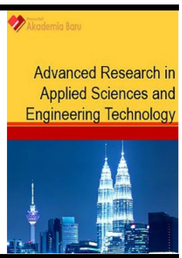
Penerbit Akademia Baru

Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage: www.akademiabaru.com/araset.html

ISSN: 2462-1943



Lane detection using a stereo vision camera

Open Access

Masoud Samadi [1,*], Mohd Fauzi Othman [2], M. Farihin Talib [1], A. A. Anuar [1]

[1] Centre for Artificial Intelligence and Robotics, Universiti Teknologi Malaysia, 54100 Kuala Lumpur, Malaysia
[2] Department of Electronic System Engineering, Malaysia-Japan International Institute of Technology, Universiti Teknologi Malaysia, 54100 Kuala Lumpur, Malaysia

ARTICLE INFO

Article history:
Received 31 May 2016
Received in revised form 30 June 2016
Accepted 15 August 2016
Available online 19 December 2016

Keywords:
Lane detection, Stereo vision, Disparity map

ABSTRACT

Nowadays, intelligent vehicles have received a considerable attention among the researchers to reduce the number of collisions and road accidents. One of the challenging tasks for these vehicles is road lane detection or road boundaries detection. In this research, a lane detection algorithm was developed to detect the right and left lane markers on the road by using two cameras which act as a stereo vision for the system. It is based on edge detection by using Canny Edge Detection to reduce unnecessary data on the images and to perform features recognition for the lane. After the features has been extracted, the algorithm is followed by Hough Transform method to generate the detected lines on the image obtained from the stereo vision camera. The algorithm has to work in different environment to be used in real world applications. The stereo vision algorithm is implemented to generate disparity map of area. This helps to gain more information on environment, such as the estimated distance of the lines, the distance of the vehicle to the turns. The experiment result shows the detection of right and left lane on the road with disparity map to determine an estimate of the distance of detected lanes from the stereo vision camera.

1. Introduction

The requirement for transportation has increased significantly from time to time. There are a lot of vehicles and transportation on the road now. Unfortunately, more vehicles on the road means there a higher number of accidents that can happen. According to the World Health Organization, road traffic injuries caused an estimated 1.24 million deaths worldwide in 2010, slightly decrease from 1.26 million in 2000 [1]. Up to 90% of these accidents are caused by driver faults. Some of the main causes are driving in sleepy or tired condition, drunk driver, usage of mobile phone while driving, bad health condition and disobeying road regulations [2].

* *Corresponding author.*
E-mail address: solariseir@ieee.org (Masoud Samadi)

One of the solutions for these problems that have received considerable attention is automated driving system. The research in automated driving has gained interest from researchers worldwide. A lot of different aspects have to be considered in developing the technology to be utilized wisely. Lane detection is one of them. This technology has been an active research topic for many systems such as adaptive cruise control, lane change assist and fully autonomous driving system [3,5].

Road lane detection system should navigate autonomously or assist driver in straight and curved, white and yellow, single, and double, solid and broken and pavement or highway lane boundaries. Furthermore, the system should be able to perform under noisy conditions such as shadows, puddle, stain, and highlight [4]. The algorithm consists of three main parts, which pre-processing, post-processing and lane recognition. These parts imitate the human abilities to recognize road lane from viewing with the eyes based on stereo vision properties, analyzing by the brain and then providing an analyzed result.

The advantage of the analysis of stereo images instead of a monocular sequence of images is the possibility to detect directly the presence of obstacles, which, in the case of an optical flow-based approach, is indirectly derived from the analysis of the velocity field [8]. The images from stereo visions are fused through a process called binocular fusion to produce an image where depth perception can be determined. Depth perception is obtained from the displacement between the two image capture devices. The stereovision algorithm allows the elimination of the assumptions of flat road, constant pitch angle or absence of roll angle (which is the most common of all assumptions) [15].

