Auto-Parking System via Intelligent Computation Intelligence

Y. J. Huang, C. H. Chang

***Abstract*—**In this paper, an intelligent automatic parking control method is proposed. First, the dynamical equation of the rear parking control is derived. Then a fuzzy logic control is proposed to perform the parking planning process. Further, a rear neural network is proposed for the steering control. Through the simulations and experiments, the intelligent auto-parking mode controllers have been shown to achieve the demanded goals with satisfactory control performance and to guarantee the system robustness under parametric variations and external disturbances. To improve some shortcomings and limitations in conventional parking mode control and further to reduce consumption time and prime cost.

***Keywords*—**Auto-parking system, Fuzzy control, Neural network, Robust

I. Introduction

AUTOMOBILES are widely used in the daily life. However, it is still difficult for unskilled persons to manipulate them, especially in parking process. That is because non-holonomic characteristics exist due to the kinematics constraints limiting the direction of the movement [1-3]. Therefore, research of automatic parking control has gained much attention in recent years [4-5].

The research of automatic parking control for four-wheeled vehicle acquires parking knowledge by the method of reinforcement learning. Sensor-based control architecture [6] was proposed. Fully automatic vehicles generally depend on all kinds of sensors. It is difficult for the drivers to pay attention to all the equipment.

In this paper, an intelligent parking support system for wheeled vehicles is proposed. Various auto-parking control methods are proposed to improve some shortcomings and limitations in conventional parking mode control and further to reduce consumption time and prime cost.

II. Setup of the Dynamic Model

The vehicular kinematics in the parking situation can be simplified by the fact that only small velocities are applied. Thus, rolling and tilting of the car body can be neglected, i.e. it may be modeled as a rigid body in plane motion. The non-slipping condition means that the velocity vectors at the intermediate wheels must be perpendicular to the corresponding wheel axles [7].

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Since the lateral forces remain small for low velocities, it may further be assumed that all wheels roll without slipping. Using this hypothesis the front and rear tires can formally be combined to one intermediate wheel in the middle of each axis. These assumptions help completely describe the status of the car by four generalized coordinates. Fig. 1 shows the dynamic model that is used for rear parking. Here the driving speed is assumed to be low enough, so that no sliding occurs. The motion equations can be written as

$$y_\gamma \cos\theta - x_\gamma \sin\theta = 0\,, \tag{1}$$

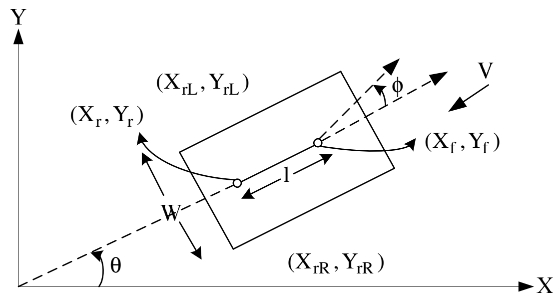

Fig. 1 The dynamic model for rear parking

where $x_\gamma = x_f - l\cos\theta$ and $y_\gamma = y_f - l\sin\theta$. Differentiating the equation (1) yields $x_f \sin\theta - y_f \cos\theta + \theta l = 0$, $x_\gamma = v\times\cos(\theta+\phi)$, and $y_\gamma = v\times\sin(\theta+\phi)$. Define the angular velocity as $\theta = v/l\times\sin\phi$. Then the center velocity of rear wheel axle becomes

$$x_\gamma = v\times\cos(\theta)\cos(\phi)\,, \tag{2}$$

$$y_\gamma = v\times\sin(\theta)\cos(\phi)\,. \tag{3}$$

Integrating (2) and (3) gets the trajectory equation of center of rear wheel axle as

$$x_\gamma(t) = l\times\cot\phi\times\sin(\frac{v\times\sin\phi}{l}t)\,, \tag{4}$$

$$y_\gamma(t) = -l\times\cot\phi\times\cos(\frac{v\times\sin\phi}{l}t) + l\cot\phi\,. \tag{5}$$

