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An Effective Method for Sky Region Detection

1 Zhao Zhijie[1], Wu Qian[1], Sun Huadong[1], Jin Xuesong[1]

[1]Harbin University of Commerce
Harbin, Heilongjiang, China
zhijiezzz@aliyun.com,wuqian_kris@126.com

Abstract. An effective method for sky region detection with color information and gradient is proposed. In the proposed algorithm, multi-border points in each column of image can be detected to complete complex sky region identification in image, and gradient and color information can be used to determine border point. The method proposed in this paper can deal with complex sky regions effectively compared with other sky detection methods, for example, sky regions are separated by buildings or flags. Experimental results have proven that the effectiveness of this method.

Keywords: **s**ky detection, sky border points, gradient information, color information

1 Introduction

The sky region detection is necessary for many areas. Sky detection can improve quality of depth map, sky region is the farthest region and have max depth information in depth map. In the application of the ground robots autonomous navigation, a robot understands the surrounding environment by the visual sensors; precise sky detection can improve efficiency of road detection for independent ground robot. Sky detection can be used for scene classification [1-3], and is often employed to achieve more effective content-based image retrieval.

Most of the current sky region detection algorithms are based on the colour information of the image. Aditya Vailaya[4]proposed a sky detection method in 2000. In the proposed method, the colour and texture information was combined. J.Luo proposed a method which can be applied to image recognition system in 2003, color information was used to classify potential sky pixels in the image, and then communication area is extracted; connected region which value is greater than preset texture threshold was selected, final sky region was detected through comparing saturation gradient of connected region[5]. Stephen Herman proposed the assumptions that sky region was always smooth and appeared at the top of the image, and the max possibility which one region in image was sky region was calculated, characteristics of color, texture, and vertical position was used, but this method often had error detection because of simple model [6].In 2013, Yehu Shen[7] proposed a sky detection method which could sketch out the shape of the boundary to separate the sky and non-sky region.

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But the sky and the non-sky are not only separated by a boundary line in scenes. For example, when there are buildings existing in the scenes, the method in [7] can not detect all sky region. So the concept of border point is proposed and border points in each column of image can be detected to complete complex sky identification.

2 Backgroud

Reference [7]employed the image gradient information for sky detection, and the definition of sky border position function is shown in equation (1):

$$1 \le b(x) \le H(1 \le x \le W) \tag{1}$$

where W and H are the width and height of the image, and b(x) determines the sky border position in the x^{th} column. Thus the description of the sky and the non-sky region in image is shown as equation (2):

$$\begin{aligned} sky &= \{(x,y) \mid 1 \le x \le W, 1 \le y \le b(x)\} \\ ground &= \{(x,y) \mid 1 \le x \le W, b(x) < y \le H\} \end{aligned} \tag{2}$$

Gradient image of input image is calculated, then different sky border position functions can be obtained by custom threshold t. Different values of energy function are calculated, sky detection is completed by energy function optimization. Energy function is defined as equation (3):

$$J_n = \frac{1}{\gamma|\Sigma_s| + |\Sigma_g| + \gamma|\lambda_1^s| + |\lambda_1^g|} \tag{3}$$

$\Sigma_s \Sigma_g$ are the covariance matrix of pixels of sky and non-sky region, the region obtained by different sky border position functions, $\lambda_1^s \lambda_1^g$ are the first characteristic value of $\Sigma_s \Sigma_g$ respectively. If threshold t exceeds 600, Jn(t) is nearly a constant. So the threshold and step is determined as follows:

thresh_min = 5, thresh_max = 600, search_step = 5 (4)

3 Sky detection method based on border points

3.1 Outline of proposed method

1) The input image is pre-processed with the method in [7], and then color information of obtained sky region is counted.
2) The input image is converted into a greyscale image, its corresponding gradient image with the sobel operator is calculated [8].
3) Sky border points of each column are determined, and sky and non-sky areas are obtained by equation.
4) Energy function value of sky and non-sky region is calculated by equation (3).
5) The threshold is changed, and step 3 and 4 is repeated.

