COST-EFFECTIVE ROCK-ART RECORDING IN A PRODUCTION ENVIRONMENT: IS THERE A WIDER MESSAGE?

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ABSTRACT

At the CIPA Congress held in 2005, the first author presented a paper which described the development of a simple, cost effective method to record and document rock-art (Chandler and Fryer, 2005). The approach combined simple stereo-pairs acquired with consumer-grade digital cameras, used control implemented by either a scale-bar or coordinated targets and utilized commercial photogrammetric software to extract DEMs, orthophotos and create fly-thru visualizations. The method was originally developed and applied to Aboriginal rock-art, including both pictographs and petroglyphs at a range of sites and scales.

The technique has subsequently been adopted and used in production by the Northumberland and Durham Rock Art Recording Project, to spatially capture 1500 known rock-art motifs located in the northeast of England. This project, scheduled to run between 2004 and 2007, has developed a toolkit to enable non-intrusive digital recording of both the rock art and host rock surface. About 60 volunteers from the local community have been recruited and trained using a methodology specially designed for them to use with ease. This has been achieved through collaboration between Loughborough University, the two County Councils and English Heritage, who have played both a critical funding and coordinating role. This collaboration has provided the opportunity to develop both technical and logistical aspects of the methodology, and this paper will summarise how photogrammetry has contributed to the recording project, illustrated by example panels that have been captured by the volunteers. The methodological development will be described and how, through training and education, the volunteers have come to terms with using it. The paper will also indicate how the methodology ought to develop for future projects, particularly where camera-object distances of both greater and less than 1.5m are used. This would include the full range of carved panels that might be experienced 'out in the field', including smaller artefacts held in museum collections; use of higher resolution consumer grade cameras and practical ideas on how wide-scale calibration may be provided for non-specialists.

Of wider significance to heritage recording beyond rock-art, is the message that it is only simple recording methods which allows non-specialist volunteers to carry out the substantive fieldwork and data acquisition required. Mobilizing this resource generates additional benefits beyond the obvious labour cost savings. Wider local involvement: helps people to develop an understanding of the historic environment; helps local communities to care for their historic environment; and, in the process will assist in getting the historic environment on other people's agendas. This is politically significant, in the UK at least, because it relates directly to four Corporate Strategy Aims identified in English Heritage's Research Strategy document (English Heritage, 2005). Simple approaches stimulate and harness enthusiasm for the historic environment and directly address one of the key threats identified: the problem of labour and skills shortages. The Northumberland and Durham Rock Art Recording Project certainly demonstrates just how valuable the volunteer field-worker can be for data acquisition, if provided with appropriate tools.

1. INTRODUCTION

Most methodologies reported in the academic literature are rarely used in a production environment and it is a frequent criticism that technology transfer to the wider community is infrequently achieved (House of Commons, 1998). One of the constraining factors has always been the gap in expertise between exponent and potential practitioner, which means that if adopted, usage is normally temporary, at best. This paper demonstrates forcibly that simple methodologies are more readily adopted by practitioners and are more likely to be successfully implemented. Moreover, if both simple and cost effective methodologies are introduced, then even the unpaid voluntary sector can embrace the innovations, can develop them further and eventually, surprise us all.

The application area described in this paper is in the field of rock-art recording, which is found throughout the world and represents one of the few physical traces left by ancient civilizations that are directly accessible. The creation of some sort of facsimile of rock art is desirable, allowing for its scientific study and providing some protection against loss in the event of destruction. During a six-month period of study leave spent in Australia, the first author developed a simple methodology for recording aboriginal rock art, (Chandler and Fryer, 2005; Chandler et al., 2005a; Chandler et al., 2007) including both petroglyphs and pictographs (engraved and painted images respectively). This combined the use of consumer-grade digital cameras, simple control and commercial digital photogrammetric software to extract digital elevation models (DEMs) and orthophotographs and to create fly-through models. The technique has subsequently been adopted and used in production by the Northumberland and Durham Rock Art Recording Project, to capture 1500 known rock-art motifs located in the northeast of England. The work has been achieved through collaboration between Loughborough University, two County Councils and English Heritage, who have played both a critical funding and coordinating role. This project, scheduled to run between 2004 and mid-2007, has developed a toolkit to enable non-intrusive, three-dimensional, digital recording of both the rock art and the host rock surface. A significant aspect of human resourcing has been the recruitment of 60 volunteers from the near local community to carry out the rock-art recording activities. Initial training and education and early field experiences proved critical in the refinement of both technical and logistical aspects of the methodology, which will be described. The paper will also indicate how the methodology should evolve for future projects.

