Joshua Genova
CIVE 6374 – Optical Imaging Metrology
Spring 2023

Lab #5

Tasks 1:

A.) Points 100, 104, 105, 200.

Image 27

X^C (m)	99.1813
Y^C (m)	-628.2502
Z^C (m)	1842.2475
ω (°)	-0.2151
ϕ (°)	1.4566
κ (°)	90.1951

Image 28

X^C (m)	105.1158
Y^C (m)	-170.3082
Z^C (m)	1833.9863
ω (°)	-0.4713
ϕ (°)	0.5106
κ (°)	88.461

B.) Points 100, 104, 105, 200, 201.

Image 27

X^C (m)	99.2689
Y^C (m)	-628.2943
Z^C (m)	1842.2306
ω (°)	-0.2124
ϕ (°)	1.4612
κ (°)	90.1958

Image 28

X^C (m)	105.1261
Y^C (m)	-170.2981
Z^C (m)	1833.9808
ω (°)	-0.472
ϕ (°)	0.511
κ (°)	88.4608

C.) Points 100, 104, 105, 200, 201, 202.

Image 27

X^C (m)	99.2712
Y^C (m)	-628.3206
Z^C (m)	1842.22
ω (°)	-0.2102
ϕ (°)	1.4616
κ (°)	90.1957

Image 28

X^C (m)	105.222
Y^C (m)	-170.4222
Z^C (m)	1834.0193
ω (°)	-0.4619
ϕ (°)	0.5171
κ (°)	88.4607

D.) All

Image 27

X^C (m)	99.2627
Y^C (m)	-628.3256
Z^C (m)	1842.2276
ω (°)	-0.2102
ϕ (°)	1.4609
κ (°)	90.195

Image 28

X^C (m)	105.1891
Y^C (m)	-170.4356
Z^C (m)	1834.0609
ω (°)	-0.4598
ϕ (°)	0.5149
κ (°)	88.4618

Task 2:

$Tol_{coords} = \frac{S\sigma_{obs}}{10} = 0.003$ S = 5000, σ_{obs} = 6 µm

$Tol_{tilt} = \frac{\sigma_{obs}}{10c} = 0.000224°$ c = 153.358 mm

$Tol_{kappa} = \frac{\sigma_{obs}}{10x_{max}} = 0.000213°$ x_{max} = 161.645 mm

All experiments converged after **3 iterations.** We used 6 µm from the RMSE of the Affine Transformation from Lab 1. A safety factor of 10 is included in each formula to be more conservative about the tolerances. x_{max} is obtained from the given image size, finding the distance to the corner.

Task 3:

A.A.) Points 100, 104, 105, 200.
Standard Deviation

Image 27

X^C (m)	0.2024
Y^C (m)	0.1506
Z^C (m)	0.0509
ω (°)	0.0117
ϕ (°)	0.0115
κ (°)	0.0024

Image 28

X^C (m)	0.1708
Y^C (m)	0.1496
Z^C (m)	0.0806
ω (°)	0.0111
ϕ (°)	0.0083
κ (°)	0.0036

A.B.) Points 100, 104, 105, 200, 201.
Standard Deviation

Image 27

X^C (m)	0.1163
Y^C (m)	0.1416
Z^C (m)	0.0443
ω (°)	0.0107
ϕ (°)	0.007
κ (°)	0.002

Image 28

X^C (m)	0.0898
Y^C (m)	0.1264
Z^C (m)	0.0596
ω (°)	0.0095
ϕ (°)	0.0049
κ (°)	0.0023

A.C.) Points 100, 104, 105, 200, 201, 202.
Standard Deviation

Image 27

X^C (m)	0.1068
Y^C (m)	0.1345
Z^C (m)	0.0406
ω (°)	0.0101
ϕ (°)	0.0066
κ (°)	0.0018

Image 28

X^C (m)	0.0817
Y^C (m)	0.1025
Z^C (m)	0.0547
ω (°)	0.0076
ϕ (°)	0.0043
κ (°)	0.0023

