GEOS 639 – Geodetic Imaging

Lab 2 / Homework 2: Structure from Motion Processing with Agisoft PhotoScan Professional

Instructor: F.J. Meyer

Homework 2 issue Date: Feb 15, 2022 **Homework 2 due date: Mar 01, 2022**

Introduction

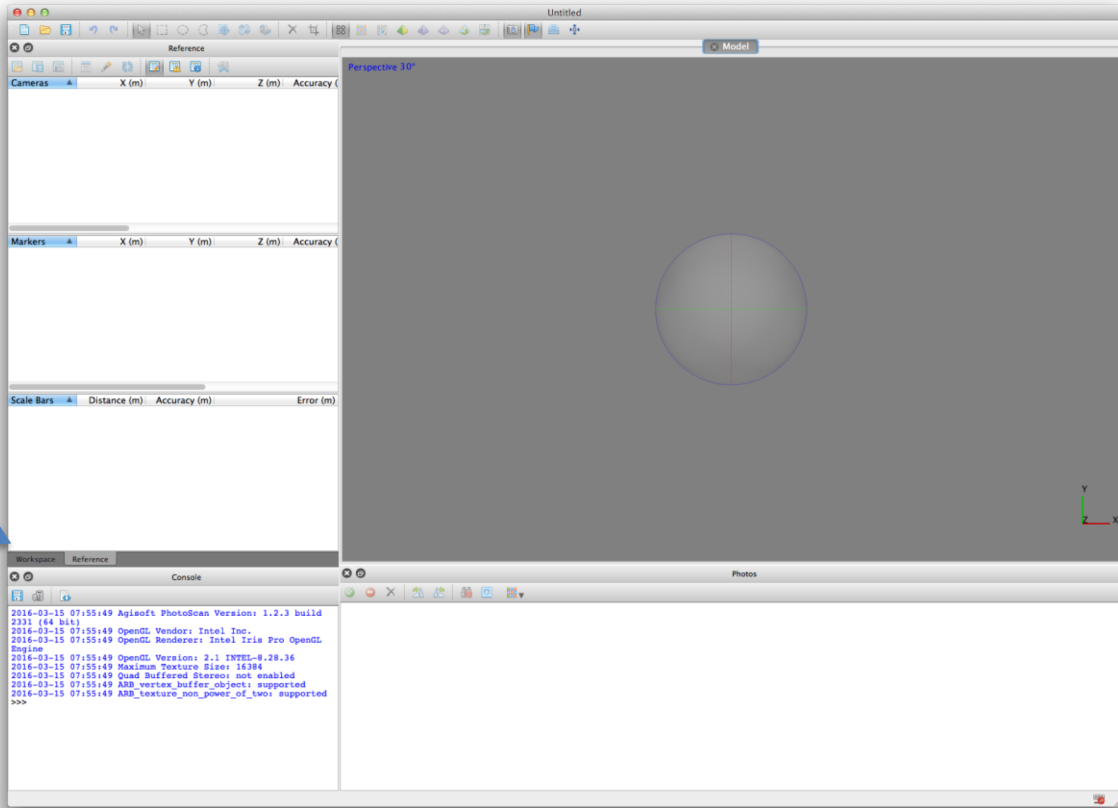
Agisoft Photoscan Professional is a commercial structure from motion (SfM) software package that has been installed on the lab computers for student use. It is available under the Start menu and can be started through Start->All Programs->Agisoft->Agisoft Photoscan Professional. For the purposes of this lab a set of test data have been prepared for your use. It should be downloaded following the instructions in Step 2. The test dataset consists of approximately 100 images of the village of Minto, AK. These were taken with a standard DSLR-type camera flown on a helicopter, however, they do not have embedded GPS locations. Instead, a file of camera positions has been provided and these will serve as a substitute for EXIF GPS data.

This lab will walk you through the basic process of using Photoscan for SfM processing. **At the very end of this lab**, you will find one page of instructions for **Homework 2**, which will ask you to reprocess some processing steps with different setting and analyze the resulting changes.

1) Start up PhotoScan Professional

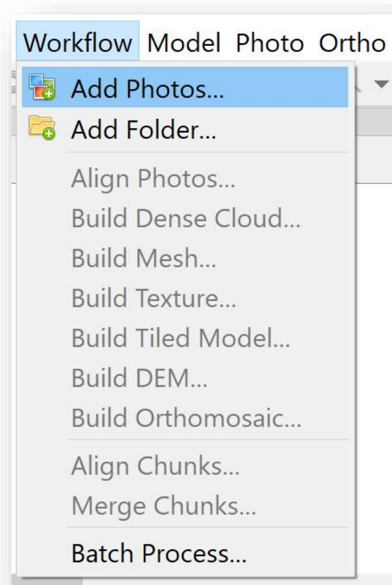
Under the Start menu, go to All Programs-> Agisoft -> Agisoft Photoscan Professional. It should open a window that looks something like this:

Reference/
Workspace
Tabs



It is possible that you will get a pop-up message about a new version of the program being available. If you do simply close that; the version that is installed is a very recent version. If your window doesn't look quite like this it may be that the Workspace tab is open instead of the Reference tab. This is fine. Feel free to click around and familiarize yourself with the interface.

