

Obstacle Avoidance Strategy and Implementation for Unmanned Ground Vehicle Using LIDAR

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ABSTRACT

Regarding safety, obstacle avoidance has been considered as one of the most important features among ADAS systems for ground vehicles. However, the implementation of obstacle avoidance functions to commercial vehicles are still under progress. In this paper, we demonstrate a complete process of obstacle avoidance strategy for unmanned ground vehicle and implement the strategy on the self-developed Arduino based RC Car. In this process, the sensor LIDAR was used to detect the obstacles on the fore-path. Based on the measured LIDAR data, an optimized path is automatically generated with accommodation of current car position, obstacle locations, car operation capability and global environmental restrictions. The path planning is updated in real time while new or changing obstacles being detected. This algorithm is validated by the simulation results with the RC car. The comparison will be discussed at the end of this paper. The successful implementation of the proposed strategy demonstrates the feasibility of this obstacle avoidance methodology, which can be applied to commercial autonomous vehicle.

KEYWORDS: ADAS, LIDAR, Path Planing, Optimization, Bicycle Model, RC Car

CITATION: Wang, Y., Goila, A., Shetty, R., Heydari, M. et al., "Obstacle Avoidance Strategy and Implementation for Unmanned Ground Vehicle Using LIDAR," *SAE Int. J. Commer. Veh.* 10(1):2017, doi:10.4271/2017-01-0118.

I INTRODUCTION

Obstacle/Collision Avoidance has been one of the most important features in Advanced Driver Assistant Systems (ADAS) for ground vehicles. The basic collision avoidance will significantly improve vehicle and drivers safety. Many commercial vehicles have actually been equipped with the feature, called 'collision warning with auto brake'. The conventional sensors – like ultrasonic sensor and Radar, sometimes laser and camera – have been used in commercial vehicle for obstacle detection. If sensors detect a potential imminent crash, the collision avoidance system would either warn driver or take actions to brake automatically, or even steer away. Due to numerous unexpected possibilities on the road, current applications of the collision avoidance feature could be helpful in some cases but could also be unhelpful or even harmful in other cases [1]. Apparently, the market demand of obstacle avoidance system is huge [2], the desire to improve the technology is urgent. In addition, the obstacle avoidance is widely accepted as one significant trend in developing ground autonomous vehicle [3]. The feature of obstacle avoidance which enables vehicle driving safely without hitting other vehicles, is the one of the basic requirements for autonomous vehicles.

In this research, we tried to develop one complete process of obstacle avoidance feature for ground vehicles by using Robot Car (RC). This process started with data collection, and then data processing, path planning and finished with precise vehicle control. In obstacle detection, the sensor LIDAR, short for Light Detection And Ranging, was employed to detect the obstacles on the fore-path because

LIDAR has high accuracy within large detecting range [4, 5]. With data collected and processed, the path planning is one of the most critical steps for obstacle avoidance success.

Path planning research has been investigated for many years. Different approaches have been proposed to generate the path in the past, such as, curving fitting method [9], potential-field method [12], A*/D* search method [7], method of choose from pre-defined paths [6], random tree search [10, 11], and Multiple Point Constraint (MPC) optimization [8]. Each method has its own pros and cons in terms of algorithm capability, computational load, smoothness of generated path, etc.

Curve fitting [9] is based on picking feasible points on the fore-path and drawing a polynomial function, to fit the chosen feasible points. It is straightforward but hard to handle complicated situations. Potential field method [12] is applied to make vehicles following the steepest gradient of an artificial potential field, however, the path could be trapped in local minima in the field. A*/D* [7] search algorithm has been very popular in path planning because it can tackle very complicated situations and efficiently calculate an optimal route if there is one, but the path generated by A* search is grid-size dependent that may not be smooth. It would be a challenge to control the vehicle to follow the non-smooth path precisely, especially when the vehicle moves at high speed. The method of choosing from pre-defined paths [6] could be very efficient, since the feasible solutions are calculated and ready before vehicles confront obstacles.

The vehicle is picking one path from the group of predefined paths that can avoid obstacles. This method can cover certain pre-defined scenarios. Random tree search [10, 11] is recommended for more complicated cases, but it requires efficient guiding heuristics to reduce the computational time.

