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Pix4Dmapper Exercise 1: Image Processing for UAS Imagery

Introduction

Pix4Dmapper is a photogrammetry software suite compatible with UAS (unmanned aircraft system) imagery that enables you to define areas of interest, select processing options, add ground control points (GCPs), and create and edit point clouds, digital surface models (DSMs), meshes, and orthomosaics. Default templates provide automatic processing for new projects and can be customized for more control over data and output product quality.

This exercise will introduce you to the general workflow for processing UAS imagery in Pix4Dmapper. Please see exercise 2 for a more in-depth look at some of the settings and tools found in Pix4Dmapper. As you work through this exercise, please refer to the Pix4Dmapper Help Documentation for additional information about each of the steps. The help documentation can be found on the Pix4D website or by clicking the **Help** tab within the software interface.

Objective

- Become familiar with the user interface and features found within Pix4Dmapper.
- Learn how to georeference imagery and create a dense point cloud, a 3D textured mesh, a digital surface model (DSM) and an orthomosaic with Pix4Dmapper.

Prerequisites

- Download and unzip exercise data of the embankment and spillway at Tony Grove Lake in northern Utah: TonyGrove_subset_20191015.zip
- Download exercise data Ex1_TonyGrove_GCPs.txt **(optional)**
- Review the Appendix located at the end of this document
- Install and activate Pix4Dmapper (please see Pix4Dmapper Installation Guide for details)

NOTE: *If you experience cursor misalignment throughout this exercise, open your* ***File Explorer*** *and navigate to your* ***Program Files*** *folder on the Drive you installed Pix4Dmapper. Right click on the pix4dmapper.exe file and in the* ***Properties*** *window, select the* ***Compatibility*** *tab. Enable* ***Disable display scaling on high DPI settings*** *and click* ***OK****. You may need to close and reopen Pix4Dmapper for the cursor to be recalibrated.*

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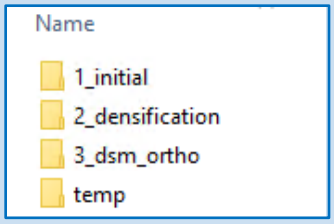
Part 1: Getting Started

In this first part of the exercise, you will navigate the project creation wizard, which consists of five windows, to configure important settings and options for your Pix4Dmapper project. This section will acquaint you with folder directories where the project outputs will be stored, where you can manage the camera model's parameters, select coordinate systems, and select your processing options template.

A. Create a Project

1. Launch Pix4Dmapper by searching Pix4Dmapper in the Start menu bar and click **New Project**.
2. Name the project TonyGrove and set your file directory. Make sure the radio button for New Project is selected and click **Next**.

NOTE: *Structured subfolders will be generated within your project folder along with your LOG file, which you can use to review your settings and accuracy once your project is finished. You can locate your generated reports in* ***1_initial****, your point clouds in* ***2_densification****, and your digital surface model and orthomosaic in* ***3_dsm_ortho****.*



If you leave the file directory as the default pathway, your project folder will be created at ***This PC****,* ***Documents****,* ***Pix4D****. If you want to save the project folder elsewhere, you can specify a desired directory upon creating a new project. After you finish processing, you can go to this folder to access the products and to import them into other GIS software, such as ArcGIS Pro, for further investigation and use.*

B. Add the imagery

1. In the Select Images window, click on **Add Images** and browse to the unzipped folder for TonyGrove_subset_20191015 in which the imagery is stored. Select all 105 images and click **Open**, then **Next**. It may take a moment for Pix4Dmapper to read the geotag data.
2. Leave the following parameters as their default values:
   i. Datum: WGS 1984; Coordinate System: WGS 84 (EGM 96 Geoid)
   ii. Geolocation Accuracy: Standard
   iii. Selected Camera Model: FC6310_8.8_5472x3648 (RGB)
3. Click **Next**.
4. In the Select Output Coordinate System window:
   i. Ensure that the Unit is specified as meters (m).
   ii. Leave the following parameters as their default values:
      (a) Autodetected: WGS 84 / UTM zone 12N

(b) Advanced Coordinate Options: unchecked.

