Agisoft Photoscan 1.3.1 Tutorial

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The following tutorial shows you how to process drone-based aerial imagery to create 3D point clouds, DEMs, and orthomosaics with Structure-from-motion photogrammetry[1]. The examples used in the tutorial are from DJI Phantom 3 & 4 imagery taken at Santa Rita Experimental Range in southern Arizona and in Northern California.

Initial Photo Assessment

Before importing any photos, you should examine the overall set to determine which ones you would like to use. You should also write which photo numbers below to which view aspect, ex: Nadir 0001 - 0200, North Facing 0201-0400, etc. In the end this will help the user avoid confusion and assist in being able to quickly differentiate ground control points (GCPs).

Add Photos

- *Workflow>Add Photos.* You can also drag and drop photos directly onto the project as an alternative method for adding photos to the project. The groups of photos you add will be put into a 'chunk', which is essentially a project file. In the example below, I added 258 aerial photos, which Photoscan will refer to as 'cameras' (See Fig. 1A). All of the added photos will appear in the 'Photos' pane (Fig. 1B). You have the ability to double click on any image to take a closer look at it. If the photos have coordinate geotags (GPS coordinates) at the time of image capture, their locations are graphically displayed in the 'model' pane (Fig. 1C) as long as the 'show cameras' feature is enabled. 

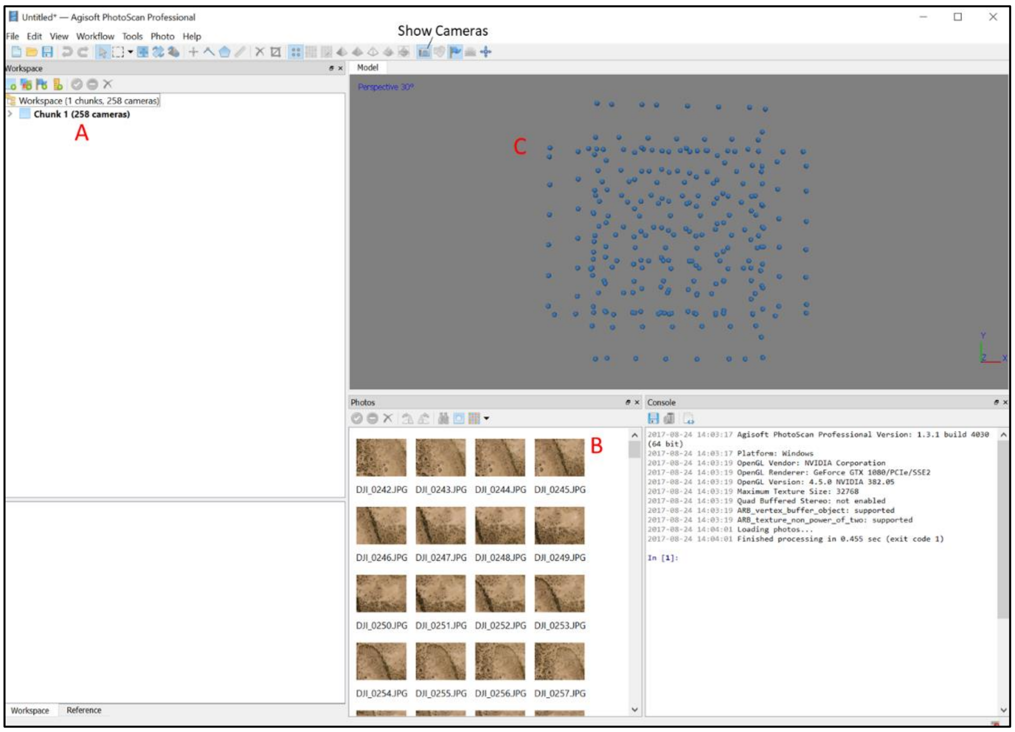


Fig. 1

In the 'reference' pane, the GPS coordinates of each photo will be displayed typically in lat/long WGS 1984 (Fig. 2).

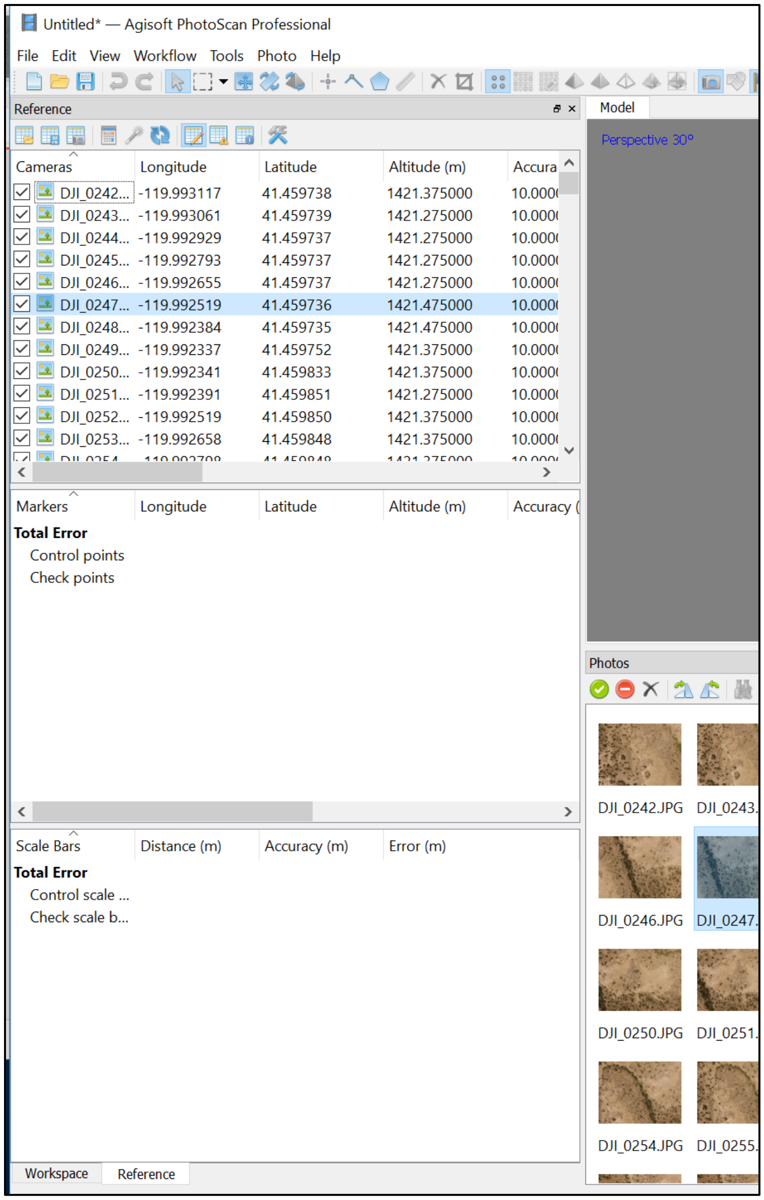

Untitled* — Agisoft PhotoScan Professional
File Edit View Workflow Tools Photo Help
Reference
Cameras Longitude Latitude Altitude (m) Accura
DJI_0242... -119.993117 41.459738 1421.375000 10.000
DJI_0243... -119.993061 41.459739 1421.275000 10.000
DJI_0244... -119.992929 41.459737 1421.275000 10.000
DJI_0245... -119.992793 41.459737 1421.275000 10.000
DJI_0246... -119.992655 41.459737 1421.275000 10.000
DJI_0247... -119.992519 41.459736 1421.475000 10.000
DJI_0248... -119.992384 41.459735 1421.475000 10.000
DJI_0249... -119.992337 41.459752 1421.375000 10.000
DJI_0250... -119.992341 41.459833 1421.375000 10.000
DJI_0251... -119.992391 41.459851 1421.275000 10.000
DJI_0252... -119.992519 41.459850 1421.375000 10.000
DJI_0253... -119.992658 41.459848 1421.375000 10.000
Markers Longitude Latitude Altitude (m) Accuracy (
Total Error
Control points
Check points
Scale Bars Distance (m) Accuracy (m) Error (m)
Total Error
Control scale ...
Check scale b...
Workspace Reference
Model
Perspective 30°
Photos
DJI_0242.JPG DJI_0243.
DJI_0246.JPG DJI_0247.
DJI_0250.JPG DJI_0251.
DJI_0254.JPG DJI_0255.

Fig. 2

Initial Photo Alignment

This task computes the camera position and orientation for each photo and builds a sparse point cloud model which defines the relative 3D geometry for the chunk. The building block for photogrammetry is finding features in an image (rock, tree branch, etc.) then finding that same feature in other overlapping images[2].

-*Workflow>Align Photos*

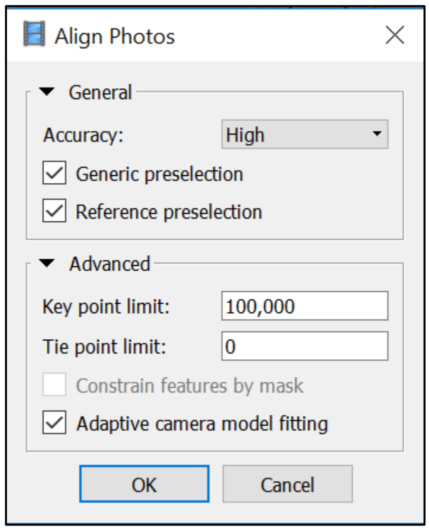


Fig. 3

You have the option to set accuracy from lowest to highest[3]. It is best to use ‘high’ or ‘medium’ quality. Do not use ‘highest’. The higher the accuracy setting, the longer the processing time will be. Chunks with a few dozen photos will process quickly, but chunks with hundreds to thousands of photos could take many minutes or hours to complete.

Generic preselection and reference preselection (if GPS coordinates are present) could speed up alignment[4]. Make sure all the cameras have a check mark next to them in the Reference pane (as shown in Fig. 2). The check mark indicates that you are using the camera coordinates to set a coordinate system for the sparse point cloud and speed up the process. Keep the rest of the settings as you see in Fig. 3. I bumped up the key point limit for each image to 100,000 and set the tie-point limit to 0 which means unlimited[5].

Once photos have been aligned, a green check mark should display in the top, right corner of the thumbnails in the Photos pane. The location and the orientation of all aligned images will display in the Model pane (Fig. 4).

