LiDAR-Based Object Detection in Instrumented Vehicles: Implications for Driver Behaviour Analysis and Autonomous Systems

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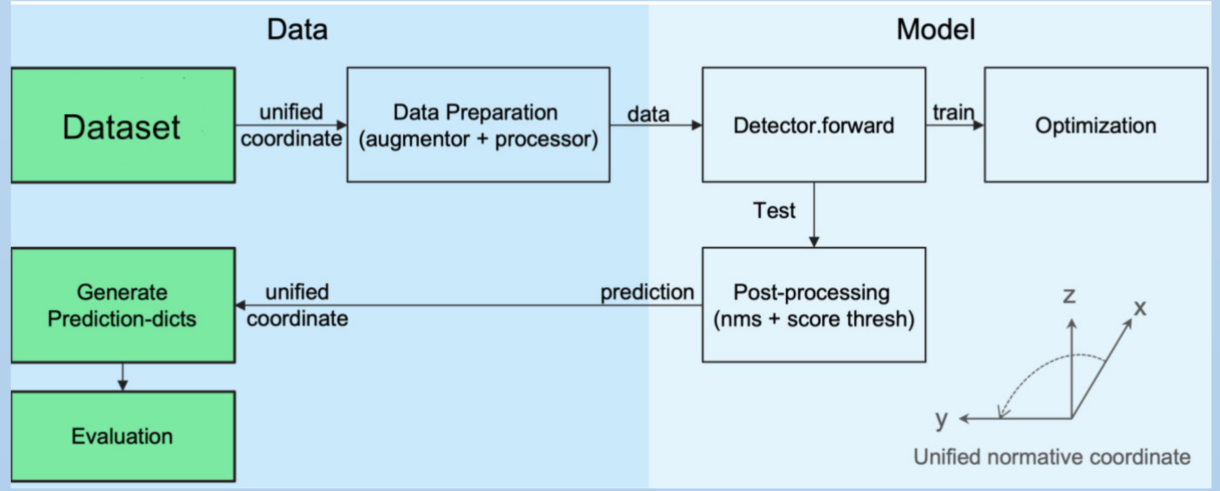
ABSTRACT

This project aims to understand advanced techniques in LiDAR-based object detection to analyse driver behaviour within the context of automated vehicles. The research focuses on understanding the methodology and testing of pre-trained models, specifically the PointPillars algorithm, using MATLAB and Python programming languages. The KITTI dataset is crucial in facilitating testing and data pre-processing. By accurately identifying various objects, such as pedestrians, vehicles, and obstacles, in the surrounding environment, this research project seeks to gain valuable insights into driver behaviour, ultimately improving the safety and efficiency of autonomous driving systems.

INTRODUCTION

LiDAR technology collects data by emitting laser pulses into the surrounding environment and measuring the time it takes for the pulses to return after interacting with objects. The resulting data is in the form of a point cloud, which represents the spatial coordinates and intensity values of individual points. The collected LiDAR data is processed and analysed to detect and track objects of interest. This involves utilising pre-trained models that have learned to recognise specific object classes and estimate their positions within the point cloud. The KITTI dataset serves as a valuable resource in this project, providing a diverse and realistic collection of scenarios for testing and data preprocessing. It enables the evaluation and validation of the developed object detection algorithms using real-world data.

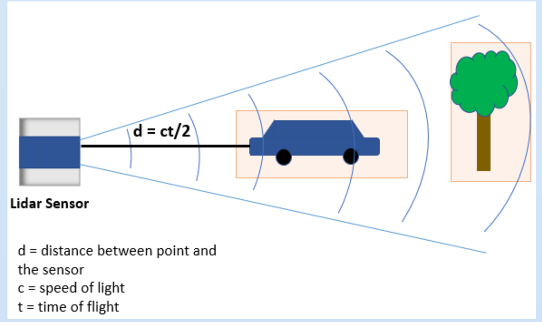


Basic Structure for Object Detection

METHODOLOGY

The methodology employed in this research project revolves around LiDAR-based data collection and object detection using pre-trained models. The primary focus lies in understanding the uses and constraints associated with different formats, including .pcap, .pcd, .bag, .txt, etc. and how different models use them. LiDAR data collection involves the utilisation of sensors such as the Velodyne VLP16 sensor, which captures high-resolution point clouds providing a 360-degree view of the environment.

