopedia of archaeological methods and explanations. I could not present all aspects of the archaeological research process nor all available computer science methods. Because any book needs to be focused, I have had to obviate many important aspects that in other circumstances would be interesting. If a majority of readers find the book relevant, and I have the chance to do more research work in this "computable" archaeology, new chapters on archaeological site formation processes or intelligent virtual archaeology environments will follow. The technology is evolving, and each day sees some new advancement. For all information that couldn't be included in the book, and for periodic updates of theories, techniques and technologies, the reader is referred to its related Web page: http://antalya.uab.cat/perhistoria/Barcelo/IGIBook.html.