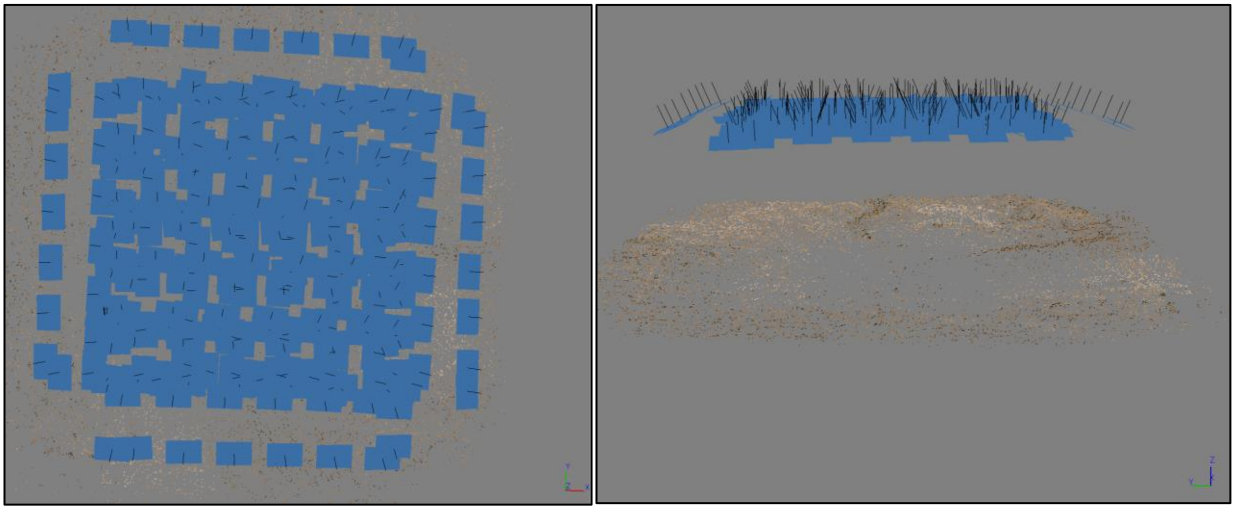


Fig. 4. Nadir view of aligned photos (left); side view of aligned photos (right)

Once the photos have aligned, please inspect the camera locations and orientations. Is it possible that some photos may not align properly or may not align at all. Misaligned photos might be in a completely wrong location or tilted in a bizarre way. Fig. 5a shows photos that did not align and Fig. 5b shows images that are aligned incorrectly.

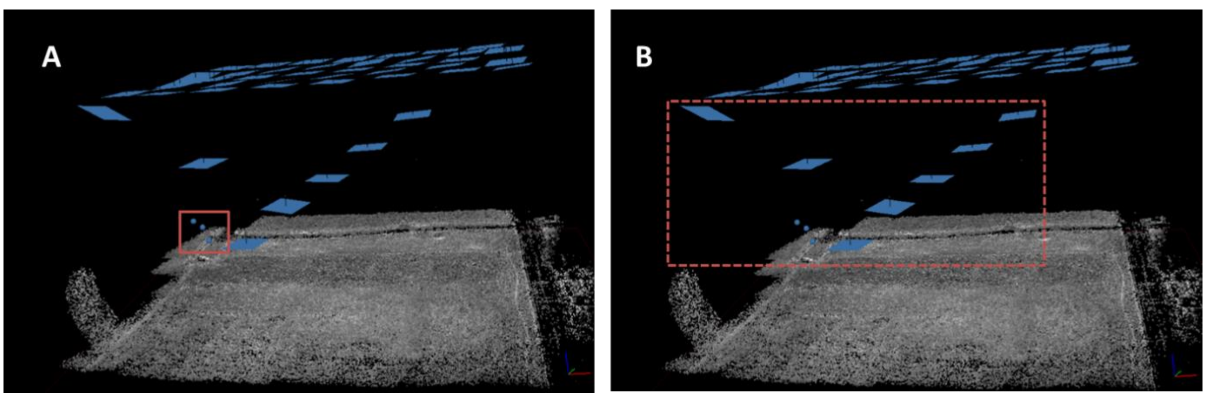
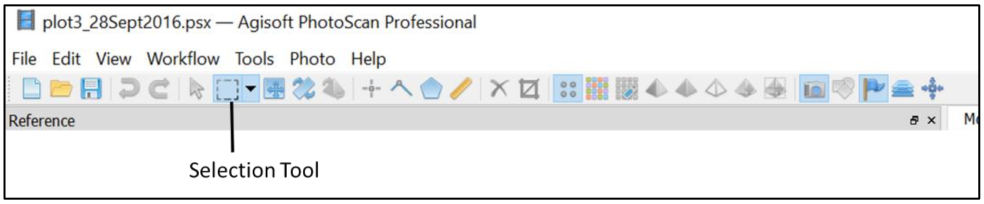


Fig. 5

We have the ability to re-align these individual problem photos without realigning all of the photos. To do this, you need to select the individual photos that did not align or align correctly. Use the selection tool to select these photos in the Model pane.



The photos you select will be highlighted in the Photos pane. Right-click those photos, *reset camera alignment*, then *align selected cameras* (Fig. 6). If the photos still will not align correctly, delete the photos from the project chunk by right-clicking the photo and *Remove Camera*.

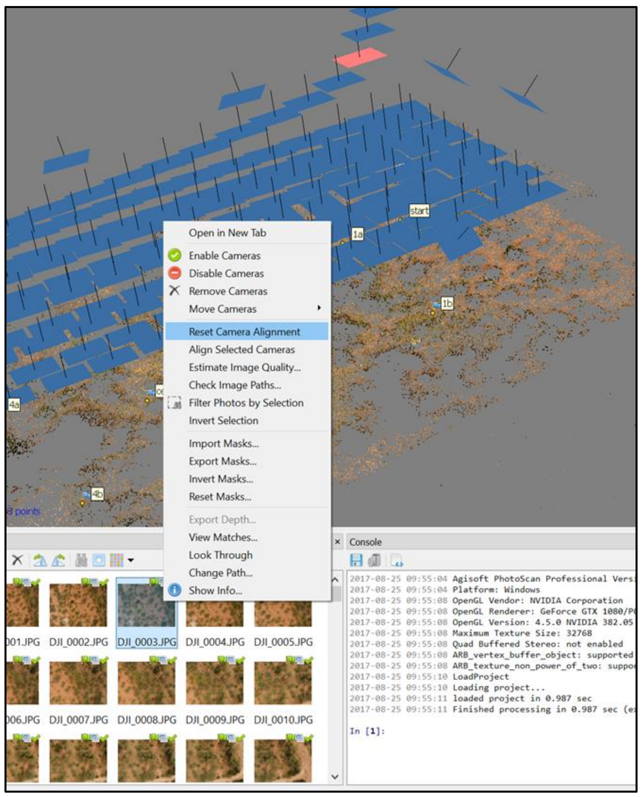


Fig. 6

Referencing

Referencing is the act of giving a sparse point cloud real world coordinates to correctly scale and georeference the point cloud. If the aerial images have GPS coordinates (which Phantoms do), then you already established a coordinates system during the initial alignment, but it is likely not very accurate[6]. Adding ground control points (GCPs) will likely improve the accuracy of the coordinate system to improve scale, georeferencing, and slope. If you want to make precise measurements from point clouds, DEMs, or orthomosaics, then GCPs are highly recommended.

Using an object of known length, or scale-bar, is an easier and faster way to reference photogrammetric point clouds (Fig. 7). The theory is that by telling the software program the length of a known object, it will extrapolate that length to correctly scale the 3D point cloud. However, by using only scale-bars, and not using GCPs, we can expect the absolute georeferencing of the point cloud to be shifted (in x, y, or z planes) and the slope to not be perfect.

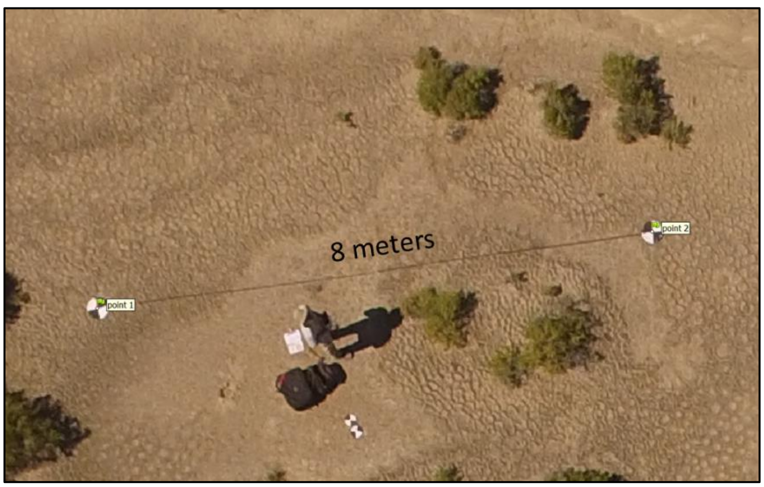
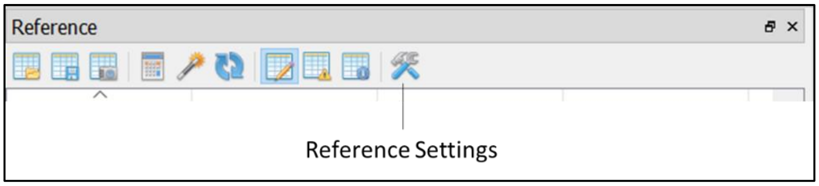


Fig. 7

The choice of whether to use GCPs, scale-bars, or just the GPS coordinates of the aerial images for referencing will depend on the intended use of the imagery products[7].

The workflow for using GCPs or scale-bars is very similar, so we will go through the workflow for each reference method together, and point out differences between them as we go.

The first order of business when referencing sparse points clouds is to set the coordinate system and accuracies of the references[8]. You do these tasks in the *Reference setting* window.



If you cannot find the Reference pane, perhaps you need to enable it. On the main toolbar select *View > Panes > Reference*

If you are using GCPs, set the coordinate system to the system that the GCPs were collected (Fig. 8). In this example, the GCPs, were surveyed with a RTK GPS unit using NAD83 UTM Zone 12. The marker accuracy (in meters) should be an estimation of how accurate the GPS was during the survey. For RTK systems, the accuracies could within a few centimeters. For Trimble systems that differentially correct locations based on CORS stations, the accuracy could be within 10 cm or so. The marker accuracy (in pixels) is the estimation of how accurate you can identify the GCP target on the imagery. Use the default value of 0.1 pixels.