2. PAST USE OF PHOTOGRAMMETRY FOR ROCK ART RECORDING

An early example of photogrammetry being used to record rock surfaces is reported by Atkinson (1968) where a special stereo-metric camera system was used to manually measure contours of carved features on some of the standing stones at Stonehenge in the UK. Scogings (1978) used a similar method to record petroglyphs at Kinderdam, 300 km west of Johannesburg, South Africa. Features were again represented using contours, generated manually at 1mm intervals on a 1:1 scale plot. In a series of related projects, Rivett (1979) and Ogleby and Rivett (1985) demonstrated the benefits of photogrammetry for recording aboriginal rock-art, including both petroglyphs and pictographs. Fieldwork was conducted at a series of sites around Australia, including Kakadu National Park, Northern Territory; Whale Cave, NSW; Quinkin, Queensland; Hawkesbury, NSW; and various cave sites in Western Australia. Their "Handbook of Photogrammetry" (Ogleby and Rivett, 1985) was a key text, at that time, describing how to conduct a photogrammetric survey for field archaeology. More recently, Ogleby (1995; 1999; 2000) has continued to demonstrate the benefits of photogrammetry to a wider archaeological audience, including the Ayutthaya temple in Thailand (Ogleby, 1999) and Mount Olympus in Greece (Ogleby, 2000). In these two examples, an important final product has been the virtual model, enabling the visualization of the site from any perspective.

The International Committee for Architectural Photogrammetry (CIPA) was established to improve the recording of cultural monuments using photogrammetry and related methods. The conference proceedings of CIPA provide ample examples where imagery is being used to record (Peipe and Stephani, 2003; El-Hakim et al., 2005) and in some instances, even recreate, (Grün et al., 2004) our heritage. Patias (2007) provides a full review for the heritage sector and Remondino and El-Hakim (2006) review the current status of three-dimensional image-based modelling. One of important recommendations of CIPA is the "3x3" principle (Herbig and Waldhausl, 1997), which promotes the acquisition of photography suitable for photogrammetric measurement.

Figure 1 Petroglyph and simple scale control

The principles include three geometrical rules (control, base/distance ratio, normal photography); three photographic rules (constant camera geometry, soft illumination, film type); and three organisational rules (sketches, care, checks). It is disappointing that these principles and photogrammetric methods have not been adopted more widely outside the CIPA community. Indeed, one of the tasks identified by CIPA is to "bridge the gap" (Letellier, 2001) between the information user and the information provider, as highlighted within the RecorDIM initiative. In rock-art recording, Palumbo and Ogleby (2004) note that the impediment preventing wider adoption of photogrammetry is the lack of inexpensive, portable, automated and easy to use systems. It is believed that the simple methodology described briefly below and reported upon more fully prior (Chandler and Fryer, 2005; Chandler et al., 2005) and now being used in production (Chandler et al., 2007) demonstrate that a significant step towards achieving that objective has now been realised.

3. THE TECHNIQUE

3.1 Image acquisition

The methodology uses a simple stereo pair to provide the basic building block and provide stereoscopic coverage of rock-art sites, suitable for recording both petroglyphs and pictographs. For many simple sites, a single stereo pair is theoretically all that is required, but multiple stereo pairs provide redundancy, increased coverage and additional viewpoints. Conventional image pairs which are normal to the object (that is, with both camera axes perpendicular to the approximate plane of the object) can be acquired, but the author has obtained very good results with convergent imagery. If lighting permits, images can be acquired using a handheld camera, otherwise a modest camera tripod is required. A wide variety of consumer-grade digital cameras can be used; the author had access only to a three mega pixel Nikon (Coolpix 3100) during initial testing in Australia. Most Consumer-grade digital cameras are nowadays equipped with a variable zoom and auto-focus lens. The widest zoom setting should be adopted, which provides the largest object coverage and simplifies camera calibration procedures (Chandler et al., 2007).

