Association *of* Archaeological Illustrators & Surveyors

Technical Papers

ASSOCIATION *of*
ARCHAEOLOGICAL
ILLUSTRATORS
& SURVEYORS

AAI&S TECHNICAL PAPERS

The Association has had requests from both individuals and organisations for a chance to obtain Technical Papers which have sold out. This folder has been compiled using photocopies of AAI&S Technical Papers 1-7 (edited by Richard Bryant). These papers are now out of print although some are presently under revision.

The reader should be aware that some of the advise is now very dated particularly as work on information technology and computer aided design has advanced at an enormous pace. However even the old information is of considerable interest in the history of archaeological illustration in general and of the Association in particular. Paper 4 was a joint publication with IFA (their Paper 10) and was assigned this number at a later date as Technical Paper 4 was never produced
The papers are as follows:

1. **The Preparation of Archaeological Illustrations for Reproduction**
   by A.S. Maney (1980)

2. **Computers in Archaeological Illustration**
   by J.D. Wilcock (1982)

3. **Drawing Ancient Pottery for Publication**
   by C. Green (1983)

4. **Preparation of Artwork for Publication**
   by C. Philo and A. Swann (IFA Technical Paper 10 1992)

5. **The Archaeological Illustrator and the Law of Copyright**
   by M. Vitoria (1984)

6. **Photogrammetry & Rectified Photography**
   by R.W.A. Dallas (1981)

7. **Drawing for Microfiche Publication**
   by R. Bryant (1984)

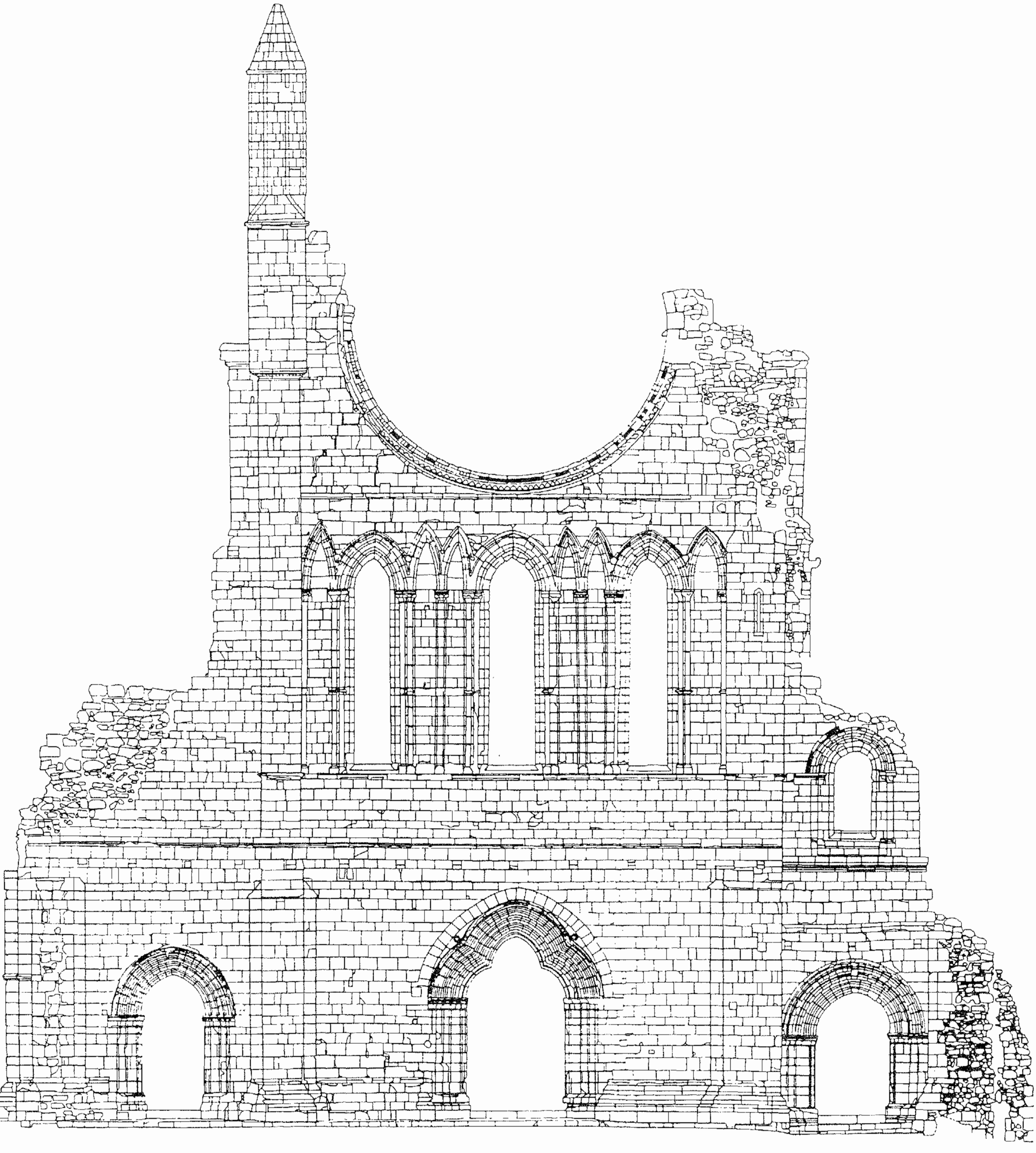
Mélanie Steiner (Technical Papers Editor 1999)

added 2006

12. The Survey and Recording of Historic Buildings
by David Andrews, Bill Blake, Mike Clowes and Kate Wilson

CI/SfB(A3): 6 revised) (A3)

Surveying with a camera
PHOTOGRAMMETRY



Introduction

A two-part feature by ROSS DALLAS discusses a valuable alternative to conventional survey techniques for measuring elevations. 'Photogrammetry' is the science of measurement and analysis from photography. Technological advances in camera and photogrammetric equipment have established the technique as the standard system for the production of large and small-scale maps.

There are two principal applications by which photogrammetry can provide invaluable information for the architect. First, in the preparation of line drawings of elevations and sections using stereophotography. This is a complex technique involving specialist skills which can produce drawings more quickly, more accurately and probably more economically than by using conventional measuring systems. Second, and as a lower cost alternative, there is 'rectified elevation photography'. This is a technique for producing approximately scaled elevation photographs with the major inherent errors reduced or eliminated. It is not a particularly accurate process, especially when applied to buildings with a substantial depth variation. However, for small projects, the technique may be applied by an amateur photographer, though large and complex projects—perhaps requiring tilted cameras and rectification—will require a specialist. This week Part 1 describes the photogrammetric method of preparing elevation drawings. A future article, Part 2 'Rectified Photography', includes advice on how the method can be carried out by the architect.

R. W. A Dallas BSc is the chief surveyor for the Photogrammetric Unit of the Institute of Advanced Architectural Studies, University of York.

1 (previous page) *Byland Abbey, North Yorkshire. West front. The original drawing was draughted at 1:50 scale. The drawing was direct draughted in ink using 0·2 mm line width. No redraughting has taken place. (Drawing prepared by the Photogrammetric Unit, Institute of Advanced Architectural Studies, University of York. Crown copyright, Department of the Environment, Directorate of Ancient Monuments and Historic Buildings.)*

Stereophotography with the Officine Galileo stereometric camera.

Architectural measurement using stereo principles

A single photograph of a façade is not an accurate source for measurement, for reasons discussed in the next article on 'Rectified Photography'.

Photogrammetric measurements are therefore derived using stereo pairs of photographs. Stereo measurement is based on simple geometric properties of the triangle. If two angles and the distance between them are known, the other values of the triangle can be calculated, **2**. In conventional surveying we would measure the angles at A and B with a theodolite. A photograph can also record the horizontal and vertical angles, **3**. A ray of light from the object passes through the lens centre and is imaged on the film. Its position can then be obtained by two components at right angles.

We can now consider how this leads to stereo measurement. Figure **5** shows how this happens initially in two dimensions. A pair of photographs are taken of the façade. In photograph 'A' light rays from the façade are imaged and recorded on the film plane. Similarly, for photograph 'B', light rays from the same points of detail are imaged and recorded on the film plane. Following film processing, the photographs (negatives or film positives usually) are located in the photogrammetric plotting instrument and orientated in direct relation to the original camera locations. Figure **4** shows that if we project rays of light back through the two lenses the rays from camera/projector A will intersect with rays of camera/projector B to define the cross-section of the façade.

