Lessons Learned from OSU PacTrans & ODOT UAS Projects

Chase Simpson, Chris Parrish, Dan Gillins, Matt Gillins

UAS in Transportation Workshop
July 30-31, 2018
3+ Years’ of Research Projects

1. PacTrans Small project: Cost-effective Bridge Safety Inspections Using Unmanned Aerial Vehicles (UAVs), 2015-2016
2. ODOT SPR 787: Eyes In The Sky: Bridge Inspections With Unmanned Aerial Vehicles, 2015-2017
3. FHWA project with Parsons Brinckerhoff (now WSP): Effective Use of Geospatial Tools in Highway Construction
Specific Project Goals

1. Evaluate the performance of UAS-based methods for inspecting bridges

2. Identify which ODOT inspection requirements can and cannot be satisfied with a UAV inspection

3. Provide a cost-benefit analysis of performing UAV inspections for communication towers and bridges

4. Develop procedures/guidelines for how to safely and effectively perform UAS inspections of bridges and communication towers
Test Bridge Inspections

Bridges Inspected

(1) Independence Bridge
(2) Crooked River Bridge
(3) Mill Creek Bridge
(4) St. Johns Bridge
  - Preliminary
(5) Winchester Bridge
(6) St. Johns Bridge
  - Detailed
Test Bridge Inspections

Independence Bridge: Sept 2015

Location:
• In Independence, OR

Airframe(s) used:
• DJI Phantom 3 Pro

Flight Objective:
• Familiarize with bridge inspection workflow
• Capture high quality imagery/video for inspection purposes

Details:
• Large deck plate girder bridge
• 675.4 m long
  • Longest span: 46.3 m
• Classified as Fracture Critical
Independence Bridge
Captured Imagery
Test Bridge Inspections

Crooked River Bridge: July 2016

Location:
• 8 km north of Terrebonne, OR

Airframe(s) used:
• senseFly Albris

Flight Objective:
• Capture high quality imagery for inspection purposes
  • targeting specific areas difficult to inspect using traditional methods
• Create 3D model using SfM

Details:
• Steel Arch Bridge
• 141 m long
  • Longest span: 100 m
• Pedestrian Only
Crooked River Bridge

Captured Imagery
Schematic representation of overlapping images taken from a UAS and the flight path using manual flight mode with sensor assistance (from Javadnejad et al. 2017, with permission)
Crooked River Bridge
Captured Imagery
Crooked River Bridge
Captured Imagery
Post-Processing

Structure From Motion

• Relatively new photogrammetric approach
  – Leverages advanced image matching algorithms from the field of computer vision

• Many requirements are relaxed, as compared with conventional photogrammetry:
  – Can work with a wide range of viewing geometries and consumer-grade cameras
  – Well suited to UAS imagery!
  – Highly automated, easy to use software
Additional Survey Equipment

Ground Control Survey Equipment

(a) Total station used to position photo identifiable features on bridge Example (c) & (d)

(a) GNSS Antenna occupying an aerial ground control target
Crooked River Bridge

Post-Processing Results – Pointcloud & Orthomosaic

An orthophoto of the profile of the Crooked River Bridge produced from processing the images using SfM. (from Javadnejad et al. 2017, with permission)
Test Bridge Inspections

Mill Creek Bridge, July 2016

Location:
• 17 km NW of Warm Springs, OR

Airframe(s) used:
• senseFly Albris

Flight Objective:
• Capture high quality imagery for inspection purposes
  • targeting specific areas difficult to inspect using traditional methods

Details:
• Cantilevered Warren deck truss bridge
• 163 m long
  • Longest span: 50 m
Mill Creek Bridge
Captured Imagery
Mill Creek Bridge

Captured Imagery
Test Bridge Inspections

St. Johns Bridge (Prelim Test), Sept 2016

Location:
• St. Johns Portland, OR

Airframe(s) used:
• senseFly Albris
• DJI S900 w/ Sony WX500 (30x optical zoom)

Flight Objective:
• Test use of optical zoom camera
• Capture high quality imagery for inspection purposes
  • targeting specific areas difficult to inspect using traditional methods

Details:
• Metal Riveted Warren deck truss
• Wire Cable Suspension
• 1100 m long
  • Longest span: 368 m
St. Johns Bridge (Preliminary Test)

Captured Imagery
St. Johns Bridge (Preliminary Test)

Captured Imagery
St. Johns Bridge (Preliminary Test)

Captured Imagery
Test Bridge Inspections

Winchester Bridge, March 2017

Location:
• Winchester, OR

Airframe(s) used:
• senseFly Albris

Flight Objective:
• Capture high quality imagery for inspection purposes
  • While receiving real-time input from onsite inspectors

Details:
• Warren deck truss bridge
• Southbound bridge of I-5
• 500 m long
  • Longest span: 42 m
Winchester Bridge
Captured Imagery
Winchester Bridge
Captured Imagery
Winchester Bridge

Captured Imagery
Test Bridge Inspections

St. Johns Bridge (Detailed Test), April 2017

Location:
• St. Johns Portland, OR

Airframe(s) used:
• senseFly Albris

Flight Objective:
• Capture high quality imagery for inspection purposes
• Week long in-depth inspection
• Test inspecting directly under deck

