GEOG 892: Geospatial Applications for Unmanned Aerial System (UAS)

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Processing UAS Data Using Pix4D Software – Exercise 2

The County Line Road - Dayton, Ohio

Date Description:

The dataset for this exercise was provided by Woolpert, Inc. **. The imagery was flown over a section of the County Line road in Dayton, Ohio. The actual platform was Woolpert's UAS-surrogate called the "Renaissance" system. The Renaissance payload is similar to their UAS payload and is flown on board a small manned aircraft (Cessna 182). They fly such platform whenever the project requires flying over non-participants people on the ground. The dataset contains the following items:

1) 150 JPEG files.
2) Coordinates values for 9 Ground Control Points in NAD83 (2007), Ohio State Plane Coordinates System – South Zone, in US Survey foot and Elevations are provided in NAVD88, Geoid 12A (File name: County_Road_Control_points.xlsx).
3) Coordinates values for 8 Check Points in NAD83 (2007), Ohio State Plane Coordinates System – South Zone, in US Survey foot and Elevations are provided in NAVD88, Geoid 12A (File name: County_Road_Check_points.xlsx).
4) Screen shots for the locations of the ground control and check points.
5) Airborne GPS coordinates values for the photo center for each aerial image in NAD83 (2007), Ohio State Plane Coordinates System – South Zone, in US Survey foot and Elevations are provided in NAVD88, Geoid 12A (File name: County_Line_ABGPS.xlsx).
6) NIKON D800E camera Users' Manual.

The mission was flown with NIKON D800E camera with 85mm lens from an altitude of about 1100 ft. AGL resulted in imagery with a ground resolution of about 2 cm. The following table lists the NIKON D800E specifications:

NIKON D800E	Single-lens reflex digital camera
Image Size (pixels)	7,360 × 4,912
Sensor Size (mm)	35.9 × 24.0
CCD Size (micron)	4.87777

Focal Length (mm)	85.00

Software Requirements:

You will need the following three software to complete the assignment, please contact your program administrator to help you with installing the first two software:

1. Microsoft Excel for the accuracy analysis
2. ArcGIS with Spatial Analyst license to enables you to create contours
3. Pix4D, you will get a limited time education license through the class

Assignment Tasks:

1) Down load the dataset from the PENN State Box folder under the following link: https://psu.box.com/s/v07k57uqp8mi0uj0adbej5n9u1k140jm
2) You need to create a new project in Pix4D following the instruction you used for the WireGrass exercise. Include your name in your project name such as CountyRoad_YourLastName
3) Import the imagery. Change the coordinate system using File→image properties manager. During import, set the following options:
    a. Change the coordinate system during import to NAD83(NSRS2007)/Ohio South (ftUS);
    b. Use the “Advanced” option to setup the “geoid height above GRS 1980 ellipsoid” to “0.0”, see Figure 1.
    c. Unlike exercise 1, the wiregrass dataset, where the GPS-derived camera position is impeded into the header of the jpeg file, the imagery for this exercise does not have impeded camera position or photo center. Here you will practice importing GPS-derived camera position or image center from a file. Import the file “EOs_NAD83_2011_NAVD88_Pix4d.txt”. Remember to remove the first 6 header lines before import. You will need to click on “From file” of the “image Geolocation” in the “Image Properties” interface.

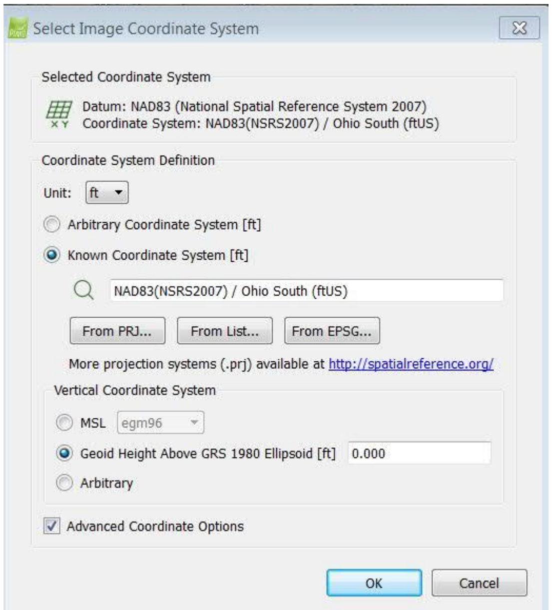

Figure 1 Selecting image coordinates system

4) Import the ground control points coordinates using File→GCP/MTP manager. During import, set the following options:
   a. Change the coordinate system during import to NAD83(NSRS2007)/Ohio South (ftUS);
   b. Use the "Advanced" option to setup the "geoid height above GRS 1980 ellipsoid" to "0.0", see Figure 2.
   c. Change the type of the 8 check-points type from "3D GCP" to "check point", see Figure 3.

