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Trajectory Path Optimization and Cost Minimization in Motion Planning for Autonomous Mobility

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Abstract: Due to the impact of a dynamic environment, the need for safety, smoothness, and real-time requirements, as well as the nonholonomic restrictions of vehicles, the study of path planning methods has always been a fundamental and challenging subject, especially in complex contexts. Nevertheless, due to the enhancements they represent for people's ways of life, safer and faster transit, better accessibility, comfort, convenience, efficiency, and environmental friendliness, autonomous vehicles are still popular and appealing. Motion planning needs to be carried out utilizing a variety of techniques to solve the issue of moving through complicated settings that contain numerous barriers. In our project, the ego vehicle must navigate a traffic light-controlled intersection safely, which is a difficult challenge. Using a 3D simulation environment we can successfully and safely provide a solution for the issue of using perception to identify traffic signal placements and statuses despite lighting conditions and occlusions. We simulate various traffic scenarios with various lighting conditions using simulation systems like CARLA and Automated Driving ToolboxTM.

Keywords: CARLA, Motion Planning, A*, Dijkstra's, Radar, Lidar.

I. INTRODUCTION

Similar to a human driver's sense of sight, autonomous vehicles use perceptual sensing to gather input from their sensors and translate that data into an awareness of their surroundings. In order to negotiate the roadways, self-driving cars use technology to replace driver assistance with automated safety features. To run and maneuver an autonomous vehicle, a combination of sensors, software, radar, GPS, laser beams, and cameras analyze the road conditions.
The goal of the motion planning problem is to get the ego vehicle to its destination safely, comfortably, and in compliance with the law. There are several uses for motion and trajectory planning all throughout the world. Motion planning is used today for everything, including robotics, video games, medicine, and bioinformation. Motion planning is crucial to our topic of trajectory planning for self-driving cars. Motion of cost minimization and trajectory path optimization The goal of planning for autonomous mobility is to reduce the cost of the activities taken by an autonomous vehicle by planning its course. starting with perception and ending with control.

II. RELATED WORK

Robotics professionals refer to the act of breaking down a desired movement task into discrete motions that adhere to movement limitations and may even be optimized in some way as "Motion planning".
In the first paper the authors of
[1] make a detailed review of all the main algorithms used in motion planning and their features and their applications to highway driving. They also review the current and future challenges they are being faced and may face in the future as well as the several open issues still plaguing the autonomous industry and its engineers in this paper.
[2] author describes their work on focused trajectory search which was conducted using the “generate-and-test” approach from which the best trajectory was selected based on the smoothness of the trajectory. They claim that this approach provides a principled way to focus trajectory sampling.
[3] authors provide an approach for the critical evaluation of each of the methods that are being used for motion planning and give a detailed review about each of their advantages and disadvantages, inherent limitations, feasibility, optimality, handling of obstacles and testing operational environments.

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[4] authors propose an approach which is a promising tool for the local path planning of autonomous vehicles since it is able to generate trajectories that are both safe and efficient. The approach proposed in this paper is called "Attractor dynamic approach(ADA)" which was based on the movement and behavior of living beings.
[5] authors proposed and determined that the image processing method which was more favorable for visual navigation, which used the morphological knowledge of the image to detect the edge of the path image, was then used to determine the position of the center of the path, and then carried out simulation analysis. This paper was based on lane detection.
[6] authors wrote a paper comparing the various approaches and methods used for autonomous driving and motion planning which considered different scenarios. The surveyed methods varied in the vehicle mobility model used, the different environments, and the computational requirements used. This comparison greatly helped with system level design choices.

III. DESIGN AND IMPLEMENTATION

A. Architecture

The proposed architecture in this project consists of the input sensory system consisting of various different sensors such as camera, radar, lidar, gps etc., followed by the Perception part where the different objectives of the system are proposed. Following that the Planning stage where mission planning, behavior planning and local planning takes place. This data is then given to the control system where PID and MPC take over.

