THE DEVELOPMENT AND APPLICATION OF
COMPUTER-AIDED MONO-PHOTOGRAMMETRY
FOR RECORDING ARCHITECTURAL FACADES

(VOLUME TWO)

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requirements of the Council for National Academic Awards
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Leicester Polytechnic
CONTAINS

PULLOUTS
**LIST OF CONTENTS**

**VOLUME ONE**

**LIST OF FIGURES**
vi

**LIST OF APPENDICES**

vii

**PREFACE**
x

### 1.0 INTRODUCTION

1.1 Background to investigation 1
1.2 Aims and objectives 7
1.3 Research methodology 8
1.3.1 Management of investigation 8
1.3.2 Data gathering and analysis 10
1.3.3 Selection of sample façades 12
1.4 Thesis organisation 16

### 2.0 THE PURPOSE OF SURVEYING

2.1 The need for surveys 18
2.1.1 What is a survey? 18
2.1.2 Aspects of surveying 20
2.2 Surveying practice 21
2.2.1 Survey applications 21
2.2.2 Generators of surveys 24
2.2.3 Survey specification 27
2.3 Building surveys 31
2.3.1 Condition surveys 32
2.3.2 Measured surveys 35

### 3.0 HISTORICAL DEVELOPMENTS IN RECORDING METHODOLOGY

3.1 Introduction 38
3.2 The development of surveying methods 41
3.3 The recording of buildings 48
3.3.1 Treatises, paintings and prints 48
3.3.2 Architectural drawings 51
3.3.3 Architectural photography 55

### 4.0 PRACTICAL SURVEYING AND RECORDING

4.1 Direct surveying 63
4.1.1 Building measurement 63
4.1.2 Building interpretation 67
4.2 Indirect surveying 75
4.2.1 Photographic surveying 78
4.2.2 Rectified photography 87
4.2.3 Close-range stereo-photogrammetry 91
4.2.4 Other techniques 105
4.3 Synopsis of recording practice 107
5.0 COMPUTER-AIDED MONO-PHOTOGRAFMETRY
   5.1 Introduction 110
   5.1.1 Justification for investigation 110
   5.1.2 Development of methodology 113
   5.1.3 Programme of application 117
   5.2 Mechanics of computer-aided mono-photogrammetry 119
   5.2.1 Photography 120
   5.2.2 Dimensional control 135
   5.2.3 Image restitution 141
   5.3 Analysis of project data 149

6.0 SUMMARY AND CONCLUSIONS
   6.1 Rationale for investigation 160
   6.2 A solution to a recognised problem 162
   6.3 Aspects concerning practical application 166
   6.4 A contribution to the developing practice of recording architectural façades 169

BIBLIOGRAPHIC AND UNPUBLISHED SOURCES 174

---ooo---

VOLUME TWO

APPENDIX A Case studies 1
APPENDIX B Measured and photographic surveys 156
APPENDIX C Specification and references for equipment 159
APPENDIX D Published and presented material 175

---ooo---

-iii-
LIST OF FIGURES

Figure 1. Principal entrance, Hawthorn Building. 6
Figure 2. Heraldic panel and urns, Hawthorn Building. 7
Figure 3. South elevation, Scraptoft Hall. 12
Figure 4. Detail of doorcase, Scraptoft Hall. 13
Figure 5. Central section, Jewry Wall. 19
Figure 6. External dimensional control, Bolsover. 27
Figure 7. South aisle (south wall), Bolsover. 28
Figure 8. South aisle (west wall), Bolsover. 29
Figure 9. East and west faces, King's Mill Viaduct. 35
Figure 10. South elevation, Lacock Abbey. 41
Figure 11. Blocked doorway and tympanum, Ault Hucknall. 47
Figure 12. Doorway in north bailey wall, Tickhill Castle. 49
Figure 13. North elevation, Bagshaw Hall. 55
Figure 14. Principal elevation, Kirby and West building. 60
Figure 15. Gazebo, Kelham Hall. 67
Figure 16. Details of gazebo, Kelham Hall. 68
Figure 17. North-west elevation, Eyre Chapel. 73
Figure 18. West elevation, Flacketts. 83
Figure 19. West side, Aylsham Market Place. 90
Figure 20. Rectified view, Norman cellar. 96
Figure 21. Rectified view showing present walls, Norman cellar. 97
Figure 22. Perspective view of Norman cellar. 98
Figure 23. Terracotta balustrade, Castle Ashby House. 105
Figure 24. West elevation, Hales Street Grammar School.

Figure 25. South elevation, Hales Street Grammar School.

Figure 26. East elevation, Hales Street Grammar School.

Figure 27. North elevation, Hales Street Grammar School.

Figure 28. Vertical dimensional control, Ely Cathedral.

Figure 29. West face of south-west transept, Ely Cathedral.

Figure 30. East face of sacristy, Church of St Mary de Castro.

Figure 31. South-east elevation, Burleigh Cottage.

Figure 32. North-east elevation, Burleigh Cottage.

Figure 33. North-west elevation, Burleigh Cottage.

Figure 34. South-west elevation, Burleigh Cottage.

Figure 35. South-east elevation of gatehouse, Leicester Road Cemetery.

Figure 36. North-east elevation and railings, Leicester Road Cemetery.

Figure 37. South-west elevation, Field Cottage.

Figure 38. South-east elevation, Field Cottage.

Figure 39. North-east elevation, Field Cottage.

Figure 40. North-west elevation, Field Cottage.

Figure 41. Digitising accuracy.

Figure 42. Lens distortion: 35mm shift lens.

Figure 43. Lens distortion: 35mm shift lens.

Figure 44. Lens distortion: 28-50mm zoom lens.

Figure 45. Lens distortion: 35-70mm zoom lens.

Figure 46. Lens distortion: 70-150mm zoom lens.
**LIST OF PLATES**

<table>
<thead>
<tr>
<th>Plate</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Principal entrance, Hawthorn Building.</td>
<td>5</td>
</tr>
<tr>
<td>2.</td>
<td>Heraldic panel and urns, Hawthorn Building.</td>
<td>8</td>
</tr>
<tr>
<td>3.</td>
<td>South façade, Scraptoft Hall.</td>
<td>11</td>
</tr>
<tr>
<td>4.</td>
<td>East face, Jewry Wall.</td>
<td>17</td>
</tr>
<tr>
<td>5.</td>
<td>Central section, Jewry Wall.</td>
<td>18</td>
</tr>
<tr>
<td>6.</td>
<td>Colour computer image, Jewry Wall.</td>
<td>20</td>
</tr>
<tr>
<td>7.</td>
<td>South aisle (south face), Bolsover</td>
<td>24</td>
</tr>
<tr>
<td>8.</td>
<td>South aisle (west face), Bolsover.</td>
<td>25</td>
</tr>
<tr>
<td>9.</td>
<td>South aisle (interior), Bolsover.</td>
<td>26</td>
</tr>
<tr>
<td>10.</td>
<td>East face, King's Mill Viaduct.</td>
<td>33</td>
</tr>
<tr>
<td>11.</td>
<td>Arch 5, east face, King's Mill Viaduct.</td>
<td>34</td>
</tr>
<tr>
<td>12.</td>
<td>West and south façades, Lacock Abbey.</td>
<td>39</td>
</tr>
<tr>
<td>13.</td>
<td>South façade, Lacock Abbey.</td>
<td>40</td>
</tr>
<tr>
<td>14.</td>
<td>West face of nave and aisles, Ault Hucknall.</td>
<td>45</td>
</tr>
<tr>
<td>15.</td>
<td>Blocked doorway and tympanum, Ault Hucknall.</td>
<td>46</td>
</tr>
<tr>
<td>16.</td>
<td>Doorway in north bailey wall, Tickhill Castle.</td>
<td>48</td>
</tr>
<tr>
<td>17.</td>
<td>North façade, Bagshaw Hall.</td>
<td>53</td>
</tr>
<tr>
<td>18.</td>
<td>North façade, Bagshaw Hall.</td>
<td>54</td>
</tr>
<tr>
<td>19.</td>
<td>Principal façade, Kirby and West building.</td>
<td>58</td>
</tr>
<tr>
<td>20.</td>
<td>Principal façade, Kirby and West building.</td>
<td>59</td>
</tr>
<tr>
<td>21.</td>
<td>Colour computer image, Kirby and West building.</td>
<td>61</td>
</tr>
<tr>
<td>22.</td>
<td>Gazebo, Kelham Hall.</td>
<td>65</td>
</tr>
<tr>
<td>23.</td>
<td>Detail of gazebo, Kelham Hall.</td>
<td>66</td>
</tr>
<tr>
<td>24.</td>
<td>North-west gable, Eyre Chapel.</td>
<td>72</td>
</tr>
<tr>
<td>25.</td>
<td>North-west gable at 45°, Eyre Chapel.</td>
<td>74</td>
</tr>
</tbody>
</table>

-vi-
Plate 26. Unfiltered exposure, Eyre Chapel. 75
Plate 27. Red filter, Eyre Chapel. 76
Plate 28. Yellow filter, Eyre Chapel. 77
Plate 29. Green filter, Eyre Chapel. 78
Plate 30. West façade, Flacketts. 82
Plate 31. West side from north, Aylsham Market Place. 88
Plate 32. West side from south, Aylsham Market Place. 89
Plate 33. Copy of Weatherhead print, 1861, Norman cellar. 95
Plate 34. Ornate pier to balustrade, Castle Ashby House. 102
Plate 35. Ornate pier to balustrade, Castle Ashby House. 103
Plate 36. Section of lettering to balustrade, Castle Ashby House. 104
Plate 37. South and west façades, Hales Street Grammar School. 110
Plate 38. South and east façades, Hales Street Grammar School. 111
Plate 39. Victorian west façade, Hales Street Grammar School. 112
Plate 40. East face of north aisle, Hales Street Grammar School. 113
Plate 41. West front, Ely Cathedral. 122
Plate 42. West face of south-west transept, Ely Cathedral. 123
Plate 43. East face of sacristy, Church of St Mary de Castro. 129
Plate 44. View from east, Burleigh Cottage. 134
Plate 45. View from east, Burleigh Cottage. 135
Plate 46. View from north, Burleigh Cottage. 136
Plate 47. South-east façade of gatehouse, Leicester Road Cemetery. 143
Plate 48. Section of railings, Leicester Road Cemetery.  144
Plate 49. North-east and south-east façades, Field Cottage.  150
Plate 50. North-east and north-west façades, Field Cottage.  151
Plate 51. TEKTRONIX 4111 terminal with 4957 tablet.  165
Plate 52. OLYMPUS OM-3 body with OLYMPUS Zuiko perspective-control lens.  172
Plate 53. KENNET ENGINEERING 'BEMBO' tripod with MANFROTTO 3-way tilt-pan head.  173
**LIST OF APPENDICES**

**VOLUME II**

**APPENDIX A: CASE STUDIES**

<table>
<thead>
<tr>
<th>Case Study</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Hawthorn Building, The Newarke, Leicester</td>
<td>2</td>
</tr>
<tr>
<td>II</td>
<td>Scraptoft Hall, Scraptoft, Leicestershire</td>
<td>9</td>
</tr>
<tr>
<td>III</td>
<td>Jewry Wall, St Nicholas Circle, Leicester</td>
<td>14</td>
</tr>
<tr>
<td>IV</td>
<td>The Church of St Mary and St Laurence, Bolsover, Derbyshire</td>
<td>21</td>
</tr>
<tr>
<td>V</td>
<td>King's Mill Viaduct, Mansfield, Nottinghamshire</td>
<td>30</td>
</tr>
<tr>
<td>VI</td>
<td>Lacock Abbey, Lacock, Wiltshire</td>
<td>36</td>
</tr>
<tr>
<td>VII</td>
<td>The Church of St John the Baptist, Ault Hucknall, Derbyshire and Tickhill Castle, Tickhill, South Yorkshire</td>
<td>42</td>
</tr>
<tr>
<td>VIII</td>
<td>Bagshaw Hall, Bakewell, Derbyshire</td>
<td>50</td>
</tr>
<tr>
<td>IX</td>
<td>Kirby and West Building, Western Boulevard, Leicester</td>
<td>56</td>
</tr>
<tr>
<td>X</td>
<td>The Gazebo, Kelham Hall, Kelham, Nottinghamshire</td>
<td>62</td>
</tr>
<tr>
<td>XI</td>
<td>Eyre Chapel, Newbold, Chesterfield, Derbyshire</td>
<td>69</td>
</tr>
<tr>
<td>XII</td>
<td>Flacketts, Flacketts Lane, Sudbury, Derbyshire</td>
<td>79</td>
</tr>
<tr>
<td>XIII</td>
<td>The Market Place, Aylsham, Norfolk</td>
<td>84</td>
</tr>
<tr>
<td>XIV</td>
<td>Norman cellar, Guildhall Lane, Leicester</td>
<td>91</td>
</tr>
<tr>
<td>XV</td>
<td>Terracotta balustrade, Castle Ashby House, Castle Ashby, Northamptonshire</td>
<td>99</td>
</tr>
<tr>
<td>XVI</td>
<td>Grammar School, Hales Street, Coventry</td>
<td>106</td>
</tr>
</tbody>
</table>
Case Study XVII South-west transept, Ely Cathedral, Cambridgeshire 118
Case Study XVIII The Church of St Mary de Castro, Castle Street, Leicester 126
Case Study XIX Burleigh Cottage, Loughborough University, Leicestershire 131
Case Study XX Leicester Road Cemetery, Loughborough, Leicestershire 141
Case Study XXI Field Cottage, 28/30 Main Street, Ratcliffe-on-the-Wreake, Leicestershire 147

APPENDIX B: MEASURED AND PHOTOGRAPHIC SURVEYS

I. Measured surveys 156
II. Photographic surveys 157

APPENDIX C: SPECIFICATION AND REFERENCES FOR EQUIPMENT

I. GABLE CAD System 159
II. Photographic System 166
III. Surveying System 174

APPENDIX D: PUBLISHED AND PRESENTED MATERIAL


APPENDIX A: CASE STUDIES

The following notes describe aspects of the case studies undertaken for this work, with comments based on a standard set of headings. The case studies are presented in a chronological order so that the reader might follow the development of the technique through the observations made and results achieved.

The range of building types recorded in these case studies includes polite and vernacular domestic, commercial, industrial, ecclesiastical and, what might loosely be termed, landscape structures. In addition, specific details, aspects of townscape and subjects of archaeological interest have been recorded.

Each study includes a graphic and photographic record of the subject within the text, and a larger-scale drawing inserted in the pocket at the back of this volume. These text illustrations have been reproduced at scales that provide the largest image for the page format used and, as such, are not necessarily to conventional architectural scales.

This flexibility of scale is achieved by storing the information in a digital form, and allows the drawings to be produced at a range of scales suitable for different aspects of the development process. In this respect, a number of the large study sheets have been arranged to demonstrate this flexibility of output. A scale bar has been included on these drawings unless a conventional plotting scale has been adopted.
Case Study I


DESCRIPTION: The door surround to the principal entrance of the Hawthorn Building, the subject of this case study, is composed of a series of regularly shaped and jointed blocks, having a detailed panel above, flanked by two projecting circular drums, each surmounted by an ornate urn. Beneath, a series of curved steps rise up from the footpath to the base of the surround.

The Hawthorn Building was the original College of Art and Technology, the north range, which includes this doorway, being in a stripped Classical idiom dating from 1937 (Pevsner, 1984, 225).

OBJECTIVES: This initial study was undertaken as a means of assessing the potential for using a 35mm photographic system for data capture, and manual digitisation as the chosen method for the input of selected data into a CAD system. It was chosen as the subject for this primary experimentation as it exhibited certain features that were considered to be important in the further development of the technique.

The regularity of the blocks to either side of the doorway provided an opportunity for testing the standard of digitising over a total of twenty-eight similar shapes, and checking the incidence of lens distortion. The detail of the central panel provided a challenge, in itself, and a case for repeating certain features, notably the supporting lions *rampant regardant*. The projection of the drums, carrying the urns in the round, and the flight of steps, represented, what were considered to be, elements beyond the capabilities of the technique at the time the study was undertaken.

PROBLEMS: As the base of the door surround lies some 1,280mm (4.2ft) above footpath level, it was impracticable to provide normal-case photography, centred on the subject, with the camera sited on the opposite side of the road. Additionally, at this time, all photography was being performed using a wide-angle zoom lens (SUPER-PARAGON PMC
28-50mm). As a result, whilst the camera was levelled and the film plane parallel to the subject, the angle of view caused an apparent vertical shift in the projecting elements, increasing the view of the undersides of the drums and urns.

METHOD: In order to minimise the acknowledged effects of lens distortion, especially when using a lens of limited optical quality, the camera was positioned to record the subject within approximately the middle fifty per cent of the viewfinder. The scale of the photograph, once printed, was approximately 1:42.

Additional photographic coverage was given to the detailed central panel to provide a larger-scale photograph from which to digitise fine detail.

A level staff was included within the composition to provide the necessary dimensional control, in addition to limited horizontal taping. Colour photography was used, later to be rejected in favour of black and white recording.

RESULTS: Considering first the accuracy of digitising, the variations in joint width achieved were individually measured and related to those established by direct measurement on site. Given that the actual joint width is 40mm (1.57in.), the mean, taken from twenty-six digitised cases, was 42.8mm (1.68in.), with a sample standard deviation of 11.4mm (0.44in.).

In considering the effects of lens distortion, it was apparent that there was limited visible distortion of the image in the central portion of the print. The horizontal and vertical lines of the building fabric adjacent to the door surround were, however, visibly affected.

The heraldic panel was successfully recorded using the larger-scale detail photograph. Identical features were repeated, and attention given to creating a simple representation of the subject without the use of hatching or tone.
The projected drums and, in particular, the urns, were recorded as flat planes, with some interpretation required to correct for the distorted view caused by the low camera position. A greater line weight was used at the edges of the drums to represent their projection, although, without the necessary rendering, or an accompanying plan, it is difficult to visualise their true three-dimensional form. The steps were similarly recorded as individual planes. In neither case, however, was any attempt made to adjust the scale of these elements to take into account their projection from the face of the door surround.

CONCLUSIONS: Primarily, the results from this first study offered encouragement for further experimentation, and brought about an awareness of the difficulties inherent in adopting a photographic central projection for recording subject-matter that includes projected or recessed elements, and elements which exhibit curvature.

The criteria, set out in Section 5.3, for the analysis of case-study material, cannot realistically be applied to this, or other early studies, as such early experimentation was necessarily undertaken in order to test certain theories, and establish a basis on which to develop. It can, however, be submitted that the standard of graphical information, both in terms of dimensional accuracy and content, is considered to be higher than that readily attainable within a similar period of time using direct measurement.

REFERENCES:
PLATE 1.
PRINCIPAL ENTRANCE
HAWTHORN BUILDING
HAWTHORN BUILDING, THE NEWARKE, LEICESTER
PLATE 2.
HERALDIC PANEL AND URNS
HAWTHORN BUILDING
Case Study II

SITE: SCRAPTOFT, Scraptoft Hall, Leicestershire.

DESCRIPTION: An early Georgian house of three storeys, five bays wide, with the top pediment curving up at the ends and in the middle (Pevsner, 1984, 369). The central doorway has a scrolled open pediment on brackets, with the second-floor window above arched; the other windows having keystones and large aprons. All windows have the original thick glazing bars.

OBJECTIVES: Following on from the initial application of 35mm photography and CAD restitution presented in Case Study I, the purpose of this study was to record the south façade of this building, with the potential for repeating elements, in particular the window apertures, and establishing procedures for photographic data capture and image restitution.

PROBLEMS: This façade is essentially composed of one plane, with only minimal articulation in the form of the doorcase and the pediment. As such, it presents a suitable subject for applying central-projection photography.

Given the height of the building, it was necessary to position the camera on a high tripod in order the avoid the convergence of vertical lines. The ground rises gently at this point on the site, allowing the photography to be accomplished with reasonable ease.

METHOD: Close-up photographs of the doorcase, part of the quoining and one of the ground-floor windows were taken, digitised and magnified to provide a 'library' of elements. The overall plane of the façade was then digitised, with markers placed at the corners of the door and windows, and itself magnified. The library elements were then added as sub-files, repeated as necessary, and snapped on to the pre-positioned markers. In this way, the façade was built up as a series of elements placed on to a blank elevation.
RESULTS: This façade provided an opportunity for examining the use of repeated features, at various levels of complexity, and how a single feature, notably the doorcase, could be recorded to a high degree of detail from a suitable photograph.

