Parabolic Model Based Lane Detection and Tracking

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Abstract- Lane detection is the initial and main key role in the context of Advanced Driver Assistance Systems (ADAS) and autonomous driving in the case of complex and challenging tasks of road scenes. While in the process of lane detection, environmental conditions, and road conditions seriously influencing the results of the lane detection. Among several approaches discussed for lane detection, the Hough transformation is a commonly used method in lane detection and the parabolic model seems to be dominant among all. The disadvantage of the Hough transformation is that it can detect only straight lines and comparatively depend on environmental conditions. In this paper, present a method of segmenting and detecting lanes using bird's eye view through inverse perspective mapping (IPM) and tested in a small-scale environment. Next to the detection process, detected boundaries in consecutive video frames were tracked through a parabolic model.

Keywords – Inverse perception mapping, Hough transformation, Lane detection, Parabolic model

I. INTRODUCTION

A tremendous amount of research projects were conducted over the past few decades and even now autonomous driving technology has become one of the research hotspots in the field of computer vision, computer graphics, and artificial intelligence since the 1920s [1, 2]. In the 1980s researchers were able to develop automated highway systems [3, 4] and in 1986 John F. Canny developed an algorithm to find edges in an image called canny edge detector [5, 6]. Some of the widely used lane detection models and techniques [7-12] attempt to determine mathematical models for road boundaries such as simpler models like linear functions or complex models like parabolic/spline functions. In comparison, simpler models are more robust with image artifacts but do not provide an accurate fit. However, complex models are more flexible as well as more sensitive to noise. Accuracy of the lane detection does not only depend on the model, which is used to detect the lanes, but it also depends on the weather condition of the environment. All-weather lane detection system [13] based on simulation interactive platform has good real-time, robustness, and stability for lane detection under different illumination and different road conditions. Line Segment Detector (LSD) [14] has some limitations of lane detection in some cases with poor road conditions such as blurry lane boundaries due to insufficient paint and shadows from objects. However, the proposed method gives better performance under different environmental conditions. Some of the approaches of lane detection have been classified either feature-based or model-based [11, 15]. Feature-based methods detect lanes by low-level features like lane-mark edges [16, 17] in contrast, Model-based methods represent lanes as a kind of curve model which can be determined by a few critical geometric parameters [8]. Jung and Kelber [1] proposed a linear lane model applied for the initial detection of the video sequence, and a linear-parabolic model for all the following frames and Cho et al. [18] successfully developed a video processing based driver-assist system. This system works quite well under most test conditions. According to the review of lane detection techniques by Kaur and Kumar [19], they studied the Hough Transform algorithm which first defines the Region of Interest (ROI) from input image for reducing searching space; divided the image into the near field of view and far-field of view and presented a lane detection technique based on H-MAXIMA transformation. As we mentioned, there are many methods implemented for lane detection and among those, the most used two are Hough-based detection and color segmentation based detection. Hough-based detection and color segmentation based detection are effective, but there are some problems when we use those separately. Failures like detect unwanted lines or not detect any existing lines of Hough-based detection and these methods are very sensitive to the scene condition.

II. Proposed Methodology

Initially, parameters were described that are required to implement parabolic model-based detection and Hough Transformation based detection individually and look at their results. Process followed is as shown in Figure 1. In Hough Transformation based detection, first, initial frame converted into greyscale, ROI application, use thresholding, then canny edge detection, and finally lines were detected by Hough line transformation. To test the Hough transformation, captured images and videos at the university premises were used. Next, we describe our proposed method, which uses the extracted data from the video stream and improves the efficiency of lane detection. We have applied the parabolic model method for the detection of lanes in a single frame of video and then implemented it to the whole video. In this method IPM methodology is used to best fit lines. The lane detection and tracking method processes captured images and videos based on a special small-scale environment (model environment) and real-world environment and the video was extracted lane marking positions frame by frame. Distance between two lanes and the width of a single lane is defined as 10cm (l) and 1cm respectively while height (h) to the camera from the ground is 15cm, (Xc, Yc, Zc) are the camera coordinates, (Uw,Vw) are the image coordinates and (Xw,Yw,Zw) are world coordinates as shown in Figure 2. A frame is processed in two subsequent steps. First, information on the lane markings position is amplified and extracted from the frame in a processing stage. Then, depending on whether previous estimates of the position exist or not, the exact position of the lane markings is detected in a lane detection step or tracked in a lane tracking step.

