

Minimum requirements for metric use of non-metric photographic documentation

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1 Introduction

Within the context of historic buildings conservation, the importance of documentation is well recognised¹. Photographic documentation is largely used but texts treating specifically of historic buildings documentation are very rare². There are numerous books on architectural photography³, but the aims of architectural photography and of architectural photographic documentation are not identical. In more general texts, recommendations are usually basic⁴ and less structured than those concerning metric documentation, even if there is an abundant use of illustrations and pictures.

At present, applicants submitting their case for listed building consents (LBC) are encouraged to use photographic documentation, together with plan and elevation drawings. But this is not compulsory and no guidance is given⁵ - and yet, photographs potentially contain much information that might be useful for the assessment of a situation and the formulation of a judgement for approval or rejection of proposed work.

Photographic documentation is rarely presented as a potential source of metric information. Technical guidance concerning how to take pictures is found in specialist photogrammetry textbooks. Simple and synthetic recommendations have been distilled by CIPA⁶. As a result of this dearth of guidance, photographic documentation is rarely systematic and frequently suffers from insufficient planning.

¹ "3.4 Applicants for listed building consent must be able to justify their proposals. They will need to show why works which would affect the character of a listed building are desirable or necessary. They should provide the local planning authority with full information, to enable them to assess the likely impact of their proposals on the special architectural or historic interest of the building and on its setting.", PPG15

"An authority should not accept an application for consideration until it has sufficient information to provide such understanding.", PPG 15, Annex B.3

"Recording the building before any alterations are made is vital", Michell, p.17

² BUCHANAN, *Photographing historic buildings for the record*, HMSO, London, 1983; RCHME, *Recording Archaeological Field Monuments, a Descriptive Specification*, Swindon, 1999

³ HARRIS, *Professional architectural photography*, Property Service Agency, 1988

⁴ See for instance the 12 lines concerning photographic documentation in Cox, pp.14-141. Mc Kee, describing the standards used by the Historic American Building Survey is much more detailed.

⁵ "The inclusion of photographs can be particularly helpful - of all elevations in demolition cases, or of the part of the building affected (interior or exterior) in alteration and extension cases.", PPG 15, Annex B.3

⁶ WALDHÄUSL, P., OGLEBY, C.: 3-by-3- Rules for Simple Photogrammetric Documentation of Architecture. In: J.G.Fryer (Editor): *Close Range Techniques and Machine Vision*. Proceedings of the Symposium of Commission V of ISPRS in Melbourne, Australia, 1-4 March 1994. IAPRS XXX/5, 1994, 426.

In these circumstances, documentation quality relies entirely on the individual's skills and knowledge.

- The aim of this document is to provide such guidance and to present techniques that can be used by Local Authorities or other bodies to extract metric information from photographs.

Following from this Introduction:

Chapter 2 contains a literature review centred on the use of non-professional data sets to retrieve metric information about historic buildings. Available techniques are identified.

Chapter 3 situates photography in the general framework of documentation of historic buildings. Criteria concerning documentation strategy, setting of the scenes and choice of equipment are defined.

Chapter 4 discusses the problems, limitations and needs related to the criteria defined in Chapter 3. The influence on metric information retrieval is studied.

Chapter 5 studies the influence of the criteria's parameters on the accuracy of metric measurements that have been retrieved by using the techniques of rectification, orthophotography, stereophotography, and photogrammetry. Results are validated on data-sets obtained by application of the criteria to two case studies.

Chapter 6 summarises the results of the previous chapters. A list of minimum requirements is provided in the form of a detachable checklist which is designed to insure that metric information can be retrieved from photographic documentations.

Minimum requirements for metric use of non-metric photographic documentation

2 Literature review

The basic requirements for post capture metric data retrieval from non-metric photographic records have been laid out in 1994 by Walhausl and Ogleby (1994)⁷ in a paper today known as the 3x3 Rules for Simple Photogrammetric documentation of Architecture.

The rules are divided in 3 fields: geometric, photographic and organizational. They are very synthetic and qualitative in nature and they represent the minimum standard to obtain a 3 dimensional restitution of an architectural object from non-metric photography. The rules (see Appendix A) have been applied extensively for the purpose of documenting historic buildings and architectural objects.

Since 1994 substantial debate has ensued aimed at:

- i. defining the field of application of these rules,
- ii. specifically determining their relevance to new technological developments in the field and the need for redefinition with respect to digital applications.

Various authors have recently proposed solutions for the use of a simplified and inexpensive photographic recording approach to respond to the increasing pressure for the documentation of cultural property. Following the 3x3 rules, Almagro (2001)⁸ states that, from the topographic point of view only a few points on the images and one measured linear distance are necessary and, so far as equipment is concerned, cameras with screens with a resolution of one or two Mega pixels (such as Kodak DC 200, or Nikon Coolpix700) represent the minimum requirement to deliver sufficiently good metric content. Although he does not provide accuracy figures, he considers the results obtained with digital cameras of better quality than the ones obtained by

⁷ Waldhäusl, P., Ogleby, C.: *3-by-3- Rules for Simple Photogrammetric Documentation of Architecture*. In: J.G.Fryer (Editor): *Close Range Techniques and Machine Vision*. Proceedings of the Symposium of Commission V of ISPRS in Melbourne, Australia, 1-4 March 1994. IAPRS XXX/5, 1994, 426

⁸ Almagro, A., *Simple methods of photogrammetry: easy and fast*, in CIPA Heritage documentation, XVIII International Symposium of CIPA, Potsdam, 2001

scanning film negatives by desktop scanners. Pomaska⁹ (2001) seems to indicate opposite results and D'Ayala¹⁰(2003) has obtained better resolution using large film format scanned with an ordinary scanner. For the calibration of the cameras Almagro uses bundle adjustment in the software version implemented in ORIENT¹¹.

Valentova et al. (2001)¹² present an application of the 3x3 rules as a pilot study for a general procedure to be implemented in order to create a database and to measure photo documentation of historical buildings in the Czech Republic. The equipment used is a theodolite, a measuring tape and SRL digital cameras¹³. The work is carried out by undergraduate students. Again there is no indication of the level of accuracy obtained.

The CoBRA approach advocated by English Heritage (Clark 2001)¹⁴ recognizes the essential role of documentation as a first step towards informed conservation. Increased interest in the preservation and reuse of historic buildings, together with new digital photographic and archiving technologies, result in the production of possibly valuable digital documentation by non-specialist. This has alerted English Heritage to the need for issuing a simple set of guidelines describing the documentation of heritage buildings with non-metric cameras. These guidelines can possibly be included in PPG15¹⁵ and PPG16.

⁹ Pomaska, G., Image acquisition for digital photogrammetry using off the shelf and metric cameras, in CIPA Heritage documentation, XVIII International Symposium of CIPA, Potsdam, 2001

¹⁰ D'Ayala D., Final Report EPSRC project: *An Interactive Logbook for the Management of the Conservation Process for Cathedrals: Wells Cathedral Central Tower and Scissors Arches*. EPSRC March 2003

¹¹ http://www.ipf.tuwien.ac.at/products/produktinfo/orient/html_hjk/orient_e.html

¹² Valentova, M., Dolansky T., *Data collecting for project of Czech historical monuments documentation*, in CIPA Heritage documentation, XVIII International Symposium of CIPA, Potsdam, 2001

¹³ Olympus Camedia 2500L and 2000C. The only type of camera which is discouraged to use are compact cameras with zoom.

¹⁴ Clark, K., *Informed conservation*, 2001, English Heritage

¹⁵ Guidelines on the preparation of applications can be found in the annex B.3 of PPG15.

Within this specific remit, the aim is to identify the essential requirements that can reasonably be included in such guidelines and to provide quantification of the various parameters. Three essential issues can be identified:

- i. correlation between initial purpose of the photographic documentation and later exploitation of the images
- ii. minimum equipment requirements.
- iii. metric content extraction.

The first issue to be noted is that applications for LBC are usually prompted by a need or intention of the owner to implement changes to his/her property. This is not necessarily compatible with the use that EH or the local authority intend to make of the submitted material, that is, the retrieval of metric data. A few authors debate the issue of purpose of documentation against survey technique¹⁶, and others propose various approaches for the exploitation of archival documentation for extraction of geometric data¹⁷; however no literature has been reviewed on later use of conservation plans submission material.¹⁸

Considerations on completeness and coherency of documentation, and adherence to the 3x3 rules would suggest that all perimeter walls shall be recorded and that for each of them there should be at least a stereo couple in order to obtain 3-d metric models. Hence, the question arises concerning whether it is legitimate to request a minimum documentary set (both photographic and cartographic) and what should be the extension of such set. English Heritage has issued guidance on survey drawings¹⁹,

¹⁶ Weferling U., The influence of the surveying and documentation of building geometry to different investigation purposes, XVIII CIPA International Symposium, Potsdam, 18-22 September 2001, pp. 402-406

¹⁷ Brauer-Burchardt C., Voss K., Façade Reconstruction of Destroyed Buildings Using Historical Photographs, XVIII CIPA International Symposium, Potsdam, 18-22 September 2001, pp. 543-550

¹⁸ Available examples relate to documentation requirements or methodology for conservation programmes of high profile properties, such as: Westerlund K., Documentation in the process of preserving and improving the historic value and developing the property for future use, XVIII CIPA International Symposium, Potsdam, 18-22 September 2001, pp.367-369

¹⁹ Riley, Wilson-North, Metric Survey Specifications for English Heritage, EH 2001

but similar specification for photographic documentation is lacking at present. Rules can be defined to document the entire property or to produce a self-sufficient set of whatever portion of the property is the object of the application. This of course has economic implications and the added costs of a complete documentation should be quantified. The evidence provided by English Heritage would seem to indicate that the second option is the current practice²⁰.

Hence, with respect to the issuing of guidelines, possible categories of extension of the documentation, which need to be further investigated during the case studies, are:

- external documentation only - partial or complete
- internal documentation only - if the application relates to internal alteration or repair, partial or complete (each room)
- both external and internal - partial or complete.

The second issue is about minimum equipment requirements. Pomaska²¹ provides an exhaustive review of possible equipment sets and the corresponding level of accuracy to be achieved in relation to digital photogrammetric use of images.

Extensive literature shows that metric content is fully recoverable from non-metric photographs.²² The quality of the recovery is a matter of resolution of the digital image obtained. The literature also generally highlights that, if there is sufficient photographic coverage, then control points or control measurements are not needed to obtain rectified 3-D images of the object (albeit with dimensions and orientation which are not absolute).

It is however always advisable to use a fixed-focus lens as most software works with pre-calibrated camera parameters. Various authors propose simple calibration

²⁰ See the leaflet produced by English Heritage: Photos and drawing to help your application

²¹ Pomaska, G., Image acquisition for digital photogrammetry using off the shelf and metric cameras, in CIPA Heritage documentation, XVIII International Symposium of CIPA, Potsdam, 2001, pp.490-495

²² Visnovcova J., Zhang L., Gruen A., Generating a 3D model of a Bayon tower using non-metric imagery, Asian Journal of Geoinformatics, Vol.2, No.1, September 2001, p.11-18, 3.7 MB PDF

techniques for non-metric cameras²³, and information exists on the calibration of specific digital non-metric cameras on line²⁴. It is claimed that an accuracy of up to 1/2000 can be achieved with an Olympus Camedia C2020 with a viewer of 1600x1200 pixels, in close range photogrammetry for object up to 20 m away from the camera. The choice of a wide angle lens will be very likely for documentation of internal proposed alterations, given the usually restricted dimensions of internal spaces and depths of field available. A correct evaluation of the distortion created by lenses under these conditions is rather critical to the recovery of any meaningful metric content and specific routine have been suggested.²⁵

The third issue (listed above) concerns the extraction of metric content and the availability of suitable techniques. This issue is best suited to a preliminary discussion fronting the guidelines and should take the form of a checklist against which it can be verified that provisions included in the guidelines are necessary and sufficient to the extraction of metric content.

Assuming that any given set of photographs follows the 3x3 rules, there is a wealth of literatures and approaches - and also a rather wide range of software packages - that are able to extract metric content. Even if the 3x3 rules are not fully complied with (e.g. lack of stereo couples or lack of camera orientation and calibration) monoscopic photogrammetry used in conjunction with orthophoto rectification is considered as a relatively low range and cost effective means of obtaining metric data and general documentation from essentially two-dimensional objects²⁶. This procedure is therefore suitable for relatively flat facades. It also adapts itself better to internal spaces than the use of stereoscopy. The level of resolution of the original image and the level of accuracy required for the final measurements are, again, the leading parameters.

²³ G. Karras & D. Mavromati. [Simple calibration techniques for non-metric cameras](#). XVIII CIPA International Symposium, Potsdam, 18-22 September 2001

²⁴ http://support.erdas.com/focus3/inside_the_sensor.html ,
http://www.racurs.ru/pdf/lite_e.pdf

²⁵ Swaminathan R. and Nayar S.K., "*Non-metric calibration of wide-angle lenses and polycameras* ", IEEE Computer Society Conference CVPR 99, Vol. 2, pp. 413-419, 1999

²⁶ <http://www.netSPACE.net.au/~gangel/>

Phidias²⁷ is an example of commercial software currently available. Phidias Duo and Phidias Mono are at the lower end of the spectrum of this family of applications based on Microstation Cad. Phidias Duo works with stereo couples and is suitable for small object and Phidias Mono uses one image at a time and performs rectification and mosaic of orthophotos. The input is represented by digital images, and the quality of these depends on the primary source, either digital or analogue, and the acquisition method (resolution of the scanner for negatives, use of Photo-CD, direct transfer from digital cameras, etc.). Photographs are oriented by using complete bundle adjustment. Measurements are then generated by monoscopic localisation of homologous points. The accuracy of measurement is related both to the possibility of zooming on the image and of obtaining points from up to 8 images at a time. Further features include automatic target and edge detection, and the use of homogenising functions in order to create proper orthogonal drawings. It also allows for image rectification by projective transformation by using a minimum of four points per image, without the need for camera calibration data. Naturally, the level of accuracy that is attainable depends on the resolution of the scanned image. The software producer affirms that, for an image of 3000 pixel per line there would be a possible error of 20 mm in 20 m for images with no targets. This equates to an error of 1/1000.

For Windows platforms, Photomodeler Pro²⁸ represents the lower end of the spectrum of available software. The programme works with a number of primitives, from which surfaces are developed that can then be rendered with the photo shots. The primitives and their derivatives can be measured and viewed at subpixel accuracy by using the zoom facility. Other features available are total bundle adjustment for camera orientation and camera calibration. The producer commissioned a number of accuracy tests. For architectural applications, these tests were performed by Klaus Hanke of Innsbruck University²⁹. One test consisted of surveying the corner of a brick wall tower using natural reference points, a non-metric 35 mm camera and a desktop scanner. Eight photos taken at two different levels were used. Accuracy is measured both in terms of points coordinates and in terms of distances, and are presented in

²⁷ http://www.phocad.de/Produkte/PHIDIAS_Info_en.pdf

²⁸ <http://www.photomodeler.com/pmpro01.html>

²⁹ Dr. Klaus Hanke, Accuracy Study Project of Eos Systems' PhotoModeler at <http://www.photomodeler.com/pdf/hanke.pdf>

terms of the calibration routine used, i.e. whether nil, partial or total distortion factors are taken into account. The figures range from 1/1700 to 1/2790 for distances, while the accuracy is marginally better for actual point coordinates. The accuracy reduces only marginally if only one set of photographs is used. Of course, in reality, the accuracy will be probably reduced by the complexity of the depth field of the surveyed surfaces.

Other applications driven by academic research are available on Internet:

Arpenteur³⁰, based on self-correlation and generation of geometric primitives, uses two images and again homologous points. This system is available on Internet but is not straightforward to use.

Total Calib³¹ proposes a solution to the calibration problem of projection matrices in absence or excess of data, by using a semi-automatic approach. The problem of accurately choosing matching points and the robustness of the associated calculation (an optimisation process) are usually the discriminating criteria for this type of software.

ARCHIS³² is the trade mark of a family of software package for 2D and 3D Digital mapping, produced by Galileo Siscam Technology. These packages are designed to solve photographic rectification, photomosaic and photogrammetric survey in the fields of architecture, archaeology and conservation. A particularly interesting aspect of this package is the feature called DLT (direct linear transformation) which allows external orientation of enlarged images or portion of images when the interior orientation parameters are not known.

These packages all relies on the possibility of carrying out total bundle adjustment to resolve the orientation, scaling and distortion of the digital images. However, for the purpose of defining minimum requirements, it is worth considering the possible alternatives to this approach and the extent of their applicability and level of accuracy. Techniques for rectification and techniques for scaling and orienting images will be discussed in turn.

A wide range of techniques exists for rectification, some of which are very simple. However, there are some limitations. In order to obtain good results, even with the

³⁰ <http://photogeo.u-strasbg.fr/Arpenteur2x/AcceuilVersion2x.html>

³¹ <http://www-sop.inria.fr/robotvis/personnel/sbougou/TotalCalib/>

³² http://www.siscam.it/prodotti/archis_ame.htm

simple techniques, the object should be plane (e.g. a wall), and since only a single photograph is used, the mapping can only be carried out in 2D.

The rectification could in theory be neglected, but only if the object is flat and the picture is taken without any horizontal or vertical tilt towards the object. In this case, the photograph will have a unique scale factor - which can be determined - if the length of at least one distance on the object is known. Basic software to achieve rectification is represented by some of the Photoshop routines.³³ These allow stretching of the original image in order to correct perspective deformation, using the basic methods of paper strip and optical rectification.

Numerical rectification requires the knowledge of the coordinates of a minimum of four point on the image and on the real object, if the camera calibration is not available. Numerical routines are then used to compute the correct transformation matrix for all other points. In more sophisticated applications and with large amount of data, differential rectification can be applied between groups of points on the same image leading to digital elevation models (DEM)³⁴.

Monoplotting is the numerical rectification of images in three dimensions and is typically applied to the photo unwrapping of developable surfaces in order to obtain 2D drawings from 3D data.³⁵ Karras has also shown that relatively good accuracy on metric information can be obtained from the rectification of single images, using vanishing points and exploiting the facts that human constructions are essentially cubic and anyway characterised by sets of parallel lines.³⁶

³³ <http://www.bris.ac.uk/is/selfhelp/documentation/photoshop-t1/photoshop-t1.pdf>

³⁴ These were first developed for USGS topographical modelling. For the connection to building survey see for instance www.ge.ucl.ac.uk/information/publications/1997

³⁵ G. Karras, P. Patias & E. Petsa 1996. [Monoplotting and photo-unwrapping of developable surfaces in architectural photogrammetry](#). International Archives of Photogrammetry & Remote Sensing, 31(5):290-294

³⁶ G. Karras & E. Petsa. ,1999 . [Metric information from single uncalibrated images](#). Proc. XVII CIPA International Symposium, Olinda, Brasil

Digital rectification is carried out using projective transformation. It yields good results for plane surface and can be modified to deal with several planes at different depth, however this is not automated and implies substantial operator time.³⁷

Once the image or the content object has been rectified, absolute measurements can only be obtained if an element of scaling is available. There are two possible approaches: recover the scale from known size of standard objects included in the photogram, or provision in it of metric objects, such as rulers.

A possible alternative, that should be feasible in the case of PPG15 applications, is the use of the photo set in conjunction with the drawing set. A set of simple drawings are usually available that represent the area object of the application. If this is the case, then measures can be extracted from the drawing and applied by analogy to the photo. The scale of the drawing could be used directly; however due to likely errors in drawing representation, it is advisable that any dimension actually measured should be recorded in writing on the drawing. Although this approach could be very useful, the level of accuracy is deemed to be relatively low.

The 3x3 rules also suggest the introduction in the photogram of plumb lines, so that verticality can be recovered with good accuracy.

