GRY 552 FINAL PROJECT

CAN SURVEY QUALITY MEASUREMENTS BE DERIVED FROM A PHOTOGRAPH USING SIMPLE PHOTOGRAMMETRIC TECHNIQUES?

By:

Jeremy Thomas

Can Survey quality measurements be derived from photographs using simple photogrammetric techniques? This question inspired the idea that was to become my final project for Photogrammetry or GRY 552. Theoretically you can use an orthophoto, (a photograph that has been corrected of all errors and is mathematically consistent throughout the photo), shadow lengths and a known scale factor to derive very accurate measurements of objects in the photo. Typically this technique is done using air photos taken at a known altitude, but for my experiment I wanted to test the accuracy of this technique by using photographs taken from the ground with a side perspective rather than a top view. This is a useful experiment because if the theory holds true, you can truly get survey quality measurements from taking a snap shot of the desired object with a digital camera using a cheap photogrammetry program to analyze it. After applying some simple photogrammtric techniques you should be able to derive a measurement with centimeter accuracy. This is especially useful for someone who might need to know an objects height and does not have access to an extremely expensive total station (TPS). As far as I know this experiment has never been done before, however, similar experiments have been done using air photos, as have other similar experiments using shadow length to calculate an objects height from the ground. All you need is a tape measure, and a simple understanding of geometry. For instance, if you are six feet tall you can use your shadow length to create an equation to solve for the object's height, in this case a flag pole. You are casting a shadow that is mathematically similar to the shadow that is being cast by the object that you wish to know the height of. For example, you are standing next to a flag pole of unknown height that you wish to know. Using your tape measure, you have a friend measure from your toe to the end of the shadow that you are casting, and find that the shadow length is 9.7 feet. Now you measure the length of the shadow cast by the flagpole, and you find that the length of the shadow cast by the flagpole is 63.8 feet. You now have an equation that you can use to solve for the height of the flagpole.

$$6ft/9.7ft = X/63.8ft$$

after you cross multiply you get

$$9.7X = 382.8$$

$$X = 382.8/9.7$$

X or height of flagpole = 39.46 ft

Using this formula you are assuming that the angle cast by the sun is the same on you and the object of interest, and that the object is precisely 90 or perpendicular to the ground.

My experiment is completely different and supposedly more accurate than the previously described experiment. I took photo's with a digital camera with a focal length set at 3.7 mm of objects and their shadows on level ground. Using adobe illustrator to assign (x,y) coordinates to the top of the object of interest, the toe of the object of interest, and where the shadow converges with the ground to create a triangle I can use to calculate the objects height. This created a 90 degree triangle in 3 of my 4 experiment objects. The only outlier as far as oblique triangles in my experiment was the library bell tower., because it was built on a hill, it was more difficult to accurately calculate its height. Using simple geometry and triangle solutions, I was able to determine the heights of the experimental objects in centimeters in adobe illustrator, and compare them to the actual heights of the objects measured with a survey quality Total Positioning System (TPS). The objects I decided to include in my experiment where all on Missouri State University campus: Strong Hall, a trash can-concealing fence just north of Strong Hall, the Meyer Library bell tower, and the ROTC repel tower just north of Meyer Library. All of the sample structures where on level ground and built at a right angle or perpendicular to the ground, except the Meyer Library bell tower. The bell tower is built on a hill and the shadow is cast downhill from the base of the bell tower. This created a slightly oblique triangle that was more difficult to calculate and had a greater risk of error than the other three experiment objects. The nice thing about the photogrammetric techniques is that you don't even need the shadows to find the heights of the objects. All you need are (x,y) coordinates on the top of the building and at the toe of the building, simply subtract to find the difference in y values, and that is the height of the building in centimeters in the photograph at the scale you are viewing it in adobe illustrator. The shadows form triangles that you can assign coordinates to and calculate to check your answer when you subtracted the x coordinate, but they should be exactly the same. There are several opportunities for human error to occur throughout my experiment, all of them will slightly change the final answer. This makes it very difficult to get survey quality measurements from the photograph. The main two sources of human error in my experiment are assigning coordinates to the photograph, and accurately calculating the scale of the photo. If these two steps are done perfectly then survey quality measurements should be the result, however if these steps have error, then that error will be distributed proportionally greater as the height of the object gets greater and survey quality measurements will not be the result.

