Lane Detection and Tracking For Intelligent Vehicles: A Survey

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Abstract— **Nowadays, Lane detection and tracking modules are considered as central requirements in every Intelligent Transportation System (ITS) development. The extracted lane information could be used in several smart applications for lane keeping systems, lane departure warning and avoiding collisions with other vehicles. In this proposed work, we are presenting, reviewing and comparing the different vision based algorithms used for detecting road lanes in autonomous vehicles.**

***Keywords*— Lane detection, Lane tracking, Machine Learning, Hough transform, Vision based algorithms, Image segmentation.**

I. INTRODUCTION

Intelligent Transport Systems (ITS) refer to the wide-ranging of advanced applications or services involving transport engineering, communication, information technologies and geographical positioning. ITS thus make it possible to manage the externalities linked to mobility (noise, pollution, congestion), but also to improve the comfort and safety of goods and people and optimize the management of infrastructure and public policies related to the entire transport system [1]. Those facts led to attract several researchers and automakers to focus on the evolutionary process of the automotive industry, where the development of Advanced Driving Assistance Systems (ADAS) will allow the technology to become mature and gradually lead to the development of autonomous vehicles. Perception techniques and more precisely those related to lane detection are not only a first step towards semi-autonomous driving but will then open the way to fully and advanced automated vehicles.

Lane detection is the process to locate road markers and then interpret this information to an intelligent system in the ITS [2].

Lane detection is finding the white or yellow horizontal markings on the surface of the painted roads and draw boundaries limiting the lanes. Lane tracking use the previously detected lane markers and adjusts itself according to the motion model and uses temporal coherence to track boundaries in a frame sequence. Vehicle Orientation is detecting position and orientation of vehicle within the lane boundaries.

Defining a consistent and well robust lane detection system is difficult and challenging research topic, this fact could be justified by the complexity and the variability of case conditions. As shown in Figure 1, lane and road appearance diversity is an imposing factor on lane detection, lanes marks and lane width are existing indifferent variants and are not normalized. Besides severe occlusions could be created by the near vehicles which could not be ignored. Moreover, visibility conditions are limiting the performance of the systems (weather conditions, lighting, haze and night conditions…).

Figure. 2 Different situations and scenarios for lane detection

Lane detection and tracking systems are using several modules for building reliable results. Vision based approach using cameras are the most typical techniques adopted for lane detection. Light Detection and Ranging (LIDAR) are commonly used also as possible solution for lane and road detection. The Geographic Information Systems (GIS) are also used as an important complementary global positioning information of the vehicle.

II. GENERIC MODEL

By analysing the existing vision-based literature [3], [4], we can deduce a generic methodology for processing gathered images from road environment for the lane detection and positioning. Figure 2 presents the possible functional decomposition of lane detection and tracking systems.

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In general, lane detection based in perception algorithms must include the well spread used sub-systems:

1. Image Cleaning: This pre-processing stage have several main aims, to remove the inevitable noise during image acquisition, normalize scenes, enhance interesting features, exclude obstacles and eliminate shadows impact using through several filters;
2. Features Detection: Segmentation methods are applied on raster images, in order to extract one or more related features according to the information sought in the image, the extracted areas can be points and their neighborhoods, lines or regions.
3. Model Application: Based on the road and lane marks model assumption, an adequacy is thus applied between the latter and the collected;
4. Tracking integration: the main idea behind the lane mark tracking system is to help in the decision of selecting which line should be chosen as the line that best represents the lane mark for a given frame
5. Coordinates Translation: The aim of this final step is to ensure the mapping between the image and real coordinates, based on the camera parameters and calibration.

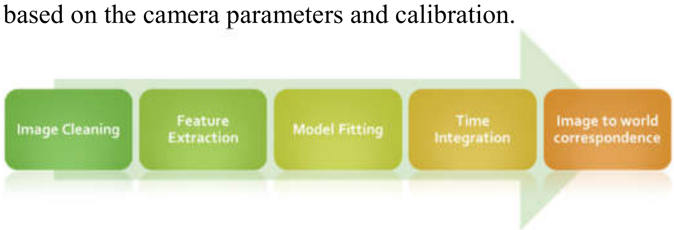

Figure.2: Generic Model for Lane detection

III. State of Art

The pre-processing stage is planned to mainly eliminate the noise effect on the images, which helps in reducing the false positive results. The algorithms assuring those operations could be classified into two families: Quality enhancement and Illumination adaptability [5]. Concerning the illumination issue, every reliable Lane detection system should be able to adapt to the various lighting circumstances (ephemeris, sun position, shadows, tunnels…). Managing such situations and taking those factors into account, is a decisive step for the correct extraction of features from the gathered images.