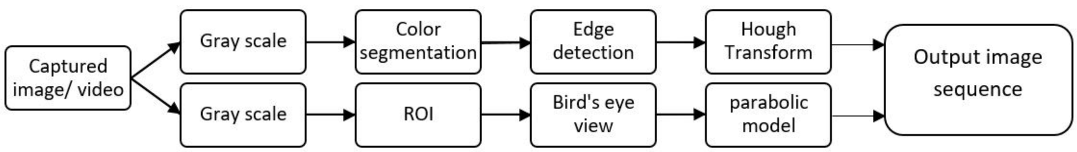

Figure 1. Lane detection methodology

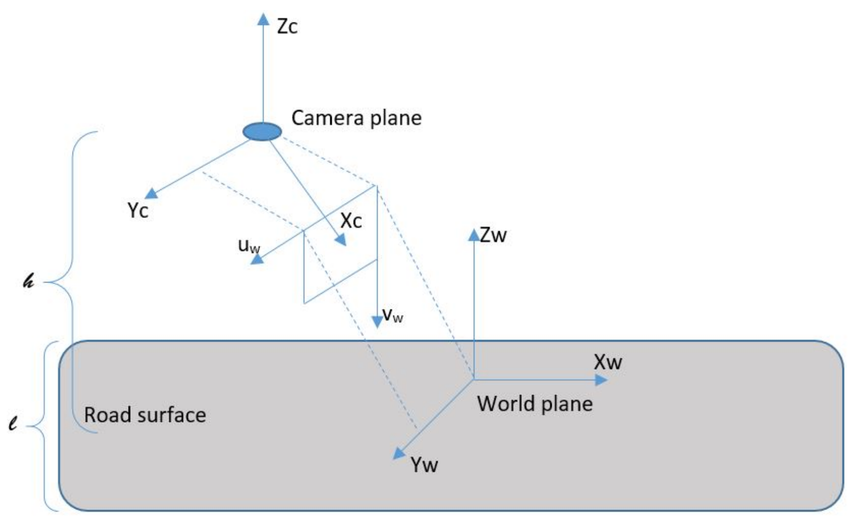

Figure 2. Camera projection in the model environment

A. Parabolic method –

The methodology of lane detection using the parabolic model was illustrated in Figure 3. This process consists of two main tasks. As the initial step camera calibration was done and, in this step, firstly, 25 images of the checkerboard were captured in different angles of the camera to calibrate our normal camera. Secondly, all images were inserted selecting a standard camera model and calibrating the camera. Thirdly evaluate the calibration accuracy and adjust parameters to improve detection accuracy. Finally, export the camera parameters as an object and used this object to detect lanes. The image flow collected by the normal camera lens has a certain degree of distortion as a monocular camera, therefore we used a camera calibrator app in MATLAB to calibrate a normal camera. At this step, we extracted the parameters of the camera. Camera parameters include intrinsic, extrinsic, and distortion coefficients.

