IJARESM
INTERNATIONAL JOURNAL OF ADVANCED RESEARCH IN ENGINEERING, SCIENCE & MANAGEMENT

SURVEY: COLOR BASED ROAD SEGMENTATION APPROACHES

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Abstract: Recently, there are an increased number of research activities focusing on the Computer vision development system. Road detection is a process of detecting the road area including its boundaries and lane-markings from an image captured by a camera. Vision-based road detection is a key component for autonomous vehicle. Reliable image based road detection is a key to the success of many road scene understanding applications, such as autonomous driving, personal navigation, obstacle detection and driver assistance system. Road detection is main a difficult computer vision problem because of the large variability of images which are acquired worldwide at different times of the day, with changing weather, lighting, and variable road conditions. The main purpose of vision based road detection is to detect the road areas from the above challenging conditions. So it is essential to develop image processing based road detection from the color images of road that segments the roads with lane marking, shadow, and varying illumination conditions. This paper is focus on various approaches which are used to detect road area from the structured and semi- structured roads and various measuring parameters which are used for the quantitative analysis of the roads.

Keywords: Computer vision based image processing, Road detection, Structured roads, Semi-structured roads.

INTRODUCTION

Road detection from a driving scene is a popular topic which usually helps the intelligent on-vehicle system to get a better understanding of the environment so that it can improve traffic safety and efficiency. Among the popular vision-based researches, road

detection not only provides straightforward information for path planning but also helps to obtain precise obstacle detection and road profile estimation. So the vision based navigation is an essential task for the road detection. In recent years, with the development of machine vision technology, research on intelligent vehicle vision perception has been gradually increasing [1]. In road research area, the biggest problem is the surrounding environment such as, road curvature, road heights, roadblocks, lighting (weather), shadows and the unclear or even non-existence physical lane lines. There are two major trends on road detection through image processing, i.e.: single camera-based detection (monocular) and detection using two or more cameras (stereovision) [2]. The main goal of vision-based road detection is detecting traversable road areas ahead of an ego-vehicle using an onboard camera. In this paper, we focus on vision-based road detection. That is, detecting the free road surface ahead of the ego-vehicle using an onboard camera (see Figure 1).

Figure 1: Goal of vision-based road detection is identifying road pixels in an image [10]

The rest of this paper is organized as follows. Sections II discuss the related work to the road detection. Section III highlights various research methodologies that are used for the road detection. Section IV discusses road detection based on the types of road. Section V gives the summary of various road detection methods. In Section VI we talk about quantitative analysis of road detection approaches. The last we gives conclusion about this paper.

II. RELATED WORK

Many researchers are focusing on the road detection research. Recently, several approaches for image-based road detection have been proposed. In [1], a novel shadow diminishing gray value conversion method for tackling illumination related effects is proposed and an improved feature extraction method is used to identify lane markings from the shadows. In [2], the authors propose to detect the road using RGB Histogram Filterization to determine area between the slopes, which is considered to be the road area and Boundary

Classification to determine the identification of road and non-road using Hough-Transform (HT) combined with Canny Edge Detection algorithm. In [3], road-area detection is done using an algorithm that is composed of two modules: Boundaries Estimated Module to estimate boundaries based on the intensity image and road areas are subsequently detected based on the full color image and Road-Area Extraction Module that is effectively extracts the road area and reinforces boundaries that most appropriately fit the road-extraction result. In [4], there is an online road detection that conducts an exhaustive evaluation of different classifiers and the effect of using different color representation to characterize pixels. It consists of two stages: Color conversion and Pixel classification. In [5], Region Similarity based Analysis method is used. In this approach, a free road region candidates are estimated first based on intensity similarity search which using statistical feature analysis (SFA) [to generate an intensity similarity image of road image] combined with a breadth-first search (BFS) [to detect the road region candidates] algorithm to segment different intensity similarity regions in a road image. The similarity between a road model by drivers selected and the road region candidates is expressed by a metric derived from the Bhattacharyya distance. The road region can be identified by voting scores for these similarity measures.

