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Two Dimensional Color Space and Color Shifting

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Synopsis

This paper proposes a new framework for color analyzing approach to cope with illumination changes in outdoor scenes. This approach enables us to manipulate easily the color of an image. In this paper, we introduce two main concepts: (i) two dimensional color space (*XY* space) and (ii) color shifting for an object composed of uniform color regions. They are potentially applicable to various tasks such as image retrieval, image indexing, image reproduction, image enhancement, segmentation and recognition of objects with uniform color regions. The characteristics of the proposed framework have been demonstrated through the experimental results using outdoor scene images taken under a great variety of various illumination conditions.

KEYWORDS: two dimensional color space, color shifting, uniform color regions, illumination conditions, signboards

1. Introduction

Color has been widely used in various tasks such as image segmentation, pattern recognition and classification, and so on. Clearly, for such tasks to be successful, the color must be stable across illumination change.[1)] A color image is a function of many parameters, for example, light source color, scene and object geometry, object shape and albedo, and camera parameters. Existing works in relevant aspects of color vision can be divided into two categories: computational color constancy and physics-based modeling. In addition, there have been many researches who related to color vision in the areas of parametric classification,[2,3)] machine learning techniques,[4)] color-based segmentation,[5)] color-contrast landmark detection,[6)] illumination estimation,[7)] and color indexing.[1,8,9)]

Moreover, the problem of color representation affects almost every field in computer vision. Many methods have been suggested for modeling and representing colors. The *RGB* color space is widely used for image capture and display, however it is not always considered the appropriate representation for color. Other color spaces have been suggested to create more intuitive color representation. There are many such spaces (*HLS*, *HSV*, and so on), but they are not enough to overcome the difficulties under illumination changes. So, we introduce a two dimensional (2D) color space (*XY* space) that is well suited to image processing in outdoor scenes. Moreover, we investigate the nature of color shifting based on time. Our proposed approach is possible to apply any objects that composed of uniform color (UC) regions as shown in Fig.1.

Fig. 1. Examples of objects with UC regions in outdoor scene.

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2. XY color space

Color is of interest to working in computer vision. In 1931, CIE defined the virtual primary colors *XYZ* as the standard.[10] The representation of the *RGB* color space in 3D-polar coordinates (hue, saturation and brightness) can sometimes simplify this task by revealing characteristics not visible in the rectangular coordinate representation. The *rgb* space (Eq.(1)) is a normalized form of the *RGB* space and is used to eliminate the effect of brightness. Here, we define the *XY* space using the *rgb* space. This space is suitable for image processing especially in outdoor scene images. The aspect of the *XY* space is described in Fig.2. The relation between *RGB* and *XY* space is described in Fig.2(a). *XY* space with colors on $R+G+B$ = 256, 64, 128, 384 and 512, respectively are shown in Fig.2(b). In Fig.2(c), the ellipse region painted by black color represents the achromatic region which is predefined by using the pixel values of white color from various types of signboards under different illumination conditions. Here, the *XY* space is defined as follows.

$$r = \frac{R}{R+G+B}, g = \frac{G}{R+G+B}, b = \frac{B}{R+G+B}. \quad (1)$$

$$\vec{E}_x = \left(\frac{\sqrt{2}}{2}, -\frac{\sqrt{2}}{2}, 0\right), \quad (2)$$

$$\vec{E}_y = \left(-\frac{\sqrt{6}}{6}, -\frac{\sqrt{6}}{6}, \frac{\sqrt{6}}{3}\right), \quad (3)$$

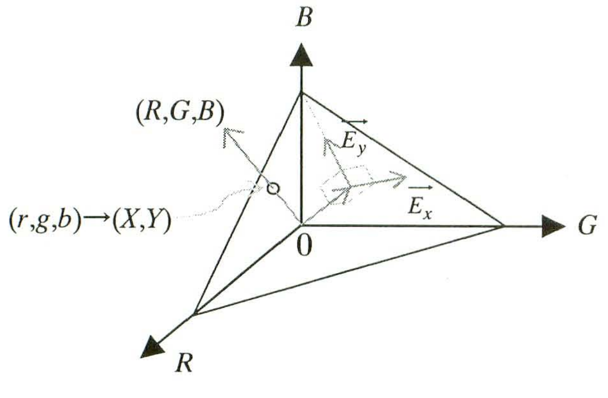
where $\vec{E}_x$ and $\vec{E}_y$ are perpendicular to each other and unit vectors.