In order to achieve a saving in time with the recording of the smaller windows to the second-floor accommodation, the standard window file was distorted to maintain the proportion of the glazing.

The detail recorded on the doorcase is unfortunately partially lost when the elevation is reproduced at a small plotting scale, resulting in some 'blocking-in'. This suggests that a predetermined level of detail should be set, appropriate for the particular application, in order to avoid the production of 'overworked' drawings.

CONCLUSIONS: This study provides an example of recording apertures; and where repetition is present, savings may be achieved by creating a library of standard elements. The repetition of such elements should only be undertaken, however, after careful dimensional checks have been made to ensure that there is dimensional similarity. It is the presence of subtle differences that unconsciously contributes to our enjoyment of the architectural composition.

REFERENCES:
PLATE 3.
SOUTH FAÇADE
SCRAPTOFT HALL

-11-
SCRAPTOFT HALL, SCRAPTOFT, LEICESTERSHIRE

Figure 4
Case Study III

SITE: LEICESTER, Jewry Wall, St Nicholas Circle, Leicestershire.

DESCRIPTION: The Jewry Wall represents part of the remains of a Roman public bath, a 7,300mm (23.9ft) high section of typical Roman masonry with layers of local freestone bonded by Roman bricks (Pevsner, 1984, 207). This contains two arches that were once entrances into the bathing complex, the wall being the western wall of a palaestra (exercise hall).

OBJECTIVES: To record the individual surface stones and bricks that make up part of the east face of the wall in order to provide a base drawing for petrological analysis.

PROBLEMS: In digitising, difficulty was experienced in tracing the true profile of the masonry, as many of the stones and bricks had decayed. In places, the colour of the mortar was also similar to that of the adjacent stones, which presented a false image from which to digitise. The irregular surface profile led to some areas being obscured by shadow, and subsequently mistakes being made in reading cracks as joints. The friable nature of the masonry caused some difficulty in securing markers to the surface. Where facing stones had been removed, the exposed corework required careful interpretation in order to discern the profiles of remaining stones.

METHOD: Simple horizontal and vertical dimensional control was obtained by securing tape markers to the surface of the wall. The camera was levelled and positioned using an optical square to ensure that the film plane was parallel and at right angles to the surface.

Exposures were bracketed in response to the varying lighting conditions encountered, and to ensure that all the stones were recorded out of shadow. All the stones and bricks were then digitised from a print, at an approximate scale of 1:26, to show their correct profiles and joint widths, where possible.
At this time a perspective-control (or 'shift') lens (OLYMPUS ZEIKO 35mm) was purchased, specifically for the photographic recording undertaken for this project. It was subsequently used for all future studies, except where specified.

RESULTS: A line drawing was produced, checked and marked up on site by a geologist, and the image amended to show the petrology of the constituent stones, both as a hatched drawing and as a colour image. The obvious stratification of stone and brick provided evidence for the building lifts and possible salvage of material.

Once the record had been prepared, a Data Management routine was initiated within the CAD system, to identify the number and area of stone types, based on the individual hatch specifications. The results from this analysis are presented below. It is possible to calculate, from this, volumes based on an actual, or assumed, depth, as suggested by Foster (1989) (see Section 6.4).

<table>
<thead>
<tr>
<th>Material Specification</th>
<th>Numbers</th>
<th>Area (sq.m.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay tile</td>
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<td>1.95</td>
</tr>
<tr>
<td>Igneous from S-W Leics.</td>
<td>175</td>
<td>3.40</td>
</tr>
<tr>
<td>Mountsorrel granodiorite</td>
<td>76</td>
<td>1.66</td>
</tr>
<tr>
<td>Charnwood slates</td>
<td>83</td>
<td>1.93</td>
</tr>
<tr>
<td>Triassic sandstone</td>
<td>25</td>
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<tr>
<td>Liassic mudstone</td>
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<td>1.60</td>
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<tr>
<td>Millstone grit</td>
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<td>0.23</td>
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<td><strong>Total</strong></td>
<td><strong>599</strong></td>
<td><strong>11.12</strong></td>
</tr>
</tbody>
</table>

CONCLUSIONS: This technique provided an acceptable record of part of the Jewry Wall, allowing a petrological analysis to be graphically represented for archaeological evaluation. Where such small areas of masonry are to be studied, indirect photographic data capture negates the use of a string grid for detailed recording purposes. Once the data has been digitised, it is a simple matter to amend the image to
take into account requirements for presentation.

REFERENCES:


PLATE 4.
EAST FACE
JEWRY WALL
PLATE 5.
CENTRAL SECTION
JEWRY WALL
PLATE 6.

COLOUR COMPUTER IMAGE

JEWRY WALL

-20-
Case Study IV

SITE: BOLSOVER, The Church of St Mary and St Laurence, Derbyshire.

DESCRIPTION: The original church was thirteenth century in date, but fires in 1897 and 1960 left only the west tower and Cavendish Chapel of 1624 remaining from the earlier building. The present church dates from 1961-2, incorporating both tower and chapel in its layout (Pevsner, 1978, 92).

The area around Bolsover is heavily mined for coal, and subsidence has affected large numbers of buildings in the locality. Such a fault passes diagonally under the body of the church, and has compromised the structural integrity of the south aisle and west tower.

OBJECTIVES: To record the south and west walls of the south aisle, both internally and externally, in order to provide a detailed drawing of individual stones and fenestration, together with deformation patterns associated with the subsidence.

PROBLEMS: The internal surfaces of the aisle walls were heavily encrusted with a skin of salts that had been allowed to build up as a result of moisture migration within the fabric of the wall. This effectively obscured the masonry joints, making the recording of individual stones impracticable.

Although internal photography was undertaken at a time when direct sunlight penetration was avoided, this light was, however, brighter than the internal conditions, and loss of detail was experienced on the photographic prints around the windows. In order to have successfully recorded such detail, the photographs should have been taken at night or in low-light conditions using artificial illumination, or with neutral-density filters placed externally over the windows in order to reduce the amount of penetrating light.

METHOD: The aisle is of three bays in length, divided externally by two-stage projecting buttresses. Each length of intervening wall,
incorporating windows of geometrical tracery and the faces of the buttresses, was photographed and digitised separately, magnified and brought together to produce a composite elevational drawing.

The churchyard to the south of the aisle is raised up by 500mm (1.6ft) above the base of the wall, forming a 2,800mm (9.2ft) wide path at the lower level. This facilitated the inclusion of the whole height of the aisle wall in the photographs. Distress in the fabric, due to the effects of subsidence, had caused cracks to appear at points of maximum rotation, and window jambs and mullions to distort. Internally, only the window openings and random stones were plotted, sufficient to show the width and direction of the cracks.

Dimensional control was obtained using a total-station theodolite, providing a framework within which the digitised elevation was fitted. Survey targets were fixed to the surface of the walls, both internally and externally, sufficient to provide reliable control points that would be visible on the photographs, despite the projection of the buttresses. A pattern of three or four targets for each bay was considered to provide the most accurate control.

Each target was recorded as horizontal and vertical angle measurements taken from two survey stations, and their positions derived graphically by intersection. Closed series levelling was also undertaken to establish a constant datum, internally and externally, from which heighting information and ground levels could be established.

RESULTS: The completed drawing provided a record of the individual stones comprising the external south and west walls of the south aisle, together with an outline record of the internal walls. By comparing the cracks and deformation patterns on both of these drawings, it is possible to determine the severity of the distress and estimate the extent of stonework repairs needed.

CONCLUSIONS: The use of a total-station theodolite to establish dimensional control proved wholly suitable for this task, allowing each digitised bay to be magnified and aligned accurately and quickly.
Levelling of the internal aisle floor and external ground level allowed an accurate graphical relationship between the two to be made, demonstrating that the external ground level had been raised up by some 500mm (1.6ft) above the finished floor level.

Photography of the internal faces, which included the windows, would have been better undertaken at a time of low-light conditions with artificial illumination, or using long exposures in conjunction with window filters.

In recording the windows, each traceried light and stone section was digitised on a point-by-point basis, this resulting in a somewhat irregular line for these elements. In later studies, specifically Case Studies XVI and XVIII, tracery has been recorded using arcs, as described in Section 5.2.3, which allows each light to be recorded to a greater accuracy, with a smoother curve.

The accuracy achieved in this study is considered to be greater than that attainable by hand measurement over a similar period of time. In order to provide a similar level of detail, extensive direct measurement would, no doubt, have been required, this being particularly time-consuming when recording the traceried windows.

Given this evidence, the use of computer-aided mono-photogrammetry has provided an acceptable record, appropriate for its intended use, on a basis which resulted in a saving of time and, hence, cost.

REFERENCES:

PLATE 7.
SOUTH AISLE (SOUTH FACE)
BOLSOVER
PLATE 8.
SOUTH AISLE (WEST FACE)
BOLSOVER

-25-
PLATE 9.
SOUTH AISLE (INTERIOR)
BOLSOVER
EXTERNAL DIMENSIONAL CONTROL,
CHURCH OF ST MARY AND ST LAURENCE, BOLSOVER, DERBYSHIRE
CHURCH OF ST MARY AND ST LAURENCE, BOLSOVER, DERBYSHIRE
CHURCH OF ST MARY AND ST LAURENCE, BOLSOVER, DERBYSHIRE

Figure 8
Case Study V

SITE: MANSFIELD, King's Mill Viaduct, Nottinghamshire.

DESCRIPTION: This pre-locotive, five-arch, viaduct, dated 1817, represents an important part of the county's industrial heritage and, as such, has the status of both a listed building and a scheduled ancient monument (County Monument 152). At the time that this study was undertaken, the structure was suffering from localised stone decay and tree-root jacking, partly the result of a lack of maintenance over previous years.

OBJECTIVES: This survey was commissioned to provide a record of both upstream and downstream faces of the structure in their entirety, illustrating all stones, pattress plates and areas of distress. This was to be used to communicate the nature and scope of necessary repair and consolidation work, and to stand as a record of what changes were to be made, as required by the Department of the Environment, as advised by the Ancient Monuments Inspectorate of the Historic Buildings and Monuments Commission for England, when granting Scheduled Monument Consent.

The author was subsequently responsible for supervising this work as part of his involvement with the architectural practice concerned. Further information on the scope of this project has been given by Watt (1989), a copy of which is included in Appendix D.

PROBLEMS: The west, or upstream, face is ideally placed for normal-case photography, with the ground sloping upwards away from the structure, where the water is diverted down a fall from the present reservoir. The east face is, however, set at an angle to the river banks, and so required the use of a telephoto lens (VIVITAR 70-150mm) from further downstream, and interpretation from oblique photographs.

The program for analytical rectification of oblique data, AERIAL, was not available to the author at the time that this work was commissioned. It would have been possible, had it been so, to record
parts of the structure from oblique photographs, instead of relying on photographs taken at a distance.

**METHOD:** Horizontal dimensional control was obtained by taping between the pilasters, with an overall check to the total length of the structure given by optical means. Limited vertical measurements were taken from the parapet down to ground level, with reliance being placed chiefly on the levels taken as part of a related topographic survey.

Each bay was digitised separately, and then brought together to create an entire elevational record for each face. Revisions, in the form of additional information supplied by direct measurement of obstructed areas of stonework, was added to a base drawing by the architects on site, and transferred to the CAD file in order to provide a complete record for subsequent reproduction.

**RESULTS:** A number of stones were found, on initial inspection, to have been wrongly drawn, due to incorrect interpretation of cracks and surface discolouration. These were corrected prior to the release of the drawings for use.

A good standard of dimensional accuracy was achieved, as determined by direct comparison once the structure had been scaffolded for the contracted works. A random sample of fifty direct measurements were taken, giving an absolute mean of 17.9mm (0.70in.) and a sample standard deviation of 17.5mm (0.68in.). Thus, 68% of this sample was within a range of 0.4mm (0.015in.) to 35.5mm (1.4in.).

**CONCLUSIONS:** The described technique provided an acceptable record of the elevational fabric, suitable for use as part of the contract documentation and as an archive record appropriate to the status of the structure as a scheduled ancient monument. The addition of a complete photographic record, supplemented only by later coverage of the soffits of the arches, proved to be invaluable in proposing methods of stone repair, and as a record of the viaduct prior to work being undertaken for the county Sites and Monuments Record.
Initially, rectified photography was considered for this project, as the faces of the structure are essentially planar and so appropriate for the technique. The individual scaled photographs could have then been arranged as a montage and printed on to tracing paper or film to provide a base drawing for further use. In this respect, it would have offered a satisfactory means of recording, given the nature of the work.

Having, instead, used computer-aided mono-photogrammetry as a means of recording the structure, the final record has provided satisfactory results, appropriate to their intended use. The stonemason who, later, undertook the work, found the clarity of the drawings, and the use of different plotting scales for communicating various aspects of the work, helpful and to be recommended.

The author is indebted to the members of the Historic Buildings Team of Derek Latham and Company for allowing King's Mill Viaduct to be used as a subject for experimentation, whilst developing the techniques of computer-aided mono-photogrammetry.

REFERENCES:
PLATE 10.
EAST FACE
KING'S MILL VIADUCT

-33-
PLATE 11.
ARCH 5, EAST FACE
KING’S MILL VIADUCT
KING'S MILL VIADUCT, MANSFIELD, NOTTINGHAMSHIRE

Figure 9

-35-
Case Study VI

SITE: LACOCK, Lacock Abbey, Wiltshire.

DESCRIPTION: This nationally-important medieval monastic building, adapted to a Tudor mansion in c.1540 with the addition of an octagonal tower and twisted chimneys, and altered in the Neo-Gothic style in 1753, and later in 1828, was, at the time that this study was undertaken, being recorded and analysed by the Royal Commission on the Historical Monuments of England. The National Trust was similarly involved with recording the buildings of Lacock village.

OBJECTIVES: The intention of this study was to demonstrate the potential offered by computer-aided mono-photogrammetry for recording the visible evidence of previous building lines and openings in the south façade.

PROBLEMS: The façade in question is composed of four main planes, with obvious projections in the form of buttresses, oriel windows and the south-east tower. Given the nature of the dimensional control taken, it was not possible to accurately record these elements, although an attempt was made to illustrate a level of obvious detail by recording the position of their intersections with the main walls, and interpreting detail from the photographs. Certain areas of masonry were obscured by foliage, these requiring additional manual inspection to present a complete record.

The use of the perspective-control lens avoided the convergence of vertical lines, due to the low camera station adopted in relation to the height of the façade. It would, however, have been better to adopt a higher camera position, using a hoist or scaffold tower, rather than to rely on the maximum shift offered by the lens. It was only after this study had been performed that distortion tests revealed the increased distortion associated with such usage.

METHOD: Each of the four main planes were photographed separately to provide suitably-sized images from which to digitise detail, and to
avoid the obstruction of fabric by the projection of the buttresses or oriels. The approximate scale of each print was 1:80. It would have been advantageous to take close-up photographs of specific details, to provide a source for later interpretation.

The magnification of the digitised images was based on horizontal dimensional control only, as no facilities were available at the time for providing vertical measurements. Where the subject has been positioned centrally on the print to avoid excessive image distortion, the use of horizontal control only for restitution has proved acceptable, although vertical control should be taken, wherever possible, to provide for instances where differential magnification is required.

RESULTS: The results from this study gave a satisfactory visual representation of the 'fossilised' history for this façade, suitable for inclusion as part of an analytical study. The use of computer-aided mono-photogrammetry for this type of work has the advantage of providing a graphical record that can be produced by the surveyor or historian involved, as a basis on which to add further information as it becomes available.

CONCLUSIONS: In order to emphasise the line of the projecting oriels, and any other such detail, on the photographs, the use of coloured string secured to the surface of the wall to follow the line of the mouldings would have been useful, assisting also in digitising a smooth curve, especially if the stone was decayed or in shadow.

The use of colour photography for data capture provided no additional benefits over black and white coverage.

As an historical note, the main oriel window shown on the elevation was the subject for the first photographic negative, taken by Fox Talbot in 1835: 'Lattice Window (with the Camera Obscura) August 1835. When first made, the squares of glass about two hundred in number could be counted, with help of a lens' (Anderson and Doyle, 1985, 642).
REFERENCES:

PLATE 12.
WEST AND SOUTH FAÇADES
LACOCK ABBEY
PLATE 13.
SOUTH FAÇADE
LACOCK ABBEY
Case Study VII

SITE: The Church of St John the Baptist, Ault Hucknall, Derbyshire and Tickhill Castle, Tickhill, South Yorkshire.

DESCRIPTION: Ault Hucknall possessed what Pevsner (1978, 70) describes as a typical Derbyshire church - low and all embattled - although with an unusual crossing tower. The building is eleventh century in date, although parts appear pre-Conquest in origin. At the west end of the church is a highly barbaric tympanum showing a centaur (which may be St Margaret emerging from the body of the Devil) on the left, and the lamb and cross on the right. In the lintol there appears a man (possibly St George) fighting a dragon.

Motte and bailey earthworks and wooden defences were constructed at Tickhill by Roger de Buisli for William the Conqueror between 1066 and 1100. In 1129/30 Henry I strengthened the defences of the castle, including the erection of the remaining gatehouse, and in 1179/80 Henry II's programme of castle building included the construction of a stone keep. Following the Civil War, the keep was pulled down to the plinth course and the stone used by the Hansby family in the building of the present, though much altered, house.

During the landscaping of the surrounding land at Tickhill in the nineteenth century, the doorway, which is the subject of this study, was used to provide access through the north bailey wall from the promenade to the walkway around the castle. Above it is the Hansby's coat of arms, including the three sheldrakes with ermine represented by five triangular shapes. Although Hippsley-Cox (1985, 21) states that 'the stone jambs and lintols from the house' can be seen inserted into the wall, Bostwick (1990) considers that the doorway was used as a garden gate through the boundary between the formal gardens and the wilderness, a concept that was popular in the early part of the seventeenth century.

OBJECTIVES: These two studies were undertaken to demonstrate the potential of computer-aided mono-photogrammetry for recording specific
details of architectural or historical interest to a high standard of detail and dimensional accuracy.

The tympanum at Ault Hucknall represents an important example of eleventh-century carving that is typical of a number in the region. The condition of the carving is poor, and this presented an opportunity for recording what remains discernible.

The doorway through the bailey wall at Tickhill, with its heraldic panel over, has recently been repaired, and new jamb stones inserted. This study provided an opportunity for recording this intervention, and comparing the profiles of both existing and new stones.

PROBLEMS: Neither subject presented problems for data capture or image restitution, although care had to be given in digitising the carvings to avoid any subjective interpretation due to the current state of decay.

METHOD: Each of the subjects were recorded using normal-case photography, with taped dimensions taken for the magnification of the digitised images. Each of the stones were recorded as shapes, with mouldings constructed as chains.

In order to record the irregular profiles of the stones, the system set-square was placed at zero, and a small tolerance used to facilitate digitisation of uneven lines. The carvings were recorded in a similar manner using chains, the individual points of which were placed at close intervals.

RESULTS: Both studies resulted in accurate line drawings of their subjects, which illustrated the potential of computer-aided mono-photogrammetry for this type of recording work. The drawings could also be used as a basis on which to communicate repairs and other works where attention needs to be given to individual stones.

CONCLUSIONS: Whilst it is possible to record small areas of masonry to this high level of accuracy and detail, it would be inappropriate to
consider the use of computer-aided mono-photogrammetry for large areas
of stonework. In both instances, normal-case photography would have
provided a similar record, which could have been printed to scale.
These studies demonstrate, however, the potential offered by the
technique for small-scale detailed recording requiring specific
standards of accuracy and content.

REFERENCES:
BOSTWICK, D. (1990). Discussion on the origins of the
doorway at Tickhill Castle. 27 February 1990.


PLATE 14.
WEST FACE OF NAVE AND AISLES
AULT HUCKNALL
PLATE 15.
BLOCKED DOORWAY AND TYMPANUM
AULT HUCKNALL

-46-
CHURCH OF ST JOHN THE BAPTIST, AULT HUCKNALL, DERBYSHIRE
PLATE 16.
DOORWAY IN NORTH BAILEY WALL
TICKHILL CASTLE
TICKHILL CASTLE,
TICKHILL, SOUTH YORKSHIRE

Figure 12
Case Study VIII

SITE: BAKEWELL, Bagshaw Hall, Derbyshire.

