Michigan Tech Transportation Institute

Memo

To: USDOT/RITA research team members

From: C. Brooks, D. Evans

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Re: Work plans – progress to date

The following summarizes the work plans associated with our proof-of-concept feasibility studies.

Spectral Reflectance

The assessment of spectral reflectance will be completed using representative, *in situ* measurements along with several specimens made in the lab as needed beyond the initial testing done at two southeastern Michigan bridges. These samples could include several different types of depressions to simulate a flaw in the surface. Samples containing different levels of chloride will also be measured to see if spectra could indeed be used for sensing chloride ingress. The results of these multiple samples will be compiled in a database of reflectance curves. Once this is completed, a field demonstration will be performed to assess whether or not the curves correlate to actual defects in bridge elements. This will establish if spectral analysis is indeed an effective method to detect and distinguish bridge surface conditions and defects. The project leader will review progress on this area to see if additional lab testing is needed beyond what has already been completed.

3D Optics (including Photogrammetry)

The overall optical processing is expected to comprise techniques that are both 2- and 3-dimensional in nature for this work plan. Much useful information is present in 2D images, and these are both easier to collect and easier to process, and are part of the process of creating 3-D data. Our plan will be to use the 2D images to form a preliminary analysis of the surface, and based on those results, determine if the more complicated (and more informative) 3D processing is needed.

For 2D analysis parts of this work plan, we expect to use a variety of standard image processing algorithms, including (but not limited to), edge-detection, image morphology (e.g. dilation and erosion), statistical analysis (e.g. histograms), and other segmentation algorithms. These will be used to determine the nature of the surface (cracked, spalled, etc.) in a general way, and to make decisions about further processing.

For the 3D processing of optical imagery, we have identified three methods. All use multiple realizations of 2D images collected by standard digital SLR cameras to extract 3D information, rather than using the direct (but much more expensive) 3D sensors (such as LiDAR). For all three methods, we will perform an assessment on how capable the methods are of producing useful assessments of bridge deck surface indicators, such as spalling and cracking, first by using a lab specimen displaying various levels of these indicators. These three methods are:

1. Standard stereo-photogrammetry, including an accurate lighting model to be able to deal with hole/bump ambiguities. We will test both commercial and MTRI in-house photogrammetric processing tools as part of the lab work plan.

2. 3D point-cloud generations from multiple images, followed by surface finding (using, for example, Marching Cubes or Marching Tetrahedra) and then surface characterization (in terms of roughness, cracking, etc.). Software implementing these methods has been developed at MTRI for other programs, and is available for this application. The implicit surface-finding algorithm, Marching Tetrahedra, takes 4 points in 3-space that form a cube, divides that cube into 6 tetraheda by cutting diagonally through the cube, and the points in the clouds nearest each of these vertices are found. The resulting associated triangular facets are then used to form the surface. Because adjacent cubes share all edges in the connected surface, there will be no "holes" in the surface where edges do not match, and the surface normals are available for each facet (allowing immediate analysis of the surface variability).

3. Plenoptic processing, in which a series of 2D images is used to be able to extract detailed depth-of-field information, and thus full 3D characterization of the surface. There are commercial sensors available for this: http://www.petapixel.com/2010/09/23/the-first-plenoptic-camera-on-the-market/ or existing cameras may be fitted with a custom lens:

http://www.raytrix.de/index.php/rx.html to make these measurements. Commercial software also exists allowing processing of these 3D images. Assessing the capabilities of commercial tools to help in 3-D assessment is a goal of this work plan.

Digital Image Correlation

Digital image correlation is to first be tested in the laboratory on a steel beam to determine whether further field testing should be completed. Test preparation requires applying a pattern of fiducial marks; in this case, white paint dots were sprayed on the beam during an initial lab study. Pictures of the beam are then taken using a digital SLR camera while the beam is loaded. The images are then processed in MATLAB; from the displacement of the dots on the beam the deflection can be measured along with vibrations of the beam. If the tests in the lab show promising results the testing will continue on bridges in the field. The project leader will review progress on this area to see if additional lab testing is needed beyond what has already been completed.

