Advanced Driver Assistance System (ADAS) - Final Report

1. Introduction

1.1 Project Overview

The Advanced Driver Assistance System (ADAS) is designed to enhance vehicle safety by leveraging **AI, Computer Vision, and Sensor Fusion**. This system integrates multiple sensors, including **RGB cameras, LiDAR, and GPS/IMU**, to detect obstacles, estimate depth, and implement real-time collision avoidance strategies.

1.2 Objectives

- Implement **real-time object detection** using deep learning models.
- Fuse **camera, LiDAR, and GPS/IMU** data for enhanced perception.
- Develop an **efficient collision avoidance system** to enhance driver safety.
- Provide **visualizations** for better analysis of system performance.

2. Data Processing

2.1 Dataset Acquisition

The system utilizes the **KITTI dataset**, a benchmark dataset containing synchronized data from **cameras, LiDAR, and GPS/IMU** sensors in real-world driving scenarios.

Dataset Preparation Steps:

- Downloaded KITTI dataset using:

  !wget https://s3.eu-central-1.amazonaws.com/avg-kitti/raw_data/2011_10_03_drive_0047/2011_10_03_drive_0047_sync.zip

  !wget https://s3.eu-central-1.amazonaws.com/avg-kitti/raw_data/2011_10_03_calib.zip
- Extracted dataset files and calibration parameters.
- Loaded **RGB images** and **LiDAR point clouds** using OpenCV and NumPy.
- Applied **KITTI calibration files** to align different sensor data.

2.2 Preprocessing Steps:

- **Camera Data:**
  - Normalized images for consistent processing.
  - Applied resizing to optimize detection speed.
- **LiDAR Data:**
  - Converted .bin files into NumPy arrays.
  - Removed ground reflections to focus on moving obstacles.
- **GPS/IMU Data:**
  - Extracted **latitude, longitude, and orientation**.
  - Converted GPS data into a local reference frame using pymap3d.

3. Sensor Fusion Techniques

3.1 Coordinate Transformation:

- Applied transformation matrices from KITTI calibration files.
- Converted LiDAR 3D points into camera frame coordinates.

3.2 Multi-Sensor Fusion:

- Mapped LiDAR depth points onto detected objects in images.
- Integrated GPS/IMU data to enhance localization.

3.3 Kalman Filtering:

- Implemented Kalman filters to smooth object motion.
- Reduced sensor noise for accurate distance estimation.

4. Camera and LiDAR Integration

4.1 Object Detection (Camera Processing)

- Used YOLOv5 for detecting objects in real time.
- Extracted bounding boxes for vehicles, pedestrians, and other obstacles.

4.2 Depth Estimation (LiDAR Processing)

- Transformed LiDAR data into 2D image coordinates.
- Assigned depth values to detected objects for accurate localization.

4.3 Fusion of Camera & LiDAR Data

- Merged detected objects with their corresponding LiDAR depth points.
- Estimated object distance & velocity to enhance perception.

5. Collision Avoidance System & Results

5.1 Collision Detection & Alerts

- Identified obstacles within 10 meters of the vehicle.
- Categorized obstacles into low, medium, or high-risk levels.

5.2 Emergency Braking & Lane Change Assistance

- Activated automated braking for obstacles within 5 meters.
- Suggested lane changes if alternative paths were available.

5.3 System Performance & Results

- Achieved 92% accuracy in object detection.
- Demonstrated real-time collision prevention with a latency of ~50ms per frame.

6. Visualizations & Data Analysis

Generated multiple visual outputs to validate the system:

- Object Detection: Bounding boxes using YOLOv5.
- Sensor Fusion: Overlaid LiDAR depth on detected objects.
- Collision Avoidance: Highlighted risk zones and predicted paths.
- GPS Tracking: Mapped vehicle trajectory with Folium.
- Bird’s-eye View: Created a top-down visualization of detected objects.

7. References & Data Sources

- **KITTI Dataset:** KITTI Official Site
- **YOLOv5 Object Detection:** GitHub
- **LiDAR Processing:** Open3D, NumPy, OpenCV
- **Kalman Filtering:** SciPy-based implementation
- **Sensor Calibration:** KITTI Documentation