In [6], Axis-calibration algorithm (Sky removal for axis-calibration, Log-chromaticity space by geometric mean) is combined with a stereovision based method (Confidence interval classification). In [7], Fast Road Detection in which Binary Map (Illumination intrinsic image generation, Confidence interval-based pre-detection, Road extraction by stereo vision) is combine with Confidence Map (Likelihood distribution of pre-detection, Likelihood distribution of plane extraction, Confidence map generation). In [8], Region-based road detection method is used for the detection. In [9], Road detection from a single image algorithm using two vision-based road detection methods are present: first, Pixel-based methods which use characteristics such as color or texture measured over local neighbors in order to formulate and threshold on a likelihood that pixels belong to the road part or the background and second Boundary-based methods which typically work best on well-structured roads, such as highways. In [10], the road detection approach uses Illuminant Invariance Theory on color images to classify road pixels to provide reliable road detection results despite lighting variations and shadows.

Basically, the main drawback of vision system is their sensibility to illumination conditions such as shadows, backlighting and low rising sun conditions. Especially, shadows are most impactive since they often appear and may lead to false object detection. Thus, road

detection in varying illumination conditions becomes a really hard issue, which should be handled with care before further processing [7].

III. RESEARCH METHODOLOGY

Road lane detection is one of the most mature technologies in commercially available Advanced Driver Assistance Systems (ADAS) and autonomous driving systems. However, they provide useful assistance only in specific situations such as highway driving, or driving on well-preserved roads. This is not the general case though; many roads lack distinct markings, while others have no markings at all. Driving in unstructured and even unpaved rural roads is also a great challenge. Such challenges require a more general drivable path detection algorithm and this is robust road detection in all kinds of environments, at any time of the day and under different weather conditions [12]. In simple word, road detection means extracting road boundaries and lane markings. Generally, there are two types of road detection approaches [14]: For structured roads with yellow or white lane markings such as highways and for unstructured roads. According to the various types of road, the road detection can be classified into structured road, semi-structured road and unstructured road detection.

A. Structured Road Detection

For structured roads, land markings is one of the most commonly used methods, fixed-threshold and Hough transform [1] and boundary based methods such as Hough transform[1], Hough-Transform (HT) combined with Canny Edge Detection algorithm [2], mathematical morphology [3], etc. have been utilized to detect the road marking or boundaries. However, these methods only consistently work for structured roads with noticeable road borders or markings.

B. Semi-Structured Road Detection

For semi structured with border only, the boundary based methods like Binary Map combine with Confidence Map [7] and Region-based method random forest classification [8], etc. are used to obtain road boundary.

C. Unstructured Road Detection

For unstructured road without marking or borders, the histogram-based segmentation [11] for road boundary detection is proposed to find the drivable road region. However, the drawback is that needs many different types of road images to train a classifier for good segmentation.

IV. ROAD DETECTION BASED ON THE TYPES OF ROAD

According to the types of road, we can be roughly classified the road detection techniques (Fig.2) into three categories: *(A) Edge based Road detection* which is only used for structured road (where lane marking is present. *(B) Feature based Road detection* (Feature like color, shape, intensity etc.) that is used for structured and semi structured road. *(C) Texture based Road detection* that is used for unstructured, structured and semi structured road.