> ***NOTE:*** *You can check Advanced Coordinate Options to further explore and set alternative output and vertical coordinate systems for adjusting the geoid height but for this exercise, we recommend using the default settings.*

5. Click **Next**.

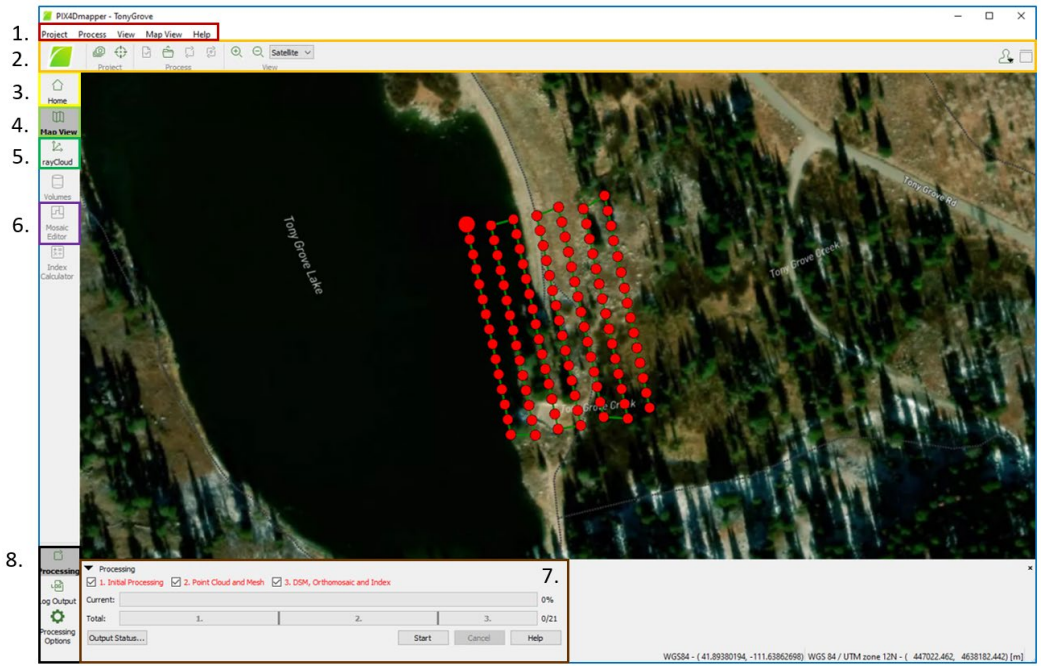
C. Select Template

1. Under Processing Options Template, navigate to the Rapid tab, then select **3D Maps – Rapid/Low Res**.
2. Uncheck **Start Processing Now** since we'll explore our processing options before we start aligning the images.
3. Click **Finish** to finalize the initial project setup.

> ***NOTE:*** *Depending on what outputs your project requires and what imagery you are loading, you can opt for different templates. For producing Point Clouds, DSMs, 3D Meshes and Orthomosaics from aerial imagery, you will select either Standard or Rapid **3D Maps**. Rapid will produce lower quality results more quickly so we will use rapid for this exercise. These options are also good for measuring volumes, digitizing houses and roads, and generating contour lines. For producing Point Clouds and 3D Meshes from ground-based imagery, you will select either Standard or Rapid **3D Models**. This option is good for 3D models of buildings, statues, and other objects. If you opt to use Standard processing for larger image files, you may want to consider running the process overnight.*

D. Exploring the Main Viewer

When you have completed your initial project setup, Pix4Dmapper will open in Map View. Map view consists of the following main components, color coded to match the following figure:



1. Red: Menu bar

   Here you can find five menu bar items: Project, Process, View, rayCloud and Help. Depending on which tab you select, you can open, save, and create new projects, define properties of images and ground control points (GCPs), change your output coordinate system, update processing options, change which View Toolbar items are displayed, change navigation modes depending and access online support and community forums.

2. Orange: Toolbar

   Depending on the status of the project and which options have been selected, some buttons within the Toolbar may be grayed out. These tools are divided into six subcategories: Project, Process, View, Navigation, Clipping and Point Cloud Editing. From these options, you can update image geolocation and camera model information, select, or change your coordinate system, import, edit, add, or remove ground control points, force open the Quality Report, reoptimize your outputs, change how you view your data and edit and correct your point cloud if errors occur (e.g., reclassification). On the far right of the Toolbar you can access the login information, manage licenses and privacy preferences as well as access the shortcut button for turning on and off the Sidebar.

3. Yellow: Home Tab, View Toolbar

   Home takes you back to your Welcome View window where you can select to generate a new project, open an existing project or access community forums and tips.

4. Light green: Map View Tab, View Toolbar

   Map View will display a 2D map version of your project with a satellite imagery background when images are geotagged.

5. Dark green: rayCloud Tab, View Toolbar

   The rayCloud tab is where you can visualize different elements such as cameras, GCPs, dense point cloud output, classification of cloud points and a textured 3D mesh. Here, you can also georeference your project, improve accuracy, create orthoplanes and other objects, measure distances and surfaces and export your point cloud files. Volumes enables you to draw and visualize volumes, measure them and import or export them also.

6. Purple: Mosaic Editor Tab, View Toolbar

   When Mosaic Editor is selected, you can visualize the DSM, DTM and mosaic, as well as improve the visual aspect of the orthomosaic.

