Aerial Photography and Photogrammetric Processing using Structure From Motion

Mark Laker: Kenai National Wildlife Refuge
Overview

– Acknowledgments
– Technology
– Components of System
– Processing Workflow
– Projects – A variety of Applications
– Strengths and Limitations
– Building Regional Capacity
Acknowledgments

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Some Acronyms

• SfM: Structure From Motion
• GCPs: Ground Control Points
• DEM: Digital Elevation Model
  – DSM: Digital Surface Model
  – DTM: Digital Terrain Model
• CORS: Continuously Operating Reference Station (used to increase position accuracy)
• GNSS: Global Navigation Satellite System (GPS + GLONASS). GLONASS doubles satellites in AK.
Technology: Photogrammetry

- The science and art of obtaining reliable measurements by means of photography.

Extensive network of ground control points

Typically used to create image mosaic and topographic maps.
Structure From Motion (SfM)

- To create a robust and automated scene reconstruction workflow from a collection of photographs.

Developed from Computer Vision field. Uses traditional photogrammetry algorithms, and texture mapping plus object recognition to mosaic images.

Does not require an initial coordinate system
System Components

– Aircraft (fixed wing or helicopter)
– Camera (Nikon D800, 24mm, 35mm, or 50mm lens)
– Camera Control
  • Intervalometer: controls camera shutter and GPS event
  • CamRanger: Wifi connection to camera, iPad control
– GNSS (GPS+GLONASS) Control
  • Aerial Control
  • Base Station
– Software
  • Agisoft Professional (SfM)
  • GrafNav (GNSS processing)
General Project Workflow

- Determine Aircraft, flight parameters and camera setup from desired resolution
- Develop flight lines
- Place ground control markers
- Collect photos
- Process Aerial and Ground Control Points
- Process orthophotographs and DSM
- Archive data
It’s All About the Resolution

- Resolution: Focal Length and Height
  - 24mm or 35mm for all but high resolution (< 2in)
  - Height above ground level (AGL) is main factor
- Select Aircraft: speed, terrain and safety
  - blur is an issue at low AGL (< 500 ft.)
  - Very High resolution (< 1in.) may require a helicopter
- Calculate distance between transects (40% ortho. only, 50% to 60% for ortho + DEM)
- Higher resolution = closer transects = more time
Closeup Resolution Comparison

20 inches: Satellite

7 inches: DSLR

4.5 inches: DSLR

1.5 inches: DSLR
And a little Higher Up

- 20 inches: Satellite
- 7 inches: DSLR
- 4.5 inches: DSLR
- 1.5 inches: DSLR
Getting Ready to Fly...

– Create flight lines
  • For orthophotos you need 40% side lap, 50% for Digital Elevation Model (DEM)

Mountainous terrain may require varying distance between flight lines.
How Accurate Do You Want Need It?

• <1.5 m. Precise Point Position (PPP) solution (with no GCPs, CORS, or base station).
• <1 m. Differential GNSS post-processing with CORS or base station (no GCPs).
• <8 cm. Differential GNSS post-processing with 1 to 3 Ground Control Points.

*These are conservative estimates for difficult terrain.
Ground Control and Base Stations

- Need 1-3 GCPs (Two for correction, one for accuracy check)
  - Only need to do this once. You can register future acquisition to first.
- If area is > 100 miles from CORS you need a mobile base station for differential correction
Process Camera Positions and Ground Control Points

- GrafNav software is used to solve camera position using the event marker time stamp.
SfM software Aligns Photos

Aligns photo by matching pixels on overlapping photos and creates an initial sparse point cloud.
Create Dense Point Cloud

The sparse point cloud is refined through lens and camera calibration, and GCPs to develop an very accurate and dense point cloud.
Create DEM from Point Cloud

The point cloud can be meshed to produce a DEM
Create Orthophotographs

The point cloud is also used to create an orthometrically corrected image mosaic from the aligned photos.
Create an Accuracy Report

Camera Locations

Fig. 3. Camera locations and error estimates. 
Z error is represented by ellipse color. X,Y errors are represented by ellipse shape. 
Estimated camera locations are marked with a black dot.

<table>
<thead>
<tr>
<th>X error (m)</th>
<th>Y error (m)</th>
<th>Z error (m)</th>
<th>Total error (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.093570</td>
<td>0.975324</td>
<td>0.166970</td>
<td>0.205689</td>
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</tbody>
</table>

Table 2. Average camera location error.
Archive Point Cloud and Orthophotographs

SfM!
A Variety of Applications

– Orthophotography
  • High Resolution
  • Accuracy
  • Efficient

– Digital Elevation Model
  • Resolution
  • Vegetation height
  • Snow depth and change detection (in progress)

– Processing Historic aerial photos

– Multispectral
Funny River Fire

- Photographed 220,000 in less than 16 of flying
- Cost after processing was ~ 10 cents/acre
Small Projects

Agisoft can export to KMZ file and viewed in Google Earth
Yukon Flats: Willow Project
High Accuracy With Ground Control
5.0 cm off horizontal
10 cm off vertical
Ground Sample Distance = 17 cm
Looking for Willow Bands
DSM in ArcMap
Some Issues with Large Conifers
Historical Aerial Photos

• Scanned 471 black and white 1968 aerial photos (well some unfortunate grad student did)
• Spent about 4 hours on this as a proof-of-concept.
• Put them all into Agisoft without any control and let it have at it.
Aligned 360 of 471 photos. Georeferenced with 5 GCPs.
Point Elevation (meters)

- 511 - 1058
- 418 - 511
- 326 - 418
- 234 - 326
- 142 - 234
- 50 - 142
- 0 - 50
SfM Strengths and Weaknesses

• Strengths
  – Very cost effective (10-15 cents/acre) compared to traditional photogrammetry and LiDAR
  – Orthophotographs – High resolution and accuracy
  – Automated processing (batch and python scripting in Agisoft)
  – *DEMs – High resolution and accurate
  – Relatively low equipment cost
SfM Strengths and Weaknesses

• Weakness
  – Combination of Technical Complexity and Art: electronics, photography, GPS, GIS, logistics...
  – Flying consistent transects is not easy
  – No Digital Terrain Model in forested area
  – Anything on or around moving water (waves)
  – Requires bright and calm days to fly
Building Regional SfM capacity

• Current Limitations
  – Mark Lakers time
  – Aircraft and pilot availability
  – Additional equipment ~ 30K

• Some solutions (relative to regional interest)
  – Expanding partnerships with BLM and State (ADGGS)
  – Hiring a technician (based out of RO or KeNWR)
  – Dedicated aircraft/Pilot