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LOGIC AND COMPUTING: A HISTORICAL BACKGROUND

1. Introduction

Computer science refers to a complex set of scientific disciplines that are concerned with the formal study of tools, methods and processes for the representation of information and its elaboration. As in other technical-scientific disciplines, a set of concepts, principles, and logical-mathematical properties constitutes the theoretical foundation of computer science, which is grounded on the development of formal models of computation to design new IT tools and applications. Theoretical computer science has accompanied the dissemination of computer systems in the various areas of human activity by creating the conceptual and cultural aspects on which to promote technological innovation.

The theoretical apparatus of computer science often concerns topics that have been studied even before the advent of electronic calculators (Ausiello 2007; *Per il centenario di Alan Turing* 2014). This phenomenon also characterizes the history of Humanities Computing in general, and Archaeological Computing in particular, where the link between logic and computing materializes in the debate on the definition of formal models and of a formal language, which is the kind of language machines understand (see, in particular, Orlandi 1992, 1997). Therefore, the aim of this paper is to briefly illustrate the earliest theoretical contributions to the pioneering application of computers to archaeological research and the resulting effects.

As we will show, the logic-computing binomial is crucial in archaeology, where computing mainly appeared as an ancillary technique of applied mathematics until the 1960s, when a crossdisciplinary approach emerged and the interrelationship between culture and technologies was central in the construction of the new discipline.

2. The Bibliography of Archaeological Computing: a cultural bridge between the past and the future

A recent research work, carried out as part of the international project on The History of Archaeological Computing, jointly promoted by the Italian National Research Council and the Accademia Nazionale dei Lincei (http://archaeologicalcomputing.lincei.it/), allowed us to publish online the database of the Bibliography of Archaeological Computing (Fig. 1). The database was regularly implemented during the first ten years of publication of the international scholarly Journal «Archeologia e Calcolatori» (1990-1999), and covers a period ranging from 1989 to 2000. The dataset was revised and

Fig. 1 – The homepage of the Virtual Museum of Archaeological Computing (VMAC): the Bibliography of Archaeological Computing is listed among the Highlights.

made available online in the Virtual Museum of Archaeological Computing (Moscati, Orlandi 2019), featuring more than 2,700 titles.

Data structuring and updating led us to re-appreciate the analysis of the results, which were published for the first time in the 10th issue of the Journal (Moscati 1999), by linking the period under investigation with the achievements of the previous decades and the challenges of the years to come. A first quantitative discussion of the results achieved was presented in the 30th anniversary issue of the Journal «Archeologia e Calcolatori» (Caravale 2019), and a more in-depth study is in preparation (Caravale, Moscati in press).

The first part of this paper, therefore, focuses on the earliest accounts and classification of computer applications in the Humanities that span from theoretical debates to methodological reflections. In the early 1960s, boundaries between the many disciplines belonging to the Social Sciences and Humanities were still blurred in their relationship with new technologies: that is why literature, linguistics, psychology, history, anthropology, archaeology, all made progress together towards the new solutions offered by the application of computer science.

As a consequence, the few pioneering works in archaeology were listed in the first volumes of the Computer Literature Bibliography, published by the National Bureau of Standards of the United States Department of Commerce (Youden 1965, for the years 1946-1963; Youden 1968, for the years 1964-1967). In addition, important theoretical and methodological contributions

Fig. 2 – The interactive itinerary of the VMAC dedicated to the legacy of J.-C. Gardin and R. Ginouvès in the publication of archaeological results, by Virginie Fromageot-Laniepce.

to archaeological computing were published in the second half of the 1960s and the beginning of the1970s in the Journal «Computers and the Humanities», established in 1966 with funding from IBM and the United States Steel Foundation. The part concerning archaeology within the Journal's Annual Bibliography was edited for the first year by Dee F. Green and then by Robert Chenhall, the founder in 1965 of the «Newsletter of Computer Archaeology» and one of the first of scholars to be interested in developing and promoting computerised cataloguing systems.

