ADVANCES IN THE PHOTOGRAMMETRIC RECORDING OF CULTURAL MONUMENTS

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Introduction

The process of creating records of significant sites and monuments has been in action for centuries, with a marked increase in formal activity during the last 50 years or so. Since the Second World War especially, many nations have become more concerned with preserving their cultural heritage (C. of A., 1985). Part of the conservation process is the need to document as fully as possible the monument or site under study as recommended by the Venice Charter of the International Council on Monuments and Sites (ICOMOS), and the revised version created in Australia (the Burra Charter).

Photogrammetry has been used intermittently for over a century around the world to fulfil part of this need for documentation. This paper will look at the contribution that modern digital technology can make to that recording process, and at how advances in the techniques and technologies of photogrammetry have increased the actual and future application areas. The emphasis will be on the use of photogrammetric recording processes, but will not be confined to this particular technology.

What is photogrammetry?

Photogrammetry is simply the art, science and technology of making measurements with photographs. This implies that a collection of photographs forms the basis of the measurement process; photographs that can be acquired rapidly on site and later analysed using quantitative and qualitative criteria. Up until around 15 years ago it was necessary to use a camera designed specifically for photogrammetric purposes, one that had a known and invariant geometry between the lens and the film plane and between index marks inside the camera. Generally a minimum of two photographs were taken of an object so that the pair of photographs overlapped and provided a viewer with the opportunity to observe the area common to the two photos in three-dimensions (stereo). With suitable, high-precision measurement equipment (stereo-plotters), three-dimensional information regarding the shape and situation of the object could then be obtained. This information was often presented in the form of maps and plans, closely resembling the measured drawings obtained by hand (see Figures 1 and 2 for examples).

Figure 1: Professional Chambers, Collins Street, Melbourne

Figure 2: Secret-Sacred Room, Bobot Haus Tambaran, Lower Sepik, Papua New Guinea.
The recording of cultural property

It should be stated now that photogrammetry is not the complete solution to the recording requirements in all situations. Indeed, in some instances photogrammetry is not capable of being used at all, although this is not reflected in the literature as generally only successful applications tend to be published. The discipline does have its successes, and when used by researchers who understand the techniques and technology, as well as the inherent limitations, photogrammetry can be an integral part of a site documentation process.

The use of photogrammetry in recording cultural monuments and artefacts has been documented in Ogleby and Rivett (1985) as well as in the proceedings of the Symposia of the Comité Internationale du Photogrammétrie Architecturale (CIPA) and in the Archives of the International Society for Photogrammetry and Remote Sensing (ISPRS), in particular Commission V. There is a working group within Commission V of the ISPRS which is solely concerned with the application of photogrammetry in architecture and archaeology, which also forms a liaison with ICOMOS to create CIPA. There has been a long involvement of the application of photogrammetry to the recording of monuments, in fact the scientific discipline that was to become ‘photogrammetry’ was used to document architectural treasures long before the technology was routinely applied to topographic mapping.

The impact of non-metric photogrammetry and analytical restitution

Advances made in computing technology and analytical processes over the last decade or so now mean that the photogrammetric system elements, like the geometry of the camera and photogrammetric measurement machines, can be mathematically compensated for by parameters in algorithms rather than being constrained by high machining tolerances. These developments led to the adoption of a new term (albeit a misnomer) - ‘non-metric photogrammetry’. Although the use of non-survey cameras for aerial mapping has been slow to become accepted (except for non-conventional applications), their use in architecture, archaeology, medicine and manufacturing are now common and to a certain extent has driven the development of new processes and equipment.

The most significant advantage in the analytical compensation for the internal geometry of the camera (known as interior orientation) is that the cameras used today are better designed for actually taking photographs; that is, they accept a greater range of film types, the lenses are generally ‘faster’ (they allow more light to pass through resulting in shorter exposure times), the lenses can be focussed for use close to the object, and there is a wide range of accessories available to enhance the resultant photographic product.

Analytical (and digital) photogrammetric stereo-plotters also permit a greater flexibility with respect to camera orientation in the field. The previously conventional geometry of the terrestrial stereo-pair consisting of parallel camera axes with small differential tilts between left and right photographs, and limited common tilts between projection surfaces, often constrained not only the location of the exposure station, but also the mounting devices used to orient the camera. The use of non-metric cameras and analytical stereo-plotters frees photogrammetry from many of the constraints that limited its effective application in other disciplines, including recording items of heritage value (Ogleby, 1993). This freedom has meant that cameras can be, and have been, suspended from kites and balloons, flown in model aircraft, hand held on the ground and in helicopters and light aircraft, lifted by pneumatic hoists and scissor-lift platforms, and even used on camera tripods.

