Title: Extracting Roadway Geometric Features from Aerial Images using Computer Vision and Machine Learning Techniques for Highway Transportation Management and Safety Analysis

ABSTRACT

The frequent occurrence of natural hazards, such as tornadoes and hurricanes, has posed significant challenges to the resiliency of rural transportation systems, especially in the Southeastern United States. Accurate and timely information about roadway conditions is crucial for both everyday transportation management and disaster response. This dissertation explores the application of artificial intelligence (AI) and computer vision techniques to enhance the collection, analysis, and interpretation of roadway geometry data, focusing on case studies from Florida. The study aims to optimize data collection processes, improve post-disaster recovery, and ensure roadway safety, particularly for rural regions prone to extreme weather events.

The first part shifts focus to hurricane resilience, specifically assessing the impact of Hurricane Michael (2018) on Calhoun County, Florida. Satellite imagery from Sentinel-2, analyzed using Google Earth Engine (GEE) and GIS, is used to assess debris accumulation. Spectral indices, particularly the Normalized Difference Vegetation Index (NDVI), is applied to quantify vegetative debris along roadway segments in the most populated areas of the county. The findings indicate that vegetative debris heavily impacted roadway accessibility, particularly in the northeastern region of the county. This information is critical for agencies seeking to prioritize their response efforts and ensure the rapid restoration of transportation infrastructure.

The second part of this dissertation investigates the impact of tornadoes on rural transportation infrastructure, focusing on post-tornado debris assessment in Leon County, Florida. This county experienced significant damage from two Enhanced Fujita (EF)-2 and an EF-1 tornadoes in May 2024. The research employs satellite imagery from the Planetscope satellite and Geographic Information Systems (GIS) to assess debris accumulation along roadway segments and its effect on accessibility. The same NDVI-based approach is used to quantify debris volume by comparing pre- and post-tornado images. The findings reveal substantial debris accumulation in the south-central part of the county, affecting both the most populated areas and critical roadway segments. The study achieved a 74% accuracy rate in identifying impacted locations when compared to ground-truth data, offering valuable insights for transportation agencies tasked with disaster response and recovery.

In addition to addressing post-disaster recovery, this dissertation also focuses on the everyday responsibilities of transportation agencies, particularly the collection of up-to-date roadway geometry data. Accurate roadway data is essential for the planning, maintenance, and rehabilitation of infrastructure, but the large scale of the U.S. highway system makes traditional data collection methods costly and time-

consuming. Current methods include field inventory, mobile LiDAR, and aerial-based techniques such as drone or satellite imagery. While effective, these methods are often labor-intensive, expensive, and limited by weather conditions, necessitating the development of more efficient, AI-driven approaches.

The third and fourth case studies introduce a novel AI-based methodology for detecting roadway pavement markings—such as turning configurations, crosswalks, bicycle lanes, and stop features—using high-resolution aerial imagery. This research utilizes the YOLO (You Only Look Once) deep learning model to automatically identify and extract roadway features from high-resolution aerial images, significantly reducing the need for manual data collection. The models were tested on public roadways in Leon County, Florida. The bicycle and pedestrian lane models achieved accuracies of 95% and 86% respectively while the roadway feature model had an accuracy of 97%. The roadway feature model was used to compile a comprehensive inventory of roadway geometry features such as railroad crossings, crosswalks, bicycle, school zone markings, bus lanes, stop or yield, slow, and turning lane configurations (i.e., left-through, right-through, merge, through, left-only, right-only, left-right, u-turn, center, left-right-through), demonstrating its potential for large-scale data collection. The methodology offers a safer, faster, and more cost-effective alternative to traditional methods, reducing equipment costs and improving crew safety.