Politecnico di Milano - Courses on Photogrammetry
Laboratory report

Lab 01

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CFU group:	10	Date:	05/11/2022
Lab Topic:	01 - Close Range Photogrammetry		

Description of the performed activity *(max 50 lines)*

The laboratory activity had as a goal the realization with the software *Photomodeler* of a 3D model of a Rubik's cube. In order to realize an accurate photogrammetric project, proper camera calibration is essential to recover the internal orientation and distortion parameters. Firstly, then, photos were taken of a calibration grid and of a Rubik's cube. The photos were taken with a reflex camera Nikon D3100, which has self-rotation and auto-focus disabled. Some precautions were taken in order to keep the same parameters throughout the calibration photos and the cube photos, mainly avoiding changing the zoom settings and switching off the camera. For the grid acquisition, 12 photos were taken: two photos rotated of 90° on either side and a nadiral photo. This was done to un-correlate the estimated parameters. The grid, composed of 100 targets – of which, 4 coded ones – had to take as much space as possible in all the different camera set-ups to cover all the sensors and had to fit as much of the lower end of the image as possible (*fig.1-2*). For the cube, 8 pictures were acquired: 4 parallel to each side and 4 parallel to each edge (*fig. 3-4*). A final note concerning the quality of the result has to be made, since the photo quality is greatly affected by the low-quality lightning at the time of acquisition and scarce photographic ability of the author.

The photos acquired were then uploaded onto the software which performed the camera calibration automatically by using the bundle-block adjustment (thence, *BBA*). The estimated parameters resulting from the calibration are available for consultation in *calibration1.txt*. The calibration quality indicator, *total error*, was larger than the sought-after value 1 - based on the software a priori assumption that $\hat{\theta}_0^{\,2} = 1$. A chi-squared statistical test was performed, its null hypothesis being that the estimated total error was equal to the a priori value. As predicted, the value was too high to be acceptable and so the outlier rejection process was initiated, by removing all the residual errors larger than 1.5, careful not to remove coded targets. The calibration process was re-run and, while the total error improved, the statistical test was not yet passed. The value of the total error is: $\hat{\boldsymbol{\theta}}_{\boldsymbol{0}}^{\,\boldsymbol{2}} = \mathbf{3.436}$ (*calibration2.txt*) Considering the sub-par conditions in which the images were acquired, the error was evaluated using another test, solving for the accuracy. The test revealed that the accuracy of the border would have needed to be of **3.36 pxl.** In that case, the test would have been passed. (*fig. 5*)

Subsequently, the cube images were uploaded. In this specific case, an additional 9th photo was added to the procedure by mistake, but since the 8-photo indication was a compromise between computational power and redundancy of points, the addition of a supplementary one did not seem too much of a stretch and was kept in the procedure. Firstly, then, the homologous points of the referenced grid were collimated, because sharper and better-defined than others. Ideally, all the crosses had to be collimated; however, due to a lack of time, a well-distributed sample was selected instead, excluding points that were not well in focus, yet still making sure that each was visible in at least 3 images. An initial BBA was performed, where the total error came out as: $\hat{\boldsymbol{\theta}}_{\boldsymbol{0}}^{\,\boldsymbol{2}} = \mathbf{0.923}$. This error is lower than the previous one because of the manual collimation. Also worthy of note is the lower redundancy of the points at this step: 9, instead of 100. A unit of measurement for the model of 36 cm (distance between point 1.1 and 1.7) was set, knowing the distance between two crosses being 6 cm.

Lastly, the 8 corners of the cube were collimated, and the BBA was performed once more, resulting in a not much-improved total error: $\widehat{\boldsymbol{\theta}}_{\boldsymbol{0}}^{\ \boldsymbol{2}} = \mathbf{0.817}$. Indeed, since the points were manually collimated on rounder corners, the accuracy could not have been much higher. The 3D model was finally created by connecting the corners of the cube with lines and creating surfaces on the model in a clockwise fashion (*fig. 6*).

By using a caliper with an accuracy of 0.05 mm, the edge of the actual object was measured to be **53 mm**. A different statistical test, the z-test, was performed on every edge to see if the null hypothesis (i.e., "*the computed value of the edge is equal to the one measured on the real object*") stood. Since the Euclidean distance between two points is non-linear combination, the variance had to be propagated by firstly linearizing the observation equation. Moreover, this was done by wrongly assuming that the coordinates of the two points composing the lines are not dependent from one another. The result of this test was otherwise very satisfactory, as all the lines satisfied the null hypothesis (*fig. 7*).

Another statistical test was performed, checking the value of the areas by averaging the square of its sides and propagating the variances. The test wasn't satisfied for **half of the areas** computed (*fig. 8*). We could go on and test against the total cube's surface, which would yield even worse results. The GSD was also calculated and yielded a value of **0.017 mm**, comparable to the accuracy of the caliper of 0.05 mm (*fig.9*).

