Terrestrial Photogrammetric Survey of Arltunga Historic Reserve, Northern Territory

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The Conservation Commission of the Northern Territory has recently funded a study for conservation and presentation of historic sites at Arltunga Historic Reserve, Northern Territory. Support for this project has come from the National Estate Programme. The study concentrated upon investigative and recording work in the field as a preliminary to a capital works programme. Previous documentation work at Arltunga was carried out by conventional surveying techniques. While they may have been adequate in establishing a useful initial record of the various sites within the reserve, the resultant documentation was not precise and detailed enough to serve as a basis for their conservation. The vast number of building remains, the irregularity of their construction and their fragile nature, together with the higher recording accuracy requirements, called for the employment of a systematic and non-contact measuring method. Consequently a substantial terrestrial photogrammetric survey was carried out as a part of the study. In the following a detailed description of the photogrammetric scheme is given.

1. SITUATION

The Arltunga Historic Reserve, managed by the Conservation Commission of the Northern Territory since 1975, is situated about 120km east of Alice Springs, in Eastern Aranda country. The reserve is some 45 square kilometres in extent, dominated by steep ranges and numerous outcrops of metamorphic rocks. The elevation of the land ranges from 350m in the plain country, over which a visitor passes on the approach to Arltunga from Ross River, Bitter Springs and the Simpson Desert fringe, to some 700m in the White Range. The reserve comprises part of the site and ruins of a remote mining settlement of the late 19th and early 20th century. It does not cover the mines and building remains at the White Range, owing primarily to the existence of a mining lease at the time of proclamation. In addition there are some other outlying mines and associated building structures clearly related to the goldfields which are not included in the reserve or protected in any way. Although the detailed description of the site is outside the scope of this paper, its significance arises from the quality of the physical evidence that remains as a resource for the study and understanding of now extinct life and work styles, as well as from the impact the events at Arltunga had upon the development of South and Central Australia. The highly visible evidence of mining activity includes not only the mines and machinery used but also the miners' dwelling places and their graves. In addition, Aboriginal camp-sites and art-sites of various kinds are present. The Arltunga Historic Reserve thus offers a very considerable potential for both prehistoric and historic research. The initial identification work at Arltunga was done by Forrest.[1] Further investigative and recording work at Arltunga was carried out on behalf of the Conservation Commission of the Northern Territory by Service Enterprises Pty. Ltd.,[2] the terrestrial photogrammetric survey as described herein being an integral part of the study, and by Richard Allom Architects.[3] The latter study outlines proposals for the site's conservation. Excavations, confined to the White Range settlement, were carried out by Holmes.[4]

2. PHOTOGRAMMETRY

Photogrammetry may be defined as the science concerned with the task of reconstructing the shape, size and position of objects from their photographic images. The principal application is in the area of mapping, particularly topographic mapping from aerial photography. Apart from mapping, photogrammetry terrestrial mode, using photography taken from ground-based cameras, has been increasingly applied in many non-topographic fields where indirect and rapid spatial measurement may be required, such as in medical research, forensic science, vehicle and machine construction, shipbuilding (to name a few) and, as is the case here, for the recording and measurement of historic monuments and sites.

The basis of photogrammetry as a method of making spatial measurements is the fact that a photograph taken by a photogrammetric camera is a central perspective image of the object photographed. The geometric relationship that existed between the object and its photographic image can be reconstructed in two dimensions on account of geometry recorded on the photograph. Since most applications of photogrammetry require three dimensional information, stereophotogrammetry is employed. Photographs are taken from different viewpoints, forming a stereopair which provides additional information in the third dimension. Photogrammetry, therefore, can be considered as a means of creating a spatial model of the object photographed (a precision spatial model which can be measured). Thus the actual physical measurement of the object is replaced by a measurement of its image in this model. Although our model may be purely mathematical, resulting in numerical data, the complex object situations encountered in the application of photogrammetry to the recording of historic monuments and sites generally demand the use of an analogue process, where a three-dimensional model of the object is physically reconstructed in the stereoscopic plotting instruments. Thus plans, maps, profiles or other graphic forms of recording of the objects photographed may be obtained. The record of measurement in digital rather than graphic form is also possible. The three coordinates at any point of the model may be recorded and stored on tape for later use.

