Research on Visual Navigation Algorithm of AGV used in the Small Agile Warehouse

WU Chun-Fu, Wang Xiao-Long, Chen Qing-Xie, Cai Xiao-Wei, Li Guo-Dong*
College of Mechanical and Electrical Engineering, Longyan University, Longyan, China
Corresponding author: liguodong.sdu@foxmail.com

***Abstract*—With the development of logistics industry, the logistics automated warehouse is ahead in the race toward the direction of multi-user, multi-variety and flexibility automated warehouse. Traditional AGVs (automatic guided vehicle) are difficult to meet the new demands of logistics warehouse. This paper presents a method to extract the deviation of AGV's navigation path based on threshold segmentation of chromatic aberration according to the actual needs. The paper realized high precision path tracking of robot by the path tracking controller adopting the idea of beforehand closed loop control. Finally, the logistics warehouse environment was simulated, and the navigation performance of the designed AGV was fully tested. The experimental results show that the visual navigation AGV features of flexible navigation, high precision and smooth operation and can satisfy the demand of flexible storage.**

Keywords—AGV; visual navigation; flexible storage

I. INTRODUCTION

With the rapid development of national economy, logistics industry market demand continues to increase; the application of automation technology in modern logistics industry is more and more widely. The storage process of logistics link needs through artificial storage stage, mechanized storage stage, automatic warehousing and integrated automation warehouse [1], it is toward intelligent storage phase with rapid development. The small agile warehouse in intelligent storage system mainly dominated by small smart handling, named AGV, it can achieve goods automatic handing, storage, sorting, etc. It can realize the application requirement of many varieties and users, and it has a lot of advantages that include the early investment of equipment, late operation and maintenance low cost. At present, the domestic mature reliable small agile warehouse system has not yet appeared. In view of this, we research and development for AGV of the small agile warehouse. In this paper, on the basis of simple introduction for the robot system architecture and focusing on AGV vision navigation algorithms design, in the end, experiment and application results are given.

II. SYSTEM ARCHITECTURE OF VISUAL NAVIGATION FOR AGV

A. The fuctional requirements

The visual navigation for AGV in this paper, which realize automatic tracking, swerve on the key point and automatic driving, and the navigation line with laying on the ground for the path identification. Visual navigation through WiFi reception background scheduler instruction, According to the corresponding scheduling requirements to drive to the under of the shelf, it hunts rely on the camera at the top of the AGV, parks after alignments the shelves, jacks hook and picks up shelves, then the shelves will be transported to the designated location by AGV. In the whole process, visual navigation becomes the end of the actuator of scheduling software, to achieve a flexible transport logistics warehouse.

B. The mechanical structure

The visual navigation for AGV adopts double differential drive platform. There are two wheel hub motor for driving wheels, in the before and after each have two supporting roller as return roller. The car body is divided into forehold, middle deck and afterhold. In the center of the middle deck is equipped with jacking device, and it used to implement the function of jack-up shelves. The forehold is used to place control system board, motor driver and the motor of jack.

C. Control system structure

The control system structure of visual navigation for AGV is shown in Fig.1. The communication of AGV through WiFi and backend server, remote clients through the Internet network remote submit warehouse task, monitor warehouse environment and warehouse equipment operation. The entire warehouse into an organic whole through the network, and information management concatenate with the whole process of warehouse equipment, shelves and the goods. The core controller adopts double ARM controller, Main controller is responsible for parsing backend directives, motion control, condition monitoring and information feedback, etc. Monitoring controller is responsible for monitoring Working state of the main controller, collect the sensor data and feedback to the main controller, and emergency control task, etc.

III. PATH DEVIATION OF VISUAL NAVIGATION FOR AGV

A. AGV visual processing

Vision navigation is based on image processing technology of AGV navigation path for identification, which can identify the path line separated from background image [2], according to the algorithm for AGV car body and the relative position between the paths marking information, Calculate variation of the AGV body relative to the path line. In the AGV Based on the visual navigation, the accuracy of visual processing results directly determines the precision of the AGV [3]. In this paper, the designed process of visual processing scheme for AGV is shown in Fig.2, it is divided into two parts of image acquisition and image processing. The acquisition of image quality is high, not affected by the interference of outside light basically, and after greatly reduced the difficulty of image processing, Due to the design of mechanical structure and adopt measures such as artificial auxiliary light source lighting. However, restricted to AGV size, line navigation camera navigation line only 10 cm off the ground, ordinary camera view only about 60 °, which is difficult to meet the demand of navigation. Therefore, we use the wide angle camera. It captures the chassis before two rounds of all the images, but the image distortion will happen. According to the characteristics of nonlinear distortion lens, the image distortion can be divided into axisymmetrical radial distortion, centrifugal distortion and thin prism distortion, in order to simplify the calculation, the axisymmetric radial distortion is only considered. The underlying image processing uses DSP which is weak processing ability. We adopt the method of a piecewise polynomial for correction, which do a polynomial calculation, this algorithm can fast to deal with distortion image under the condition of loss small precision.