As it appears evident from the above discussion, the extraction of metric data from non-metric documentation is an entirely feasible pursuit and a wide range of techniques and corresponding equipment is available. The discriminatory parameters are the associated accuracy and corresponding costs (in terms of either equipment or operator time). These in turns are variables that can only be fully evaluated in relation to the specific situation considered, both with reference to the initial aim of the photo set and the later requirements for extraction of metric data.

As a result, it is considered that the remainder of this study should be developed and the results presented on the assumption that the obtainable accuracy is the independent parameter.

³⁷ Wiedemann, A.; Hemmleb, M. & Albertz, J., Reconstruction of historical buildings based on images from the Meydenbauer archives, IAPRS, Vol. XXXIII, Amsterdam 2000, B5/2, pp. 887-893

3 Methodology

3.4 Introduction

Charters and other texts produced by national and international organisations such as ICOMOS or UNESCO emphasise the importance of documenting³⁸ architectural heritage and any conservation activity carried out. There are numerous reasons for producing documentation of a historic building, e.g. for:

- conservation works (purpose: to carefully analyse a situation to prepare a sensible intervention)
- management (purpose: to record and monitor a situation in order to act efficiently)
- appraisal
- assessment of the structural condition
- constituting an archive
- publication
- research in architectural history.

³⁸ PPG 15, 3.22; Ministry of Defence, p.59;

Venice Charter (1964): "ARTICLE 16. In all works of preservation, restoration or excavation, there should always be precise documentation in the form of analytical and critical reports, illustrated with drawings and photographs. Every stage of the work of clearing, consolidation, rearrangement and integration, as well as technical and formal features identified during the course of the work, should be included. This record should be placed in the archives of a public institution and made available to research workers. It is recommended that the report should be published";

Burra Charter (1999): "The cultural significance of a place and other issues affecting its future are best understood by a sequence of collecting and analysing information before making decisions. Understanding cultural significance comes first, then development of policy and finally management of the place in accordance with the policy";

EARL, p.51: "It is the central argument of this study that it is not the imposition of some ready-made philosophical system but a full understanding of the problem that is most likely to produce a defensible solution."; EARL, pp.52-54.

In addition, there are the similarly numerous – and often complementary – media used to produce such documentation; examples include measured drawings, photographs, texts, architectural description, and technical reports³⁹.

Many professionals can be involved, including architects, historians, archaeologists, engineers, conservation officers and planners. While each usually has different perspectives and requirements⁴⁰, all share a common desire to shed light on a complex situation.

The geometry of the object is not the only parameter to be recorded. All specificities making the object unique are meaningful⁴¹; all potential values – architectural, artistic, historical, scientific and social – are parameters to consider⁴².

Documentation encompasses a wide range of activities that include surveying, testing and monitoring and gathering textual or iconographic material. For the purposes of this report, only one specific aspect will be considered, that of photographic

³⁹ Following RCHME, *Recording Historic Buildings*, p.2, there are three types of records: written accounts, drawings, and photographs. New categories should be considered for records like 3D computer models or databases.

⁴⁰ For architectural purposes, it may, for instance, be good practice to include sections through the openings – and for structural purpose to include sections through supporting elements. Similarly, the precise analysis of the stone surface needed by a conservator may be confusing for an archaeologist trying to understand the stone pattern.

⁴¹ **The Nara Document on Authenticity** (1994): "9. Conservation of cultural heritage in all its forms and historical periods is rooted in the values attributed to the heritage. Our ability to understand these values depends, in part, on the degree to which information sources about these values may be understood as credible or truthful. Knowledge and understanding of these sources of information, in relation to original and subsequent characteristics of the cultural heritage, and their meaning, is a requisite basis for assessing all aspects of authenticity.

13. Depending on the nature of the cultural heritage, its cultural context, and its evolution through time, authenticity judgements may be linked to the worth of a great variety of sources of information. Aspects of the sources may include form and design, materials and substance, use and function, traditions and techniques, location and setting, and spirit and feeling, and other internal and external factors. The use of these sources permits elaboration of the specific artistic, historic, social, and scientific dimensions of the cultural heritage being examined."

⁴² **Burra Charter** (1999): "5.1 Conservation of a place should identify and take into consideration all aspects of cultural and natural significance without unwarranted emphasis on any one value at the expense of others."

documentation annexed to applications for listed building consent for transformation or demolition⁴³.

3.5 Guiding concepts

3.5.1 Objectivity

Within the context of documentation of historic buildings, there is no such thing as a fully-objective record⁴⁴: the activity of heritage conservation is partly subjective. The differences of attitude according to country or period illustrate very well the cultural dimension⁴⁵ that has to be taken into account. A specialist interprets facts, while a decision-maker weighs contradictory requirements. The chief variables are

- (i) the particular attribute to be documented (e.g. window frames, deformations, construction methods),
- (ii) the level of abstraction ,
- (iii) the method of expression.

However, it is also true that every respectable school of thought wishes to establish its opinions on an objective basis⁴⁶. The present interest in cultural heritage strengthens this need with respect to conservation practice. An objective basis is also the guarantee to having a firm ground on which to debate the conservation choices⁴⁷. What is not often sufficiently clear (intentionally or otherwise) is the position of the demarcation line between objective and subjective information. It is certainly debatable and contentious, but different types of data have admittedly different levels of objectivity and the use of any specific set of data necessarily influences any

⁴³ PPG 15, B.3

⁴⁴ MOLYNEUX, p.25: "A chimera of the archaeological method is objectivity, which of course can never be fully achieved"

⁴⁵ **Burra Charter** (1999): "5.2 Relative degrees of *cultural significance* may lead to different *conservation* actions at a place". This observation parallels the definition of what is heritage. The successive creation of the *SPAB*, the *Georgian Group*, the *Victorian Society* and the *Twentieth Century Society* is a clear illustration of that process. See Earl, pp.19-20.

⁴⁶ TORSELLO

⁴⁷ EARL, p.36.

decision-making process⁴⁸. The manner in which a survey is executed significantly influences further actions. Unrecorded elements are tacitly considered uninteresting⁴⁹ and later on are forgotten, i.e. it is possible that their very *existence* will be forgotten. Carrying out a survey is a two-time process⁵⁰. During the first *qualitative* phase, a model is developed. It consists of two constituents: a space of states (whose dimensions can be coordinates, colour, temperature etc.) and a law of behaviour, expressing relations between a set of variables and parameters. During the second *quantitative* phase, the parameters of the model are measured. In this way, a continuous problem is transformed in a discrete one. A simple model of a column could consist of a circle (law of behaviour) drawn on a sheet of paper (space of states), the parameter being the radius.

Particular survey techniques are related to specific laws of behaviour. In order to ascertain whether a wall is plumb, inclined or bulged, it is not sufficient to measure its dimensions: there is also the need to measure the position of a number of internal points with respect to a vertical reference line. The quality of the results follows the quality of the two phases. In the case of photography, the model is a 2D image of a 3D object. The qualitative decisions of the operator concern the choice of camera, film, point of view, lighting conditions etc. The quantitative operation automatically follows the shot itself by way of the camera 'sensor'. Photographs taken at dawn with a disposable camera will not have the same quality as photographs taken under controlled light with a medium format camera.

The discrete character of surveying should not be interpreted as a weakness. Reality conveys an almost infinite amount of information. To grasp it, one needs to abstract. It is the surveyor's work to emphasise the important, to find an expressive representation of the situation. In that respect, photographs are not exemplary. Variations of colours are subtle on a photograph but do not indicate whether a stone is sandstone or limestone. To produce a more readable representation, the interpretation of a specialist

⁴⁸ MOLYNEUX, p.27: "The important element for me is always to attempt to distinguish between the evidence and its interpretation."

⁴⁹ MAINSTONE: "any approach that starts only from the geometric form is more likely to result in a desire to modify this organism to make it conform with the analysis."

⁵⁰ FEIFFER C., *Il progetto di conservazione*, 6th ed., Milano, 1993

using possibly other data is required. Abstraction can range from a low level (e.g. type of stone) to a much higher level (e.g. an associated code system).

However, surveys should not be too finalised, so that the user is left with some freedom of interpretation and, possibly, can engage in critical discussion and alternative interpretations. Thus, a balance between emphasis and 'openness' is necessary. Photographs record much more information and subtlety (e.g. texture, colour, weathering)⁵¹ than line drawings; they define a specific situation as it exists at a moment in time.⁵² Moreover, being partly the result of an automatic process, they are, possibly, more 'objective' and can actually testify to how far a metric survey is faithful to the object.

It can be stated that, while photography is a valuable tool for acquiring the data relating to the state of a building, the abstraction associated with the production of measured drawings is essential for the correct analysis of that state.

3.5.2 Values

In order to define the elements worth recording in the documentation process, it is convenient to consider listing criteria. English Heritage uses the following criteria to assess the importance of a building⁵³:

- **Architectural interest:** all buildings which are nationally important for the interest of their architectural design, decoration and craftsmanship; also important examples of particular building types and techniques, and significant plan forms.
- **Historic interest:** this includes buildings which illustrate important aspects of the nation's social, economic, cultural or military history.
- **Close historical association** with nationally important buildings or events.

⁵¹ SWALLOW, p.97

⁵² BARTHES, p.120: "Le nom du noème de la photographie sera donc: «ça-a-été»". They are records of the particular.

⁵³ English Heritage, "What Does Listing Mean ?", <http://www.english-heritage.org.uk/default.asp?wci=MainFrame&URL1=http%3A//www.english-heritage.org.uk/default.asp%3Fwci%3DNode%26wce%3D6763>; see also the discussion in Earl, p.51.

- **Group value**, especially where buildings comprise an important architectural or historic unity or are a fine example of planning (such as squares, terraces and model villages).

The listing descriptions provided above can be used as an initial guideline but they are not exhaustive⁵⁴. In the same document (PPG 15) it is also stated that "The . . . rarer a building is, the more likely it is to be listed". It is therefore important to record the elements liable to make it unique, special or, on the contrary, make them good examples of a particular type. The PPG 15 speaks of interest and rarity, while RCHME speaks of significance⁵⁵. Documentation has to identify and record those features worth preserving⁵⁶.

The recorder's choices are critical⁵⁷. Some may be tempted to limit the documentation to the main features. It is to a certain extent a 'political' choice potentially leading to 'façadism' or transformation of a real and complex building into a simple illustration of a theory⁵⁸. What is seen today as uninteresting may appear tomorrow as extremely

⁵⁴ PPG 15, 3.5: ". . . list descriptions may draw attention to features of particular interest or value, but they are not exhaustive . . ."

⁵⁵ RCHME, Recording Historic Buildings, p.1

⁵⁶ PPG 15, Annex C.2: "Each historic building has its own characteristics which are usually related to an original or subsequent function. These should as far as possible be respected when proposals for alterations are put forward.";

PPG 15, 3.1: "Once a building is listed (or is the subject of a building preservation notice), section 7 of the Act provides that consent is normally required for its demolition, in whole or in part, and for any works of alteration or extension which would affect its character as a building of special architectural or historic interest.";

EARL, p.23 gives examples of damages that can result from replacement of 'minor' elements such as fences or windows.

⁵⁷ COX, p.137: "A good recorder, with the luxury of more single-minded time on site than many others, will notice what may be less obvious, small or rare items that might be forgotten in the course of a major repair scheme and deserve to be drawn in order to bring them to the attention of others"

⁵⁸ AUBREY (17th Century), quoted by MOLYNEUX, p.26: "In the year 1655 was published by Mr Webb a book entitled Stonehenge Restored (but written by Mr Inigo Jones) which I read with great delight: there is a great deal of learning in it. But, having compared his scheme with the monument itself, I found he had not dealt fairly, but had made a rule, which is conformed to the stone: that is, he framed the monument to his own hypothesis, which is much differing from the thing itself. This gave me an edge to make more research..." [I emphasise]

valuable⁵⁹. The importance of thorough recording is emphasised by the common loss of minor details which may disappear at the moment of new conservation work, leading to loss of integrity or of historical evidence⁶⁰.

The thoroughness of the exercise is entirely reliant on the competence and awareness of the surveyor who, in deciding what to include in the survey, will perform a continuous assessment of the relative and absolute value of each feature. As the intention is to record both 'good' and 'bad' aspects of the current state, a balance should be struck between selection and exhaustiveness⁶¹. A group value can also be attached to a building. Therefore, a consideration of context is also very important.

3.5.3 Learning process

In comparison to other documentation techniques, photographic documentation is fast and is apparently straightforward to carry out. This view can be misleading: surveying is a learning process and a certain period of contact time between the operator and the object is necessary to assimilate the features recorded, whatever the purpose of the recording. A deeper knowledge of the building will inform sensible decisions.

As already stated, documentation is a two-stage process involving qualitative and quantitative stages. In the case of photography, the second (quantitative) stage is straightforward. To achieve good documentation standards, the first (qualitative) stage requires good planning and accurate evaluation of all relevant parameters (type of camera, film etc.). Photographic documentation is also part of the more general documentation process. Knowledge will be acquired during the preparation of the measured drawings, which can then be used to prepare an improved standard of photographic documentation.

3.5.4 Continuity

Documentation should not be seen as an activity confined within a set time. In the long term, it should aim at giving to the building what medical files are for patients. Therefore, a basic requirement is that the results of documentation should be available

⁵⁹ EARL, p.80

⁶⁰ **Venice Charter** (1964): "*ARTICLE 3*. The intention in conserving and restoring monuments is to safeguard them no less as works of art than as historical evidence."

⁶¹ BOLD, p.67: "Judgments of significance are inevitable and, in concentrating the mind of the recorder, highly desirable."

for future use⁶². Documentation could also represent the basis for a logbook, informing an approach of regular maintenance. Not all elements in a building have the same lifespan⁶³. Hence, starting from the objective basis of a documentation set, further investigations, a maintenance campaign or minimum intervention may be decided optimally⁶⁴. In a report by CIPA on Heritage at risk, guidelines are given for using photographs⁶⁵ to monitor condition.

⁶² Venice Charter (1964), Article 16; "The records associated with the conservation of a place should be placed in a permanent archive and made publicly available, subject to requirements of security and privacy, and where this is culturally appropriate." Burra Charter (1999)

⁶³ FITCHEN

⁶⁴ ICOMOS International Wood Committee, Principles for the Preservation of Historic Timber Buildings (1999): "3. A coherent strategy of regular monitoring and maintenance is crucial for the protection of historic timber structures and their cultural significance";

Brereton, p.3: ". . . the detailed design of repairs should also be preceded by a survey of its structural defects over as long a period as possible . . . "

⁶⁵ "The purpose of photographic documentation is not an issue for itself; it is a task for future use. To take images just for a publication immediately afterwards, or just for demonstration of the view of the site, is a poor documentation. Maintenance and future management of the site need more. Photography is needed not only to prove a state or to give evidence of the past, but also to allow for change and trend detection.

As a zero/base document for any later comparison we use normal or - professionally - special photographs, analogue or digital, black and white or colour, still video or film, normal or wide angle or panoramic, as appropriate. For easy comparisons, we should have concentric images, taken from one and the same standpoint in order to really detect the changes of objects, instead of those taken according to different perspectives. Also the time of the year and of the day should be comparable; thus we can overlook the differences of light and shadows and concentrate on the real changes of the site. The same camera and objective is fine, but not absolutely required, because in any case concentric photography is a cross-section document of the same bundle of rays and any pair of images will be collinear and rectifiable to each other. However, the film type should be the same as the last time. If it is wished to change from black and white to colour images, both are necessary. Black and white for the comparison with the last epoch and colour as a new beginning for the follow-up comparisons.

The standpoint, therefore, has to be carefully recorded on a sketch or map or protocol for later use, or reconstructed by resection prior to production of the follow-up photography.

Monitoring photography is more than 'just' photography. The special requirements need special consideration, need thinking about consequences. Monitoring is a duty if we want to detect changes in due time, so that the costs of interventions are a minimum, or if we want to prove that everything is unchanged, complete and the same." <http://www.international.icomos.org/risk/2002/cipa2002.htm>

Photographs taken on the occasion of new interventions are, therefore, not only elements necessary to bring understanding⁶⁶ but they are also records of the building's situation at a particular time. In this respect, the photographs themselves are also important documents⁶⁷. This, in turn, poses the problem of archiving and access⁶⁸.

If the survey is part of a programme of intervention, surveying activities should not stop when the works informed by them start⁶⁹. Photographs are a good tool to assist in the documentation of repairs⁷⁰. During repairs (e.g. a floor being opened, a partition being broken)⁷¹, portions that were previously hidden can become accessible to the surveyor⁷² and some new evidence may become available. New constraints or better solutions can emerge. Photography is particularly suited for this kind of recording, as the timeframe of the work may not allow a conventional metric survey. Photographs can be taken quickly and, if certain provisions are taken, they can be used at a later stage to generate metric surveys with photogrammetric techniques.

3.5.5 Fabric

Documentation should not stop at the surface. Architecture is three-dimensional and substantial⁷³. Photographs on the other hand record only the surfaces. It means that, generally, they cannot provide a complete documentation. Integration with other documentation techniques is necessary. Moreover, each photograph is taken from one point of view, failing to provide a synthetic image of the building as an organism and an analytical view of the details under scrutiny, as it is achievable through drawings.

⁶⁶ PPG 15, B.3

⁶⁷ MC KEE, p.63

⁶⁸ COPLIN, p.64; MC KEE, p.63; Buchanan, p.31

⁶⁹ EARL, p.81

⁷⁰ MICHELL, p.17: "If any dismantling is carried out at temporary repair stage, successive photographs will be needed as parts of the structure are removed." Clark

⁷¹ PPG 15, 3.24

⁷² Property Services Agency, p.38 (or Ministry of Defence, p.39): "Photographs taken before, during and after work form a useful record. Where security permits they should be taken at every opportunity to record details of the work and parts of the building which are not usually visible."

⁷³ EARL, p.75 "Invisible does not mean unimportant."

3.5.6 Documentation sets

Information gathered during documentation may be large and manifold. Previously disregarded attributes or aspects may also be included as a result of the evolution of conservation theory. This broadening leads to better definitions of a building's significance.

The study of a specific dimension implies objectivity and subjectivity. Classifying and organising data facilitates understanding and represent a first step toward interpretation. From raw data (i.e. dimensions or new data already recorded), a synthesis (interpretation or decision) can be constructed, which can be of generic value and wider applicability than the specific case.

The history, construction, and physical condition of a building are interrelated, and data can be acquired in different formats; thus it is critical to *organise* the available information, for which the metric survey is a natural support. Sets of thematic drawings (geometry, materials, pathologies etc.) can be prepared. A specific set prepared by one specialist can bring insight to other specialists who are working on other sets. Looking at the pathology of stonework, possible strategies can be discussed to ensure their conservation.

Usually during the elaboration of such drawings, some aspects will be considered, while others may be disregarded. It is the responsibility of the recorder to define the aspects assumed as meaningful, a decision that often depends on the purpose of the recording ⁷⁴. For a majority of thematic drawings, the basic operation consists of defining categories (e.g. types of stone) and identifying the zones of each artefact in which each category applies (e.g. column number 12 is in Douling Stone). The aim of these drawings is to emphasise aspects that are possibly not immediately evident from the photographs. The drawings constitute the synthetic result of the interpretative work carried out by a specialist, involving close observation, possibly some testing, and discussions with research partners.

Photographic documentation also has an important role within the context of thematic sets. Its more 'objective'⁷⁵ nature makes it a good control instrument. If a graphic

⁷⁴ FREEMAN, p.200: "Decide on the building's essential qualities, those you want to emphasize; these will direct the technique you use"; Buchanan, p.10

⁷⁵ SWALLOW, p.97;

document asserts that some architectural elements are heavily damaged and should be replaced, photographs can be used to verify the statement (Figure 1). More generally, they can be used to better understand the criteria used to classify situations and, possibly, contest them.