2) Load your Image Set



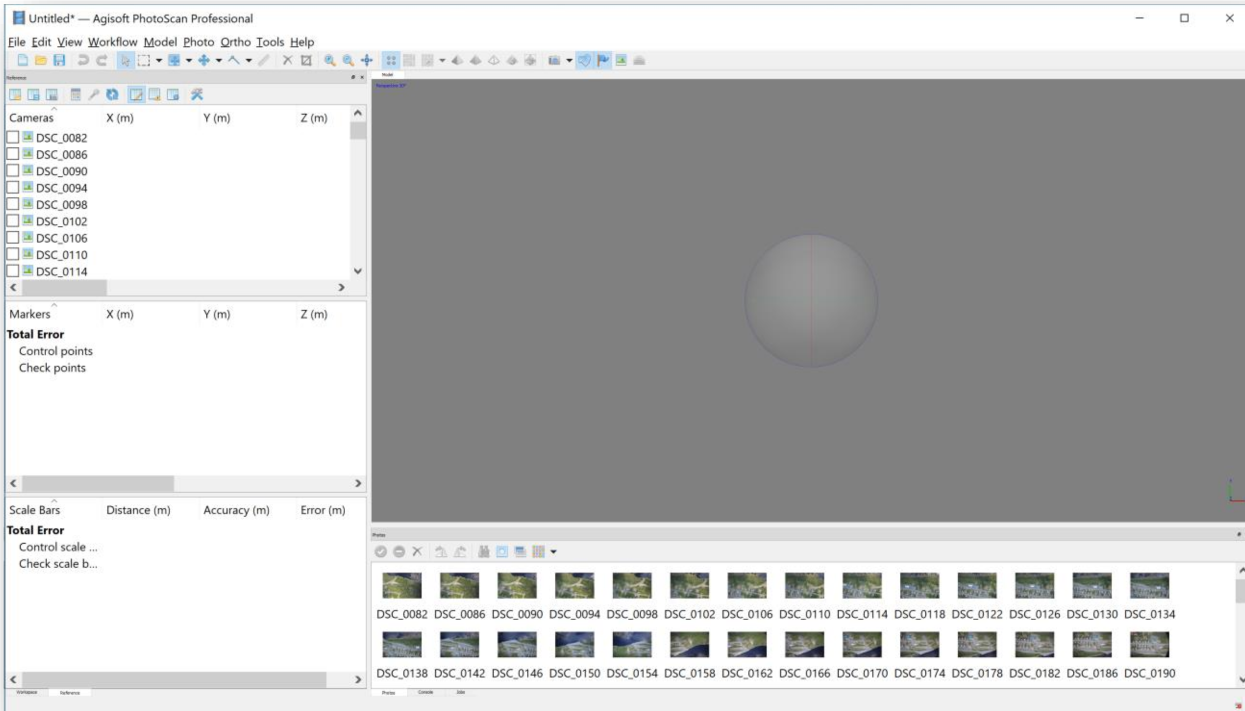
The first thing you will do is load your image set into the program. The image set is located here:

https://drive.google.com/open?id=1hcaUVIf9MhDrZO6PLpY4-2ounTrrTQSR

Please download and unzip the data.

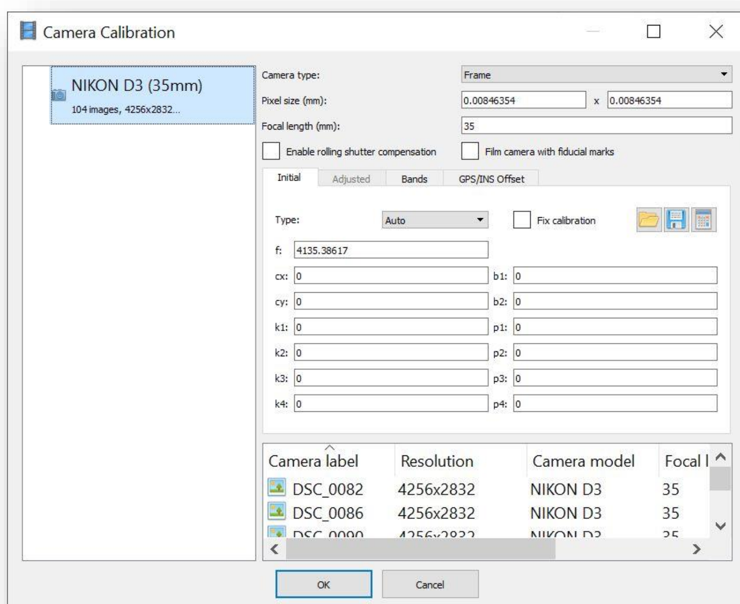
The folder contains a set of JPG images from a DSLR camera. Under the **Workflow** menu, select "**Add Photos…**"

This will open up a standard file selection dialog box. Navigate to where you have saved the shared folder and select all the .JPG images that are in that folder. Then select OK. Your main PhotoScan window should now look something like this:



Note that the images have been loaded, but you do not see their positions on the screen yet. That is coming up once the camera coordinates were loaded.

3) Check Camera Calibration Settings



Before processing, we want to see if the camera information has been read properly. Under the **Tools** menu select "**Camera Calibration**" and another dialog will pop up.

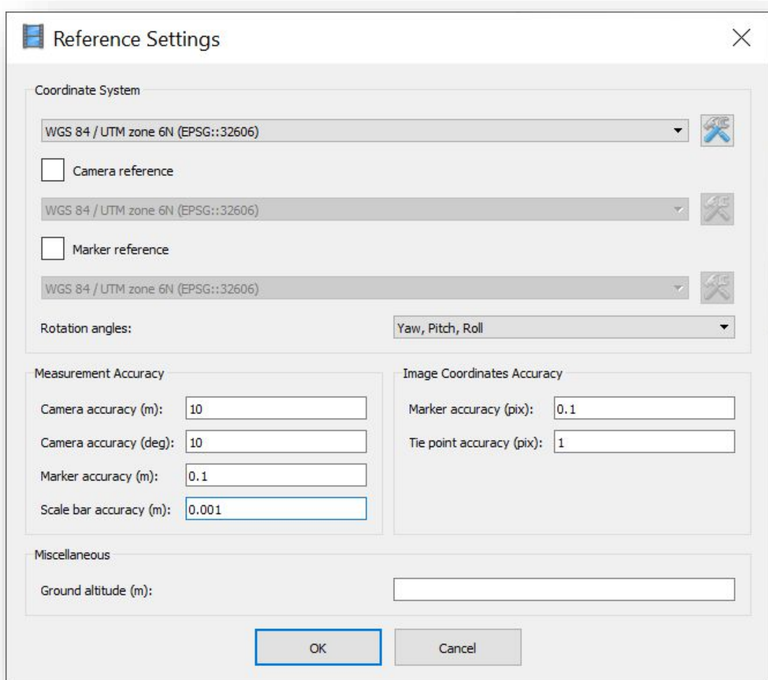
If you look at the lower pane, you will see that the camera has been identified as a Nikon D3 and the lens focal length is also identified at 35mm. This type of information is normally available for any modern camera.

The type of camera is automatically selected as *Frame*. This is fine for this camera. If you were using a heavily distorted camera, such as a GoPro or DJI Phantom camera you would want to change the Camera Type to Fisheye for the best results.