Velodyne VLP16 Sensor

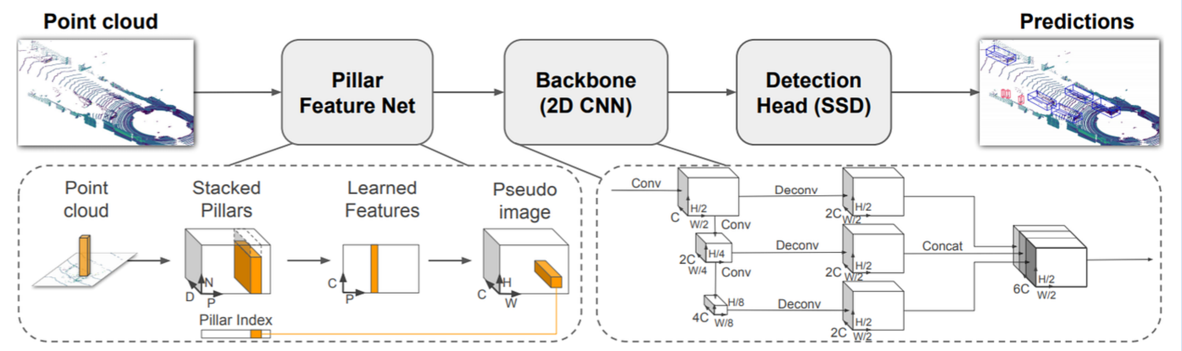


Working Principle

The PointPillars method is a popular technique used in LiDAR-based object detection. It combines the efficiency of 2D convolutional neural networks (CNNs) with the 3D information provided by LiDAR point cloud data. It has the following steps-

1. The 3D space around the vehicle is divided into a grid of pillars to organise the LiDAR point cloud data.
2. Points within each pillar are grouped into 3D grids or voxels, simplifying the representation of the dense point cloud data.
3. Then the 2D convolutional neural networks (CNNs) process each voxel, extracting meaningful features capturing local spatial and point-wise information.
4. Features from the voxels are aggregated within each pillar using max pooling, creating a fixed-size representation for efficient processing.
5. Pooled pillar features are inputted to an RPN, which predicts 3D bounding boxes around potential objects in the pillar grid.
6. Predicted bounding boxes are refined and filtered using non-maximum suppression (NMS) to obtain the final set of detected objects.

The PointPillars method efficiently combines 2D CNNs with 3D LiDAR data, dividing the space into pillars, extracting features from voxels, and predicting object bounding boxes.

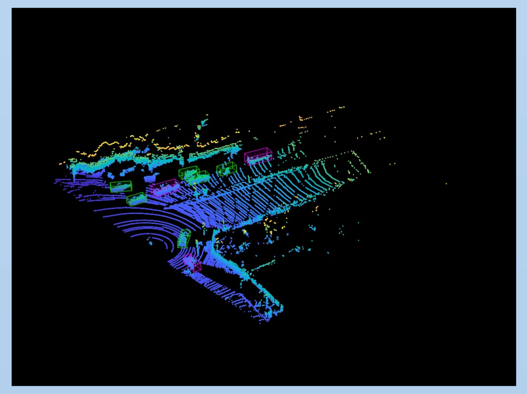


Point Pillars Algorithm Methodology

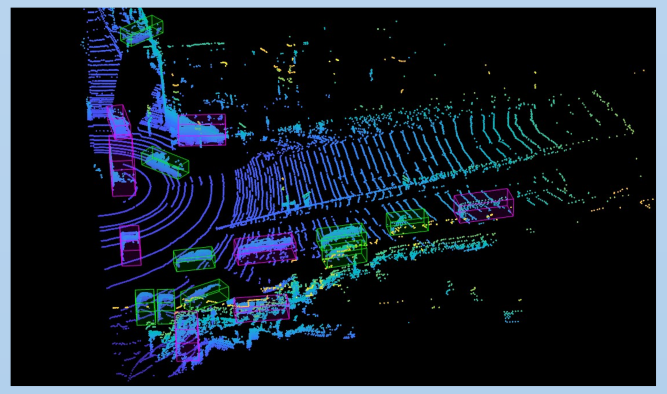
Accurate object detection enables understanding the surrounding environment, including the presence of other vehicles, pedestrians, and obstacles. By analysing the detected objects, one can gain insights into driver behaviour, such as vehicle following distances, lane changes, and interactions with other road users. Driver behaviour analysis can help assess driving patterns, predict intentions, and identify potential safety risks, leading to improvements in automated driving systems. The combination of LiDAR, 3D object detection, and the PointPillars method provides a comprehensive and reliable approach for studying driver behaviour and enhancing automated driving technologies.

RESULTS

The PointPillars model, applied to the KITTI dataset, have demonstrated significant accuracy in object detection and classification. The PointPillars method achieves an accuracy of 77% for cars, 52% for pedestrians, and 62% for cyclists. It is important to note that this model has been pre-trained on a large and diverse dataset, the KITTI dataset, which provides a benchmark for LiDAR-based object detection tasks. The accuracy achieved by this model showcases capability to accurately identify and classify objects. As part of this research project, a dataset was collected to further explore object detection and classification in a specific context. Approximately 20 minutes of data in .pcap format and around 30 minutes of data in .bag format were collected. This dataset, specific to our context, provides an opportunity to evaluate the performance of pre-trained models and investigate object detection within a different environment. The collected dataset serves as a valuable resource for future research and development, allowing for the training and fine-tuning of object detection models tailored to our specific requirements of the Indian surroundings. By leveraging this dataset, further insights can be gained into driver behaviour analysis in the context of automated vehicles within our specific locality.