Consequently, the trajectory equation of the rear left wheel is

$$x_{\gamma L}(t) = (l\times\cot\phi - \frac{w}{2})\times\sin(\frac{v\times\sin\phi}{l}t)\,, \tag{6}$$

$$y_{\gamma L}(t) = -(l \times \cot\phi - \frac{w}{2}) \times \cos(\frac{v \times \sin\phi}{l})t + l\cot\phi \ . \quad (7)$$

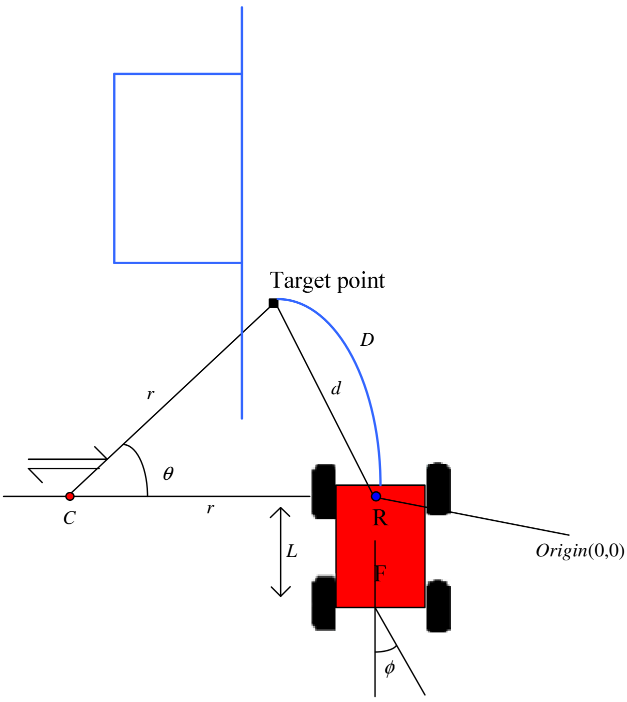

Fig. 2 Setup of the parking coordinates

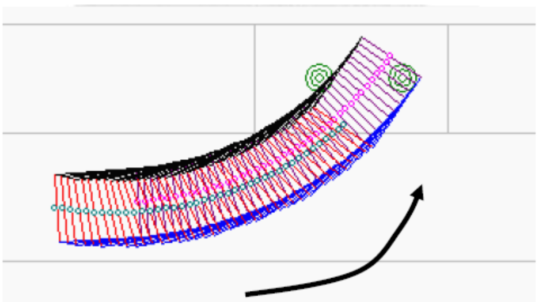

Fig. 3 Sketch of trajectory for rear parking motion.

The trajectory equation of the rear right wheel is

$$x_{\gamma R}(t) = (l \times \cot\phi + \frac{w}{2}) \times \sin(\frac{v \times \sin\phi}{l} t) \quad (8)$$

$$\gamma_R(t) = -(l \times \cot\phi + \frac{w}{2}) \times \cos(\frac{v \times \sin\phi}{l} t) + l\cot\phi \quad (9)$$

Basically, one can apply the above trajectory equations to establish dynamic model and obtain the relationship between vehicle and target point as shown in Fig. 2. When the parking area is detected, the coordinate of corners is also obtained. Therefore, one can determine the driving distance and the turning angle, as shown in Fig. 3. The definitions of the related parameters are as follows: r is the rotation radius, C is the circle origin, D is the arc, d is the distance between the rear wheel axle of car and the target point, ϕ is the turning angle of front wheel axle, L is the length of the car body, and θ is the inner angle (radiant).

The sketch of the trajectory planning is shown in Fig. 3. Since the dynamic model of rear parking is obtained, trajectory planning can be made for rear parking motion.