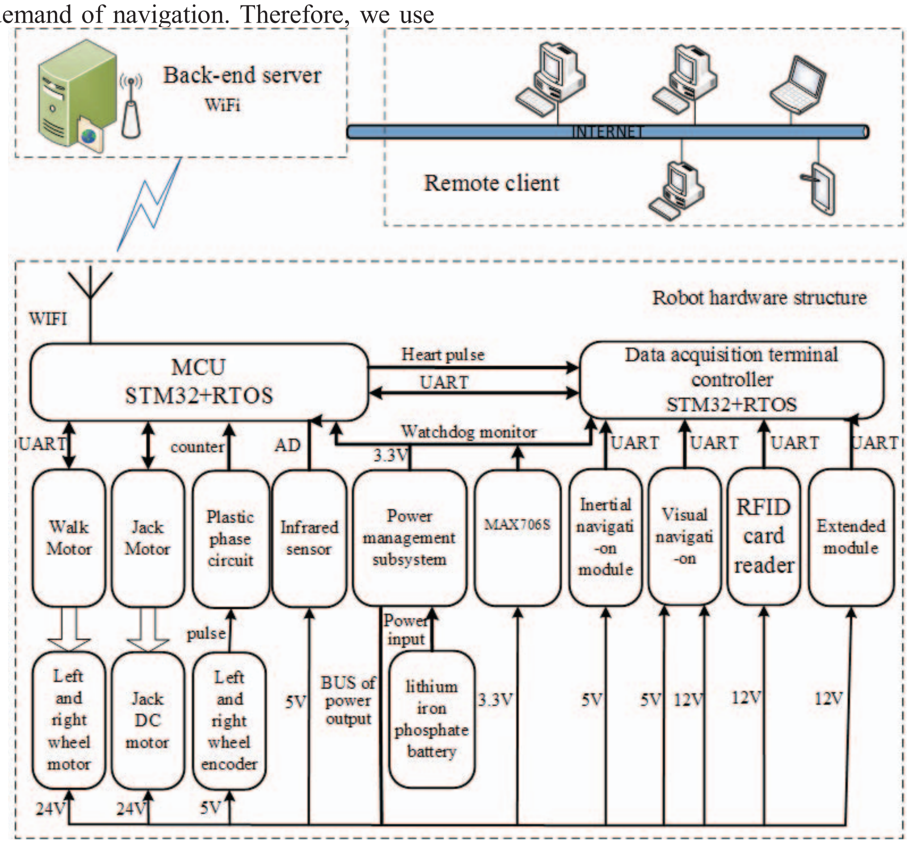

FIG.1 THE CONTROL SYSTEM STRUCTURE OF VISUAL NAVIGATION FOR AGV

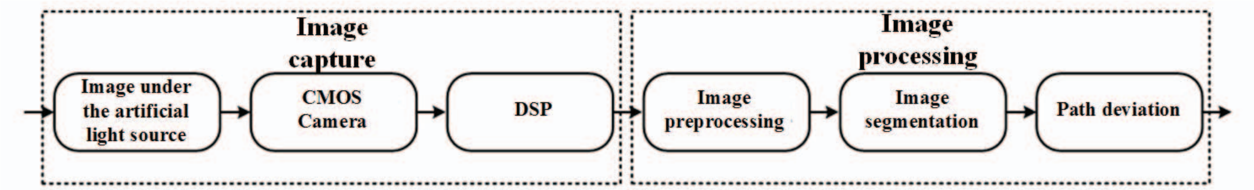

FIG.2 THE DESIGNED PROCESS OF VISUAL PROCESSING SCHEME FOR AGV

Based on visual navigation for AGV core using DSP to collect and process images. Image transmission in CMOS camera then into the DSP, made image preprocessing, image segmentation and path deviation calculation process within the DSP. And it ensure the whole process from image processing to capture path deviation is calculated time less than two frames of image capture time interval, to maximize the use of every frame image. Complete the path tracking after processed results convey to the AGV bottom motion controller.

