Lane Departure System Design using with IR Camera for Night-time Road Conditions

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Abstract – **Today, one of the largest areas of research and development in the automobile industry is road safety. Many deaths and injuries occur every year on public roads from accidents caused by sleepy drivers, that technology could have been used to prevent. Lane detection at night-time is an important issue in driving assistance systems. This paper deals with vision-based lane detection and tracking at night-time. This project consists of a research and development of an algorithm for automotive systems to detect the departure of vehicle from out of lane. Once the situation is detected, a warning is issued to the driver with sound and visual message through "Head Up Display" (HUD) system. The lane departure is detected through the images obtained from a single IR camera, which identifies the departure at a satisfactory accuracy via improved quality of video stream. Our experimental results and accuracy evaluation show that our algorithm has good precision and our detecting method is suitable for night-time road conditions.**

Keywords – **Lane detection, Hough transformation, IR camera, "Head Up Display", Night-time Road Conditions.**

1. Introduction

Lane detection at nighttime is an important issue in driving assistance systems. Typically, lane detection is used for localizing lane boundaries in the given road images, and can help to estimate the geometry of the road ahead. A significant amount of research has been carried out in the area of lane analysis. There are several useful technologies of lane detection which have achieved good results for daylight conditions. However, most of these algorithms were focused on lane detection on highway roads or on roads where there are few vehicles and obstacles ahead or the road was empty at daytime.

This project consists of a research and development of an algorithm for automotive systems to detect the lane departure at nighttime. There are a number of types of night vision displays that can relay infrared or thermo graphic information to the driver. The earliest night vision systems used heads up displays, which projected warnings and alerts on the windshield within the driver's field of vision.

With recent advances of Head-up Display technology in cars, Augmented Reality becomes interesting in supporting the driving task to guide a driver's attention.[4] Some researchers define AR in a way that requires the use of head-mounted displays (HMDs).[5] Other systems use an LCD that's mounted on the dash, in the instrument cluster, or integrated into the head unit. Automotive night vision systems have been around since 1988, but they are still found primarily in luxury vehicles. The technology is typically optional equipment, and it can be quite expensive. The first night vision systems were introduced by GM, but a number of other automakers now have their own versions of the technology.

According to the European Commission for the Automobile Industry, nearly 50 percent of all accidents occur at night. Since the same study showed about 60 percent less traffic at night, it's clear that a disproportionate number of accidents occur between dusk and dawn. Since night vision isn't widely available, there is no conclusive data. However, other technologies that increase nighttime visibility have been shown to reduce accidents. Since technologies like adaptive headlights have helped reduce nighttime accidents, it's possible that a lane tracking with night vision will have similar effects. It's clear that the proper use of a lane detection system can help an alert driver avoid certain collisions.

2. MATLAB Image Matrices

In MATLAB, the basic data structure is the array. This is also true of images stored in MATLAB. Images can be thought as made up of "pixels" or dots in the image. These pixels can vary in dimensions, for example VGA (i.e. the standard pixel dimensions for many early monitors or cameras), is 640 pixels width by 480 height. When this image is stored as an array in MATLAB, it corresponds to a 2 dimensional array of 640 columns by 480 rows. This allows powerful image processing work to be done using MATLAB. It is important to note, that the first

element in a MATLAB image matrix (i.e. (1, 1)) is the top left most pixel in the image. In Cartesian co-ordinate, this would be the bottom left pixel. For the remainder of this report, whenever references are given to co-ordinates in images, this will refer to the MATLAB image space co-ordinates.[2]
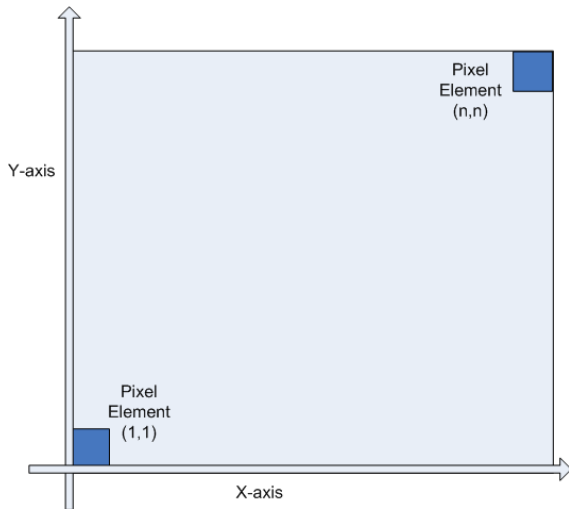

Figure 1. Cartesian and MATLAB Image Space

RGB Color image arrays in MATLAB contain an extra dimension to store the extra color information. This dimension is 3 elements wide. Each element corresponds to the red, green, and blue color information of the image. Thus each pixel can vary in color from (0,0,0) (black) to (255,255,255), (white).

