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A Tale of Two Houses

Photogrammetry 2017

PHOTOGRAMMETRY generally is the science of measurement using photographs. Pre-computer-age photogrammetry relied on known dimensions of an object shown in a 2D photo to extrapolate other dimensions. But much as our own stereo vision allows us to make assessments as to the size and relative distance of objects, today's photogrammetric software can document an object by comparing a series of photos that capture the object from different vantage points. By calculating the focal distance of the lens and keying details between photos from differing angles, photogrammetric software can create a dimensionally accurate 3D model of an object.

Let's look at SketchUp first, which many designers and builders use to produce graphic models. While SketchUp cannot perform full-fledged photogrammetry (some known dimensions of an object need to be keyed in to generate usable results), the powerful PhotoMatch feature within SketchUp allows users to integrate photos with a SketchUp drawing, to several useful ends. First, it allows a SketchUp model to be placed in proper relation to the site or to an existing structure, to render with precision a proposed addition or modification. I've used this feature as a sort of reverse photogrammetry—in placing a proposed outbuilding, say, relative to an existing building, I can fiddle with the exact placement until the siting looks good to the eye, then I can go back and measure and set the proposed location. More commonly, PhotoMatch is useful to draw a 3D rendering of a proposed addition, showing the existing structure (Fig. 1).

More germane to the topic is a form of photogrammetry that can be implemented through the PhotoMatch feature. Let's say you're documenting a building to which you have limited access. With a little information, you can use PhotoMatch to extrapolate heights, roof pitch, and dimensions of features. You can also use it to compare an ideal state (square, level and plumb) to photos taken on site to determine actual conditions.

The example exercise uses photos of the Sandown (N.H.) Meetinghouse, 1773. First, the known width and length of the building provide dimensions for a simple box in SketchUp, used to scale the photo to the proper dimensions. Set the view of this box to roughly match the viewpoint of the first photo to be matched (Fig. 2).

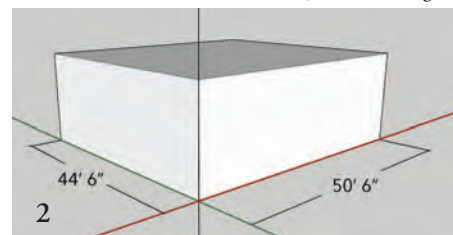
Now it's time to import the first photo. From the Camera menu, choose "match new photo" to begin the process. The first look at the imported photo is a mess (Fig. 3). Set the origin (yellow square near cornerboard) to an easily referenced location on the photo, and start to align the red and green axes to assumed level lines on each face of the building. When dealing with an older structure that may have walls out of plumb or a sagging roof, the choice of reference lines is key. It might seem that projecting level lines onto the building with a laser when taking documentation photos would help, but if the walls are not plumb the lines will appear skewed.

My approach is initially to make a best guess (Fig. 4) and then adjust the level lines as I flesh out the model. (A building wildly out of plumb and level is probably not a viable candidate for this



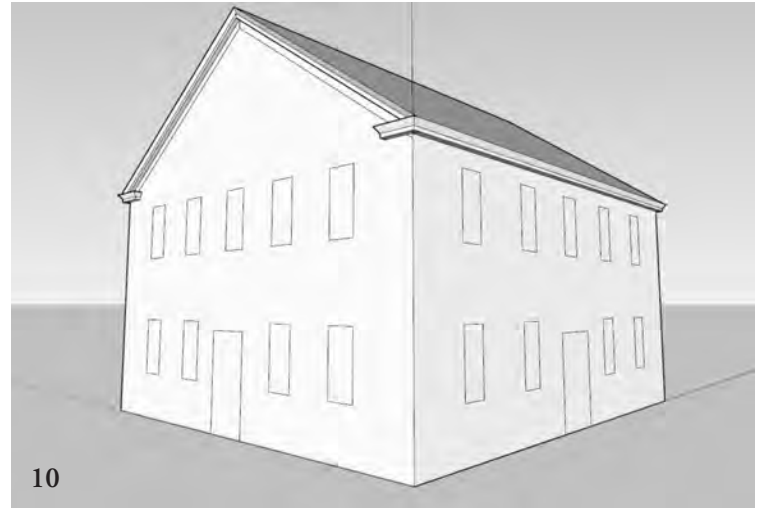
Jack Witherington

1 SketchUp model integrated with photo to show proper size and accurate location of proposed structure in relation to existing house.





