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Using Computational Methods to Understand the Past in The Present

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Abstract

Cultural heritage is a wide concept; an expression of the ways of living developed by community and passed on from generation to generation (ICOMOS 2002). In this paper I examine the idea that "archaeological heritage" is the information we can extract from material evidence from the past with use of scientific analysis. As prehistoric stones and ancient potsherds do not speak for themselves, the transformation of archaeological material into scientific data and into explanatory knowledge is the most challenging aspect of modern archaeological methodology. New techniques based on artificial intelligence, virtual reality and reverse engineering are needed to approach cultural heritage in a explicitly functional way. The challenge is to demonstrate how we may put our knowledge of the past to beneficial use in helping people to understand where the present came from and shaping their way into some future.

Short Communication

Archaeological heritage should not be reduced to a series of objects presented in museums or depicted as pictures in books. It should be converted into knowledge that needs to be acquired, processed and transferred. This knowledge will provide information about our past that is basic for understanding our present and to produce our future in a rational way.

Archaeological observables are something to be explained, and not something that merely documents the past. Archaeologists' intention should be to study social events, that is to say, the material consequences of social actions performed sometime in the past, some of which are perceivable in the present and are recognized as cultural assets due to its relevance for understanding modern identities. Therefore, preserved material evidence about the past (objects, buildings and landscapes) should be linked to our scientific knowledge of social history in an interactive way. My assumption is that the "function" of the object in the past is a sign of what people could be made with it there and then. What is seen here and now but was produced/ used there and then becomes a sign of its own historical signifier. And as sign, it is involved in paradigmatic relations (substitutions) as well as syntactic combinations. The paradigmatic order is the order of historical possibilities, offering substituting items for the signification and places them at the disposal of the action, in a given state of semiotic values. On the other hand, the syntactic order is that of the irreversible sequences, fixing the order of the cognitive actions-historical explanation- which must be carried out to achieve a certain goal, in a certain space-time context.

The starting point in this paradigm shift is that we are not referring to "monuments" or "reliques" but to past objects and buildings having historically resulted from the articulation between human intention and the physics of materiality. The knowledge of the way artefacts, buildings and landscapes were created and used in the past should reflect the causal interactions that someone had or could potentially have had with needs, goals and products in the course of using such elements. That means that material entities preserved from the past and recognized as cultural assets in the present should be explained by the particular causal structure in which they are supposed to have been participated. To achive those goals we should focus on processes, rather than on static visual/non-visual components. This constant interaction between task and object, between what ancient people could do in the past and what we know today about what they wanted to do then can be defined as the archaeological (historical)-explanation cycle.

What is the role of computer technology in solving those problems? Current computer technology is part of the problem, although it should be part of the solution. Virtual archaeology, for instance, has developed as an independent branch of archaeology; in the last decade the availability of powerful hardware and software tools has accustomed the public to a formal perfection in computer graphics, while the quality of the digital products is improving day by day thanks to rapid technological development. This process has led, on the one hand, to some very impressive results, but on the other, it has meant that the message in the cultural communication of archaeology is often conditioned by a mainstream and superficial idea of antiquity. The lack of interest of many archaeologist, and the needs to make fast profit of current investments have resulted in a proliferation of products in which there is no guarantee of quality or reliability of content.

Nevertheless, investigating historical heritage through computer methods and artificial intelligence approaches can provide new insights into the complex dynamics of human past. The goal should be to unveil production, construction and building processes through time, by rendering public and accessible, the reasoning form their builders in the past. This is a real example of a Reverse Engineering approach to the study of ancient remains, which can be defined by the process of extracting missing knowledge from the past, by going backwards through its development cycle and analyzing its structure, function and operation. Through reverse engineering and computer simulation mechanisms, it is possible to advance from a physical-to-digital stage to an explanation stage, by simulating the ancient artefacts' and building' functions and inferring possible inherent working and/or use processes. In this way, we may analyze and evaluate potentialities, constraints, quality, robustness and effectiveness, by controlling the flow of information and vulnerabilities of a hypothetical model.