$$\vec{E}_x \perp \vec{E}_y, \quad |\vec{E}_x| = |\vec{E}_y| = 1 \text{ (unit vector)}. \quad (4)$$

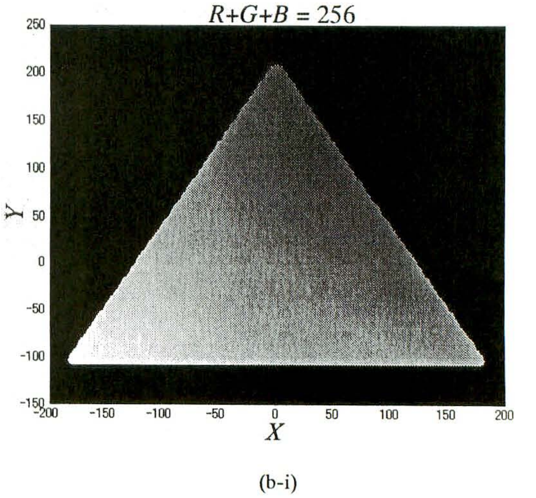
Each pixel value of an input image is transformed from the *RGB* space to the point (X,Y) on the *XY* space as follows.

$$\vec{a} = (r,g,b) - \left(\frac{1}{3}, \frac{1}{3}, \frac{1}{3}\right), \quad (5)$$

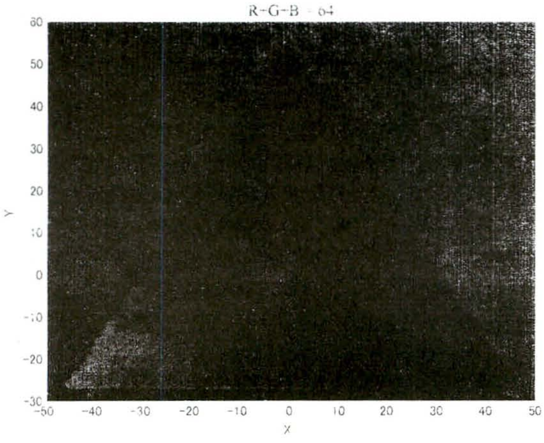
$$X = \vec{a} \cdot \vec{E}_x, Y = \vec{a} \cdot \vec{E}_y. \quad (6)$$



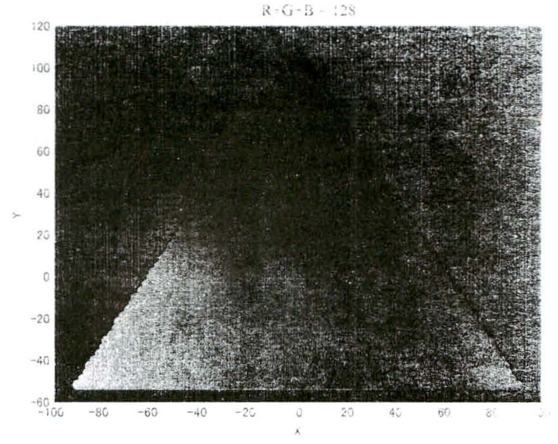
(a)



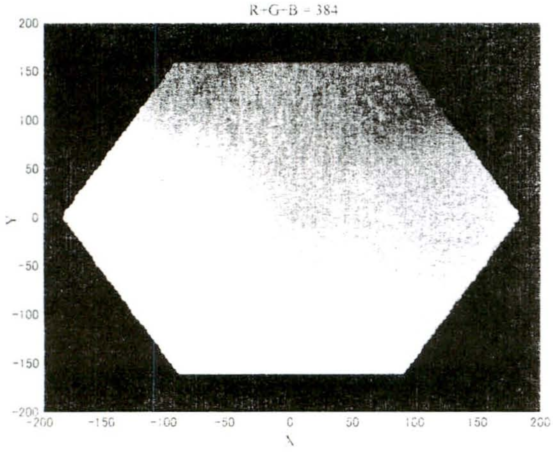
(b-i)