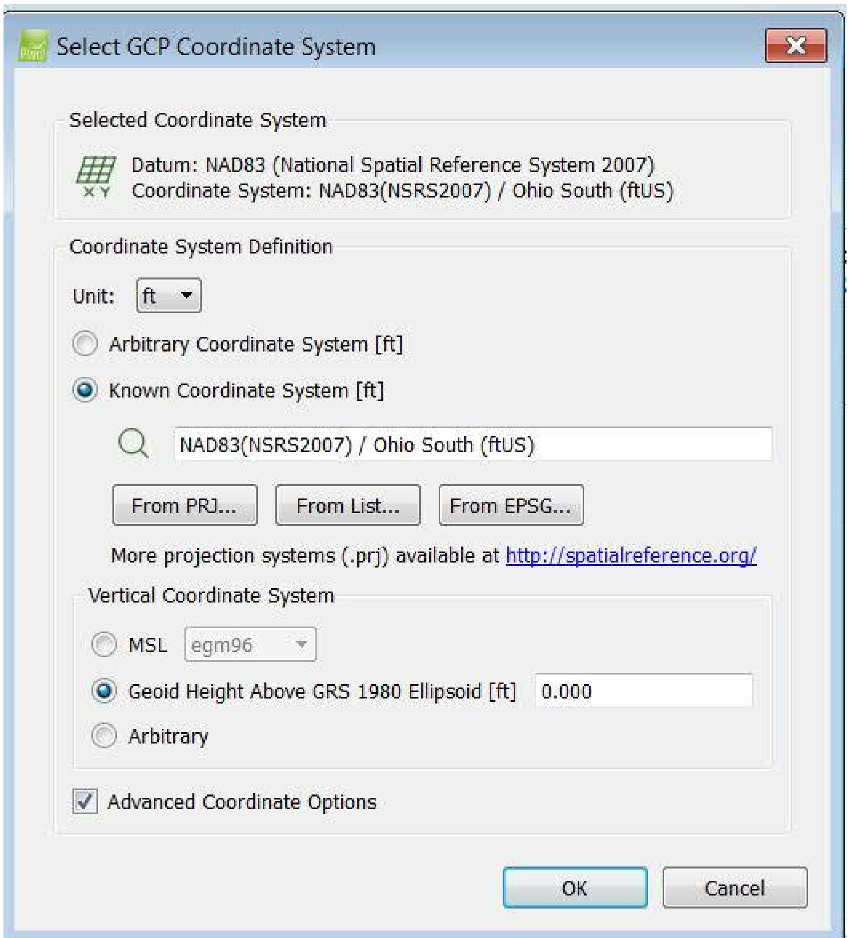

Figure 2 Selecting GCP coordinate system

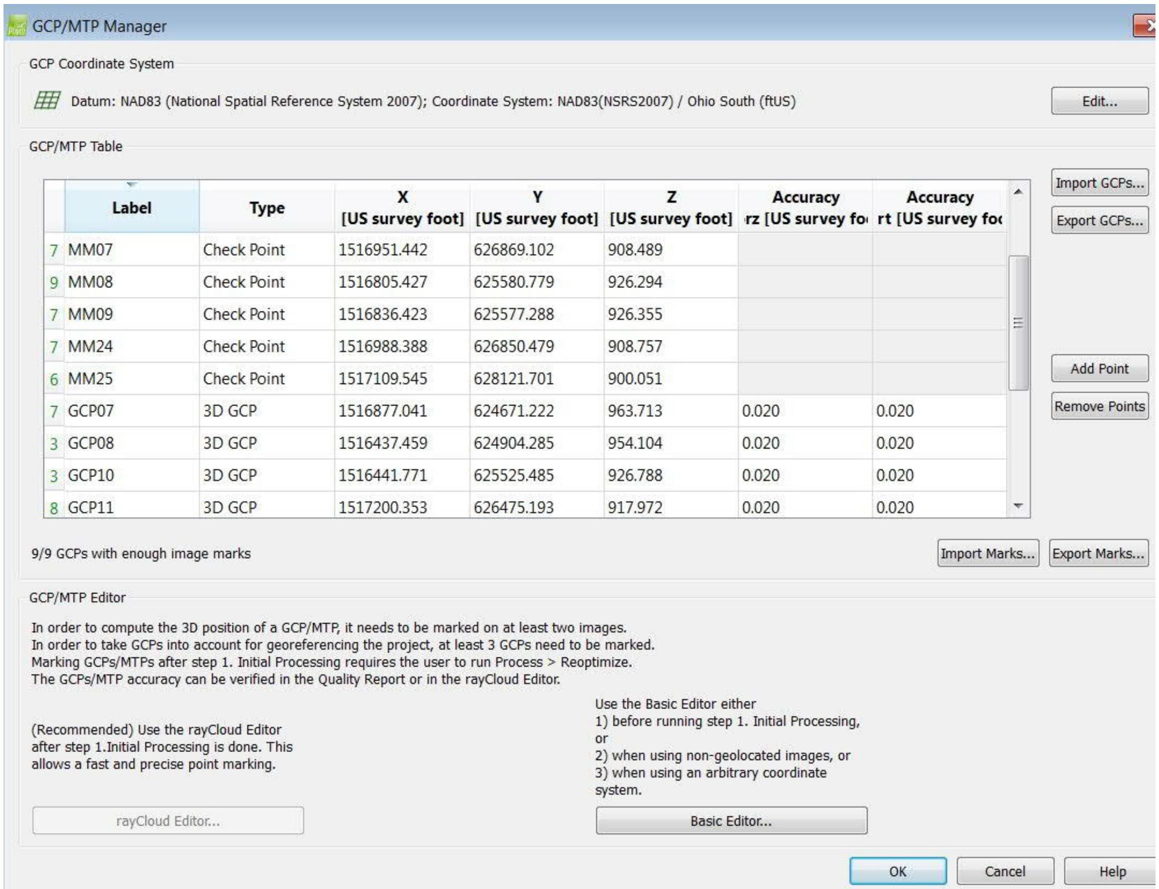

Figure 3 Assigning point type

5) Run local processing -> Initial Processing -> Rapid check only, toggle "Point Cloud Densification" and "DSM and Orthomosaic Generation" off;
6) Measure the 9 ground control points and the 8 check points using File -> GCP/Manual Tie Point Manager -> Basic Editor. Use the photo pics to figure out the exact location for each of the 9 GCPs and the 8 check-points. Figure 4 illustrate the approximate locations of these points.

Figure 4 Ground control and check points layout

7) Use the “processing options” tab in the lower left of the interface to setup the value of the pixel resolution to 2.0 [cm/pixel] which is within the tab ”DSM and Orthomosaic Index”, see Figure 5.
8) In addition, choose the two options sequentially to create DTM as it is illustrated in Figures 6 and 7. DTM in Pix4D terminology is a bare-earth surface model created from the DSM after it is cleaned out from buildings, trees, cares, and any above ground features. DTM is the product you need to generate the contours from. Contours should

represent the topography of the ground and not features above the ground. The DTM, once it is produced, can be found in the following folder:
\your_project_name\3_dsm_ortho\extras\dtm
The DTM will be created in raster TIFF format.

