# One Part in 300,000.
# Precision and Accuracy Discussion.

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## Introduction

We conducted an experiment to determine PhotoModeler's precision using commonly available and reasonably priced equipment. We demonstrate that any customer can achieve very high precision with PhotoModeler Pro 5. In addition we discuss two common terms, Precision and Accuracy, and why they are important to understand.

## Accuracy and Precision

We first discuss an important distinction when one describes the accuracy of a measurement system. We present the definition of two key terms: *Accuracy* is the agreement of a measurement with a recognized standard or the "true" value; and *Precision* is the degree of which similar or repeated measurements show the same results. The Wikipedia article at en.wikipedia.org/wiki/Accuracy gives good descriptions of accuracy and precision.

You need high precision to get high accuracy but highly precise measurements are not necessarily accurate. With the appropriate setup PhotoModeler can give you both.

In measurement, and photogrammetry in particular, precision and accuracy are words that are sometimes confused. Why would that be? It may be that photogrammetric programs calculate good estimates of precision solely from their internal information. Since these figures can be presented clearly, it is easy to fall into the trap of looking at these precision values as if they represent true accuracy. In fact accuracy validation can **only** be done by comparing results against an accepted measurement (a standard or a measurement of known higher accuracy).

PhotoModeler provides a number of tools for assessing quality. The two main sources of information are the Precision values and the Residual values. The Residual values tell you how much disagreement there is between the marked location on a photograph and the predicted location given the camera parameters and the solved 3D point location. If we have a point marked on a number of photographs and those marked points all have small residuals (less than a pixel) then we have more confidence that the 3D point is solving well. If all points in a project have small maximum residuals then we have more confidence in the whole project. The Precision values are computed by the processing algorithm - they are estimates of how precise the locations of 3D points and camera positions are in 3D space. The smaller the precision value, the more likely the actual point location falls into a small volume. Conversely, points with large precision values fall somewhere in a larger volume and so it is harder to predict the correct location.

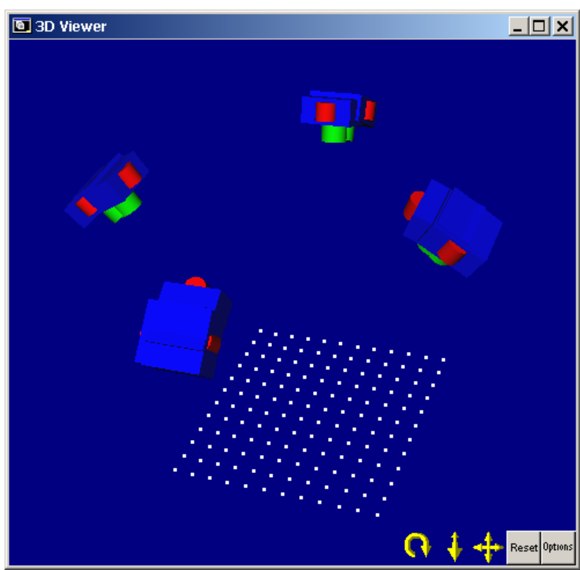
The Precision values in PhotoModeler and other photogrammetric packages are estimates computed from the geometry of the project. PhotoModeler shows these values at 'one-sigma' for each axis. One-sigma is the 68% probability threshold. For example, if a 3D point has an X coordinate of 320.0mm and an X precision value of 0.2mm this means there is a 68% probability that the X coordinate lies between 319.8mm and 320.2mm.

These precision predictions are based on internal project information and do not tell us how the point or its coordinate relate to any external or "true" value.

### The Experiment

The experiment was completed with a grid of target dots that was approximately 1.5m by 1.5m square. The target dots were laser-print black on a white background and 1cm in diameter. The camera used was a Canon Rebel XT with an 8 megapixel sensor and 20mm Canon fixed lens. All targets were marked automatically with PhotoModeler's sub-pixel circular-target marker and no manual intervention. The processing included field calibration (where the adjustment algorithm includes the camera parameters in the solution to fine tune them for a particular project).

