PHOTOGRAPHIC SURVEY OF MOSAIC AND TILED FLOORS – A METHODOLOGY

D. P. Andrews*, N. J. Beckett, M. Clowes, S. M. Tovey

English Heritage, Metric Survey Team, 37 Tanner Row, York, YO1 6WP, UK
david.andrews@english-heritage.org.uk

*Corresponding author

KEY WORDS: Cultural Heritage, Archaeology, Conservation, Mosaic Floors, Rectified Photography, Orthorectification, CAD, Colour

ABSTRACT:

Historic floors which consist of mosaic or decorative tiles are often of high cultural or academic value, but by their very nature are vulnerable to decay and damage. On the other hand floors and footings are often the only surviving parts of a ruined building, especially in an archaeological context. They present particular conservation challenges and therefore often require a high quality metric record. The English Heritage Metric Survey Team has approximately 20 years experience in the photographic recording of mosaic and tiled floors. This paper will briefly review traditional analogue methods for producing a photographic montage and then go on to describe the development of digital methods. Both single image digital rectification and orthophotography (orthorectification using stereo-photography) will be examined. Methods for producing the required photography and control will be outlined. This will include strategies for obtaining suitable photographic coverage as well as attempts to equalise exposure. Control of different forms and levels of precision have been employed and their relative merits will be discussed. The advantages and disadvantages of using montaged rectified photographs or multi-image orthophotography will be examined. As well as an image of adequate metric precision there is also a need for correct colour and consistent colour balance. Maintaining a true representation of colour throughout the chain of the various processes including delivery to the end user is a major challenge. The issues involved will be examined but a total solution is yet to be found.

1. INTRODUCTION

Recording historic floors has always been a challenge mainly because they are characterised by large areas of repetitive detail but also exhibit minor variations due to wear, damage, repair or errors in the original creation. For these reasons an image-based approach is usually employed. Before the advent of digital image processing, producing a photographic product which covered an entire floor was a difficult and time-consuming job. More usually a compromise product such as individual photographs and a key was accepted. The development of digital rectification software and digital photogrammetry has meant that it is now much easier to produce a scaled photographic montage of an historic floor that can be printed out or used in a digital environment. Increased use of digital imagery has also brought its own problems. In the past colour balance was only affected by exposure and processing conditions, now every piece of equipment and type of media used has an input.

2. WHY RECORD?

Mosaic and tiled floors are an important part of our cultural heritage and it is commonly agreed that it is desirable if not essential to have records of such artefacts in order to aid academic study, improve access and as a last resort should a disaster occur. Any academic paper on the subject of mosaics or tiles will be illustrated with photographs and drawings but a scaled photographic product should give a better understanding of the subject. A digital image of a floor can be used on a web site, for example, to aid peoples' understanding and enjoyment of it. In some cases this will be the only way to experience the floor. This could be because physical access is a problem for the disabled. Some floors in working buildings may be covered with furniture and so not normally entirely visible (Dallas in Fawcett 1998). In other cases, mosaic floors have been only briefly revealed as the result of an archaeological dig and must be recorded before re-burial if they are to be studied in any detail. Floors are inherently vulnerable to damage and wear. As well as the obvious fact that they are walked on, and increasingly so in the modern age of mass tourism, floors have also suffered from among other things burials, the insensitive installation of services and the theft of tiles and tesserae. Fawcett asserts that the mass tourism of the past 50 years has caused more damage to historic floors than that inflicted over the last 700 years of general use and abuse (Fawcett 1998). Many historic floors are in working buildings such as Cathedrals so it is not normally an option to completely prohibit foot traffic. For this reason it is important to record floors to enable the monitoring of wear. It is also one of the guiding principles of conservation that all interventions, such as restoration work are recorded. Even if wear is not a major problem and no conservation work is planned, it will always be sensible to have some sort of ante-disaster record in case of a cataclysmic event. This record would in the worst case become a substitute for the real floor if it were totally destroyed, or become a guide to its restoration if salvageable damage occurred.

3. PHOTOGRAPHY

The challenge in photographing a floor is achieving a suitable vantage point. An ordinary photograph can be taken

at an oblique angle from, for example, the triforium in a cathedral. When the photography is to be used for rectification or photogrammetry the camera needs to be as square on as possible to the subject. Also each individual photograph must have a negative scale commensurate with the anticipated scale of the final product. As a general rule the final product should be no more than a six times enlargement from the negative scale – so a 1:10 scale orthophotograph would require photography at a minimum of 1:60 scale. If using a 50mm lens this means the camera would need to be a maximum of 3 m from the subject. These constraints can be met in a number of different ways.