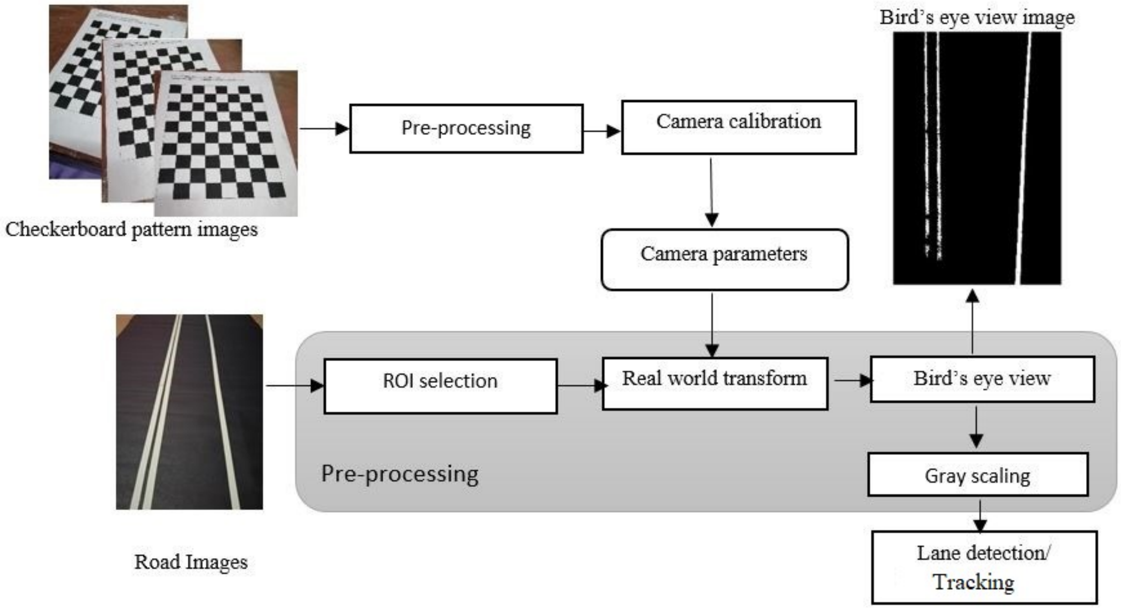

Figure 3. Lane detection methodology using parabolic model

When considering different types of road conditions, only a small part of the image is of actual interest, the part that shows the street. The ROI contains all essential information for the subsequent lane detection step and the rest of the frame can be discarded. The size of the ROI is a driving parameter that determines the computational speed and effort of lane detection/ tracking. When using parabolic lane detection using MATLAB we defined ROI in-vehicle coordinate system where parameters as, the distance ahead of the sensor, spaces to one side of the lane, and bottom offset for our model environment shown in Figure 2. ROI was defined in world units as, look 15cm to left and right; 10cm ahead of the sensor. Then the captured color image is converted to a greyscale to make the method faster, less computational. In our proposed method, images and videos are captured from both mobile phone and digital cameras. The camera is adjusted in a way that the vanishing point of the road should be placed on the top of ROI based on camera place adjustment. To convert the true color RGB image to grayscale image, the rgb2gray function is used. This function converts RGB images to grayscale by eliminating the hue and saturation information while retaining the luminance. It converts RGB values to grayscale values by forming a weighted sum of the R, G, and B components as the algorithm.

$$0.2989 * R + 0.5870 * G + 0.1140 * B \qquad (1)$$

The birdsEyeView object is used to create a bird's-eye view of a 2-D scene using IPM. To transform an image into a bird's-eye view, pass an image to a birdsEyeView object and that image to the transformImage function. To convert the birds-eye-view image coordinates to or from vehicle coordinates, use the imageToVehicle and vehicleToImage functions. All these functions assume that the input image does not have lens distortion. Coordinates of the region to transform into a birds-eye-view image, specified as a four-element vector of the form [xmin xmax ymin ymax]. The units are in world coordinates, such as meters or feet, as determined by the Sensor property. The four coordinates define the output space in the vehicle coordinate system (X_V, Y_V).

The parabolicLaneBoundary object contains information about the parabolic lane boundary model in MATLAB. This object creates an array of parabolic lane boundary models from an array of [A B C] parameters from the parabolic equation as in Equation (2). Points within the lane boundary models are in world coordinates. Coefficients for parabolic models of this form, specified as an [A B C] numeric vector or as a matrix of [A B C] values. Each row of parabolicParameters describes a separate parabolic lane boundary model in MATLAB. After extracting lane features from the birds-eye-view, parabolic points were extracted and plotted in both birds-eye-view and raw image.

$$y = Ax^2 + Bx + C \qquad (2)$$

B. Hough Transformation method –

The Hough based detection steps include Conversion of RGB image to grey image, Masking image, Edge detection using a canny edge detector, Define ROI, and Detect Hough lanes. The Hough transform is an image

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processing technique for feature extraction. It is more commonly used for the detection of lines in an image but can also be used to detect any arbitrary shapes, for example, circles, ellipses, and so on. The underlying principle of the Hough transform is that every point in the image has an infinite number of lines passing through it, each at a different angle. The purpose of the transform is to identify the lines that pass through the most points in the image, i.e., the lines that most closely match the features in the image. In this case we referred to the process explained in [19].

