Joint Transportation Research Program

Principal Investigators: Ayman Habib, Purdue University, ahabib@purdue.edu, 765.496.0173
Darcy M. Bullock, Purdue University, darcy@purdue.edu, 765.494.2226
Program Office: jtrp@purdue.edu, 765.494.6508, www.purdue.edu/jtrp
Sponsor: Indiana Department of Transportation, 765.463.1521

SPR-4407 2021

Road Ditch Line Mapping with Mobile LiDAR

Introduction

Roadside ditches are designed to minimize local flooding risk by draining water away from the roadway. In addition to transporting road runoff, roadside ditches play a critical role in the transport of pollutants and the increase in peak storm flows since they substantially alter natural flow pathways and routing efficiencies. An improved management of roadside ditches is not only crucial to roadway maintenance but also lays the foundation for assessing their impact on the natural hydrologic and nutrient transport network. While ditch networks are being increasingly incorporated in distributed hydrologic modeling, the ability to accurately extract drainage networks from remote sensing data remains challenging. Specifically, high-resolution, large-scale data that can capture the ditches, often narrow and covered by vegetation, through an efficient field survey is the current bottleneck.

Mobile LiDAR Mapping Systems (MLMS) have witnessed tremendous growth of their applications in the field of remote sensing. Such systems are capable of collecting high-quality, dense point clouds in an efficient manner. Mapping ditches using high-resolution LiDAR can be a cost-effective alternative to field surveys for prioritizing and planning ditch maintenance. It also eliminates the unnecessary exposure of survey crews to work hazards in traffic zones. This study assesses the feasibility of using mobile LiDAR techniques for mapping roadside ditches for slope and drainage network analyses. The following research aims are addressed: (1) evaluate the ability of different MLMS grades to provide quantitative measures of the condition of roadside ditches and (2) develop data processing strategies for characterizing the ditch lines.

Findings

- The performance of different grades of MLMS units was assessed in terms of spatial coverage, relative vertical accuracy, and absolute vertical accuracy. These MLMS units included an unmanned ground vehicle, an unmanned aerial vehicle, a portable Backpack system along with its vehicle-mounted version, a medium-grade wheel-based system, and a high-grade wheel-based system.
- Point cloud from all the MLMS units agreed within the ±3 cm range for solid surfaces, such as paved roads, and ±7 cm range for surfaces with vegetation along the vertical direction.
- The portable Backpack system that could be carried by a surveyor or mounted on a vehicle was the most flexible MLMS for mapping roadside ditches, followed by the medium-grade wheel-based system.

The portable Backpack system mounted on a carrier vehicle.

- The cross-sectional/longitudinal profiles of the ditch were automatically extracted from LiDAR data and visualized both in 2D image and 3D point cloud.
- The slope derived from the LiDAR data was found to be very close to highway cross slope design standards of 2% on driving lanes, 4% on shoulder, as well as a 6-by-1 slope for ditch lines.
- Potential flooded regions are identified and visualized both in point cloud and images. A recall score of 54% and 92% was achieved by the medium-grade wheel-based and vehicle-mounted portable systems, respectively.

Implementation

- *System calibration:* The relative position and orientation (hereafter denoted as mounting parameters) between the LiDAR and imaging sensors and the GNSS/INS unit are estimated using an in-situ calibration procedure. This procedure estimates the mounting parameters by minimizing discrepancies among conjugate points, linear features, and/or planar features obtained from different LiDAR units and cameras in different drive-runs/flight lines.
- *Ground filtering:* A ground filtering approach adapted from the cloth simulation algorithm is proposed to separate bare earth points from above-ground points. First, the original cloth simulation approach is used to extract the bare earth point cloud. Next, the rigidness of the cloth is redefined based on the point density of the bare earth point cloud. Finally, the cloth simulation is applied again to obtain a refined bare earth point cloud and the final digital terrain model (DTM).
- *Cross-sectional profile extraction:* A cross-sectional profile with a given length and width can be extracted from the point cloud, bare earth point cloud, and/or DTM at any location. The orientation of the profile should be perpendicular to the direction of the road, which is derived using the vehicle trajectory information. Once the profile is extracted, the slope along the profile is evaluated using the bare earth points. The results are visualized in both 3D point clouds and 2D images.
- *Drainage network and longitudinal profile extraction:* The drainage network is identified by calculating the flow direction and flow accumulation using the DTM. A longitudinal profile is the one along the "valley" of a ditch. It is identified by removing tributaries and connecting major streams of the drainage network.
- *Potential flooded region detection and visualization:* Potential flooded regions can be identified by detecting areas where the LiDAR points are absent. First, a binary point density image over the region of interest is generated. A median filter is then applied to reduce the noise caused by irregular point distribution. Next, the boundary between the black and white cells is traced. A region of interest is reported if its area is larger than a user-defined threshold. The reported regions of interest are visualized both in 3D point cloud and 2D images.
- *MLMS units:* The MLMS units as well as data acquisition and processing strategies developed by the research team can collect information of existing ditch geometry with efficient field surveys. The tool can be used for comparison between planned-built and existing ditch geometries at a network and project level for the INDOT.

Recommended Citation for Report

Habib, A., Bullock, D. M., Lin, Y.-C., & Manish, R. (2021). *Road ditch line mapping with mobile LiDAR* (Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2021/26). West Lafayette, IN: Purdue University. https://doi.org/10.5703/1288284317354

View the full text of this technical report here: https://doi.org/10.5703/1288284317354

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