Optimizing Orthomosaic Modelling with UAV Imagery in Highly Dense Forests Using GIS

McClain Martensen

April 21st, 2021



The Boiling River Project

- Dedicated to the preservation and study of a sacred geothermal river in the Amazon
- The Boiling River area holds significance for its peculiar collection of non-volcanic thermal rivers: the Salt River (a salty thermal stream), the Hot River (a thermal freshwater stream), and the Boiling River.
- Over 700 km away from the nearest active volcanic center







Andres Ruzo: First Geologist to Prove the Legend of the Boiling Amazon River

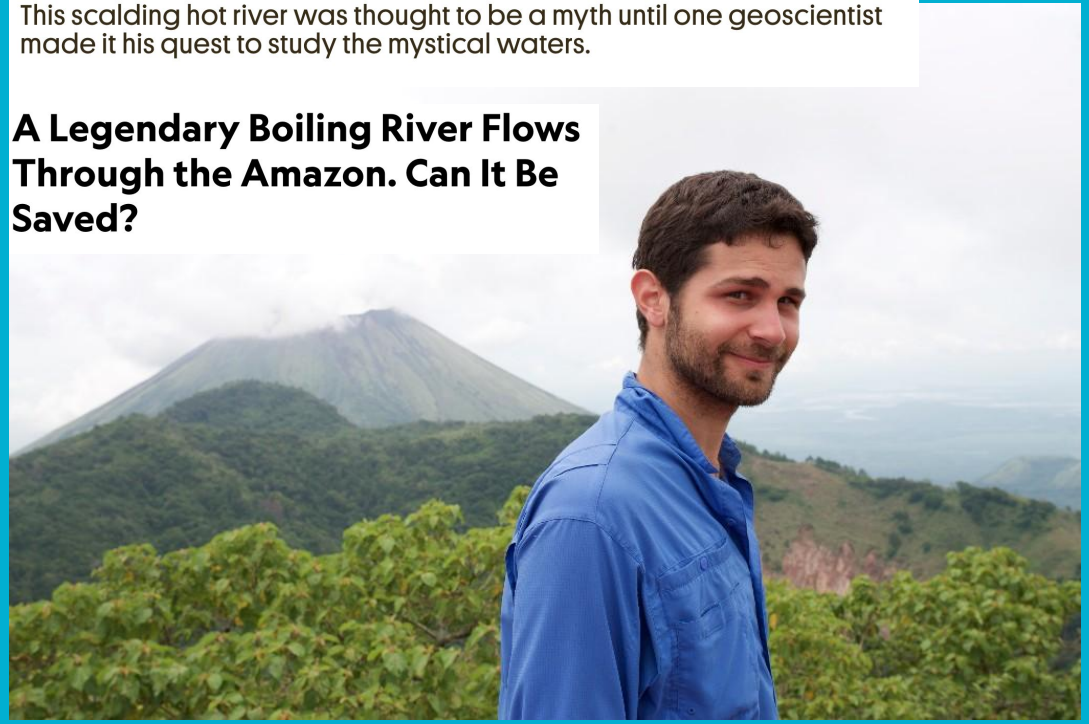
September 11, 2019

The Boiling River of the Amazon

Puerto Inca, Peru

This scalding hot river was thought to be a myth until one geoscientist made it his quest to study the mystical waters.

A Legendary Boiling River Flows Through the Amazon. Can It Be Saved?







Located in Eastern Peru

Near the city of Pucallpa and the Peru/Brazil border

Why do we need these maps?

Because we are in the middle of Peru, satellite imagery through Google doesn't provide imagery that has high enough resolution to analyze the bottom of the river. (We can't go in to look at it because you will die)

We also want a good basemap to visualize data from other studies at the boiling river (ecology, ichthyology, microbiology)

Why Drones?

Because LIDAR is really our only other viable option for this kind of analysis, drones provide a much cheaper alternative to getting plane to fly over the area. (Tens of thousands of dollars cheaper)



