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Robust Lane Detection by Removing Overlapped Objects for Complex Driving Scene Analysis

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Abstract: Human mistake is virtually always to blame in situations involving motor vehicles, which can have fatal consequences. When it comes to lane detection, the analysis of driving scenarios that is carried out by dashboard cameras that are placed in vehicles as part of advanced driver assistance systems (ADAS) is of the utmost significance. The initial developments in lane detection systems resulted in the creation of two distinct varieties. Image processing and deep segmentation have typically relied on a number of different methods. The techniques of deep segmentation are not yet capable of resolving many of the most important and challenging issues. We came up with a solution to the problem of object lanes overlapping each other and developed a dependable technique for lane detection that can be used in driving scene analysis systems. The method that is provided for real-time object detection makes use of the real-time object detection algorithms that are the most up-to-date and effective currently available; these algorithms are collectively referred to as YOLOv5. By identifying the object-lane that is overlapping the lane that has been unequivocally found by removing items that have overlapped, it is possible to solve this problem.

Keywords: ADAS, Lane Detection, Object Detection, YOLOv5, Sobel Filter

1. Introduction

Accidents involving motor vehicles are almost always the result of human error. By reducing the number of accidents caused by humans, ADAS devices can help avoid or prevent injuries or deaths. These systems carry out driving scene analysis with the assistance of dashboard cameras installed in automobiles. Lane detection [1] is an extremely important component of autonomous driving since lanes have the potential to act as essential indicators that influence how vehicles are maneuvered on highways. The two types of mainstream procedures for lane detection are known as traditional image processing methods [2] and deep segmentation methods [3]. Deep segmentation algorithms have been quite successful in this industry due to the excellent representation and learning capabilities that these algorithms possess. Regrettably, there are still a number of critical and challenging problems that have not been resolved [4]. The overlap of objects or impediments is one of the most significant issues, as it entirely alters the division of the lanes. This is one of the most essential concerns.

The rest of this paper is organized as follows: section II describes the background of this research. Section III presents a review of the related works in the literature. Section IV describes statement of the problem. Section V presents the proposed solution. Section VI describes the conclusion and future work.

2. Background

2.1. Image Processing

Image processing is one component of a further global image analysis or computer vision system's low-position component section. The results of image processing can have a considerable impact on the ability of the posterior high-position portion to recognize and evaluate picture input [5]. The alteration of images is what constitutes image processing, and some of the techniques involved include super-resolution, de-noising, and de-hazing, amongst others. During the preliminary stages, the conversion of images' color spaces is utilized. Color space has been heavily utilized in our daily lives and in the work that we do for a very long time. The following will provide an introduction to some of the most popular color spaces that are now in use, such as RGB, CMYK, HSV, and YUV [6]. Table 1 presents the most prevalent color spaces.

Table 1. *Commonly used color spaces [6].*

Color Space	Relevance to equipment	Applications	Meaning
RGB	Related	TV, CRT monitors for computers	R, G, B represent the 3 primary colors of red, green and blue respectively
CMYK	Related	Printing Industry	C, M, Y, K represents the four colors of printing: cyan, magenta, yellow, black
HSV	Related	Computer monitors	H: Hue, S: Saturation, V: Brightness
YUV	Related	TV, image transmission	Y: Brightness, U, V: Chromaticity

Edge detection is a technique used in image processing that finds points in a digital image that exhibit discontinuities, sometimes known as rapid changes in image brightness. This technique was developed by Microsoft Research. When looking at an image, the points where the brightness of the image changes dramatically are known as the borders (or boundaries). The following are a few of the more common methods, however there is a wide variety of options available. Edge detection methods such as Prewitt, Sobel, Laplacian, and Canny are utilized frequently today. In the following subsection, we will discuss the Sobel edge detection approach that was implemented in the solution that we proposed.

2.2. Sobel Filter

The Sobel filter is a form of edge discovery that ultimately leads to the edges being pressed and secured. Picture processing methods that need rooting the image grade and silhouettes employ it for those purposes. It is utilized for pictures that have variable pixel dimensions for each row and column [7]. In Figure 1, the horizontal grade element, denoted by *Gx*, and the vertical grade element, denoted by *Gy*, are utilized in order to locate the edges that are familiar with the separate procedures. The drivers can be used separately to determine the individual directions of the edges, or they can be combined into a single direction by adjusting the absolute magnitude grade.