There has been some research on lane detection [6–11], and a wide variety of algorithms of various representations including fixed-width line pairs, spline ribbon, and deformable-template model. Detection and tracking techniques from Hough transform to probabilistic fitting, edge detection, bilateral filter, lane boundaries projective model has been proposed. Bilateral filter is a simple and non-iterative scheme [12] which smoothen the image while preserving edges and lane boundaries projective model using lane model, gradient direction feature, lane likelihood function and lane prior information to obtain lane posterior probability. All the methods can identify the straight lanes in a very effective manner but all these methods have ignored the detection of curved lanes [14]. This paper presents a robust road lane detection algorithm to detect the left and right lanes in different weathers and non-ideal lighting conditions. The algorithm consists of optimization of Canny edge detection and Hough Transform. The system captures images from a front viewing vision sensor placed facing the road, then a series of image processing is applied to generate the road model. Canny edge detection performs features recognition, followed by Hough Transform for lane generation of the road. The methods have efficient image contrast and better curved lane detection.

2. Methodology

2.1. Lane detection algorithm

The block diagram of the lane detection system is displayed in Fig. 1. The image of the road captures by two cameras which is mounted on the vehicle. These images are used to generate information for detection part. In this stage, the left and right images of the road are using in the computational part which is the pre-processing stage of the methodology. The lane detection algorithm consists of two parts; left detection part for the left camera and right detection part for the right camera. The part is divided so that the configuration can be edited easily without having to reconstruct the algorithm over and over again. For the first step of the algorithm, image acquisition has to be done for further image processing. The users have the options to whether use real-time video processing or video files that have been recorded. After that, we have to set the Region of

Interest (ROI) for the image obtained. Hence, we designed a mask to eliminate the background information and only use the desired area for detection.

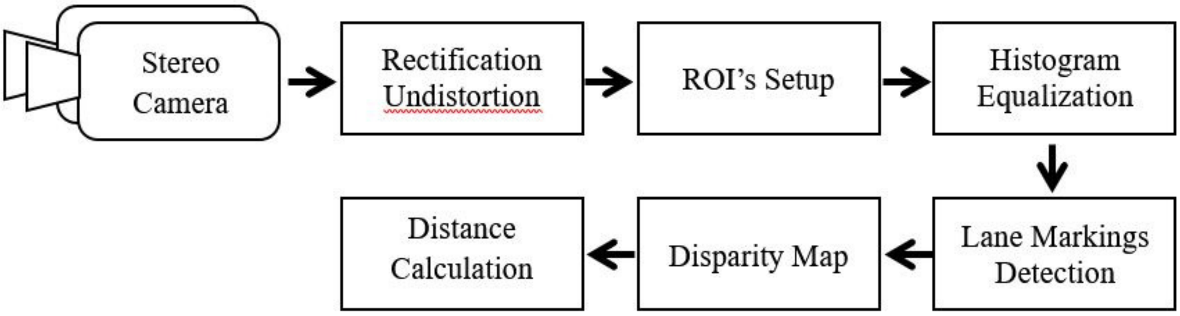


Fig. 1. System workflow

The next step is to improve the contrast in the images. It is important for the images to have a solid contrast for the lane to be easier to detect. This is done by executing histogram equalization. It is a graphical representation of the intensity distribution of the image which quantifies the number of pixels for each intensity value considered. The images obtained are converted from any sources to equalize the histogram of the images on all the three channels. After that Edge Detection will take place to perform feature recognition for the system which is to make the lines on the desired lanes appear clearly for the detection part. Edge Detection uses two thresholds value which are upper and lower thresholds. The pixel is considered as an edge if a pixel gradient is higher than the upper threshold value. On the other hand, it cannot be accepted if a pixel gradient value is below the lower threshold.

After the edge detection has been done, the next step is to apply the Hough Transform method. This is where the lane detected on the image is generated on the output images. As mentioned in the literature review sections, for each point of (x_0, y_0) , the equation for the group of lines that goes through that point is:

$$\rho_\theta = x_0 \cos\theta + y_0 \sin\theta \quad (1)$$

Each pair of (ρ_θ, θ) represents each line that passes by (x_0, y_0). Sinusoidal curves are obtained after the group of lines has been plotted. To detect a line, the number of intersections between curves has to be determined. From that, the line represented by that intersection has more points if there are a lot of curves intersecting. In general, a lower threshold value of intersections is needed to detect a line. This method keeps track of the intersection between curves at every point in the images.