The greatest source of human error is accurately calculating the scale of the photo. When calculating the scale of the photo, you must understand that the scale is not consistent throughout the photo. Distant objects appear smaller than they are, and can not be used to accurately measure the scale of the object you are trying to measure. It is crucial that you use an object of known length, and that it is the same distance from the camera as the object you are trying to measure. It is also very important that the object you are using for scale to be exactly perpendicular to the lens of the camera. If it is angled toward or away from the camera, it’s full known length will not be accurately represented and your scale will be wrong. If your scale is off, then that error will be distributed proportionally as the object height gets greater. In other words, a few tenths of a centimeter off here and your height could be off several feet on a very tall object. The second largest source of potential human error is assigning coordinates to the object. The mouse itself is a limitation because it jumps ever so slightly rather than smoothly sliding. It skips a few hundredths of a centimeter rather than going one decimal place at a time. This makes it virtually impossible to assign a perfect coordinate, but the error created in this step does not expand exponentially as the object gets taller like the scale calculation. This is because it is not multiplied it is only subtracted, so it does not cause as much error as using a bad scale factor but as the scale gets smaller, the error created by a bad coordinate gets greater. Another source of human error can occur when taking the photograph itself. It is important to hold the camera parallel to the ground so that the scale will be consistent throughout the object you are measuring. Taking the photo from an elevated position may cause error as well. Two of my experiment objects I photographed from an elevated position and, although I did try to hold the camera parallel to the ground there may be some error caused by taking the photo from an elevated position. I tried a variety of camera angles and elevations so that I could test the potential error and compare it to a photo taken perpendicular to the object and on level ground with the camera parallel to the ground. I also experimented with the scale by using objects that are not perfectly perpendicular to the lens on some experiments and perfectly perpendicular on one control experiment. Out of my four photographs only one should truly be survey quality or centimeter accurate. The others we will see how much scale and human error throws the measurements off. The first photograph I took was of the ROTC rappelling tower. I took it at a slightly elevated position with the camera parallel to the ground, I used the side of the rappel tower for scale even though it was at an angle that was almost perpendicular to the lens, but not quite. The second photo I took was of a trash can-concealing fence in the blue parking lot just north of Strong Hall. This picture I took on ground level with the camera perfectly parallel to the ground and perfectly perpendicular to the board on the side of the trashcan fence that I used for scale. This photograph should yield a measurement of the height of the fence that is truly survey accurate. The third and fourth pictures I took for my experiment were taken from the top of the new parking garage just south and west of Strong Hall. Obviously they were taken from an elevated position, one photo was of the west face of Strong Hall and the other was taken of Meyer Library bell tower. I used the strip of brick sidewalk that was the exact same distance as the west face of strong hall for scale in experiment three. It was exactly perpendicular to the lens so the only reason for this photo to have error is because the sidewalk I was using for scale is below the focal point of the image. Distortion radiates from the center of the photo, and if the sidewalk I used for scale was distorted, the height of the building may be off several feet because of its tall height. On the Meyer Library bell tower, I used the side of the tower that was most perpendicular to me, even though it wasn't perfectly perpendicular to me, and measured its width to use for the scale calculation. Since this face was not perfectly perpendicular to the lens and the tower is the tallest structure on campus, the height I calculate using photogrammetric techniques will probably not be up to par with survey quality. Another factor to consider is the shadow cast by the tower is not on level ground andtherfore creates a more complicated, oblique triangle to calculate to check my scale measurement. I will be very surprised if I can get within a few feet of the correct height using the photogrammetric techniques with this photograph.

Now that I have laid out all the assumptions and the basic idea behind the photogrammetric techniques that I used in my experiment, here are the results. The first object that I photographed was the rappel tower just north of the Meyer Library, standing in between the two at a slightly elevated position.

(Experiment 1)

Experiment 1

As you can see there are very few objects that can be used for scale in this photo. I decided to use the width of the tower from the inside of the left support pole to the inside of the right support pole. As you can see the fence just in front of the camera is covering the base of the right support pole, so I measured five feet up from the base of each pole so that I could see both points that I was measuring between to get the photograph's scale in adobe illustrator. When measuring the distance between the inside of the poles in adobe illustrator I got a distance of 7.726 cm. When using a tape measure I found that that distance is actually 11 ft 4 in. which is 136 in. or /.3937, 345.4406cm. If 7.726 cm in the photograph is equal to 345.4406cm in real life, then the photo scale is 1cm : 44.7114cm. I used adobe illustrator to assign coordinates to the top of the platform of the rappel tower of (x = 37.959, y = 38.559) and at the bottom of the tower the coordinates were (x = 37.959, y = 7.126). Subtracting y values gives you 38.559-7.126 = 31.433 cm for the height of the tower. If 1 cm = 44.714cm, then 31.433 * 44.714 = 1405.495162 cm, or *.3937 = 553.343 in or / 12 = 46.11 ft. The coordinate for the point where the shadow cast by the rappel tower converges with the ground was (x = -21.096, y = 7.126). This created a right triangle that gave me the height of the building at 46.11 ft just like my previous calculation. When measuring with the TPS or Total Positioning System, I found the actual height of the tower to be 38.23115 ft. This was calculated by the formula,

$$\tan(HA) = x/ HD$$

where HA is the horizontal angle turned from the base of the tower to the top of the tower platform, x represents the height of the tower, and HD is the horizontal distance from the TPS to the base of the tower. The HA was measured at 5.316667, the HD was 410.82 ft.

$$\tan(5.316667) = x/410.82$$

$$x = 38.23115 \text{ ft.}$$

This is a difference of 7.87 ft from the height that I calculated using photogrammetric techniques. The reason that it was off by that much is because the side of the tower I used for scale was not perfectly perpendicular to the lens of the camera.