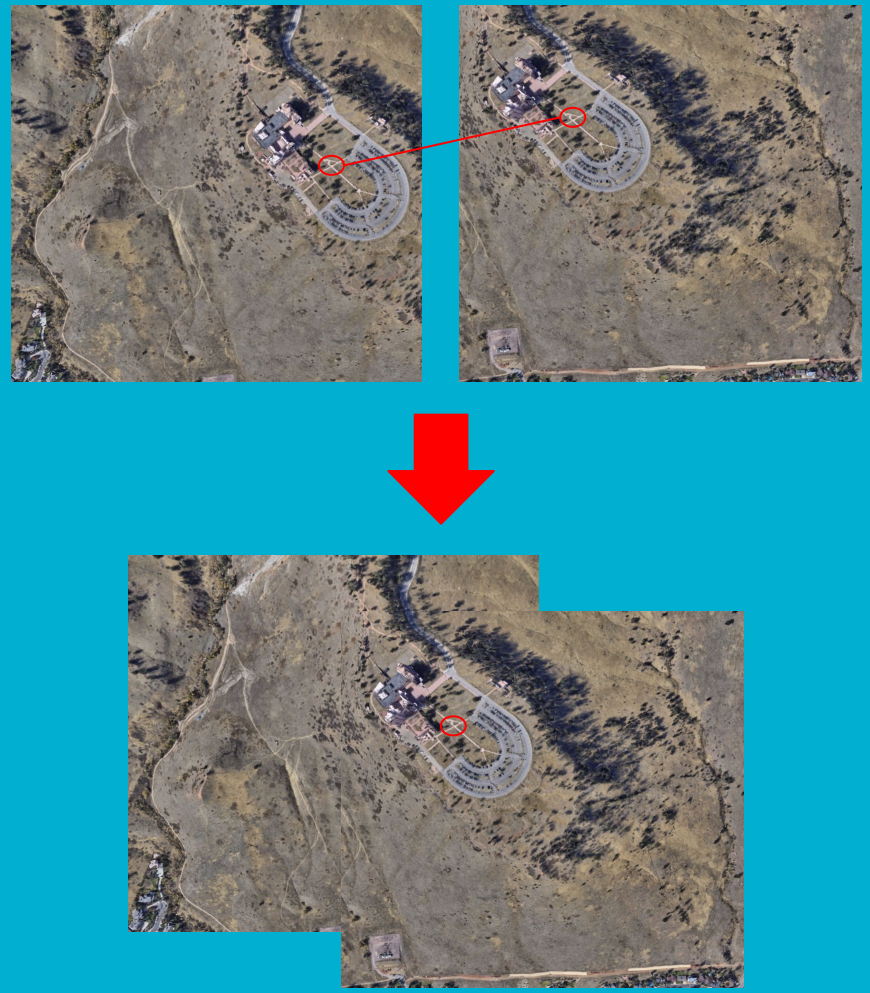
Google Earth



Screenshot of Orthomosaic

Orthomosaics

- Software: ArcPro and Pix4D
- Finds digital tie points between overlapping aerial photos.
- Each photo has about 10,000 -30,000 tie points
- Stitches together the image to create a spatially accurate, high-resolution map
- Comparable to aerial maps made with satellite imagery







Tie Point

Most orthomosaics generate 50,000 - 500,000 tie points depending on photo resolution and object variation (distinct objects and color differences that the computer can detect)

Research Question

How can I make the most spatially & visually accurate aerial map for areas that have low object variation (forests, deserts, large water bodies)?



Why are dense forests so difficult?

No Ground Control Points (GCPs) - used to make it easier for the computer to create tie points and have more spatial accuracy

- The canopy was too thick to lay down GCP's. Plus we were carrying a ton of equipment and were going on extensive hikes to get to some of these flight locations





No object variation - When the photos all look the same (have the same color scheme), the computer can't tie points as easily cause all of the pixels have the same color values

2 Completely Different Photos!





Methodology

1. Data Collection and Organization
2. Compare Orthomosaics for Pix4D & ArcPro
3. GCP Post Photo Analysis
4. Analysis on Sun's Positioning and its Effect on Processing
5. Uncertainty Models

Methodology

1. Data Collection and Organization
2. Compare Orthomosaics for Pix4D & ArcPro
3. GCP Post Photo Analysis → Geometric Distortion
4. Analysis on Sun's Positioning and its Effect on Processing → Radiometric Distortion
5. Uncertainty Models

