Texas A&M Summer Research

Local Path Planning

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Need statement

- Given a robot and a description of the environment, plan a conflict-free path between the specified start and goal locations.

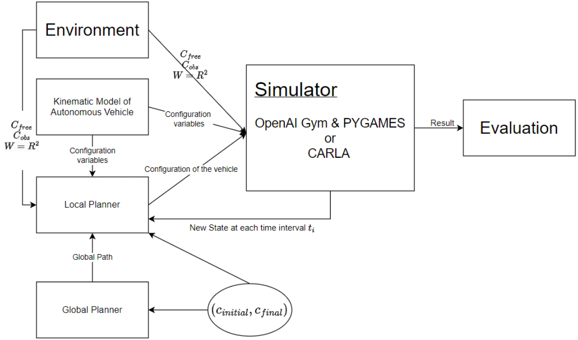


Figure: Proposed System Diagram

Revision: Objectives

Basic Objectives

1. Implement a lane-changing algorithm for an autonomous vehicle.
2. Model the autonomous vehicle as a **non-holonomic** vehicle.
3. Use a reliable path planning algorithm, i.e. if solutions exist, then the planner outputs at least one feasible solution.
4. Simulate the planning scenario in CARLA simulator [3].

Advance Objectives

1. Have a limited field of view where obstacles can be detected.
2. Implement a local planner that deals with dynamic obstacles.

CARLA Simulator

CARLA

- CARLA simulator is a powerful open-source platform for autonomous driving research and development. It provides a realistic and customizable virtual environment to test and evaluate algorithms and systems for autonomous vehicles.

Non-Holonomic Vehicle

Non-Holonomic

1. A type of vehicle that has constraints on its motion, particularly on its steering angle and velocity.
2. They can't move in any arbitrary motion.
3. They aren't constrained in terms of configuration.
4. These constraints typically arise from the vehicle's mechanical design.
5. Examples of non-holonomic vehicles are:
    1. Four-Wheel Ackermann Model
    2. Bicycle Model

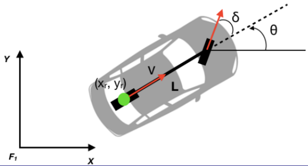
Bicycle Model

Introduction

1. The model can be expressed as a simplified version of the four-wheel Ackerman model.
2. Does well in capturing vehicle motion in normal conditions.
3. The state of the model can be expressed as

$$\begin{bmatrix} x \\ y \\ \theta \\ \delta \end{bmatrix} \ni \theta \text{ is the heading angle and } \delta \text{ is the starting angle.}$$

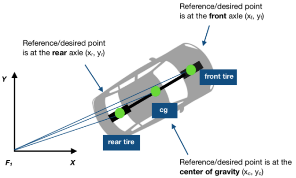
4. The heading angle in a vehicle refers to the orientation or direction of the vehicle with respect to a reference frame. The wheelbase is denoted by L
5. The inputs to the model are $\begin{bmatrix} v & \phi \end{bmatrix} \ni \phi$ is the steering rate.

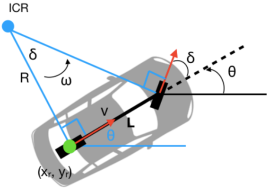


Bicylce Model

Equations of motion

1. To analyze the model a reference point must be selected. This can be on the centre of the rear axle, the centre of the front axle, or at the centre of gravity.
2. In our example moving forward we will consider the reference point to be on the center of the rear axle.
3. In order to get the new state we must first compute the state change rate $\begin{bmatrix} \dot{x} & \dot{y} & \dot{\theta} & \dot{\delta} \end{bmatrix}$
4. $\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \\ \dot{\delta} \end{bmatrix} = \begin{bmatrix} v\cos\theta \\ v\sin\theta \\ v\frac{\tan\delta}{L} \\ \phi \end{bmatrix}$ [2]
5. The vehicle rotates about the instantaneous centre of rotation (ICR).

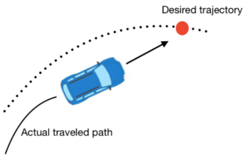


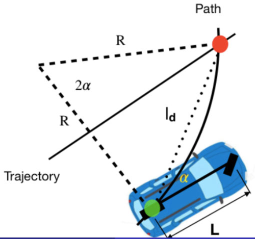


Pure Pursuit Controller

Controller

1. It is a method of vehicle lateral control.
2. A geometric path tracking controller is any controller that tracks a reference path using only the geometry of the vehicle kinematics and the reference path.
3. It uses a look ahead distance l_d. It is the distance between the target point and the rear axle.
4. The angle between the vehicle's body heading and the look-ahead line is referred to as α.
5. R is the radius of rotation about the Instantaneous Centre of Rotation (ICR).

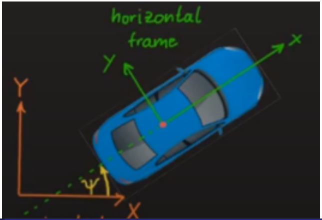




Pure Pursuit Controller

Equations

1. $\delta = \arctan(\frac{2L \sin \alpha}{l_d})$
2. $\alpha = \arctan\left(\frac{t_y - y}{t_x - x}\right) - \psi \ni (t_x, t_y)$ is the target coordinate, (x, y) is the current coordinate and ψ (yaw) is the angle between the inertial frame and horizontal frame about the z axis.
3. The pure pursuit is a simple control algorithm, i.e. it does not take dynamics into account. Thus if l_d is tuned for smaller velocities then the vehicle would behave very aggressively for larger velocities.
4. A solution for this problem is basing the look ahead distance on velocity, i.e. $l_d = K_{dd} * v_f \ni v_f$ is the forward velocity and K_{dd} is a constant.



Simulation Result

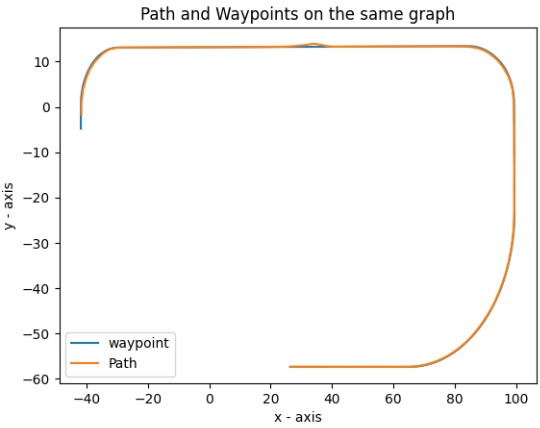


Figure: Waypoints refer to the path that needs to be followed. And, path refers to the implemented path

Simulation Result

Figure: This is a screenshot from the simulation. The blue dotted curve is the path that the car needs to follow

Conclusion

Conclusion

1. A non-holonomic vehicle is a type of vehicle that has constraints on its motion, particularly on its steering angle and velocity.
2. The chosen model to implement a 4-wheeled vehicle is the 2D Bicycle Model.
3. The control algorithm used is the Pure Pursuit controller, i.e. a geometric path-tracking algorithm that outputs the vehicle steering angle.

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