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Airborne Data Acquisition

Lab 1 Image Orientation – Spatial Resection

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0. Main Task

Learn how to use ApplicationsMaster to complete interior orientation and exterior orientation from this lab, which is stated clearly from the manual book. And then analyze and compare the results in three different versions by choosing different control points.

1. Block set-up/interior orientation

1.1 Create Project

Start the ApplicationsMaster and create a new project. Click File/New File and choose Frame project.

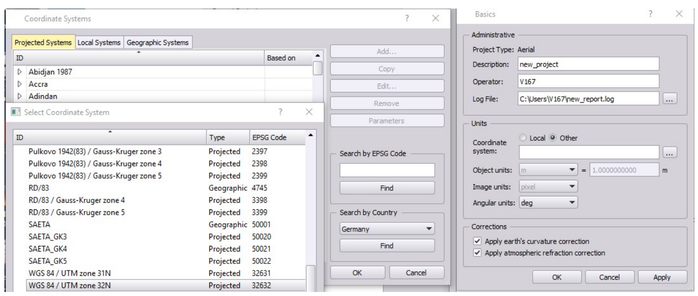

Figure 1. Create new project

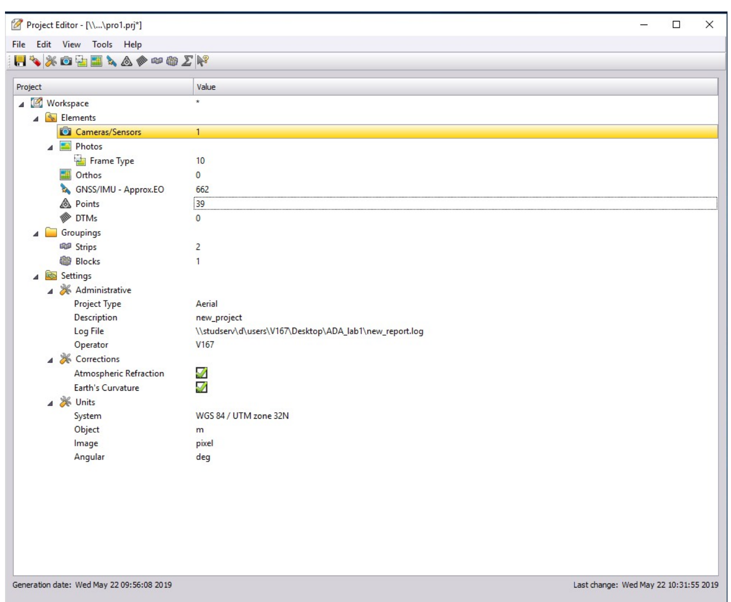

Figure 2. Overview of our project

1.2 Add Camera

Double click on “Camera/Sensors” and we can define Camera ID as “VaihingenTest2008”. The Camera ID is used to be identify the camera, if more than one camera is in use. Select sensor type as “CCD Frame” and brand as “DigCAM_50_50mm” due to the camera description, and other parameters.

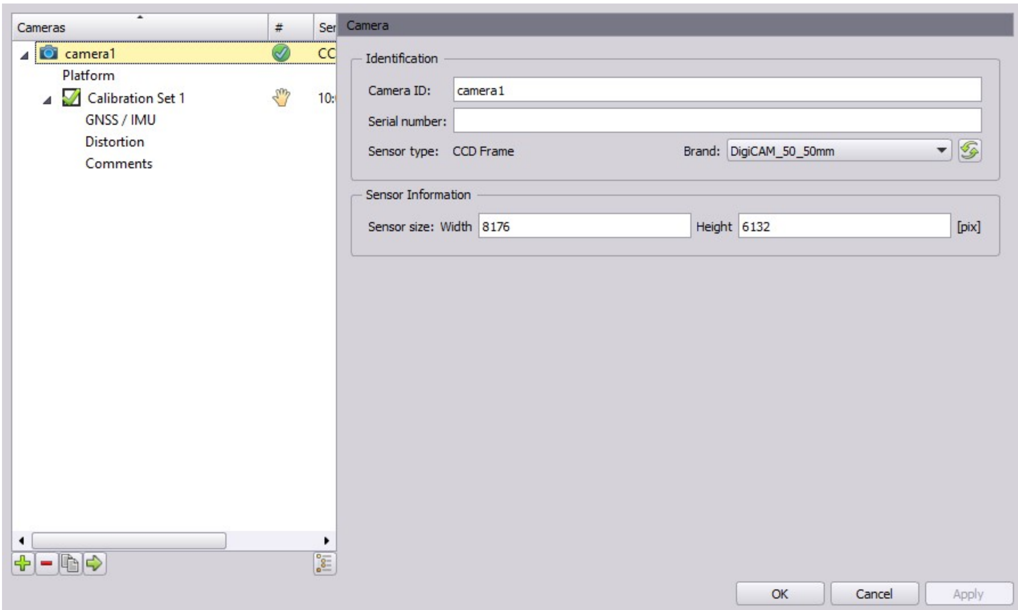

Figure 3. Camera set

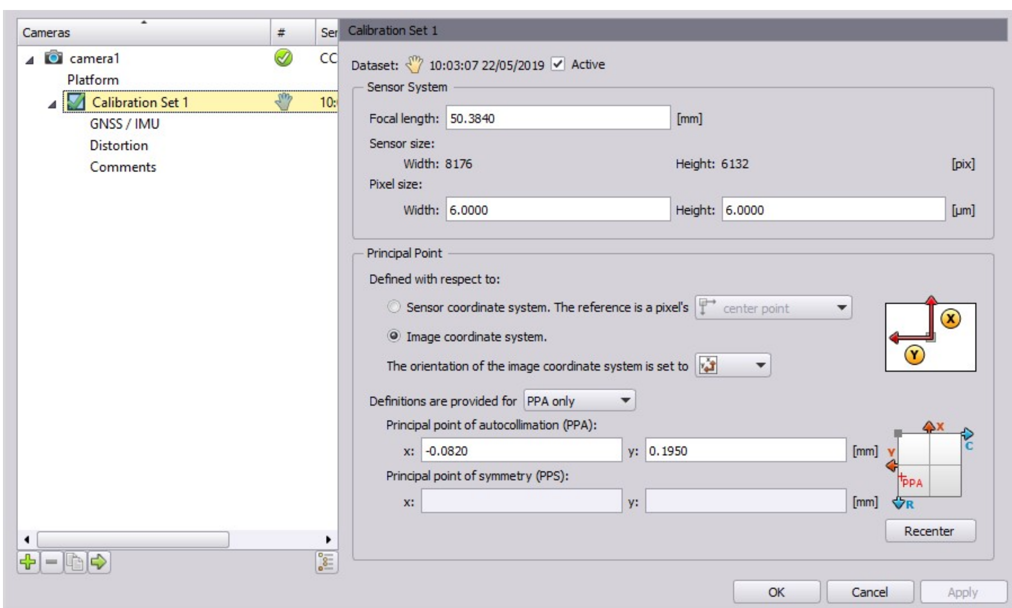

Figure 4. Camera parameters

We also adjusted the parameters in GNSS/IMU and Distortion menu, in order to complete the whole parameters setting.

