Infrastructure Condition Assessment Based on Low-Cost Hyper-Spatial Resolution Multispectral Digital Aerial Photography

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About Us

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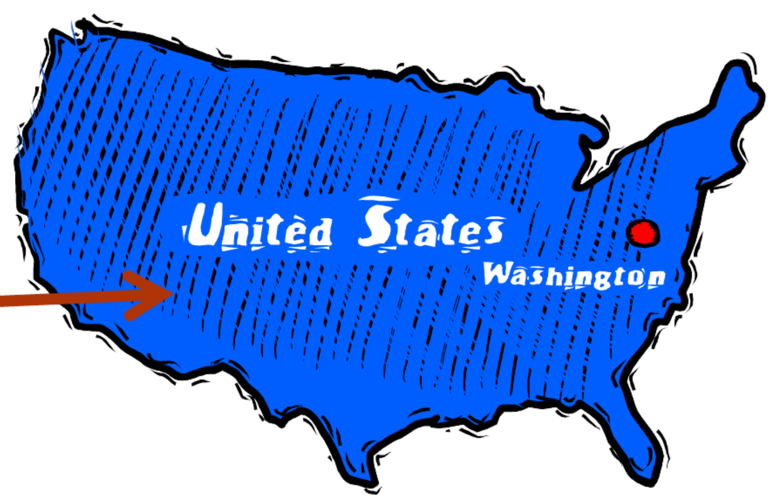


Decision Making Relies on Infrastructure Condition Assessment

- Maintenance/Repair/Rehabilitation
- Routine assessment
- Post-disaster assessment

www.nbcdfw.com

Current Assessment Methods Have Limitations

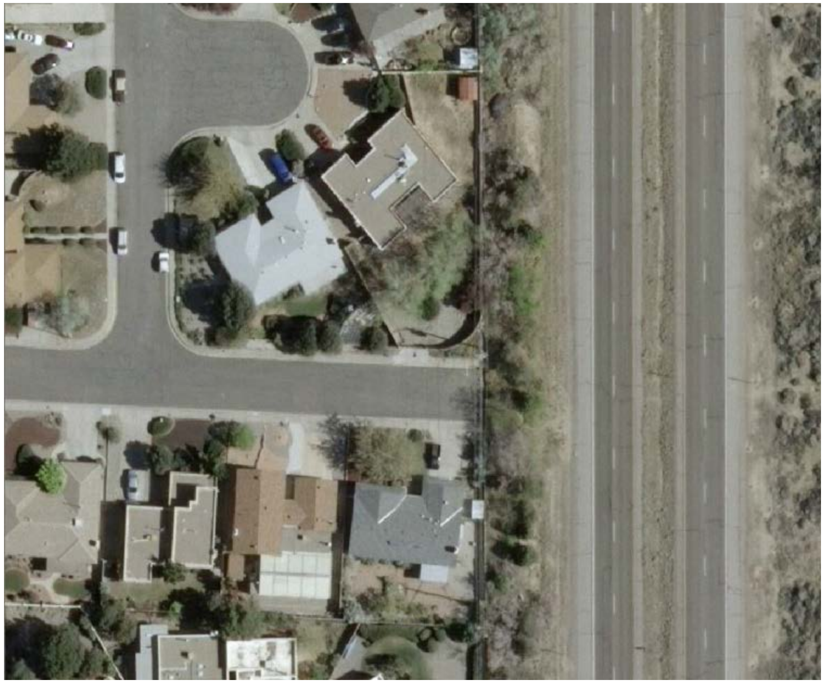
- "Boots on the ground"
- Experts visually inspect the condition or using vehicle-mounted electronic sensors
- Can collect detailed condition data
- Expensive, time-consuming, potentially dangerous to inspectors, requiring specialized staff on a regularly basis, high degree of variability

nps.gov

gvmc.org

Current Assessment Methods Have Limitations

- Electronic sensors deployed on airplanes that fly over infrastructure
- Becoming more and more popular (Jensen and Cowen 1999)
- Image spatial resolutions limit the ability to detect and assess small defects such as cracks on pavement surfaces

