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Research on Preprocessing of Color Image for Vision based Mobile Robot Navigation

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Abstract: There are special requirements on image processing in speed and robustness for vision based mobile robot navigation. But mobile robot captured scene color image's processing has a high computational complexity and low robustness. To reduce data volume and improve robustness, a novel preprocessing method on color image for mobile robot navigation based on principle of threshold segmentation in HSV color space is proposed. Firstly, color image changed from GRB to HSV. Thinking of H component is instable when saturation level is too low, so the principle for single threshold gray image segmentation be used to choose a threshold T on S and divide S into high saturation and low saturation region, we can use H as segmentation basis in high saturation region and V in low saturation region. Then project H component to high saturation region and V component to low saturation region, H and V is stretched to different scope after projection. So, the S component contains not only color information but also gray information and reduces color image from three-dimentions to two-dimentions. Experimental results show that this method has more significant effects in improving the processing speed and robustness of illumination variation and shadows.

Key words: Mobile robot, vision based navigation, color image, image preprocessing, color projection

INTRODUCTION

Mobile robot is an important realm of robot research and engineering application. Along with the continuously developing of the compute and robot technique, the modern mobile robot already has been widely used at the industry, military and science research etc. According to statistics that about 60% of mankind information is gained from sense of vision and the sense of vision provide the most credible and detailed information of environment for mankind (Bishop, 2000). Vision sense signal also has added advantage, such as: wide detection scope, target information integrity, acquiring environment information rapidly, having no noise and harm to environment etc. In recent years, with the development of image processing ability, visual sensor is widely used on mobile robot in navigation and obstacle recognition. Vision based navigation has become a hot-point in mobile robot research.

The color image can provide more abundant information than gray image, so it has greater value for robot comprehension environment. However, vision based navigation required scene image processing must be real-time and robust against illumination changing and shadow. Color image has too many data, so it can hardly attain real-time processing (Liu *et al*., 2009).

To improving processing speed, there are two main directions in existing researches. The common one is to convert color images into gray images and extract navigation information (Zhang *et al*., 2007). This method loses color information and the target segment is not precise and the gray image is not good robust to illumination changing, shadow and water stains etc. The other direction is to segment images in each component in RGB or HSV color space, then blend the partition into a result, or segment the image directly on one component according to the characteristic of robot work environment (Zhan and Jia, 2008; Shao-Qiu, 2009). There are some drawbacks in these two methods: the former method has to deal with large mount of data, so it can hardly attain real-time and blending data is also very difficult; the latter reduced a lot of data, but lost the relation of each component, which easily result in mistake partitioning.

This study puts forward a color images preprocessing method in HSV color space base on threshold segmentation for vision based mobile robot navigation. Firstly, a threshold is chosen in saturation component and then divided S into high saturation region and low saturation region. Secondly, H (Hue) component is projected to high saturation region and V (Value) to low saturation region. Finally, in order to avoid different component having the same value after projection, H and

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V been stretched to different region. Thus the S component hold not only color information but also gray information and the image be reduced from 3D to 2D. The experiment results shows that this method has good effect at raising segmentation quality, improving real-time and robust to illumination and shadow etc.

THE PRINCIPLE OF PROJECTION

Color spaces choice: It is very important to choose an appropriate color space in vision based navigation, there are many color spaces for color information expression and different color spaces have dissimilarity of applying purpose and background. HSV is the most commonly used color space since it gives different piece information in every component. It approaches the color sense of people. HSV also has a added advantage that V is independent with H and S. Illumination is closely connected with V and irrelevant with color information that contained in H and S. The three component's values are all in [0,1]. So, we choose HSV in this study.

Method of projection: In color images, the color information mainly comes from H component, H can keep stable relatively under different illumination, so it has been a main basis for color image segmentation in a lot of past researches. But as mentioned in study (Ohba *et al*., 2000), H will become unstable when saturation and illumination is too low, if we still carry on segmentation image on H, mistake detection or severity over segmentation phenomenon will appear. Generally, low brightness is caused by shortage of illumination and on the contrary low saturation is caused by too strong illumination. These two phenomena all have closely contact with V. So, we can consider to divide the image into two parts: high saturation region and low saturation region. We can use H as segmentation basis in high saturation region and V in low saturation region.

The HSV is a 3D space, the data volume is a little bit great, while in the robot vision navigation, image processing in real-time is required. According to the above analysis, we can see that the basis for color image segmentation can be chosen between H and V according the value of saturation, when saturation is high, differentiation of target in image mainly depends on color information, on the contrary, it mainly depends on brightness. So, we can project H and V to 2D surface according to the value of S. The principle of projection as Fig. 1.

In Fig. 1, Ts is the threshold chosen used the method. When saturation S>Ts, H is projected to S, otherwise V is projected to S.

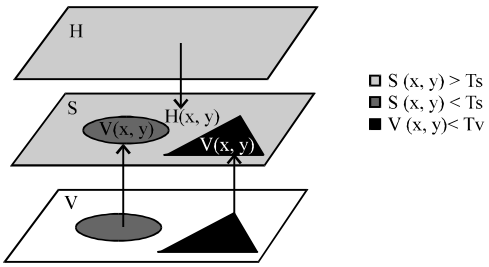

Fig. 1: The sketch map of projection in HSV color space

Avoiding H and V have the same value in S after projection, they all should be stretched in different scope, projection formula as follows:

$$S(x,y)=\begin{cases} H(x,y)*\alpha & (S(x,y)>Ts) \\ V(x,y)*\alpha+\beta & (S(x,y)<Ts \text{ or } V(x,y)<Tv,\ \beta>\alpha) \end{cases} \quad (1)$$

The S (x, y) is an pixel on S, H (x, y) is a correspond pixel on H and V(x, y) is correspond pixel on V, Ts is the threshold on saturation and Tv is the threshold on brightness. α is the stretch factor and β is the value of scope after projection. The above projection formula means that project V (x,y) to S(x,y) when the value of saturation is smaller than Ts or brightness smaller than Tv. Otherwise, project H(x,y) to S(x,y). Avoiding appears same value on H and V after projection, the value is stretch to different scope. After preprocessing, the image S became a 2D image as gray image, it's data volume is reduced and containing the color and brightness information.