6) Entire sky regions are detected by searching sky and non-sky region corresponding to maximum energy function value.

3.2 Definition of border point

The experimental image database comes from Corel image database [9] The Washington University School of Computer Science and Engineering [10]. Through statistics and analysis of a large number of images, we find that color and gradient of the pixels in sky border change greatly. As the sky region in image is smooth, gradient of pixels in this region is small. However, in the border of sky and non-sky, the gradient changes greatly. Since the gradient also changes greatly when edges of objects exists and texture pattern changes a lot in the image. Sky region is smooth and it has also some colour properties, the pixel which separates sky and non-sky region in each column of image is called border point.

3.3 Determination of border point

The first border point (sky area to non-sky area) is determined by a predefined threshold t with gradient information. The predefined threshold t is shown as equation (4).The second border point (non-sky region to sky region) is determined by statistics of sky colour information, the sky which is obtained through pre-treatment. It's given that most sky regions are blue, namely that b component of this region is great. Therefore, b component of color is considered to determine the second border point. But white objects are often appeared in the scene, for example, white buildings and white cars. They have parallel characteristics in the ways of gradient and b component compared with sky region. Therefore, in order to detect sky regions correctly, the judgment of r and g components should be added. Through statistics of sky, the average of each color component can reflect characteristics of sky region in some extent. So, average of color component is as judgment and different input image can adjust adaptively. The specific form is shown as follows. The pixel to be detected satisfying equation (5) is the second border point:

$$r_x - r_{\arg} < \delta_1 and g_x - g_{\arg} < \delta_2 and b_{\arg} - b_x < \delta_3 \tag{5}$$

$r_{\arg} g_{\arg} b_{\arg}$ are the average value of r, g and b components of known sky region, $r_x g_x b_x$ denote r, g and b components of the pixel to be detected. $\delta_1 \delta_2 \delta_3$ represent the floating range. $\delta_1 \delta_2 \delta_3$ equals to ten percent of $r_{\arg} g_{\arg} b_{\arg}$ respectively. They are empirical parameters which are derived through a number of experiments. The third border point is similar to the first border point, so it is determined as the first border point.

4 Experimental results

It's known that the proposed method is feasible and effective compared with the method in [7]. The results are shown in Fig.1, where the black regions are detected sky regions.

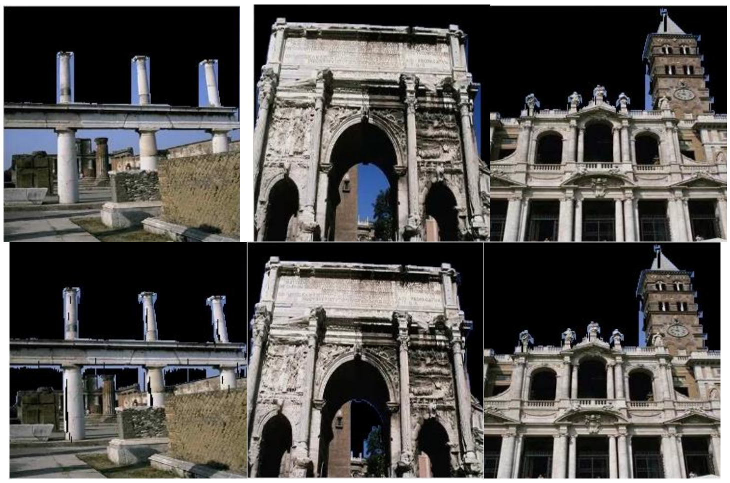

Fig. 1. the first row are the results of the method in [7], the second row are the results of the proposed method

5 Conclusions

In this paper, an effective sky detection method is presented, and the border points in each column of image can be detected to complete complex sky region detection in image. The proposed method is feasible and effective for the images which sky regions are separated by complex objects such as flags or buildings.

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