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### Editorial

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## Editorial

Guillaume Robin  
University of Edinburgh  
School of History, Classics and Archaeology  
William Robertson Wing, Old Medical School  
Teviot Place  
Edinburgh EH8 9AG  
United Kingdom  
[guillaume.robin@ed.ac.uk](mailto:guillaume.robin@ed.ac.uk)

There are many different ways to approach and study rock art both in the field and in the lab (Bednarik 2007; McDonald and Veth 2012). For example, decorated sites can be mapped and analysed spatially using Geographic Information Systems (GIS); the manufacture of rock paintings can be studied through chemical analyses using portable spectrometry (e.g. pXRF) or sampled for AMS radiocarbon dating. But the most frequent and fundamental task for rock art fieldworker consists of producing pictures such as photographs or drawings in order to visually document and analyse the art and its context.

Recording rock art is a complex process that does not simply aim at reproducing what is visible on the field. Recording is an operation that involves selecting and extracting the information considered as important from a rock face in order to transfer this information to both specialists and general public (Aujoulat 1993; Domingo Sanz 2014). Recording rock art, just as recording an excavated structure or a stratigraphy, is not reproducing the visible reality: it is interpreting the reality in order to make it more understandable archaeologically.

For a long time, the traditional way to record rock art was to use tracing on paper or plastic sheet directly applied to the rock surface (GRAPP 1993). But from the 1990s, the emergence and development of computer imaging techniques have initiated a 'digital revolution' in rock art studies as in many other fields of the humanities. To sum up this very briefly, in 30 years we have gone from flat, two dimensional black and white drawings of rock motifs to interactive 3D models rendering both the contextual setting and the complex content of the art. How has this digital transition impacted our methods as well as our general approach and understanding of rock art?

This special issue of *Digital Applications in Archaeology and Cultural Heritage* is dedicated to digital imaging techniques for the study of rock art and results from a two-day workshop held in May 2014 at the McDonald Institute for Archaeological Research, University of Cambridge, UK. The aim of the workshop was to bring together international specialists working on different rock art contexts from different periods and areas (from Palaeolithic caves to Neolithic chambered tombs in Europe and to more recent rock art traditions in the USA and Africa) in order to share the recent technical developments in their own field and to discuss their advantages and limitations, as well as the future challenges for rock art digital techniques.

The 15 articles of the present issue reflect this geographical and chronological diversity and provide an overview of the different techniques currently used across regions and chronological contexts. Photo-processing techniques, frequently used to detect and record faint paint on rock surfaces, are presented by Miguel Angel Rogerio-Candelera, by Natalia Cortón Noya, Ángela López García and Fernando Carrera Ramírez, and by David Robinson

and colleagues, while Jean-Loïc Le Quellec, Claudia Defrasne and Frédérique Duquesnoy give a critical assessment of the widely used DStretch photograph enhancement programme. Reflectance Transformation Imaging (RTI) and its application to prehistoric rock carving are the focus of the article by Marta Diaz-Guardamino, Leonardo García Sanjuán, David Wheatley and Víctor Rodríguez Zamora. Photogrammetry, which allows to build 3D models from photographs with an increasingly high resolution, is more and more used in the field of rock art studies. Many articles in this issue describe how they can serve various purposes (see Plisson and Zotkina; Dessi *et al.*; Alexander *et al.*; Cassen *et al.*; Cortón Noya *et al.*; Williams and Shee Twohig). Finally, 3D laser scanners have long been used to record rock art contexts such as caves or chambered tombs. Recent developments and original applications are described by Camille Bourdier and Oscar Fuentes, and by Kenneth Lymer. All these techniques and technologies have evolved quite rapidly in the past few years. The present special issue is aimed at giving an overview of state-of-the art developments through a collection of very recent, and often still on-going, research projects.

### **Experimenting with digital imaging techniques for the study of rock art (1980-2015): a brief historiographic overview**

Digital techniques have been used in archaeology for many years and this special issue gives the occasion to look backwards and get an overview of this phase of technical transition from direct tracing to computer methods in rock art studies (see also Loendorf 2001; Bednarik 2007, chp. 5; Brady and Gunn 2012; Mudge *et al.* 2012; Domingo Sanz 2014). A rapid bibliographical research from my computer and various libraries has resulted in over 90 references (mostly journal articles and book chapters) published between the early 1980s and today and whose title deals specifically with the topic of computer methods applied to the recording of various rock art contexts from around the globe. This bibliography is certainly not exhaustive, I probably missed many articles from regionally-focused journals or volumes across the world, but it gives us an acceptable basis of information to look at historical trends in the experimental development of digital applications to rock art.

