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The Road Detection Technology of Vision Navigation for Picking Robot

[1]Xiong Juntao, [2]Zhong Pengfei and [3]Zou Xiangjun

[1]*College of Mathematics and Information, South China agricultural university, guangzhou, 510642, China*
E-mail: 309283022@qq.com
[2]*College of Mathematics and Information, South China agricultural university, guangzhou, 510642, China*
[3]*South China agricultural college engineering college farm machinery and equipment key technologies Ministry of Education key laboratory, Guangzhou, 510642, China*

Abstract

Vision navigation technology of the autonomous walking robot has been conducted in the research. Based on the characteristics of picking robot working environment, the visual system for the independent walking car is designed, which applies monocular camera to obtain images of marking lines on the surface of road for pre processing. Using the image gray contrast constraints determines the information of the effective area on the surface of road. Then the Hough linear detection combined with constraint will be used for the recognition and detection of the indication line on the surface, and the information of visual examination path will be fed back to the car control system as following. Through the ultrasonic sensors on the head of the walking car, the walking car can detect the obstacle at the same time. According to the real-time feedback data of ultrasonic sensor, fuzzy propulsion and calculation determine the information of the obstacles on the road surface ahead of time in order to achieve the function of real-time obstacle avoidance. The result of visual navigation test shows that maximum deviation of the car walking straight line based on visual navigation system is 1.5cm and the maximum deviation of curve walking is 6cm. The success rate of obstacle avoidance is 96.67%, which can meet the requirement of the vision navigation of picking robot and provide technical support for the autonomous navigation and intelligent operation of picking robot.

Keywords*: Picking robot; Visual navigation; Road detection*

1. Introduction

As regard to the intelligent effectively work of the agricultural robot, independent walking and visual navigation are both of important functions. How Picking robot realizes the road detection and real-time navigation in complex unstructured environment is one of hot spots in the current research.

Visual navigation of mobile robot research begining in the late 1970s, concentrated mainly in the United States, Europe, and Japan, and a few developed countries [1]. Amy j. Briggs, United States of Middlebury College, developed a mobile robot by self-similar landmark for navigation [2]. P. Saeedi et al of the University of British Columbia in Canada based on visual sensor, designed a path-tracking method of 3D target tracking in the natural environment [3]. Kise et made use of binocular stereo vision system to detect the information of farmland environment in agriculture [4]. Shan et al. studied the

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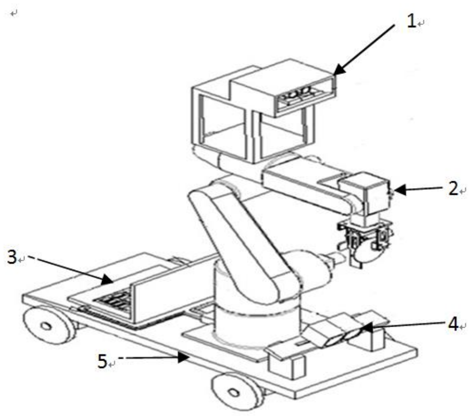
monocular camera for the extraction of farmland information and realized the detection of visual navigation line [5].

There are also some researches for robot vision navigation in the domestic. The National University of Defense Technology has researched and developed the Chinese first vision guiding vehicles [6]; Tsinghua University has developed a THMR-V vision guided mobile robot which realized automatic lanes tracking in the structured environment, road tracking in the structure environment, dynamic obstacle avoidance in the complex environment and so on [7]. In agriculture, Sun Yuanyi and others extracted the visual navigation of information across the cotton fields, using Hough line detection to determine the walking road information between the ridge of cotton fields [8]. Ren Yongxin conducted a research about vision navigation of the cucumber picking robot on greenhouse environment of cucumber growth [9].

In conclusion, the technology of the robot installing camera an onboard on are the most popular applications in the research of visual navigation. This study will utilize self-made picking robot mobile platform-AGV trolley for visual navigation research and make use of the camera for real-time detection and localization. The visual information will be fed back to the car control system. Then the control system combining the information of camera with the information of ultrasonic sensor, calculates the information fusion, and finally realizes the car visual navigation. This study provides technical support for picking robot autonomous navigation and intelligent operation.