DESCRIPTION: A late seventeenth-century building with a central block of two storeys plus an attic, having a balustraded parapet and a central entrance with a segmental pediment (Craven and Stanley, 1982, 16). The traditionally-gabled wings are of three storeys with mullioned fenestration having top banding.

OBJECTIVES: This study set out to record the principal (north) façade of the building, comprising the central block and two projecting gabled wings, including their returns, with each stone clearly identified to provide a base drawing in connection with a grant application made to the Historic Buildings and Monuments Commission for England for replacement stone and other works (Oulsnam, 1989).

PROBLEMS: The garden area to the north of the building is restricted to 12,000mm (39.3ft), which prevented the camera from being sited at a sufficient distance from the face to undertake normal-case photography for all storeys, even with the lens shifted to its full extent. This necessitated the use of vertically-angled photography to record high-level fabric, and subsequent interpretation from a number of photographs to position certain stones.

METHOD: Horizontal and vertical control dimensions were taken on both gables and on the central block, together with a standard window to allow for this detailed element to be repeated. Vertical dimensions were taken upwards from the plinth line, with the sloping ground level related back to this datum beneath. Each storey was digitised separately using the banding as definite breaks, and brought together once completed.

The individual stones of the elevations were constructed using shapes, which gave the potential for calculating the number and surface area of stones. Given the small scale of the photographs, generally in the order of 1:35 to 1:45, a number of the resulting shapes overlapped each
other, and joint widths were not uniform. It would have been better to use *chains* for this aspect of the project, allowing joints to be correctly aligned, and editing to be minimised.

Obstruction of areas of the ground storey by vegetation, and the part-basement, required subsequent manual taping.

**RESULTS:** The completed drawing provided a graphical record of the individual stones comprising the north façade, adequate for the purpose of indicating certain stones or areas of masonry requiring attention following a visual inspection.

A period of two-and-a-half hours was spent on site taking photographs and control dimensions, which included a period for additional manual measurement for obstructed areas. A total of ninety-five hours, or twelve eight-hour days, was then spent in restituting the data and printing the results to a scale of 1:50, although this could have been reduced by constructing the elevation of *chains*, instead of *shapes*, which required a period for editing. The site operations therefore represented 2.6% of the total project time.

**CONCLUSIONS:** The process of editing proved to be time-consuming and could have been avoided by providing larger-scale photographs from which to digitise. This would have necessitated some form of visible vertical break, such as gained through the use of a series of plumbed lines, with which to align the completed digitised 'bays', rather than relying on horizontal features present on the façade.

It is preferable to use definite features to break a façade into suitable bays, rather than invent idealised ones that pass through individual stones and cause difficulties in matching adjacent bays when composing the whole elevation.

It was found prudent to take oblique, as well as square-on, photographs of wall faces and details, in order to provide an alternative source for manually constructing areas that were obstructed or in shadow. The presence of an obstruction in the garden prevented suitable photographs
being taken of the top storey of the west gabled wing, necessitating interpretation from horizontal and vertical oblique photographs.

This particular aspect of the study prompted investigations into the analytical rectification of oblique photographic data, and led subsequently to the purchase of the Bradford Aerial Photograph Rectification System (BAPS), AERIAL.

This study provides evidence for the effective use of computer-aided mono-photogrammetry in producing record drawings, on a stone-by-stone basis, for use in connection with programmed repairs to an historic building. The results provide a dimensional accuracy that is appropriate for the task, and at a level of detail which is considered in excess of that achievable using manual techniques over a similar period of time.

REFERENCES:


PLATE 17.
NORTH FAÇADE
BAGSHAW HALL

-53-
PLATE 18.
NORTH FAÇADE
BAGSHAW HALL
Figure 13
Case Study IX

SITE: LEICESTER, Kirby and West Building, Western Boulevard, Leicestershire.

DESCRIPTION: The single-plane façade of this former creamery, fronting on to Western Boulevard, is made up of faience blocks of five different colours, each colour being used to define a particular detail or feature.

OBJECTIVES: This study was undertaken to illustrate the potential for recording the façade of a building, using computer-aided mono-photogrammetry, with which it might be possible to identify and quantify defects, and to communicate possible works of repair.

PROBLEMS: In order to photograph the façade to a suitable scale for digitising, it was necessary to produce fragmentary coverage, including separate photographs for the higher fabric. This would have presented problems in image restitution, were it not for the similar windows and surrounds that unite the various images.

METHOD: Each faience block was constructed as an individual shape, similar to the procedure established in Case Study III, in order to make use of the Data Management routine for calculating the number and surface area of the coloured blocks. This resulted in a similar problem to that encountered in Case Study VIII, namely the need for post-digitising editing in order to remove overlapping shapes.

Horizontal, and limited vertical, dimensional control was taken using running taped measurements, with additional dimensions for the standard window details.

RESULTS: The completed drawing provides a graphical record of the façade, on which individual blocks might be identified for subsequent works. In this respect, rectified photography would have been possible, although the necessary fragmented coverage would have required the construction of a photographic montage.
The Data Management survey, based on the façade recorded, gave the following information relating to the number and surface area of the faience blocks:

<table>
<thead>
<tr>
<th>Material Specification</th>
<th>Numbers</th>
<th>Area (sq.m.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>855</td>
<td>84.76</td>
</tr>
<tr>
<td>Blue</td>
<td>464</td>
<td>47.78</td>
</tr>
<tr>
<td>Dark grey</td>
<td>177</td>
<td>26.54</td>
</tr>
<tr>
<td>Dark green</td>
<td>117</td>
<td>14.52</td>
</tr>
<tr>
<td>Light green</td>
<td>85</td>
<td>11.90</td>
</tr>
<tr>
<td>Hatched openings</td>
<td>18</td>
<td>76.65</td>
</tr>
<tr>
<td>Total (excl. openings)</td>
<td>1,698</td>
<td>186.50</td>
</tr>
</tbody>
</table>

CONCLUSIONS: Where coding of individual stones or, in this instance, blocks, is required in order to communicate the nature and extent of planned interventions, it is possible to add suitable text, either as individual numbers, or a letter and number system of referencing, and relate this to the Data Management survey. This could be utilised when preparing specifications, especially if the system of Co-ordinated Project Information (CPI) is being followed.

In this particular study, where the colour of the various elements was of importance, colour photography would have been more appropriate than black and white coverage. In order to ensure that each shape was specified with the correct colour, the photographs were photocopied to provide a set of booking-sheets on which to mark the various colours at a later stage.
PLATE 19.
PRINCIPAL FAÇADE
KIRBY AND WEST BUILDING
PLATE 20.

PRINCIPAL FAÇADE

KIRBY AND WEST BUILDING
PLATE 21.
COLOUR COMPUTER IMAGE
KIRBY AND WEST BUILDING
Case Study X


DESCRIPTION: This octagonal gazebo, considered to have been designed by Anthony Salvin (1799-1881) in c.1845, stands in the grounds of Kelham Hall, itself designed by Sir George Gilbert Scott (1811-78) in 1858-61. Pevsner (1979, 153), however, notes that the arcaded summer house, looking like the work of Salvin, apparently incorporates some of Scott's spare marble columns.

OBJECTIVES: The author was initially commissioned to produce a dimensional record of this structure, suitable for indicating the nature and extent of proposed repairs. In so doing, it offered an opportunity for demonstrating the flexibility of computer-based draughting, and the potential for presentation graphics.

PROBLEMS: The domed roof, covered in cast-lead slates (Thornton, 1988, 123), presented the most obvious problem, in that computer-aided mono-photogrammetry is not capable of providing a dimensionally-accurate record of such a three-dimensional element. As a result of this, it was necessary to represent the roof as a series of arcs, defining the ribs and illustrating its overall geometry.

Additionally, the two columns to the front face of the structure exhibit an entasis, or swelling curve on the shaft, necessitating a careful choice of CAD element to record such a subtle profile.

METHOD: A pattern of horizontal and vertical control dimensions was taken, appropriate for the level of detail to be recorded, and to ensure that each element could be satisfactorily restituted. Each face was found by direct measurement to be sufficiently alike to allow for repetition, given the proposed use of the drawing.

The eight faces were photographed, with detailed coverage of particular features, such as the attic-storey strapwork, mouldings and side openings. Once one face had been digitised, including its decorative
features, it was repeated to provide a record of the other seven faces, and alterations made as necessary.

The columns were digitised using open-splines, with the tension set to represent their gentle-curving profile.

RESULTS: After the eight faces had been recorded in sufficient detail, including brick courses, to provide a useful record for the intended use, opportunity was taken to arrange them around a simple plan, creating a drawing suitable for presentation purposes. The adjacent fabric to each of the subject faces was represented in outline only.

CONCLUSIONS: The resulting drawings of each face of the structure were suitable in both detail and accuracy for indicating repairs and replacement of missing features, such as the finials. It would be possible to compose a sheet to any desired scale, suitable for the nature of proposed works.

The presentation drawing provided a demonstration of how the digitised files may be manipulated to create a drawing of visual interest, whilst maintaining the level of dimensional accuracy.

Where there is such a high level of repetition, as found with this structure, there are obvious advantages to be gained from employing digital means for recording, this providing a reduction in time and, hence, cost. Computer-aided mono-photogrammetry provided a suitable technique for recording the faces of this structure, although there can be no reliance placed on the dimensional accuracy of the domed roof, as recorded.

The completed record of this structure was entered for the Construction Industry Computing Association (CICA) CAD Drawing Competition (1989), and was selected for use in the CICA calendar for 1990. A similar drawing was submitted for the Folly Fellowship/Lawson-Price Measured Drawing Competition in March 1990.
REFERENCES:


PLATE 22.
GAZEBO
KELHAM HALL

-65-
THE GAZEBO, KELHAM HALL, KELHAM, NOTTINGHAMSHIRE

Figure 15
Case Study XI

SITE: NEWBOLD, Eyre Chapel, Chesterfield, Derbyshire.

DESCRIPTION: This small stone-built chapel, 13,480 x 6,650mm (44.2 x 21.8ft) in size, originally passed from secular to ecclesiastical use in the early fourteenth century, becoming the property of the Roman Catholic Eyre family. It was sacked by Protestants in 1688 (Pevsner, 1978, 148), and was used as a cowshed until restoration by the Eyres in 1887, and again by the Chesterfield and District Civic Society in 1987.

OBJECTIVES: This study was undertaken in order to validate the program for analytical rectification, AERIAL, on increasingly oblique photographs, and to consider the use of colour filters for enhancing the photographic image prior to digitising. The building was chosen as it was of a convenient size for single-handed direct measurement, offered scope for undisturbed fieldwork, and possessed a wide range of surface colours.

PROBLEMS: There were no specific problems encountered in recording this building, its use as a case study being to provide a model for testing aspects concerned with data capture and image restitution.

METHOD: The north-west gable façade was chosen as the subject for analytical rectification, as it presented a single plane with limited height and geometrically-regular features, such as the rectangular window opening and triangular gable, lying above a horizontal band. Exposures were taken at 15° increments from a position square-on to the face, with an additional view looking up at an approximate angle of 45° from in front of the subject.

Horizontal and vertical control dimensions were taken to allow selected points to be assigned notional grid references with which AERIAL controls the transformation of digitised points in the process of analytical rectification.
Each of the photographs was subsequently digitised and rectified by AERIAL, to produce line plots showing the relative positions of certain features from which to evaluate the success, or otherwise, of this particular aspect of image restitution.

In addition to the above, the south-west façade was chosen as the subject for tests involving the use of colour filters, for enhancing the photographic image and so assisting in the process of digitisation. This particular face was selected as it offered a variety of stone colours from which to judge the relative merits of each case. Red, yellow and green filters were employed, with an unfiltered exposure acting as a reference for visual evaluation.

RESULTS: The line plots produced by AERIAL demonstrated a marked reduction in point accuracy as the angle of incidence for photographic recording was increased.

There was little discrepancy at the reference points for cases between 15° and 45°. After this, the points were subject to increased displacement, with total distortion of the features occurring at the acute angle of 75°. The plot for the vertically-angled image was comparable with that for the similarly-angled horizontal view.

The results from the test involving the use of colour filters confirmed the general rule that a particular filter will lighten the black and white reproduction of objects its own colour, and darken complementary colours. Thus, the red filter darkened the sky and grass in the foreground, the yellow lightened some of the stones, and the green generally darkened the stones of a naturally darker hue.

Overall it would seem that if a feature displaying a particular colour requires enhancement, then colour filters may be beneficially used. For the work of this project, however, when generally the whole façade is being recorded, their use remains limited.

CONCLUSIONS: This study provided evidence for the successful rectification of an oblique photographic image, leading to the use of
the AERIAL program in Case Study XIV. The reduction in accuracy experienced with the greater angle of view was to be expected, and a realistic maximum of $45^\circ$ accorded with the findings of Dr. J. Williams, who has used AERIAL during his work at Brougham Castle (Cumbria) (Williams, 1989).

The results gained from the use of colour filters were disappointing, and presented no quantifiable benefits. The filters used were those based on the COKIN system of glass filter held in a screw-mounted holder. Some distortion of the image may be introduced by such an element, and Brooke (1988) has suggested that gelatin filters may be more appropriate.

The use of polarizing filters, although not tested in this work, may be of benefit. In colour photography the saturation of coloured objects with reflective surfaces would be improved, and in black and white photography polarizing light, being light reflected at an acute angle from a reflective surface, would be blocked.

The lenses used in this project were all protected by neutral-density filters, these having no effect on the recorded image. They are useful, as Hedgecoe (1977, 336) points out, where a long exposure is required to obliterate people from the scene, this often being the case when recording in an urban context.

REFERENCES:


PLATE 24.
NORTH-WEST GABLE
EYRE CHAPEL

-72-
EYRE CHAPEL, NEWBOLD, CHESTERFIELD, DERBYSHIRE

Figure 17
PLATE 25.
NORTH-WEST GABLE AT 45°
EYRE CHAPEL

-74-
PLATE 26.
UNFILTERED EXPOSURE
EYRE CHAPEL

-75-
PLATE 27.
RED FILTER
EYRE CHAPEL
PLATE 28.
YELLOW FILTER
EYRE CHAPEL

-77-
Case Study XII

SITE: SUDBURY, Flacketts, Flacketts Lane, Derbyshire.

DESCRIPTION: Flacketts is a three-bay timber-framed structure that lies approximately one mile from the village of Sudbury. Shaw (1988) considers that the front (west) façade, with the earliest fabric lying at the north gable end, is possibly fifteenth century in origin. Incised assembly marks on the timbers suggest that the house originally extended south by two bays, although the studs beneath the midrails have been removed and the wall built up in brick in the late nineteenth century.

The second phase of building, dating from the late sixteenth, or early seventeenth, century, is represented by the central box-framed bay with small straight braces, its erection necessitating the destruction of the earlier south bay. The third phase saw the addition of a bay to the south in the early to mid seventeenth century, including a new brick stack which replaced the smoke hood. The roof appears to be of one date, possibly from the third phase.

OBJECTIVES: This particular study was undertaken to provide a comparison, both in terms of procedure and product, with conventional manual measurement and drawing, as undertaken by an archaeologist producing a series of drawings as part of an interpretative study.

It additionally provided an opportunity to record the finely-detailed bargeboards, the irregular profiles of the studs and the deformation of the framing, the latter associated with localised settlement beneath the dormer window. These items could not have been recorded to a similar level of detail, except by extensive manual measurement or resorting to photographic-based methods.

PROBLEMS: No specific problems were encountered with this study, although additional measurements were taken at the gable end to fix the height of the ridge, and allow representation of the chimney stack at its true scale. With a simple photographic record, the image of the
stack and ridge would be displaced, and reproduced at a different scale, due to the changes in depth associated with the adoption of a central projection.

METHOD: This single-plane façade, 14,950mm (49.0ft) in length and with an approximate eaves height of 3,320mm (10.9ft), was recorded in two parts, the photographs overlapping to give coverage of both dormer cheeks. Taped running dimensions picked up the position of specific studs in order to provide a check on overall horizontal magnification. Vertical measurements were taken from ground level to the eaves, apex of the dormer windows, and also to the ridge, taken at the gable end.

Both photographs were digitised, and the resulting images magnified and brought together using one of the full-height studs as a natural break. Brick coursing was checked for continuity of line across this break, and a continuous ground line formed.

The dormer window was digitised from one photography, with particular attention being given to the pierced bargeboards. By forming the curves with arcs added as start, finish and intermediate points, it was possible to maintain the gently-flowing lines. Once one half had been completed, it was patched, repeated, handed and the two halves brought together and edited to produce a symmetrical construction.

The undulating ridge line was directly digitised, patched and magnified to the correct length, thereby maintaining its true line. It was then raised up to its correct height, as established by direct measurement, giving an appropriate representation.

The brick stack was similarly digitised, patched and magnified according to its true dimensions, established by a combination of direct vertical measurements and counting of brick courses, referred to a previously measured standard brick panel.

RESULTS: In terms of providing a comparison with direct measurement and recording, the photographs and control measurements took a total of thirty minutes, with nine hours spent restituting the information and
producing a scaled line drawing. Manual sketching, measuring and recording took two persons a total of one and a half hours on site, with a further five hours spent by one to produce a scaled pencil drawing. This represents an 19\% increase in time when comparing computer-aided mono-photogrammetry with hand survey, although a higher standard of dimensional accuracy and detail, especially of the stud profiles and deformation patterns, was achieved.

CONCLUSIONS: This study demonstrates that even for small, apparently simple façades, there are benefits to be gained in using computer-aided mono-photogrammetry, in terms of accuracy and content. Although the time taken to produce a record drawing was greater when using computer-aided mono-photogrammetry, the work was undertaken single-handed with a reduced period of time spent on site.

Whether it is appropriate to use this technique for a particular project depends, however, on the purpose for which the record is required. Square-on and oblique photography would have presented a suitable visual record for interpretative study, with rectified photography possible giving a scaled record.

In this particular case, the drawing was also required to act as the basis for a working drawing associated with timber repairs and the considered insertion of additional windows. For this reason, a graphical record was considered to be more appropriate and suitable for the level of detail required. It should be noted that the process of hand survey allowed the archaeologist the opportunity of inspecting each timber and noting incised assembly marks and redundant peg holes. This would have required an additional inspection had an indirect technique been chosen.

REFERENCES:
PLATE 30.
WEST FACADE
FLACKETTS
Case Study XIII

SITE: AYLSHAM, The Market Place, Norfolk.

DESCRIPTION: The Market Place, having a Charter dated 1519, and with references to markets held here as far back as 1296, is now owned by the National Trust. It has changed little in its appearance over the last century and a half, the whole forming a 'very harmonious collection of Georgian buildings including some good eighteenth-century façades' (Sapwell, 1960, 61).

The shop-front to Number 14, the chemists, is, in particular, a charming piece of early Victorian Neoclassical design, which Pevsner (1962, 78) refers to as a 'delightful front with fluted columns'. The Black Boys Inn, on the south-west corner, is historically Aylsham's leading inn, and is of the Queen Anne period or a little later.

OBJECTIVES: The importance of recording aspects of townscape and urban fabric is rapidly increasing as the infrastructure of settlements is being changed to meet the demands of modern lifestyles and businesses. Historic streets and their frontages are presently being recorded by groups and individuals, such as the Architectural Heritage of Britain, with a view to preserving a visual record of architectural styles and social conditions. Such records are also of significance when assessing any form of alteration or development by way of visual impact analyses.

This study was therefore undertaken to determine the relative merits of computer-aided mono-photogrammetry as a method for recording in such instances. The west side of the market place was chosen as it presented a range of building frontages in terms of varied fenestration patterns, doorcases and surface details.

PROBLEMS: The three northerly buildings are situated opposite a group of later shops and offices, whilst the rest face across the open market space. These required a fragmented photographic coverage in order to construct their elevations.
Additionally, it was necessary to consider how to represent the ridge lines, whether at the lower level depicted in the photographs, or at their true levels, to be established by direct measurement or other means. The representation of the dormer windows and chimney stacks, set back from the main planes of the façades, required similar consideration.