To separate out the road marking data from the rest of the image data, a color filter needs to be used. A RGB window needs to be created that would compare the RGB value of every pixel in the image. If the RGB value was found to be inside the window limits, it would be given a value of 1. If not, it was given a 0. To do this, the pixel values of the sections of the image that contained the road markings were analyzed.

Spurious pixels that were passed by the filters had to be removed from the binary image before lane departure detection could be done. It was seen that these pixels were normally part of small groupings, or without any neighboring pixels at all. Also, any pixels that were part of road markings were in large groupings of more than 15 or so pixels. Therefore, what was needed was an algorithm that could remove the smaller grouping of pixels but leave the others untouched. From studying the MATLAB 7.0 it was realized that MATLAB had an inbuilt function called "bwareaopen" that does this. From testing, it was found that the algorithm worked best when a minimum limit of 15 pixels per group was used to remove the noise.[1]

3. Approach for Lane Detection from Image

Lane detection is a complicated problem under different light/weather conditions. In this project we analyzed first: the images are captured from the road, assuming the lanes on the road are straight and need to be detected, at nighttime and with good weather conditions. And the next step; we detected road lane markers in a video stream in nighttime conditions.
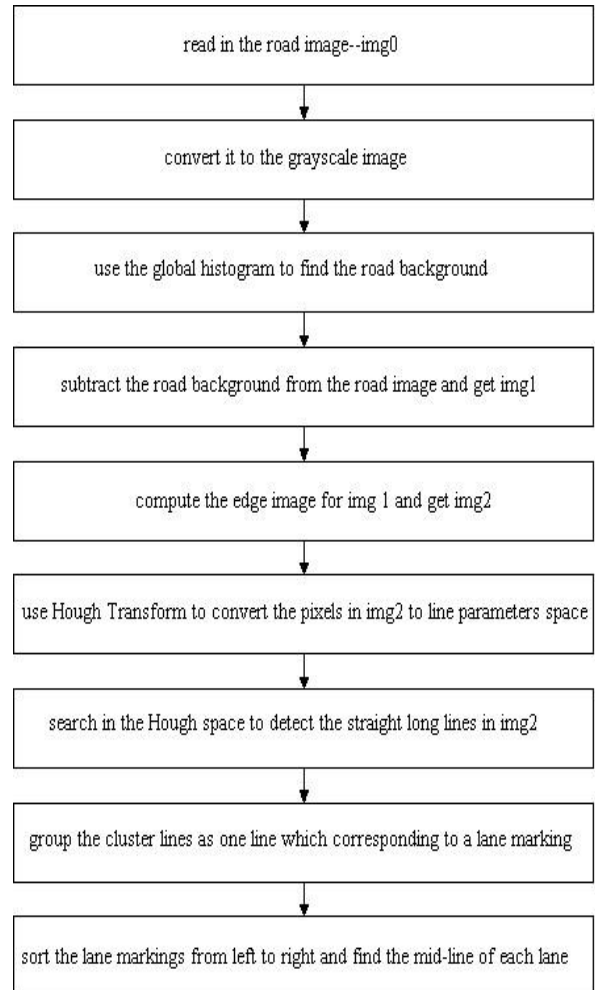

Figure 2. The lane detection algorithm

Fig.2 is the flowchart of the lane detection algorithm, which is based on edge detection and Hough Transform. First the RGB road image is read in and converted into the grayscale image. Then we use the global histogram to find the road background gray and subtract it from the grayscale image to get img1. Edge operation is executed on img1 and lane marking features are preserved in img2. The key technology here is using Hough Transform to convert the pixels in img2 from the image coordinate (x, y) to the parameter space (ρ, θ), and then search in the Hough space to find the long straight lines, which are lane marking candidates. The candidate lines are post-processed: delete the fake ones, select one line from a cluster of closing lines as a lane marking. Finally the

lane makings are sorted by their position on the road from left to right.

