CAA2014
21st Century Archaeology

Concepts, methods and tools

Proceedings of the 42nd Annual Conference on Computer Applications and Quantitative Methods in Archaeology

Edited by

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Foreword

This volume brings together a selection of papers proposed for the Proceedings of the 42th Computer Applications and Quantitative Methods in Archaeology conference (CAA), held in Paris (France) from 22nd to 25th April 2014.

The conference venue was Paris 1 Panthéon-Sorbonne University, in the main building next to the Panthéon. Workshops were held at the Institute of Art and Archaeology and the EHESS School. This was the first time in 42 years that the CAA had come to France, and we are proud to have hosted this important scientific event in Paris.

CAA2014 welcomed 477 participants from 39 countries. Altogether 397 papers were presented in 26 different sessions. The 5 round tables and 12 workshops also contributed to the success of the conference.

The program was divided into different themes and this structure has been maintained in the arrangement of articles in the various chapters of this book.

We are grateful to the following institutions which made the conference possible and supported it financially. Paris 1 Panthéon-Sorbonne University, the *Mairie* of Paris, the CNRS, the EHESS – Ecole des Hautes Etudes en Sciences Sociales, the INRAP – Institut national de Recherches Archéologiques Préventives, the research laboratories from the Maison de l'archéologie et de l'ethnologie, Nanterre – UMR Trajectoires & UMR Arscan. We would also like to thank the staff of the university and the student volunteers.

We hope that the congress participants, the contributors and all people interested in computing in archaeology will enjoy these proceedings.

Proceedings of the 42nd Annual Conference on Computer Applications and Quantitative Methods in Archaeology
CAA 2014 - 21st Century Archaeology/F. Giligny, F. Djindjian, L. Costa, P. Moscati, S. Robert (eds.)

Computers and Mathematics in Archaeology, Anatomy of an Ineluctable Success!

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Abstract

Over the last fifty years the use of computer science and mathematics in archaeology has undergone continuous development and to date it has become an almost indispensable tool at any stage of the archaeological procedure: documentation, planning and data recording during surveys and excavations, laboratory studies, landscape analysis, reconstruction of social systems, archiving, mediation within the scientific community and amongst a broader public. New technologies have revolutionised the discipline: archaeological information systems, data retrieval systems, geographic information systems, 3D, the Internet, multidimensional data analysis, mathematical modelling and multi-agent systems. But the most ambitious contribution lies in the field of the formalisation of a general theoretical framework of the discipline, the independence of which from any paradigm and ideology could raise archaeology to the level of the leading scientific disciplines.

Keywords: Computational archaeology, emergence, development, scientific context

1. Introduction

The increasing success over the last fifty years of scientific contributions related to computer applications and quantitative methods in archaeology may now be analysed from different technological and sociological points of view in order to understand the absolute relevance of such contributions to archaeology and the way in which the specialists of computational archaeology could play a major role in the future of modern archaeology.

2. The very beginnings of quantitative and computational archaeology

Several references mark the very beginnings of quantitative and computational archaeology which developed in the 1950s.

The book '*The Application of Quantitative Methods in Archaeology* ' edited by R. F. Heizer and S. F Cook (Heizer & Cook 1960) was the publication of the eponymous Wenner-Gren symposium organised at the Burg Wartenstein conference centre (Austria), from 1st to 9th July 1959, at which participants included J.D. Clarke, A. C Spaulding, A. C. Blanc, F. R. Matson, H. Vallois and W.W. Howells. The conference officialised the existence of quantitative archaeology, which had emerged about ten years prior, when Brainerd and Robinson published the first algorithm of seriation in 1951 and Spaulding the first statistical method for typometry in 1953.

In 1955 Jean-Claude Gardin, with the assistance of Henri Seyrig, then at the French Institute of Near Eastern Archaeology in Beirut, launched the first application of data retrieval systems in archaeology using mechanographic machines and later an IBM 650 computer. In 1957 he founded the CADA laboratory (*Centre d'Analyse Documentaire en Archéologie*) which set out the famous nine descriptive codes (1957-1969) marking the beginnings of semiotics and data banks in archaeology (Gardin 1956, 1976). From 20th to 30th June 1962 D. Hymes (Indiana University) organised a second Wenner-Gren symposium at the Burg Wartenstein conference centre entitled ' *The Use of Computers in Anthropology* ' in collaboration with P. Ihm, R. W Needham, J. Cl. Gardin, S. Ciccato, S. Lamb, Th. Sebeok (Hymes 1965).

