DRISI
Caltrans Division of Research, Innovation and System Information

Research Results

Truck Classification using LIDAR sensing technology

Investigating truck classification along rural highways using LiDAR sensor array technology and axle-based and body-based models

Traffic Operations

AUGUST 2022

Project Title:
UTC TO 036 - Investigation of Truck Data Collection using LIDAR sensing technology along Rural Highways

Task Number: 3436

Start Date: May 1, 2020

Completion Date: September 30, 2021

Task Manager:
John Slonaker
Sr. Transportation Electrical Engineer (Specialist)
john.slonaker@dot.ca.gov

WHAT WAS THE NEED?

Detecting and classifying trucks on state highways is important for planning and budgeting for road maintenance, because, even though trucks represent a small percentage of total traffic, they cause most of the damage to pavement. Conventional classification technology such as inductive loop sensors and piezo-based automatic vehicle classifiers are not widely deployed along many rural highway corridors, because electric power service is often not available and installation is too costly and requires road closures. Meanwhile, temporary sensors such as pneumatic road tubes wear out quickly, expose workers to live traffic in typical deployment and retrieval procedures and can only generate axle spacing information without characterizing trucks in any other way.

Permanently mounted out-of-pavement detection and classification technology with sufficient resolution to distinguish trucks and other vehicles according to the Federal Highway Administration (FHWA) classification scheme is needed to safely gather information to adequately assess the impacts of truck activity on state highways. This reliable classification data is required to obtain federal funding through the Highway Performance Measurement System (HPMS) to ensure adequate maintenance of state highways by quantifying freight activity.

WHAT WAS OUR GOAL?

The purpose of this study was to investigate the use of LiDAR technology for accurate classification of trucks, according to the established FHWA scheme, along rural highway corridors as an alternative to in-pavement detector infrastructure.

WHAT DID WE DO?

This study explored the use of Light Detection and Ranging

(LiDAR) technology to develop new truck classification models, utilizing a reconstruction procedure that combines frames of sparse point clouds to generate a dense point cloud representation of vehicle objects to facilitate accurate truck classification. A preliminary investigation of LiDAR intensity on trailer surfaces was also performed to evaluate the potential of identifying fleet characteristics, e.g. company logos, of trucks.

The data used in this study were collected from the entrance ramp to the San Onofre truck scale from the Southbound I-5 Freeway in Southern California. The LiDAR sensor was placed in horizontal orientation above a traffic cabinet and was configured to scan the surroundings at a frequency of 10 rotations per second with a 180-degree LiDAR Detection Zone – each rotation generating a single 3D point cloud frame.

The first step in data preprocessing involved background subtraction – the removal of the large set of points in the raw point cloud not associated with vehicles. This was followed by object detection, which determines the individual vehicle objects in the LiDAR field of view. The third step involves identifying the same vehicle point cloud object across multiple consecutive LiDAR frames through a process known as data association. These individual frames of the same vehicle are then combined to yield a dense reconstructed LiDAR representation of the vehicle.

Two classification models were developed from this preprocessed dataset. One was an FHWA axle-based classification model that used features from the lower profile of the reconstructed truck point cloud. The other was as a body configuration-based model that used a novel deep neural network architecture called PointNet that can detect critical features for classification from raw point cloud inputs. Finally, an algorithm to correct initial LiDAR intensity data was developed that resulted in a reduction in the variance of intensity values that provided a distinct contrast of fleet features, e.g. logos, against the background.

WHAT WAS THE OUTCOME?

The axle-based classification model developed in this study outperformed the axle-based classification model from a previous study that used only single LiDAR frames both in terms of accuracy and robustness. The model classified vehicles into 10 distinct FHWA classes with an average classification rate of 79 percent.

The body configuration-based model was able to classify heavy-duty trucks in much more detail, with a close relationship to their industry affiliations. This model was able to classify 31 different vehicle types (mostly trucks) and achieve an average classification rate of 90 percent for both trucks with trailers and single-unit vehicles.

WHAT IS THE BENEFIT?

This study advanced the state-of-the-art in LiDAR vehicle detection and classification technology, particularly for commercial freight vehicles. This technology will eventually enable Caltrans to quantify heavy truck traffic on state highways more accurately and reliably, which will allow it to better plan and budget for pavement maintenance.