Radar Testing

The radar testing will be completed using an AKELA radar unit that is moved along a track at a constant speed for collection of SAR data in the laboratory. The first test was completed at MTRI using concrete blocks with metal rods placed under them to determine the depth at which the radar can penetrate. The radar will then be tested on several slab specimens that have simulated defects in order to assess the technology's capability of detecting them. The radar will also be tested on several concrete beam samples that are at various stages of degradation. These tests will allow for the determination of the technology's applicability for detecting defects in the field. Initial work has started on this lab experiment and results will be reported in the coming quarter.

EO Airborne / Satellite Imagery

The assessment of EO (electro-optical) airborne/satellite imagery for detecting bridge condition indicators was determined by the project team to be more practical for a field demonstration rather than an individual laboratory test. The work plan will be included with the field demonstration plan. We will also include a review of the work done as part of the www.tarut.org study by Brooks, Shuchman, and others on using visible and near-infrared satellite imagery to assess road condition.

LiDAR, Acoustics

LiDAR is not going to be assessed in the field or laboratory in this project due to the USDOT-RITA-funded work being done at The University of North Carolina at Charlotte. It was also determined at this point that acoustics would be difficult to assess within the bounds of study and that because the technology is not strictly remote sensing it would not be considered for this study beyond the initial performance evaluation.

Optical Interferometry

The testing of optical interferometry includes both the testing of speckle pattern interferometry (SPI) and shearography. The SPI measuring process is performed using a high-resolution digital SLR with a coherent light source (laser light) illuminating the target. In this experiment a sheet of paper covering a hole is flexed under illumination in order to assess the technique's ability to measure strain gradients and displacements of the paper. These data are processed quickly by computer programs. Shearography was assessed using a Michelson interferometer to capture the deformations or displacements of a target surface. Shearography data are analyzed by looking for phase shifts that result from these tiny deformations or displacements. Data was collected at a very fine scale (sub-millimeter) during an initial test. The data will be reviewed by the project leader in collaboration with the remote sensing experts at MTRI to see if any further testing should be done beyond the current demonstration.

Thermal IR

The assessment of thermal IR, as with EO airborne/satellite imagery, will be part of the upcoming field demonstration as the project team is still coordinating with a potential commercial partner on a field demonstration which could also include a lab testing component. Additional information will be assessed and included in the next quarterly report.

StreetView-Style Photography

StreetView-Style Photography, or panoramic photography that is projected into a 3D coordinate system, will be assessed in the future as both an individual test and as part of the field demonstration. We will assess the ease of extending MTRI's existing vehicle-mounted multi-camera image capture for higher resolution photography. From the bridges in the greater Ann Arbor area and possibly Oakland County, one or more will be selected for a drive-by data collect. The images will be processed at MTRI to tie geospatial coordinates to each image. These images will be displayed in a simple GIS such as Google Earth and analysts will assess whether or not the technology allows for convenient and rapid evaluation of bridge condition from the office. We will also assess the potential to demonstrate an existing commercial system as part of either a lab or field study, such as the Trimble MX8 system (http://www.trimble.com/geospatial/Trimble-MX8.aspx?dtID=overview&).

InSAR

Based on our commercial sensor evaluation, InSAR is of value in detecting displacement and potentially vibration of the bridge as a whole. The assessment of this technology will involve the acquisition of SAR images from a commercial currently-available platform. MTRI will leverage its expertise in SAR processing to improve upon the permanent scatterers technique, in which structural elements of a bridge that respond brightly to radar illumination will be tracked in the interferograms for enhanced spatial resolution. If it is determined that existing structural elements will not be sufficiently bright to be used as permanent scatterers, then corner reflectors will need to be installed on a target bridge. This investigation will be conducted during the field demonstration.