Images by Andrea Warchaizer unless otherwise credited



2 Box to match known width and length of building. Height arbitrary. Note red and green x and y axes.

3 Jumbled green and red axes once aligned to known axes in photos, software determines focal length and camera position.

4 Axes aligned with assumed level locations on each face. Note blue axis (plumb line) does not yet line up with building.

5,6 Scale set within PhotoMatch so photo aligns with SketchUp model (pink lines). Misalignment at corner assumed for now to be out-of-plumb building.

7 Figuring roof lines by drawing lines on known plane (front face of building), connecting lines and mirroring result.

8 Repeat PhotoMatch process with another photo to check accuracy of provisional roof outline. Not bad, but see Fig. 9.

9,10 Roof still not exact match with photos. Perfect SketchUp model (10) cannot accurately reflect imperfections of real building. After much trial and error, switching between photos to check consistency, roof pitch appears to be $8\frac{1}{4}:12$.



method of analysis, nor are photos taken with a fisheye lens.) Once the axes on the PhotoMatch screen align properly with the photo, scale the latter to match the accurately-sized box drawn to start. Adjusting the view of the drawn model to match the x and y parameters infers the z parameter in the software. The photo thus tells the software the distance of the camera from the object, the lens focal length and the angle of view. “Pull” on one of the solid line axes until the photo matches up with the drawn model (Figs. 5 and 6).

Since SketchUp hasn’t all the abilities of dedicated photogrammetry software, tracing the outlines of the building will not produce proper results at this early point. Working from known or assumed locations, the model must be built up by iteration. For example, to model the roof plane and determine the roof pitch, draw a vertical line from the centerline of the gable-end wall plane to intersect the bottom of the frieze trim, and another vertical line at an arbitrary distance from the centerline. Connecting the tops of the two lines should align with the roof pitch. Mirroring this line about the center will check whether it accurately reflects the roof pitch. Since the sample building is a bit out of plumb, repeat this process with additional imported photos until the closest match is reached on the roof pitch (Figs. 7 and 8).

Once several photos have been imported, the process can continue of drawing other key elements of the building, such as the roof trim and window locations, checking each photo for agreement and correcting the model accordingly (Fig. 9).

If one photo does not jibe with the others, you may need to re-adjust the axes in that view or change assumptions as to what parts of the building are out of square. You must draw from known points on the model (corner, midpoint, etc.), progressively building the 3D virtual structure (Fig. 10), checking along the way that it matches the photo evidence.



11 In SketchUp Photomatch, software can extract dimensions from perspective views despite distortion of photo.

Once the drawn model and photos are reconciled satisfactorily, measurements of building features can be taken directly off the photo views. Because the “matched” photos account for the distance of the camera from the building and the focal length of the lens, measurements can be pulled from a perspective view of the building as well as a perpendicular (Fig. 11).

The level of accuracy and detail on a model depends on its intended purpose. Modeling an existing building to show how an addition will relate to the original, it’s sufficient that the drawing depict the correct relationship between old and new, with a little room for small inaccuracies to be adjusted in the field.

If old and new roof lines must precisely align, on the other hand, the SketchUp procedures must be followed up with additional on-site measurements to make sure the model was exactly right. I’ve used this method to confirm roof pitches, to visualize renovation changes and to fill in the blanks on missed measurements. However, PhotoMatch is not a complete photogrammetric process, and it has limited precision.

PhotoModeler PhotoModeler is Windows software designed to extract measurements from photographs of buildings or other objects and with them build 3D models of the original. Begin by taking the photos of the building to be modeled, overlapping each view with the next such that at least 50 percent of the building features visible in one photo are visible in the next. Camera position needn’t be fixed, but cameras with zoom lenses need to be left at one focal length.

Depending on site conditions, getting a complete set of photos encompassing the building can be difficult. Our example building, the Sandown Meetinghouse, offers a clear view of the front gable end and two eaves sides. The building backs up to woods, and in shooting this façade through the trees I tried to capture a view of at least each corner of the façade (Fig. 12).

With photos in hand, calibrate the camera to get best results. PhotoModeler uses the focal length of the camera to plot the camera’s distance from the object, and from there to extrapolate object dimensions. (As an experiment, I built two versions of the same model, one using photos taken with a Nikon DSLR camera and using the software’s calibration protocol, and the other using photos taken with my Galaxy S7 phone and using “automatic” calibration. With manual input of points, I did not get a significant difference in accuracy between the DSLR photos and the ones from my phone.) Calibrate the camera by printing out a series of targets and photographing them from multiple angles and



12 PhotoModeler software requires series of overlapping views, such that at least half of previous view is visible in next view.

while rotating the camera 90 degrees in either direction, as directed by the software. The software processes the results to determine the focal length of the camera’s lens (Fig. 13).