THE METHOD OF THRESHOLD SELECTION

It is critical to choose a appropriate threshold for the above projection formula. The ideal threshold is the value of S on which the H component becomes unstable. But lots of experiments show that the critical value has close relation with both color and brightness, so it is difficult to find out a definite value to be the threshold and current researches have not put forward any methods. We can see this question as an image segmentation question in substance, it divides S into two parts: high saturation Sh and low saturation Sl. If we look Sh as background region and Sl as object in gray images, the method for single threshold gray image segmentation can be used to segment S. The method of the biggest class square deviation has the advantage of high efficiency and real-time, so it is used in this study to find out Ts, the detail of method is as follows:

Supposing the pixel number of S is N and the value scope is [0,1], there are ni pixels in i gray level:

$$pi = ni/N \; i \in [0,1] \qquad \sum_{i=0}^{1} p_i = 1$$

The pixel in the S be divided into two classes C0 and C1 according threshold Ts, C0 contains the pixel which value between 0 and Ts and C1 contains the pixel which value between Ts and 1, the mean value of the whole image is:

$$uT = \sum_{i=0}^{1} ip_i$$

The mean value of C0 and C1 is:

$$u_0 = \sum_{i=0}^{Ts} ip_i / w_0 \qquad u_1 = \sum_{Ts}^{1} ip_i / w_1$$

Among them:

$$w_0 = \sum_{i=0}^{Ts} p_i, \qquad w_1 = \sum_{Ts}^{1} p_i = 1 - w_0$$

The class square deviation can be defined as follow:

$$\partial^2 = w_0(u_0 - u_T)^2 + w_1(u_1 - u_T)^2 \qquad (2)$$

When try each Ts value in [0,1], the value of Ts which can make the ∂^2 max can be the threshold.

It is relatively easy to choose the Tv, after compared segmentation effect of different images that appear shortage of illumination on H, Statistics shows that when the V lower than 0.15, the segmentation effect become bad. So, 0.15 adopt as Tv in this study.

RESULTS AND DISCUSSION

In order to verify the effectiveness of proposed method, we chose a lot of scene images captured by mobile robot in different environment and illumination. And wrote program on MATLAB platform and simulated on the computer which CPU main frequency is 1.8 G, main memory is 1 G. It needs about 0.1 sec for processing a 640×480 image. We segment each image on H, gray image and preprocessed image with method in this study, in order to compare the effect, the edge is extract with canny operator in each image.

Figure 2a-d and 3a-d show the scene images of mobile robot captured on structural and unstructural road, (b)the edge extracted on H (Zhan and Jia, 2008; Shao-Qiu, 2009) is obviously over segmented on road because S is too low on road and H is not stable on it. (c) The edge on gray image (Zhang *et al*., 2007) is obviously over segmented on tree and grass because illumination is not homogeneous on it. (d) The edge extracted from image preprocessed with this study method projected V on road and H on tree and grass, so the object extracted from image is relatively integrated and little over segmentation phenomena.

Figure 4a-d show the scene images of mobile robot captured on road with shadow, in (b) and (c) the road extracted on H or gray image are

Fig. 2: Compare on structural road segmentation result. ((a) The primary image, (b) the edge extracted on H (Zhan and Jia, 2008; Shao-Qiu, 2009), (c) the edge on gray image (Zhang *et al*., 2007) and (d) the edge extracted with this study method)

Fig. 3: Compare on un-structural road segmentation result. ((a) The primary image, (b) the edge extracted on H (Zhan and Jia, 2008; Shao-Qiu, 2009), (c) the edge on gray image (Zhang *et al*., 2007) and (d) the edge extracted with this study method)

Fig. 4: Compare on road with shadow segmentation result. ((a) The primary image, (b) edge extracted from H, (c) edge extracted from gray image and (d) edge extracted with method in this study)

obviously over segmented on road because unstable H and un-homogeneous illumination because of shadows. (d) The edge extracted from image preprocessed with this study method projected V on road, so the road extracted from image is relatively integrated and roburst against shadow on road.

From above examples, we can see that the preprocessing method has overcome the drawback of current method and combined the advantages of color and gray image segmentation method, so it has good effect at segmentation quality, sufficiently processing speed and satisfactory accuracy, as well as robust against illumination changing and shadow etc.

CONCLUSION AND FUTURE WORK

Aimed at the drawback in color image preprocessing and special request in vision based mobile robot navigation, a novel method of projection in HSV color space is presented. The S component is dividing into high and low saturation region. The H is projected to high saturation region and V to later and used color information as segment basis in high saturation region and brightness in later. The projected image is stretched in color space. This preprocessing method overcame the high computational complexity, bad efficiency, over segmentation and mistake detection depended only on color or gray information. The experiment results show that the preprocessing method proposed in this study has great effect on real-time treatment and robust.

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