You will also see that the focal length and principle point offset have been estimated in this screen. The units on those values are image pixels. Note that the remaining interior orientation parameters are set to 0. If you knew your camera's calibration parameters you could either enter them here or load from a text file. This can be useful particularly if you are using a heavily distorted lens.

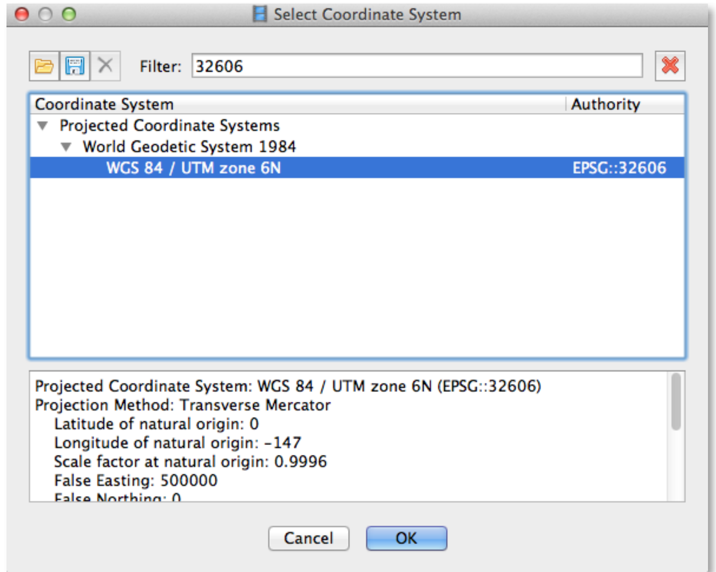
4) Set Reference Settings

Once the images are loaded you need to set up the reference system for your imagery and ground control. In general, you want your image positions and ground control in the same reference system, however, this is not absolutely required. In this case, both our camera positions and ground control are in UTM 6N coordinate system. To view the reference settings make sure you are in the **Reference tab** in the main window and select the reference button: . This will open up the **Reference Settings** dialog box.



In this dialog you set not only the coordinate system for your project, but also the accuracy of your cameras and ground control. Under the coordinate system dropdown you probably won't have the coordinate system you are interested in. If you select **More…** from this drop down you will get the Coordinate System dialog. In the filter type 32606, which is the EPSG code for UTM 6N.

Select the coordinate system and hit OK. In the Reference Settings dialog please set the **Camera accuracy** to 10m (should be the default) and **Marker Accuracy** to .1m (10cm). In general it's a good idea to set these accuracy numbers at what you think is actually reasonable for your data.

