Architectural photogrammetry: software and methods

by Sauro Agostini

Your guide to architectural photogrammetry programs and photographic equipment, plus how to evaluate the different characteristics of software and hardware

Introduction

There are a lot of programs on the market nowadays for architectural surveying using photography. The prices of these programs vary, as do their performance, functions, accuracy and characteristics.

It's not easy to find your way around all these programs just by looking at their specifications in the brochure or ad, nor even by hastily trying out the demo.

And the terminology used to describe the programs is often insufficient to fully assess them, because so much depends on how they are applied.

In this article we will take a look at some of these characteristics and explain how to evaluate them when examining a program.

Methods of photogrammetry

Photogrammetry – measurement using photographs – employs various different methods, depending on the information sources available. Here are the main ones:

Stereo photogrammetry

The classic method of photogrammetry, based on photographs taken by two special cameras which are set up parallel at a certain distance from each other.
The cameras must be metric or semi-metric with a particular kind of lens and parameters used in stereo-photogrammetry.

This is a fairly accurate system, but very costly, chiefly due to the cost of the metric cameras. It has the advantage of being able to operate on very irregular surfaces, as long as they are 'mapped out' with a series of reference points.

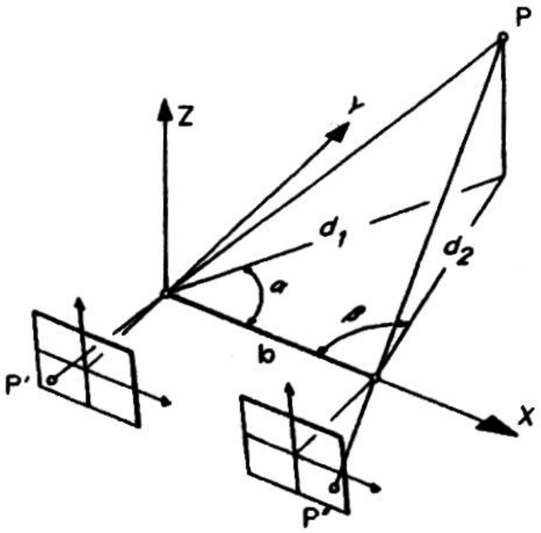


Diagram of stereo photogrammetry on the ground, with the two projection areas of the metric cameras, at known distance and focus

Photogrammetry with two or more photograms

Similar to the previous system, except that two photograms are taken from two different positions with normal cameras. This system is not very accurate and is therefore rarely used for architectural surveying.

Photogrammetry with measurements

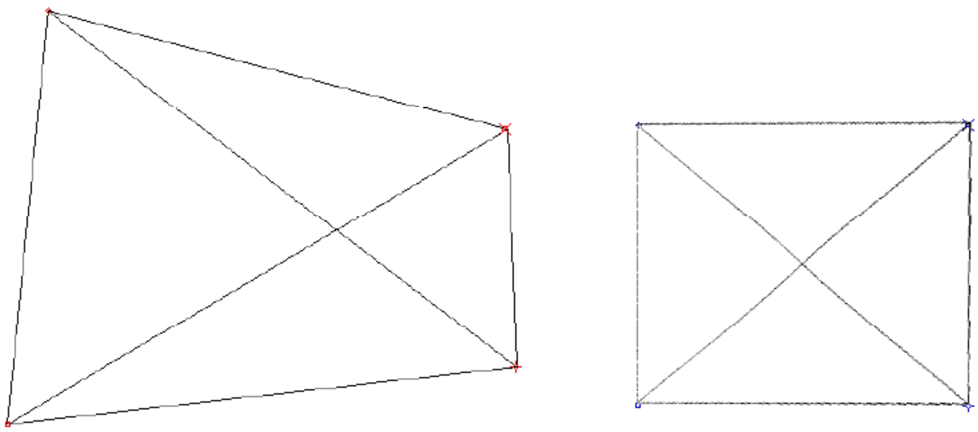
In this method of photogrammetry, perspective distortion is eliminated through measurements taken on the object of photogrammetry. This is the commonest kind of photogrammetry in today's programs, so we shall concentrate on this in our study.

Straightening-up of photographs

This kind of perspective distortion elimination is based on an inverse perspective transformation called homography. The mathematical calculation requires 4 fixed points of known measurements, through which it is possible to determine all the other points on the same level.

The 4 points can be inserted in various ways – directly, using alignments, geometrical figures, etc. but the concept remains the same.

