Integration of UAV Sensor Data into Michigan DOT Workflows

TRB Annual Meeting Lectern Session 1086:
“Advances in Sensing and UAV Technologies”
Monday, January 25, 2021, 1:00 – 2:30pm Eastern

Presentation P21-20572

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Objectives for Phase III MDOT UAV Integration project (2019-2022)

A. Enable everyday usage of UAS by MDOT
   A. Build from Phase I Demonstration (2013-2015) and Phase II Implementation (2016-2018) MDOT research projects with Michigan Tech

B. Work closely with MDOT Sections to get UAS capabilities into their hands through efficient access to UAS collected data, platforms, sensors, and software tools

C. Develop and deploy four use cases from MDOT Sections
   A. Traffic Operations Surveillance Monitoring
   B. Bridge Inspection
   C. Construction Inspection
   D. LiDAR for Design Surveys

D. Deploy and integrate the use of UAS capabilities and data usage as part of day-to-day operations,

E. Recommend how to effectively work with the private sector to take advantage of rapidly developing sensors and platforms
Use Case 1: Traffic Operations
Types of results:

- **Type of traffic studies**
  - Trajectory analysis
  - Speed studies
  - Traffic volume studies
    - Cumulative inflow and outflow count
    - Inbound and outbound flow rate

- **Road facilities**
  - Freeways
  - Arterials

- **Traffic operation use cases**
  - Left-turn analysis at intersections
  - OD flows in the weaving areas
2020 results

- **Use Case 2**: Use drones to monitor rural corridors – with real-time traffic video streaming
  - Data collection site: Williamston Rd / I-96
    - Williamston Rd videos were attempted on October 7, 2020 (winds went above 30 mph)
      - Streamed to YouTube
    - Additional day to get I-96 WB / Williamston (Exit 117) traffic video data completed on November 5, 2020
      - Transmitted to MTRI server
      - Streamed to YouTube
      - Analyzed – YOLO algorithm
Weaving area applications

- Initial results for two short video clips
  - OD flows (about 5-min: 08:39:39~08:45:32)
    - M14 (O) | 103 | 23
    - US23 (O) | 145 | 44
  
  - OD flows (about 5-min: 08:59:28~09:05:56)
    - M14 (O) | 77 | 26
    - US23 (O) | 110 | 32
Use Case 2: Bridge Inspection Assessment
Seven standard geospatial outputs for UAS sensing of bridge decks
Automated spall detection

- Automated spall detection algorithm (developed by Brooks, Dobson, Aden, Graham)
- Applied to high-resolution 3D elevation model (DEM) of bridges created from UAS images
- Merriman East: 4.4% spalled (150.0 ft²)
- US-31/White River: 79.2 ft² (1.1%) spalling in 2017 vs. 33.6 ft² (0.5%) in 2014
Quantitative thermal analysis results

Existing thermal method: ASTM D4788 - 03(2013)
Standard Test Method for Detecting Delaminations in Bridge Decks Using Infrared Thermography
TADDA

Thermal Analysis & Delamination Detection Algorithm

Detects delaminations based on thermal and optical image inputs.

New updates in algorithm:

A more user-friendly GUI. Advanced (Pro) version that enables in detail user interventions.
Beyer Rd –
New results:
8.79 m² vs. 8.61 m²
previously
(94.64 ft² vs. 92.73 ft²)

Uncle Henry –
New results:
9.4 m² vs. 4.96 m²
previously
(101.2 ft² vs. 53.4 ft²)

Manual sounding surveys:
Beyer: 29.1 m² (313.3 ft²)
Uncle Henry: 17.5 m² (188 ft²)
Laplaisance Creek Bridges
Context Capture 3D Model
**Project Plans**

- Schedule of activities
- Quantity of planned work

<table>
<thead>
<tr>
<th>Activity</th>
<th>Measurement Unit</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement Breaking and Removal</td>
<td>square yard</td>
<td>Length Pavement Removed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Width Pavement Removed</td>
</tr>
<tr>
<td>Culvert Installment</td>
<td>foot</td>
<td>Length Culvert</td>
</tr>
<tr>
<td>Earthwork</td>
<td>cubic yard</td>
<td>Length Ditch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Width Ditch</td>
</tr>
<tr>
<td>Open-Graded Underdrain</td>
<td>foot</td>
<td>Thickness Ditch</td>
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<td>Placing Separator and OGDC</td>
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<td>Length Underdrain</td>
</tr>
<tr>
<td>Mainline Pavement</td>
<td>square yard</td>
<td>Length Lane Paved</td>
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<td></td>
<td></td>
<td>Width Lane Paved</td>
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<tr>
<td>Shoulder Pavement</td>
<td>square yard</td>
<td>Length Shoulder Paved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Width Shoulder Paved</td>
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**UAV Data**

- Digital Elevation Models
- Hillshade
- Ortho

**As-Planned Parameters**

- Production rate
- Geometry information
- Estimated work completed

**Project Parameters**

- Production rate
- Geometry information
- Estimated work completed
Parameter Detection in Civil 3D

Approaches:
- Horizontal Design
- Vertical Design

Outputs:
- Model alignment;
- UAV parameter data;
- Work quantities.
Progress Analysis

Production Rate = \frac{\text{Length} \times \text{Width Pavement Removed}}{T_{final} - T_{initial}} \quad \text{(square foot/minute)}
Bridge Progress Monitoring

