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OPTIMAL PATH PLANNING FOR AUTONOMOUS VEHICLES USING ARTIFICIAL POTENTIAL FIELD ALGORITHM

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ABSTRACT–This paper proposes an optimal path planning algorithm to make the autonomous vehicle follow the desired path profile while avoiding nearby obstacles safely. Also, it utilizes only readily available sensors equipped with typical autonomous vehicle system. For optimal path planning, an artificial potential field (APF) algorithm to derive both desired vehicle longitudinal velocity and desired vehicle yaw angle in real time is newly designed, which includes both a repulsive field for avoiding road boundaries and nearby obstacles ahead, and an attractive field for following the proper lane. Next, the path tracking control algorithm consists of longitudinal and lateral motion controllers. Especially, a model predictive control (MPC) for vehicle lateral motion causes the yaw angle error between the desired path profile and the vehicle to approach zero. Then, it can derive an optimal front steering angle considering vehicle state and input constraints. Using CarSim and MATLAB/Simulink simulations, the effectiveness of the proposed algorithm in this paper is verified in some driving scenarios. Accordingly, its high performance for the path planning and tracking of autonomous vehicles can be clearly confirmed.

KEY WORDS : Optimal path planning, Autonomous vehicle, Artificial potential field, Model predictive control, Obstacle avoidance

NOMENCLATURE

v_x : vehicle longitudinal velocity, km/h
ψ : vehicle yaw angle, deg
l_f : distance between the vehicle center and the front axle, m
l_r : distance between the vehicle center and the rear axle, m
t : track width, mm
$a_{x\&y}$: vehicle longitudinal and lateral accelerations, m/s^2
μ : tire-road friction coefficient, -
R_e : tire effective rolling radius, m
m : total mass of vehicle, kg
T_w : total wheel torque, N·m
β : vehicle sideslip angle, deg
C_f : tire cornering stiffness of front axle, N/deg
C_r : tire cornering stiffness of rear axle, N/deg
r : vehicle yaw rate, deg/s
δ_f : front steering angle, deg
I_z : vehicle yaw moment of inertia, kg·m^2
s : travel distance of vehicle, m

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1. INTRODUCTION

As autonomous driving technology becomes more and more popular, interest in optimal path generation technology is also increasing (Gonzalez *et al.*, 2015). The autonomous vehicle basically follows the desired path profile specified by the driver, and when a nearby obstacle is detected in the front direction of the vehicle, it must quickly avoid it (Li *et al.*, 2016). In addition, there are several lanes on city roads and highways, and both ends of the road must never be crossed (Rasekhipour *et al.*, 2016). These points must be taken into account in creating an optimal path so that safe autonomous driving technology can be implemented on city roads and highways (Lu *et al.*, 2020).

1.1. System Configuration of Autonomous Vehicle

In order to develop a path generation algorithm, it is necessary to understand the system configuration of a typical autonomous vehicle. To obtain vehicle state information, longitudinal and lateral acceleration sensors, yaw rate sensor (gyroscope), wheel speed sensors, steering angle sensor, and global positioning system (GPS) are utilized. Also, lidar and vision sensors that recognize information on surrounding obstacles (type, distance, size, speed) and information on surrounding environments are