The ideal case of the road scene is solid white line as the lane boundary, white dash line is the lane separator.

However, the road geometry is not so ideal in the real world, the lane boundaries might be broken; the vehicles on the road will also affect the detection accuracy of the road geometry.

Lane edges are the objects of interest in this work. The features of interest are those that discriminate between lane markings and extraneous (non-lane) edges. Most features of the lane markings are preserved as edges, which is directly caused by the edge function of Matlab. If we use the edge function directly on the original image, much lane marking edge information is lost. Then we consider other preprocess methods to preserve the lane marking information before the edge operation. Background subtraction is a solution.
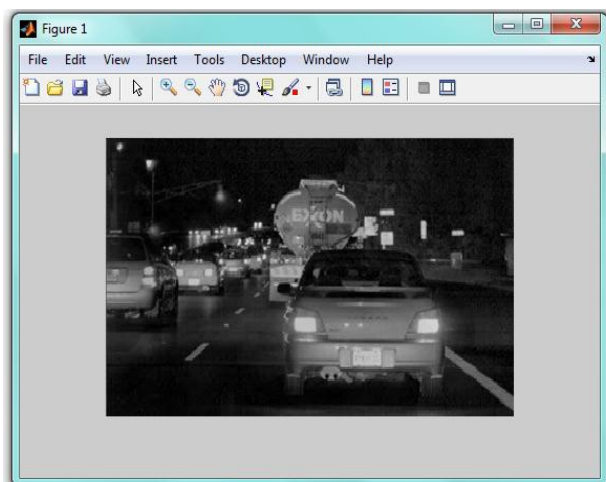

Figure 3. The lane detection algorithm

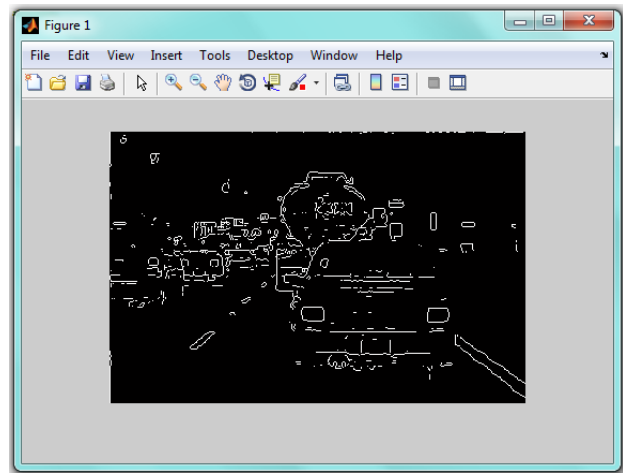*Figure 4. Subtract background from original image to get image 1*

Figure 5. Edge image of the road image to get image 2

The Hough transform is used in a variety of related methods for shape detection. These methods are fairly important in applied computer vision; in fact, Hough published his transform in a patent application, and various later patents are also associated with the technique. Here we use it to detect the straight lines. Fig.6 is the fundamental idea to convert each pixel in the image to parameter space. We define the origin of the image coordinate as the upper-left point.
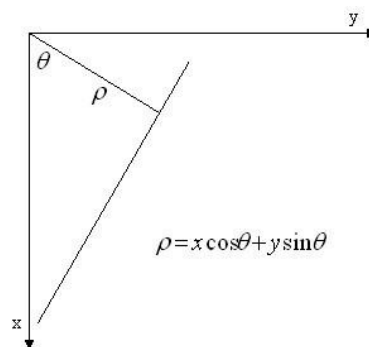

$$\rho = x\cos\theta + y\sin\theta$$

Figure 6. Hough transform for detecting straight lines

A count array $[\rho][\theta]$ is constructed for each candidate line and some other arrays are constructed to record each line's start/end position. Since the lane markings are not close to the origin and they are not horizontal in the image (for autonomous driving application, the camera is mounted on the vehicle with front view), we only detect the straight lines with restriction, '*Theta*',-60:0.5:60 and also the calculation time cost is reduced.