3.2 Control

Control can be of two forms. The simplest is to employ a scale bar (Figure 1), which allows final data to be extracted to a known scale. Furthermore, if the scale bar can be placed horizontally it is generally possible to extract data within a coordinate system that is approximately related to the local vertical. If the object is too large to be captured using a single stereo pair, or extracted data needs to be oriented exactly to the local vertical or other reference datum, then targeted control should be adopted. Targets can be stuck temporarily to non-engraved sections of the rock surface using either self-adhesive or another separate fixative, such as clear silicone bathroom sealant, which can then be removed easily after the photographs have been acquired. The three-dimensional coordinates of each target need to be determined using either a theodolite intersection method or reflectorless EDM (Chandler et al., 2007).

3.3 Photogrammetric data processing

Data processing was carried out originally using the Leica Photogrammetry Suite (LPS) (Leica Geosystems, 2005) but other commercial digital photogrammetric packages have proved suitable for creating DEMs and

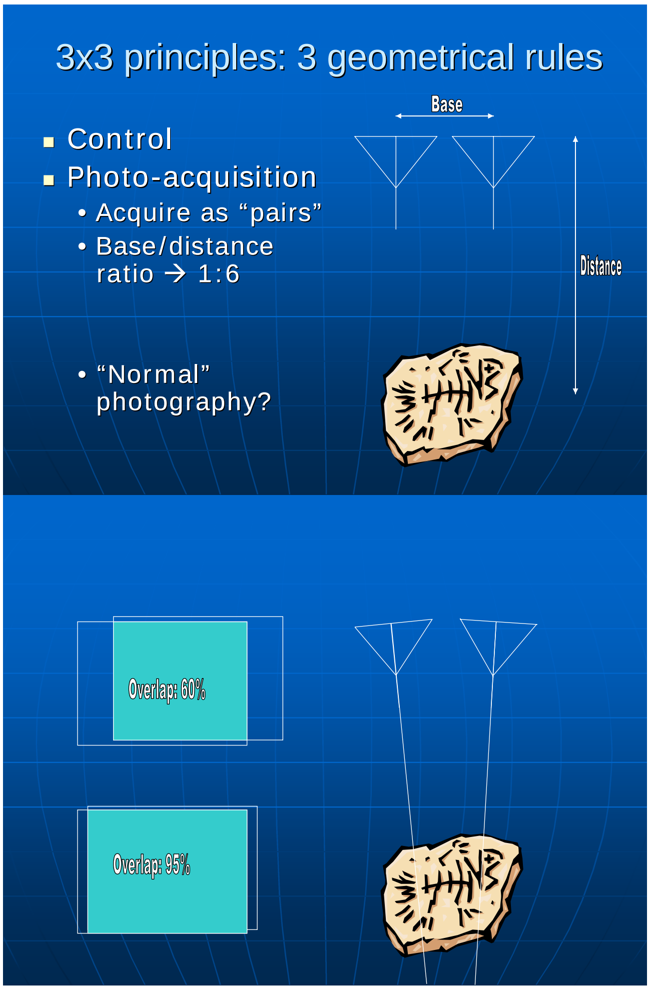

Figure 2 Presentation slides illustrating satisfactory photo acquisition

orthophotographs from each stereo pair, once exterior orientations have been achieved. Once generated these two files can be used to create flythrough visualizations (Chandler et al., 2007), which convey the nature of the derived datasets very simply, particularly to the layperson.

