Clothoid-Based Real Time Path Planning for Autonomous Driving

Hye young An, Won Seok Choi, Seong Gon Choi*
Chungbuk National University
youngflow@naver.com, wschoi@chungbuk.ac.kr, *choisg@cbnu.ac.kr

Abstract

We propose clothoid-based real time path planning for autonomous driving. Autonomous driving requires path planning and trajectory control to generate a feasible path. A path is usually established using GPS or predefined path information. However, it can be difficult to obtain the necessary path information due to environmental factors and surrounding conditions. To achieve that, we propose an algorithm that enables real-time clothoid-based path planning and trajectory control utilizing the detected lane, minimum turning radius, and driving radius. We simulated four different speeds (ranging from 20 km/h to 50 km/h) at a single-lane roundabout. The obtained simulation results show that our algorithm has no problems in real-time driving at various speeds.

I. Introduction

Nowadays, autonomous vehicles have a huge potential for the transportation of people and goods. The vehicles should be able to automatically define and navigate paths from their current position to an addressed destination. Moreover, accurate and powerful trajectory control based on the explored path is essential for autonomous driving.

Most studies for trajectory control of vehicles use predefined paths and the Global Positioning System (GPS) [1]. However, it may be difficult to obtain GPS information due to several factors (e.g., being blocked by tall buildings, tunnels, or mountain roads). In addition, in a real environment, it is impossible to use the predefined path, or it can be changed for various reasons. As a result, vehicle stability issues may occur when controlling the vehicle based on the collected path points.

Therefore, we present a real-time path planning algorithm and trajectory control for AVs. In the path planning algorithm, lanes are detected based on various sensors (LiDAR, Radar, Camera, IMU, and Odometry), including GPS, and the next moving position of the vehicle is selected based on the detected lane. As the vehicle drives, it is important to ensure that the angular velocity continues at the transition point between the line and the curve. Our goal is to create a smooth, natural, and easy path to drive between the generated points. A clothoid curve is one of the most applied transition curves in road modeling because it can be parameterized by control points [2]. Internal control points are selected so that the curves meet smoothly. In addition, a pure pursuit algorithm is applied to generate a vehicle trajectory based on the control point [1].

As a result, our goal is to achieve feasible autonomous driving by generating a clothoid-based real-time path through sensor-based lane detection and utilizing the trajectory calculation results.

II. Proposed method

The main aim of this study is to generate a feasible real-time path that should provide a continuous position, direction, and curvature at any location and be smooth, natural, and easy to drive. Therefore, the path must be able to be described with accurate road geometry representation.

Our idea consists of three steps: first, an algorithm that determines the next position based on the lane detected by the sensor, second, an algorithm that generates a clothoid curve, and third, an algorithm that generates a trajectory.

A. The next position determination algorithm

Based on Figure 1, the next point is selected in the following order:

- Straight lines and road curves are detected by the sensor.
- The minimum turning radius of a vehicle is the radius measured by the vehicle’s outer wheels while making a complete circle. The minimum turning radius based on the heading of the vehicle and the driving radius according to the
vehicle speed are virtually drawn (part ① in Figure 1).

- The intersection between the vehicle’s minimum turning radius and lane is calculated (part ② in Figure 1).
- It calculates the midpoint of the line segment connecting the two calculated intersections (part ③ in Figure 1).
- The intersection of the line segment (the midpoint of the rear axle, the midpoint found above) and the driving radius becomes the vehicle’s goal point (part ④ in Figure 1).
- Based on the driving radius at the midpoint of the rear axle, this is the next point calculated relative to the rear axle by C. The trajectory generation algorithm below (part ⑤ in Figure 1).

B. The clothoid curve generation algorithm

The clothoid curve is curve defined by the property that the curvature is linear with the arc length [2]. Clothoids generate kinematically feasible paths with a bounded piecewise linear continuous curvature and low curvature rate change. The clothoid curve is computed via the Fresnel sine and cosine integrals with given initial and final angles and curvatures.

C. The trajectory generation algorithm

The trajectory control algorithm geometrically determines the steering angle at which to drive the vehicle from its current position to the next position on the path. This is one of the classic techniques of lateral control based on the bicycle model. It uses vehicle position and odometry to control vehicle speed and steering to follow a reference path. The pure pursuit algorithm selected for trajectory control is efficient in execution because of its low computational complexity. In addition, pure pursuit has proven sufficiently suitable for autonomous driving in terms of passenger comfort and safety [1].

III. Simulation

To validate the proposed algorithm, our approach uses Python’s matplotlib to simulate vehicle motion at roundabouts, including both circular arcs and straight lines. The simulation environment is composed by taking into account the single-lane roundabout environment and the vehicle according to the design guidelines of the Ministry of Land, Infrastructure, and Transport (South Korea) [3]. Therefore, in a simulation environment, we tested the roundabout speeds from 20 km/h to 50 km/h as recommended by the guidelines.

Figure 2 shows the trajectory of vehicles at various speeds. As a result, it is possible to confirm that the vehicle is driving safely by setting a path in real time. In Figure 2, it can be seen that the clothoid-based trajectory with a speed of 50 km/h is smoother and more natural than the normal trajectory path.

IV. Conclusion

In this paper, a trajectory control that generates a clothoid–based path in real time using a sensor and tracks the path was studied. We simulated on a single-lane roundabout including circular arcs and straight lines. As a result, the vehicle follows the trajectory safely and smoothly, generating a path in real time from 20 km/h to 50 km/h. The result shows that our algorithm has no problems with real time clothoid–based path generation and trajectory control in any environment.

In further studies, we will study the relationship with other vehicles in more complex environments.

ACKNOWLEDGMENT

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education(2020R1A6A1A12047945).

*corresponding author is S.G. Choi (choisg@cbnu.ac.kr)

References