Figure 1: St Swinthin Church, London Rd (facade on Walcot Street), Bath

In the particular case of applications for permits of transformation or demolition, the use of thematic sets is probably rather uncommon. They are, nevertheless, useful tools for accurately defining the architectural interest of a building and its present condition. As such, they should be used more often.

Of course, photographers are not going to agree completely; their Art lie in this subjectivity. Barthes, p.103: "(...) images partiellement vraies, et donc totalement fausses"; Barthes: Photography is an interaction between an operator, an observer and an object.

3.5.7 Redundancy

Every piece of information is associated with uncertainty. Documentation data should be supplemented by information about the quality of the data⁷⁶. Control procedures offer a way to assess quality. An example can be given of the control that photographs can exert on metric surveys: if an arch is to be measured, the first operation would be to prepare a conceptual model; the surveyor might consider that the arch is a simple circular arch defined by a centre and a radius and draw it accordingly – but a comparison with a photograph could show that the arch is slightly pointed, demonstrating the inadequacy of the conceptual model chosen. Thus, photographs, giving a record of every visible element, also provide a validation system for the choices made in the metric survey.

3.6 Classification of situations

Complex situations involving important buildings comfortably funded will require and allow more detailed documentation than modest houses being subjected to simple works. In this section, situations will be classified according to building type, application type, timeframe and budget. The aim is to provide methods for defining, in any particular case, reasonable (minimum and maximum) limits for the required documentation. However, formal limits can be hard to fix in practice; they can also be controversial and probably not always effective. The approach chosen is to present a set of examples from which the reader can be ‘enlightened’ and, in consequence, take sensible decisions for the specific case in hand. This approach will also help to clarify the range of application that might be expected of the guidelines. Note that RCHME defines four levels of recording⁷⁷ but the categories are very broad and the number of photographs recommended is certainly too low for metric information retrieval.

⁷⁶ RCHME, *Recording Historic Buildings*, p.1: "A record should aim at accuracy. The level of record and its limitations should be stated."

⁷⁷ RCHME, *Recording Historic Buildings*, p.4

3.6.1 Building type

The different grades of protection (I, II*, II) reflect the *importance* given to a building. This tool is rigid and does not always serve the needs of a building⁷⁸. Grade II buildings may not always receive the attention they deserve. Grades attempt to measure the importance of a building but other factors may be relevant in assessing its needs, such as size, richness of details, originality, or state of conservation. The concept of ‘importance’ may also be dangerous. One of the aims of documentation is to record aspects of a building which might disappear – such ‘disappearances’ often being the result of an owner not perceiving an aspect as sufficiently valuable to retain. This judgement of value may be associated only with the contingent economic situation of the estate market, rather than with the historic value of the feature to be removed. Public authorities and other concerned bodies may have a different opinion and should have the means to assess it properly. Moreover, in the case where demolition is granted, the recording will be the only remaining document.

Scale also has an influence on the documentation needs. As a matter of principle, bigger buildings certainly require more extensive documentation and, consequently, the organisation of that documentation becomes more complex. If a willing but untrained individual is able to produce a decent photographic documentation of a single house, a proper recording of a mansion may require the services of a professional (see 4.5).

The physical size of a building is not the only factor affecting documentation needs. In some cases, the *richness of detail* may require a more sophisticated documentation tool. If some crafts used in the building are no longer in use, special care has to be taken⁷⁹ to document the specific artefacts, with the result that photographs may be essential to give a proper understanding of the lost craft. In some cases, single elements of particularly important value will require major attention. Some architectural or structural features may also require special attention or equipment. Structural and surface pathology, decorated elements in darker places, for instance, are typical examples of this category.

⁷⁸ Earl, p.46

⁷⁹ EARL, p.46



Figure 2: 1, Wood Street, Bath

Buildings with protruding volumes (e.g. bow windows, porch, dormer windows) and articulated plans require more photographs to be fully recorded.

The use of a building also contributes to its value and its complexity of function can require a more thorough documentation. If the *variations of luminance* are important, then photographs are more difficult to take. This can be the case if some elements are very dark and other very light. In that case, the question of lighting is of prime importance (see Figure 2 and 4.6.3).

The condition of the building in its *context* may also complicate the documentation process. Vegetation, lack of distance, poor lighting conditions

In order to develop a more precise classification, it would be extremely useful to have statistics about typical Grade II buildings. Grade II buildings have certainly a great variety.

3.6.2 Type of application for LBC

The reason for applying for Listed Building Consent naturally influences the documentation requirements. For example, if a façade is going to be cleaned, then it is particularly important to record the original surface with close-up photographs. If openings are going to be altered, it should be possible to measure their original

dimensions and position with suitable accuracy. In the following a list of typical submissions is provided, and for each of them the essential aspects to be covered by a photographic documentation are identified. While the list is certainly non exhaustive, this procedure highlights a method that can be valuably applied to other cases.

- Extension – what was in its place before, what is going to be destroyed, what were the general facade proportions, what elements are likely to be damaged, including in the neighbouring areas during the works. Specifically:
 - Conservatories – how the back façade is going to be affected; materials used
 - Garages – how the garden is going to be affected
 - Attics – how the streetscape will be altered; situation of the houses in the neighbourhood
 - Other substantial extensions – how the original plan and elevation of the building are going to be affected.
- Demolition – all elements to be demolished shall be photographed as this will be the only record available in future. Specifically:
 - External – how the original plan and elevation of the building are going to be affected. Architectonic details lost. Previous condition revealed.
 - Internal
 - Partitions – how the perception of the original layout changes
 - Fireplaces – how the perception of the original room changes
- Alterations – what is the structural condition of the building i.e.
 - External
 - Size of openings: shop windows
 - Fabric of openings: frame (material or size), double glazing
 - Curtilage change (railing)
 - Internal
 - Size of rooms
 - Position of staircases
- Repairs – what were the colours and proportions; what were the original technique and materials for:
 - Roofs

- Plumbing
- Painting
- Repointing
- Cracks
- Settlements
- Structural works

3.6.3 Timeframe and budget

Factors making a building worthy of conservation also make it worthy of a complete documentation. Such factors also facilitate the demonstration of the necessity for a suitable documentation budget. Assembling photographic documentation is considerably faster than producing measured drawings; however, careful planning is necessary for completeness and accuracy to be ensured. The relative speed of the operation implies that simple photographic documentation is usually relatively cheap. Its cost is certainly very low in comparison to the overall costs of the works. In more complex cases (e.g. involving large spaces, difficult lighting conditions), special equipment may be necessary to achieve good standards of documentation. Very often, this requirement is accompanied by the need to resort to the service of professionals. This is probably the key question to answer in relation to timeframe and budget.

3.7 Definition of criteria

Criteria to ensure good documentation can be derived from the guiding concepts and the classification of actual situations, presented in the two previous sections. For the purpose of this discussion, these criteria are organised into the following three operational categories: documentation strategy, setting of the scene and choice of equipment. The reasons for this categorisation are briefly illustrated below, while a more detailed discussion of the parameters included in each category is conducted in Chapter 4.

3.7.1 Documentation strategy

Parameters concerning individual photographs cannot be decided independently. Choices are made according to the intended function of the general documentation goal (e.g. to define the building's identity and cultural significance). Photographs

should perform an important function in any well-thought documentation set. They complement other forms of documentation (the measured drawing set, in the first instance) and the correlation and complementarity of different sets should be considered before initiating the process. Furthermore, in order to provide a good understanding of a building's situation, the set needs to be well organised, coherent and complete. Context and details need to be documented with same accuracy.

3.7.2 Setting of the scene

Individual photographs are taken following the documentation strategy. The parameters of choice concern the 'where?' and the 'when?' and include definitions of the camera positions & orientation and the choice of lighting conditions (i.e. season, day, hour, additional lighting). A proper referencing strategy facilitates the presentation of the case and enhances the effectiveness of data retrieval.

3.7.3 Choice of equipment

The quality of the final documentation very much depends on the choice of equipment and on the way it is used. It is theoretically easy to specify guidelines; however, in the framework of *Listed Building Consents*, budget and availability will be the driving parameters, and the use of sophisticated equipment and techniques will be uncommon. It is therefore important to understand what can be expected from simpler equipment and techniques and to define where improvements are more easily made.

On the other hand, guidelines related to *documentation strategy* and *setting of the scene* are harder to specify but easier to achieve and can therefore be more prescriptive. In the next section, factors of influence will be discussed for each of these categories, having in mind the construction of a case for Listed Building Consents. The general approach will be to reinforce the peculiarity of photographic documentation for providing rich and objective data.

4 Definition of problems, limitations and needs

4.4 Introduction

The skills of the recorder are critical to achieving high-quality photographic documentation⁸⁰. Those skills involve knowledge of both photography and architecture. Very often, the quality of photographs taken to document a building is low. More precisely stated, imperfect photographic documentation fails to fulfil the general aim of qualifying the building, presenting the elements necessary to the understanding of its present situation and of the proposed changes.

Hiring a professional photographer will probably improve the quality of the photographs but it is not necessarily a guarantee of better documentation quality. The objectives of the documentation, the elements important to survey and the dimensions to emphasise have to be clearly stated and understood beforehand⁸¹. Good planning is necessary to make decisions about the point of view and the lenses and lighting conditions to be used. This is done through observation of the building, sketching and careful thinking. Only then is it possible to define the necessary equipment and shooting sequence. In the context of the following problems, limitations and needs are discussed with reference to the criteria identified in 3.7.

4.5 Documentation strategy

A thorough photographic documentation should include both general and detailed views of the exterior, of the interior and possibly of special features⁸². The documentation set should be complete, coherent, correlated to other documentation and rationally organised. In the following text, the measures to be taken to achieve these aims will be discussed and illustrated by examples, together with the pitfalls associated with any lack of compliance to these criteria.

⁸⁰ MC KEE, p.64

⁸¹ MC KEE, p.70

⁸² MC KEE, p.64

4.5.1 References

For photographs to be effectively utilised, the subject that each represents and the circumstances of the shoot, should be known. Indexing is especially important when the building is complex and the number of photographs is large but, in practice, it is very often lacking⁸³.

- All sets of photographs should always be accompanied by a written record containing details of the county, civil parish, building site name or street number, national grid reference⁸⁴, photographer, date and reference number⁸⁵.
- The equipment used (i.e. camera, lens and accessories) should also be recorded.
- For listed buildings, the grade of listing must be included.
- Each view has to be identified by a reference number, time of the shot, orientation, viewpoint, floor, room number.
- The use of a precise glossary facilitates understanding (N.B. English Heritage gives some archival recommendations for image-based surveys.)
- Each print/negative should be protected in a sleeve, with a standard label⁸⁶.
- The reference number should follow EH convention⁸⁷.
- Digital files should be stored on a CD-ROM⁸⁸.

When photographs are used in conjunction with metric documentation, the position and orientation of the camera should be recorded on a drawing set (on plans or elevations). This will also facilitate the control of the positioning criteria.

The best way to proceed is to record directly all the data in a notebook⁸⁹ or on a purpose made form (Figure 3). Digital cameras have the advantage of being able to store metadata with the image files (new camera models very often use the EXIF

⁸³ Ministry of Defence, p.39: "(...) photographs annotated to make a document of permanent value"

⁸⁴ More information can be found on the Ordnance Survey's Internet site <http://www.ordnancesurvey.co.uk/downloads/Natgridpdf/20241.pdf>

⁸⁵ RCHME, *Recording Historic Buildings...*, p.2; Buchanan, p.22

⁸⁶ LUNNON, 3.6.2., 3.6.3

⁸⁷ LUNNON, 3.1.1. In this document, there is no abbreviation for "photographic survey". The letter I (like image), could be used. Note: the sequential number can be higher than 99.

⁸⁸ LUNNON, 3.1.4.

⁸⁹ BUCHANAN, p.11

standard⁹⁰). In this case, it is important to avoid any manipulation with image-processing programs, as the metadata is lost when files are subsequently saved.

Page /

Building
 Ref¹ Name and/or address
 National Grid²

Civil Parish County Listed I II* II

Type of work

Photographer(s)		Camera(s)		
Ref	Name	Ref	Make	Model
<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>

Lens(es)		Negative(s)⁴		
Ref	Make	Model	Focal Length	Ref
<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>

Other equipment

Ref⁵ I Photographer Camera Negative⁶ - Lens Tripod

Date / / Time : f/ at 1/ s. F.D.⁷ Flash

Description⁸

Ref I Photographer Camera Negative - Lens Tripod

Date / / Time : f/ at 1/ s. F.D. Flash

Description

Ref I Photographer Camera Negative - Lens Tripod

Date / / Time : f/ at 1/ s. F.D. Flash

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Date / / Time : f/ at 1/ s. F.D. Flash

Description

Ref I Photographer Camera Negative - Lens Tripod

Date / / Time : f/ at 1/ s. F.D. Flash

Description

¹ Choose a three letters code to identify the building
² This information can be found on an Ordnance Survey map. The first two characters identify the 100x100 km grid (visible on the corner of the map). The next three characters are numbers specifying the eastings up to 100m (using the grid printed on the map). The last three characters are numbers identifying the northings. More information can be found on the Internet Site of the Ordnance Survey <http://www.ordnancesurvey.co.uk/>
³ Film Compact: 1; Digital Compact: 2; 35mm Film SLR: 3; Digital SLR: 4; Other (film based): 5; Other (digital): 6
⁴ Add a reference for each new film
⁵ The three first characters are used for the code identifying the building. The next two characters are numbers identifying the year and the last three characters are sequential numbers identifying the photograph.
⁶ In case of analogue camera, write the negative reference in the first two boxes and the exposure counter number in the last three boxes. In case of digital camera, the first two boxes are used to identify the batch index number (set of pictures stored contemporaneously in the memory-card) and the last three boxes for the automatic index number assigned by the camera.
⁷ F.D. is the focus distance.
⁸ The position and orientation of the camera should be indicated on a plan

⁹⁰ <http://www.exif.org>

Figure 3: Photograph set recording form

4.5.2 Correlation between photographic set and other documentation sets

Photographic documentation has to be considered within the general framework of documentation⁹¹. Some of the information conveyed is common to other techniques and some is specific. To include aspects common to different sets is important because they bring redundancy and allow verification. Specific aspects are also important because they increase the depth of the documentation.

Measured surveys can give the necessary metric information to scale and orient the pictures (4.6.1). The question of accuracy of the measured drawings is important. Lines on a drawing are the result of adjustments between measurements and drawing topology. It is therefore important to have the dimensions indicated on the drawing. This information is less likely to be incorrect. If the measured drawings follow common standards of accuracy, then the correlation between the photographic set and the drawing set will be sufficient for retrieval of metric content from the photographic set.

4.5.3 Completeness

It is essential to provide a set of photographs that is adequate for the full understanding of the object of the application. This does not necessarily mean that every part of the building has to be photographed. For example, if photographic documentation is carried out to accompany a requirement to transform a window in a mansion, it is probably inappropriate to demand a complete documentation of the building – however, the part intended to be transformed must certainly be fully documented. On the other hand, incompleteness of a photographic set may arise from the fact that some attributes simply have not been properly recorded.

For instance, colour may be an important value of an architectural element and, if black and white photographs are used, it will not be visible. Cracks and deformations are elements that are particularly difficult to document, as they appear much less

⁹¹ See for instance, RCHME, *Recording Historic Buildings*.

visible on pictures than they are in reality⁹². To demonstrate that some attributes are not important, it is necessary to document them. Being relatively rapid to produce, photographic documentation can be used to show that attributes not emphasised in measured drawing documentation are not important. For example, it may be sufficient to take just one colour photograph to show that colour is not a concern.



Figure 4: United reformed church, Bath, Argyle st.

Although photographic documentation can be exhaustive in terms of an application, it may be the case that the number of photographs is not sufficient or the set is too loose for the purposes of metric data retrieval. To orient the photographs, corresponding points have to be identified on each photograph of a set. The photographs must therefore overlap (more than 50% when following the 3x3 guidelines). A minimum number of points common to other photographs of the set have to be present on each photograph and be regularly spread on its surface. This minimum number depends on the particular situation (e.g. whether the camera is calibrated or un-calibrated). Each

⁹² The lighting conditions are important (see 4.3.3). Humidity can have an influence on the visibility of pathology (taking advantage of transient phenomena due to difference in porous behaviour of materials). References can be used to qualify and quantify the problem (dimension of the crack, comparison between a straight and deformed element).

point should preferably be visible on three or more pictures. To achieve good accuracy, the angles between corresponding rays must be as close as possible to 90°. Convergent lines of sight are therefore ideal. To retrieve internal orientation parameters (the coordinates of the principal point) with accuracy, it is also useful to have photographs taken with the camera in different orientations (e.g. landscape and portrait in one or two directions)⁹³.

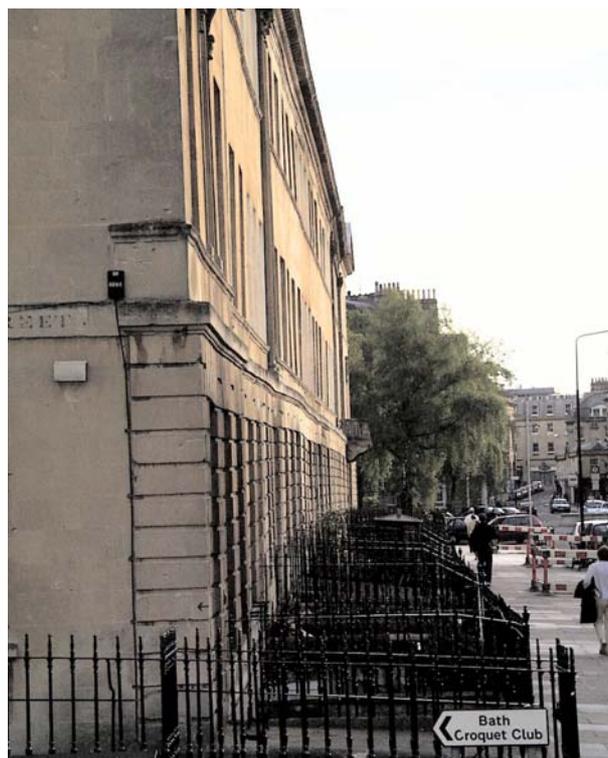


Figure 5: Great Pulteney Street, Bath

4.5.4 Context and details

Photographs present limited views of a complex situation. It is important to know the context and the details, to document the situation at every relevant scale. At least one photograph documenting the situation of the building in its environment⁹⁴, its relations to vegetation, other constructions, gardens, fences etc. is certainly necessary.

⁹³ FRASER in ATKINSON, p.273

⁹⁴ BUCHANAN, p.32; RCHME, *Recording Historic Buildings...*, p.3-4

PPG 15, 3.5: "the particular physical features of the building (which may include its design, plan, materials or location) which justify its inclusion in the list: list descriptions may draw attention to features of particular interest or value, but they are not exhaustive and other features of importance (eg. interiors) may come to light after the building's inclusion in the list;"

On the other hand, small details not clearly visible in general photographs can increase very much the building value or help to understand its condition. Texture, quality of detailing, chimneys, sculptures and also aspects of decay are important to document. The original texture of a facade can be irretrievably altered by a cleaning operation. It has to be noted that context is not always properly documented by general views. The quality of details of the context may not be visible on low scale photographs (Figure 6).



Figure 6: Details of basements, Great Pulteney, Street, Bath.



Figure 7: 11, Edward Street, Bath

Very often, wooden or metallic elements are rich in details and require a higher scale of documentation. Differences of colour resulting in high contrast may complicate the extraction of information in photographs of lower scale (Figure 7).