Methodology

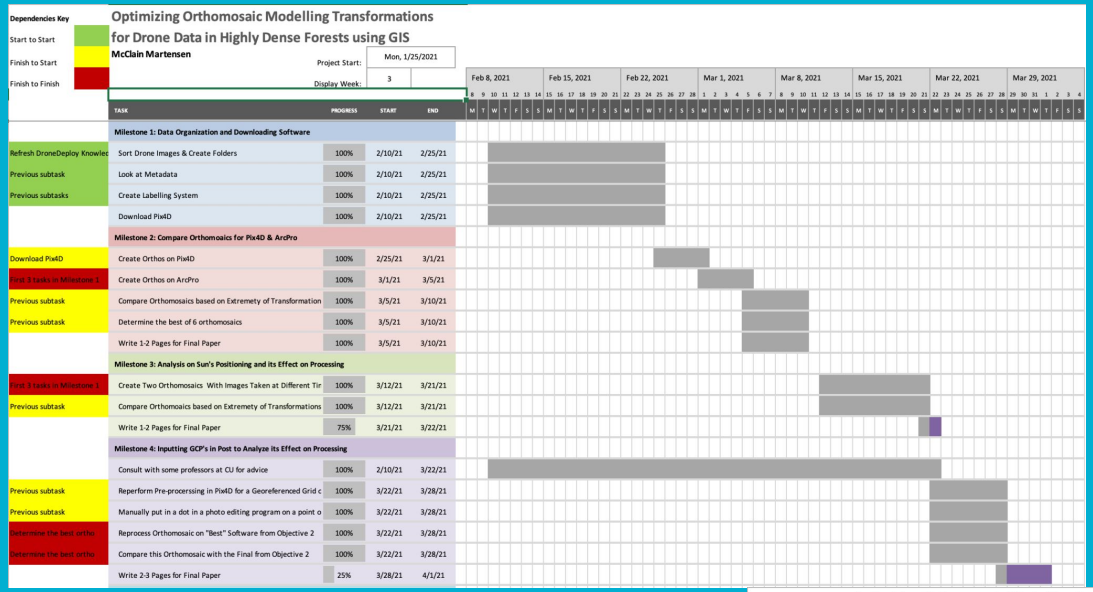
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Two Primary Types of Distortion

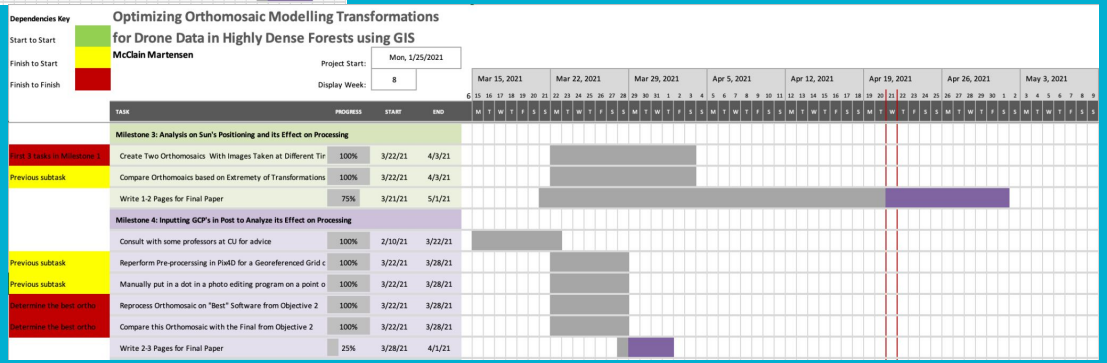
Geometric: Caused by inaccurate translation of scale and location. Main source of *spatial* inaccuracies.

Radiometric: Caused by the angle of the sun or atmospheric conditions when the photos are taken. Usually causes holes in the mosaic because there is too much light reflectance. Main source of *visual* inaccuracies.