2.2. Stereo vision algorithm

Stereo vision camera acts as the medium or the input sensor to obtain data and information of the road. Both of the images from right and left cameras go through the distortion function in order to fix the lens distortion and the calibration matrix is used to rectify them. The differential transform is a non-parametric algorithm and has the ability to work in different kinds of environment [9]. It is used to determine the disparity map of the captured images. Equation 2 is used for the transform.

$$\zeta = (p_1, p_2) = |p_1 - p_2| \quad (2)$$

$P1$ presents the pixel located in the window, whereas the adjacent pixels are demonstrated by $P2$. The result of ζ is the absolute differential value between the center pixel of the window and the neighbourhood pixels.

$$I_{diff}(u,v) = \max_{i=-\frac{n}{2}} \max_{j=-\frac{m}{2}} (\zeta(I(u,v), I(u+i, v+j))) \tag{3}$$

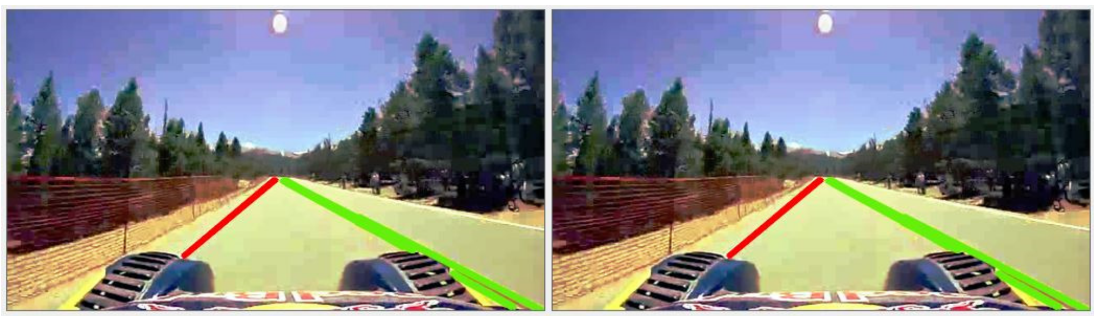
I_{diff} denotes the maximum differences between the center pixel of an $m \times n$ window and all of the neighbouring pixels. The distance obtained from the left and right cameras are displayed as pixel values in the disparity map image. The disparity map should visualize the lanes and other objects in the images in grey scale formed with different disparity on the colour. The objects which are nearer to the camera will appear brighter than the objects that are further. The distance of detected lanes in the image can be determined from the pixel density value in the disparity map. Based on experiment, an equation can be extracted from the relationship between the distance and pixel density values of the disparity map to determine the estimated distance which is:

$$Distance(x,y) = -101.5 \times \ln[Disparity(x,y)] + 586.3 \tag{4}$$

This equation brings about the depth value of a point with coordinates [x; y] by using the disparity map pixel [x;y] density value. The distance is in meter and is used in the lane detection algorithm of the system.

3. Results and discussion

The algorithm is tested on different stages to make sure that the detection is effective on various road conditions. Fig. 3 shows the results of lane detection algorithms on a sample video file. For this test, we used a core i7 CPU with 8 GB of RAM, and the algorithm was running on a window 10 operation system. The program developed in C++ language with Visual Studio 2015 programing environment. Fig. 2 shows the stereo image of a recorded video, as it can be seen the proposed algorithm detects the left and right lines. Fig. 2a is the image taken by the left camera and Fig. 2a belongs to the right camera.



(a) (b)

Fig. 2. Lane detection on random video file

The left line marked as red and the right line is green. The number of lines detected can vary according to the threshold value. From the results, it shows that the higher the threshold value, the fewer lines detected. The threshold value that is used for the result above is 50. Moreover, the lines have various orientations, ensuring that oddly oriented lane markings are also detected.

After that the algorithm selects the best two candidate lines that qualify as left and right lanes markers on the road. The output shows perfect match with the lane marking on the road. Two Point Grey Flea 3 cameras with USB 3.0 bus are used for the real-time experiments. These cameras could transfer an image of 1920 * 1080 with 60 frame per second speed. Fig. 3 displays the Point Grey cameras and the way they are connected to each other. They are installed on a pan and tilt servo motors to rotate around via computer.

Fig. 3. Stereo Vision Cameras

Figure 4 shows the results of the algorithm in the real-time experiment inside the university campus. Due to traffic rules and regulations we couldn’t take the experimental vehicle to the outside roads, hence all the real-time experiments are done inside the campus area. Fig. 4(a) is the image captured by the left camera and Fig. 4(b) is the right camera’s image. As these figures demonstrate the proposed algorithm detects the left and right lane markers a defined them by red and green marks.