In other words, computer technologies should help us in discovering what cannot be seen (social causes) in terms of what is actually seen (material effects) and we know for certain that it was produced sometime in the past. This explanatory process can be divided into three very general categories, and the idea is to program computers to perform them "out of the mind of the researcher". If a task implies obtaining information about the empirical characteristics of an archaeological site or some archaeological material and producing a representation useful for other tasks (description, representation, analysis, explanation), then it falls in the SENSE category. If the task is based on processing information (either from primary data or some previous theoretical knowledge about the material evidences of social action) about how to generate descriptions "automatically", representations, analysis, and explanations, this is an instance of cognitive planning behavior. Finally, and most importantly, cognitive tasks producing explanations fall into the ACT category. It is necessary to insist in the fact that I view scientific reasoning as a form of behavior, and then we need to consider that computer programs may act. Obviously, I am speaking about epistemic actions. Expressed in its most basic terms, the epistemic action to be performed may be understood in terms of predicting which explanations should be generated in face of determined evidence. In that sense, explanations are for the computer a form of acting. Explanation is not an explanatory structure, nor something that explains, but a process of providing understanding. Explanation is something that people do, mechanically, with the help of a machine, and not an eternal property of sets of sentences.

The main argument presented in this paper is that archaeological reasoning can be formalized in terms of information-processing machines, which transform inputs into outputs. These mechanisms are usually called automata. Simply stated, an automaton is a discrete processing mechanism, characterized by internal states. Computers provide a perfect example of a physical system in which output is related to input in a far more complicated way that could ever be expressed as a stimulus-response pattern. Programmed appropriately, they can respond selectively and conditionally to well-defined (and in some cases, even not-so-well-defined) categories. The problem an "automated archaeologist" must solve can be defined in formal terms as the transformation of any incoming sensory vector into an appropriate conceptual vector, which should be consistent with a hypothetical causal model of the input vector. That is, given a description of archaeologically observable features and a set of already known mechanisms corresponding to hypothetical social activities, actions, and/or behavior models known to the automatic archaeologist, it should assign correct causal explanations to the material consequences of social actions.

Here lies the basis of an "automatic" approach to archaeology, or if you want, a "mechanically" driven way of reasoning about the past. I am speaking about storing and retrieving abstract mathematical or logical descriptions implemented in a computer program, which takes the geometrical, spatial and material perperties of the current observation at the archaeological site as input and which returns an explanatory structure as output. Essentially, the idea is to set up appropriate, well-conditioned, tight feedback loops between input and output, with the actual and past observations as the medium for the loop.

We can say then that an automated archaeologist "perceives" some reality because it is able to recognize input information according to previously learnt categories. The goal of explanation is to perform relevant associations between input and output correctly, in the sense that the recognition reflects a meaningful property of the world in terms of what has been already learnt of its formation process through previous experiments or controlled observations, and which is independent of the particular data that is being interpreted. First, a visual sub-system has classified the percept as being a member of one of a large number of results from known causal processes according to visible properties, such as its shape, size, color, and location, and relations between them. Second, this identification allows access to a large body of stored information about this type of object, including its function and various forms of expectations about its future behaviors. This two-step schema has the advantage that any functional property can be associated with any object, because the relation between the visual characteristics of an object and

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the information stored about its function, history, and use can be purely arbitrary, owing to its mediation by the process of categorization.

This procedure seems to ask for an organized "library" of internal representations of various prototypical perceptual situations, situations to which the results of perceptions are associated. Explanatory understanding consists then in the apprehension of the problematic case as an instance of a general type. Such a representation would allow the machine to anticipate aspects of the case so far unperceived, and to deploy practical techniques appropriate to the case at hand. Consequently, automated understanding can be understood as the generator of a set of descriptions of the actual physical world that might be sufficient (perhaps in concert with other contextual information) to identify instances of social actions performed in the past, according to what the robot knows about them from the laboratory experiments, computer simulations or ethnoarchaeological analogies.

Clearly, nothing is gained if we merely assume that x occurs, because y occurred (where x refer to archaeological observables, and y to different acts, events or processes that happened somewhere and somewhen). Such descriptive mechanisms, even if true, are not explanations but are themselves something to be explained. Statistical regularities don't explain, but require explanation by appeal to the activities of individual entities and collections of entities. Studies offering models for the detection of event-related properties typically fail to distinguish between description and explanation. Archaeologists should intend to build historical explanations in terms of the description of some hypothetical mechanism connecting different temporal states on the same reality. The idea is to discover changes in the temporal and spatial trajectory of some properties of an entity, which appear to be causally linked to changes in properties of another entity. That is to say, social actions cannot be understood without a frame of reference created by the corresponding social motivation or intention.