7. Brown: processing Menu

   Under the Processing Menu, Processing Options generates a pop-up window where you can edit your parameters for each of the individual steps: Initial Processing, Point Cloud and mesh and DSM, Orthomosaic and Index.

8. Black: Processing View

   The Current bar shows the processing status of each sub-step is displayed as a percentage, and the Total bar will show the processing status of all steps that have been selected as the number of completed steps. Before hitting the Start button to run the process, each step can be checked as to whether the user wants to run the three-step process as a batch, or section by section. To stop the processing part way through, the user can hit the Cancel button.

Part 2: Image Alignment and Calibration

After loading the images and setting up the project file, Pix4Dmapper gives you the option to run Initial Processing. In this step, Pix4Dmapper aligns the images to one another using Structure from Motion (SfM) algorithms. The first part of this is that it finds thousands of contrasting features in each image, which are saved as key points. It then compares key-point patterns between images to identify and create automatic tie points (ATPs). Once the ATPs are identified, the software uses aerial triangulation to estimate the camera-calibration parameters and to refine the image coordinates. location of the images. Doing so improves the accuracy of the 3D model and products.

NOTE: *In this exercise, the images you use are already georeferenced, enabling you to immediately start processing. In the case where your images may not be georeferenced, refer to the Appendix to learn how to place initial Ground Control Points (GCPs) using your Ex1_TonyGrove_GCPs.txt file and the Basic Editor tool and rayCloud. This is an optional step that you can practice when you have sufficient time.*

A. Image Alignment and Calibration

1. If you cannot see the Processing menu at the bottom left of the screen, navigate to and click on the **View** tab in the main menu and then click **Processing**.
2. In the Processing menu at the bottom left of the main window, confirm that *Step 1 - Initial Procesing*, *Step 2 - Point Cloud and Mesh*, and *Step 3 - DSM, Orthomosaic, and Index* are red. Ensure that *Step 1* is checked, and uncheck *Step 2* and *Step 3*, then click **Start**. Depending on your computer's technical specifications, this can take a few minutes to run.
3. Review the generated Quality Report to ensure that your data passes the Quality Checks listed at the beginning of the document.This will automatically export as a PDF to your project folder and update each time you run a new step.

NOTE: *Your Quality Report will also offer insight into Calibration Details where you check if all cameras have calibrated correctly in addition to the overlap the images possess and the uncertainties between the initial GCP placements versus their computed placements. By using further georeferencing tools later, we will try to improve both the meter and pixel accuracy as specified in the Ground Control Points Table on page 7.*

4. If not already selected, select the **rayCloud** tab on the left hand side of the software interface and navigate around the cameras and ATP cloud in the main window. Left click and hold to pan around and zoom into the point cloud as you move your mouse or finger on your trackpad, and hit shift in addition to rotate the point cloud.
5. Monitor the processing status bar at the bottom of the Pix4Dmapper interface. After it completes the Initial Processing, go ahead and save your project (**Project**, **Save**).

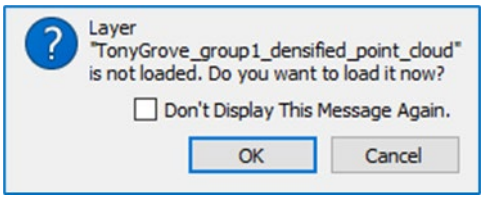
Part 3: Creating a Dense Point Cloud and Orthomosaic

By running *Step 2 - Point Cloud and Mesh*, Pix4Dmapper's image processing algorithms can create a dense point cloud by using the ATPs as a starting point. The total number of points, usually in the thousands to millions, depends on several factors, including but not limited to, image overlap, image content, and settings specified. The dense point cloud will provide a 3D representation of your study

area and enable the generation of a textured mesh and DSM. In *Step 3 - DSM, Orthomosaic and Index*, you will use the DSM as the input to generate the orthomosaic output.

A. Generating a Dense Point Cloud

1. Click on **Processing Options** in the bottom left-hand corner of the main window. Under the Point Cloud and Mesh section, locate the Point Cloud tab at the top. Under the Point Cloud Classification section, check **Classify Point Cloud**.
2. Click **OK** to close Processing Options.
3. In the **Processing** menu at the bottom left of the screen, confirm that *Step 1 - Initial Processing* is green and that *Step 2 - Point Cloud and Mesh*, and *Step 3 - DSM, Orthomosaic, and Index* are red. Make sure you uncheck *Step 1* so as to not overwrite what you have already created, check *Step 2* and make sure *Step 3* is unchecked. Then click **Start**. Expect for this to take several minutes to run.
4. Close your generated report, then navigate to **Layers** on the left-hand side of the screen and uncheck **Cameras** and **Tie Points.**
5. Under **Layers**, check **Point Clouds** and click **OK** in response to the warning message as shown below. Navigate around your dense point cloud.