4. APPLICATION IN A PRODUCTION ENVIRONMENT

The two year pilot project known as the Northumberland and Durham rock-art project was established to record 1500 prehistoric engravings located in the northeast of England. It involved collaboration between the two authors and the county councils of Northumberland and Durham. During the early stages of the project (January, 2005) a decision was made to purchase six Nikon Coolpix 5400 digital cameras, following successful use of the Nikon Coolpix 3100 in Australia. The near doubling of image resolution to 5 Mega-pixel was perceived to be particularly valuable alongside the ability to save images directly in TIFF format rather than compressed JPEG as typically provided on such low-cost cameras. All six digital cameras were calibrated at Loughborough University, using a procedure that involved acquiring six images of a 3D and planar testfield specifically constructed for this project. The control field design was similar to that used previously (Chandler et al., 2005b). However it was slightly larger (1.2 × 0.9m) to allow the cameras to be calibrated at an object distance of 1.5m, which was deemed an optimum range over which to acquire the required stereo-coverage using the Nikon 5400’s.

4.1 Initial training and education

In April 2005, the first author ran a one-day, weekend workshop, attended by 50 of the enthusiastic rock-art volunteers, where four presentations were provided. The first two described how cheap digital cameras were used to record aboriginal rock-art. This was followed by a presentation which discussed the purpose of recording and raised various issues, including: the accuracy and density of extracted data and the natural division of tasks/roles between fieldwork and data extraction. The basic controls of the Nikon Coolpix camera were explained and the 3 x 3 of principles (Herbig and Waldhausl, 1997) outlined. A particular focus was an explanation of how to acquire appropriate stereo-imagery (Figure 2). The simple recommendation was to emphasize the benefits of a “base to distance ratio” method of acquisition, combined with slight camera convergence to provide overlaps of approximately 95%). Methods of providing photogrammetric control were then discussed - a scale-bar for simple panels (Figure 1) and 3D control for larger, more complex examples - but also included the relative strengths and weaknesses of each approach. The final presentation focused on how to use LPS to extract DEMs and orthophotos (Leica Geosystems, 2005), but it also emphasized the point that stereo-imagery could itself remain the ‘primary’ record, rather than any of the processed data that may or may not be extracted at a later date. The workshop was crucial because it fired enthusiasm within the group, and within weeks the volunteers had begun to go out and acquire their own imagery.

4.2 Early field experience

Since the project started in August 2004 the primary focus had been on recruiting, training and allocating the volunteers into six regional recording teams distributed across both counties. Although most could, given time, sufficiently operate a digital camera to capture an acceptable ‘narrative’ image of a rock-art panel, not all volunteers of diverse ages and mixed abilities could immediately engage with the unfamiliar methodology of taking stereo-photography. Some immediately embraced the approach whilst others showed considerable reticence so it was decided to allocate photogrammetric recording tasks to two volunteers per group. Even though some recording work commenced in November 2004, application by the volunteers themselves did not start in earnest until June 2005. This followed a series of on-site training courses provided by the second author in how to acquire the primary ‘field package’ incorporating stereo-photography using the Nikon 5400 (Figure 3) and a simple configuration of scale-bars. Alongside the ‘primary stereo-pair, taken as normal to the object as practically possible, a number of convergent pairs taken around the panel were also acquired.

Another issue faced by all project teams was the variable weather and lighting conditions experienced across site. To improve processing results evenly lit images, using natural light, are preferred to the more traditional 'raking-light' approach where shadows are purposefully introduced to emphasis three dimensional relief. Although both narrative and stereo-photography required 'conflicting' approaches to illumination, in practise the latter was adequately controlled using a variety of shading devices including umbrellas, sheets and more recently portable tents and shelters.

Figure 3 Stereo-photography training at Doddington, Northumberland (Image courtesy of Tertia Barnett)

Although the original intention was to concentrate on 'field package' acquisition for all 1500 rock-art panels, great interest had developed across the teams in processing some their own imagery so as to generate 3D surface models and visualizations, as introduced by the first author within his April 2005 workshop. At the time English Heritage were researching a number of the 'lower-cost' photogrammetric software packages including Topcon's PI-3000 'Image Surveying Station'. Although many could theoretically process this level of field package, PI-3000's combined ability in importing/setting-up 'consumer-grade' imagery based solely on scaled distances and, using its own pixel-matching algorithm, subsequently generate, visualize and export 3D surface models, was found to be particularly suitable for this project. It is also appeared more 'user-friendly' than other similar level of processing package. Following acquisition of a number of software licences and further education, training and guidance from the first author during February 2006, several of the volunteers quickly became adept at processing their own imagery within PI-3000. Despite the considerable increase in technical content, the majority had few problems in generating a range of outputs from their own imagery, including 3D surface models and orthophotographs (Figure 4).

