Accuracy Study Project of Eos Systems' PhotoModeler

-Final Report -

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Summary:
The aim of this study project was to test the accuracy of Eos Systems' photogrammetric soft-copy close-range program "PhotoModeler" using different types of cameras with different types of calibration of these cameras and different numbers and arrangements of photographs.

To properly document the various levels of accuracy one can achieve with PhotoModeler, the results have been compared with high accuracy measurements from other standard surveys methods.

The results are very promising, the achieved accuracy in the distances between measured points is in the range of 1:1700 to 1:6500 of the object's size. Regarding the points' coordinates the average accuracy reached up to 1:8000. That is what we had expected to get from this kind of data and what is regarded to be an international standard for e.g. architectural applications.

1. Accuracy Study Procedure

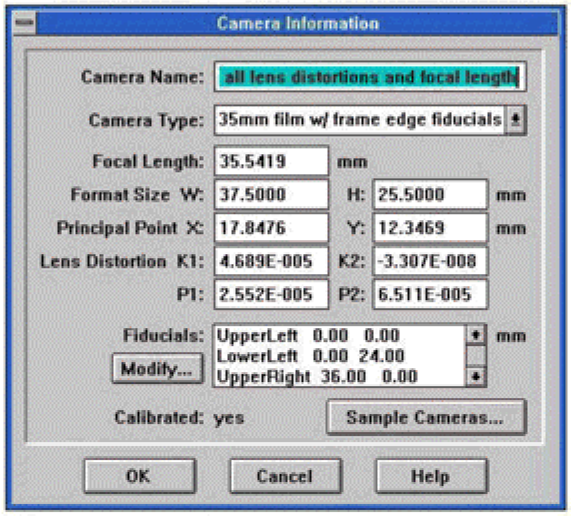
1.1 Gather up survey data for the study target area.
1.2 Take 6 to 8 photos of the wall with a metric camera (P32) (1/2 from the ground and 1/2 high-up looking down).
1.3 Repeat the same exposures with a non-metric 35mm camera.
1.4 Take the PhotoModeler calibration photos for the 35mm camera.
1.5 Calibrate the 35mm camera using PhotoModeler calibrator three times (normal, radial only & no lens distortion).
1.6 Scan the film: P32 on Pro PhotoCD, and 35mm on desktop-scanner from prints.
1.7 Set up four cameras in PhotoModeler
 - P32 with precalibrated radial distortion curve and reseau
 - 35mm calibrated by PhotoModeler with no lens distortion (frame fiducials)
 - 35mm calibrated by PhotoModeler with radial lens distortion (frame fiducials)
 - 35mm calibrated by PhotoModeler with both lens distortion (frame fiducials)
1.8 Mark all the points on all P32 images.
1.9 Process with all photos taken and then reprocess using photos from just low positions.
1.10 Mark all the points on the 35mm images.
1.11 Process with all 35mm photos taken and then reprocess using photos from just low positions.
1.12 Compare results of 3D positions and measured lengths of the projects against each other and against survey data.

2. Software

Three software programs were used in this study: Adobe Photoshop 3.0 for image enhancement, PhotoModeler Calibrator for calibration of non-metric camera, and PhotoModeler 2.1 for image marking and bundle adjustment.

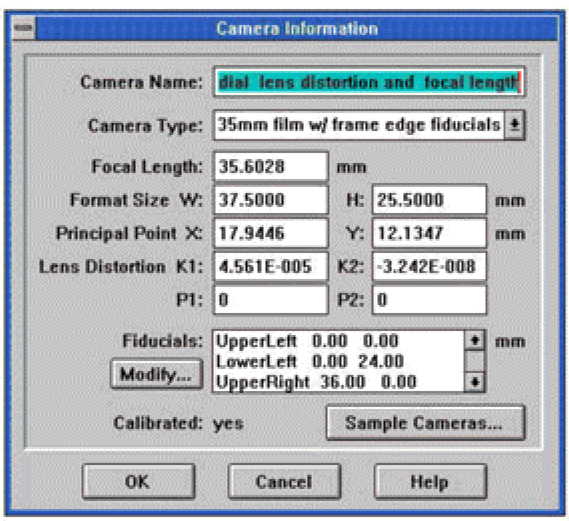
2.1. Calibration

All calibration of the non-metric camera has been done using Eos Systems' "Calibrator" software Version 2.1. The calibration was done using the standard procedure from the User Manual with 10 images. In addition to the standard calibration, two further calibrations were carried out by modifying lens distortion deviation values in the calib.ini file. By changing these values to negative before processing, the values have been fixed and have not been adjusted during calibration.