3. Naming the discipline

The emergence of a new discipline requires a name. In our case a lot of names were used, following the evolution of computer sciences:

- *quantitative archaeology* (Heizer & Cook, 1960);
- *computer applications and quantitative methods in archaeology (*CAA);
- *data processing and mathematics applied to archaeology* (Djindjian and Ducasse 1982);
- *archaeological computing* (used as the title of the '*Archaeological computing Newsletter* ' (1984-2008) published by the Oxford University ; this name was used by the University of Southampton for its ' *Archaeological computing research group* '; and is also the name of the laboratory created by I. Johnson at the University of Sydney in 1992) ;
- *computational archaeology* (Wikipedia; seems to replace the previous name or to be specific to computerised mathematical modelling in archaeology);
- *digital archaeology/ digital antiquity* (used unfortunately by the web community for the history of the Internet instead of ' archaeology of the digital ', but also by the ' digital antiquity service tdar ' (digital archaeological record), by the center of digital heritage (University of York) and by DigAR Lab, the digital archaeology research lab (University of Washington, Seattle);
- *digital applications in archaeology and cultural heritage* (the name is used by the on-line peer review created by B. Frisher (DAACH);

– *archaeoinformatics* (name sometimes used by German speaking archaeologists).

The name ‘ *archaeological computing* ‘ seems to be the most popular although ‘ *computational archaeology* ‘ would be the most appropriate because there are equivalent uses in other sciences. The name ‘ *digital archaeology* ‘ or ‘ *digital antiquity* ‘ is a more recent coining, probably due to the success of the digital revolution in technology, by analogy with ‘ *digital heritage* ‘ and the current development of virtual reality and 3D applications.

4. Positioning the discipline

What is and what could be the academic position of our discipline ?

- A vertical specialty ?
The vertical organisation is the favourite one in the academic world, more particularly at university where the creation of a chair means that a discipline really exists! To my knowledge to date there is not a single chair in computational archaeology at any university in the world. Nonetheless M. Baxter was professor in statistical archaeology at Nottingham University (UK), J. Barcelo is associate professor in quantitative archaeology at the University of Barcelona (Spain) and I hold a chair of archaeological methods and theory at the Paris 1 Pantheon Sorbonne University. I suggest here that it is necessary to create a chair of archaeological methods and theory at all the universities hosting a department of archaeology, which would be in charge of archaeological skills training, and which should be headed by a specialist in computational archaeology.

Computational archaeology research laboratories (general purpose or devoted to GIS, virtual reality, archaeological data banks, etc.) are more frequent. A typical example is the laboratory led by J. Johnson at the Sydney University (see above) or the ‘ Archaeology Data Service ‘ at York University (UK) headed by J. Richards. The first was probably Irwin Scollar, head of the department of technical and computer methods in archaeology at the Rheinisches Landesmuseum in Bonn (Germany) from 1971 to 1991.

- A transversal way to improve archaeological knowledge?
Obviously the most effective way to develop computational archaeology applications would be to share projects and lectures with all the archaeological specialties which are most often structured according to geographic areas and temporal periods, whether at university or in research institutes. This implies some kind of matrix organisation which theoretically would be well adapted to the integration of a variety of disciplines related to different sciences (physics, geology, zoology, botanic, computing, mathematics, etc.). It is disappointing that this approach was unsuccessful in many conservative countries such as France, Italy and Spain, where the governance is in the hands of influential scholars (in their position or in the commissions they are members of) and does not result from a dialogue between all scientists that aims to define the global needs and the strategy of a department. Such an organisation, which is so efficient in the very dynamic and competitive world of industry and services, is unfortunately not possible in our academic world. As a consequence the progression of our discipline is slowed down by an institutional and sociological opposition, probably in the same way as for archaeometry.

5. Defining the professional skills and qualification as well as the academic position

Just as for any new scientific discipline, the pioneers of computational archaeology were scientists with a variety of rich backgrounds including hard sciences and human sciences. They trained many students who became the second and third generation of specialists of the discipline, for example John Willcock of the School of Computing at North Staffordshire Polytechnic or myself at the Paris 1 University.

With regard to the scientific production of our colleagues, it is possible to define different profiles of activities:

– Computer scientists or engineers who consider archaeology as a serious hobby. Some of them are very renowned specialists in their own discipline and their research in archaeology reaches a very high scientific level.
– Computer scientists who are interested in archaeology as a field of application for their new computing research. They may have the opportunity to obtain a grant from the European Union or from a national institution and they use archaeology as a display window for their advanced computerised projects. Current applications in digital heritage seem to belong to this category.
– Archaeologists who are involved in quantitative and computational techniques for their research (statistics, mathematical modelling, GIS, 3D, etc.).
– Archaeologists who are using modern archaeological methods (of course using computers).
– Archaeologists who are involved in the production of formalised (and then computerised) archaeological knowledge.