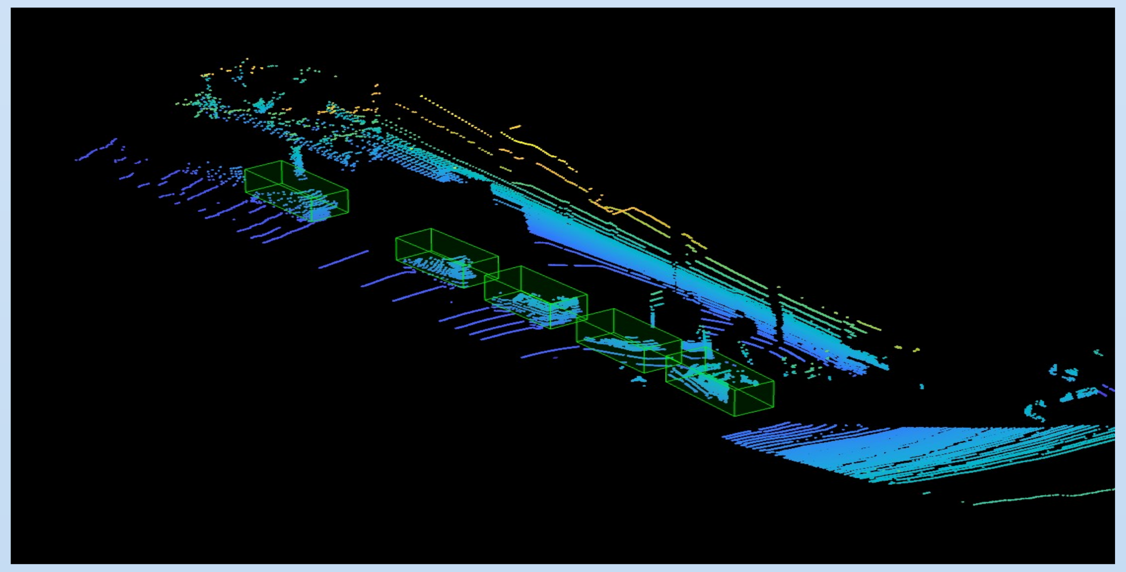
LiDAR View before augmentation



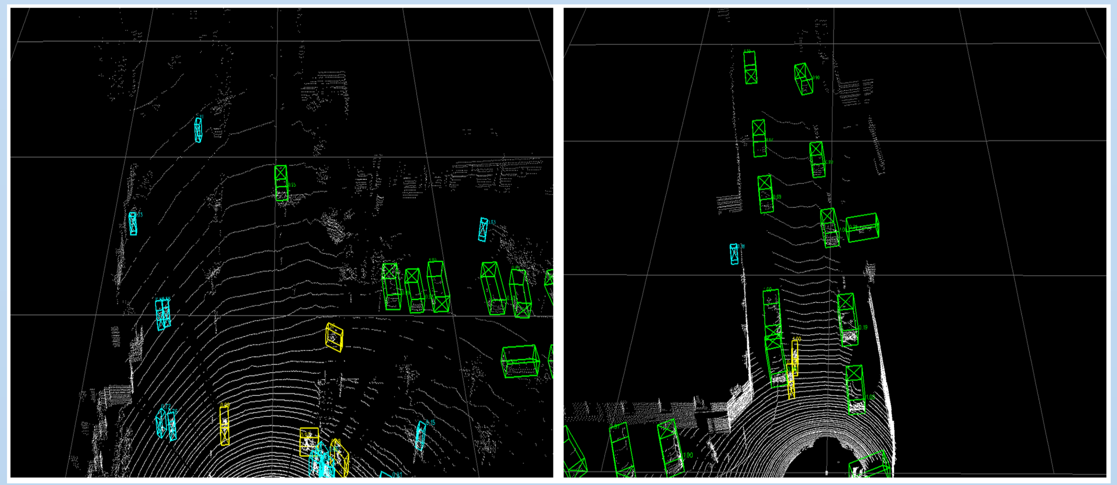
LiDAR View after augmentation

CONCLUSION

Through this research project, a significant milestone has been achieved in the development of LiDAR-based object detection techniques for driver behaviour analysis within the Indian context. By leveraging pre-trained models, along with the KITTI dataset as a benchmark, accurate object detection and classification have been demonstrated. The collection of a dedicated dataset specific to Indian surroundings, in both .pcap and .bag formats, has provided an opportunity to train data that aligns with the local environment. Through accurate 3D object detection, potential hazards can be identified promptly, allowing for proactive safety measures. Analysing driver behaviour in relation to detected objects helps identify risky actions, predict intentions, and enable timely interventions, thus reducing the risk of accidents. A deeper understanding of driver behaviour enables the development of intelligent and intuitive human-machine interfaces. By recognising and adapting to the behaviour and intentions of human drivers, autonomous vehicles can better communicate and collaborate with their occupants, enhancing the overall user experience and trust in autonomous systems. In conclusion, this research project has successfully established a methodology for pre-processing and training LiDAR data within the Indian surroundings.



Prediction on Test Data



Object Detection on the KITTI Dataset

REFERENCES

- "PointPillars: Fast Encoders for Object Detection from Point Clouds" by Alex H. Lang et al. (CVPR 2019)
- OpenPCDet - Github Repo

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