9) Once you finished measuring all ground control points and check-points, run again local processing -> Initial Processing but select "Full Processing" this time and toggle on the two processing steps: "Point Cloud Densification" and "DSM and Orthomosaic Generation". This step will create the following:
   a. Ortho mosaic located in the folder: \ProjectName\3_dsm_ortho\ 2_mosaic
   b. Digital Surface Model (DSM) located in the folder: \ProjectName\3_dsm_ortho\ 1_dsm
   c. A processing report, save it as a pdf file;

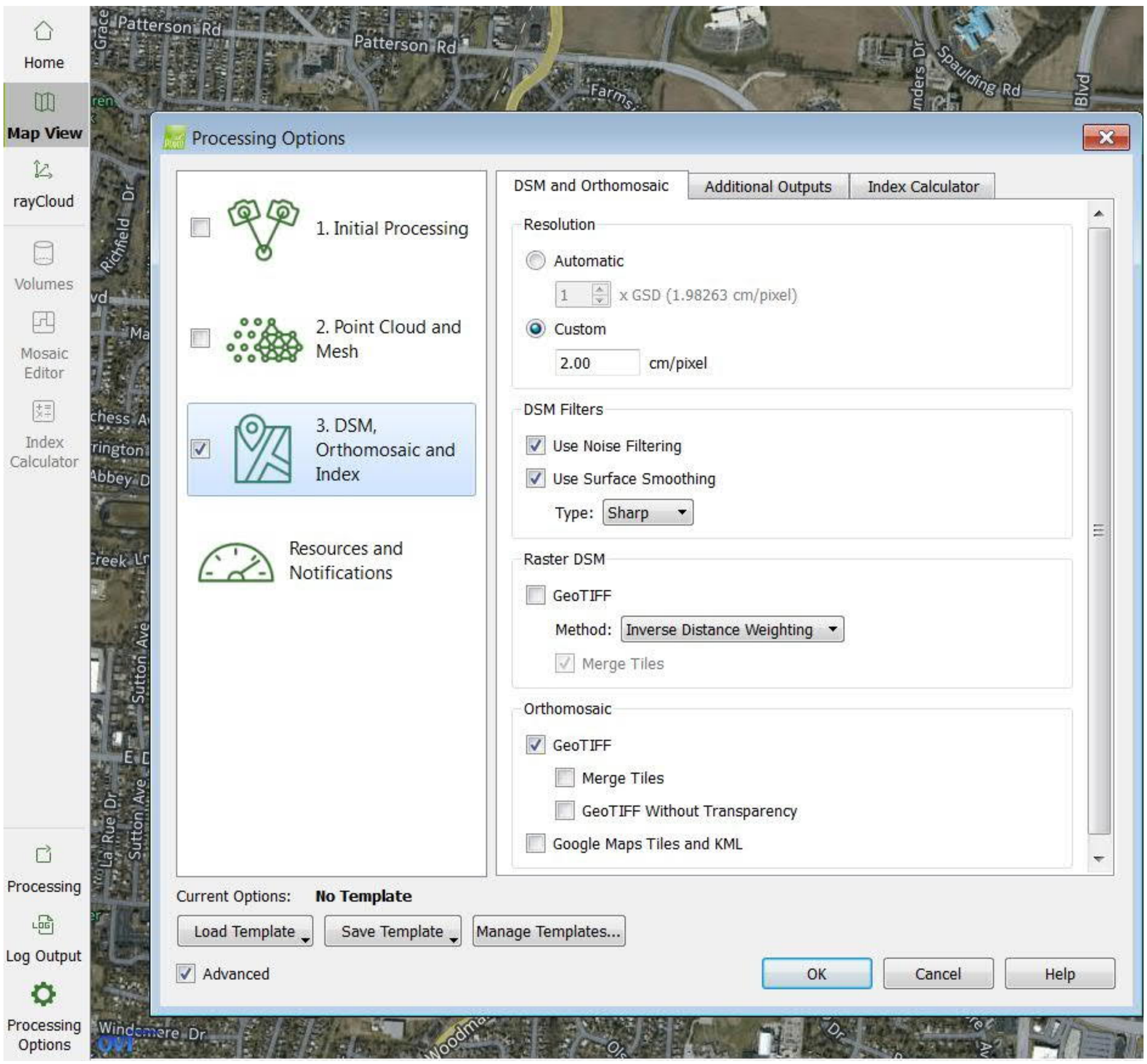

Figure 5 Orthomosaic setup

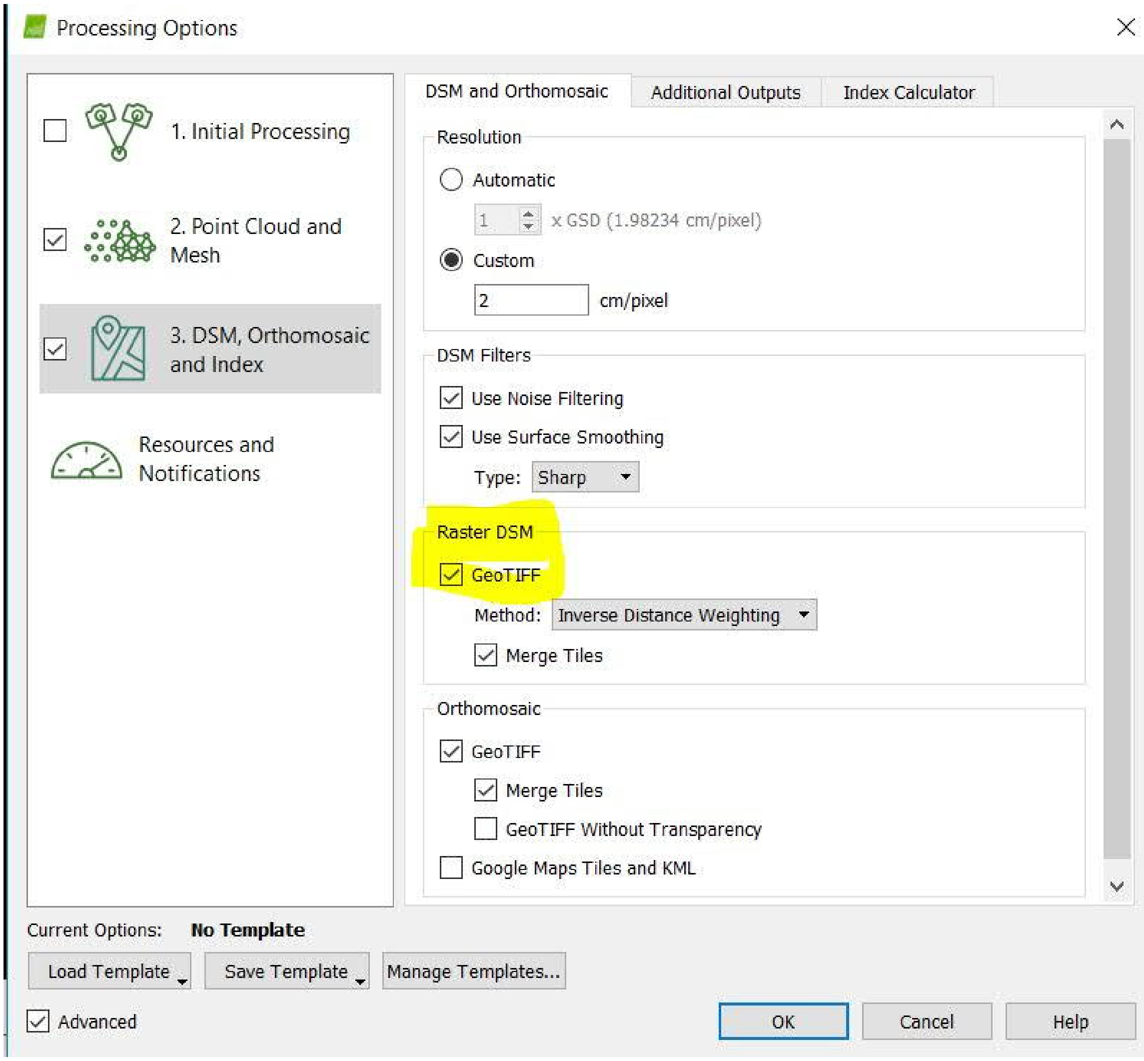

Figure 6 DTM setup in the “DSM and orthomosaic” tab

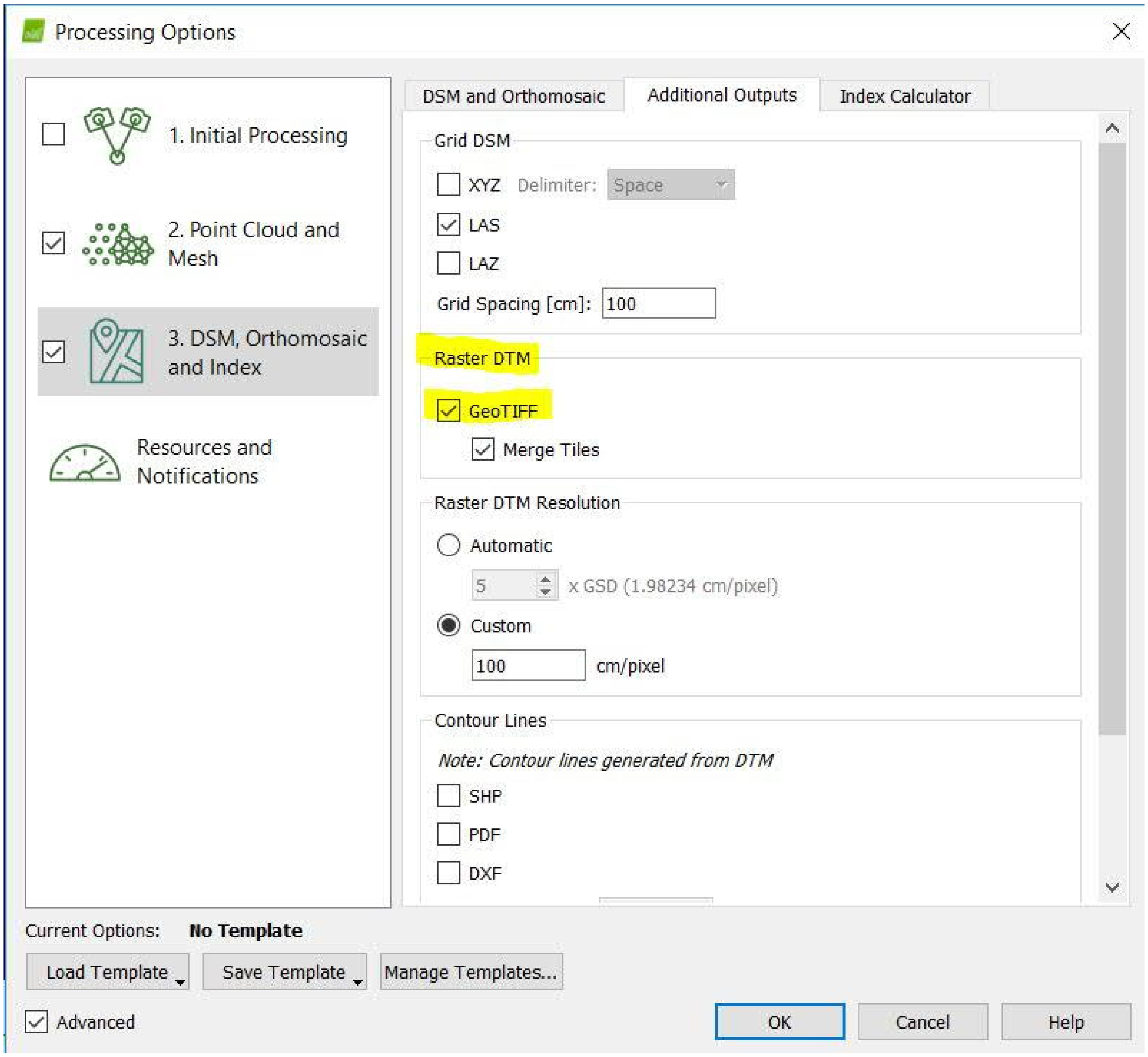

Figure 7 DTM setup in the "additional outputs" tab

10) Review the finished ortho mosaic, DTM, the DSM, and the quality report and check any anomalies presented in the products or reported in the final report;
11) Before submitting your processing report. please review the following few sections of the report to make sure that your processing was successful:
    a. Quality Check section: Make sure that "Dataset" row says: "150 out of 150 images calibrated (100%), all images enabled". If it doesn't, then you have some of the imagery were not utilized in the solution. Also the "Georeferencing" row has the statement: "9 GCPs (9 3D)". If it doesn't, then you have some of the GCPs were not utilized in the solution. (see figure 8)

