Title
Drone Imagery Processing Procedure

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DRONE imagery processing procedure

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E4E and the Aburto Lab at SIO collaborate to use machine learning algorithms to classify mangroves in aerial imagery taken by drones. First the images must be orthorectified and stitched together to create composite orthomosaics.

This procedure describes how to produce the image products required by the machine learning algorithms, including a color correction procedure, 3D model construction, and creation of a digital elevation model (DEM) and orthomosaic. It also includes a procedure for compensating for geometric distortions that may be found in poorer quality imagery.

To collect your imagery, please reference our drone flight manual (https://escholarship.org/uc/item/2zv0z6zm).

This version of the manual covers image processing procedures preparation using DJI drone products and associated software for processing Red-Green-Blue (RGB) imagery. To cite this manual, please use the following: Hsu, A. J.; Dorian, J. B.; Qi, K.; Lo, E. K.; and Guerrero Martinez, B. 2019. Drone Image Manual: UCSD Mangrove Image Processing (Version 1.2). University of California, San Diego, Centro para la Biodiversidad Marina y Conservación, and the Gulf of California Marine Program. San Diego, California, USA.

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File Organization

With several terabytes of data, it is important for our organization to have a consistently applied method for organizing our files. This section describes the file organization scheme so that our staff and volunteers can locate and utilize the resources they require.

Physical Storage

Depending on the amount of data one plans on collecting, physical storage is important. For regular use, we suggest that storage of at least 2 TB is acquired.

Naming Conventions

The naming convention used in this project typically refer to data and files in the context of region, date, site, and flight. Consider the following example while reading the following sections.

psc_2018-07_site01_flight05_120m_tc

Region

We differentiate large geographic areas as regions, typically referred to with local municipality names. The example uses the region “psc”. It is an abbreviation for Puerto San Carlos. We try to use three-character region abbreviations.

Date

Since we revisit the same sites over time, it is important to include the date of the data collection. Our expeditions are infrequent enough that we can use just the year and month, shown in YYYY-MM format. This format ensures that sorting chronologically and alphabetically yield the same results.

Site

Within a region, we typically drive around and image a number of mangrove forests, each considered a site. While it would be ideal to have consistent names for each site, we have not adopted a standard site designation. Instead, each site is assigned an ordinal number representing the sequence in which the site was visited during that expedition. This means that the site number is only consistent within each expedition. The same site may have a different number in different expeditions. The site is typically expressed as “site##” for naming purposes.

Flight

Each site is imaged multiple times at different altitudes and possibly with different drone or camera settings. Flights are numbered, starting from one for each site. The flight is typically expressed as "flight##".

Altitude

While most flights operated at 120m, some flights vary, so it is valuable to include the altitude. Other common altitudes include 10m, 20m, and 50m.

Corrections (Optional)

There are a variety of correction methods that are sometimes applied to the imagery. Common corrections include:

- cc - color-calibrated
- rc - reflectance-calibrated
- tc - tides used for altitude calibration

Folder Organization

The file organization scheme follows a similar hierarchy to the naming convention described above, with some additional divisions for data types and formats. The following diagram outlines the organization structure found on the Data drive. Folders are marked in <angle brackets>. File names are shown in "quotations". Region abbreviations are shown as "abc".

- **Local Computer**
  - Appropriate Project Folder
    - Expeditions: "YYYY.MM-country-regionname"
      - Sites: "abc-YYYY-MM-site##"
        - **DJI Phantom 4 Pro images (RGB): "dji"**
          - Flights: "flight##_altitude"
            - DJI Images (JPEG): "DJI_####.jpg"
        - **Final Products: "output"**
          - RGB Orthomosaic: "abc_YYYY-MM_site##_altitude_RGB"
          - MULT Orthomosaic: "abc_YYYY-MM_site##_altitude_MULT"
          - DEM Image: "abc_YYYY-MM_site##_altitude_DEM"
          - NDVI Image: "abc_YYYY-MM_site##_altitude_NDVI"
        - **Project Files: "projects"**
          - PhotoScan project folder "project_name files"
          - PhotoScan project: "abc_YYYY-MM_site##.psx"
          - QGIS project: "abc_YYYY-MM_site##.qgs"

Caution copying or dragging and dropping files. Each flight contains gigabytes of data and takes a while for the computer to load. After navigating to a folder, wait for it to fully load before "selecting all" to either copy or drag. Failure to do so may result in some files being left behind.

