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RESEARCH PAPER

Intelligent Vehicle's Path Tracking Based on Fuzzy Control

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Abstract: Autopilot vehicle is an important part of intelligent transportation systems. The objective is to develop the driver assistance systems on highway and urban road, to help or even to replace the driver, which may reduce traffic accidents and improve the efficiency of traffic system. A method based on machine vision and fuzzy control is proposed to realize intelligent vehicles' autopilot. It uses the CMOS sensor as its path recognition device to draw its lane centerline through image analysis. Taking the feedback speed as the additional input, the study forms the closed-loop control and establishes one graduation fuzzy controller which controls vehicle direction with two fuzzy controller combinations and replaces traditional PID control vehicle speed by fuzzy control. Compare with the conventional PID algorithm and the fuzzy control algorithm, the improved fuzzy control algorithm ensures a high speed and steady running of intelligent vehicle with smaller over modulation in corner.

Key Words: intelligent transportation; intelligent vehicle; autopilot; fuzzy control; vision-based navigation

1 Introduction

In recent years, many countries in the world are making great efforts to research and develop intelligent transportation systems. Automatic driving system, an important part of intelligent transportation system, is aimed to develop a driver assistance system that can help or even replace the driver to achieve automatic control of vehicles and auto-driving on highway and urban road environments. With the help of automatic driving vehicles, traffic accidents can be reduced and the efficiency of road transportation system can be improved[1]. With the development of computer technology and image processing technology, automated-guided vehicles based on vision navigation and intelligent control become a hotspot research. The navigation method of marking line through image recognition has become one of the main development directions in automatic-guided vehicle navigation because the establishment and change of guidance lane are relatively easy and cheap[2]. Furthermore, the image processing speed is faster and the real-time property of this control system is better compared with other visual methods such as three-dimensional vision recognition technology.

An intelligent vehicle is system that is composed of sensors, control mechanisms, and control algorithms. The control algorithm has strong relationship with the stability and the rapidity for the whole system. At present, the common control algorithms are proportion integral differential adjust (PID), enhancement proportion integral differential adjust (EPID), optimum control algorithm, fuzzy control algorithm, and so on. The control of intelligent vehicle is a very complex control problem that classical PID and EPID controls cannot accurately measure and estimate the parameters of the model. Although optimum control algorithm[3] may solve some shortcomings of the PID control algorithm, its flaw lies in applying much simplification to the model. In addition, the optimum control needs to build a system identification model for the executive mechanism, and requires more accurate models and sensors. The fuzzy control algorithm does not require the system to establish a precise mathematical model, and it can obtain good control performance with certain experiences and experiments. Ref. [4] introduced an intelligent vehicle's automated driving system based on the fuzzy control and Ref. [5] introduced a self-organizing fuzzy controller used in an AGV automatic navigation car. However, the two fuzzy control methods only used the visual information obtained by image acquisition and did not take the real-time speed into consideration. In this study, the feedback speed and image information are combined to establish a graduation fuzzy controller composed by two fuzzy

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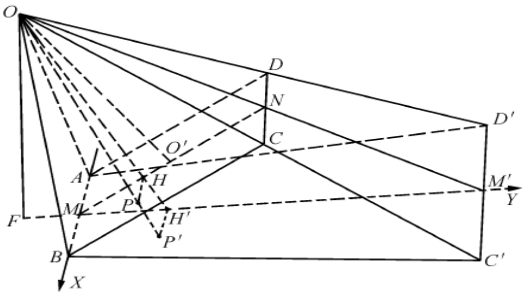

Fig. 1 Corresponding relationships between road plane and image plane

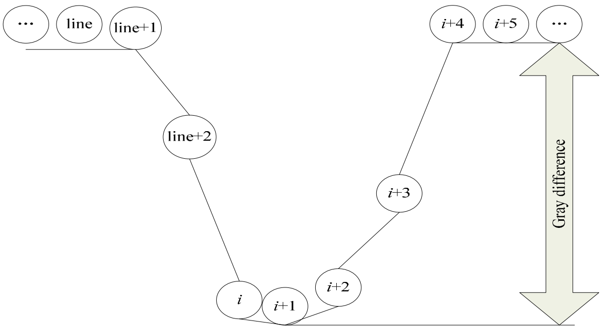

Fig. 2 Edge detection algorithm for lane line

controllers and this graduation fuzzy controller is used to control direction. Furthermore, the fuzzy control is used to replace traditional PID to control the speed of vehicles.