Details:
• Metal Riveted Warren deck truss
• Wire Cable Suspension
• 1100 m long
  • Longest span: 368 m
• Flight limited to eastern 550 m from center of main span
St. Johns Bridge (Detailed Test)

Captured Imagery
St. Johns Bridge (Detailed Test)

Captured Imagery
St. Johns Bridge (Detailed Test)

Captured Imagery
St. Johns Bridge (Detailed Test)

Captured Imagery
St. Johns Bridge (Detailed Test)

Captured Imagery
St. Johns Bridge (Detailed Test)
Captured Imagery
Test Tower Inspections

Towers Inspected

(1) Woodburn Tower
(2) Washburn Butte Tower
(3) Corvallis Maintenance Tower
(4) Grizzly Mountain Tower
Washburn Butte Tower

Flight Planning
Test Tower Inspections

Woodburn Tower, April 2016

Location:
• 3 km NNW of Woodburn, OR

Flight Objective:
• Familiarize with tower inspection workflow
• Capture high quality imagery for inspection purposes
• Create orthomosaic of site
• Create 3D model using SfM

Details:
• Owned by Marion County
• A-Frame tower with triangle base
• 5 installed antennas
• 53 m tall
Woodburn Tower
Captured Imagery
Woodburn Tower

Captured Imagery
Woodburn Tower

Point cloud generated using PhotoScan
Test Tower Inspections

Washburn Butte Tower, April 2016

Location:
• 6km north of Brownsville, OR

Flight Objective:
• Capture high quality imagery for inspection purposes
• Create orthomosaic of site
• Create 3D model using SfM

Details:
• A-Frame tower with square base
• 8 installed antennas
• 48.8 m tall
Washburn Butte Tower
Collected Imagery
Washburn Butte Tower
Collected Imagery
Washburn Butte Tower

3D Modeling Results
Washburn Butte Tower

3D Modeling Results
Washburn Butte Tower

3D Modeling Results
Washburn Butte Tower

3D Modeling Results - Organization

Selected Location
Washburn Butte Tower

3D Modeling Results - Obstructions
Test Tower Inspections

Corvallis Maintenance Site Tower, April 2016

Location:
- Corvallis, OR
- ODOTS District 4 maintenance yard

Flight Objective:
- Capture high quality imagery for inspection purposes

Details:
- Rectangular tower with square base
- 2 installed antennas
- 27.4 m tall
Corvallis Maintenance Site Tower

Collected Imagery
Corvallis Maintenance Site Tower

Collected Imagery
Test Tower Inspections
Grizzly Mountain Tower, July 2016

Location:
- 23 km NW of Prineville, OR

Flight Objective:
- Capture high quality imagery
- Create 3D model using SfM

Details:
- A-Frame tower with square base
- 9 installed antennas
Grizzly Mountain Tower

Findings

• Over 10 towers near mountain summit

• Detected significant frequency interference using a spectrum analyzer
  – 2.4 and 5.0 GHz frequencies

• Interference from nearby Wireless Internet Service Provider (WISP) towers

• Unable to perform any flights
  – Tried all possible radio frequencies available
Cost Benefit Analysis

Procedures

1. Establish baseline costs for bridge inspections conducted *without* the use of UAS by compiling existing data from ODOT
   – 33 bridge inspection project budget spreadsheets
2. Determine the percentage of bridges that ODOT inspects that are suitable for UAS inspection
   – Airspace, proximity to populated areas, vegetation, size of bridge, etc.
3. Establish which project cost categories could be reduced (not eliminated) through use of UAS:
   – Personnel time (field and office)
   – Equipment rental/usage (e.g., snooper trucks)
   – Traffic control
   – Travel (including lodging, meals and incidentals)
Cost Benefit Analysis

Procedures (cont’d)

4. Estimated annual cost savings = (average cost savings per suitable bridge) × (# of bridges/yr inspected by ODOT) × (percentage of bridges suitable for UAS inspection)

5. Estimate costs:
   – Cost of purchasing 3 UAS
   – Annual maintenance cost
   – Data storage

\[
B = \$10,200(730 \times 0.16) = \$1,191,360
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\[
\sum C = \$117,237 + \$4,500 + \$5,700 = \$127,437
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\[
BCR = \frac{\$1,191,360}{\$127,437} \approx 9
\]
Project Key Findings

Operational Considerations

• Sensor-assisted and waypoint-assisted flight modes are most useful flight modes for bridge inspection
  – But, unmanned aircraft pilots must be proficient in entirely manual flight, due to the possibility of losing GPS

• UAS with front-mounted, variable-tilt cameras are advantageous for bridge inspection

• Wind condition is the most important environmental variable in UAS bridge inspection
  – Illumination conditions and camera settings (ISO, f-stop and focal length) are critical to obtaining high-quality imagery
    • UAS bridge inspection flight crews should have at least a basic level of expertise in photography
Project Key Findings

Overarching conclusions

- UAS can assist to varying degrees in many required elements of a bridge inspection
  - Very well suited for initial and routine inspections and for satisfying report requirements related to geometry and structural evaluation
- Cracks, pack rust, connections, hardware and bearing locations were all determined to be readily-identifiable in the imagery collected in this project, with the recommended flight procedures
- Cost-benefit analysis provides strong indication of positive ROI for implementing UAS in ODOT’s bridge inspection program
  - Should be refined as more data becomes available
- UAS are likely to be an increasingly valuable tool to State DOTs in bridge inspection
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