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博　士　論　文　概　要

論　　文　　題　　目

Study on Color Barycenter Approach for Road Sign Detection and Contrast Enhancement

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Recently, driver assistance systems (DAS) with various devices and information processing technologies are being developed to support safe and comfortable driving. In-vehicle camera is one of them and widely used in practice because it captures intuitive images that can be easily understood by operators. Aim to achieve the purposes of adaptive cruise control and collision avoidance in DAS with in-vehicle camera, it is a crucial step to extract the key information contained in the captured images, such as road signs, front cars and obstacles. Image processing technologies are naturally to be used to detect road signs and other objects. Some basic processing methods like contrast enhancement needs to be used to make the detection easier.

The captured images from in-vehicle camera are various different because of changes of natural environment, such as day-night and backlighting. These changes always make the color of image too bright, too dark, or deviated. The influenced colors cannot provide robust characteristic for object detection, and lead to the difficulties in the detection and lower the accuracy of object detection.

This research aims to develop a novel color calculation approach and find a reasonable way to analyze colors precisely. The proposed color calculation approach, which called as color barycenter approach considers the relationship of three components of RGB color model. Based on this, the road sign detection and contrast enhancement technologies are developed. In order to improve the accuracy of road sign detection, the distribution of color barycenter is presented and separated based on statistic feature by linear curve analysis and constrained clustering in different representation. In order to solve the problems of low quality image, the histogram based adaptive separation and mapping (HASM) framework is proposed for contrast enhancement. Also, the histogram based multi-image mapping and merging (HMMM) approach is studied as the improved version of HASM.

The thesis consists of six chapters as follows:

Chapter 1 introduces the background and problems of in-vehicle camera image processing in DAS firstly. Then, the technologies of color-based road sign detection and its preprocessing contrast enhancement are introduced. Lastly, the motivation is described and the main contributions are summarized.

Chapter 2 presents the original color barycenter approach, and introduces its creation, representation and significant. To create the color barycenter, a color triangle is mapped from RGB color model by three steps. Firstly, present a point (color) in RGB color model as a vector, and then mapping it onto red, green, and blue axes of the RGB as three vectors. Secondly, project the three vectors onto the 2D plane with 120-degree angle respectively. Lastly, connect the three vector apexes to create the color triangle. During the projection, the angle of vectors and original point is fixed. This means one color only can be projected to one corresponding color triangle. Then calculate the geometry barycenter of the color triangle as the color descriptor. For all colors, the set of barycenters will show as a hexagon representation (HR). Any barycenter in this region can be used to reflect the color (hue) and color intensity (saturation). Besides this, the distribution of color barycenter can be used to describe the color for image analysis and segmentation. For describing and analyzing the color barycenter more clearly and easily, it is transformed from HR to polar coordinate representation (PCR) and then to cylinder representation (CR) successively. Finally, to verify the effectiveness of color barycenter in color analysis, the widely used HSV color model is compared. Generally, the proposed color barycenter approach is more intuitive, accurate and robust for color analyzing and processing. It can perform better separation than HSV color model about 14.85% in PSNR and 11.25% in SSIM by K-means clustering.

Chapter 3 improves color barycenter approach to create a new lightness component to express more details of the original color image and combine it with the hue and saturation component of color barycenter to achieve conversion with RGB color model. To calculate the new lightness component, the distances from the barycenter to three apexes of the corresponding color triangle are used as the weights of red, green, and blue components. Based on this, the relationship of different components of RGB color model is considered to make the new lightness component clearer and it is better than the corresponding component of HSV, YUV, and LAB color models by comparing of image entropy (IE), average gradient (AG), and anisotropic quality index (AQI). The IE and AG of improved color barycenter approach are increased about 1.38%~5.82% and 0.58%~7.12% respectively. The AQI is increased about 20.0%~31.11% than HSV and LAB color models and worse than YUV color model about 2.22%. To evaluate the color presentation ability of improved color barycenter approach, the K-means is used to reduce the color into 7 clusters with higher PSNR than other color models about 1.45%~14.44%. Benefitting from this advantage, the improved color barycenter approach helps to improve lightness analysis.

Chapter 4 segments the color barycenter in different representation with different corresponding approaches for road sign detection. Although the color barycenter approach is significant and gives the intuitive distribution of colors, it cannot be used directly for segmentation. To use them to segment road signs in different representation, the segmentation approaches are studied. In HR, the prior knowledge based statistic feature is used to fix the thresholds for color barycenter separation. In PCR, the linear curve analysis based adaptive separation approach is used to fix the multi-thresholds. And in CR, the constrained clustering method is used to separate the color barycenter, which can overcome the shortcomings in HR and PCR. After color segmentation, the size, aspect ratio, and color ratio are used to verify each road sign candidate. Experimental results show that the proposed color barycenter segmentation approaches are able to detect road sign with robust, accurate performance and invariant to light and scale in complex surroundings. Generally, the average precision rate of single road sign completeness is improved about 3%~10% and the average accuracy of detection is improved about 6%~14% comparing with other four reference methods under different conditions.

Chapter 5 utilizes the improved color barycenter approach to describe the lightness component and convert with RGB color model. Under the improved color barycenter approach, the HASM framework and HMMM approach are presented for contrast enhancement. In AHSM, the histogram is separated by binary tree structure with the proposed adaptive histogram separation unit (AHSU). Although the HASM can obtain good enhancement results, it cannot work well for backlighting images. To improve this, HMMM is proposed. In HMMM, a mapping function is studied to obtain several images with different contrast, which can enhance different region in different images and then merge them by best patch selection. To obtain the best patches, image entropy is calculated and the mix-Gaussian filter is used to smooth the merged image. By the local and global enhancement, the image becomes clearer and looks natural in dark and bright regions. Generally, the proposed contrast enhancement method can obtain better results than other state-of-the-art methods, and the image entropy is increased about 11%.

Chapter 6 concludes thesis and gives some future works such as front car detection and obstacle detection in in-vehicle camera image processing.