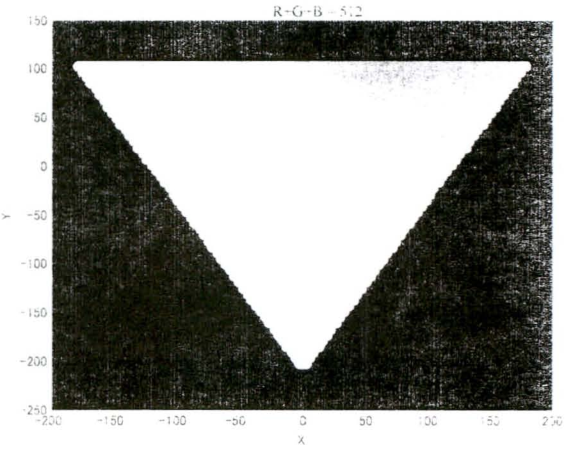
(b-ii)



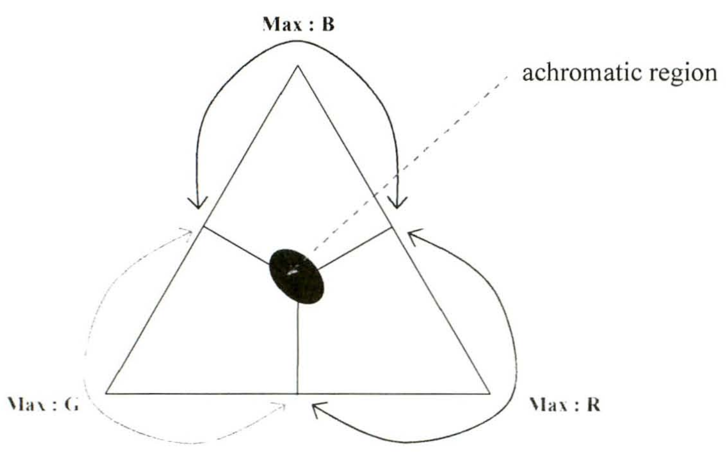
(b-iii)



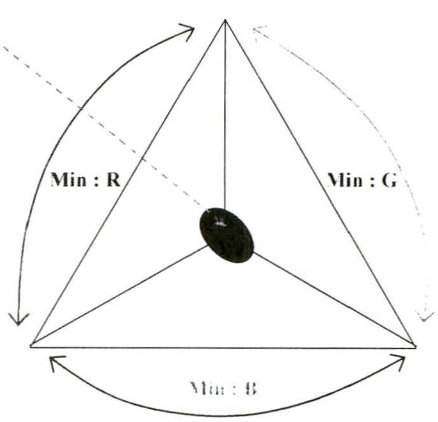
(b-iv)



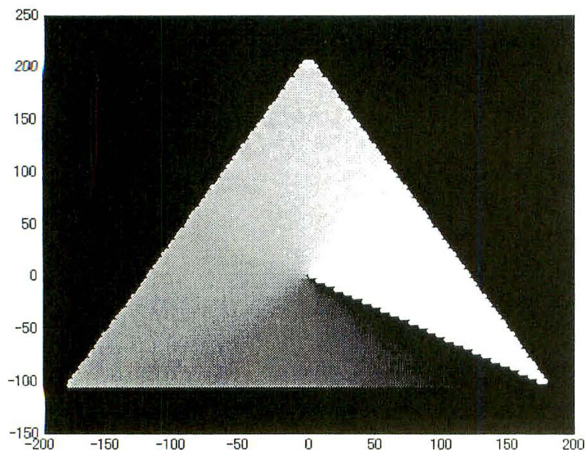
(b-v)



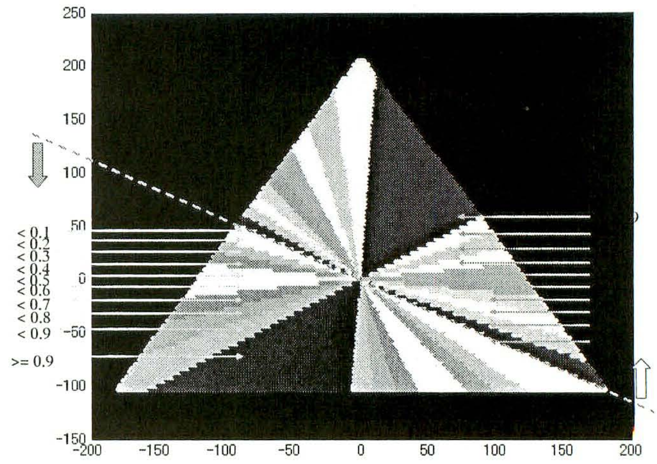
(c-i)