METHOD: The façades of the first five buildings, from south to north, were recorded using one exposure for each, with additional close-up coverage of the shop-front belonging to the fifth, Number 14. The sixth building was recorded using four exposures; the seventh with three, including one oblique; and the eighth with three also.

Dimensional control was provided by one horizontal measurement across each façade, using pilasters and other obvious features as points of reference. Vertical control consisted of one vertical measurement, taken from footpath level up to the eaves, for each façade. These vertical control dimensions were spaced along the frontages in order to record the sloping ground level, measured down from the aligned eaves courses.

Once each façade had been digitised and magnified, they were all brought together to form a continuous record of the shop frontages, with sufficient detail to be reproduced at a scale of 1:100, or individually at 1:50.

With regard to the roof ridges, dormer windows and chimney stacks, it was decided to represent them in their true positions and to a correct scale. It was not possible to directly measure the height of any of the ridges, as was done in Case Study XII.

The number of bricks forming the shaped gable to the Black Boys Inn were counted, so allowing its ridge line to be positioned. It is worth noting that a number of oblique views were taken of the buildings in question, and these provided a useful source for such interpretation.
As each photograph provided a partial overlap with those buildings to left and right, it was thus possible to continue the ridge line from building to building, with only one obvious break, at the junction of Numbers 14 and 15.

The chimney stacks were directly digitised from the photographs, and then patched and magnified by factors derived from the counting of brick courses. The dormer windows were constructed in a similar manner, the magnification factors being calculated by relating the number of adjacent pantiles to the bricks of the stacks or gable wall.

RESULTS: The completed drawing provides a graphical record of the buildings fronting on to the Market Place and, as such, offers a useful tool with which to control alterations likely to materially affect the external appearance of these properties. As a record of townscape, it may also be used to indicate the essential characteristics of successful composition for use in a design guide or as a teaching aid.

CONCLUSIONS: In considering the mechanics of this particular study, the photography took thirty minutes and the provision of all control measurements a further forty-five minutes. The computer time taken for restituting the images and producing a scale drawing was eighty-three hours or ten eight-hour days. The time on site therefore represented 1.5% of the total time spent on this study.

Given this information, Mr. R. Dallas, Chief Surveyor for the Photogrammetric Survey Unit at the Institute of Advanced Architectural Studies, York, commented that it would seem unlikely for a photogrammetric record to have been prepared in such a period of time, although the result would be to a higher accuracy, especially with projecting features, such as the bowed entrance to the Black Boys Inn, and the recessed dormer windows and chimney stacks (Dallas, 1989).

It is in this type of work that Dallas sees the strengths and wider applications of computer-aided mono-photogrammetry, rather than in precision recording of large and complex architectural, or archaeological, subjects.
In evaluating these results, it would appear that computer-aided mono-photogrammetry is able to be used in the production of record drawings and visual images, with savings in time, and hence cost, over photogrammetry and, certainly, hand survey.

The amount of drawn detail needs to be appropriate for the intended use of the record. At a scale of 1:100, much of the detail on the individual façades is lost through 'blocking-in', whereas at 1:50, additional details may be required. In achieving this balance, it is possible to create separate 'layers', showing different sets of information, by utilising the flexibility of data manipulation offered by the CAD system.

The results of this study demonstrate that a series of building façades may be economically recorded using computer-aided mono-photogrammetry, where the intention is to provide a graphical record as an end in itself, or as a tool for the implementation of a visual impact analysis.

With reference to the former, a copy of the drawing has been sent to the Honorary Archivist of the Aylsham Parish Council, who has added it to the town's archives, together with brief notes describing how the drawing was produced.

REFERENCES:


PLATE 31.
WEST SIDE FROM NORTH
AYLSHAM MARKET PLACE

-88-
PLATE 32.
WEST SIDE FROM SOUTH
AYLSHAM MARKET PLACE
Case Study XIV

SITE: LEICESTER, Norman Cellar, Guildhall Lane, Leicestershire.

DESCRIPTION: The presence of the cellar was first brought to public attention in the proceedings of the British Archaeological Association Committee (Archaeological Journal, 1, 1845, 390-391), where it was described as lying beneath the Sexton's house and possessing 'curious arches'. Upon demolition of this house in 1861, the cellar was photographed before it was again built over and used as a store.

The west wall, shown in an extant archive photograph, became the subject for this project when the author was approached by the Leicestershire Museums, Arts and Records Service to prepare a drawing from the photograph showing individual stones and tiles, many of which had been destroyed or hidden at the time of the Victorian alterations.

The cellar has recently been identified as eleventh or twelfth century in origin, with confirmatory finds including tenth to twelfth century pottery from the lowest levels. It is presently being considered for scheduling as an ancient monument.

Additional background information, together with an account of how the drawing was prepared, have been given by Watt and Ashton (1988, 9 et seq.), a copy of which is included in Appendix D.

OBJECTIVES: This study provided two challenges, in the restitution of data from an oblique photograph and the use of an archive data source, both extending the terms in which computer-aided mono-photogrammetry might be used. It additionally represented a case for the application of image-enhancement techniques within the framework of the present method.

PROBLEMS: As the data source was already available, and could not be improved on by further photography, it remained only to experiment with techniques of image-enhancement in an attempt to provide the clearest image from which to work.
Careful consideration had also to be given to the methods employed in providing the necessary dimensional control, with the additional requirement that notional grid references had to be assigned to points upon which to base the process of analytical rectification.

Restitution from the oblique source was undertaken using the AERIAL rectification program, itself described in Case Study XI. The rectified point co-ordinates had then to be translated into a format suitable for CAD editing and reproduction.

METHOD: The cellar is located underneath a building and an adjacent entrance from Guildhall Lane, with access restricted to a single manhole. It is therefore in total darkness, and had an accumulation of debris over the floor at the time of this work.

The method chosen for dimensionally controlling the rectification of individual stones from the photograph was reliant on the identification of individual stones, both on the photograph and in the cellar. This was achieved by choosing specific stones of a unique shape that lay in a suitable position, relative to the blocked arched openings.

Those areas of the wall that had lain in shadow at the time of original exposure were too dark to be interpreted. The print was therefore subjected to a series of image-enhancement routines in an attempt to improve the image. This was undertaken by the Vision Automation Inspection Group in the School of Electronic and Electrical Engineering (Leicester Polytechnic).

Once the control points had been established, the position of each point was recorded using a total-station theodolite, to provide a graphical control 'map', with the points recorded as a series of XY co-ordinates.

In order to minimise any error at this critical stage, it was considered appropriate to record each point twice. Additionally, a number of overall dimensions were taken, using both total-station theodolite and tape, to allow for the later construction of a
three-dimensional digital model of the cellar.

The chosen control points were digitised from the source photograph, and each assigned their X, Y co-ordinates. The following point-by-point digitisation of each stone was automatically rectified by AERIAL, producing an orthographic view of the subject wall composed of individual lines. This aspect of the study took a total of fifty minutes.

It was necessary, at this stage, to transfer the resulting co-ordinates and lines from the personal computer, on which AERIAL is mounted, into the CAD system for editing and reproduction. This was achieved by downloading the data into a HUSKY HUNTER field computer and passing it to the GABLE IDS draughting module as a collection of open chains. These were subsequently edited to remove the incidence of crossed chains, and trimmed to produce a file of closed chains.

A three-dimensional digital model of the cellar was prepared and the completed elevation set in context, providing a graphical record of the surviving masonry for later analysis and comparison with manual inspection.

RESULTS: The resulting drawings provide a graphical representation of the subject wall, including the blocked openings, both as a separate record, and in the context of the present cellar accommodation. Opportunity was also taken to show the wall with the present brick divisions in place, and removed, the latter providing an indication of the original fabric that has been lost or obscured, and the extent of the masonry beyond the present floor, walls and ceiling.

It was, in addition, possible to provide a dimensional check on the results achieved by referring to the direct measurements taken by Mr. Flower in 1844, as reported in the Archaeological Journal of 1845. It was impracticable to identify with any certainty the exact points from which these imperial measurements were taken but, as a general indication of accuracy, comparisons gave a variance of ±10-20mm (±0.39-0.79in.). There is a facility within GABLE to switch between
metric and imperial measurement, which was used in this instance.

CONCLUSIONS: The archive photograph, on which this study was based, provided the only visual record of the cellar prior to its adaptation in 1861 and, as such, presented a unique source for investigation. The results from this study represent a valuable graphical record of the west wall and its features in the present cellar arrangement, and have been used during the subsequent architectural and historical interpretation of this monument.

The drawings have been included with the documentation prepared by the Leicestershire Museums, Arts and Records Service, and sent to the Chief Inspector of Ancient Monuments (Historic Buildings and Monuments Commission for England), as evidence for the proposed scheduling of the cellar as an Ancient Monument.

REFERENCES:
PLATE 33.
COPY OF WEATHERHEAD PRINT, 1861
NORMAN CELLAR
COMPLETE WEST WALL, NORMAN CELLAR, GUILDHALL LANE, LEICESTER
Figure 22

PERSPECTIVE VIEW, NORMAN CELLAR, GUILDHALL LANE, LEICESTER
Case Study XV

SITE: CASTLE ASHBY, Terracotta balustrade, Castle Ashby House, Northamptonshire.

DESCRIPTION: The present lettered balustrade, which encloses the descending tiers and terraces, was designed by Matthew Digby Wyatt (1820-77) in the 'ancient' style of Renaissance Italy for Charles, 3rd Marquess of Northampton, and was manufactured by Italian craftsmen and sculptors employed at the terracotta works of J.M. Blashfield in Stamford (Lincs.). It is now, however, in a poor state of repair, with structural failure having caused partial collapse, and erosion of the fireskin leading to extensive surface decay. The cost of restoring the 400m (440yds) of balustrading, and steps, has been estimated to be in the region of £600,000 to £850,000.

OBJECTIVES: Sections of the balustrading have previously been recorded manually by the present Marquess's architect to provide a basis on which to indicate repairs and adaptations, including the insertion of expansion joints. It was the intention of the author to demonstrate, through this particular study, that computer-aided mono-photogrammetry might be used to record small-scale sculpture and other features, which lend themselves to orthographic representation, as an alternative to hand measurement and manual presentation.

PROBLEMS: The 13,000mm (42.6ft) length of balustrading chosen for this study contains two highly-detailed piers with ornate urns, two further plain piers with urns, and a selection of individual letters, balusters and visible defects.

Much of the detail on the piers, and the urns themselves, is three-dimensional in nature, and cannot, as such, be accurately recorded using computer-aided mono-photogrammetry. It would be necessary to employ stereo-photogrammetric techniques to record such detail accurately, if this were necessary.
The minimal height of the subject, relative to its length, required consideration to be given to the method of photography used for data capture, and how to dimensionally control the section so as to allow each part to be simply and accurately brought together to form a continuous record. It was also necessary to consider how best to represent the various elements where they were damaged or deformed.

METHOD: The subject length of balustrading was divided into six sections by the use of plumbed lines taken from the top rail down to ground level. The balustrading was then photographed so as to incorporate two lines in each view, with additional photographic coverage of the detailed piers and urns. Simple running dimensions were used to provide horizontal control, with vertical measurements taken of the piers and of an individual baluster.

Each of the piers was digitised from the larger-scale prints, with attention given to the high level of detail and individual defects, such as cracks and missing parts. It was not possible to record the detail from the rounded elements, and these were recorded in outline only.

Each of the six sections were then digitised, using the plumb lines as a vertical reference for any movement that had taken place. The top and bottom rails are composed of moulded butt-jointed sections, and a typical section from each was digitised and patched for use as a standard assembly. This was achieved by positioning the patch according to the line of the rail, and distorting it to the length of the actual section. In this way the undulations of the top rail were recorded, with joint widths and cracks accurately represented. A standard baluster was similarly digitised and repeated as necessary, with cracks digitised on to the surfaces as necessary.

Once all the sections and piers had been magnified to their true scale, each was brought together to form a continuous record of the balustrading and printed to a scale for comparison with the manually-prepared drawings.
RESULTS: The completed drawing was sent to the Estate Manager for Castle Ashby House, who held copies of all the initial survey drawings. Although he felt that what had been produced by computer-aided mono-photogrammetry was superior to that previously prepared, no direct comparison was possible as the length in question had not been manually surveyed (Pearson, 1989).

CONCLUSIONS: Despite not being able to compare the product of this study with that of a manual survey, it provided an opportunity to demonstrate how computer-aided mono-photogrammetry might be usefully employed to record structures that have a high level of surface detail and, in the case of rounded elements, lend themselves to limited orthographic representation.

There is sufficient similarity in a number of the elements within the complete length of balustrading to consider a CAD-based system of presentation, if the entire structure were to be recorded. The methods of data capture and image restitution used in computer-aided mono-photogrammetry represented an effective means of producing such a record, given the limitations imposed on recording three-dimensional elements by adopting a central projection.

As a rider to this study, it was considered appropriate by Compton Estates Management Services to commission an independent photographic survey of the entire balustrade rather than to invest in further dimensional surveys at a stage before a decision has to be taken to fully restore the balustrading; remove it entirely; reduce its extent and retain only those sections visible from the drawing rooms; replace it with a new balustrade of contemporary design; or remove both terraces and balustrading completely and restore the original Capability Brown landscape.

REFERENCES:
PLATE 34.
ORNATE PIER TO BALUSTRADE
CASTLE ASHBY HOUSE
-102-
PLATE 35.
ORNATE PIER TO BALUSTRADE
CASTLE ASHBY HOUSE

-103-
PLATE 36.
SECTION OF LETTERING TO BALUSTRADE
CASTLE ASHBY HOUSE

-104-
Figure 23

TERRACOTTA BALUSTRADE, CASTLE ASHBY HOUSE, NORTHAMPTONSHIRE
Case Study XVI

SITE: COVENTRY, Grammar School, Hales Street, West Midlands.

DESCRIPTION: The present church building represents the only remains of a hospital founded in the twelfth century, to which additions have been made in the late nineteenth, and early twentieth, centuries. At the Dissolution, John Hales was allowed to acquire properties in and around Coventry, on the condition that he founded a school in the city. This he did, moving it to St John's Hospital in 1573, where it remained in Hales Street until 1885.

Since this time, the building has housed many uses, been twice threatened with demolition, and damaged during air raids in the Second World War. It is currently being restored and will be used for mixed activities, the work requiring both extensive repair and consolidation of decayed stonework.

OBJECTIVES: The author was commissioned to produce a set of elevational drawings, showing individual stones and details, suitable for communicating the nature and extent of stonework replacement and repairs, and fulfilling the condition for recording placed in the Schedule Monument Consent granted for this work.

As a case study, this work represented an opportunity for preparing a record of the entire exterior of the building, which included traceried windows, high-level fabric and cases of severe erosion and decay.

PROBLEMS: There were six main faces to record, of which only three offered scope for normal-case photography. The east end of the church was adjacent to a modern row of shops, and this led to the adoption of an alternative recording technique based on the use of a total-station theodolite. Photographs were used as a visual record only, being taken at an acute angle, both horizontally and vertically.

The northern face of the church and those of the north aisle were partially obstructed by vegetation, and photography was limited by the
close proximity of a boundary wall. These elevations were therefore prepared from fragmentary photographic coverage, with hand measurement being necessary to record the lower fabric. It was possible to locate the camera on the flat roof of a modern extension to the church in order to photograph the higher levels, but this again required fragmented recording.

The requirement for an accurate representation of the window tracery was successfully met, although the east window could not be recorded externally, and an alternative approach was adopted.

METHO D: Each of the faces were photographed in a manner that recorded the full height of the wall surfaces on the prints. The height of the roof ridge was subsequently set by direct measurement. The south façade was recorded using four prints, breaking the length in to the buttressed bays, suitable for digitising. Those faces that lay to the north of the building were recorded in a fragmented manner, as stated above, due to obstruction and difficulties of access.

Dimensional control was based on horizontal measurements, run across the faces to pick up key features and used to tie the individually digitised images together, and limited vertical measurements. Additional sketches and measurements were taken in areas where there was obstruction or extensive decay.

Each face that had been recorded with normal-case photography was restituted in the manner established by previous studies, using chains to construct the individual stones and features. Where faces were digitised from a number of prints, these were brought together using a visible break, and composed to form one drawing.

The east face could not be recorded satisfactorily by photography, either for direct digitising or rectification, and so selected points were accurately recorded using a total-station theodolite linked to a field computer in a way that allowed an outline of the wall and its features to be recorded as a series of XY co-ordinates. These formed the basis for an outline drawing that was used in a later manual
survey. It was necessary to use a diagonal eyepiece on the theodolite, as sighting through the instrument was not possible given the angle at which the telescope was inclined.

The tracery was recorded to glassline as a series of arcs, constructed using start, finish and intermediate points, with completed lights repeated as necessary. The east window was recorded in a similar manner, using an internal photograph of the tracery, and set within the opening established externally. The close proximity of the modern building limited the light coming through this window, and so reduced the amount of flare to an acceptable degree. It would otherwise have been necessary to record the window internally at night using artificial illumination, or by applying a neutral-density filter in the form of a continuous sheet over the outside face of the window.

RESULTS: The drawings produced for this commission recorded the individual stones, visible features and external defects for the whole exterior of the building, sufficient for communicating the nature and extent of repairs and replacement of stone.

The manner in which the east face was recorded provided an accurate basis on which to add detail derived from manual surveying and photographic interpretation. All the drawings were checked on site by an archaeologist working on this project, and formed part of the final contract documentation.

CONCLUSIONS: This study provided a record with which the architect could communicate his wishes in a manner appropriate for use by the stone masons on site, and by the Historic Buildings and Monuments Commission for England with regard to the assessment of grant assistance.

The dimensional accuracy of this record was considered appropriate for its intended application, although its content was held to be of greater importance, given the detailed nature of the repair work intended. The costs of producing this record were also considered to be lower than those anticipated for a manual survey, given the
limitations of access imposed by the restricted site conditions.

The time taken to produce the drawings was 166 hours or twenty-one eight-hour days. These were at a scale of 1:50, although the architect initially considered 1:20 to be applicable. It was decided, however, that the smaller scale would be sufficient to show the level of detail required, being appropriate to the technique and scale of photographs that were used.
PLATE 37.

SOUTH AND WEST FAÇADES

HALES STREET GRAMMAR SCHOOL
PLATE 38.

SOUTH AND EAST FACADES

HALES STREET GRAMMAR SCHOOL
PLATE 39.
VICTORIAN WEST FAÇADE
HALES STREET GRAMMAR SCHOOL

-112-
PLATE 40.
EAST FACE OF NORTH AISLE
HALES STREET GRAMMAR SCHOOL

-113-
WEST ELEVATION, GRAMMAR SCHOOL,
HALES STREET, COVENTRY

Figure 24
SOUTH ELEVATION, GRAMMAR SCHOOL, HALE'S STREET, COVENTRY

Figure 25
EAST ELEVATION, GRAMMAR SCHOOL, HALES STREET, COVENTRY
NORTH ELEVATION, GRAMMAR SCHOOL, HALES STREET, COVENTRY
Case Study XVII

SITE: ELY, South-West Transept, Cambridgeshire.

DESCRIPTION: Although there was a Minster at Ely from 673, work on the great Abbey started in 1083, the main body of which, including the western transepts, was complete by the early thirteenth century. In 1322 the Norman crossing tower collapsed, and by the mid fourteenth century, both the Lady Chapel and octagonal tower, with its stone octagon and timber lantern, were complete. The north arm of the west transept collapsed in the fifteenth century, and, although rebuilding was begun, no progress was made.

The west end, with the remaining south-west transept, seems to have followed the completion of the nave after a short interval. The west face of the transept is noticeable for the many tiers of blank arcading, 'the lowest tier being plain and narrow, and the second introducing enrichment of arching in two layers behind each other. The third tier is larger and contains windows, these having a tripartite stepped setting with diapered walling between them. Above them lies the Gothic motif of the pointed arch, with windows arranged in tripartite stepped groups, with sunk quatrefoils in circles to the spandrels above. A corbel table and later battlements end the composition' (Pevsner, 1954, 270).

OBJECTIVES: The author was approached by the consultant architects with responsibility for the fabric of Ely Cathedral to consider recording the south-west transept, with the intention of providing a set of record drawings on which to base a future phase of repair and consolidation.

