Road Extraction through Color-Based Segmentation

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***Abstract*—This paper addresses the issue of effectively extracting road regions from a set of images using color-based segmentation techniques. By leveraging the HSV color model, our approach enhances the robustness and accuracy of road segmentation under varying lighting conditions and diverse road appearances. The proposed method demonstrates significant improvements in the identification of road areas with good performance.**

***Keywords*—Road extraction, computer vision, color segmentation. HSV model**

I. Introduction

Road segmentation is a crucial step for lane detection, which is essential for navigation in autonomous driving systems. Accurate lane detection ensures the safe and efficient movement of autonomous vehicles by enabling them to maintain their lane position and navigate complex driving environments [1]. The importance of solving this problem lies in its direct impact on the safety and reliability of autonomous driving, making it a critical area of research in computer vision.

To address this problem, many algorithms have been proposed. Some of the most common methods include region growing, watershed segmentation, and threshold segmentation. Region growing involves selecting seed points and performing homogeneity tests to identify common regions. Watershed segmentation involves selecting markers and gradually expanding from these markers into regions. Threshold segmentation involves selecting a suitable threshold and comparing each pixel with the threshold to identify the desired region. However, these methods have limitations in terms of performance and accuracy under varying conditions.

In this paper, the chosen algorithm for road extraction is threshold segmentation. This is mainly due to its superior performance compared to other common methods. However, we have modified the traditional thresholding method, which is commonly applied to grayscale images. Instead, we employ a method that improves upon the normal thresholding approach: color-based segmentation. Color segmentation uses a specific color model, a mathematical representation of color pixel values, to achieve accurate segmentation [2]. The advantage of using color-based segmentation is its ability to compare multiple color planes, rather than just one as in grayscale images, leading to higher accuracy.

Some of the common color models used include RGB (Red, Green, Blue), HSV (Hue, Saturation, Value), CMYK (Cyan, Magenta, Yellow, Key/Black), and NTSC (National Television System Committee) [3]. For this paper, the proposed algorithm utilizes the HSV color model for color segmentation. This choice is due to HSV's intuitiveness to human vision and its ability to produce better segmentation results by focusing on human perception [4].

II. Methodology and Approach

The methodology proposed in this paper mainly involves two steps: preprocessing to remove noise and color segmentation. The input is a set of RGB images, and the output is a region mask that identifies the road regions.

A. Preprocessing

To ensure higher accuracy in segmentation, the images first need to be preprocessed to remove noise. Noise in images can lead to incorrect segmentation, thus affecting the overall performance of the algorithm. To address this, a 9x9 Gaussian filter and a 9x9 average mean filter are both applied to the input images. The Gaussian filter helps in reducing high-frequency noise while preserving edges, and the average mean filter smooths the image by averaging pixel values. This dual filtering approach makes the images more resilient to noise, ensuring that the subsequent segmentation step operates on cleaner data.

B. Color Segmentation

In this study, we implement color-based segmentation using the HSV color model to accurately extract road regions from images. The input image is first converted from the BGR color space to the HSV color space, leveraging HSV's alignment with human color perception, which distinguishes between color and intensity more effectively.

To achieve this, we define specific HSV thresholds to create a binary mask that isolates the road region. This involves selecting lower and upper bounds for the HSV values that correspond to the road surface. Additionally, to focus the segmentation on the relevant part of the image, known to be below a horizontal cutoff separating the sky from the ground, we limit the mask to areas below a specified y-coordinate, effectively ignoring the upper portion of the image.

To determine the ideal HSV thresholds and y-coordinate, we first plot the image in the HSV color model. This visualization helps identify the most suitable threshold values and the exact location of the horizontal cutoff. This mask is then applied to the original image to obtain the segmented road region. This approach enhances segmentation accuracy by utilizing multiple color planes, as opposed to traditional grayscale thresholding methods that consider only one plane.

III. Results and Discussion

For the evaluation of the proposed algorithm, I utilized a dataset from Kaggle known as the “Road Segmentation Dataset” [5]. This dataset comprises 30 RGB images with a resolution of 720 by 1280 pixels. The images were captured from a moving vehicle and depict various road regions from different angles and perspectives. To ensure a fair comparison with the ground truth, preprocessing steps were applied to the ground truth images to match the segmented road regions. The performance of the algorithm was evaluated using both quantitative and qualitative measures.