Image Processing

Once the individual images have been calibrated if needed, we import them into MetaShape to process them and generate orthomosaics and other image products.

Needs

- Paid Agisoft Metashape license (www.agisoft.com)
- GIS software, such as ArcGIS (paid) or QGIS (free)

Note that these softwares will have updates to their programs.

Setup

The MetaShape project must be set up properly for the processing of our images. This involves checking settings prior to beginning work, and setting up the first chunk.

Review File Organization

Once the MetaShape project is started it will reference the location of photos on the computer, so after a project is started we do not want to move the images. Make sure that all the raw and calibrated images are properly organized in the computer.

Check Settings

Tools > Preferences > Advanced

- Strip file extensions from camera labels - Check
- Load camera calibration from XMP meta data - Check
- Load camera orientation angles from XMP meta data - Uncheck
- Load camera location accuracy from XMP meta data - Check
- Load GPS/INS offset from XMP meta data - Check

Create First Chunk

Create the first chunk by right-clicking in the workspace and selecting "Add Chunk". Name the chunk consistently with the file organization methods described earlier.

<area>_YYYY-MM_site#_<elevation>_combined
(e.g. lap_2018-07_site6_120m_combined)

Importing

You must first import images from your drone to Metashape. If you have multiple sets of images (i.e. additional multispectral images), import the other sets. Because we use a single DJI drone (Phantom 4 Pro), our examples will use "DJI".

DJI Images

1. Right-click on the chunk you created earlier. Under “Add”, select “Add Photos...”.
2. Navigate to the color-calibrated images from the DJI, select them all and click “OK”.
3. Expand the chunk
4. Right-click on the Cameras folder and select “Add Camera Group”.
5. Right-click on the new folder and select “Rename...”.
6. Name this group flight#_<elevation>_DJI (e.g. flight2_120m_DJI)
7. Select all the photos that were just imported.
8. Drag them into the new camera group folder you just created.

Select Flights

If imagery is present from multiple altitudes, it is significantly faster to process one altitude at a time (hours vs. days). Right-click on all camera groups that are not from the desired altitude and select “Disable” to postpone their alignment.

Remove Unwanted Images

Poor images have a negative impact on the resulting orthomosaic. Since we fly the drone with a high degree of overlap, some images can be left out while still constructing a complete final image. Note that the multispectral images have less overlap and therefore less tolerance to missing images. Be more conservative when removing multispectral images than RGB images.

Scroll through the images in either the Workspace or the Photos pane and consider the following:

Consider the subject of the image.

1. Photos of the landing pad or lense cap should be removed.
2. Photos clearly taken outside of the intended flight path, such as during take-off, should be removed.
3. Photos with significant motion blur should be removed.
4. Photos of the calibration target should be removed.

Check Reflection Masks

Quickly review the images for strong reflections from the sun. If necessary, use the steps in “Reflectance Calibration” on page 10.

Alignment

The first stage of processing in MetaShape is Alignment, where the software looks for clear points in common between multiple photos. It uses these as anchor points that it uses to position each photo/camera in 3D space. The collection of these forms a sparse point cloud.

Settings

The alignment option is in the Workflow menu. Alignment can be performed with several quality settings. These determine the amount of downsampling that is performed on the images prior to analysis. For high altitude flights it is best to start by aligning with "High". If not all photos align, try again with "Medium" or "Highest". Low altitude flights, however, should always be processed with Highest quality. Always be sure that the "Adaptive Camera Modeling" option is disabled to prevent some forms of geometric distortion. The default settings of 40,000 key points and 4,000 tie points works well.