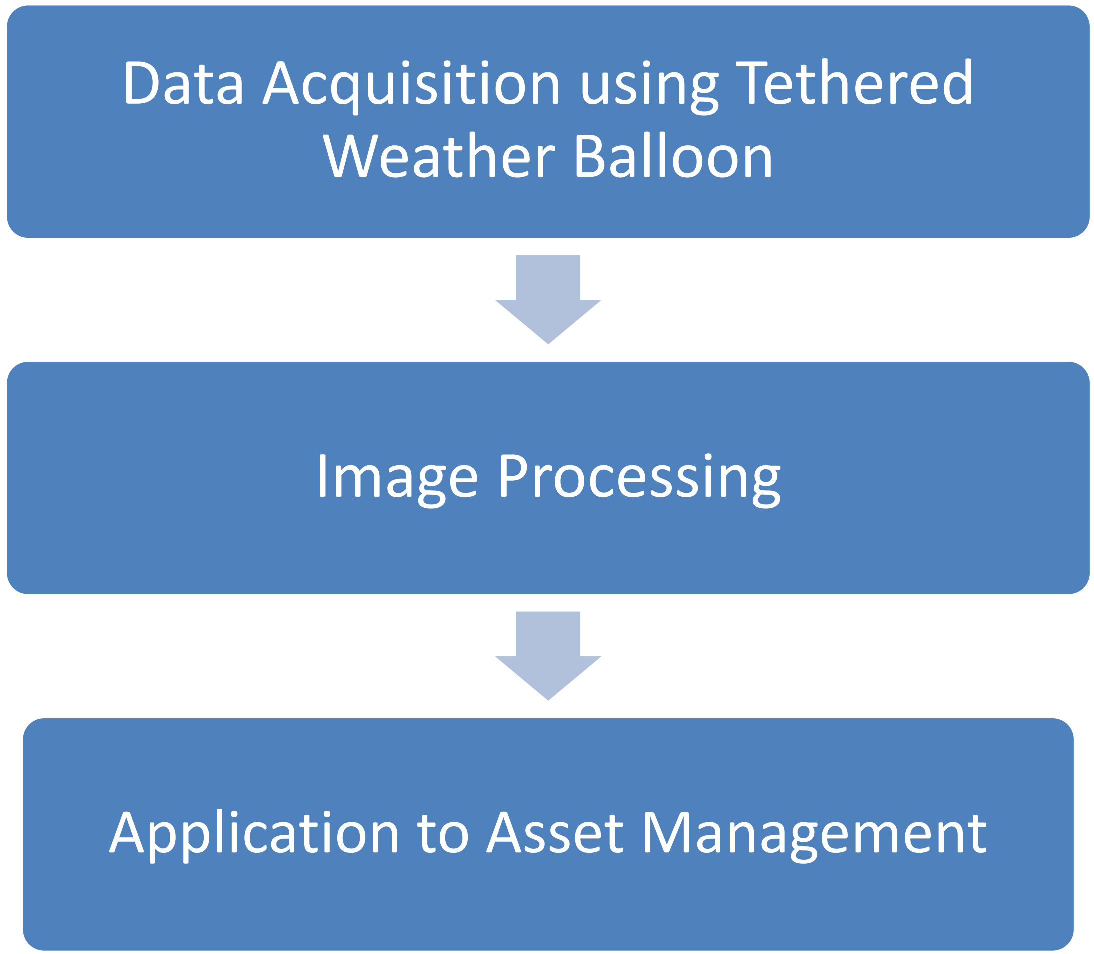


rgis.unm.edu

Improved Data Collection Possible Using Hyper-Spatial Resolutions

- Unmanned Airborne Systems (UAS)
  - A trend that is all but certain to continue
  - Legal use of UAS is severely restricted in the U.S. because of safety concerns
- A tethered helium weather balloon as a surrogate of UAS for hyper-spatial resolution aerial data collection

