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Rail Highway Grade Crossing Roughness Quantitative Measurement Using 3D Technology

Teng Wang[1], Reginald R. Souleyrette[1], Daniel Lau[2], and Peng Xu[3]
[1] Department of Civil Engineering, University of Kentucky, Lexington, KY
[2] Department of Electrical and Computer Engineering, University of Kentucky, Lexington, KY
[3] School of Transportation, Beijing Jiaotong University, Beijing, China

Quality of surface is an important aspect affecting both the safety and the performance of at-grade rail-highway crossings. No quantitative method currently exists to quickly and economically assess the condition of rail crossings in order to evaluate the long-term performance of crossings and set a quantitative trigger for their rehabilitation. The conventional method to measure the surface quality of crossings is based on expert judgment, whereby crossing surfaces are classified as poor, fair, or good after an inspector visits and drives over the crossing. However, actual condition of the crossing could be different from the subjective rating. Poor condition rating crossings may not always present the most cost-effective locations for preventive maintenance to lower overall life-cycle costs. A quantifiable and extensible procedure is desired. With rapid advances in computer science, 3D sensing and imaging technologies, it seems logical that a cost-effective quantitative method could be developed to determine the need to rehabilitate rail crossings and assess long-term performance. Fundamental to the quantification of crossing condition is the acquisition of an accurate 3D surface model of the crossing in its present state. This research reports on the development of an accurate, low cost and readily deployable sensor capable of rapid collection of this 3D surface. The research is seen as a first step towards automating the crossing inspection process, ultimately leading to the quantification and estimation of future performance of rail crossing.

Introduction

While track roughness may be evaluated by the railroad geometry car, highway crossings are usually qualitatively evaluated. Previous work by the University of Kentucky [1] investigated a laser-based inertial profiler and rolling dipstick for applicability in evaluating rail crossing roughness. Results were of limited practicality. In that research, investigation of alternative technology was recommended

Due to the heterogeneous nature of a highway rail crossing (longitudinal and lateral slopes), it is difficult or impossible to field rate a crossing (by driving over it) and establish its performance for many combinations of crossing vehicle types, speeds, and lateral placement. To model its performance, an accurate 3D terrain model is required. The goal of the research is to develop and test a low-cost sensor based on 3D structured light technology for measuring rail crossing surfaces and to develop a method for evaluating crossings to support both safety and maintenance programs. The data and information shown here are based on the conference paper presented at the 2014 Joint Rail Conference [2] by the research team.

Design and Build Data Acquisition System (DAS)

We have designed, built, and tested a 3D structured light-based data acquisition system (DAS) that creates an accurate surface point cloud of a crossing. The scanner has a minimum scan area of 3’ x 5.1’ when the projector’s lens is 42” above ground and a maximum scan area of 6’ x 10.2’ when the projector’s lens is 80” above the ground. The DAS camera has 1280 x 800 pixel resolution. Therefore, pixels are about 0.25 centimeters average in size when the lens is at its highest point above the ground. It is possible to scan at a rate of about one scan per 30 seconds in the field.

As a scanner platform, a rail cart was built to include a frame with wheels, a laptop computer with structured light data capturing software, an 1100 watt AC/DC converter, power cables, and power provided by the battery of a test vehicle as shown in Figure 1.

Figure 1. DAS prototype.

A series of lab tests have been performed to test the camera, lens, projector, and software. During these tests, the DAS prototype was incrementally improved. For example, lenses were changed to the wide angle variety in order to capture larger scanning areas. The center supporting beam has been replaced by a taller one (also to provide a larger scanning area). Scanning software was also updated after debugging.

Field Tests

Several field tests have been conducted at crossings around Lexington, KY and at the site of the Bluegrass Railroad Museum in Versailles, KY. Figure 2 pictured one field test at the crossing (USDOT 719862A) on Beasley Rd., Versailles, KY. There was one scanner mounted at each end of the beam of the DAS. Each scanner took one scan of one side of the crossing alternatively to avoid light pattern crossing each other. In the end, there were a total of 52 scans collected for this crossing. The test took about two hours. During the scanning process, each scan was 6’ x 10.2’ in size and had a one foot overlapped area in the longitudinal direction with the other scans before and after it. Two scanned 3D point clouds were shown in Figure 3.

