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Authoritative Intelligent Perfect Parallel Parking Based on Fuzzy Logic Controller for Car-Type Mobile Robot

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Abstract

This paper tries to design and implement an intelligent system for parallel parking at highest quality, full intelligence and ideal speed. To park in a parallel way, one should identify space appropriate for parking making use of Ultrasonic Sensor and 3D Vision Sensor, and upon confirmation by driver parking operation is completed by intelligence being conducted Fuzzy Logic. Ultrasonic Sensor is capable of identifying objects and obstacles in the longitudinal course. As a car forms an angle with street side and parked cars when parking at an appropriate place, we have accompanied it with a 3D-camera and solved this problem very easily. In order to find an appropriate parking place, a two-stage scenario is used, which is called longitudinal and lateral (diagonal) movements.

Key Words: Fuzzy Logic, Intelligent Parallel Parking, Linguistic Variables, Car-type mobile robot (CTMR).

1. Introduction

In the advance societies of today, where advance in production and industry arena have the last word, machine vision has played a considerable role in the ever-increasing trend of growth in societies. And as we are very well aware, Parallel Parking is considered one of the problems of most drivers in metropolises and a cause of traffic creation. Finding an appropriate space to park and/or inability of driver to, properly and at appropriate speed, park in a parallel way may magnify the problem.

The main objective of this paper is to design a control system for a driver, which prevent any damages to our car and the cars parked nearby. In order to achieve this objective, we will make use of 3D-Visions Technology, which help us:

- to find and focus on object and obstacles in the way of driver
- to develop an environment easy and understandable for driver with 3-D visions

In recent years, the issue of auto intelligent park has been considerably draw attention. This system can appropriately and ideally park the car for low-experienced drivers, because the system works without any need for driver's interfere. The parking stages include finding a parking space and parking in that space. Basically, car parking is divided into two groups [1, 3]:

- Parallel Parking
- Garage Parking

The paper investigates parallel intelligent parking. Since the fuzzy logic was introduced by Professor Lotfizadeh in 1965 [4], this logic has played a conspicuous role in design and production in the industry arena. Fuzzy Inference System can be expressed in the form of a decision mechanism system for operating system guiding through use of adjustable fuzzy rules.

Nowadays, the most renowned papers make use of fuzzy logic in their theories. One of the advantages of this logic is that car parking behavior can be defined and used with the very linguistic variables. In addition, in the car parking system with fuzzy theory, the experiences of a driver can be used for designing and/or adding. If commands are appropriately taught to fuzzy logic, then, complexities of calculation will be minimized and hardware packages will easily support it.

Many of the related studies deal with the car-like vehicle backing problems are shown in the style of computer simulations. Several researches use the active distance sensor (e.g. infrared and ultrasonic sensors) to detect the specific parking space, and then backing the car into the correct area with its specified designed methods[5,6]. In [7], the authors used the ultrasonic sensors and a servo CCD camera on the nonholonomic mobile robot. For some parking control solution, Ref [8] utilizes the CCD camera to get the global vision of the parking lot. In [9], the authors adopted six infrared sensors to measure the relative distance between the CTMR and the surroundings. References [10] and [11] discussed

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about the lane recognition and provided image processing by using their proposed methods. With increasing hardware design technology very quickly, several researches not only focused on the control methods validation but also complete the vehicle implementation in a real environment [12, 13].

In this paper tries to design and implement an intelligent system for parallel parking at highest quality, full intelligence and ideal speed. For achieving this purpose, the car must be equipped with ultrasonic sensors and camera for finding a suitable place. Gathering information about unknown environments is really important in this project. So in order to find an appropriate parking place, a two-stage scenario is used, which is called longitudinal and lateral (diagonal) movements. After that, use a great algorithm to park the car on that place automatically, based on fuzzy logic rules. In this section, for solving the problem of car parking, several input and output variables should be first defined, each of which has parameters with special roles.

2 Car's Parking Kinematics

Parking kinematics of cars can be modeled according to Fig. 1. Generalized coordinates of this model are x, y, θ and $\emptyset$. Position of reference point O is shown by x and y. The car orientation is represented by the angle θ.

Steering angle of the front wheels is shown by $\emptyset$ which is a control parameter. The other control parameter is the rotation angle of the rear wheel that is proportional to the track of the rear wheel center and is shown by β.

$$\rho\,\beta = \int \sqrt{\left(\frac{dx}{d\theta} - \mathrm{r}\sin\theta\right)^2 + \left(\frac{dy}{d\theta} + \mathrm{r}\cos\theta\right)^2}\; d\theta$$

In the above equation ρ is the radius of the wheels.