Gradient enhancing conversion [6] generates from an input color image, an intensity image that has maximized gradients at the lanes edges. This process provides detection of the lane boundaries in various illumination. Yoo et al. [7] revisits the lane detection algorithms based on the gradient differences between roads and lanes, the original methods were based on gray level conversions of the images which is not evident with illumination changes. For those reasons they proposed an algorithm based on linear discriminant analysis for maximizing lane gradient in an output image from an original color image.

The shadows are major a major source of corruption, [8] performed several color transformation and combined color channel to generate normalized intensity between brightness and shadows areas. [9] had worked on the detection Nighttime and observed the impact of the nighttime on the color-space of the road surface, so they provided conversion on the RGB channels. Also, Figure 3 explains the equalization process by which all gray levels of the image are forced to be equiprobable.

For the second category of quality enhancement, the adaptive bilateral filter (ABF) [10] is a sharpening and smoothing algorithm. This contrasts with image enhancement techniques that seek to improve the appearance of an image without reference to a specific model for the degradation process. The restoration framework is particularly valuable because in conjunction with a training-based approach, it provides a context within which the free.

Du et al. [11] proposed a view-based method for lane detection using an adaptive threshold applied on the ridge image based on its histogram, also morphographic bridge connection is applied to eliminate the noise effect that is perturbing the medial axis. Then an intensity check is completing the operation.

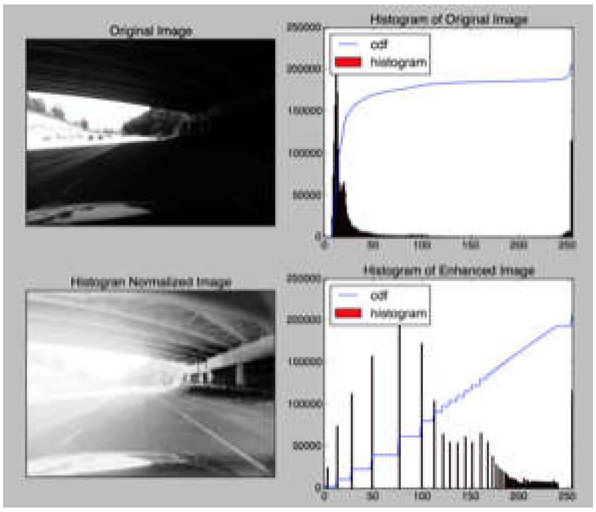

Figure.3: Histogram Equalizations

The median filter [12] is a non-linear filter, often used for noise reduction. Noise reduction is a conventional pre-treatment step to improve the results of edge detection processing.

Once the input images smoothed and denoised, several features could be extracted. The Canny edge operator is frequently used [6], this algorithm looks for contours by testing both the norm and the gradient direction of the image at a point. if the norm of the gradient is less than the norm of the gradient of one of its two neighbors along the gradient, then the gradients that are not local maxima are suppressed. The final step to apply is the hysteresis: two thresholds τ_h and τ_1 are defined, if the norm of the gradient in one pixel (x,y) is greater than τ_h, this pixel (x,y) is added to the contour as well as all the connected pixels to (x,y) along the normal at the gradient for which the radiant standard is greater than τ_1.

Since Canny operator is taking only the amplitude into consideration, [13] proposed the calculation of gradient amplitude but also its direction by the usage of the usage of convolution operators like Sobel filter.

Symmetrical Local Threshold [14] is used for lane feature extraction, with this method, rather than using global image information, the focus is on local phenomena, a sweeping window range is applied on every input pixel (x,y) to calculate the average intensity.

To be labeled as lane feature point every pixel should have its intensity greater than its neighbors, consequently it will be mapped.

Hough transform (HT) [15] is one of the standard shape recognition techniques in the field of artificial vision, invented in by Paul Hough, it allows a parametric representation of the image from its usual spatial representation. The HT enables the detection of lines, but also shapes like curves, elliptical circles and other more complex objects. The approach of this technique is to try to accumulate within a space of representative parameters, data that confirm the existence of certain forms. The principle of this transformation took its basis on the assumption that infinitely, many lines pass through a point, the only difference being in the orientation (the angle θ). The goal then is to determine which lines are closest to the expected pattern.

We get a sinusoid called "Hough space" when we transform all possible lines that connect one point to another. That is, calculating the value of r for each angle. If the curves relating to two points intersect, then the point of intersection in the Hough space corresponds to the parameters of a straight line that connects these two points. It is then easy to detect lines in the image by looking for the intersection in the parameter space.