B. Image filter processing

AGV car needs to collect image in the process of walk. The image data from DSP will presence sensor noise, photo grain noise, transmission noise and other image noise. And they present state of random distribution, influence the precision of image processing, and may even lead to image processing error. So we need to adopt the method of smoothing to weaken or eliminate noise, and keep the edge information for the later do image space effectively.

In this paper, we use the filter in the spatial domain for image processing, image processing theory, the pixels of space known as the spatial domain. So the space domain filters direct effect on the pixel, the common of a neighborhood average filter and median filter. We have these two kinds of filter, compares the results with the experiment result is shown in Fig.3. Fig 3 (a) is based on the original image of Cr Chroma. Fig. 3 (b) is edge detection image of without filtering, due to reasons such as reflective has a large number of white light interference on the navigation line, which is not conducive to calculate. Fig. 3 (c) is the Sobel edge detection of image after neighborhood average filtering. Fig. 3 (d) is Sobel edge detection of image after median filtering. By contrast, both of filter method can suppress the image noise, but some area average method to remove the edge information, the edge information preservation is better about median filtering method. Coming up from the complexity of these algorithms, median filtering algorithm is simple, it can complete the image filtering in a shorter period of time and further improve the filtering effect.

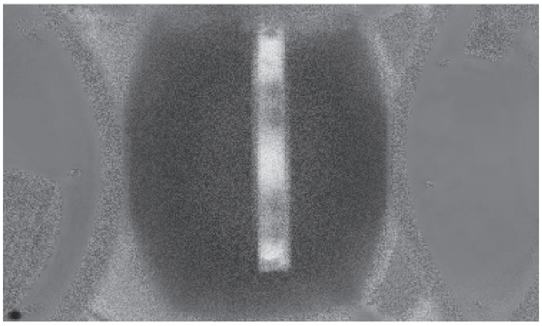

Fig 3 (a) Based on the original image of Cr Chroma

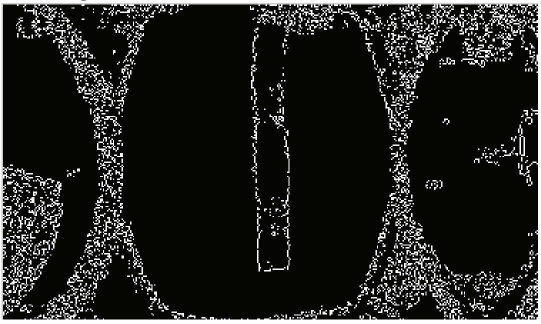

Fig 3 (b) Edge detection image of without filtering

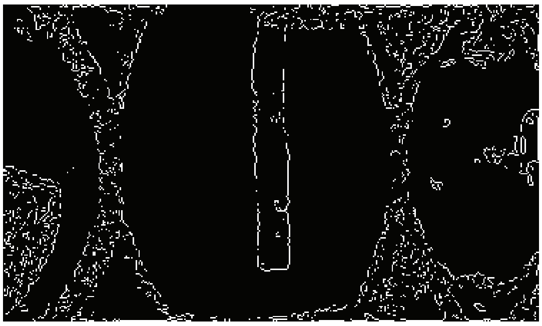

Fig 3 (c) The Sobel edge detection of image after neighborhood average filtering

Fig 3 (d) Sobel edge detection of image after median filtering

Fig.3 Neighborhood average filtering and median filtering

C. *Path deviation extraction algorithm*

The actual image of captured by AGV field patrol cameras as shown in Fig.4. The green background is the road, red ribbon is navigation line, left and right sides are walking drive motor. When image processing, nothing to do with the navigation areas of the images is needed to be removed. The image within the dashed rectangle box in Fig.3 is part of the need to be processed. This paper adopts the CMOS camera for pavement image acquisition, returned to YCbCr image format. In order to reduce the amount of calculation of the image processing, improve the speed of image processing, we directly for image segmentation based on difference color signal of Cr. And we use threshold method [5], separate the path line from the background.