Specialists in computational archaeology occupy very different academic positions, sometimes depending on the sociology of archaeology in the different countries. Among them are:

– Archaeologists using modern techniques, methods and formalisation. In this case they may occupy major academic positions in archaeology, at universities or in research institutes. But they are first of all specialists in an archaeological period and a geographical area, as for instance F. R. Hodson (European protohistory), C. Renfrew, G. Cowgill (Mesoamerica), J. D. Clark (Neolithic), or myself (European Upper Palaeolithic) and many others!
– Technicians working for archaeologists who are not familiar with computational techniques.

A typical case is the French CNRS employing specialists in computational archaeology (for example specialists in archaeological data retrieval systems or geographic information systems) as engineers, technicians or administrative staff (ITA) and not as researchers. This means that the recruitment commissions of the CNRS (sections 31 and 32) reject all the applications with a computational archaeology profile. And as a consequence students do not choose to do a PHD in computational archaeology, because they know they will get a researcher job neither in the CNRS nor at universities (as was also the case for archaeometry). This situation seriously hinders the development of modern methods and techniques in French archaeology.

– A specialised laboratory as part of an archaeological institute

The decision to found a specialised laboratory is linked to major investment (equipment, salaries and office) necessary to its establishment and often results from a long struggle by the pioneer at the creation of the laboratory. By contrast to archaeometry laboratories (for example absolute dating or ceramology or geophysics), nowadays the creation of a laboratory of computational archaeology does not require a major material investment. It should even be stressed that such laboratories existed in France in the 1960s and the 1970s (CADA, LISH) in human and social sciences, but were finally closed. The context of the recent creation of a virtual reality laboratory in Bordeaux by R. Vergnieux (Archéovision) after a long struggle with the Ausonius archaeological institute is symptomatic of these difficulties.

However, multidisciplinary studies carried out in joint projects together with archaeologists are a prerequisite for these laboratories to guarantee their success. This seems to be a major difficulty in countries where the organisation of archaeology is very conservative. Otherwise they are forced to work separately and independently, as was the case for the department of use wear analysis in Saint-Petersburg created by Y. Semenov in the 1950s and it seems to be the case currently with the laboratories of paleogenetics.

-An institution providing specialised services
Examples of private laboratories are rare. Their existence depends on the attitude of governments applying liberal politics in archaeology as for example in rescue archaeology. Start-up companies have been created for 3D processing in archaeology and cultural heritage.

A major topic is the scientific background of students in archaeology. Archaeology is increasingly taught in Humanities, although it is a discipline that uses methods and techniques related to physics, mathematics, computing, earth sciences and others. Such a situation may depress the scientific level of the future generations of archaeologists.

Be that as it may, an archaeologist using computational archaeology will be considered as a statistician or a computer scientist! That is not news! Remember that A. Glory (a priest studying palaeolithic art) described A. Leroi-Gourhan as a technician in mechanics, because he used punched cards (and knitting needles) to study European Palaeolithic art! So don't worry if your colleagues say you are a system engineer because you are using Powerpoint! Or a driver if you have a driving licence! But this is not a sound reason not to encourage our students to become skilled archaeologists!

6. Academic reviews devoted to computational archaeology

The existence of academic reviews devoted to computational archaeology confirms its status as a scientific discipline. Several of them have disappeared, others still exist:

1965-1976 *Newsletter of Computer Archaeology* (Arizona State University)

1967 *Computers and the Humanities*

1982-1992 *Archéologie et ordinateurs* (CRA CNRS)

1984-2008 *Archaeological computing Newsletter* (Oxford University)

1990 *Archeologia E Calcolatori* (CNR)

Archeologia E Calcolatori has published one volume per year and special issues since 1990.

7. Conferences on computational Archaeology

As mentioned above, the first conferences on computational archaeology were held at the end of the 1950s, notably the Wenner-Gren symposia.

In 1970, the conference of Mamaia (Romania) 'Mathematics in the Archaeological and Historical Sciences' was the place where the most renowned statisticians met archaeology: Rao, Kruskal, Kendall, Sibson, La Vega, Lerman, Wilkinson, Solomon, Doran, Ihm, Borillo, Gower. And where archaeologists demonstrated that they were skilled in the use of statistics: Moberg, Spaulding, Cavalli-Sforza, Hodson, Orton, Hesse, Ammerman, Goldmann.