2. Vision System

Picking robot vision system for navigation is composed of: Monocular CCD cameras and HC - SR04 type ultrasonic sensor. The prototype structure of picking robot is shown in Figure 1. Figure 2 is the structure drawing of the walking car with 1 camera and 5 uniform distributed ultrasonic sensors on the head of the car. The car independently walking is mainly achieved by using electrodes to control bearing forward left and right turning.



1. Binocular vision camera 2. Mechanical arm 3. Computer 4. Navigation cameras 5. Mobile car

Figure 1. Picking Robot Structure

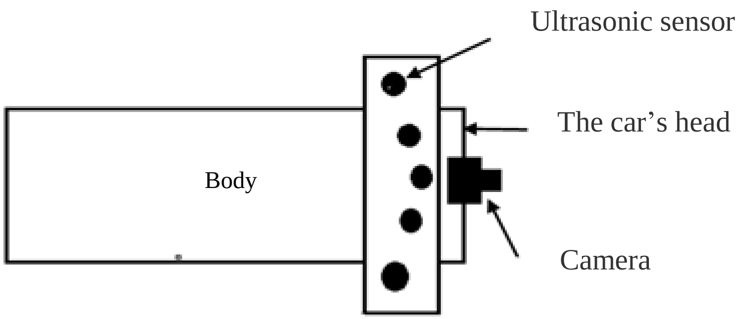


Figure 2. Diagram of Vehicle Structure

3. The Method of Visual Navigation

The navigation car used by picking robot is AGV (Automated Guided Vehicle). It is automated guided vehicle that can follow a prescribed guide path, transports with security and have various transportation functions [10]. The navigation vision system is designed and picking manipulator is placed in the car, namely the realization of independent walking. The working environment of picking robot is shown in Figure 3. The robot walking path is the surface of orchard road. Due to the characteristics of unstructured environment, black lines is laid on the ground in the orchard road for the visual navigation to obtain the information of the road.

a. operations of robots picking

b. scene of lychee garden

Figure 3. Working Scene Graph of Picking Robots

3.1. The Road Visual Detection Technology

With the camera to take pictures in real time, the control system will get the information of road after real-time image processing. Specific ideas: by the real-time video image to preprocess and the edge detection of road on each frame, Hough line detection will be used to identify the path. Finally the data of path is fed back.

In the actual environment, environmental interference factors will appear in the process of road recognition, such as light and other debris objects, etc. Therefore the research chooses the room that has the ceramic tile floor and outdoor cement floor, two kinds of path situations according to the real environment. The indoor tiles will be reflective, and there are many fine lines to interfere in the research, as shown in Figure 4a. If the threshold segmentation is directly applied to the image based on color space component, the result will be highly affected by the light, as shown in Figure 4b. The texture of indoor tiles is clarity and mass. If directly detected by HOUGH lines, there will be a lot of interference as shown in Figure 4c. The detection of the outdoor cement road is shown in Figure 5. Too much interference noise which greatly impacts on the detection of cement road in the outdoor results in the unsatisfactory of Hough examination path in the final.


a.Thin line with detection


b. Threshold segmentation reflective floor

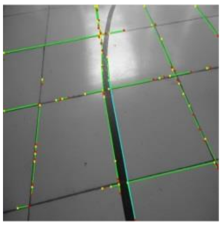
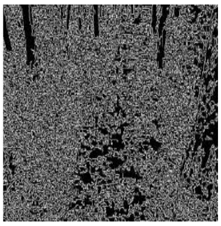

c. Hough line of grayscale image

Figure 4. Results of Indoor Image Processing for Road Detection


a. Cement road in the sun light


b. Detection of image edge


c. Hough detection of the straight line

Figure 5. Results of Outdoor Image Processing for Road Detection

Based on the above situation in this research, the research idea of road detection is following:

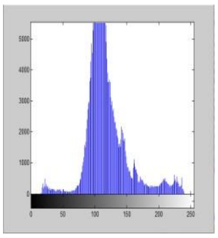
(1) The Image Preprocessing

The road grayscale image for preprocessing to remove interference is selected. Because the edge of ceramic tile is relatively small and orbit and the path is relatively coarse according to indoor road, the corrosion expansion or median filter is used to remove the edge. By observing the gray histogram of indoor and outdoor road, its peaks and troughs is found significantly. Thus the interference lines can be removed by median filtering. Although there will be some black border, the line detection can eliminate the edge when conducting line detection. As shown in Figure 6b.

(1) indoor road


a. original image


b. median filtering for greyscale image


c. grayscale histogram

(2) outdoor road

a. original image b. median filtering for greyscale image c. grayscale histogram

Figure 6. Results of Road Image Preprocessing

(2) Contrast Constraints

In the process of road surface detection, there is a great contrast between the marking lines and the surface on the road. During the detection of the road edge, gray scale contrast will be used to reduce the interference factors aiming to obtain path edge. Specific ideas as following;

Assuming the pixel I_i is the edge on the road, the pixel will meet the following conditions:

$$\frac{\tilde{I}_{sign}}{\tilde{I}_{road}} \geq e^{\lambda} \tag{1}$$

Road line on the left:

$$\tilde{I}_{sign} = \frac{1}{n}\sum_{j=0}^{n} I_i(x+j, y), \ \tilde{I}_{road} = \frac{1}{n}\sum_{j=1}^{n} I_i(x-j, y) \tag{2}$$

Road line on the right:

$$\tilde{I}_{sign} = \frac{1}{n}\sum_{j=0}^{n} I_i(x-j, y), \ \tilde{I}_{road} = \frac{1}{n}\sum_{j=1}^{n} I_i(x+j, y) \tag{3}$$

Among them, $\tilde{I}_{sign}$ is the average value of gray road logo lines. $\tilde{I}_{road}$ is the average gray value of road surfaces . n is the width of the lane lines. λ is a numeric value greater than 0. By formula (1), there will be a certain proportion between the grayscale average of road marker and that of pavement. In according to the proportion, marking area can be determined. As shown in Figure 7. In different weather conditions, the detection of road edge based on grayscale contrast can determines the effective area of road lines, but there may be a lot of noise interferences.

a. road detection in cloudy day b. road detection in sunny day c. night road detection

Figure 7. Results of Road Line Detection based on Gray Scale Contrast

(3) Hough Linear Detection based on Restraint

By the method of Hough detecting straight line, combined with the constraint condition, the detection of road can be realized. After using gray contrast determined the region of road detection, the Hough straight line will be examined, but there will be also many disturbance factors. While the data of road will be fed back to the vehicle control system, it is necessary to filter the image data.

Hough transform is a mapping from two-dimensional space to parameter space [11]. With regard to the linear transform, the mapping is expressed as the relationship between a certain point on the two-dimensional space and a curve on the parameter space. The mapping relationship is expressed as the formula.

$$\rho = x\cos\vartheta + y\sin\vartheta, \rho \geq 0, 0 \leq \vartheta \leq 2\pi \tag{4}$$

$\rho : l$ is the distance to the origin

ϑ : Angle between ρ and x [12].

Specific ideas for line detection; each frame of the film images are divided into 3 parts, and then the examination and the recognition of Hough straight line will be applied separately to each part of images separately. Lines of each part will be filtered for and the optimal straight line will be selected. Finally most superior straight lines from three parts is connected together, namely the path of detected straight line. Image is divided into 3 parts as shown in Figure 8.