Figure 1 Rollei 6006 semi-metric camera set up on an extension bar with a Macbeth chart in the image.

The most common method is to use an extension bar and a tripod (see Fig. 1). This allows the camera to look straight down at the surface of the floor without imaging the tripod legs. There is, however, a compromise to be made between the length of the bar and the number of photographs required. A long bar will allow a photograph without any interference from the tripod legs but as the bar will tend to oscillate, it will be necessary to wait a long time after moving the camera set up (until the camera is still) before taking the next photograph. The possibility of vibration will also limit exposure times. A shorter bar will not oscillate but it will be necessary to take more photographs because tripod legs will appear in a portion of each photograph. Each strip of photography will have to be substantially overlapped by the next in order to achieve complete un-obscured coverage.

Another method of achieving the correct camera to subject distance is to take oblique photographs from a tall tripod. Whilst digital rectification software and to a lesser extent digital photogrammetric systems can accommodate oblique photography it is not an ideal solution. It should be remembered that because the photograph is oblique the scale will vary across the image. Therefore it will be necessary to either take a photograph where part of it is at a larger scale than required or to discard part of the image because it is at too small a scale. Using a tall tripod has its own practical difficulties. In order to look through the viewfinder the photographer will require a step ladder and, if the surface is rough, a colleague to steady it. If the floor is particularly fine or delicate it will be necessary to protect it from the feet of the ladder in some way.

If the only suitable camera available has a longer lens it will be necessary to set the camera further away from the subject to achieve economical coverage. A camera with a 100 mm lens could be set up 6 m from the floor in order to produce a negative scale of 1:60. A vantage point 6 m above a floor could be found using a scaffold tower or a hydraulic lift. This sort of equipment brings its own problems, however, and would only be appropriate in very specific circumstances. An archaeological site where a floor has been revealed and has to be recorded rapidly is perhaps one example. Otherwise the problems of using a hydraulic lift inside a building or moving a scaffold tower without damaging the floor are probably insurmountable.

The English Heritage Metric Survey Team generally use a standard photographic tripod with a short extension bar. Using a 50 mm lens with the camera about 1.5 m above the subject gives a negative scale of 1:30, allowing for final products at up to 1:5 scale. Although good quality photography is obtained relatively easily this approach does result in more photographs and therefore more control than strictly necessary. For most work a Rolleimetric 6006 semi-metric camera is used with Kodak NC160 colour negative film. Colour negative is used as opposed to colour transparency because of its wider exposure latitude. Kodak NC160 is a professional film for use in controlled lighting. Each batch is guaranteed consistent so only film from a single batch is used on any one project. The NC (Natural Colours) prefix means there is no particular colour bias and the very fine grain gives better resolution, although it requires a longer exposure time. The camera has a reseau plate fitted and has been calibrated so that it can be used in a digital photogrammetric workstation (DPW). The use of calibration information also improves results in Rolleimetric MSR, the digital rectification software used by the team. To obtain correct and consistent exposure a professional spot meter is used.

4. CONTROL

A photographic survey product, be it a single scaled image, a rectified photography montage or an orthophotograph, requires some sort of control. This can range from a simple scale bar through to targets with 3-D co-ordinates.

A single rectified photograph can be produced using only a scale bar. To achieve accurate scaling in both axes, however, requires two scale bars or known distances. The distances can be measured between points of detail on the floor or targets can be attached. If more than two photographs are to be montaged together, a grid of targets will be required with at

least two targets appearing in the overlap between the frames. It is possible to co-ordinate a grid of targets using a tape measure by a system of braced quadrilaterals. The distances between each target are measured as well as the distances to the targets diagonally opposite. Once back in the office the grid can be constructed on the drawing board using ruler and compass or in a Computer Aided Drafting (CAD) programme. This is, however, time consuming work which must be undertaken with meticulous attention to detail if accurate results are to be achieved.