Figure 2. Field Test at the crossing (USDOT 719862A) on Beasley Rd. Versailles, KY.

Figure 3. Sample of data collected in the field.

Data Analysis

Each 3D point cloud “tile” is measured as 10’ x 6’ in area with 1280 x 800 resolutions at the size of about 30 megabytes. Two adjacent scans can be stitched and merged by using data comparison (using our scanning software) within the overlapped area. For example, in the field test, there were a total of 52 scanned 3D point clouds collected for that crossing. By using the overlapped area of every two contiguous scans, all scans were stitched and merged into one whole crossing surface 3D cloud as shown in Figure 4.

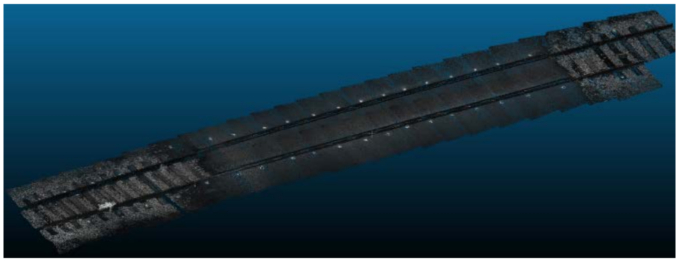

Figure 4. A highway rail crossing surface 3D point cloud.

After all the 3D point cloud tiles were merged into one crossing surface, each point had X, Y, Z coordinates recorded (to the nearest millimeter). A color-coded rendering of the crossing surface elevations can be seen in Figure 5. Blue indicates lower elevation, while red shows the higher elevations. With the 3D point cloud, the distance between any two points of the crossing can be measured. Locations where a vehicle (truck, trailer, etc.) may get high-centered or hung-up on the crossing may be directly computed given vehicle dimensions of wheel base and clearance height.

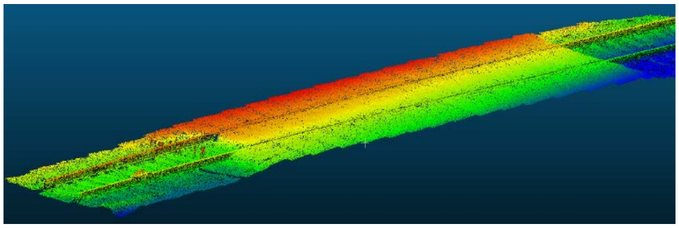

Figure 5. Elevation distribution of the crossing.

Using the 3D point cloud, crossing roughness may be quantified as depth and area of cracks, area and volume of bumps or potholes, or other formulations. An example displaying surface curvature gradient is illustrated in Figure 6. Blue areas are relatively flat as compared to red areas in this visualization.

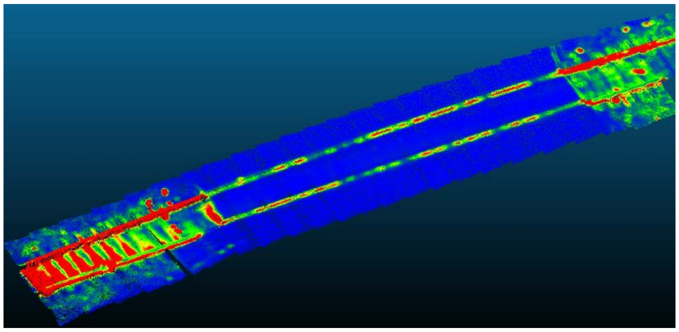

Figure 6. Surface condition (roughness) of the crossing.

Summary and Future Research

This research is only the first step in a larger effort to develop a quantitative method to assess the condition and performance of highway rail grade crossings. Further steps include:

1) Development of a roughness index based on crossing geometry.
2) Development and validation of a highway vehicle dynamics model that uses the 3D point cloud and vehicle characteristics to facilitate modeling of vehicular accelerations at various speeds and lateral positioning.
3) Development of a crossing condition index based on vehicular accelerations for a design vehicle(s).

Reference

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[2]. Wang, T., R. Souleyrette, D. Lau and P. Xu, "Rail Highway Grade Crossing Roughness Quantitative Measurement Using 3D Technology," Proceedings of the 2014 Joint Rail Conference, Colorado Springs, CO, April 2-4, 2014.

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