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More complex photogrammetry projects

Andrew Davidhazy

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Andrew Davidhazy

Imaging and Photographic Technology

Rochester Institute of Technology

If you are looking for projects that are sure to fire up your imagination as well as exercising your intellectual abilities I would like to suggest that you consider dabbling in basic photogrammetry. This is the science of making measurements from images. Typically these measurements might involve determination area, of elevation above a certain reference mark or distance from the camera or subject volume

The projects described below would be suitable for anyone with some interest in basic physics, mathematics and photography. I fact I believe they are suitable for anyone who wishes to find a technical application for their cameras.

The premise of this presentation is that while many can identify with photography as a way of making family records and recognize it as an aesthetic outlet for their creativity, photography is often only perceived in terms of its historic or creative potential. Less obvious is the fact that photography can also serve as a vehicle with which to dabble in applied mathematics. In this case we will take liberal exception with absolute accuracy and will concentrate more on the fundamental principles at work.

What follows is a description of how simple photography based exercises can be used to learn a fairly sophisticated application of trigonometry, much as the shadow method of determining the height of a flagpole is often used even at the elementary school level to introduce students to trigonometric principles.

Photogrammetry is a branch of scientific photography concerned with the technical application or imaging devices, such a simple cameras, for the express purpose of generating images from which measurements of subject characteristics will be made.

Briefly, in aerial and terrestrial photogrammetry a pair of photographs is made of a subject from two different but well established viewpoints. This pair of photographs is commonly referred to as a "stereo pair". Once developed or digitally recorded and then printed, these are placed side by side and carefully positioned so that measurements made from the pair can then be interpreted as subject locations measured from the camera positions based on elementary trigonometric principles.

A major drawback of the technique when attempted in simplified fashion, is that it is quite difficult to position the two prints properly. This results in substantial errors creeping into the measurements that are subsequently made from the photographs, I would like to suggest, however, that this difficulty can be overcome and that one can effectively become acquainted with principles of trigonometry, photography and photogrammetry, through the use one's own personal cameras and reliance on readily available 1-hour processing services.

Since your own personal cameras are used the project becomes even more interesting. In addition to using your own camera you could also try some manual skills by building your own "stereo bar", test its performance and then use it to measure unknown distances.

STEREO BAR

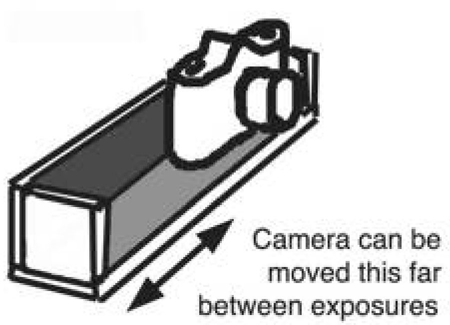


Figure 1

Briefly, a stereo-bar need be nothing more than a device that can be securely fastened to a sturdy support, such as a desk or a window sill, and so designed that it allows a camera to make a photograph from each of two positions while keeping the camera's optical axis, or pointing direction, undisturbed. A simple L channel, as shown in **Figure 1**, made out of straight wood with stops at either end is quite suitable for the purpose. It should be about 2 feet long if measurements to about 50 feet or more will be made.

DETERMINE THE DISTANCE FROM THE CAMERA TO AN OBJECT

Although for this first application a stereo-bar is not absolutely needed it's use will make it somewhat easier to complete the project. One simply needs to line up the back of the camera with a straight edge or surface and move the camera from one place to the other. The edge of a desk, a convenient wall, or even a windowpane against which the lens is firmly pressed will all work adequately. One only needs to remember to move the camera along a level surface without twisting it.

Since one major problem associated with making measurements from stereo pairs arises from the difficulty of lining up the two separate images, the method suggested here is based on the principle of making the two successive exposures, one from each of two independent locations or from two ends of the stereo bar, onto the same piece of film! You might think that if you do this the resulting image would he a complete mass but this is not necessarily the case.

Of course, the camera used for this project should therefore have a provision for making multiple exposures on the same piece of film. Many simple box cameras and some modern 35 mm cameras allow this but it may take some reading through the instruction manual to find out the mechanism to accomplish it.

Alternatively, the slowest possible film could be used, the shutter set on "B", locked in the open position, the lens set to its smallest aperture and the exposure controlled by a card quickly removed from and replaced in front of the lens. After the two exposures have been made this way the shutter is again closed.