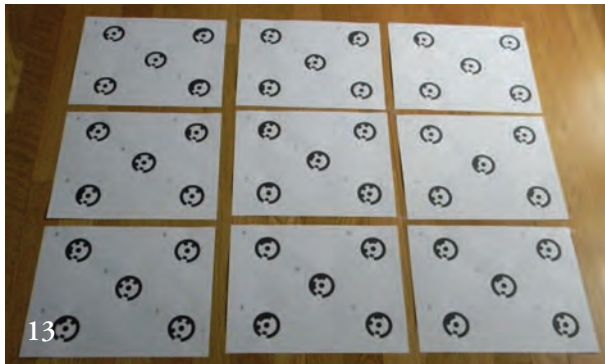
With calibration complete, open a new file and add selected photos of the building (more can be added later as needed). Choosing the first photo, click on each corner or landmark of the building (a laborious process). Be judicious and consistent in choosing which points to pick. To start, pick the main corners of the building, deciding, for example, always to pick them at a point just above the water course at the base and just below a chosen trim element at the top of the wall. Repeat the process, adding more and more reference points. If you start with too many points at once, it will be difficult to distinguish between them without time-consuming zooming in and out of the photos.

Depending on how the model is to be used, you may be able to model detail in one area and repeat it throughout—for example, model the roof return detail for one corner of the building and then copy and mirror it throughout once the model is exported to preferred software (say AutoCAD) for further use.

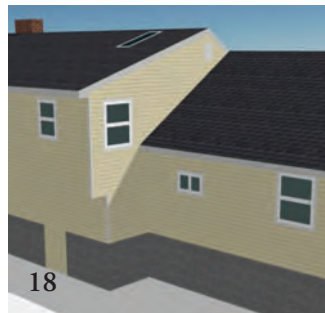
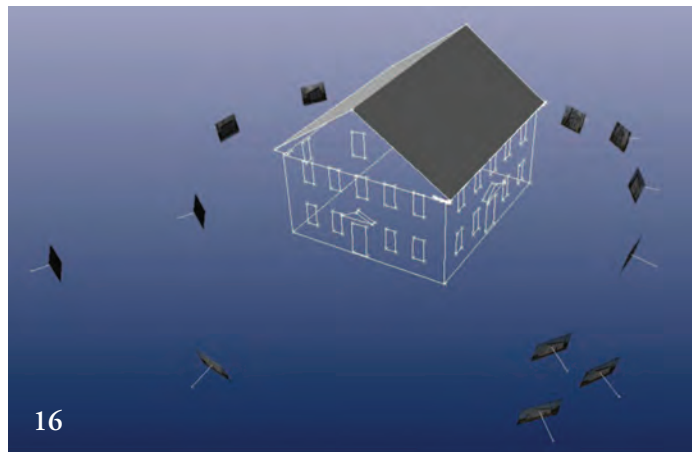
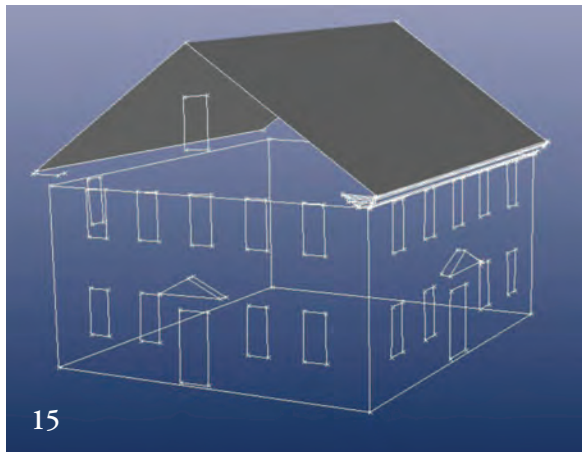
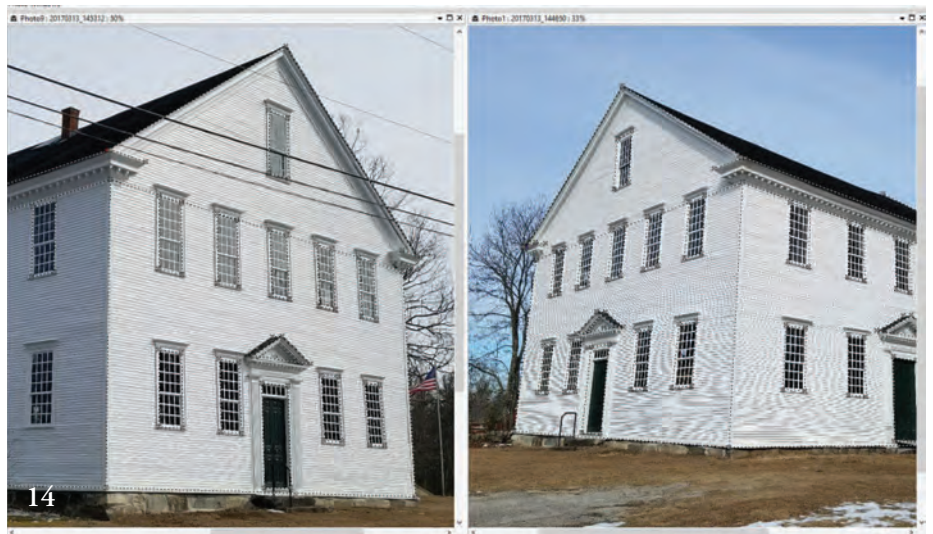
Once the chosen points visible in the first photo are picked, open a view of a second, overlapping photo and begin cross-referencing the picked points to the new photo (Fig. 14). Then pick a new set of chosen points visible in the second photo (but not in the first) and open a third overlapping photo to reference. And so it goes, progressively, as you move around the building. The picking and referencing become easier as the software starts to predict where the referenced point is located on the next overlapping photo. It will also highlight any referenced point that appears in an unexpected location.