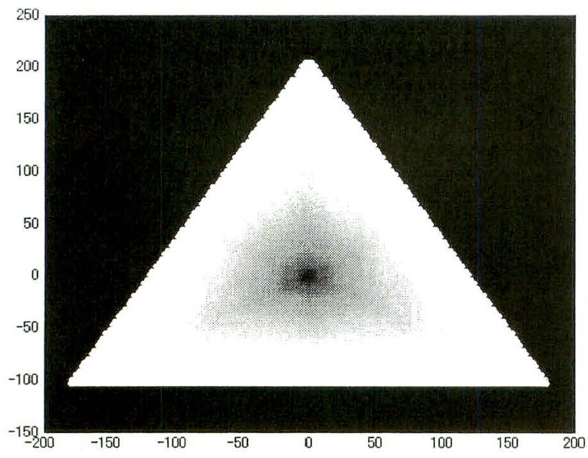
(c-ii)



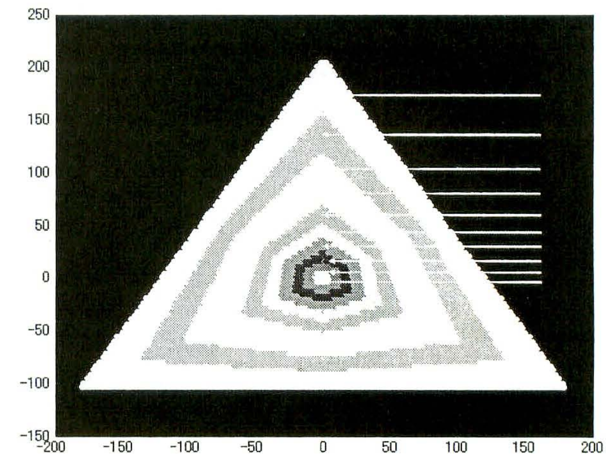
(d-i)



(d-ii)



(e-i)



(e-ii)

Fig. 2. XY space: (a) relation between *RGB* and *XY* space, (b) *XY* space with colors on *R+G+B* = 256, 64, 128, 384, and 512 respectively, (c-i) and (c-ii) analysis of *XY* space, (d-i) and (d-ii) Hue and sin(Hue) on XY space, (e-i) and (e-ii) Saturation and sin(Saturation) on XY space.

3. Color shifting with time

Color representation is a crucial factor for color image segmentation and recognition. Many attempts have been made to find the best color space for the task, yet no one model has proven to be always superior to others.[11] Here, we introduce the color shifting with time. In order to explain the color movements, we take examples of road signs and signboards, both are composed of UC regions. Most road signs consist of two or more uniform color regions. Ones considered here are composed of three colors: red, white, and blue. The outdoor scene colors always vary due to illumination changes and weather conditions. For example, Fig.3(a) shows the road sign images taken at different times in the same day. Fig.3(b) shows the cropped colors (red, white, and blue) of small squares. Although their respective pixel values are significantly different from those of the other time in the *RGB* space, they change in the similar pattern (Fig.3(c)). In Fig.3(c), the red, blue and yellow markers correspond to red, blue and white colors of the road signs, respectively.

Three kinds of illumination changes are tested on Fig.4. In Fig.4(a), the road sign images are taken under daytime, evening and nighttime, respectively. The mean pixel value of each road sign' colors are presented on *RGB* space in Fig.4(b). In this figure, red, blue and green markers represent red, blue and white colors of road sign. According to this figure, we can notice the color shifting with time. The relations of blue, red and white colors on *rb* space are shown in Fig.4(c). In Fig.4(c), blue data is referenced as origin.

In Fig.5, we tested the commercial signboard taken under different times (9AM through 4PM). Fig.5(b) represents the *RGB* ratios of the signboard colors. Their cropped colors on *RGB* and *XY* space are described in Fig.5(c) and (d). The mean value of the cropped color on *RGB* space is shown in Fig.5(e). The markers 'star', 'circle', 'rectangle', and 'triangle' represent white, green, orange, and red color of the signboard respectively.