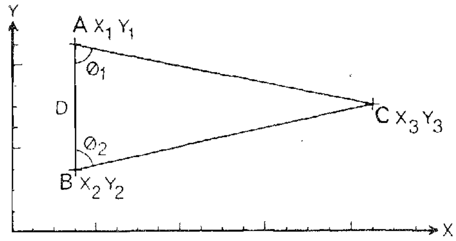
Figure **6** shows how it applies equally in elevation. In 3D this is called a stereo-model.

This simple construction of the stereo-model is the basis of the stereo photogrammetric measuring process. It has been explained here in a very simple, graphical manner, though in practice the system relies on an advanced mathematical approach and highly specialised equipment.

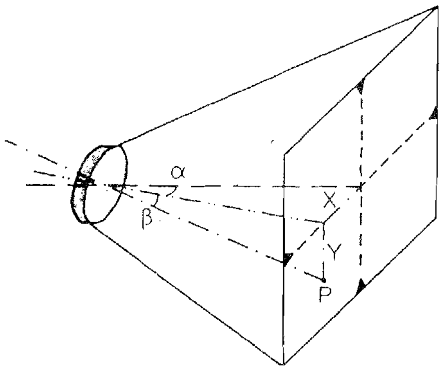
Stereo viewing

Stereo viewing is not fundamental to the photogrammetric measuring process but it greatly facilitates it. It is possible to measure co-ordinates from two photographs without viewing stereoscopically; this can be achieved by computing the values needed for measurement. This is, however, a very slow and complex mathematical process.

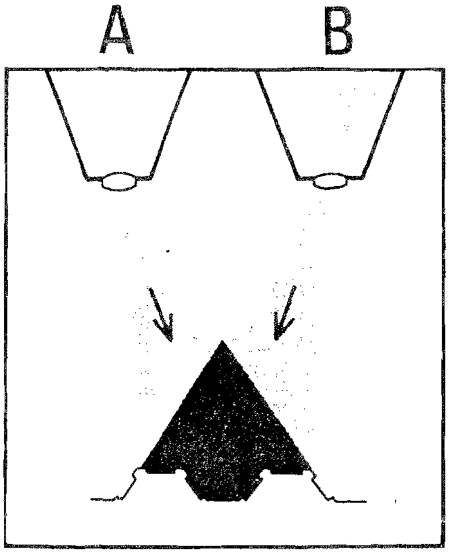
Two types of stereoscope are shown, **7**. All stereo viewing is based on the same principle whether it is a Victorian stereo viewer, 'Viewmaster' cards, 3D movies of the '50s or advanced photogrammetric plotting instruments. The practice is based on the theory of our own eyesight. When we view an object our brains receive two independent views (one from each eye) which our brains fuse into one stereoscopic image. We are able to do this because the separation between the eyes causes viewing angles to be slightly different. Our brains are capable of 'computing' from angles and distances the relative depth appreciation of objects one from another.



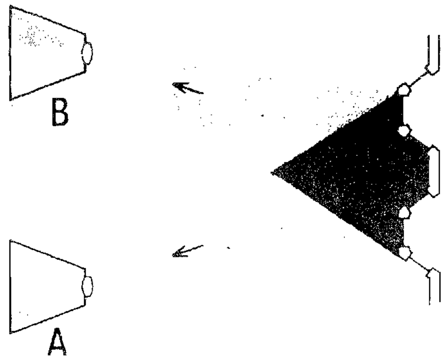
2 Properties of a triangle. Many surveying techniques are based on the triangle. In surveying, it is usual to work on a co-ordinate system. If A and B are given co-ordinate values X_1 Y_1 and X_2 Y_2 we can then compute the co-ordinates of point C as X_3 Y_3, since the values of ϕ_1 and ϕ_2 and the distance D are known.



3 The geometry of a camera. The position of any ray can be defined on the film plane by a horizontal and vertical component, either the angles at the lens centre, α and β, or by the co-ordinates X and Y on the film plane.

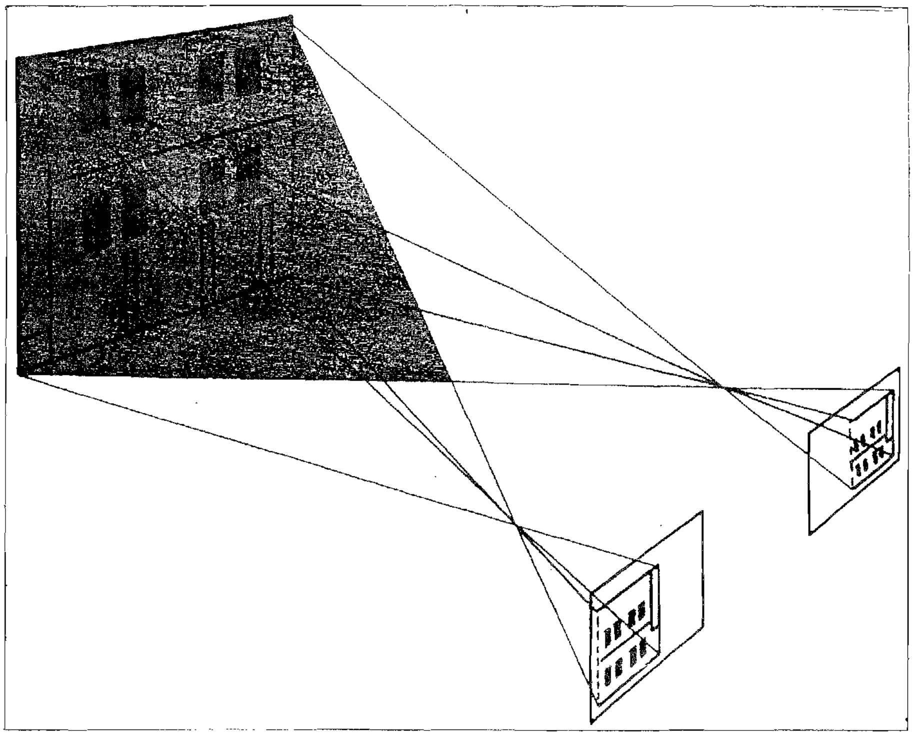


4 The two photographs are set up in a stereo-plotting machine. The instrument is designed so that the photographs can be oriented to correspond to the taking camera positions. The images from the two photographs are then projected and, as the rays from matching details intersect, the position of the feature is defined.

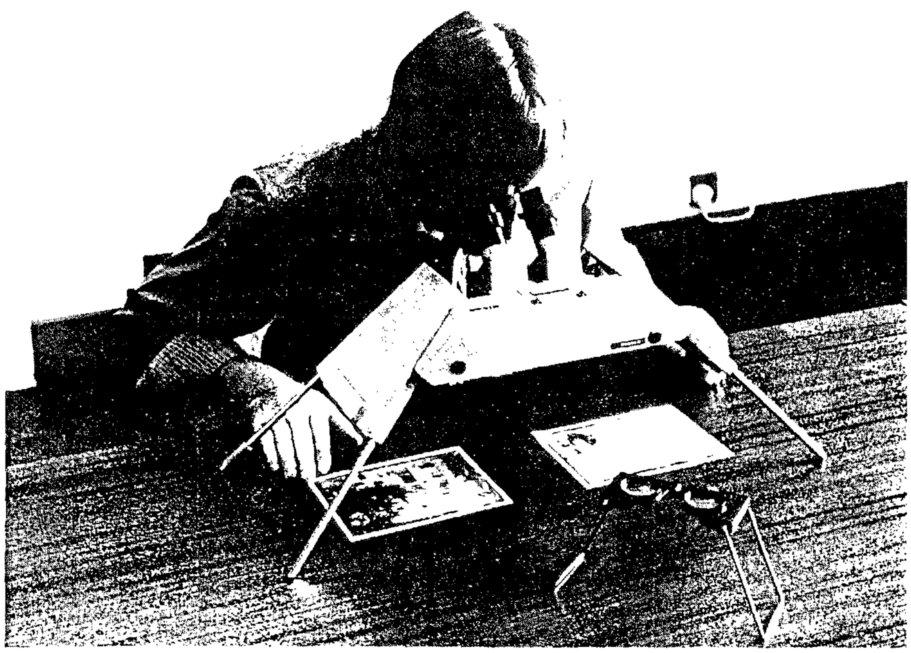


5 The principle of recording in stereo. Instead of taking only one photograph, two photographs of the same section of façade are taken from different viewpoints as shown.