Figure.4 Hough Transform: Accumulator matrix

The HT then exists for each point of the image and for each value of c to calculate its vector norm r and weight the pairs (r, θ) as a function of the number of times the pair is found in other words, each one Time, when two identical pairs (r, θ) are encountered in the image, the weight of the pair is increased. The pair with the strongest weight then corresponds to a line recognized in the picture as shown in Figure.4.

The interest in most of the times lies in the search for several lines within a given image, the HT applies also to those cases with some modifications. The idea is then to no longer consider the maximum in Hough's space, but to analyse the various maxima that can be found. The difficulty remains in the detection of these points without detecting twice the same line. The solution is then to go through the space parameter by looking zone by zone according to an exclusion window.

Kim et al. [2] proposed a Forward Collision Warning system integrating Lane detection Module. Their lane detection algorithm is basing on single camera inputs to define regions of interest (ROI), which are subset of an image, defined by given boundaries. The second step is detecting candidates' lanes by applying a bird's eye view transform named Inverse Perspective Mapping (IPM) [16] which allows to remove the perspective effect from the gathered image and then to remap it into a new two-dimensional domain and by using KALMAN filter the next lanes are tracked.

Tran et al. [17] worked on a horizontal line detection algorithm. This method detects in the grayscale image a horizontal line that will be used to extract an image sub-region. This designate image locates the lanes position and contribute to optimize the computing cost. To determine the first minimum that occur in the upper curve, a vertical mean distribution method is used. This minimum position is considered as the horizontal line position. According to illumination conditions, search along the vertical mean curve is considered. The Canny edge detector is then applied on sub-extracted image. Threshold is applied to differentiate potential lanes from the positive false candidate resulted from noise in the edge image. Then k-means clustering and RANSAC algorithm are used to detect the lanes boundaries.

Bottazzi et al. [18] presented a lane detection algorithm based on histogram and using illumination invariant. A triangle prior module is adopted to generate dynamic region of interest (DROI). The process is starting with the calculation of the histogram from the image and road frame, which is allowing the comparison of both of the latter which makes it possible to extract the illumination discrepancies. The detection of lanes markers is assured by the segmentation method which is followed by Lucas Kanade tracking to track the lanes [19].

After edge map generation a Hough transform is applied to get a first lane detection. The Hough transform cannot represent curved lanes, so curve fitting is used for detecting curved lanes. A quadratic curve model is used to construct the curved lanes. Training data consist of road and lane classes. For the first frame the training data is given manually and for remaining frames the training data are updated for adapting illumination changes.

The first step proposed by Duong et al. [20] is to generate Bird's eye view mapping which is removing noise and perspective effects based on the warp perspective mapping. This method is simpler than the IPM already presented. This image is processed during Edge detection where each pixel value is compared with its right and left neighbours in order to produce an edge map, to clean the noise the morphology opening operation was also applied. this method is enhanced using a sliding window step. The Hough transform is used for Line detection and Lane fitting is finally done.

Tsai et al. [21] proposes a new lane detection algorithm, using boundary identification and Sobel edge detector for gradient direction founding. Next the gradient orientation gathering is ensured by the application of circular masks. The initial gradient is determined based on the largest histogram bin for orientation. The probing circular mask is used to avoid deviation. A third order polynomial fitting is also used.

Y.Yenİaydin et al. [22] introduced the “neighbourhood AND operator” method for feature extraction by merging the binarized image and resulted image after Sobel operator application, the bird eye view is obtained by applying the IPM, histogram plot is then generated to define the candidate lanes in the Right and left sides of the road based on the peak values which allows to build the lane detection model considering the least-square error.

IV. CONCLUSIONS

The available literature of perception models for autonomous vehicles has involved the different aspects that allows the vehicle sensing its environment like road perception modules as road edges, traffic lanes and so on. Several advancements were made in these detection fields. Most of the strategies are based on Vision or Lidar approaches and are very simple for detecting. Despite all the progress made concerning the lane detection and tracking area, there are still opportunities for improvement because of the wide range of variability on the vehicle environments, as dynamic motion of obstacles, parked and moving vehicles, bad quality lines, sharper curves, irregular and strange lane shapes or emerging and merging lanes.

Several improvements of lane detection and tracking algorithms must be considered such as the improvement of the complexity and the efficiency of the algorithms, the management of large size databases (Big Data), the identification of extreme cases and the adaptation of these algorithms to the wide range of variability in the lane environments.

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