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Research paper

Real-time Lane Detection Based on Image Edge Feature and Hough Transform

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Abstract

Background and Objectives: Lane detection systems are an important part of safe and secure driving by alerting the driver in the event of deviations from the main lane. Lane detection can also save the lives of car occupants if they deviate from the road due to driver distraction.
Methods: In this paper, a real-time and illumination invariant lane detection method on high-speed video images is presented in three steps. In the first step, the necessary preprocessing including noise removal, image conversion from RGB colour to grey and the binarizing input image is done. Then, a polygon area as the region of interest is chosen in front of the vehicle to increase the processing speed. Finally, edges of the image in the region of interest are obtained with edge detection algorithm and then lanes on both sides of the vehicle are identified by using the Hough transform.
Results: The implementation of the proposed method was performed on the IROADS database. The proposed method works well under different daylight conditions, such as sunny, snowy or rainy days and inside the tunnels. Implementation results show that the proposed algorithm has an average processing time of 28 milliseconds per frame and detection accuracy of 96.78%.
Conclusion: In this paper a straightforward method to identify road lines using the edge feature is described on high-speed video images.

Introduction

Due to the growing number of cars, there are many accidents in the world each year and lots of financial and human losses [1]. The main cause of many accidents is human errors such as fatigue, drowsiness, lack of concentration or unawareness of the road conditions [1]. In recent years, car companies have made efforts to add driver assistance systems to the car to help the driver control and steer the car [2]. Driver assistance systems are now increasingly being used as an option to provide greater security for luxury cars [3]. Road diversion warning systems, crash warning systems, lane detection systems for lane departure, intersection and traffic light detection systems, and objects detection systems in front of the vehicle are some of the driver assistance system [4]-[6]. Among the driver assistance systems that have been proposed so far, the lane detection system is very important in preventing vehicle deviations and road accidents. Cars that have driver assistance systems are called smart cars [2]. The role of road line detection is significant in the field of intelligent vehicles and has many applications in unmanned vehicles [2]. Smart cars collect information from road lines and guide the car in between these lines [3].

Lane detection means locating the boundaries of the lines in an image of the road without prior knowledge of the location of the road lines [2]. The lane detection system is designed for the quick response and timely warning to the driver in the event of a deviation from the main route, which allows better control over the vehicle. Lane detection system has been proposed as an important technology for safe driving. This system prevents the vehicle from deviating by correctly determining the position of the vehicle and moving between the road lines.

In lane detection systems, there are several ways to extract road lines. These include the installation of magnetic indicators on roads and the use of sensors, high-precision GPS and image processing [7]. The most accurate way to find road lines is to embed magnetic markers all over the road that can be detected by sensors on the car [7]. Another way to determine the current location of a vehicle is to determine the global difference in position relative to road lines [8], which is also relatively expensive. The most accessible and affordable way to identify road lines is image processing that uses a video camera to extract road lines from the image [8]. Since video images contain valuable information about the environment [9], they play an important role in lane detection. In lane detection systems, in-car cameras are used which are placed behind the windshield.

For example, the study by Bertozzi (1998) has applied the GOLD system which is one of the most popular lane detection systems based on road imaging by a camera installed in a car [10]. The detection of the route is based on the technique of matching the model that obtains the road lines. Furthermore, the location of the obstacles in front of the car is done based on the processing of stereo images. In this method, the perspective effect of the image is removed so that the pattern matching technique can be used [11]. Then, the parts of the straight lines of the image are extracted by searching for horizontal patterns of dark-light-dark lighting using a horizontal edge detector. Then parts that are close together or have the same direction are combined to eliminate the possibility of error by noise or blockage. Finally, the lines that match with a road model are selected [12].

A. Literature Review

This study has done a review of 9 papers conducted from 2015-2020. For the aim of this study, all reviewed studies have applied have Hough transform with more details in the following:

The study by Bhujbal and Narote (2015), uses Hough transform and Euclidean distance. First, the image is transferred from the RGB space to the YCbCr space. The Y component of the image is used to identify the lines since the human visual system is more sensitive to light. To improve the speed and accuracy of the system, the lower part of the image is selected as the area of interest. Equalization of histograms is used in the area of interest to increase the contrast between the road surface and the road lines, and, a binary image is obtained by Otsu thresholding [13]. The area of interest is then divided into two sub-areas and for each sub-area, the Canny edge detection and the Hough transform algorithms are used to identify the left and right lines of the road separately [14].

