LiDAR-Based Environmental Object Classification System

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Problem Statement

There is a lack of 3D LiDAR object classification models that work with multiple LiDAR data formats, are scalable in terms of the data size, number of object classes, and the ease of adding features, and are efficient in real-time applications.

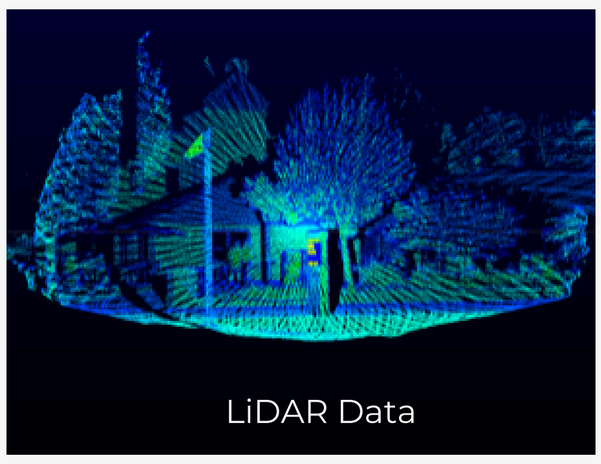
Design Requirements

- Our model requires stability and adequate system specifications
  - RTX 1080 graphics and 16GB of RAM.
- It must maintain object detection accuracy above 75% while operating within a 500ms real-time constraint
- Compliance with key standards is also essential
  - IEEE 1588-2008 for data synchronization
  - ISO/IEC 20889:2018 for preserving personally identifiable information
  - IEEE 1451 standards for interoperable data exchange

Data Collection

- Data was collected at various campus locations
- Livox Mid-40 LiDAR sensor and a webcam
- The data returned was a collection of points in a 3D space called a point cloud in a file type unique to Livox

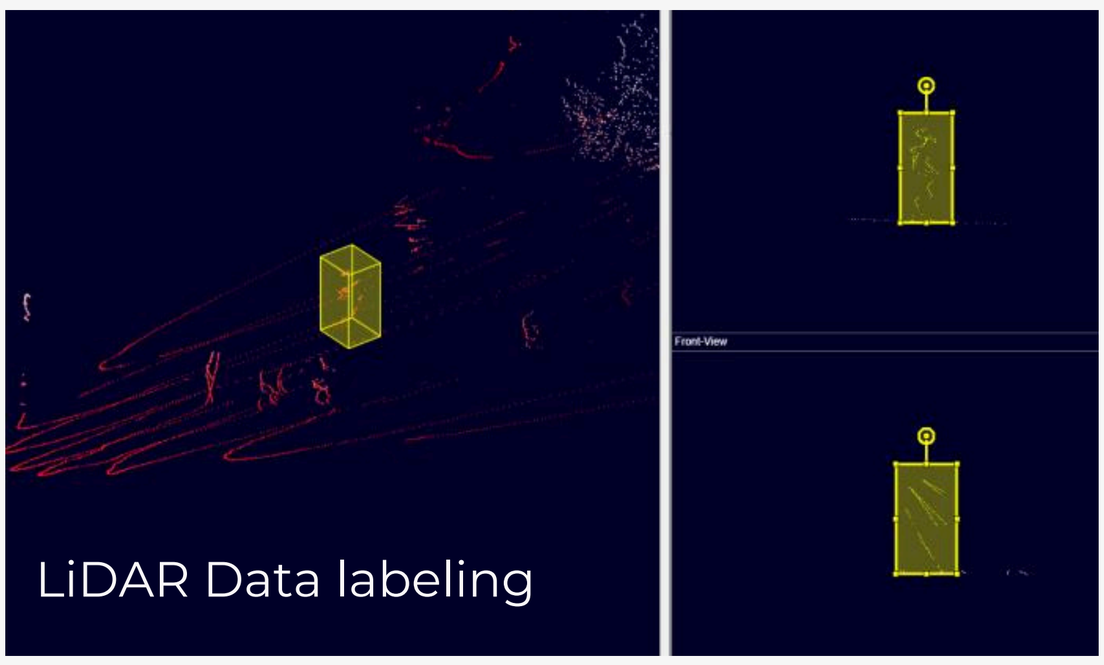
[1] Livox Mid-40 provided to Client by the late Dr. Ahmed Kamal