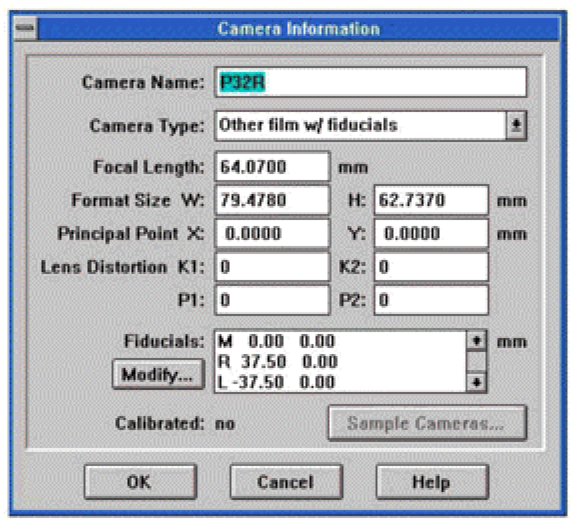


Calibrated camera parametrs
(all lens distortions and focal length)

Calibrated camera parameters
(without lend distortion, just focal length)



Calibrated camera parameters
(with radial lens distortion and focal length)



Camera parameters for the metric camera

2.2. Image enhancement

The images have been reduced in size, where necessary, to just under 16 Mbytes each to guarantee they could be loaded into PhotoModeler 2.1.

If necessary a contrast stretching completed the image preprocessing. All imaging has been done using bilinear interpolation procedures to avoid loss of accuracy and details.

2.3. Bundle adjustment

The photogrammetric processing has been done using Eos' PhotoModeler Ver. 2.1.
The handling of the images happened in the common iterative way:

- approximate marking of points
- shifting to exact position in a zoomed window
- after first processing a moving of single points according to their residual vectors
- second processing
- if necessary repeating of last 2 steps.

The resulting point coordinates have been written to ASCII file and prepared and formatted for further comparison processing.

3. Test Field

3.1. Targets

The Test Field used in the study is a brick wall located on the University of Innsbruck campus.

The corners of the bricks are well-defined and are used as natural targets for all measurements done in this project. This type of target seems to be most similar to the needs of the typical PhotoModeler client.

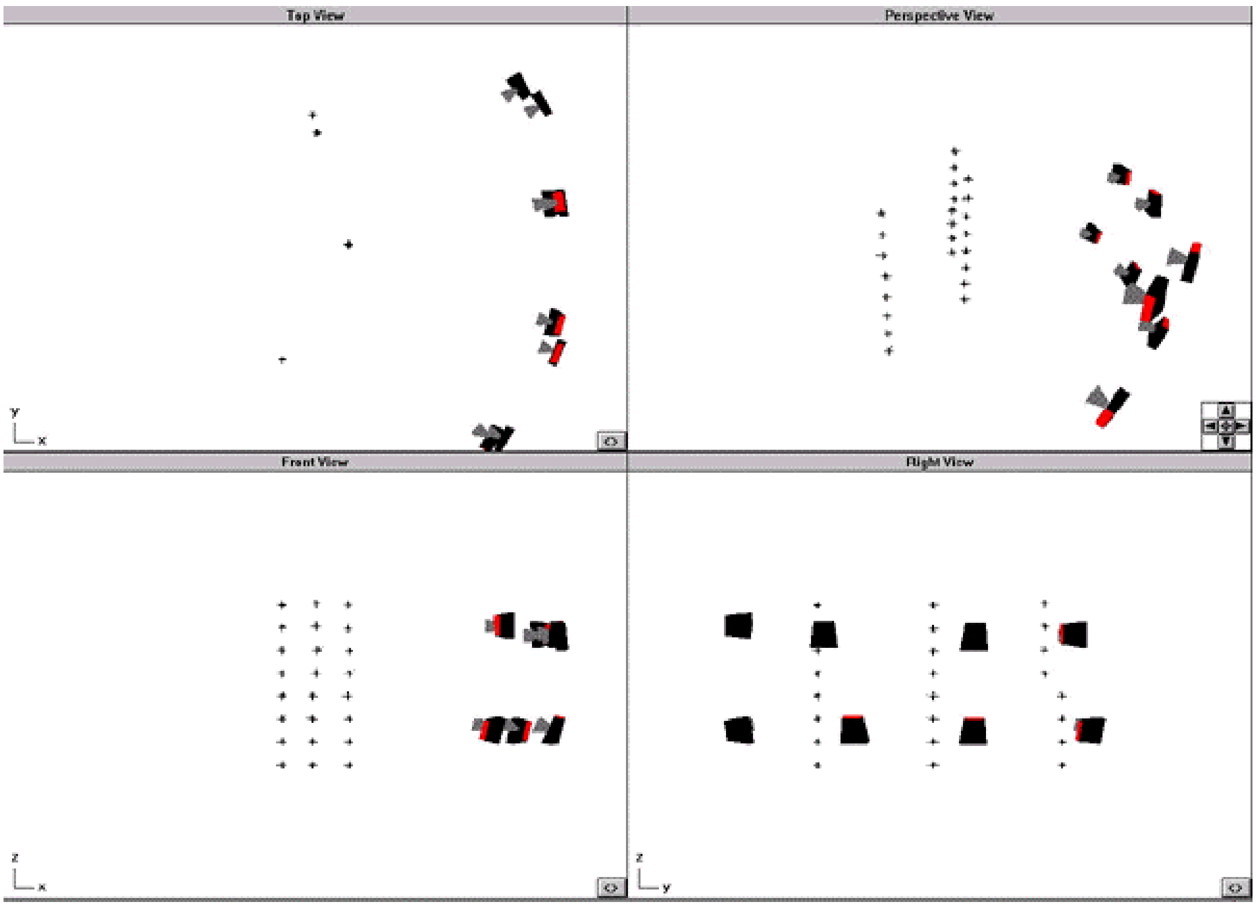
The 13 vertical columns are numbered from 1 to 13 and the 8 horizontal rows are numbered from A to H. So the point numbers start from left-low (A1) up to right-high (H13). The overall largest dimension of the object (used when discussing accuracy ratios later on) is 12m.