Review Geometry

In the Workflow menu, select Build DEM. Select "Sparse cloud" in the Data Source field and press OK to build a DEM Once the DEM is visible, inspect it for significant irregularities. Some possible problems include:

- Model is tilted to one side
- Model is curved upward or downward around the center
- Model is "scrunched" where images appear to have been placed too close together
- Model is broken into different planes that do not align with each other

If these problems are encountered, experiment with the following and repeat the alignment process to find a better result:

- Change the quality to any of the other options
- Try enabling "Adaptive Model Fitting"
- Tide calibrating (page 11)

Filtering

Once the alignment is complete and the geometry is acceptable, filter out the points with high uncertainty values. To do this:

1. Right-click on the chunk and select Duplicate. (This serves as a backup)
2. Rename the old and new chunks to indicate that they will be unfiltered and filtered respectively
3. Select Tie Points in the Workspace window for the copied chunk.
4. In the Model menu, select Gradual Selection.
5. Select reconstruction uncertainty.in the Criterion menu.
    - Select a threshold level of 20.
    - Click OK

If filtering removes a majority of the points, delete the new chunk and try again with a higher threshold level.

Dense Point Cloud

Once the cameras have been precisely positioned during the alignment process, MetaShape can fill in a large number of points, adding detail and creating a dense point cloud.

Select “Build Dense Cloud…” from the Workflow menu. The quality determines the resolution of the orthomosaic that will be generated in later steps. Choose Ultra High for the highest resolution and click OK.

DEM

Metashape can use the dense cloud to create an estimate of the surface terrain elevation in raster form, called a digital elevation model (DEM). Select “Build DEM” from the Workflow menu. Make sure that “Dense Cloud” is selected as the source data and click OK.

Orthomosaic

With the DEM built, MetaShape can project the original images onto the surface model, resulting in a single ortho-rectified composite image. Select “Build Orthomosaic” from the Workflow menu. Make sure that “DEM” is selected in the surface menu and click OK.

To export the orthomosaic, right-click on it in the Workspace, hover over “Export Orthomosaic” and select “Export JPEG/TIFF/PNG”. Usually the “Write alpha channel” is desired, but if the resulting orthomosaic displays improperly (random colored pixels), try exporting again with this option disabled.

Corrections

Color Calibration

Prior to processing images into orthomosaics and other finished products, we may calibrate the values in the raw images.

Needs

- Photo editing software, such as Adobe Lightroom (paid) or GIMP (free)

Color differences resulting from changes in weather, time of day, and season can reduce the accuracy of the machine learning algorithms. We have a color calibration procedure to correct for these differences, though it is only partially effective.

Since this procedure is not highly effective, it does not need to be performed on all images. It should be applied when color is noticeably unusual. Reference previous image sets and compare color consistency to determine if this is necessary. Correction is performed on a per-site basis, including multiple flights flown close together, never including multiple sites.

If color calibration is needed, this correction can be done in Adobe Lightroom and requires at least one image of a gray card taken in the field directly before or after the flight. We recommend taking images of the gray card before and after each flight since the need to color calibrate the imagery won't be known until after the flight.

Here is the color correction workflow that we use for Adobe Lightroom:

1. Transfer the raw images you want to calibrate to a storage drive
2. Open Lightroom CC
3. Open the directory that contains the raw images. It can be confusing to process multiple sites at once because Lightroom consolidates images into a single folder, so processing a single site at a time is recommended.
    a. Select all the photos for the site you want to correct, including the images of the calibration card.
4. Navigate to the Development tab in the upper-right
    a. Click on the image with the calibration card
    b. Zoom in on the calibration card
    c. Click the eye-dropper tool.
5. The cursor should now show as a pixel grid when hovering over the image.
    a. Scroll the wheel on the mouse to get as many pixels in the grid as possible.
    b. Click on the center of the calibration card to get a color sample.
    c. Lightroom will process the sample and adjust the temp and tint to correct the color in the image.
6. Right-click the icon for this image in the image preview pane in the bottom of the screen.
7. Set the image as the reference.
8. Select all images in the image preview pane.
9. Click Sync.
    a. A synchronization options window should appear.
    b. Make sure the checkboxes for the Color section are checked.
    c. Click Synchronize.
    d. Lightroom may take a few seconds to update all the image previews.
10. Click File and select Export
    a. Choose your output directory set the image type to TIF.
    b. Make sure the option is selected to copy file metadata.
    c. Export.

