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Original Research Paper

Network level pavement evaluation with 1 mm 3D survey system

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ABSTRACT

The latest iteration of PaveVision3D Ultra can obtain true 1 mm resolution 3D data at full-lane coverage in all 3 directions at highway speed up to 60 mph. This paper introduces the PaveVision3D Ultra technology for rapid network level pavement survey on approximately 1280 center miles of Oklahoma interstate highways. With sophisticated automated distress analyzer (ADA) software interface, the collected 1 mm 3D data provide Oklahoma Department of Transportation (ODOT) with comprehensive solutions for automated evaluation of pavement surface including longitudinal profile for roughness, transverse profile for rutting, predicted hydroplaning speed for safety analysis, and cracking and various surface defects for distresses. The pruned exact linear time (PELT) method, an optimal partitioning algorithm, is implemented to identify change points and dynamically determine homogeneous segments so as to assist ODOT effectively using the available 1 mm 3D pavement surface condition data for decision-making. The application of 1 mm 3D laser imaging technology for network survey is unprecedented. This innovative technology allows highway agencies to access its options in using the 1 mm 3D system for its design and management purposes, particularly to meet the data needs for pavement management system (PMS), pavement ME design and highway performance monitoring system (HPMS).
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1. Introduction

Accurate and timely information on pavement surface characteristics is critical for evaluating the performance, condition, and safety of pavement infrastructure. Both pavement design and management rely on these and other information for comprehensive pavement evaluation. Pavement data collection technologies have been improved gradually in the last few decades. However, due to sensor and computing limitations, limited research funding, and inherent difficulties to meet stringent requirements of precision and bias, to

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automatically obtain pavement cracking and other distress data have not been realized by the necessary hardware and software. In addition, roughness, rutting, and macro-texture data are currently obtained through separated instrumentation on a relatively small area within a pavement lane.

Pavement engineering as an area of study has suffered from inadequate and poor quality distress data. High quality pavement distress data for the next-generation pavement design system, pavement ME design (DARWin-ME), is critically needed to facilitate the calibration of prediction models and further validation of relevant mechanistic models. Further, many state highway agencies have collected pavement distress data, particularly cracking data, for years through manual, automated, or semi-automated means. However, such data sets are of poor quality due to problems associated with consistency, repeatability, and accuracy of collected data and subsequent analyses. In addition to being slow and unsafe when conducted in the field, manual survey results show wide variability (Wang, 2004). Automation technology for pavement survey has long been sought and tested for precision and bias (McGhee, 2004; Wang et al., 2011; Wang, 2011). The early operating system is based on 1 mm 2D laser images of pavement surface, which poses challenges in terms of further improving its accuracy and consistency. Cracks, along with many other pavement surface defects, all have their own unique and distinctive characteristics in the 3rd dimension, which are lost in 2D images. Therefore, developing a new technology that can capture realistic pavement surface characteristics in the digital domain at sufficiently high resolution, or actual surface models of pavements, is a necessary task.

Recently, the research team at Oklahoma State University has developed and implemented 3D laser imaging based sensors for pavement condition survey. With the latest PaveVision3D Ultra (3D Ultra for short), the resolution of surface texture data in vertical direction is about 0.3 mm and in the longitudinal direction is approximately 1 mm at data collection speed of 60 mph. All pavement surface data gathered at this speed, and 1 mm resolution would provide engineers advantages in both visualization and analysis.

This paper introduces the 3D Ultra technology for rapid network level pavement survey on Oklahoma interstate highways. The collected 1 mm 3D data are automatically analyzed with comprehensive solutions for automated evaluation of pavement surface including longitudinal profile for roughness, transverse profile for rutting, predicted hydroplaning speed for safety analysis, and cracking and various surface defects for distresses. The pruned exact linear time (PELT) method, an optimal partitioning algorithm, is implemented to identify change points and dynamically determine homogeneous segments to assist DOTs effectively through using the available 1 mm 3D pavement surface condition data for decision-making.

2. 3D Ultra data acquisition system

2.1. Overview

The PaveVision3D laser imaging system has been evolved into a sophisticated system to conduct full lane data collection on roadways at highway speed up to 60 mph (about 100 km/h) at 1 mm resolution (Wang, 2011). Fig. 1 demonstrates the digital highway data vehicle (DHDV) equipped with 3D Ultra. 3D Ultra is able to acquire both 3D laser imaging intensity and range data from pavement surface through 2 separate sets of sensors. Recently, two 3D high resolution digital accelerometers have been installed on the system, which are capable of reporting compensated pavement surface profile and generating roughness indices. The collected data are saved by image frames with the dimension of 2048 mm in length and 4096 mm in width. In summary, the 1 mm 3D pavement surface data can be used for.

Fig. 1 – DHDV with 3D Ultra (WayLink).

(1) Comprehensive evaluation of surface distresses: automatic and interactive cracking detection and classification based on various cracking protocols;
(2) Profiling: transverse for rutting and longitudinal for roughness (Boeing Bump Index and International Roughness Index);
(3) Safety analysis: macro-texture assessment in term of mean profile depth (MPD) and mean texture depth (MTD), hydroplaning prediction, and grooving identification and evaluation;
(4) Roadway geometry survey: horizontal curve, longitudinal grade and cross slope.

2.2. Hardware system

With the high power line laser projection system and custom optic filters (Fig. 2), DHDV can work at highway speed during daytime and nighttime ensuring image quality and consistency. As the latest imaging sensor technology, 3D Ultra is able to acquire both intensity and range laser imaging data from pavement surface through 2 separate sensors. In addition to the 3D camera sensors, the

Fig. 2 – Laser imaging principle (WayLink).

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