In the study by Son, et.al. (2015), a method of detecting road lines is provided that is resistant to changes in lighting. In this method, first, the edges of the image are extracted using the Canny edge detection, the image lines are obtained using Hough transform, and the collision location of the identified lines is calculated. The centre of the district with the most votes is chosen as the vanishing point and the bottom area of the vanishing point in the image is selected as the region of interest. For the proposed algorithm to be resistant to changes in brightness, the yellow and white lines of the road are determined separately. Then, the binary image is created by determining the binary value 1 for the areas related to the road lines and the value 0 for the rest of the image areas. Then, the areas of the lines are marked and the centre of each area is calculated using the connected component clustering method in the binary image. The angle of each area and the point of contact with the y-axis are also calculated. Areas that have the same angle and intersection are combined to form an area, and the left and right lines of the road are determined in the image [15].

In the study by Duong, et.al. (2016), the input image is first taken out of perspective mode so that the road lines are parallel to each other [16]. The image obtained from the colour mode is then converted to grey, and the edges of the grey image are extracted using the edge recognition algorithm [17]. Small image noises are removed using the morphology expansion operator. Then, the road lines are identified using the Hough transform and compared with the previous image frame lines. If lines fit, they are preserved, otherwise, the next Hough transform lines are checked.

To simplify the process of recognizing lines, in the study by Lotfy, et. al. (2016) the road image in front of the car is obtained from the bird's eye view, which makes the road lines parallel. Two one-dimensional filters of Gaussian and Laplace are used to identify the edges of the image [18], and the binary image is obtained by using the Otsu threshold and calculated using the Hough transform of the image lines. Next, the main road lines are obtained using a series of horizontal lines and their points of contact with the image lines are identified with the help of the least mean square algorithm [19].

The study by Ozgunalp and Kaymak (2017) has presented a robust lane detection algorithm in Hough domain. The proposed algorithm uses road images to statistically estimate expected position and deviation on the road width. Furthermore, a mask is created in Hough domain to apply necessary restrictions to road width and vehicle position [20].

The study by Li, et. al. (2018) has proposed a new method for pre-processing and selecting the area of interest. In this method, the input frame is read first and then, the preprocessing process is performed on the input image, then the region of interest is selected, and the road lines are identified. In the pre-processing process, the image is first transferred to the HSV space and the white features of the image are extracted. Then, a Gaussian filter is used to reduce the noise effect and smooth the image. The image is then converted to binary by threshold processing. The bottom half of the image is then selected as the area of interest. The edges of the image are extracted using the edge detection algorithm, and the main lines of the road are identified using the Hough transform. Finally, the extended Kalman filter is used to detect and track road lines in real-time [21].

The study by Andrade, et. al. (2018) has presented a novel strategy for lane detection with good accuracy levels. The input image is reduced from three to one layer and the sharpness is improved. In this study, the region of interest is defined based on the minimum safe distance from the vehicle ahead. Hough Transform is used to achieve a smooth lane fitting [22].

In the study by Sun, et. al. (2019), a multi-stage Hough space calculation is proposed for a lane-detection task. An efficient Hough Transform was introduced to extract and classify line segments from images [23]. Kalman filtering was employed to smooth the probabilistic Hough space across frames to eliminate the disturbance from occlusion [24], movement of the vehicle, and classification error. The filtered probabilistic Hough space was used to remove line segments with low probability values (threshold was set as 0.7) and to keep those with high probability values [25].

The study by Marzougui, et. al. (2020) has defined a Region of Interest (ROI) [26] to ensure reliable real-time system. Hough Transform is defined to extract boundary information and to detect road lane markings edges. Otsu's threshold is used to enhance pre-processing results [27], to deal with lighting problems and to obtain gradients information. The proposed method ensures accurate lane tracking and collects valid information on vehicle orientation [28].

B. Aim and Objectives

There are several challenges in providing a suitable algorithm for detecting road lines including sunlight at different times of the day, the shade of buildings, trees and cars, different weather conditions, the darkness of night, headlights at night, the light inside tunnels, faint lines, continuous and discrete lines and covering Lines by other cars. This study aims to develop an algorithm that detects road lines in real-time and with high speed. The developed algorithm is resistant to changes in lighting conditions during the day.