Quality Check

Images	median of 9505 keypoints per image
Dataset	150 out of 150 images calibrated (100%), all images enabled
Camera Optimization	2.54% relative difference between initial and optimized internal camera parameters
Matching	median of 5314.54 matches per calibrated image
Georeferencing	yes, 9 GCPs (9 3D), mean RMS error = 0.046 US survey foot

Preview

Figure 8 Quality Report Section of the report

Geolocation Details

Ground Control Points

GCP Name	Accuracy XY/Z [US survey foot]	Error X [US survey foot]	Error Y [US survey foot]	Error Z [US survey foot]	Projection Error [pixel]	Verified/Marked
GCP07 (3D)	0.020/ 0.020	-0.002	0.002	-0.022	0.407	7 / 7
GCP08 (3D)	0.020/ 0.020	0.046	-0.024	0.360	0.406	3 / 3
GCP10 (3D)	0.020/ 0.020	0.025	0.001	0.122	0.130	3 / 3
GCP11 (3D)	0.020/ 0.020	-0.008	-0.001	0.021	0.538	8 / 8
GCP12 (3D)	0.020/ 0.020	0.022	-0.005	0.083	0.009	3 / 3
GCP13 (3D)	0.020/ 0.020	-0.022	0.004	0.087	0.530	7 / 7
GCP14 (3D)	0.020/ 0.020	0.029	-0.006	0.202	0.077	3 / 3
GCP16 (3D)	0.020/ 0.020	0.013	0.001	0.058	0.047	3 / 3
GCP17 (3D)	0.020/ 0.020	-0.003	0.003	0.015	0.305	8 / 8
Mean [US survey foot]		0.010969	-0.002773	0.102942		
Sigma [US survey foot]		0.020191	0.008111	0.110119		
RMS Error [US survey foot]		0.022978	0.008572	0.150743		

Figure 9 Ground Control Points Errors

0 out of 8 check points have been labeled as inaccurate.

Check Point Name	Accuracy XY/Z [US survey foot]	Error X [US survey foot]	Error Y [US survey foot]	Error Z [US survey foot]	Projection Error [pixel]	Verified/Marked
MM08	0.0200/0.0200	0.0430	-0.1354	-0.1623	0.2279	9 / 9
MM09	0.0200/0.0200	-0.0226	-0.0424	-0.2210	0.2617	7 / 7
MM24	0.0200/0.0200	0.0137	-0.0453	0.1201	0.2714	7 / 7
MM25	0.0200/0.0200	0.0788	0.0294	0.5804	0.1768	6 / 6
MM04	0.0200/0.0200	0.0709	-0.0395	0.2720	0.2095	7 / 7
MM05	0.0200/0.0200	0.1028	-0.0159	0.2884	0.1711	6 / 6
MM06	0.0200/0.0200	0.0123	-0.0341	-0.1449	0.2042	8 / 8
MM07	0.0200/0.0200	0.1535	-0.0681	0.1971	0.2349	7 / 7
Mean [US survey foot]		0.056567	-0.043909	0.116237		
Sigma [US survey foot]		0.053000	0.043638	0.258708		
RMS Error [US survey foot]		0.077517	0.061905	0.283621		

Localisation accuracy per GCP and mean errors in the three coordinate directions. The last column counts the number of calibrated images where the GCP has been automatically verified vs. manually marked.

Figure 10 Check points Errors

b. Preview section: Make sure that ortho mosaic and the DSM look normal as in Figure 8.
c. Geo Locations Details – Ground Control Points section: Make sure that all values for the Error X [ft.], Error Y [ft.], Error Z [ft.] are under 0.2 ft. or so. Your "RMS Errors" should range from 0.01 to 0.2 ft. Larger values are indicative of bad pointing during measurements. If so, try to zoom in as much as you can

before you accept the measurement, see Figure 9. In addition, make sure that you have a table that lists the “check points” residuals right after the table in Figure 9, see Figure 10. The residuals of the check points in Figure 10 should be more or less similar to the residuals of the control points of Figure 9.

12) Value Added Products Development:

a. Planimetric Map: Create a planimetric map like the one given in Figure 11 by following the following instructions:

Import the ortho mosaic tiles generated in the folder \ProjectName\3_dsm_ortho\2_mosaic into ArcMap and compile the following features for the County line road and all roads connected to it into a shape file:

i. Road edges;
ii. Road centerlines;
iii. Sidewalks edges;
iv. All utilities along the roads such as manholes, catch basins, valve covers, light poles, etc. Create attributes in features table and give each utility feature the proper name.
v. Name the shape file “YourLastName_CountyRoad_map.shp”
vi. Make sure that you include all files that support a shape file such as the one listed below for a shape file called “MMS_GCPs”:

MMS_GCPs.cpg
MMS_GCPs.csv
MMS_GCPs.dbf
MMS_GCPs.prj
MMS_GCPs.sbn
MMS_GCPs.sbx
MMS_GCPs.shp
MMS_GCPs.shx

P.S.: If you do your map compilation in ArcGIS, you need to provide two shape files one for the line-type features, i.e. road edges and center lines and one for the point-type features such as utilities. Make sure that your lines follow accurately the edges of the roads and sidewalks and the round corners of the road-to-road turns should be smoothly followed.