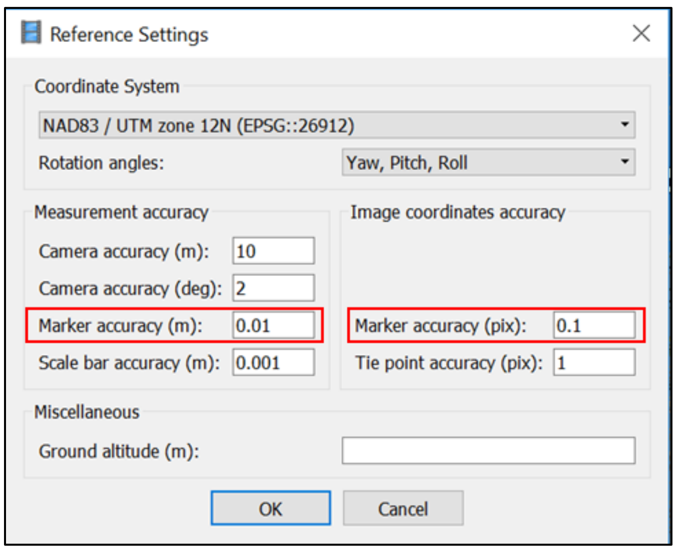


Fig. 8

If you are using scale-bars for referencing, you can leave the coordinate system in WGS 84 for now (this is coordinate of the image GPS). For scale-bars we are interested in the 'scale bar accuracy (m)'. Input what you think the possible error of your scale bar measurement could be in meters (Fig. 9). Keep the 'marker accuracy (pix)' the same as default.

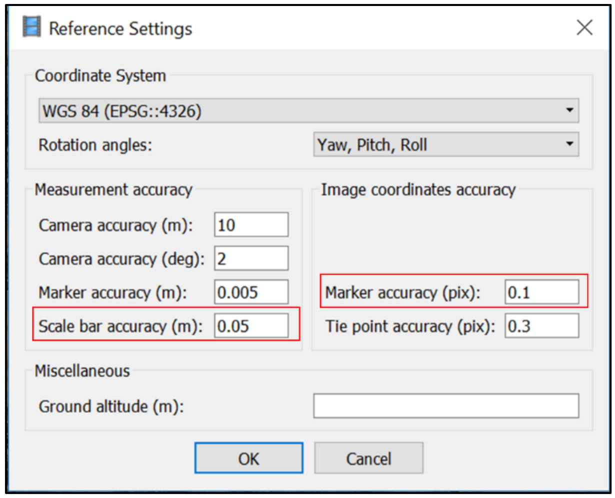


Fig. 9

After setting the reference system and input accuracies, it is now time to identify the locations of all the GCPs in the photos. Photoscan calls these ‘markers’. If you are using scale-bars, this procedure is identical except we are identifying the two ends of a visible linear feature.

Double click on a photo in the Photo pane. Navigate to a visible target and right-click in the center of the target (Fig. 10). *Create Marker*. Type in the coordinates of the marker in the Reference pane. The ‘accuracy’ of each marker should be the same as what you input in the ‘Reference settings’ tool (in this case 0.01m). If these markers are for scale-bars, you will not have any coordinates for them. That is OK.

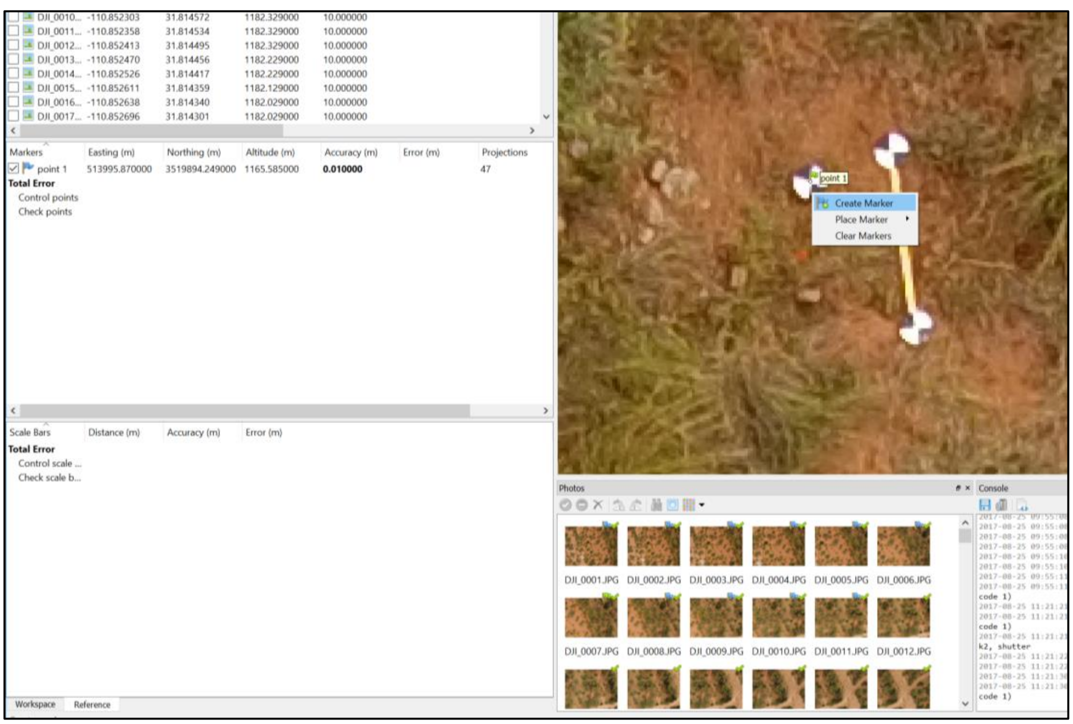


Fig. 10

Because the photo alignment has already been completed, Photoscan will try to find that same target in all photos. In Fig. 10, you see that ‘point 1’ has 47 projections. That means that there are 47 total photos that contain that marker. You will notice in the Photos pane that photos containing that marker will have a blue flag on top of it. A blue flag indicates that Photoscan has estimated the location of the marker but it needs to be reviewed and adjusted by the user.

You must now go to each photo that has a blue flag and adjust the marker location to the center of the target. You do this by clicking and dragging the point with the mouse cursor. Yes, this can be time consuming if you have many markers and many images. One way to speed up the process is to right-click on the marker in the Reference pane and click *Filter Photos by Markers* (Fig. 11). This command will show only photos in the Photos pane that contain the marker of interest. Transitions from photo to photo is easier because of this filter. To remove the filter press the *Reset Filter* button in the Photos Pane (Fig. 12).

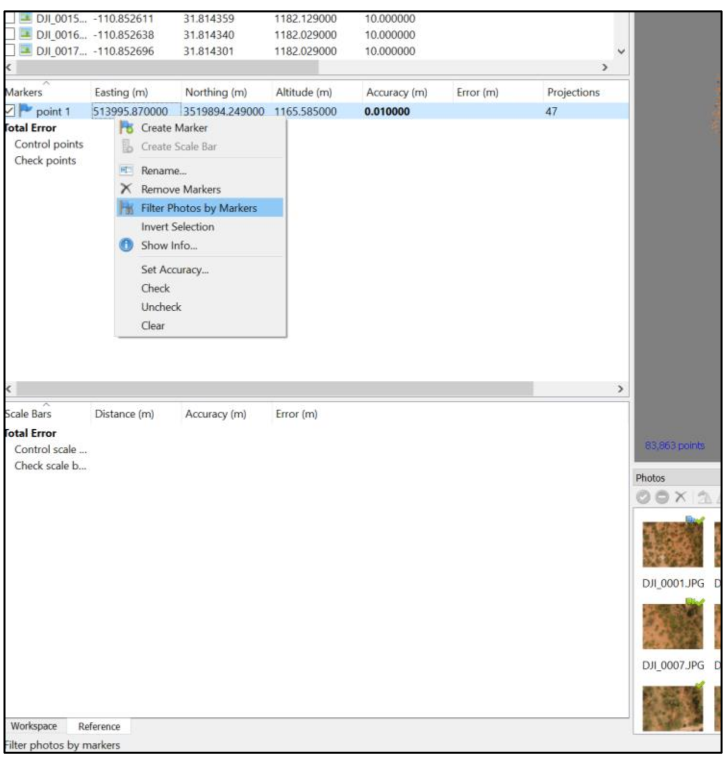
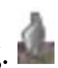


Fig. 11

Fig. 12

Once a marker has been adjusted by the user, the flag will become green. 

There will likely be times when the GCP target is too blurry or is obscured behind vegetation. This prevents you from accurately placing the marker in the center of the target. In these cases, you should disable the marker from this photo. Right click the marker and *Remove Marker* (Fig. 13). The symbol will go from a flag to a grey looking thing. 
If you cannot place a marker accurately on the center of the target, do not place it at all!

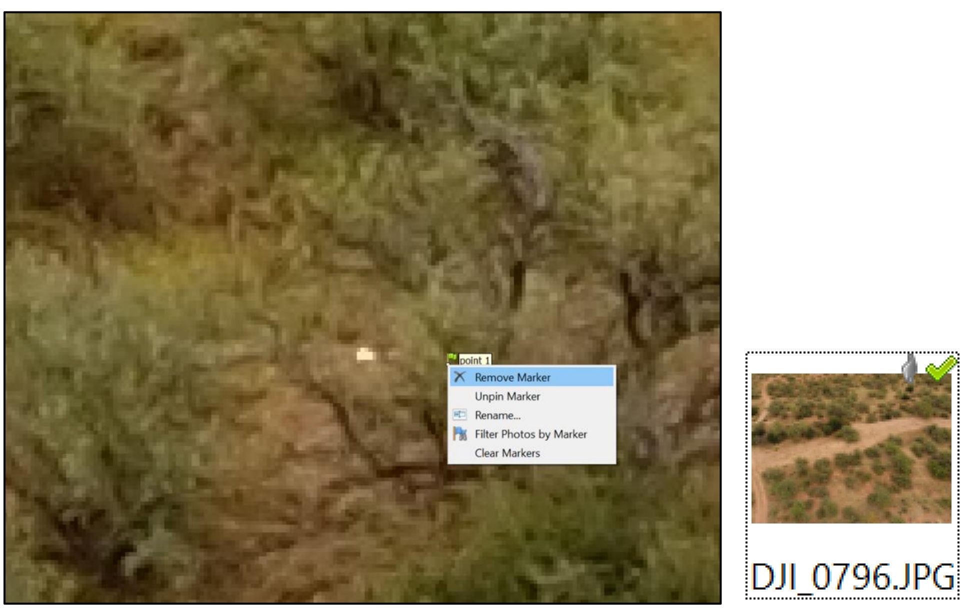


Fig. 13

If you are using scale-bars, you have identified the two ends of the scale-bar. Now you need to tell Photoscan that the two markers are connected and represent a linear feature. In the markers section of the Reference pane, select both of the markers (using shift key). Right-click the selected markers and *Create Scale Bar* (Fig. 14). You will notice that a scale-bar has been created in the scale-bar section of the reference pane. Fill in the distance of the scale-bar in meters and estimate the accuracy of this measurement. This accuracy should be the same as what you input in the 'Reference settings' tool (in this case 0.05 m) You will also notice that a scale-bar has been created in the 3D model pane.