Research Overview

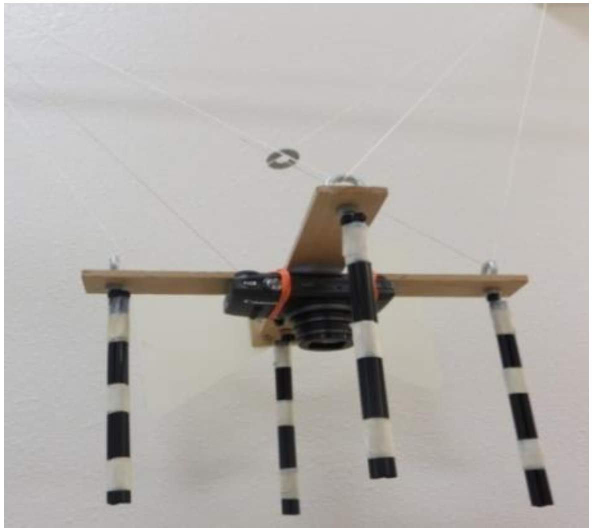


Data Acquisition

HSR-DAP Collection

- Used a Low-cost URSS
- Helium weather balloon
- Camera rigging part
- Canon camera SX260HS
- Ten study sites
  - Pavement segments
  - ~200 overlapping images for each site
  - Site size 20-meter by 15-meter