In the second experiment I took a photo of a trash can retaining fence that is just north of Strong Hall. I took this photograph from ground level on level ground, and the object I used for scale was the width of one of the boards on the fence that was perfectly perpendicular to the lens of the camera. There should be no error in scale calculation in this experiment.

Experiment 2

I used the first board on the right to get my scale and found it to be 1.693 cm wide in adobe illustrator. The board measured 8 in. (20.32 cm) with my tape measure so the scale of the photograph was 1 cm : 12.0023 cm. As you can see the trash can fence is built in the corner of a parking lot and notice that there is a 3 in. curb that is hiding the toe of the fence. I assigned coordinates to the top of the fence (x = 5.962, y = 26.211), and to the top of the curb where the fence meets it (x = 5.962, y = 6.174), and to the point where the shadow converged with the ground (x = 39.546, y = 6.174). The height of the fence from the top of the curb was 26.211 – 6.174 = 20.037 cm in adobe illustrator.
20.037 * 12.0023 = 240.49 cm or 94.68 in. The actual length of the board of the fence was 96 in or 8 ft. This was of by a few inches, but only because of the trash can being 3 in below the ground level, this experiment proves that survey quality accuracy is possible from photogrammetric techniques, as long as the scale is properly calculated, and the photo taken perpendicular too the object of interest and parallel to the ground.

The third and fourth experiment photographs were taken from the top of the new parking garage just south of Strong Hall. The third experiment was a photo taken of the west side of Strong Hall and the shadow it is casting.

Experiment 3

I used the red brick side walk for scale because it was in the center of the photograph and was the same distance from the camera as the tallest part of the building. The brick side walk measured 2.223 cm in adobe illustrator, and measured 72 in. or (182.88 cm) in real life. This makes a scale of 1 cm : 82.267 cm for the photograph that is experiment 3. I assigned coordinates to the top of the building (x = 34.996, y = 43.109) and the base of the building (x = 34.996, y = 10.407), and at the base of the shadow (x = -7.867, y = 10.407). This gave the building a height of 43.109-10.407 = 32.702 cm in adobe illustrator, which equals 32.702 * 82.267 = 2690.307 cm or 88.26 ft in real life. When using the TPS I found the actual height of the building to be 81.569 ft, giving a difference of 6.69 ft. Not bad but not survey quality, the reason for the difference was probably human error in scale calculation, or because the object used for scale was not exactly in the center of the photo and error radiates from the center or principle point of the photo.

The last photograph I took for my project was of the Meyer Library bell tower. Like experiment 3, experiment 4 was taken from the top of the new parking garage. I didn't have any objects perfectly perpendicular to the lens and the same distance from the lens as the bell tower to use for scale, so I used the best info I had which was the width of the bell tower itself. It was not perfectly perpendicular to the lens so the scale measurement will have some error in it. The width of the bell tower measured 3.173 cm in adobe illustrator, and 21.5 ft or (655.32 cm) in real life. This gave the photograph a scale of 1 cm.: 206.53 cm.

Experiment 4

I assigned coordinates to the top of the tower (x = 28.116, y = 38.065) and coordinates to the base of the tower (x = 28.963, y = 16.475) , and coordinates to the base of the shadow that was cast downhill from tower (x = 8.079, y = 13.852) This creates an oblique triangle that is more difficult to calculate to check my height of the building, but it checks at 21.59 cm for the height of the tower. When multiplied by the scale the height you for the bell tower using photogrammetric techniques is 21.59 * 206.53 = 4458.98 * .3937 = 1755.5 / 12 = 146.29 ft. When using the TPS I got an actual height of 122.07 ft and a difference of 24.22 ft. This is a perfect example of how a little bit of error in scale can through your calculation way off on a tall object. It is absolutely crucial that the object being used for scale be perpendicular to the lens or your final answer will be off when using photogrammetric techniques.

In conclusion it is possible to get survey quality accuracy from a photograph using photogrammetric techniques, but there are many assumptions and criteria that must be met in order to get a truly accurate measurement. In order to get an accurate measurement you must calculate an accurate scale. In order to calculate an accurate scale you have to use and object of known length that is the same distance from the camera as the object you wish to calculate the height of, and it also must be perfectly perpendicular to the lens of the camera. It is also important that the object you are using for scale to be near the center of the photograph because error radiates from the principle point. Also you must accurately assign coordinates to the object of interest and have a set focal length on the camera in order to get an accurate measurement. Also, the photograph must be taken parallel to the ground with the object of interest near the center of the photo. If you eliminate all human errors and properly calculate the scale, you will get a very accurate result as in experiment two, however if the scale is not calculated properly you will get a measurement that is not survey quality accurate as you can see in experiments 1, 3, and 4.