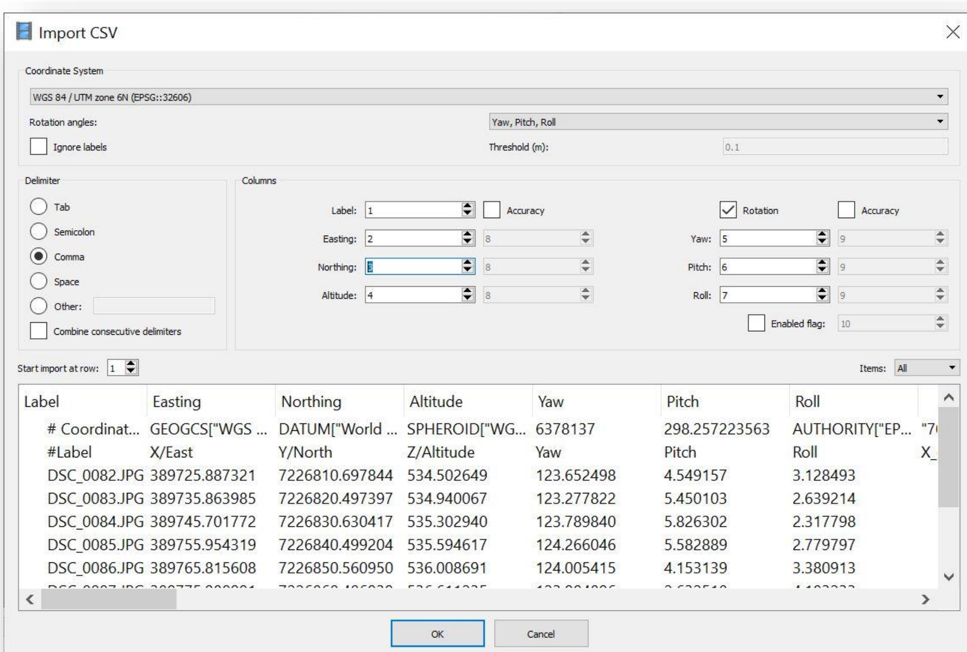


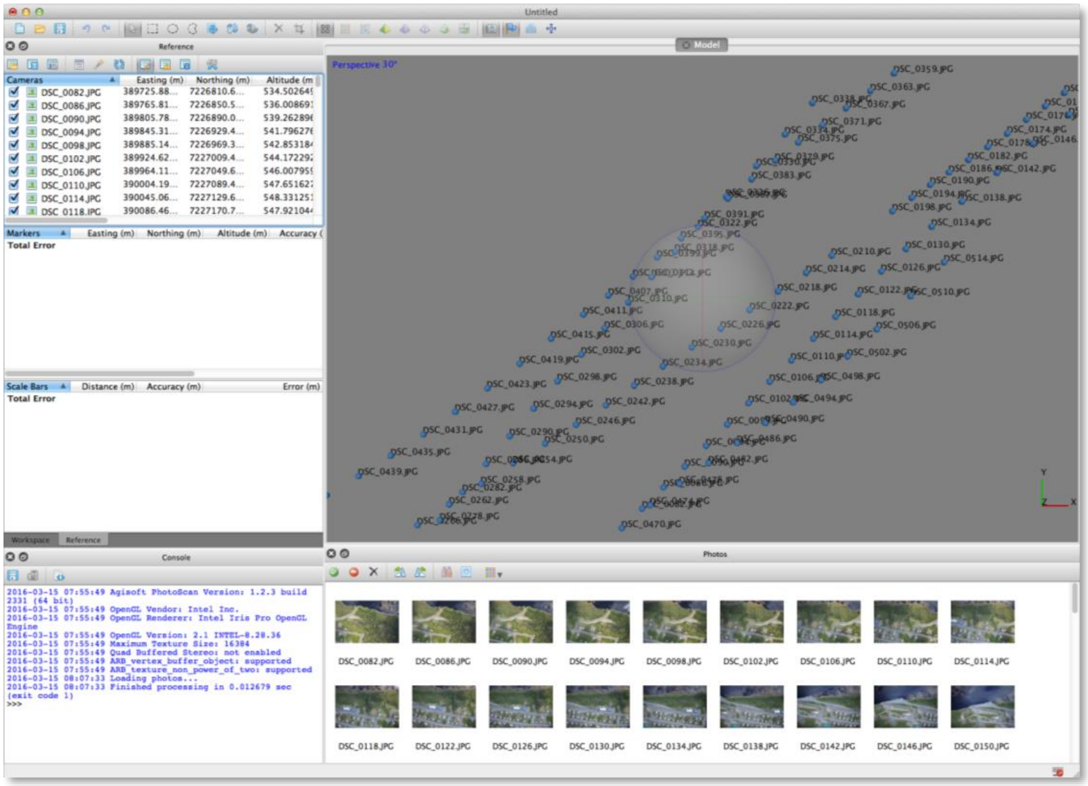
5) Load Camera Positions

Now we can load the camera positions from the provided text file. The file is called *Minto-Camera-Positions.txt* and is available in the shared folder. In the **Reference tab** select the **Import** button: . This will open up a standard file select dialog and you can select the camera position file here. After selecting the file you will get the Import CSV dialog.

Make sure to set the Coordinate System to 32606. Then you need to make sure that the values from the file are in the appropriate parameter. In this case, Easting is column 2, Northing is column 3, and Altitude is column 4. Your Label **MUST** match your filename. If you are generating this file for a different project you need to make sure that the Label matches the filename or else the data will not be properly assigned. Once you have the settings set up properly select OK. You may get a dialog that will say the system didn't find some of the cameras. This is fine, just say **"No to All"** when asked if you want to create them.

You should now have the image positions loaded and you can see the estimated positions in the main Model window. Your screen should look something like the figure on top of page 6 (next page).



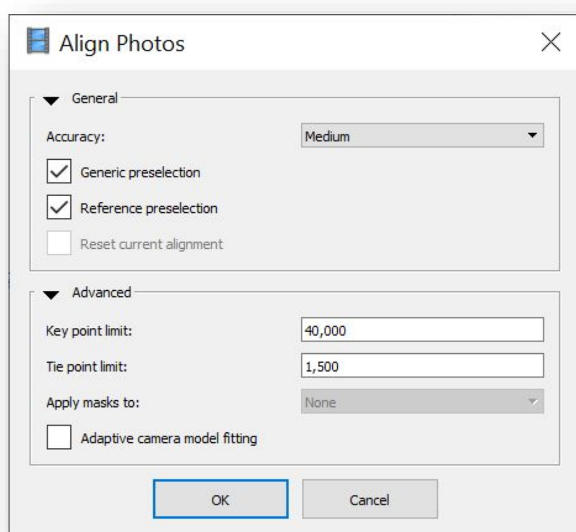


At this point the images are loaded with positions and these initial positions will be used by Photoscan to reduce alignment time.

6) Align Images

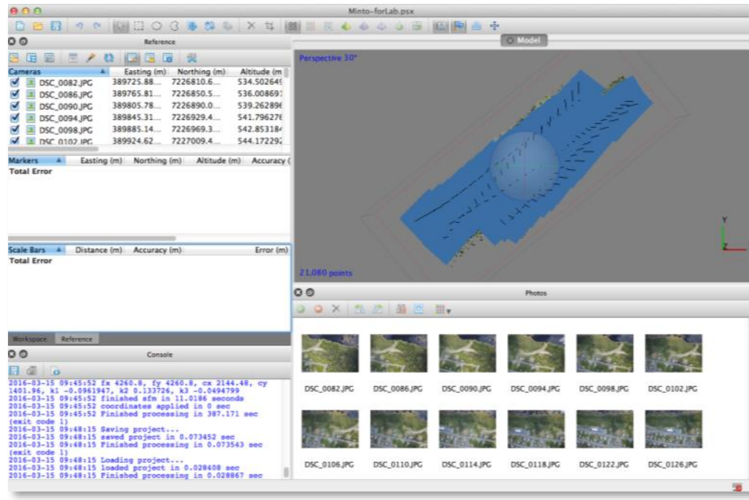
Finally, we are ready to do some initial processing. Under the **Workflow** menu select "**Align Photos…**" and the align dialog will open up.

In order to reduce the amount of time for processing, the settings in the image in the bottom right corner would be good to start. If you are processing your own project data you very likely would want to use the **High** or **Highest** accuracy setting. For the most part a key point limit of 40000 and tie point limit of 1500 are good places to start. If you want to get as many tie points as possible, you can set the limit to 0 and this will use all the matched key points as tie points.

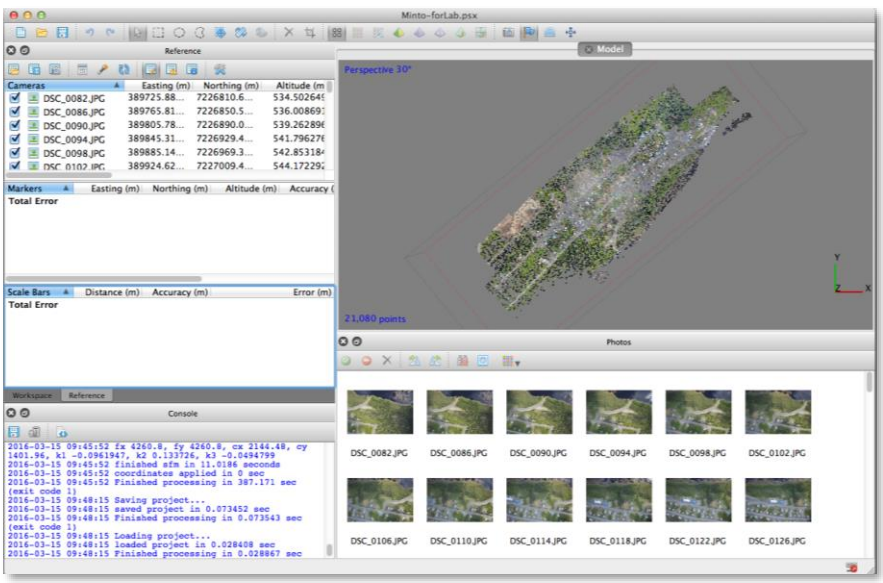


Once you have this set, select OK. This will probably take about 10 minutes to run. Once complete, you will get your sparse point cloud and see the estimated camera positions. Your main window should look something like

You can turn on/off the camera overlays by selecting the  button in the main toolbar of window. With the cameras turned off, the main window should show the sparse point cloud (see image at the end of Section 5).