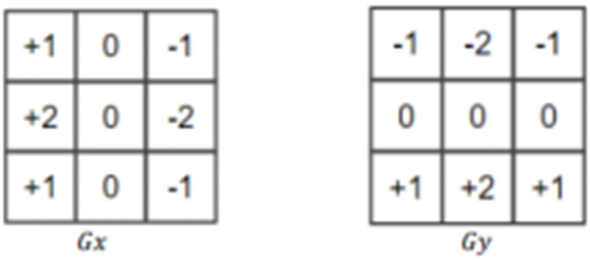


Figure 1. *Horizontal and Vertical gradient components [7].*

2.3. YOLOv5 Object Detection

Object detection is one of the initial jobs that are performed in computer vision. This task involves detecting the location on an image where specific objects are present and then classifying those things. The YOLO (You Only Look Once) algorithm was developed in 2015 as a replacement strategy. It recast object detection as a regression problem and was designed to operate in an extremely simple neural network. Because of this, the article detection field exploded, and as a result, significantly more impressive achievements were produced than just ten years before. To this day, YOLO has been improved to a total of five versions, and it is currently regarded as one of the most effective object detection algorithms on a global scale. This achievement was accomplished by combining a number of the most cutting-edge innovative ideas being developed within the field of computer vision research. The most current iteration of YOLO, which has been given the name YOLOv5 and is known as the 5th generation of YOLO, was not developed by the person who initially developed YOLO. On the other hand, the YOLOv5 performs better than the YOLOv4 when it comes to both accuracy and speed [8].

3. Related Works

The majority of conventional methods involve the extraction of a mixture of highly specialized visual qualities by making use of a variety of factors, such as color. Chiu et al. present a new method that is based on color information, and they claim that this method can be applied in complicated environments [9]. Data on their size, form, and velocity were utilized by Cheng et al. in order to differentiate them from actual lane markings [10]. Lee et al. offer a reliable and real-time vision-based lane detecting system with an effective region of interest [11]. This is done in an effort to reduce the amount of background noise. Ridges, an image feature that is not as commonly used as edges, are the ones that Lopez et al. adopt since, according to them, it is more effective in finding a solution to this problem [12]. MSER and the Progressive Probabilistic Hough Transform are both components of the novel lane detection and tracking algorithm that was described in Mammeri and colleagues' paper (PPHT) [13]. The majority of these approaches are prone to failing because they are overly sensitive to shifts in illumination and variations in road conditions.

4. Statement of the Problem

The use of the BDD100k dataset that was trained with DeepLab v3 to determine the direct lane in which the user is now traveling [14, 15]. Nevertheless, while utilizing DeepLab v3, it is not possible to differentiate between the foreground and background by isolating elements such as pedestrians and vehicles. The problem of overlap that they have is seen in Figure 2.

Figure 2. *The overlapping problem using deep segmentation method [14].*

5. Proposed Solution

As was discussed earlier, there are a few different approaches to lane detecting. In addition to the deep learning object detection strategy, we also make use of a more conventional image processing method in order to handle the problem of objects that overlap. We can deduce from the shape of the lane that it is about the lines and edges by looking at the shape. As a result of this, we initiate the process of analyzing the scene and initiating the process of specifying the region of interest (ROI), and we discover that all lane scenes concentrate on the middle-bottom area, which always contains the drivable lane as well as the front of the derived vehicle. The region of interest (ROI) is shown in Figure 3 as having a yellow background and a red border. Our attention is focused on the topic that will be analyzed. The region of the ROI needs to be calibrated so that it corresponds to the various environmental factors, such as the kind of camera being used, its position, focal length, and direction angle, as well as the kind of lanes.

After the ROI has been calibrated, we will use the Sobel filter technique to find the edges within the image frame. After converting the image frame to HLS and HSV color spaces, separating the V channel, and calculating the x-directional gradient, the result was displayed. In order to develop an image processing pipeline that allows lane lines to be recognized using an edge detection method, we generate a threshold binary picture using color transformations gradients. This picture is then used as the basis for the pipeline. Experimenting with various gradients, thresholds, and color spaces can result in a wide variety of intriguing solutions if you take the time to do so. In order to construct an image processing pipeline, we opted to use a combination of gradients to detect lane lines in addition to a mix of S channel thresholds in the HLS color space and V channel thresholds in the HSV color space. Both of these color spaces use the HLS color space. The image frame that is displayed in Figures 4-5 is the result of using the Sobel-x filter algorithm as well as conducting the color space conversion. At long last, the visual frame was transformed into a binary image.

