Driving Pathfinding of Unmanned Autonomous Ground Vehicle Using Measurement Data Diffusion

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***Abstract*—The state of road changes quite often due to the automobiles and pedestrians when the main driving unit controls the unmanned autonomous vehicle along the planned path. The vehicle acknowledges of whether there are obstacles on the driving path using a sensor array and creates the new driving path and adaptively updates route to control the vehicle. This research proposes a novel way to find the possible driving path by diffusing the measurement data collected by the sensor array which contains the unscaled info of the detected obstacles. With the possible driving field, we can recognize whether the current path would be affected by the obstacles, and also possibly create a new driving path to avoid them. Using the driving map created by this way, we made a new driving path applying A^* algorithm and tested on a unmanned autonomous vehicle (i.e., converted KIA Soul). As a result, after creating the new driving path, we were able to carry out the avoidance driving safely at low speed, also the vehicle drives swiftly and smoothly when we modified the avoidance path within the possible driving field.**

***Index Terms*—Measurement data diffusion, Sensing & actuation, Mechatroincs, Driving path, Driving map, Path planning, Collision avoidance, Autonomous driving.**

I. Introduction

When moving, an autonomous vehicle determines its waypoints by detecting environment in its proximity and calculating its location. However, driving condition in general may be ever changing due to the other moving objects such as pedestrians and vehicles on the road under tracking. Therefore, it is highly necessary to detect and avoid such unpredictable moving objects for safe autonomous driving.

There have been numerous research activities to propose better tracking algorithms and collision avoidance methods. The most widely adopted tracking techniques include: 1) a method to pursue predetermined lookahead points [1], 2) a method to pursue an equidistance lookahead point [2, 4], and 3) a method to pursue a moving vector [3].

The main objective of the proposed work is to report a novel path planning/tracking technique with collision avoidance, which is designed for a prototype unmanned autonomous ground vehicle developed by center for automobile mechatronics parts at Keimyung University, Daegu, Korea.

This paper is organized as follows. The following chapter explains how the proposed technique is to use pure pursuit method proposed in [2, 4] to partition the entire track information to set up a number of waypoints so the proposed autonomous vehicle can use them as lookahead points while driving. In Section III, a novel method to scale up the measurement data generated by a laser sensor array to build a obstacle map for efficient collision avoidance will be discussed. Then, experimental results collected from the proposed autonomous vehicle will be presented and discussed in Chapter IV.

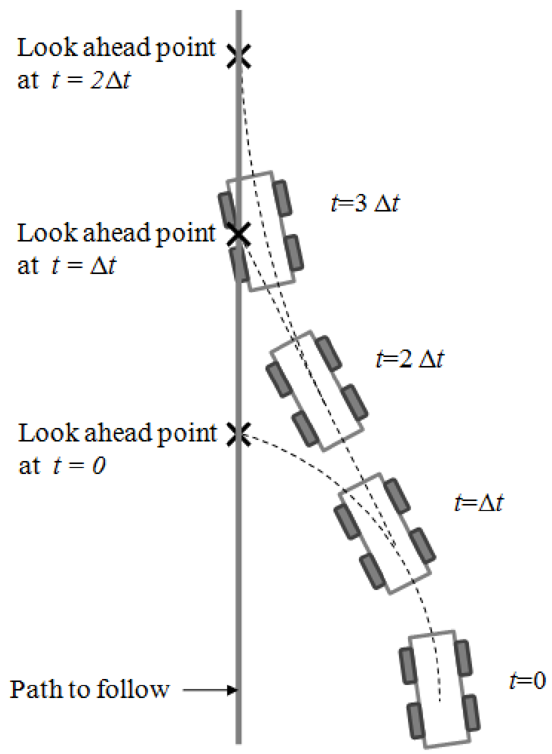

Fig. 1. Sequential vehicle position tracking using pure pursuit method.