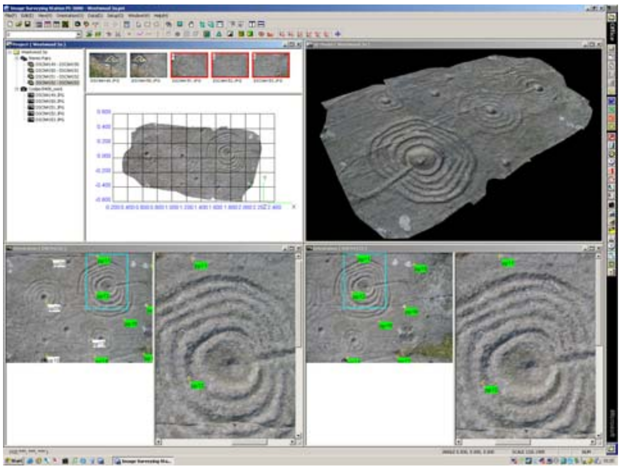

Figure 4 Weetwood rock-art panel as processed by Joe Gibson using Topcon PI-3000 software

4.3 Further refinement

The original methodology was based on recording a panel measuring approximately 1m x 1m. Taking into account both the image resolution and angular coverage of the Nikon 5400, the base/distance and overlap requirements set-out by the first author, a calibrated focus setting of 1.5m was chosen. Although this enabled many panels to be recorded at this range, it quickly became clear that adaptation was required to deal with the wide variety of sizes where rock-art is typically encountered including smaller, portable stones, as held in museum collections, as well as larger, more complex panels.

By including several portable stones within one stereo-pair, adequate imagery was acquired from 1.5m. However it was felt that such objects should preferably be singularly recorded from a much closer range e.g. 1m or less, which would require additional calibration of the Nikon 5400 camera. Within the timescale of the project this was not possible but the calibration of cameras at multiple focus settings should become a pre-requisite within any future rock-art recording project. Here the provision of accessible, 'easy-to-use' calibration routines alongside the potential for an on-line archive of calibration files, pertaining to individual digital camera/lens combinations at various focus settings is recommended. The ever-increasing pixel resolution of both digital compact and digital SLR cameras, coupled with their ever-decreasing cost, will undoubtedly aid further widespread application and adoption of photogrammetry.

The team that experienced greatest difficulty were working in north Northumberland where they had responsibility for recording many large panels. Although the scale-bar approach provided adequate results over the 1.5m range, to maintain accuracy across several adjacent stereo-pairs required a more complex approach on site using temporary targets placed on the host rock surface, preferably co-ordinated in three dimensions using total station observations, to aid referencing and 'tie-point' observation. However with the extra cost of bringing in a total station plus the additional training/education of volunteers in using such equipment on site, this was deemed 'a step too far' for this project However along with the possible inclusion of GPS, this should once again be considered within future projects.

5. DISCUSSION

5.1 Technology and the volunteer

One particularly pleasing outcome of the project is how a significant proportion of the volunteers have learned how to carry out the photogrammetric processing tasks themselves. Originally, it was envisaged that volunteers would carry out photo acquisition only, and a photogrammetrist would take the responsibility for creating DEMs and orthophotos of just a few exemplar sites. The imagery and control would form the "record" and data would only be extracted at some point in the future, if necessary. What has proved remarkable about the project has been the willingness to learn and then carry out the photogrammetry by the volunteers themselves. It is now expected that come the end of the project in 2007, data from virtually all of the 1500 sites will have been processed by the volunteers except for a few very simple petroglyphs located on insignificant rock outcrops. Typically, one or two members of each of the six teams has taken responsibility for this process and they now regard the activity of extracting DEMs, orthophotos and generating fly-through displays as routine. Some of the credit for this must of course go to the developers of the commercial photogrammetric software now in use, and, in particular, software engineers at Topcon and Leica Geosystems. However the author's believe that it should be more widely recognized that voluntary workers do have the ability to develop new photogrammetric skills and that such an approach gains other and more political benefits.