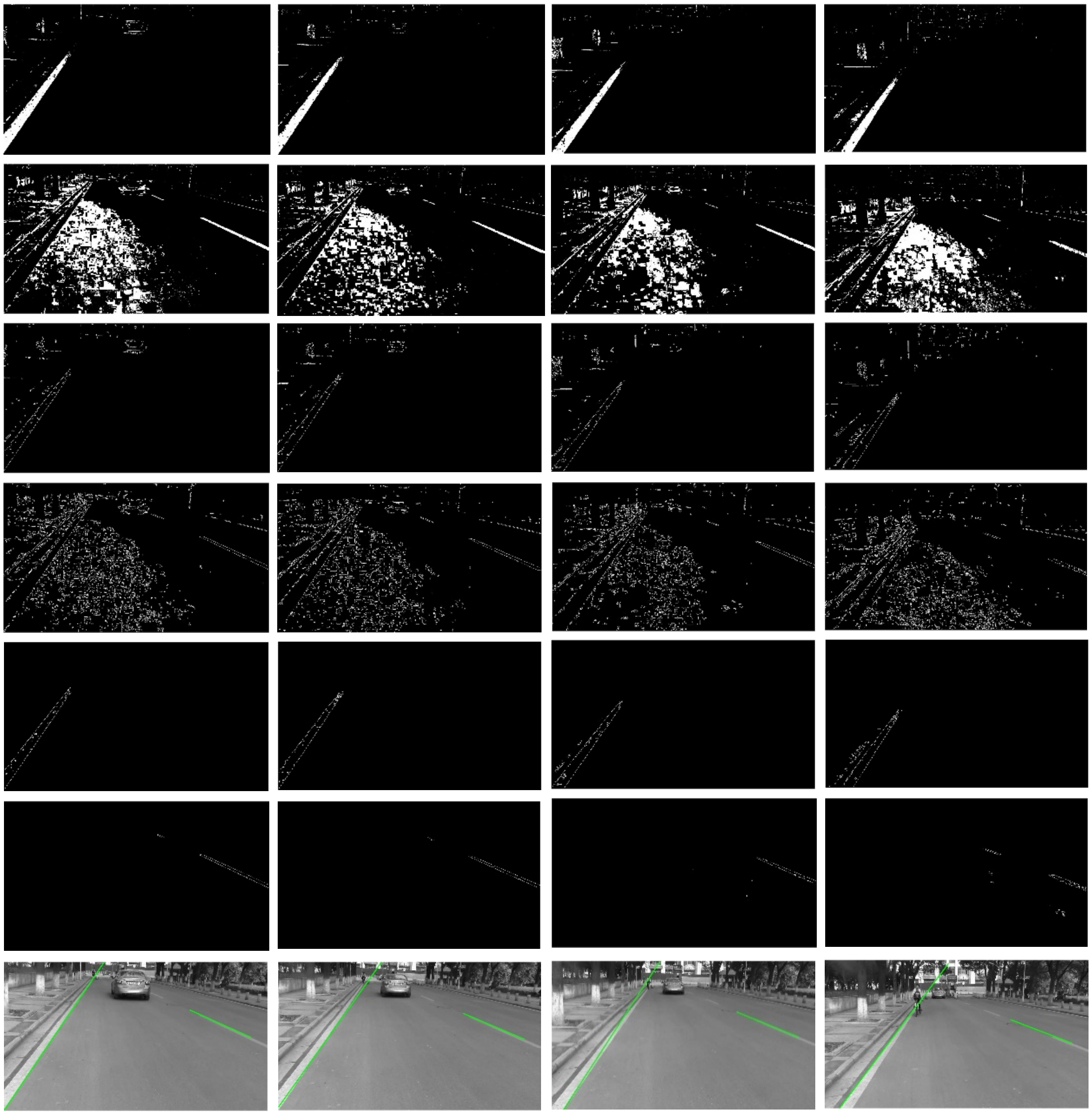
ColourThresholder app in the MATLAB is used for Masking images for left and right lanes. Colour images could be modeled with many color spaces like RGB, CMYK, and HSV. Every color space could be converted to others by using some formulas. In our proposed algorithm, the acquired image is in RGB, and we convert it to the HSV color model as we use the HSV color model. The reason that we use the HSV color space model with an ordinary threshold value in our method is that to detect lanes in lane detection using RGB color space model we should use all three components R, G, and B, and they are all important for processing to detect the lanes. But when we use the HSV color space model, just Saturation S and Value V are important for processing to detect the lanes because of their considerable variations. This feature causes fewer computations, and we have a faster algorithm to detect the lanes.

Then edges are obtained from the masked image and closed edges with smaller areas are ignored. In this step, to find lane boundaries in the image we use one of the edge detection methods called Canny Edge Detection. Then ROI points were extracted from the image. Finally, the Hough function is used to get the Hough Transformation of the binary edge detected image, which gives the Hough values.