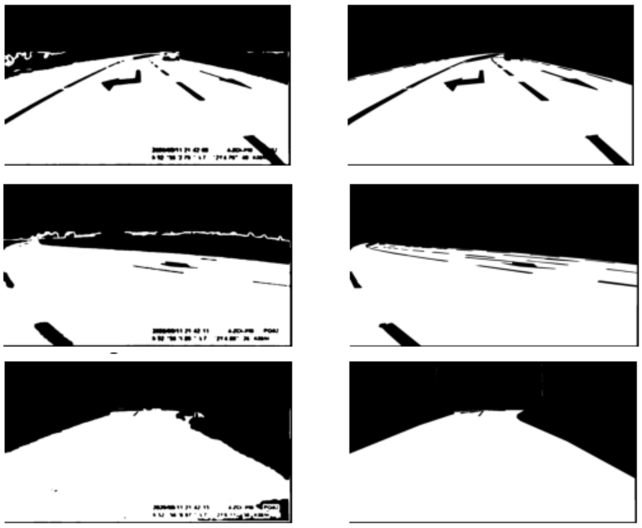

Fig. 2. Visual results of segmented road regions of few images. The images on left are road regions masks segmented by proposed algorithm. The images on right are road regions in ground truth masks. The white area represents the road regions.

A. *Visual Inspection*

For qualitative evaluation, we performed visual inspection to assess the performance of the proposed algorithm. As illustrated in Fig. 1, the algorithm effectively produced segmentation masks that closely resemble the ground truth masks. However, a limitation was observed where certain regions or objects, such as vehicles with similar colors to the road, were mistakenly included as part of the road region. T

B. *Quantitative Metrics*

For quantitative evaluation, we calculated accuracy, precision, recall, and the F1-score for each image to assess the algorithm's performance comprehensively. Accuracy is used to measure the overall correctness of the algorithm. Precision indicates the proportion of true positive results among all positive identifications. Recall **r**eflects the proportion of actual positives correctly identified by the algorithm. F1-Score **p**rovides a harmonic mean of precision and recall, offering a single metric to evaluate the algorithm's performance. These metrics were computed using the following formulas:

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \tag{1}$$

$$Precision = \frac{TP}{TP+FP} \tag{2}$$

$$Recall = \frac{TP}{FP+FN} \tag{3}$$

$$F1 - Score = 2 \times \frac{Precision \times Recall}{Precision+Recall} \tag{4}$$

The computed results for the proposed algorithm are summarized in Table I:

TABLE I. AVERAGE QUANTITATIVE EVALUATION

Test	**Measures**			
	Accuracy	***Precision***	***Recall***	***F1-Score***
Proposed Algorithm	96.77%	97.93%	96.20%	97.05%

The results indicate that the proposed algorithm performs exceptionally well in segmenting road regions, with an accuracy of 96.77%, precision of 97.93%, recall of 96.20%, and an F1-score of 97.05%. These metrics suggest that the algorithm is highly effective in correctly identifying road regions and minimizing false positives, achieving a strong balance between precision and recall.

However, visual inspection reveals that the algorithm sometimes misclassifies non-road objects with similar colors as road regions. This limitation suggests that while the algorithm is effective, there is room for improvement, particularly in distinguishing between road surfaces and objects with similar color characteristics. Future enhancements could involve refining the color thresholds or incorporating additional features to reduce these false positives and improve the algorithm's robustness.

Overall, the proposed algorithm demonstrates strong performance in road segmentation, with high quantitative metrics and promising visual results. Addressing the identified limitations could further enhance its effectiveness and accuracy.

IV. CONCLUSION

In this paper, we proposed a color-based road segmentation algorithm utilizing the HSV (Hue, Saturation, Value) color model to enhance the accuracy and robustness of road region extraction from RGB images. This approach was designed to address challenges related to varying lighting conditions and diverse road appearances, demonstrating significant improvements over traditional grayscale thresholding techniques.

Our algorithm achieved notable performance metrics, highlighting the algorithm's effectiveness in accurately identifying road regions and minimizing false positives, showcasing its strong performance in real-world applications.

However, the visual inspection and quantitative analysis revealed that the algorithm's performance is also affected by illumination issues. Variations in lighting conditions can impact the HSV color representation, leading to occasional misclassification of non-road objects with similar colors as road regions. This limitation indicates that while the algorithm is effective, there is a need for further refinement to improve its robustness under different illumination scenarios.

Overall, the proposed algorithm offers a robust and efficient solution for road segmentation, with promising results and room for improvement in handling illumination variability. Addressing these issues will further enhance the algorithm’s effectiveness and contribute to the advancement of autonomous driving systems.

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