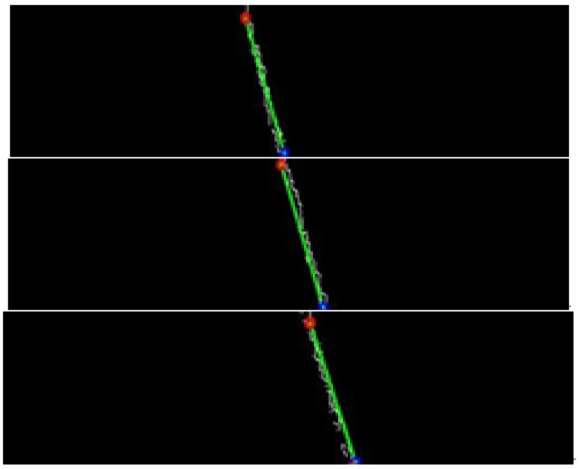
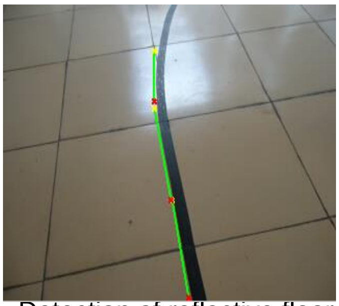


Figure 8. Regional Segmentation of Road Image and the Results of Hough Line Detection

The rules of Hough line detection for image filtering is using the constraint of line length and angle. Here establish two screening standards;1）the beginning and the end of two straight lines should be relatively close. 2）the deflection amplitude of track should not be too large, so the cosine of the angle between the two lines will be close to one .

$$E\ (v_1, v_2) = (1 - \cos(v_1, v_2)) + Dist(v_1, v_2) \tag{5}$$

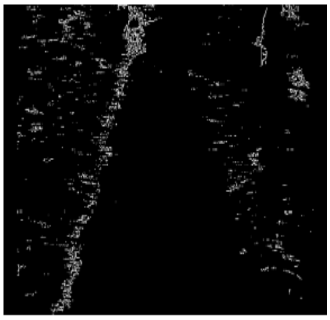
v_1, v_2 represent the adjacent two points of the two straight lines at one's beginning and the other's end, $Dist(v_1, v_2)$ represents the distance of consecutive points in one straight line head and other's tail. E (v_1, v_2) represents the screening of the evaluating value, and the smaller its value is, the greater the detection line meets the requirements. All combinations were worked out in three regions by enumerating and then through the filter criteria minimum value is selected. The result is shown in Figure 9.




a. Detection of reflective floor b. Outdoor road detection


c. Detecting effect of cement c. Detecting effect of cement

Figure 9. Results of the Road Detection after Linear Filtered

a. Original image b. Line detection and contrast constraint


c. Remove the noise d. Result of examination

Figure 10. Path examination result of outdoor concrete roads

3.2. The Road Visual Positioning Technology

After processing the detection image of road, visual positioning will be calculated to achieve the navigation of AGV. The walking control system of the car mainly depends on the single-chip motor to control steering and walking. The baseline which is straight through the optical center of the camera is established on the car's head. The angle calculated by the baseline and the straight line after visual inspection will be transformed into the parameter of the controlling motor so as to control the car driving motor running and steering.

The camera coordinate system and the world coordinate system are shown in Figure 11. Two parallel slash represent for the detected road, U-V represents for the camera coordinate system and XYZ represents for the world coordinate system in the chart. The world coordinate system coincides with the image coordinate system, and the origin of coordinates is the camera’s optical center. So the included angle between the detected road line and Z axis can be calculated for the control system to realize the parameters calculation of car’s navigation in the Figure11.