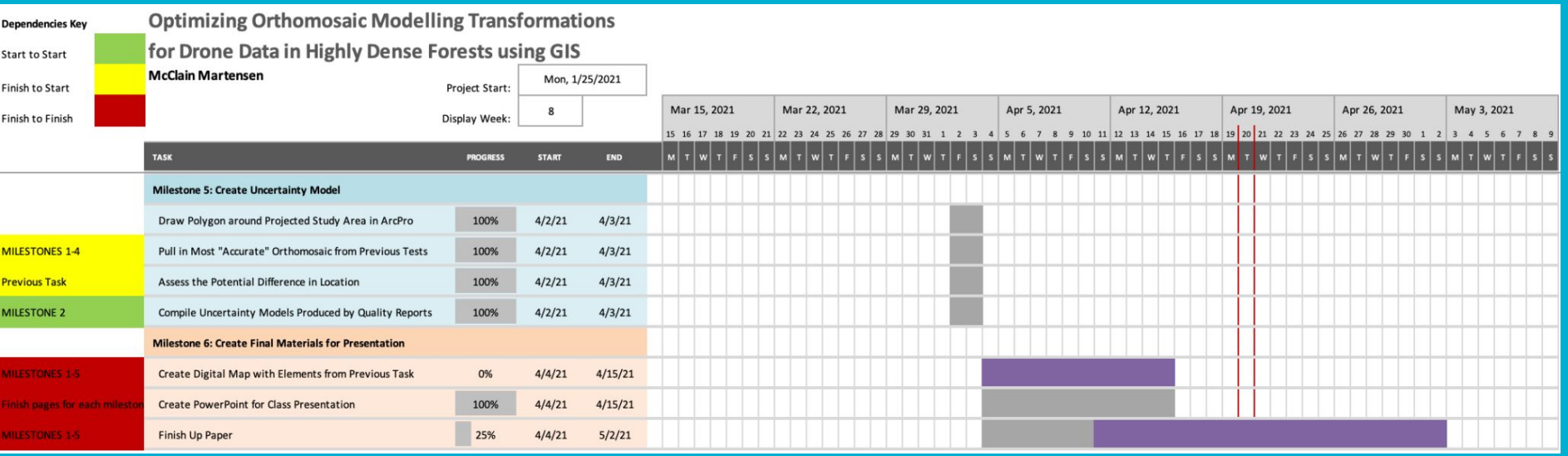
Gantt Chart & Timeline



Ended up switching the order of Milestones 3 and 4



Gantt Chart & Timeline



Dependencies Key	TASK	PROGRESS	START	END
Start to Start	**Optimizing Orthomosaic Modelling Transformations for Drone Data in Highly Dense Forests using GIS**			
Finish to Start	**McClain Martensen**			
Finish to Finish	Project Start: Mon, 1/25/2021			
	Display Week: 8			
	Milestone 5: Create Uncertainty Model			
	Draw Polygon around Projected Study Area in ArcPro	100%	4/2/21	4/3/21
MILESTONES 1-4	Pull in Most "Accurate" Orthomosaic from Previous Tests	100%	4/2/21	4/3/21
Previous Task	Assess the Potential Difference in Location	100%	4/2/21	4/3/21
MILESTONE 2	Compile Uncertainty Models Produced by Quality Reports	100%	4/2/21	4/3/21
	Milestone 6: Create Final Materials for Presentation			
MILESTONES 1-5	Create Digital Map with Elements from Previous Task	0%	4/4/21	4/15/21
Finish pages for each mileston	Create PowerPoint for Class Presentation	100%	4/4/21	4/15/21
MILESTONES 1-5	Finish Up Paper	25%	4/4/21	5/2/21

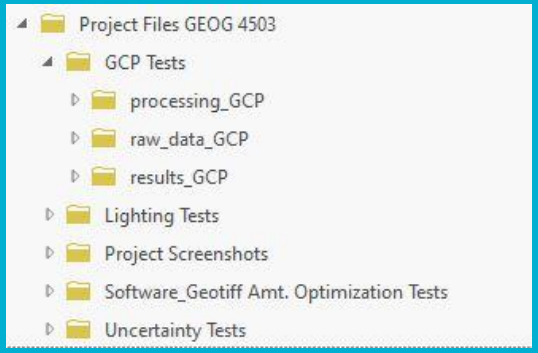
Data Sources & Organizing

1. Data Collection and Organization
2. Compare Orthomosaics for Pix4D & ArcPro
3. Analysis on Sun's Positioning and its Effect on Processing
4. GCP Post Photo Analysis
5. Uncertainty Models

I collected all of the data for this project between 2018-2019. Because of this, I was already very familiar with my data and didn't have much trouble organizing it.

Unfortunately, this data was collected by a 16/17 year old who was still actively learning about GIS and remote sensing. I wasn't as aware of lighting, flight coverage or camera angles.

I collected this data with 2 drones: Phantom 4 Pro and a Mavic 2 Pro with a Hasselblad camera attachment (one of the best cameras on the market for a mavic).





MAVIC



PHANTOM

Methodology - ArcPro vs. Pix4D

1. Data Collection and Organization
2. Compare Orthomosaics for Pix4D & ArcPro
3. GCP Post Photo Analysis
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I wanted to test the difference between the mosaiking functions on both ArcPro and Pix4D to see if one had a better outcome than the other.

I hadn't used these functions in over a year (both software had multiple updates between that time), so I wanted to see if any of their functions improved.

To test this, I did 3 analyses with different amounts of photos/coverage to see if there was a max amount of coverage that would start to make the processing less effective.



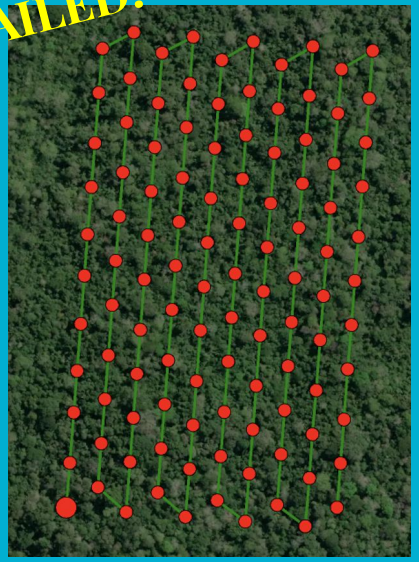
Pix4Dmapper

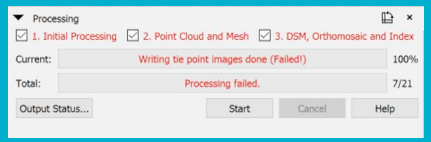


Methodology - Pix4D Results

1. Data Collection and Organization
2. Compare Orthomosaics for Pix4D & ArcPro
3. GCP Post Photo Analysis
4. Analysis on Sun's Positioning and its Effect on Processing
5. Uncertainty Models

FAILED!





