

# PATH PLANNING FOR VEHICLE ACTIVE COLLISION AVOIDANCE BASED ON VIRTUAL FLOW FIELD

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**ABSTRACT**—According to the inherent nature of the fluid that can naturally avoid obstacles, a path planning method for active collision avoidance of autonomous vehicles is presented based on the virtual flow field. Firstly, the mathematical model of the virtual flow field on the road is established by using the theory of hydrodynamics. Then a fifth degree polynomial curve is adopted to construct the virtual hazard area of the obstacle vehicle to prevent the fluid into this area, and it can be easily resized by adjusting the parameters of the lateral and longitudinal safety distance. Finally, Computational Fluid Dynamics (CFD) simulations are performed to quantitative predict the dynamic behavior of the ego vehicle on the straight or curved road and the desired path for active collision avoidance can be determined based on the calculation result of the flow field. The simulation results show that the proposed path planning method takes into account the dynamic characteristics and kinematic constraints of the vehicle, and ensures that the vehicle doesn't collide with the dynamic and static obstacles on the road.

**KEY WORDS** : Virtual flow field, Collision avoidance, Computational fluid dynamics, Path planning, Autonomous vehicle

## NOMENCLATURE

$V$	: velocity vector of the fluid, m/s
$\rho$	: density, kg/m <sup>3</sup>
$F_b$	: body force acting on the fluid element, N
$F_s$	: surface force acting on the fluid element, N
$f_x$	: the component of body force in the $x$ -direction, N
$f_y$	: the component of body force in the $y$ -direction, N
$\sigma_{xx}$	: normal stress, N/m <sup>2</sup>
$\tau_{yx}$	: shear stress, N/m <sup>2</sup>
$a$	: acceleration, m/s <sup>2</sup>
$\mu$	: dynamic viscosity, kg/(m·s)
$d$	: safety distance in the lateral direction, m
$s$	: safety distance in the longitudinal direction, m
$R$	: turning radius of the vehicle, m
$C_f$	: cornering stiffness of the front tire, N/rad
$C_r$	: cornering stiffness of the rear tire, N/rad
$l_f$	: distance from the CG to the front axle, m
$l_r$	: distance from the CG to the rear axle, m
$\omega_r$	: yaw rate of the vehicle, rad/s
$I_z$	: yaw moment of inertia, kg·m <sup>2</sup>
$\delta_f$	: steering angle of front wheel, rad

## 1. INTRODUCTION

The active collision avoidance system of autonomous vehicles can effectively prevent the occurrence of traffic accidents and significantly improve the safety of the vehicle (Rasekhipour *et al.*, 2017). Therefore, related intelligent technologies have been extensively studied in recent years, which can be summarized into the following four subsystems: perception (Asvadi *et al.*, 2018; Andrade *et al.*, 2019; Caltagirone *et al.*, 2019), decision-making (Gindele *et al.*, 2015; Li *et al.*, 2018), path planning (Dolgov *et al.*, 2010; Chu *et al.*, 2015; Hu *et al.*, 2018), and path tracking (Park *et al.*, 2015; Xia *et al.*, 2016; Brown *et al.*, 2017). Path planning is one of the basic operations required to realize collision avoidance for autonomous driving vehicles. With information about obstacles location given by onboard sensors and road geometry information provided by highly automated driving map, a path planner generates a dynamic path for the vehicle to avoid collision with other vehicles or obstacles (Paden *et al.*, 2016). Path planning has been widely studied by scholars for decades, and many methods have been developed for autonomous vehicles. Graph search based algorithms, such as Dijkstra (1959) and A\* algorithm (Hart *et al.*, 1968), are used to find the shortest path in the state space. The autonomous vehicle “junior” from Stanford University used a modified version of the A\* (hybrid A\*) to plan a kinematically feasible trajectory in a discrete four-dimensional

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