3.2. Survey measurements

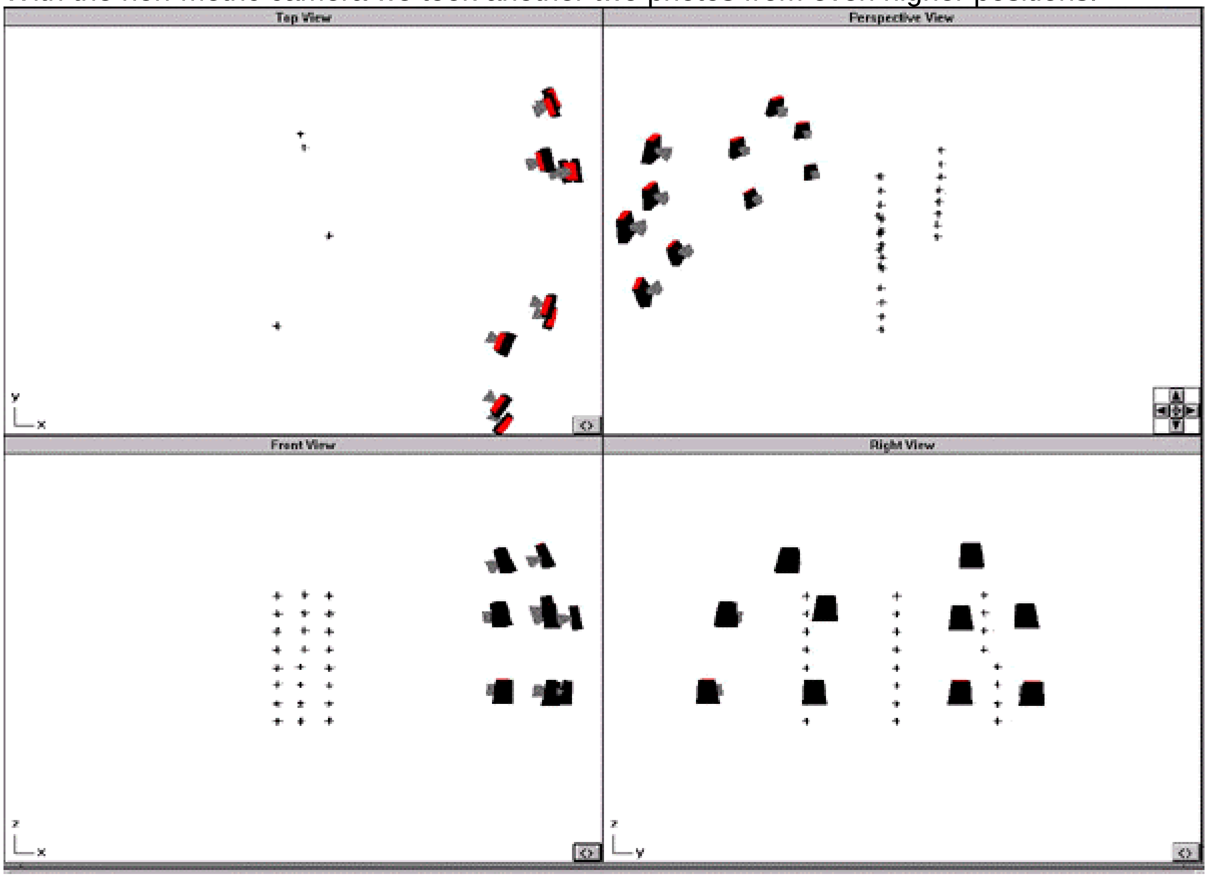
For comparison purposes, all of the points were surveyed with a theodolite (Leica T2002 high precision theodolite). They have been determined by spatial intersection from three survey stations and further least-squares adjustment. The accuracy of the points lies between 1.0 and 1.5 mm absolute.