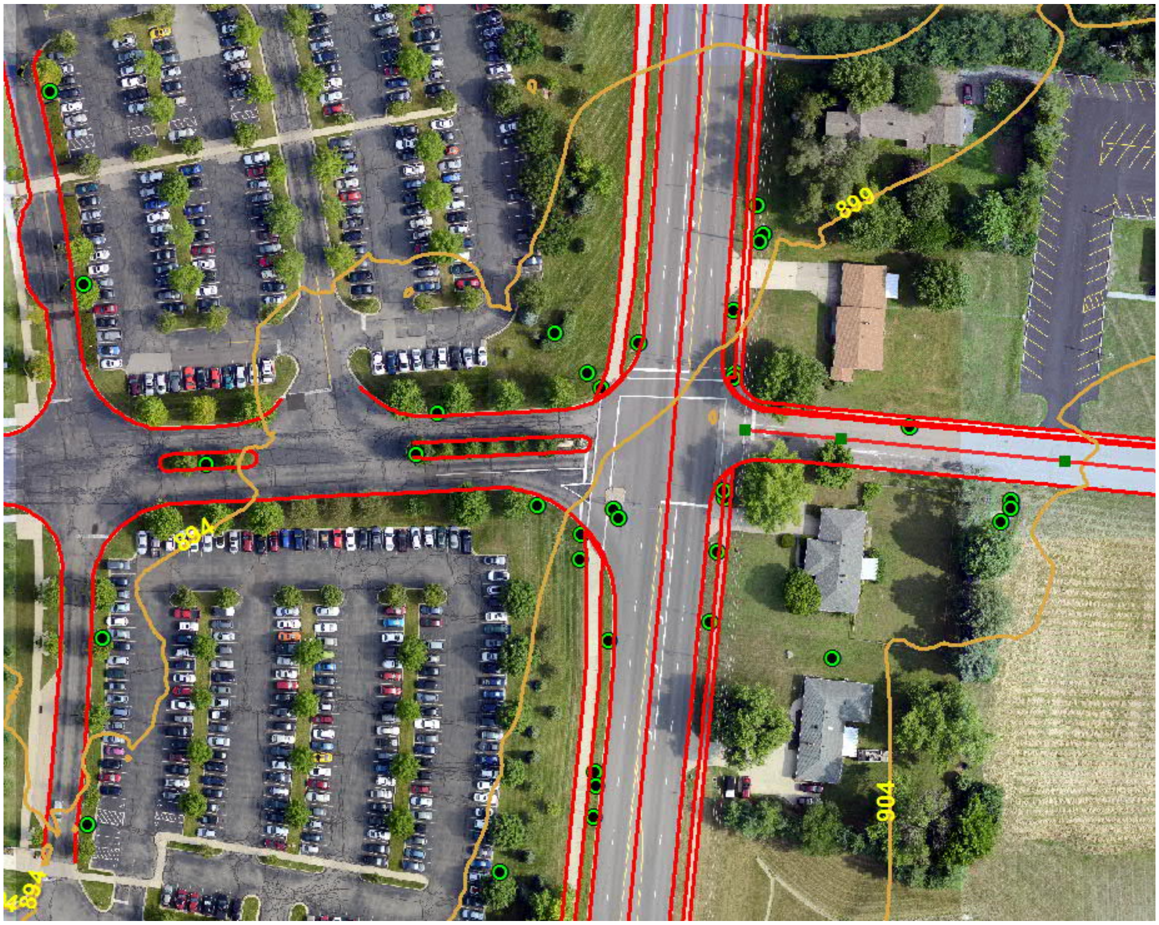

Figure 11 Planimetric Map

b. Topographic Map: Import the points cloud (DTM) generated in the folder \your_project_name\3_dsm_ortho\extras\dtm into ArcMap and generate <u>five-foot</u> contour interval.

i. Name the shape file "YourLastName_CountyRoad_contours.shp"

ii. Make sure that the contours elevation is within the range of the ground elevation or around 900 ft., refer to the ground control file for the proper elevation value of the ground.

iii. Make sure that you are using the DTM and not the DSM. DTM is cleaned surface as illustrated in Figure 12 while DSM is a surface with all above ground features such as buildings and trees present in it as illustrated in Figure 13.

iv. Contours generated from DSM is aesthetically not pleasing as there are too much information in it, see Figure 14, while contours generated from DTM is smooth and the file size is much smaller, see Figure 15.

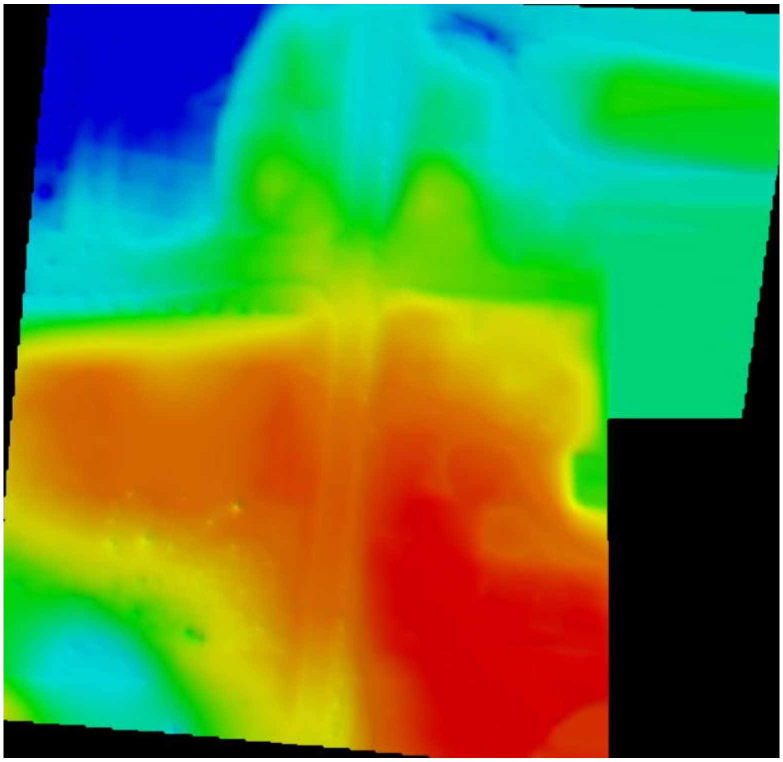

Figure 12 DTM surface (bare-earth)