Photogrammetric survey may be divided into three distinct phases, namely: photography or data acquisition, measurement or data evaluation, and data presentation. In the first phase, consideration is given to the desired accuracy of the final product, the camera to object distance, (often controlled by the circumstances of the site) the availability of photogrammetric instrumentation (in both the data acquisition and data evaluation phases) and the camera locations during photography. The photographs are then taken in order to obtain the necessary images that are to be measured. They may be taken in either of two ways. A single metric camera may be used and the two photographs taken from spatially separated exposure positions. An alternative method is to use twin cameras mounted rigidly at either end of a connecting bar of fixed length, allowing the pair of photographs to be taken simultaneously. These cameras are known as stereometric cameras.

In the second phase, the measurements are made in an analogue type plotting instrument whose viewing system enables an operator to view the model stereoscopically. A measuring mark is used to measure the model in all three dimensions. Its movement throughout the model is usually mechanically transferred to a plotting table pencil at the predetermined scale. Prior to measuring the model, its scale and attitude is determined by a comparison of the object control points, surveyed previously by theodolite, with their photographic images. The data presentation phase involves a cartographic enhancement of a stereoplotter pencil compilation manuscript.

The use of terrestrial photogrammetry as a means of three dimensional recording of historical monuments and sites has been practised outside Australia for decades, particularly in Europe. Several countries have set up special photogrammetric units to undertake comprehensive recording programmes of their architectural heritage. In addition, academic institutions and commercial photogrammetric organisations are carrying out projects.

In Australia, although terrestrial photogrammetry has been used for topographic mapping of large scale engineering works, its use in architectural heritage recording has been limited and generally confined to projects undertaken in *ad hoc* fashion by individual workers in several academic institutions. An exception to this state of affairs has been a major research project conducted by Rivett for the Australian Heritage Commission.[5] His report, evaluating the various areas of terrestrial photogrammetry application to the recording of monuments and sites through several pilot projects, is a valuable contribution in that it provided a stimulus to further activity in this field.

3. PHOTOGRAMMETRIC INSTRUMENTATION USED

A Wild P31 Universal Terrestrial Camera, equipped with a wide-angle lens, calibrated focal length of 99.30mm which can be set directly in most of the stereoplotting instruments for aerial photography, was used for the photography described in this paper (Fig. 1). The camera, of relatively recent manufacture, was designed for topographic surveys at medium distances as well as close-range applications.

The P31 consists of two main parts, the camera support and the actual high precision metric camera, which can be conveniently replaced by a Wild T2 theodolite if angular observations or distance measurements are required from the camera stations. The camera support incorporates a tilting ring with four locking positions, so that the longer dimensions of the 83/90mm × 117mm useful image format of the glass plate can be positioned horizontally or vertically. Additionally, the principal point is offset by 15mm relative to the format centre, enabling optimum utilisation of the format. The tilting ring can be rotated about the horizontal

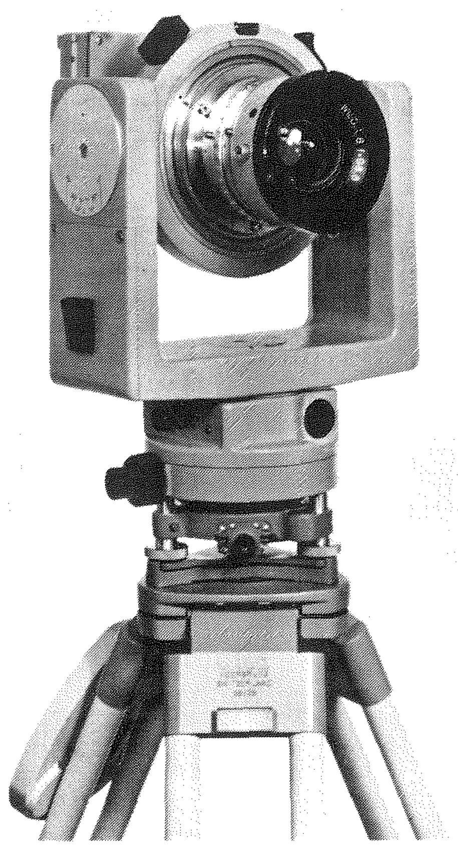

Fig. 1: A Wild P31 Universal Terrestrial Camera (Courtesy of Wild Heerbrugg).

axis, so that the camera can be set at tilts of $\pm 7^g$, $\pm 14^g$, $\pm 25^g$, $\pm 30^g$ and $\pm 100^g$, the last angle allowing a photograph to be taken vertically upward. Fixed stops for rotations about the vertical axis are featured at $\pm 25^g$. The lower part of the camera support carries the orientation telescope, so that the direction of the camera axis may be set in relation to the other camera station.