IMAGES

Image 1: A truck is detected and scanned by the Velodyne LiDAR detector as it passes by on the entrance ramp to the San Onofre truck scale beside the Southbound I-5 Freeway.

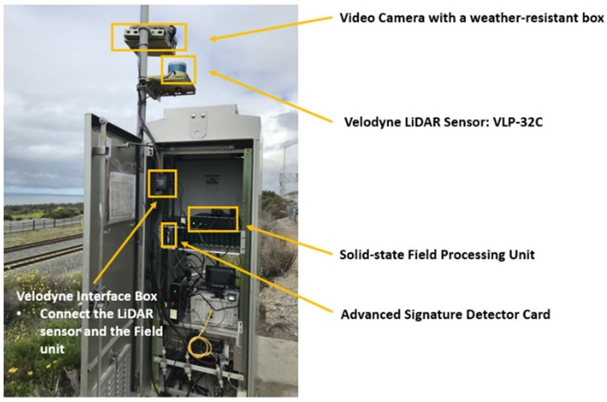

Image 2: Components of the test equipment cabinet at the test site

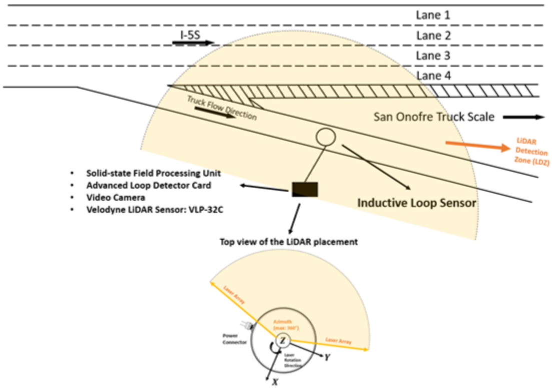

Image 3: LiDAR detector view of the detection area

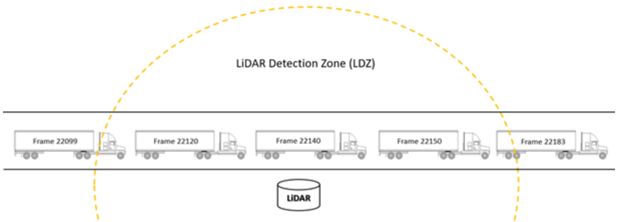

Image 4: The LiDAR detector scans multiple frames of each passing vehicle

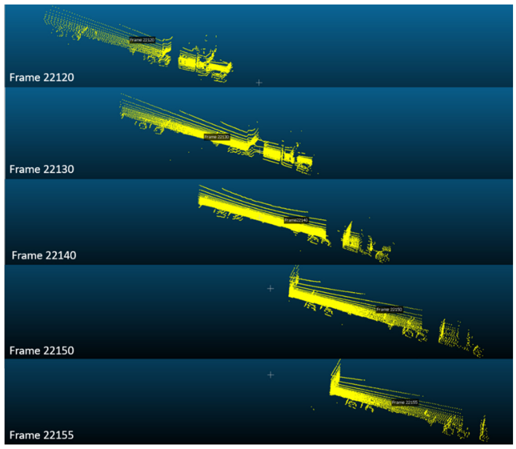

Image 5: Multiple LiDAR scans of each vehicle will be combined into a single image for classification

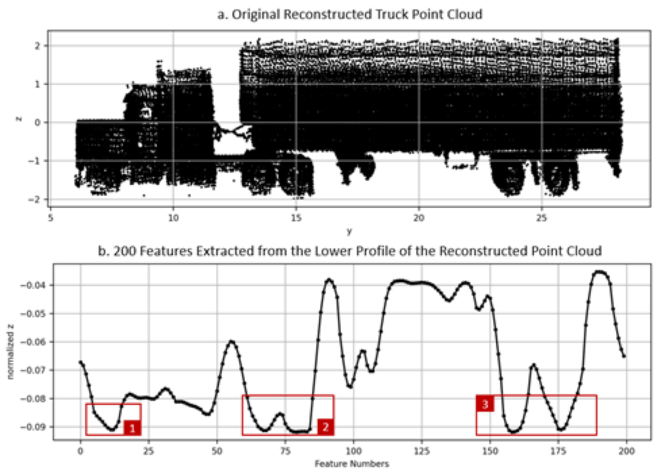

Image 6: Axle count and spacing information is extracted from the reconstructed LiDAR point cloud data.