The following figure shows the study project in PhotoModeler's 3D Viewer: the grid of 3D points and the 12 camera stations as four groups of three. Note the 90 degree rolled rotations of some camera stations which assist with field calibration:



### The Results

The following table shows the resulting Precision values over all target points:

| | X | Y | Z |
|---|---|---|---|
| RMS Precision (1-sigma) [meters] | $4.1 \times 10^{-6}$ | $4.0 \times 10^{-6}$ | $6.6 \times 10^{-6}$ |
| Max. Precision [meters] | $8.5 \times 10^{-6}$ | $7.5 \times 10^{-6}$ | $1.0 \times 10^{-5}$ |

The RMS Precision values are the root-mean-squared precisions over all points for that coordinate. The Max. Precision values are the maximums over all points for that coordinate.

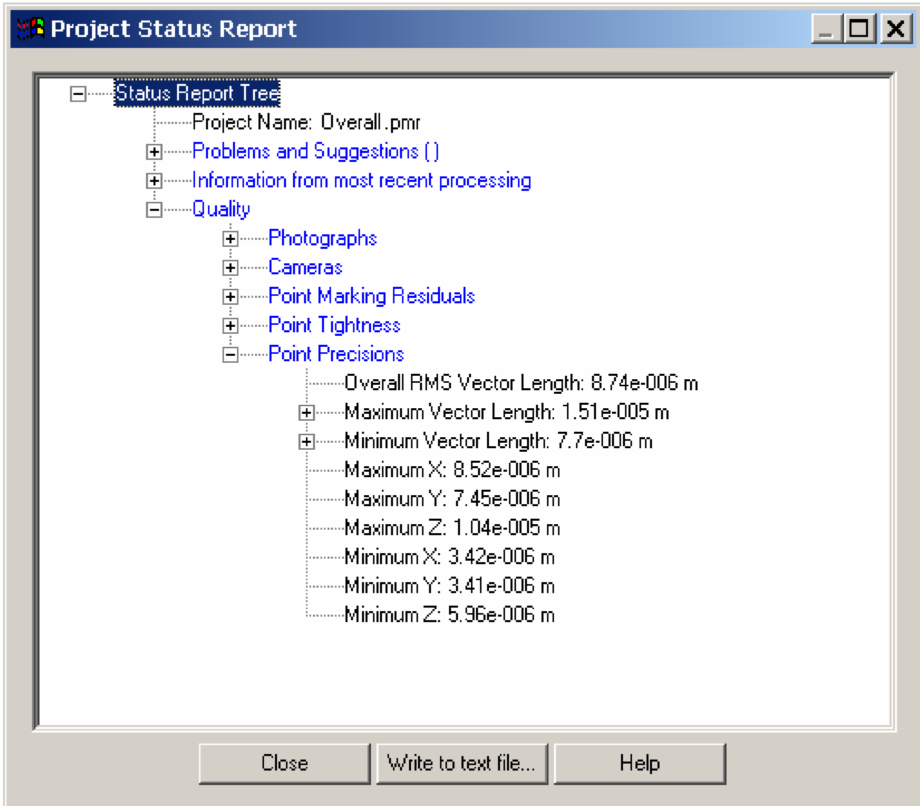
The grid is 2.22m in its largest dimension (the diagonal) and so the 1 part in N precision values are:

| | X | Y | Z |
|---|---|---|---|
| RMS Precision (1-sigma) | 1 in 540,000 | 1 in 550,000 | 1 in 335,000 |
| Max. Precision | 1 in 260,000 | 1 in 298,000 | 1 in 213,000 |