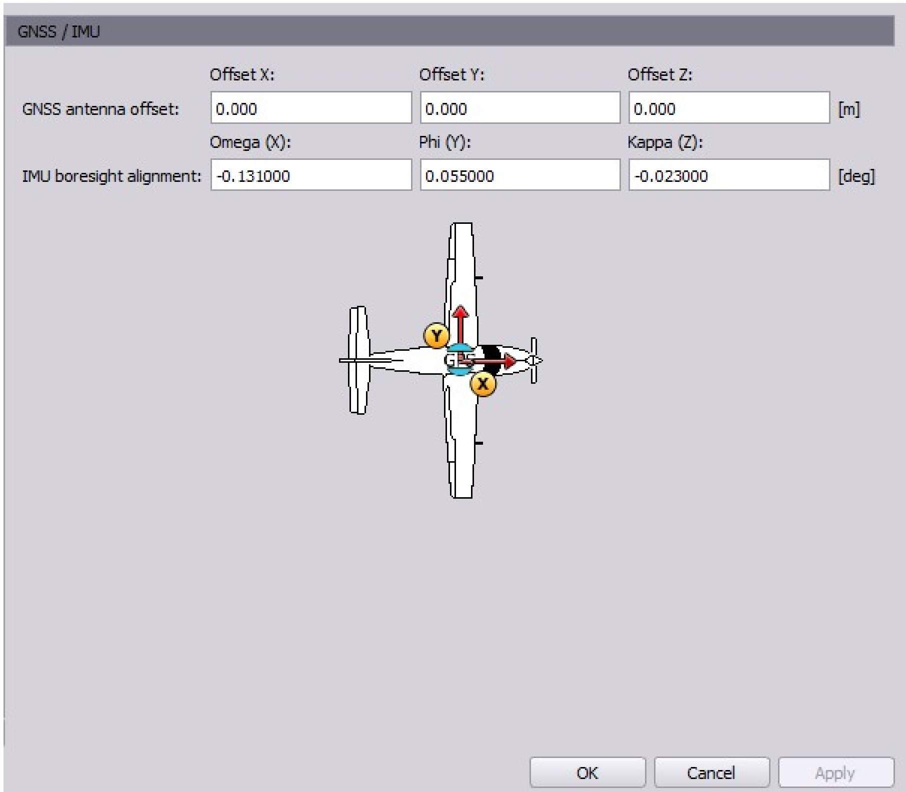

Figure 5. GNSS/IMU setting

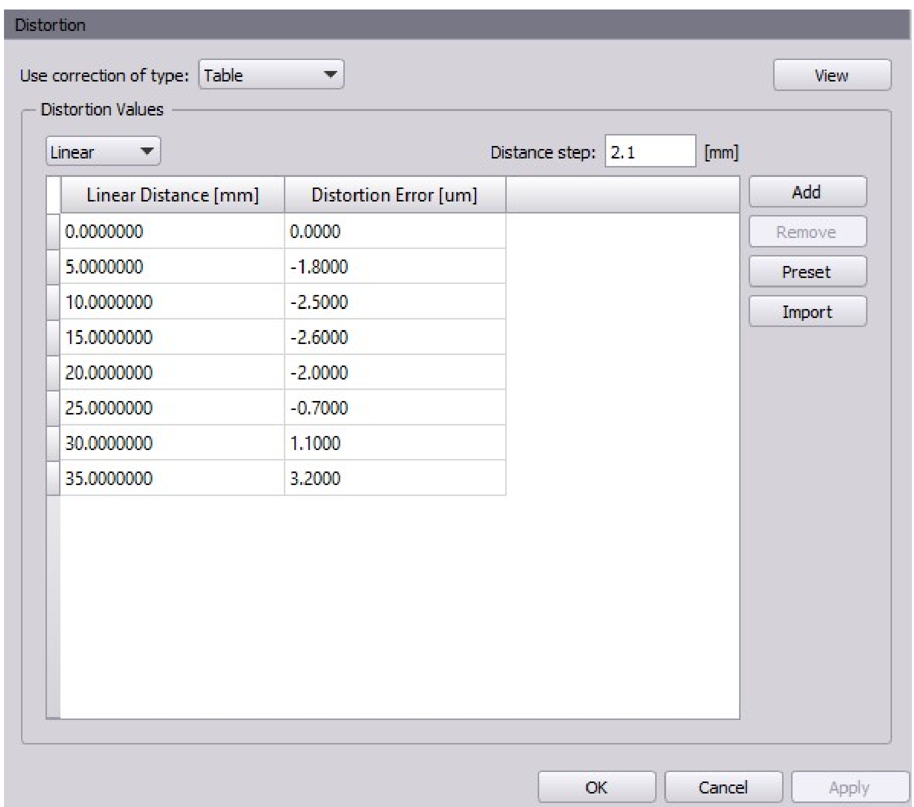

Figure 6. Distortion setting

1.3 Import Image

Next step is import the image. This part is crucial and the most likely where mistakes happens. Since we need match every image with the GNSS points insight, we need to change the ID of every image, which means we remove the prefix of every image and just save with the last three numbers. As we chose the images from 199-203 and 244-248, we import them and set the terrain height to the mean value.