4.5.5 Coherency

Different scales make comparisons more difficult. If the desire is to argue for the replacement of some elements and the conservation of others, then it is important to document them in a similar way. Furthermore, to achieve a given accuracy in the metric measurements retrieved from photographs, their average scale has to be roughly similar. Hence, taking pictures from approximately the same distance from the building and from similar angles will comply with the requirements of both application and metric retrieval.

4.6 *Setting of the scene*

Specific photographic scenes are defined by the equipment used (camera, lens and accessories), by the position and orientation of the camera, by the lightning condition at the moment of the shot and by the possible references included in the scene. In the

following, the influence of environmental condition on the documentation content of the photographs will be discussed. The question of the choice of equipment will be presented in the next section (4.7).

4.6.1 Reference targets

Photographs taken for documentation purpose seldom include material targets used as reference points. It does not mean that the photographs cannot be used to extract metric information but the operation might consequently become more difficult and the results less accurate. In photogrammetric terms, the 3D model of a building can be constructed just by using the photographs and identifying corresponding points on each of them. Nevertheless, in that case, no information is available to scale and orient the model. One distance measurement (for example, the width of the building) is sufficient to provide a scale. At this stage the model is already metric and can be used to obtain measurements of distances. A plumb line can provide a reference for vertical orientation. It can be easily set from an overhanging roof or a balcony, but it may be more difficult to set in the absence of protruding elements. Note that, if a plumb line is used, it has to be of a colour contrasting with the background and its thickness has to be sufficient to be visible on the photographs. This discrimination can scarcely be achieved with the typical resolutions of digital cameras. In that case, the extremities of the line, the plumb and the fixing point, have to be clearly identifiable. To have a fully oriented metric model, four more parameters need to be determined: the coordinates of a point and the orientation in plan.

All measurements could be taken at a later stage (if the building is not demolished in the mean time) but it is, of course, better to have them taken together with the photographs. If target points are placed on the structure before the photographs are taken, then the subsequent restitution using photogrammetric techniques can theoretically be faster and more accurate. Special care has to be taken in order not to damage the building⁹⁵.

⁹⁵ LUNNON, 1.5



Figure 8: Targets distribution on the building (12, Cavendish Road, Bath)

Without targets, points are more difficult to identify. The sharpness of a point is a function of the contrast between the point and its background. It may be quite difficult to identify precise points or features on a building. Edges are frequently worn away by the weathering process. Using targets of simple and regular shapes drawn on a blank background allow position to be defined with sub-pixel accuracy. On the other hand, without targets and depending on the situation, it is normally not possible to define material points more precisely than to about 1-3 pixels. Some guidelines are given in the *Metric Survey Specifications for English Heritage*⁹⁶. The surface of the target should be matt and not reflective. A minimum of four measured targets should be visible on each image. This number may be sufficient when the camera is calibrated but is not sufficient if internal parameters have to be estimated. In practice, ten targets or more should be visible on each photograph. They should be regularly spread on the object (Figure 8), in different planes if possible, but not necessarily on the object to be measured. Of course, they should not hide important features and it is

⁹⁶ LUNNON, 2.2

better to place them on plain surfaces. Ladders and long sticks can be used to fix targets in places where it is difficult to obtain access. The size of the target points has to be sufficient (see Figure 11); however, the specifications state that a target should not be greater than 60mm x 40mm. For lower resolution cameras, this size is too small if an identification text has to be readable (characters have to be about 10 pixels high). But it is sufficient in most case to have the target point without written reference. The image of the target will occupy approximately 8 pixels (*PhotoModeler 5* recommendation). If the photographs are taken with an analogue camera, and assuming a 4000dpi film scanner, then the image of the target should be approximately 50 μ m on the negative (i.e. 1/700 of the width of a 35mm negative).

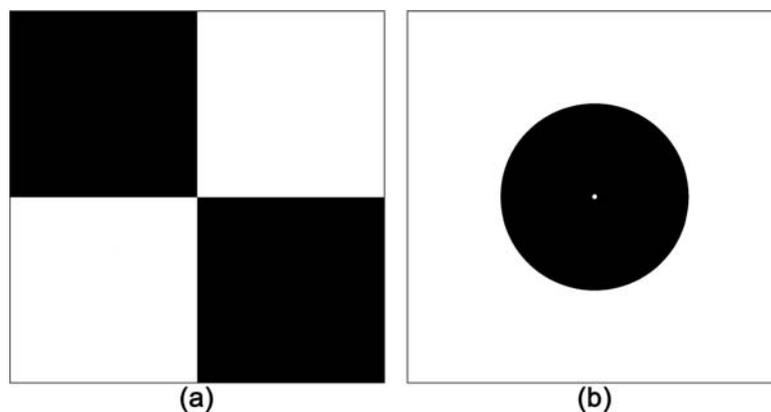


Figure 9: Model of target points: (a) for manual marking, (b) for automatic marking (the white point in the centre is used to target the centre)



Figure 10: Detail of image of targets

The positions of reference points or targets can be measured. Such information can be used to scale and orient the model or directly orient the photographs individually. The

measurement of points in three dimensions is a specialist operation⁹⁷, made relatively simple by the use of a reflectorless total station. However, in the absence of the necessary skills and/or equipment, simpler methods involving items such as tape measures and plumb lines have to be resorted to, which might prove more time consuming and potentially less accurate.

As for all other procedures involving measurements, it is always advisable to have redundant information: e.g. measure more than one distance and have more than one plumb line. The question of the accuracy of all measurements is of course important.

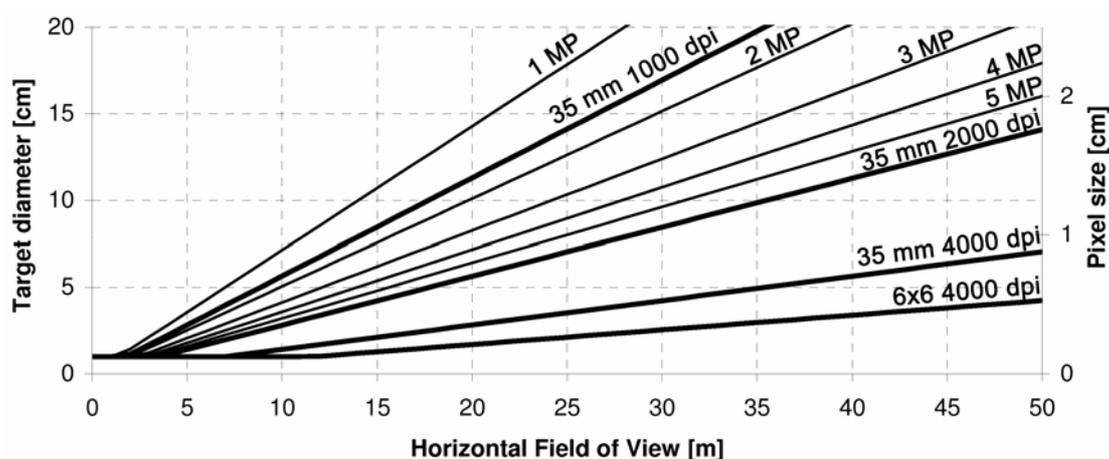


Figure 11: Minimum dimension to give to the target. Number of MP (Mega pixels) refer to digital cameras and dpi (dots per inch) refer to scanners used to scan the films.

Very often, surveying books recommend placing a yardstick, a telescopic staff or a ruler beside the object to serve as a reference. The advantage of this technique is that the dimensional reference is stored in the photograph itself. There is no risk of losing the measurement or associating it with wrong elements. The actual measurement is then made by the user of the photograph, without risk of incorrect interpretation. To give more accurate results, the size of that reference should be of the same order as the extent of the photograph; however, this requirement may be difficult to meet for buildings because long staffs are not commonly available.

Measurements of elements on the building or of distances between targets can also be used to scale the model. In these cases, what is measured has to be clearly identified on a plan, an elevation or on a copy of one of the photographs. Even if no measurements have been taken, it may be possible to scale the model. Usually, the easiest way is to go on site and to measure elements that are visible on the

⁹⁷ LUNNON, 2.2.1: English Heritage prescribes an accuracy of ± 4 mm for control points.

photographs and which are not affected by the transformations. Some elements of standard dimension may also be visible on the photographs. Dimension of vehicles, containers or street furniture can provide useful references.

4.6.2 Point of view

Photographs may not be well targeted; they can fail to document the important elements. This default can take many forms. For example, a photograph of a facade may not include the total extent of the facade because one corner has been cut off, or some elements may be barely visible because the camera was too far away from the subject. Elements can be hidden by trees (Figure 12), scaffoldings, cars or furniture. In similar cases, more photographs are sometimes necessary to give a complete coverage⁹⁸. Sometimes obstructing elements can be moved away⁹⁹ or, if tree foliage is hiding the architecture, one can wait for winter¹⁰⁰.

Viewpoints can be inadequate for the retrieval of metric information. Requirements may vary according to the technique used. To document a facade, a frontal view gives a good image of the proportions and is a good base for rectification¹⁰¹; however, it may not be easy to ascertain the volume of the roof¹⁰². To use an image for the purpose of photogrammetric interpretation, it is necessary to have a set of overlapping photographs with good angles between corresponding rays (Figure 38). This means that, for a façade, two opposing diagonal views may form a better minimum set. Photographs including two façades can be used to connect parts of the survey. Points visible on three photographs can have their accuracy assessed. Redundancy is very important in surveying. The 3x3 rules recommend having both frontal and oblique photographs, so that a minimum set for a façade comprise at least three photographs.

⁹⁸ MC KEE, p.64

⁹⁹ MC KEE, p.65; BUCHANAN, p.13

¹⁰⁰ BUCHANAN, p.56

¹⁰¹ LUNNON, 4.3: "alignment of each image plane with the principal plane of the object area to within ± 3 degrees of parallelism"

¹⁰² BUCHANAN, p.34



Figure 12: Laura Place, Bath

The viewpoint can be too far away from (or too close to) the object. If the photographs are used to retrieve metric information and to allow for a given accuracy, the shots must be taken at a distance that cannot exceed a given limit¹⁰³. To frame the object to be surveyed, they cannot be too close. The photographer has then to choose suitable stations in the zone defined by those two criteria. Those problems are discussed further in section (5.3.8). Photographs can also lack clarity. The relevant elements may be overshadowed by accessory elements¹⁰⁴.

4.6.3 Light

In photography, the question of light is central. This includes the question of contrast and temperature of the light. The human eye is able to record scenes with variations of luminance of about 10 stops¹⁰⁵. Negative films can record about 7 stops and slide

¹⁰³ The object size of a pixel can be used as a first estimate. A photograph of a facade 10m wide with a digital camera having an horizontal resolution of 2000 pixels will lead to pixels having an object size of 5mm.

¹⁰⁴ BLAKER, p.14

¹⁰⁵ A stop corresponds to a variation of exposure of 2. It depends on exposure time and aperture of diaphragm.

films only about 5 stops. Digital cameras can approach 8 stops¹⁰⁶. In a real scene, the difference of luminance between parts of high and low illumination can be too great to be reproduced. Figure 21, taken with a digital camera, shows details in the shadows that would have been lost in a print.

To record all the variations of luminance, the light has to be well balanced. A correct contrast is then necessary to produce images with clear density variations. Contrast has to be stronger if the variations of luminance are small and weaker if they are important. If the variations of luminance are important (when photographing window frames from the interior, for example), it is advisable to take a set of photographs with different settings. The first exposures can be carried using the outside light and appropriate settings, with additional exposures using the interior light; possibly further photographs may be taken at intermediate settings. When using one of the simpler automatic cameras, it may not be possible to have manual control over the shutter speed and lens aperture. However, it may be possible to control the illumination by using some 'tricks'. For example, the camera can be oriented towards a surface having the desired average illumination and situated at the same distance as the object to photograph. The release button can be half-pressed to trigger auto-focus and auto-exposure. Then, keeping the button half-pressed, the camera can be oriented toward the object and the final shot taken.

Strong expression (e.g. shadows, mist, unusual point of view, grain) can be interesting from the photographic point of view but can reduce the quality of a photograph as a document¹⁰⁷. If only one set of photographs is taken, it is probably better to keep it neutral so that more features may be recorded¹⁰⁸. Bright thin overcast is the ideal light condition; it provides strong diffuse light with little shadow. Sunny days with passing clouds are also interesting; they give the opportunity to wait for the desired lighting (Figure 14).

¹⁰⁶ <http://www.cliffshade.com/dpfwiw/exposure.htm#dynamic>

¹⁰⁷ DE MARÉ, p.178: "photographing beautiful structures, or photographing structures beautifully, or doing both together"

¹⁰⁸ SWALLOW, p.98; BUCHANAN, p.13, p.27



Figure 13: Bath, Bath st.: (a) 6/5/2003 14:29 f/5.6 1/350s, (b) 9/5/2003 10:40 f/2.8 1/225s



**Figure 14: The pump room, Stall Street, Bath:
(a) 6/5/2003 14:31 f/5.6 1/800s, (b) 6/5/2003 14:32 f/5.6 1/270s**

The character of a building depends greatly on its interaction with the environment, and light can have a substantial effect. The atmosphere of a place can be completely changed by a uniform lighting. Good photographers can capture these effects. If metric information has to be extracted, diffuse light is certainly the best condition¹⁰⁹.

¹⁰⁹ FREEMAN, p.201: "You must find a balance between a plain record and too subjective an interpretation"

Shadows are potentially disturbing. Large shadows cutting a scene can lead to the contrast of luminance exceeding the dynamic range of the film or sensor (Figure 15). For metric interpretation, requiring the identification of edges, shadow lines can be confusing¹¹⁰. The impact of shadows is function of the angle of incidence of the light and of diffusion of the light. The angle of incidence depends on the orientation of the facade, on the time of day and on the time of year. Early and late lights are more horizontal and perpendicular to the facades¹¹¹. In winter, light can penetrate more deeply in interiors¹¹². It is advisable to check at different times of day to determine the best moment for each shot.



Figure 15: The Harington Club, Harington Place, Bath

¹¹⁰ BUCHANAN, p.41

¹¹¹ FREEMAN, p.202

¹¹² HARRIS, p.97

For architectural photography, a horizontal angle of incidence of 45° on the facade is often recommended¹¹³. The situation is more complex for documentation. It is very likely that the ideal moment won't be the same for each photograph. The shadow length depends on the height of the protruding element and on the angle of incidence. They can have a positive and a negative influence. They emphasise features, facilitating the interpretation, they can also make visible joints and texture. Front lighting flattens the texture but illuminates all the elements visible from the viewpoint. Raking light can emphasise tenuous features like texture or cracks (Figure 16).

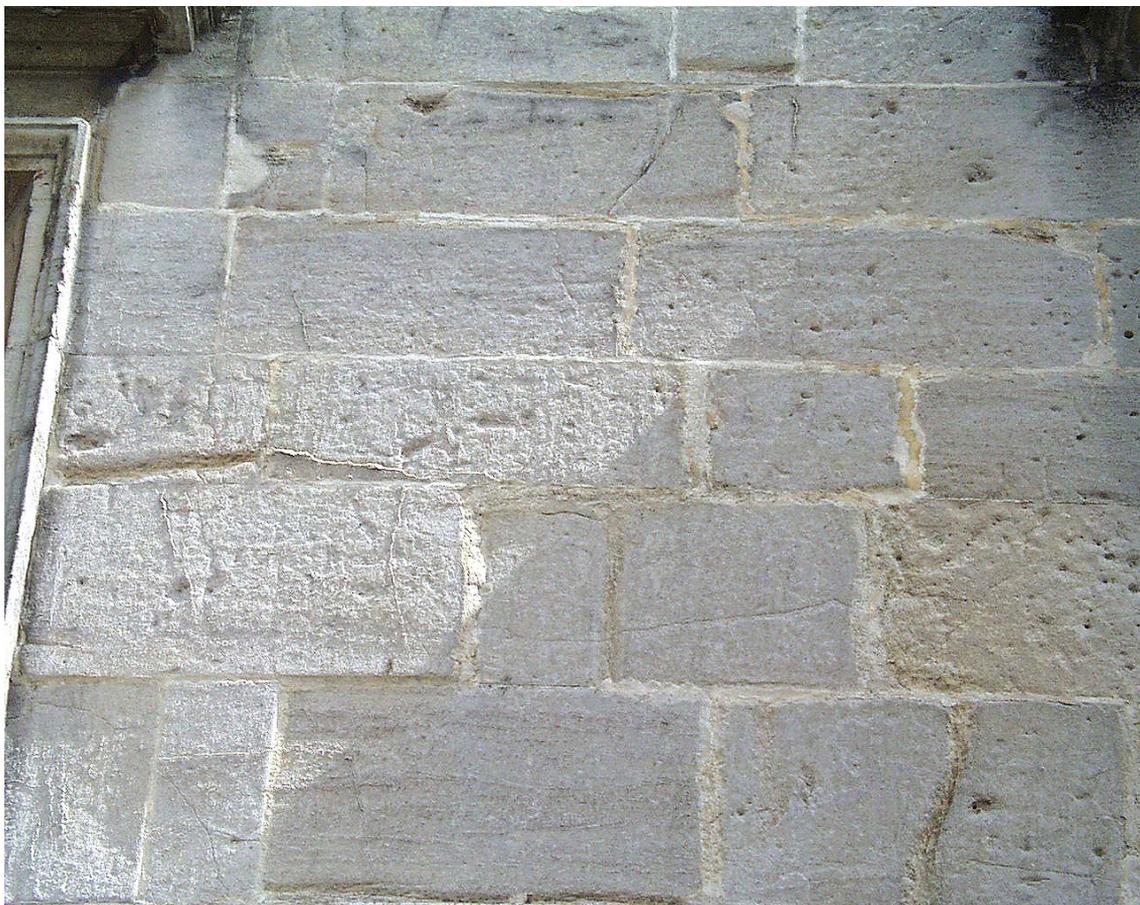


Figure 16: Bath, Influence of light on texture

North facades are, of course, never perpendicularly illuminated. It is, therefore, usually better practice to take pictures on a cloudy day, with plenty of diffuse light, while avoiding facing the sun. If direct illumination is desirable during the summer,

¹¹³ BUCHANAN, p.40; HARRIS, p.95

then such a facade can be photographed during the early morning or late afternoon. Photographs taken in the direction of the sun very often have flares (internal reflection) and ghosts (images of the diaphragm), frequently if lesser quality lenses are used. In narrow streets, it is sometimes necessary to wait for the sun to be aligned with the street.

The time of year also has an influence. The light does not have the same qualities in summer and in winter. At a given moment of the day, winter light is more horizontal and warmer (more red). In many cases it is probably not possible to wait until the conditions become perfect but, for important projects, it is a factor to consider. Local weather forecasts can be consulted beforehand by telephone or on the Internet (<http://www.meteo.gov.uk>).



Figure 17: Blessed Virgin Mary, Claverton:

(a) f/2.8 1/100s. with flash: sharp but flat, (b) f/2.8 1/4s. without flash: out of focus

For interior views, the question of light is particularly critical. Normal lighting conditions are often very unbalanced and some elements will remain in shadow. A

flash can be used but it is not a perfect solution. Flash tends to flatten the scene¹¹⁴ (Figure 17) and it can cast very strong shadows that completely hide some elements (this can be corrected by diffusing the light, using reflection from a light surface). Furthermore, if the scene has different planes, the lighting conditions will be satisfactory only at a particular distance. Objects closer to the camera will be over-exposed and objects further away will remain in the dark¹¹⁵. The short duration of the flash makes the resultant conditions difficult to foresee and control (except in the case of professional lighting with preview lamps). Additional tungsten lights are easier to locate and are straightforward to control¹¹⁶. Nevertheless, flashes can give good results for photographs of window frames taken from interior rooms. Experimentation is easier with digital cameras. For important elements, it may be advisable to take a set of photographs with the flash and another set without it.