During this first period of experimentation, literature surveys were aimed not so much at producing systematic lists of applications – indeed still sporadic – as at exploring the new field of knowledge that was emerging thanks to the spread of computers. The objective was to recognise the fields of application, to verify the different approaches, and to predict the future trajectory of the discipline. Only in the late 1980s and early 1990s, they were followed by the publication of the earliest bibliographical reviews specifically dedicated to archaeological computing.

3. The pioneering contributions

The changing role of theoretical and applied archaeology was approached from different interdisciplinary perspectives. Jean-Claude Gardin, George L. Cowgill, Robert G. Chenhall (Gardin 1965, 1971; Cowgill 1967; Chenhall 1968) were among the first scholars who systematically analysed the impact of computers on the automatic processing of archaeological data (Figs. 2-3).

Several approaches to the subject matter soon emerged. They can be closely related to the diverse background and research purposes of the three scholars and, in general, to the new quantitative approach in archaeology. Indeed, a wide range of scientific methods and instruments increasingly became part of archaeological research: from statistical techniques to automatic data processing, from archaeometric data analysis to geophysical prospection techniques, from information retrieval systems to data banks, from aerial photography to remote sensing methods, etc. Archaeological research was, therefore, provided with the possibility of building up a new

Fig. 3 – The interactive itinerary of the VMAC dedicated to Robert G. Chenhall, by Stephen Fox.

area of "objective" data and experimenting with computation, simulation, and computer graphics techniques.

The adoption of mathematical and statistical methods gained particular success in the United States, thanks to the methodological foundations laid out by scholars such as Albert C. Spaulding (Spaulding 1953) and the extension of the New Archaeology cultural movement (Binford 1965; Binford, Binford 1968). This movement rapidly spread out in Europe, giving birth to the so-called British New Archaeology that pushed the discipline further towards the new frontiers of computing archaeology.

The distinction between the automatic processing of scientific information and the application of mathematical and statistical techniques was evident. This basic distinction – that Jean-Claude Gardin masterfully defined as *analyse documentaire* and *calcul*, respectively – allows us today to provide a comprehensive overview of the achievements made in those days (Djindjian, Moscati 2016).

4. The classification of archaeological computing applications: from the 1970s to the 1980s

In a short time, computer applications to archaeology were classified into four main macro-areas: statistical applications, automatic classification, documentary systems and databases, simulation techniques. 1975 marked another important step in archaeological computing, as James E. Doran and Frank R. Hodson published the first handbook on *Mathematics and Computers in Archaeology* (Doran, Hodson 1975) (Fig. 4). The volume was divided into three parts: 1) Basic archaeological and mathematical tools; 2) Data analysis; 3) Beyond data analysis. Problems and prospects.

The book achieved an enthusiastic response, confirming the existence of a new autonomous field of studies, and it helps us today to retrace the main theoretical lessons of the first few decades after the birth of archaeological computing. In addition, the solid scientific background of the two authors, who were not keen on the dogmatic approach promoted by the New Archaeologists – as noticed by Jean-Claude Gardin (1977) – marked also the separation between New Archaeology and Archaeological Computing. In the meantime, database applications were developing. They appeared in the 1970s and exploded in the 1980s (Chenhall 1971; Borillo, Gardin 1974; Ginouvès, Guimier-Sorbets 1978; Gaines 1981; Guimier-Sorbets 1990). In Europe, databases were the keystone for the opening of computer science to classical archaeology and art history and to the introduction of information systems in the inventory and management of cultural heritage (Fig. 5).

The rigid constraints of numeric data analysis were successively superseded by the creation of a new framework in which to manage archaeological