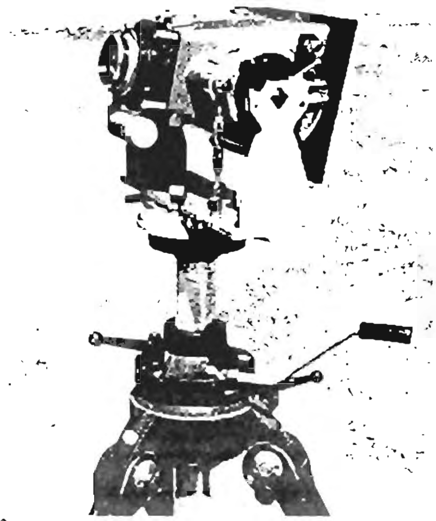
5



6 Stereo geometry in three dimensions. Figs 4 and 5 showed the recording and projections of matched rays in two dimensions. The principle applies equally well in three dimensions. The geometry and mathematics involved are more complicated but the underlying principle is the same.



7 Mirror stereoscope and hand-stereo. The stereo photographs have an extra value as they can be used for interpretation as well as providing drawings. The larger instrument is a mirror stereoscope, which enables the whole area of the stereo-model to be seen at one time. The small hand-stereo cannot show the whole stereo-model at once (stereo-pairs for interpretation only can be taken with any camera).



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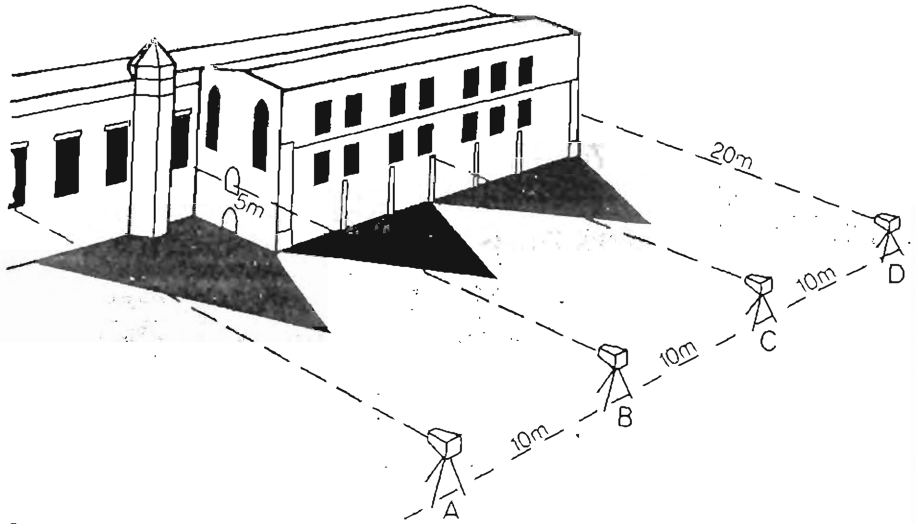

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10

8 A 'metric' camera. These cameras are precisely manufactured to the finest tolerances. A variety of models are produced by survey instrument manufacturers, such as Wild ('Heerbrugg') and Zeiss ('Oberkochen' and 'Jena'). The camera illustrated is an Officine Galileo 'Veroplast'. 'Stereometric' cameras are also commonly used in architectural recording. These consist of two identical cameras rigidly attached to both ends of a base bar, normally of 120 cm length. These cameras are particularly suitable when working at close range.

9 A typical layout of camera stations to record a façade. A base line is laid out parallel with the façade and a series of photographs are taken from it. To form one stereo-model only half of each photo is used, eg the right half of photo A and the left half of photo B (from a survey of the Deanery, Durham Cathedral, for Donald W. Insall and Associates).

10 A typical stereo-pair, taken with an Officine Galileo 'Veroplast' camera. The negative format of this camera is 13 cm × 18 cm and the photographs are shown reduced approximately by half.

11 Obtaining control measurements using a theodolite. This technique is usually necessary where high accuracy is required. Four points per stereo-model are selected and theodolite readings made to them. This enables co-ordinates to be computed.

Site photography and production of drawings

Obtaining the stereo photographs

The first stage in a photogrammetric survey is to obtain suitable photographic coverage. Unfortunately, conventional cameras are generally unsuitable for this purpose and it is necessary to use a specially manufactured 'metric' camera. Metric cameras are constructed to a particularly rigid design with near distortion-free lenses, enabling consistent resolution of the geometric properties of the photograph, **8**.

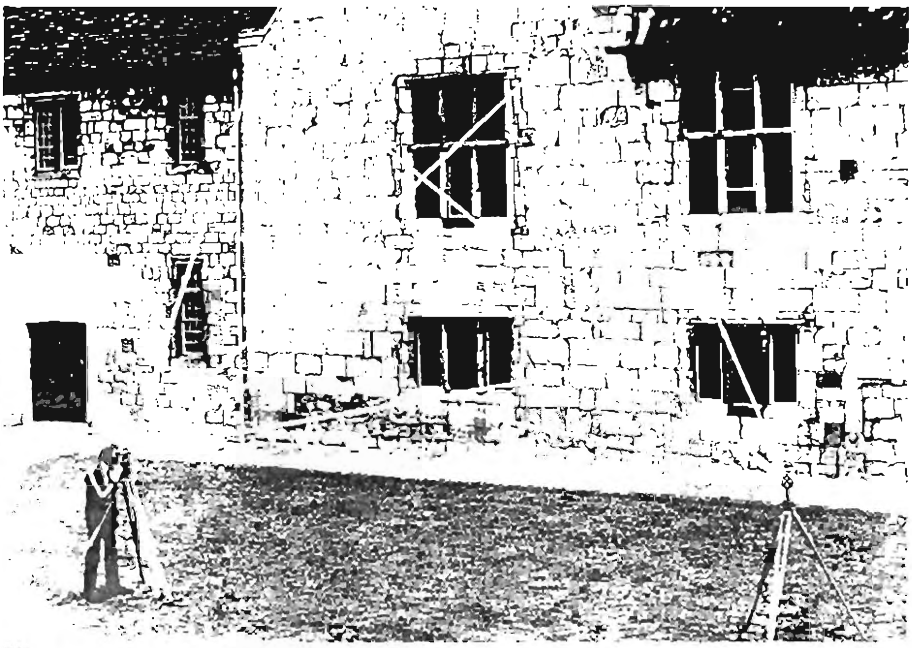
The entire façade to be surveyed should be photographed stereoscopically, **9**. This would produce three stereo-models. For 1:50 scale drawings photographic scales of between 1:100 and 1:300 are usually provided, representing photographic distances from the façade of between 10 m and 50 m depending on the camera used, **10**. The photography is usually taken on black and white film or glass plates.

Measurements for scale

The stereo-model contains the correct 'shape' of the façade and an approximate knowledge of its scale is obtained from the photograph. This value is not accurate enough to produce an exact plotting scale and, to obtain this 'control', measurements must be made on the façade. There are several methods of providing this data, **11**. The most thorough and accurate method of obtaining such control measurements is by using a theodolite to co-ordinate points on the façade. This method is usually found to be necessary on large or complex buildings where several stereo-models require joining in order to complete the drawing.

Stringent controls are also necessary to determine deformation or produce accurate cross-sections and profiles. The introduction of complex surveying methods may prove costly and, in many instances, is unnecessary. Such methods may be replaced by the relatively inexpensive and simple practice of providing tape distances between identifiable markers or natural features on the building, **12**.