The **table** (Figure 1) below presents the references in a chronological order and classified into three categories. The first column is for publications presenting advances in digital tracing and photographic enhancement techniques; the second table shows works dealing with 2.5D and 3D photographic techniques, such as Polynomial Texture Mapping (PTM) and Structure From Motion (SfM or photogrammetry), and a third column presents articles discussing applications of 3D scanning to rock art sites.

This rudimentary bibliographical overview gives us three main information. The first one is that digital applications to rock art were first experimented in the early 1980s, which is much earlier than I expected. For example, Michael Rip (1983) in South Africa and Norbert Aujoulat (1987) in France were probably the first archaeologists to use a computer for the colour enhancement of photographs of rock paintings (see also Brady and Gunn 2012). These experimentations gave good results although the processes themselves were fairly limited technically: computers were off course not as powerful as today then; moreover the photographs themselves were analog images (not digital ones) that had to be scanned before being processed, which influenced both the operating time and results quality of the technique. Similarly, in the 1990s, first attempts by Clifford Ogleby (1996) and Russell Kirsh (1997) to build digital 3D photogrammetric models of rock paintings and petroglyphs on a computer were limited because based on analog photographs and low-powered computers (see also early, computer-free, photogrammetric recording of rock art panels: Clouten 1974;

Rivett 1977, 1978, 1980, 1983; Turpin *et al.* 1979). However, it is interesting to note that various techniques we are routinely using today, such as colorimetric enhancement of photographs or 3D photogrammetry, were already experimented before digital photography was in use and with relatively limited computer power. In other words, the idea of the application was there before the techniques became really available.

The second information that we learn from this global bibliographical overview is that the year 2000 marks a major turning point in the methods used to record rock art. The year 2000 is the real starting date of digital applications in rock art studies and this is reflected by a 'boom' in the number of publications addressing that specific topic. The sudden expansion of digital techniques and their wide use and application in the field of rock art studies from that particular moment is due to the simultaneous availability of three important technologies: digital cameras, which were created and commercialised before the 2000s but began to be really efficient and affordable at the end of the 1990s; powerful computers, which then became able to run sophisticated image processing software such as Adobe Photoshop; and 3D laser scanners, which also became more technically and financially available to the archaeology and heritage sectors at the very end of the 1990s.

Finally, the third information highlighted in table is that most recent works do not use one single technique but a combination of several 2D and 3D techniques to study rock art sites. I will further discuss this particular trend below.

### **Rock art and digital visualising techniques: issues and challenges**

Digital recording techniques have many obvious advantages over traditional analog ones. Today most of rock art specialists prefer to work with digital cameras, computers and digital technologies because, contrary to rubbing or direct tracing for example, they do not require a physical contact with the art and are therefore non invasive. But the main advantage is archaeological: digital techniques have enabled archaeologists to answer questions that were not possible to answer before with traditional techniques. Over the last 20 years, digital imaging techniques have made crucial contributions to the field in different ways.

One of the most important advances is their capacity to detect and record faint carvings and paintings that are not visible with the naked eye. A typical example are the photographic enhancement techniques such as DStretch: spectacular examples of painted panels being completely reinterpreted after the virtual recovery of invisible details are presented in the articles of Le Quellec and colleagues (Sahara) and Robinson and colleagues (California). Similar results can be obtained by other photo-enhancement techniques, using Principal Component Analysis of colours (see contributions by Rogerio Candelera *et al.* and Domingo Sanz *et al.*) (see also Hollmann & Crause 2011). Photogrammetric techniques also allows to virtually explore areas that are not accessible to the human eye. In the present volume, Serge Cassen, Valentin Grimaud, and Laurent Lescop present for the first time a frontal view of pecked motifs located on a face of a capstone in Gavrinis megalithic tomb which is obscured by an adjacent stone and therefore not visible in real conditions. Using macro lenses on their digital cameras, Hugues Plisson and Lydia Zotkina have produced very accurate 3D photogrammetric models of milimetric sections of incised and pecked marks on the rock, allowing us to understand the tools, gestures and strategies of prehistoric 'artists' in the manufacture of rock art in Russia, France and Portugal, which would not be possible to observe in so much details directly on the field or from laser scan data.