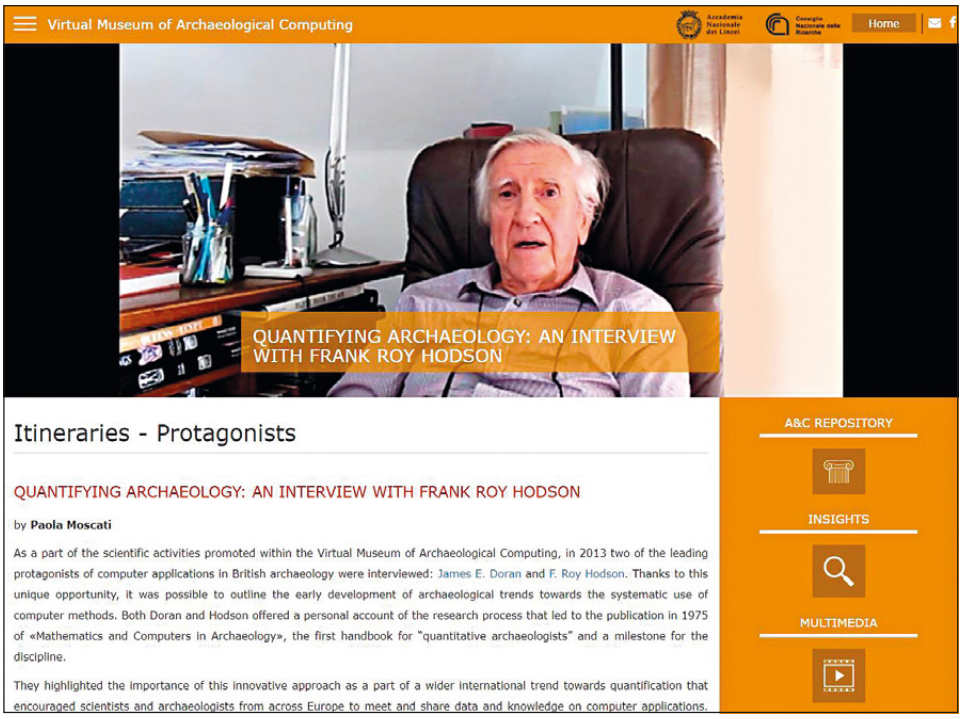

Fig. 4 – The interactive itinerary of the VMAC dedicated to F.R. Hodson's interview held in 2013, by Paola Moscati.

data, in order to ensure a progressive convergence between logic and computing. Logic and databases are inextricably intertwined, as logic provides a set of tools able to formalise data structuring/description procedures and to study data management tasks. In addition, the history of the relational data model – introduced in 1970 and diffused in archaeology only ten years later – is that of a scientific and technological revolution, in which the mathematical concept of relation represents the formalism for describing and representing data.

The spread of data management information systems contributed to the distinction of two main archaeological research streams: i) the application of mathematical and statistical techniques – mainly in prehistoric studies – as a powerful interpretative tool for artefacts classification and the study of spatial distribution patterns; ii) the use of databases and information systems for inventory and cataloguing purposes, often with the specific aim of establishing a computer platform on which to record, query and retrieve information coming from archaeological *corpora*. In addition, a third sector