Reflectance Calibration

Reflectance in imagery poses challenges to high quality reconstructed imagery of the site. We recommend flying outside the hours of 11 AM to 1 PM to avoid reflectance in the imagery. However, there are instances when this is not possible. As such, we can mask out this reflectance. Keep in mind when masking that the more imagery that is masked, the more uncertainty MetaShape will have when aligning images and generating point clouds. Only mask the areas that really need it.

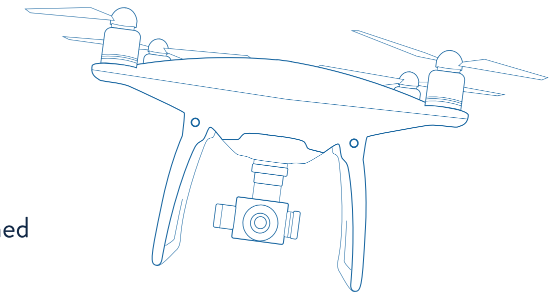
Needs

- Agisoft MetaShape

Use the steps below to remove both direct sun reflections and objectionable hot spots in each image.

1. Open the Photo view to see thumbnails of all images
   a. Double-click an image to view in full resolution.
2. Under the Photo menu, select the Intelligent Scissors tool.
   a. Use the cursor to draw a polygon one point at a time over the area that needs a mask.
3. After completing a polygon, click the Add Selection button in the toolbar.
4. Repeat steps 2 and 3 as needed to cover all reflections.

Image: Some examples of reflectance.



Tide Calibration

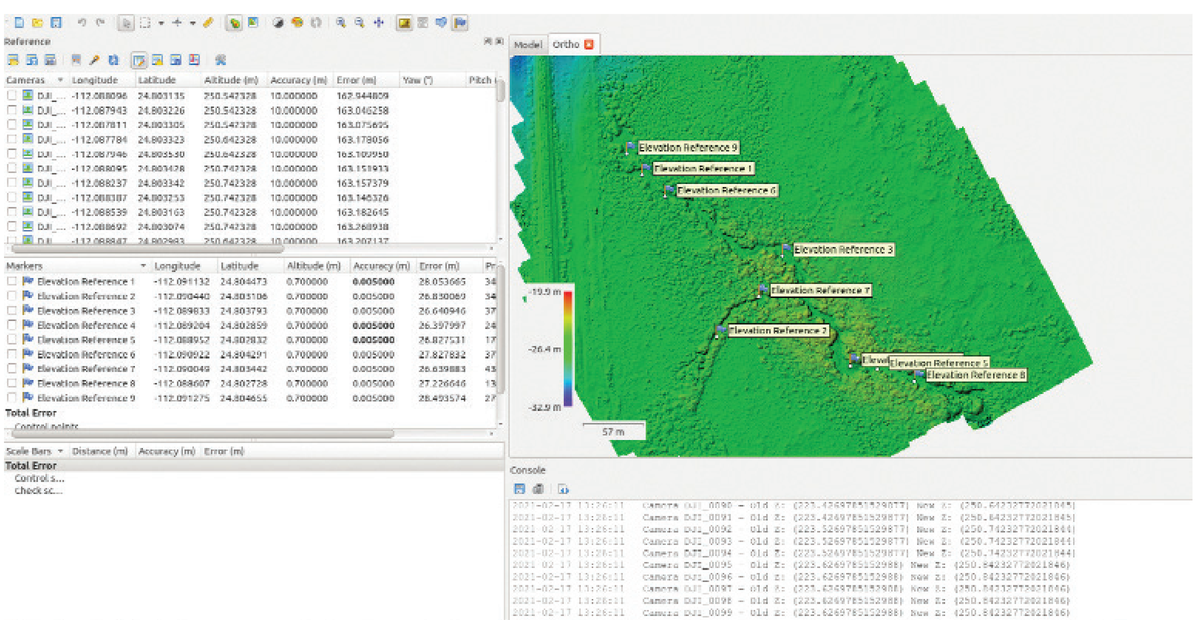
Prior to processing images into orthomosaics and other finished products, we may calibrate the values in the raw images.

