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An illumination robust road detection method based on color names and geometric information ☆

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Abstract

Road detection is a basic task in automated driving field. In existing methods, detecting lane marks is a frequently used approach. However, road marks could fade with time, or even do not exist on some roads. Considering these factors, road region segmentation from background is much more reliable. One of the difficulties in this area is dealing with variant illumination conditions. Existing methods make some progress on reducing the influence of shadows, but they are still not satisfactory. Taking this into account, we put forward an improved shadow-free road detecting method based on color names, whose performance exceeds the existing methods. In addition, to further improving our performance on application, we adopt vanishing point detection and fuse two confidence maps to reduce the interference of sidewalk regions. Experiments on KITTI dataset depict that the proposed method is efficient. Moreover, the improved road detection method has low-complexity, which meets the requirement of practical usage.

Keywords: Road detection; Illumination robust; Color names; Vanishing point

1. Introduction

Road detection is one of the most important topics in different areas of computer vision, such as autonomous vehicle. Many researches have been conducted in the past decade, which lead to some well-performed strategies (Hillel, Lerner, Dan, & Raz, 2014) proposed in literature for road detection. However, the performance of these methods could become unsatisfactory when there are strong differences in illumination of the scenes. To overcome this problem, many shadow-free feature extractors are proposed by researchers. Although the illumination-robust feature extractors (Alvarez & Lopez, 2011; Finlayson, Hordley, Lu, & Drew, 2006; Maddern et al., 2014) do improve the performance of road detection to some extent, they ruin some important messages behind the image, especially some weak but essential borders in road detection. There are also many road detection methods (Kelber & Jung, pp. 72–79; Southall & Taylor, 2001; Wang, Teoh, & Shen, 2004; Yanqing, Deyun, Chaoxia, & Peidong, 2010) based on borders or boundaries, but their performance are rely on correct boundary detection and suitable road models. Although plenty of work has been done on road detection, the consequence are still required to be improved.

Road detection methods for RGB images can be divided into two main categories: feature-based and model-based

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methods. Feature-based methods (Benligiray, Topal, & Akinlar, 2013; Huang, Kong, Li, & Zheng, 2007; Scharwächter & Franke, 2015) are focused on extracting local visual features of road, such as color (Kong, Audibert, & Ponce, 2010; Rotaru, Graf, & Zhang, 2008; Sun, Tsai, & Chan, 2006), brightness (Veit, Tarel, Nicolle, & Charbonnier, 2008; Wang, Mei, Kong, & Wei, 2014), gradient, texture (Huang et al., 2007) and their combinations (Scharwächter & Franke, 2015; Wang, Ji, & Su, 2009), which can be based on to distinguish road region from background. The algorithms based on features mainly process the images on pixel level, which means road shape has little influence on these methods. However, illumination and shadows will cause fake edges to feature-based methods, which cause significant impact to segmentation, classification, etc. High level information is applied to model-based methods (Kang, Lee, Hur, & Seo, 2014; Kim, 2008; Li, Cai, Xie, & Ren, 2012), such as global road models (Wang, Ren, & Yang, 2016). Therefore, model based methods are robust to shadows, but sensitive to road shape. For example, if the road shape is S-curve, a linear assumption could fail and the detecting outcome could be unsatisfying due to model mismatch. There are also some methods based on multi-sensor, which can deal with road detection well, but it is beyond the scope of this paper, in which we only talk about visual input.

In this paper, in order to deal with the problem above, we propose a new shadow-free extractor based on color names. Furthermore, vanishing point detection is introduced to overcome the drawbacks of feature-based methods on road detection. Ultimately, We put forward a new combination method to fuse the consequences of both modules to get the final confidence map, which goes a step further to reduce the influence of shadows.

The rest of this paper is organized as follows. The normal existing methods and our approach are introduced in Section 2. Section 3 shows the experiments and corresponding results of our approach, as well as the comparison with other existing methods. We draw our conclusion in Section 4. Note that this paper is best viewed in color.

2. Materials and methods

2.1. Existing road detection methods

To deal with the impact of shadow interferences to feature-based methods, shadow-free features are expected. In RGB space, each component contains brightness and color information, so that it has been tried to do color space conversion (Rotaru et al., 2008; Sun et al., 2006), such as HSI, YUV, or Lab space. Take Lab as an example, L component represents luminosity, while a and b components contain color information. The color components are insensitive to illumination to some extent, so that it is believed suitable for road detection with shadows.

However, the methods above do not perform well in road detection with severe shadows. In order to completely remove the influence of shadow, researchers tried to find stable features, which are irrelevant to illumination. Log-chromaticity space (LCS) (Finlayson et al., 2006) is one of the well-known methods to remove shadows. In the LCS, sets of different materials are distributed regularly in parallel lines. The band-ratio chromaticity is defined as

$$\chi_j = \frac{\rho_q}{\rho_p}, \quad q \in 1,2,3, \; q \neq p, \tag{1}$$

in which, ρ_1, ρ_2 and ρ_3 represent red (R), green (G) and blue (B) components in RGB space respectively, ρ_p indicates the normalizing component, and ρ_q refers to the rest two components. Then, a shadow-free feature map τ can be extracted by

$$\tau = \exp(\cos\theta \cdot \log\chi_1 + \sin\theta \cdot \log\chi_2), \tag{2}$$

here, θ is a camera-determined parameter.

This algorithm is taken a step further by Alvarez and Lopez (2011), applying $p = 2, q = 1,3$ in new equation and removing the exponential operation in sake of speed improving. The new equation is as follow,

$$\tau_\theta = \cos\theta \cdot \log R/G + \sin\theta \cdot \log B/G, \tag{3}$$

This equation has another form proposed by Maddern et al. (2014),

$$\tau_\alpha = (1-\alpha)\cdot\log R + \alpha\cdot\log B - \log G + 0.5, \quad \left(\alpha = \frac{\sin\theta}{\cos\theta + \sin\theta}\right), \tag{4}$$

which is the same as the former one, except a constant term.

Plenty of work has been done on different color spaces, such as RGB, HSI, YUV, or Lab space, but natural language color naming spaces are neglected, such as color name space (Weijer, Schmid, Verbeek, & Larlus, 2009). Color name space is learned from real-world images, mainly collected from Google Image. It shows novel effect on image retrieval and image annotation. Quantities of tasks have been better solved due to application of color name space, such as salient object detection (Lou, Wang, et al., 2017; Lou, Xu, Xia, Yang, & Ren, 2017), visual tracking (Danelljan, Khan, Felsberg, & Weijer, 2014), etc. Taking this into account, color name space is used in the proposed approach of this paper.

Model-based road detection is another branch. In general, road is in a structured framework, which makes it reasonable to do road detection by model-based methods, like Hough transform (Southall & Taylor, 2001) and Spline model (Kelber & Jung, pp. 72–79; Wang et al., 2004), etc. The drawback of these methods is that clear borders and boundaries are required. To detect unstructured roads or structured roads without remarkable borders and markings, Kong et al. (2010) compute the Gabor orientation