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Obstacle Avoidance of Mobile Robot using Fuzzy Logic and Hybrid Obstacle Avoidance Algorithm

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Abstract. The road accidents due to traffic problems and human erroneous driving are the major challenges for researches. The self-driving car or mobile robot is the solution to avoid such mishaps. In this paper, an attempted has been made to develop obstacle avoidance algorithms for bicycle vehicle model of mobile robots. The hybrid obstacle avoidance algorithm is proposed on the merits of line, wall following and tangent bug algorithm. The trajectory generated from the hybrid obstacle avoidance algorithm is fed into the overwhelming controller of the bicycle vehicle model of mobile robot for avoiding obstacles. Then, the fuzzy logic (FL) based obstacle avoidance controller is proposed. Twenty-three set of rules are proposed for fuzzy logic approach. Both the obstacle avoidance algorithms are implemented on the bicycle vehicle model of the mobile robot. The dynamic model of the mobile robot is developed using bond graph theory and is converted into Simulink block using S-function directly from the library of SYMBOLS Shakti software. The vehicle model is equipped with three ultrasonic sensors to measure the distance from the obstacles. Three input membership functions and one output membership function are considered in fuzzy logic controller. During avoiding two static obstacles and reaching the target, the comparison of obstacle free paths traced by both obstacle avoidance algorithms is done in this paper.

Keywords: - Hybrid obstacle avoidance, fuzzy logic controller, mobile robot, bond graph.

1. Introduction

The majority of the accidents occur on the road because of human harsh driving. The solution to solve this dilemma is the development of the self-driving vehicle. A self-driving vehicle is able to sense its environment and navigate to the target without human assistance. It has capability to reduce mishaps due to driver’s fault [1]. A controller is developed for analyzing the dynamics of vehicle [2, 3]. The Automated guided vehicle (AGV) is also helpful in various tasks. The combination of fuzzy and Vector field histogram (VFH) is also suitable to bypass the obstacles [4]. Jun et al. used used Light detection and ranging (LIDAR) sensors for obstacle avoidance of mobile robot [5]. The use of geometry modelling for object avoidance approach is mentioned in [6]. The fuzzy controller may be used for local and global navigation and steering control of the robot [7]. Xiong et al. used two FL controllers to control the intelligent vehicle [8]. The modified artificial potential field method to generate trajectory for wheeled mobile robot is presented in [9]. To find shortest path with obstacle avoidance for wheeled mobile robot based on fuzzy, ant colony optimization technique are proposed in...
[10]. The wheel mobile robot using arduino board with ultrasonic sensor and compass is developed for avoiding static obstacles [11]. Predicting the movement trends of the obstacle using movement laws of the dynamic obstacle is proposed for mobile robot to plan the obstacle free path [12].

The bond graph (BG) is a useful technique to model complicated systems. BG approach is extensively applicable in vehicle dynamics [13]. BG is used to study the bicycle vehicle model for obstacle avoidance using overwhelming controller [14]. In this work, the hybrid Obstacle avoidance algorithm (OAA) is proposed using line, wall following and tangent bug algorithm. Then, FL based OA controller is proposed. A set of 23 rules are created on the basis of three inputs and one output membership functions. After that, the BG model of Bicycle vehicle model (BVM) is build using SYMBOLS Shakti software. The development of the hybrid obstacle avoidance algorithm by using the merits of line following, wall following and tangent bug algorithm is a new work. This algorithm is used to follow the shortest possible path based on the geometry of obstacle by following its circumferential boundary. Also, the fuzzy logic based OAA is useful in identifying not only the position of the robot but also, it is capable to determine the orientation of the robot w.r.t. the target. This is the novelty of the work. The work is organized in the following sections: First, the hybrid obstacle avoidance and fuzzy based algorithms are proposed. Then, BG model of BVM is developed and converted into Simulink block. After this, both the obstacle avoidance algorithms are implemented on the BVM and result regarding obstacle free path is compared. Finally, the conclusions are drawn.