You can navigate in the main window by grabbing and turning the trackball that is displayed in the middle of the Model window. If you hold down the Control key and then mouse you will move the model itself within the window. This is useful when you want to zoom into particular regions of your model.



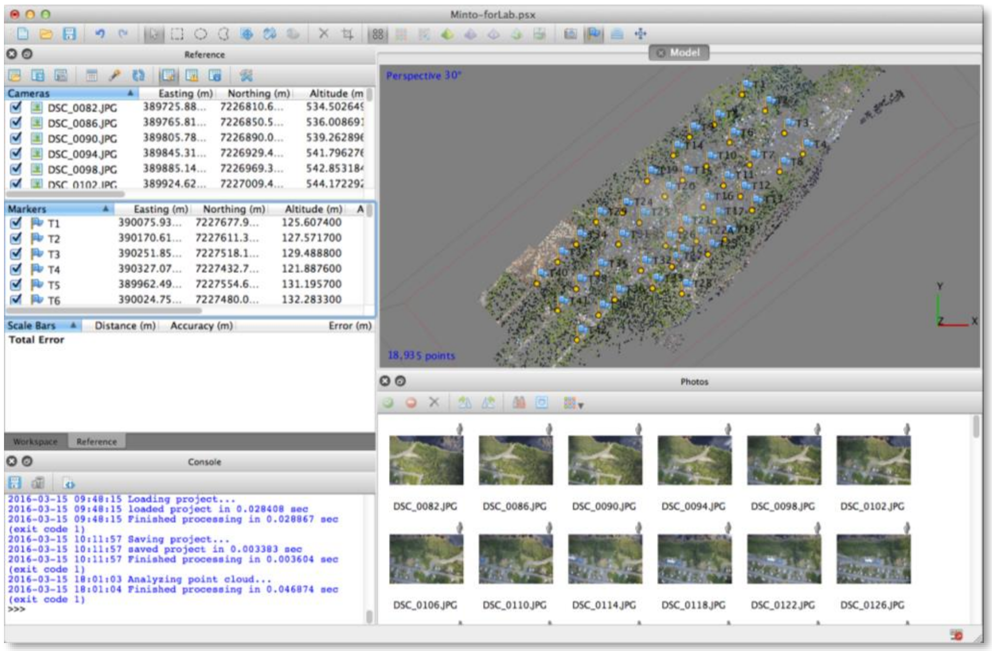
7) Perform Gradual Selection

Gradual selection is not a required step, but can be useful to get rid of lower quality points from your sparse cloud. Select **Model->Gradual Selection** to pull up the dialog box. You can change the settings and in the main window you will see points be selected and deselected. If you set Reprojection Error at 0.35 you should get about 10% of your points selected. You can then delete these points from the project by hitting the **cut button** in the toolbar . Feel free to play around with different options and settings to see how it impacts the number of points selected.

8) Load Ground Control

Ground control positions have been provided in the file titled *Minto-MarkerPositions.txt*. Load this file as you did the camera position file using the **Import** button under the reference pane. You will note that the Easting/Northing in this file is backward from the camera position file. Make sure you select the right column for each value. Remember that in Alaska the Northing is always an order of magnitude larger than the Easting.

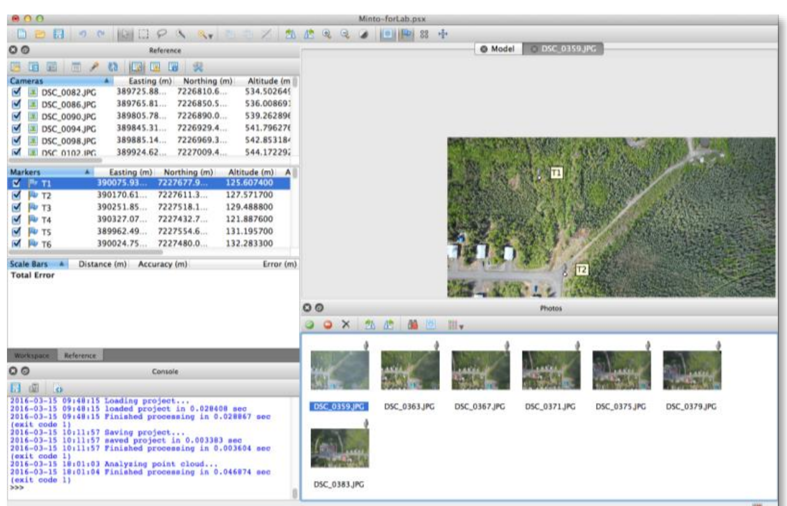
PhotoScan will ask you if you want to create new markers for these points, select **Yes To All** and these points will be created. You should see them in your main window now as yellow dots.



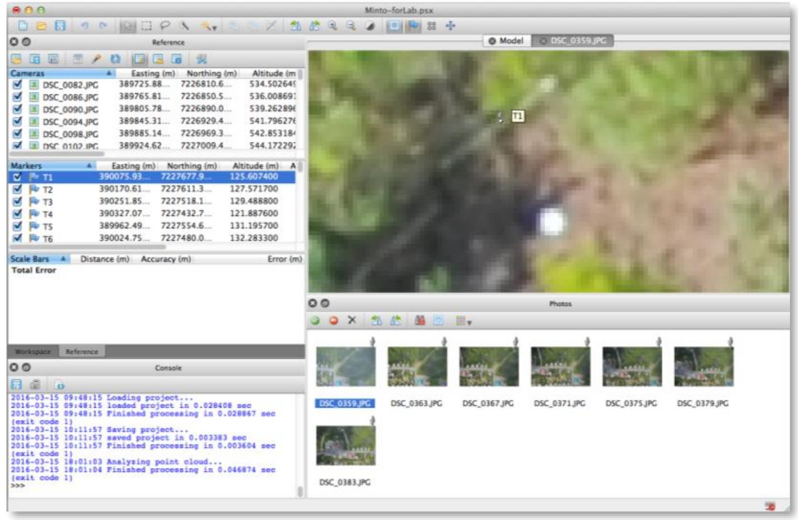
While these have been loaded, they are not really placed in the project yet. That's the next step.