The non-linear behaviour of films also has to be noted, because the long exposure often needed for interior photography requires an augmentation of the exposure time given by an exposure meter. For exterior photography, floodlights can be used to reduce the contrast between different zones (between lit and unlit parts of a cornice, for example)¹¹⁷.

4.6.4 Colour

In some cases, colour is an important element to record. Colour reproduction is influenced by the quality of the light and, in particular, by its temperature. This effect is clearly illustrated by the yellow dominance of photographs taken under tungsten lightning (about 2900°K) when using a daylight film (calibrated for 5500°K). The temperature of daylight varies according to the atmospheric conditions, from about 2000°K at sunset to more than 10000°K for a clear blue sky. If a precise reproduction of colours is not important, no special care should be taken. If it is important, then filters or special films may be needed. The situation is even more complex for interior photography when the scene is illuminated with sources having different

¹¹⁴ SWALLOW, p.106

¹¹⁵ FREEMAN, p.204

¹¹⁶ BUCHANAN, p.15

¹¹⁷ BUCHANAN, p.51-52

temperatures. If precise reproduction of colour is required, it is necessary to include reference charts in the photographs¹¹⁸.

Traditionally, photographs intended for archiving were always black and white. The use of colour photography was discouraged because of its lesser resistance to change over time¹¹⁹. Today, it is claimed that the quality of colour negatives is substantially improved but, as a matter of fact, time has not yet provided direct evidence¹²⁰. Digital images have the advantage that their colours are perfectly stable in time.

Apart from correcting light temperature, filters can be used for colour separation in order to emphasise elements (see 4.7.6) Polarising filters reduce reflections on shiny elements, while colour filters can be used to reinforce the contrast of certain colours.

4.7 Equipment

Within the context of documentation, the selection of equipment is directly related to the range of detailing present and the need for recording it. High-resolution photographs are therefore desirable, as, for a given level of detail, the number of shots required is reduced. This is particularly useful for buildings rich in details.

The projective behaviour of a camera depends on a set of parameters that includes focal length, lens distortions and focus. The aim of internal calibration of the camera is to determine these parameters. Usually, internal parameters vary for each shot depending on zoom and focus settings¹²¹. To facilitate metric extraction, it is better to keep the settings constant. The camera model can thus be kept constant and its parameters estimated more robustly from the available set of photographs and the corresponding points identified on them. Moreover, it is easier for computer software to handle such a case.

¹¹⁸ Macbeth ColorChecker or Kodak Color Control Patches and Kodak Gray Scale Q13 for instance.

¹¹⁹ BUCHANAN, p.16

¹²⁰ Except when necessary, RCHME still recommend the use of B&W. RCHME, Recording Historic Buildings, p.4

¹²¹ To give an example, the principal distance of a 50mm lens is 50mm for objects at ∞ , 50.05mm for objects at 50m and 50.5mm for objects at 5m.

4.7.1 Measure of quality

In order to be able to discuss the influence of diverse parameters related to equipment, an objective measure has to be defined. The final results, in the form of image files, are produced by a process involving a chain of ‘devices’. In the case of analogue photographs, they are: original object with its luminance, atmosphere, lens, camera body, film, development, scanner and imaging (edge enhancement, compression etc.). In the case of digital photographs, the factors of film and development are not present. To produce high-resolution photographs, all the above parameters are important. Each of them affects the quality of the next link's input and therefore the final quality.

To study the sharpness of an image, the traditional measure is the resolving power, expressed by the number of lines that can be identified in one millimetre. A special target¹²² is photographed and the limit of discernability of adjacent lines is measured on the final support (negative, print or file). As the criteria employed by any one observer may vary, this is not an objective measure. Nowadays, quality is measured by the **modulation transfer function (MTF)**¹²³. This measure is reproducible and independent of the contrast.

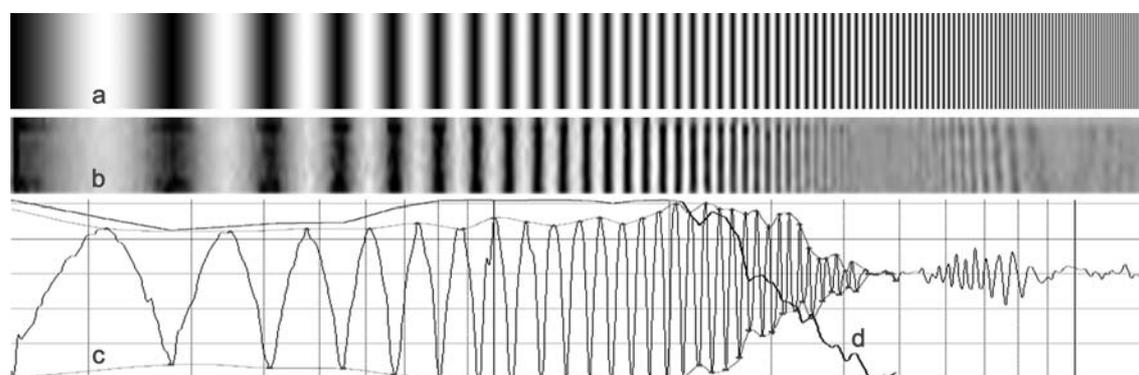


Figure 18: Modular Transfer Function (MTF): (a) original target, (b) digital image, (c) variations of luminance, (d) MTF function

The contrast γ between a region of luminance L_1 and another region of luminance L_2 is defined by:

$$\gamma = \frac{L_1 - L_2}{L_1 + L_2} \quad (1)$$

¹²² USAF 1951 lens test chart for instance.

¹²³ MEYER-ARENDRT, pp.186-196

The MTF can be determined using a specific target¹²⁴ printed with sinusoidal variations of density and with a decreasing length of wave λ (Figure 18.a). When the variations of luminance are slow (low frequency), the contrast is well transferred but, when λ increases, the capacity of the system to transfer contrast decreases (lines closely spaced just appear grey). The modulation transfer factor $T_{(\lambda)}$ is the ratio between the contrast at low frequency (which is assumed to be perfectly transferred) and the contrast at a given frequency λ :

$$T_{(\lambda)} = \frac{\gamma_{(\lambda)}}{\gamma_{(0)}} \quad (2)$$

The graph of $T(\lambda)$ is the modulation transfer function (Figure 18.d). The resolving power R of a system in lines pairs per mm can still be used, but it needs to be given for a given reduction of contrast. R_{50} indicates, for instance, the line pair spacing producing 50% of reduction of contrast.

An important advantage of the technique is that the MTF of complex systems can be calculated by multiplying the MTFs of each of the components. In order to illustrate these aspects, in the next chapter a more global approach will be used by taking photographs of the special target with different equipment configurations. In this way, it will be possible to quantify differences between sets of equipment.

4.7.2 Tripod

Vibrations occurring during exposure blur the resulting photograph which produces a reduction in resolving power. The use of tripods is therefore very important. Long exposures make their employment compulsory but, even for short exposures, the absence of a tripod significantly reduces sharpness. Puts¹²⁵ states that 30 to 40 lp/mm is the maximum resolving power to expect from handheld shots taken at 1/500s. The shot should be triggered by a flexible cable or by a timer. If the camera has a mirror, it is better to lock it in the upper position (if possible) to further reduce vibrations.

Tripods keep the camera in position and thus allow the operator to adjust the different

¹²⁴ KOREN [<http://www.normankoren.com>] provides detailed explanation on how to measure MTF.

¹²⁵ Puts E., *Exploring the limits of 35mm BW Photography* [<http://www.imx.nl/photosite/technical/highres.html>]

parameters (position, framing, exposure etc) independently, one after the other.

Heavier models are steadier. Higher extension models allow photographs to be taken at a greater height from ground, which is usually the better viewpoint for recording facades. Specialists may, in some circumstances, use more sophisticated devices such as masts or kites.

4.7.3 Atmosphere

Atmospheric conditions influence the clarity (or blurring) of images. Photographs should not be taken when the weather is hazy. This point is obvious but, when lenses of great focal length are used, the effect can be marked, even in apparently good weather conditions. When the temperature increases, the air also becomes more turbulent. This is the reason why ideal conditions are most likely to be encountered on cold winter days.

It has to be noted that blue light is scattered to a greater extent¹²⁶. Therefore, the red channel of a colour photograph has a greater chance of being sharper. The effect is clearly visible only for long distance photographs or for pictures taken under adverse weather conditions. UV filters for colour emulsions or digital images and UV or yellow filters for black and white films block the higher frequencies.



Figure 19: Wales, Cadair Idris: (a) blue channel, (b) red channel

4.7.4 Lenses

The quality of lenses varies widely. For high resolution, the lens has to be of good quality, which implies greater cost. As a matter of principle for documentation, it is generally best practice to use lenses of 50mm focal length with 35mm cameras

¹²⁶ JACOBSON, p.136

because their field of vision corresponds to that of the human eye. However, the requirements may be different for the retrieval of metric information. If the pictures are going to be used for rectification, it is best to use long-focus lenses: the resulting images are closer to parallel projections. As the photographs can be taken from further away, fewer elements will be hidden by 'shadows' created by protuberant objects such as cornices. On the other hand, long-focus lenses increase the effects of atmospheric interference and so the resolution can decrease¹²⁷.

In practice, it may be that these general statements do not apply. Available distance to frame the intended scene is often insufficient and it becomes unavoidable to use wide-angle lenses. This is especially the case for interiors, where extreme wide-angle lenses may be necessary. Non-professional photographers usually do not own such lenses. Indeed, the number of photographs necessary to give a complete coverage of an interior space may be too high to be practical.

It is better not to use a zoom lens. Changes in focal length potentially influence all the internal parameters. As they contain a larger number of mobile elements, zoom lenses are also less stable¹²⁸ and their optic is usually of lesser quality. If they are used, they should be set permanently on their widest angle or longest focal length, which are the only precisely reproducible settings.

It is advisable not to use special lenses that allow perspective corrections. Such a choice goes against the usual recommendations for architectural photography. Lens movements introduce extra unknown parameters. To produce images free of disturbing vertical convergence, corrections can always be made at a later stage with software (with PhotoShop for instance, possibly with the PanoTools plugin).

The parameters affecting the resolving power of lenses will be discussed in turn in the following sub-sections.

4.7.4.1 Focus

To document buildings and record as many elements as possible, the depth of field has to be controlled to obtain sharp images of all the relevant points of the object¹²⁹. This is achieved by setting a small aperture size. Except in very bright exterior

¹²⁷ BLAKER, p.108

¹²⁸ FRYER in ATKINSON, p.172

¹²⁹ BLAKER, p.15

conditions, this usually requires long exposure times and hence the use of a tripod. In fact, only points situated on one plane are perfectly in focus. All the other points have an image of finite size (the circle of confusion) whose diameter increases with the distance between the point and the plane of perfect focus. If an admissible diameter c is fixed for the circle of confusion, i.e. a dimension sufficiently small to consider the circle of confusion as a point, it is possible to define the hyperfocal distance h . This is the closest distance at which objects keep a sharp image when the lens is focussed at infinity:

$$h = \frac{f^2}{cN} \quad (3)$$

where f is the focal length and N is the f-number (diaphragm aperture: example 22 for f/22 or 5.6 for f/5.6). If a 50mm is set on f/22 and focussed at infinity, the circle of confusion will have 23 μ m at 5m. This is about the size of a pixel if the negative is scanned at 1200dpi. If the focus is set on a shorter distance u , the extreme planes of sharpness will be at distance:

$$d_{\min} = \frac{hu}{h+u} \quad , \quad d_{\max} = \frac{hu}{h-u} \quad (4)$$

respectively.

For metric documentation, two strategies are possible:

- (i) the simplest one is to permanently set the focus to infinity¹³⁰. In that way, the internal calibration of the camera will remain constant and every point situated farther away than the hyperfocal distance h will remain sharp on the photograph. If it is more convenient, the focus can be locked on a shorter distance u .
- (ii) the focus can also be set in order to maximise the sharpness. In that case, to achieve maximum accuracy, the distance d used to focus has to be recorded and the internal calibration parameters have to be changed for each individual photograph. The lens formula can be used to calculate the principal distance p .

$$\frac{1}{f} = \frac{1}{d} + \frac{1}{p} \quad (5)$$

Note that special lenses allow the depth of field to be increased.

¹³⁰ In some automatic cameras, the focus can be set to infinity putting the camera in "Landscape" mode.

4.7.4.2 Diffraction

From the explanation above, it could appear that the focus will be perfect if the aperture is infinitely small. In practice, diffraction limits the sharpness at small aperture. Because of diffraction, the image of a point is a circle, the Airy disc, whose diameter is given by:

$$c_{Airy} = 2.44\lambda N \quad (6)$$

where λ is the wavelength of the light (red:700nm, violet: 440nm) and N is the f-number. For green light, the more sensible to the human eye, the diameter is therefore:

$$c_{Airy} = 1.34N \quad [\mu m] \quad (7)$$

There is hence an optimum for any couple of d_{close} , d_{far} (more below, **Error! Reference source not found.**). In order to minimise the effect of diffraction and distortion, lenses should always be cleaned before taking shots.

4.7.4.3 Aberration

Real lenses cannot perfectly reproduce points and straight lines. Points become spots and lines become curved strips. These defaults are called aberrations (chromatic, spherical, coma, astigmatism, curvature of field and distortion)¹³¹. Good lenses have better characteristics but, in practice, compromises are always present in their design. This is more complicated when other exigencies arise. Fast lens design generally sacrifices flatness of field or other characteristics¹³². Zoom lenses have more complex requirements. Usually, wide-angle lenses have more aberrations. Chromatic aberrations are often visible as coloured fringes in high contrast zone (edges of dark elements on a sky background for instance, Figure 20).



Figure 20:City Markets, Bath

Most of the aberrations increase with the aperture of the diaphragm. Chromatic

¹³¹ Lens aberrations are described in details in JACOBSEN, pp.57-66 or in most Optics textbooks.

¹³² BLAKER, p.106.

aberrations can be partly corrected by software¹³³ or by taking black & white photographs with a filter.

4.7.4.4 Distortions

Distortions are aberrations affecting the geometry of the image and not its sharpness. Image of straight lines may be convex (barrel distortion, Figure 21) or concave (pincushion distortions) in relation to the principal point. They are not influenced by the aperture of the lens. Distortions are usually more pronounced for wide-angles and cheaper lenses. Corrections are necessary to achieve good results and software is available for this operation.

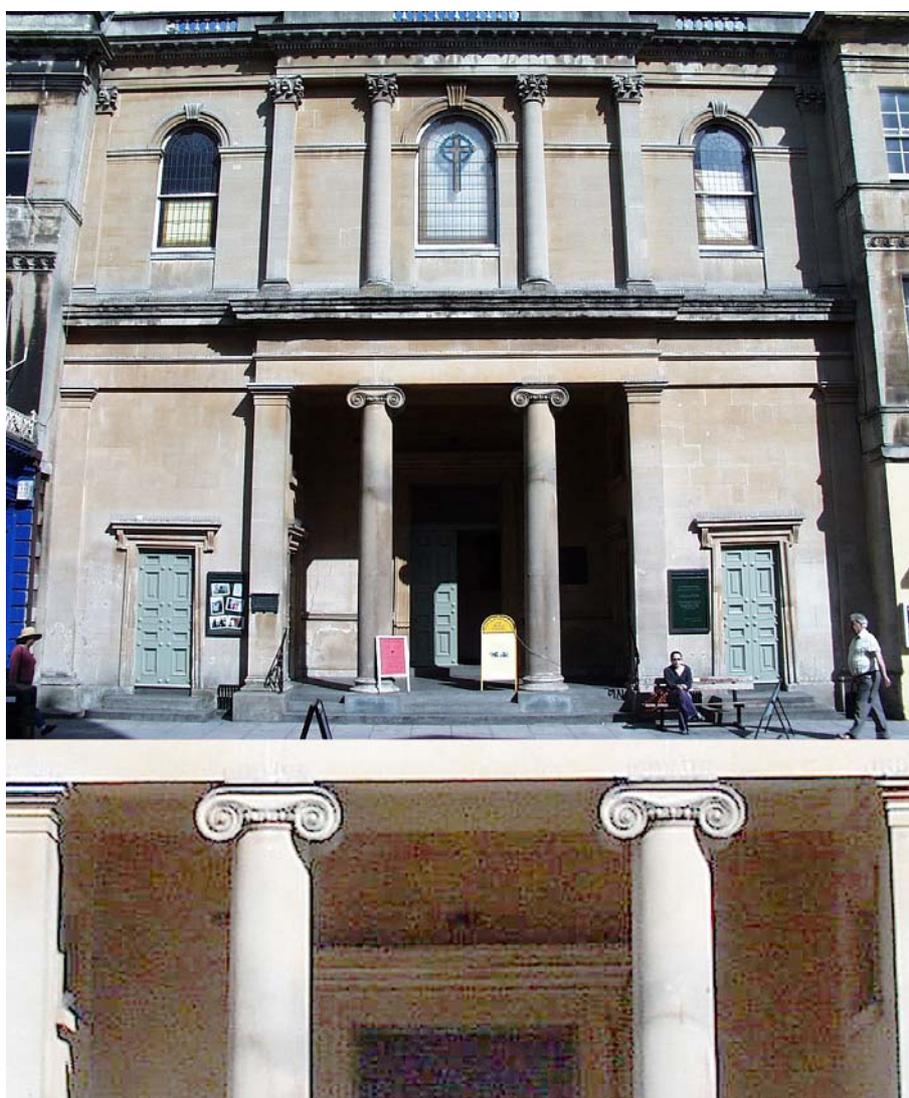


Figure 21: United reformed church, Argyle Street, Bath: (a) general view, (b) detail of the porch after contrast and lightness corrections.

¹³³ With the Panorama tool for instance.

In order to better understand the combined effects of the various parameters discussed above and arrive at an optimal choice of focus distance and diaphragm aperture the two strategies considered in 0 are applied to the definition of the same shot.

In the first strategy, the focus is set to infinity. The closest plane which has to be on the focus can be determined¹³⁴, and this defines the depth of field. The optimum aperture N_o can then be found equating the circle of confusion resulting from the depth of field (Equation 3) and from the diffraction (Equation 6)¹³⁵.

$$N_o = \frac{f}{1.6\sqrt{\lambda h}} \quad (8)$$

In the second strategy, the focus is set precisely. The distances of the closest and farthest planes which are in focus can be determined as before, by using the camera meter. Using equations 4, the best focus distance u , intermediate between the two planes, can be computed¹³⁶ (see Figure 22):

$$u = 2 \frac{d_{\max} d_{\min}}{d_{\max} + d_{\min}} \quad (9)$$

Using equations 4 again, the hyperfocal distance h can be computed.

$$h = 2 \frac{d_{\max} d_{\min}}{d_{\max} - d_{\min}} \quad (10)$$

and the optimum aperture N_o is found replacing h in Equation 8 by its value calculated

from Equation 10:

$$N_o = \frac{f}{2.2} \sqrt{\frac{d_{\max} - d_{\min}}{\lambda d_{\max} d_{\min}}} \quad (11)$$

¹³⁴ This can be done, for instance, using the camera and focussing precisely on a point of the plane.

¹³⁵ This is a simplification. Light distributions in the two kinds of spots should be taken into account, summed and the MTF of patterns of such resulting points should be computed. A slightly better estimate can be found equating the MTF at 50% of the two light distributions. The results do not change much; the factor 2.2 of equation 11 is replaced by a factor 2.

¹³⁶ In practice, on many cameras, it may be difficult to adjust the focus very precisely. The mechanisms and its few graduations are not very helpful.