2. **Obstacle avoidance algorithm (OAA)**

2.1 **Hybrid obstacle avoidance algorithm**

A hybrid OAA is proposed to avoid the static objects by a biped robot. The hybrid obstacle avoidance algorithm comprises of utilizing the advantages of line following algorithm, wall following algorithm and tangent bug algorithm for avoiding static obstacles while reaching the target by the biped robot. In this algorithm, assumptions of the pre-defined location and geometry of obstacle along with the nature of target and obstacle being static are considered. The flow diagram of hybrid OAA is depicted in Fig. 1(a). Initially, the robot follows the predefined path using line following algorithm. If any object is sensed by ultrasonic sensor and if the distance between the robot and the object is less than the specified distance, tangent bug algorithm comes into the picture. Using image-processing technique, the current pose and orientation of the robot is calculated from the data sensed by the overhead camera. These data are fed to the control unit which calculates the minimum distance of the robot to reach the target by avoiding the obstacle. Then, the robot follows the wall following algorithm maintaining safe distance from the obstacle. After the obstacle is avoided, the robot again follows the predefined path to reach the target. The detail flow chart of OAA is show in Fig. 1(b).

2.2 **Fuzzy logic obstacle avoidance algorithm**

The fuzzy logic approach for obstacle avoidance is proposed. The inputs to the controller are the distances from the target and the obstacle, heading angle. The controller output is the steering angle of the vehicle. The block diagram of fuzzy based obstacle avoidance controller is depicted in Fig. 2. A set of 23 rules are proposed to avoid the static and dynamic obstacles by the four-wheel mobile robot. Three ultrasonic sensors are mounted on the head of the robot to capture the data i.e. distance from the obstacles. Figure 3 shows the fuzzy controller input and output membership functions.

3. **Bond graph model of bicycle vehicle model**

Bicycle vehicle model is half model of the full vehicle model and helps in studying the vehicle behavior. The heave, roll and pitch motions and suspension dynamics are not considered during modelling. Line diagram of the BVM is illustrated in Fig. 4(a) and (b) show its word BG. The steering angle \( \delta \) is decided the turning of the front wheel. The power is given to rear wheel. Normal and tangential velocities for front and rear wheels and Newton-Euler equations are required to complete bond graph model of bicycle vehicle and this model is illustrated in Fig. 4(c). The BG model is converted into the Simulink block which is further used in the MATLAB software for implementation of the OAA.
Figure 1 (a) Flow diagram and (b) Flow chart of obstacle avoidance algorithm [10]

Figure 2 Block diagram for navigation and obstacle avoidance of bicycle vehicle model

Figure 3. The fuzzy membership functions (a-c) Input and (d) Output

4. Simulation results

The performance of the hybrid OOA and fuzzy logic OAA using bicycle vehicle model is proposed. Table 1 shows the case considered under simulation work. In this scenario the two circular static objects are considered in the path of the bicycle vehicle model from start to target point. The location of the object is depending upon the position of the object centroid w.r.t. to center line. Table 2 shows the simulation parameters.
Table 1. Case for simulation

| Cases | No. of object | Position of object centroid | Geometry |
|-------|---------------|----------------------------|----------|
| Case-1| Two           | Left of center line        | Circular shape |
|       |               | Right of center line       |           |

Table 2. Simulation parameters

| Parameters | Description     | Value   |
|------------|-----------------|---------|
| $w$        | Wheel radius    | 0.254 m |
| $m_v$      | Mass            | 924 kg  |
| $a$        | CG to front wheel distance | 1.31 m |
| $b$        | CG to rear wheel distance | 0.62 m |
| $k_p$      | Spring stiffness | $10^8$ N/m |
| $r_p$      | Damping stiffness | $10^8$ Ns/m |

The comparison of hybrid obstacle avoidance and fuzzy logic obstacle avoidance controller for avoiding two static obstacles is shown in Fig. 5. As depicted from the Fig. 5 the fuzzy logic controller generates the object free path, which is close to the obstacles as compared to the hybrid obstacle avoidance algorithm. Hybrid OAA maintains safe distance from the obstacles. So, Fuzzy logic obstacle avoidance algorithm may be used when safe distance is not important but time to complete the path is more significant.

5. Conclusions

The obstacle avoidance algorithms were developed and implemented on bicycle vehicle model. By using line, wall following and tangent bug the hybrid obstacle avoidance algorithm was developed. Also the fuzzy logic obstacle avoidance algorithm was proposed. Three inputs and one output membership functions are developed for the fuzzy controller. The bond graph approach is used to develop the bicycle vehicle model. This model is then converted into the Simulink block. The practicality of both algorithms has been compared for two static obstacles in bicycle vehicle model. The fuzzy logic obstacle avoidance algorithm generates the object free path, which is close to the obstacles as compared to the hybrid obstacle avoidance algorithm.

![Figure 4](image_url)

Figure 4. (a) Graphical representation, (b) Its word bond graph and (c) BG model
Figure 5. Comparison of obstacle free path using hybrid and fuzzy logic obstacle avoidance algorithm

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