V2V Cooperative Perception for Connected and Autonomous Vehicles (CAVs)

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Abstract

Connected and Autonomous Vehicles (CAVs) rely on on-board computing and wireless communication to detect objects and hazards in real time using advanced machine learning algorithms. This information can be shared with nearby road users: pedestrians, cyclists, and other vehicles. This project aims to analyze input point cloud and image data from sensors to accurately detect objects around a vehicle and communicate detections to nearby vehicles using Vehicle-to-Vehicle (V2V) Communication standards. It is challenging to accurately detect and communicate information in real-time, given the mobility and high-speed conditions of CAVs, therefore we will implement algorithms to detect objects along efficient communication methods to exchange information for cooperative perception in a timely, accurate, and energy-efficient manner.

Methods and Materials

Using **ROS Noetic,** we interface with our multimodality system

- Ouster OS2 LiDAR – 3D information
- Intel RealSense D455 Camera – 2D information
- Delphi Aptiv ESR – Trajectory information
- Cohda MK6 Antennas – V2X communication
- NVIDIA AGX Orin Jetson – Compute Device

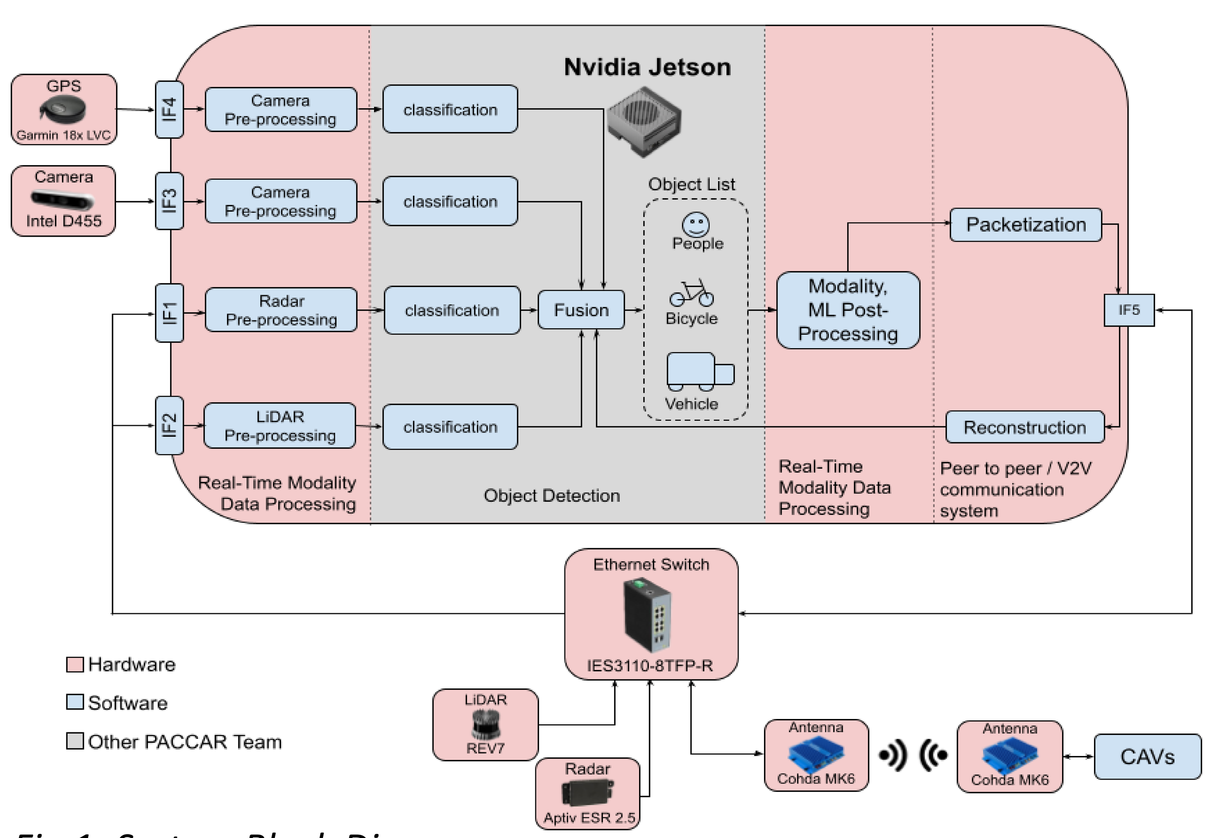

Fig 1: System Block Diagram.