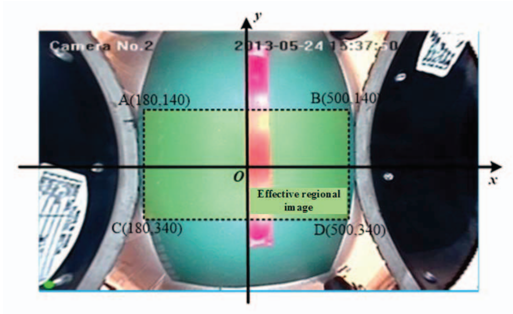

Fig.4 Actual image of captured

After get the path lines shown in Fig. 5, the centerline of the path is needed to extract. In this paper, the path of separated is divided into 6 paragraphs lines and directly to the X axis projection, and got six paths middle point, the paths used least square method for fitting the midline point, the midline of the path equation is obtained [6]. According to the midline of the path equation calculates the lateral deviation e and angular deviation α.

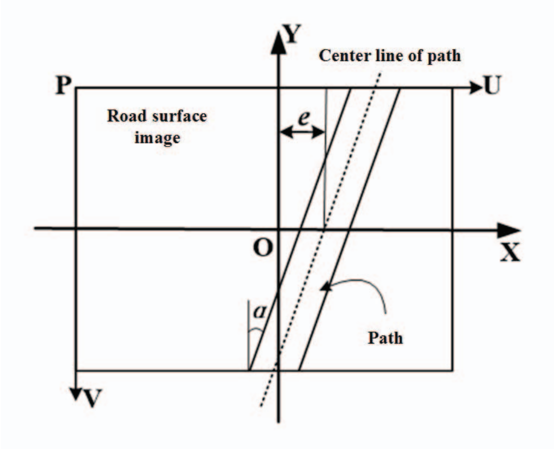

FIG.5 THE ROAD NAVIGATION DIAGRAM

IV. PATH TRACKING OF VISUAL NAVIGATION FOR AGV

The path deviation of being extracted is AGV path tracking feedback signal of the controller, to form a closed loop position. But there are two errors of the visual processing returns, lateral deviation e and angular deviation α. To address these two problems, in this paper, the idea of advanced at closed-loop control of path tracking is adopted [7].

The idea is an imitation of the drivers. When drivers, eyes are always aim on the information of road ahead, to form the optimal driving path, but not too concerned about the body of the current position. Our AGV finds the navigation lines are straight lines. So master control system uses two feedback signals of e and α calculates the virtual path equation, then gets the deviation E_k of car head center and the center of path.

$$E_k = e + L\_HB \times \tan\alpha \qquad (1)$$

E_k calculated by e and α as shown in Fig.6, master control system realizes the path following based on E_k controls AGV.

AGV walking platform adopts double difference driven way. Assume that VL is about AGV's left wheel linear velocity and VR is the right, V is the synthesis moving speed, ω is its rotating angular velocity, and the axis distance of two rounds is 2L, according to the differential drive platform model [8], we can know that:

$$\begin{cases} V = \dfrac{V_L + V_R}{2} \\ \omega = \dfrac{V_R - V_L}{2L} \end{cases} \qquad (2)$$

From the formula (2), we can see that the ω is decided by the speed difference of two rounds. The average of speed's sum decides the AGV's centroid motion synthesis speed. The block diagram of path tracking control of AGV is shown as Fig.7. First of all, we set a speed baseline value V_Base, different V_Base represents the different AGV movement speed. The AGV angular velocity is controlled by the speed differences. Then, AGV car body has not too big deviation because of running, and finally completes the path tracking.