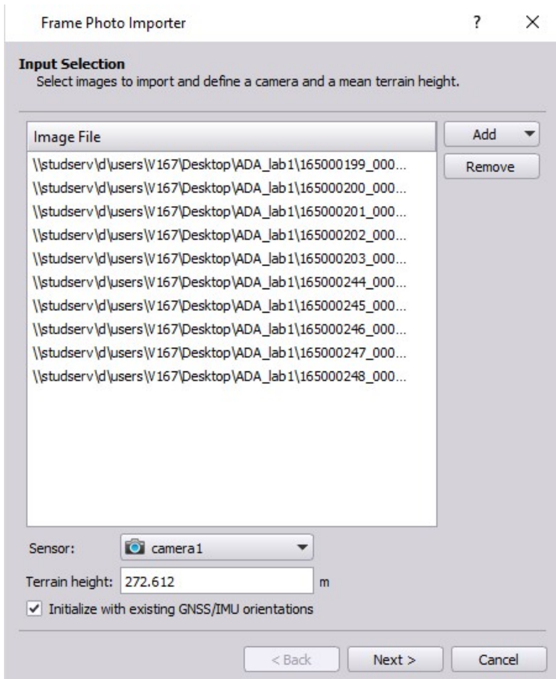

Figure 7. Set terrain height

At ID setting part, we separate the ID from the file names.

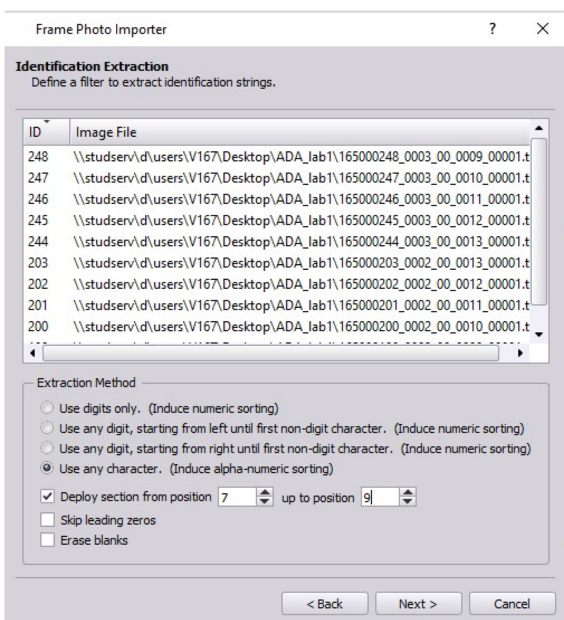

Figure 8. ID set

After press next button several times we finish this import part.

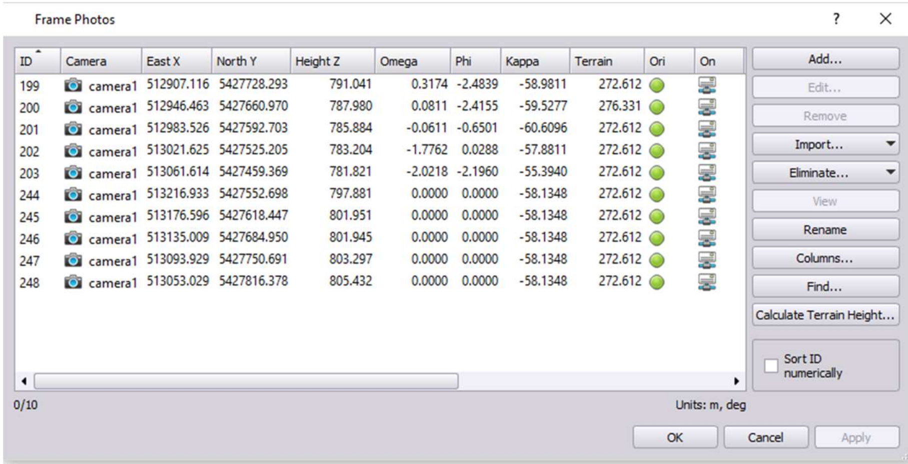

Figure 9. Import completed

1.4 Import GNSS/IMU Data

Select Points in the Project Editor, choose Import, find the GPS file, then we begin to load the GNSS/IMU EO data. After that, assign the columns to their right intent.

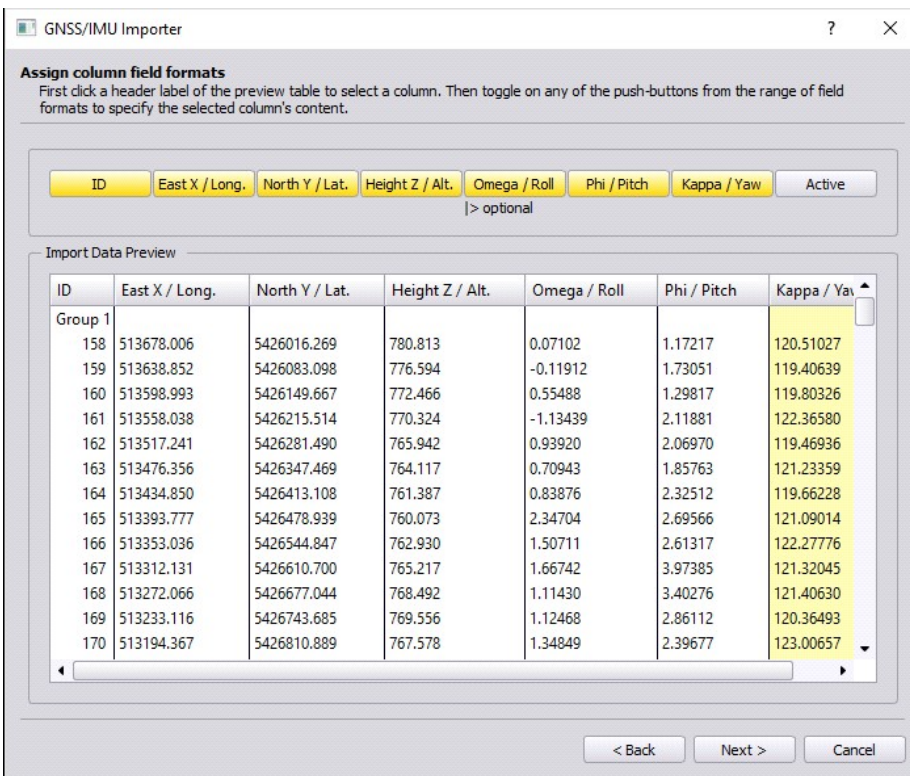

Figure 10. Set columns

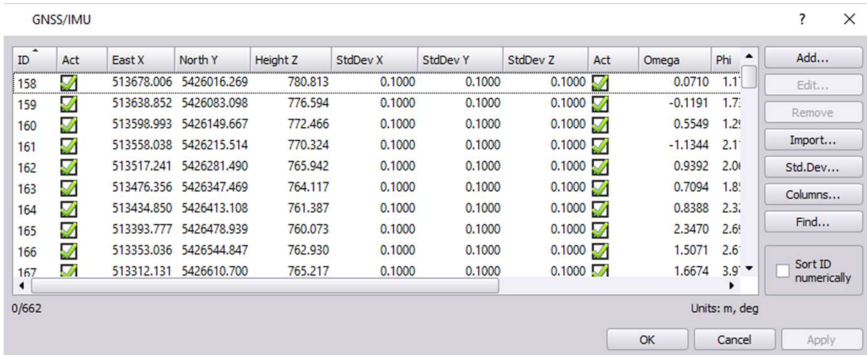

Figure 11. GNSS/IMU set

1.5 Import Control points

Select Points to import control points and set their stds.