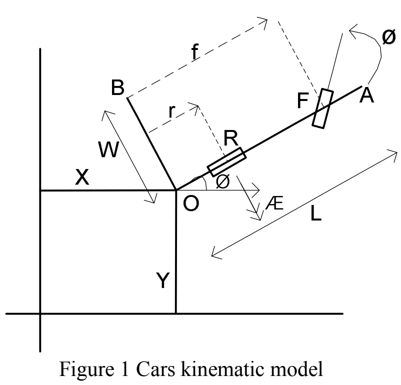

Figure 1 Cars kinematic model

It has been assumed that the absolute velocity of the points R and F are perpendicular to the wheel axes. This assumption imposes two nonholonomic constraints (Eq.) on the model.

$$\begin{bmatrix} -\sin\theta & \cos\theta & r\cos\theta \\ -\sin(\theta+\emptyset) & \cos(\theta+\emptyset) & f\cos(\theta+\emptyset) \end{bmatrix} \begin{bmatrix} dx \\ dy \\ d\theta \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

This study does not intend to make use of mathematic formula in the design, because design of the behavior of parking system can be conducted by fuzzy logic perspective in such a way as to intelligently and exactly implement driver's behavior. As we know, the fuzzy logic perspective does not include these mathematical formulas, instead, it includes a set of orders that can investigate and model the behavior of driver during parking and under special conditions.

3. Ultrasonic Sensor Module

Ultrasonic waves are the mechanical waves whose fluctuation frequency is beyond the human auditory scope, that is, KHz 20. An ultrasonic sensor often has a receiver and a sender of ultrasonic waves; and upon facing an obstacle these waves are reflected and return to the sensor, and given the return time and the quality of the reflected waves, we can obtain factors like distance to obstacle, type of obstacle and velocity of obstacle. It is noteworthy that s materials qualitatively differ in transmission and reflection of ultrasonic waves. A system for measurement and estimate of distance and longitudinal determination of space is required to sense and measure the distance of object and car parking in unknown environments. Making use of this module that transmits an ultrasonic pulse and develops output based on return of such a pulse after facing objects at specified time, the distance can be estimated. The distance to destination can be easily calculated and estimated by measuring return frequency bandwidth. The said module is shown in Fig. 2.

Figure 2 Ultrasonic sensor module

4. Car Parking Stages

The objective is to find an appropriate car parking space between the cars parked in street side. For this purpose, in the normal state, car moves forward and in the direction of the parked cars. After finding an ideal space and standing in the state of start point, it begins to move backward and laterally until it stands in its place. In this theory, the car being first seen is called Car B and the second car is called A. The parking stages are show in Fig. 3.

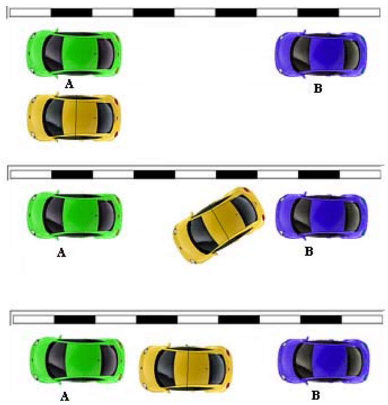

Figure 3 Car parking stages

In order to intelligencize car, it should be equipped with an Onboard PC, a camera, being installed in the back, ABS Sensor and an ultrasonic sensor on the left of front bumper.

5. Algorithm for finding car parking space

In this paper, in order to find an appropriate parking space, a scenario is defined in two stages as shown in Fig. 4 [14]. At the first stage, which is known as forward move (longitudinal move), car moves in the direction of cars parked. This is for calculation of appropriate parking space, and, for this purpose, ultrasonic sensor is used. Making use of such a sensor and receiving its frequencies by a receiver, obstacle in the way of car and distances can be calculated.

At the second stage, which is also known as lateral (diagonal) move, after finding appropriate parking space and standing at the start point, car begins its lateral move backward making use of vision sensor to stand in the appropriate place. As the car forms angles with objects and cars nearby, to determine and estimate distance is somewhat difficult and sometimes impossible for ultrasonic sensor. Thus, 3D-technology is used to obviate this problem. It is noteworthy that the use of ultrasonic sensor can implement this operation, yet, quantity and angles of sensor should be changed and sometime increased, because, at some angles, frequency reflection does not reach to the intended dispatching receiver and calculations face problem.

Longitudinal map is used to estimate car parked in the parallel direction and lateral map to estimate car parked in the upright direction. Then, ideal park space is obtained as per the theory defined between A and B cars. To calculate car park theory, the data obtained from ultrasonic sensor and 3D vision sensor is combined to determine the selected space.