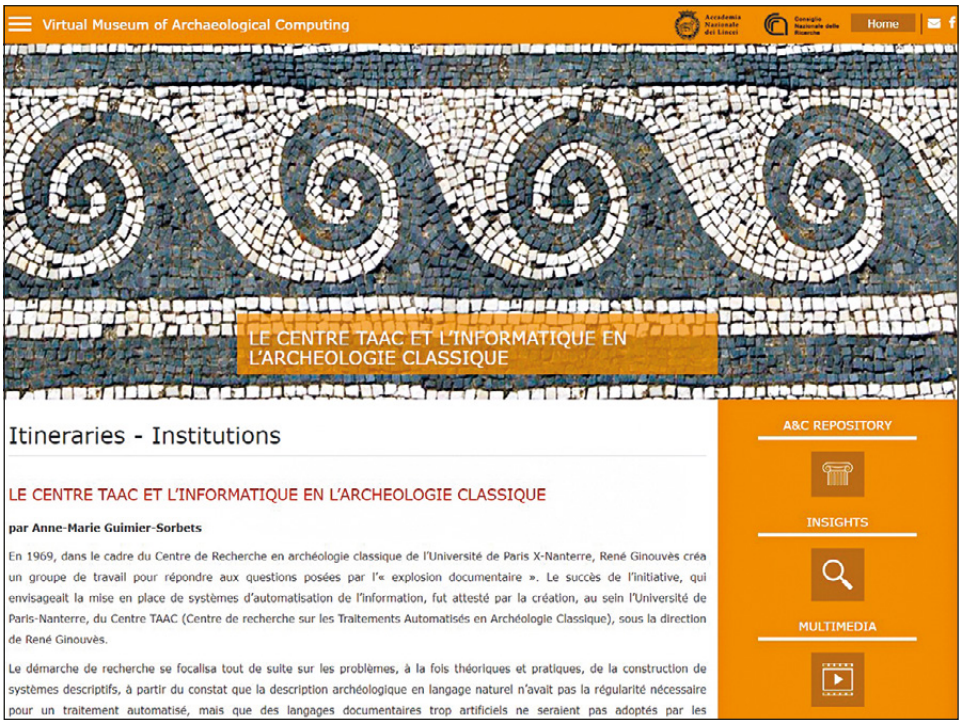

Fig. 5 – The interactive itinerary of the VMAC dedicated to computer science and classical archaeology, by Anne-Marie Guimier-Sorbets.

of applications gradually opened up to the use of databases, focusing on the management of excavation data (Fig. 6).

Two exemplary books seal these three decades of theoretical speculation, offering a reconstruction of this long historical path enriched by an extensive bibliographical apparatus: Gardin's book *Le calcul et la raison. Essais sur la formalisation du discours savant* et Djindjian's book *Méthodes pour l'archéologie*, both published in Paris in 1991 (Gardin 1991; Djindjian 1991). The first one highlights the importance of the formalisation and symbolic representation of knowledge in the explanation of complex historical phenomena and the affirmation of the logico-semantic approach of "logicist" analysis as opposed to the hypothetico-deductive approach of quantitative archaeology (Genet 1992). The second one emphasises the importance of a new interdisciplinary and global approach to archaeological research, by pivoting around acquisition, treatment and data analysis methods.

Fig. 6 – The interactive itinerary of the VMAC dedicated to the first European postgraduate course on Data Processing and Mathematics Applied to Archaeology (Valbonne-Montpellier 1983), by Paola Moscati.

5. The repository of «Archeologia e Calcolatori»

Since 1990, the articles published in the Journal «Archeologia e Calcolatori» have been classified on the basis of two distinct categories: Computer typology, to describe the methods of data analysis and processing, and Subject field, to describe the main areas of archaeological research involved in the computer revolution. This double classification system was designed to play a preparatory role in the investigation of the subject matter, providing a synthesis framework of the research sectors directly involved in the use of computer tools and, at the same time, of the most common applications.

The classification was subdivided into the following groups: Archaeometry; Classification of archaeological finds; Cultural Resource Management; Data dissemination and education; Documentation, conservation and restoration; Epigraphy and numismatics; Excavations, topography

and urban planning; Geoarchaeology; Theoretical and methodological problems. This list covers the most prominent areas of archaeological research: from field investigations to the analysis and interpretation of archaeological records and the management, safeguarding and promotion of archaeological heritage.

From a technical point of view, nine categories were identified that take into account the achievements and application challenges faced by archaeological computing in the 1990s, which was significantly marked by the advent of Geographical Information Systems, for extensive research purposes linked to the multi-layer and multi-scale georefenced data management, and by the Internet, for communication strategies and the implementation of and access to multimedia resources: Computer graphics, IP, CAD; Data encoding and metadata; Database; GIS and cartography; Multimedia and web tools; Remote Sensing; Simulation and Artificial Intelligence; Statistics; Virtual Reality and 3D modelling. Finally, a tenth category was added to cover the History of applications and research projects.

Over the years, we have repeatedly tested the appropriateness of our classification against the evolution of digital archaeology and ICT tools and it has become an essential part of the description model of the textual resources in our digital repository, when the Journal joined in 2005 the Open Archives Initiative, implementing the OAI-PMH protocol (Moscati 2018). This choice to contribute to the open access movement has allowed us to cooperate with initiatives aimed at the aggregation of cultural and scientific digital contents, such as CulturaItalia and Europeana, the European digital cultural library.