(continued on p253)



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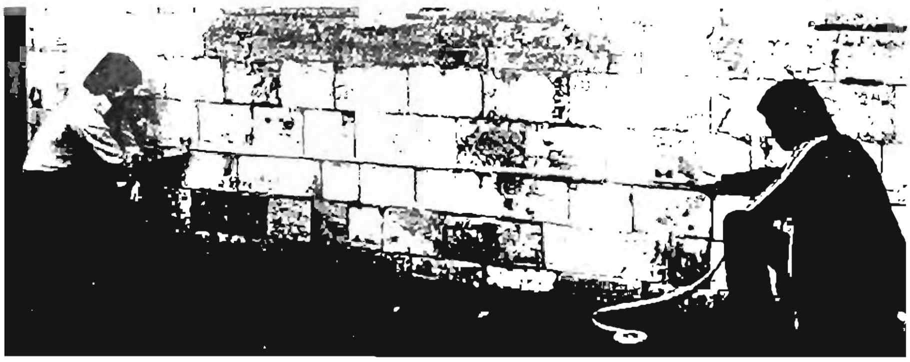

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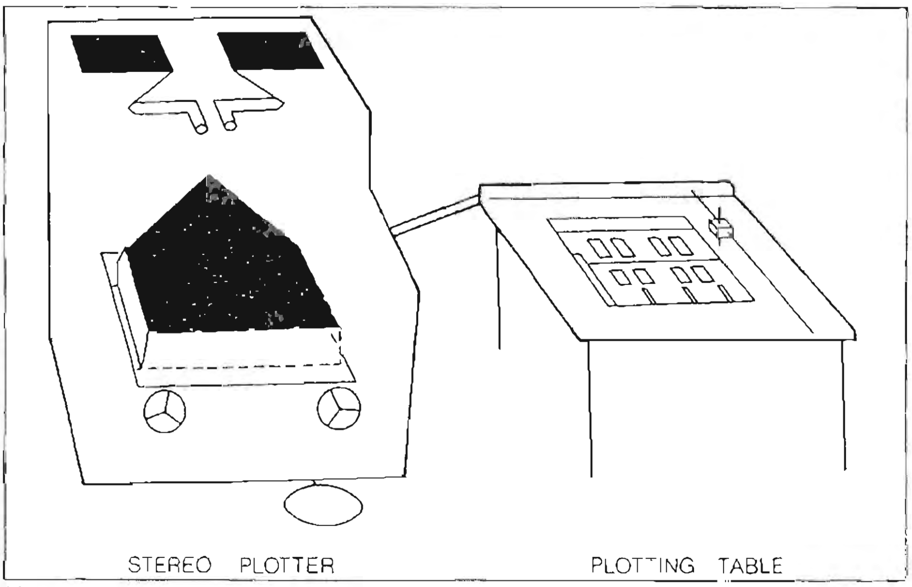

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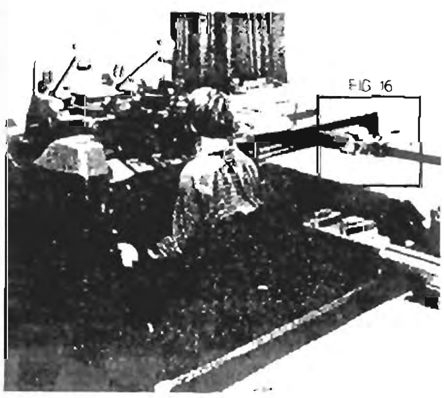

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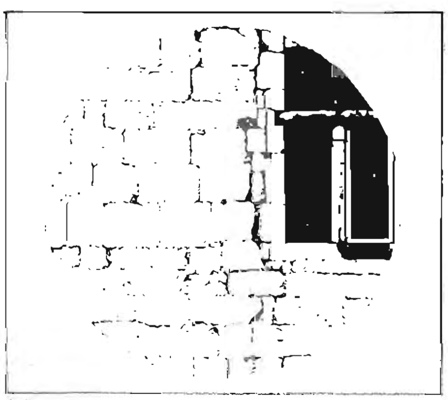

15

Plotting the drawings

Architectural survey drawings are produced on a photogrammetric stereo-plotting instrument, **13, 14**. There are a number of different makes of these machines but, while appearances differ, they all work on the same principle. The operator, looking through the eyepiece, sees only a small part of the stereo-model, **15**. Viewing is enlarged and in stereo, thus enabling depth appreciation and detection of any discontinuities, cracks etc which may exist. In the centre of the eyepiece a very small black spot can be seen. This is called the measuring mark or floating point (so called because it appears to 'float' when viewed in stereo), and to produce a drawing the operator very carefully traces the measuring mark round all the architectural detail, controlling it with hand wheels. The drawing is produced on the linked drawing table, **16**. The accuracy of the plotting relies on the skill of the operator. Any level of detail may be drawn out from the photographs. Plans and vertical sections can be produced or simply the 'depth' or related features recorded. The drawings are usually produced to 'line-width' accuracy on stable, transparent polyester film.

12 *For small façades or less critical specifications, scale control can often be provided adequately by taped distances. Alternatively, levelling staffs can be included in the stereo-model.*

13 *This diagram shows the principal parts of the stereo-plotting machine. The negatives or diapositives are positioned in projectors calibrated to relate to the geometry of the metric camera used for the photography. The stereo-model is 'projected' into the space below (a mathematical projection, not a solid model). A binocular viewing system enables the operator to see the stereo-model. He or she can scan different parts of the stereo-model by using the hand-wheels and foot disc.*

14 *A stereo-plotting instrument. This instrument is a Thompson-Watts 'Mark II' plotter designed for aerial survey but suitable for architectural photography. If compared with* 13, *the major parts of the plotter can be identified. These machines are referred to as analogue plotters. A new generation of instruments called analytical plotters, based on computers and micro-processors, are now replacing these instruments, though the analytical plotters are based on similar principles.*

15 *When the operator looks through the eyepieces of the machine, only a small portion of the stereo-model is seen. The black dot is the 'measuring mark'.*

16 *When the operator controls the measuring mark, a mechanical linkage causes a precise related movement of the drawing implement.*

17

Examples

On these pages are shown some typical examples of photogrammetric surveys. These examples range from scales of 1:25 to 1:200, and show some of the different types of façades which can be surveyed photogrammetrically.

17 *The south elevation of Audley End, Essex. In addition to the architectural detail, all stonework joints have been shown. (Crown Copyright. Prepared on behalf of the DOE, Directorate of Ancient Monuments and Historic Buildings, by the Photogrammetric Unit, Institute of Advanced Architectural Studies.)*
18 *A survey of buildings in the Bow Lane conservation area, London. Drawn at 1:200 scale. Over 50 buildings were recorded in this survey. This type of streetscape survey has been used extensively on the Continent (surveyed by Meridian Airmaps Ltd, on behalf of the Corporation of London, Department of Architecture and Planning. Then chief architect E. G. Chandler FRIBA, MTPI).*
19 *Part of the Great Hall, Winchester Castle, Hampshire. Drawings at 1:25 scale were prepared in advance of restoration (surveyed by Photarc Surveys Ltd, on behalf of Hampshire County Council. County architect C. Stansfield Smith MA, DipArch(Cantab), ARIBA).*

Photogrammetry:

- is faster than conventional hand survey
- is more accurate, both locally and overall; measurements are accurate to one or two cm and can be scaled directly off the elevation drawings
- requires very short site times and involves little or no disruption on site—no scaffolding of the building is required
- can produce drawings at different scales and showing different levels of detail from the same photographic coverage
- is particularly useful for recording complex features
- shows building deformations
- expands the range of surveying services available to the architects, as it enables surveys to be carried out quickly and economically which, with conventional survey methods, would not be feasible.