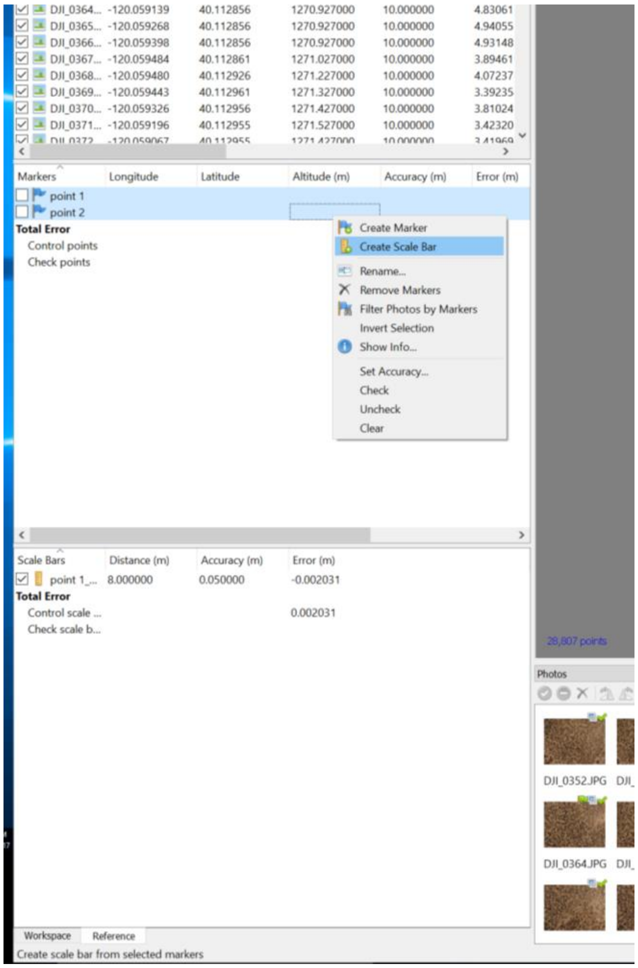
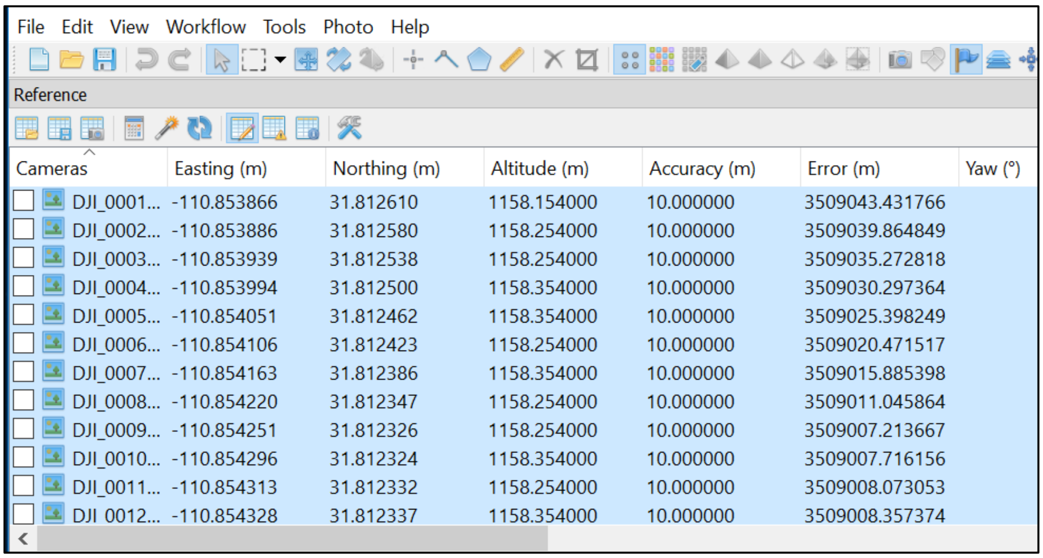


Fig. 14

Sparse Cloud Optimization

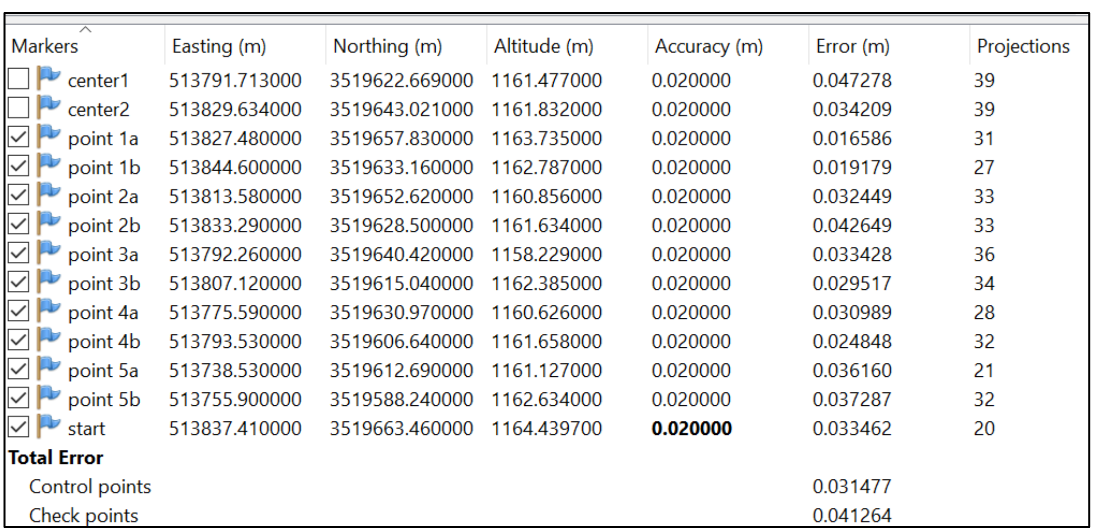
In the previous section, we identified the references (either GCPs, or scale-bars). Now we will incorporate these references to improve the dimensions of the sparse point cloud. The first thing we need to do is uncheck all of the cameras in the reference pane. We do not want to use the GPS camera coordinates because they are likely not very accurate. You can speed-up the unchecking by selecting all of the cameras with the shift key then unchecking one camera (Fig. 15).



Cameras	Easting (m)	Northing (m)	Altitude (m)	Accuracy (m)	Error (m)	Yaw (°)
DJI_0001...	-110.853866	31.812610	1158.154000	10.000000	3509043.431766	
DJI_0002...	-110.853886	31.812580	1158.254000	10.000000	3509039.864849	
DJI_0003...	-110.853939	31.812538	1158.254000	10.000000	3509035.272818	
DJI_0004...	-110.853994	31.812500	1158.354000	10.000000	3509030.297364	
DJI_0005...	-110.854051	31.812462	1158.354000	10.000000	3509025.398249	
DJI_0006...	-110.854106	31.812423	1158.254000	10.000000	3509020.471517	
DJI_0007...	-110.854163	31.812386	1158.354000	10.000000	3509015.885398	
DJI_0008...	-110.854220	31.812347	1158.254000	10.000000	3509011.045864	
DJI_0009...	-110.854251	31.812326	1158.254000	10.000000	3509007.213667	
DJI_0010...	-110.854296	31.812324	1158.354000	10.000000	3509007.716156	
DJI_0011...	-110.854313	31.812332	1158.254000	10.000000	3509008.073053	
DJI_0012...	-110.854328	31.812337	1158.354000	10.000000	3509008.357374	

Fig. 15

We *do* want to use the GCP or scale-bar coordinates to optimize the initial alignment. Check all of the GCPs you want to use (Fig. 16). You can leave a few markers unchecked to serve as check points (aka validation points).



Markers	Easting (m)	Northing (m)	Altitude (m)	Accuracy (m)	Error (m)	Projections
center1	513791.713000	3519622.669000	1161.477000	0.020000	0.047278	39
center2	513829.634000	3519643.021000	1161.832000	0.020000	0.034209	39
point 1a	513827.480000	3519657.830000	1163.735000	0.020000	0.016586	31
point 1b	513844.600000	3519633.160000	1162.787000	0.020000	0.019179	27
point 2a	513813.580000	3519652.620000	1160.856000	0.020000	0.032449	33
point 2b	513833.290000	3519628.500000	1161.634000	0.020000	0.042649	33
point 3a	513792.260000	3519640.420000	1158.229000	0.020000	0.033428	36
point 3b	513807.120000	3519615.040000	1162.385000	0.020000	0.029517	34
point 4a	513775.590000	3519630.970000	1160.626000	0.020000	0.030989	28
point 4b	513793.530000	3519606.640000	1161.658000	0.020000	0.024848	32
point 5a	513738.530000	3519612.690000	1161.127000	0.020000	0.036160	21
point 5b	513755.900000	3519588.240000	1162.634000	0.020000	0.037287	32
start	513837.410000	3519663.460000	1164.439700	**0.020000**	0.033462	20
Total Error						
Control points					0.031477	
Check points					0.041264	

Fig. 16

If you are only using scale-bars for referencing, check mark the scale bar while keeping all of the images unchecked (Fig. 17).

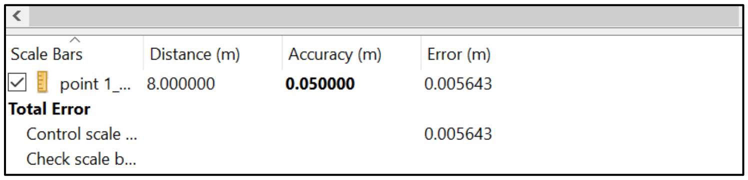


Fig. 17

Click on the *Optimize Cameras* button in the Reference pane[9] (Fig. 18).