ROS Noetic Ninjemys - Robot Operating System (ROS)

- Provides a flexible framework for writing robot software by offering tools, libraries, and conventions

Putty - simulated terminal used to communicate with the MK6s.

- Code is not Directly implemented on the MK6s
- Command called ACME is used to set the MK6s into CV2X Transmit and Reception modes. Packets are then forwarded between the computers and the MK6s.

Results

On the **pre-processing** side, our system is able to:

- **Synchronize** incoming LiDAR and Camera data
- **Format** data according to the KITTI dataset
- **Pass** formatted data to object detection algorithms

Using created **calibration files** for the camera and the LiDAR, we are able to obtain object lists with the collaborative efforts of the Multi-Modal PACCAR group.

Fig 2: Object detection on toy car with 70% confidence.

On the **post-processing** side, our system is able to:

- **Packetize** object lists for UDP transmission
- **Transmit** data according to ETSI standards
- **Receive** data with an average delay of 62ms and minimal packet loss as can be seen in figure 5 below

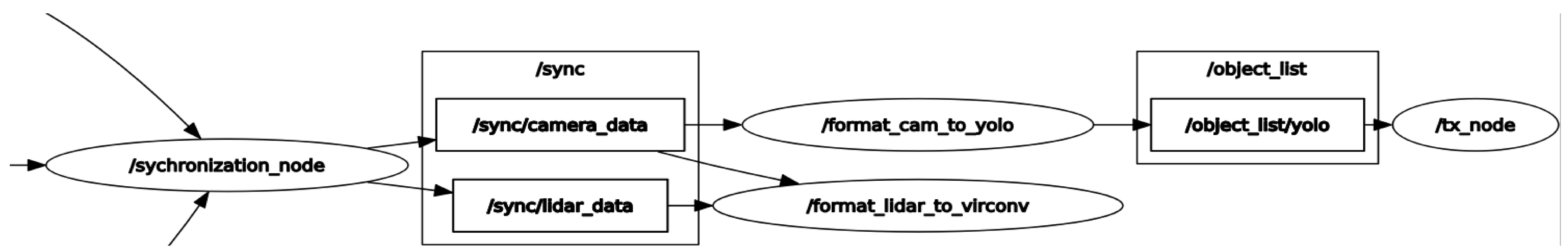

Fig 3: Data Pipeline

Our Real-Time Data Pipeline:

Synchronization Node:

- **Intakes** the raw camera feed, lidar point clouds, and camera information (timing analysis)
- **Uses "ApproximateTimeSynchronizer"** to align nearest data points in time
- **Outputs** aligned data to ROS topics for further processing

Format Nodes:

- **Intakes** aligned data (Image and Point Cloud)
- **Uses CV_BRDIGE** to manipulate data for processing
- **Outputs** formatted data to YOLOv8 and VirConv algorithms