Parameter Extraction Example

● Component: Pier

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Measurement (m)</th>
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<tbody>
<tr>
<td>Pier Diameter</td>
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<tr>
<td>Pier Height</td>
<td>3.14</td>
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<tr>
<td>Pier Spacing</td>
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<tr>
<td>Pier Cap Width</td>
<td>0.88</td>
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<tr>
<td>Pier Cap Length</td>
<td>17.2</td>
</tr>
<tr>
<td>Pier Cap Height</td>
<td>1.21</td>
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Milestone / Use Case 4: LiDAR UAS for Design Survey

- M13/US23, November 6th, 2019 Standish, MI LiDAR survey
  - MLS (mobile LiDAR) and UAS (drone-borne) LiDAR survey
  - Comparison of MLS and UAS data
    - MLS - RIEGL VMX-1HA
      - Up to 2,000,000 measurements/second
    - UAS - RIEGL MiniVux-DL
      - Up to 100,000 measurements/second
    - Traditional survey data
Milestone / Use Case 4: LiDAR UAS for Design Survey

<table>
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<tr>
<th>ALL Data Points</th>
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</thead>
<tbody>
<tr>
<td><strong>Data Source</strong></td>
<td><strong>Average Point Spacing (ft)</strong></td>
</tr>
<tr>
<td>UAS</td>
<td>0.09</td>
</tr>
<tr>
<td>MLS</td>
<td>0.04</td>
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<table>
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<th>GROUND ONLY Data Points</th>
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<tbody>
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<td><strong>Data Source</strong></td>
<td><strong>Average Point Spacing (ft)</strong></td>
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<tr>
<td>UAS</td>
<td>0.9</td>
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<tr>
<td>MLS</td>
<td>0.084</td>
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**UAS DATA SUMMARY**

<table>
<thead>
<tr>
<th></th>
<th>SCATs</th>
<th>VATs</th>
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</thead>
<tbody>
<tr>
<td>Radial RMSE (ft)</td>
<td>0.08</td>
<td>0.17</td>
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<tr>
<td>NSSDA HORIZONTAL Accuracy at 95% Accuracy Level (ft)</td>
<td>0.13</td>
<td>0.29</td>
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<tr>
<td>NSSDA VERTICAL Accuracy at 95% Accuracy Level (ft)</td>
<td>0.11</td>
<td>0.08</td>
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</table>

**MLS DATA SUMMARY**

<table>
<thead>
<tr>
<th></th>
<th>SCATs</th>
<th>VATs</th>
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</thead>
<tbody>
<tr>
<td>Radial RMSE (ft)</td>
<td>0.05</td>
<td>0.07</td>
</tr>
<tr>
<td>NSSDA HORIZONTAL Accuracy at 95% Accuracy Level (ft)</td>
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<td>0.12</td>
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<tr>
<td>NSSDA VERTICAL Accuracy at 95% Accuracy Level (ft)</td>
<td>0.03</td>
<td>0.02</td>
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Milestone / Use Case 4: LiDAR UAS for Design Survey

- M13/US23, November 6th, 2019 Standish, MI LiDAR survey
  - Area surveyed following leaf-off
    - Treed areas contained mix of deciduous and evergreen
  - Traditional survey elevation data compared with UAS LiDAR elevation data for “soft surfaces”
    - LiDAR pts within 0.5 ft diameter of the traditional survey were averaged and compared to the traditional survey elevation
Milestone / Use Case 4: LiDAR UAS for Design Survey

- For n=26 surveyed locations, the average difference between the traditional survey data and drone LiDAR data survey was -0.34 ft, with a standard deviation of 0.61 ft.
Milestone / Use Case 4: LiDAR UAS for Design Survey

  - Vegetation & leaves still present
  - Experimental ground control points (3x3 & 2x2 ft GCPs, 2x2 & 4x4 ft chevrons)
  - Test of different drone flight velocities, grid patterns
Milestone / Use Case 4: LiDAR UAS for Design Survey

- US-127 survey near Rives Junction, North of Jackson
  - Ortho images of sites created from Mavic 2 imagery
  - Images show detailed comparisons of commonly used surveying targets (2x2ft folding mesh target, 1x1 ft 4 inch wide reflective chevrons) and experimental targets (3x3 ft reflective plywood, 4 foot reflective plywood chevrons)
US-127 NORTH SITE UAV (RGB)
NOTE: TARGETS NOT THAT VISIBLE

US-127 NORTH UAV
(GRAYSCALE)
NOTE: TARGETS SOMEWHAT MORE VISIBLE
US-127 SOUTH SITE (RGB) CROSS HATCH FLYING PATTERN
Milestone / Use Cases 5 & 6: Integrate results with MDOT databases and workflows

- Focusing on assessing how to integrate the UAS-collected data and outputs from use cases 1-4 with MDOT databases.
- For each use case a filing system will be setup to properly store data to achieve optimum functionality.
- All of the uploaded datasets will include standardized metadata in XML format that will document geospatial data quality.
- Focusing on ensuring that the collected data are well aligned with the needs of SMEs and MDOT decision-makers.
  - Specific quantities measured
  - Metrics reported
  - Quality and granularity of the data being measured
  - Reporting format
Team lead:
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Collins Engineers: Barritt Lovelace

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