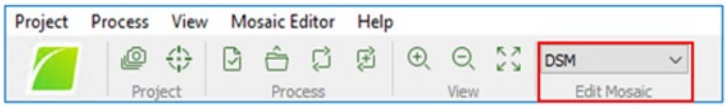
NOTE: *To tilt view your dense point and mesh, hold shift as you left click on your mouse or trackpad and move in the direction you would like to view the generated products from. Use the scroll wheel to zoom in and out. Left click to move horizontally. Click and hold the scroll wheel to orbit. To view all points within your dense point cloud, hit the* ***View All*** *button on the View toolbar.*

6. Under **Project**, click **Save**.

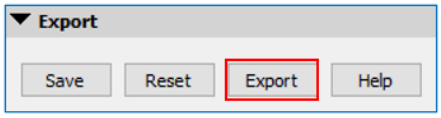
B. Generating an Orthomosaic

1. In the **Processing** menu, ensure that *Step 1 - Initial Processing* is still unchecked, uncheck *Step 2 - Point Cloud and Mesh* and check *Step 3 - DSM, Orthomosaic, and Index*. Click **Start**.This may take several minutes to run.
2. Note how the newly generated Quality Report resembles the previous one with additional information about your orthomosaic. Click **Close**.
3. On the left-hand side panel, click on **Mosaic Editor**.
4. In the main menu at the top of the software interface, click **Mosaic Editor**, then **View** followed by **Show DSM** to view your DSM and navigate around the output using the same methods to zoom, pan and tilt as described in Part 3.

5. In the main toolbar, click on the **Display Mosaic** dropdown and select **Mosaic (group 1)** to view and explore the orthomosaic output.



6. In the **Mosaic Editing** menu on the right-hand side, click the **Export** button to have the output saved to your project folder pathway (see following figure). If you encounter a warning message about exporting your orthomosaic, click **OK**.



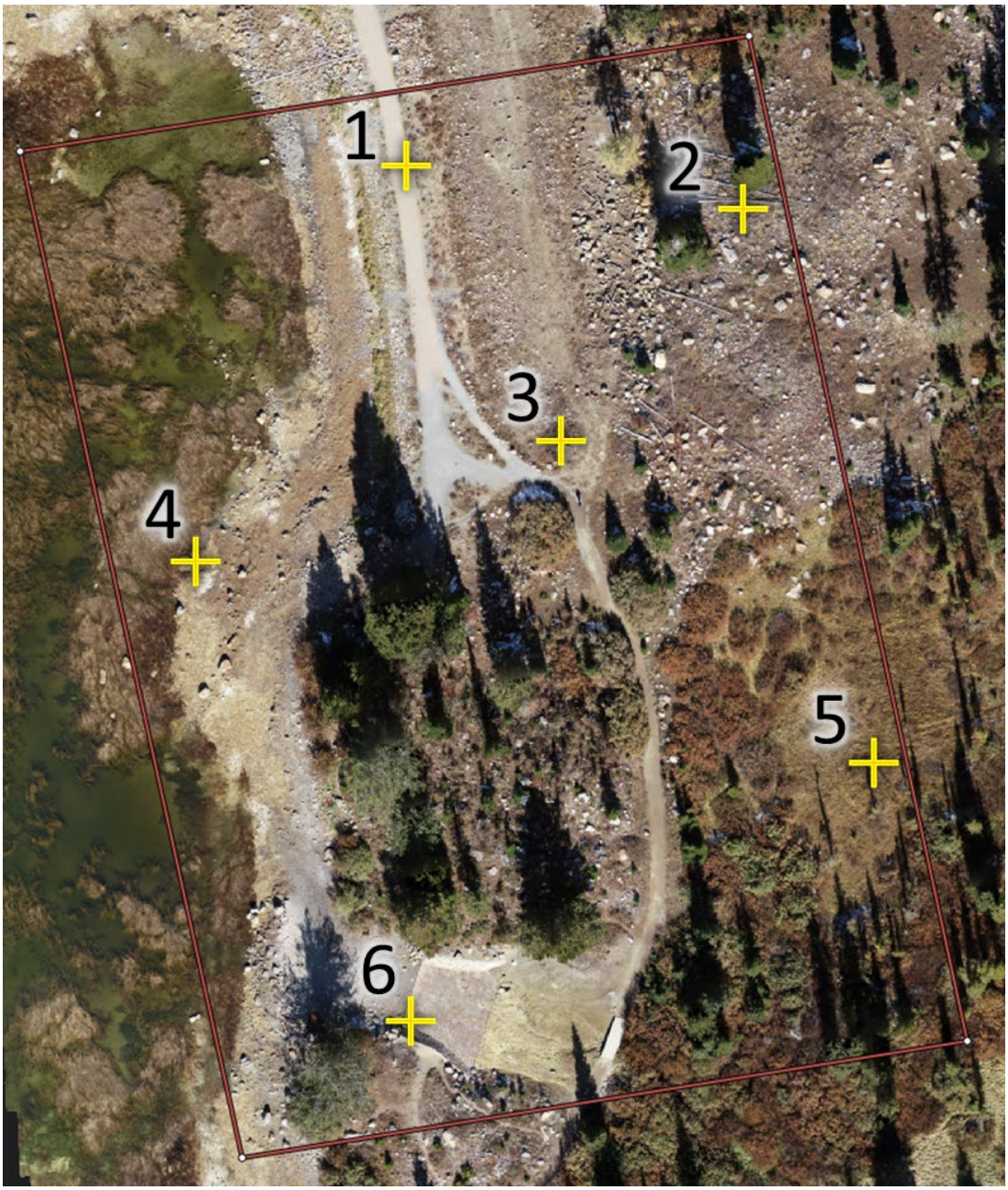
7. Under **Project**, click **Save**.