Basic guidance for commissioning a photogrammetric survey:

- in general, employ a similar brief to that used for a land survey eg RIBA *Architect's job book* (section B4.5)
- specify the areas of the façade to be covered and indicate what detail is required

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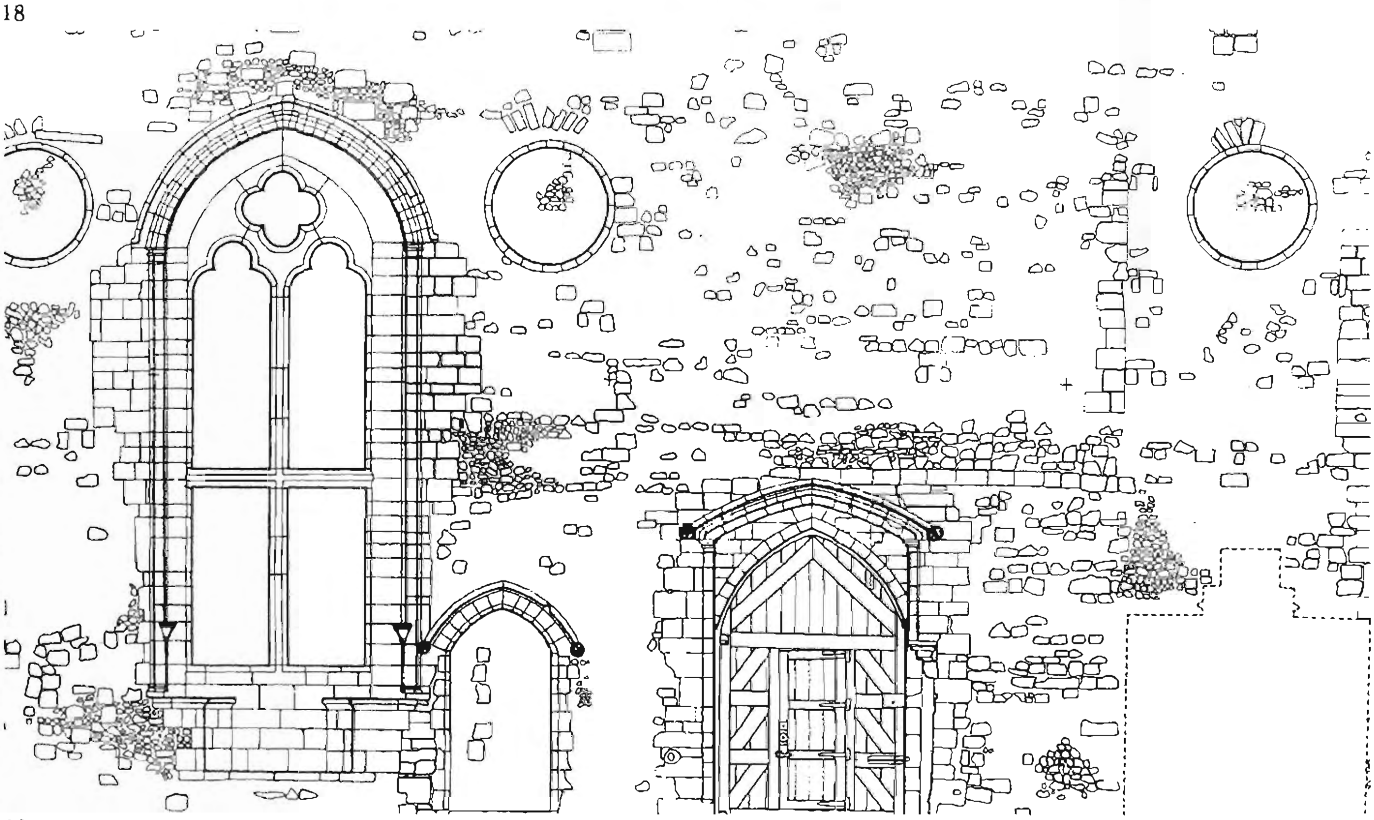

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- survey to be plotted to 'line-width' accuracy
- indicate other information required eg position of cross-sections
- as it is unusual to be able to complete a survey entirely by photogrammetry (trees and shrubs etc can obscure parts of the façade) knowledge of the areas (and indeed of the need for those areas) to be completed by hand survey will be useful
- as considerable use can be made of the stereo photographs, the eventual ownership of the pictures and their conditions of storage must be stated clearly at the outset
- with particular reference to the long-term value of the photogrammetric survey, an evaluation of extra drawings which may be required at a future date will influence the scale of the reproduced drawings requested. This will also have a bearing on the selected methods of control.

Survey firms

Fairey Surveys Ltd,
Reform Road, Maidenhead, Berks, SL6 8BU (0628 213 71)
Huntings Surveys Ltd,
Elstree Way, Borehamwood, Herts, WD6 1SB (01-953 6161)
Meridian Airmaps Ltd,
Marlborough Road, Lancing, Sussex, BN15 8TT (090 63 2992)
Photarc Surveys Ltd,
22 North Street, Wetherby, West Yorks, LS22 4NN (0937 64936)
Plowman, Craven and Associates,
Grosvenor Building, 104-108 London Road, St Albans, Herts, AL1 1NX (0727 65831)
J. A. Storey and Partners,
92-94 Church Road, Mitcham, Surrey, CR4 3TD (01-640 1971)
Terrestrial Surveys Ltd,
Millfield House, 153a Hull Road, York (0904 411981)

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Professor Douglas Wise, director of Institute of Advanced Architectural Studies; H. G. Yexley MVO, DipArch (Oxford), RIBA, superintending architect, Directorate of Ancient Monuments and Historic Buildings; M. Clowes, T. Davies and J. Waywell of the Photogrammetric Unit; M. Grist of Meridian Airmaps Ltd; Photarc Surveys Ltd; J. Turner of Plowman, Craven and Associates; and G. Stoker of Terrestrial Surveys Ltd, for providing examples. Graphics by Tony Davies; photographs by Ross Dallas; copyright of all material belongs to R. W. A. Dallas except where otherwise stated.

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Surveying with a camera

RECTIFIED PHOTOGRAPHY

In the second of two articles Ross Dallas demonstrates how the competent photographer can record to scale the elevations of buildings.

Rectified photography

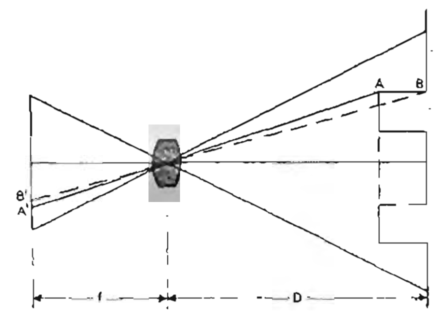
In the first article on photogrammetry (AJ 30.1.80 p249) the camera was introduced as an architectural surveying tool. It may also be used to obtain scaled or rectified photographs. The process does not have the accuracy of the photogrammetric survey and is also subject to other limitations which will be described. Nevertheless, it has much to commend it. This product is sometimes referred to as rectified photography, a term used in aerial survey, where distortions due to camera tilts are eliminated by a process of reprojection through a rectifying enlarger. However, if the photograph taken parallel with the façade is printed to scale, the process can be simplified. It is sometimes referred to as photo-mosaic, photo-montage, photo-drawing or square-on photography. Some simple elevation photography may be carried out on a do-it-yourself basis though a complex job requiring a high degree of accuracy should be referrred to a photogrammetric survey company or specialist architectural photographer.

Theory

A photograph is a central projection. This means that all the rays of light from the object being photographed pass through the centre of the lens before being imaged on the film emulsion. This introduces four major drawbacks in the use of photography as a survey medium for the architect:

- displacement of the image due to changes in 'depth' in the object being photographed, **2**
- scale changes: planes of the façade at different 'depths' will be imaged at different scales, **2**
- a varying scale across the photograph caused by lack of parallelism between the plane of the film and the plane of the façade, **3**
- the camera and enlarger system may introduce inaccuracy as the rays of light passing through the camera lens or enlarger lens may be distorted, **4**.