publiclab.org

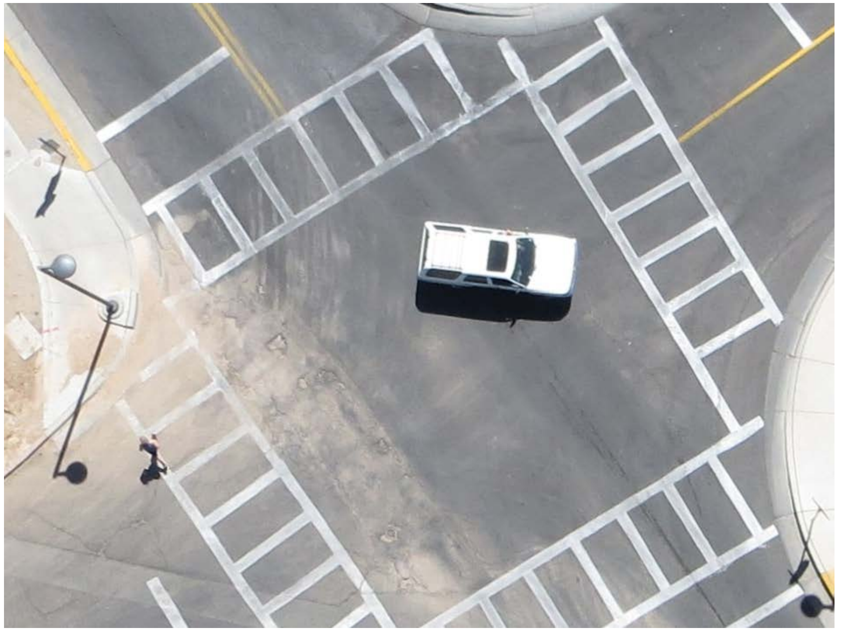


Data Acquisition

HSR-DAP Example 1

1 centimeter (~ half inch) DAP

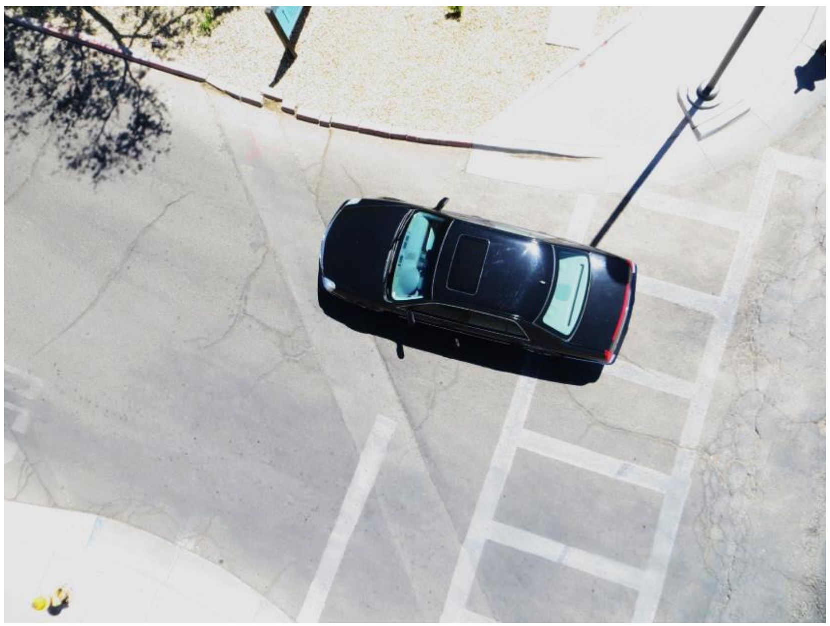
Zoomed in 1 centimeter (~ half inch) DAP



Data Acquisition

HSR-DAP Example 2

3-millimeter (~ 1/10 inch) DAP



Zoomed in 3-millimeter (~ 1/10 inch) DAP

Data Acquisition

Ground Reference Data

- Trained two-person crew
- Collected by using standard pavement surface manual evaluation protocol (HPMS Field Manual)
- Rutting, alligator cracking, and transverse cracking

Alligator Cracking

Transverse Cracking

Rutting

Data Acquisition

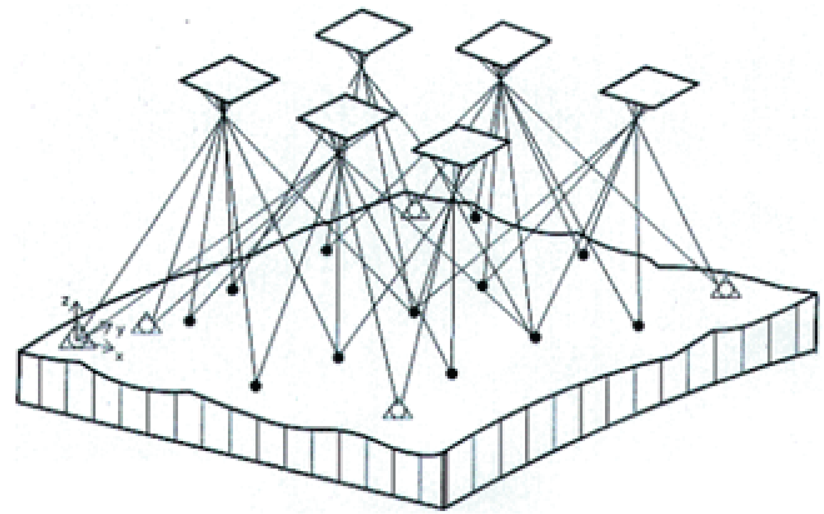
Ground Control Points (GCPs)

- A Real Time Kinematic (RTK) system was used
- Used for image registration to ground
- Sixteen GCPs for each study site
  - Ten used for image processing
  - Six used for accuracy assessment

Data Analysis

Aerial Triangulation (AT)

- Also known as structure from motion (SfM)
- Basic photogrammetric method for analyzing aerial images to determine X, Y, and Z ground coordinates of individual points based on measures from a series of overlapping aerial photographs
- Used to generate orthophotos and digital surface models (DSMs) for each study site
- Ten GCPs were used for each study site, the remaining six were used for accuracy assessment