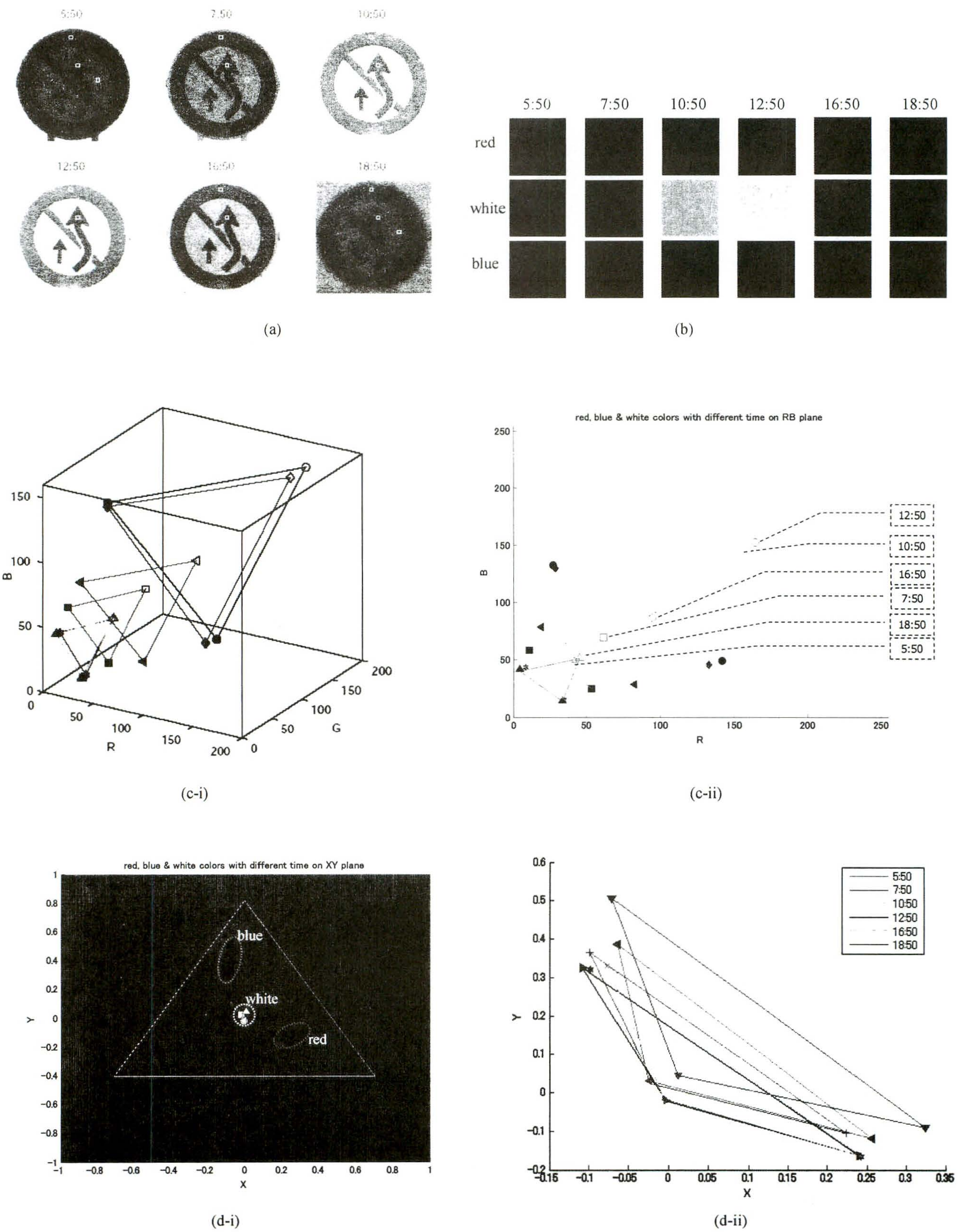


Fig. 3. Road signs within one day: (a) images of the same road sign taken at the different times, (b) their cropped colors, and (c-i) and (c-ii) color shifting on the *RGB* space and *RB* plane, (d-i) and (d-ii) color shifting on the on the *XY* space.