Ultrasonic sensor is also used to prepare longitudinal map of car parked. When the car is moving, ultrasonic sensor obtains the spaces of cars parked. Longitudinal map of parked cars is used to obtain information and data of the distance travelled by our car and determine such a distance. In fact, ultrasonic information is correct and accurate as long as its return is perpendicular to the direction of ultrasonic sensor. 3D-sensor is used to reconstruct 3D points in car parking tests. A mass of 3D points reconstructed for the estimate of surface space constitutes lateral map.

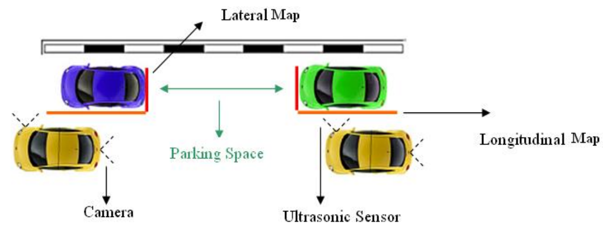

Figure 4 Detecting targets (in parallel parking)

6. Automatic parking based on Fuzzy Logic

After definition of park space by the scenario as mentioned earlier, there is a need for implementation of an intelligent system without user's interference to park car in park space. The paper makes use of a controller that is defined by fuzzy logic, linguistic variables and a set of if-then commands. The four stages of fuzzy logic being used here are as below:

- Fuzzification
- Inference
- Combination and Construction
- Defuzzification

Fuzzification**:** At this stage, realities are defined according to fuzzy logic. Input and output of the system are first introduced, and then appropriate if-then rules are used. The raw data should be used to form membership functions. The system is now ready for exerting fuzzy logic.

Inference**:** When inputs reach to the system, inference evaluates all if-then rules and determines their authenticity degree. If a given input has not been correctly specified by an if-then rule, the partial accordance is used to determine an answer. There are a great many ways to find partial response, which are beyond the scope of this study.

Construction**:** In this section, all figures obtained from the inference section (stage) are combined together. Different fuzzy rules have different results. It is therefore necessary to consider all rules. There are numerous methods for doing so, the explanation of all of which may not be considered in this study.

Defuzzification: At this stage, the fuzzy value obtained from the construction stage is changed into some usable data. This part of work is often complex, because fuzzy set should not directly changed into usable data. This stage is considered very important thanks to requirement for discrete signals by the controllers of physical systems.

6.1. Linguistic Variables

Linguistic variables are those whose acceptable values are in the form of numbers, words and sentences of human or machine languages. As numerical variables are used in mathematic calculations, linguistic variables (commentary or non-numerical) are used in fuzzy logic. Linguistic variables are expressed according to linguistic values (commentary values) that are expressed in the set of terms (words/expressions): Linguistic terms are attributes for linguistic variables. What will be done in this paper by fuzzy logic is to define and implement linguistic variables for car parking and its intelligencization, which will be discussed as follows. In order to solve the problem of car parking, several input and output variables should be first defined, each of which has parameters with special roles in the problem considering the system input and output. Input linguistic variables include "frontCar", "rear Car" and "Kerb" and "ϴ". Each of these variables has parameters for "rearCar", "frontCar", parameter "closing" and for "kerb", parameters "close" and "far" and "middle" and for "ϴ", which is the angle between car and kerb, parameters "zero" and "positive" and "negative". Output linguistic variables will be used as below: "direction" and "steering". For "direction" parameters "forward" and "backward" and for "steering" parameters "turnright" and "turnleft" will be defined. The linguistic variables are show in Fig. 5.

7. Conclusion

In this paper, an intelligent system has been designed according to fuzzy logic controller and by use of 3D vision system and ultrasonic sensor for finding parking space. We equip our car making use of ultrasonic sensor and 3D sensor that are among preliminary and necessary equipments. We are of the opinion that ultrasonic sensor alone does not have desirable and appropriate efficiency and therefore, we have used it in combination with 3D visions and camera so as to make sure of finding appropriate parking space. Finally, we have made use of fuzzy logic that can be considered as the system brain in intelligencization.

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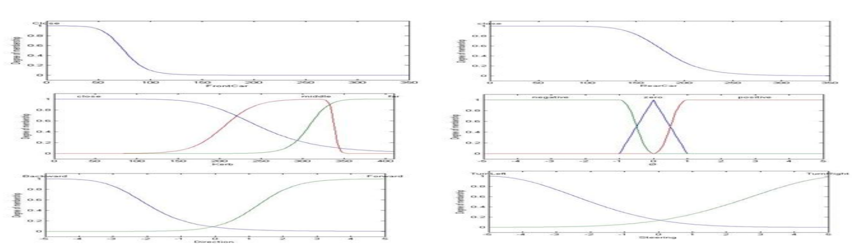

Figure 5 Membership functions for fuzzy input and output variables