Methodology

This paper detects road lines in real-time using video images taken from the road by a camera installed inside the car. The camera is installed inside the car behind the windshield and almost in the middle to provide an image of the road. The proposed method for identifying road lines consists of three steps: the pre-processing, selection of the region of interest, and determination of road lines. The pre-processing stage includes noise removal, conversion of the image from RGB colour space to grey space and binarization of the input image. Then, a polygonal area is selected in front of the car as the area of interest as road lines are in a certain area in front of the car In the third step, edges of the image in the area of interest are detected using Canny edge detection algorithm, and the main lines of the road are identified using the Hough transform. The flow chart of the algorithm is presented in Fig. 1.

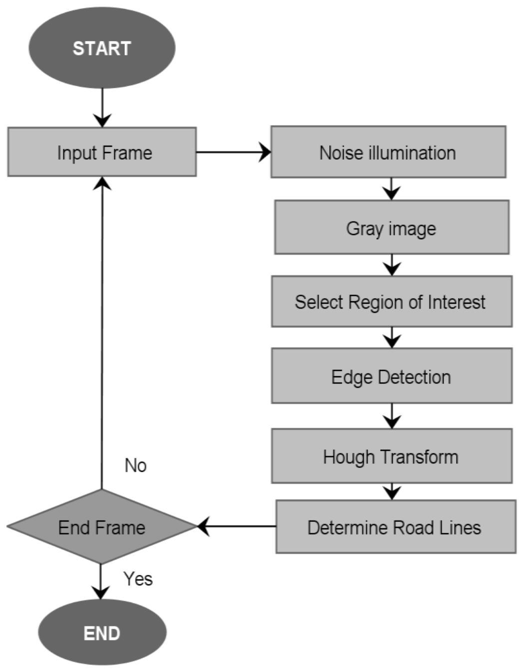

Fig. 1: Flowchart of the proposed method.

Preprocessing

At this stage, the images noise captured by the camera installed inside the car is removed using a

Gaussian filter [29] and the image becomes smoother. Figure 2 and Fig. 3 show input and output image after applying the Gaussian filter, respectively.

Fig. 2: An example of the input image.

Fig. 3: Input image after noise removal.

To reduce the algorithm calculations, the input image is converted from RGB colour space to grey space. Fig. 4 shows the input image in grey mode. Then, the input image is changed from grey space (Fig. 4) to binary image (Fig. 5) using the Otsu algorithm [30] to get the adaptive threshold.

Fig. 4: Input grey image.

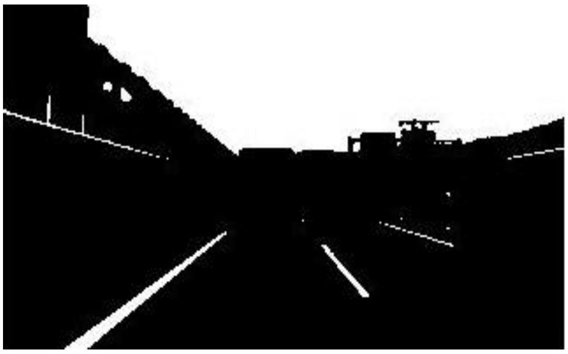

Fig. 5: Input binary image.

Selecting the Region of Interest

In the images obtained from the road surface, the road lines are in front of the car and on both sides. In this paper, a dynamic polygonal area of the image in front of the car is selected as the region of interest using a trapezoidal mask. In the design of the trapezoidal mask, the information of the vanishing point of the image is used. A trapezoid is created in the lower part of the vanishing point that covers the area in front of the car. Figure 6 shows a mask designed for the input image sample in which the part related to the area of interest is one and the rest of the image is zero. By applying this mask to the input binary image, the favourite area that includes the road lines in front of the car is selected.

Figure 7 shows the output binary image after applying the designed mask to the input binary image.