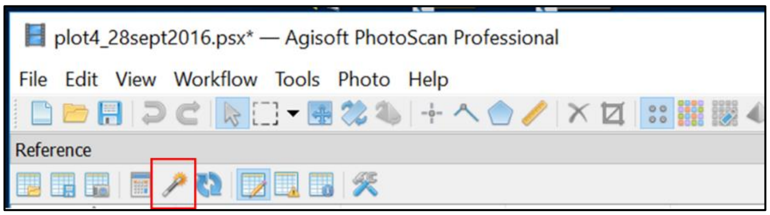


Fig. 18

Select the optimization parameters as seen in the graphic below (Fig. 19)[10].
Rolling shutter correction is important because Phantom cameras and many other inexpensive sensors have an electronic rolling shutter instead of a mechanical shutter[11].

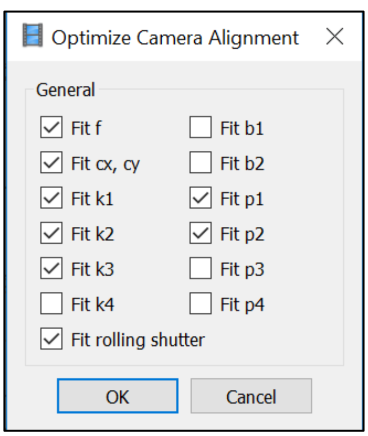


Fig. 19

<u>Lens distortion parameters</u>
f = focal length (in pixel units)
cx, cy are the principal point coordinates (dead center of image)
k1, k2, k3, k4 = radial distortion parameters
b1, b2 = affinity and non-orthogonality (skew) coefficients
p1, p2, p3, p4 = tangential distortion parameters

Removing Low Quality Sparse Points

Of the tens of thousands of sparse point, thousands are probably inaccurate and need to be removed. This will improve the overall accuracy of the 3D scene. We can filter out poor points using the *Gradual Selection* tool (Fig. 20). Please know that the following guide is a rough rule of thumb. Each individual project will have inherent accuracies that may call for more or less sparse points being removed.

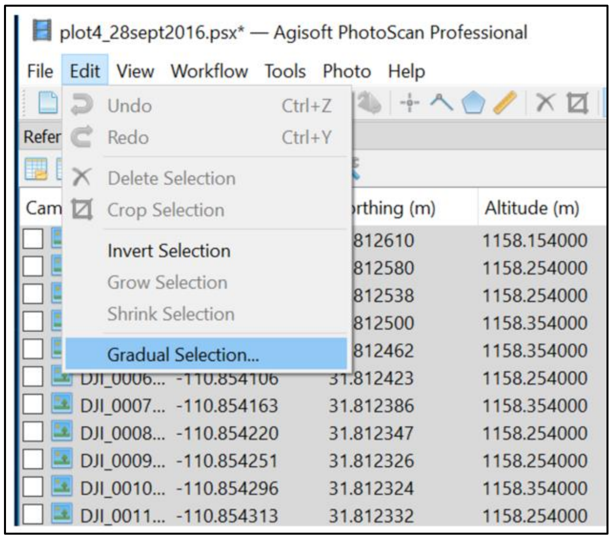
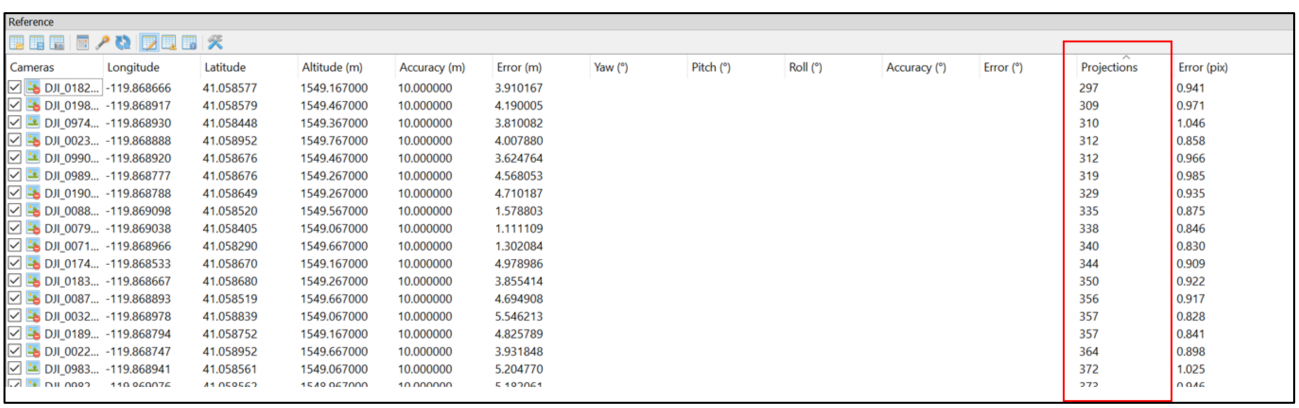


Fig. 20

The appropriate accuracy level and the total number of points to delete will depend on the specific project. We want to delete poor points without deleting too many. As a rule of thumb try to keep at least 100 tie points (aka sparse points) for each image. The number of tie points per image can be seen the image Reference Pane. Here Photoscan calls them ‘Projections’


Reference

Cameras	Longitude	Latitude	Altitude (m)	Accuracy (m)	Error (m)	Yaw (°)	Pitch (°)	Roll (°)	Accuracy (°)	Error (°)	Projections	Error (pix)
DJI_0182...	-119.868666	41.058577	1549.167000	10.000000	3.910167						297	0.941
DJI_0198...	-119.868917	41.058579	1549.467000	10.000000	4.190005						309	0.971
DJI_0974...	-119.868930	41.058448	1549.367000	10.000000	3.810082						310	1.046
DJI_0023...	-119.868888	41.058952	1549.767000	10.000000	4.007880						312	0.858
DJI_0990...	-119.868920	41.058676	1549.467000	10.000000	3.624764						312	0.966
DJI_0989...	-119.868777	41.058676	1549.267000	10.000000	4.568053						319	0.985
DJI_0190...	-119.868788	41.058649	1549.267000	10.000000	4.710187						329	0.935
DJI_0088...	-119.869098	41.058520	1549.567000	10.000000	1.578803						335	0.875
DJI_0079...	-119.869038	41.058405	1549.067000	10.000000	1.111109						338	0.846
DJI_0071...	-119.868966	41.058290	1549.667000	10.000000	1.302084						340	0.830
DJI_0174...	-119.868533	41.058670	1549.167000	10.000000	4.978986						344	0.909
DJI_0183...	-119.868667	41.058680	1549.267000	10.000000	3.855414						350	0.922
DJI_0087...	-119.868893	41.058519	1549.667000	10.000000	4.694908						356	0.917
DJI_0032...	-119.868978	41.058839	1549.067000	10.000000	5.546213						357	0.828
DJI_0189...	-119.868794	41.058752	1549.167000	10.000000	4.825789						357	0.841
DJI_0022...	-119.868747	41.058952	1549.667000	10.000000	3.931848						364	0.898
DJI_0983...	-119.868941	41.058561	1549.067000	10.000000	5.204770						372	1.025

Fig. 21

Gradual Selection of Reconstruction Uncertainty (Fig. 22)

In the gradual selection window, the 'Criterion' drop-down menu allows you to choose different way of assessing error of sparse points. Let's start with 'Reconstruction Uncertainty'[12]. The goal is to eliminate any point that has uncertainty > 10. Use the slide bar to set the level to 14. You will notice points will become highlighted pink when selected. In this case, all points that have error of 14 and higher will be highlighted. In the bottom left corner of the Model pane, you can see the total number of points and the number that have been selected.

Click *OK* on the window then hit the delete button on the keyboard. After you have deleted the points, do another Optimization routine with the parameters as before. After Optimization is complete, do another round of using Gradual Selection to select poor Reconstruction Uncertainty. This time, select and delete all points that have a reconstruction uncertainty error greater than 10. Run another Optimization procedure using the same parameters as before.

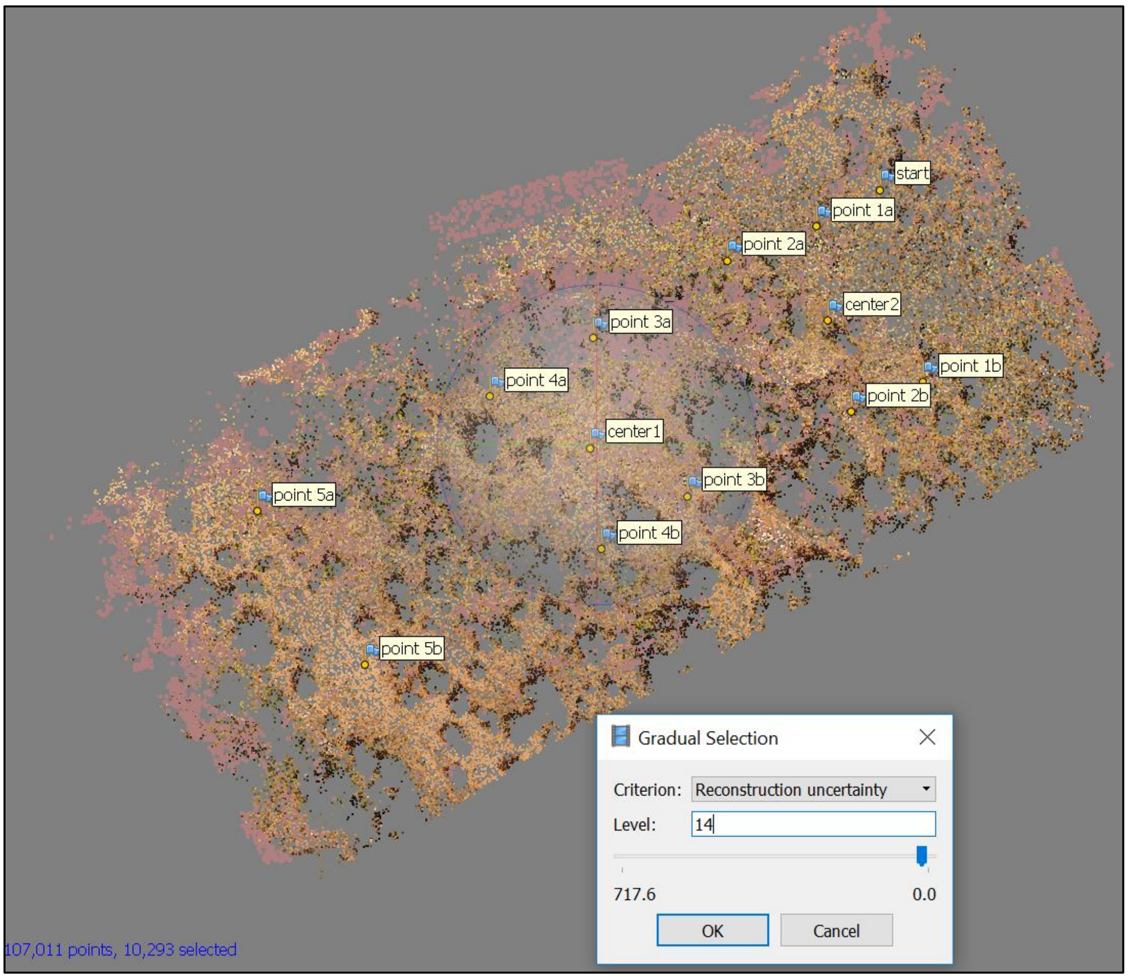


Fig. 22

Gradual Selection of Projection Accuracy (Fig. 23)