This conference probably influenced the organisation of the first CAA conference (Computer applications and quantitative methods in archaeology) in Birmingham in 1973. This was the beginning of an annual conference cycle, held for the first time in Birmingham, then elsewhere in the UK, after 1992 in Europe and from 2006 outside Europe. It describes itself as: '*CAA is an international organization bringing together archaeologists, mathematicians and computer scientists. Its aims are to encourage communication between these disciplines, to provide a survey of present work in the field and to stimulate discussion and future progress*'.

During its 1976 world congress in Nice (France) the IUPPS (International Union of Prehistoric and Protohistoric Sciences) decided to create scientific commissions for their inter-congress activities. Commission 4 '*Data*

management and mathematical methods in Archaeology' was then launched. Over the last 35 years commission 4 organised one or more sessions at each congress every four years as well as inter-congress conferences (Amsterdam, Denver, Sydney, Scottsdale, Paris, Leiden, etc.). At the 2006 conference in Lisbon commission 4 decided to change its name to '*Archaeological methods and theory :formalization, quantification, mathematics and computerization*'.

National conferences on computational archaeology were held, in particular the ' *Workshop on Archaeology and Computers* ' in Vienna (Austria), organised each year since 1995 by W. Börner and the ' *Journées d'Informatique et Archéologie de Paris* ' (JIAP) in Paris held biannually since 2008.

CAA also has several national branches organising additional conferences.

Dedicated sessions were also organised at national (for example SAA in the USA) or international archaeological congresses (for example WAC or EAA) and it can be assumed that there is currently no archaeological congress without computational archaeology sessions.

The rapid development of virtual archaeology, for which cultural heritage is a more gratifying market of application than archaeology, prompted the creation of subdivisions in computational archaeology. The 1998 CAA conference in Barcelona gave rise to a separate publication (Barcelo, Forte and Sanders 2000). In 2000, the first VAST conference (International Symposium on Virtual Reality, Archaeology and Cultural Heritage) was organised in Arezzo (Italy) by F. Niccolucci and the 14th international VAST symposium was held in Pistoia (Italy). The biannual 'Virtual Retrospect ' conference has been held in Bordeaux (France) since 2003.

Virtual reality (VR) is a very dynamic field of research and its application to cultural heritage is very spectacular. For example, in 2009 as many as five VR conferences on archaeology were held: in Malta, Trento, Paestum, Bordeaux, Seville (' i*nternational charter of virtual archaeology* ') as well as over a dozen on general virtual reality! In 2013, all these events converged to become the ' *Digital Heritage* ' conference in Marseille (France).

The very rapid development of 3D archaeology, which is not only concerned with cultural heritage, may possibly revolutionise field archaeology as well as all data processing that takes place following excavations and surveys, and it could create the conditions necessary for the creation of further subdivisions in computational archaeology.

8. What techniques are used in computational archaeology?

Computational archaeology uses almost all the techniques and tools related to applied mathematics:

- Applied mathematics
- Sampling
- Statistics including graphics, elementary statistics, statistical tests, Bayesian statistics,
- Multidimensional data analysis
- Algorithms
- Graph theory
- Mathematical modelling
- Signal processing
- Image processing
- Multi-agent systems
- Etc.

Computational archaeology also uses almost all the computing applications:

- Semiotics
- Data Retrieval Systems
- Ontologies
- Data Base Management System,
- Archaeological Information System
- Geographic Information Systems
- Virtual Reality
- 3D recording and processing
- Publishing
- CAD (computer-aided design) / CAM (computer-aided manufacturing)
- Internet X.0
- Office automation
- Etc.

All these techniques are of course software programs that the archaeologist has downloaded onto his/her personal computer or workstation, which is powerful enough to run almost all of these applications. The long list reveals the great effort that archaeologists have to put into training in order to be able to use all the software tools. It confirms the need for courses in computing applications very early in academic archaeological training.

9. What archaeological methods use computing tools?

I have frequently pointed out the prime importance of separating the level of techniques (which are steadily improved and often replaced) from the level of methods or best practices (which are only optimised). The techniques are the field of competence of computer scientists or statisticians whereas the methods are the field of competence of archaeologists. For example, it is fundamental to distinguish sample dating (involving a laboratory's competence in radiocarbon dating) from site dating (involving an archaeologist's competence).