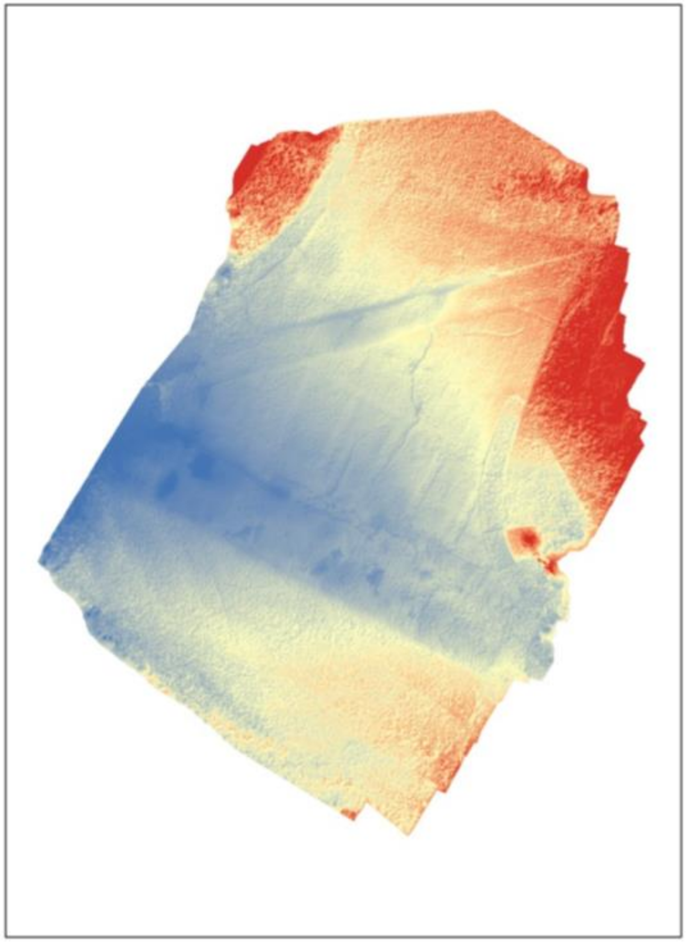
Vrmapping.net

Data Analysis

Example of AT Output

3-millimeter (~ 1/10 inch) Orthophoto

3-millimeter (~ 1/10 inch) DSM

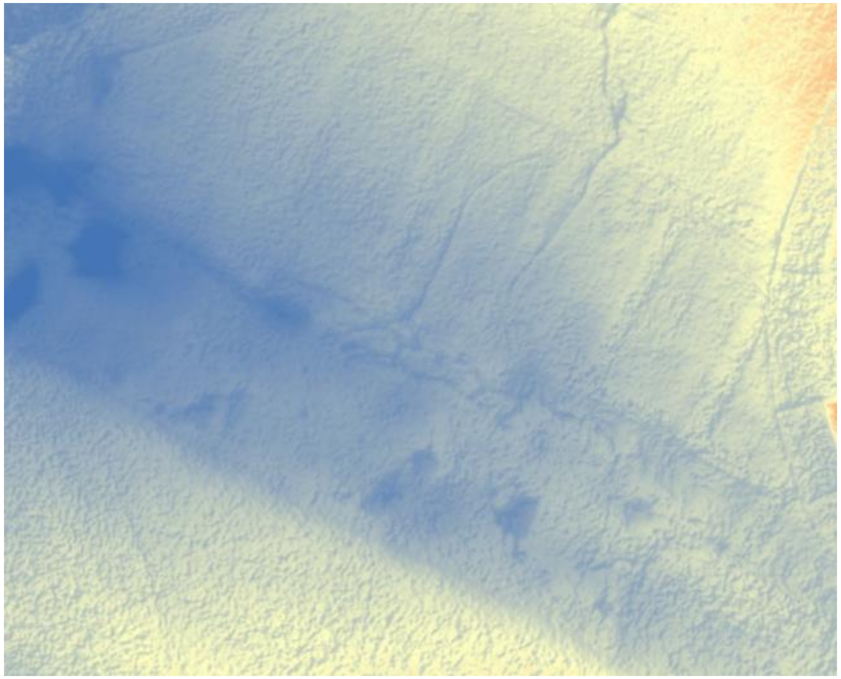


Data Analysis

Example of AT Output

Zoomed in 3-millimeter Orthophoto

Zoomed in 3-millimeter DSM



Data Analysis

AT Product Accuracy Assessment

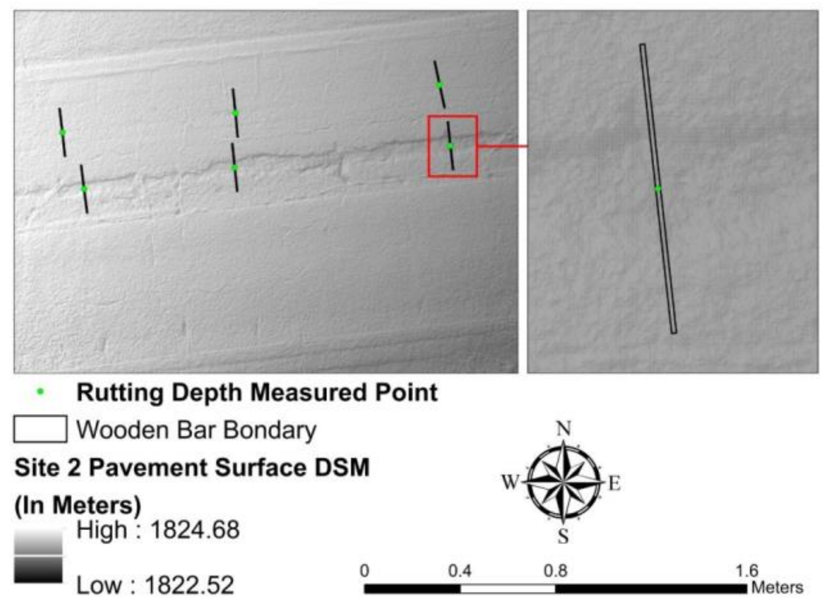
Site Name	Image Frames	Horizontal Accuracy (in meters)	Vertical Accuracy (in meters)
Site 1	122	0.002	0.006
Site 2	135	0.005	0.004
Site 3	183	0.005	0.003
Site 4	177	0.004	0.009
Site 5	181	0.003	0.007
Site 6	180	0.004	0.006
Site 7	165	0.004	0.004
Site 8	133	0.004	0.006
Site 9	126	0.003	0.005
Site 10	189	0.003	0.004
Overall	1591	0.004	0.006

Application to Asset Management

Rutting Depth Measurement

- For onsite evaluation, rutting depth measured as lowest point from pavement surface
- DSMs exhibit the modeled 3-dimensional pavement surface
- Point and polygon were created on DSMs to simulate the locations of the actual measuring points and wooden bars
  - Measured at both inner and outer wheel paths
  - Each wheel path measured 3 time

