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Bridge Condition Assessment Using Remote Sensors: Development of the 3-D Optical Bridge-evaluation System and the Bridge Condition Decision Support System

Michigan Technological University

Executive Summary

Managing an aging infrastructure continues to challenge transportation authorities as they align asset maintenance and replacement priorities with limited funding. The United States is home to over 600,000 highway bridges, of which nearly 10% are structurally deficient. This project (*Bridge Condition Assessment Using Remote Sensors*: DTOS59-10-H-00001), funded by USDOT through the Commercial Remote Sensing and Spatial Information Program, focused on the applicability of low cost, commercially available remote sensing technologies for assessing the condition of bridges.

Numerous remote sensing technologies were evaluated for their ability to measure associated high priority challenges at specific superstructure zones. Ranking criteria included commercial availability, measurement capabilities, cost, ease of data collection, complexity of analysis, stand-off distance and traffic disruption. Remote sensing technologies that scored as most promising included optical photogrammetric methods, passive infrared (IR) thermography, Light Detection and Ranging (LiDAR), digital image correlation (DIC), ultra-wide band imaging of GPR, synthetic aperture radar (SAR) and multispectral satellite imagery.

Based on these ranking results, promising technologies and systems were further developed, evaluated, and compared to ground truth (e.g., hammer sounding, chain drag) via laboratory and field testing on in-service Michigan bridges. Spall and delamination maps were generated from the optical and thermal IR images using commercial software and an automatic detection algorithm. Integration of the maps into ArcGIS allowed for a streamlined analysis that included integrating the results of the complementary technologies, including visual inspection and ground truth results.

There have been several successful outcomes, including a demonstration Decision Support System to integrate traditional inspection reports with remote sensing bridge condition data in a user-friendly, map-based interface. Another successful outcome has been development of the 3-D Optical Bridge-evaluation System (3DOBS), an easily deployable system used for rapidly assessing surface condition indicators such as the location, area, and volume of spalls. Several initiatives have been inspired and guided by these outcomes.

Findings & Outputs

As a result of lab and field testing, 3D optical technology could be applied to high-resolution, automated spall detection for concrete bridge decks. Early testing used a standard high-resolution digital (DLSR) camera to collect overlapping imagery, and 3D modeling software to create a sub-centimeter resolution Digital Elevation Model (DEM) of the surfaces (Figure 1). From this, the 3D Optical Bridge-evaluation System (3DOBS) was developed for demonstration and implementation.

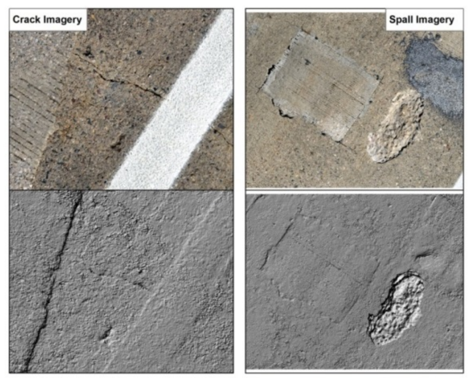

Fig 1: High-resolution 3DOBS output of cracks and spalls.

3DOBS was developed into a vehicle-mounted system that elevates the DSLR above a bridge deck so that at least one full lane width is within the field of view. Overlapping imagery is collected and processed through close-range photogrammetric software to produce DEMs of the bridge deck. The DEM is then run through an automated spall detection algorithm, which detects all spalls that are a minimum specified size and generates a GIS layer showing the location of the spalls on the bridge deck. This software allows the user to choose the minimum size of the spalls to be detected and to mask out bridge joints.

Products & Outcomes

All deliverables and reports from the original USDOT project are available at (http://mtri.org/bridgecondition/). The deliverables include reports on the "State of Practice", "Commercial Sensor Evaluation" and findings from the field demonstrations of each of the remote sensing technologies. The final report is also posted to the website. Included are summaries of the development and testing of the initial version of 3DOBS and the Bridge Condition Decision Support

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System (BCDSS), two major products that came out of the USDOT/CRS&SI project.