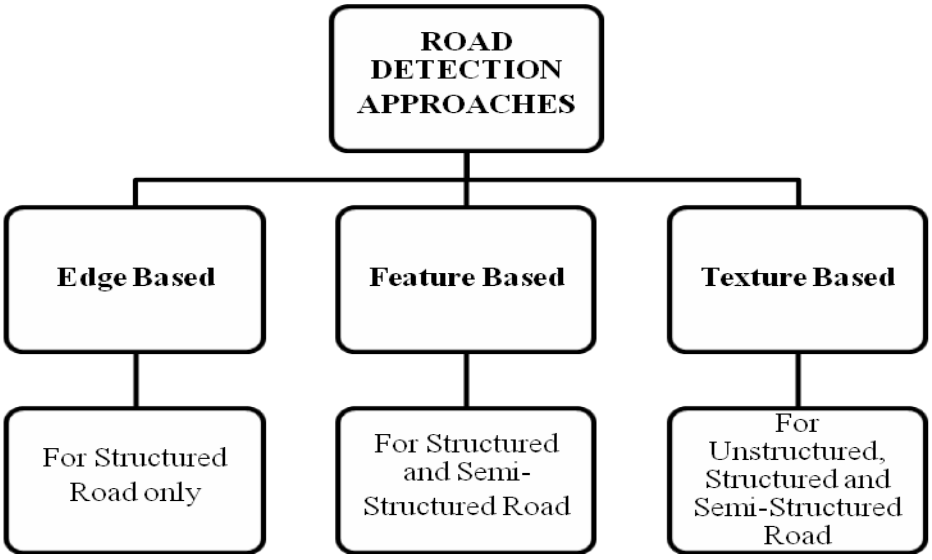

Figure 2: Road Detection Approaches

A. *Edge based Road detection*

Edge based road detection includes a variety of mathematical methods that aim at identifying points in a road image at which the image brightness changes sharply or the road has discontinuities. Edge based road detection is a fundamental tool in computer vision based image processing particularly in the areas of feature detection and feature extraction. The purpose of detecting sharp changes in road image brightness is to capture important events and changes in properties of the road scene. Authors in [1] have discussed that road boundary points are expected to be extracted from filtered binary image. There are many edge detection methods, but the detection result is usually noisy due to edges not being road boundaries. In this paper, most existing lane-marking feature extraction methods utilize gradient to find the edge of lane-markings. However, edge-detection methods can't effectively identify lane-markings from shadows since the shadows also have gradient like lane-markings. Although pixels of lane-markings have saturation value much higher than those of the pixels of road surfaces in many cases, the saturation value vary greatly among different lane-markings according to their dilapidated degrees. Thus the edge based techniques for road detection are not particularly suitable when identify lane-markings from shadows.

B. Feature based Road detection

Many computer vision algorithms use feature based methods as the initial step of the road detection. Feature based road detection methods focus on identification of features that are used to describe the road such as color, shape, intensity of the road. There are various feature based road detection methods which are used for boundary and lane marks detection of the road. Authors in [1] have proposed a feature based approach that can solve the most illumination problems in road detection. It is also robust against water on road surface and fits roads of small curvature well. There is an improved feature extraction method that is used to identify lane markings from the shadows. There are most existing lane-marking feature extractions methods utilize gradient to find the edge of lane-markings. Most existing methods of road boundary detection and lane-marking detection are combined to provide better performance. Figure 3 shows that process considering in [1] for the road detection. Here simply an input image given to the system and proper road detection is getting at last with boundary and lane marking extraction.

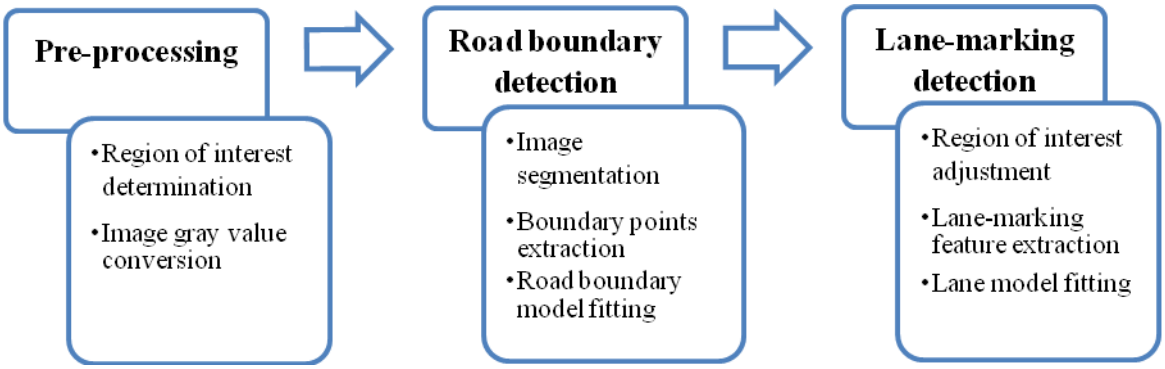

Figure 3: Basic block diagram of road detection [1]