Needs

- Agisoft MetaShape, with DEM and orthomosaics already built
- Download adjust_dem_to_ref.py from github: https://github.com/UCSD-E4E/biomass-mangrove/blob/master/est_biomass/adjust_dem_to_ref.py

Use the steps below to remove both direct sun reflections and objectionable hot spots in each image.

1. Identify shoreline, which is typically right against the water where the elevation is flat
   a. Use the DEM and Orthomosaic to visually inspect
2. Place Markers at these locations
   a. Right click -> Place Marker
   b. Try to add at least 5-6, the more the better to avoid noise
   c. Avoid areas that have geometric discrepancies, choose flat places
3. Set markers as reference points
   a. Go to the "Reference" panel
   b. Change all the point names to "Elevation Reference #"
4. Reset altitudes of references
   a. a. Check corresponding trip logs and select a time around the middle of flight
   b. Look up tide table at flight date/time:
      i. tbone.biol.sc.edu/tide//sites_allalpha.html
   c. Set "Altitude" to the tide height at the time
      i. All references should have the same value in "Altitude"
5. Run the script to adjust DEM
   a. Select Tools -> Script -> select script from file
   b. Run script: <pathfile>/adjust_dem_to_ref.py
   c. Click "Adjust"
6. Right-click the icon for this image in the image preview pane in the bottom of the screen.
   a. Click on the image with the calibration card
   b. Zoom in on the calibration card



Mangrove Biomass Calculations

Some applications of the calibrated orthomosaics include calculating above ground mangrove biomass. A global, linear allometric equation (Saenger & Snedaker, 1993) can be applied to the mangrove extent of the tide calibrated DEM. The resulting layer is in units of Mg per hectare, which can also be used to determine total biomass of the surveyed sites.

General mangrove biomass equation (Mg/ha): 10.8 x *Canopy Height (m)* + 34.994

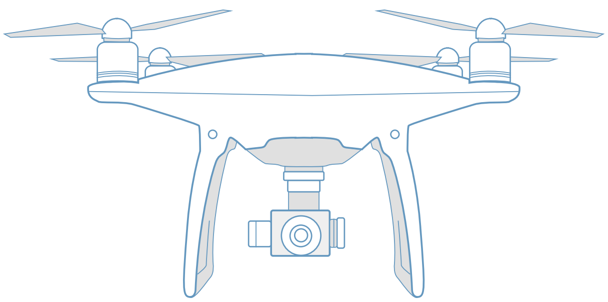
A Python script that automatically outputs a raster layer of a site's biomass with the calibrated DEM and mangrove/nonmangrove labels shapefile as inputs is publically available as a GitHub repository (https://github.com/UCSD-E4E/biomass-mangrove, https://github.com/UCSD-E4E/biomass-mangrove/wiki).

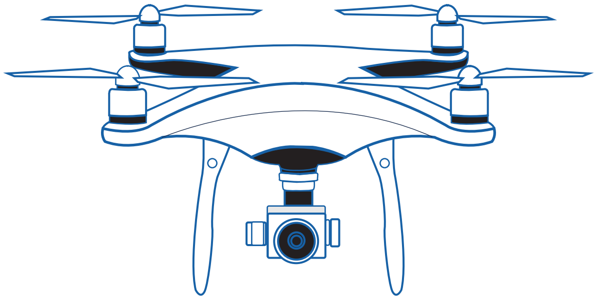
To calculate total biomass (Mg) of a site, a conversion factor must be multiplied against the biomass layer's cell values (Mg/ha). This is determined from the area of a single pixel, the layer's smallest element (expressed in units of m2), which can be found using the resolution of the DEM raster. For example, if the drone's resolution is 3.125 x 3.125 cm, its total area expressed in ha would be 9.766 x 10-8. The product of the summation of all biomass pixels in the biomass layer with this factor is the total biomass expressed in Mg.

Biomass Conversion factor (ha): $\frac{(\text{resolution (m)})^2}{10000}$

References:

Saenger, P. and Snedaker, S.C., 1993. Pantropical trends in mangrove above-ground biomass and annual litterfall. *Oecologia,* **96**(3), pp.293-299.





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Gulf of California Marine Program

UC San Diego ENGINEERS FOR EXPLORATION

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