This procedure follows the same workflow as the previous *Gradual Selection* only we are selecting points with poor Projection Accuracy[13]. The goal is to eliminate points that have error greater than 5. Select Projection Accuracy from the drop-down menu and move the slider to somewhere around 6. This will highlight (in pink), all points that have error of 6 or greater. Click OK and delete these points with the keyboard delete button. After you have deleted the points, do another Optimization routine with the parameters as before. After Optimization is complete, do another round of using Gradual Selection to select poor Projection Accuracy. This time, select and delete all points that have a reconstruction uncertainty error greater than 5. Run another Optimization procedure using the same parameters as before.

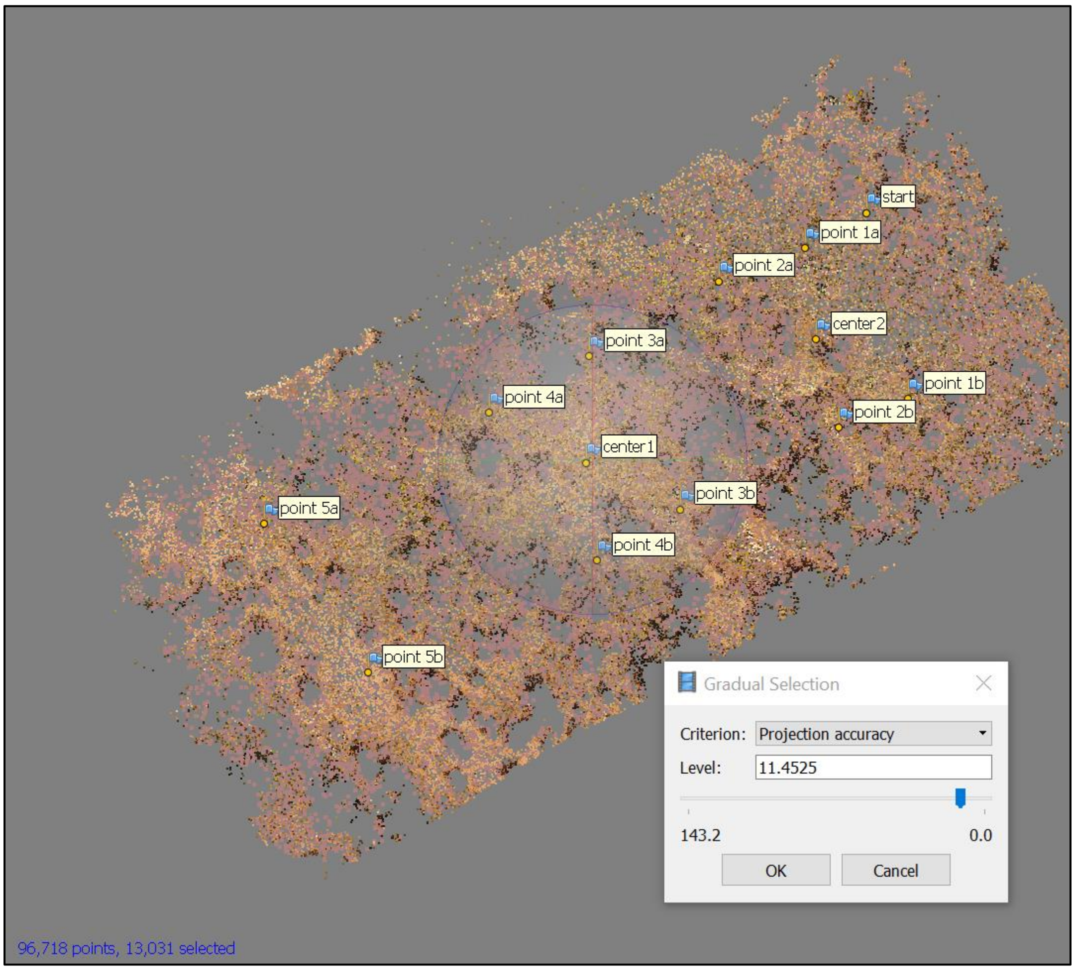


Fig. 23

Gradual Selection of Reprojection Error[14] *(Fig. 24)*

The goal is to select and eliminate about 10% of the points with the worst error. The level where this occurs will differ from project to project. It should generally be below level 1. Delete the 10% of the points with worst reprojection error.

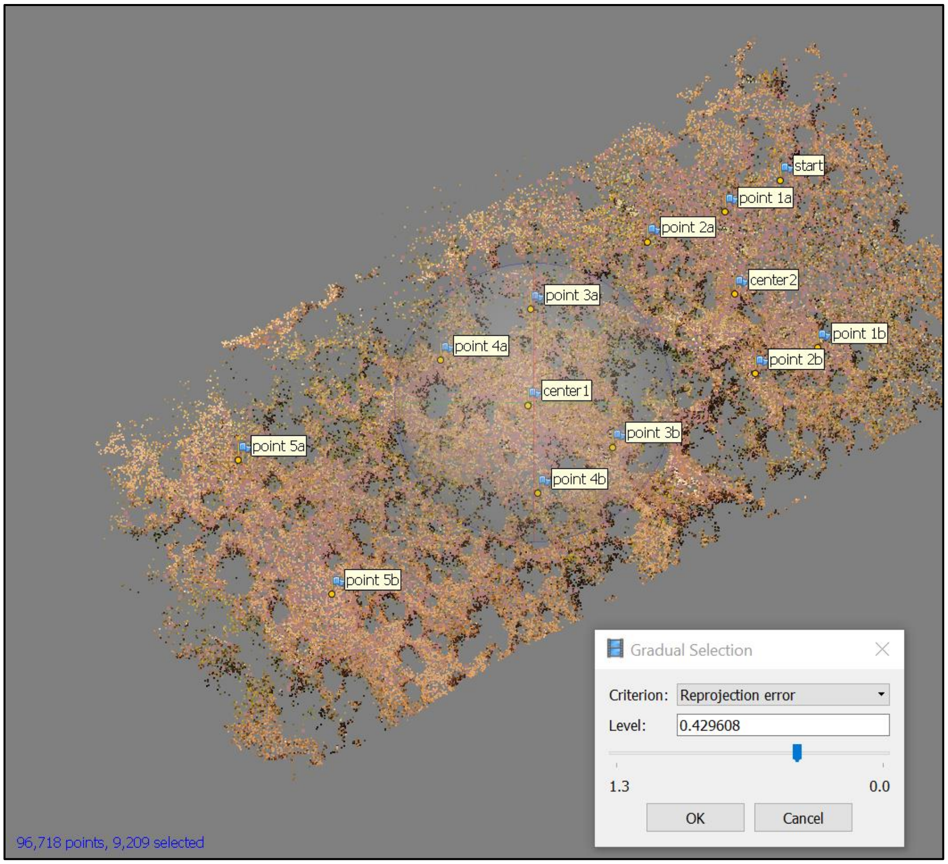
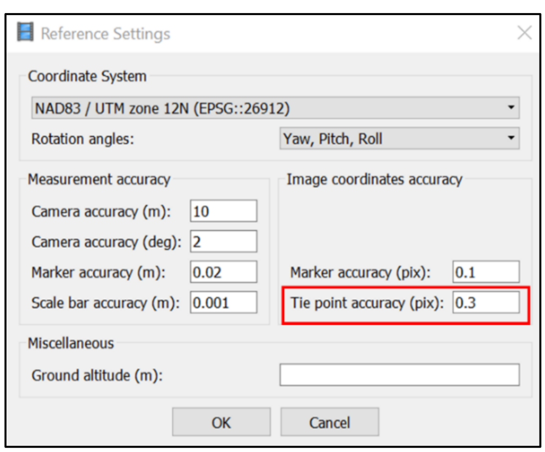
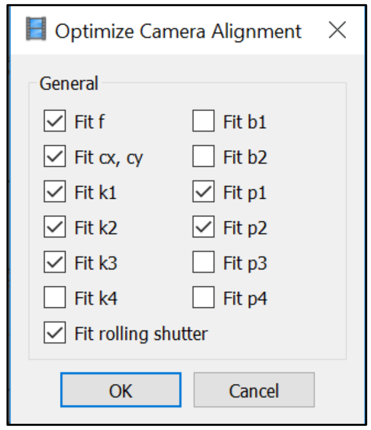


Fig. 24

After deleting the poor quality points, open up the *Settings* window  and change the Tie point accuracy (pix) to 0.3



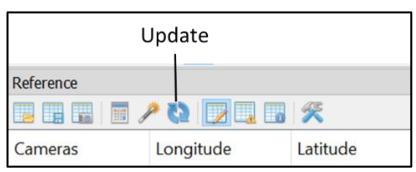
Do one more Optimization procedure. Same distortion parameters as all the previous optimizations.



If you are using scale bars for referencing, you will notice that all this optimization really altered the direction of ‘up’ in the 3D model. The final step will be to correct this model orientation. Uncheck mark all of the cameras in the reference pane. This action is the opposite of Fig. 15. With all of the cameras unchecked and all GCPs checked, push the *Update* button on the reference toolbar.

