Transportation Infrastructure Assessment Using High Resolution Remote Sensing

David Dean (dbdean@mtu.edu), Colin Brooks, Richard Dobson, Chris Roussi
Michigan Tech Research Institute  Ann Arbor, MI

Tim Colling, Tess Ahlborn, Thomas Oommen, Tim Havens, Melanie Kueber
Michigan Technological University, Houghton MI

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Two Different Applications of Close Range Photogrammetry

- Unpaved Road Condition Assessment System (URCAS)
  - UAV based data collection
  - In-house SfM image processing, distress quantification

- Bridge Deck Surface Condition evaluation (3DOBS)
  - Truck based data collection system
  - Agisoft Photoscan for image processing
  - Arc Python tools for distress extraction

- Both systems use close range photogrammetry to extract road surface condition data
3DOBS

- 3D Optical Bridge-evaluation System
- Designed to apply a low-cost remote sensing method to bridge deck condition analysis
- Uses close range photogrammetry to extract distresses from overlapping imagery.
- USDOT funding
First version used Nikon D5000 to capture imagery

- Camera mounted in back of truck 9’ above bridge deck
  - Full lane width in field of view
  - Truck drove ~2 mph to maintain 60% image overlap
Overlapping Imagery
Data processing

- Use Agisoft PhotoScan to create 3D model
  - Automatically aligns photos
  - Earlier versions did not recognize geotagging
  - Reference points were needed to generate DEM

- Current version (v1.0) works well
  - Now recognizes geotagged images, no grid necessary

- Other software available (Pix4D, Correlator 3D, others)
Intermediate Process Outputs

- Orthomosaic
- 3D Model
- Digital Elevation Model (DEM)
Updated Data Collection

- 3DOBS Highway Speed version
  - Uses Red EPIC sensor
  - 13.8 MP@60fps
  - Allows operation at near highway speeds (45mph +)
Updated Data Collection

- 3DOBS “High Res”
  - Uses Nikon D800 (or similar hi-res sensor)
  - ~36 megapixels, ~2-3 fps,
    Operates up to 5 mph
  - High resolution images for bridge deck scoping/crack detection
High resolution imagery produced from 3DOBS High Res (36 mp)

On the left is high resolution imagery of crack detection.

Right is high resolution imagery showing spall detection.

Same image processing algorithms as 3DOBS v1
Spall Detection Algorithm

- Written in ArcPy
- Able to locate and characterize spalls by area and volume.
- Can limit the minimum size of spalls detected.
- Shapefile is generated during processing, is not final output
- Final output is a condition metric for bridge deck
Thermal Delamination Detection

- BridgeGuard Thermal Data
  - US 131 SSB over White Creek Ave near Grand Rapids, MI
  - Tested 8/9/13 at 3:45 pm
  - Same bridge deck as 3DOBS example above
Thermal Delamination Detection
Near Highway Speeds project funded by MDOT

Project is ongoing

Includes Thermal and Bridge Viewer Remote Camera System (BVRCS) inputs
  - Integrating 3DOBS with a commercial vehicle-mounted thermal IR bridge deck assessment system

Final output is integrated GIS layer containing spall and delamination location and size, including % of bridge deck that is spalled, delaminated.
Characterization of Unpaved Road Condition

- Develop a cost effective method for determining the condition of unpaved roads within a larger road network
  - Commercially viable, cost competitive
  - Platform: manned aircraft or UAV
Road Characteristics