NOTE: *Sometimes distortions may occur in an orthomosaic due to errors in the surface model and features not fully visible in overlapping images, especially if there is a lot of tall vegetation. You may wish to generate new products using different settings or edit your existing one. If there are relatively low number of distortions, you can use the Mosaic Editor to improve your outputs, see* ***Pix4Dmapper Exercise 2: Additional Steps for Processing UAS Imagery****, otherwise, consider rerunning Step 3 after making changes to the project's parameters by exploring the settings for each step under* ***Processing Options****.*

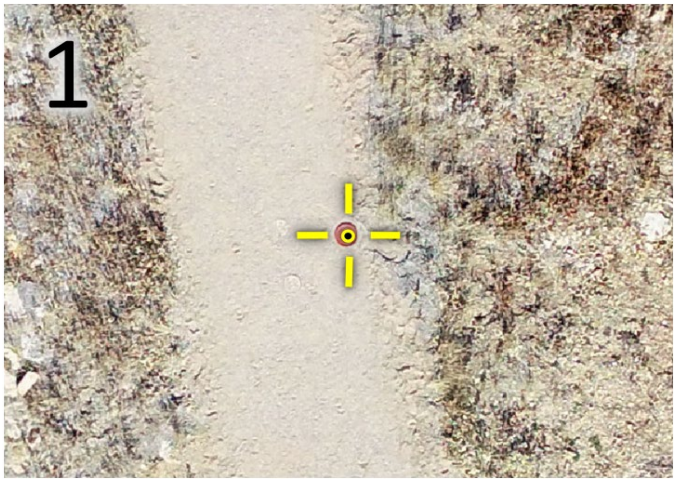
Conclusion: Congratulations! You have completed this first Pix4Dmapper exercise for processing UAS Imagery! In this exercise, we learned how to use Pix4Dmapper to align images, add GCPs for georeferencing purposes and create a dense point cloud and orthomosaic. Additional resources, including a few tutorials and a very helpful user forum, can be found on the Pix4D website.

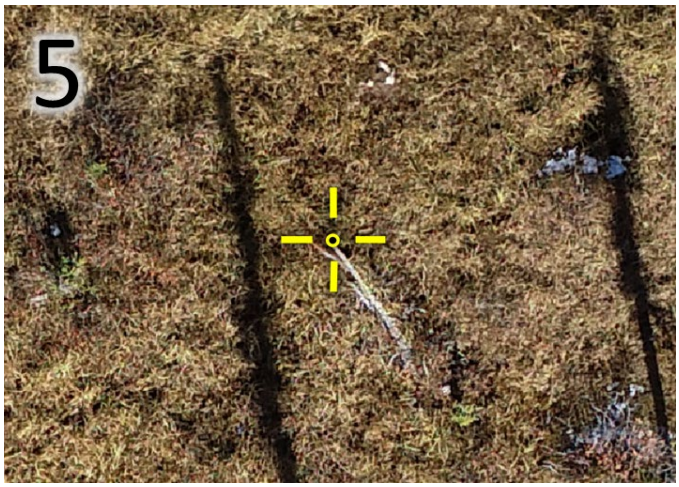
Appendix A: Ground Control Points (GCPs)