110 Photos
60% Overlap
Standard for Urban Mapping



165 Photos
70% Overlap



220 Photos
85% Overlap

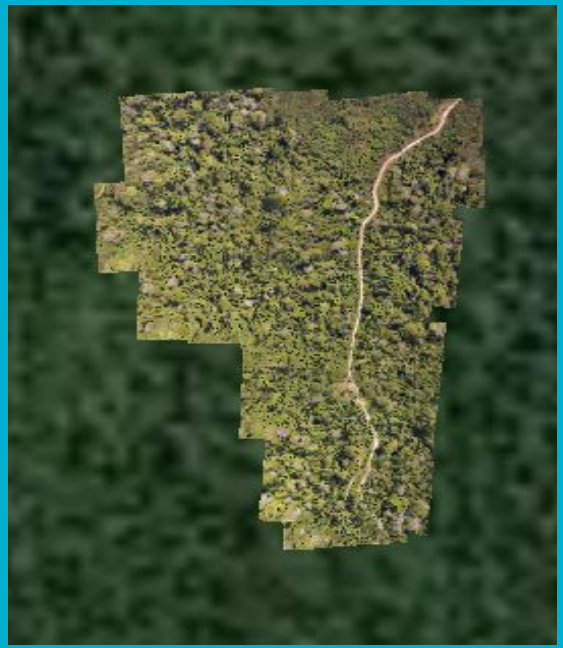
Methodology - ArcPro Results

1. Data Collection and Organization
2. Compare Orthomosaics for Pix4D & ArcPro
3. GCP Post Photo Analysis
4. Analysis on Sun's Positioning and its Effect on Processing
5. Uncertainty Models

ALSO FAILED!



110 Photos
60% Overlap
Standard for Urban Mapping



165 Photos
70% Overlap



220 Photos
85% Overlap

Methodology - Results

1. Data Collection and Organization
2. Compare Orthomosaics for Pix4D & ArcPro
3. GCP Post Photo Analysis
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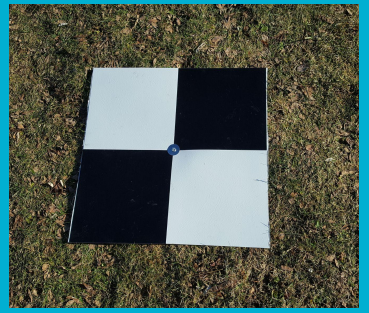
When I first conducted these tests I originally wanted to stick with Pix4D for the rest of the project. However, when I imported the Pix4D orthomosaic into ArcPro to test its ability to georeference, the was way off.

ArcPro offered more in terms of spatial accuracy, color matching/balancing and editing tie points

Methodology - GCP Tests

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2. Compare Orthomosaics for Pix4D & ArcPro
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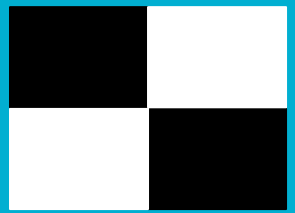
I wanted to test if I could manually input ground control points into my photos in photoshop then re-process the orthomosaic to see if it's more accurate than the originals.



Real life GCP







Digital GCP





Without GCP





With GCP

Methodology - GCP Tests

43,322 more tie points with the digital GCPs!

1. Data Collection and Organization
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0 of 114,289 selected



0 of 157,611 selected

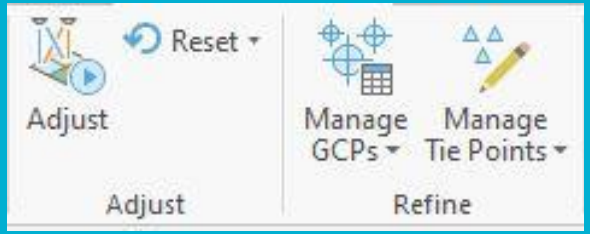
Methodology - GCP Tests

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Computational Methods / Block Adjustments

- **Disparity**—Generate seamlines based on the disparity images of stereo pairs. This method can avoid seamlines cutting through buildings.
- **Voronoi**— Generate seamlines using the area Voronoi diagram.
- **Radiometry** — Generate seamlines based on the spectral patterns of features within the imagery.
- **Edge Detection**—Generate seamlines over intersecting areas based on the edges of features in the area.
- **Geometry**—Generate seamlines for overlapping areas based on the intersection of footprints. Areas with no overlapping imagery will merge the footprints

Block adjustments are a technique used in remote sensing where a transformation is computed for a block of overlapping images. It assesses the relationship between the photos and how they will be merged together.