3.3. Photogrammetric configuration

With each camera four photos have been taken from ground and four photos from a lift platform about 6 m above the first positions.



With the non-metric camera we took another two photos from even higher positions.



4. Photogrammetric Measurements

4.1. Metric camera WILD P32

The high-precision metric camera used in the study was a LEICA (formerly WILD) P32.

The negative format is 6 x 9 cm and the focal length is about 64 mm. The camera has 5 fiducial marks (One on each side of the frame and one in the principal point (not in the middle, because this principal point is asymmetric !). Roll film (FUJI NPS 160 ASA) was used with this camera and scanned via Kodak Pro PhotoCD with a resolution of 4096 x 6144 pixels in full color. The digital images were then reduced to greylevel and also to a resolution of 3271 x 4165 pixels to fit PhotoModeler 2.1's requirements for photo import (<16 MB).

The metric camera is already well calibrated and these values have later been used for further processing.

4.2. Small format camera Ashai Pentax

The second camera was a Ashai Pentax small format camera with a wide angle lens of 35 mm focal length. The film used was a Kodak EKTAR 100 ASA. We made prints from the negatives in size of 18 x 18 cm including the negative's frame. These prints were scanned with a desktop scanner (Agfa ARCUS II) at a resolution of 230 lpi which resulted (after cropping to fit the negative format) in images of 1721 x 2521 pixels each. Before further processing the 35mm camera was calibrated using Photomodeler's 2.1 Calibration software.

The calibration image was printed on a HP Designjet 650 to a size of about 180 x 270 cm. The calibration was carried out three times: without the parameters of lens distortion, with radial parameters only and with full (radial and tangential) distortion parameterisation. The 10 photos used in calibration pattern underwent the same image processing as above.

5. Comparison and Results

To guarantee that the coordinates generated by PhotoModeler were in the same coordinate system as those of the theodolite survey, 24 control points framing the testfield were marked in the PhotoModeler projects.

That means:
x-axis points approximately away from the wall
y-axis perpendicular to x-axis (approximately along face of wall)
z-axis is vertical

The evaluation of the different methods was done in two independent ways:
- comparison of the measured points' coordinates in x,y,z
- comparison of all distances between all points (about 4850 - 4950 distances)

In some images single points could not be measured because of missing or bad contrast. So the actual number of measured points differs from the maximum (13 x 8 = 104). The metric camera project has 100 points and the non-metric camera projects 99 points.

For both evaluation methods the computation of average errors = sum(abs(diff))/n and of root mean square errors = sqrt(sum(diff*diff)/n) where diff is the difference in coordinate or distance values and n is the number of points. These reporting methods lead to significant values for the accuracy of the evaluated method.

The projects have been named as follows:
- project 1 (camera 1) is small format, calibrated with full distortion
- project 2 (camera 2) is small format, calibrated without distortion
- project 3 (camera 3) is small format, calibrated with radial distortion
- project 4 (metric camera)

Table 1 shows the results of the comparison of coordinates between test field and measurement for all 99 points that had been visible.

All numbers specified in centimeters.