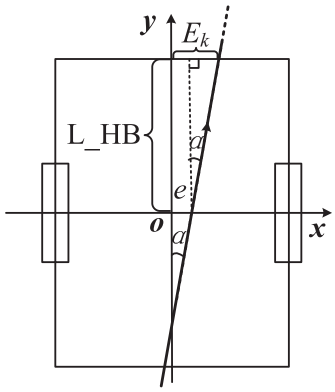

FIG.6 CALCULATE DIAGRAM OF EK

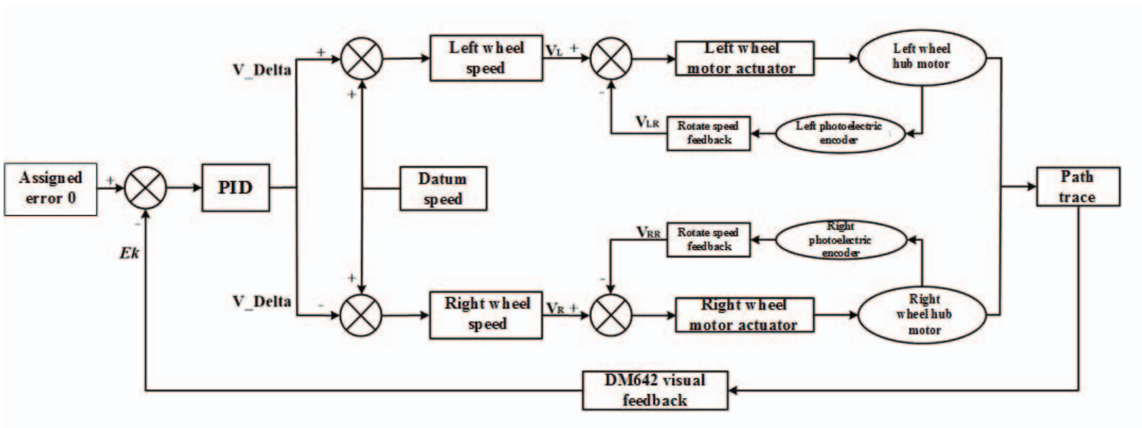

FIG.7 THE BLOCK DIAGRAM OF PATH TRACKING CONTROL

V. NAVIGATION PERFORMANCE TEST OF AGV

A. The building of artificial warehouse

In order to verify the AGV vision navigation performance, in the first a artificial warehouse is needed to build, its location of warehouse layout is shown in Fig. 8. The green part is removable shelves, the red line is the navigation path line, grey area is RFID tags [8], and it holds the absolute position coordinates. AGV navigation along the red line to walk, when it pass every RFID tags, the RFID read-write device below AGV will return label information, and server side determine the current position of AGV based on this information. The actual warehouse simulation structures as shown in Fig. 9.

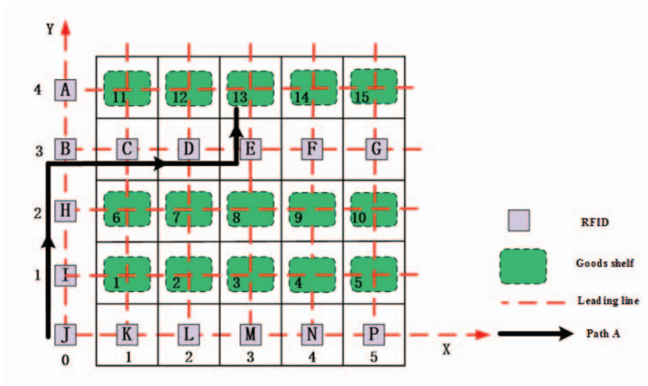

FIG.8 THE LOCATION OF WAREHOUSE LAYOUT

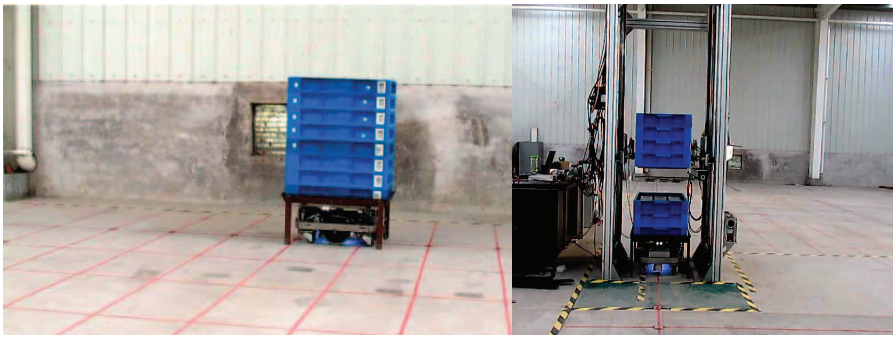

FIG.9 THE ACTUAL WAREHOUSE SIMULATION STRUCTURES

B. The navigation path planning

AGV starting point is located in the J point, server side scheduling system requirements need it is located in the location of the 13 shelves and carry it to the point of J. Firs, AGV has a best first walking route from Warehouse management system, as shown that solid line of black arrow in figure 7. It along the direction of Y axis from the J point to point B, right turns 90° after arrived at point B, then run along the direction of X axis to E, left turn 90 ° into the under of 13 shelf after arrived at point E, AGV according to the original road to return to the point of J when it lifts the shelves.