Post Project Initiatives

Due to several successful outcomes of the USDOT/CRS&SI project, the Michigan Department of Transportation (MDOT) has supported four additional initiatives in partnership with Michigan Tech. *Evaluation of Bridge Decks using Non-Destructive Evaluation at Near-Highway Speed* (MDOT Report RC-1617, 2015) continued development of the 3DOBS system so that it could operate at near-highway speeds (>45 mph) while integrating thermal IR bridge delamination detection technology as shown in Figure 2.

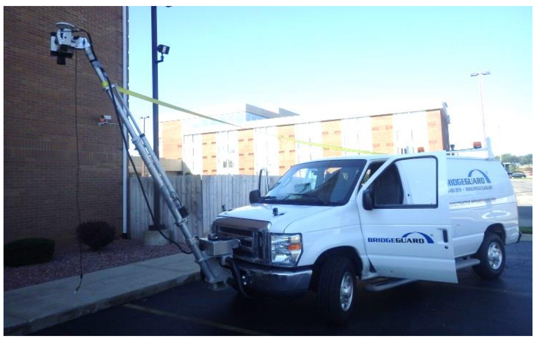

Fig. 2: 3DOBS mounted alongside a thermal camera and GPS system on the BridgeGuard van.

With an upgrade to the RED Epic camera, the system can capture imagery up to 60 frames per second at "5K" (13.8 megapixel resolution). Both the RED Epic and thermal cameras are mounted underneath a high accuracy Trimble GPS. The GPS track log is used to geotag the extracted RED Epic frames to georeference a base ortho image on which all other data can be overlaid. Outputs include detected spalls and potential delaminations layers, an ortho image, a DEM of the bridge deck, and a mosaicked thermal layer. All of the outputs can be viewed in a GIS such as ArcGIS.

A follow-on initiative included a pilot study to evaluate six large deck bridges in southern Michigan with a deck surface area greater than 90,000 sq. ft. Data collection was completed on all six bridges within one week with minimal traffic disruption. Figure 3 is an example of the combined RED imagery of 8 Mile Rd, which is used as the base layer for other data outputs. Condition states are generated per span based on NBI deck rating criteria (MDOT Report RC-1617B, 2016).

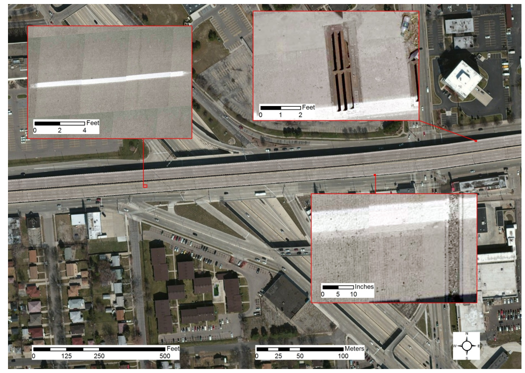

Fig. 3: High resolution mosaicked image of the 8 Mile Rd. bridge over M-10 referenced over Bing Maps imagery.

These remote sensing technologies are further being deployed through an UAV research initiative with MDOT. Five UAV platforms combined optical, thermal and LiDAR sensors to assess critical transportation infrastructure, including bridges, confined spaces, traffic flow and roadway assets (*Evaluating the Use of Unmanned Aerial Vehicles for Transportation Purposes*, MDOT Report RC-1616, 2015). In addition, the project team gave a series of technical demonstrations at the ITS World Congress in Detroit in September 2014.

Most recently, Michigan Tech and MDOT have partnered on a fourth initiative to enhance the previous UAV project by developing near-time data collection and storage concepts for the most viable UAV platforms and sensing technologies. Activities also include pilot projects to deploy and implement on-board sensors for specific MDOT business practices.

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