- Unpaved roads have common characteristics
  - **Surface type**
  - **Surface width**
    - Collected every 10', with a precision of +/- 4”
  - **Cross Section (Loss of Crown)**
    - Facilitates drainage, typically 2% - 4% (up to 6%) vertical change, sloping away from the centerline to the edge
    - Measure the profile every 10’ along the road direction, able to detect a 1% change across a 9’-wide lane
  - **Potholes**
    - <1’, 1’-2’, 2’-3’, >3’ width bins
    - <2”, 2”-4”, >4” depth bins
  - **Ruts**
    - Detect features >5”, >10’ in length, precision +/-2”
  - **Corrugations (washboarding)**
    - Classify by depth to a precision of +/-1”
      - <1”, 1”-3”, >3”
    - Report total area of the reporting segment affected
  - **Roadside Drainage**
    - System should be able to measure ditch bottom relative to road surface within +/-2”, if >6”
    - Detect the presence of water, elevation +/-2”, width +/-4”
  - **Float aggregate (berms)**

Representative Sample Road Segment
  • approx. 100’ long, 2 per mile

2 Part Rating System (per distress)
  • Density
  • Percentage of the sample area

Severity
  • Low
  • Medium
  • High
Candidate Remote Sensing Platforms for Unpaved Road Condition Assessment

- Two platforms required to carry sensor were evaluated in this project:
  - UAS (UAV)
  - Fixed-wing manned

- Factors affecting choice are
  - Size, weight, and power (SWAP) requirements
  - Range, altitude, and speed requirements
  - Reliability
  - Cost
Data Collection Platforms

- **Manned fixed wing aircraft**
  - Generally can fly no lower than 500 feet
  - STC may be required to attach camera/sensor to outside of aircraft
  - Must fly from nearby airport to site and return
  - Can be difficult to frame imagery and maintain proper image overlap
  - May be better suited to larger projects
Data Collection Platforms

Unmanned Aerial System (UAS)

- At ~100’, forward speed must be low, to be able to image with the required scene overlap at the maximum sustainable frame rate of the sensor
- Low ground speed → rotary wing aircraft, since fixed-wing would stall
- Must be able to loft 5kg of sensor, controller, and batteries
- Must be able to fly for 20min under full load, in sight of safety pilot
Distress Measurements

- Measurements are taken of all distresses within the segment
  - Potholes
  - Rutting
  - Washboarding
  - Loose aggregate
Platform Performance

- Total flight time: 16 minutes (not including a 2 minute reserve)
- Flight time for a 200 m section: 4 minutes
- During collects aircraft is flown at 2 m/s and at an altitude of 25 m and 30 m (below 100’),
- Rural areas only
Collected Imagery – 25m, 2 m/s
Collected Imagery at 25m, 36mp camera
Distress Detection: 3D Reconstruction

Bundler output

Densified point cloud

3D surface from point cloud
3D data examples
Important to categorizing distresses by severity
Obtaining 0.9 cm ground sample distance
Distress Detection – Potholes

- Canny Edge detection used to locate edges
- Hough Circle Transform is used to locate potholes

Note: Circles near edges ignored.
Distress Detection – Washboarding

- Gabor Function is a convolution based filter that gives localized, directional frequency information
- Oriented complex sinusoid with Gaussian Envelope
Distress Detection – Washboarding
Ground Truth Corrugation Area: 19.6 sq. m

Computed Corrugation Area: 17.2 sq. m

Missing due to area threshold
Distress Detection – Crown

- Slopes taken from outside edge to center
- Minimum of two (the worst grade) reported
URCI Assigned Distress ID & Ranking in the RoadSoft GIS DSS
Conclusions – 3DOBS

- The 3DOBS process and system was successfully deployed as demonstration of 3D optics/close range photogrammetry technology
- The system has been upgraded to operate at near highway speeds
- A high-resolution DEM and overview image can quickly and easily be created
- An automated spall detection algorithm was written to determine the location of spalls and calculate area and volume of individual spalls
- The exported data are formatted to be integrated into bridge condition decision support systems to be used as part of bridge asset management efforts
Conclusions - URCAS

- The UAV capable system is able to be rapidly deployed to unpaved roads for characterization
- Able to generate a high resolution 3D height-field
- Current system works best for rural areas with little or no tree cover
- Distresses can be characterized and quantified
- Data are exported for analysis in RoadSoft GIS
Thank You!

Questions?