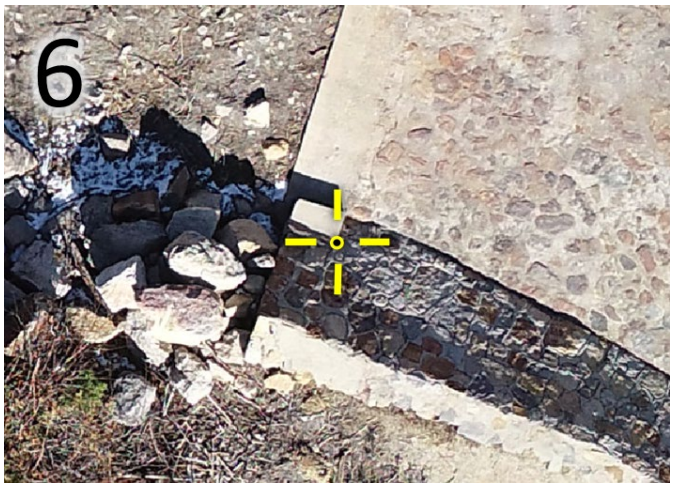
GCPs are crucial for geospatially positioning and scaling the imagery. Point coordinates are generally obtained with a GPS unit in the field or by using a reference image (as was done for this exercise). When images are not georeferenced, each GCP needs to be located and added to each image it intercepts. The graphic below shows marker locations corresponding to the Ex1_TonyGrove_GCPs.txt file.



Refer to the following zoomed-in images to know where to place markers. Since the scale and placement depends upon these markers, it is important to place them as accurately as possible.







Adding GCPs

This optional part of the exercise would be performed *after* setting up your project, and *prior* to **Part 2: Image Alignment and Calibration**.

UAS images typically contain geotagged coordinates (embedded in the files) to georeference the outputs. For some projects, these geotagged coordinates, which are usually accurate to within 2 meters horizontal accuracy, are all that are needed to create the outputs. However, if the images lack geotagged coordinates or if you wish to improve the accuracy of the products, Pix4Dmapper has tools to place GCPs on the images. Ground coordinates for GCPs generally come from another reference image or by collecting the information in the field with a GPS unit. The latter method generally produces the most accurate results but is also the more expensive and labor intensive of the two. Since this exercise consists of a subset of the original collection, the GCPs provided to you in this exercise were created using a combination of both methods.

A minimum of three GCPs are needed to georeference the model. For better results, it is recommended to distribute five to ten GCPs throughout the model. GCPs can be added either before or after the images are aligned. In most cases, it is easiest to add them after image alignment. However, to give you experience with both approaches, we'll explain how to place three of the six GCPs before image alignment, and then place the remaining three using a different tool after the images are aligned.

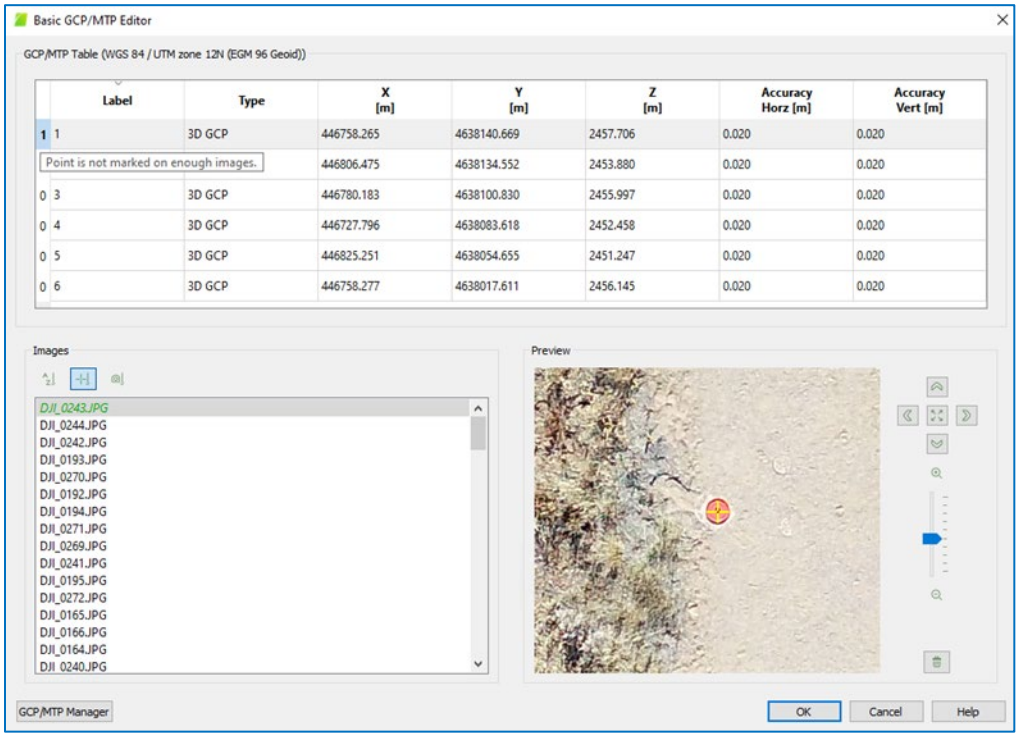
A. Adding Ground Control Points

1. Under **Project** in the main window, click **GCP/MTP Manager**.
2. Click **Import GCPs**.
3. For **Coordinates Order**, select **X, Y, Z** then **Browse** and locate the Excel spreadsheet with the GCP coordinates in the course downloads folder titled Ex1_TonyGrove_GCPs.txt. Click **Open** and **OK**.
4. Click **Basic Editor**.