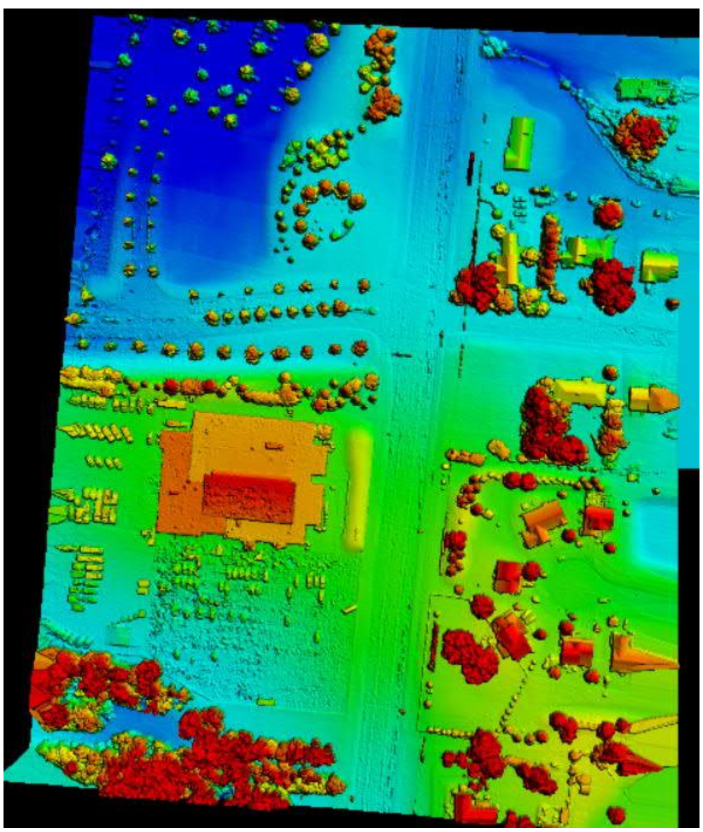

Figure 13 DSM surface

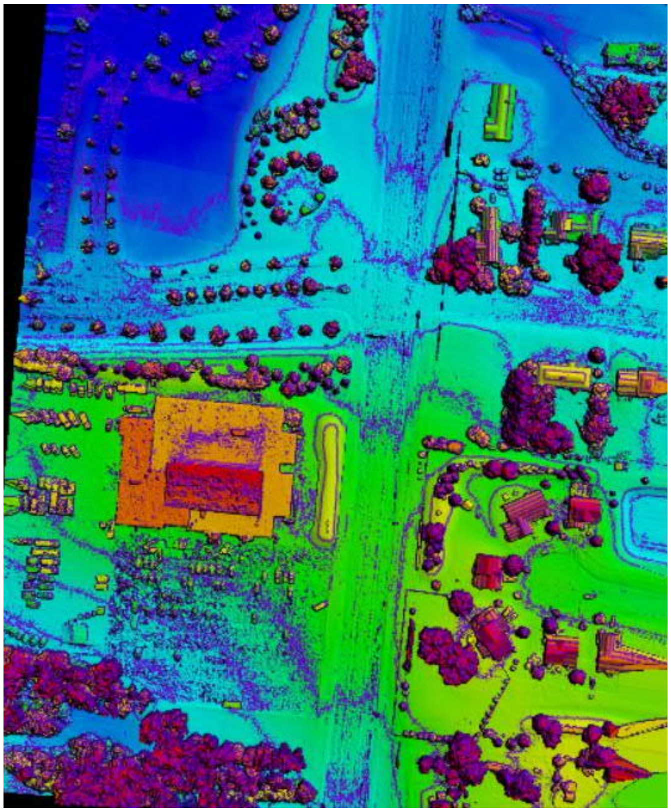
Figure 14 Contours generated from DSM

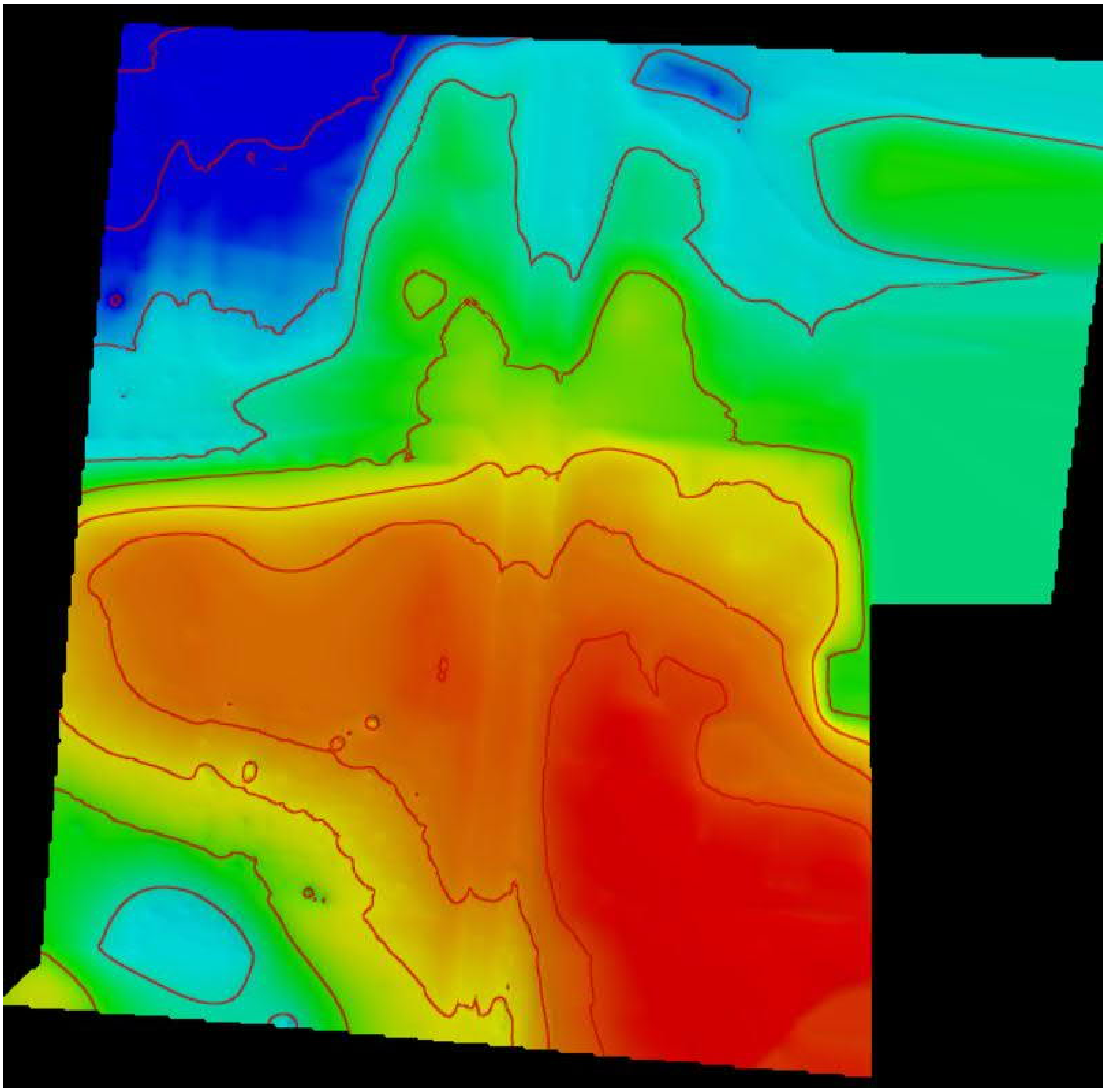

Figure 15 Contours generated from DTM

c. Ortho Accuracy Determination: Before you provide clients with the ortho products you need to categorize the positional accuracy of the ortho tiles. You will find that these check points in the orthos will not fall exactly at the surveyed location and there will be slight shift between the surveyed coordinates and the point location on the ortho. To measure these shifts, import the ortho tiles into ArcMap and visit and record the exact location on the orthos for each of the 8 check points, labeled MM. Tabulate your measurements for the coordinates for each point in an excel spread sheet and calculate the following values as illustrated in Table 1**:

   i. Mean $\bar{x}$:

$$\bar{x} = \frac{1}{(n)}\sum_{i=1}^{n} x_i$$

where:

x_i is the i^{th} error in the specified direction

n is the number of checkpoints tested,

i is an integer ranging from 1 to *n*.

ii. Standard Deviation s_x:

$$s_x = \sqrt{\frac{1}{(n-1)}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

where:

x_i is the i^{th} error in the specified direction,

$\bar{x}$ is the mean error in the specified direction,

n is the number of checkpoints tested,

i is an integer ranging from 1 to *n*.

iii. Root Mean Squares Error $RMSE_x$:

$$RMSE_x = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_{i(map)} - x_{i(surveyed)})^2}$$

where:

$x_{i(map)}$ is the coordinate in the specified direction of the i^{th} checkpoint in the data set,

$x_{i(surveyed)}$ is the coordinate in the specified direction of the i^{th} checkpoint in the independent source of higher accuracy,

n is the number of checkpoints tested,

i is an integer ranging from 1 to *n*.

Suggested ortho accuracy determination procedure for ArcGIS users:

- open the Pix4D generated orthos tiles in ArcGIS,

- import your shape file that contains the check points,

- Edit the shape file by moving the symbol for each check points to be aligned with the actual features where this check point was surveyed at (use the pics in the \GCPs\ folder)