9) Place Ground Control Points and Check Points

Placing the ground control is the only real manual part of this process. In the Markers pane, select marker T1 and right click on it. Then select **Filter Photos by Marker** from the contextual menu. This will show you only the photos with that marker in them. They will each have a small grey flame next to them. That means they have ground control in them, but none of the points are placed yet. Double click on the first image

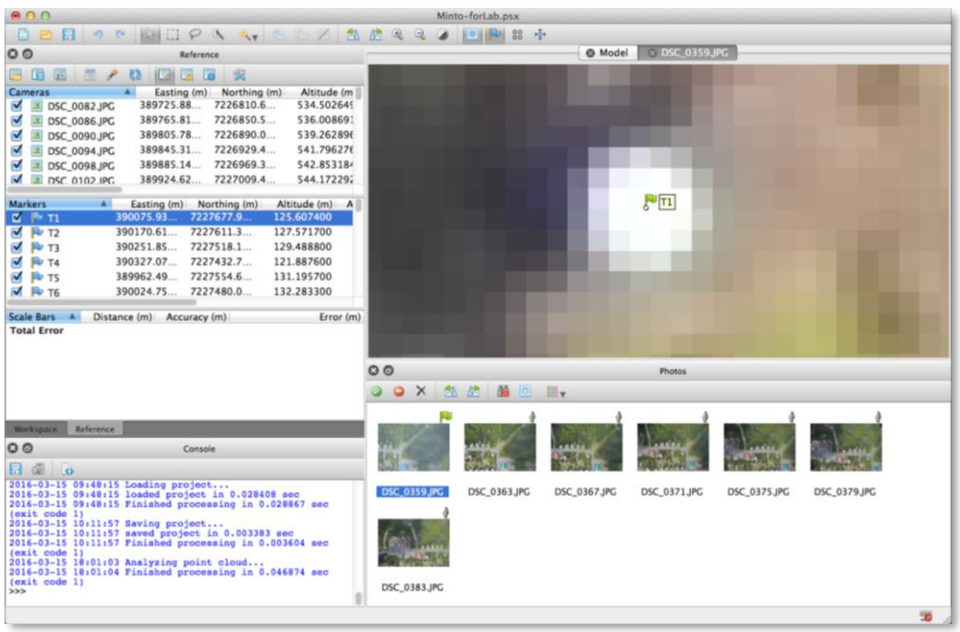


in the Image pane. This will load the image in the main window and center on point T1, which is the selected point.



Zoom into the point until you can clearly see the white control marker (see figure to the right).

Here you can see the point from the file is not well aligned with the actual control target. This is because the sparse cloud is aligned to the camera positions, which are not as accurate as the control points. In the main window grab the control point and move it to the center of the white target, then zoom into the target a bit more to get it centered nicely.



Note that the grey flame has turned into a green flag. This means the point is placed in the project. You can move directly to the next image by hitting the Page Down button. This will retain the zoom level and makes for a bit more efficient placing of markers. Do this for the remaining images in this set. You will note that as you set more points the remaining positions will improve their accuracy.

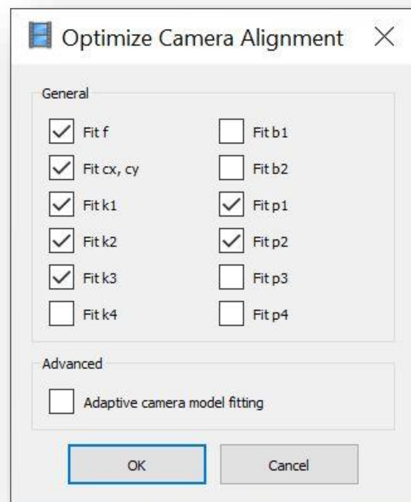
Continue placing points that will be used to control the model. **Place at least points T1, T4, T40, T42, T14, T18, T28, and T29. These will be used as control**. Pick an additional 3 or more points spread throughout the AOI that will be used as check points. Place them using the above method and when all images are placed then uncheck the control point in the marker pane. That will reserve the unchecked points as check and not control points.

10) Optimize Alignment and Check Errors

Once the control and check points are place you can scroll to the right in Marker pane to see the estimated error for each point and the aggregate error at the bottom. These values will probably vary from a few tens of centimeters to 5 or 6 meters for the worst points. Remember this is still based on the camera positions, so errors are to be expected.

11) Perform Absolute Orientation and Camera Self-Calibration using Bundle Block Adjustment

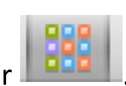
Next we will apply the control and generate our absolute model using bundle block adjustment. To do this, select the **Optimize** button in the **Reference pane** . This will bring up the **Optimize Camera Alignment** dialog box (See at right).