An automated archaeologist may understand archaeological observables in terms of a priori affordances: relationships between observed properties and the inferred properties/abilities of people having generated those properties. The affordances of any archaeological evidence become obvious in its use and/or formation process. Both involve establishing and exploiting constraints (between the user/producer and the material evidence of his/her action, the user/producer and the natural environment, and the material evidence and the natural environment). Physical affordances, closely related to constraints, are mutual relationships that involve both the agent and the material elements she/he manipulates (and the environment he/she operates).

The implementation of such causal affordances or potentialities inside a machine to explain what it "sees, is usually called computer "simulation" of a causal process [1-5]. By running such a "virtual world" archaeologists can test the accomplishment a tool or a building had in the past to effectively fulfill a specific action or task, which has been formally described and parameterized; that is to say, whether the object or building was used in a certain way and to satisfy a specific goal. Such an approach can be characterized as "understanding by building". It is is based upon the general assumption that theory building would be better served by synthesis (simulation) than analysis (logics). Here, the problem-to-be-solved is translated into a design issue: How can we design an artificial archaeologist so that it will exhibit the desired epistemic behaviors? I have tried to give some posible answers to this question in my book Computational Intelligence in Archaeology [6].

For this sort of cognitive task to work, a virtual world, that is, the computer simulation of observed things in a reconstructed environment, should be defined in terms of precipitating conditions generating an increase in the probability of occurrence of an effect, and not in terms of a single linear mechanism. The visual attributes observed at the archaeological record cannot be shown to follow from some general law that, given certain initial conditions at time t0, will inevitably produce the thing or event that the intelligent machine is trying to explain at time t1. Nevertheless, the automated archaeologist can suggest that those effects seem to have a different degree of probability in some circumstances than in others. The automated archaeologist will study the non-linearity of the observed instances of cause-effect relationships, and will try to make emphasis on the cases that deviates from what was hypothetically predicted (simulated). What is assumed is that the past is not necessary like the present, and not any action performed here and now should produce the same consequences of an action performed there and then. The key of this approach lies in the study of the intrinsic variability of a causal process in experimental or ethno-archaeological circumstances.

In other words, the starting point of the explanation of the archaeological record by means of computer simulation is not the reproduction of one particular object but the investigation of the mathematically possible development of specific classes of model systems. As these pure systems usually generate a lot more different paths of development than are known from real human history, we should limit these possibilities by introducing known historical constraints from previous knolwedge. The key question is then why these constraints appeared in reality. This particular procedure was aptly described by Bateson with the concept of "cybernetic explanation" [7]. The suggestion that scientific reasoning might simply consist in a sequence of input-output or perception-action associations has been suggested, among others, by Howard Margolies (1987), Paul Thagard [8] and Paul Churchland [9,10]. The core idea seems to be that scientific reasoning does not involve any introspection into the process of thinking, but rather is itself a process of pattern recognition. Models should be specified a priori; the adaptation or learning is achieved by estimating model parameters from

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the available data. A priori models account for any deterministic variability, whereas deviations from the model are random and statistically independent for different subsets. Explanation represents an expected, deterministic aspect of the data, although the deterministic uncertainties can be implemented in terms of unknown model parameters [11,12].

In any case, archaeological explanations should not be considered as semantic abstractions or verbal labels but opportunities some explanatory context affords. Interpreting the shape, texture, materiality and spatio-temporal location of some archaeologically observed items must be grounded in an understanding of both the social and natural events that have influenced the presence/absence, alteration, and displacement (relative to it as a primary site of production, use or discard) of its individual components and of the assemblage as a whole. In other words, the a priori contents of the problem-solver are not concepts, but a kind of "pre-concepts" having dynamic, adaptive nature. They are a bridge between the mind and the experience. Concepts-as-potentialities belong to the a priori content of the mind, whereas concepts-as-actualities come immediately close to the world of experience.

Artificial intellence, virtual reality and reverse engineering help us to define how ancient objects, buildings and landscapes were shaped and used in the past, even if we do not have access to any written description by any contemporaneous witness, starting from the identification of the choices made (among the many possible) in an hypothetical reconstruction of the production process (the cause). In this way we can investigate scientifically and explain to wider audiences the effects of social actions considering alternative explanatory scenarios, where the parameters of possible behaviors can be changed and tested.

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