- Export the table for the X, and Y from the modified shape file locations

- Subtract each X or Y from the original surveyed location of the check points as provided to you, this represents the errors or residuals.

- Compute statistics as in Table 1.

*** Review the new "ASPRS Positional Accuracy Standards for Digital Geospatial Data" for examples on how to calculate these values. You can download a copy of the standards from:*

http://www.asprs.org/wp-content/uploads/2015/01/ASPRS_Positional_Accuracy_Standards_Edition1_Version100_November2014.pdf

Table 1 Sample Accuracy Computations work sheet

	Measured on Ortho Value		Ground Surveyed Value			
Point ID	Easting (E) (US Survey Feet)	Northing (N) (US Survey Feet)	Easting (E) (US Survey Feet)	Northing (N) (US Survey Feet)	ΔE (Easting) (US Survey Feet)	ΔN (Northing) (US Survey Feet)
201	488381.2036	2203197.213	488381.280	2203197.500		
202	487744.9408	2206492.296	487744.890	2206492.360		
203	486682.5497	2209465.27	486682.650	2209465.170		
204	489593.2599	2209353.507	489593.300	2209353.240		
205	489688.8728	2206071.432	489688.850	2206071.480		
206	491397.4638	2203471.662	491397.600	2203471.730		
207	494766.3509	2204848.436	494766.730	2204848.620		
208	493607.3862	2206521.996	493607.340	2206522.320		
209	491786.9334	2208260.88	491786.910	2208260.810		
210	491690.7112	2206086.898	491690.810	2206086.880		
				Number of check points:	10	10
				Mean (Bias)		
				StDEV		
				RMSE		
				RMSEr		

13) Assignment Deliverables: Drop your Pix4D quality report, the two CAD files, and the accuracy computations in lesson 8 drop box on Canvas.

The deadline for submitting the materials is by the end of lesson 8.

Important:

1) Please do not share the data with anyone and if you present or publish any results derived from the County Line road dataset, give credit to Woolpert, Inc.

2) Please go through the online instructions on how to use Pix4D. You can launch it from inside the software under the “help” tab or through the following link:
https://support.pix4d.com/hc/en-us/articles/202557359-Getting-Started
https://www.pix4d.com/support/