The wide-angle lens is corrected for the visible and infrared regions of the spectrum and has a fixed focus of 25m. The focusing on the different object distances is achieved by means of the insertion of spacer rings of different thicknesses, between the lens and camera body, by the user himself or herself. This permits a range of focus from 2m to infinity. The resultant changes in principal distance are recorded photographically. The shutter, equipped with a cable-release, provides for exposure times of 1 to 1/500th of a second. The camera takes photographs on 100mm × 125mm glass plates or on black-and-white or colour roll film.

The camera was loaned for the purpose of this survey by the Darwin Community College.

The survey photography was plotted in a Wild Autograph A5 stereoscopc plotting instrument at the School of Surveying, South Australian Institute of Technology. This instrument, characterised by stable and simple mechanical construction, is representative of the early universal plotters category. It is well suited for plotting from terrestrial photographs owing to generous tilt ranges. The instrument employs the mechanical projection principle, the restitution of a spatial model being simulated by mechanical means.

4. TERRESTRIAL PHOTOGRAMMETRIC SURVEY

The photographic work was preceded by the establishment of a planimetric and altimetric control network, over the reserve and White Range, by the traverse method. This proved to be a substantial part of the overall task, as the

reserve and White Range contain in excess of 200 individual and group structures. Nevertheless, it was felt that such a control net, apart from constituting an independent and adequate basis for the purposes of this survey, would also provide a coherent mapping system for further scientific research by other workers.

Traversing for horizontal control was based on survey marks established by earlier surveys. These marks were connected to the Australian Map Grid System. Survey for vertical control was based on the national Australian Height Datum. Using an existing bench mark at Arltunga as a datum, a level-run was undertaken to the White Range with temporary bench marks being established in the vicinity of the sites concerned. These bench marks were later used to obtain reduced levels of all camera stations and associated control points. The accuracy of any heighted control point was estimated at ±0.02m, with an accuracy of ±0.005m between points at a particular site. The accuracy of horizontal control in relation to the Australian Map Grid was estimated at ±0.1m, although in relation to each other at a particular site coordinates are accurate to ±0.01m. The aforementioned accuracies, anticipated in both the planimetric and altimetric control network, were well within the limits imposed by a photogrammetric scheme.

The establishment of a primary control net of coordinated survey marks was followed by the acquisition of survey photographs. The photography acquisition is a very important phase of a terrestrial photogrammetric survey, in that it constitutes the basis from which the desired end-product, the measured drawings, will be finally developed. It involves the site's initial reconaissance and establishment

Fig. 2: Survey photograph of the Police Residence chimney taken from the right-hand base terminal. The original negative is 83mm × 117mm. The camera calibrated focal length (99.30mm), and the photograph number (11), are recorded on the photograph during exposure.

Fig. 3: A planimetric plot of the Police Residence chimney. Original scale of drawing 1:10.

of photographic baselines, and the actual photography acquisition, together with control-points-data acquisition.

The standard approach adopted in the photography acquisition phase of a survey involved the employment of the Wild P31 camera in the so-called 'normal mode', with the camera axes parallel to each other and perpendicular to the camera base terminals. Photography at the majority of sites required inclined camera axes to obtain adequate vertical cover. The site building remains were generally photographed from three or four separate baselines, depending on the coverage obtained with each stereopair of photographs.

Difficulties were encountered on a couple of sites, largely due to topography where the ridge tops, overlooking the gullies in which the structures were located, offered only limited area for an establishment of baselines.

The baseline lengths were kept below 1/10th of the maximum camera-to-object distances, in order to satisfy the requirements of accuracy. To ensure that the photographic structures were in the optimum focus at the chosen aperture settings, use was made of spacer rings, an option provided by the camera manufacturer. Apart from one site, where the standard 25m focusing ring was employed, the majority of the site structures required employment of a 7m ring.