Today, data integration, the development of advanced ICT tools, and the deployment of international e-infrastructures allow archaeologists to process and investigate disparate data sources, addressing simultaneously all the issues raised by archaeological research. «Archeologia e Calcolatori», ready as ever to the new challenges arising from the computer analysis of archaeological data, is now planning new strategies to enrich and refine the classification and sharing of its textual resources. Web mapping strategies, according to the guidelines of open source international standards, and Social Network Analysis (SNA) techniques are being tested to explore and highlight the relationships between archaeological research areas and digital technologies (Cantone, Caravale 2019).

6. Future perspectives

The old debate on the relationship between logic and computing, as well as between theory and applications, is now a distant memory. The shift from the epistemological approach of archaeological computing to

the instrumental approach of digital archaeology, together with the main concerns of Digital Heritage, have introduced methodological changes and new research objectives (Moscati 2019b). Digital archaeologists have to embrace many disciplines, experiment with merged methodologies, and make use of many tools, as strategies of conservation, preservation, prevention, and dissemination interpenetrate the acquisition, documentation, and interpretation processes. In addition, archaeology plays a key role in laboratories and digital infrastructures aimed at developing heritage science resources.

Among the most important challenges for the future of digital archaeology, we can quote the reconstruction and visualisation of the past in 3D, the promotion of public involvement, the wider adoption of the Open Science paradigm, the access to and the rapid dissemination of scientific results through e-infrastructures. Therefore, a new classification of the textual resources of «Archeologia e Calcolatori» should be planned in the near future as a unique opportunity to prioritise the automatic extraction of new topics and model the domain of computer applications in archaeology thanks to semantic technologies and ontology-based knowledge representation.

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REFERENCES

Ausiello G. 2007, *Informatica teorica*, in *Enciclopedia della Scienza e della Tecnica*, Istituto della Enciclopedia Italiana Treccani (http://www.treccani.it/enciclopedia/informatica-teorica_(Enciclopedia-della-Scienza-e-della-Tecnica)/).

Binford L.R. 1965, *Archaeological systematics and the study of culture process*, «American Antiquity», 31, 2, 203-210.

Binford L.R., Binford S.R. (eds.) 1968, *New Perspectives in Archaeology*, Chicago, Aldine Publishing Company.

Borillo M., Gardin J.-C. (eds.) 1974, *Banques de données archéologiques. Actes du Colloque (Marseille 1972)*, Paris, Editions du CNRS.

Caravale A. 2019, *La banca dati bibliografica degli anni Novanta. Dati quantitativi e analisi statistiche*, in Moscati 2019a, 109-122 (https://doi.org/10.19282/ac.30.2019.08).

Caravale A., Cantone F. 2019, «*Archeologia e Calcolatori*». *Classificazione geografica e tematica per la condivisione della conoscenza*, in Moscati 2019a, 93-107 (https://doi.org/10.19282/ac.30.2019.07).

Caravale A., Moscati P. in press, *La Bibliografia di Informatica Archeologica. Gli anni Novanta*, Firenze, Edizioni All'Insegna del Giglio.

Chenhall R.G. 1968, *The impact of computers on archaeological theory: An appraisal and projection*, «Computers and the Humanities», 3, 1, 15-24.

Chenhall R.G. 1971, *The archaeological data bank: A progress report*, «Computers and the Humanities», 5, 159-169.

Cowgill G.L. 1967, *Computer applications in archaeology*, «Computers and the Humanities», 2, 1, 17-23.

Djindjian F. 1991, *Méthodes pour l'archéologie*, Paris, Armand Colin.

Djindjian F., Moscati P. (eds.) 2016, *Dossier: Jean-Claude Gardin (1925-2015)*, «Les nouvelles de l'archéologie», 144 (https://journals.openedition.org/nda/3448).

Doran J.E., Hodson F.R. 1975, *Mathematics and Computers in Archaeology*, Edinburgh, Edinburgh University Press, 1975.

Gaines S. 1981, *Data Bank Applications in Archaeology*, Tucson, The University of Arizona Press.

Gardin J.-C. 1965, *A typology of computer uses in anthropology*, in D.H. Hymes, *The Use of Computers in Anthropology*, London-The Hague-Paris, Mouton, 377-397.

Gardin J.-C. 1971, *Archaeology and computers: New perspectives*, in *Use of Computers, Documentation and the Social Sciences*, «International Social Science Journal», 23, 2, 189-203.