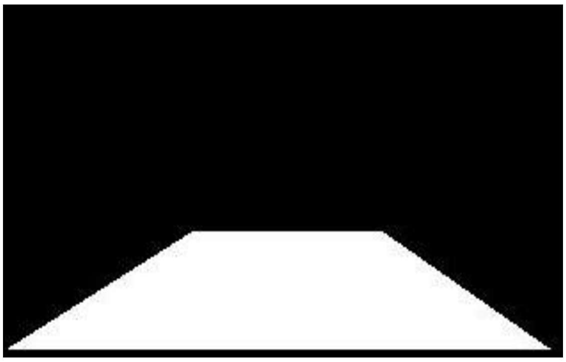

Fig. 6: Mask to determine the interest area.

Fig. 7: Binary image after applying a mask.

Determination of Road Lines

One of the most useful and effective features in identifying objects in images is the use of image edges. The edge of the image is the part where the brightness suddenly changes. Assuming that the amount of light intensity on the road is uniform and is different from the brightness of the lines, the boundary between the lines and the road (edge) can be found. There are many algorithms in this field, including Sobel, Canny, Roberts, and Prewitt [15]. This paper uses the Canny edge detection algorithm [31]. Identifying the edge in the Canny edge detection algorithm involves six steps. The first step is to filter the original image and remove the noise, for which a gaussian filter with a simple mask is used. The second step is to find strong edges using the gradient amplitude at any point. For this purpose, two masks are applied to the image, the gradient amplitude is calculated in the direction of x and y and the edge strength is calculated using (1).

$$|G| = |G_x| + |G_y| \quad (1)$$

where $|G|$ is the edge strength, $|G_x|$ is the gradient amplitude in the direction of x and $|G_y|$ is the gradient amplitude in the direction of y.

The Canny algorithm consists of two masks, one vertical and the other horizontal, as can be seen in Fig. 8.

-1	0	+1
-2	0	+2
-1	0	+1

Gx

+1	+2	+1
0	0	0
-1	-2	-1

Gy

Fig. 8: Canny algorithm masks.

The third step obtains the direction of the image edges obtained using Canny masks by (2).

$$theta = arctan\left({}^{G_y}/_{G_x} \right) \quad (2)$$

Where $theta$ is the direction of edge, G_x is the gradient in the direction of x and G_y is the gradient in the direction of y.

In the fourth step, the directions obtained in the previous step are matched to one of the four directions of 0, 45, 90 and 135 degrees. The fifth step is to suppress the non-maximum edges in which the direction is checked and the edges that cannot be detected are removed. In the sixth step, the hysteresis method is used in the Canny algorithm, for which two upper and lower threshold values are defined. Any pixel with a gradient greater than the lower threshold is accepted and with a gradient lower than the lower threshold is rejected. By applying the Canny edge detection to the binary image, we get the edges of the image are obtained. Figure 9 shows the result of applying the edge finder algorithm to the previous step image.

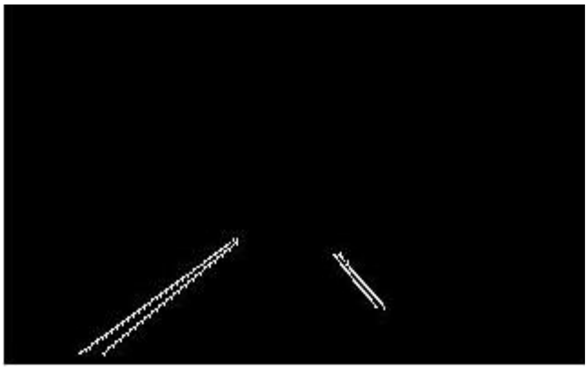

Fig. 9: Apply the Canny algorithm to the image.

In the following, the main lines of the road are identified by using the Hough transform. Hough transform is a feature extraction technique used in digital image processing, machine vision and image analysis [28]. The purpose of this conversion is to find different shapes in the image. Hough transform was initially used to identify image lines and it was used to identify various shapes such as circles and oval. In this algorithm, Hough transform is used to estimate the location of road lines and mark them. Then the closest lines to the car on both sides are considered as road lines on the left and right as shown in Fig. 10.

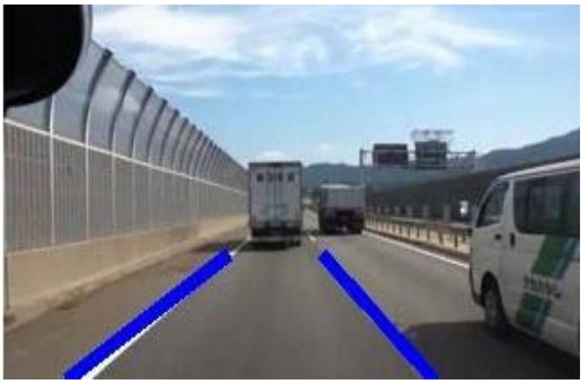

Fig. 10: Algorithm output image.

