Placer River Trail Bridge Inspection Using Small Unmanned Aircraft Systems

Fall Tactical Fire Remote Sensing Advisory Committee
October 29, 2015
Boise, Idaho

Mark Riley, U.S. Forest Service
Rod Dell’Andrea, U.S. Forest Service
Everett Hinkley, U.S. Forest Service
Bob Goetz, U.S. Forest Service
David Lattanzi, George Mason University
Ali Khaloo, George Mason University
Keith Cunningham, University of Alaska Fairbanks
G O A L S

1) Use a UAS to collect high resolution natural color stereo pair and video imagery of the Placer River Trail Bridge to evaluate as an alternative or supplemental tool to traditional structure inspection techniques.

2) Evaluate dense Structure from Motion (dSfM) image processing techniques to produce a measurable 3D wireframe bridge model.

3) Compare dSfM point cloud to laser scanner point cloud.

UAS image data collection: June 9 and 10, 2015
Forest Service Region 10, Washington Office, and Glacier Ranger District, Chugach National Forest: implementation, planning, coordination

University of Alaska Fairbanks: UAS, pilots, lead researcher

George Mason University: data collection, processing, analysis
Mapping Vegetation on the Copper River Delta

**Location**

Anchorage

89-km (55 miles) south of Anchorage

Placer River Trail Bridge

Girdwood
• Longest clear span, glued-laminated, timber truss pedestrian bridge in North America at 280 feet
• Anticipated operational service life of 75-years
• Completed in July 2013
• Managed for pedestrian use (Glacier Ranger District)
• Remote site; accessible via Alaska Railroad
Purpose built hexacopter “Ptarmigan”
Based on DJI S800 airframe

Gyrostabilized Sony Nex7 and GoPro
~20 min/flight (LiPo batteries)

A higher order data collection tool.
Two pilots (one acting as spotter) and generator to power equipment
<1 hr to set up and have safety briefing
Base station
Programmable flights
GPS or GNSS signal essential (if lost, return home function)
Live video feed

Programming flight
Live video feed
DATA COLLECTION

FARO Focus laser scanner set up in 12 locations
Vortex shedding was a UAV stability concern, but not an issue.
DATA COLLECTION

Upward-looking GoPro video imaging beneath structure

Lighting is a minor issue

Mostly manual control
Imaging top of structure
DATA COLLECTION

Still frames collected with nominal 90% overlap
>90% imagery useable for SfM (Photoscan Pro)
~4 hrs total flight time

Table 1  Summary of Data Acquisition Mission

<table>
<thead>
<tr>
<th>Type of Data</th>
<th>Sensor Type</th>
<th>No. of Images/Scans</th>
<th>Size (GB)</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imaging</td>
<td>Nikon D800E</td>
<td>2222</td>
<td>34.9</td>
<td>Ground-based imagery</td>
</tr>
<tr>
<td></td>
<td>Sony Alpha NEX-7</td>
<td>2626</td>
<td>24.7</td>
<td>UAS-based imagery</td>
</tr>
<tr>
<td>Video</td>
<td>GoPro</td>
<td>10</td>
<td>7.57</td>
<td>-</td>
</tr>
<tr>
<td>Laser scanning</td>
<td>FARO Focus3D</td>
<td>24</td>
<td>4.26</td>
<td>-</td>
</tr>
<tr>
<td>3D Point Clouds</td>
<td>-</td>
<td>5</td>
<td>13.71</td>
<td>-</td>
</tr>
</tbody>
</table>

90GB and 5000 images, video, and laser scans
Bridge plans used for point of reference and to assist with autopilot navigation
Data Analysis
DATA ANALYSIS

**Goals**
- Recreate flaws
- View underside of deck
- Track long-term camber/motion

**Challenges**
- Massive data set
- Confusing data
- Image degradation
- High contrast scene
Gap between end of kerf plate and sawn kerf in brace

\[ \sim 2.325'' \]
• Images to 3D model: Structure-from-Motion
  – triangulate features across image set
  – Software: Photoscan and SURE

• Small details, big model
1. Separate clouds for big and small details
   – Image capture plan is critical!
2. Merge the sparse models
3. Generate dense reconstruction
   – SURE vs Photoscan

Geometry  Intermediate  High-res
Cloud     Clouds       Clouds
Dense Point Clouds

- Geometry cloud
- Intermediate clouds
- High-res clouds
RESULTS

- 500 hours of computation time
- 14 billion points
- Need good rendering support!
Bolt head not flush with plate
POINT CLOUD RECONSTRUCTION
Mapping Vegetation on the Copper River Delta

POINT CLOUD RECONSTRUCTION
POINT CLOUD RECONSTRUCTION
• As bridge ages, it sags
  – does it age gracefully?
• Rate of sag is a health indicator
• Required level of accuracy $\leq 10\text{mm}$
• Point cloud deviation analysis
• Models from repeated inspections
• Accuracy based on cloud resolution
• Sub-millimeter measurement is possible
1) Angle of incidence for most of the structure is achievable only with a UAS

2) A UAS is an effective means to obtain thousands of high resolution (~0.5-cm) stereo pair images of a structure in a short amount of time

3) For this bridge, and with low wind speeds, vortex shedding was a minor, surmountable issue
4) Dense Structure from Motion (dSfM) image processing techniques are [currently] the most effective way to produce highly detailed and accurate measureable **multispectral** 3D models in a short period. Depending on collection parameters, dSfM can produce a denser point cloud than lidar.

5) For this remote location, privacy was not a concern

6) Proposed FAA rules are sufficient for this type operation
7) Proof-of-concept costs are not reflective of future costs; costs will decrease for subsequent projects

8) The mission was successful and is replicable for other similar projects
9) Could not get interior of bridge with UAS as it was too bulky to operate safely; a hand-held Nikon D800E was used to collect stereo imagery for dSfM processing.

10) Takes a powerful computer and several weeks of processing to produce accurate and detailed dSfM models.
A sUAS minimizes the time spent on site and increases safety by removing potential points of failure - such as suspended platforms, ladders, and harnesses - and potentially dangerous situations from the conventional inspection equation.

Proposed FAA rules will be sufficient for 90% of Forest Service sUAS operations across multiple disciplines.

Cost of using sUAS for project work, such as structure inspections, will decrease as Forest Service sUAS policy evolves and methods mature.

A sUAS is a higher order data collection tool that needs to be more effectively utilized by the Forest Service.
1) **Science**: processing, analysis, reporting, technology development

2) **Policy Development**: Forest Service and FAA

3) **Effective Implementation**: Guidelines and new projects