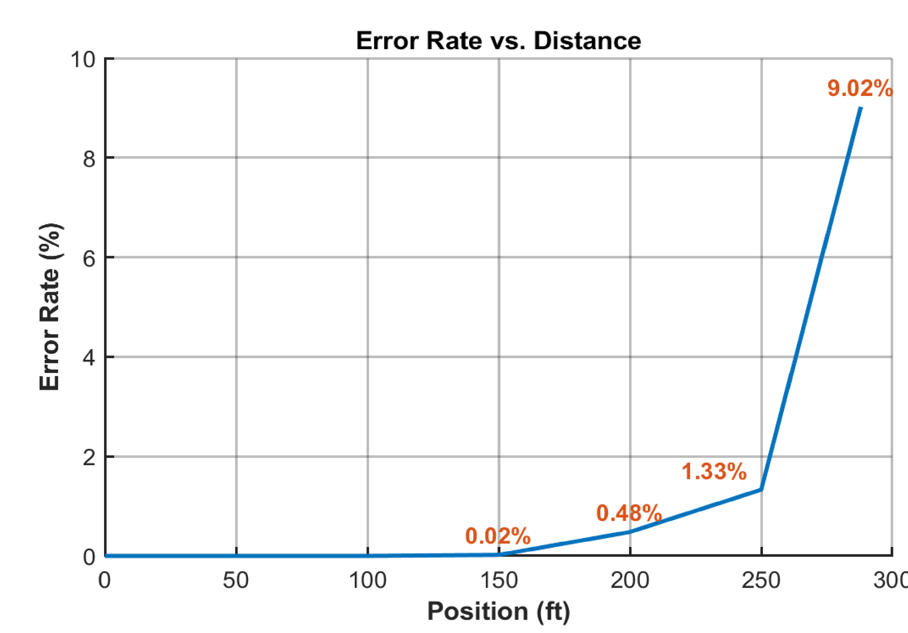

Fig 4: Packet Failure Rate vs Distance between transceivers

Packetization:

- **Using UDP packets means lost data is lost unrecoverable**
- **Object Oriented Packet Division** is our method of reducing data loss. Object Lists are broken down into partial lists for each packet.
- Each list contains only **complete objects**, so if a packet is lost, we still have some data to use for **V2V Fusion**
- The **objects** are **divided** between packets **evenly** to further reduce data loss

Transmission and Reception:

- **Headers** contain timestamp and packet information for error an analysis
- **Frame IDs** are used to discern which frame a transmitted packet's objects belong, when a new Frame ID is seen the list is published for use in V2V Fusion

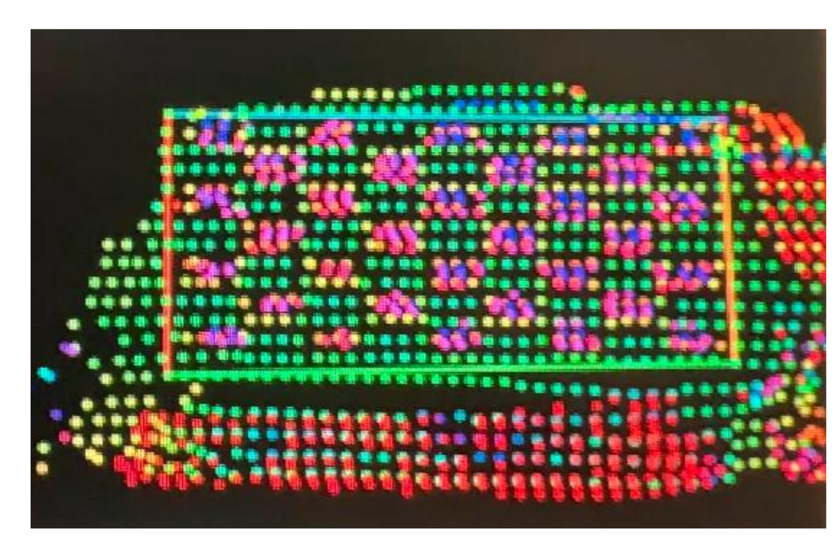

Fig 5: LiDAR calibration file generation tool using checkerboard matrix.

Background

Recent advances in object detection algorithms have been implemented in vehicles from Tesla, Baidu, and others. These systems demonstrate the power of modern AI in autonomous driving.

Smaller research groups, such as **UCLA's Mobility Lab**, have developed **large-scale datasets** and tested **state-of-the-art algorithms** on their own platforms.

- High accuracy has been achieved in **offline settings**.
- **Real-time processing** using inputs from **LiDARs and cameras** remains a challenge.
- No **Vehicle-to-Vehicle (V2V) communication** has been tested in these implementations.

This project focuses on:

- Maintaining **high detection accuracy** comparable to offline models.
- Enabling **V2V communication** to share **hazardous situation alerts** between vehicles.

Future Direction

This project will be **continued next year** by a subsequent PACCAR team from Western Washington University.

Main **objectives**:

- Improving security measures for CV2X transmission
- Completing MultiModal Fusion
- Completing V2V Fusion
- Time Syncing between devices
- Complete RADAR implementation

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