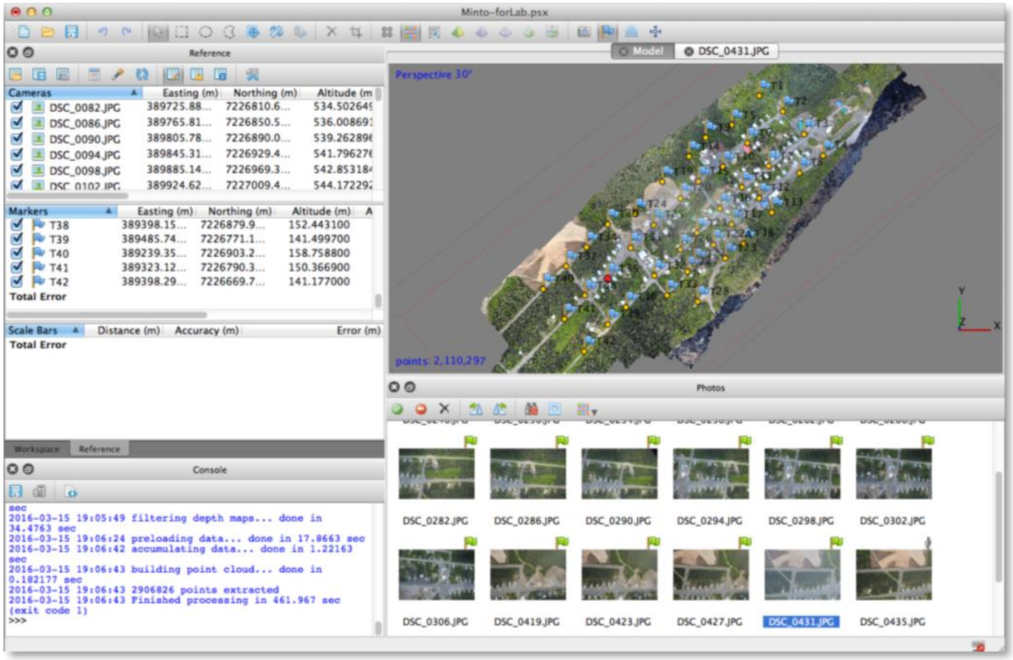


Within the bundle block adjustment we have the option to perform a camera self-calibration by estimating the radial lens distortion parameters k_1, k_2, and k_3 as well as the tangential distortion parameters p_1, p_2. Given the quality of these images and lack of extreme distortion, the default parameter optimization should be fine. Select **OK**. Once optimization is complete go look at the errors in the marker pane again. Your control point errors should have reduced to a few millimeters and your check point accuracy should be a few centimeters.

12) Generate Dense Cloud

Under the **Workflow** menu select **Build Dense Cloud**. In the dialog box select “Low accuracy” for your point cloud. This should allow the dense cloud to be easily generated during the lab. In real usage you would want to use an accuracy setting that is best for your data. The lab data would process very nicely at High accuracy, however, it would take longer than the lab allows.

Once processing is complete select the dense model visualization option in the toolbar . You should now see the dense cloud visualized in the main window. Note also that the point count shown in the main window has gone up from 10,000 or so points to over 2 million.

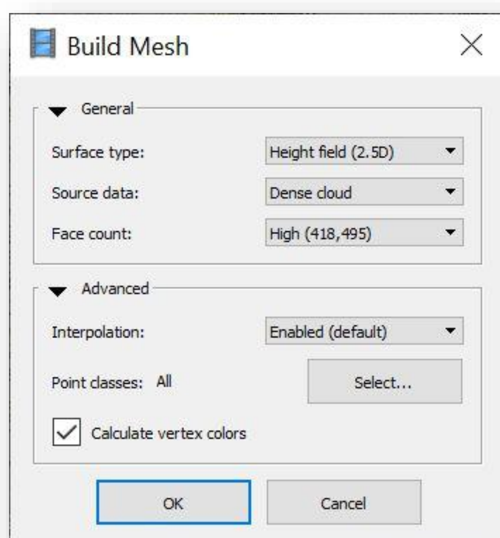


Height variation can be easily seen in the dense cloud. Navigate around a bit and see how the features look. Remember to hold down the Control key to translate the model in the window. If you zoom closely into the model you can see the irregular spacing of the dense cloud points. The dense cloud can be output in a variety of formats, including Stanford PLY and LAS using the Export Points option under the File menu. You could then visualize the cloud in external tools.

Once the dense cloud is built you have two options for generating a model. You can generate an irregular mesh directly or you can generate a regularly space DEM. Either can be used to output your final product. The best choice will depend on your data and the structure of your region.

13) Build Mesh

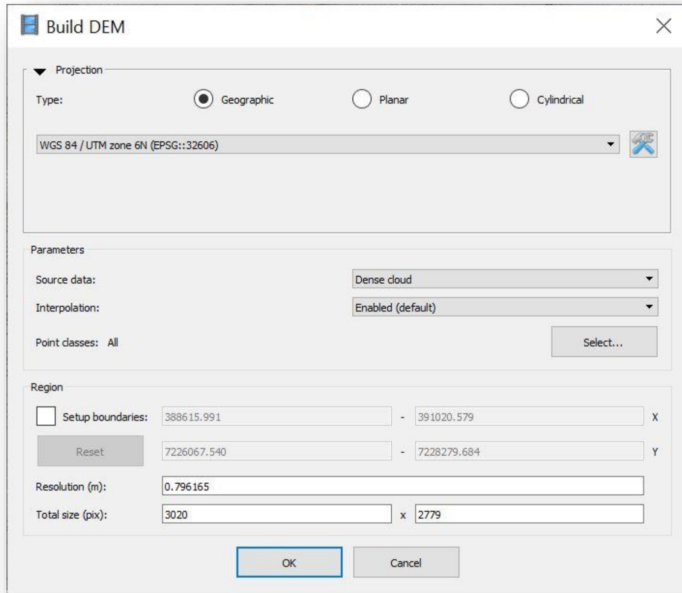
The mesh, as defined by PhotoScan, is the triangulated irregular network derived from the points in the dense cloud. This step is relatively simple step and is started from the **Workflow-> Build Mesh** menu.



For the lab use the settings given here (Height Field/Dense Cloud/High). In general, if you working with map-type data you will want to select "Height Field" as your surface type. The "Arbitrary" surface type should only be used when you are modeling a 3-D object. It will take longer to process than Height Field.

If you want to manually enter the number of faces, select "Custom" and enter a value.

14) Generate DEM

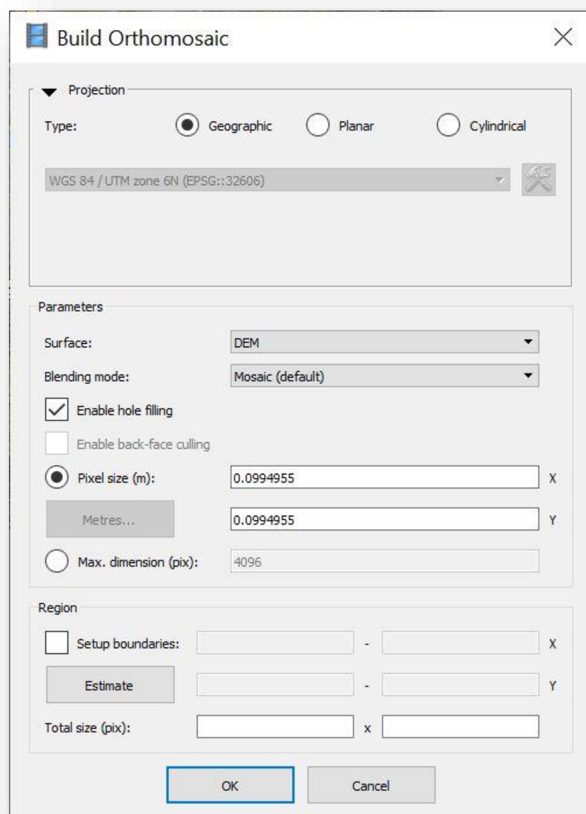


If you are working with terrain data you will most likely be generating a DEM. This is a regularly spaced grid of elevation points based on your dense point cloud. Under the **Workflow** menu you will find an option for **Build DEM**. This will bring up a dialog that looks like