NOTE: *The basic editor is used before processing the imagery. To add GCPs after processing you should use the rayCloud editor, which you will do with the remaining three GCPs later in this exercise.*

GCPs can be manually created using reference imagery and a digital elevation model (DEM). However, keep in mind that your products will only be as accurate as the reference data. In this exercise, GCP coordinates are provided, but tools like ArcGIS Pro or Google Earth can be used for displaying reference data and for obtaining the needed GCP coordinates. To create your own GCPs, you'll need to locate unchanged features (rocks, road intersections, trails) that are clearly visible in both the UAS imagery and the reference imagery. You would then make note of the longitude, latitude, and elevation (x, y, z) values of those features, as found in the reference data viewer (ArcMap or Google Earth). This information can then be added into the GCP/MTP Table located in the GCP/Manager window.

5. Review the images shown at the beginning of this Appendix) to see the locations of each GCP.
6. Click on the first GCP in the **GCP/MTP Table**.



7. Mark the target on at least ten of the corresponding photographs DJI_; 0243.JPG, 0244.JPG, 0242.JPG, 0193.JPG, 0270.JPG, 0192.JPG, 0194.JPG, 0271.JPG, 0269.JPG, 0241.JPG, 0165.JPG, 0166.JPG, 0164.JPG, 0319.JPG, 0320.JPG and 0318.JPG. Do this by sorting your images in numerical order using the sort button. Then double click on the image name in the bottom left panel and using the controls on the right, zoom in and place the GCP on the thumbnail image. Be cautious when placing your markers; some images may include more than one marker and it is important to select the correct one to avoid having to restart the process. Once completed, check that the number displayed next to the first GCP in the table reads 16. This is the number of images in which you have placed the corresponding GCP.

NOTE: *It is important to note that all images in this sample dataset are oriented with north being up, which makes it easier to place the GCPs. This won't always be the case since some flight plans have the UAS rotate 180° at the end of each flight line and/or may fly east and west flight lines. Therefore, with other datasets, you may notice that some of the images are rotated as you are placing your GCPs.*

8. Do the same for the second and third marker.
   i. For the second marker, you will locate the GCP in ten of the following photographs DJI_; 346.JPG, 345.JPG, 347.JPG, 318.JPG, 317.JPG, 344.JPG, 319.JPG, 320.JPG, 272.JPG, 271.JPG, 273.JPG, 270.JPG and 269.JPG.
   ii. For the third marker, you can locate the GCP in any of the ten following photographs DJI_; 275.JPG, 274.JPG, 239.JPG, 238.JPG, 276.JPG, 273.JPG, 240.JPG, 315.JPG, 314.JPG, 316.JPG, 237.JPG, 272.JPG, 241.JPG, 313.JPG, 317.JPG, 197.JPG, 198.JPG, 196.JPG, 349.JPG, 195.JPG, 350.JPG, 346.JPG and 347.JPG.

NOTE: *To zoom in on the thumbnail image to place a GCP, you can pinch zoom using your computer's trackpad, use the scroll wheel on your mouse, or drag the pointer on the scale bar to the left with*

magnifying glasses. To pan around the image, you can either left click and hold on your mouse and drag the image to the area you want to view, or you can use the arrows above the scale bar on the right. To reset the image to its original state, click the button located in the middle of the four arrows used for panning.

9. Once the first three GCPs have been placed on their respective images, click **OK**.
10. Under **Project** in the main window, click **Save Project**.