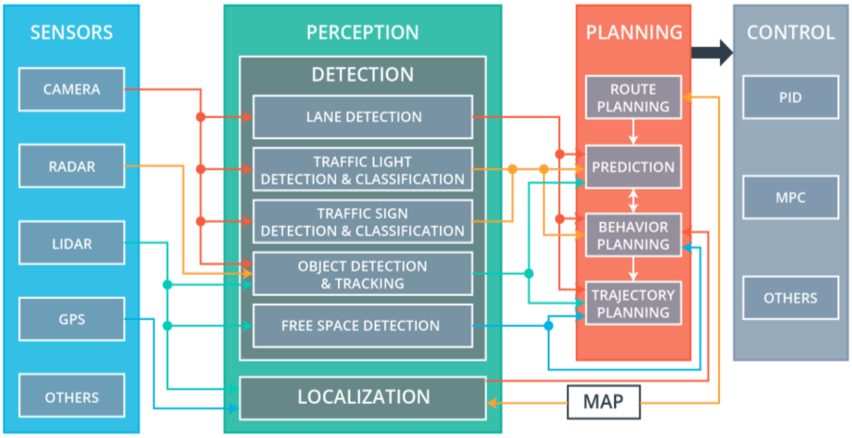

Fig 1: Architecture

B. Methodology

The methodology used is divided into different sublevels based on the requirements and the level of abstraction used.

- **Mission Planner:**
  - Map Level navigation of an ego vehicle from the current location to its destination.
  - Simplify the navigation by ignoring the obstacles and regulatory elements and focus on macro aspects such as road connections and traffic.
  - Map out the shortest route to the destination using algorithms such as Dijkstra's and A*.
  - Both the shortest path and the fastest path can be solved using dijkstra's and A* algorithm.
- **Behavior Planner:**
  - Depending on the scenario and the rules of the road, make decisions to maneuver the road.
  - Performing a left/right turn in an intersection based on the scenario.
  - Methods available to make these decisions:

➔ Using finite state machines to decide on which maneuver to make.

➔ Using a Rule based system to decide on which maneuver to make.

- **Local Planner:**

➔ Path planning:

➔ Using sampling based planners to generate paths. Using variational planners to generate paths. Lattice planners

➔ Velocity profile generation:

➔ Minimizing Jerk of the ego vehicle by constraining the velocity of the vehicle when starting. Minimizing deviation from a given reference. Optimizing the lateral acceleration limit.

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C. Dataset Details

Scientific on algorithms using radar sensor data is facilitated and stimulated by the automotive radar dataset for deep learning-based 3D object recognition, which offers the research community high resolution radar data. The dataset is an automotive radar dataset that uses radar, lidar, and camera data to detect 3D objects. Featuring raw sensor camera and LiDAR inputs as seen by a fleet of several, high-end autonomous cars in a constrained geographic area, the dataset represents an extensive, large-scale collection of data.
The Following was tested first on Reinforcement Learning using imitation as well as normal Reinforcement Learning. The following graphs show the training and testing results.