2 Lane recognition

2.1 Correction of image perspective distortion

When a picture is being taken, the best position of a camera is to be vertical to the photography plane. In this way, the image can be reproduced according to the proportion of the original geometry. In the intelligent vehicle's design, the camera is usually not vertical to the ground to gain images. It is above the ground at a low height and is installed at a certain angle with the ground. Therefore, based on the camera's geometrical optics model, the keystone distortion, which is the so-called perspective distortion, will appear in the captured image, as shown in Fig. 1.

In the path recognition, image perspective distortion can bring a series of issues. For example, vertical lines will be photographed as oblique lines, and the distant bends will be shrunken, which will lead to curvature miscalculation. Furthermore, different proportions of captured images will lead to miscalculations of slopes and turning points of bends. Therefore, the image perspective correction is very critical to improve the accuracy of lane features extraction.

According to geometric mathematical modeling, the coordinates of captured images and scenery world have the following relations, and the concrete inference process is shown in Ref. [6].

$$\begin{cases} p_y' = \dfrac{h(H\tan\gamma_0 + 2P_y\tan\alpha_0)}{H - 2\tan\gamma_0\tan\alpha_0 P_y} \\ P_x' = \dfrac{\sqrt{h^2 + (P_y')^2}\,2P_x\tan\beta_0}{W} \end{cases} \quad (1)$$

where P_x' and P_y' are the abscissa and ordinate in the world coordinate respectively, P_x and P_y are the abscissa and ordinate in the image coordinate, respectively; h is the installed height of the camera. H and W are length and width of the image, respectively; $2\alpha_0$ and $2\beta_0$ are vertical vision angle and horizontal vision angle of the camera lens, and γ_0 is the elevation angle of the camera.

2.2 Extraction of lane centerline

The path information obtained by image sampling will be stored in a two-dimensional array. The values of rows and columns of this two-dimensional array are coordinates of the captured image. If the coordinates of edge points of a marking line are obtained, the position of this marking line can be distinguished. The characteristic of edge points of a marking line is that the absolute value of the gray difference between the left and right elements of one edge points will be higher than a threshold; on the contrary, it will be less than this threshold. In this way, whether or not two adjacent points in each row are in the edge of lane line can be known until the gray difference between the two points is calculated, and we can also know the information of gray changing in the edge according to the polarity of this difference.

Compare the absolute value of gray difference between the two adjacent points with the threshold from the most left point to the right because there may be fuzzy deviation in the actual edge of the road, points with an interval of two points, rather than adjacent points, are chosen to calculate the gray difference. Therefore, if line is a starting point, line+3 will be recorded as i if the difference between line and line+3 is higher than the threshold. Then calculate whether the difference between two points separated by two points is higher than the threshold value from i to the last point in the line. If it is higher, this point will be recorded as j, and the coordinate value of $(i+j)/2$ will be set as the center of the marking line, as shown in Fig. 2. The center position of this marking line is $[i+(i+1)]/2$.

The path marking line is usually a continuous curve, so the left edge points of the two adjacent rows are close. Tracking edge detection algorithm uses this feature to simplify edge detection. If one left edge point of a line has been searched, the next left edge point of line will be found near this searched edge point. This approach is always finding the left edge point of the next line near the searched left edge points, and hence this approach is called "track" edge detection algorithm.

According to the extracted feature points of path lines, the lane center position is calculated and the center line is fitting out to determine the tracking trace. Ref. [7] has used quadratic