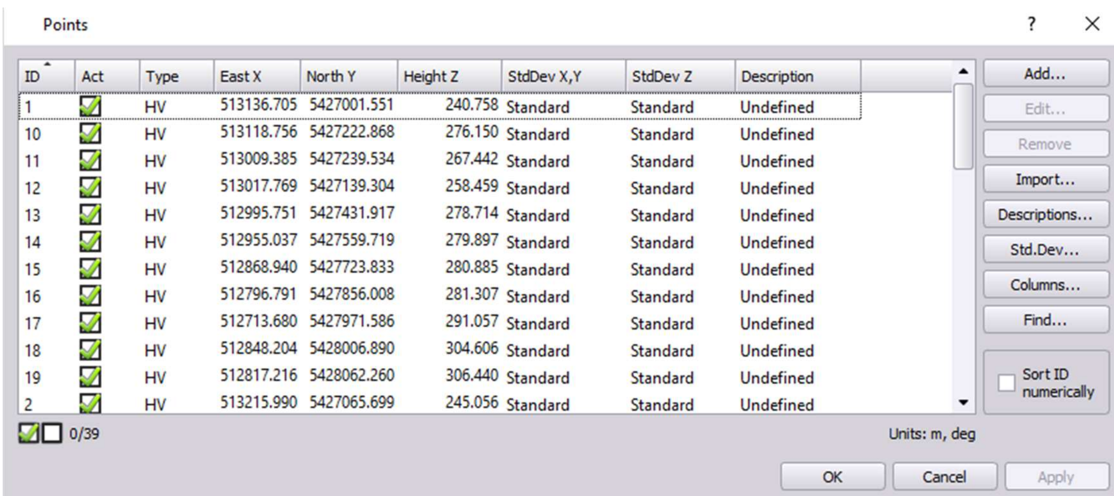

Fig 12. Control Points

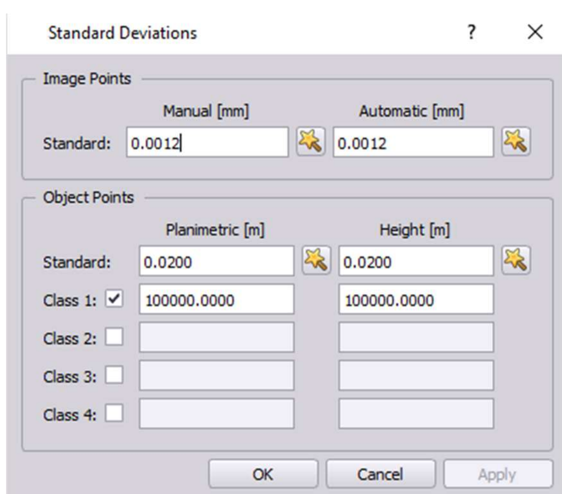

Fig 13. STD

1.6 Create Strips

Since we got all the data, but we have to set the relation between images and flight strips. Open the project file to create strips. These strips should contain the right images in correct flight direction. Set the crab angle to zero. We select 244-248 as Strip 1 and 199-203 as Strip 2.

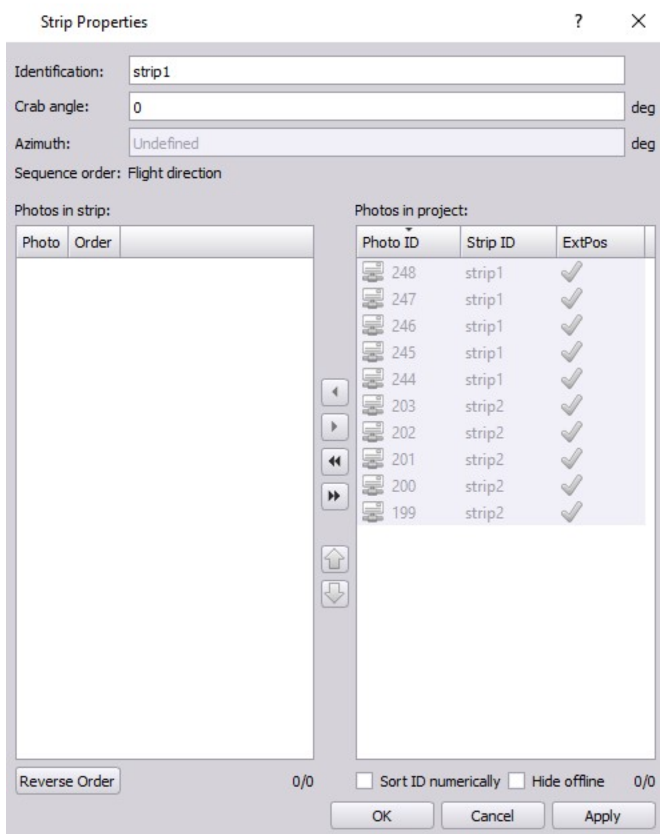

Figure 14. Strips

1.7 Create Blocks

Strips bring all the images in the same flight together, then we need block to bring the whole images together.