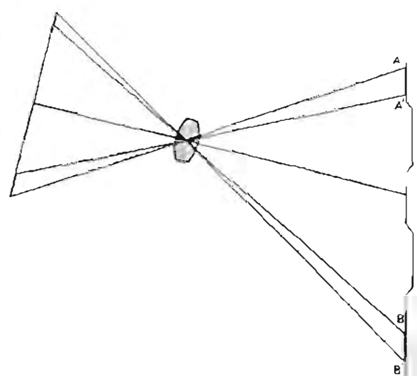
1 (previous page) *Ardingley Mansion, Wakehurst Place, rectified photography. A complex example of the technique. Due to the different planes, several photographs have had to be individually scaled and matched. (Surveyed by Plowman, Craven and Associates on behalf of the Property Services Agency, Central Survey Branch, DCES, Department of the Environment, Crown copyright.)*



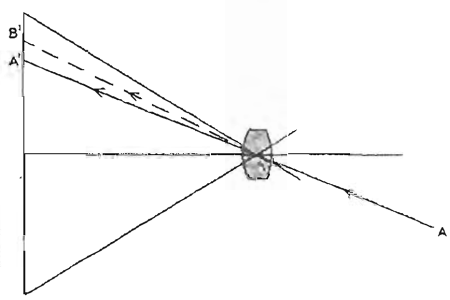
2 *Causes of scale and displacement errors. Point A on the buttress is imaged at A' on the film plane. The true position on the façade which requires to be recorded is B, which should be imaged at B'. The scale of a photograph is a function of*

$$\frac{\textit{focal length } (f)}{\textit{distance to the façade } (D)}$$

As the front of the buttress is closer to the lens, it is at a larger scale on the film.



3 *Incorrect alignment. If the film plane is not parallel with the façade, there will be a scale change across the negative. Sections AA' and BB' have the same length, but will be imaged at different scales.*



4 *Lens distortion. The ray of light AA' should be a straight line, but the lens causes the ray to be 'bent' so that it meets the film plane at B'. Distortion is noticeable at the very edge of the lens field.*

Appropriate application

Simplified rectified photography will provide good results given the following conditions:

- when the facade is 'flat' as shown in photographs **11** and **12**
- when the camera is accurately set up parallel with the façade in the horizontal and vertical planes.
- when the photographic equipment employed is good enough to introduce only negligible distortions.

Practice

Equipment

Satisfactory results can be obtained with almost any good quality modern camera and enlarger. If a professional survey firm is employed it may use a photogrammetric camera and enlarger which will remove the principal errors through distortions, but the use of this equipment cannot remove displacement and scale errors. A 35 mm SLR, 120 roll film or a professional monorail camera can all be used satisfactorily. If much work of this type is anticipated a monorail camera, taking cut film in the 5in × 4in format, will provide the best all-round results, **5**. It is useful to have a selection of lenses of varying focal length to provide optimum coverage, but no other specialised photographic equipment is needed.

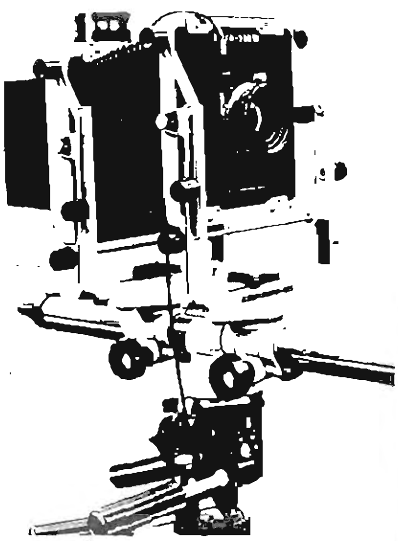
Fieldwork

Obtaining the photographs

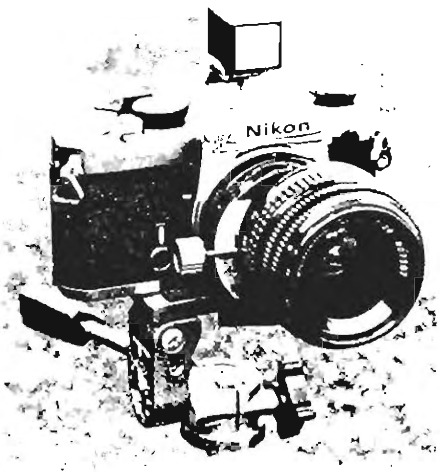
Start by examining the façade. Does it have much 'depth'? Small variations such as string courses will not matter but features such as buttresses, perhaps 1 m or 2 m deep, will introduce substantial scale and displacement errors. It will usually be necessary to photograph and/or scale these features separately. The positioning of the camera will depend on the shape and size of the facade and the required scale of the negative. The precise scale of the negative is not critical, but the enlargement of the final scale should not exceed about ×4 to obtain the best quality prints, ie for a 1:100 elevation the photo scale should not be greater than 1:400. Photographic techniques are similar to those used in normal photographic work. Black and white film such as Ilford FP4 or Kodak Plus-X will generally give the best results, although colour film can be used.

Aligning the camera

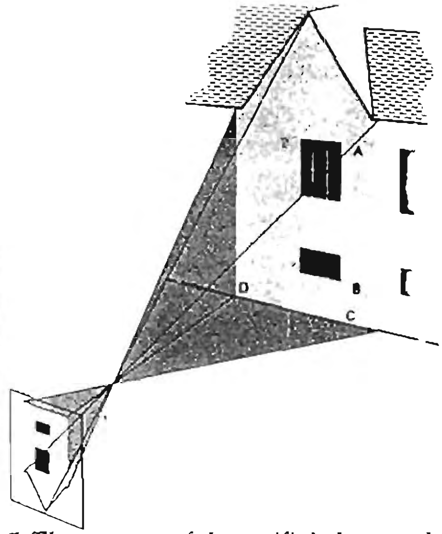
Considerable care must be taken to ensure that the film plane is parallel with the plane of the façade both vertically and horizontally. To achieve this a tripod is essential, **6**. By using a bubble level the camera will be levelled 'vertically' to the façade. For the film plane to be parallel horizontally the whole camera must be rotated. There are a number of ways of achieving this, **8**. Although it is possible to rectify tilts on an enlarger it is not recommended that the amateur tilts the camera to include upper parts of the façade. Survey firms and professional photographers have the equipment and skill to remove tilts accurately during enlarging, but for the amateur it is much easier to avoid the problem by moving further back or raising the camera.



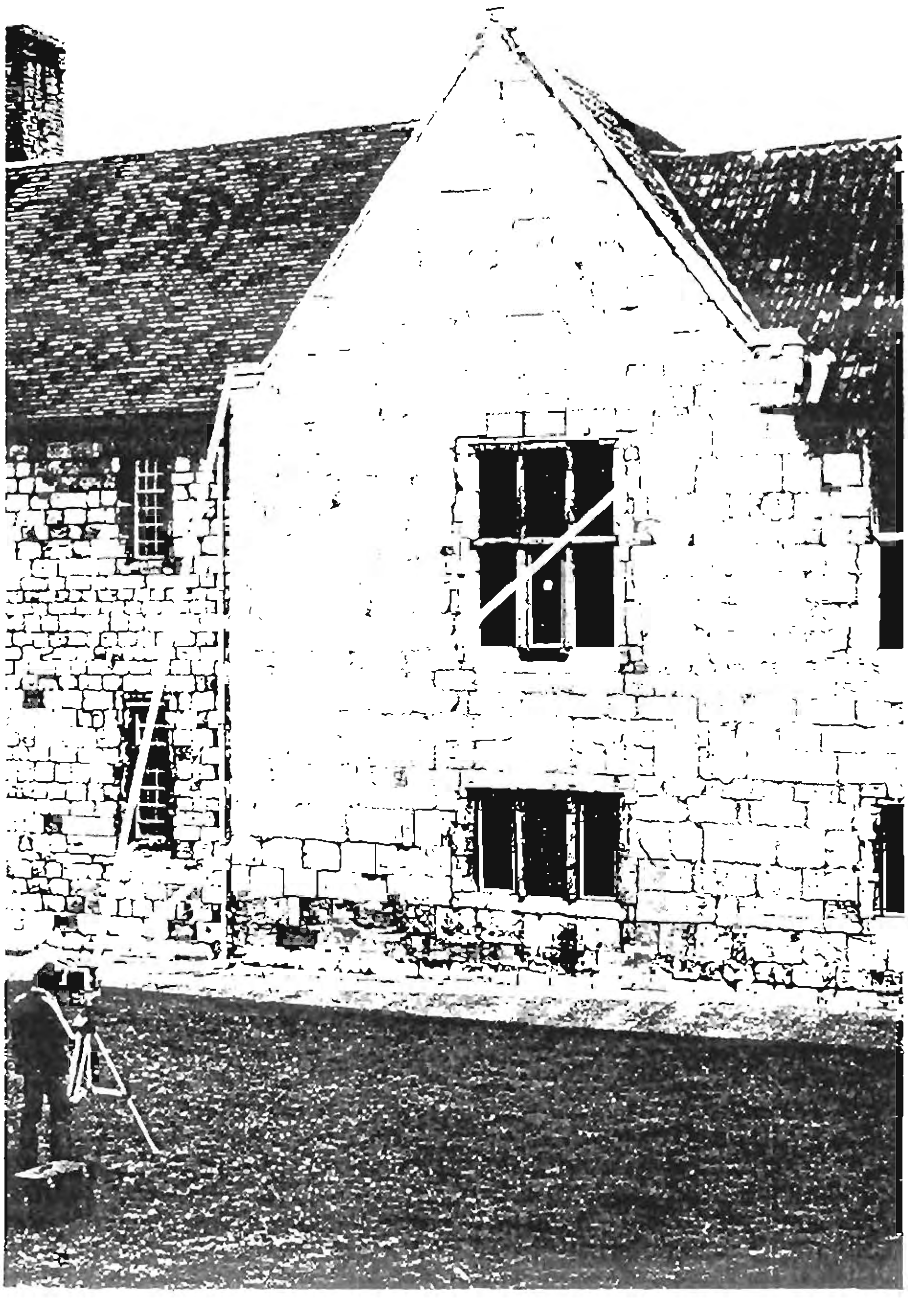
5 *Monorail camera. Although these cameras are normally only used by professional photographers, they are quite easy to operate in practice. The rising front and side movements are used, allowing optimum coverage of the façade and much higher photographic quality.*