Results

The IROADS database [32] is used to evaluate the performance of the proposed algorithm. The database consists of 7 collections with a total of 4700 image strings. It covers almost all possible road conditions, including daylight, night darkness, excessive sunlight, tunnel light, day and night rainfall, and snowy roads. The dimension of each frame in this database is 360 * 640. Given that this paper examines the different lighting conditions per day, four sets of data from the IROADS database, including daytime driving in sunny, rainy, snowy, and in-tunnel conditions, are reviewed.

Figure 11 shows the results of road line detection using the proposed algorithm in different driving conditions per day.

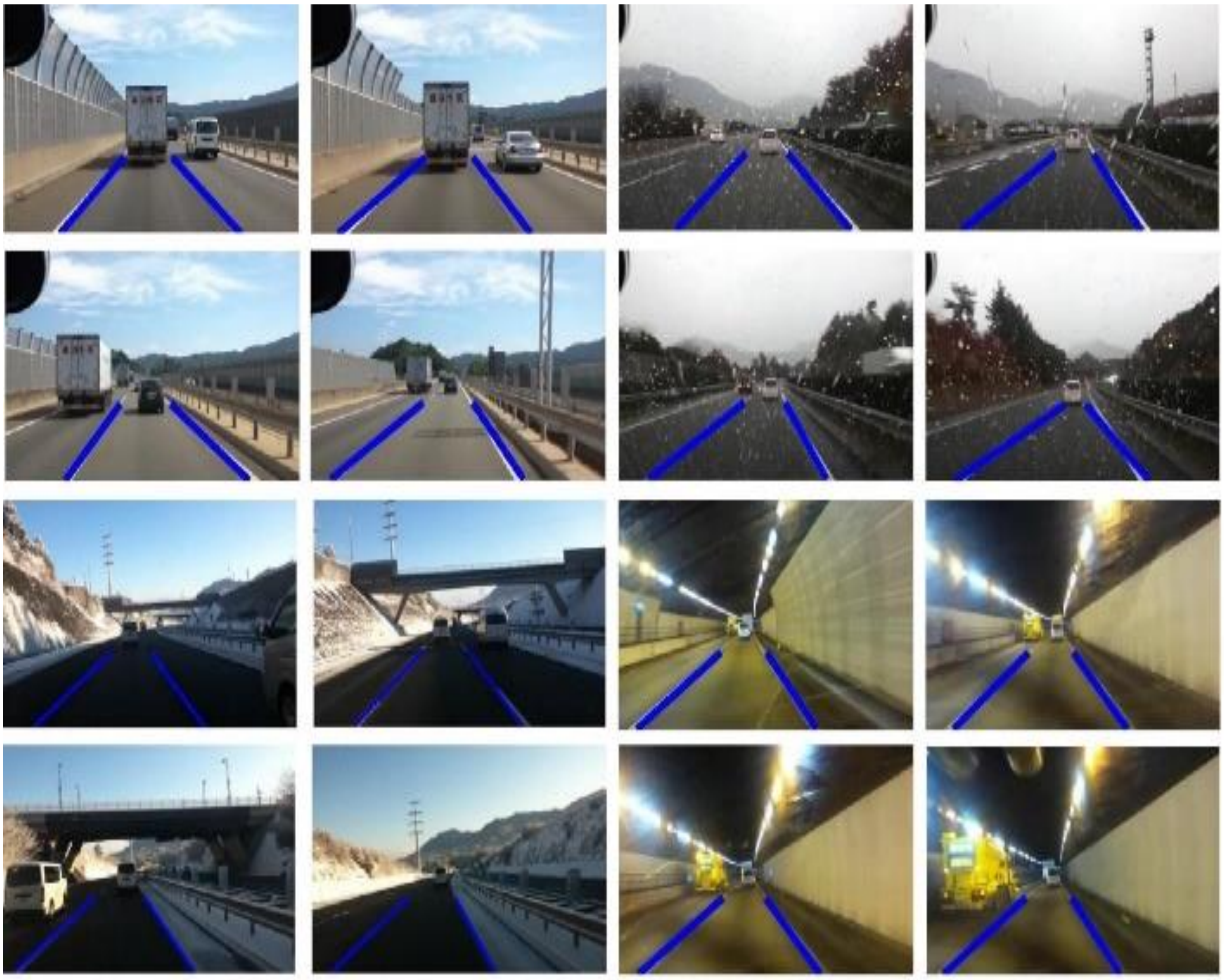

Fig. 11: Several results of the proposed algorithm.