III. Parking Control Methodology

While the Vehicle is moving in unknown and changing environment and finding a parking area, obstacle mode are pursued through proper reaction of the vehicle by the sensed information from the environment. Also, there is a manual driving mode. For these purposes, human driving intelligence is merged to form the reaction behavior patterns for the Vehicle motivation. The designs of controllers are described by mathematical functions and also by intelligent method such like fuzzy logic control [8-10] and neural network [11]. Since the fuzzy set theory was first introduced by L.A Zadeh in 1965, FLC becomes a popular research field and has been applied to industrial and consumer's electronics widely. While the back propagation neural network, or propagation of error, is a common method of teaching artificial neural networks how to perform a given task. It was first described by Paul Werbos in 1974, A "renaissance" in the field of artificial neural network research. It is a supervised learning method, and is an implementation of the Delta rule. It requires a teacher who knows, or can calculate, the desired output for any given input. In this section, we also discuss about the fusion technique of image processing and ultrasonic long and short distance range sensor.

A. Position Control by Fuzzy Logic Controller

When the target point is decided, a relative distance is given too. That distance becomes desired distance in FLC, through the calculation, the actual distance will approach to the distance gradually [8-9].

B. The Design of Collision Prevention System

In collision prevention system, the long distance ultrasonic sensor is the main device, and short distance ultrasonic sensor is the assistance one. When detected the range between Vehicle and obstacle over than the safety range, the system will automatically prevent collision. The Eq. (7) stated below is about the relation of the safety distance and velocity.

$$D_s = d_m \times v_s \times R \quad (7)$$

where D_s is safety distance, d_m is minimum distance, and v_s is vehicle speed, R is ratio constant.

This system is applied in different mode conditions, such as Kane Following, Tracking Parking area and auto-parking,. When Vehicle is moving, the certain sensors are taken as first priority to manage the prevention. When the measured distance is smaller than D_s , Vehicle will brake for a while, then according the current mode condition to make the proper decision.

C. Controller Design for Lane Trace Following

The controller is based on rear parking neural network model, the given information from long/short Ultrasonic Sensor scanning will be used as input and then output the appropriate control parameter. In this section will discuss the controlling of the front wheel (steering) and the controlling of speed by FLC with the fuzzy rules in Table 1.

D. Rear Parking Neural Network Apply in Steering Control

Fig. 4 shows the structure of the Rear parking neural network model, it is built up by three layers: input layer, hidden layer (probability unit), and output layer. The input neurons θ_l , θ_r , and d represent the left or right line angle, and distance between Vehicle and lane respectively as shown in Fig. 5. The definition of input neurons θ_l , θ_r and d

While the output neuron θ_τ is represent the current front wheel orientation angle. The hidden layer is established in Bayes' theorem as Eq. (8) and (9). Note that the probability $P(y|x)$ is represented by Gauss function. The purpose of using sigmoid function is due to obtain the sign of independent variable and also since back propagation requires that the activation function used by the artificial neurons is differentiable.

$$P(x|y) = P(x)P(y|x) / P(y) \tag{8}$$

$$P(y|x) = sigmoid(y) \times gauss(y) \tag{9}$$

where $gauss(y) = (\sigma\sqrt{2\pi})^{-1} \exp(-0.5(y-u)^2 / \sigma^2)$ and $sigmoid(y) = y / \sqrt{1+y^2}$.

From Eq. (8), we define that weight $w(y) = P(x) / P(y)$ for the reason of $w(y)$ is unobtainable. In other word, $w(y)$ is obtained only updated by rear parking neural network, after correlative epoch will approximate to correct probability value. The value of output neuron is determined by the two hidden neurons as listed in Eq. (10), it indicates the probability of orientation turning angle, then multiply a constant will form an turning angle.

$$P(\theta_t) = \frac{P(\theta_t \mid d) + P(\theta_t \mid \theta_l - \theta_r)}{w(d) + w(\theta_l - \theta_r)} \tag{10}$$

The calculation of rear parking algorithm is an important and crucial process, because it determines the correctness of the updated weights. In the general condition, we have desire value as learning target for the output value to figure out the error, but in the practical lane trace following condition, the desire value is not exists.

If the weights value adjusted manually by trial and error will consume a lot of time and obtain an inefficient result. Hence, an important assumption is taken; assume the route is a straight line while the Vehicle is turning. This assumption is established only if the computation times is enough short.

The configuration of intelligent parking support system is shown in Fig. 6.