6 *A 35 mm SLR camera, fitted with a 'shift' (similar to a 'rising front')* lens which allows optimum use of the negative to be made. A 'Kaiser' level bubble is fitted in the accessory shoe. With the 35 mm format a gridded focusing screen is useful.*



7 *The geometry of the rectified photograph in three dimensions. The lines AB and CD show the best arrangement for taping the control, or for positioning levelling staffs for scale. The taped distances can be measured between details on the façade, or between targets attached to the façade.*

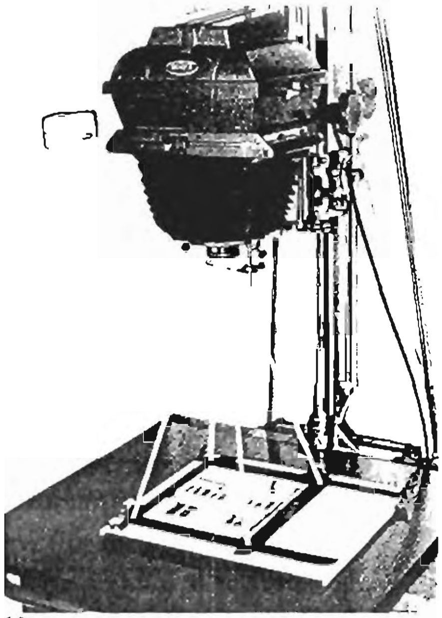


8 *Taking the photograph. First carefully level the camera so that the film plane is vertical. The camera must then be swung so that the film plane is parallel with the façade. The centre point of the gridded screen should coincide with the centre line of the lens. With a 35 mm camera without interchangeable screens, the centre of the focusing area can usually be judged quite accurately by eye. To adjust the camera, use one of the following methods which should cover most situations.*

- *'3,4,5' method. Use tapes to set out a line at right angles to the building. Set the camera accurately over this line with a plumb bob. Swing the camera until the centre point of the grid is exactly aligned with the tape. The film plane will now be parallel with the building façade.*
- *Optical square. An optical square is a sighting device made with two prisms set at right angles to each other. Either by standing with one's back to the façade or on a base line laid out parallel with the façade, a right angle can be viewed and the camera aligned as above.*
- *If the parapet of the building is straight and level, swing the camera until one of the horizontal grid lines is exactly parallel with it.*
- *Mark off two vertical equal distances on the façade at each edge of it. Swing the camera until the distances seen in the viewfinder are identical, using the grid of 'dividers'.*

* A 'shift' lens is adjustable to correct the converging verticals which give the appearance of a building leaning back when a normal lens is used

9



10

9 The rectified photograph. As this façade has virtually no 'depth', measurements can be scaled off quite accurately. Because the roofs recede, their correct height is not recorded, their true height is indicated by the dashed lines.

10 Printing the photograph. Most enlargers can be used quite satisfactorily. Use a spirit level to check that the film plane, the lens plane and the easel are parallel. The scaling is of course critical. The taped distance should be drawn to scale and the image size adjusted until it exactly matches this distance.

Measurement for scale

In order that the photographs can be printed to scale, it is necessary to tape 'control' measurements on the façade. The best arrangement to ensure a balance between economy and accuracy is to have one vertical and one horizontal taped distance, **7**. Where several photographs are to be joined together, the vertical measurement need not be made for every photograph. It may also be useful to level two points per photograph.

Control measurements could be obtained by the use of a theodolite, but it is unlikely that this would produce a significant improvement in the accuracy of the product while greatly increasing the cost of the survey.

Office work

Printing the negatives

Each photograph must be enlarged exactly to scale using the 'control' tape measurements as shown in **10**. There are three main approaches to reproducing the scale photographs:

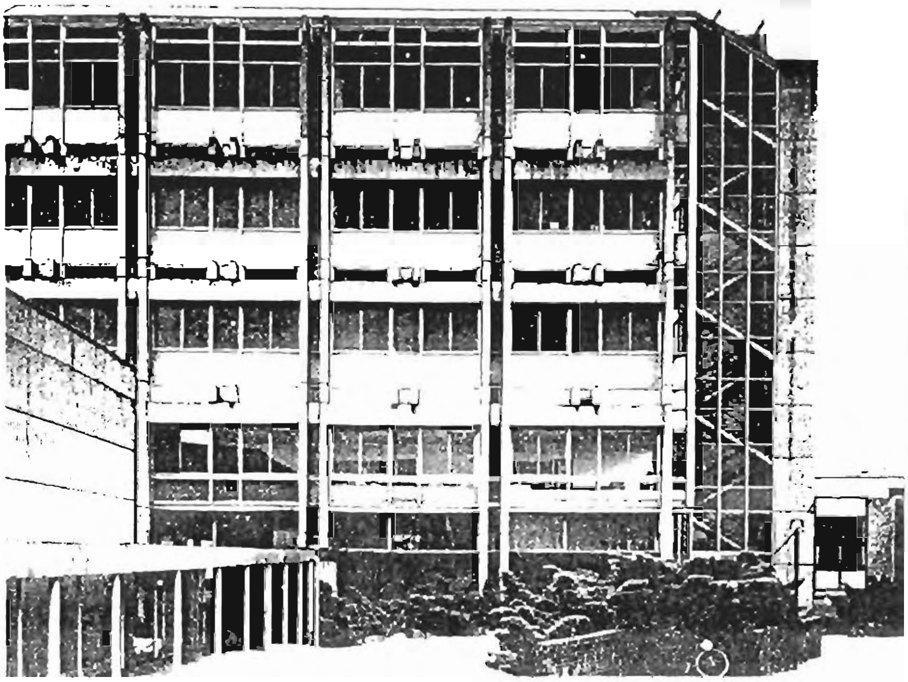
- bromide prints: if only one copy of the print is required, a black and white bromide print can be made as usual
- where dyeline copies of a simple façade covered by one or two photographs are required, the negatives can be printed onto transparent film
- where multiple copies of a complicated façade are required, entailing the printing of a number of photos onto the same sheet, 'screening' similar to newsprint must be employed (this is a professional technique involving equipment which the architect would not normally possess).

Printing onto transparent film is a straightforward process. Suitable films include Agfa Gevaert Rlp, Kodak PL4 or Ozalid P3.3P. These films have emulsions with characteristics very similar to conventional photographic paper, and can be exposed and developed in the same way.

