CIVE 6374 – Optical Imaging Metrology
Take Home Final Exam
Due Date: May 4th, 2023 at 1:00 pm – Late Exams Will Not Be Accepted, No Exceptions

Question #1 – 5 points

Consider a block of 8 images. Within the image block, we have 5 control points and 27 tie points observed in the following number of images:

Type of Point(s)	Number of Images Point is Visible In
One 3-D Ground Control Point	3
Two Horizontal Control Points	3
Two Vertical Control Points	2
Fifteen Tie Points	2
Ten Tie Points	3
Two Tie Points	4

a) If the control points are treated as known (constants), then define the total number of observations (n), the number of unknowns (u), and the redundancy (r) of the adjustment.
b) Recompute n, u, and r if we have GPS estimates of the perspective centers at image exposure, and both the GPS PC coordinates and the control points are treated as weighted coordinate parameter observations.

Question #2 – 10 points

Given the following rotation matrix from object space to image space:

$$M = \begin{bmatrix} -0.727438 & -0.041167 & 0.684938 \\ 0.376558 & -0.858411 & 0.348330 \\ 0.573619 & 0.511307 & 0.639943 \end{bmatrix}$$

Compute the values for omega, phi and kappa assuming the following order of rotations:

1. R = R3*R2*R1
2. R = R1*R2*R3
3. R = R3*R1*R2

Give your answers in decimal degrees, to four decimal places.

Question #3 – 15 points

You have been provided with 17 images, acquired of a checkerboard pattern using a Canon Powershot G5 Camera, which is a 5 Megapixel (2592 by 1944 pixels) sensor. The images were acquired with an F-number of 2, and an exposure time of 1/20 of a second. The squares of the checkerboard pattern are exactly 10 cm square.

Use the image calibration module (Camera Calibrator in the Image Processing and Computer Vision Toolbox) provided in MATLAB to estimate camera calibration parameters for the G5.

1. Determine the most appropriate calibration model for the camera from the options available in MATLAB (do NOT use the skew correction). The most appropriate model should be the minimum amount of parameters without sacrificing accuracy. Justify your selection of the final distortion model. Provide the distortion parameters AND their estimated errors. Transform the principal point solution from a digital image to a fiducial coordinate system.
2. Are there any calibration images that appear to be outliers? If so, why do you think those image(s) are causing larger measurement errors? Do the camera calibration parameters estimated change significantly if you remove the outlier image(s)? Justify why you would characterize the change in parameters as significant/not significant (Hint: the significance level may be different for different distortion parameters).
3. The Matlab calibration model returns two values for the focal length. Briefly discuss why two values are returned, and how these would be used in the collinearity equations (this may require some literature review).

Question #4 – 20 points

The following image measurements and control point coordinates are given for a three image photogrammetry problem. Assume that the image measurements are w.r.t. the camera principal point, and that these are corrected image measurements (i.e. distortion, principal point offset already removed). All measurements are given in mm. The calibrated camera focal length is 152.015 mm, and the estimated accuracy of the image measurements is +/- 7 µm.

Point #	Image 1		Image2		Image 3	
101	-82.78126	77.04770			107.78893	-64.53038
102	-84.33568	-76.42112			106.33940	53.17603
103			61.37025	-66.66664	-70.89541	41.60770
104			31.84041	85.47374	-54.16113	-71.34199
201	-67.78223	10.06956			94.71953	-11.80857
202			29.80099	-14.83694	-50.27644	3.69505
203	59.99241	2.85763	-40.30439	-3.37658	0.54230	-5.61244
204	26.38874	103.20207	-68.24677	93.05171	22.68632	-80.83538

205	92.61486	85.94785	-11.21862	75.57427	-22.49678	-64.45849
206	43.45145	-102.05791	-50.62780	-105.32096	10.91377	68.25076
207	90.59823	-85.27867	-10.25437	-87.03436	-19.96999	55.00498

Using a bundle adjustment, derive exterior orientation parameters for each of the cameras and estimate ground coordinates for the pass points. Compute estimated accuracy for both EOPs and pass point coordinates. To initialize your bundle adjustment, use the following initial approximates for the EOPs and pass point coordinates.

Approximate EOPs (given in meters and degrees)

Image	X	Y	Z	ω	ϕ	κ
1	700	735	1250	0	0	45
2	1100	1175	1250	0	0	45
3	900	950	1625	0	0	-135

Approximate Pass Point Coordinates (given in meters)

Pass Point ID	X	Y	Z
201	235	430	235
202	1250	1260	255
203	875	995	270
204	243	1335	230
205	645	1505	280
206	1295	440	200
207	1395	740	245

Ground points 101 to 104 are control points. Their coordinates are given in the table below (in meters). Assume that the control point coordinates are errorless.

Control Point ID	X	Y	Z
101	-186.47	682.53	226.80
102	577.27	-48.43	247.90
103	1659.17	1160.29	208.00
104	798.76	1760.02	256.40

Note: If you can find an open source (or other) software tool to run the above bundle adjustment, then you do not have to program it yourself. However, if you cannot, a solution using your own code in MATLAB or Python is acceptable.

Additional Questions:

1. Are any of the image measurements outliers? If yes, rerun the adjustment with those image observation(s) removed. Does it make a difference in the final solution?
2. Is the estimated accuracy given for the image measurements correct? Based on the adjustment results, is the actual image measurement accuracy lower or higher? Justify your answer.
3. The estimated standard deviation for the final coordinates of one of the pass points is significantly higher than the others. Which point is it? Why do you think the estimated accuracy of this point is worse that the others?

<u>Submit</u>

- Hard copy of code and answers to all of the above questions. No softcopy submission required. If you do not get to a final solution, please document and submit all of the steps you have undertaken. I will give partial credit for partial solutions to question #4.