LiDAR Data

Webcam fooage

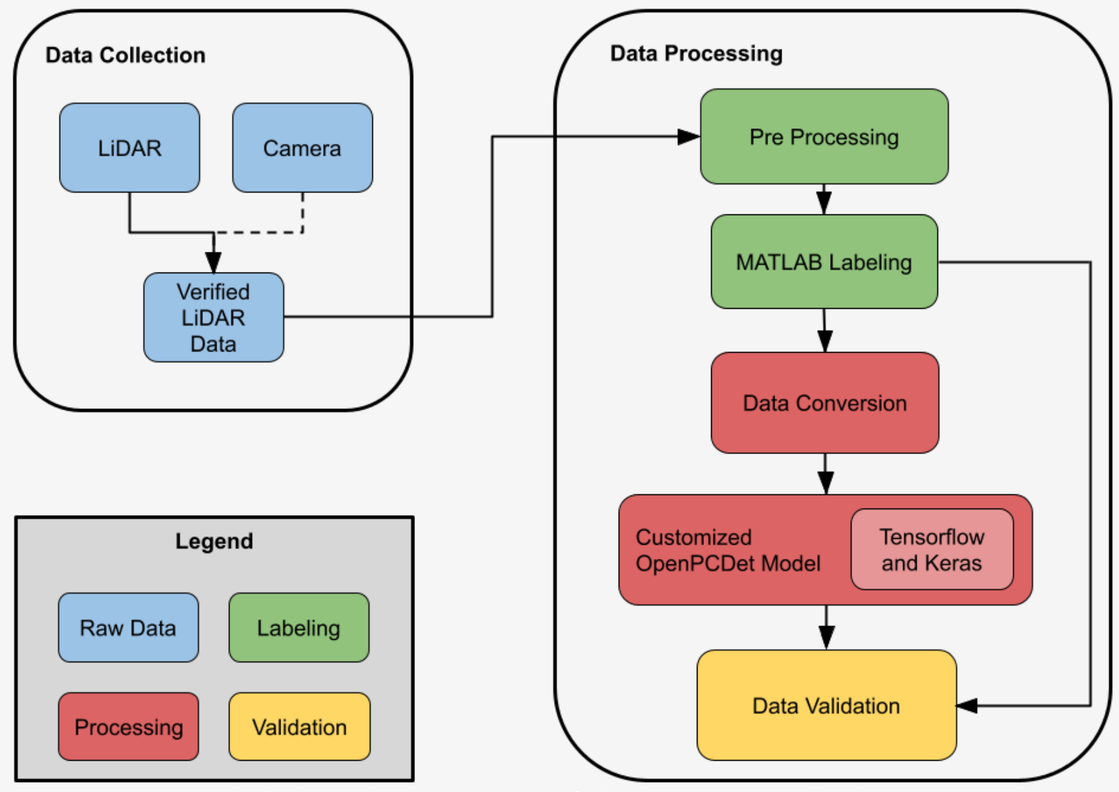
Data processing



LiDAR Data labeling

- The collected data was manually labeled for each object when it entered and left the scene
  - A MATLAB algorithm automatically labeled the object between those two key frames
- After labeling, the labeled data was exported from MATLAB as a .csv file
  - The .csv was converted into .txt files using our Python script to conform to OpenPCDet's input
- A separate Python script was used to convert our unlabeled data into .npy files
- OpenPCDet requires the entire point cloud dataset in .npy format and the labels in .txt format

System Design



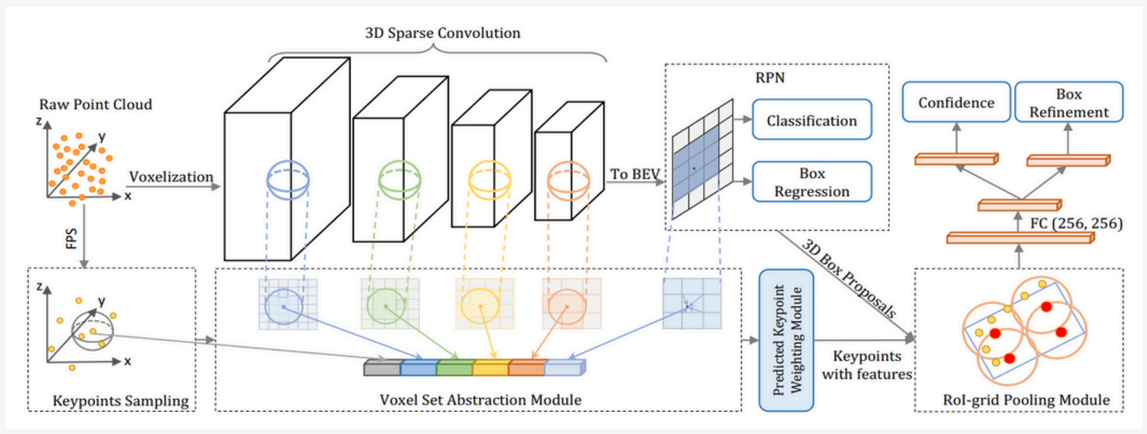
High level overview of the system design