Perspective distortion elimination should not be confused with a simple elimination of perspective vanishing lines which can be done using many graphic or artwork programs. The result, however, is not accurate, because the scale is not constant nor is it measurable.



Perspective transformation. The diagonals now meet exactly in the center of rectangle

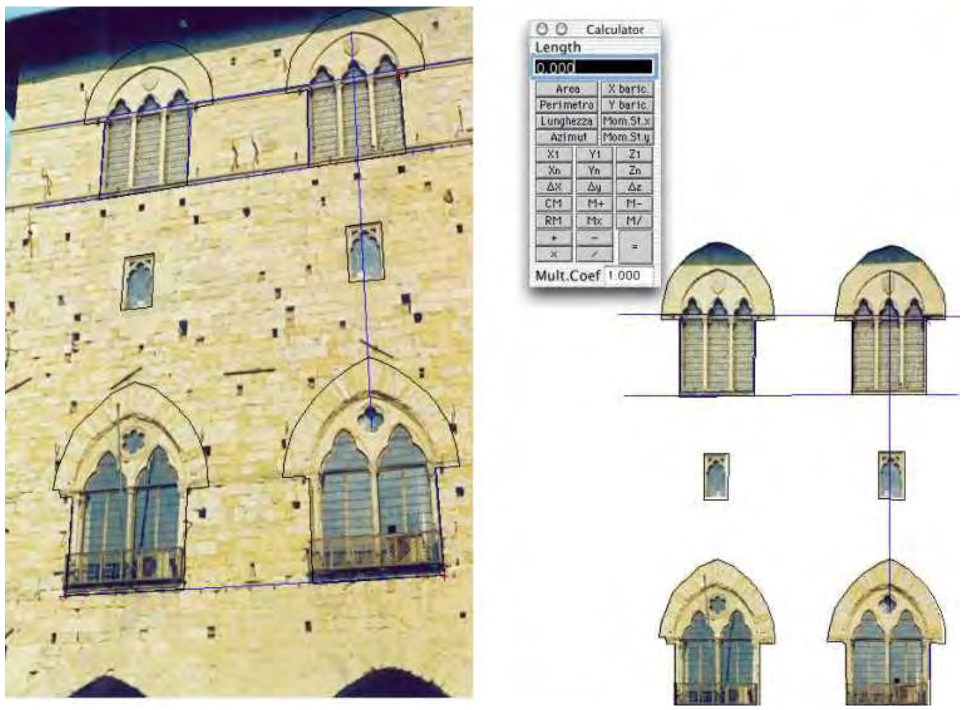
Linear transformation. The diagonals meet at a point of linear proportion to the rectangle corners. Thus they become curved.

The straightening-up of photographs is done layer by layer, so if the building has several layers, which are on different levels, it is important to choose a program which allows you to treat them separately and then recompose them in a view or scaled drawing. The majority of programs in circulation can not do this easily or accurately.

Elimination of irrelevant parts

Photographs contain many elements which are of no relevance to your measurements. These elements can confuse the picture or, if not on the layer which is being straightened up, can appear deformed or of unlikely dimensions. For this reason, it is important to be able to work on parts of photos, to eliminate right away irrelevant elements, often those in the foreground or background.

Other times, you may only be interested in a few elements of the photographic view, such as elements requiring renovation or construction details.



Being able to select immediately just the parts you are interested in means saving time on elaboration, immediate results and no need to re-elaborate your work using other programs.

Many programs do not allow this kind of selection. Some will let you select only rectangular parts. DigiCad 3D not only allows you to define very precisely all sizes and shapes of part, but also enables you to recompose intersecting parts using accurate measurements and in perfect scale.

Control of transparency

The photographs used for straightening up are opaque, which means that if you place them on top of another element, they will hide what is underneath.

When a rectangular photograph is straightened up, the original image assumes an irregular trapezoid shape, now leaving opaque white parts inside the rectangle.

If you then remove parts which are not rectangular, these too will appear inside an opaque rectangle, because an image is always rectangular.

