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Principal Investigator: Andrew Tarko, Purdue University, tarko@purdue.edu, 765.494.5027

Program Office: jtrp@purdue.edu, 765.494.6508, www.purdue.edu/jtrp

Sponsor: Indiana Department of Transportation, 765.463.1521

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Performance Measure That Indicates Geometry Sufficiency of State Highways

Volume II—Clear Zones and Cross-Section Information Extraction

Introduction

Current evaluation methods of the Indiana Department of Transportation's (INDOT's) Roadway Asset Team for proposed corridor projects account for road geometry improvements by a much generalized categorization. A new method that considers the change in geometry improvements in a more detailed fashion is presented in Volume I of this report.

As part of this study, we investigated feasible ways of extracting additional elements from available datasets to support asset management in Indiana. To test the extent to which cross-section and clear zone information may be extracted in a reliable and practical way, we examined available data sources for their suitability. We combined the use of orthophotos, LiDAR point clouds, digital elevation, and surface models to identify remote sensing methods that are capable of extracting the required features efficiently and proposed a framework for determining the paved surface, average grade, and embankment slopes, extracting the obstructions near the traveled way such as trees and man-made structures.

Findings

Existing road network datasets, which we initially considered using as the reference for extracting information on road geometry and roadside features, did not have the required spatial accuracy to define the road extent and the clear zones. The datasets we recommend are orthophotos and the LiDAR datasets that are acquired in the scope of a statewide program, which are expected to be updated on a regular basis if not continuously.

Based on the estimated paved surface centerline and width, we were able to generate cross-section lines and calculate the slopes along these lines. Interpreting the slope values requires attention if a back slope is expected to start before two samples of elevation values are available on the foreslope. This situation is related to the slope calculations of very rapid falls followed by flat land. Slope calculations may be affected by the quickly changing slope values due to averaging.

The thinning algorithm does not result in intersections that coincide at a single node. If the intersections must be conserved topologically, an effort is required to edit them. However, this does not affect the cross-section information since the road extent and clear zones are defined based on the extracted paved surface extent. Similar to the options for whether to complete the missing parts of the alignment, intersections may or may not need to be topologically conserved as a single node. The decision in this case is whether the alignment extracted from aerial imagery will be required to serve as a replacement for a complete network in which the intersections are subject to further analysis, not just simply in aiding the estimation of the approximate paved surface width and reconstructing the surface extent.

The LiDAR dataset provides the capability to extract features within the clear zones at the roadside in a limited fashion, helping to extract the buildings and trees within the clear zones. It is not possible to extract vertically aligned features such as fences, walls, posts, signs, and so forth due to the limitations of the acquisition technique. Mobile or terrestrial LiDAR acquisition would be more suitable for extracting such features. Also, extracting individual trees out of a group of trees that are close to each other was not possible using the available dataset. In cases where there is prior knowledge of tree types in the area, individual trees may be estimated based on assumptions regarding the type and structure of those tree types.

Implementation

We have employed and pipelined different software as tools for the implementation of the proposed framework in the study area. Our main concern has been the availability of the algorithms that we have proposed and their convenience for performing quick tests with the existing datasets. Hence, we have not aimed at establishing an operational-level software integration.

In summary, we have employed ESRI ArcGIS software for the preprocessing of the orthophotos and DEMs, LAStools for the preprocessing of LiDAR point clouds, Monteverdi interface of Orfeo Toolbox for the classification of the paved road surface from the orthophotos, ArcGIS for the vector-based cleaning and generalization of the classification results, Matlab and Wolfram Mathematica for the morphological cleaning, thinning, pruning, boundary extraction, and generalization, ArcGIS for the reconstruction of the paved road surface as well as generating the cross-section lines using Python scripting and also calculating the slopes, LAStools for LiDAR ground filtering and point cloud classification, and R programming language libraries for the delineation of classified points.

This pipelining of software is not the only available and certainly not the most efficient way of performing the tasks of the proposed framework. The methods and algorithms mentioned in their respective sections of the report may be combined with a more efficient integration of software tools. Several tools that we preferred to use based on convenience may be eliminated and the tasks performed by these tools may be switched to other tools already used to perform other tasks. As an example, Matlab may be used for implementing SVM classification of the images instead of Orfeo Toolbox, as well as for handling all morphological operations. It will require some additional effort to combine these tasks under one tool that will work at an operational level.

As mentioned previously, the proposed framework is not a fully automated process. Human involvement is required at several steps, most importantly while collecting training samples for classification, which is performed once and then applied throughout the entire study area. Collected samples must represent all occurrences of the pavement types in the study area.

Other instances of human involvement include setting the parameters for determining the size of small components, simplification level, buffer sizes for removing the branches from the boundary raster or for calculating the pavement width, ground filtering, point cloud classification, and delineation of the classification results. Once these are determined adequately based on the properties of the study area, they may be used reliably.

Finally, human involvement may be required for completing discontinuities as necessary and for editing intersections if they are required to be topologically conserved as a single node.

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