GENERATES SEAMLINES!



Disparity



Geometry



Edge Detection

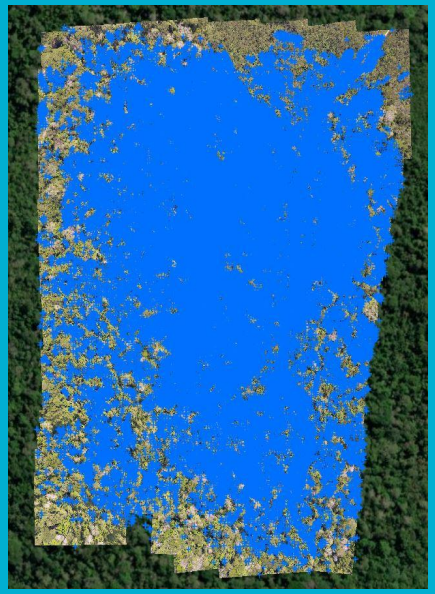


Radiometry



Voronoi

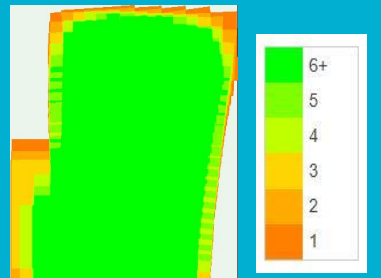
Number of Registered Tie Points



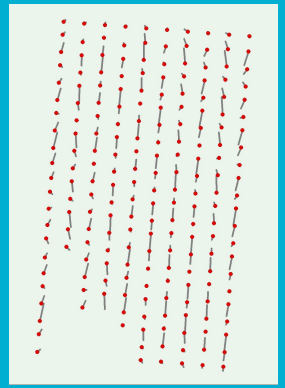


VORONOI METHOD

Registered Overlapping Photos



Original Photo GPS Point Residuals



Methodology - Lighting Tests

1. Data Collection and Organization
2. Compare Orthomosaics for Pix4D & ArcPro
3. GCP Post Photo Analysis
4. Analysis on Sun's Positioning and its Effect on Processing
5. Uncertainty Models

I wanted to test if there was a good way to adjust orthomosaics in post that used photos that were taken in the middle of the day to look like the ones taken in the morning or afternoon.

This is my favorite example of how much the sun azimuth can affect image quality and orthomosaic processing.



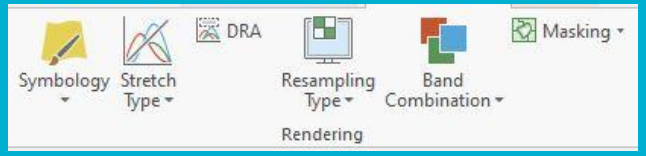




Methodology - Lighting Tests

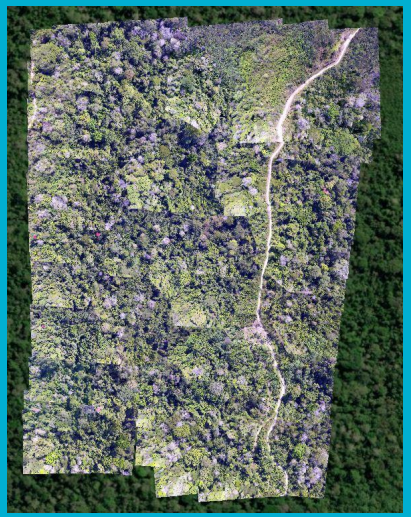
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After playing around with the orthomosaic editor on ArcPro and looking through forums about color matching for orthomosaics, I came across ArcPro's color balancing/matching toolbar where I tested out 3 different techniques.