(a) (b)

Fig. 4. Lane Detection during Real-time Scene

The displacement distance presented between the left and right cameras is projected as pixel values in the disparity map image. The disparity map should visualize the images in grey scale formed with different disparity on the color. The objects which are nearer to the camera will appear brighter than the objects that are further away. The distance of each object in the image can be determined from the pixel density value in the disparity map. The distance between the stereo vision cameras and detected lane can be estimated. Fig. 5(a) shows the real-time experiment with distance estimation on the detected lane. Fig. 5a is the image captured by the left camera and Fig. 5(b) belongs the right camera. Fig. 5(c) shows the angles of each detected lines and their relative distance to each other and the distance of the center of the lines to the vehicle. Both lines are marked as red because of their angles and their relative distance to each other. These lines are very close to each other (around 90cm from each other) which means the vehicle cannot fit in between them. The center of the lines is 2.5 meter away from the vehicle which is a point we chose for display propose only. The distance of the vehicle and all points of lines are stored in a matrix to be used later. Also, the angle of each section of lines and their relative distance to each other are stored as well.

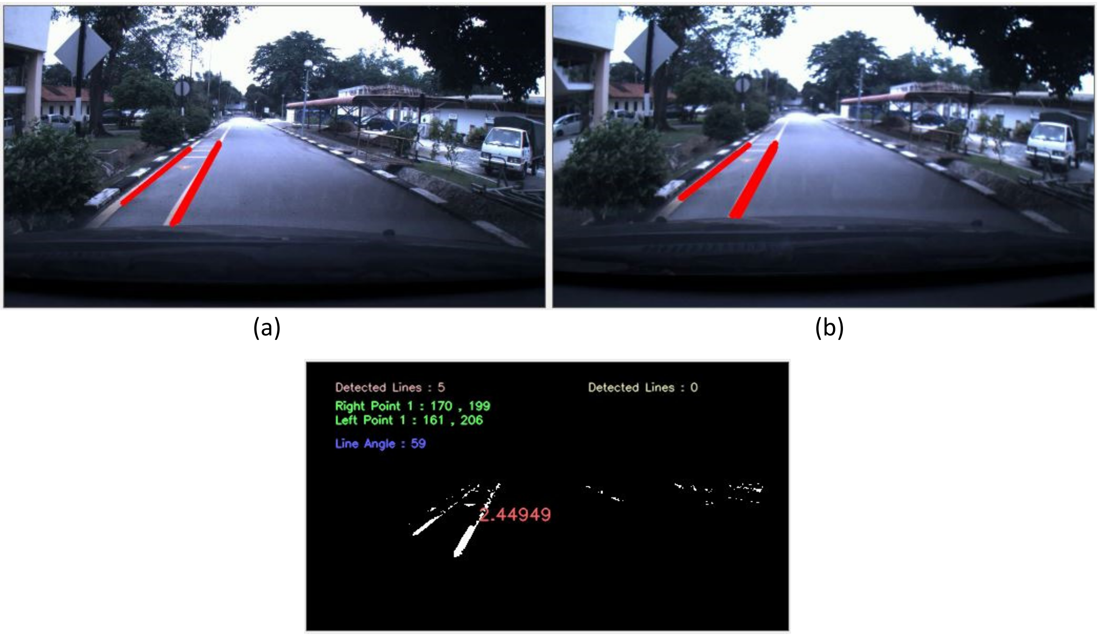


Fig. 5. Distance Estimated with Disparity Map on the Lane Detection Result

4. Conclusion

The proposed method had the ability to detect lane markers in the real-time experiment. It is also easy to use and at a low cost. The lines in an image are found from the equation for every possible line through a point of the image. Moreover, the depth information of the target object is achieved from the disparity map through the stereo vision algorithm and the distance estimation can be obtained.

This research shows that it is possible to use the stereo vision cameras as the input sensors for the system. This can help the automotive industry as safety precautions in situations that involve human errors such as sleepy and inattentive drivers and drivers. The results obtained proved the efficiency and performance of the algorithm in various situations. This project can also be a kick start for a better technological advancement in autonomous driving system technology.