Complex superimpositions of motifs are another old problem in rock art studies that has been solved by digital visualising techniques in recent years. Several techniques have been applied to reconstruct the chronological sequence in the execution of the motifs. Robert Gunn has used DStretch to unfold superimposed paintings in Australia, providing us with an elaborate Harris matrix showing the complex ‘art stratigraphy’ of the site (Gunn *et al.* 2010). A similar situation with superimposed engravings has been solved by using RTI in the rock art of Côa Valley in Portugal (Mudge *et al.* 2012). In this volume you will find further developments of this approach: Serge Cassen and his colleagues reconstruct the numerous steps that have resulted in the conspicuous geometric decoration covering the whole surface of upright stones in Gavrinis, supporting this by a Harris matrix; Robinson and colleagues use various processing in Photoshop to identify four main phases for painted panel E at Pleito; Marta Diaz-Guardamino and colleagues use RTI to explore various phases of modification and reworking of Late Bronze Age engraved stele in Spain, giving new insights into the complex biographies of these objects; Camille Bourdier and Oscar Fuentes use laser scan data to study complex sequences of superimposition and reworking at the Late Palaeolithic sculpted frieze of Roc-aux-Sorciers in France, successfully identifying remaining parts of sculpted animals belonging to previous phases in the sequence, which sheds new lights on the history of the site.

For a long time, rock art studies have focused on the study of motifs only with little attention to their immediate physical context and landscape setting. One reason for that is that adapted tools allowing to deal with these different scales were not available. One major advance of digital technologies and methods has been to provide platforms where individual motifs, their micro-topographic context (rock surface) and general setting could be integrated and examined simultaneously. Such a methodology often involves the combination of several techniques into integrated ‘packages’, with each technique completing the gaps and limitations of the other. For example, Ines Domingo Sanz and colleagues working in decorated shelters of the Levantine region in Spain have combined 2D photographic techniques to detect and explore the content of faint paintings with 3D techniques in order to place the art in its larger physical context (Domingo Sanz *et al.* 2013). Such an approach is very well illustrated in the present issue by the PITOTI project on Valcamonica rock art, in the Italian Alps (see article by Alexander *et al.*). The project’s team is designing various technologies with cameras fixed on portable scanners and drones in order to produce Structure From Motion models at various scales, from details of the pecked motifs to the landscape setting of rock art panels. Serge Cassen and colleagues are also combining different techniques at different levels (time-of-flight laser scanner, portable light scanner, photogrammetry, DStretch, digital tracing) in order to solve the challenge of producing a comprehensive and detailed recording of a megalithic chambered tomb, from the millimetric peck marks of the engravings to the huge mass of the cairn covering the monument (see also Cassen *et al.* 2014). The impressive and innovative work of David Robinson and colleagues in California is another demonstration of the promising potential of combining various techniques within a same methodological strategy: using various portable technologies (pXRF, portable scanners, cameras, etc.), they are able to collect data on the chemical composition of the paintings, their content and complex superimposition, 3D context, etc. and to integrate them within a same digital platform. The original contribution by Kenneth Lymer shows how laser scan data can be efficiently processed through GIS software, creating an interesting collaboration between two techniques normally used separately. More and more colleagues in rock art studies are now thinking their methodological approach in similar multi-technical, integrated way, taking the best of each technique and building robust

processes. Combining techniques definitively looks like the standard of future fieldwork research in rock art.

Other strengths of digital applications in rock art studies can be cited such as the storage and conservation of digital data (not physically affected by deterioration through time as films, paper or plastic sheets can be) or their contributions to heritage management (monitoring techniques, e.g. Barnett *et al.* 2005; Plets *et al.* 2012) and as dissemination opportunities (e.g. interactive website, virtual visits, etc.).

But using digital techniques also implies several issues and challenges. Some practical issues with using these technologies on the field are quite obvious, such as the portability of the equipment (often to be carried to remote sites), the cost of the techniques (they need to be affordable for humanities-grade budgets), their ease of use (archaeologists normally have reasonable but limited engineering skills) and the problem of the size of the data for both processing and storage (especially for 3D and laser scan data). These aspects are discussed by various articles in the present issue, in particular by Silvia Tomaskova whose fieldwork on rock engravings in South Africa includes the setting up of a low-cost and user-friendly recording methodology which could be easily transferred to and used in the longer term by local communities. Similar concerns are presented in the article by Riccardo Dessi and colleagues from Sardinia who are working on designing a computer programme to create real-time 3D models of rock art from photographs, offering new solutions to both academic sectors and communities in the island and beyond.