III. Experiment and Results

A. Hough Transformation Lane Detection Results –

This reference method is used for experimental results and comparison; we may proceed by using a single frame of video and may implement the methodology for multi-frames. The experiment starts with the extraction of the initial frame and the true-color RGB image is converted into the greyscale image as shown in Figure 4. Greyscale image is converted into a binary image (Black and white) and to remove extra objects which are surrounded by the left and right lanes. From each video, four frames have experimented with Hough based detection and Video1 results were expressed in Figure 4. Each column represents four frames, and six rows represent left lane mask, right lane mask, left lane edges, right lane edges, extracted left lane, extracted right lane, and detected left and right lanes respectively using Hough transformation.



(a) Frame1 (b) Frame2 (c) Frame3 (d) Frame4

Figure 4. Experimented results from video1

B. Parabolic Based Lane Detection Results–

Different frames were captured under the road type of continuous center line and used the parabolic model to detect road lanes as shown in Figure 5. Three rows and columns in the Figure 5 represent, original images that are taken in two different frames (1 and 2) and (a), (b), (c) and (d) represent extracted lines from a birds-eye view, plotted left and right lines in bird's eye view and original frame respectively.

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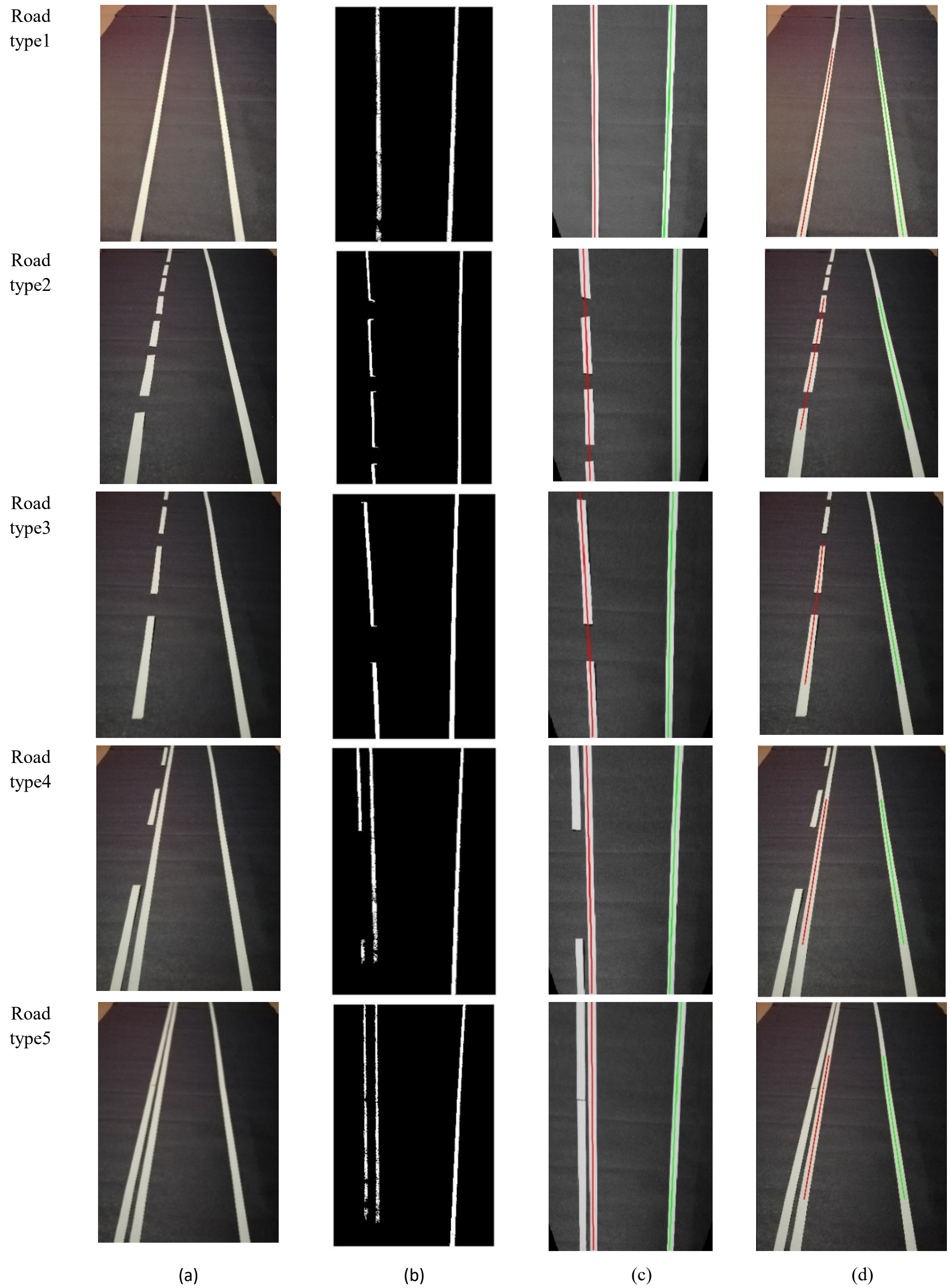
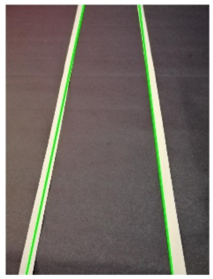
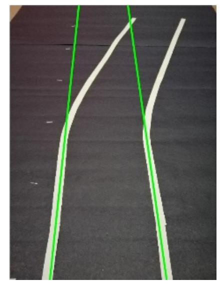
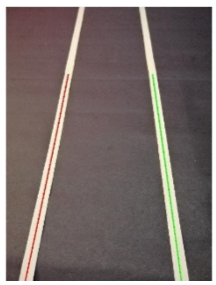
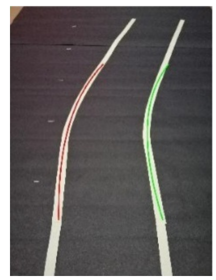