As the software processes the input, open a three-dimensional view of the model (Fig. 15). At this point you can pull measurements right off the referenced photos. A query on the long dimension of the building yields a length of 50 ft. 6 in., exactly what I measured in the field. I did not enter this information into the PhotoModeler software: the software yielded the dimension by processing the images and the referencing between them, using the camera calibration. The software determines the camera locations for each view as well (Fig. 16).

A PhotoModeler permanent license is priced at \$995, a monthly subscription at \$49. If you prefer to outsource your photogrammetry at a lower price, Hover (www.hover.to) is a photogrammetric service for appraisers, insurance adjusters and general contractors, and may be of use to readers for quick documentation of existing conditions in a structure. The Hover



13 Targets are photographed from multiple angles of view to calibrate camera.



14 Cross-referencing photos in PhotoModeler, a slow process.

15 Model takes shape, roof trim modeled at one corner only since later it can be copied and mirrored in CAD program. This stage represents about three hours of clicking and referencing.

16 Camera locations inferred and displayed by software.

app prompts the user to take eight photographs of a building (four of each façade and four from each corner). Within 24 hours a combination of software and human overview returns detailed dimensioned drawings of the building exterior, including material takeoffs (Figs. 17–20). The Hover Professional platform allows for export to other CAD systems. While not necessarily a replacement for more detailed documentation of existing conditions, Hover provides a good first pass at gauging overall size and scope of work of a project. At this writing, entry level is \$30 for a very basic model (such as the Sandown Meetinghouse would generate), up to \$110 for more complex models, with a monthly subscription priced on additional services desired.

The field of photogrammetry, from simple to sophisticated, is

17 Detail of actual building to be modeled by Hover, a remote service.

18 Detail of Hover model, delivered in 24 hours.

19, 20 Window dimensioning and locating on model.

in rapid development. The PhotoModeler software I acquired over the winter has been updated twice since then. The Leica BLK360 (\$15,990), introduced in the fall of 2016 (and which captures 360,000 points per second in a range of 60 meters with 4mm accuracy, all in a package not much larger than a pint of beer), is currently taking reservations for delivery in 20 weeks; clearly the demand for such a unit is higher than estimated. Expect to see an increase in availability of photogrammetry software, hardware and services, at increasingly lower prices. —ANDREA WARCHAIZER
Andrea Warchaizer (awarchaizer@gmail.com) operates Spring Point Design in Sandown, N.H. To view a demonstration of the SketchUp Photomatch process on the Guild YouTube page, search TFG and Photogrammetry.