TOTAL LINES: 49

Attachments

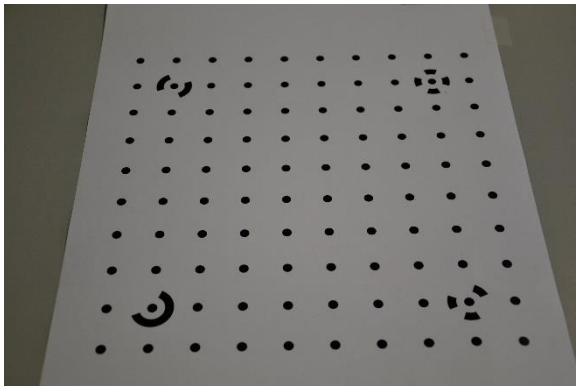

Figure 1 - Calibration grid photo

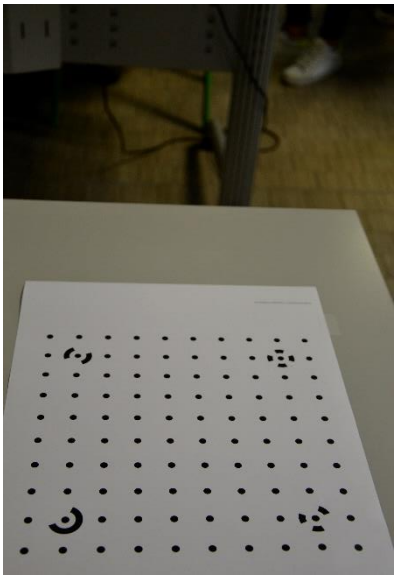

Figure 2 - Calibration grid image 2

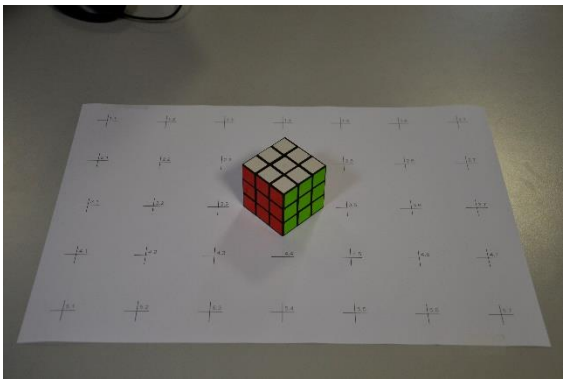

Figure 3- Cube edge-side

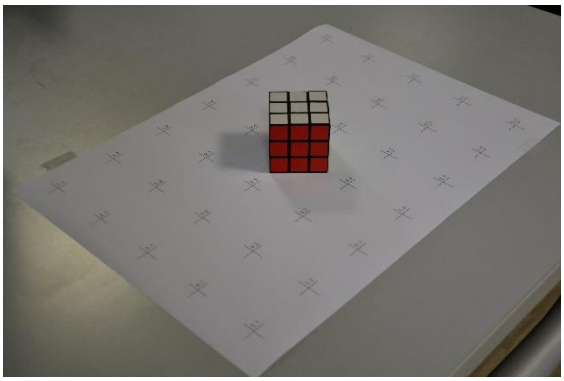

Figure 4 - Cube face-side

	A	B	C
1	# observations	# unknowns	sigma0_hat (total error)
2	2400	72	3.436
3		8	
4		80	
5			
6	Threshold (theoretical)	Chi^2 value (experimental)	Passed?
7	2433.17	27390.14	N
8			
9	Inverse Test	Value Obtained	
10	Accuracy of border (pxl)	3.36	
11			

Figure 3- Results of Chi^2 and Pixel Accuracy

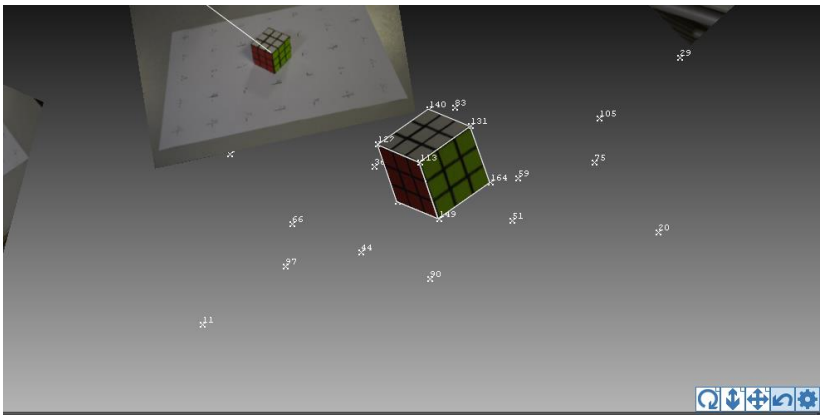

Figure 6- 3D Cube Model

z_exp	z_lim	Passed?
1.73	1.96	PASSED
1.92	1.96	PASSED
0.52	1.96	PASSED
0.51	1.96	PASSED
1.50	1.96	PASSED
1.46	1.96	PASSED
1.70	1.96	PASSED
1.53	1.96	PASSED
0.33	1.96	PASSED
0.73	1.96	PASSED
1.30	1.96	PASSED
1.26	1.96	PASSED

Length on Cube	5.3
Caliper Accuracy	0.05

Figure 7- Results of Z-test

z_exp	z_lim	Passed?
3.602321	1.96	NOT PASSED
2.0926249	1.96	NOT PASSED
1.7918618	1.96	PASSED
1.9935231	1.96	NOT PASSED
1.2879624	1.96	PASSED
1.5393138	1.96	PASSED

Area_meas	28.09
Accu_meas	0.05

Figure 8- Results of Z-test on Areas

GSD

fw	D	c	#pxl	GSD
24.28	90	36.3	3456	0.017418503

Figure 9- GSD Calculation