Figure 5. Experimented results of different lane types

Similarly, curved lanes were detected using the parabolic model by converting the grey image into the birds-eye-view of the real road image then extracted lanes from black and white image of the birds-eye-view and detected lanes of both birds-eye-view and real image. It is noticeable that the lanes are detected accurately.

For lane detection, we used Hough Transformation and Parabolic model and we experimented with each separately. Hough transformation experimented with both captured videos of real road scene and small-scale environment and the parabolic model experimented only in the small-scale environment since it requires camera calibration. We found that more accurate results appeared under the parabolic model than the Hough transformation. Moreover, the parabolic model can be used to detect curved lanes as well as straight lines as shown in Table 1 where the Hough method only performs detecting the straight part of the lane. When detecting curved lanes using a Hough based method, we can further proceed with the linear model with two ROI regions in the upper and lower part of the image.

Table - 1 Lane detection comparison

Method	Detected Straight Lines	Detected Curved Lanes
Hough Transformation		
Parabolic lane detection		

IV.CONCLUSION

In heavy traffic countries like China, India, and other Asian countries, where avoiding the number of accidents become the major concern and it is difficult to identify the exact location and detection of lanes for a human eye. It is important to make the Intelligent Transport System more robust and as well in other ways, lane detection and tracking are some of the important future applications of auto-drive vehicles.

Till now so many different vehicle companies and researchers have used different ways and developed different algorithms under different conditions to make the intelligent transportation systems more robust to noise and detection, but they usually operate under a certain type of scene conditions and are more complex to implement under different conditions and real-world environments. Our main goal of this work is to gain deep knowledge in lane detection and tracking. As in the case of lane detection we described and implemented the Hough Transform and edge detection by using the canny algorithm. Then we described the parabolic model as more efficient not only for finding both straight and curved lines. Our proposed method provides the system to detect the lines much better in this case.

The difficulties we faced is collecting quality images since the results depend on the quality or the resolutions of the captured images and videos. Because we took images and videos from a mobile phone camera, it may result in blur and dark images when the light of the surrounding environment is low. Therefore, image capturing was done only in the daytime. When considering sensors, considerable time is needed to study of the application of those sensors and using LIDAR and Radar which are costly devices.

Our proposed methods were implemented in MATLAB R2018b on an HP (Pavilion g4 Notebook) computer with CPU of Intel ® Core™ i5 3230M with the processor frequency of 2.6 GHz and RAM of 12.00 GB. We have processed captured custom videos (Video1, Video2, and Video3) and captured images around the Wuhan University o Technology premises. As future work, a formal evaluation of the performance should be made. Moreover, vehicle detection, tracking and distance estimation is ongoing, we believe that the detection algorithm is robust enough, but results could be improved by using more advanced tracking methodologies for future work. Furthermore, lane detection was implemented in a small-scale environment using both parabolic and Hough transformation methods that can be further modified to implementation of small vehicles or real-world situations like implementing automatic wheelchairs.

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