Further Georeferencing and Reoptimizing

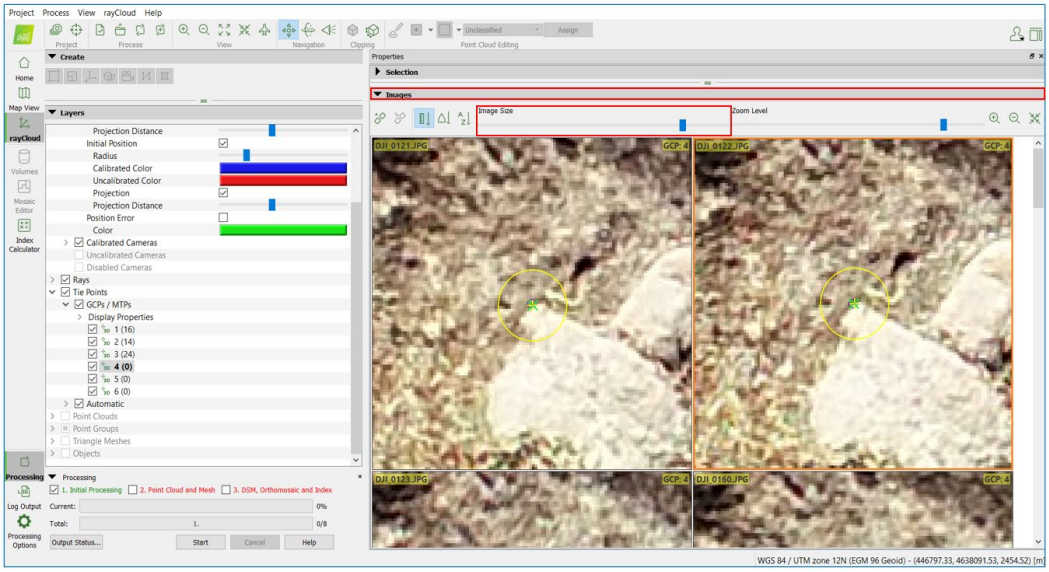
This optional part of the exercise would be performed *only* if you have manually added the first three GCPs from the **Adding GCPs** section of the Appendix. Complete **Part 2: Image Alignment and Calibration**, then you can proceed with the following steps.

The main advantage of the rayCloud is that it automatically estimates which images GCPs fall on since the images have already been aligned. This makes placing GCPs with the RayCloud much faster than using the Basic Editor tool which is referenced in the Appendix. It is best to place GCPs on all images where you can clearly see where the GCP should be placed. After you finish adding the six GCPs, you will reoptimize the camera calibration to improve the overall model accuracy.

A. Georeferencing with rayCloud

1. Under the **View** tab in the main menu, ensure **rayCloud** and **Show Sidebar** are turned on.
2. Under **Layers** on the left-hand side, click the drop-down bar next to **Cameras**, and do the same again for **Display Properties**.
3. Under **Display Properties**, locate the line for **Position Error** and uncheck the box.
4. Drag the edge of the sidebar, located on the right, towards the left of the screen so that it fills most of the window.
5. In the **Layers** list on the left-hand side, click the drop-down bar next to **Tie Points** if it is not already expanded, and do the same again for **GCPs/MTPs** and again for **Display Properties**.
6. Click on the fourth GCP listed. Collapse the **Selection** section in the sidebar to close the image details and drag the **Image Size** slider to increase image thumbnail sizes.

***NOTE:** As in Part 2, you can place your cursor on each image and zoom in and out using your trackpad or mouse scroll wheel. To pan the image, left click and drag. If necessary, hold your cursor over an image and tap the spacebar for it to fill your screen if you need to see it at a larger scale. Tap the spacebar again to return the image to its original size within the side panel.*



7. Review the images shown in the earlier section of this Appendix to find the target for the fourth GCP. Try to locate the GCP in image DJI_0121.JPG, displayed in the sidebar. Take note that by placing the first three GCPs and running the initial processing step, the images containing the GCP have been autogenerated and it will now be quicker to place the remaining ones. Click the center of the target. Click **Delete** or drag and drop to reposition the GCP if it is incorrectly placed. If you notice something looking odd in this step, revisit the **Adding GCPs** part of this Appendix to ensure all previous markers were correctly placed.
8. Confirm the location of the same GCP in image, DJI_0122.JPG. The yellow circle that appears around the GCP confirms that it has been marked successfully.
9. Click **Selection** to expand the GCP's details and then click **Apply.** Collapse the Selection section once again. This will automatically place the GCP on the remaining images for you.
10. Drag the **Zoom Level** slider to the right until you can see the target for the GCP clearly in the remaining images. Click on the green crosses to confirm the location of it in each additional image.
11. Expand the **Selection** section once again and hit **Apply**. If more images appear, continue through the process of confirming the GCP location and clicking **Apply** until no more new images appear.
12. Follow steps 6. through 12. for the remaining fifth and sixth GCPs.
13. Close the sidebar by clicking the "**X**" to the right of **Properties**.

B. Reoptimizing

1. Under **Process**, click **Reoptimize** and then save your project. Click **OK** if a warning message appears.

NOTE: *Running Reoptimize will rerun the first step of the 3-step process, Step 1 - Initial Procesing if it has already been run. If the operation to rerun the first step fails, make sure you do not have the previously generated Quality Report open in Adobe.*

2. You can now proceed to **Part 3: Creating a Dense Point Cloud and Orthomosaic**.