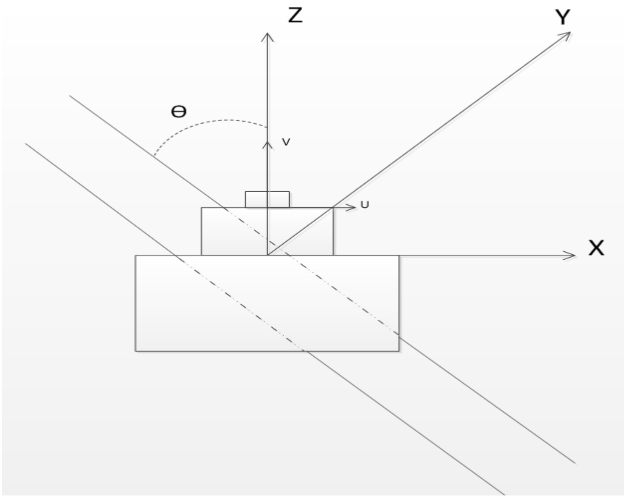


Figure 11. Visual Coordinates Diagram

3.3. Road Visual Obstacle Avoidance

The structure of the car is shown in Figure 2. Five ultrasonic sensors are placed on the head of the car, respectively located at the Less Left, Less Right, Left, Right and Middle of five directions in order to measure the distance information of each directions, and output data indicates the direction of AGV vehicle movement. While on the road the control system gets the distance information from the five ultrasonic sensors, establish fuzzy language collection and the fuzzy control rules. The fuzzy controller uses five ultrasonic sensors to collect data to continuously correct the car's direction in order to achieve obstacle avoidance function of the car.

(1) The fuzzification of inputs. While on the road, five ultrasonic sensors turn ranging to measure the distance and the ranging can be considered approximate synchronous due to fast rotation. By comparing the distances of five ultrasonic obtaining, obstacles can be considered to be located at a minimum distance from the ultrasonic sensor. When the measured distance is more than one metre, the system will ignore the presence of obstacles and so it can greatly improve the efficiency and reduce the range of error.

The input of fuzzy controller for obstacle avoidance AGV is composed of two parts: the direction and distance information of barriers. The fuzzy subsets of direction include the Left (L), Less left (LL), Middle (M), Less Right (LR), Right (R). The fuzzy subsets of distance include {far , middle , close, death}.The obstacle distance in the interval [0cm, 5cm] can be considered as a fuzzy subset of " death "; Obstacle distance in the interval [5cm, 35cm] can be considered as a fuzzy subset of " close "; Obstacle distance in the interval [35cm, 65cm] can be considered as a fuzzy subset " middle "; Obstacle distance in the interval [65cm, 100cm] can be considered as a fuzzy subset of "far"; More than 100cm can ignore the existence of obstructions. The above classification of distance is determined by the body length and the running speed of AGV.

(2) The fuzzy inference rules. The output of the fuzzy controller system stands for the turning direction of AGV. The car's turning directions are divided into 5 fuzzy subsets. Respectively:

Turn Left—TL, Turn less Left-- TLL
Turn Visual—TV, Turn Right-- TR
Turn Less Right—TLR

Among them TL (TR) is at a 45-degree angle left turning (right turning), TLL (TLR) is at a 30-degree left turning (right turning); Fuzzy control rules are primarily based on the "sense-reasoning" behavior in biology. Avoidance will be in accordance with people's driving thinking to reason. The following inference rules of fuzzy control are given according to the experience. As a matter of experience, the fuzzy control inference rule is shown in table 1. According to the fuzzy control table, fuzzy control table is obtained by using the MATLAB programming to realize synthetic fuzzy reasoning. The movement-control program of robot calculates motion path according to the fuzzy control table. The fuzzy control process of the car walking is shown in Figure 12.

Table 1. Fuzzy Control Inference Rule Table

	Long-distance	Middle-distance	Short-distance	Dead-distance
Left side	No response	Less right turning	Right turning	Stop
Less left side	Less right turning	Right turning	Right turning	Stop
Less right side	Less left turning	Left turning	Left turning	Stop
Right side	No response	Less left turning	Left turning	Stop