1) *Pre-processing:* Removing the interference of redundant information is the main task of image preprocessing. In this paper two steps are used first is region of interest determination based on the probability of finding the interested target. In this, the lower two-thirds of an image is temporarily selected as ROI for road boundary detection. Second is Image gray value conversion because of the red, green, and blue channels are highly correlated, it is inefficient to process all channels by analyzing nearly the same picture three times. Therefore, grayscale conversion is employed to convert the input color image to a grayscale image of single-channel representation.
2) *Road boundary detection:* For road boundary detection, image segmentation for removing noisy points using morphological filter applied to the binary image, boundary points extraction for extracting left and right boundary points and road

boundary model fitting using Hough transform to find the best fitting straight lines are used.

3) *Lane-marking detection:* For Lane-marking detection, region of interest adjustment, Lane-marking feature extraction by calculating the probability of lane-marking and extracting lane-marking points by applying simple fixed-threshold segmentation to the obtained feature grayscale image and lane model fitting using Hough transform applied to the binary image to fit the lane-marking points are used.

In [2], RGB Histogram Filterization process is used to determine area between the slopes, which is considered to be the road area and Boundary Classification which is the process that determine the identification of road and non-road using Hough-Transform (HT) combined with Canny Edge Detection algorithm. Online road detection that used in [4] is conducted an exhaustive evaluation of different classifiers and the effect of using different color representation to characterize pixels. B. Wang, V. Frémont and S. A. Rodríguez Et. Al. [7] presented the a Color-based Road Detection and its Evaluation on the KITTI Road Benchmark to obtain a better understanding of the environment for Advanced Driving Assistance Systems (ADAS), in order to improve traffic safety and efficiency and to provide straightforward information of free road area without any training. José M. Álvarez and Antonio M. ´Lopez Et. Al. [10] have been proposed a Road Detection based on Illuminant Invariance to identify road pixels in an Image using vision-based road detection that is robust to shadows. This algorithm combines an illuminant-invariant feature space with a road class-likelihood classifier in a frame-by-frame framework to provide reliable road detection results despite lighting variations and shadows. The novelty of the approach relies in exploiting the invariance to lighting variations of a feature space that has not been used before in the road-detection context.

C. *Texture based Road detection*

Texture based road detection methods focus on identification of textural differences between road and non road regions to segregate between them. Mainly texture based methods uses boundary extraction approach using various texture properties of an image and identifies road region between two boundaries. In 2012, C.M. HSU, F.L. LIAN, Y.C. LIN, C.M. HUANG and Y.S. CHANG, Et. Al. [5] have been presented a Road Detection method based on Region Similarity Analysis to estimate the road region from image captured by a vehicle-mounted monocular camera and to detect road regions in real road scenes. This system is generating intensity similarity regions of road image using region similarity analysis. Then, color and

texture information of these region candidates are used to classify road regions by using similarity measures. Next, the road regions can be identified by voting scores for their feature similarities.

V. SUMMARY OF VARIOUS ROAD DETECTION METHODS

In previous sections various types of road detection methods were discussed. Broadly these methods are feature based methods. Table 1 shows the comparison between various popular road detection approaches proposed so far and discussed in last sections. All the methods are separated based on types of road structures, used methodology, type of dataset used in it, measuring parameters and remarks.

Table 1
Comparison of various road detection methods

Paper no.	Road modal used	Methodology used	Type of dataset used	Measuring parameters	Remarks
[1]	Structured roads with shadows	Illumination-Robust Feature based road detection: Novel shadow dimini-shing gray value conversion method and an improved feature extraction method	Online dataset ROMA.	Saturation and modified saturation, efficiency of Hough transform, probability of lane marking	It can solve the most illumination problems. Road boundary detection and lane-marking detection are combined to provide better performance.
[2]	Structured roads	RGB Histogram Filterization, Boundary Classification	Captured Image by the Camera of Canon 600D	Probability for histogram and Maximum and minimum peak point value(for each color)	The system has worked quite well and able to distinguish road and non-road. It is promising in recognizing and distinguishing the condition of the road and non-road with good lighting conditions.