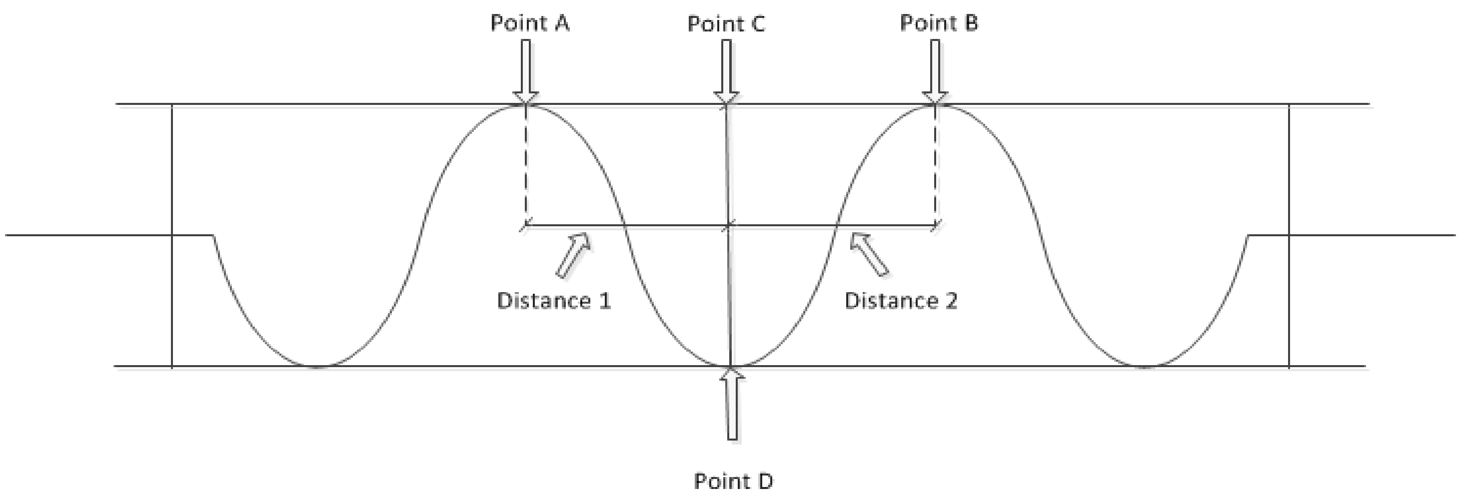
bmt-institute.vn



Application to Asset Management

Rutting Depth Measurement

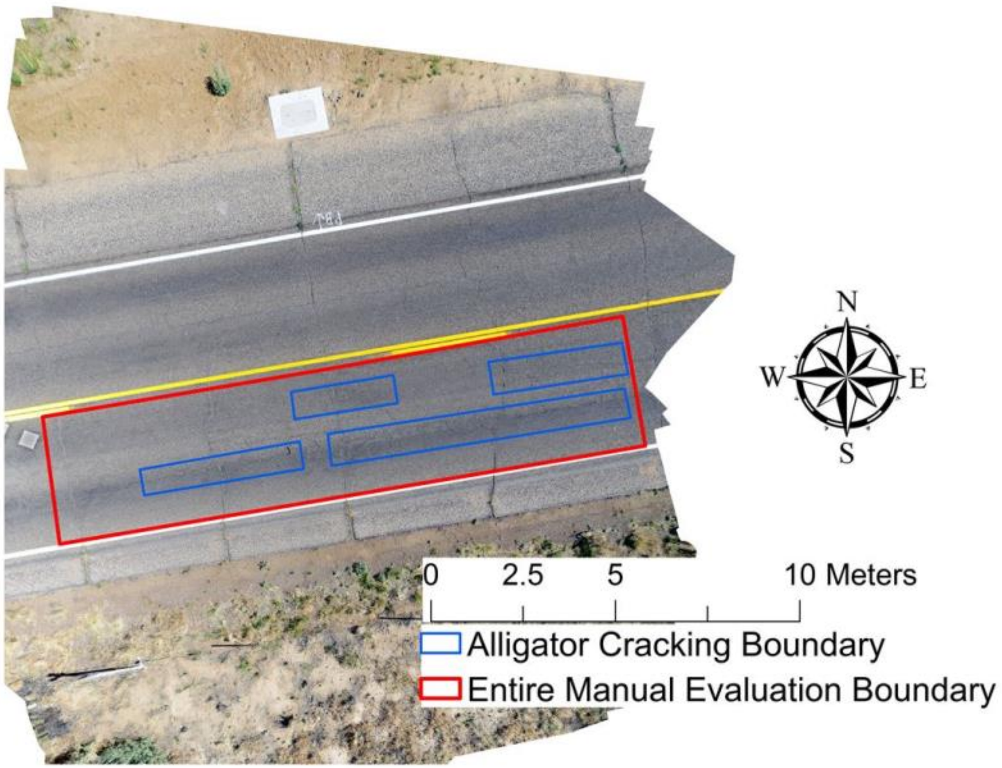
- Point A and B – Highest points of the rutting section
- Point C and D – Measured points of the rutting section, from Point C to Point D is the rutting depth
- Under most circumstances the heights of Point A and Point B are different
- $Height\ of\ Point\ C = \frac{Height\ of\ Point\ A \times Distance\ 1 + Height\ of\ Point\ B \times Distance\ 2}{Distance\ 1 + Distance\ 2}$
- Rutting Depth = *Height of Point C – Height of Point D*



