Centralized Motion Planner for Autonomous Vehicles in a City Grid

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***Abstract*—Localized motion planning on-board an Autonomous Vehicle (AV) using SLAM (Simultaneous Localization and Mapping) has been implemented. This individual motion planning of the route by AVs does not account for other AVs' routes, urgency, other such parameters and can lead to deadlock situations. A centralized computation unit that provides the registered AVs with a optimal motion plan is proposed by this project. A central planner will find a optimal motion plan for all the AVs in its control area. This central planner will consider the fuel constraint, priorities, speed constraint, etc while planning.**

***Index Terms*—Centralized Motion Planner, multi-robot motion planning, City Commute planning, Path Planning, Autonomous vehicles, Mobile Robots, Collision avoidance, Traffic Planning, Multi-robot systems**

I. Introduction

Traffic Management and seamless traversing of Autonomous Vehicles (AVs) is going to be a crucial part of our system once we get to a point where all the vehicles on-road are AVs. Coordinated control of the traffic of AVs will help build efficient transportation systems with better collision avoidance and traffic control. These types of scenarios are also visible in industrial warehouse multi-robot systems. This project proposes to design a centralized motion planning unit. This central unit will be responsible to providing the AVs with global motion plan while letting the AVs take care of obstacle avoidance and local planning. The goal of the central unit is to find optimal motion plans for the all the AVs in its neighbourhood. This including prioritizing high priority vehicles like ambulance, VIP vehicles,etc. Central Unit will try all cost to avoid total deadlock situation and find trajectories for AVs with minimum time-to-destination.

Bolu et. al. [2] have worked with multi-robot systems in smart warehouse for planning efficient paths without deadlocks and collision using a central Warehouse Management System which communicates with the multiple robots and designs path plans for them, with each robot has its on system which is responsible for collision and deadlock avoidance. Baber et. al. [1] have worked on coordinated multi-robot systems using central server for planning paths and avoiding collisions at turnings.

II. Background

With advent in Autonomous Vehicles (AV) technology, soon on-road vehicles will be autonomous and will be able to travel to desired location without human interaction. These AVs will be need to plan their trajectories through the city. There are motion planners for individual AVs that can plan these trajectories, but they are not sufficient or sophisticated enough to coordinate their motion and can lead to sub-optimal trajectories, mismanagement of emergency vehicles, or deadlock problems. [6] At intersections, flow of vehicles need to be managed to maintain a smooth traffic flow. Typically, intersections utilize red lights to ensure safety, but these are not ideal, as vehicles are not moving for a certain period of time. Work has been done for improving the efficiency of vehicles passing through a single intersection without halting in [3]. However, vehicles were considered to move in a straight path and not make turns. Some of the concepts discussed can be modified and expanded upon, to create a grid with a centralized motion planner. [4] uses a hierarchical approach to solving this problem, using one layer each for defining the topography, planning the path of an individual AV, and for managing conflicts that may arise in these planned paths.

III. Proposed Methods

We plan to design a system for seamless movement of AVs through a town, without stopping at any intersections, while avoiding all collisions. To implement this, we plan to make a 2 dimensional city grid with multiple cars spawning in it as point robots. Each car will have its own destination to and a path to reach it. We will implement a centralised controller which will handle deadlocks and help avoid collision. This project makes the following assumptions.

Assumptions :

- All roads are one-lane and one-way.
- Vehicles have 5 discreet speed levels.
- Vehicles have finite fuel that is spent based on the length of the path.
- Emergency vehicles can appear which need priority to reach their destination the fastest

A. Registration of AVs with Central Planner

AVs will send a registration packet to the central planner with necessary information including start location, goal location, fuel limit, and priority level. Based on this information, central planner will calculate the optimal motion plan for all the AVs and send it to them. The global path plan will factor in prioritization for emergency vehicles such as ambulances or firetrucks, and the fuel limit will ensure vehicles with a low fuel level reach their destination earlier. For the purpose of this project, this communication will be done via ROS using client/service model.

B. Motion Planning algorithms

This project will be working a 2D grid world that can be easily converted into a graph. Efficient Graph searching algorithms can be used for motion planning. These are subjected to change in future with further study of the subject [5]. Central Planner will use one of the following algorithms to find optimal trajectories for the AVs. Optimal trajectories can be defined as

- A*
- ARA*

C. Constraints

Once an optimal motion planner has been designed for the project, the project also plans to explore some more scenarios which would add constraints to the motion planner.

Multiple levels of priority will be given to vehicles like police cars, fire fighters and school buses. According to the priority of the vehicle different speed and path will be allotted to the vehicles in the system.

During particular cases like new year events, road repairs, etc. certain roads might be intermittently closed, solving these constraints can be added. When a vehicle is at low fuel levels it would reroute to a charging station and priority will be given according to its charging levels.

IV. Goals

- Centralized Motion Planning Unit
- Priority routing to emergency vehicles.
- Effective Hand-off between two neighbouring central planners.
- Different speed limits on roads and vehicles shall be considered.
- Fuel limits of the AVs shall also be considered by the centralized planner.

V. Expected Results

This project expects to design a central motion planning unit that would be able to handle motion planning of multiple AVs entering and exiting its coverage region. It should be able to avoid deadlock situations and give a optimal trajectories for all of the AVs. This algorithm should also be able to take into account different fuel constraints of the AVs, their priority levels, and other constraints. This project also intends to visualize the working of this planner on a 2D Grid based simulation environment. City Grid visualization will be built to towards that end.

VI. Task Division

We propose the following task division in table I.

TABLE I
TASK DIVISION

Name	Task
Harin Vashi	City grid visualization, Motion planning system design, constraint design
Rushikesh Deshmukh	City grid visualization, ROS Module design, Motion planning system design
Piyush Malpure	ROS Module design, Motion planning system design, constraint design

VII. Planned Schedule

The planned schedule is proposed as shown in table II

TABLE II
SCHEDULE

From	To	Task
-	31-Jan-2022	Project Proposal
1-Feb-2022	8-Feb-2022	Designing City Grid
9-Feb-2022	16-Feb-2022	One Point car motion plan design
20-Feb-2022	21-Feb-2022	Project Proposal Update
22-Feb-2022	8-March-2022	ROS setup for multi-car system
8-March-2022	21-March-2022	Central Motion planner for multi-robot system
22-March-2022	04-April-2022	Exploring motion planning algorithms for the system
05-April-2022	18-April-2022	Adding constraints and testing
19-April-2022	25-April-2022	Final testing of system
26-April-2022	29-April-2022	Project Report, Presentation

References

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