A.D.) All

Standard Deviation

Image 27

X^C (m)	0.1014
Y^C (m)	0.1296
Z^C (m)	0.037
ω (°)	0.0098
ϕ (°)	0.0061
κ (°)	0.0017

Image 28

X^C (m)	0.0807
Y^C (m)	0.0997
Z^C (m)	0.0516
ω (°)	0.0074
ϕ (°)	0.0042
κ (°)	0.0022

B.A.) Points 100, 104, 105, 200

Image 27

Correlation Coefficient Matrix						
	X^C	Y^C	Z^C	ω	ϕ	κ
X^C	1.0000	-0.5819	-0.7132	0.6492	0.9952	0.7198
Y^C	-0.5819	1.0000	0.8441	-0.9914	-0.6328	-0.2941
Z^C	-0.7132	0.8441	1.0000	-0.8798	-0.7502	-0.4335
ω	0.6492	-0.9914	-0.8798	1.0000	0.6974	0.3531
ϕ	0.9952	-0.6328	-0.7502	0.6974	1.0000	0.6968
κ	0.7198	-0.2941	-0.4335	0.3531	0.6968	1.0000

Image 28

Correlation Coefficient Matrix						
	X^C	Y^C	Z^C	ω	ϕ	κ
X^C	1.0000	0.3347	-0.6037	-0.3313	0.9886	-0.8906
Y^C	0.3347	1.0000	-0.8851	-0.9932	0.2292	-0.4376
Z^C	-0.6037	-0.8851	1.0000	0.9058	-0.5219	0.6514
ω	-0.3313	-0.9932	0.9058	1.0000	-0.2249	0.4416
ϕ	0.9886	0.2292	-0.5219	-0.2249	1.0000	-0.8467
κ	-0.8906	-0.4376	0.6514	0.4416	-0.8467	1.0000

B.B.) Points 100, 104, 105, 200, 201

Image 27

Correlation Coefficient Matrix						
	X^C	Y^C	Z^C	ω	ϕ	κ
X^C	1.0000	-0.5682	-0.6227	0.6071	0.9891	0.5427
Y^C	-0.5682	1.0000	0.8275	-0.9941	-0.6396	-0.1355
Z^C	-0.6227	0.8275	1.0000	-0.8555	-0.6804	-0.2180
ω	0.6071	-0.9941	-0.8555	1.0000	0.6768	0.1660
ϕ	0.9891	-0.6396	-0.6804	0.6768	1.0000	0.4946
κ	0.5427	-0.1355	-0.2180	0.1660	0.4946	1.0000

Image 28

Correlation Coefficient Matrix						
	X^C	Y^C	Z^C	ω	ϕ	κ
X^C	1.0000	-0.1455	-0.1193	0.1424	0.9738	-0.6996
Y^C	-0.1455	1.0000	-0.8606	-0.9921	-0.2904	-0.1227
Z^C	-0.1193	-0.8606	1.0000	0.8940	0.0085	0.2976
ω	0.1424	-0.9921	0.8940	1.0000	0.2884	0.1370
ϕ	0.9738	-0.2904	0.0085	0.2884	1.0000	-0.5983
κ	-0.6996	-0.1227	0.2976	0.1370	-0.5983	1.0000

B.C.) Points 100, 104, 105, 200, 201, 202

Image 27

Correlation Coefficient Matrix						
	X^C	Y^C	Z^C	ω	ϕ	κ
X^C	1.0000	-0.6714	-0.6915	0.6956	0.9918	0.4440
Y^C	-0.6714	1.0000	0.8179	-0.9952	-0.7124	-0.2099
Z^C	-0.6915	0.8179	1.0000	-0.8403	-0.7201	-0.2434
ω	0.6956	-0.9952	-0.8403	1.0000	0.7360	0.2197
ϕ	0.9918	-0.7124	-0.7201	0.7360	1.0000	0.4107
κ	0.4440	-0.2099	-0.2434	0.2197	0.4107	1.0000