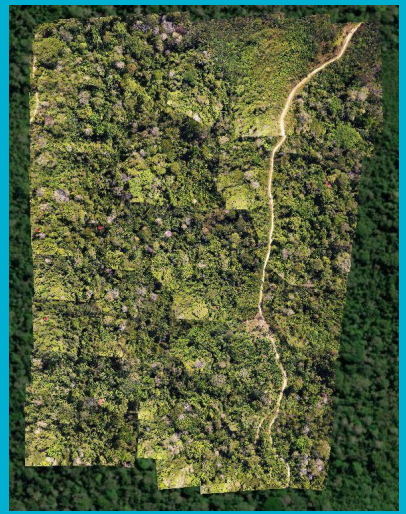




Dodging



Standard Deviation

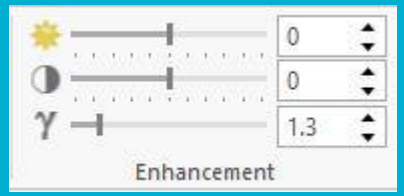


Histogram

Methodology - Lighting Tests

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Methodology - Lighting Tests

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Afternoon Dataset

vs.



Noon Dataset

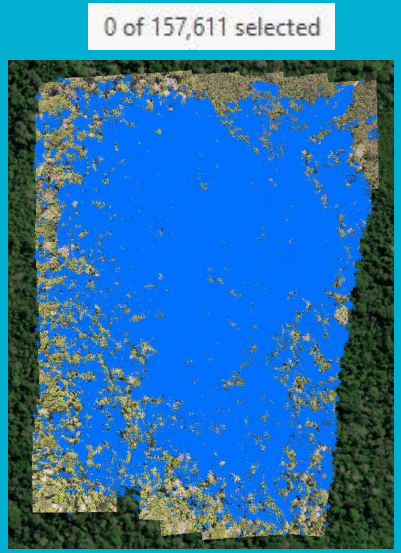
Methodology - Uncertainty & QC Models

1. Data Collection and Organization
2. Compare Orthomosaics for Pix4D & ArcPro
3. GCP Post Photo Analysis
4. Analysis on Sun's Positioning and its Effect on Processing
5. Uncertainty Models

The uncertainty models I've created for this project include

- Tie point density
- Photo Overlap
- Photo connectivity
- Solution points
- Area coverage in relation to flight paths.
- Original photo GPS point residuals

I generated/created uncertainty models for every orthomosaic I made to test the spatial accuracy. These are the models from the final orthomosaic.



Tie Point Density

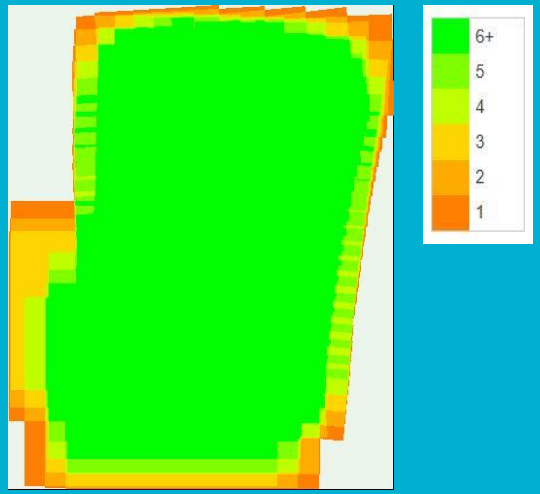


Photo Overlap

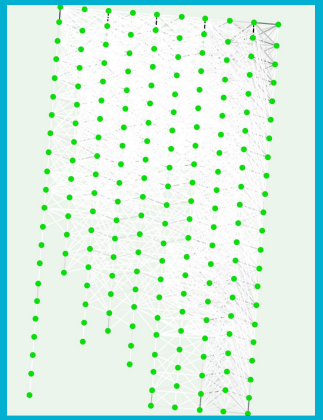


Photo Connectivity

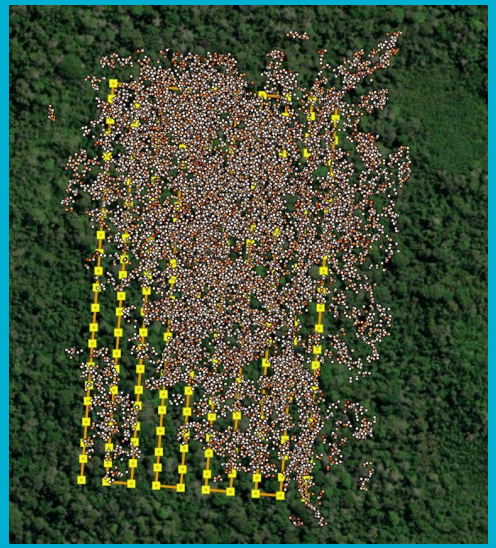
Green points are image positions after block adjustment. A link between two images means there are tie points found between the two

Methodology - Uncertainty & QC Models

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2. Compare Orthomosaics for Pix4D & ArcPro
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5. Uncertainty Models