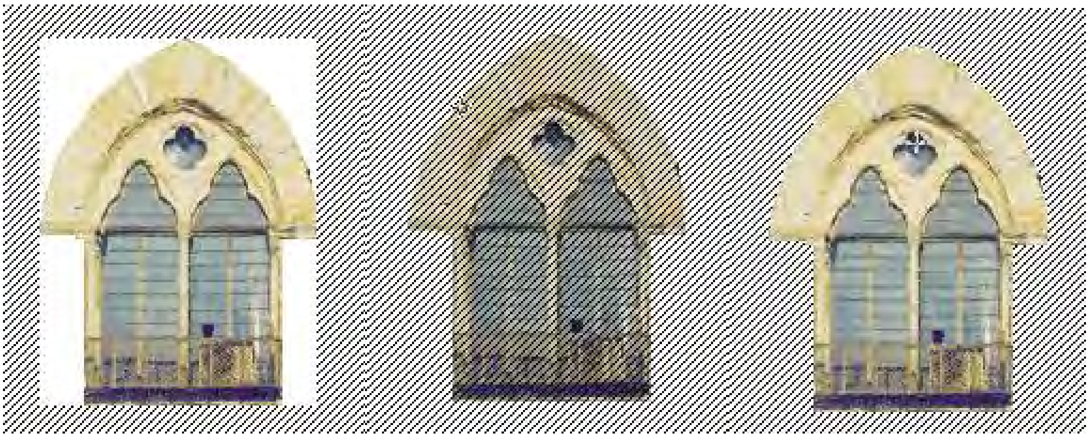
Being able to control the transparency of images is something you normally find in creative graphic programs, vectorial or not. But this control is important in photogrammetry, too. DigiCad has excellent transparency control.

We all know how the opaque image works.

But a completely transparent image can be placed over other elements. It is particularly useful to be able to place it over a vectorial drawing, as in the case of a perfectly straightened-up front view placed over a drawing of the same front view, which results in a photograph with corners drawn in.

An image can be only partly transparent – for example, it is very useful to make the white parts transparent, thus outlining the subject of the image, so that it is no longer just a rectangle, but takes on the shape of the element you are interested in. thus, the rose window of a church will have a circular outline.

This allows you to superimpose elements, one upon another, without leaving white patches. You can superimpose them mosaic-style – for example, you could take a general view of a building's facade from a distance away, thus with few visible details, and then add parts of photos taken closer up, or with a different lens, in order to add detail and accuracy to your image.



A straightened-up image of a window is laid over a grid to show transparency. The image is always rectangular. The first image is a classic opaque one, which totally covers the grid. The second is completely transparent, while the third is only transparent where the white part is, resulting in a cut-out effect of exactly the part wanted, which is now completely super-imposable over other images or drawings.

Eliminating optical distortion

Ignoring optical distortion is one of the commonest errors in architectural work.

Nowadays everybody uses digital cameras, whose zoom lenses have considerable optical distortion. And even the best fixed lenses have some optical distortion, normally greater in wide-angle views

Optical distortion should not be confused with perspective distortion – it derives from the lens' spherical aberration and from the way and the accuracy with which the lens has been manufactured.

Makers of lenses attempt to reduce distortion either by using enormously expensive aspherical lens or by making groups of lenses with varying focuses.
This problem is greater with variable focus lenses – so-called zooms – where it is nearly impossible to obtain satisfactory correction of the range of focus.

Unfortunately, articles about cameras, especially in computer journals, hardly ever discuss this characteristic, which one cannot miss if one simply photographs a rectangle. Try taking a photo of a rectangle or grid with your camera on wide-angle, then check the edges – you will see that the lines have become curved, with the classic 'barrel' effect. The difference between the true line and your curved line is the optical distortion and is normally expressed as a percentage.


In the photo on the left, optical deformation is very evident, while in the one on the right it has been corrected. The left-hand photo is useless for architectural photogrammetry, as it contains unacceptable errors.

Deformations of 2 - 2,5% are quite normal and are extremely dangerous in architectural surveying. 2,5% means that straightening up the facade of a 40 m building will result in being 1 meter out, which is a huge error and one that will destroy the rest of your work.

So it is essential that optical distortion is eliminated before an image is straightened up.

Curved or irregular surfaces

Photographic straightening-up deals with flat surfaces, because homography is concerned with the inverse perspective projection of a plan.
But what happens with curved surfaces, such as the Leaning Tower of Pisa or the Colosseum, or even with irregular surfaces, such as a piece of ground?

In these cases we must use a network of points, called a mesh, taken from the surface of the building. This mesh is laid over known coordinates or measurements, thus straightening up the curved surface.

The curved surface of the Colosseum has been transferred to a plan using a mesh of points which are shown in red on the original photo and in blue on the final result.

Meshes are also useful for surfaces which are not perfectly flat, where 4 points are not sufficient to obtain a good result.

Images and drawings

Depending on their setup and interface, photogrammetry software can be divided into two groups: CAD or raster (pictorial).