Application to Asset Management

Alligator Cracking Measurement

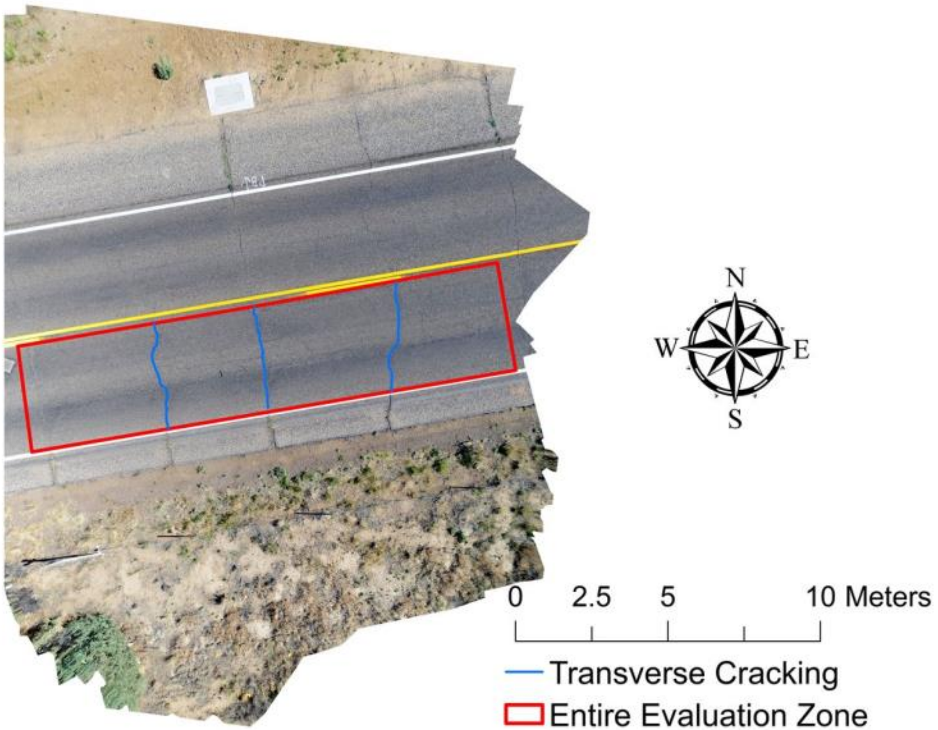
- For onsite evaluation, alligator cracking reported as the percentage of total alligator cracking section area (square feet) to the nearest 5% at a minimum
- For the proposed method, polygons were digitized to represent the entire manual evaluation boundary and the alligator cracking boundary
- Area percentage = alligator cracking area / entire evaluation area



Application to Asset Management

Transverse Cracking Measurement

- For onsite evaluation, inspectors count the number of transverse cracks extending at least half the lane width to estimate the total length of cracking in terms of feet per mile
- For the proposed method, polylines were digitized to represent transverse cracking and calculate the total length
- Total length of the evaluation zone can be measured with the help of the entire evaluation zone polygon



Application to Asset Management

- Measurements from DSMs compared to manually-collected data at the same locations

- Orthogonal linear regression revealed that the HSR-DAP derived measurement and the manual measurement fit closely to the regression lines
  - Paired t-test cannot be used because these data clearly violate the assumption that there is no linearity between the two groups of sample values
  - Orthogonal regression examines if two continuous variables are statistically different from each other
  - Orthogonal regression does not assume independence between variables

Conclusions

1. Results indicate that the pavement surface conditions measured by manual methods and the HSR-DAP method are not statistically different from each other
2. The proposed HSR-DAP method could be more consistent than manual method
3. In the near-term, the proposed method could be used to measure infrastructure conditions in situations where field inspectors cannot evaluate except with considerable labor costs or where vehicles cannot access
4. In the long-term, the proposed method is capable of completely replacing field infrastructure condition assessment

Acknowledgements

New Mexico Department of Transportation

Earth Data Analysis Center

Research Allocations Committee

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