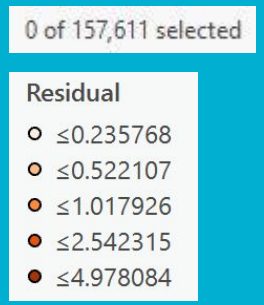
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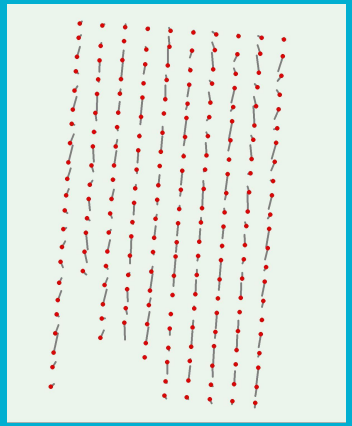
- Tie point density
- Photo Overlap
- Photo connectivity
- Area coverage in relation to flight paths
- Original photo GPS point residuals



Area Coverage in Relation to Flight Paths

Solution points are the same as tie points, but they show the residual of how much the photos had to transform to connect





Original Photo GPS Point Residuals

Red points are the initial positions of images from the drone's internal GPS.

The lines in gray are 3x larger than the actual residuals. Meant to show direction of stretch

Results





Future Work

- Use orthomosaics to make one big basemap of the entire village/boiling river area (15 sq. km). I currently just have different orthomosaics for different flights. Working to merge them seamlessly together
- Use my high res river orthomosaics (that I will reprocess with this method) to generate 3D point clouds to possibly perform flow rate and water volume calculations.
- Orthomosaics will be used to analyze fault lines throughout the river
- This basemap will hopefully be used in published research papers. Used as a reference to visualize all of the data collected by our field team (Ecology, microbiology, and ichthyology).





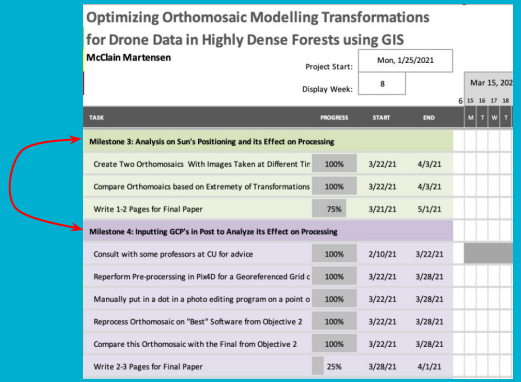
Major Risks that Came Up throughout the Project

I didn't have access to a good enough computer to process some of these maps as efficiently as they could've been. When I did get to work on the lab computer, I realized better RAM and Graphics Card plays a noticeable difference in the final result (visually and spatially). Had to reprocess a lot of maps near the end of March.



It was a lot harder to predict the amount of time it would take to process some of the maps. Some took upwards of 1-2 days. Had to adjust my schedule pretty frequently to fit within the processing times.

I was very behind schedule when I noticed I should use ArcPro over Pix4D. Had to end up switching the order of my lighting tests and GCP tests because the software was different.



Optimizing Orthomosaic Modelling Transformations for Drone Data in Highly Dense Forests using GIS

McClain Martensen

Project Start: Mon, 1/25/2021

Display Week: 8

Mar 15, 202

TASK	PROGRESS	START	END
Milestone 3: Analysis on Sun's Positioning and its Effect on Processing			
Create Two Orthomosaics With Images Taken at Different Tir	100%	3/22/21	4/3/21
Compare Orthomoaics based on Extremety of Transformations	100%	3/22/21	4/3/21
Write 1-2 Pages for Final Paper	75%	3/21/21	5/1/21
Milestone 4: Inputting GCP's in Post to Analyze its Effect on Processing			
Consult with some professors at CU for advice	100%	2/10/21	3/22/21
Reperform Pre-procerssing in Pix4D for a Georeferenced Grid c	100%	3/22/21	3/28/21
Manually put in a dot in a photo editing program on a point o	100%	3/22/21	3/28/21
Reprocess Orthomosaic on "Best" Software from Objective 2	100%	3/22/21	3/28/21
Compare this Orthomosaic with the Final from Objective 2	100%	3/22/21	3/28/21
Write 2-3 Pages for Final Paper	25%	3/28/21	4/1/21

Lessons Learned

- DON'T PROCRASTINATE!!!
- Don't make your scope too big
- Don't actively process from your hard drive/don't have it plugged in when processing.
- Try to process everything on the same computer
- Don't make orthomosaics on your Mac... you will destroy your graphics card :(
- Take the gantt chart more seriously

THANK YOU!!!

Questions? Suggestions?