Since only one "double exposure" will be made on the film no major adjustment of exposure needs to be made under most conditions. Use the same aperture/shutter speed for both of the sequential exposures.

In principle, objects located very far away from the camera Will hardly move across the film as the camera is moved from one side of the stereo-bar to the other, while subjects located at closer distances from the camera will move considerably. The degree of movement of the image of a given subject will depend on the lens focal length, the subject distances and distance between the two photographs.

In fact, as shown later, the process can be used to determine the focal length of the camera lens if there is an object in the scene whose distance from the camera is known.

The operating principle here is that once you know that a given object distance will cause a particular separation, known as "parallax", unknown distances can by determined by an inverse relationship that exists between the separation between these other images and the distance from the camera to them.

In other words, the Object Distance to an object at an unknown distance can be determined by multiplying the distance of an object at a known distance by its Parallax and dividing by the Parallax for the object at an unknown distance.

$$\text{Unknown Object Distance} = \frac{\text{Known Object Distance} \times \text{its Parallax}}{\text{Parallax for Object at Unknown Distance}}$$

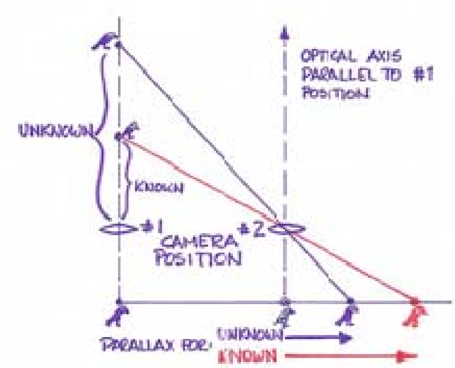


Figure 2

To amplify on this further, as shown in **Figure 2**, an image whose parallax is one half the magnitude of that of an object whose distance is known will be caused by an object that is twice as far as the object whose distance is known. The advantage of this method is that for most practical purposes the measurements are independent of camera, lens focal length, distance between the two photographs and the size of the enlargements that you happen to work with. It is suggested that you use the same measurement units throughout.

It is true that the precision of the measurements is increased by making the distance between the two photographs as large as possible while still including the "standard" object as well as the unknown object in both photographs. In addition it is helpful to enlarge the original negatives as much as possible.

Even though 4x6 inch color prints are useable, enlargements to 8x10 inches make the measurement process based on standard rulers more accurate. Another way to increase accuracy is to enlarge the negative with a slide projector to truly large proportions. Although you might think that you must use slide or transparency film to place your images in a slide projector, B&W or color

negatives can be mounted in a slide mount and projected to large sizes with standard Carousel projectors.

You could even experiment with making the two exposures on color film but using a red an a green or blue filter for the second. If a slide made this way is projected on a screen through a red filter, the image formed by the green filter becomes mostly visible and the green filter will make the red image visible. This makes it easy to check on the difference between the left and the right hand views.

Based on the procedure described above, namely making sure to include an object at a known distance in each of two photographs taken from different locations, object distances to unreachable subjects can be quite simply determined.

DETERMINE THE FOCAL LENGTH OF A CAMERA LENS

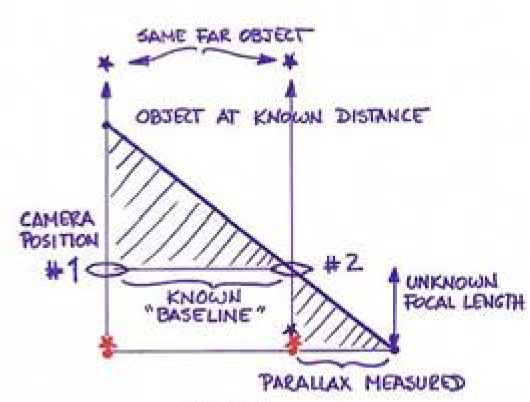


Figure 3

But you can go further. The method also yields the basis for quite accurately determining the focal length of the camera lens. For this you need to accurately know the distance between the two exposures and the distance to a subject that will be included in both pictures. The stereo-bar must he used for this application as the distance between the two photographs must also be accurately known. The lens focusing scale should he set to the infinity mark and for best results both a near object, the distance to which is accurately known and a very far object, possibly a mile or so away, must also be included in the photographs.