Image 28

Correlation Coefficient Matrix						
	X^C	Y^C	Z^C	ω	ϕ	κ
X^C	1.0000	0.0179	-0.2684	-0.0407	0.9775	-0.7619
Y^C	0.0179	1.0000	-0.8442	-0.9888	-0.0858	-0.1686
Z^C	-0.2684	-0.8442	1.0000	0.8939	-0.1806	0.3347
ω	-0.0407	-0.9888	0.8939	1.0000	0.0637	0.1892
ϕ	0.9775	-0.0858	-0.1806	0.0637	1.0000	-0.6749
κ	-0.7619	-0.1686	0.3347	0.1892	-0.6749	1.0000

B.D.) All

Image 27

Correlation Coefficient Matrix						
	X^C	Y^C	Z^C	ω	ϕ	κ
X^C	1.0000	-0.6460	-0.6515	0.6717	0.9916	0.4949
Y^C	-0.6460	1.0000	0.8183	-0.9953	-0.6910	-0.2575
Z^C	-0.6515	0.8183	1.0000	-0.8411	-0.6758	-0.2620
ω	0.6717	-0.9953	-0.8411	1.0000	0.7161	0.2576
ϕ	0.9916	-0.6910	-0.6758	0.7161	1.0000	0.4598
κ	0.4949	-0.2575	-0.2620	0.2576	0.4598	1.0000

Image 28

Correlation Coefficient Matrix						
	X^C	Y^C	Z^C	ω	ϕ	κ
X^C	1.0000	0.0217	-0.2533	-0.0356	0.9783	-0.7660
Y^C	0.0217	1.0000	-0.8600	-0.9903	-0.0979	-0.2249
Z^C	-0.2533	-0.8600	1.0000	0.9018	-0.1410	0.3610
ω	-0.0356	-0.9903	0.9018	1.0000	0.0850	0.2281
ϕ	0.9783	-0.0979	-0.1410	0.0850	1.0000	-0.6799
κ	-0.7660	-0.2249	0.3610	0.2281	-0.6799	1.0000

C.A.) Points 100, 104, 105, 200.

Residuals and RMS **(mm)**

	Image 27		**Image 28**	
ID	**vX**	**vY**	**vX**	**vY**
100	-0.0008	0.0046	-0.0013	0.0033
104	0.0061	0.0043	0.0002	0.0026
105	-0.0032	-0.0054	0.0011	-0.0022
200	-0.0021	-0.0035	0	-0.0037
RMS	0.0036	0.0045	0.0008	0.003

C.B.) Points 100, 104, 105, 200, 201.
Residuals and RMS **(mm)**

	Image 27		Image 28	
ID	**vX**	**vY**	**vX**	**vY**
100	0.0021	0.0072	-0.0013	0.0031
104	0.0079	0.0051	-0.0001	0.0028
105	0.0010	-0.0043	0.0011	-0.0023
200	-0.0001	-0.0033	-0.0004	-0.0037
201	-0.0109	-0.0046	0.0007	0.0000
RMS	0.0061	0.0051	0.00083	0.002694

C.C.) Points 100, 104, 105, 200, 201, 202.
Residuals and RMS **(mm)**

	Image 27		Image 28	
ID	**vX**	**vY**	**vX**	**vY**
100	0.0016	0.0077	-0.0028	0.0061
104	0.0078	0.0034	-0.008	-0.0007
105	0.0004	-0.0047	-0.0003	0.0003
200	-0.0005	-0.0035	0.0013	-0.0054
201	-0.0111	-0.0052	-0.0007	0.0034
202	0.0017	0.0024	0.0105	-0.0037
RMS	0.0056	0.0048	0.0055	0.0039

C.D.) All
Residuals and RMS **(mm)**

	Image 27		Image 28	
ID	**vX**	**vY**	**vX**	**vY**
100	0.0013	0.0075	-0.0032	0.0067
104	0.0096	0.005	-0.0082	0.0041
105	0.0011	-0.0019	-0.0047	0.0058
200	-0.0009	-0.0033	0.0013	-0.0059
201	-0.0106	-0.0046	-0.0013	0.0028
202	0.0035	0.0031	0.0108	-0.0008
203	-0.0042	-0.0057	0.0054	-0.0127
RMS	0.0058	0.0047	0.006	0.0065