It was pointed out by the author, at this time, that the technique of computer-aided mono-photogrammetry was not suitable for recording high levels of detail, multi-planed façades or curvature. As a result, it was agreed that only the western face of the transept would be recorded, to provide an outline drawing on which additional detail could be added by the architects at a later stage. This work offered
the scope for recording a substantial subject, with various planes and architectural detailing, for which an accurate framework of dimensional control would be required.

PROBLEMS: The physical size of the subject presented problems in photographing the fabric, without the use of either a hoist or scaffold tower. In addition, the amount of surface detail, and recessed planes, offered a considerable challenge both for controlling and restituting the information by manual digitisation. The fabric to the north side of the face had also suffered from settlement, this having resulted in a marked displacement of stones, especially at the higher levels. This deformation was recorded as accurately as possible, and in itself caused difficulties in resolving the representation of affected fabric.

METHOD: The façade is divided vertically by a central pilaster, and into six stages horizontally by moulded string courses, with a crenellated parapet at the top. These natural divisions were followed in photographing the fabric, and later when digitising the surface detail. It was decided at a later stage, however, to use photographs that recorded the entire width of each stage, rather than the parts on either side of the pilaster, in order to allow for the repetition of certain features and details, and facilitate the processes of magnification based on the XYZ co-ordinates.

The first two stages were recorded using normal-case photography taken from a point directly in front of the façade. Higher fabric was recorded from a greater distance to minimise the convergence of vertical lines, although producing a smaller-scale print. The highest stages did, however, exhibit signs of distortion, although this was itself reduced by establishing the joint positions from the central part of the print and extending the lines out to the edges. Additional photographs were taken, both from a distance using a telephoto lens, and at an acute vertical angle, to provide a source for later interpretation.

The dimensional control established for this study was provided by two-point intersection using a total-station theodolite. Where a
façade comprises a single plane, it is possible to record points as XY co-ordinates from a single station a known distance from the face. Where the façade is composed of a number of separate planes, points can be recorded as a series of XYZ co-ordinates from two stations.

A base line of known length was established on the ground in front of the façade, and the main plane nominated as a reference plane, measured from the two stations at either end of the base line. Detail points were identified at each stage of the façade, using the intersection of joints or relative to recognisable features, and marked on to booking sheets in the form of large-scale photographic prints taken on a previous inspection. These points, forty-eight in total, were recorded from both stations, and their intersections established graphically in two dimensions on the CAD system, giving a plan of the various planes and an elevational control file.

Once all the information had been digitised from the photographs, making use of chains and arcs only, each of the files was magnified to fit with the control points, and composed to form a complete elevational record. Each of the files contained a great deal of information, and it was found easier to locate them by their control points only, this being achieved by suppressing all information except for the markers used to indicate the control points, and reinstating the files once they had been accurately positioned.

As each file contained information up to a definite horizontal break, it was possible to bring the files together with a minimum of editing required at the junctions.

RESULTS: The level of detail recorded on the drawing was limited in order to produce a base drawing for later extension by the architects concerned. Although there would have been much repetition of individual details and features, it would have greatly increased the amount of time spent preparing the drawing.

Although dimensional control was provided for the recessed planes, it was not possible in practice to record these planes, or their detail,
to the same accuracy as achieved for the main plane. This was due to problems of parallax, created by the low camera stations adopted, and obstruction by adjacent fabric. It is at this point that stereo-imaging would have been required to present a true image from which to abstract information, in the form of stereo-photogrammetry.

The finished drawing did, however, provide a useful outline drawing for later application, taking a total of 169 hours or twenty-one eight-hour days, to produce. This included time on site for photography and optical surveying, as well as for computer restitution.

CONCLUSIONS: It is evident from this study that the technique of computer-aided mono-photogrammetry is not suitable for the production of accurate record drawings of such subject matter, where there are problems of scale, access, detail and numerous planes to be resolved. This study did, however, produce an end result of some merit for which the architects felt that there would be a use.

If the time taken for this study had been charged at a realistic rate of £250/day, it would have cost a total of £5,250.00, with an additional £54.00 for photography and £70.00 for travelling expenses, totalling £5,374.00. The architects had commissioned Terrestrial Surveys of York to produce a full photogrammetric survey of the east end of the Cathedral, including all side elevations of the buttresses, in 1987/8, and this was charged at just under £6,000.00. Taking inflation into account, it is obvious that for this sort of work, stereo-photogrammetry provides the most suitable solution for producing accurate elevational records, whether for archive purposes or as a tool for planned interventions.

REFERENCES:
PLATE 41.
WEST FRONT
ELY CATHEDRAL

-122-
PLATE 42.
WEST FACE OF SOUTH-WEST TRANSEPT
ELY CATHEDRAL

-123-
Ground level

VERTICAL DIMENSIONAL CONTROL,
SOUTH–WEST TRANSEPT, ELY CATHEDRAL

Figure 28
SOUTH-WEST TRANSEPT,
ELY CATHEDRAL, CAMBRIDGESHIRE

Figure 29
Case Study XVIII

SITE: LEICESTER, The Church of St Mary de Castro, Castle Street, Leicestershire.

DESCRIPTION: The subject for this study was the eastern face of the present sacristy, a modern addition to a church, the oldest part of which dates back to the early twelfth century. The vestry, as it was, generally follows a design put forward in 1851 by the noted nineteenth-century writer on church architecture, M.H. Bloxam (Pevsner, 1984, 215).

The eastern face comprises a traceried window and doorway, in clearly-coursed ashlar walling beneath a lean-to roof. The tracery is cusped and foiled, set beneath a four-centred arch, with the doorway conceived of an equilateral arch having side lights and a boarded door with fine wrought-iron hinges.

OBJECTIVES: This study was devised as a means by which the procedures and products of computer-aided mono-photogrammetry might be compared and contrasted to those of direct manual recording, relative to a small-scale, though complex, subject. This particular traceried window and doorway was chosen as it offered a number of features that would make demands on the techniques chosen, especially with regard to the tracery and mouldings. The subject was thus recorded by manual measurement and draughting, and computer-aided mono-photogrammetry.

PROBLEMS: The procedures for this work were as described in previous studies, with normal-case photography used both as a source for digitisation and interpretation of detail. The manual recording was based on conventional hand sketching and measurement, performed solely by the author, and manual draughting. There were no particular problems encountered within this study, although the accurate recording of the tracery and mouldings tested both computer-assisted and manual draughting skills.
METHOD: Normal-case photography was provided of the subject, with additional oblique and close-up coverage as a source for interpretation. Simple control dimensions were taken using tape and rod. Digitising was performed from a single print, and the completed record printed to scale.

The manual survey comprised a hand sketch of the subject, on which direct measurements were marked, with no additional photography or other aids to recording used. The drawing was first prepared in pencil on paper to the chosen scale, and then transferred on to tracing paper using ink. The site measurements were taken by the author using a steel tape and rod, with the use of a step-ladder.

RESULTS: The times for the various processes undertaken during the production of scale drawings of the subject using computer-aided mono-photogrammetry and hand survey were as follows:

<table>
<thead>
<tr>
<th>Computer-Aided Mono-Photogrammetry</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Photography</td>
<td>5 mins.</td>
</tr>
<tr>
<td>Dimensional control</td>
<td>5 mins.</td>
</tr>
<tr>
<td>Restitution</td>
<td>8 hrs 45 mins.</td>
</tr>
<tr>
<td>Editing and reproduction</td>
<td>1 hr</td>
</tr>
<tr>
<td>Total</td>
<td>9 hrs 55 mins.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hand Survey</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sketching</td>
<td>2 hrs 5 mins.</td>
</tr>
<tr>
<td>Direct measurement and booking</td>
<td>1 hr 15 mins.</td>
</tr>
<tr>
<td>Draft in pencil</td>
<td>4 hrs 30 mins.</td>
</tr>
<tr>
<td>Inking to completion</td>
<td>3 hrs 40 mins.</td>
</tr>
<tr>
<td>Total</td>
<td>11 hrs 30 mins.</td>
</tr>
</tbody>
</table>

It was found necessary to edit the drawing produced by computer-aided mono-photogrammetry once examination of the subject had been undertaken, as certain details had been misinterpreted from the photographs. Hand surveying, in this respect, allowed a closer
examination of the subject, and the opportunity for consideration of smaller details, such as the mouldings and other complicated components.

For this reason, drawings that are produced by the author as part of a commission are presented as 'unverified machine plots', unless checked on site. It is considered appropriate that the person(s) who commissions such a survey should have the opportunity to study the drawing in detail, and compare it against the building or monument on which they will be working.

CONCLUSIONS: It is evident from this study that computer-aided mono-photogrammetry can be used to produce an accurate record drawing of a small, though complicated, subject, in a time that is comparable with hand survey. In this particular case, a 14% saving in time was achieved. Additionally, once the image had been digitised, the subject could be reproduced to various scales as required.

It is considered by the author that CAD could have been used as a tool for translating the site sketches and measurements into an accurate drawing instead of using manual draughting techniques. This could have been done with a potential reduction in time due to the amount of repetition present in the composition. This comparison between computer-aided and manual draughting is, however, outside the scope of this present project.

REFERENCES:
PLATE 43.

EAST FACE OF SACRISTY

CHURCH OF ST MARY DE CASTRO

-129-
CHURCH OF ST MARY DE CASTRO
CASTLE STREET, LEICESTER

Figure 30
CASE STUDY XIX

SITE: LOUGHBOROUGH, Burleigh Cottage, Loughborough University, Leicestershire.

DESCRIPTION: Burleigh Cottage is a Grade II listed building, formerly described as the gardener’s cottage in Burleigh Park, and now used as the security office for Loughborough University. Dating from the sixteenth and seventeenth centuries, its double-L plan is made up of a number of differing materials, and recent alterations have left a pattern of mixed fenestration.

OBJECTIVES: This study was undertaken as part of a commission to record the small, though complex, building by way of plans, sections and elevations, with commentary on the condition of the fabric, prior to repair and refurbishment as part of the portfolio of buildings held by Loughborough University.

The plans and sections were produced using CAD, based on site sketches and measurements, undertaken by the author and Mr. R. Ashton. The building has suffered from structural movement and material decay, and, as a result, it was decided to use a total-station theodolite to record an accurate 'footprint' of the building that would act as a dimensional control for the production of all drawings.

The external faces of the building contain much visible detail, both of architectural and historical importance, and due to this it was decided to use computer-aided mono-photogrammetry as an appropriate technique for producing the elevations. The resulting drawings were checked on site by the author, at the request of the architects.

PROBLEMS: The present building is composed of four parts, an original stone cottage of one-and-a-half storeys, with external gable stack and adjacent bread oven; a timber-framed wing to the front and a brick wing to the rear; and a recent brick and flat-roofed extension. These various materials had to be accurately represented, with attention given to the present window types and surface details.
The two gable walls of the original cottage could not be wholly recorded using normal-case photography, that to the south-west being obscured by a Portacabin and to the north-east by a boundary fence, both allowing only the top portions of the walls to be photographed. The remaining walls were photographed square-on to their faces, with additional detail photographs for interpretation. The gable of the rear brick extension is partly covered by ivy, and little detail could be recorded for this elevation.

METHOD: The elevations were prepared by digitising from the photographic prints in the established manner, with particular attention given to changes in materials, architectural details and visible decay.

Dimension control was based on the 'footprint' established initially, with vertical measurements related to a Temporary Bench Mark (TBM). Where full photographic coverage was impracticable, sketches and hand measurement provided the necessary information to complete the part-digitised elevations.

RESULTS: The elevations, based on the use of computer-aided mono-photogrammetry, formed part of the measured survey, all the drawings having been prepared using CAD, which allowed a high standard of presentation to be achieved, with consistent annotation and layout. The complete set of drawings took 134 hours or seventeen eight-hour days to produce, the elevations of which represented seven days work. The client received a complete photographic record, in addition to the graphical information, these being forwarded to a consultant structural engineer to assist in developing a programme of strengthening and repair.

CONCLUSIONS: Considering the elevations in isolation, it would be justifiable to state that the accuracy achieved in this study was probably greater than required for the work under consideration. It does, however, indicate that computer-aided mono-photogrammetry can be used in the production of dimensional records at a vernacular level,
either to stand alone as a specific record or part of a full dimensional survey.

It is important to be aware of the use for which the drawings have been commissioned, so that the standards of accuracy and detail can be matched with the intended use. In this particular study, surface information, including the deformation of brick courses and decay of timbers, has been recorded, which increased the time for restitution and production of record drawings. Given these considerations, it is the opinion of the author that computer-aided mono-photogrammetry provided an economic means of recording the external faces of this building.

Although the amount of repetition within the plans and sections was minimal, it proved beneficial to use CAD for the production of these drawings, given the dimensional framework established using a total-station theodolite, and the graphical capabilities of the system.
PLATE 44.
VIEW FROM EAST
BURLEIGH COTTAGE

-134-
PLATE 45.
VIEW FROM EAST
BURLEIGH COTTAGE

-135-
Figure 31

SOUTH-EAST ELEVATION, BURLEIGH COTTAGE, LOUGHBOROUGH
NORTH-WEST ELEVATION, BURLEIGH COTTAGE, Loughborough

Figure 33
Figure 34
Case Study XX

SITE: LOUGHBOROUGH, Leicester Road Cemetery, Leicestershire.

DESCRIPTION: Pevsner (1984, 285) said of this site that it has the best cemetery buildings in the county, comprising the original gatehouse and two Decorated chapels linked by a three-arched loggia topped by an elaborate spire, the work of Bellamy and Hardy of Lincoln (1856-7). The subjects for this study were the principal façade of the gatehouse and cast-iron railings facing on to the Leicester Road.

OBJECTIVES: This study does not directly represent work carried out by the author, but has, instead, been included as evidence for how computer-aided mono-photogrammetry might be used for the recording of a complex subject by someone who has had limited operating experience using CAD, and who has been given only basic instruction in this method of recording. I am indebted to Mr. H. Dennis, research student at the Leicester CAD Centre, for permission to use his work.

PROBLEMS: Both subjects represented highly detailed fabric that would have required extensive hand measurement to record them to a similar standard of accuracy and detail. The finely carved bargeboards are located some 2,100mm (6.9ft) above ground level on the principal face of the gatehouse, and would have required the use of a ladder or other form of access to perform a manual survey.

METHOD: The photographs of both gatehouse and railings were taken by the author as part of an external photographic survey of all the buildings on the site, which preceded a full measured survey and production of detailed CAD-based drawings for use in a project involving repair and conversion to residential usage. It was decided by Dennis to use computer-aided mono-photogrammetry for recording the principal face of the lodge and the railings, rather than rely on computer draughting from site measurements, due to the complexity and high level of detail presented by the bargeboards and cast-iron sections. The necessary dimensional control was, therefore, obtained by direct measurement taken as part of the overall building and land
survey.

RESULTS: Both of the subjects were recorded directly from photographs, and restituted in the usual manner. Despite his limited experience in using this technique, Dennis was able to produce a highly-detailed drawing of the central part of the gatehouse in twenty-five hours and of the section of railings in seventeen hours. His choice of CAD element differed from that of the author, instead adopting an approach that complemented his developing working style.

CONCLUSIONS: The images prepared using computer-aided mono-photogrammetry were combined with those produced from direct measurements, by computer draughting, resulting in a complete set of highly detailed drawings. It is possible, using digital data, to compose a record from various sources, whether it be direct measurement, computer-aided restitution from photographs or visual interpretation.

REFERENCES:

PLATE 47.
SOUTH-EAST FAÇADE OF GATEHOUSE
LEICESTER ROAD CEMETERY

-143-
SOUTH-EAST ELEVATION, CEMETERY GATEHOUSE, LOUGHBOROUGH CEMETERY, LEICESTERSHIRE

Figure 35
NORTH-EAST ELEVATION, CEMETERY GATEHOUSE, LOUGHBOROUGH CEMETERY, LEICESTERSHIRE

Figure 36
Case Study XXI

SITE: Field Cottage, 28/30 Main Street, Ratcliffe-on-the-Wreake, Leicestershire.

DESCRIPTION: Field Cottage is a Grade II listed timber-framed building of the late sixteenth, or early seventeenth, century, having a rubblestone plinth, red-brick nogging and Swithland slated roof. The two-bay timber frame has wall posts and a brace remaining to the front, with closely set studs to the south-east gable end. Inside are two ceiling beams with moulded chamfers and tiebeam trusses with diagonal braces and clasped principal rafters.

OBJECTIVES: The author was commissioned to produce detailed measured drawings of this building, comprising four elevations, two plans and a cross-section, to satisfy demands for an archive record, and on which to base a programme of repair and renovation. It was possible to obtain normal-case photography for only one complete face of the building, and parts of two others, the remainder being reliant on direct hand measurement and draughting.

In this respect, Field Cottage represented a challenge for measurement and recording, with an opportunity to use computer-aided mono-photogrammetry for parts of the external faces, with attention given to the forms of construction and surface detail.

METHOD: The building is in a poor structural condition, suffering from the direct ingress of rainwater and the effects of previous alterations. As a result, the walls are generally out of plumb, with substantial bulging and partial collapse on the south-west face.

Normal-case photography was used to record the north-east, and parts of the north-west and south-west, façades, with oblique coverage used internally and externally as a source for interpretation. The author was required also to provide photographs of specific details to form part of an archive record prior to renovation.
The structure was manually measured and recorded to provide data for the preparation of the required drawings, produced using CAD. A total-station theodolite was used to record a 'footprint' of the building at ground level externally and internally at first-floor level due to the obvious deformation of the walls. Closed series levelling was performed both inside and out, with inverted levels recorded for all external features. This technique was used extensively on the south-east face to locate the position of each horizontal timber member.

Those parts of the building that had been recorded by normal-case photography were digitised directly from the prints, the elevations being completed with additional draughting from site measurements. The remaining elevations, section and floor plans were draughted using the CAD system.

RESULTS: The drawings achieved a high standard of dimensional accuracy and detail content appropriate to the status and condition of the building. The production of all drawings took a total of sixty hours or seven-and-a-half eight-hour days, of which approximately two days were spent on the elevations.

Given the condition of the building, it is considered by the author that it would have been difficult to achieve a comparable level of accuracy using manual techniques, especially in respect of the deformation present in the walls.

CONCLUSIONS: The use of computer-aided mono-photogrammetry for producing the elevations, where practicable, allowed the deformation of the walls and other defects to be recorded without the need for extensive manual measurement. This was an important consideration at the time, as the work was carried out during a period of strong winds that caused a number of slates to be dislodged.

The purpose of this commission was to record the building prior to its renovation, and to produce a set of drawings that could be used to communicate the necessary works. It is the opinion of the author that
the techniques employed were able to provide the required record in a shorter period of time than would have been possible using manual methods, to a higher standard of dimensional accuracy and detail content, and at a lower cost to the client.
PLATE 49.
NORTH-EAST AND SOUTH-EAST FACADES
FIELD COTTAGE
-150-
PLATE 50.
NORTH-EAST AND NORTH-WEST FAÇADES
FIELD COTTAGE

-151-
SOUTH-WEST ELEVATION, FIELD COTTAGE, RATCLIFFE-ON-THE-WREAKE, LEICESTERSHIRE

Figure 37

-152-
SOUTH-EAST ELEVATION, FIELD COTTAGE,
RATCLIFFE-ON-THE-WREAKE, LEICESTERSHIRE

Figure 38
NORTH-EAST ELEVATION, FIELD COTTAGE, RATCLIFFE-ON-THE-WREAKE, LEICESTERSHIRE
NORTH-WEST ELEVATION, FIELD COTTAGE, RATCLIFFE-ON-THE-WREAKE, LEICESTERSHIRE

Figure 40
APPENDIX B: MEASURED AND PHOTOGRAPHIC SURVEYS

The author has undertaken, or assisted in, the following measured and photographic surveys during the course of this investigation, commissioned by architects and surveyors for a variety of purposes. This involvement has allowed the author to become familiar with traditional and advanced survey techniques, and develop a structured approach to photographically recording historic buildings and ancient monuments.

I. MEASURED SURVEYS

Pex Building, Leicester (January 1987).

Manor Farm, Long Duckmanton, Derbyshire (March 1988).

Tapton, Sheffield – site survey (May 1988).