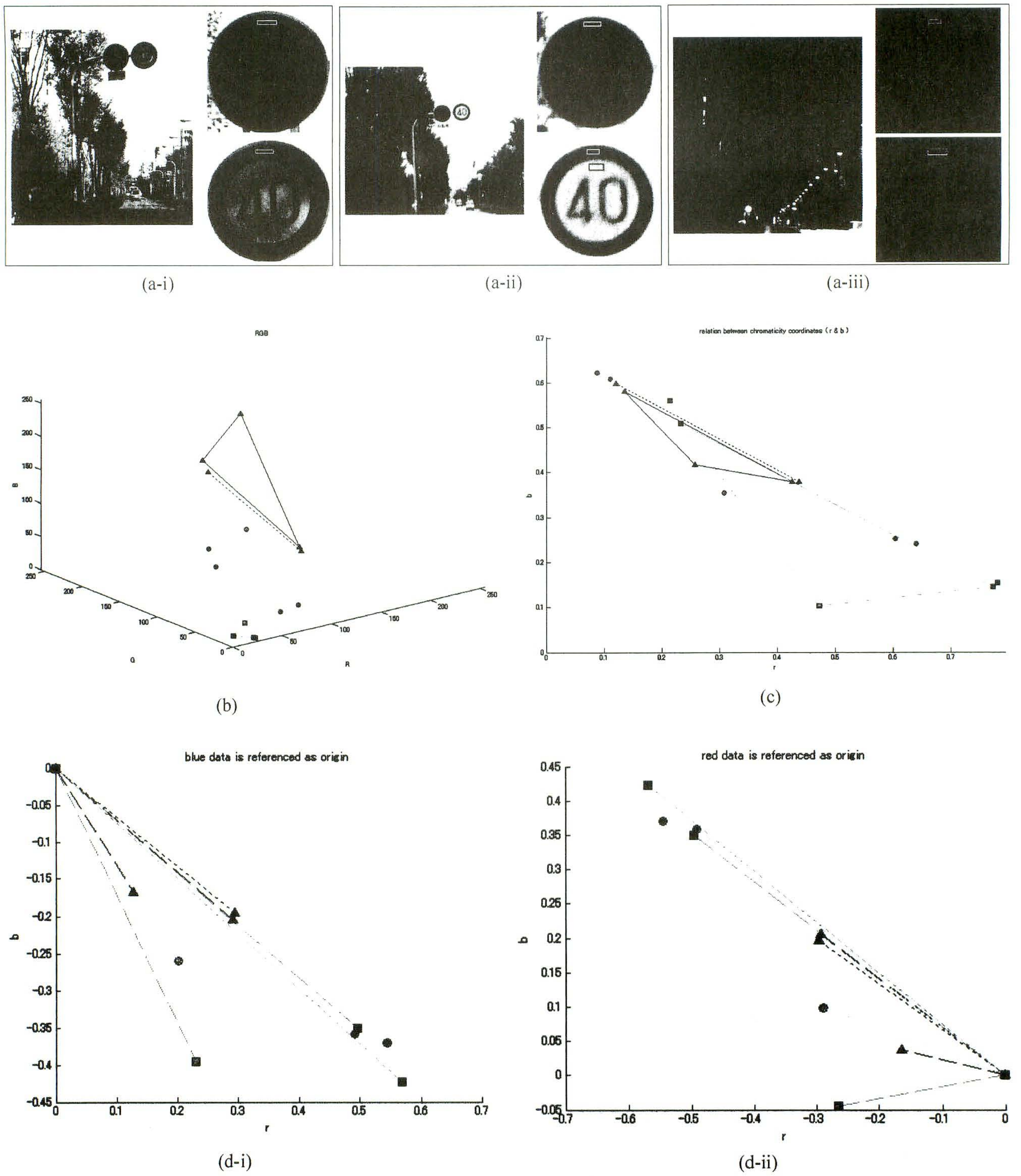


Fig. 4. Color shifting: (a-i) daytime, (a-ii) evening, (a-iii) nighttime, (b) and (c) their cropped colors on *RGB* space and *rb* plane, (d-i) relation of blue, white and red color on *rb* space (blue data is referenced as origin), (d-ii) relation of blue, white and red color on *rb* space (red data is referenced as origin).