The stereo-pair

The stereo-pair remains the most effective method of acquiring photographs for the photogrammetric analysis of cultural monuments. Certainly higher accuracies can be obtained by surrounding an object by an array of convergent photographs and using a bundle adjustment solution to the measurement of coordinates, however it is not possible to actually view the form of the object under study. This is still only really possible by using the stereo-pair, and as many heritage monuments consist of complex shapes the ability of the observer to interpret shape and form enhances the information content of the photogrammetric record.

Modern photogrammetric analytical instruments like the affordable ADAM MPS-2 and digital systems like the low cost Leica DVP, the not-so-low cost Intergraph ImageStation and the Leica DSW 100 are all designed to facilitate the observation and measurement of stereo-pairs. The photogrammetric systems can generally also create digital Computer Aided Design (CAD) models of the object under study, where the observer places graphic elements into a computer file as part of the interpretation process.

Single Photograph Rectification

Much of the existing photography of cultural monuments consists of single photographs, either ‘snapshots’ acquired over the last one hundred years or so or photographs taken as part of a conventional documentation program. These photographs can provide considerable visual information regarding the condition of the monument and its site, as well as limited metric information regarding size and shape.

Images of planar façades have been rectified to scale photographically for many years, and often the rectified image alone was a sufficiently useful document to facilitate the repair or restoration of the building. The same rectification function can now be performed on
desktop computers using simple software packages designed for picture publishing or photo-illustration. The images can be presented as photomaps with annotations, and output on high resolution colour printers easily and in a very cost effective manner. For example, the Macintosh computer on which this paper was written has been used to rectify images of stained glass windows, converted to a digital format by the use of a desktop scanner, using Adobe's Photoshop picture processing package.

Photographs can also be used to provide the basis for texture and surface maps for computer rendering of CAD models. For example, the shape of the interior of the dome of St Marcus’ Basilica in Venice was determined from photogrammetric observation, then images of the frescoes were warped and reprojected onto the inside of a hemispherical surface to give a computer based three dimensional representation of the structure (Brumana and Galeazzo, 1992).

Recording and documentation case studies

Several case study examples will now be reviewed in order to demonstrate some of the current applications of using the technology described so far in the recording and documentation process. These studies will cover both the diagrammatic and descriptive aspects of site and monument documentation.

Rock Art Recording

Rock art recording in Australia has been occurring in a very sporadic manner since the arrival of the Europeans, starting with the sketches and paintings of explorers (Walsh, 1988). Methods involving drawing and sketching have been used, often using metric drawing aids like string grids so the record could be scaled. Photography naturally plays a vital role in the present documentation of rock art, however much work has also been done in Australia in developing photogrammetric methodologies to provide a reliable metric record of the motifs and the site (Ogleby, 1987 & 1992; Ogleby and Rivett, 1985).

As mentioned previously, recent developments have now made it possible not only to use conventional cameras as a reliable recording instrument, but also to reconstitute the resultant stereo-model to any reference plane. The latter feature has greatly improved the application of photogrammetry as a rock art recording tool; rarely does artwork in a rock shelter occur on a surface that can be projected onto an orthographic reference plane without significant distortion of the motifs. The facility to observe three dimensional line strings from the stereo-photographs directly into a CAD environment means that the model of the site record can be viewed on the computer independently from the orientation of the initial photographs. It is also relatively simple to combine derived data with the original imagery so that the limits of interpretation are placed in context.

Image Enhancement

The basis of most rock art recordings is a photograph, very little else can contain the amount of detail that a photograph is capable of displaying. Some rock painting sites are relatively easy to photograph, whilst many others (in Australia at least) are difficult because of the age of the motifs, the state of preservation of the site or the material used to create the images. Modern image enhancement procedures would appear to offer much to assist in the enhancement of photographs of indistinct paintings.

In a recent project undertaken by the University of Melbourne two image enhancement systems were evaluated as to their usefulness in modifying digital rock art images. One system was a fully configured image processing system designed for enhancing satellite imagery (PC-Erdas), the other a photo-illustration package (Adobe Photoshop). The investigation showed that for many image enhancement operations, there was no appreciable benefit in using the more expensive remote sensing system. The procedure adopted was an interactive interpretation approach applied to the most distinct colour channel, in this case the green component of the red-green-blue (RGB) image as the material used for the drawing of the motifs was red in colour. Picture elements (pixels) that could be seen to represent areas of pigmentation were selected as ‘training sets’ on Erdas and via the ‘magic wand’ tool in Photoshop. These selections were then used to seed a classification of the image, then the results interpreted and the process run again. Various image enhancement operations were run before the selected areas were chosen in an attempt to aid the operator in the detection of suitable areas. Although the ‘best’ drawing of the motif was that traced off the original photographs by the researcher who had visited the site, it was successfully shown that the procedure adopted was capable of improving the representation of the motif in the photograph. The results of this investigation are shown in Figures 3 and 4.