For future works, the whole system can be improved to detect turns and curves and distance to junction and turns by implementing stereo vision techniques in autonomous vehicles.

Acknowledgment

We would like to thank the Centre for Artificial Intelligence and Robotics (CAIRO), Universiti Teknologi Malaysia (UTM) and Malaysia-Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia (UTM) under Grant No: Q.K130000.2543.10H12 for providing the research facilities and support.

References

[1] World Health Organization. Violence, Injury Prevention, and World Health Organization. *Global status report on road safety 2013: supporting a decade of action*. World Health Organization, 2013.

[2] Naghavi, M., H. Wang, R. Lozano, A. Davis, X. Liang, and M. Zhou. "GBD 2013 Mortality and Causes of Death Collaborators. Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013." *Lancet* 385, no. 9963 (2015): 117-71.

[3] Rodrigues, Maradona, Andrew McGordon, Graham Gest, and James Marco. "Adaptive tactical behaviour planner for autonomous ground vehicle." In *Control (CONTROL), 2016 UKACC 11th International Conference on*, pp. 1-8. IEEE, 2016.

[4] Li, Qing, Nanning Zheng, and Hong Cheng. "Springrobot: A prototype autonomous vehicle and its algorithms for lane detection." *IEEE Transactions on Intelligent Transportation Systems* 5, no. 4 (2004): 300-308.

[5] Jeon, Jeongmin, Sung-Ho Hwang, and Hyungpil Moon. "Monocular vision-based object recognition for autonomous vehicle driving in a real driving environment." In *Ubiquitous Robots and Ambient Intelligence (URAI), 2016 13th International Conference on*, pp. 393-399. IEEE, 2016.

[6] Franke, U., and I. Kutzbach. "Fast stereo based object detection for stop&go traffic." In *Intelligent vehicles symposium, 1996., proceedings of the 1996 IEEE*, pp. 339-344. IEEE, 1996.

[7] Ross, Bill. "A practical stereo vision system." In *IEEE Computer Society Conference On Computer Vision and Pattern Recognition*, pp. 148-148. Institute of Electrical Engineers Inc (IEEE), 1993.

[8] Bertozzi, Massimo, and Alberto Broggi. "GOLD: A parallel real-time stereo vision system for generic obstacle and lane detection." *IEEE transactions on image processing* 7, no. 1 (1998): 62-81.

[9] Samadi, M., Othman, M.F., Talib, M.F., "Fast and Robust Stereo Matching Algorithm for Obstacle Detection In Robotic Vision Systems." *Jurnal Teknologi* 78, no. 6-13 (2016) 129-136.

[10] Ieng, Sio-Song, Jean-Philippe Tarel, and Raphael Labayrade. "On the design of a single lane-markings detectors regardless the on-board camera's position." In *Intelligent Vehicles Symposium, 2003. Proceedings. IEEE*, pp. 564-569. IEEE, 2003.

[11] Wang, Yue, Eam Khwang Teoh, and Dinggang Shen. "Lane detection and tracking using B-Snake." *Image and Vision computing* 22, no. 4 (2004): 269-280.

[12] Zhou, Yong, Rong Xu, Xiaofeng Hu, and Qingtai Ye. "A robust lane detection and tracking method based on computer vision." *Measurement science and technology* 17, no. 4 (2006): 736–745.

[13] Prakash, J., M. B. Meenavathi, and K. Rajesh. "Linear feature extraction using combined approach of Hough transform, Eigen values and Raster scan algorithms." In *Intelligent Sensing and Information Processing, 2006. ICISIP 2006. Fourth International Conference on*, pp. 65-70. IEEE, 2006.

[14] Guo, Jinghua, Ping Hu, and Rongben Wang. "Nonlinear Coordinated Steering and Braking Control of Vision-Based Autonomous Vehicles in Emergency Obstacle Avoidance." in *IEEE Transactions on Intelligent Transportation Systems* 17, no. 11 (2016): 3230-3240.

[15] Du, Xinxin, Kok Kiong Tan, and Kyaw Ko Ko Htet. "Vision-based lane line detection for autonomous vehicle navigation and guidance." In *Control Conference (ASCC), 2015 10th Asian*, pp. 1-5. IEEE, 2015.