There are many straight lines detected by Hough Transform, here we particularly search in the Hough space to find the long straight lines, which are lane marking candidates (shown as green lines in Fig.7). Fig.8 shows the first 5 straight lines of road, which

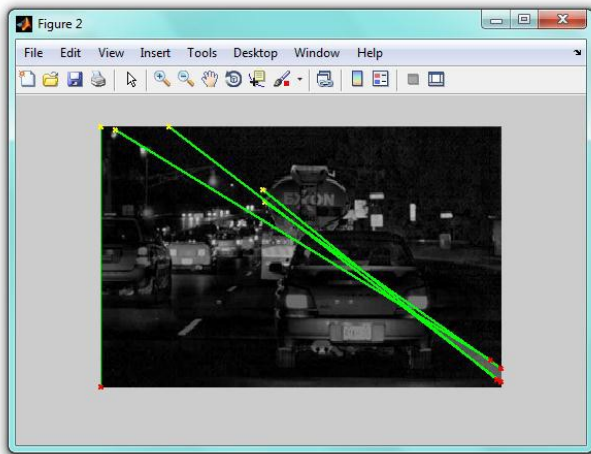have the biggest count number, i.e. the lane markings include more edge pixels than other lines in the image.

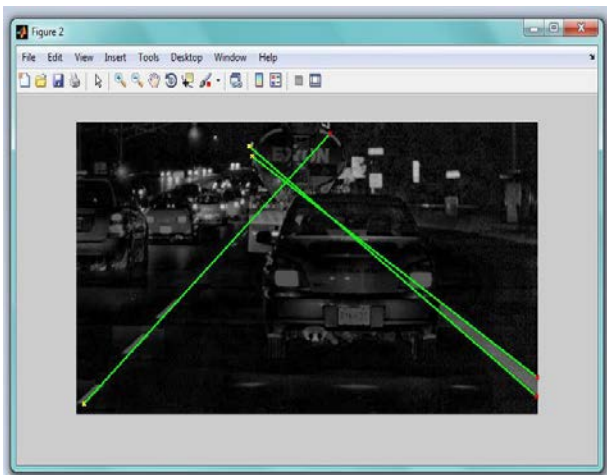

Figure 7. Lane marking candidates (shown as green lines)

Figure 8. Final detection result for Fig.3 .The lane markings detected by the algorithm almost match the lane markers in the real world.

4. Approach for Lane Detection from Video Stream

This study detects and tracks road lane markers in a video sequence and notifies the driver if they are moving across a lane. "Hough Transform", "Hough Lines" and "Local Maxima Finder System" objects are used to create line detection and tracking algorithms. The example implements this algorithm using the following steps:

- Detect lane markers with using our approach from image in the current video frame. Match the current lane markers with those detected in the previous video frame.

- Find the left and right lane markers.

- Issue a warning message if the vehicle moves across either of the lane markers.

To process low quality video sequences, where lane markers might be difficult to see or are hidden behind objects, the example waits for a lane marker to appear in multiple frames before it considers the marker to be valid. The experimental example uses the same process to decide when to begin to ignore a lane marker. We used the sample codes from Matlab-Mathworks named as "Lane Departure Warning System" example.[3]

Fig.9 shows the lanes of road that are detected using IR Camera. IR Camera enhanced the white images visually. At Fig.8 we didn't detect lines with daylight camera.

Figure 9. Lane Tracking with IR Camera

Fig.10 shows that the algorithm doesn't work perfectly, the road conditions caused noise that prevents the process.
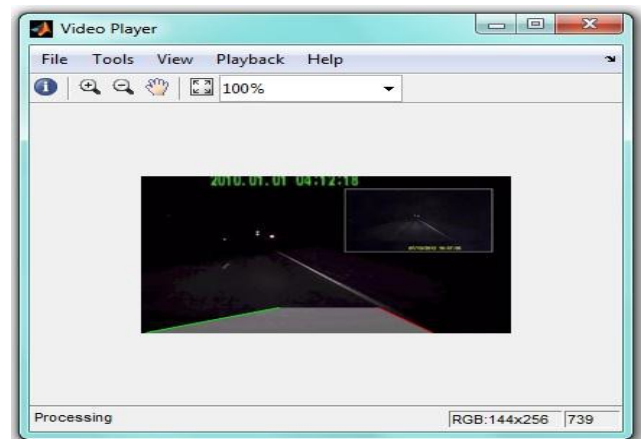