The results of the proposed algorithm on each frame of the input image have the following two modes.

1) Correct detection, in which the lines on both sides of the car are identified correctly.

2) Incorrect detection, in which the lines on both sides or one side of the car are not correctly identified. The identification rate of the proposed algorithm is measured by the labels prepared earlier using (3).

$$DR = \frac{C}{T} \times 100 \quad (3)$$

Where DR is the detection rate (%), C is the number of correctly recognized frames and T is the total number of frames.

The average detection rate for 2828 frames of IROADS database in different daylight conditions is 96.78%, which is summarized in Table 1.

The proposed method is implemented by MATLAB software on laptop with 1/8 GHz CPU and 8 GB RAM and the average time required to process each frame is 28 milliseconds. Therefore, the proposed algorithm detects road lines in good time with high accuracy.

Discussion

To verify the performance of the lane detection algorithm, the proposed algorithm was compared with several algorithms mentioned in the literature.

Table 2 shows the comparison of results by Son's method [15], Cao's method [33], Hu's method [34] and the method applied in this study on the IROADS database [32].

According to the results of this experiment, the proposed method achieves better results in all categories except for in the Tunnel scenario. This is mainly because the line indicators in this scenario are dimmed due to the lights inside the tunnel and are not recognized for the proposed method.

However, results can be improved if information from previous frames is used.

Table 1: Identification rate of the proposed algorithm under different conditions

IROAD database	Total number of frames	Number of incorrect detection frames	Identification rate (Percentage)	Number of frames per second
IROAD Daylight	903	32	96.45	**35.2**
IROAD Rainy Day	1049	7	99.33	**35.6**
IROAD Snowy Day	569	31	94.55	**36.2**
IROAD Tunnel	307	21	93.16	**35.8**
Total	2828	91	96.78	**35.7**

Table 2: Detection result comparison

Methods	Evaluation Index	IROAD Daylight (903)	IROAD Rainy Day (1049)	IROAD Snowy Day (569)	IROAD Tunnel (307)	Total (2828)
Son's Method [15]	Identification Rate (%)	95.79	88.27	86.64	93.51	90.81
Cao's Method [33]	Identification Rate (%)	96.12	93.42	92.44	94.14	94.17
Hu's Method [34]	Identification Rate (%)	96.23	94.75	93.67	**94.46**	94.99
The method in this Study	Identification Rate (%)	**96.45**	**99.33**	**94.55**	93.16	**96.78**

The results show the effectiveness of the proposed algorithm in detecting lanes with varying conditions.

The proposed algorithm doesn't use tracking yet as detecting lanes is carried out in each image independently without using any temporal information.

Although the proposed algorithm for detecting road lines works correctly in 97% of the time, it can have errors in 3% of the cases, such as the fading of road lines, the coverage of road lines by the side car and car's direction change by the driver.

Figure 12 shows several frames in which the proposed algorithm has erroneous detection or non-detection of road lines.

The current algorithm works on the image edge property with acceptable results. Future studies by authors plan to use the color information to classify different lane boundaries (white solid lines, double yellow lines, etc.) and to employ tracking on top of the detection step which would help get rid of a lot of these false detections.

Fig. 12: False detections samples.

Conclusion

Lane detection means locating lane boundaries in a road image without prior knowledge of its location.

Lane detection system is designed to alert the driver in the event of deviations from the main lane, which enables better control of the vehicle on the road. In this paper, a straightforward method to identify road lines using the edge feature is described on high-speed video images.

In the proposed algorithm, first the necessary pre-processing, including noise removal, image conversion to the grey mode and then to binary mode, was performed.

Then, a polygonal area in front of the car was determined as the preferred area. Finally, road lines were identified using the Canny edge detection algorithm and Hough transform.