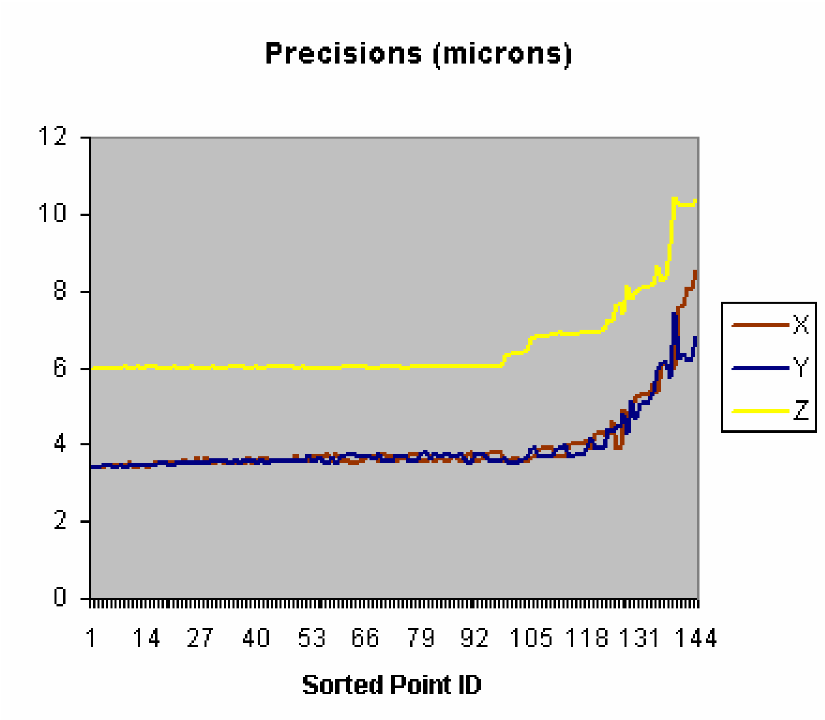
We often use these '1 in N' type numbers in photogrammetry to denote precision and accuracy because photogrammetry is for the most part not dependent on scale. Hence the smaller the object, the smaller the precision value is in absolute terms. For example, using a similar setup to this experiment but a different size grid you would find the X coordinate precision to be 0.2 ten-thousandths of a inch for a one foot object or one thousandth of an inch for a 50 foot object.

Why are the Z precision values worse than X and Y precisions?  This discrepancy shows us another reason why studying precision values can be useful. We are modeling a flat grid where all the camera stations are above the grid and pointing down and so PhotoModeler cannot determine the height of the targets to the same degree of precision as the position on the plane. If there had been more 'spread' in the height of the camera stations (which may not be physically possible) the Z precisions would have been smaller.

The following screen shot shows the Project Status Report from PhotoModeler for this project. You can see the reported summary of precision values:




Another way to look at the precisions is to sort them by size. The following graph shows the precisions in X, Y and Z in microns. It is clear that the Z values are not as precisely determined as the X and Y values.




Using the Z values as our worst case we have a one-sigma RMS precision of 1 part in 335,000 and a maximum (worst case) precision of 1 part in 213,000.

Note that no filtering was done on the data to remove poor quality points and marks, as might be done in some projects and experiments.

## Summary

In this test case with standard equipment, PhotoModeler demonstrated an RMS precision of 1 part in 300,000. Getting back to our definitions of *accuracy* and *precision* let's ask the question, "Can we say that this PhotoModeler project is accurate to 1 part in 300,000?" The answer is, "No, we can't", as we don't want to fall into the trap of confusing precision and accuracy. 1 part in 300,000 *could* be the project accuracy but without comparing the measurement results to an accepted external source of measurements we cannot know. For practical purposes, we can assume that for most projects the accuracy would be lower than this.

For most customer projects it is the accuracy that is important. The results have to fit into the real-world (a production process, architectural drawings, etc.) and you want to know how accurate your project is, not how precise it is. You want to know how the PhotoModeler results compare with your accepted standard (whether they be survey measurements, tape measurements, GIS coordinates, or laser tracker data). If you are interested in doing such a test with your accepted standard, Eos would be happy to assist.

You will want a highly precise tool because without precision you cannot get accuracy. To ensure that your projects are accurate as well as precise you need to consider your datum and/or scale definition and how accurate they are. You can have a precise project but if your scale is 0.1% off then the accuracy of the whole project will be off too. To minimize this possibility you can use redundant scales or control points to correctly tie your project to your desired external coordinate definition. In addition you will want to ensure that the points or targets that PhotoModeler is identifying precisely match the locations in your scene or object that are important to your task.

Accuracy comes from precision. Start with a highly precise tool, such as PhotoModeler, and you are more than half way to your goal. Carefully defining the scale and datum and precisely identifying the correct object points will get you the rest of the way.