II. Path following method

Path data is assume to be given for the proposed autonomous ground vehicle. In order to follow the given path, the pure pursuit method proposed in [2] is used. In this method, lookahead points on the path to follow are used to determine the movement of the vehicle under control as shown in Fig. 1.

If coordinates of the current lookahead point are (x, y), then

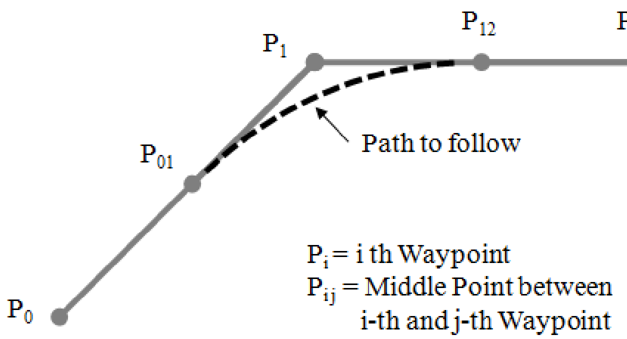

Fig. 2. Path segmentation with curved waypoint.

steering radius R can be calculated with respect to distance L between the vehicle and the lookahead point as follows:

$$R = \frac{L^2}{2x} \tag{1}$$

The given path gets partitioned into equal segments to generate lookahead points. A curved path can be also partitioned into smooth sections using the following equation:

$$P(u) = \frac{(1-u)^2 P_{01} + 2u(1-u)P_1 + u^2 P_{12}}{(1-u)^2 + 2u(1-u) + u^2} \tag{2}$$

where $0 \geq u \geq 1$ is an adjustment parameter for the current lookahead point, P_i is the i_{th} waypoint, and P_{ij} is the middle point of the i_{th} and j_{th} waypoints as shown in Fig. 2.

With respect to the current lookahead point, steering angle of the vehicle, δ, can be calculated by Ackerman's steering angle equation using the steering radius, R, and vehicle's wheel base distance, B, as follows:

$$\delta = \frac{B}{R} \tag{3}$$

III. Obstacle Avoidance

The proposed autonomous ground vehicle uses an array of laser scanners to detect and avoid obstacles while driving on the path obtained by the path following method described in the previous chapter. However, the raw measurement data from the sensor array should be post-processed to be useful since detected obstacles are merely expressed as dots in the raw measurement data map, and also boundary lines of the road may not be even visible in many occasions, as shown in Fig. 4-(a). Thus, the raw measurement data map is scaled up to to the size of the proposed autonomous vehicle and road boundaries are drawn to generate the final obstacle map as shown in Fig. 4-(b). This proposed measurement data map scaling technique is referred to as the measurement data diffusion. Then, the current driving path can be displayed on the obstacle map to determine the possibility of collision as shown in Fig. 4-(c). If there is an obstacle on the current driving path, an alternative collision avoidance path can be generated as shown in Fig. 4-(d).