If you have not saved your project yet PhotoScan will force you to do so at this point. You should save your projects as .psx files. If you want to build DEMs or orthomosaics this is a requirement.

You should be able to use the default options for your DEM, but make sure the coordinate system is properly set and that your source data is the Dense Cloud. You can also subset if you want using the Setup boundaries option, but for the lab data you do not need to do so. Note here that you DEM post spacing is also calculated. It will be based on the density of the dense cloud you generated. If you generate a denser cloud you will have a lower post spacing.

15) Generate Orthomosaic



Once you have your DEM generated you can generate the data required for the orthomosaic. This is found under **Workflow->Build Orthomosaic**. This will bring up the dialog to the right.

As with the DEM generation, the defaults should probably be acceptable. You will want to make sure you're using the DEM you just generated for the orthomosaic generation and "Mosaic" as the blending mode. The pixel size given here is based on the max resolution of the input imagery. It is not dependent on the density of your point cloud or DEM and generally should not be changed unless you are generating a low-resolution model as a quicklook or similar.

16) Export DEM/Orthomosaic

Your final products, both DEM and orthomosaic, can be exported using the appropriate option under the **File** menu. You can export both in a variety of formats, but the ones you will use most often are probably Geotiff and Google Earth KMZ. Note that with both DEM and Orthomosaic export there is an option to split the products into tiles if you are exporting Geotiff or geoJPEG. This is often useful when you have a large mosaic that will be too large to export as a single file.

!! Make sure to save the DEM file and keep it in a secure spot. You will need the DEM file for Homework 2!!

17) Generate Product Report

Finally, your data have been processed and products output. You can generate a report that includes information about your processing project. Under the **File** menu select "**Export/Generate Report…**" and give your report a title.

!! Make sure to save the Product Report file and keep it in a secure spot. You will need this report to answer some of the questions in Homework 2!!

17) Save Project

Under the File menu in PhotoScan, save your project under a sensible name. **← This is also needed for Homework 2.**

End of Lab Section

–

*See next page for **Homework 2** instructions*

Homework 2 Instructions (20 total points)

Homework 2 due date: Mar 01, 2022

Introduction

We will consider the work in the lab as the "**reference run**". For the homework assignment I am asking you to create a ***modified*** model run whose results you should compare to the results of the reference run. You will need the DEM file and the Project Report file from the reference run to conduct the homework. **You will also need access to PhotoScan for this homework.**

For Homework 2, please conduct the following analyses:

1) Change Camera Coordinate Accuracy and Redo Bundle Block Adjustment (6 points)

Load your reference project into PhotoScan and examine the "Cameras" and "Markers" tabs in the reference panel (panel on the left). The "Cameras" panel shows all camera coordinates together with their presumed initial accuracy and their final estimated accuracy. The "Markers" tab shows similar information for the identified GCPs.

- Write down the "Total error" estimate on the bottom of the "Cameras" tab and the total error estimate on the bottom of the "Markers" tab. They correspond to the average error for camera positions and GCP locations that were estimated in the reference run.

Mark all cameras and right click. In the appearing menu, select "**set Accuracy ...**" and change the accuracy setting for all camera positions from the current setting of 10m to the new setting of 0.1m. Also change the Accuracy of the camera orientation from 10˚ to 1˚.

Also mark all markers and right click. In the appearing menu, select "**set Accuracy ...**" and change the accuracy setting for all marker positions from the current setting (0.1m) to 10m.

- Now redo **Step 11** of the reference run ("Optimize Camera Alignment) with the modified camera accuracy setting by clicking on the  symbol.
- **Provide a table** comparing the *total camera position error* and *total marker position error* of both the **reference run and modified run**.
- **Provide a summary description of** how these error numbers have changed
- **Provide an explanation** of the observed changes

2) Rerun Dense Cloud Generation and DEM Generation Steps

Continue to rerun **Steps 12 – 14** of processing flow with modified settings.

3) Export DEM of Modified Run and Export Modified Project Report (4 points)

Export the DEM created during the modified run as GeoTIFF (give it a useful name). Also export the Project Report of the modified run.

- **Provide plots** of the reference run and modified run DEMs side-by-side with color scale information
- **Provide** the two Project Reports as attachments to your homework.

4) Compare DEMs of Reference and Modified Run (4 points)

Compare reference run and modified run DEMs in ENVI or a GIS tool. In ENVI you can use Change Detection (under the Utilities tab) and/or band math (also under the utilities tab). In ArcGIS you will find appropriate tools in the Spatial Analyst Toolbox. Please note that in ENVI the band math option won't work "out of the box" if the sizes of the two DEMs are different. If that's the case, do Change detection first and perform band math on the co-registered bands that are created during change detection processing.

- **Provide a summary** of the DEM differences that you can identify.
- **Provide an explanation** for why the DEMs might be different in the observed way.

5) Compare Reference and Modified Run Project Reports (6 points)

Open the two project reports for reference run and modified run.

- Look at ***page 4*** of the reports (Camera Calibration) and compare the estimated camera calibration results for the two runs.
    - **Provide a summary** of the differences that you can see in the plots of camera distortions?
    - **Provide a summary** of the difference that you see in the estimated camera distortion parameters?
    - **Provide an explanation** for the observed changes?

- Look at ***page 5*** of the reports and compare the error ellipses for the estimated camera positions.
    - **Comment on** how the absolute error and the distribution of errors of camera positions change?
    - **Explain the changes** that you are seeing