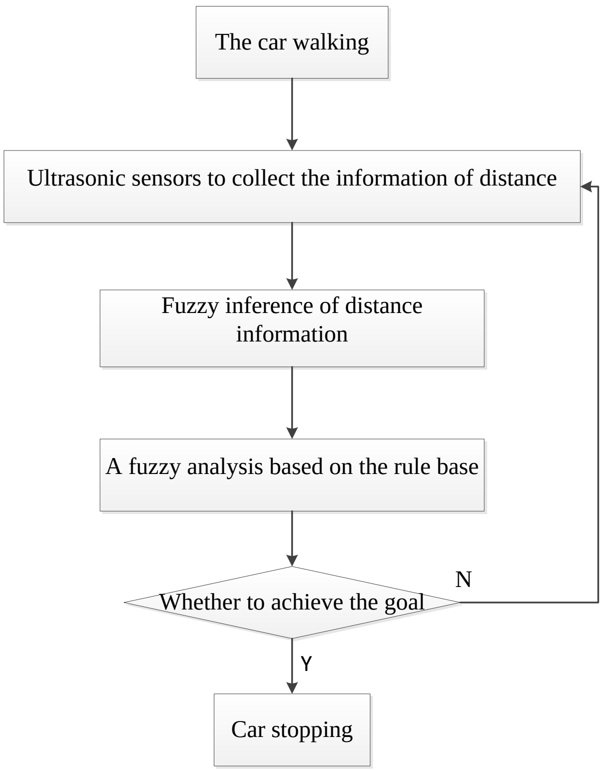


Figure 12. Car-avoidance Fuzzy Control Flow Chart

4. Experimental Design and Analysis of the Results

The research designs an experiment of automatic visual navigation for AGV. The test choose the reflective floor and cement floor as sites, and the test time is around 10 minutes. The process of test is: firstly, a black tape is posted on the two kinds of ground, and the tape's shape is an irregular round. The car will be placed on the black tape, then operating control system and applying the road detection and visual navigation. The experiment is based on four-degree of freedom picking manipulator architecture. In order to verify the effect and traceability of controller when the car walks on the field road with straight line and curve line, the initial speed of testing car is 0.5m /s. Straight and curved path tracking results are shown in Figure 13 and 14. From the Figure we can see that the fuzzy controller can accurately track a straight path with deviation in 1.5cm, and also has a very good tracking performance on curved paths whose maximum deviation is less than 6 cm. While in the process of walking, the random obstacles are placed 30 times in the front of the car. With 29 times of the successful obstacle avoidance, the success rate is up to 96.67%.