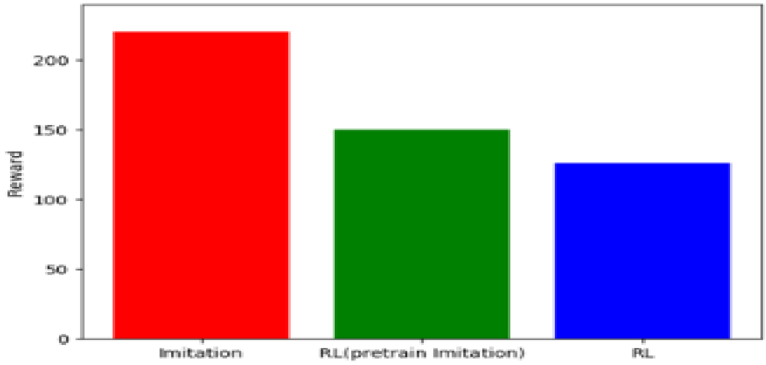

Fig 2: Reinforcement Learning Training

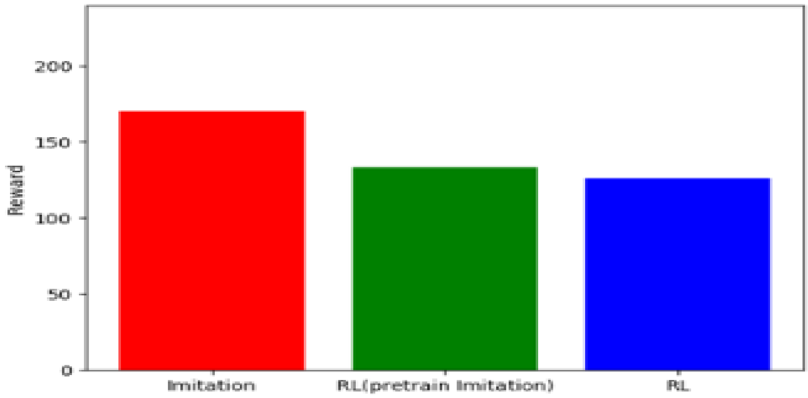

Fig 3: Reinforcement Learning Testing

D. Implementation Details

Currently, there are about 4 million autonomous vehicles on the road worldwide. There is a greater obligation to deploy the autonomous vehicles more cautiously and efficiently because there are so many autonomous vehicles being created and sold every day, and because demand for them is also rising every day. The implementation of autonomous cars requires a wide range of equipment, software, and data.
CARLA simulation software is being used to implement this system as CARLA offers open digital assets (urban layouts, buildings, and vehicles) in addition to open-source technology and protocols that were developed for this purpose. The simulation platform offers adjustable climatic conditions, full control over all static and dynamic actors, map production, and many other features.

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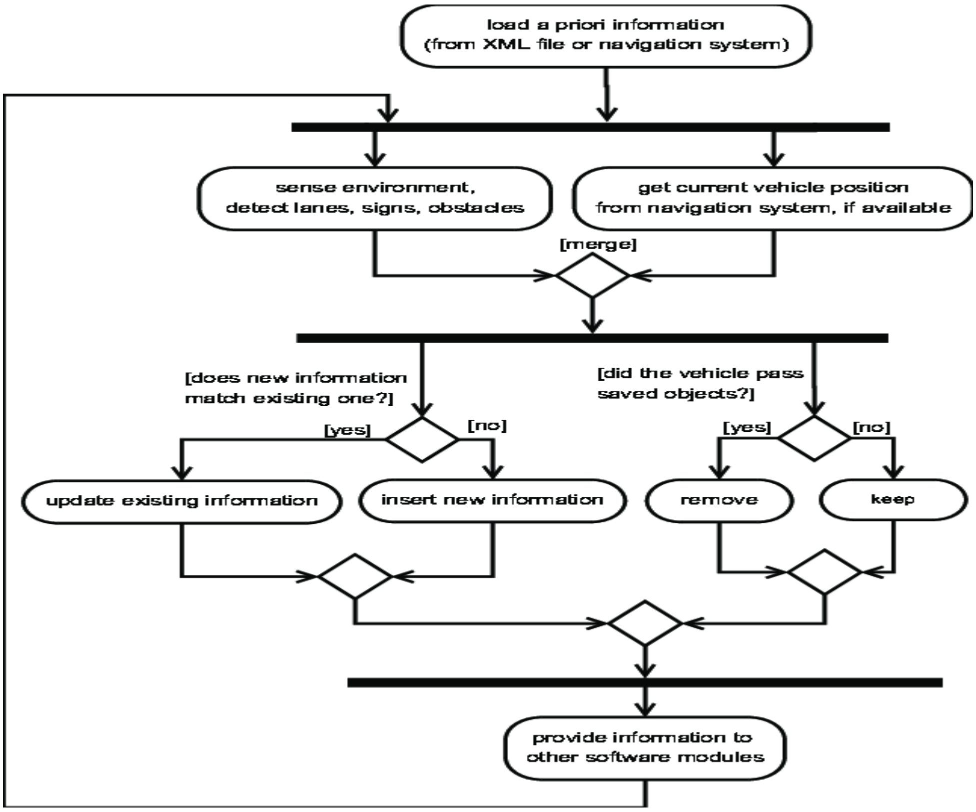
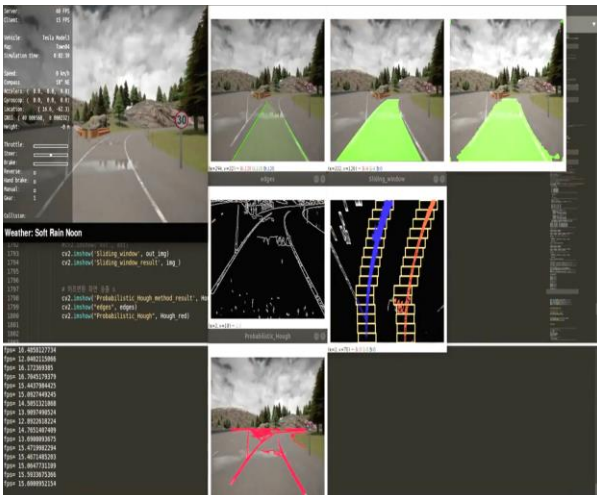