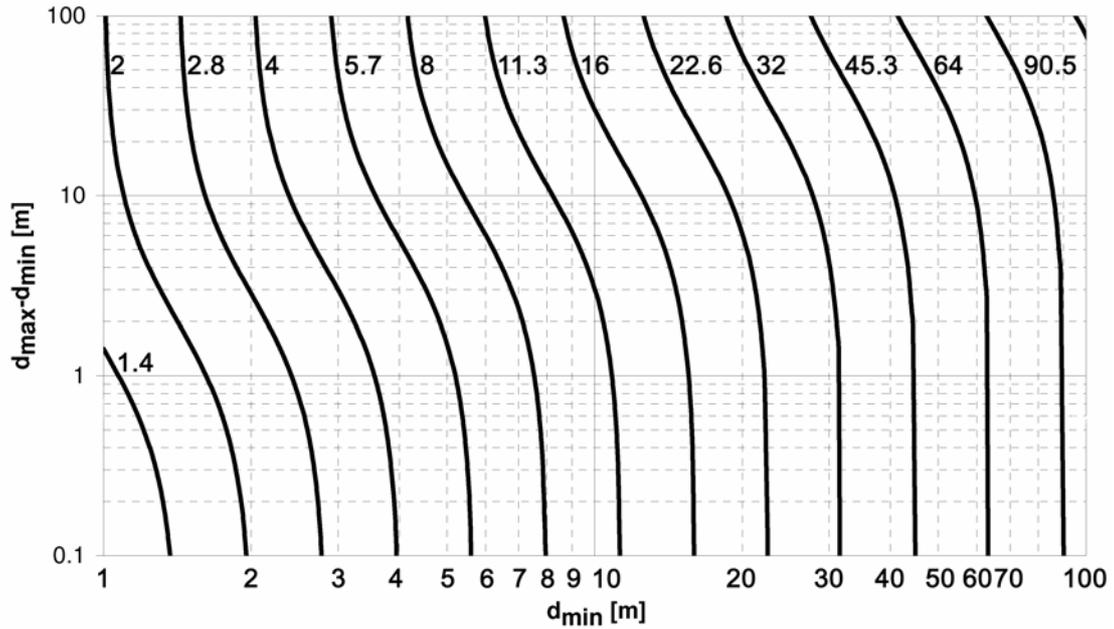


Figure 22: Optimum focus distance

These results are presented in Figure 23 for a 50mm camera. Equation 8 does not take into account the aberrations, whose influence depends on the specific lens design. In order to account for them, it is usually recommended not to use the 2 largest aperture of the lens. The optimum aperture is then:

$$N = \max(N_o, 2N_{\min}) \quad (12)$$

The diameter of the circle of confusion can be calculated using Equation 6. It will have to be smaller than the size of a pixel to obtain a perfectly sharp digital image.

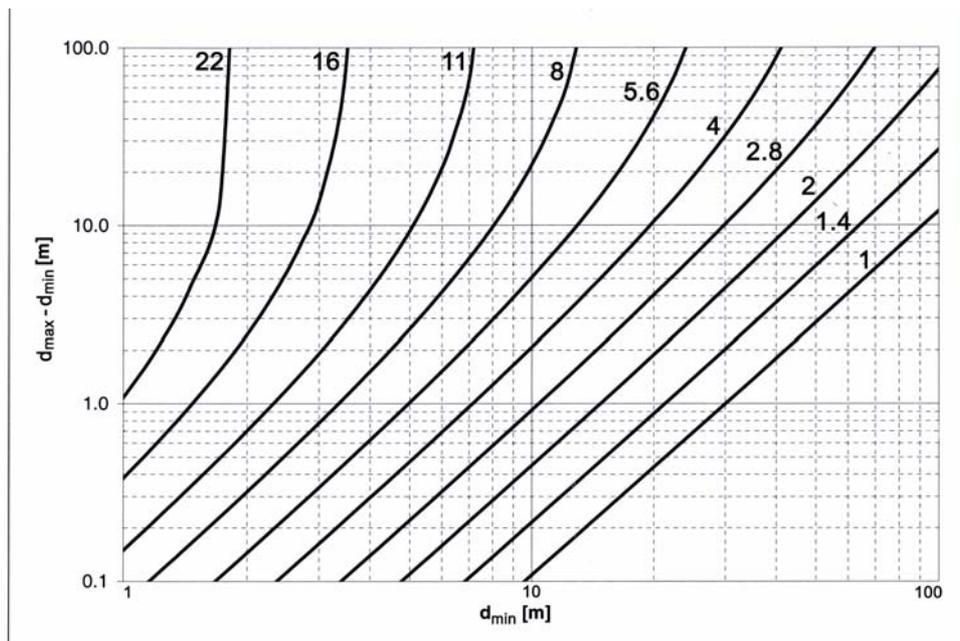


Figure 23: Optimal Diaphragm aperture for a 50 mm camera lens

4.7.5 Camera body

For photogrammetric work it is recommended that the area to be covered with a negative of 24x36 mm should be about 3.6x5.4m¹³⁷. In practice, the scale of the images is likely to be smaller, as it would otherwise require a large number of photos to document an entire building. Nevertheless it is advisable, especially when using analogue cameras, to use the largest format available, even if this is smaller than the photogrammetric standard.

Not all cameras can take shots with long exposures. This can be problematic when films of low sensitivity are used in dark conditions. Cheap automatic cameras have a number of disadvantages. Their optic is of lesser quality and is probably less stable. And, because of the automatic mechanism, it may not be possible to fix focus and aperture. To take the greatest advantage of data coming from such cameras, the software has to allow for variation in their internal parameters.

Negatives are not kept perfectly flat (i.e. in one plane) during exposure. They usually bulge. This is the reason why expensive photogrammetric cameras have the negative sucked against a flat backing plate before exposure. Following Monaghan¹³⁸, 60% SLR have an average of 0.2mm bulge. The circle of confusion c_b resulting from a bulge b is given by:

$$c_b = \frac{b}{N} \quad (13)$$

and it is adversely influenced by the diaphragm-aperture N .

Film bulges also deform the geometry. Special photogrammetric cameras normally have *reseaux* etched on a glass plate, in front of the film. *Reseau* marks can be used to correct the film deformation¹³⁹. If such a camera is available (very unlikely), it should of course be used. Digital cameras are not significantly subjected to this kind of deformation.

¹³⁷ LUNNON, 4.3.4 proposes negative scales of 1:200 for 1:50 output scale and 1:100 for 1

¹³⁸ Quoted by KOREN at <http://www.normankoren.com/Tutorials/MTF6.html>, up to 0.5mm following FRYER in ATKINSON, p.170

¹³⁹ FRYER in ATKINSON, pp.170-171

4.7.6 Film

The choice of the emulsion influences the final result. Factors to consider are speed, grain, dynamic range and colour sensibility. Low-speed film records more details. Buildings are static objects and, because it is recommended to always use a tripod to minimise vibrations, it is also better to use emulsions of low speed. Slide films have a smaller dynamic range (5 stops) which makes them less desirable, except for scenes with low variations of luminance. Their colours also fade more rapidly over time. Black and white photographs have a disadvantage that, in some circumstances, zones having different hue are reproduced by identical shades of grey. Black and white emulsions are mainly sensitive to luminance. The more common panchromatic emulsions respond to red, green, blue (and ultra-violet) light and reproduce luminance close to that which the human eye perceives. Orthochromatic films are not sensitive to red light, while infrared films are sensitive to lower frequencies (below those of visible light). Film types and filters may enhance differences¹⁴⁰, separate the colours and facilitate interpretations.

Negatives are the primary documents: they contain greater detail and their dynamic range is higher than prints. Very importantly, they include a full frame, allowing the use of the border of the frame as fiducial marks, facilitating the photogrammetric process. It is advisable to always include negatives with the prints when filing an application.

For digital photographs, on the other hand, it is important to produce hard copies¹⁴¹. Digital information may theoretically have perfect conservation characteristics but the question of the evolution of the supports makes the issue of long term storage and archiving rather complex¹⁴².

¹⁴⁰ JACOBSON, p.135. BLAKER, 1976, p.59: With the use of filters, it is possible to reproduce the behaviour of orthochromatic films with panchromatic emulsions. See also <http://www.crime-scene-investigator.net/filters1.html>

¹⁴¹ RCHME, Recording Historic Buildings, p.6

¹⁴² RCHME, Recording Historic Buildings, p.1 "the report and supporting material should be produced on a medium which can be copied easily and which is archivally stable"; see <http://www.tasi.ac.uk/advice/delivering/digpres.html> for a discussion of the future of digital archives

4.7.7 Scanner / sensor

If photographs are used for the extraction of metric information, they will be most likely acquired in or be transformed to a digital format. If an analogue camera has been employed, then the negatives have first to be scanned in order to be used. This can be done with dedicated film scanners (with resolution up to about 4000dpi). Some flatbed scanners also allow the scanning of negatives by using a special device (with resolution up to about 3200dpi)¹⁴³.



Figure 24: Cavendish Road, Bath. Scanning of the full format of the negative

If photographs are used for photogrammetry, the ability of the scanner to scan the full format is particularly critical. Generally stated, the extent scanned should correspond (or be normalised) to a constant part of the field of vision of the lens. If this is not the case, then calibration parameters cannot be considered constant between photographs and the supplementary parameters introduced will lead to lower accuracy. If the frame border is visible on the scan, its corners can be used as fiducial marks¹⁴⁴. In the unlikely case of photographs taken with a camera equipped with a *reseau*, its points or lines can also be used.

¹⁴³ It has to be noted that the quality of dedicated film scanners is normally higher. The sensor resolution of flatbed scanners is misleading, in particular because this type of scanner do not maintain the focussing (see Sergei Sherbakov, <http://www.digit-life.com/articles2/epson3200>). It appears that the effective limit for this kind of scanner is about 2000dpi.

¹⁴⁴ FRYER in ATKINSON, pp.171-172

The Shannon sampling theorem states that the sampling interval has to be at least half the size of the smallest interesting detail¹⁴⁵, but this is an absolute minimum. In practice, resolution depends also on phase differences. As a function of the relative position of the lines to the sensor, between 2 and 3 pixels are necessary to define a line. MTF can be used to quantify this aspect.

Scanners produced for photogrammetric works have more precise mechanisms and give more stable and accurate scans¹⁴⁶ than a typically available commercial scan. As already discussed, however, the final resolution of an image depends on all the elements in the optical chain (0), and 4000 dpi scanners provide resolution comparable to the best combination of lenses and emulsion.

With a 1200dpi scanner, one can obtain a 1133x1700 scan image from a 24x36 negative. Today, not all digital cameras can provide a better resolution. If the size of the negative was 6x6, then the resulting image would have digital dimensions of 2834x2834, or about 8 MPixels, which is a resolution well above a typical consumer's digital cameras. These figures show the continued relevance of the analogue process.

The final resolution can be used as a measure of the potential accuracy. If a building 30m wide is photographed with a digital camera having 1200 pixels of horizontal resolution, then the object size of a pixel will be of the order of 2.5cm. Generally speaking, in these circumstances it cannot be expected to have accuracy much higher than 5cm. For photogrammetric documentation, English Heritage recommends pixel sizes of 5mm for output scales of 1:50 and pixel sizes of 3mm for output scales of 1:20¹⁴⁷. This standard is considered to be too high for the photographic documentation of Listed Building Consents. However, consider (for example) a typical Georgian terrace façade 7 meters wide and about 12m high: with an analogue negative 24x36 in portrait orientation and a 1200 dpi scanner, a pixel size of 7mm can be achieved; with a digital camera of the above specification, the pixel size would be of the order of 10 mm, twice the maximum size recommended by English Heritage.

Finally it should be noted that, for digital cameras, the number of pixels is not directly related to the number of MPixels. The number of MPixels refers to the cells in the

¹⁴⁵ SONKA, p.20

¹⁴⁶ DOWMAN in ATKINSON, p.66

¹⁴⁷ LUNNON, 4.3.4

sensor but not all of them are used. It is therefore better to refer to the horizontal and vertical resolution.

4.7.8 Imaging techniques

Post-processing may increase or reduce the image quality. Compression algorithms (JPEG compression) for instance, will introduce variations in the image leading to lower resolution. It is therefore better to use no-loss compression algorithms and save files in formats supporting them (TIFF for instance).

Using mathematical models of the degradation mechanism, image restoration can be used to improve the quality of a photograph. This is an area of intense research in astronomy and medical imaging. Degradation due to out-of-focus, uniform camera movement or atmospheric turbulence can be greatly corrected (e.g. by inverse filtration, wiener filtration). Simple filters are already available and effective in commercial software. In Adobe PhotoShop, for instance, the high pass filter or, more simply, edge enhancement filters can be used. The values of R_{50} may increase.

Within the framework of Listed Building Consents, the best policy is for owners to provide uncompressed images that are not retouched. It is also better if digital cameras are set to a 'no sharpening' mode, as this will ensure that unaltered images are transmitted, containing the full original information.

5 Validation of Criteria

5.1 Introduction

5.1.1 Objective

In order to assess the relative importance of the recommendations outlined in the previous chapter, tests were conducted on two existing buildings. Photographs were taken by heritage conservation students¹⁴⁸, using different types of cameras and techniques. Their limited experience in photography is thought to be representative of the average listed building consent applicant. The tests were organised in order to address the relative importance of the following issues:

- use of good quality camera
- use of good film, even for low-quality cameras
- use of tripod, even for low-quality cameras
- precision in focus setting
- precision in aperture of diaphragm setting
- use and positioning of targets
- number of shots in the modelling phase
- level of convergence of shots

The assessment was carried out for the first five issues, by measuring the sharpness of the shots taken with the modulation transfer function technique (5.2), and for the last three by considering their aptitude to produce accurate photogrammetric measures assessed using the software *Photodeler Pro 5* (5.3). The tasks were also designed to test the guidelines in their present state of development to determine points which may be unclear or impractical.

¹⁴⁸ Maisie Wong, 4th Year MEng in Civil and Architectural Engineering, University of Bath, and Solidea Faedo, MSc in Conservation of Historic Structures, University of Padua.

5.1.2 Buildings

Two buildings were chosen in Bath: a grade II* house situated in 12 Cavendish Place, (Figure 25) currently undergoing internal alterations and a grade II building, St Mary School (Figure 26) being converted to town houses.



Figure 25: Cavendish Place, n.12, Bath



Figure 26: St Mary School, Bath

The exercise relied on existing drawings of the buildings, rather than carrying out a complete survey; it focused on some typical architectural elements (i.e. exterior and interior elements, general views and details) with the aim of addressing the eight issues listed above at different scales. A set of photographs was taken for each scale or architectural detail. Note that each set contains a greater number of photographs than would be taken under normal documentation circumstances. It should also be noted that the sets of photographs taken do not relate to a specific application for listed building consent. The complete sets are described below for each of the two buildings:

12 Cavendish Place:

- Exterior, the whole facade
- Exterior, lower part of the facade
- Exterior, detail of the facade (pediment)
- Interior, window
- Interior, door
- Interior, fireplace
- Interior, cornice

St Mary School:

- Exterior, East facade
- Exterior, South facade
- Exterior, West facade
- Exterior, crest
- Interior, internal corner
- Interior, North window
- Interior, detail of the roof construction

5.1.3 Equipment

Different types of camera were used (Figure 27).

A photogrammetric camera (to provide an upper benchmark of what can be achieved):

- *Wild P32* camera, format: 8x6 cm; principal distance: 64mm; aperture of diaphragm: f/8-f/22; shutter speed: 1-1/500s.

Two 35mm SLR cameras:

- A *Nikon FM2* camera equipped with a *Voigtländer Color Zoomar Mc* zoom lens; focal length: 28-70mm¹⁴⁹; aperture of diaphragm f/3.5/4.5-f/22; shutter speed 1-1/4000s.
- A *Canon AE1* camera equipped with a *Canon FD* lens; focal length 50mm; aperture of diaphragm f/1.8-f/22; shutter speed 1-1/10000s.

A 35mm compact camera:

- *Olympus Superzoom 115* camera; focal length: 38-115mm; aperture of diaphragm f/3.9-f/10.8.

Two digital compact cameras:

- An *Olympus C-1400L* camera; focal length 9.2-28mm¹⁵⁰; aperture of diaphragm f/2.8/3.9-f/11; shutter speed 1/4-1/1000s.; maximum resolution: 1280x1024 pixels.
- A *Canon Ixus v2* camera; focal length 5.4-10.8mm¹⁵¹; aperture of diaphragm f/2.8/4-; shutter speed 1-1/1500s.; maximum resolution: 1600x1200 pixels.

¹⁴⁹ Zooms were used only on their maximum and minimum settings.

¹⁵⁰ 35mm film equivalent: 36-110mm

¹⁵¹ 35mm film equivalent: 35-70mm



Figure 27: Cameras

The analogue cameras were operated in manual mode (focus and exposure); the digital camera were operated in automatic mode. Higher quality digital cameras include a manual mode, but most users opt for the fully automatic mode.

Some photographs were taken with a tripod and some others without.

A range of different films was used:

- A low speed black & white film: *Ilford Pan F* (50 ASA)
- A normal speed colour film: *Fujicolor Superia Realia 100ASA*
- A high speed colour film: *Fujicolor Superia X-TRA 400*

To test the influence of the aperture of diaphragm, photographs were taken with four different settings ($f/3.5$, $f/8$, $f/16$ and $f/22$). The distance was set to infinity or set precisely on focus (with best and worst film).

Given the variety of equipment available today, it is impossible to be exhaustive and to fully characterise the influence of equipment within the scope of this work. To this end a larger number of tests should be conducted in a more controlled environment. The aim of the present exercise is to identify the feasible range of acceptable quality of photographs taken by non-professional photographers in real circumstances.

5.1.4 Preparation of the scene

Circular targets were placed on each building to assist the orientation of the camera during the photogrammetric processing. Their size was calculated in order to produce images of approximately eight pixels on the digital camera photographs. As far as possible, the targets were regularly spread on the object. In practice, particularly at the School, access made uniform spread difficult to achieve. The facade of the house was chosen to test the resolution of the images in different circumstances. Two large-scale modulation transfer charts (Figure 28) were placed on the first floor balcony (Figure 29).

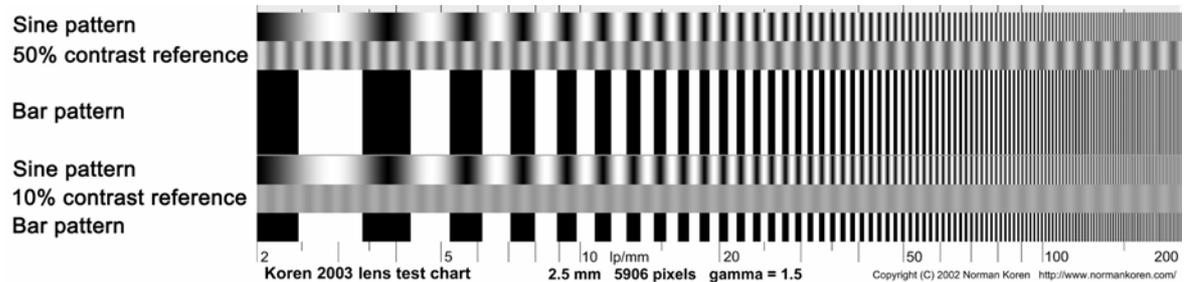


Figure 28: Modulation Transfer Chart



Figure 29: Cavendish Place, n.12, Bath. Targets and lens charts

5.2 Resolution measurements

5.2.1 Objective

Within the limited timeframe of the project, a reduced number of settings were chosen to address the issues concerning the influence of film, aperture of diaphragm, focus distance and use of tripod. While it would have been possible to construct *Photomodeler* models for each set of photographs to compare the various parameters, it is actually faster and more reliable to compare the resolution of the photographs directly. Nevertheless, between three and five converging photographs were taken for each of the settings to allow for the possible construction of photogrammetric models at a later stage.