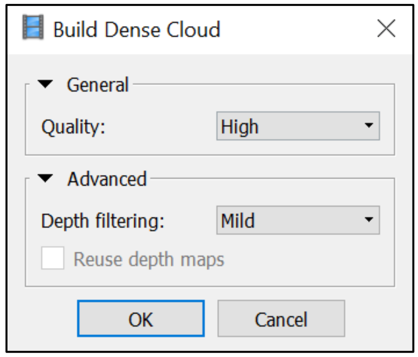
NOTE:

If you are building a dense point cloud from GCPs only, ensure that all the cameras in the Reference Pane are Unchecked. And the GCPs, that you have chosen to use, are checked before you select update.



Build Dense Point Cloud

Workflow>Build Dense Cloud



If you want to build very detailed 3D point clouds, I recommend using the ‘high’ quality setting. Ultra dense quality processing can take a very long time and usually is not necessary for most applications. It is important to know that processing time is a function of the number of total images in the chunk. As the number of images increases, processing time will increase at an almost exponential rate. Depth filtering is a procedure to automatically eliminate outlying points. I generally choose ‘mild’ so vegetation will keep most of its detail. Using aggressive filtering will remove the detail of tree branches, but this setting could be useful if your only interest is a good bare-ground model.

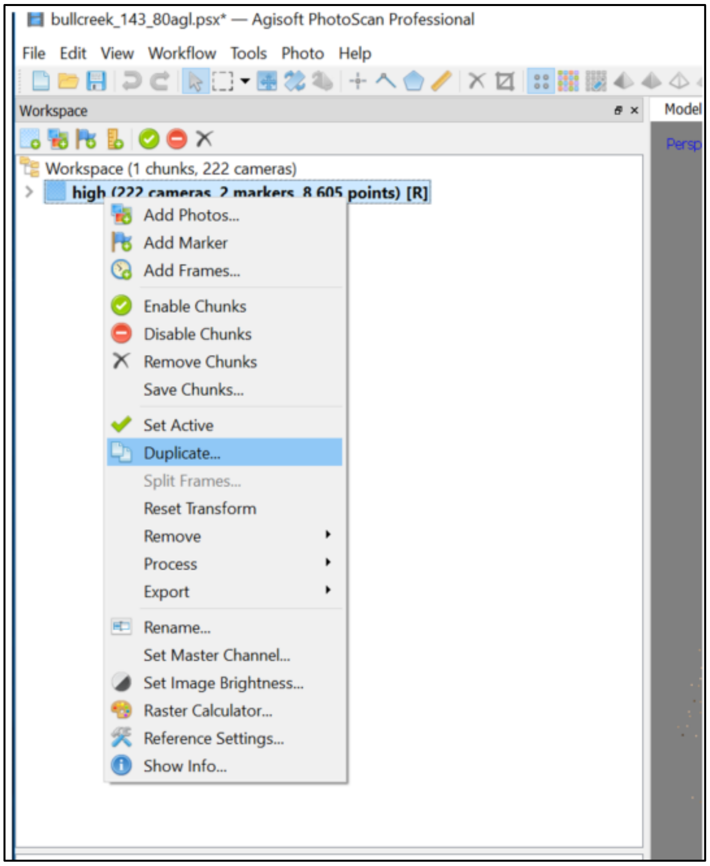
If the goal of your photogrammetric processing is to make a good orthomosaic, you should choose a lower quality dense cloud such as ‘medium’ or ‘low’.

If you want to produce a very detailed point cloud and orthomosaic, you should follow two separate workflows. In the ‘Workspace’ pane, right-click your chunk and select *Duplicate*. This will create a carbon copy of your chunk. You now have two separate project files that can follow different workflows. One chunk should be used for high density point cloud generation. The other chunk can be used for low-density point clouds that are better for orthomosaics.

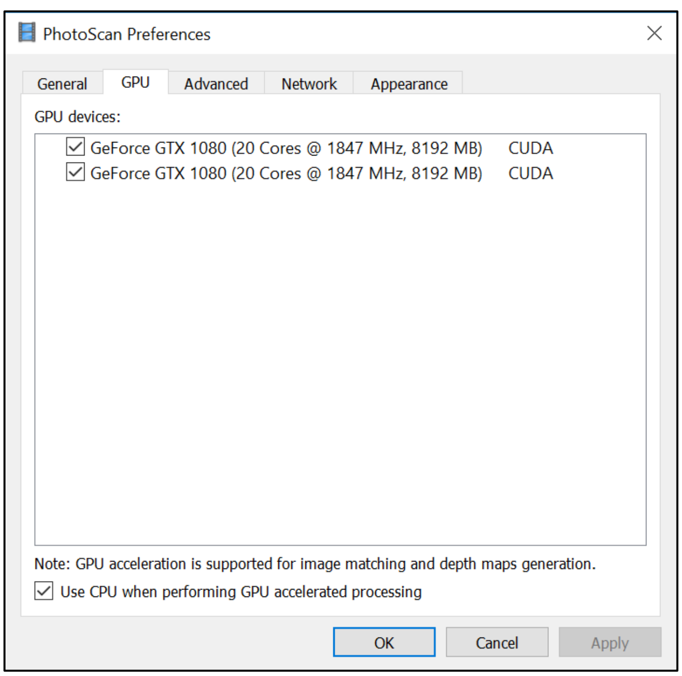
NOTE:

The creation of dense point clouds can take a very long time if the create dense point cloud workflow is run all at once. To speed up this process the project can be split into chunks and then processed.

To break the dense point cloud creation process up piecemeal, use the resize region tool  (located on the tool bar) and set the region to a portion of the original sparse point cloud. Set the box, then duplicate the area (chunk). Move the region box by selecting its upper most sphere and drag it to the next region and again duplicate the chunk. Repeat as necessary.



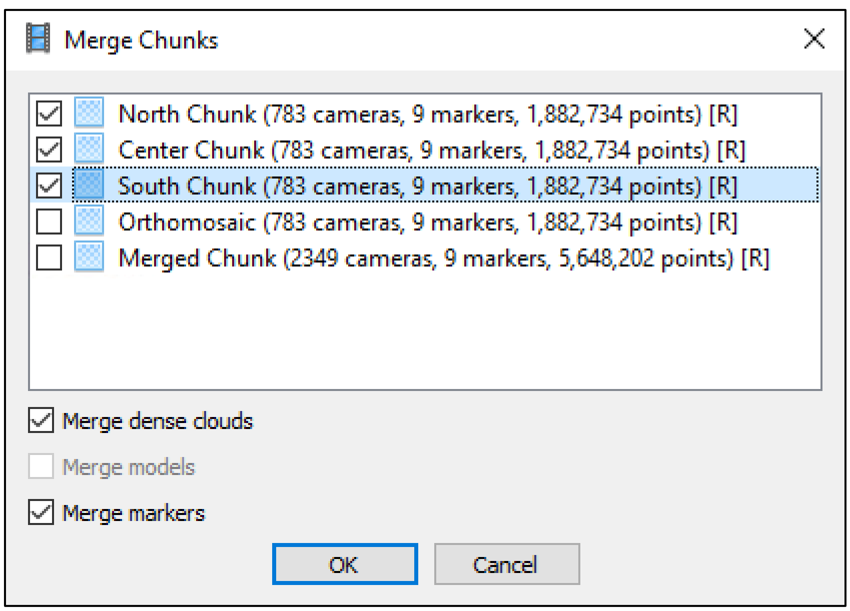
Dense Point cloud generation can be significantly faster when using Graphics Card GPU. Before you start reconstructing the dense point cloud, make sure that your graphic card is recognized and enabled. To do this go to the main menu and select *Tools* > *Preferences*.



Once the dense point cloud has been created, you will notice that each image in the 'Photo' pane will have an additional icon next to the green check mark. This icon indicates that a depth map has been made for this image.

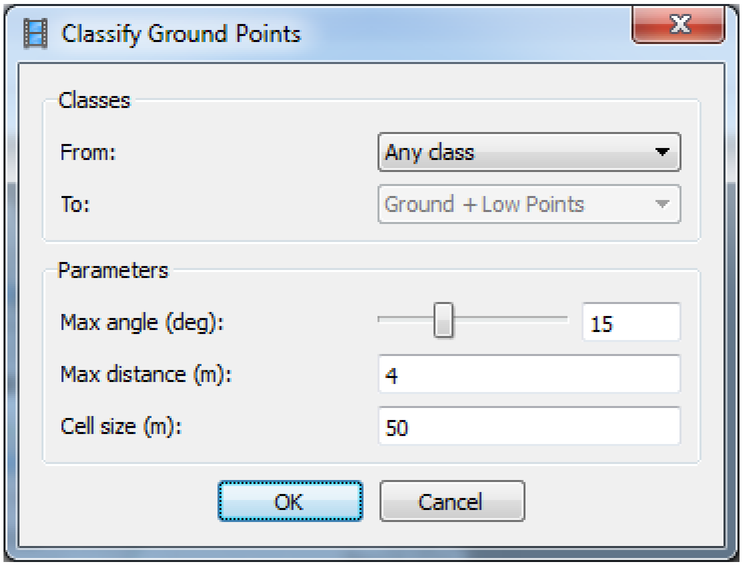
If the dense point clouds were created in separate chunks, then after they have been made the chunks will need to be merged so that they can be used to export one continuous point cloud. To do this go to:

Workflow>Merge Chunks
Select the Chunks you wish to merge and also check the boxes for *Merge dense clouds* and *Merge markers* (if markers were used). Select OK to merge the chunks.