The camera stations and auxiliary points set out on the production of baselines to facilitate alignment of camera axes, were marked on the ground with metal spikes. The form of targeting of control points, vital to the stereopair's successful restitution in a stereoplotting instrument, was a small cross made by affixing white insulating tape to the site structures.

The survey of control points completed the fieldwork. The coordinates of control points were established by horizontal and vertical theodolite observations from each terminal of the baselines. All of the coordinates were known to an accuracy better than the 0.01m necessary for the photogrammetric scheme. Both the camera stations and the ground control were connected to the national reference system in planimetry and height, namely the Australian Map Grid and the Australian Height Datum.

Stereopairs of Arltunga Police Station and Residence, known under a standard nomenclature adopted for the reserve as Sites 256 and 257 respectively, were chosen first for photogrammetric plotting, owing to the abnormal rate of deterioration of these building remains. These structures, of local stone in lime-mortared random bond, are typical of the official buildings category at Arltunga and contrast to other very much less formal structures, especially at White Range. Four stereopairs from four bases were taken to record each site. Figure 2 shows the Police Residence chimney in a print reproduced from the right negative of a stereopair from the P31 camera. Normal-case configuration of camera axes was applied and the survey photographs were taken with camera axes inclined 7 grads upwards, from a 0.858m base, at a taking distance of 6.5m from the structure.

The resulting stereopair was then oriented in the A5 stereoplotter, following the well-established operational sequence of the photogrammetry analogue approach. The procedure consists of centering the principal points of the two negatives on the negative carriers and the re-establishment of the camera focal length. A stereomodel was achieved through the restitution of the relative orientation between the two camera positions at the time of exposure. This was done by setting the known parameters of the so-called exterior orientation, namely the camera inclination and parallelity, camera separation and relative height. Further manipulation, utilising elements of relative orientation available in the instrument, was required to reduce the effects of the small deviations from the known exterior orientation parameters. The scale of photography, together with the stereoplotter transmission ratios between the machine and the plotting table, were the main factors in influencing both the largest attainable stereomodel scale at 1:20 and the final plot scale of 1:10. The stereomodel was then scaled, where the survey control was made to agree closely with the coordinates determined during the fieldwork.

After these adjustments, measurement and drawing commenced. Figure 3 shows the desired end-product of the survey, a planimetric plot where each individual stone has been faithfully reproduced.

5. CONCLUSION

The necessity for and importance of reliable survey data, in making an accurate assessment of the means necessary to conserve and manage places of historic significance, is widely recognised. Photogrammetry can be a valuable and often indispensable recording tool for providing this data, as it has the technical and economical advantages over the traditional measuring techniques including that of hand drawing and measurement. Its employment is advantageous especially at places such as Arltunga, where the recording and measuring requirements are considerable. The vast number of sites, their geographical separation at Arltunga and White Range, and the irregular construction and fragile nature of the building remains, collectively make an employment of photogrammetry imperative. The fieldwork is rapid, and does not necessitate physical contact with the objects photographed, especially important at sites like Arltunga where the building remains are on the point of collapse. Notwithstanding the fact that a majority of survey photographs are still to be plotted, the detailed measured drawings produced so far provide sufficient evidence of the efficacy of the photogrammetric approach in this application. They are an accurate and objective document of Arltunga architecture. Moreover, the drawings, together with survey negatives, constitute an instantaneous historical record of the state of the surfaces of the building remains, against which future deterioration and changes can be readily monitored. In this context the terrestrial photogrammetric survey, as described herein, corroborates the conclusion reached by many who have ventured into this application of photogrammetry. This is that photogrammetry, when considered as an integral part of the study, has the required attributes to satisfy the conservation worker's recording and measuring requirements.

ACKNOWLEDGEMENTS

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NOTES

1. Forrest, P. 1981. A report on historic sites and materials at Arltunga to the Conservation Commission of the Northern Territory. (Unpublished).
2. Service Enterprises Pty. Ltd., 1982. A pilot study for the initiation of recommended conservation action and presentation of selected historic sites, Arltunga Historic Reserve, for the Conservation Commission of the Northern Territory. (Unpublished).
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