Figure 2 A Leica TCRM1103 is used to co-ordinate control targets

A more efficient and accurate method is to use a theodolite and Electromagnetic Distance Meter (EDM). There are various approaches that can be employed. Intersection is probably the most accurate but requires angular observations to each target from two different survey stations using both faces of the instrument. To speed up the process it is useful to have an assistant to identify and point out the targets, as they can be difficult to see from a distance. To avoid confusion such as observing the wrong target or the same one twice, it is sensible to number all the targets individually before applying them to the floor. To reduce the number of observations required with only a minor reduction in accuracy it is possible to co-ordinate the targets using angle and distance observations. If using a standard EDM, a mini-prism with a small spike at the back is required. It is necessary to first observe the angles and then have an assistant introduce the mini-prism for the distance measurement. For the best results it is still advisable to observe the angles using both faces of the theodolite. The advent of the Reflectorless EDM (REDM) has made the mini-prism redundant, as distance measurements can now be taken direct from the target. The REDM is probably not quite as accurate as conventional EDM with a mini-prism, especially at more oblique angles. The improvement in the speed of measurement, however, means that the distance can be measured each time the angles are observed, i.e. using both faces, thus allowing an average distance to be calculated.

A Leica TCRM 1103 total station theodolite in REDM mode is used by the English Heritage Metric Survey Team to co-ordinate targets for photographic surveys of floors (see Fig. 2). The theodolite is motorised which means it can drive back through the targets to allow the angles to be observed on the other face and a second set of distances to be measured. The observations are computed using Landscape software and latterly Geosite from Survey Supplies Ltd. The targets used are 10 mm in diameter and printed on self-adhesive vinyl. They can be applied to and removed from most historic floors without causing damage.

5. PROCESSING

The rapid development of computer technology over the last 10 years has made the use of digital imagery common place, and allowed access to digital rectification and digital photogrammetry software by most practitioners. Having said that, the production of rectified photography by traditional means is still a useful method.

5.1 Rectification

Rectified photography relies on the fact that a photograph taken square on to a completely flat plane is analogous to an orthographic projection of that plane. For this reason it is most suitable when a floor is completely flat (see Fig. 3). Slight undulations will produce slight scale errors but they may be acceptable if within the scale tolerances required for the survey. Larger undulations mean that an orthophotograph will be required.

5.1.1 Analogue

The traditional analogue method of producing a rectified photograph involves taking photographs as square on as possible to the floor. They are then printed to scale in the darkroom using an overlay plot of the control points. Each individual print must then be spliced together so that it fits to the adjacent prints and the control overlay. The edges of the prints will be cut to follow lines of detail such as the edges of tiles. In order to improve the appearance of the join when the prints are stuck together, it is usual to feather the print by removing some of the substrate paper using an abrasive. This allows the remaining emulsion to be stuck down flush. The resulting montage of prints is a one-off, so to make copies it must be re-photographed with a large format copy camera.

5.1.2 Digital

The power of the standard desk top PC has reached a stage where digital rectification is available to all. Professional, fully featured rectification software such as Rolliemetric MSR does cost in the region of 2500 Euros but less sophisticated packages such as Monobild are available for as little as 350 Euros. Digital rectification obviously requires digital images and these are usually acquired by scanning conventional negatives. Digital cameras and digital backs for conventional cameras are reaching a stage of development where it is now perfectly possible to use ‘born digital’ images for digital rectification. The size of the digital chip is still smaller than a medium format film frame so more photographs, more control and more time spent on processing will be required. Professional rectification systems usually allow for the correction of lens distortion assuming calibration information is available. Others will contain a calibration routine. Here, digital rectification has a distinct advantage over analogue methods that allow no possibility of correcting for lens distortion.

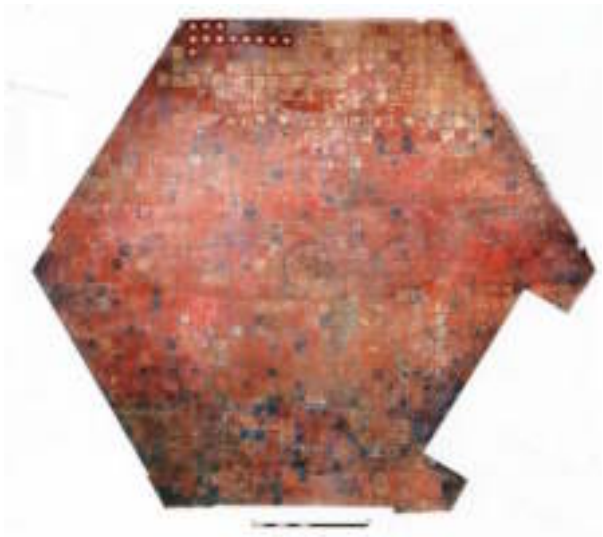

Figure 3 Rectified photography montage of a tiled floor from Windsor Castle, UK

As with analogue rectification control can range from scaled distances to full 3-D control. Some packages also feature perspective correction which, assuming the subject contains horizontal and vertical lines, means only one distance measurement is required for scaling. If a number of images are to be montaged together, it will be necessary to have full control in the form of co-ordinated targets or detail points. Many rectification packages have a montaging routine but often the results are not particularly satisfactory. An alternative is to montage the images using photographic manipulation software such as Photoshop. As well as allowing adjustment of contrast, colour etc, the images can be cut along lines of detail and feathered. In this approach it is essential to have full control so that targets can be matched together pixel by pixel. It is also helpful to import an image of the control that can be overlaid as a check on the accuracy of the montaging.