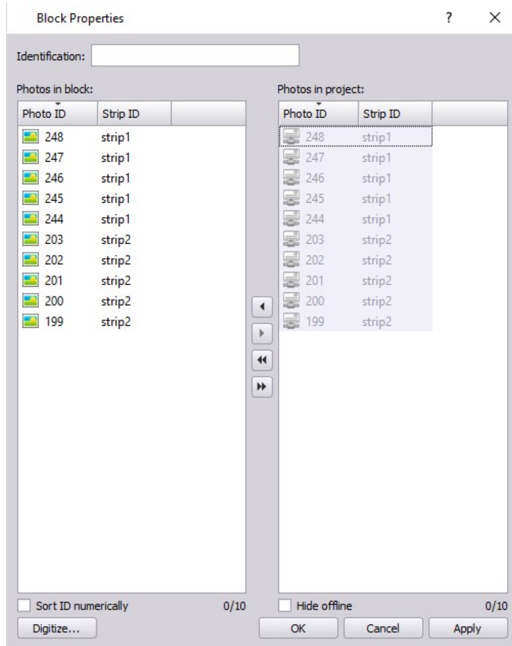

Figure 15. Block

Finally, we get all the data and relations we need, then just one click for all process to get the interior orientation.

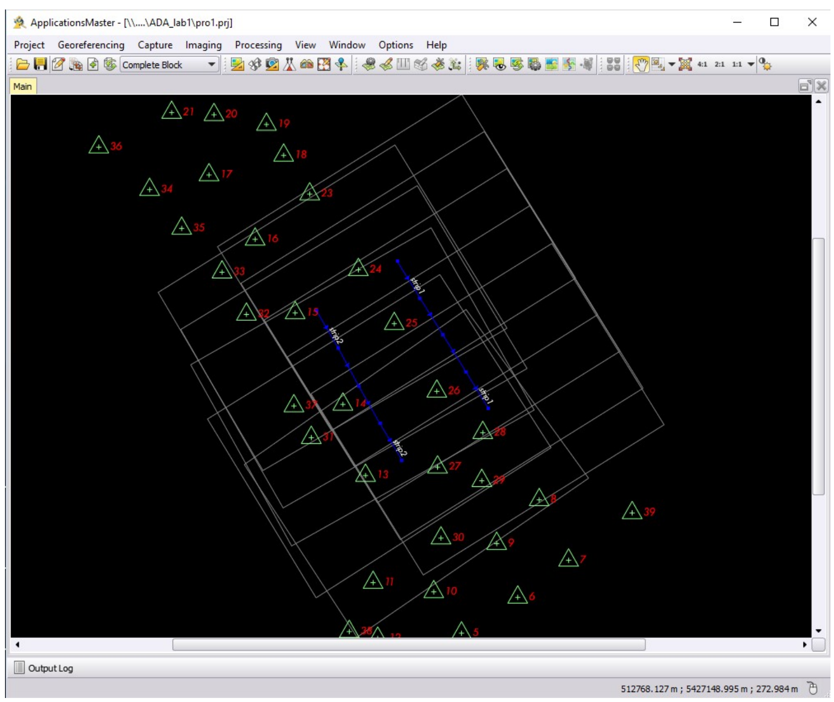

Figure 16. Project created

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Question: How is the interior orientation defined for the DigiCAM camera?

The interior orientation is to transform from the pixel coordinates system to the image coordinates system, we need to conduct translation along x direction tx, translation along y direction ty, as well as scaling m.

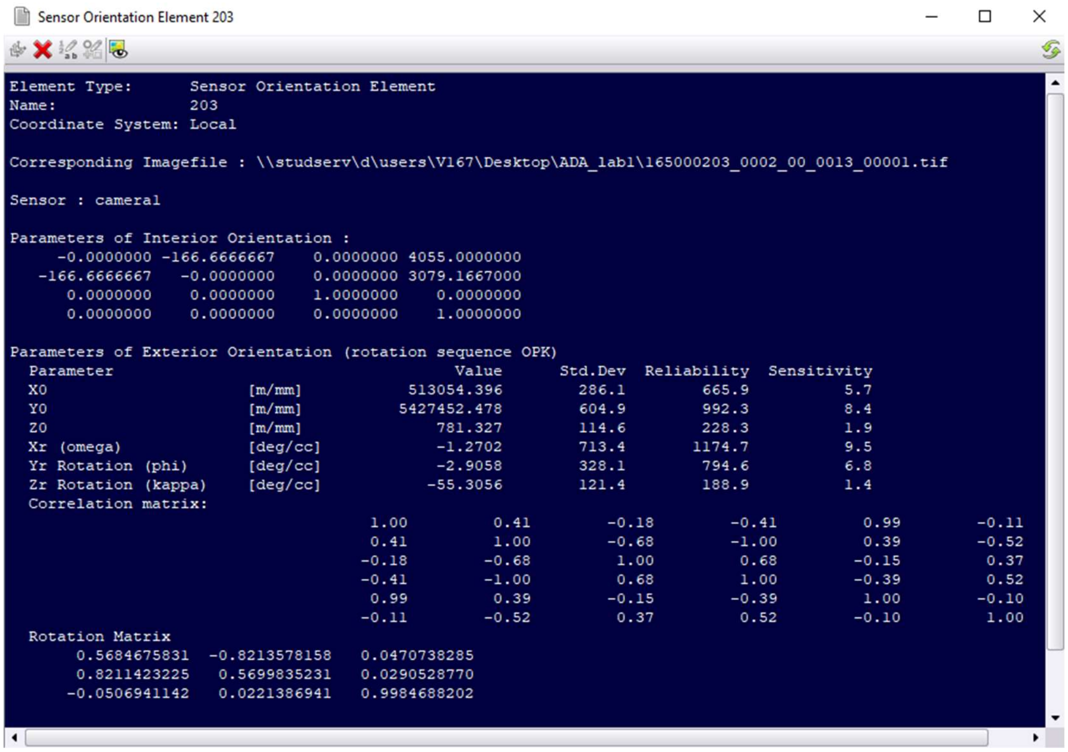

Figure 17. Interior orientation

In this matrix, the translations are the entries of the last column as we can see

$$t_x = 4055.0000$$
$$t_y = 3079.1667$$

The size of the pixel is 6mm, so the scaling factor m is calculated as below:

$$\mathrm{m} = \frac{1}{6mm} = 1.667$$

Multiply the factor into the rotation matrix, we can obtain:

$$\begin{pmatrix} -0 & -166.666667 & 0 \\ -166.666667 & -0 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

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2. Spatial resection

The exterior orientation is orientating one image to meet the object coordinate. The exterior orientation demands that the interior orientation is already done.

Click the button and choose 203 as our orientating image, which contains enough control points. Then we can choose control points from 3D Point Observations window, see the image and the points we chosen from Zoom Window.