Diff.	[cm]	camera 1	camera 2	camera 3	metric camera
r. m. s. e.	x	0.64	0.65	0.63	0.30
	y	0.38	0.52	0.37	0.22
	z	0.34	0.42	0.30	0.15
	Distances	0.57	0.82	0.54	0.25
average	x	0.55	0.52	0.54	0.24
	y	0.31	0.42	0.29	0.18
	z	0.26	0.32	0.25	0.11
	Distances	0.45	0.70	0.43	0.20
	Ratio (12m)	1:2670	1:1700	1:2790	1:6000

Table 2 shows the results of the comparison of coordinates between testfield and measurement for the ”good” points.
”Bad” points have been selected by the criterion of their differences being >2x the average of the others and removed after that for a second run of comparison. This was done to show that most of the points have an even better accuracy.

Almost all of the removed points lie along the middle edge where the two walls come together and the contrast was very low because of missing mortar around the corners of the bricks.

Diff.	[cm]	camera 1	camera 2	camera 3	metric camera
r. m. s. e.	x	0.53	0.47	0.53	0.25
	y	0.36	0.50	0.34	0.20
	z	0.33	0.35	0.29	0.13
	Distances	0.53	0.74	0.49	0.22
average	x	0.42	0.31	0.42	0.19
	y	0.27	0.32	0.24	0.15
	z	0.22	0.21	0.21	0.09
	Distances	0.44	0.63	0.40	0.18
	Ratio (12m)	1:2730	1:1900	1:3000	1:6670

Table 3 shows the results of the comparison of coordinates between test field and measurements for the 99 points using only the 4 lower images for camera 1 (35mm camera radial distortion model) and metric camera only.

Diff.	[cm]	camera 1	metric camera
r.	x	0.75	0.48
m.	y	0.42	0.36
s.	z	0.38	0.23
e.	Distances	0.61	0.41
av	x	0.58	0.39
er	y	0.34	0.28
ag	z	0.31	0.18
e	Distances	0.48	0.33
	Ratio (12m)	1:2500	1:3640

Table 4 shows the results of the comparison of coordinates between test field and measurements for the ”good” points using only the 4 lower images. ”Bad” points have been selected by the criterion of their differences being >2x the average of the others and removed after that for a second run of comparison (see above)

Diff.	[cm]	camera 1	metric camera
r.	x	0.49	0.43
m.	y	0.38	0.33
s.	z	0.37	0.23
e.	Distances	0.52	0.38
av	x	0.33	0.32
er	y	0.24	0.24
ag	z	0.25	0.16
e	Distances	0.42	0.31
	Ratio (12m)	1:2860	1:3870

6. Conclusion

During this study PhotoModeler showed its competence for a wide area of photogrammetric applications. The achieved accuracy is dependent of a number of factors concerning the used camera and its handling, but also the object, its size and not to forget the clear definition (natural vs. targeted) of the measured points.

In this study, we used natural targets (corners of bricks) that were well defined but not as well as one would expect with a high contrast photogrammetric target.

It was no surprise, that the metric (and precalibrated) camera with its not-distorted (<4 micron) lens led to the best results. On the other hand, the commonly available, non-metric, small-format camera's results are not much worse.

The highest accuracy of the metric camera's results can only be available using the highest standard for each step of the whole process. That means highest possible resolution for scanning and also the optimal configuration of camera positions. Processing of only the 4 lower images led to about half accuracy.

The use of only the lower images of the non-metric camera on the contrary did not lead to a significant decrease of accuracy.

The influence of distortion parameters is hard to evaluate. If the distortion is very significant and it is possible to describe it by tangential and radial parameters, a full parameterisation leads to significant increasing of accuracy. If the distortion is generally small or hardly described by these parameters, there will be no positive effect.

Nevertheless the study shows that using full distortion calibration brings the best results. In our special case no significant difference in the results between full distortion and only radial distortion can be seen. This could be different with other lenses.

The best way to take the photos is to find a good configuration with good angles of intersection between the rays, don't change the inner orientation by focusing (switch off Autofocus) and use a calibrated camera (including all distortion parameters) to have good values for the camera's inner orientation in the photogrammetric bundle adjustment.

The results in general are very promising, the achieved average accuracy for distances between points lies in the range of 1:1700 (for 35mm, no lens distortion compensation) to 1:6500 (for metric camera) of the object's size. For the points' coordinates the average accuracy reached 1:8000.

These accuracies are what we would expect to get for natural targets, what corresponds also to the photogrammetric theory and what meets the requirements for e.g. architectural applications.

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