The latter uses only images, much like programs such as PhotoShop or Gimp Print, while the former have typical CAD functions which allow for vectorial drawing.

For architectural surveying the CAD interface has undoubted advantages, as it enables you to have both images and drawings in the same document.

If we can then import and export drawings from other CAD programs, then the flexibility is even greater. For example, one can import a drawing of the front view of a building and use it as a basis for photographic straightening up, then re-export the end result.

CAD interface also allows graphic constructions which increase the number of points available for the straightening up, by reconstructing points outside the image, by means of intersections and other types of geometric construction.

It is unusual for a program to be able to operate both on vectorial and graphic data.
DigiCad 3D does just this, in a unique and interactive way, which lets you see immediately the results of straightening up, while drawing on the photograph.

Mosaicing

It is often impossible to take the entire facade of a building in just one photograph. You have to take several photos then mount them together in a mosaic to form the picture.

Many programs claim to do mosaics of several photos, but what they actually mean can vary a lot. Some do no more than straighten up several photos in one document, leaving the user the task of mounting them together as best he can, with programs such as PhotoShop.

Excluding such kinds of program, many other alternatives remain:

– Precision or approximate mosaicing. In precision mosaicing, the photograms are aligned and superimposed according to precise and measured reference points, while in the approximate version, the mosaicing is done by moving the photograms using the mouse and superimposing them by sight.

– Relative or progressive mosaicing. In relative mosaicing each photogram is superimposed on the preceding one using 2 or more common points. But this means that one small error is transmitted to all successive photograms and is multiplied proportionally to the number of photograms in the mosaic. In progressive or absolute mosaicing each photogram is positioned independently, according to points which are measured with reference to a fixed point, for example the left-hand corner of the building. In this way errors are not reproduced, but are limited, no matter how many photograms are involved. A special example of progressive or absolute mosaicing is the use of a drawing of a facade as a base onto which the various images of the mosaic are mapped.

The 6 photos round the edge have been mounted into one single photo-mosaic in the center.

- Mosaicing of one or more layers. If the building's facade has protruding or sunken elements, each of these parts is on a different layer, therefore the front view must be reconstructed by means of a mosaic with several photos or different parts of the same photo. Not all programs allow mosaicing of different layers.

- Mosaicing of non-adjoining parts. It is often impossible to photograph all parts of a building – some may be inaccessible or be hidden by other elements, such as trees. In such cases it is important that the program of photogrammetry is capable of creating an accurate and scaled mosaic, even though incomplete.

- Superimposed mosaicing. In this type of mosaicing general views are taken of the facade as well as photos of certain details. These are then superimposed on the main image for greater detail and precision where necessary. This technique makes great use of the transparency function mentioned above as it needs to be able to use all shapes of cut-outs in order to obtain the exact outline of architectural details.

- Mosaicing of curved surfaces. Curved or irregular surfaces need mosaicing too, in fact, they have greater need of surveys from different angles. This type of mosaicing is only possible, of course, if the program can straighten up the surfaces first.

- Mosaicing over a drawing. Photos or parts of photos are mapped over a drawing which has normally been imported in some standard vectorial or raster format. Each photo is made to correspond to a part of the scale drawing with excellent results.

This image was obtained by straightening up parts of photographs of a convent and matching them to the corresponding parts of a scale drawing, in order to highlight and measure the parts of the facade needing restoration. Note that the front view contains elements on different layers. Various techniques described in this article have been used, such as working on selected parts of an image, mosaicing and transparency control.
(project architect: Matteo Lamberti)