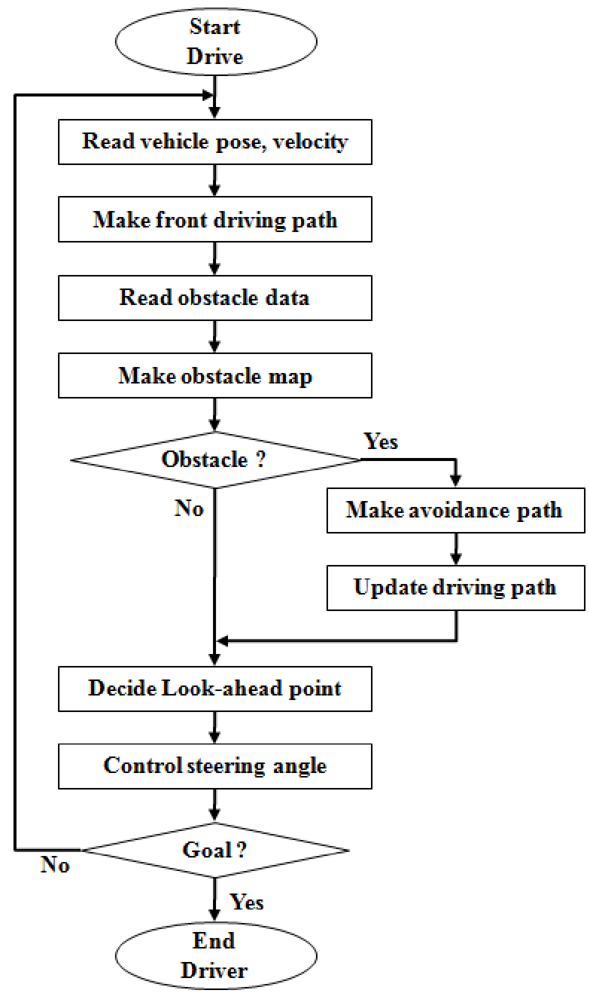

Fig. 3. Flow chart for path tracking and obstacle avoidance.

After detecting an obstacle on the diffused measurement data map, it is possible to use a collision avoidance pathfinding algorithm such as A^* algorithm to get a collision avoidance path. It is also important to merge the existing path and the new collision avoidance path properly to ensure a smooth driving for maximum possible speed. The entire pathfinding and driving procedure is formally described in the flow chart shown in Fig. 3. First, current vehicle driving data such as location, direction and speed gets collected from various onboard sensors including GPS, compass and accelerometer. Second, a multi-segment driving path is generated. Third, a laser scanner sensor array is used to collect obstacle data to make an obstacle map. Then the obstacle map is used to detect an obstacle on the current driving path. If there is an obstacle on the way, a collision avoidance pathfinding algorithm is used to generate an modified path. A new lookahead point can be made on the collision avoidance path and Ackerman's steering angle equation is used to control the vehicle's movement. The proposed procedure is iterated until the proposed vehicle arrives at the goal.

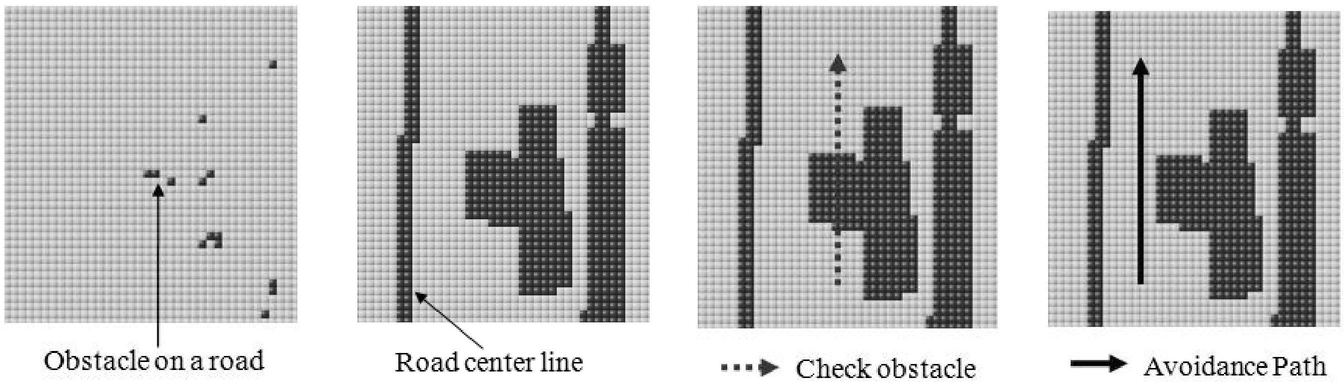

Fig. 4. Obstacle avoidance using diffused measurement data map: 1) Collect raw measurement data from the laser scanner array, 2) Create a scaled data map with a road center line added, 3) Check obstacles on the planned path, and 4) Find a new path for collision avoidance.

Fig. 5. Experimental unmanned autonomous vehicle prototype developed by center for automotive mechatroincs parts at Keimyung University in Korea.