King's Mill Viaduct and site, Mansfield, Nottinghamshire (July 1988).


Home Farm, Bowood Estate, Bowood, Wiltshire (July 1989).


Field Cottage, 28/30 Main Street, Ratcliffe-on-the-Wreake, Leicestershire (January 1990).

Former Boots shop unit, Mander Centre, Wolverhampton (January 1990).

Former Climax Cinema, Birmingham (February 1990).

Various National Westminster Bank PLC branch premises:
Stratford Broadway, London (June 1987).
East Ham, London (June 1987).
Hackney, London (February 1988).
Clacton, Essex (June 1988).
Leicester (July 1988).
Porthmadog, Gwyned (October 1988).
Knaresborough, North Yorkshire (November 1988).
Headington, Oxford (November 1988).
Fleetwood, Lancs. (December 1988).
Rochdale, Lancs. (February 1989).
Newark, Notts. (February 1989).
Cowes, Isle of Wight (April 1989).
Gosport, Hants. (July 1989).
Bromley, Kent (April 1990).

II. PHOTOGRAPHIC SURVEYS

King's Mill Viaduct, Mansfield, Nottinghamshire (July 1988).

St Michael's Church, Queen Street, Derby (August 1988).

Pentney Priory, Pentney, Norfolk (October 1988).

Tickhill House, Tickhill, South Yorkshire (November 1988).

Carnfield Hall, Alfreton, Derbyshire (November 1988).

Waxham Great Barn, Waxham, Norfolk (December 1988).

Harewood Castle, Harewood, Yorkshire (January 1989).

St John's Chapel, Belper, Derbyshire (March 1989).

Leicester Road Cemetery, Loughborough, Leicestershire (September 1989).

St Matthew’s Church, Duddeston, Birmingham (November 1989).


Paston Barn, Paston, Norfolk (December 1989).

Field Cottage, 28/30 Main Street, Ratcliffe-on-the-Wreaks, Leicestershire (January 1990).

St Lawrence’s Church, Ingworth, Norfolk (April 1990).

Various National Westminster Bank PLC branch premises, as above.
APPENDIX C: EQUIPMENT REFERENCES AND SPECIFICATION

I. GABLE CAD SYSTEM

GABLE (Graphic Aids for Building Layout and Evaluation) is a computer-modelling system developed at Sheffield University (School of Architecture), initially for teaching and research purposes, but now available commercially through GABLE CAD System Limited. The underlying philosophy behind GABLE was to give designers a modelling tool that would increase their understanding of the performance of any building in terms of space, daylighting, acoustics and energy (Kirkwood, 1988, 26).

GABLE 4D SERIES offers an integrated suite of systems with two-dimensional draughting (IDS), three-dimensional visualisation (OMS), database management (DMS), building modelling (BMS) and ground modelling (GMS), selected as individual modules according to the functions required. Each system is capable of being used separately or in combination.

This work has been concerned solely with the use of the GABLE 4D SERIES 'Integrated Drafting System' (IDS), as a tool for the restitution of dimensional data from photographs. The following details relate to aspects of this particular system and have been abridged from the System Concept Manual (GABLE CAD Systems Limited, 1984) and IDS Reference Manual (GABLE CAD Systems Limited, 1985). A full introduction to the command language is provided in the respective introductory manuals.

The command pad for interactive graphical commands is divided into four sections: elements are the nouns that vary from module to module; verbs may be applied to the nouns in the element list and usually represent some manipulation of an element - a full command using a verb and noun is issued in that order (e.g. add line or delete shape); draw provides varying means of re-drawing a current file, either in full or partial detail; board commands control the way in which the screen
behaves as an interactive drawing board.

The IDS elements, verbs and board commands used predominantly in this work are:

**ELEMENTS**

**ARC:** A circular element that may be defined by its centre position, and its start and finish angles, measured anticlockwise from horizontal, or by its start and finish points, together with a chosen intermediate point.

**CHAIN:** An open linear element of between three and 248 sides, defined by a sequence of points.

**CLOSED-SPLINE:** A closed polygonal element of between three and 248 sides defined by a sequence of points, in which the first and last are at the same location, with a cubic b-spline fitted to the vertices.

**IDS-BOX:** A rectangular element that defines the area of an IDS drawing file, and is automatically created when a drawing is stored, if none already exists.

**LINE:** A linear element defined by its start and end positions.

**MARKER:** A symbolic element from a standard library defined by its centre point.

**OPEN-SPLINE:** An open linear element of between three and 248 sides defined by a sequence of points with a cubic b-spline calculated from the line.

**PATCH:** A closed polygonal element of between three and 248 sides defined by a sequence of points in which the first and last are at the same location, and specified to collectively group elements in the drawing. The patch may be activated, where all the elements are drawn, and can be identified as separate elements, or used to identify the whole patch; or de-activated.

**SHAPE:** A closed polygonal element of between three and 248 sides defined by a sequence of points in which the first and last are at the same location.

**SUB-FILE:** A sub-file represents a complete IDS drawing file defined by the centre-point of its IDS-Box, and may be activated or
de-activated.

TEXT: An alphanumeric element from a user-defined library, defined by the upper-left-hand corner of a system-generated enclosing box.

VERBS

ADDTRIM: A command that will snap and overlay an element onto an existing element.

DOUBLE-TRIM: A command that will cut two elements, and extend or shorten them to a common point of intersection.

HAND: A command that will re-draw an element or sub-file mirrored to the left or right, according to the location of the point of identification to the left or right of the centrepoint.

MAGNIFY: A command that will magnify an element, sub-file or patch by single or variable factors.

RADIAL-REPEAT: A command that will give a selected number of copies of a chosen element to be drawn larger or smaller at a given distance.

REPEAT: A command that will copy an element, sub-file or patch to a specified direction and distance.

TRIM: A command that will cut an element, and extend or shorten it in relation to a chosen target.

BOARD COMMANDS

DIGITISE: A command that allows an image to be traced and co-ordinates defined at selected points.

LINK: A command that allows access to other modules within the GABLE suite of systems.

PAN: A command that allows a drawing to be moved on screen to display other parts.

PLANCHEST: A command that provides a menu of administrative functions.

SCALE: A command that allows the screen to be re-scaled and re-drawn.

SET-SQUARE: A command that defines the angular relationship between sequential points.

SNAP: A command that identifies corners or ends of elements in a current drawing.
TOLERANCE: A command that controls the size of the pick-box cursor and the degree of accuracy with which any part of an element can be identified. The value of the tolerance changes in direct proportion to the scale value, and thus remains constant on the screen.

ZOOM: A command that allows part of a drawing to be selected and re-drawn in proportion to the screen.

Leicester CAD Centre is equipped with a DATA GENERAL MV2000 32-bit computer, driving TEKTRONIX 4111 and 4207 colour terminals with 4957 graphics tablets, supporting GABLE 4D Series software (Plate 51). The AERIAL rectification program is mounted on an OLIVETTI M24 personal computer, using a GRAPHTEC KD3300 tablet.

The TEKTRONIX 4957 tablet has an active area for digitising of 297 x 297mm (11.7 x 11.7ins.) and is fitted with a four-button cursor used for converting the graphical information presented on a photographic print (or drawing) into a digital form for entry into the host computer. When the tablet is set to point-mode, a single XY co-ordinate pair is sent from the tablet when the cursor button is pressed; stream-mode provides a continuous flow of co-ordinates while the cursor is within the active area. The resolution of the tablet is about 350 points/in. (0.07mm or 0.0028in.) allowing a digitising accuracy of ±0.254mm (±0.01in.) nominal over the active area.

The GRAPHTEC KD3300 tablet has an effective digitising area of 305 x 305mm (12 x 12ins.) and an effective digitising height of up to 5mm (0.19in.). The four-button cursor can be used to send co-ordinates to the host computer in either point or stream mode. The resolution of the tablet is 0.1mm (0.004in.) giving a digitising accuracy of ±0.5mm (±0.02in.).

A simple test devised to quantify the point error introduced during digitisation has been undertaken (see Section 5.2.3) using the TEKTRONIX 4957 tablet, and an average digitising accuracy of 0.30mm.
(0.12in.) confirmed, with a standard deviation of 0.15mm (0.06in.). The histogram below (Figure 41) shows the frequency of errors in both X and Y axes (mm).

REFERENCES:


FIGURE 41.
DIGITISING ACCURACY
PLATE 51.
TEKTRONIX 4111 TERMINAL
WITH 4957 TABLET
II. PHOTOGRAPHIC SYSTEM

The photographic system used for this work has comprised an OLYMPUS OM-3 body with OLYMPUS 'Zuiko' 35mm perspective-control lens (f2.8 63' [max. 83']) (Plate 52), mounted on a KENNET ENGINEERING 'Bembo Mk 2' tripod with a MANFROTTO 'Standard 029' 3-way tilt-pan head (Plate 53). In addition, the following lenses have been used for specific tasks, and have provided references for distortion tests undertaken, as referred to below:

SUPER-PARAGON PMC 28-50mm f3.5-4.5 ?' zoom lens.
TAMRON 35-70mm f3.5 CF Macro 64'-34' zoom lens.
VIVITAR MACRO FOCUSING 70-150mm f3.8 34'-16' zoom lens.

A number of photographic accessories have been found, by the author, to be of use during this work. In order to ensure horizontal and vertical alignment of subject in a composition, the camera body used was fitted with the OLYMPUS 'Checker' focusing screen. This screen is matt finished and provides a series of cross lines, forming a grid.

For viewing the image through the viewfinder from above the camera or to either side, the OLYMPUS 'Varimagni Finder' was found to provide easy usage, especially in confined situations. This viewfinder also magnifies the image for clearer viewing either by x 1.2 for the whole screen, or by x 2.5 for the central section only. A full dioptic correction range from -7 to +3 is also a feature of this item.

The results of the distortion tests undertaken on the sample lenses used by the author for architectural photography (see Section 5.2.1) are presented below as a series of graphs, representing displacement (mm) relative to the distance of the point from the origin on the resultant prints (mm) (Figures 42-46).
LENS DISTORTION
35mm (f2.8) SHIFT LENS
NORMAL POSITION

Distance from Origin (mm)

LENS DISTORTION
35mm (f2.8) SHIFT LENS
CLOSE-UP

Distance from Origin (mm)

FIGURE 42.
LENS DISTORTION
35mm SHIFT LENS
FIGURE 43.
LENS DISTORTION
35mm SHIFT LENS
FIGURE 44.
LENS DISTORTION
28-50mm ZOOM LENS

-169-
FIGURE 45.
LENS DISTORTION
35-70mm ZOOM LENS

-170-
FIGURE 46.
LENS DISTORTION
70-150mm ZOOM LENS
PLATE 52.
OLYMPUS OM-3 BODY WITH
OLYMPUS ZUIKO PERSPECTIVE-CONTROL LENS

-172-
Missing pages are unavailable
III. SURVEYING SYSTEM

Indirect dimensional control has been provided in a number of case studies using a TOPCON GTS-38 total-station theodolite, in conjunction with a HUSKY HUNTER field computer, and a KERN GKO-A automatic level. Direct measurements have been taken using a range of steel tapes and extending rods.
The following material has been written by the author during the course of this investigation, and reflects the development and application of computer-aided mono-photogrammetry, with personal views and opinions, held at the time of writing.


2. **MEMBERSHIP OF THE BUILDING CONSERVATION GROUP**

Current Membership of the Building Conservation Group is as follows:

**Building Surveyors Division** 209
**Quantity Surveyors Division** 68
**General Practice Division** 52
**Planning and Development Division** 21
**Land Agency and Agriculture Division** 46
**Students/Probationers** 61
**Total** 457

3. **CURRENT ISSUES AND INFORMATION**

While it is generally editorial policy to encourage the submission of items for Current Issues and Information in a brief, summarised form an exception to the rule follows. It was felt that the article by David S Watt was of such value and significance that it would have been wrong to attempt to shorten or abbreviate it.

1) **COMPRESS-AGED PHOTOGRAHY: AN ALTERNATIVE METHODOLOGY FOR RECORDING BUILDING ELEVATIONS?**

**ABSTRACT**

As increasing demand for accommodation and cultural recreation continues to deplete our stock of existing heritage buildings, greater attention is justly being given to recording the fabric and contents before such things are lost or altered. Accurate dimensional information relating to the actual building structure and fabric plays an important part in creating such archives, as well as for projects involving conversion, restoration or programmed repair. Research into the development and application of computer-aided photogrammetry for architectural survey has produced useful results, enabling indirect measurement using 'simple' photography. This paper examines the potential and current methodology for surveying applications.

1. **INTRODUCTION**

For the purposes of accurately representing the elevations of a building as a prelude to repair or rehabilitation, or for the production of an archive record, a number of techniques can be relied upon to produce acceptable results. The question of what is 'acceptable' is largely dependent upon the nature of the elevation to be recorded and what use is to be made of the completed record.
It is therefore, essential for careful consideration to be given at the earliest possible stage to the various factors which should determine the selected method of recording. These can be summarized as being:

<table>
<thead>
<tr>
<th>Building Height</th>
<th>Location Access</th>
<th>Budget Speed of response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>Orientation</td>
<td>Degree of accuracy</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Obstruction</th>
<th>Surface Articulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation</td>
<td>Intricacy of detail</td>
</tr>
<tr>
<td>Outbuildings</td>
<td>Repetitive features</td>
</tr>
</tbody>
</table>

The basic recording techniques in present use have not altered to any great extent from those used by the surveyors and measurers of the eighteenth century. Advances have been made, however, with the recent application of technologies to produce a series of complimentary surveying and recording procedures. These are often wrongly viewed as being viable only for specific surveying problems, and to a great extent remain misunderstood.

At its simplest, the use of rod and tape is suitable in a number of situations where access is unrestricted and limited heights are encountered. In the latter case, the counting of brick courses remains a much-use stand-by. For more accurate recording of elevational detail, the archaeologists' string grid secured to the surface can yield respectably accurate results when manually scaled and plotted from a position directly in front of the grid. It is, however, time-consuming and inappropriate in the majority of conventional building surveys.

Remote surveying techniques in the form of photographic recording and scaling have a number of advantages over those requiring direct physical contact. Photocopy enlargements of photographs provide graphic representations which can be marked-up for repair works. This is a technique which, at the lowest order of accuracy, provides adequate results from the minimum of specialised equipment other than the usual office camera photocopier. What it cannot do with any degree of accuracy is give scaled representations, save through the inclusion of a level staff or other clearly graduated scale in the composition.

Rectified photography (also termed photo-mosaic, photo-montage, photo-drawing or square-on photography) can produce elevational records to a conventional scale, allowing judicious scaling-off and marking-up for works of repair. Problems of scale-change and variable displacement, however, render this technique inappropriate in certain cases, although greater use could be made in a number of projects.

Presently the most accurate accepted method of elevational recording is that of close-range photogrammetry. The basic requirement is a stereo-pair of photographs which can be viewed stereoscopically to create a three-dimensional optical model of the facade. This can then be interrogated to provide both two - as well as three-dimensional information for numerical output or direct line plotting. Such a precise recording technique has a number of architectural applications, providing profiles and contours, as well as conventional orthographically-projected plans, sections and elevations.
2. COMPUTER-AIDED ARCHITECTURAL PHOTOGRAMMETRY

The techniques available for elevational recording are generally understood by those who are involved in extensive recording programmes. Particularly with projects involving full analytical survey, the requisite expertise is usually available. For those involved with buildings of less significance, however, which do not attract the funds for specialist techniques, the need exists for a robust alternative which provides acceptable results with a minimum of capital expenditure and training, and yet is capable of responding to a variety of survey applications.

A technique which brings together the basics of photographic surveying and computer-aided draughting (CAD) might not, at first sight, appear to represent a particularly obvious solution. Both facilities are becoming widely established in their own right, yet together they offer the potential for a versatile alternative recording system. In principle, the use of photography for dimensional analysis forms the basis for all photogrammetry, allowing a distinction to be made between the direct measurement of an object and the indirect measurement of a photographic image.

The development of this method, termed computer-aided photogrammetry (CAP), has more in common with the manual interpretation of survey data found with traditional recording practice than in the more exclusive techniques. As such, the information may be collated by the person(s) involved with the practicalities of the project and who is ideally suited to judge what should be recorded. There need be no reliance on external operators who are often ill-equipped to make critical decisions.

What must be reconciled at an early stage in any recording programme is the level of accuracy that is actually required to achieve satisfactory end results. Close-range stereo-photogrammetry, for all its unique attributes, provides a level of accuracy which is often beyond practical necessity. Not only is this a case of overplus, but also a severe drain on an often-resisted budget. The accuracy attainable with computer-aided architectural photogrammetry (CAAP), based on a 35mm photographic system and existing CAD software, is comparable with that of rectified photography, typically 10 in 1000 or 1% scale error. This compares with 1 in 1000 or 0.1% scale error possible with close-range photogrammetry.

3. PRACTICAL RECORDING

The three stages on which the method is based, site photography, image restitution and dimensional control, can be considered to a certain extent as separate parts, although in practice each feeds into the other.
The input of data is based on manual digitisation using photographic prints which are taken square-on to the face of the building. No scale adjustment is made at the photographic stage. Dimensional control is taken on site by manual or electronic methods, and subsequently used to magnify the digitised image to the correct scale. This allows a series of digitised 'bays' to be quickly aligned and composed to form a complete elevational record. The rectification of oblique photographic images is performed analytically, with manual digitisation based on a set of mathematically-determined coordinates.

The completed record can be plotted to any scale or presented as photographic prints taken directly from the monitor screen, taking advantage of the extensive colour palette and mixing facilities available with the CAD software.

4. PRACTICAL APPLICATIONS

A large number of the recording tasks carried out to date have been to produce stone-by-stone elevation drawings for use as the basis for programmed repair and/or consolidation contracts. As well as domestic-scale buildings, similar drawings have been prepared for a 50m long five-arch viaduct, an octagonal gazebo, and a five-bay church aisle shoeing both internal and external deformation patterns. The standard of survey which is possible can be seen in the principal elevation to the seventeenth-century Bagshaw Hall in Bakewell (Derbys).

In response to the need for full analytical survey, similar elevational records can provide a useful base for representing external evidence for the sequential phases of construction, including changes in material, bonding patterns and component sizes. The south elevation of Lacock Abbey (Wilts.) provides a useful case for depicting previous roof pitches and blocked openings.

The potential also exists for archaeological survey of standing buildings with the calculation of numbers and areas of specific stone types within a subject elevation for construction analysis and petrological evaluation. For a more usual building-surveying application, the Kirby and West Building in Leicester presents a faience-clad facade of four distinct colours. A completed Data Management survey on the elevation gives the following information:

<table>
<thead>
<tr>
<th>Material Specification</th>
<th>Numbers</th>
<th>Area (sq.m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black (base)</td>
<td>159</td>
<td>26.54</td>
</tr>
<tr>
<td>Blue (surrounds/lettering)</td>
<td>615</td>
<td>69.77</td>
</tr>
<tr>
<td>White (remaining face)</td>
<td>752</td>
<td>83.25</td>
</tr>
<tr>
<td>Green (window aprons)</td>
<td>23</td>
<td>6.24</td>
</tr>
<tr>
<td>Repairs (plastic repair)</td>
<td>2</td>
<td>0.31</td>
</tr>
<tr>
<td>Openings (hatched)</td>
<td>18</td>
<td>81.59</td>
</tr>
<tr>
<td>Total (excl. openings)</td>
<td>1551</td>
<td>186.11</td>
</tr>
</tbody>
</table>

5. CONCLUSION

A wide variety of building types have been recorded using computer-aided photogrammetric (CAP) techniques, with both architectural and archaeological applications. The benefits to be derived over other forms of dimensional survey can include simplicity, flexibility and cost.
SCALE 1:104
JANUARY 1989
PRINCIPAL ELEVATION, BAGSHAW HALL, BAKEWELL, DERBYSHIRE
The potential for specific architectural survey is considered to be wide, with the attraction of being based on low-cost established technology.

Computer restitution of remotely-recorded dimensional data from existing built fabric, including entire elevations and detail, forms part of an on-going investigation into an integrated approach for computer-assisted building survey and representation.

The problems posed by recording projections and recesses within a single-plane elevation, and multi-plane facades, present a challenge which forms the basis for present work, with the continuing aim of further developing an alternative recording methodology with practical appeal for those professionals responsible for the national built heritage.