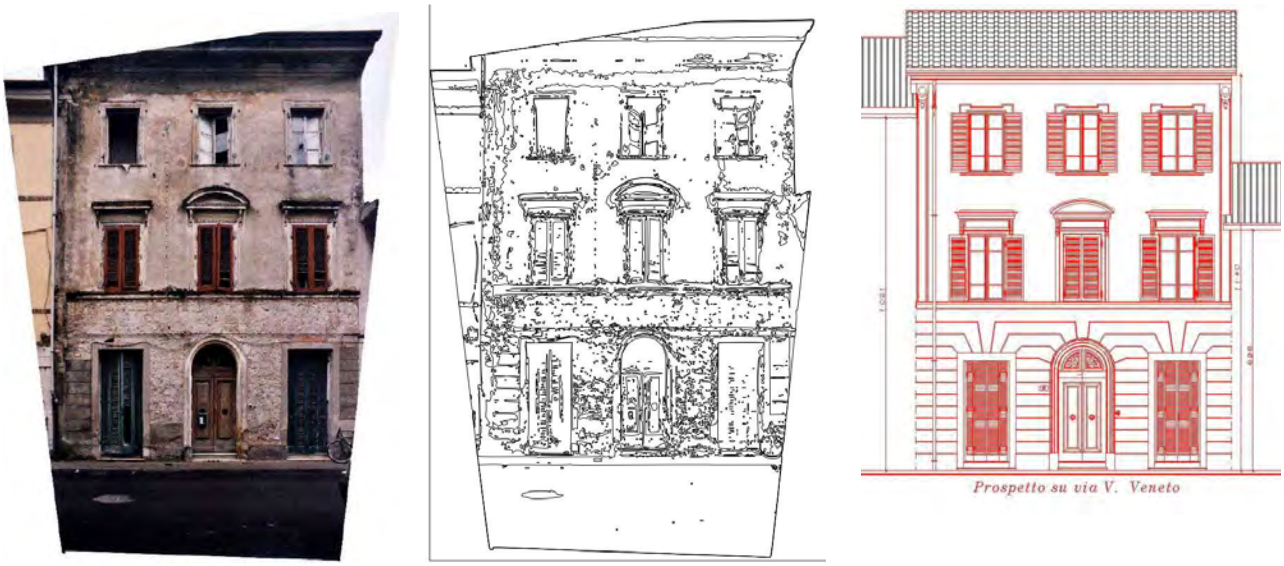
Automatic vectorialization

Sometimes users want to be able to vectorialize a photo to achieve an automatic drawing of the front view of a building.

Some programs do offer automatic vectorialization, but the results are always disappointing and cannot be used for an automatic result.

Automatic vectorialization is very complex and the results are poor even from drawings by hand. With color or black-and-white photos the end-result cannot be controlled. For example, a line is drawn where there is a marked difference in color between two faces of a corner, but often the differences are minimal and are marked, instead, where there is light and shadow. The final result is a drawing which has lines there, which shouldn't be, while the lines which should be there, are not!

In actual fact,if a vectorial drawing is needed, it is simpler to add vectorial elements such as lines or polygons to a straightened-up photo, rather than having to “clean up”, correct and add elements to a vectorialized photo.



On the left, a straightened-up photo of a building's facade. Center, the same facade after undergoing automatic vectorialization. Right, technical drawing of the facade. Clearly, the automatic vectorialization is quite different and unacceptable as a technical drawing.
(Project architect: Puccinelli)

DigiCad 3D

The majority of programs on the market do no more than simply straightening up photographs which, as we have seen, is totally insufficient for an accurate result or to resolve the variety of possible cases.

Some programs claim to do some of these things, but they do not always do them very well. A classic example is mosaicing, which is sometimes left to the user to complete by hand and by sight.

What about optical deformation? It's usually left deformed!

And yet there is a program which does everything described in this article : DigiCad 3D.
DigiCad 3D is probably the most advanced program of architectural photogrammetry available. It doesn't do stereo-photogrammetry, but has a series of functions which stereo-photogrammetric systems do not. The CAD graphic interface offers a range of further possibilities, adding flexibility when resolving the most complex of situations.

It would take too long to describe the program's characteristics in this article. Take a bok at the site of the producer, Interstudio: http://www.interstudio.net/ita.

Cameras

I am often asked for advice as to which camera is best suited for architectural photogrammetry.
Excluding metric and semi-metric cameras, view cameras and reflex cameras with tiltable lenses because of cost, there are still a great number of models available. I don't want to name names, if only because models are constantly changing and in a short time are off the market.

When choosing a camera for architectural photogrammetry, the most important points are optical deformation, maximum angle and resolution.

Reflex cameras with interchangeable mounted lenses of 28 or 24 mm are preferable. Fixed lenses normally have less optical deformation than zoom lenses.

When it comes to digital cameras, the problem is angle. Rarely do they have a angular field equivalent to a true wide-angle. Most of them have a minimum focus corresponding to 35mm or more, some 30mm. Even those digital cameras with interchangeable lenses are no better, because the CCD chip is smaller than the 24x36 film format and therefore a 24 mm angular field actually corresponds to a 35mm one.

As far as regards optical deformation, the best thing is to test it by photographing grids or rectangles. Very rarely do the technical specifications quantify this.

Nowadays resolution is no problem, as even the cheapest cameras have more than 5 Mega Pixels and should be accurate to the centimeter, when taking photos of a 30 meter facade.

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