Task 4:

Image 27 Standard Deviation Changes:

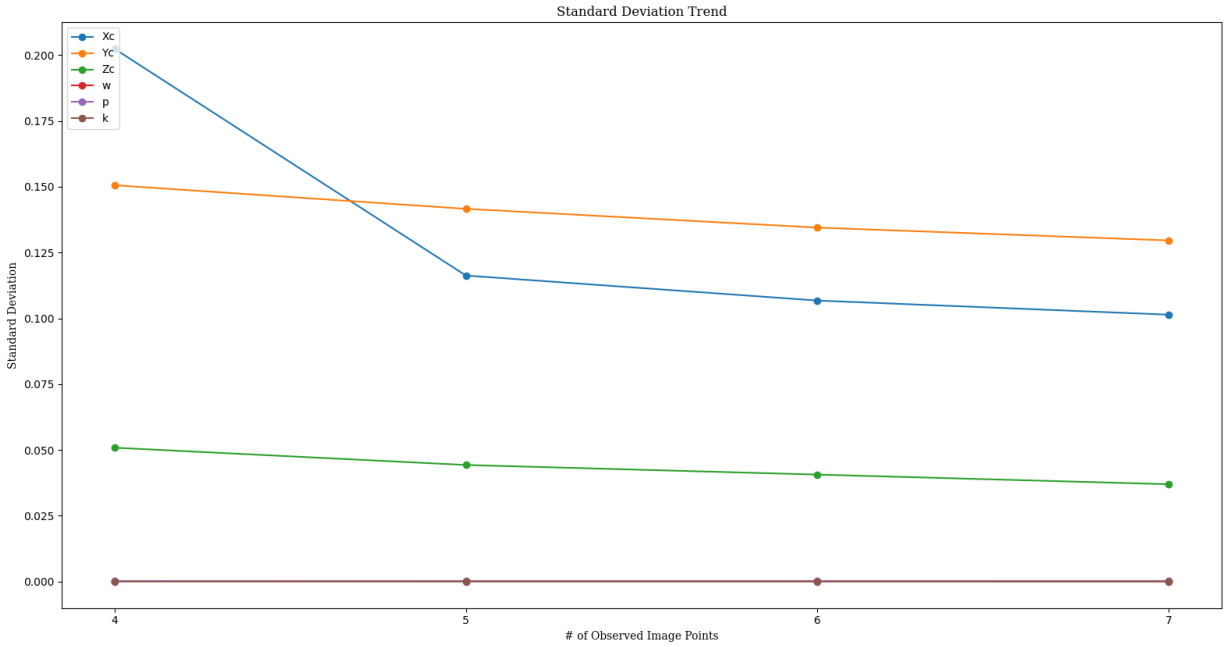
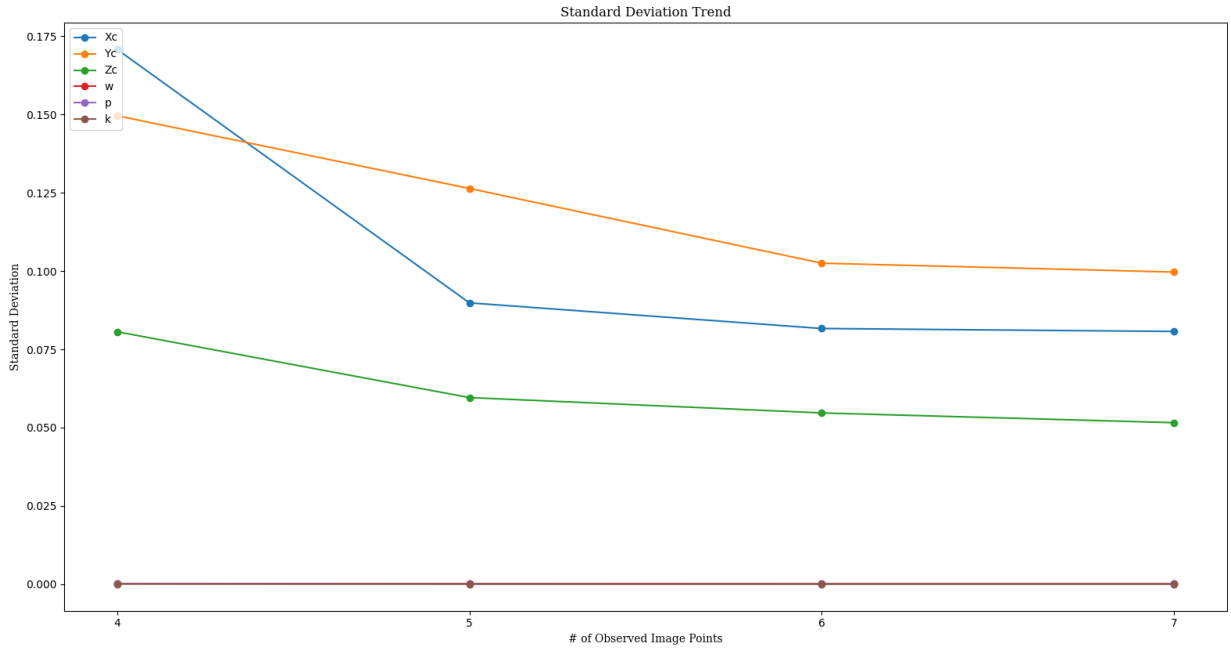