Figure 3. *The front of the derived vehicle is ROI.*

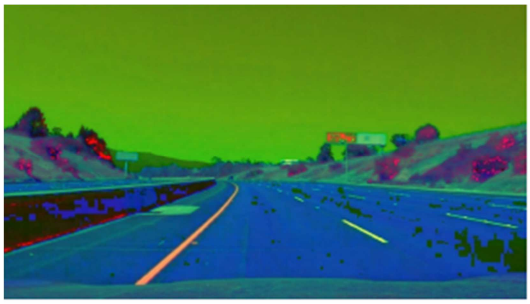
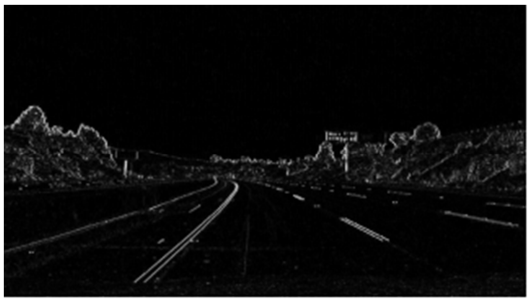


Figure 4. *Image frame converted to HSV color space.*



Algorithm I: RobustLaneDetector

Read ***frame***
original_frame ← ***frame***
Camera calibration
Select ROI
objects ← *detect objects from* ***frame***
frame ← *remove* ***objects*** *from* ***frame***
HLS ← *transform* ***frame*** *color to HLS color space*
L ← *select channel L from* ***HLS***
sobel_x ← *apply Sobel-x to L channel in* ***L***
binary ← *convert* ***sobel_x*** *to binary mage*
warped ← *warp* ***binary*** *to 2D Bird's view using ROI*
lane_border ← *find Lane border from* ***warped***
lane_curvature ← *detect lane curvature from* ***lane_border***
road ← *inverse warp* ***lane_border***
draw detected lane to original_frame
return original_frame

Figure 5. *Appling Sobel-x algorithm on V channel of image frame.*

Because of the way perspective works in images, the lines of lanes in a picture can appear to converge from a distance, even if they are actually parallel to one another. When this angle is taken into account, it is much simpler to identify the curvature of the lane lines. This might be accomplished by converting the image to a two-dimensional bird's-eye view, in which the lines separating the lanes are always perpendicular to one another. Since we are only interested in the dividing lines between lanes. On the first image without distortion, we used ROI to identify the area of interest, and then we changed the perspective to a bird's eye view, as illustrated in Figure 6 below.

Figure 6. *ROI perspective warped to generate a Bird's-eye view.*

There are many different styles of approaches that can be used to detect the lane lines. Convolution, also known as the sum of the components of two distinct signals, such as the window template and the vertical slice of the pixel image, was the technique that we utilized. In order to employ the convolution, we utilized a window approach, which may have maximized the quantity of hot pixels found in each window. In order to generate the convolved signal, the window template must first be moved across the image. Subsequently, all values that overlap must be combined together. The peak of the convolved signal is where there is the most effective overlap of pixels, and as a result, this is the location that is most likely to contain the lane marker. Detecting lane line pixels within the binary image that has been rectified requires the employment of certain approaches. In order to accommodate the left and right lines, a curved polynomial function is utilized.

In order to determine the curvature of the lane and the position of the vehicle in reference to the center of the vehicle, we took measurements of where the lane lines are and assessed how much the road is bending. Additionally, we evaluated where the vehicle was positioned in relation to the center of the lane. We presumed that the camera located in the middle of the car was operational.

In the end, the fit from the corrected picture was warped back onto the primary image, and a plot was created to determine the lane borders. This was done in order to wrap the identified lane boundaries onto the primary image and provide a numerical estimation of the lane curvature and vehicle position. An algorithm that is shown as Algorithm I incorporates all of the stages that came before it.

On the other hand, it is impossible to lessen the overlap problem while maintaining its current level of clarity. The most important aspect of this contribution is making the system more reliable. Following an analysis of the results, we came to the conclusion that the system was more reliable when there was object overlap with the eliminated lane. We used YOLOv5, which is one of the most efficient object detection algorithms, to locate the overlapping objects in the image and then delete them from the picture. According to the findings, the system is able to withstand the presence of several overlapping objects and become more reliable as a result. The results of utilizing the suggested method without first eliminating overlapped items are shown in Figure 7, whereas the results of using the proposed solution after first removing overlapped objects are shown in Figure 8. Figure 9 illustrates the ultimate outcome of the situation in which many objects overlapping the lane were resolved by applying the suggested remedy, which consisted of deleting all overlapping objects from the scene.

Figure 7. *Proposed solution without removing overlapped object.*

Figure 8. *Proposed solution with removing overlapped object.*

Figure 9. *Proposed solution with removing multiple overlapped objects.*

6. Conclusion

In this article, we present a solution to the object-lane overlapping problem that has been identified. The findings indicate that doing away with the overlapping items can, in most cases, result in an improvement to the lane detection systems. An experiment was carried out with Python to demonstrate that employing the object detection technique YOLOv5 for object detection and then eliminating overlapped objects makes the detect more robust. Despite the fact that the presented technique works properly on a wide variety of scenarios, there are still certain problems that need to be solved, particularly those involving overlapped objects on top of ROI lanes. In the subsequent work, we will combine other studies in an effort to strengthen the robustness of the suggested approach.

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