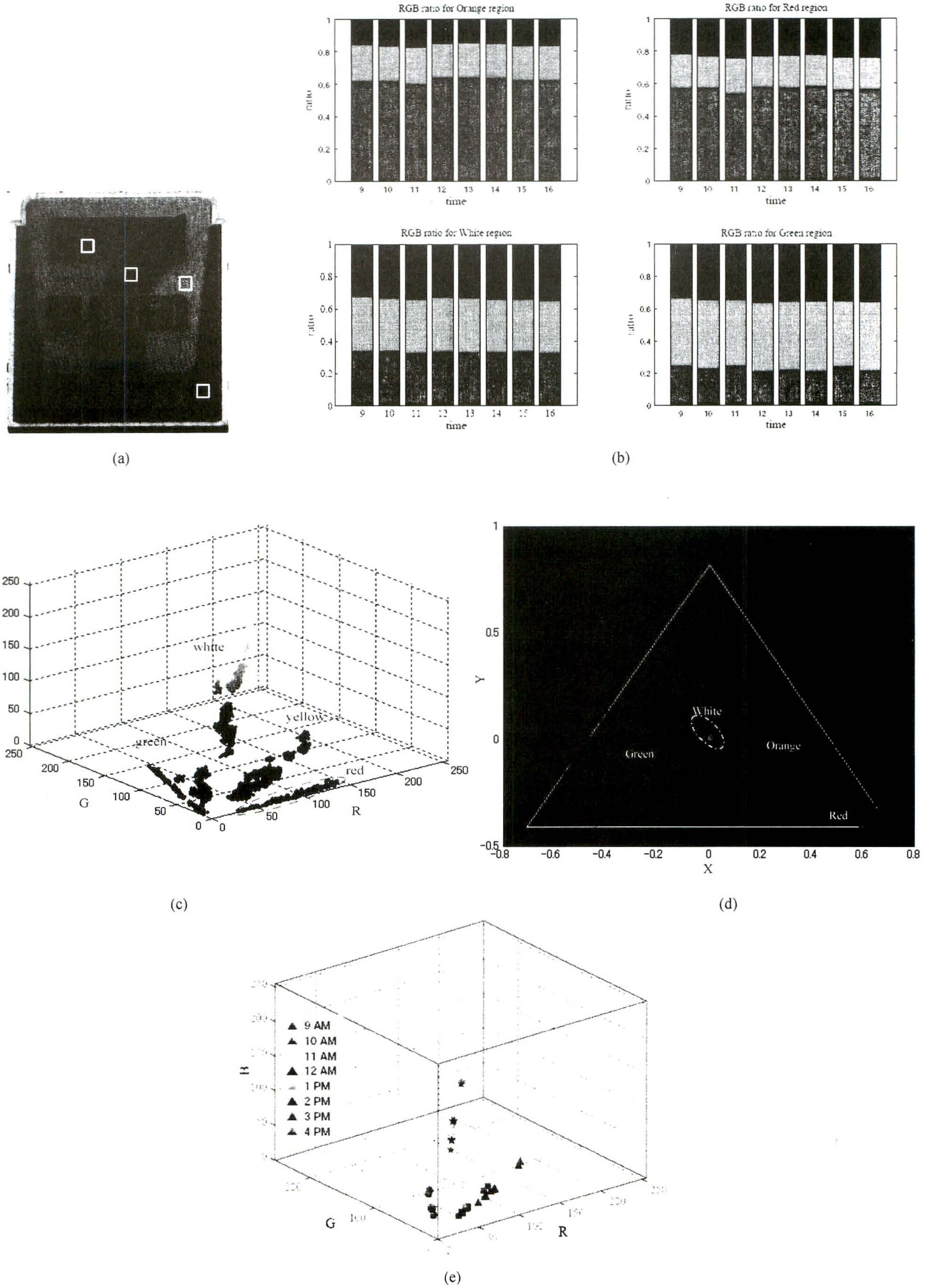


Fig. 5. Color shifting from 9AM through 4PM: (a) sample signboard, (b) their cropped colors represents by *RGB* color ratio, (c) their cropped colors on *RGB* space, (d) their cropped colors on *XY* space, and (e) the mean value of the cropped color on *RGB* space.

4. Conclusions

Large amounts of information are embedded in the natural scene. We have introduced the 2D color space (*XY* space) and discussed color shifting on several illumination changes in outdoor scenes. This paper intends to design invariant to illumination changes using these characteristics. Based on these assumptions, we addressed how to decide the color similarity by using the facts about color shifting on the *XY* space.[12] Moreover, the color analyzing results have been used for recognition systems of outdoor scene images. For experiments, we demonstrated 300 images including road signs, billboards and other visual information signboards under a great variety of illumination changes including nighttime, foggy day and rainy day. These signboards are good examples of objects composed of UC regions. The proposed method can potentially be applicable to various tasks such as image retrieval, image indexing, image reproduction, image enhancement, segmentation and recognition of objects with uniform color regions, and so on.

5. References

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