Image 28 Standard Deviation Changes:



For both images, the standard deviations of the coordinates decreased as we added more observed points. This is expected since we the larger number of observe points provided better representation. The angular parameters showed no change as they are already 0.

Image 27 Correlation Coefficient Changes:

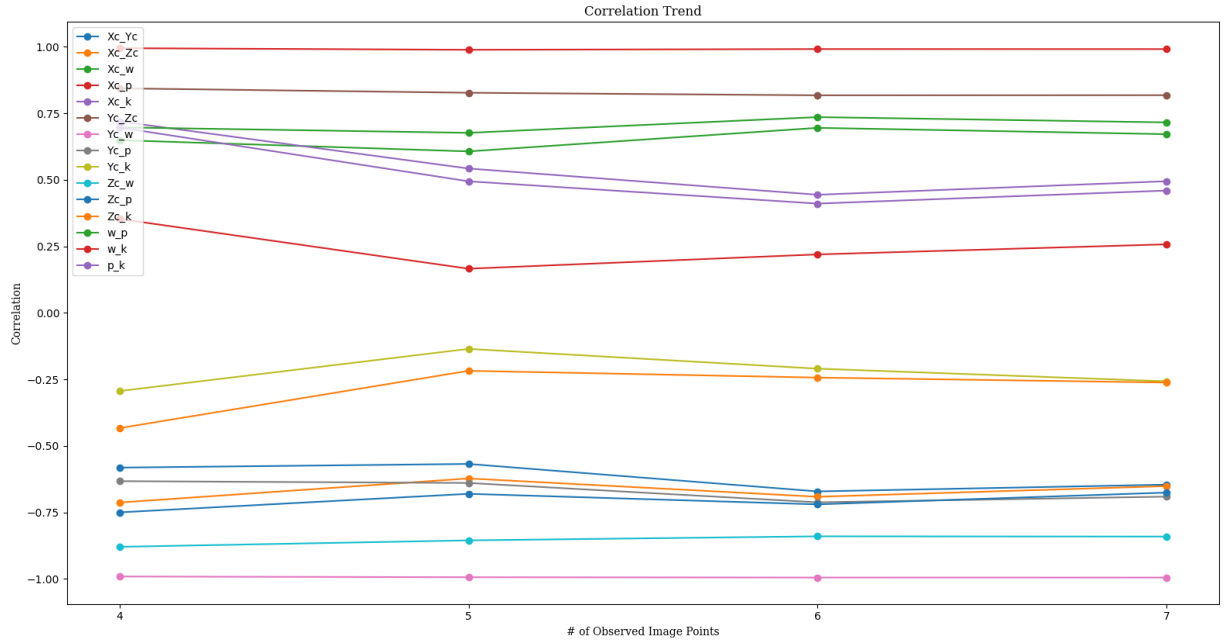
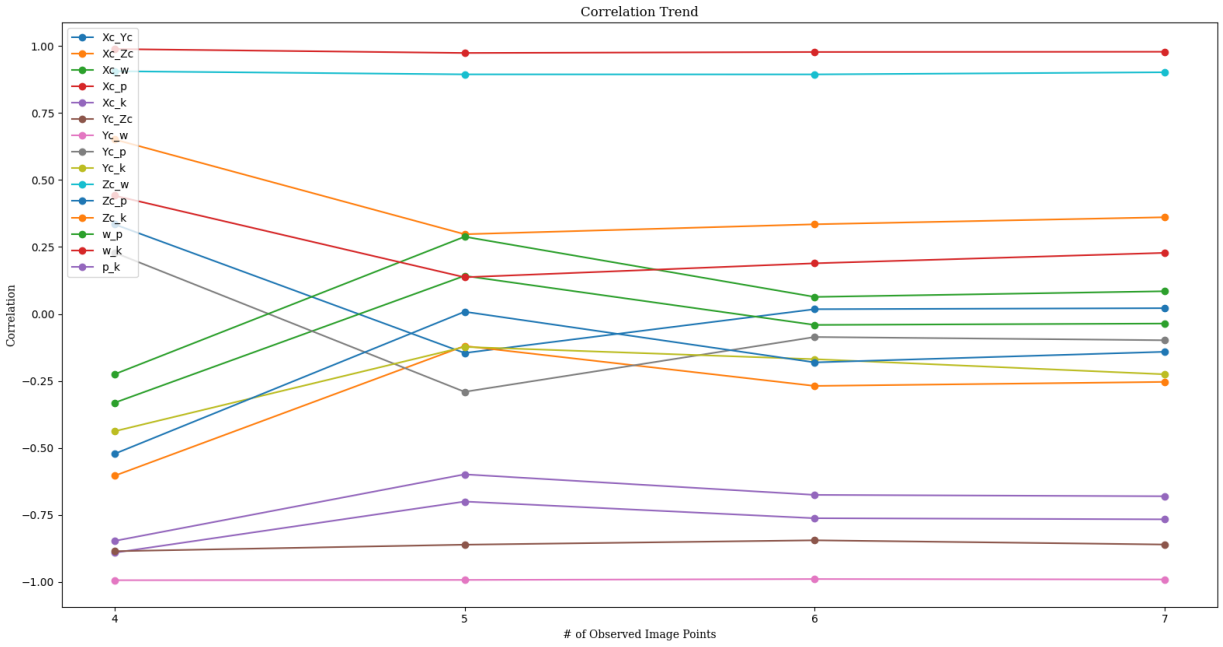


Image 28 Correlation Coefficient Changes:



We expect the correlation for each element to approach 0 as we increase the number of observed points. Correlation closer to 0 means that parameters are less correlated. This can be seen by some of the parameters in Image 28. However, Image 27 did not show this trend as we increased the number of observed points. A different approach is needed to decrease correlation, such as obtaining a more distributed set of image points.

Task 5:

	Lab 4	**Lab 5**
X^C (m)	99.4938	99.2627
Y^C (m)	-628.5518	-628.3256
Z^C (m)	1842.1882	1842.2276
ω (°)	-1.4761	-0.2102
ϕ (°)	-0.1841	1.4609
κ (°)	-90.1956	90.195

Resection uses the collinearity equations to orient a single image via least squares, while absolute orientation requires relative orientation to transform from model space to object space. Relative orientation requires two or more images. Therefore, one of the differences is the required number of images between Resection and Absolute Orientation (Relative Orientation included). Absolute orientation creates more room for error from relative orientation, which can propagate in absolute orientation. As a result, resection is more accurate.