The principle here is that far objects taken from two different points of view located near each other will be reproduced almost on the same location on the film if the film does not move between exposures. Near objects, on the other hand, will move an appreciable and measurable amount. To begin with we will assume that the film does not accidentally move between exposures and that the camera, as it is moved from one side to the other of the simple stereo-bar, points exactly in the same direction as it did when the first one photograph was taken.

To determine the focal length of the camera lens based on an enlarged print, again, first notice that far objects superimpose on each other on the print. Then measure the distance between the images of the near object.

By simple visual examination of the set-up it is evident that similar triangles are being formed in front of the camera and within the camera. This is shown in **Figure 3**. To determine the focal length of the camera lens multiply the known Object Distance by the Parallax of this Object and divide by the distance between the two camera positions, known as the Baseline.

$$\text{Focal Length} = \frac{\text{Known Object Distance X its Parallax}}{\text{Baseline}}$$

Strictly speaking this method is applicable for "contact prints" and you typically wi11 be working with enlargements. The actual focal length of the camera lens you use can be determined by taking this ÒartificialÓ focal length that you determine for the enlargement you happen to be working with and dividing it by the number of times that your print is bigger than the original negative. For example, if you are making 8X1O enlargements of 35 mm negatives, the focal length you determine for that print size needs to he divided by about 8 to arrive at the actual focal length of the camera lens.

To find out the actual magnification of the negative marks could be scribed on the negative, or slide, a known distance apart, let's say 20mm. Dividing the distance between these same marks on the enlargement by 20 mm gives the true magnification of the enlargement.

It is possible that the camera did not aim exactly in the same direction both times or that the film moved slightly, or possibly significantly, between the two exposures. If this happens one simply needs to subtract from the parallax measured for the near object the distance between the locations of the images of the far object and this result used as described above. While movements of the film can be compensated for this way, large changes in camera pointing direction can not be easily corrected and dealing with these errors is beyond the scope of this introductory project.

DETERMINE OBJECT DISTANCES BASED ON THE STEREO-BAR

Finally, once an accurate knowledge of the camera focal length is obtained, the camera and stereo-bar combination can be used to make measurements in locations where all **object** distances are unknown. Referring again to **Figure 3**, the measurements are based on a knowledge of the camera lens focal length and the baseline as follows: the Object Distance is equal to the established Focal Length times the Baseline and divided by the Parallax of the image of the object question.

Lens Focal Length X Baseline

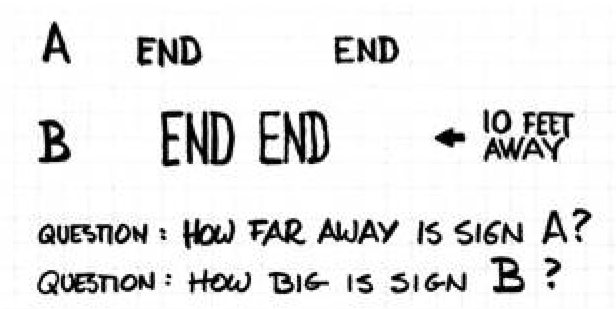
Object Distance = --

Parallax of Object at Unknown Distance

Again, if you are working with an enlargement, the actual focal length of the camera lens needs to first be multiplied by the number of times that the enlargement is bigger than the negative in the camera and then this new Focal Length is used for Object Distance determination. For example, if you are working from 8X10 enlargements your camera focal length needs to first be multiplied by about 8.

Photography is a powerful means for creative artistic expression. Hopefully this project will be of use to you as you develop an appreciation of its added potential as a useful engineering, scientific and technical tool.

Finally, I have a small "quiz" I would like to pose and ask you to answer the questions asked. Since actual units are not given you should give your answer in relative terms using sign A or sign B as the reference object size.



Answer: Sign A is ½ the distance from the camera that B is (or 5 feet) because its parallax is twice as large as that of sign B. Sign B is 4 times larger than A. The reason is that if both signs were the same size A should B twice as large as B but A is in fact only ½ Bs size here even though twice as near and therefore it must be ¼ the size of B.

If I may be of assistance to you as you give this project a chance please feel free to contact me at the Imaging and Photographic Technology department of the School of Photographic Arts and Sciences at the Rochester Institute of Technology, 70 Lomb Memorial Drive, Rochester, NY 14623. My fax number is 585-475-7750 and you can also reach me by e-mail at andpph@rit.edu