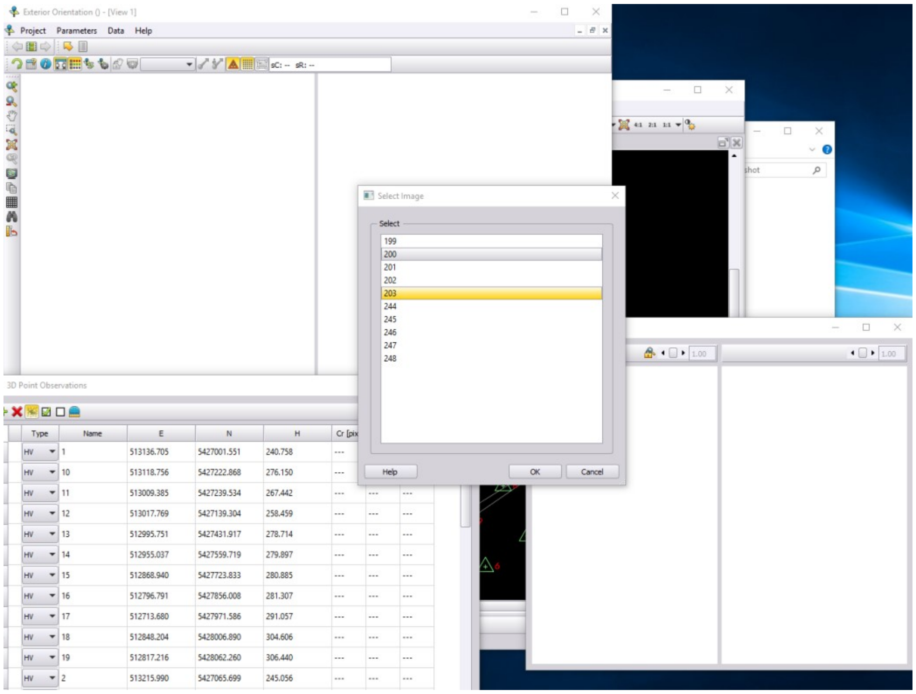
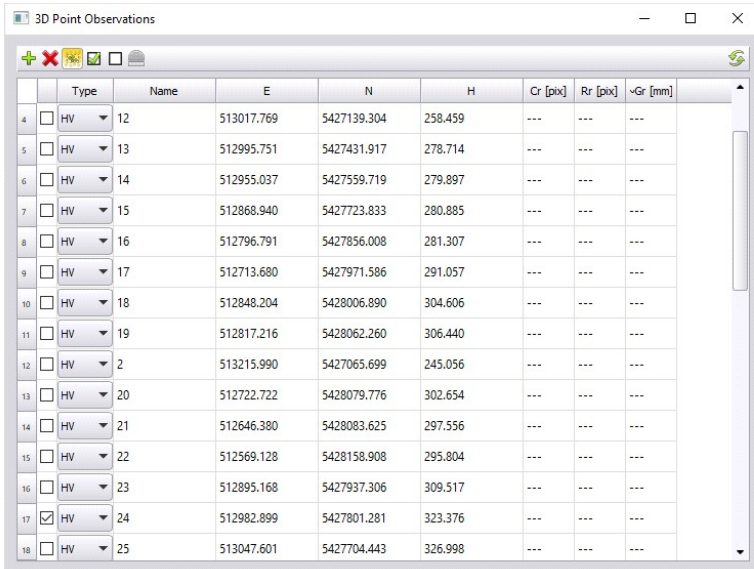


Figure 18. Overview

Figure 19. Main window



3D Point Observations

		Type	Name	E	N	H	Cr [pix]	Rr [pix]	√Gr [mm]
4	☐	HV	12	513017.769	5427139.304	258.459	---	---	---
5	☐	HV	13	512995.751	5427431.917	278.714	---	---	---
6	☐	HV	14	512955.037	5427559.719	279.897	---	---	---
7	☐	HV	15	512868.940	5427723.833	280.885	---	---	---
8	☐	HV	16	512796.791	5427856.008	281.307	---	---	---
9	☐	HV	17	512713.680	5427971.586	291.057	---	---	---
10	☐	HV	18	512848.204	5428006.890	304.606	---	---	---
11	☐	HV	19	512817.216	5428062.260	306.440	---	---	---
12	☐	HV	2	513215.990	5427065.699	245.056	---	---	---
13	☐	HV	20	512722.722	5428079.776	302.654	---	---	---
14	☐	HV	21	512646.380	5428083.625	297.556	---	---	---
15	☐	HV	22	512569.128	5428158.908	295.804	---	---	---
16	☐	HV	23	512895.168	5427937.306	309.517	---	---	---
17	☑	HV	24	512982.899	5427801.281	323.376	---	---	---
18	☐	HV	25	513047.601	5427704.443	326.998	---	---	---

Figure 20. 3D Points observation window

As we operate after the tutorial, we learned how to pick points and calculate the residuals of the exterior orientation.

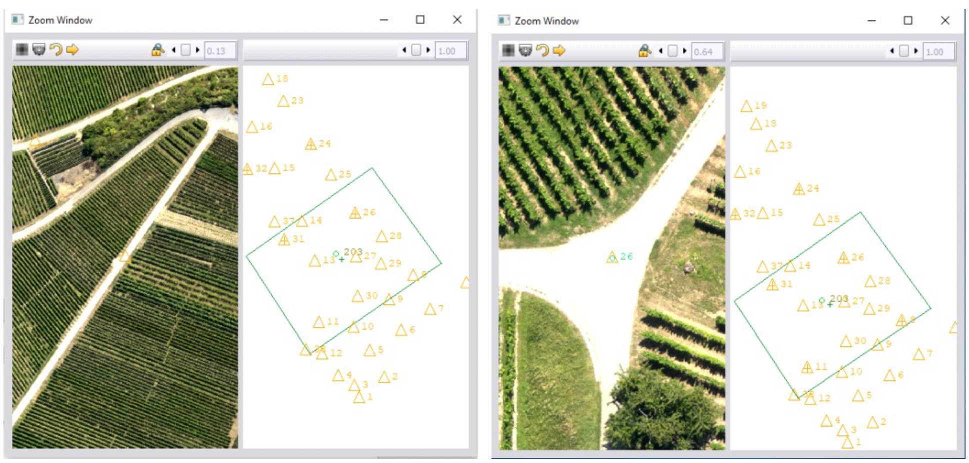
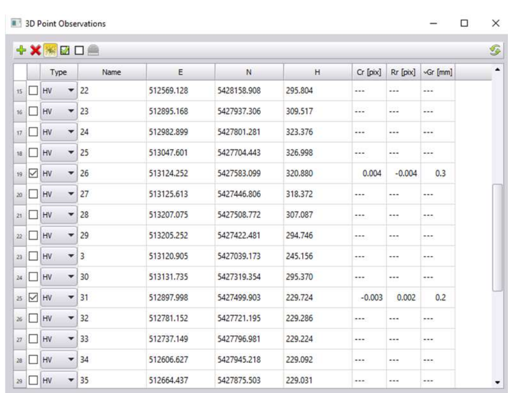


