



Ultra-high-accuracy Digital Terrain Model Mapping for Assessing Roadway Vulnerability to Sea-level Rise and Flooding: An Integrated Analysis of Mobile and Airborne LiDAR Data

Qi Chen

University of Hawaii at Manoa
qichen@hawaii.edu

Project Objective

Roadways along the coastal areas are vulnerable to inundation due to sea-level rise and flooding. However, the cost for repairing and relocating vulnerable roadways, even for short distance, is vastly large. Digital terrain models (DTMs), as a major input for simulating hydrological processes, play a key role in improving our understanding of the SLR and flooding risk of roadways and developing cost-effective mitigation and adaption plans. This research explores the use of the state-of-the-art mobile and airborne LiDAR (Light Detection and Ranging) data for producing precise DTM and conducting inundation analysis.

Problem Statement

The Hawaiian archipelago is vulnerable to multiple hazards and threats, among which are sea-level rise (SLR) and flooding. The SLR, in the events of flash flood and storm surges, can escalate coastal erosion and increase infrastructure damage. A recent report suggested that SLR and induced chronic flooding would make 25,800 acres of land unusable, compromise or lose over 6,500 structures, and result in economic loss of \$19 billion for the flooded structure and associated land. One type of critical infrastructure that can be also severely impacted by SLR and flooding is transportation. In Oahu, low-lying land is very limited and utilities such as water, wastewater, and electrical systems often run besides or beneath roadways. It was projected that over 38 miles of major roads will be chronically flooded with 3.2 feet of sea-level rise.

This study introduced the recently available mobile LiDAR for precise DTM mapping, in combination with the conventional airborne LiDAR technology. Although mobile LiDAR produces point clouds of density much higher than airborne LiDAR, its use has a few barriers to overcome: 1) the large file size (in the order of Gigabytes every mile of data) makes it notoriously difficult to process, 2) the geometric errors of mobile LiDAR systems are usually larger than the ones of airborne LiDAR systems, and 3) mobile LiDAR is not able to map out-of-the-sight terrain beyond the roadways due to occlusions caused by buildings and trees; in contrast, airborne LiDAR scanning from a high vantage point can more easily have a complete coverage over a large geographical extent. Overall, airborne and mobile LiDAR each have their own strengths and drawbacks, making them highly complementary for DTM mapping.

Research Methodology

I first checked and analyzed the three sources of geometric errors associated with mobile LiDAR data: the use of different laser beams (channels) of a given laser sensor, the use of different laser sensors in a vehicle, and the use of data collected from different driving directions (thus the different data acquisition time). The first two sources of errors are determined by the hardware system while the last source of errors are dependent on the data, which was

corrected using the Iterative Closest Point (ICP) algorithm. I then checked and analyzed the geometric mismatch between airborne and mobile LiDAR data and registered the two sets of point clouds using the ICP algorithm. The issue of demanding computation and low accuracy associated with ICP algorithm was addressed by eliminating sparse and irregular mobile LiDAR points off the driving roads and resampling the mobile LiDAR points using 10 cm by 10 cm and 10 cm voxels.

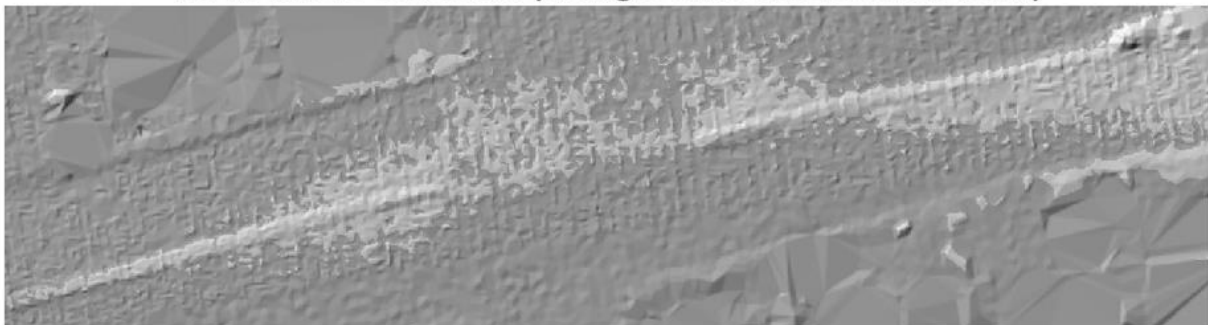
To generate DTM using only the ground returns (points), laser points from objects such as buildings, trees, shrubs, cars, traffic lights, electronic poles are removed. A strategy was developed to minimize both omission and commission errors of classifying ground returns. Then filtered ground returns were interpolated to 0.2 m DTM raster.

Finally, inundation simulations were conducted by arising the water level from the local water surface by up to 3 meters. The inundated areas were mapped using the bathtub approach.

Results

The geometric errors associated with different mobile LiDAR data and positional mismatch between mobile and airborne LiDAR were corrected effectively. The developed methodology produced a high quality DTM that carries the geometric consistency of airborne LiDAR data and the high detail of mobile LiDAR data. The more realistic inundation analysis (see the below figure as an example) can help make more informed decision in transportation planning and management.

1.5 m above sea-level (using DTM from airborne lidar)



1.5 m above sea-level (using DTM from mobile+airborne lidar)