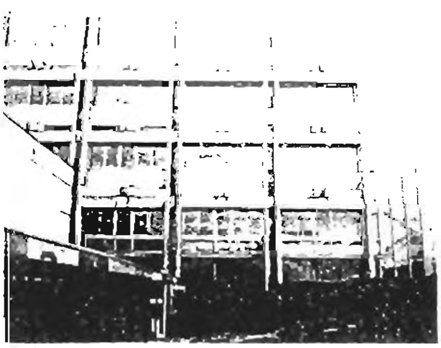
One or two photos can be printed directly onto A3 or A4 size sheets (masking the surroundings) or alternatively the film can be trimmed and mounted on tracing paper with clear adhesive. Where a number of photos have to be matched and durability is important a more complicated technique is required. Each print on the transparent film must be carefully cut and matched to the adjoining photographs, and the 'façade' then mounted on one base sheet. This may be too fragile to dyeline, and the whole sheet must be copied onto one piece of reversal film. Unfortunately, reversal films are only available with very high contrast. To cut down on the contrast, each photograph on the transparent film must be 'screened'. This process involves fairly advanced techniques and reprographic facilities. The first two processes can, however, be carried out with a good quality enlarger lens, and normal darkroom equipment.

Testing the equipment and techniques

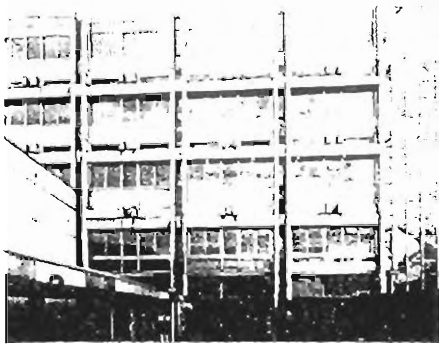
The equipment and techniques can be tested by carrying out a trial survey, and the most suitable type of building for this is a modern office block. A flat front ensures that scale and displacement errors do not affect the result, and the windows and panels provide a 'grid' for checking the 'squareness' of the negative and the final print, **11**. It is very difficult to give any absolute values for the accuracy which can be obtained with the rectified photography process. Every factor involved introduces its own variables. By using good quality equipment and technique a relatively high order of accuracy (± 40 mm at 1:50 scale) may be obtained on a façade with little or no depth variation. Experience of the product is undoubtedly the best way of assessing its suitability for a particular survey.



11a



11b



11c

12

Conclusions

Rectified or scaled photography has the following advantages over conventional survey techniques:

- the equipment used is relatively cheap, and can be used for other purposes
- the photographic image may provide far more information than a line drawing
- the process can be carried out very quickly, especially in comparison with hand survey.

The process has the disadvantage that its accuracy cannot be consistently relied upon. The effect of variations in 'depth' on the façade lead to variable displacements and scale changes. No attempt has been made to quantify this effect, because the errors depend on several variables.

Postscript—orthophotography

From the processes which have been described, it would seem that the best of both worlds could be the combination of the accuracy of the photogrammetric process with the advantage of a photographic image. There is a process which provides this, called orthophotography. Unfortunately, it is a complex photogrammetric process requiring sophisticated equipment.

The system operates by photographing minute segments of a photograph, individually corrected to scale when the stereo-model is viewed. The method therefore requires photography with a metric camera, a stereo-plotting instrument, and an orthophotoscope which is attached to the stereo-plotter. A number of photogrammetric companies in Britain now have orthophoto facilities, but very little use has been made of them for architectural surveys. ●

11 *The effects of the commonest errors in the rectified photograph process.*
11a *shows the correct result,* **11b** *shows the effect of not ensuring that the film plane is vertical. An upward tilt has produced 'converging verticals'.* **11c** *shows the effect of the camera not being parallel with the wall. The scale changes across the photograph.*
12 *A fine example of the type of façade for which rectified photography is perhaps most suitable. No 59 Bootham, York.*

(iii) Recording and drawing finds. The area where photogrammetry presents the greatest potential for the archaeologist is in the preparation of the large scale plans and sections which are needed in all excavations. These records must be made very thoroughly and they represent one of the most time consuming aspects of archaeology. The drawing of finds is also a slow process for the archaeologist and there would seem to be scope for introducing photogrammetric methods into this process as well.

The equipment suitable for architectural use will in general be satisfactory for archaeological use, but further reference will be made to this point. With regard to site work, the problems are rather different to those encountered in architectural recording. First of all, suitable methods have to be devised for elevating the camera sufficiently high over the site to allow reasonably economical photographic coverage. For most sites, an elevation of the camera of 7 m to 10 m above the surface will be required. Photography may also have to be repeated fairly frequently over the same area as further levels are exposed. The camera must therefore be kept on site and the method of elevating and manoeuvring it must be as simple and fast as possible. Hydraulic platforms provide one method of photography, but these are expensive and cannot usually be kept on site for very long. Portable scaffold towers represent a cheaper alternative. Lightweight frames of varying design have also been constructed, such as the bipod described by Whittlesey (1975). This is an A-shaped frame from which a camera can be suspended and the frame then swung over the site. A similar apparatus has been used by McFadgen (1971), but this consists of a more rigid framework with triangular supports. For more extensive sites, balloons (Whittlesey, 1975), model aeroplanes (von Przybilla & Wester-Ebbinghaus, 1979) or helicopters (Polderman, 1976) may be used to obtain photographs. While all these methods have an application, there seems to be no universal system which will be suitable for every excavation. Photography of cross sections will not usually present such problems, except where narrow trenches are involved. For both plans and cross sections, the ability to use tilted photography may make the process more flexible and economical. There is considerable scope in archaeological work for using alternative film types, such as infrared and colour for distinguishing such features as different soil layers.

The drawing and interpretation of the stereomodel is an area which presents problems which are also rather different from architectural work. It would seem essential that the photogrammetric plotting of the plans and sections is carried out by the archaeologists during the excavations. There are several reasons for this requirement. The interpretation of archaeological features requires the skills of the trained archaeologist, as it is far more difficult to interpret these features than architectural detail. The plotting must be carried out immediately, since a much higher degree of detail will be missing than is usual in photogrammetric work, and the plots must be returned to the excavation immediately for checking and completion before further excavations can take place. It is of little value taking photography and not plotting it for some months for inevitably much detail would be lost.

From a consideration of these points, it would seem that photogrammetric systems must be developed which can be used on site and directly by the archaeologists. Since archaeological budgets seem to be perpetually underendowed, the likelihood of purchasing conventional photogrammetric equipment seems highly unlikely, except by a few of the largest excavation groups. The need is for cheap, portable systems which can be operated by unskilled personnel. However, the pressures facing archaeologists, particularly in urban sites, suggest that the problems will be overcome. The need for speed in recording rescue excavations can probably be met only through the increased adoption of photogrammetric methods. The likelihood seems to be that as archaeology employs more people on a full time basis, with the typical excavation employing a far smaller number of people working all year round, more expenditure will have to be made on capital equipment in order to increase efficiency. It is in this context that photogrammetry will be most likely to find greater use in archaeology.

The recording and drawing of archaeological finds is another area where photogrammetric techniques might be considered. Some of the equipment developed for medical applications (see Chapter 6) could well be used in archaeology, but there is also scope for the development of simpler optical and photographic devices. The use of plano-convex lenses to produce orthographic projections (Williams, 1976) could be developed to help with the drawing of finds. The archaeologist does not have the knowledge of optics or measurement to develop and test such devices. It is not conventional photogrammetry but nevertheless it is an area where the photogrammetrist has skills which could be of use to the archaeologist.

5.4 PHOTOGRAMMETRY IN ARCHAEOLOGY

The application of photogrammetric techniques to archaeological recording is in principle straightforward, the methods following quite closely to those already developed for architectural recording. There are however a number of problems which have probably led to the technique not yet being particularly widely used in archaeology.

The range of recording needs in archaeology is very diverse, but there are perhaps three major areas where photogrammetry can be of most use to the archaeologist.

(i) Aerial photography, both vertical and oblique, for finding and recording sites. A considerable amount of work has been done in this field and it is now a well established technique, frequently used by the archaeologist. Most of this work is outside the scope of close range photogrammetry, and has more in common with aerial survey methods. One aspect of this air photography may be considered as close range photogrammetry and this occurs when photography is obtained at very large scales from tethered balloons, kites, model aircraft or helicopters.

(ii) Site recording in archaeological excavations including the preparation of plans, levels and section drawing.

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R W A Dallas

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