Figure 10. Errors from Noise

For indoor applications, we can control the lighting to match the display. But in outdoor applications, the AR display must work across a wide variety of lighting conditions, from bright sunlight to a moonless night.[6]

5. Lane Departure System Design

The camera positioned at the front of the vehicle rear mirror. When travelling, the system monitors road markings and their position versus the car as well as the edge of the road or lane. The system is activated whenever the vehicle leaves its current lane unintentionally and alerts the driver by making the HUD system warning on windshield.
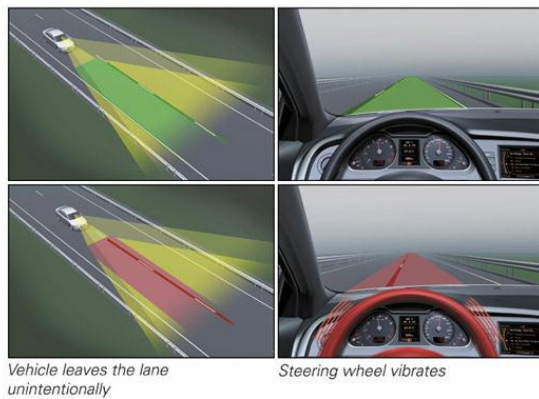

Figure 11. Audi Lane Assist System

Audi's Active Lane Assist is a system intended to help the driver stay within the intended lane of travel. At speeds above 65km/h, a camera mounted by the rear view mirror at the top of the windscreen detects lane marking ahead of the vehicle.

6. Head Up Display System

A head-up display or heads-up display also known as a HUD is any transparent display that presents data without requiring users to look away from their usual viewpoints. General Motors began using head-up displays in 1988. The first color display appeared in 1998 on the Corvette C5. These displays are becoming increasingly available in cars that have been producing recently, and usually offer speedometer, tachometer, and navigation system displays. Night vision information is also displayed via HUD on certain General Motors, Honda, Toyota and Lexus vehicles. Other manufactures such as Audi, Citroën, Saab, Nissan, and Kia currently offer some form of HUD system. Motorcycle helmet HUD are also commercially available. In 2012 Pioneer Corporation introduced a navigation system that projects a HUD in place of the driver's visor and presents animations of conditions ahead, a form of augmented reality (AR).

7. Conclusion

In this paper, we proposed an efficient, real time, and robust algorithm for detecting lanes at nighttime. The main aim of this project was to determine if a single forward facing IR camera in a vehicle could be used to determine when it was drifting out of lane at nighttime road conditions. From the above result, we find the algorithm works well for these cases. The key method includes: find the background gray range, background subtraction, edge detection, Hough Transform, find the long lane marking candidates, sort the lane marking candidates, group the cluster lines as one line, delete fake lines. To improve the robustness of the algorithm, we can consider some other methods in the future, like: B-snake (B-Snake based lane model which describes the perspective effect of parallel lines is constructed with dual external forces for generic lane boundary or marking, it is able to describe a wider range of lane structures than other lane models such as straight and parabolic models.[8]), multi-sensor fusion.

We compared our results and precision to other algorithms which can run in high way or few vehicles along with shadows, our algorithm can detect lanes in various conditions and has good accuracy both at day & nighttime. This could prove valuable in automotive applications for safety situations where the driver is not paying attention to the road, falling asleep, etc.

Much work could be done to increase the robustness of this algorithm and to improve its performance overall. Lane detection in urban streets is especially a hard problem. Challenges include: parked and moving vehicles, bad quality lines, shadows cast from trees, buildings and other vehicles, sharper curves, irregular/strange lane shapes, emerging and merging lanes, sun glare, writings and other markings on the road (e.g. pedestrian crosswalks), different pavement materials, and different slopes.[7] To start with, implementation of the algorithm onto a FPGA or DSP system would be needed before it could be used in practice in a vehicle. Some changes could also be done to the different algorithms employed by each module. A better algorithm could be developed for the obstacle detection module that could search the road ahead. When a boundary is found that has not the same features as the road surface or road markings (e.g. different color, shape, texture, etc.) a warning could be issued to the driver .

All in all, this project reached its main aim of proving that the concept of a vision based system for lane departure detection was possible at nighttime.

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