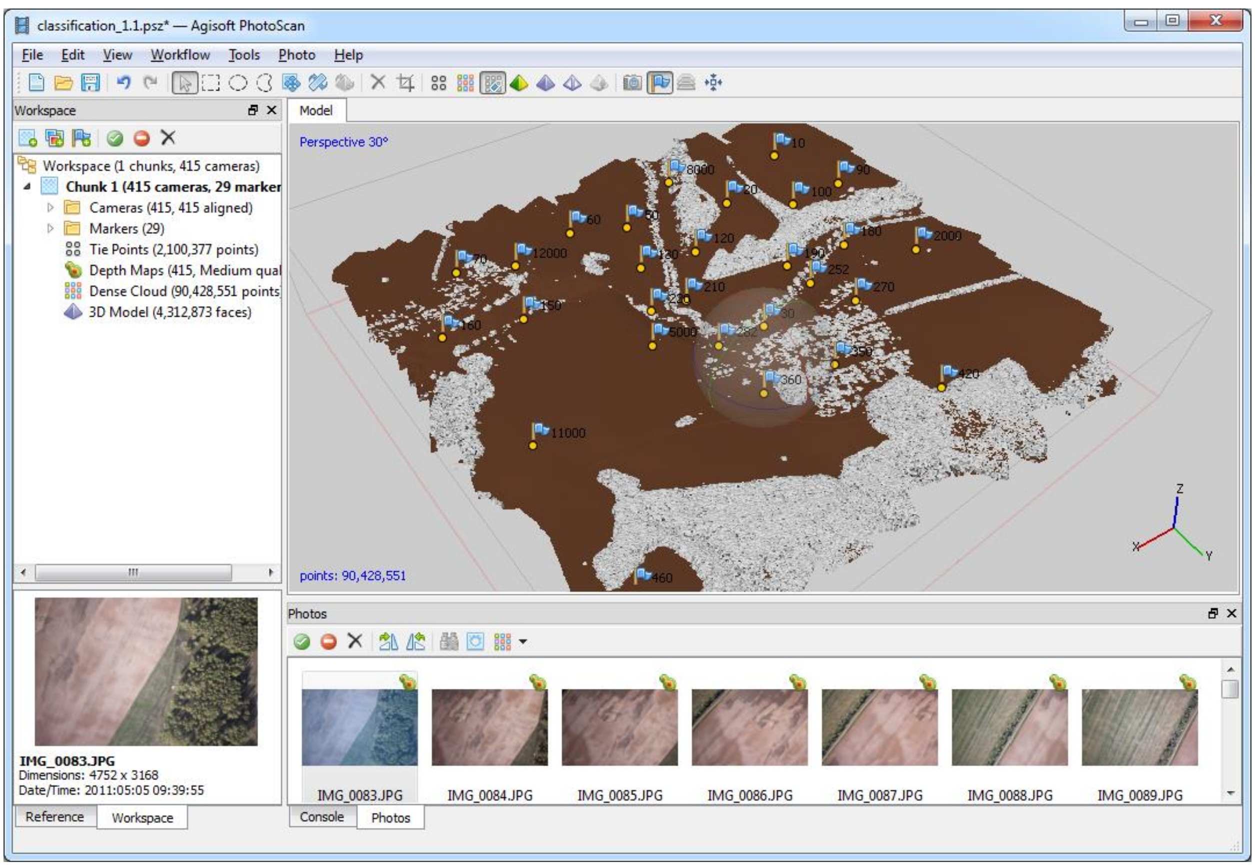


Build Digital Terrain Model (DTM)

Tools menu → Dense Cloud submenu



Adjust your cell size according to the largest area in the scene that contains no ground points.



Ground points will be colored with brown color, low-points (noise) class points will be colored by pink and unclassified points will remain white.

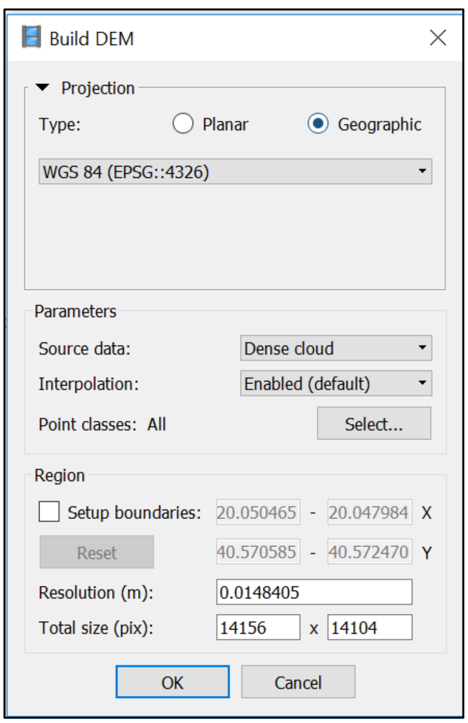
Note: It is important to reset the assigned classes for the dense cloud prior to starting the procedure again with the new set of parameters. To Reset classification results use *Reset Classification* option from Tools Menu -> Dense Cloud submenu.

Build DEM

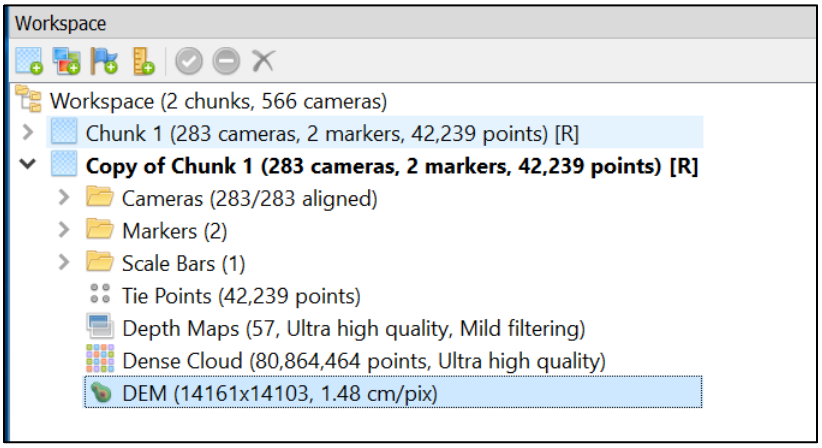
Workflow>Build DEM

There are not a lot of options for making DEMs in Photoscan. It uses an unpublished interpolation method to turn the dense (or sparse) point cloud into a gridded 2D elevation surface. The size of the grid cells is fixed and not customizable by the user. The cell size will depend on the density you specified during dense point cloud generation. For example, if you have raw aerial imagery with 3 cm ground sampling and generate an ultra-dense point cloud, then Photoscan will produce DEMS with 3 cm cells.

The only real option you have is to enable interpolation or disable it. Enabling (default) will estimate a height value for every single cell even if no points occur in the cell. If interpolation is disabled, cells without a point become no data.

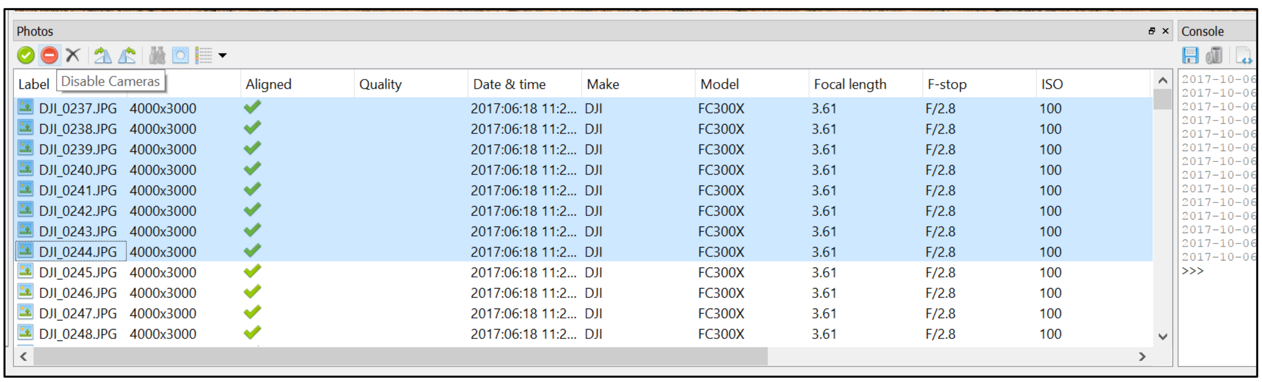


After building the DEM, you can view it in the ‘Workspace’ pane (double-click), as shown in graphic below.



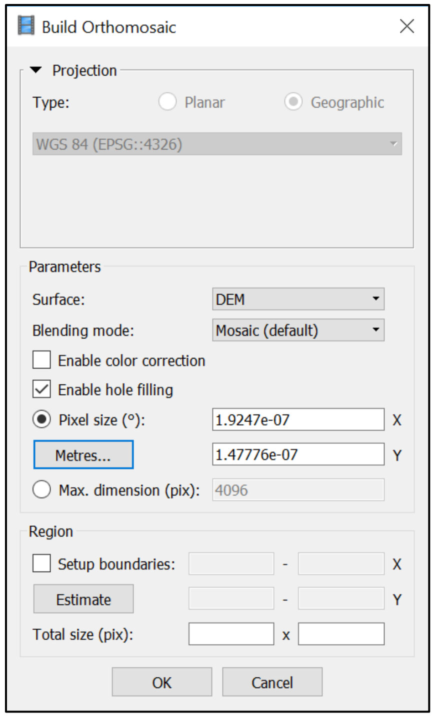
Build Orthomosaic

It is best to use only nadir images for the orthomosaic. If you have oblique images in your chunk, you should disable them before mosaicking. In the photos pane, select all of the oblique images then click the 'disable' cameras button. The button has a red circle symbol. Disabling cameras is only a temporary action that can be reversed at any time.

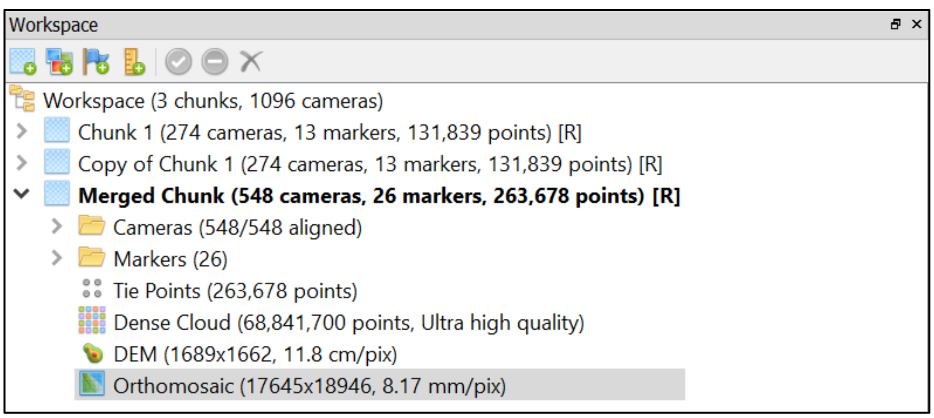


Workflow>Build Orthomosaic

When making the orthomosaic, stick with the default parameter for the blending mode. Only use color correction if there is substantial illumination difference between images. Enable hole filling.



You can view your newly created orthomosaic through the chunk menu in the workspace pane.



Export Image Products

Point clouds, DEMs and orthomosaics can each be exported out of Photoscan to be used in other software programs such as GIS. Export point clouds as .las files as this is the standard format to read and analysis point clouds. You can export DEMs and orthomosaics in a variety of raster formats.

To export a dense point cloud, go to *File>Export Points…* Name your file and select the file type (.las). Ensure the proper coordinate system has been selected is set and create the point cloud.