The IROADS database has been used to evaluate the performance of the proposed algorithm with the dimensions of each frame being 640*360.

In this paper, four datasets from IROADS database including daytime driving in sunny, rainy, snowy conditions and indoor tunnels are examined. The proposed algorithm has an average execution time of 28 milliseconds per frame and detection accuracy of 96.78%.

Author Contributions

A.A. Fallah and A. Soleimani proposed the main idea of the innovation of the paper and designed road map of the research. A. Soleimani and H. Khosravi verified the analytical methods. All authors discussed the results and contributed to the final manuscript.

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Conflict of Interest

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

Abbreviations

GPS	Global Positioning System
ROI	Region Of Interest
DR	Detection Rate

References

[1] J. R. Mani, N.D. Gangadhar, V.K. Reddy, "A real-time video processing based driver assist system," SASTech, 9: 9-16, 2010.

[2] F. You, R. Zhang, L. Zhong, H. Wang, J. Xu, "Lane detection algorithm for night-time digital image based on distribution feature of boundary pixels," J. Opt. Soc. Korea, 17: 188-199, 2013.

[3] A. Saha, D.D. Roy, T. Alam, K. Deb, "Automated road lane detection for intelligent vehicles," Global J. Comput. Sci. Tech., 12(6): 1-6, 2012.

[4] M. Rashid, M.A. Khan, M. Alhaisoni, S.H. Wang, S.R. Naqvi, A. Rehman, T. Saba, "A sustainable deep learning framework for object recognition using multi-layers deep features fusion and selection," Sustainability, 12(12): 5037, 2020.

[5] N. Hussain, M.A. Khan, M. Sharif, S.A. Khan, A.A. Albesher, T. Saba, A. Armaghan, "A deep neural network and classical features based scheme for objects recognition: an application for machine inspection," Multimed. Tool. Appl., 2020.

[6] M. Rashid, M.A. Khan, M. Sharif, M. Raza, M.M. Sarfraz, F. Afza, "Object detection and classification: a joint selection and fusion strategy of deep convolutional neural network and SIFT point features," Multimed. Tool. Appl., 78: 15751–15777, 2019.

[7] A.D. Forrest, M. Konca, "Autonomous Cars & Society," Worcester Polytechnic Institute, 2007.

[8] K.H. Lee, J.H. Bak, C.H. Lee, "Study on active steering control of vehicle for safe driving in highway with GPS information," in Proc. IEEE Intelligent Vehicles Symposium: 554-557, 2012.

[9] M.A. Khan, K. Javed, S.A. Khan, T. Saba, U. Habib, J.A. Khan, A.A. Abbasi, "Human action recognition using fusion of multiview and deep features: an application to video surveillance," Multimed. Tool. Appl., 2020.

[10] M. Bertozzi, A. Broggi, "GOLD: A parallel real-time stereo vision system for generic obstacle and lane detection," IEEE Trans. Image Process., 7: 62-81, 1998.

[11] H. Arshad, M.A. Khan, M.I. Sharif, M. Yasmin, J.M.R. Tavares, Y.D. Zhang, S.C. Satapathy, "A multilevel paradigm for deep convolutional neural network features selection with an application to human gait recognition," Expert Syst., 2020.

[12] M. Bertozzi, A. Broggi, "Vision-based vehicle guidance," Computer, 30: 49-55, 1997.

[13] N. Naheed, M. Shaheen, S.A. Khan, M. Alawairdhi, M.A. Khan, "Importance of features selection, attributes selection, challenges and future directions for medical imaging data: a review," CMES-Comp. Model. Eng. Sci. CMES, 125: 314-344, 2020.

[14] P.N. Bhujbal, S.P. Narote, "Lane departure warning system based on Hough transform and Euclidean distance," in Proc. 2015 Third International Conference on Image Information Processing (ICIIP): 370-373, 2015.

[15] J. Son, H. Yoo, S. Kim, K. Sohn, "Real-time illumination invariant lane detection for lane departure warning system," Expert Syst. Appl., 42: 1816-1824, 2015.

[16] T.T. Duong, C.C. Pham, T.H. P. Tran, T.P. Nguyen, J.W. Jeon, "Near real-time ego-lane detection in highway and urban streets," in Proc. 2016 IEEE International Conference on Consumer Electronics-Asia (ICCE-Asia): 1-4, 2016.