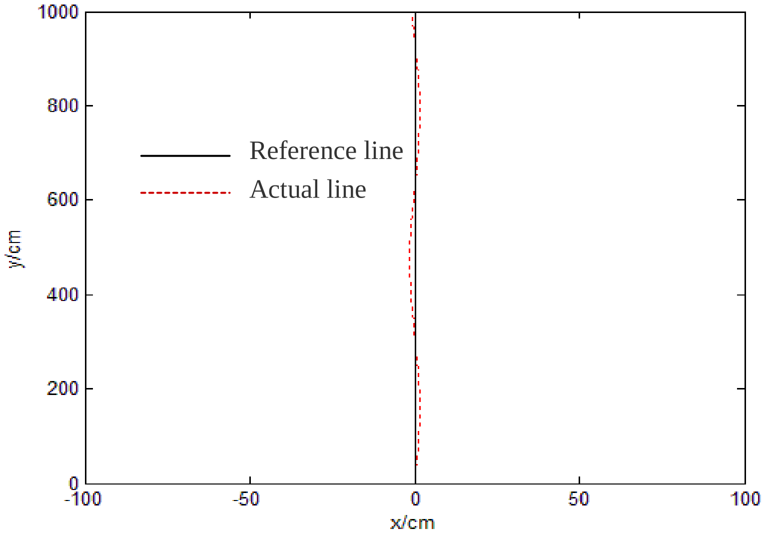


Figure 13. Results of Straight Line Detection Tracking

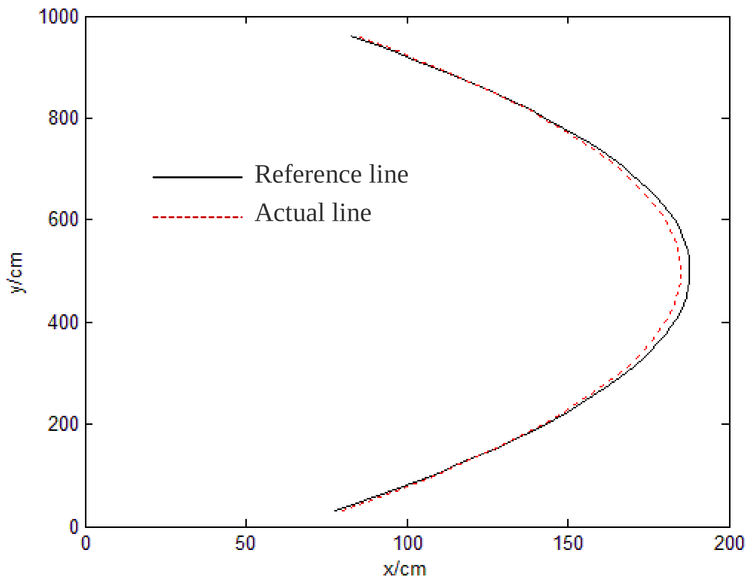


Figure 14. Results of Curve Detection Tracking

5. Conclusion

The visual navigation technology in autonomous walking for picking robot is studied. The software and hardware of visual navigation system for car to walk is designed. Through processing the road image, the improvement of Hough examination method realized the extraction of path information; With the ultrasonic sensor for real-time detection of obstacle avoidance, making use of the fuzzy real-time controller monitoring for obstacle avoidance, AGV will realize the real-time obstacle avoidance effectively during the car walking. Experimental result shows that the maximum error of the visual navigation is 1.5cm when the car walks in a straight line. The maximum error for curve walking is 6cm, and the success rate of obstacle avoidance reaches 96.67%. The study provides technical support for the walking robot's visual navigation.

Acknowledgments

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References

[1] Jiang Guixiang. Port loading and unloading automation research on key technology of robot vision navigation system. Shanghai Maritime University, **(2003)**.
[2] D.L.Boley K.T.Sutherland. A Rapidly Converging Recursive Method for Mobile Robot Localization. International Journal of Robotics Reaearch, 10,17 **(2005)**.
[3] Amy J. Briggs, Daniel Scharstein, Darius Braziunas. Mobile Robot Navigation Using Self-Similar Landmarks. Proc IEEE Int Conf Robotics and Automation,**(2000)**,pp.1428-1434.
[4] Kise M, Zhang Q. A stereov ision-based crop row detection method for tractor-autom ated gu idance. Biosystems Engineering, 4, 90,**(2005)**.
[5] Han S, D icksonM A, NiB, et al. A robust procedure to obtain a guidance directrix for vision-based vehicle guidance systems. Computers and Electronics in Agriculture, 3, 43,**(2004)**.
[6] Li Xiaoli. Vision navigation system simulation of the autonomous robot and design of driving control system. Northeast Agricultural University, **(2011)**.
[7] Zhao Guiping, Teng Wenxiang. The application and development of visual navigation technology of vehicle history. highway traffic science and technology, 4,**(2014)**.
[8] Sun Yuanyi, Zhang Shaolei, Li Wei. The navigation path identification of cotton spraying agricultural robot. Journal of Tsinghua University: Natural Science Edition, 2,47,**(2007)**.
[9] yong-xin ren, Tan Yu, hui-hua Yang, etc. Based on the fuzzy control of cucumber visual navigation of picking robot. Journal of jiangsu university (natural science edition), 4,30,**(2009)**.
[10] Zhu Haifei. AGV autonomous navigation system based on vision. Nanjing information engineering university, **(2013)**.
[11] WANG Jingxue, ZHU Qing, WANG Weixi, et al. Straight line extraction algorithm by Hough transform combining edge grouping. Journal of Remote Sensing, 2, 18, **(2014)**.
[12] Guo Siyu, Zhou Leqian,Wen He. Based on two value image neighborhood weighting straight line Hough transformation. Electronic Measuring and Instruments journal, 5,28,**(2014)**.