TABLE I
FUZZY RULE TABLE OF THE POSITION CONTROL

$\dot{X}_d$ \ X_d	NB	NS	ZE	PS	PB
NB	NB	NB	NS	NS	ZE
NS	NB	NS	NS	ZE	PS
ZE	NS	NS	ZE	PS	PS
PS	NS	ZE	PS	PS	PB
PB	ZE	PS	PS	PB	PB

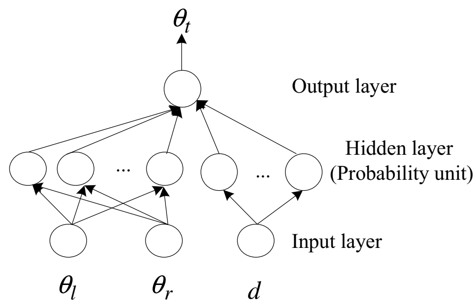

Fig. 4 Rear parking neural network model

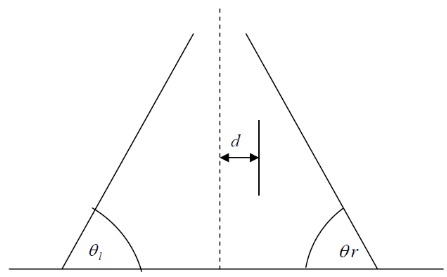

Fig. 5 The definition of input neurons

IV. EXPERIMENTAL RESULTS

According to the proposed intelligent auto-parking strategy, there are seven steps.

Step1. Search Parking Area, and take D-gear and HMI display Drive Forward.

Step2. Search Parking Area Going. The vehicle speed is below 30KM/H and HMI show searching parking slot.

Step3. Search Parking Area completed. Vehicle displays prepare to stop and HMI show slot found.

Step4. Auto parking starts. HMI show drive backward and steer turn right.

Step5. Auto Parking is going. HMI show drive backward and steer turn straight. The vehicle speed is below 8KM/H.

Step6. HMI shows drive backward and steer turn right. The vehicle prepares to stop.

Step7. Auto Parking is completed. The vehicle stops and HMI show OK, steer wheel turn straight. Brake system stop.

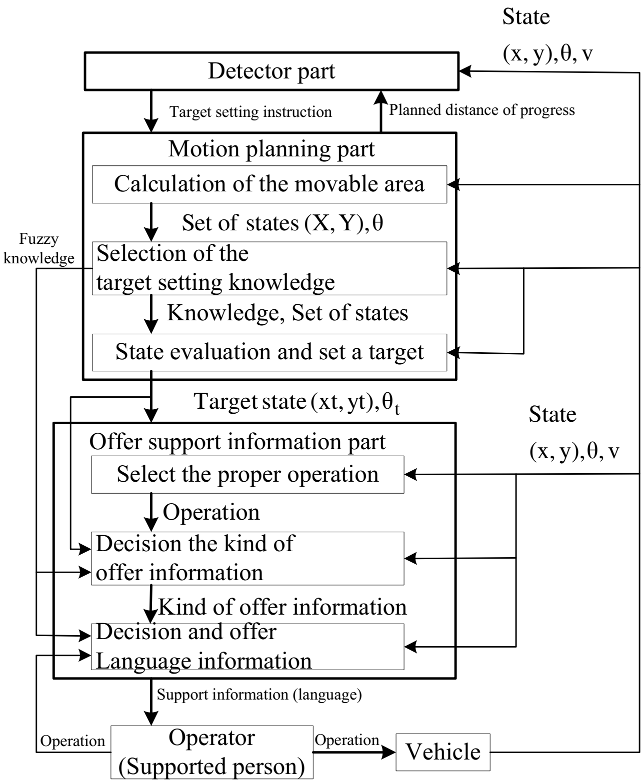

Fig. 6 Configuration of intelligent parking support system

V. Conclusion

In this paper, we have installed short/long ultrasonic sensors on the car to detect obstacles. The auto-parking system used a suitable control to drive the car into the parking slot. After analyzing the whole car APA, we have developed and implemented the intelligent auto-parking system. For the future research, we provide two views. First, the gyro and accelerometer could be considered, so that the APA actives more stable. Second, with more ultrasonic sensors and CCD cameras, an obstacle will be detected earlier.

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