* * * * * *

APPENDIX

Leicester CAD Centre, based in the Polytechnic's School of the Built Environment, has developed a multi-disciplinary approach to the recording of existing buildings and sites, with a recognised expertise in the production of three-dimensional digital building models.

The Centre is equipped with a DATA GENERAL 32-bit computer, driving TEKTRONIX colour terminals, supporting the GABLE 4D SERIES building-modelling system. Surveying is undertaken using a TOPCON GTS-3B total-station theodolite, in conjunction with a HUSKY HUNTER field computer. The photographic system used for the work outlined in this paper comprises: OLYMPUS OM-3 body; various lenses including an OLYMPUS ZUIKO 35mm perspective-control lens; KENNELL ENGINEERING 'BEMBO' tripod with MANFROTTO 3-way tilt-pan head.

ii) SASH WINDOWS

INTRODUCTION

Whether English Heritage were told or had a premonition it is not clear but it is a fact that within a short time of the drafting of the following brief note on the history of the Sash Window, HBICE were circulating a Listed Building Guidance Leaflet on this actual subject. The Commission leaflet provides very useful advice on the design and maintenance of this important joinery feature and should be seen as a necessary complement to the references mentioned at the end of the brief historical background given below.

A BRIEF HISTORICAL BACKGROUND

Until the later decades of the 17th century windows in English houses usually comprised rectangular panes of glass set in lead with hinged opening casements in wrought iron frames, the whole fixed within large openings sub-divided by heavy wood or stone mullions and transoms. From the 1670's onwards a totally new pattern of window was introduced. This was the sash window otherwise known as the double hung, vertical sliding or boxed sash. Believed to have originated in Holland, very early examples were fitted at Chatsworth according to its historian Francis Thompson (quoted in Clifton Taylor). The window type was quickly adopted by owners, a trend no doubt accelerated by their insertion at Royal Palaces.
COMPUTER-AIDED MONO-PHOTOGRAMMETRY: A COMPLEMENTARY TECHNIQUE FOR
ELEVATIONAL RECORDING BASED ON SIMPLE PHOTOGRAPHY AND COMPUTER-AIDED
DRAUGHTING.

DAVID S. WATT
BSc (Hons) Building Surveying
Dip Arch Cons (Leic)

Research Assistant
Leicester CAD Centre
Leicester Polytechnic
Leicester LE1 9BH

INTRODUCTION

It is with some trepidation that I face such a distinguished audience today to present a paper concerned with a recording technique having, at its heart, the philosophy, if not the mechanics, of established architectural photogrammetry.

Having taken as my point of reference the definition of photogrammetry offered by Arnold et al (1971, 387) as being 'dimensional analysis from photographs', I have been concerned to present a means by which the façades of buildings, monuments and other structures might be recorded to an acceptable degree of accuracy for the purposes of alteration, consolidation or repair. This has been achieved, with some success, through combining the virtues of a non-metric 35mm photographic system and current computer-aided draughting (CAD) facilities.

Working with others having responsibilities for the care and utilisation of historic buildings and monuments, it has become apparent that, whilst stereo-photogrammetry has earned its place as the recording technique par excellence, there are occasions when alternative methodologies deserve consideration.
There are many buildings presently being recorded, for one reason or another, that do not justify the rigorous approach of a photogrammetric survey. This may be for reasons of size, simplicity of form, or economics. It is here that a complementary technique can be of benefit to architects, or archaeologists, in providing a solution suited to the particular task.

**COMPUTER-AIDED MONO-PHOTOGRAMMETRY**

In architectural photography, the limitations of a central projection are understood to be image displacement and scale change due to variations in depth, varying scale when the image plane and façade are not parallel, and inaccuracies due to the photographic system in use (Dallas, 1980, 396). It is possible with care and thought to avoid or reduce these to a point where the resulting photographic record can be of use, either as a source for interpretation, or printed to scale as a rectified photograph. It may also provide the necessary data for restitution based on manual digitisation.

This, then, forms the basis for a technique that I have termed computer-aided mono-photogrammetry: computer-aided because it is based on the skills and judgement of the person involved, and mono-photogrammetry because there is no reliance on three-dimensional imaging.

The actual technique is relatively straightforward, in as much as no specific training is necessary, or elaborate equipment required. It is, therefore, capable of being applied by the architect or archaeologist in-house, for a variety of uses. It is not just buildings that may be recorded: Fig. 1 shows a section of terracotta balustrading, recorded as a comparative exercise with hand survey.

Photographs are taken using an amateur camera, set up on a tripod with the film plane vertical and level, and aligned, using a gridded screen, so as to be parallel to the façade. For most work a medium-speed black and white film (Ilford FP-4) has been used, printed on to standard
The complexity of the dimensional control taken is related to the nature of the façade itself. It may, therefore, range from simple taped horizontal and vertical distances between specific features, to two-point theodolite intersection on to survey markers.

Presently, the photographic image is manually digitised, providing, in itself, an opportunity for editing the information. Repetitive features may be repeated as desired, and colour lines or fill used to identify certain features. The completed digitised image is magnified by the respective X- and Y-axis factors, so relating the digital file to the dimensional control. Fig. 2 demonstrates the flexibility of presentation that may be achieved using CAD.

The possibility of scanning data directly from the photographic print, or negative, is being investigated, as is the ability of improving the image by applying various 'masks' to enhance contrast and delineate edges through using image-processing routines.

There are obviously many aspects of this methodology that introduce distortions of one sort or another. This is a recognised limitation of the technique, and the equipment used, and all that is being attempted is to acknowledge their presence and minimise the effects.

The products of lens aberrations have been considered, and the incidence of distortion examined. A regular 50 x 50mm plotted grid has been photographed with a sample number of lenses, the grid intersections digitised and, using the graphic capabilities of the CAD system, displacement of the points related back to a central origin. In this manner, by using the CAD system as a mono-comparator, as per Adams (1981, 57), it has been possible to compare lens-distortion characteristics graphically. As a general rule, only the middle fifty per cent of a photographic print is thus used for digitising.

In order to present a photographic image that does not suffer from the convergence of vertical lines, a perspective control or 'shift' lens
has been utilised, although lens-distortion tests have shown a greatly increased displacement of points as the lens is shifted from its 'normal' position.

Where projections and recesses occur within the main plane of the façade, separate dimensional control is taken to allow these secondary planes to be scaled individually and brought together with the remaining digitised image. Curvature and tapering elements cannot obviously be recorded in this way.

Where it has not been possible to obtain photographic coverage square-on to a façade, oblique views have been analytically rectified using a simple transformation program based on the construction of a notional control grid (Haigh, 1988). Similar work has been undertaken by Mooney (1988), and applications for archaeological survey noted by Williams (1986).

The possibility of restituting information from archive sources has been investigated, and an oblique photographic view, taken from a print dated 1861, has provided the source material for a recent archaeological recording of a section of high-status Romanesque masonry (Watt, 1989c), as part of an archaeological survey. Fig. 3 shows the rectified wall file, in the context of the present cellar arrangement.

A small, but varied, sample of building façades has been recorded to determine the practical capabilities and limitations of this technique. Within this paper it is not possible to consider each case in turn. I have thus chosen three differing projects to illustrate the methodology employed, and the standard of final output.

PRACTICAL APPLICATIONS

MANSFIELD. King's Mill Viaduct, Nottinghamshire.

This structure, dated 1817, represents an important example of pre-locomotive architecture, and is thus protected as a scheduled
ancient monument and listed building. Plan and elevation drawings were requested, the latter showing individual stones and pattress plates.

Due to the angled position of the viaduct across the river, square-on photography was readily attainable for the upstream elevation, the downstream requiring a selection of photographs from the river bank further down using a telephoto lens. Obstruction due to trees and other vegetation also necessitated this fragmented coverage.

Dimensional control was taken using steel tape and rod for each arch, with a check on total length provided as part of the plan survey. The projection of the pilasters was deemed to be insignificant in terms of displacement and scale change.

Once all arches had been photographed, digitised and magnified to scale, they were brought together to provide a continuous elevational record, plotted at 1:50 as a reference drawing, and 1:20 as the basis for identifying individual stones for replacement and repair. Overall scale accuracy was considered to be ±50mm. Fig. 4 shows the general elevational record for this structure.

LEICESTER. Jewry Wall, Leicestershire.

The remains of what was once a Roman public bath include a 7.3m high section of typical masonry with layers of local freestone bonded by Roman bricks. Part of this wall formed the subject for a petrological analysis undertaken by the local museum geologist.

As an early study, this represented a first attempt at individual stone recording. Due to the irregular nature of the masonry, identification of joints proved difficult, some being obscured by shadow and others proving to be cracks.

Although each shape represents a stone, the exact profile has not been approached. Given time, a greater accuracy in this respect would be attainable.
The nature of the CAD system used is such that the completed digital file may be interrogated to determine the number and area of the various stone types, based on individual colour or hatch specifications (Fig. 5). This has proved of interest for archaeologists concerned with understanding the distribution patterns of salvaged building materials. The data analysis is reproduced below.

<table>
<thead>
<tr>
<th>Material Specification</th>
<th>Numbers</th>
<th>Area (sq.m.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay tile</td>
<td>159</td>
<td>1.95</td>
</tr>
<tr>
<td>Igneous from S-W Leics.</td>
<td>175</td>
<td>3.40</td>
</tr>
<tr>
<td>Mountsorrel granodiorite</td>
<td>76</td>
<td>1.66</td>
</tr>
<tr>
<td>Charnwood slates</td>
<td>83</td>
<td>1.93</td>
</tr>
<tr>
<td>Triassic sandstone</td>
<td>25</td>
<td>0.35</td>
</tr>
<tr>
<td>Liassic mudstone</td>
<td>80</td>
<td>1.60</td>
</tr>
<tr>
<td>Millstone grit</td>
<td>1</td>
<td>0.23</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>599</strong></td>
<td><strong>11.12</strong></td>
</tr>
</tbody>
</table>

**AYLSHAM, Market Place, Norfolk.**

As an exercise in streetscape recording, this project provided an opportunity for illustrating a series of façades, documenting the importance of proportion and graining in the context of historic fabric (Fig. 6). It would be possible, given the nature of this technique, to demonstrate the visual impact of a proposed infill development, by inserting the new façade in the context of adjacent properties.

Simple horizontal and vertical control dimensions were taken for each unit, allowing most to be easily scaled. Two façades required several photographs to be taken, due to the close proximity of adjacent buildings. These provided sufficient information for a constructed elevational record.

Given a clear site, the measurements and photographs took seventy-five minutes. Digitising, magnifying and plotting took a total of ten working days. It would be interesting to learn how this compares with established methods of survey.

-192-
These case studies represent practical applications for computer-aided mono-photogrammetry, where each did not require highly-accurate plots, but rather reliable representations, offering a solution for a particular task.

SUMMARY AND CONCLUSIONS

Over the past two years, case studies have ranged in size and complexity from an individual doorcase to a portion of a cathedral. These have provided the framework on which to build, ensuring a spread of survey problems requiring various approaches to data capture and dimensional control.

As the technique stands at the present time, it is capable of providing useful results, to an accuracy suitable for specifying works of repair and consolidation (Watt, 1989a; 1989b). There are deficiencies inherent within the methodologies employed; these have been identified and, where possible, alternative strategies implemented.

The future of this work lies, it is felt, in improving aspects of data capture and input. Whether there are benefits to be gained from using a larger-format photographic system, such as a monorail view camera, remains untested. It is felt that 35mm photography, whilst having obvious restrictions, does represent a versatile tool with which more might be gained. Recent work by Brooke (1987) demonstrates the flexibility of this form of photography in relation to ground-based archaeological remote sensing.

Manual digitising is, as stated earlier, open to error and operator judgement. Accuracy is typically to 0.2mm. Attention is currently being given to scanning photographic images, but it is early days yet. The present work may, at least, have provided the initial stimulus, and established a manual protocol, for further developments.

Aside from the recording of building façades, staff at the Leicester CAD Centre have focused research activities on practical applications
for CAD in architectural and archaeological surveying. This has concentrated so far on development modelling, site survey/digital ground modelling, and building survey/computer modelling.

This approach has advantages for recording and analysing the structure and fabric of existing buildings, in their surroundings. It is in this context that we see our strengths, and opportunities, for future research and development.

Whilst stereo-photogrammetry remains, without doubt, the most appropriate solution for complex architectural recording, there are, within the field of understanding and conserving our cultural heritage, opportunities for relating and integrating different methods of surveying, as complementary tools, for the benefit of all.

I hope that the architectural photogrammetric community considers the work outlined in this paper to be a useful contribution to this discussion.

REFERENCES AND APPENDIX


Leicester CAD Centre is equipped with a DATA GENERAL 32-bit computer, driving TEKTRONIX colour terminals, supporting the GABLE 4D SERIES building-modelling system. Surveying is undertaken using a TOPCON GTS-3B total-station theodolite, in conjunction with a HUSKY HUNTER field computer. The photographic system used for the work outlined in this paper comprises: OLYMPUS OM-3 body; various lenses including an OLYMPUS ZUIKO 35mm perspective-control lens; KENNERT ENGINEERING 'BEMBO' tripod with MANFROTTO 3-way tilt-pan head.
Figure 1: Terracotta balustrading recorded as a comparative exercise with hand survey.

Figure 2: An elevational record of an octagonal gazebo, showing the flexibility of presentation achieved through using CAD.
Figure 3: Two-dimensional record of subject wall set in the context of a three-dimensional model.

WEST ELEVATION (UP-STREAM)

EAST ELEVATION (DOWN-STREAM)

Figure 4: Individual stones recorded for repair
Figure 5: Petrological survey undertaken as part of work on Roman wall.

Figure 6: Historic town fabric recorded in a manner suitable for visual impact analysis.
Abstract

In order to record a building or structure in its entirety, it is necessary to resolve the varying problems inherent in accurately measuring and recording the façades. Current techniques range from the use of conventional tape and rod, through to close-range photogrammetry. These methods are heavy in the use of time and equipment, and this has led to a demand for a middle-range system of surveying that requires a minimum of specialist equipment and training, and yet is capable of accurately representing complex fabric by way of a base elevational drawing for a variety of tasks, including alteration, conversion and refurbishment. Research into the development and application of computer-aided mono-photogrammetry for architectural survey has produced useful results, enabling indirect measurement using 'simple' photography. This paper examines the potential and current methodology for archaeological survey.

1. Introduction

The growing reliance being placed on existing buildings to satisfy demands for accommodation and cultural recreation has undoubtedly played an important part in forcing the initiation and maintenance of
programmed building records. As Kerr (1989) points out, this emphasis on recording comes as a direct response to an awareness of the future, engendered by experiences of the past. What must be of concern now, therefore, is how to meet this charge in a controlled and effective manner.

Any response requires resources, both in terms of skilled personnel as well as equipment. For the purposes of recording dimensional data from the façades of buildings, monuments and other structures, there are several techniques that have become established in practice. The three most widely applied are, in ascending order of complexity, hand survey, rectified photography and close-range photogrammetry.

Whilst it is true that each of these recording methodologies can provide a means to a particular end, it is important that they are considered as complementary to one another, rather than adopted as a standard solution or as a last resort for a particular survey problem. The success or failure of a recording programme, certainly in terms of failed expectations, is ultimately related to the understanding and selection of the appropriate technique or set of techniques. To take as an example the recording of Brougham Castle (Cumbria) by the Cumbria and Lancashire Archaeological Unit, hand survey, rectified photographic infill within a photogrammetric outline, computer-rectified oblique photography, and close-range photogrammetry were employed with varying degrees of success (Williams, 1986).

Perhaps more than any other consideration in a programme of recording, it is crucial that user requirements are fully understood before selection of a particular technique is made. Far too often records are produced without a clear understanding of how the completed image is, and potentially could be, used. This applied not only to elevations, but plans as well. In both of these areas, some of the most important factors for consideration in a given project are held to include:
The techniques available for elevational recording are generally understood by those who are involved in extensive recording programmes. Particularly with projects involving full analytical survey, the requisite expertise is usually available. For those involved with buildings of less significance, however, which do not attract the funds for specialised techniques, be they archaeologists, architects or building surveyors, the need exists for a robust alternative that provides acceptable results with a minimum of capital expenditure and training, and yet is capable of responding to a variety of survey applications.

A technique that brings together the basics of photographic surveying and computer-aided draughting (CAD) might not, at first sight, appear to represent a particularly obvious solution. Both facilities are becoming widely established in their own rights, yet together they offer the potential for a versatile alternative recording system. In principle, the use of photography for dimensional analysis forms the basis for all photogrammetry, allowing a distinction to be made between the direct measurement of an object and the indirect measurement of a photographic image.

The development of this method, termed computer-aided mono-photogrammetry, has proved to have certain applications with the archaeological recordings of standing buildings. In principle, it has more in common with the manual interpretation of survey data found with traditional recording practice than in the more exclusive techniques.
As such, the information may be collated by the person(s) involved with
the practicalities of the project, who is ideally suited to judge what
should be recorded. There need be no reliance on external operators
who are often ill-equipped to make critical decisions.

What must be reconciled at an early stage in any recording programme is
the level of accuracy that is actually required to achieve satisfactory
end results. Close-range photogrammetry, for all its unique
attributes, provides a level of accuracy that is often beyond practical
necessity. Not only is this a case of overplus, but also a severe
drain on an often-restricted budget. The accuracy attainable with
computer-aided mono-photogrammetry, based on a 35mm photographic system
and existing CAD software, is comparable with that of rectified
photography, typically $10 \text{ in } 1000$ or $1\%$ scale error. This compares
with $1 \text{ in } 1000$ or $0.1\%$ scale error possible with close-range
photogrammetry.

3. Practical recording

The three stages on which the method is based, site photography, image
restitution and dimensional control, can be considered as separate
parts, although in practice each feeds into the other.

3.1. Site photography

The aim of developing a methodology for easy application has been
exercised by the use of a 35mm photographic system for all site
photography (Watt, 1989). Although metric photography forms the basis
for most photogrammetric recording, the standard of accuracy achieved
with regard to image distortion is often unnecessarily high for
architectural/archaeological applications. In practice, non-metric
photography can provide adequate results (Dallas, 1980, 92 and 112).

The use of a perspective-control (or 'shift') lens, despite popular
misconceptions, has only limited usefulness, and has been shown through
distortion tests carried out by the author to present a considerable
increase in displacement relative to a central origin. As a rule-of-thumb for all lenses used, only the middle 50% of any photographic print is digitised in order to avoid the effects of barrel or pincushion distortion.

In order to reduce the effects of converging verticals, a highly-manoeuvrable tripod and step-ladder is used to achieve a maximum height of 2700mm. Where access is restricted, square-on photography has proved possible using a telephoto lens to provide a large-scale photographic mosaic. The rectification of oblique photographic images is performed analytically, with manual digitisation based on a set of mathematically-determined co-ordinates.

All recording is carried out using black and white photography, with the occasional use of colour filters for specific image enhancement. Specialist films have not, at present, been employed, although their practical usefulness has already been assessed by Brooke (1987a; 1987b).

3.2. Image restitution

In order to transfer the data from the photographic print into the CAD system, the image is manually digitised using the various elements provided by the particular software to build up the elevation. Although this is often laborious, it allows the information to be edited as the work proceeds, with the requisite architectural/archaeological input. Accuracy in digitising is typically to ±0.2mm. Where possible, elements or groups of elements can be repeated in order to reduce computer time, although its extent must be clearly defined both before digitising commences and afterwards as a note on the final drawing.

Digitised information is usually two-dimensional in nature, although three-dimensional digital input can be achieved, depending on the software and suitable dimensional control. This flexibility in orthographic and metric projection is especially useful when recording a façade with definite breaks between the various planes.
Once the digitisation is complete, the image is then magnified to fit with the dimensional control. Output can be as line plots to any scale or as photographic prints taken directly from the monitor screen. The software used for this work has an extensive colour palette with a facility for altering the hue, lightness and saturation, so allowing the creation of an individual colour map for specific applications.

3.3. Dimensional control

The purpose of the dimensional control is to allow the digitised image to be magnified to its true scale. Unlike rectified photography, the photographic printing scale is irrelevant, although the magnification factor should ideally be as small as possible to avoid unnecessary digitising error. Horizontal and vertical control can be achieved in a number of ways, depending on the complexity of the façade and the presence of physical obstructions.