[17] R. Jiang, M. Terauchi, R. Klette, S. Wang, T. Vaudrey, "Low-level image processing for lane detection and tracking," in Proc International Conference on Arts and Technology: 190-197, 2009.

[18] A. Mehmood, M.A. Khan, M. Sharif, S.A. Khan, M. Shaheen, T. Saba, N. Riaz, I. Ashraf, "Prosperous human gait recognition: An end-to-end system based on pre-trained CNN features selection," Multimed. Tool. Appl., 2020.

[19] O.G. Lotfy, A.A. Kassem, E.M. Nassief, H.A. Ali, M.R. Ayoub, M.A. El-Moursy, M.M. Farag, "Lane departure warning tracking system based on score mechanism," in Proc. IEEE 59th International Midwest Symposium on Circuits and Systems (MWSCAS): pp. 1-4, 2016.

[20] U. Ozgunalp, S. Kaymak, "Lane detection by estimating and using restricted search space in Hough domain," Procedia Comput. Sci. 120: 148-155., 2017.

[21] M. Li, Y. Li, M. Jiang, "Lane detection based on connection of various feature extraction methods," Adv. Multimedia, 2018: 1-14, 2018.

[22] D.C. Andrade, F. Bueno, F.R. Franco, R.A. Silva, J.H.Z. Neme, E. Margraf, W.T. Omoto, F.A. Farinelli, A.M. Tusset, S. Okida, M.M.D. Santos, "A novel strategy for road lane detection and tracking based on a vehicle's forward monocular camera," IEEE Trans. Intell. Transp. Syst., 20: 1497-1507, 2018.

[23] M. Fakhredanesh, S. Roostaie, "Action change detection in video based on HOG," J. Electr. Comput. Eng. Innovations (JECEI), 8(1); 135-144, 2020.

[24] M.A. Khan, Y.D. Zhang, S.A. Khan, M. Attique, A. Rehman, S. Seo, "A resource conscious human action recognition framework using 26-layered deep convolutional neural network," Multimed. Tool. Appl., 2020.

[25] Y. Sun, J. Li, Z. Sun, "Multi-stage hough space calculation for lane markings detection via IMU and vision fusion," Sensors, 19(10): 1-14, 2019.

[26] M. Taheri, M. Rastgarpour, A. Koochari, "A novel method for medical image segmentation based on convolutional neural networks with SGD optimization," J. Electr. Comput. Eng. Innovations (JECEI), 9(1): 37-46, 2021.

[27] H. Arshad, M.A. Khan, M. Sharif, M. Yasmin, M.Y. Javed, "Multi-level features fusion and selection for human gait recognition: an optimized framework of Bayesian model and binomial distribution," Int. J. Mach. Learn. Cybern., 10: 3601–3618, 2019.

[28] M. Marzougui, A. Alasiry, Y. Kortli, J. Baili, "A lane tracking method based on progressive probabilistic hough transform," IEEE Access, 8: 84893-84905, 2020.

[29] H. Xu, H. Li, "Study on a robust approach of lane departure warning algorithm," presented at the 2nd International Conference on Signal Processing Systems, Dalian, China, 2010.

[30] N. Otsu, "A threshold selection method from gray-level histograms," IEEE Trans. Syst. Man Cybern.: Syst., 9: 62-66., 1979.

[31] W. Rong, Z. Li, W. Zhang, L. Sun, "An improved CANNY edge detection algorithm," in Proc. 2014 IEEE International Conference on Mechatronics and Automation: 577-582, 2014.

[32] M. Rezaei, M. Terauchi, "Vehicle detection based on multi-feature clues and Dempster-Shafer fusion theory," in Proc. 2013 Pacific-Rim Symposium on Image and Video Technology: 60-72, 2013.

[33] J. Cao, C. Song, S. Song, F. Xiao, S. Peng, "Lane detection algorithm for intelligent vehicles in complex road conditions and dynamic environments," Sensors, 19(14): 1-21, 2019.

[34] J. Hu, S. Xiong, Y. Sun, J. Zha, C. Fu, "Research on Lane Detection Based on Global Search of Dynamic Region of Interest (DROI)," Appl. Sci., 10(7): 1-22, 2020.

Biographies

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