The sets of photographs used to compute the resolution are listed below:

- Wild P32
 - With tripod
 - Film 50ASA
 - Set focus (f/22, f/8)
- Nikon FM2
 - Film 50ASA
 - With tripod
 - Focus infinity (f/22, f/16, f/8, f/3.5)
 - Precise focus (f/22, f/16, f/8, f/3.5)
 - Without tripod
 - Precise focus
 - Best aperture
 - Film 100ASA
 - With tripod
 - Focus infinity (f/22, f/16, f/8, f/3.5)
 - Precise focus (f/22, f/16, f/8, f/3.5)
 - Without tripod
 - Precise focus
 - Best aperture
 - Film 400ASA
 - With Tripod
 - Focus infinity (f/22, f/16, f/8, f/3.5)
 - Precise focus (f/22, f/16, f/8, f/3.5)
 - Without tripod
 - Precise focus
 - Best aperture
- Olympus Superzoom 115
 - Film 100ASA
 - With tripod
 - Auto-focus
 - Auto-exposure

Without tripod

Auto-focus

Auto-exposure

- Olympus C-1400L

With tripod

Auto-focus

Auto-exposure

Without tripod

Auto-focus

Auto-exposure

5.2.2 Technique

In order to analyse the analogue images automatically, the first operation consisted in scanning the original negatives. This is not a straightforward operation if the influence of the scanner is to be minimised in favour of the potential accuracy of the negatives. To achieve good results within the available budget, the image of the targets on the negatives were photographed using a microscope (*Leica HZ 6* with a *Nikon Coolpix 995* camera, Figure 30). The size of the image of the chart on the negative is about 3 to 3.5mm on the 35mm films, resulting in a resolution higher than 13000dpi. Hence the influence of the scanning process is minimised, giving a good measure of the negative quality. For photographs taken with digital cameras, this process is (of course) not necessary.



Figure 30: Microscope used to scan the negatives

From the digital images of the modulation transfer chart, it is then possible to construct the MTF.

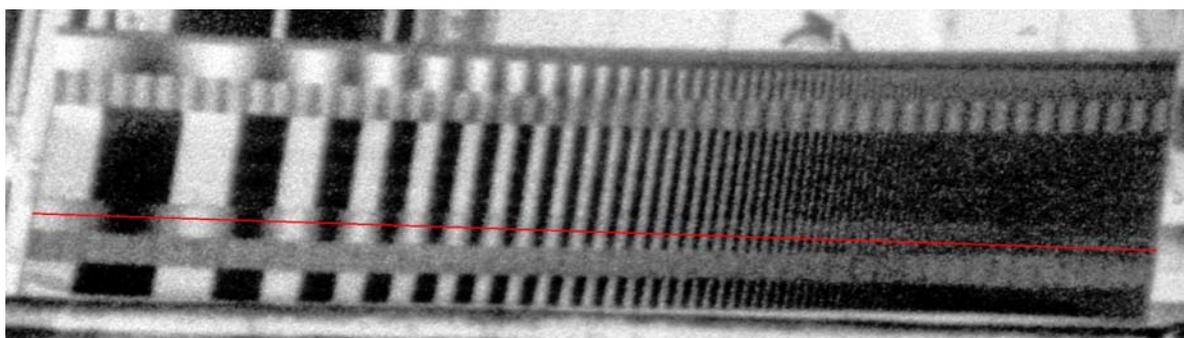


Figure 31: Scan of the image of the target on a negative (real size: 3.35mm) taken with the Nikon FM2 and the 50ASA B&W Film. The red line indicate where the section for the MTF was taken

To compute the MTF of each target image only photographs taken perpendicularly to the facade were used. Using *ImageJ* software¹⁵², the images were transformed to

¹⁵² <http://rsbweb.nih.gov/ij/>

greyscale and subjected to a histogram equalisation. Sections were then made with *ImageJ* along a line defined on the image (Figure 31). But, as Figure 32 exemplify, the sections produced are very noisy.

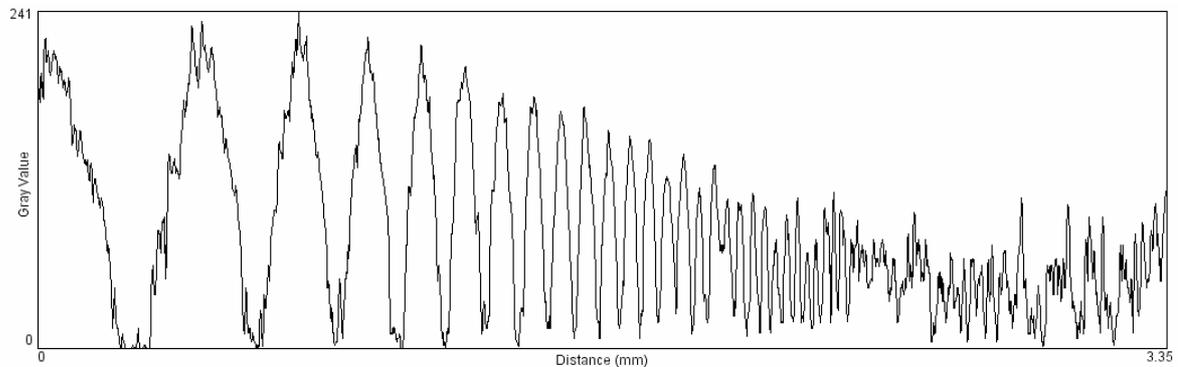


Figure 32: section through the target, along the red line defined on Figure 31

It was therefore decided to average sections made for all the lines of pixel of a band. It was decided to use the rectangular band, which is broader and give smoother sections, allowing for better comparison of the samples and more representative results. *ImageJ* allows rectangular regions to be defined as a basis for a section. In order to be able to achieve this, all images had to be re-sampled (by employing *Photoshop*) to a normalised rectangular shape (Figure 33).

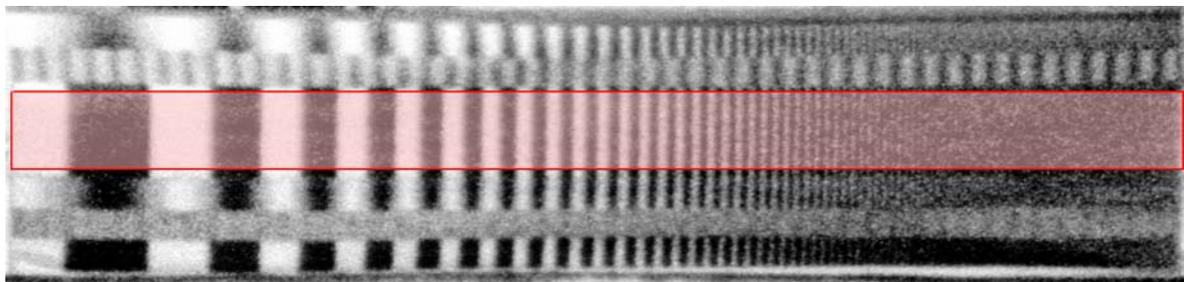


Figure 33: Same scan as Figure 31 after histogram stretching and re-sampling to a normalised rectangular shape. The red rectangle indicates where the section was taken

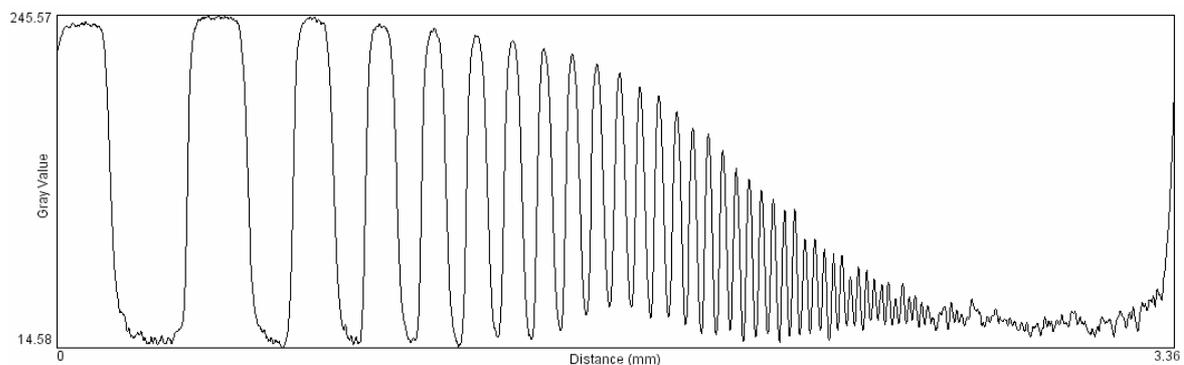


Figure 34: Section through the rectangular band defined on Figure 33

A C⁺⁺ program was written to compute the MTF. The first step was to determine the upper and lower envelopes of the section. Then, for each abscissa value and corresponding to a specific resolution, the maximum and minimum values of luminance were calculated using the envelopes. The contrast is then calculated using the formula 1, p.56.

A graph is then drawn in *Excel*. A *Tcl* script¹⁵³ program is used to provide an interface to the C⁺⁺ program and to automatically create the *Excel* file.

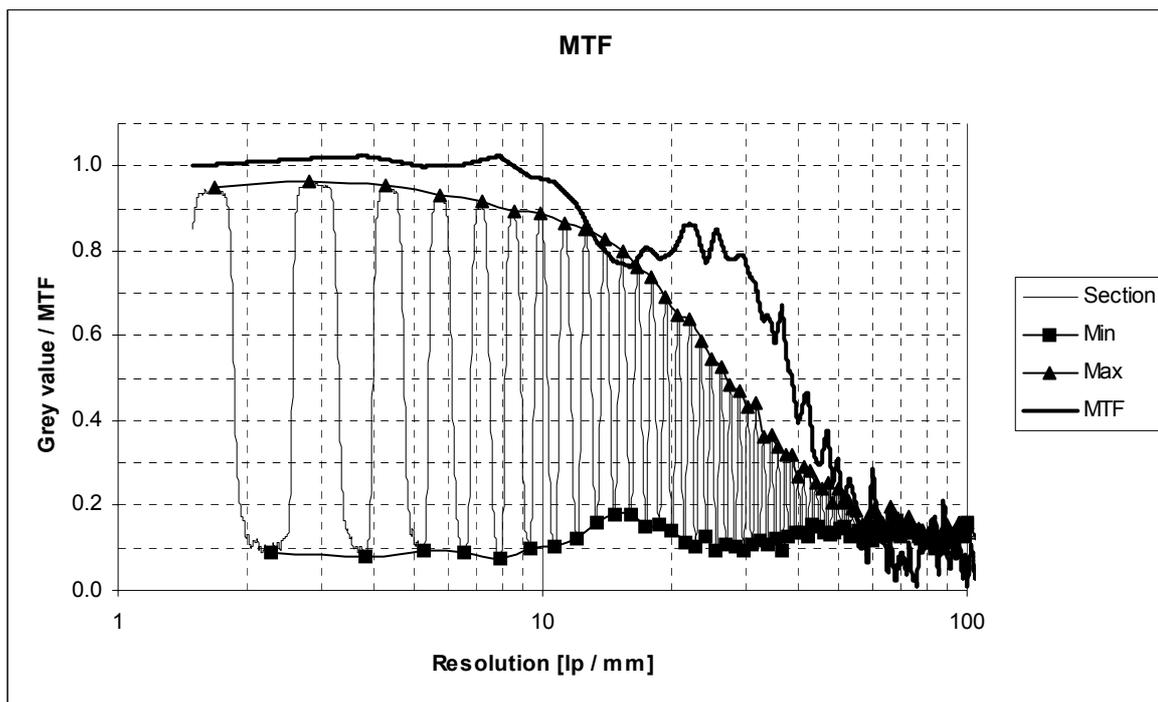


Figure 35: Excel chart of the Modulation Transfer Function

This procedure was repeated for all sample negatives for each of the chart on the balcony¹⁵⁴. In order to compare the results more easily, two values were extracted from each of the chart: R_{50} and R_{10} , the resolving power corresponding to a transmission of 50% and 10% of the contrast. R_{10} corresponds approximately to the limit of *discernability* by the human eye.

¹⁵³ <http://dev.scriptics.com>

¹⁵⁴ Se Figure 29.

5.2.3 General comments

The spread of the results obtained with the analogue cameras is rather wide and hence the confidence in the tendencies shown is correspondingly modest. Compared to analogue (film) cameras, the results obtained with digital cameras are more consistent. It is very likely that the explanation lies in the difficulty of focusing the microscope precisely; indeed some of the scans seem to be slightly out of focus and the values obtained for the left and right targets are sometimes significantly different. This is suspicious because the values derive from the same negative and the targets are approximately at the same distance from the camera. In a first attempt to get sharp scans, the digital camera was set on 'auto-focus' mode but the results were not satisfactory. The camera was then set to infinity ('landscape' mode) and the focus was adjusted using the microscope micrometer. A glass plate was used to keep the negative flat. Nevertheless, it appears that the very slight differences in pressure on the negative are sufficient to produce difference in sharpness. The values given are therefore lower estimates of the exact values. It was therefore decided to use the best values for comparisons rather than the average of the readings for the left and right targets. Some of the emerged trends are, nevertheless, sufficiently strong to let little doubts to their validity. They are discussed in detail in the following sub-sections, which address each of the first four issues listed above (camera, film aperture and focus) in turn.

5.2.4 Camera

The first observation concern the digital camera results, which are not subjected to the image acquisition problem described above. About three pixels are necessary to transmit 10% of the contrast ($R_{10} \approx 333\text{lp/kpixel}$) and four pixels to transmit 50% of the contrast ($R_{50} \approx 250\text{lp/kpixel}$). The pixel size of the targets on the images is small, resulting in quite noisy results. This could be improved by increasing the chart size on the image.

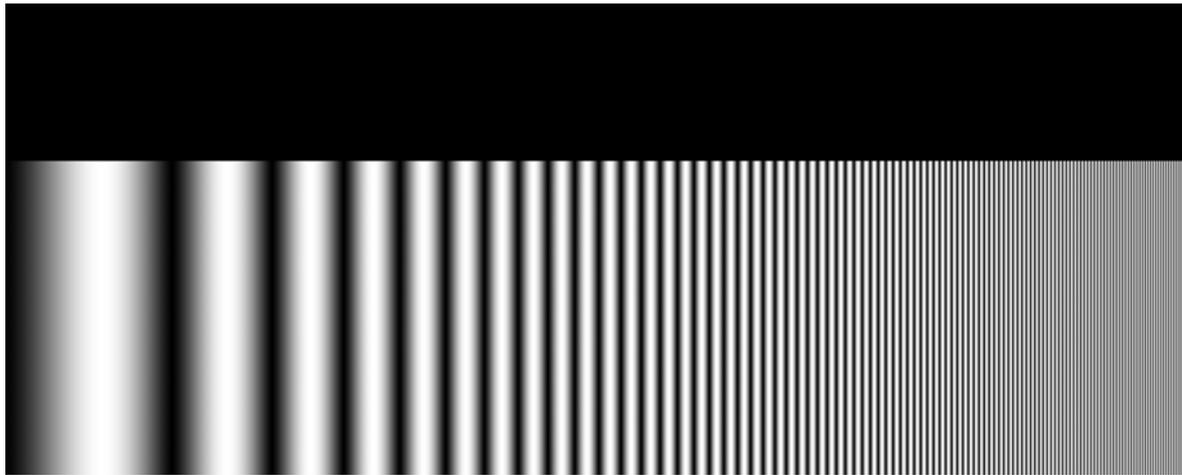


Figure 36: New Modulation Transfer Chart

The width of the sinusoidal band could also be increased. Both measures would produce more samples to average and consequently sections that would be less noisy. Large black and white areas could be provided in order to supply a reference of contrast at low frequency. A possible model is presented below (Figure 36).

Eight trials were carried out indoor with the *Olympus C-1400L* digital camera and with the new chart. Results are similar to those presented above but clearer. Without a tripod, $R_{10} = 400\text{lp/kpixel}$ for two photographs and 333lp/kpixel for the two others. With $R_{50} = 300\text{lp/kpixel}$ and 333lp/kpixel respectively. With a tripod, the results are more stable: $R_{10} \approx 400\text{lp/kpixel}$ and $R_{50} \approx 300\text{lp/kpixel}$ for all four photographs. All photographs were taken at a shutter speed of $1/47\text{s}$ with the wide-angle and at a distance of about 3m from the target. A higher speed reduces the influence of the use of the tripod, while a longer focal length or a higher resolution will increase it. Distance has a more complex influence: rotational vibrations produce no change with the distance and the influence of translational vibrations decreases with distance. The shutter speed is relatively low but not uncommon for small diaphragm aperture.

The following conclusions can be drawn in relation to the analysed images:

- The resolving powers are not so different between the various analogue cameras. The *Olympus Superzoom* camera gives slightly worst results but the difference is negligible in comparison to the difference in prices. However, it has to be borne in mind that more experienced photographers, would obtain

higher-quality results by taking full advantage of the facilities offered by superior equipment (although the measuring technique used might not be sufficiently sensitive to show the difference). Better lenses would also produce better results in the case of the Nikon FM2.

- The resolving power is not the only parameter to consider. Digital cameras yield significantly lower resolving power. To obtain, similar R_{50} , the horizontal resolution of the digital camera should have about 3000pixels (~ 7 Mpixels) and to obtain similar R_{10} , it should be even higher, about 4500pixels (~ 16 Mpixels).
- Overall the use of a tripod is shown to be beneficial for all the cameras, from the digital camera to the Nikon FM2 camera. The differences are smaller for the digital cameras.

5.2.5 Film

The 100ASA colour film and 50ASA black and white film give quite similar values for R_{10} (about 50lp/mm). The 50ASA B&W film gives a slightly better R_{50} result (about 30lp/mm instead of 25lp/mm for the 100ASA colour). The 400ASA film delivers lower figures. The *Nikon FM2* with a 400ASA film gives results comparable to the *Olympus Superzoom* with a 100ASA.

Black and white films and colour films seems to have a different behaviour. The ratio γ between R_{10} and R_{50} vary significantly. The B&W film tested behaves more like the digital camera, showing smaller values of γ compared with the colour film ($\gamma \approx 1.45$ for the digital camera and $\gamma \approx 1.7$ for the B&W film, $\gamma \approx 2$ for all colour film). This means that the contrast is well transmitted up to the resolving power limit of the film and the resulting impression of sharpness is also higher for the B&W film, while, on the other hand, the power of transmission of the two colour films tested is substantially reduced at the lower frequencies.

5.2.6 Aperture of diaphragm

The influence of the variations of the diaphragm aperture is more difficult to assess. The dispersion of the results obtained does not allow any meaningful conclusion to be drawn. More samples and a more reliable scanning technique should be used to discriminate the different cases.

5.2.7 Focus distance

Sharpness is reduced of about 15% for images taken with the focus set to infinity as compared to images taken with a precise focus (set at about 10m for the test). This result leads to different possible strategies for calculating the error committed when extracting metric data from such images. It is therefore important to record with which of the two options the images were taken, in order to process adequately the data when building the metric model. If the images are taken with precise focus, the principal distance may change between the shots. For an image taken with a camera having a principal distance p and for which the diagonal of the format is r (for a 35mm film, $r = \sqrt{24^2 + 36^2} \text{ mm} \approx 43.27 \text{ mm}$), an error dp in the principal distance will have a similar effect as an error dr when marking reference points on the original negative:

$$dr = -\frac{r}{2p} dp \quad (14)$$

If the focus is set to the precise distance o and not on infinity, the variation in principal distance can be calculated with Equation 5.

$$dp = \frac{fp}{o} \quad (15)$$

When this value is introduced in Equation 14, we obtain an equivalent error of marking:

$$dr = -\frac{rf}{2o} \quad (16)$$

The corresponding dimension of the object is reduced of a quantity dx

$$dx = -\frac{rf}{2o} \frac{o}{f} = -\frac{r}{2} \quad (17)$$

This expression is independent of distance and focal length; it solely depends on the format of the film. The smaller the format, the smaller is the potential error. If the object is photographed with a 35mm camera, dx will be approximately 2cm. If the potential error on a model has a constant absolute value, the relative error decreases with distance. Hence, if the object is situated at 10m and the photograph is taken with a 35mm camera equipped with a 28mm lens, the relative error dr will be approximately equal to 60 μm . Those figures have direct significance only if the camera calibration parameters used in the photogrammetric software correspond to an infinite focus distance, set as constant for all the photographs.