Use of the voluntary sector relates to four of the six Corporate Strategic Aims identified in English Heritage's Research Strategy document (English Heritage, 2005). The volunteers have clearly become involved with heritage recording and in the process have: developed an understanding of their historic environment; have helped local communities to care for their historic environment and have perhaps assisted in getting the historic environment on other people's agendas. Such mobilizing of the voluntary sector for heritage recording is feasible only if recording methodologies are based on cheap and simple instrumentation and is supported by appropriate training.

5.2 Line drawing or surface model?

The teams were encouraged to incorporate photogrammetry immediately into their recording toolkit, so that it could be tackled alongside the many other photography and narrative documentation duties to be performed whilst on site. As well as introducing an accurate 'third dimension', additional benefits include the provision of a stereo-record, suitable for both archiving and web dissemination, plus a capacity for both line drawing and 3D surface model generation at user-selectable resolutions. Although packages like PI-3000 and LPS both allow the user to extract line drawings, using either hand-wheels, 3D cursor or computer mouse, little use of this feature has been made by the volunteers, due principally to the perceived introduction of subjectivity into the digitising process, preferring instead to generate more objective, 3D models in both textured/untextured forms. Although rock-art recording output has traditionally been supplied in a line form, the ability to digitally remove the texture from such models, leaving just the host rock surface, has proved of enormous benefit to the volunteers in attempting to understand the underlying carvings (figure 5). However, as with laser scanning further tools, preferably automated, need development and dissemination to enable the end-user to extract any man-made features from those occurring naturally, based on such objectively acquired 3D data sets.

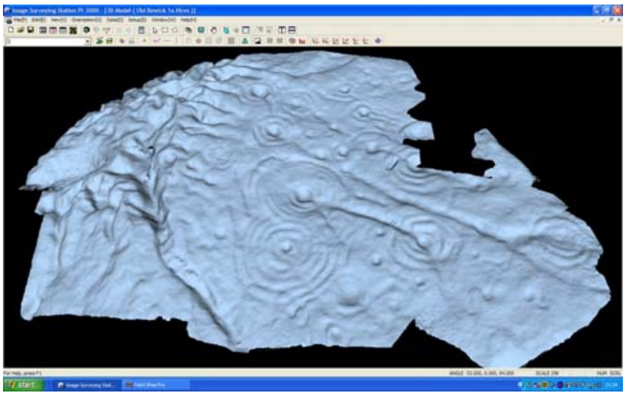

Figure 5 Old Bewick rock-art panel in untextured form, as processed by Joe Gibson using Topcon PI-3000 software

6. CONCLUSION

This paper has demonstrated that a fast, cost-effective solution to rock-art recording can indeed be provided by photogrammetry using an appropriate integration of technology and expertise. Although laser-scanning may provide 3D datasets at potentially higher resolutions, the technology is still currently too expensive, cumbersome and hard to use by the non-specialist making it difficult to justify on such a large scale as the Northumberland and Durham Rock-Art project. Conversely the availability and widespread use of low-cost, consumer-grade digital cameras makes stereo data acquisition both a viable and exciting alternative which, coupled with developments in modern digital photogrammetric software, make it particularly suitable for routine recording tasks on both a large and small scale. As photogrammetry is a non-contact method, issues concerning the subjectivity of the recorder, repeatability of the record, and potential harm to the rock surface are all avoided. Although somewhat new to photogrammetry, the value of using the non-specialist, voluntary sector to both acquire and even process 3D recording data sets is undeniable. However this is only possible through the development of recording methodologies based on cheap, affordable and easily understood instrumentation coupled with a suitable level of education and training.

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