The English Heritage Metric Survey Team uses Rolliemetric MSR and Photoshop to produce digitally rectified montages. The final image is then attached to an AutoCAD R.2000 drawing containing the control and a border for plotting out at the required scale using an HP DesignJet 1050C.

5.2 Orthophotography

Many historic floors tend not to be flat; especially mosaics that have been buried and then excavated (see Fig. 4). The availability of digital photogrammetric workstations (DPWs) means it is now possible to record these subjects accurately by producing an orthophotograph (Clowes 1997). In an orthophotograph variations in scale due to relief as well as tilts can be corrected.

In order to produce an orthophotograph, stereo-photography is required. This can be acquired in exactly the same way as described for rectified photography but at least twice as many photographs are required to cover the same area. The photography is usually scanned with a dedicated photogrammetric scanner. Interior orientation is often performed at this stage.

The imagery is then loaded onto the DPW and the relative and exterior orientations undertaken. Aerial triangulation methods can be used to set up whole strips or blocks of photography. Here an economy in the amount of control required can be achieved by using a bundle adjustment. Fewer control points are required because tie points are used to join the models together.

Once the models are set up a Digital Elevation Model (DEM) is produced using automatic stereo-matching. It is often necessary to undertake some manual editing, however. The finished DEM can then be used to produce an orthophotograph or can be used in its own right as a model of the surface of the floor. A DEM grid spacing of 10 cm is usually sufficient to map any undulations accurately enough to result in an accurate orthophotograph at architectural scales i.e. 1:50 or 1:20. To create the orthophotograph it is necessary to identify the images required and then indicate the area of each that is to be used. Seam polygons are used to determine the lines along which each image is to be cut. These polygons butt-join although the images can be feathered together thus producing one orthophotograph without visible joints. The orthphotograph routine can also be set to automatically balance the colour and exposure across the whole final image. This can have mixed results because in the case of an archaeological excavation, for example, areas of earth may appear in the images and skew the colour of the mosaic detail. As with rectified photography the orthophotograph can be attached to an AutoCAD drawing for printing. The English Heritage Metric Survey Team use a Leica Geosystems DPW running SocetSet V.4.4.1.

Figure 4 Orthophotograph of a temporarily revealed Roman mosaic at Lopen, Somerset, UK

5.3 Advantages and Disadvantages of Each Method

Each method has its own advantages and disadvantages. As a general rule, however, the greater the accuracy required the more time and money will be required to achieve it.

5.3.1 Rectified Photography

Rectified photography can be an economic and relatively quick method of producing a record of sufficient accuracy for most purposes. It requires less photography than orthophotography and the equipment and software required are cheaper. This means that it is possible for conservators rather than specialist surveyors to undertake the work. For larger projects, however, it is probably more economical to employ an experienced contractor. The disadvantage is that rectified photography will only work successfully on relatively flat surfaces.

5.3.2 Orthophotography

The main advantage of orthophotography is that it can be used to produce accurate records of undulating floors. Inherent to the process is the acquisition of stereo-photography that can be viewed in 3-D using a conventional stereo-scope or on the DPW. Another possibility is to produce anaglyph prints that can be viewed with inexpensive red/blue glasses. This allows conservators a greater insight into the floor without the need for them to purchase expensive software or visit a photogrammetric office.

As well as the orthophotograph it is also possible to produce contours using the DEM – another way of presenting the fact that a floor may not be flat. Draping the orthophotograph over the DEM can be used to produce perspective views and a number of perspective views can be combined to produce a fly-through movie.

The greater number of photographs required plus the high cost of the equipment and software, mean that producing an orthophotograph is about twice as expensive as a rectified photography montage of the same area. The high capital cost of a DPW and the amount of operator training required makes it uneconomical for non-specialists to undertake the work. There are, however, a number of experienced contractors willing to undertake such work.

6. COLOUR

Those floors deemed worthy of recording are usually decorative and this decoration is normally achieved through the use of various different colours. To facilitate interpretation and analysis it is necessary to record colour accurately, or at least consistently.