C. The navigation performance test under different load conditions

In this paper, the biggest load of AGV is 250kg. Set the state of AGV is no-load condition when it without carrying shelves, due to the different of shelf as the inventory is weight of dynamic change when handling shelves. The maximum speed is 500 mm/s, and between 0-500 mm/s continuous adjustable. In order to test different speed in different load of navigation accuracy, we chose the five commonly shown in the table 1and used 6 different loads and speeds. First of all, set up a fixed speed, and then let the AGV carrying different number of meter box (16 kg per case) walking along the selected navigation route by section V.B. On the path set eight different points to measure the deviation of AGV, 10 times test as walking average deviation was repeated and recorded. Finally change patrol speed and repeat test, test results are shown in table 1.

TABLE 1 DIFFERENT SPEED IN DIFFERENT LOAD OF NAVIGATION ACCURACY TEST

Deviation (mm) / **Speed (mm/s)** / **Load(kg)**	100	200	300	400	500
0	±0.5	±0.6	±0.8	±0.8	±1.1
48 (3 cases)	±0.5	±0.7	±1.0	±1.1	±1.4
96 (6 cases)	±0.6	±0.8	±1.1	±1.1	±1.5
144 (9 cases)	±0.6	±0.8	±1.2	±1.3	±1.5
192 (12 cases)	±0.7	±0.9	±1.4	±1.5	±1.7
240(15 cases)	±0.7	±1.0	±1.5	±1.7	±1.9

From the results in table 1, we can see that the accuracy will decrease accordingly when the speed faster in the situation of AGV has same load cases. But the accuracy along with the change of loads is not big in the condition of low speed. Because of the AGV's image sampling speed is fixed, when speed is increase, the corresponding hysteresis effect will more apparent. In addition, under the different loads, walking motor running accuracy not change much, due to the driver adopts speed current double closed loop control. Hence, in practical application, if high precision operation is needed, the given speed should be reduced, such like entering warehouse and cornering. Other cases, the precision can be sacrificed to improve the speed.

VI. CONCLUSIONS

In this paper, we aim to the actual demand, propose a mechanical and control system architecture of visual navigation for AGV in small agile warehouse. Based on the color difference threshold segmentation method to extract and merge navigation path deviation. The idea of advance at closed loop control is adopted and the path tracking controller is designed, the robot high precision path tracking is realized. Finally, in the building of the artificial warehouse navigation performance test in an all-round way is designed. The experimental results shown that the navigation is flexible, high precision, stable operation, and visual navigation for AGV can satisfy the demand of flexible storage, this study of related fields has certain reference value.

ACKNOWLEDGMENT

This work was supported by the Guided project of Fujian Science and Technology Department (2016H0026), the Natural Science Foundation of Fujian Province(no. 2015J01268), the Science and Technology Project of Fujian Education Department (JK2014049), the Training Plan of Longyan University for young teachers (LQ2013015, LQ2014006), and the project on the integration of industry, education and research of Longyan University(LC2014003).

REFERENCES

[1] Fan D Q, Du X Y. Modern Equipment Transmission System [M]. Beijing: Tsinghua University press, 2010

[2] Zhang J, Ye Q T. Research on Vision-guided Control Algorithm of AGV [J]. MACHINERY, 2003, 30(6): 21-22

[3] Zhang H B, Yuan K, Zhou Q R. Visual Navigation of A Mobile Robot Based on Path Recognition [J]. Journal of Image and Graphics, 2004, 9(7): 853-857

[4] Zhou H L, Wang L Q. A Fast Algorithm for Rectification of Optical Lens Image Distortion [J]. Journal of Image and Graphics, 2003, 8(10): 1131-1134

[5] Desouza G.N., Kak A.C. Vision for mobile robot navigation[J]. IEEE Transactions on Pattern Analysis and Machine Intelligence, 2002, 24(2): 237-267.

[6] Sun H, Ren M W, Yang J Y. A Fast and Practical Algorithm for Line Detection [J]. Computer Application Research, 2006, 2(5): 257-260

[7] Li Q Z, Gu W K, Ye X Q, et al. A Study of Intelligent Preview Control Method for Mobile Robot Road Following [J]. ROBOT, 2002, 5(3): 252-254

[8] Cao Q X, Zhang L. Wheeled autonomous mobile robot [M]. Shanghai: Shanghai Jiao Tong University Press, 2012

[9] Park J., Park Y.S., Kim S.W. AGV parking system using artificial visual landmark[J]. International Conference on Control, Automation and Systems, 2008, 1: 1579-1582.