The following list of items, which are the chapters of an archaeological textbook, shows the major role of computational archaeology in the process of archaeological investigation (Djindjian 2011):

- Archaeological BPM (business process management)
- Survey

- Excavations
- Stratigraphy
- Sampling for Rescue archaeology
- Typology
- Stylistic analysis
- Seriation
- Culture historical identification
- Intra-site spatial analysis
- Metropolitan spatial analysis
- Archaeology of the construction
- Raw material and manufacturing characterization
- Landscape analysis
- Image processing for special archaeological purposes
- Environmental studies
- Exchange systems
- Virtual Archaeology
- Demography
- Food resource management system
- Transition models
- Collapse models
- Economic models
- Network analysis
- Complex system reconstitution
- Culture Resource Management (CRM)
- Epigraphy
- Etc. !

10. Towards a generalised cognitive framework?

The books ' Analytical Archaeology ' published by J. D. Clarke (Clarke 1968) and ' Archaeological constructs ' by J.-C. Gardin (Gardin 1979) reveal that the formalisation of an archaeological construct is also the aim of computational archaeology, just as in the case of artificial intelligence (AI).

Over the last fifty years of archaeology it is possible to distinguish two different approaches with regard to archaeological constructs:

- The constructs are embedded, explicitly or not, in an ideology, a paradigm or a theory (in the Anglo-Saxon sense). In fact, they may be considered as operating an a priori reduction of the range of possibilities: evolutionism, Marxism, Neo-Marxism, functionalism, cultural ecology, gender theory, substantivism, Marrism, Kossinnism, behavioural archaeology, evolutionary archaeology, symbolist archaeology, etc.

Such a reduction may only be useful if it is used not as a dogma (which generally defines an ideology) but rather as a driving force to explore the explanations which were deduced.

- The constructs must be formalised, backed by a cognitive framework (in other words, an epistemology), which is nothing other than a theory of knowledge. An example of this kind of approach based on Peirce's logic is my paper '*Pour une théorie générale de la connaissance en archeologie*' (Djindjian 2002).

In such a context the traditional opposition between processual archaeology (New Archaeology) of the 1960s and post-processual archaeology (or symbolist archaeology or post-modern archaeology) of the late 1980s, which is also a classical opposition between structuralism and hermeneutics, appears to be obsolete in comparison with the progress registered in cognitive sciences.

It is important to point out that specialists in computational archaeology have to be considered as being the best contributors to the renewal of the theoretical framework of archaeology.

An example of such a contribution is the topic of the complementarity between the data-oriented approach and process-oriented approach in archaeology. In computer sciences there is a classic complementarity between the data-oriented approach (date bases and data storage), the computation approach (algorithmic) and the process-oriented approach (real time).

Archaeology of the 19th and 20th centuries was mainly a 'data-oriented archaeology ' following the Montelius typology and the corpus programs, renewed in the 1970s by data retrieval systems (archaeological data banks) and more recently by the Internet, making up the ' back office ' of archaeology.

The process-oriented approach concerns first the organisation of the archaeological activity (APM or archaeological process management), second the study of the reliability and the representativeness of the archaeological record (taphonomy) and third the systemic reconstruction of past societies (Djindjian, 2014).

11. A charter for ' 21st Century Archaeology'

The goal of computational archaeology is to act as a driving force for the creation of a present archaeology, able to generate improved knowledge and to reconstruct more reliable systems. The following charter of recommendations may illustrate such a programme:

- Relaunch thesaurus and ontology projects in all archaeological fields!
- Create multimedia data bases to save millions of archaeological slides and drawings!
- Write International archaeological standards!
- Start a 3D revolution in Archaeology!
- Think process and systems and renew all archaeological issues!
- Take part in multi-agent system simulations, processes of governance, social organisation, societal behaviours, beliefs, etc.!
- Ignore ideologies, paradigms, theories and the like!

- Carry out real multidisciplinary studies: be inspired by new computerised techniques and integrate but not blindly apply them because of the unreliability of the archaeological record which makes things more complex!
- Ensure high-level academic training for new generations of archaeologists!
- Create specialised laboratories in research institutes!
- Create chairs of ' Archaeological Methods and Theory'!
- Etc.

12. Conclusions : the 21st century archaeologist

The 21st century archaeologists are no longer excavators: they integrate other disciplines such as history, epigraphy, geography, anthropology, ethnology, economy, agronomy, physics, chemistry, mathematics, computer science, etc. They shoulder the very difficult task of reconstructing the complex systems of past societies based on partial, biased and meaningless archaeological and epigraphic data. They also play a role in society: knowledge of the past enables them to understand the present and to anticipate the future. They are the only scientists to conceive the depth of the time. Computational archaeology may play a major role in such a challenge, but it needs a proper name, a proper scientific review and a proper conference, well accepted and open to all specialists.

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