6.1 Colour Balance

Correct colour balance requires the reproduction of the brightness, contrast, colourfulness and hues in an image to be acceptable to the viewer (Hunt 1995). There should not be a bias toward a particular hue. This becomes particularly important when montaging together a number of photographs, as biases towards different hues in different photographs will become very apparent when juxtaposed and will emphasise the join between two photographs (see Fig. 5). Consistent colour balance can be achieved by treating all the photographs in exactly the same way. This means using film from the same batch or a digital camera, consistent exposure conditions, film development and scanning.

Figure 5 An example of poor colour balance - Brading Roman Villa, Isle of Wight, UK

The use of artificial illumination, in particular daylight balanced flash, can ensure consistent exposure as long as there is no significant contribution from daylight. Floors within buildings can be photographed at night to ensure this or a tent could be erected over those revealed in an archaeological dig.

Using exactly the same development and scanning process can produce consistent images from conventional photographs taken under consistent exposure conditions. The images from a digital camera taken under the same circumstances should also exhibit consistent colour balance. As a digital camera warms up, however, the colour rendition may vary.

Variations in colour balance can be particularly marked when terrestrial photographs are scanned using a dedicated photogrammetric scanner. This is probably partly because

they are designed for the relatively consistent exposure conditions of aerial photography, but also because the operators are generally photogrammetrists rather than scanning specialists. It has been found that it is possible to use Kodak PhotoCD as an alternative to dedicated photogrammetric scanning. (Thomas, Mills and Newton 1995). This system has been used by the English Heritage Metric Survey Team to improve colour balance in orthophotograhs (Clowes 2002).

6.2 True Colour

When studying the decoration of one floor it will usually be acceptable to have each colour reproduced consistently as long as the colours look approximately correct. When comparing two or more examples or where a floor is likely to be re-buried after excavation it will be desirable to reproduce the true colour of the decoration as accurately as possible.
In order to give an exact representation of the colours of a floor it is necessary to have a way of measuring those colours. This could possibly be achieved by recording the colours of the individual components of the floor using a colour measurement device. However, the number of different colours typically found in an historic floor would make this impractical. Even a mosaic made up of, say three different colours, will exhibit variations due to changes in the natural materials.

A more feasible approach is to place a standard colour chart, such as a Macbeth chart, in each photograph (see Fig.1). The colours of the individual elements in the chart can then be measured and corrected throughout the process. Each process and piece of equipment used will have its own effect on the colour so individual colour profiles are required for digital cameras, scanners, monitors, printers and even the type of paper used. Even then the colour rendition will only be correct if the final product is viewed under the same lighting conditions as the original. This is almost impossible to achieve because the reaction of the eyes to the lighting of a subject is also affected by the colour and lighting of the surroundings. The general aim is to reproduce the colour as accurately as possible but with the caveat that it will never be absolutely correct.

7. CONCLUSIONS

Mosaic, tiled and other decorative floors are a valuable part of our cultural heritage which should be conserved and recorded for future generations. A photographic approach is the most useful and is the only practical way of recording the many textural variations exhibited by most historic floors. Floors are usually quite flat and so can be successfully recorded using the relatively cheap and accessible method of rectified photography. Some floors, are however quite undulating and so warrant the application of orthophotography. The use of orthophotography although more expensive provides added value in the associated products such as contour maps. Colour balance is important if an acceptable looking product is to be produced. Correct representation of colour is important to some users but actually very difficult to achieve. It is also difficult to know if it has been achieved.

8. REFERENCES

Clowes, M., 1997. Mosaicing the Mosaic – Roman restoration goes digital. *Surveying World*, May/June 1997, pp 36-37

Clowes, M., 2002. Digital Photogrammetry at English Heritage: a Pictorial Review of Projects to Date. *Photogrammetric Record*, 17(99), pp 441-452.

Dallas, R. in Fawcett, J., 1998. *Historic Floors: Their History and Conservation.* Butterworth Heinemann, Oxford, pp 91.

Fawcett, J., 1998. *Historic Floors: Their History and Conservation.* Butterworth Heinemann, Oxford, pp 2.

Hunt, R.W.G., 1995. *The Reproduction of Colour.* Fountain Press, Kingston-upon-Thames, pp 71.

Thomas, P.R., Mills, J.P., Newton, I., 1995. An Investigation into the Use of Kodak Photo CD for Digital Photogrammetry. *Photogrammetric Record*, 15(86), pp301-314.