OpenPCDet

- OpenPCDet is a 3D LiDAR-specific open-source framework that provides 7 state-of-the-art object detection methods.
- It includes 5 pre-existing data sets to demo the framework with or use as training data.
- Our team worked with the KITTI dataset to
  - Understand the tool
  - Properly configure the environment
  - Discover what we should expect from our data

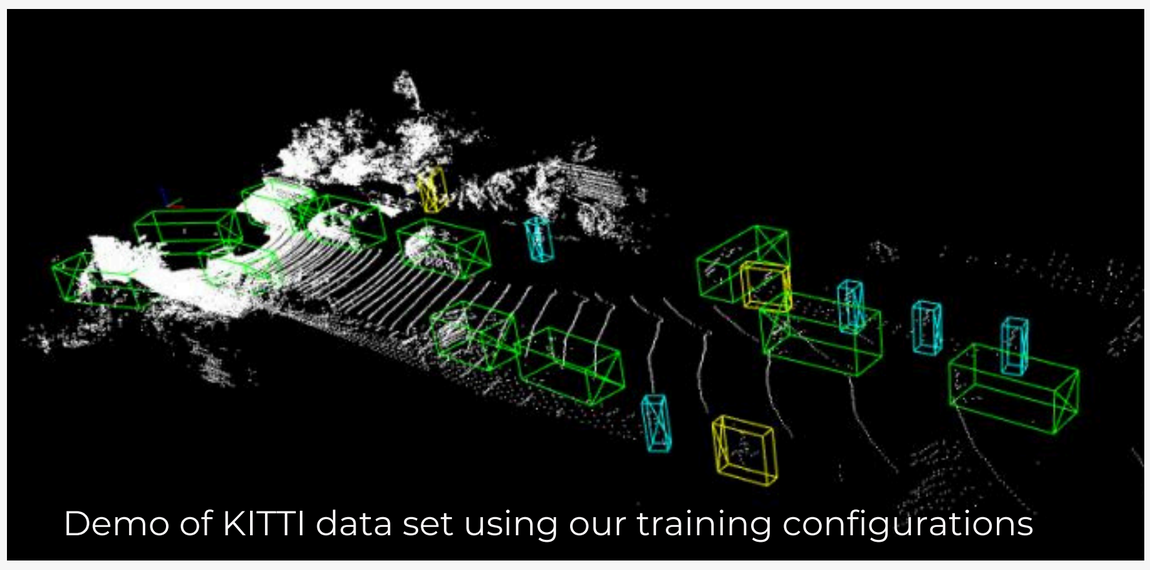
The Model

OpenPCDet supports the use of Point-Voxel Regional-Based Convolutional Neural Networks (PV-CNN), which is a method of processing point clouds that allows for increased accuracy for a minor cost compared to other leading detection models.



[2] Overall architecture of PV-RCNN

Results



Demo of KITTI data set using our training configurations

- We labeled several sets of LiDAR data to train OpenPCDet which includes over 776 labels
- Our team configured, set up, trained, and ran the KITTI dataset to replicate the benchmarks provided by OpenPCDet
- The above image shows the model labeling cars in green, cyclists in yellow, and pedestrians in blue from the KITTI dataset

References

[1] "Mid-40 lidar sensor - Livox," Livoxtech.com. [Online]. Available: https://www.livoxtech.com/mid-40-and-mid-100
[2]S. Shi et al., "PV-RCNN++: Point-voxel feature set abstraction with local vector representation for 3D object detection," arXiv [cs.CV], 2021