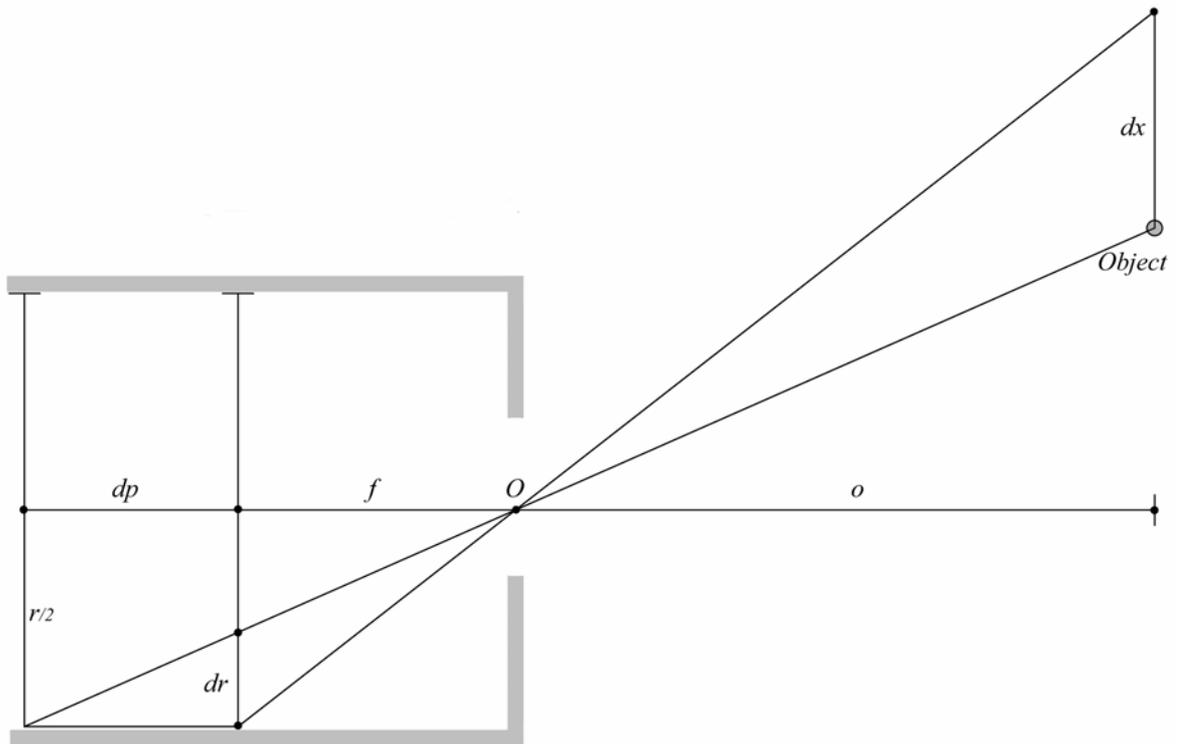


Figure 37: Influence of the focus distance

By allowing variations of the principal distance (self-calibration), it is possible to reduce the error. This will be most effective if the focus distances are fairly constant, which is usually the case. If o is much larger than f , it can be shown that:

$$dx = -\frac{r}{2} \left(1 - \frac{2}{1 + \frac{o_{\max}}{o_{\min}}} \right) \quad (18)$$

If the focus distance is known for each photograph, it is possible to adapt the principal distance in the calibration file. This can be done using the recorded camera setting (see the form in Figure 3 where there is a specific entry to record this kind of information). In practice, with ordinary cameras this is rather difficult to achieve, as the distance graduations on the lens distance meter, usually do not allow a very precise reading. The distance can also be estimated after a first orientation of the photograph, using the distance between the camera and the object.

If the focus is the same for all photographs, one calibration will be sufficient. It is possible to find the optimum principal distance which minimises the error. In that

case, errors on the principal distance are less likely but the images can be less sharp and so errors of marking on the original negatives can be greater.

5.3 Photogrammetric models

5.3.1 Objective

To answer the questions concerning the influence of the number of photographs and of good convergence, photogrammetric models were constructed. *Photomodeler Pro 5* was used to test the following situations:

- With different number of photographs (2, 3 or more) to control the importance of converging angles and redundant coverage.
- With targets and without targets to test their effectiveness to achieve a greater accuracy
- With different levels of knowledge about the camera used (no knowledge at all, some simple lens distortion correction using the panorama tools (Figure 39), with a full *Photomodeler* calibration of the camera)
- To model a situation where the distance is too short to take photographs easily. This would require taking a larger number of photographs and, consequently, the effectiveness of the process in such a case was under test.

5.3.2 Models

The following models were developed in *Photomodeler*:

- For Cavendish Road, a model of the facade and the cornice (a decorative element)
- For St Mary school, a model of the South facade and the detail of the roof construction (a constructive element)
- For St Mary school, a model of the East facade was also prepared, where the access is difficult.



Figure 38: Cavendish Place, 12, Bath. Sequence of photographs used for the construction of the photogrammetric model



Figure 39: South window, St Mary School, Bath (a) original photograph, (b) image roughly corrected for radial distortions using the Panorama tools

5.3.3 Quality assessment

The quality of the results is assessed in different ways:

- Using *Photomodeler* error estimates (maximum pixel coordinates residuals and RMS value)
- Taking a set of measurements (long and short measurements) on the model and comparing them with the values taken directly on the object.

Point marking residuals are difference between image coordinates marked on the images by the user and image coordinates calculated using internal and external calibration of the cameras. As a global indicator, the global RMS value is also used.

According to the guidelines given in *Photomodeler*, the marking residuals should be always smaller than 10 pixels, less than 3 pixels for calibrated cameras and less than 1 pixel for sub-pixel targets.

5.3.4 Marking

In some cases, it is particularly difficult to mark precisely points on the object image. This is the case for elements having a low contrast: e.g. elements in shadow, in full light, or having very similar colours (Figure 40). The light has also a very strong influence: e.g. some features may become imperceptible in certain lighting conditions. At Cavendish Place, this was the case for the interior, painted in a very light colour.



Figure 40: Low contrast making the marking difficult

5.3.5 Construction of the models

The quality of the measurements depends on the quality of the data (the set of photographs taken by the applicant) but also on the quality of the process to retrieve the 3D information. This will depend on software available, expertise (local authorities, English Heritage) and the time and energy put into the process.

To achieve a good reliability, it is important to construct the model progressively, adding points and photographs gradually. In this way, gross errors are immediately traceable and accuracy can be set to the limit imposed by the data or to the particular needs. Problems of this nature arose during the construction of models for St Mary School, where the number of photographs was particularly important. When gross errors are made but are not immediately identified, it is usually very difficult to find

their origin. This is a consequence of the least-square process used by photogrammetric software. In the specific case described here, the first results obtained did not seem to follow any logic. The differences were mainly due to the quality of interpretation. It was then decided to construct new models with more care. The conclusions are presented below.

5.3.6 Calibration of the camera

Photomodeler allows the automatic estimate of the internal calibration parameters of photographs taken by unknown camera. The easiest method is to use a sufficient set of points with known 3D coordinates. In the case of retrieval of metric data from documentation for *Listed Building Consents* submission, this is certainly seldom the case. If the number of points is sufficient, then it is possible to run a self-calibration. The internal parameters to be optimised can be set ($p, x_P, y_P, K_1, K_2, K_3, P_1, P_2$). A larger number of parameters improve the accuracy of the results but requires a greater number of points to be marked on the photographs. Note that it is possible to obtain satisfactory results by using only p (principal distance) and K_1 (first radial distortion parameter).

Even if the photogrammetric software does not allow self-calibration, the 'manual' operation is always possible. The internal parameters of the unknown camera can be estimated, starting from reasonable estimates and varying them progressively to minimise the global error. With this process, the importance of having calibrated cameras is limited. In the examples described above, using this technique, it was possible to reduce the maximum point marking residual to about one pixel. Only small and not significant differences can be observed between the results obtained using the pre-calibrated camera or by self-calibration. To estimate the coordinates of the principal point (x_P, y_P) with accuracy, couples of photographs of the set should be taken in different orientations (landscape and portrait in one or two directions). Some tests were also carried out using images with the radial distortions corrected with the *Panorama plugin* (Figure 39), estimating a main parameter (K_1) visually. This process gives better results than those without any corrections. Nevertheless, it is more convenient and accurate to use the original images and to estimate the deformation parameters in the global bundle adjustment. The format of the image can be estimated using the dimensions of the image.

5.3.7 Targets

Targets may be difficult to place. To be most useful, they have to be spread regularly on the building. In the case of St Mary School, this was not possible with the available means. More generally, it must also be taken into account that not everyone is confident on a ladder or ready to struggle with long sticks to fix targets at high elevation. It is therefore not possible to expect that targets will be placed usefully in every instance.

The presence of targets speeds up the process of marking in *Photomodeler* - but it seems that the automatic sub-pixel determination of the target centre is not very robust. Often, better overall results can be achieved by simply estimating the position of the centre. In this case, the speed factor is already less relevant and other target shapes could yield more accurate marking (see Figure 9.a). Problems were noted in some of the earlier models, which may be partly responsible for the poor results in automatic sub-pixel marking (Figure 41). Images of the targets may be too small (less than the 8 pixels recommended). This is especially a problem with low-resolution camera for which the targets may need to be very big (the biggest targets used in the test were printed on A4 paper and had a diameter of 10cm). The white area surrounding the target (necessary to provide a good contrast) can also be too small.

To mark targets in *Photomodeler*, a rectangular window is defined by the user around the black centre circle. Where perspective effects led to the inclusion of part of the surface behind the target within the capturing window, the algorithm used by *Photomodeler* yields poor results. Other software may use different improved techniques.

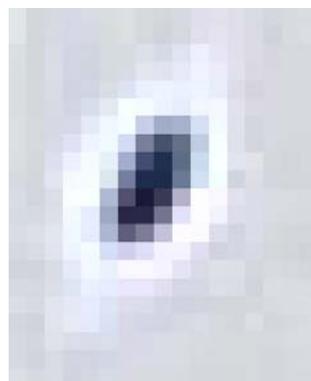


Figure 41: Image of a target; small and with a narrow surrounding white area

Notwithstanding those remarks, targets may be very useful. In some circumstance, it may be difficult to find clearly identifiable marking points on the object. In that case,

targets make the marking much easier. It is for instance the case in interiors, such as the cornice and window at the Cavendish Road site.

5.3.8 Convergence of the photographs

The accuracy σ_c of the 3D coordinate estimates is function of the accuracy σ_a of the angular measurements (related to the resolution of the scan, its deformations characteristics, sharpness of the image...) and of the geometry of the intersecting rays¹⁵⁵. Suitable configuration of camera positions and orientations and the assessment of the resulting accuracy falls within the more general problem of network design. Fraser¹⁵⁶ gives the expression:

$$\sigma_c = \frac{q}{\sqrt{k}} \frac{o}{p} \sigma \quad (19)$$

where q is a factor expressing the quality of the intersection of the rays, k is the number of redundant measurements (photographs taken at the same or very close location, in the present case this value will most often be 1), o is the average distance to the object, p is the principal distance (in pixels) and σ is the accuracy of the measurements on the scan (in pixels).

q is the factor of main interest to the present discussion. It may vary between about 0.4 for an optimised network to three or more for inadequate configurations and it is estimated from the geometry of the network of stations and points to measure¹⁵⁷. The availability of strong angles (close to 90°) between the rays defining each point is necessary to achieve accurate results. Larger sets of photographs improve further the accuracy, providing more data from which to obtain average values.

Convergence is important to achieve isotropic accuracy. When photographs are taken parallel (like it was done in the first applications of photogrammetry to close-range objects), the accuracy in 'depth' (perpendicularly to the focal plane) is much worse ($1.5 \leq q_d \leq 3$) than in the other two directions ($q_p \approx 1$). If a point is visible on photographs taken from all around it, its accuracy will be the same in all directions.

In any practical situation, accuracy will not be homogeneous. Points of a balcony, only visible on two side photographs with rays intersecting with an angle of about

¹⁵⁵ FRASER in ATKINSON; MIKHAIL

¹⁵⁶ FRASER in ATKINSON, p.259

¹⁵⁷ See FRASER in ATKINSON, pp.256-281

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30°, may have an accuracy three times lower than points visible on more photographs and with better ray-intersections. Moreover, as the points are visible on only two photographs, there is no redundant measurement and hence no way to assess the precision of the coordinates. It is not sufficient to control the convergence of the line of sight of the photographs: the convergence of the rays defining the point of interest has also to be considered.

From this discussion, it appears that it is beneficial to have a redundant set of images. The fact that the camera parameters are not known beforehand and can only be estimated through self-calibration further increase the importance of its availability.

6 Conclusions and recommendations

The discussion of results conducted in the previous chapters as outlined the factors that have a marked influence on the exploitation of photographic images for metric purposes. This discussion incorporates conclusions which lead to the recommendations summarised below. The recommendations are followed by a checklist that may be taken on site when undertaking photographic documentation for listed building consent purposes.

6.1 Recommendations

- Carefully plan the camera stations. Weak angles between camera line of sights and insufficient coverage can substantially reduce accuracy.
- Use the largest format analogue camera or the highest resolution digital camera available. Choice of camera will directly influence the potential accuracy.
- Pay particular attention to the lighting conditions. If elements are not visible on the photograph, it will certainly not be possible to extract any metric information from them.
- Accurately record details of all your actions. It is relatively easy to do and missing information can be very difficult or impossible to generate at a later stage.

Other factors also influence the potential accuracy but to a lower extent:

- Use the best equipment available
- Use a low sensitivity film
- Use a tripod whenever possible

The question of whether or not to place targets on the building has to be discussed and determined on a case by case basis. It was shown in the previous examples that they do not always significantly improve accuracy and that they may be difficult to place in some circumstances. On the other hand, there are cases in which they are useful and, in any case, they are certainly never harmful.

Further studies would need to be carried out to quantify more accurately the influence of different factors.

6.2 Checklist

6.2.1 Before visit

- Gather available documentation on the building (plans in particular)
- Record information concerning the building (reference number, building site name, county, civil parish, national grid number, listing grade)¹⁵⁸
- Record information concerning the type of work (alteration, demolition, re-painting, etc.)
- List elements, features or characteristics that are going to be affected by the works (taking context into account)
- List available equipment and check its potentials (achievable accuracy, specifications)

6.2.2 Preliminary visit

- Carefully observe the building
- If no measured survey is available, prepare sketch(es) (situation plan, floor plan with main features, orientation)
- List the values (considering volume, decoration, texture, colour)
- List the areas to be surveyed and the elements of interests
- For each element, determine the necessary level of accuracy (in mm or fraction of inches)¹⁵⁹
- Organise elements in hierarchical classes (context, general volume, area under investigation, etc.)
- For each class of element, compute the necessary distance between camera and object as a function of the equipment available and of the required level of detail¹⁶⁰

¹⁵⁸ A form similar as the one presented on Figure 3 can be used.

¹⁵⁹ This may be related to the dimension of the smallest element to be recorded. For a window frame, it may be the dimension of the smallest mouldings. It can also be related to the accuracy of the positioning of larger elements. Generally speaking, to record deformations, the accuracy of the measurements should be about 10 times higher than the maximum deformations.

¹⁶⁰ If the dimension of the smallest element to be recorded is 6mm, the object dimension of a pixel should be smaller than 2mm. If the horizontal resolution of the camera is 2000 pixels, the horizontal

- Choose fixing method (with regards to any precious and fragile surface, and on the ease of reaching the chosen points where targets should be fixed)
- Make a coarse estimate of the number of photographs necessary to cover the surface as a function of the maximum distance and of the feasible positions of the camera.
- Choose camera position, orientation and lens (make every element visible on at least 3 pictures)
- Place on the ground temporary marks with orientation (e.g. wooden sticks marked by chalk when the positions are all suitable)
- Indicate camera positions and orientations on the situation plan
- Ensure that each feature of interest on every element is visible on at least three photographs. Do not forget to consider protruding elements like window bays or balconies
- Ensure adequate convergence of the photographs (as close as 90° as possible)

Adjust camera positions and orientations to comply better to the actual constraints as arising from the situation plan

Mark on the plan or sketch the position and orientation of the camera.

- Determine the appropriate lighting condition (ideal time of exposure, possible complementary lighting)
- Choose the negative type (colour or B&W, as sensitive as possible)
- If filters are available, decide if they are useful
- Make a rough estimate of the number of necessary targets

6.2.3 Preparation

- Order the necessary shots according to ideal shooting time
- For each class of elements, compute the minimum target size in function of the equipment available and of the required level of detail
- Prepare target according to computed size and number of photographs

field of view of the camera should be about 4m. The maximum distance at which the photograph can be taken can be determined experimentally, approaching the object until the horizontal field of view is 4m or less.

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- Record general information concerning the shots (reference to the building, photographer, date, camera make and model, lens(es) make and model, accessory equipment)
- Consult weather forecast
- Possibly arrange for the street to be freed of cars
- Prepare equipment (documents, photographic equipment, accessories, measuring equipment or existing measurements, referencing, notes)
- Check battery camera, flash

6.2.4 On the site

- If possible remove furniture, vehicles or any other obtruding element
- Place at least one plumb-line (a weighted string)
- Place targets (at least 10 should be visible and well spread on each photograph; foresee connection with metric survey)
- If feasible, measure the targets with topographic methods (with a reflectorless total station for instance)
- Alternatively, measure the distances between some of the targets (long distance preferably and including at least 3 distances)
- Indicate clearly on a plan, elevation or sketch what was measured and write the value (in such a way as to avoid any ambiguity)
- Go on each station according to the predetermined shooting order
- If the light is good, proceed, if not, plan another time
- Check the contrast (is it too high to provide a clear record?)
- Set precisely the position and orientation of the camera (on a tripod)
- Carefully control the visibility of elements
- Maximise the number of visible targets on the photograph
- When possible, balance the light (with flash, projector, screen)
- Set diaphragm aperture and focus to maximise sharpness
- Calculate the necessary exposure time
- Take photograph using the timer or a remote

- When possible, bracket one stop down and one stop up¹⁶¹ (especially in the case of high contrast)
- Record reference number, record time, position and orientation (on map), lens used, focal length, focus distance, aperture of diaphragm, exposure time, negative type

6.2.5 In the office

In case of analogue camera:

- Develop the photographs
- Print the photographs on 10x15 glossy paper
- Put prints and negative in protection sleeves

In case of digital camera:

Store the files on a CD-ROM without any editing

- Print a hard copy (on A4), possibly after some contrast/brightness adjustments

Then, for both formats:

- Correlate negatives/files with prints and with the written record (write ref number on the back of the print; possibly add a reference to the file name on the written record)
- If metric survey is to be done after the photographic survey, prepare a set of plans with the position, orientation and reference number of each photograph

¹⁶¹ This mean that more than one photograph has to be taken. To give an example, if a photograph of a window frame is taken from an interior room, a first picture can be taken with the exposure time calculated to give a correct exposure for the external light (pointing the camera in the outside direction), another picture can be taken to give correct exposure for the interior light and if the lighting conditions are very different, other photographs can be taken with intermediate settings.

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