Figure 21. Pick points and show



3D Point Observations

		Type	Name	E	N	H	Cr [pix]	Rr [pix]	√Gr [mm]
15	☐	HV	22	512569.128	5428158.908	295.804	---	---	---
16	☐	HV	23	512895.168	5427937.306	309.517	---	---	---
17	☐	HV	24	512982.899	5427801.281	323.376	---	---	---
18	☐	HV	25	513047.601	5427704.443	326.998	---	---	---
19	☑	HV	26	513124.252	5427583.099	320.880	0.004	-0.004	0.3
20	☐	HV	27	513125.613	5427446.806	318.372	---	---	---
21	☐	HV	28	513207.075	5427508.772	307.087	---	---	---
22	☐	HV	29	513205.252	5427422.481	294.746	---	---	---
23	☐	HV	3	513120.905	5427039.173	245.156	---	---	---
24	☐	HV	30	513131.735	5427319.354	295.370	---	---	---
25	☑	HV	31	512897.998	5427499.903	229.724	-0.003	0.002	0.2
26	☐	HV	32	512781.152	5427721.195	229.286	---	---	---
27	☐	HV	33	512737.149	5427796.981	229.224	---	---	---
28	☐	HV	34	512606.627	5427945.218	229.092	---	---	---
29	☐	HV	35	512664.437	5427875.503	229.031	---	---	---

Figure 22. Points' details

2.1 Point selection: Version 1

The first time we choose 4 optimal points which are separated equally in the whole image.

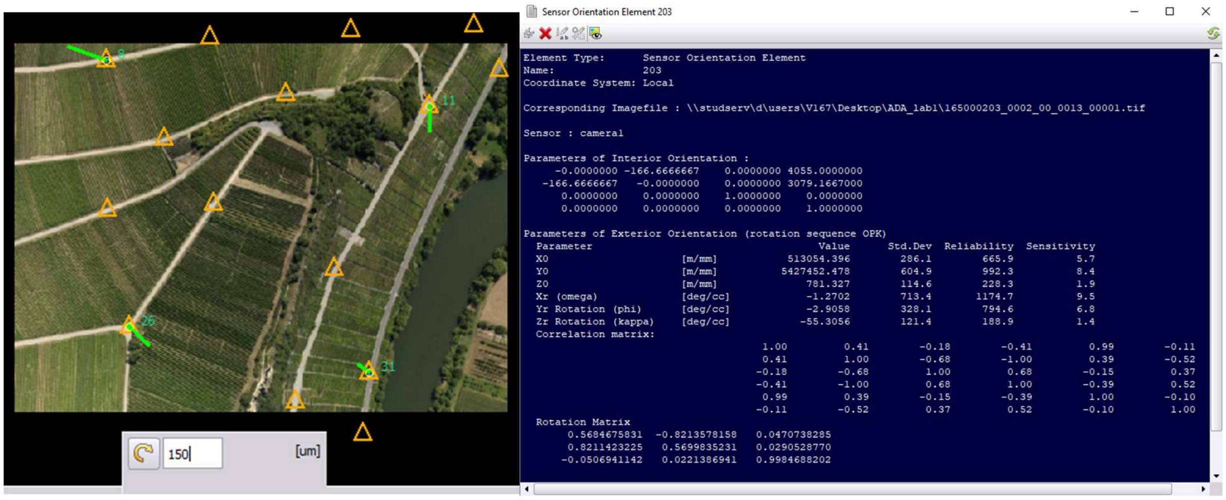


Figure 23. Version 1

1). The number of control points(max.) available in the image: 4

2). Max. redundancy: 2

2.2 Point selection: Version 2

This time we choose 4 points that are relatively near.

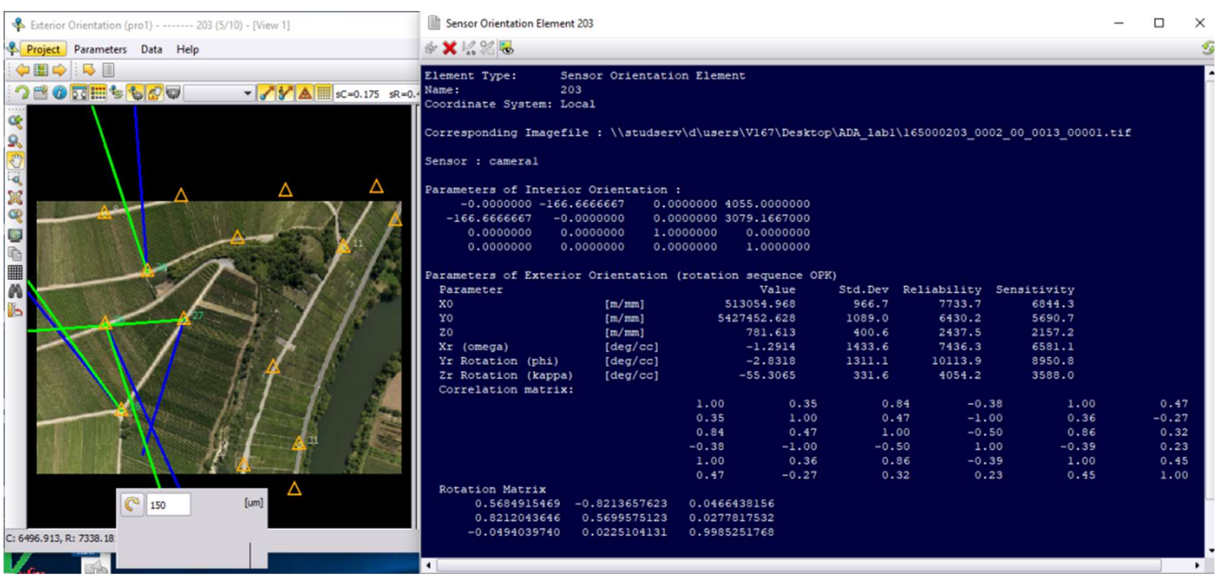


Figure 24. Version 2

1). The number of control points(max.) available in the image: 4

2). Max. redundancy: 2

2.3 Point selection: Version 3

The last time we choose all the points in the image.