Typically for a two-storey single-plane gable wall, one taped horizontal dimension across the face and one vertical dimension from a known datum would suffice. For a complex façade where a series of adjacent digitised photographs would be magnified and brought together to form a continuous elevational image, control might consist of a series of levels taken to establish a datum, and theodolite intersection on to survey markers to provide a dimensional framework within which to work. In order to locate specific features, it is often practicable to record $X$ and $Y$ co-ordinates on a specified plane in a form of digital mapping.

4. Practical applications

A large number of the recording tasks carried out to date have been to produce stone-by-stone elevational drawings for use as the basis for programmed repair and/or consolidation. As well as domestic-scale buildings, similar drawings have been prepared for a 50m long five-arch viaduct, an octagonal gazebo, and a five-bay church aisle showing both internal and external deformation patterns. The standard of survey
that is possible can be seen in the principal façade to the seventeenth-century Bagshaw Hall, Bakewell.

In response to the need for full analytical survey, similar elevational records can provide a useful base for petrological analysis. Work on part of the Jewry Wall in Leicester has resulted in a colour-coded petrological record suitable for publication or display purposes. A hatched version of this file demonstrates the flexibility for such an application.

The potential is also present for calculating areas and numbers of specific stone types within a particular elevation. This again provides a useful tool for analysing stone assignment, as with the distribution of Roman stone out of York into its hinterland, which is presently being investigated at the University of Sheffield's Department of Archaeology and Prehistory (Buckland, 1988). A completed Data Management survey on part of the Jewry Wall, referred to above, gives the following information:

<table>
<thead>
<tr>
<th>Material Specification</th>
<th>Numbers</th>
<th>Area (sq.m.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay tile</td>
<td>159</td>
<td>1.95</td>
</tr>
<tr>
<td>Igneous from S-W Leics.</td>
<td>175</td>
<td>3.40</td>
</tr>
<tr>
<td>Mountsorrel granodiorite</td>
<td>76</td>
<td>1.66</td>
</tr>
<tr>
<td>Charnwood slates</td>
<td>83</td>
<td>1.93</td>
</tr>
<tr>
<td>Triassic sandstone</td>
<td>25</td>
<td>0.35</td>
</tr>
<tr>
<td>Liassic mudstone</td>
<td>80</td>
<td>1.60</td>
</tr>
<tr>
<td>Millstone grit</td>
<td>1</td>
<td>0.23</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>599</strong></td>
<td><strong>11.12</strong></td>
</tr>
</tbody>
</table>

It is also possible to map the external evidence for the sequential phases of construction, including changes in material, bonding patterns and component sizes. The south façade of Lacock Abbey (Wilts.) provides an useful case for depicting previous roof pitches and blocked openings.
5. Conclusions

A wide variety of building types have been recorded using computer-aided mono-photogrammetric techniques, with both architectural and archaeological applications. The benefits to be derived over other forms of dimensional survey can include simplicity, flexibility of presentation and cost.

The potential for specific archaeological survey is considered to be wide, with the attraction of being based on low-cost established technology. Evidence for the broad appeal of this form of recording is evidenced by the author's involvement in the preparation of a stone-by-stone record of part of a Romanesque cellar using an oblique archive (1861) photograph (Watt and Ashton, 1988).

Computer restitution of remotely-recorded dimensional data from existing built fabric, including entire façades and detail, forms part of an on-going investigation into an integrated approach for computer-assisted building survey and representation.

The problems posed by recording projections and recesses within a single-plane façade and multi-plane façades, present a challenge which forms the basis for present work, with the continuing aim of further developing an alternative recording methodology with practical appeal for those professionals responsible for the national built heritage.

Acknowledgements

Thanks are given to David F. Oulsnam of Oulsnam Bradbury Design Partnership and R. A. Rutland, Keeper of Archaeology at the Jewry Wall Museum, for their kind permission to reproduce the files for this paper.
References


WILLIAMS, J.H., 1986, 'Brougham Castle', Synopsis of a paper given at the University of Lancaster, Department of Archaeology. (Not published).

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Leicester CAD Centre, based in the Polytechnic's School of the Built Environment, has developed a multi-disciplinary approach to the recording of existing buildings and sites, with a recognised expertise in the production of three-dimensional digital building models.

The Centre is equipped with a DATA GENERAL 32-bit computer, driving TEKTRONIX colour terminals, supporting the GABLE 4D SERIES building-modelling system. Surveying is undertaken using a TOPCON GTS-3B total-station theodolite, in conjunction with a HUSKY HUNTER field computer. The photographic system used for the work outlined in this paper comprises: OLYMPUS OM-3 body; various lenses including an OLYMPUS ZUIKO 35mm perspective-control lens; KENNETT ENGINEERING 'BEMBO' tripod with MANFROTTO 3-way tilt-pan head.
THE USE OF NON-METRIC PHOTOGRAPHY IN COMPUTER-AIDED MONO-PHOTOGRAMMETRY

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INTRODUCTION

At the present time much of the architectural stereo-photogrammetry undertaken makes use of 'metric' cameras. These specialised instruments possess several characteristics over and above those expected in an amateur or 'non-metric' camera, such that the relationship between camera body and lens is fixed and stable. The main features of a metric camera are that the value of the principal distance is accurately known; the principal point can be located, usually by the intersection of lines joining fiduciary marks placed in the focal plane; the lenses used possess high resolving power and limited distortion; and the film has minimal deformation.

On the question of photogrammetric semantics, it appears easier to define what constitutes a non-metric camera than what does not. Faig (1976) considers a non-metric camera to be 'a camera whose internal orientation is completely or partially unknown and frequently unstable', or else a camera that lacks fiduciary marks. Karara (1972) is less specific in his definition as 'one not designed especially for photogrammetric purposes'. It is, however, worth pointing out that the term 'non-metric' does not, according to Faig (1976), imply any quality statement and has, as such, nothing to do with accuracy, information content or other characteristics.
A large body of opinion has been generated on the question of non-metric photography in stereo-photogrammetry. In terms of accuracy, photogrammetrists have tended to believe that the various distortions produced by an unstable interior orientation preclude the use of non-metric cameras in close-range work.

For many applications, high orders of accuracy remain critical. In others, however, they are not required, and cannot be justified on the grounds of cost or necessity. Welch and Dikkers (1978) found that the accuracy attainable using a close-range analogue photogrammetric system based on a 35mm camera was sufficient for measuring dynamic landforms, and represented an improvement over results obtained using conventional field procedures.

Although this case is not related to architectural recording, it does indicate that non-metric photography can provide useful results, given the limitations imposed by such a choice. Dallas (1980, 92) makes the point that for the majority of architectural surveys, the high standards of accuracy attainable with the use of metric cameras are probably not needed. The most useful attributes for such work are, instead, good construction, reliability, light weight, flexibility and manoeuvrability.

In considering the practical implications of employing non-metric cameras, Torlegård (1976) finds that such usage can present both advantages and disadvantages for the photogrammetrist:

**Advantages**

(a) General availability  
(b) Flexibility in focusing range  
(c) Motor drive  
(d) Hand-held for simple orientation  
(e) Lower price

**Disadvantages**

(a) Lenses designed for high resolution at expense of high distortion  
(b) Instability of interior orientation
(c) Lack of fiduciary marks
(d) Absence of level bubbles and orientation provisions

Despite such disadvantages, Karara (1972) notes that use could be made of non-metric cameras in precise architectural stereo-photogrammetry, provided that they are appropriately calibrated, sufficient object-space control data is obtained in the form of target co-ordinates, distances and directions, and an analytical approach to data reduction is adopted.

At the present time, a number of 'partial-metric' cameras have become available which strive for a balance between the accuracies of metric cameras and the advantages of non-metric photography. Their use is considered by Dallas (1988), but only as an exception, rather than as a rule.

It can thus be concluded that for the foreseeable future, stereo-photogrammetry will continue to employ metric photography. It is, however, the case that developments in image restitution have made the use of non-metric and partial-metric photography feasible. Previously, non-metric cameras would have invariably caused problems that would be unacceptable to the photogrammetrist. The new generation of analytical plotters can achieve much with swung and convergent coverage, and there is now scope for the use of non-metric photography, in architectural photogrammetry.

DISTORTION CHARACTERISTICS OF EQUIPMENT

Consideration of the optical components on which photography for computer-aided mono-photogrammetry is based has been prompted by the use of simple or non-metric photography for data capture, in contrast to the metric cameras used in 'classical' architectural photogrammetry. The arguments for and against this have been covered above, but attention has been paid to the distortions that are inherent in the use of non-metric equipment.
The inability of a lens to render a perfect image of the subject is termed an aberration. This failing often occurs at the edges of the lens field, as light rays fail to converge to one focus. One of the most common aberrations is that of distortion, where straight lines at the edge of the field are caused to bend towards the lens axis.

Although the effects of lens aberrations are normally regarded as insignificant in conventional photography, it is considered important in this work to quantify such distortion in order to provide a check on all variables present within the recording and measuring process.

Thompson (1977) contends that the significant feature of distortion is the test of whether or not a straight line projects as a straight line. This can be assessed to varying degrees of accuracy through simple lens testing.

Cox (1974, 204) recommends that two plumb lines are photographed so that they lie at the edges of the field which the lens will cover. Where the image of the lines is concave, the lens suffers from pincushion distortion; where it is convex, then the lens suffers from barrel distortion. By comparing the increase or decrease in the width of the image against the total width of the picture, this distortion of the lens, expressed as a percentage at the corner of the field, can be calculated. Pincushion distortion is counted as positive and barrel distortion as negative using the equation:

\[
\text{Percentage distortion} = \frac{x}{b} \times \frac{a^2 + b^2}{ab} \times 100\%
\]

where:  
\[a = \text{width of picture}\]
\[b = \text{height of picture}\]
\[x = \text{increase or decrease in width of image}\]

Dallas (1982, 15) advocates the undertaking of a trial survey or 'office block' test for rectified photography to check the accuracy of the recording process, and, in particular, the degree of error present.
due to lens distortion. By photographing a modern flat-fronted office block, the horizontal and vertical lines of the building can be compared to a superimposed grid at both the negative and printing stages. Non-parallelism of these lines can be interpreted as misalignment of the camera in relation to the façade where the image appears as a trapezium. Where the image exhibits barrel or pincushion distortion, it is a product of the lens construction.

For the purposes of this work, a comprehensive test was devised to assess the amount of distortion inherent in the construction of a number of lenses based on a 35mm SLR photographic system. The intention of this series of tests was to record and quantify the amount of distortion suffered by a sample number of lenses in regular use for the photographic recording of architectural subjects. The results from these tests have been analysed to provide a figure for actual distortion and a graphical representation of relative distortion for each lens.

As this project makes extensive use of computer-aided design/draughting (CAD) facilities, these tests were designed to make use of the dimensional analysis characteristics present in such a system.

A 50 x 50mm grid was constructed and plotted at full-size, producing an A1-size regularly-gridded sheet. This was mounted and positioned so that it was vertical in plane and perpendicular to the floor surface, and photographed using the sample lenses on a standard tripod-mounted camera body. The taking-distance was varied to ensure complete coverage by the lenses, dependent upon their focal lengths, but centred on the grid.

It is important to note that the resultant distortion characteristics apply to the optics of the entire equipment. The lens manufacturers' nominal value for focal length, engraved on the lens, can usually be relied upon to within 1% or less (Cox, 1974, 32). For the purposes of these tests, the nominal values taken from the lenses have been assumed to be correct. Distortion introduced at the printing stage due to aberrations in the enlarger lens is taken to be negligible, being a
product of the standard of equipment used. Printing was on to resin-coated paper with a gloss finish in an attempt to minimise paper distortion due to changes in relative humidity, and to enhance image contrast.

Grid intersections were digitised from the resultant photographic prints, and the corresponding co-ordinates logged as relative to the central point of the grid. This is similar to the measurements made by Adams (1981) from negatives using a stereo-comparator in mono-comparator mode. Measurements of X-Y coordinates made by digitisation are subject, in themselves, to error. This, however, was found by Adams to be minimal, although the resolution is coarse in comparison with a photogrammetric stereo-comparator.

Assuming that image distortion increases with distance from the origin, the eight co-ordinates nearest to the origin were used to provide an idealised position and distance for each point relative to the origin. A statistically-correct location for each point was then calculated and used as reference for the actual co-ordinates determined.

For each lens at varying focal lengths, the deviations from true grid position were calculated and vector displacements plotted against the distance from the origin (mm). This relationship has been represented in a series of graphs as scatter points indicating relative displacement.

Hedgecoe (1980, 29) states that there is a limit over which a lens will project a sharp, distortion-free image and hence why lenses are designed for a particular format camera. Bearing this in mind, it can be stated that for each of the lenses tested, there is an optimum field of coverage, outside of which the image is subject to distortion. In practice, digitising is thus limited to an area within the middle fifty per cent of each print.
REFERENCES


WELCH, R. and DIKKERS, K., 1978, 'Educational and research aspects of non-metric, close range analogue photogrammetry', Photogrammetric Record, 9 (52), 537-547.

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-215-
PHOTOMETRIC POTENTIAL OF SMALL-FORMAT PHOTOGRAPHY

(a) Photographic system

The photographic system used in my work comprises an OLYMPUS OM-3 SLR camera fitted with an OLYMPUS 'CHECKER' gridded focusing screen; an OLYMPUS ZUIKO 35mm perspective-control or 'shift' lens, together with other fixed focal length and zoom lenses; an OLYMPUS 'VARIMAGNI FINDER' viewfinder; and a KENNETT ENGINEERING 'BEMBO MK 2' tripod with a MANFROTTO 'STANDARD 029' 3-way tilt-pan head.

This particular camera body has a spot-metering facility that enables easy field use in varying light conditions, and has been fitted with a gridded screen to facilitate alignment with a façade. The viewfinder has proved particularly useful when recording internal features or working in cramped locations.

Presently OLYMPUS have discontinued the above items in favour of supplying auto-focus equipment and the compact market, and prices are therefore not available. The BEMBO tripod is currently retailing at £121.00 and the MANFROTTO head for £42.00.

(b) Calibration

No calibration of the camera has been undertaken, nor any film-flattening device used. I have, however, attempted to identify the distortion characteristics of the various lenses used, and this has taken the form of a series of tests based on the relationship of grid intersections to a central origin. Attached are some notes concerning the methodology employed for this particular exercise (The Use of Non-Metric Photography in Computer-Aided Mono-Photogrammetry).

Given the nature of the photographic system, there are obvious restrictions to its use. In practice, digitising is limited to an area within the middle fifty per cent of each print in order to minimise the effects of distortion.
(c) Applications and conditions

All photography is of architectural subjects and is ground-based. Distortion tests for the perspective-control lens show a marked increase in relative displacement of points as the lens is 'shifted' from its normal position. For this reason I attempt to take all photographs from a position at mid-height to the façade, using either adjacent buildings or step-ladder.

The taking-distance from the face of the building is determined by framing the façade, or subject, within the central part of the view-finder. The camera is set up using the levelling bubbles built into the tripod head, and by aligning the screen grid to horizontal and vertical features, such as string courses, parapets and straight joints.

Internal photography is based on long exposures, bearing in mind the effects of reciprocity failure, with fill-in artificial illumination, where necessary.

A medium-speed black and white film, ILFORD FP4 (125 ASA), is used for most photographic recording, with printing on to resin-coated paper.

Colour filters have been used to enhance certain architectural materials and features, but with limited practical application.

(d) Practical usage

The photographic data is used in a technique of 'Computer-Aided Mono-Photogrammetry', where information is manually digitised from prints into a CAD system, scaled using dimensional control obtained on site by direct or indirect methods, and presented as line plots or colour images. This forms the basis for an investigation of practical recording methodologies, aimed at providing a reliable alternative for documenting physical interventions where high-order accuracy is not necessary.
Normal-case photography is relied upon for data capture, bearing in mind the limitations imposed by a central projection. For further flexibility, consideration has been given to using a larger-format mono-rail view camera. Analytical rectification of oblique data is currently under investigation.

(e) Standard of results

Given the limitations imposed by the methodology outlined above, satisfactory results have been obtained for practical applications. The scale accuracy of the work is typically to ±30-40mm, which is considered adequate for identifying particular features and detail for repair or consolidation.

The mechanics of data capture and image restitution are relatively simple and can be undertaken without specific training. This allows recording and documentation to be carried out in-house, giving an opportunity for acquiring a better understanding of the building, and reducing costs. This must, however, be qualified by saying that the technique is limited in its application, and can only provide a complementary tool for certain types of survey problem.

(f) Case studies and conclusions

These summaries of completed applications for 'Computer-Aided Mono-Photogrammetry' are made up of consultancy projects and research case-studies, some of which have been illustrated in papers and articles referred to below.

**Hawthorn Building, The Newarke, Leicester**

A simple doorway with regular detailing used to initiate development of photographic and digitising methodologies, and assess potential for mono-photogrammetric image restitution. Projection and curvature of elements considered problematic.
Scraptoft Hall, Scraptoft, Leics.
A single-plane façade with scope for repetition of elements, and concentration on fine detail.

Jewry Wall, St Nicholas Circle, Leicester
An opportunity to assess the potential for preparing stone-by-stone plots, specifically with an archaeological application.

St Mary and St Laurence's Church, Bolsover, Derbys.
Preparation of a stone-by-stone drawing of the subject wall for use in repair documentation.

Gazebo, Kelham Hall, Newark, Notts.
An octagonal structure with repetitive form and detailing. Problem of representing domed roof.

King's Mill Viaduct, Mansfield, Notts.
Large unconventional structure causing difficulties in photographic coverage. Extensive use made of the completed stone-by-stone drawings for repair documentation, including Scheduled Monument Consent.

Terracotta balustrade, Castle Ashby House, Northants.
Section of complex detailed balustrade completed as a comparison with hand survey.

Kirby and West Building, Western Boulevard, Leicester
A single-plane façade requiring fragmentary photographic coverage.

Market Place panorama, Aylsham, Norfolk
Streetscape involving numerous façades, each requiring individual photographic coverage and dimensional control.

Norman cellar, Guildhall Lane, Leicester
Opportunity to make use of archive photographic print, and program for analytical rectification of oblique digitised data. Three-dimensional digital model of cellar constructed with stone-by-stone wall in-situ.
South-west transept, Ely Cathedral, Cambs.
A large complex façade requiring extensive photographic coverage and advanced dimensional control by theodolite intersection on to predetermined points.

St John's Church, Ault Hucknall, Derbys.
Simple blocked doorway with carved typanum over used to demonstrate capability of producing accurate stone profiles and high level of detail.

Castle Precinct, Tickhill, S. Yorks.
Doorway with jamb stones, one half renewed. Exercise in producing accurate representation of stone profiles and high level of detail in carved panel over.

Lacock Abbey, Lacock, Wilts.
Outline drawing of south façade showing previous roof pitches and blocked openings, as an exercise in providing an accurate framework within which to supplement additional data.

Flacketts, Sudbury, Derbys.
Timber-framed façade, requiring a number of photographs to provide adequate coverage, undertaken as a comparison with hand-survey.

Grammar School, Hales Street, Coventry
Repair work to this mediaeval church requiring elevational drawings on a stone-by-stone basis.

REFERENCES


PAGES EXCLUDED UNDER INSTRUCTION FROM THE UNIVERSITY
HAWTHORN BUILDING, THE NEWARKE, LEICESTER

SCRAPTOFT HALL, SCRAPTOFT, LEICESTERSHIRE
THE GAZEBO, KELHAM HALL, KELHAM, NOTTINGHAMSHIRE

EYRE CHAPEL, NEWBOLD, CHESTERFIELD, DERBYSHIRE

Scale 1:30
Case Studies X & XI
Case Study XIV

NORMAN CELLAR, GUILDHALL LANE, LEICESTER

Scale 1:20

RECTIFIED VIEW SHOWING PRESENT WALLS

RECTIFIED VIEW

PERSPECTIVE VIEW OF CELLAR (NOT TO SCALE)
COMPUTER-AIDED MONO-PHOTOGRAFMETRY

HAND SURVEY

Scale 1:10

CHURCH OF ST MARY DE CASTRO, CASTLE STREET, LEICESTER

Case Study XVIII