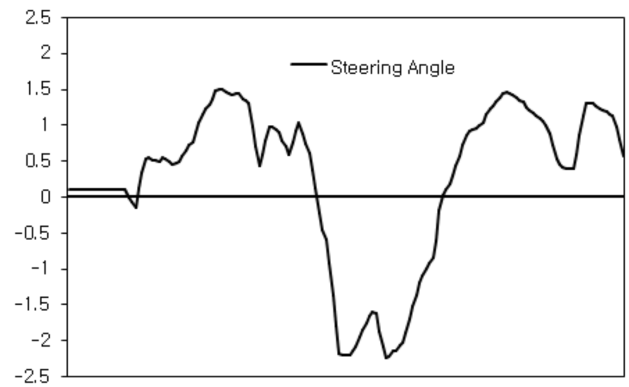

Fig. 6. Steering angle changes during obstacle avoidance.

IV. Experimental results

The proposed unmanned autonomous ground vehicle shown in Fig. 5 is being developed at Keimyung University, Daegu, Korea. The base vehicle is KIA Soul donated by KIA moters and is equipped with various measurement sensors including GPS, compass, accelerometer and laser detectors.

The proposed unmanned autonomous ground vehicle was tested on a straight track with obstacles to assure the proposed collision avoidance technique based on measurement data diffusion. Parameters and values used in the experimental test are summarized in Table I.

TABLE I
Parameters for path tracking and obstacle avoidance.

Path following velocity	30kmh
Lookahead distance	6, 9 and 15m
Obstacle sensing range	40m
Obstacle map size	80×80
Obstacle map pixel scale	0.5m
Obstacle scan cycle time	0.03sec
Wheel base distance (B)	2.55m

Three different distances (i.e., 6, 9 and 15 meters) were used to compensate the velocity of the vehicle and severity of steering angle for the selected collision avoidance path. The obstacle map is a Boolean 2-dimensional 80×80 and pixels are scaled in the unit of 0.5m.

During the experimental test drive, the proposed autonomous vehicle avoided various obstacles on the straight paved track successfully. During the experimental test drive, both steering angle and vehicle velocity were measured as shown in Fig. 6 and 7, respectively.

V. Concluding remark

In this work, we have proposed a new path following method with collision avoidance for unmanned autonomous ground vehicle. The proposed path following method is base on the pure pursuit algorithm that tracks an equidistant lookahead point on the path to follow. Also, a raw measurement data map generated by an array of laser detectors gets post-processed to generate a scaled obstacle map using the proposed data diffusion technique. Then, the scaled obstacle map is used to determine the possibility of collision on the current path. If collision is anticipated, a collision avoidance path is made by a pathfinding algorithm such as A^* algorithm.

The proposed technique was tested on a prototype un-

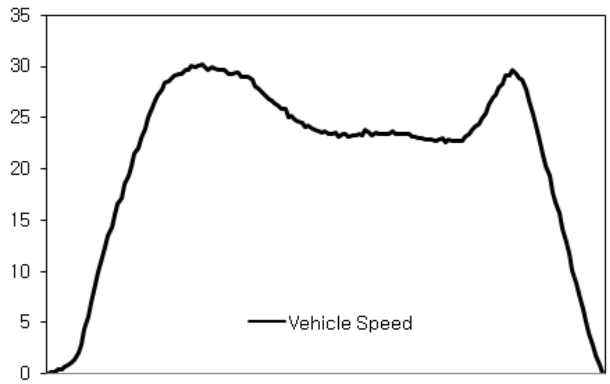

Fig. 7. Vehicle speed changes during obstacle avoidance (in km/h scale).

manned autonomous ground vehicle developed by Keimyung University. A straight track with various obstacles was used for the experimental test drive. During the test drive, the proposed autonomous vehicle successfully avoided all obstacles on the way, but the vehicle speed was temporally reduced during numerous collision avoidance maneuvers. Our future research is to increase the range and accuracy of obstacle detection to provide high-speed collision avoidance.

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