There are technical issues, then, but it seems to me that the trickiest issues are human-related: they are not in the techniques themselves but in the ways we used them. What I find particularly interesting across the 30 years of 'digital experimentation' I have presented above, are the various problems that have emerged at the meeting point between the technological and the human, between mechanical factors and human factors. The historiographic overview has raised many (mostly unanswered) questions in my mind about this aspect of our work. In particular, how has the emergence of new technologies impacted our ways to research rock art? How have we approached and used these new fancy technologies as humans with rational archaeological questions as well as irrational desires and expectations?

As rock art archaeologists, we normally use these techniques as consumers. We normally take the techniques after they were created and then we adapt them to our particular needs. Examples of *ad hoc* methods and techniques specifically created and designed by engineers in order to answer methodological needs of rock art projects remain rare – three interesting examples are included in this issue (Alexander *et al.*; Seidl *et al.*; Dessi *et al.*). This fact leads to the following question: are new techniques, at the time they become available, rapidly understood by archaeologists as an opportunity to solve methodological problems for which they were already looking for solutions? Or, contrarily, do new techniques suggest new ways of studying rock art, new methodological questions and approaches that archaeologists had not thought about before?

It is not very easy to answer this question by reading the archaeological literature only and without the help of a dedicated survey among rock art archaeologists. The proportion of controlled and random activities is rarely discussed in archaeological reports. In rock art, unsuccessful experiments have rarely been reported and published (see Díaz-Andreu *et al.* 2006 for an interesting exception) and 'incidental' positive outcomes may always be

presented retrospectively as the result of a well-designed research approach planned from the beginning! It is probable that people have used digital techniques with both precise objectives and experimental ideas in mind. This is shown by recent examples where DStretch, which is a technique designed to detect faint paintings, was experimentally tested on very subtle alpine rock incisions (Defrasne 2014) and megalithic peck marks (Cassen *et al.* 2014), with surprisingly good results. In a similarly unexpected way, Elias López-Romero has recently demonstrated how now destroyed decorated megaliths and sites can be 3D reconstructed in photogrammetry from archive photographs and films (López-Romero 2014).

Another issue that has often been under-evaluated or maybe consciously ignored by rock art specialists is the part of human subjectivity that takes part in the process of recording rock art. Most of recording techniques are not automated or mechanical processes (see Seidl *et al.* in the present issue), and involve a large part of human choice and action: in the process one has to decide between what is important and what is not, what is art and what is a natural feature of the rock surface, etc. As Michel Lorblanchet (1993) puts it, ‘relever, c’est choisir’ (to trace [rock art] is to chose). Recording techniques have the function to help archaeologists make the best choices during this process, but the part of human subjectivity remains significant, although computer techniques (especially photo-enhancement techniques) have considerably reduced it (see also Brady and Gunn 2012, 630-1).

This issue of subjectivity is directly addressed here by Jean-Loïc Le Quellec, Claudia Defrasne and Frédérique Duquesnoy, who present the result of an original and interesting experience. Frédérique Duquesnoy sent the same picture of a Saharan painted motif (already enhanced by DStretch) to nine rock art colleagues and asked them to make their own tracing of the faint painted figures. With little surprise, Duquesnoy received nine different drawings with sometimes significant differences (see video in article). This shows that we can potentially have as many different interpretations of a motif as researchers studying it. Of course, most of participants in the test are not specialists of Saharan rock art and the lack of expertise may explain such diverse results; however, the experiment is not without more general implications: although *Journal of Archaeological Science* has been the most preferred venue to publish advances in rock art recording techniques (11 papers since 2000 – see bibliography below), can we really claim that this fundamental part of our work is objective and ‘scientific’?

Digital techniques are very helpful but they are not sufficient *per se*, they would never replace what is the most important in rock art fieldwork and research: the intuition and expertise of a rock art specialist. In this volume, Serge Cassen argues that studying rock art as a cultural production necessarily implies both (subjective) intuition and (objective) analysis: rather than being incompatible, both are more efficiently used together and should not be separated in the process.

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