[7]	Structured and Semi-structured roads	Fast Road Detection in which Binary Map is combine with Confidence Map	An open-access dataset provided by Kitti-road bench-mark	F-measure, average precision, accuracy, precision, recall and false positive/ negative rate (for UM, UMM and UU set)	The experimental results show that the binary map provides a high value on the F-measure compare to the other algorithms.
[8]	Structured, Semi-structured roads and Structured Random Forest	Structured Random Forest-based Road Detection (Region-based road detection methods)	Kitti-Road dataset and data collected in typical un-structured environ-ments	F-measure, average precision, accuracy, precision, recall and false positive/nega tive rate (for UM, UMM and UU set)	It can substantially improve the accuracy of road detection over the classical pixel-wise and patch-wise random forest classifiers and, at the same time be very computa-tionally efficient.
[10]	Structured roads with shadows	An illuminant-invariant feature space is combine with a road class-likelihood classifier in a frame-by-frame framework	Image sequences acquired using an onboard camera based on the Sony ICX084 sensor	Average effectiveness and standard deviation	It provides reliable road detection despite lighting variations and shadows and suitable for handling shadows while still allowing one to distinguish road pixels from the background, including vehicles on the road.

VI. QUANTITATIVE ANALYSIS OF ROAD DETECTION APPROACHES

In this section, various quantitative measuring parameters are discussed which are used to evaluate the performance of various road detection approaches. It is not possible to justify the accuracy and effectiveness of particular method for road detection without

appropriate evaluation of the road parameters. In 2014, B. Wang, V. Frémont and S. A. Rodríguez [7] have been done the evaluations and comparisons of both, binary map and confidence map using the KITTI-ROAD benchmark which contains three different categories of road scenes: UU - urban unmarked road, UM - urban marked two direction road and UMM - urban multiple marked lanes' road. Binary map detection (BM) is evaluated both on training dataset in perspective space and on testing dataset in Bird Eye View (BEV) space Detection results are evaluated by F-measure, average precision, accuracy, and other standard measures such as precision, recall and false positive/negative rate. The binary map provides a high value on the F-measure compare to the other algorithms.

In 2011, Jose M. Alvarez Et. Al. [10] proposed an illumination invariant method for road detection. It works by combining the illuminant invariant feature space and the likelihood based classifier. The qualitative evaluation was done on test images by manually segmentating all the images in test database to generate ground truths and later on comparing the results with the ground truths. In this paper quantitative evaluations were done against ground truth using three pixel wise measures: precision P, recall R and effectiveness F are defined as below: *precision* $P = \sum (G*I_r) / \sum I_r$ and *recall* $R = \sum (G*I_r) / \sum G$ where G and I_r are the ground-truth mask and the road detection result of a given image I_{RGB}, respectively. The symbol "*" stands for pixelwise product, and $\sum$ means summation over all pixels. The effectiveness is given as $F= (2P\ R) / (P+R)$. All three measures range from 0 to 1. Precision and recall provide different insights in the performance of the method: low precision means that many background pixels are classified as road, whereas low recall indicates failure to detect the road surface. Finally effectiveness is the tradeoff using weighted harmonic mean between precision and recall. This method provides good results in the presence of shadowing effect.

CONCLUSION

- Road lane detection is one of the most mature technologies in commercially available Advanced Driver Assistance Systems (ADAS) and autonomous driving systems. In this system the color image of a road will be given as input to the software system. By referring various literature's papers, getting the basic information and various ideas about methods of road detection based on color which are used in the all papers.
- From the observation table, it is clear that the various methods are used for different kind of application and for various system such as illumination robust approaches, feature extraction, region similarity based detection, boundary detection, lane marking

detection, etc. All these methods have different measuring parameters like F-measure, accuracy, precision, recall, etc., based on these some of techniques have better performance and high accuracy and efficiency than others. Also get the knowledge about the various types of dataset such as online dataset ROMA, KITTY road dataset, Sowerby, CamVid database, etc.

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