Architectural Recording

Architectural monuments seem to generate sympathy and emotions more readily than other monuments of civilisations’ achievements. Once again, recent developments in the analytical restitution of photogrammetric records and image processing has facilitated the creation of three dimensional CAD models of buildings either using the operator’s skills of observation or computer assisted surface derivation. Work like that of Cooper, Robson and Littleworth (1992) on the Tomb of Christ in Jerusalem for example would not
Figure 3: Black and White Copy of Colour Image, Rock Art Motif.

have been possible even ten years ago; the photography could have been acquired but the restitution of this into a useful record would have been extremely difficult. In this project a very detailed three dimensional model of the Edicule of the Tomb of Christ is being constructed from the photogrammetric record using Intergraph's MicroStation CAD package, complete with texture maps generated from images acquired on site. Multiple pairs of photographs taken from many camera stations at different scales have been observed on a common site coordinate datum, so that individual scenes can be combined to create one overall representation. Ray-traced and texture-rendered images can be created using this model, from an almost infinite variety of standpoints. Additions and modifications to the Tomb that have been incorporated over the centuries can be 'removed' by selecting the appropriate layers of graphical data in the computer model, and the construction of the current monument over time can be animated. In addition, precise metric information is being made available for conservation engineers. The information is being managed in a Geographic Information System (GIS) environment on a SUN SPARCstation, giving an interactive access to the photographic collection of the site by using the cursor to highlight regions on the CAD model.

Another example of the versatility available in the restitution of photogrammetric models was a project undertaken on a quartz cracking kiln in the old mining town of Maldon. The kiln was a historic monument but was allowed to be demolished to give access to the area for gold mining. When the kilns were partly demolished the company was directed to have a photogrammetric survey done on the remains. This was done but the plans (from the CAD model) were missing the details of the parts of the kilns already removed. Luckily the mining company had taken many 35mm photographs of the structure before demolition, and these images were used to complete the plans of the structure by observing overlapping images in a stereo-plotter.

Computer visualisation techniques are able to extend greatly the information content of CAD models. Currently, an animation of the passage of the sun across the face of a 3D model of a rock shelter is being prepared which will assist in the analysis of surface salting. As well, a sandstone material-map is being projected on the many TIN (Triangular Irregular Network) facets within the model, and the digital images of the motifs are being warped onto the digital surface model in order to produce realistic animated 'walk-throughs' and 'fly-pasts'.

Another architectural reconstruction project currently under development is the computer reconstruction of the ancient Thai cities of Sukhothai and Ayuthaya. Using historical and research documentation, 'snapshot' type 35mm photographs and stereo-pairs of selected monuments, one of the temples on site is being created as a three dimensional CAD model so the feasibility of reconstructing the entire site can be demonstrated. The general size and shape of the existing remains can readily be digitised, however in order to make the model more 'realistic' it was necessary to include some of the many Buddha statues on site. This was achieved by photographing a small antique Sukhothai style Buddha.

Figure 4: Enhanced Green Band, Rock Art Motif
and observing the stereo-model in a digital photogrammetric instrument. This model can then be re-scaled to suit the architectural model, and incorporated into the 'visualisation' of the temple. Figure 5 illustrates this process.

Investigations are also in progress at the University of Melbourne toward the development of procedures for the creation of multi-media CD-ROM based heritage inventories, exploiting the technology so that images, stories, statistics, models, animations and representations can be contained on one accessible medium. For example, at one of the rock painting sites mentioned previously the photogrammetric record provided the base map for the establishment of a large scale GIS of the rock shelter. Eventually the GIS will contain the data on the conservation measures being undertaken, the location of and data associated with the salinity test sites on the rock surface, the photographs, the sketches and line drawings, and hopefully the story of the site narrated by one of the traditional owners. Once this is completed, it is a small step to produce copies of this data base on a convenient distribution medium like CD-ROM so that the information becomes an educational resource.

Conclusions

Modern photogrammetric technology has an increasingly important role to play in the recording of cultural heritage. Appropriate use of the technology can measure and map monuments, enhance and store images, add textual attribute data and derive information from a variety of data sources. It is not claimed to offer the complete solution to recording items and sites of a 'cultural' value, but it can be used to add to the other available methods to create a very powerful recording and management tool. The technology is not an excuse to abandon heritage preservation and conservation - no amount of computer technology will ever replace being there. But the appropriate use of the technology allows the inventory of the increasingly threatened cultural heritage of the world to be expedited.

Acknowledgments

All pictures of rock painting images were acquired and are published with the permission of the traditional owners. Their permission to use this information is gratefully acknowledged.

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References


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