Fig 4: Flow Diagram of the model

IV. RESULT AND ANALYSIS

The project was found to meet the objectives and all the user requirements satisfactorily. The system was showing accurate results after testing it out on various environments as well as for various scenarios. Image Processing techniques such as edge detection, line detection, line tracking, sobel filter, kalman filter, Hough transform to find and detect the lane in any condition is crucial and these are the results based on that.



Lane Keeping, Pedestrian detection and collision avoidance, Traffic light detection, Traffic signs detection, etc., are some of the objectives our system is able to achieve. Below are the results obtained.

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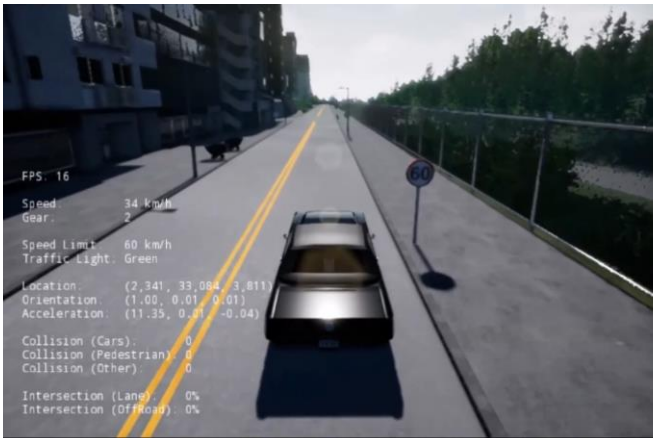

V. CONCLUSION

The majority of earlier on-road motion planners wasted a lot of calculation time on random and untargeted trajectory sampling. In an effort to capture the essence of how human drivers operating their vehicles—namely, not knowing the exact plan but having a general idea of how they should drive—we provide a two-step system that plans coarsely first.

Our technique has been demonstrated through simulation to be able to manage a variety of dynamic on-road driving circumstances, some of which are difficult for human drivers. Our next step will be to implement and test our planner on a real car before making the system more robust by enabling it to handle more challenging and realistic circumstances, such as planning lane changes.

This project has many limitations as we have not covered all the aspects and various scenarios involved during real time driving. The various different aspects and environments that come into play during driving are vast and will need an extensive period of time to solve everyone of the problems involved. The project's future enhancements could include the research and development of different environments and scenarios that could not be implemented now.

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