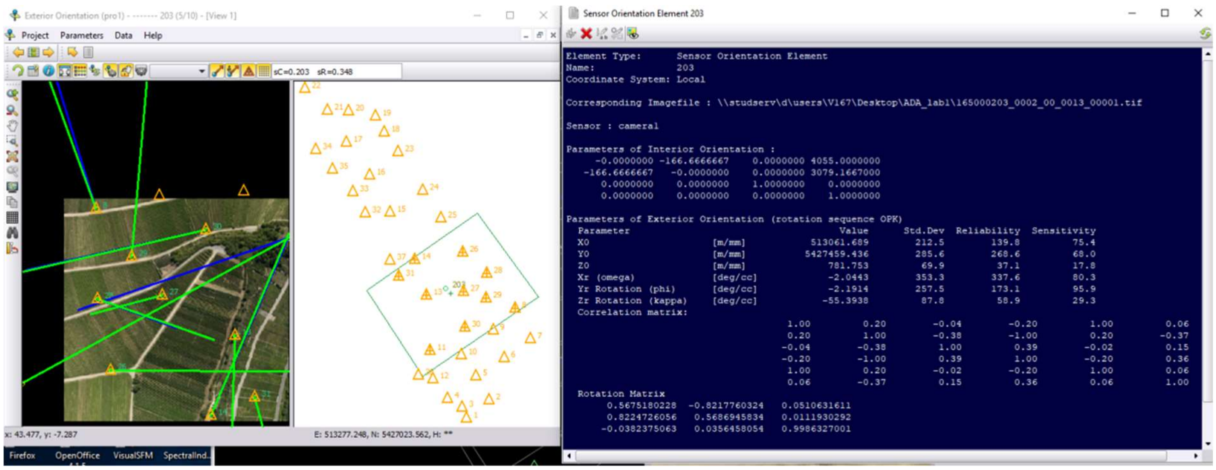


Figure 25. Version 3

1). The number of control points(max.) available in the image: 10

2). Max. redundancy: 14

3. Analysis

1) 10 control points are available for our image. Therefore the max redundancy is 14. The redundancy for the 4GCP case is 2. 3/3

2) As we can see in the images, the visualization of the residuals is shown by the blue and green line, which is largely due to the visibility of the points. The first version has the smallest residual because of the good quality of the 4 optimal points. The version 2 has a bigger residual than version 1 because the observed points don't correspond very well to pre-set control points. The residual of version 3 is also big because all control points are taken into consideration and if only several points are badly observed, the total residual would grow. 6/6

3) As for the variations of the EO parameters, we can use the version 3 as reference, and calculate the differences between version 1 and version 2. The result shows below:

Table 1. Data and differences

	Version 1	Version 2	Version 3	Version 3 - 2	Version 3 - 1
X0	513054.396	513061.689	513054.968	-6.721	0.572
Y0	5427452.478	5427459.436	5427452.628	-6.808	0.149999999
Z0	781.327	781.753	781.613	-0.14	0.286
Omega	-1.2702	-2.0443	-1.2914	0.7529	-0.0212
Phi	-2.9058	-2.1914	-2.8318	-0.6404	0.074
Kappa	-55.3056	-55.3938	-55.3065	0.0873	-0.0009

Table 2. Standard Deviations

	X0	Y0	Z0	Omega	Phi	Kappa
Version 1	286.1	604.9	114.6	713.4	328.1	121.4
Version 2	966.7	1089.0	400.6	1433.6	1311.1	331.6
Version 3	212.5	285.6	69.9	353.3	257.5	87.8

From these sheets we can tell the second version has bigger difference and variation than the first version in many terms, which means version 2 is less reliable. In this image, the Y0 has the biggest variation compared to X0 and Z0, and so does Omega compared to Phi and Kappa.

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4) Compare those three versions, we found out Version 3 has the highest accuracy among three versions since Version 3 contains the most amounts of control points. Version 1 is more precise than Version 2 although they have the same number of control points. It is of the reason that control points in Version 1 are more well-distributed compare to those in Version 2.

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5) From figure 26 we can see there are several big rates in the matrix. The diagonal values are all 1, which means every parameter is fully correlated to itself. X0 is highly correlated with Phi (Y-rotation), Y0 is highly correlated with Omega (X-rotation), and Z0 does not have a high correlation with any other parameter. This can be explained by the collinearity equation, which is shown as Fig 27.

1.00	0.20	-0.04	-0.20	1.00	0.06
0.20	1.00	-0.38	-1.00	0.20	-0.37
-0.04	-0.38	1.00	0.39	-0.02	0.15
-0.20	-1.00	0.39	1.00	-0.20	0.36
1.00	0.20	-0.02	-0.20	1.00	0.06
0.06	-0.37	0.15	0.36	0.06	1.00

Fig 26. Correlation Matrix of EO

$$\frac{1}{\lambda}\begin{bmatrix} X_A - X_S \\ Y_A - Y_S \\ Z_A - Z_S \end{bmatrix} = \begin{bmatrix} \cos\varphi & 0 & -\sin\varphi \\ 0 & 1 & 0 \\ \sin\varphi & 0 & \cos\varphi \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\omega & -\sin\omega \\ 0 & \sin\omega & \cos\omega \end{bmatrix} \begin{bmatrix} \cos\kappa & -\sin\kappa & 0 \\ \sin\kappa & \cos\kappa & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ -f \end{bmatrix}$$

Fig 27. Collinearity equation

From the collinearity equation, assuming the rotation angles are very small, we can estimate the line-elements of exterior orientation as:

$$X_S = X_A - \lambda(x - y\kappa + f\varphi)$$
$$Y_S = Y_A - \lambda(x\kappa + y + f\omega)$$
$$Z_S = Z_A - \lambda(x\varphi + y\omega - f)$$

X_A, Y_A, Z_A are coordinates of the measured point; λ is the scale factor; x, y, f are interior orientation elements. They are all constants and x, y are very small in this case (thus ‘yk’ and ‘xk’ can be neglected). Therefore, Xs has an almost linear relationship with φ; Ys has an almost linear relationship with ω; Zs has no strong relationship with any other parameters.