Gardin J.-C. 1977, *Archéologie et calcul: à propos de deux ouvrages récents*, «Revue Archéologique», 2, 307-320.

Gardin J.-C. 1991, *Le calcul et la raison. Essais sur la formalisation du discours savant*, Paris, École des Hautes Études en Sciences Sociales.

Genet J.-Ph. 1992, *Calcul ou logicisme ? À propos d'un ouvrage récent*, «Histoire & Mesure», 7, 1-2, 171-179 (https://doi.org/10.3406/hism.1992.1591).

Ginouvès R., Guimier-Sorbets A.-M. 1978, *La constitution des données en archéologie classique*, Paris, Editions du CNRS.

Guimier-Sorbets A.-M. 1990, *Les bases de données en archéologie. Conception et mise en œuv*re, Paris, Editions du CNRS.

Moscati P. 1999, *Archeologia e Calcolatori: dieci anni di contributi all'informatica archeolog*ica, «Archeologia e Calcolatori», 10, 343-352 (http://www.archcalc.cnr.it/indice/PDF10/10_23_Moscati.pdf).

Moscati P. 2018, *Le rôle de l'open access dans la diffusion des résultats de la recherche scientifique: le cas de «Archeologia e Calcolatori»*, «UISPP Journal», 1, 27-41.

Moscati P. 2019a (ed.), *30 anni di «Archeologia e Calcolatori». Tra memoria e progettualità*, «Archeologia e Calcolatori», 30, 9-138.

Moscati P. 2019b, *Informatica archeologica e archeologia digitale. Le risposte dalla rete*, in Moscati 2019a, 21-38 (https://doi.org/10.19282/ac.30.2019.03).

Moscati P., Orlandi T. (eds.) 2019, *Il Museo Virtuale dell'Informatica Archeologica. Una collaborazione tra l'Accademia Nazionale dei Lincei e il Consiglio Nazionale delle Ricerche. Atti della Segnatura (Roma 2017)*, «Rendiconti dell'Accademia Nazionale dei Lincei», s. 9, 1-120.

Orlandi T. 1992, *Informatica umanistica: realizzazioni e prospettive*, in *Calcolatori e scienze umane. Scritti del Convegno organizzato dall'Accademia Nazionale dei Lincei e dalla Fondazione IBM Italia (Roma 1991)*, Milano Etas Libri, 1-22.

Orlandi T. 1997, *Informatica, formalizzazione e discipline umanistiche*, in T. Orlandi (ed.), *Discipline umanistiche e informatica. Il problema della formalizzazione. Ciclo di Seminari (Roma, febbraio-giugno 1994)*, Contributi del Centro Linceo Interdisciplinare «Beniamino Segre» n. 96, Roma, Accademia Nazionale dei Lincei, 7-17.

Per il centenario di Alan Turing fondatore dell'informatica. Atti del Convegno (Roma 2012), Contributi del Centro linceo interdisciplinare "Beniamino Segre" n. 129, Roma 2014, Accademia Nazionale dei Lincei.

Spaulding A.C. 1953, *Statistical techniques for the discovery of artifact type*s, «American Antiquity», 18, 4, 305-311.

Youden W.W. 1965, *Computer Literature Bibliography*, Washington, U.S. Dept. of Commerce, National Bureau of Standards.

Youden W.W. 1968, *Computer Literature Bibliography*, Washington, U.S. Dept. of Commerce, National Bureau of Standards.

ABSTRACT

The history of archaeological computing has long been characterised by the distinction between the application of mathematical and statistical techniques, as part of the so-called movement of quantitative archaeology, and the use of databases and information systems for descriptive and documentary purposes. The intensity of the debate on the relationship between logic and computing, as well as between theory and applications, began to wave in the 1990s. Over time, data integration and new ICT tools have allowed archaeologists to address simultaneously all the issues raised by the archaeological research. This paper focuses on the evolution of methods and techniques in this specific research area, thanks to the analysis of literary sources, the Bibliography of Archaeological Computing, accessible via the Virtual Museum of Archaeological Computing website, and the scientific articles published in the open access international journal «Archeologia e Calcolatori».