Using optimization algorithm under Multiple Point Constraint (MPC) [8] is another comprehensive method for path planning. This approach considers equality constraints, inequality constraints, upper and lower bounds, nonlinear constraints, and vehicle capability in one formula, to customize the distance or the velocity for optimized path. The variables to be calculated are the discrete points on the fore-path. The steering angle smoothness can be controlled by applying nonlinear constraints on consecutive path points. The number of variables and constraints, so as the computing time, are depending on the obstacles layout. In this paper, we will use a method similar to MPC optimization, and make a comparison between this method and other methods, like Curve fitting and A* search.

In Section II, we will discuss an overall approach and demonstrate the overall obstacle avoidance process. In Section III, the details of implementing the process will be explained, including data collection, data process, and path planning and vehicle control. The simulation results with detailed discussions will be discussed in Section IV. The conclusions and future work are discussed in Section V.

II APPROACH

The purpose of this research is to explore the process of obstacle avoidance for ground vehicle. There are three major sections in this process: i) Data collection, ii) Path planning and iii) Vehicle control, as shown in Figure 1. Data collection is to prepare data for path planning and also monitor the real distance between the vehicle and the obstacles for the safety check. During the process, vehicle is expected to travel to designated point automatically without hitting any obstacles on its way.

In the process, sensor LIDAR is used as RC car's eye to detect obstacles around. Other sensors, like cameras, ultrasonic sensor are available but only used as optional alternatives for the car. The data collected by LIDAR, has to be processed instantly. The data processing includes filtering noise and environmental data, clustering out data for each obstacle, locating obstacles and self-locating. After data processing, the distance and angle data for obstacles will be obtained and analyzed.

The next step is to generate a obstacle avoidance path for RC car. As aforementioned, there are many ways to generate a path from LIDAR data. In this paper, three methods, curve fitting, A* search and discrete optimization all will be used in different obstacle layouts according to their own advantages. The computing time of curve fitting is almost negligible, but the path solution is not guaranteed. The curve fitting method is only applied in simple cases, like one or two obstacles. A* search algorithm is relatively fast on computation time, if grid size is not too small. This could be an alternative solution if discrete optimization method can not generate a path immediately. The path from discrete optimization is feasible and smooth for

vehicle control, which is the primary path planning algorithm used in this work. However, the optimization algorithm is sometimes not fast and could take up to 100 ms for certain obstacle layouts.

The last step is to control the RC car, to precisely follow the obstacle avoidance path. For simplicity, a bicycle model is employed and Stanley method [13] is used. Note that the steering angle limit for the vehicle is speed dependent. The higher the vehicle speed is, the less steering capability is. Vehicle control shall also be affected by noise and delay caused by data processing. The general procedure for all steps is given in Figure 1. The technical details for each part will be discussed in the next section.

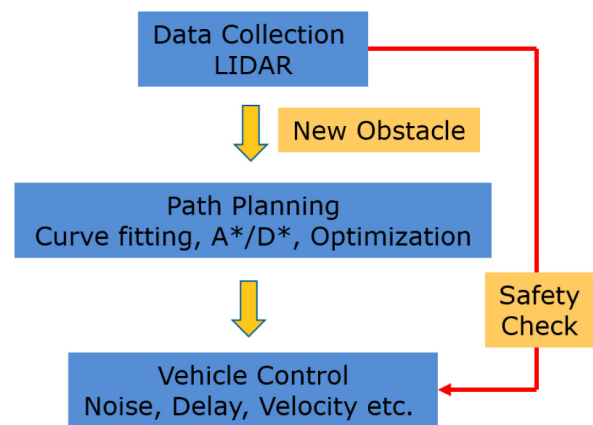


Figure 1. Obstacle Avoidance Process

RC Car and LIDAR

The research is using RC car as a platform to implement the obstacle avoidance procedure. RC car used in this work is built of a car frame, Raspberry PI III, Arduino Due, RPLIDAR and other electronic hardware. The four wheeled car can be seen in Figure 2. The data collection is achieved by sensor LIDAR. Robo-Peak RPLIDAR 360° is a single beam 2D laser scanner (LIDAR) with a maximum range of 6 meters. The produced 2D point data is used for mapping, localization and object modeling. This LIDAR was mounted on top of the car and is primarily used to detect distant obstacles and implement the collision avoidance applications. Data Processing and Path planning is finished in single-board computer Raspberry PI III. Vehicle is controlled by the microcontroller Arduino.



Figure 2. Data Collection Experiment Setup

