Research on illumination invariance colour index algorithm based on colour ratio

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Received 26 October 2013, www.tsi.lv

Abstract

Statistics of colour value of each pixel in the image are output in traditional colour histograms. Therefore, though the two same images photographed in different illuminations are consistent in colour content, they have different colour distributions in the histograms. To solve the problem, this paper introduces an illumination invariance colour index algorithm based on colour ratio. According to the colour constancy theory, although colour values of its pixels will be changed once the image is subject to illumination, colour ratios remain unchanged. Colour ratio refers to the ratio between two contiguous pixels. As per colour ratios, colour ratio image may be obtained, which depicts obvious boundaries or margins of the image content so that we statistics of colour ratio histogram can be obtained as an index mechanism to remove illumination effect. Verified by lots of tests, this method can extract useful colour characteristics and remove illumination effect, so that it can be practically used in effective computer recognition of objects in traffic videos.

Keywords: colour index, image retrieval, colour constancy, illumination

1 Introduction

Images photographed by the traffic monitoring system are affected by illumination to a great extent; as a result, objects can't be positioned and recognized by many traditional methods accurately, causing the intelligent monitoring system less intelligent and limiting its popularity. Human assistance is still needed for recognizing images in monitoring videos. Therefore, how to achieve illumination invariance in colour recognition is a key to guaranteeing the robustness of video monitoring systems.

With the simplest, most direct and effective characteristic, colour has been widely used in computer vision applications. Colour histogram is a simple and effective expression of the colour characteristic. Histogram intersection algorithm raised by Swain et al [1] is rather effective in object recognition. However, colour histogram is easily subject to illumination despite of its robustness in image rotation and affine. To remove illumination effect on colours, RGB colour space may be transformed to RG chroma space, thus making a chroma histogram. Chroma histogram, however, still can't remove the effect of illumination colour variance on image colour. To solve the problem, Colour Constancy Colour Index (CCCI), a descriptor, which is robust to both illumination intensity variance and illumination colour variance, is raised [2-10]. This descriptor removes illumination effect using the derivative of colour logarithmic space, which is extended by Gevers et al [11]. That further removes the effect of perspective and shade on colours. Since CCCI is based on derivative of colour, it relies on the margin information of images and is likely to be affected by image blurring.

This paper introduces an index algorithm based on illumination invariance. It mainly removes illumination effect, thus affecting the effectiveness of traditional index mechanism to a great extent. Therefore, illumination invariance plays a significant role in improving index technology. The algorithm raised in this paper is well applied in object recognition of traffic monitoring system, so as to assist the intelligent traffic video monitoring system, reduce human assistance and improve monitoring efficiency. Verified by a quantity of tests, this histogram technology based on colour index can effectively remove the effect of objective environmental factors on images, which is the core for solving problems in image recognition technology of intelligent traffic system. Traditional computer recognizes image through pixels of images, but a barrier for recognizing people and vehicles in images is posed by the illumination; colour index can remove the effect of environmental hue on the object recognition of computer.

2 Relevant Principle-Physical Characteristics of Colours

The colour of an object is determined by three factors:

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surface reflection of the object, illumination distribution and responsivity of colour channels. For a certain wave length λ and a point (*x*, *y*) on the surface, its illumination function is stated as follows:

$$I(x,y,\lambda) = E(\lambda)\cdot S(x,y,\lambda)\,, \quad (1)$$

where in: $E(\lambda)$ refers to illumination distribution function; $S(x,y,\lambda)$ refers to surface reflection function of the point (*x*, *y*).

Colour response of the point (*x*, *y*), i.e. transformation into visual system through Channel k. It can be expressed as:

$$\phi_k = \int_\lambda I(x,y,\lambda)R_k(\lambda)d\lambda\,. \quad (2)$$

$R_k(\lambda)$ refers to the responsively of Channel k Illumination mentioned above is independent from surroundings of the object. However, illumination perceived by people is dependent on the surroundings. Both illumination energy distribution and colour channel responsively are objective factors in physics, so the perceptual colour of object can be approximately expressed as illumination distribution of surface reflection function.

3 Illumination Invariance Algorithm Based on Colour Ratio

3.1 IMPROVED STATISTICAL COLOUR HISTOGRAM ALGORITHM

For 24-bit Windows bitmap images of true colours, there is no such a title as histogram. Only statistics of each colour value for grayscale images can be performed and presented in form of histogram. That's why the grey value of a single under a single channel is extracted in the 2nd step of the algorithm. Both histogram and colour ratio histogram are concepts designed for images under a single channel. Grey values of grayscale image pixels are stored in a matrix. Therefore, it is easy to draw a colour histogram. Only two nested loop statements are needed to perform statistics of each colour value frequency. They are stored in an array or matrix and drawn using two-dimensional coordinates.

The improved statistical colour ratio histogram algorithm is stated as follows:

Step 1: read in key images from the image library.

Step 2: position sub-blocks in images and calculate sub-block histograms; i.e. users select sub-blocks containing query images.

Step 3: calculate sub-block (*x*, *y*) colour pair tables using "eight-direction adjacent technology" with the calculate colour pair () function.

Step 4: delete the colour pairs whose differences are smaller than a certain threshold, so as to eliminate colour noise.

Step 5: fill the colour pair tables obtained from the sub-block calculation in the characteristic colour pair table of the image and rank them in descending order. Set a field value, and select the greatest colour pairs in the colour pair table as the representative features of the image.

Step 6: perform colour matching and read the N images to be compared. Calculate the colour histogram of the compared image, and search for the colour pair table for each sub-block in the target image. Do not use accurate matching. Therefore, colour pairs whose error is smaller than 2% also belong to the matching values.

Step 7: count the number of single matches. Calculate the colour pairs of a sub-block and its surrounding sub-blocks of the target image in order. Inquire the calculated colour pairs in the colour pair tables entered by users. If the difference is smaller than a threshold value, it matches and should be marked with the colour matching logo.

Step 8: if over 60% of colour characteristic colours are matched, then the image is retrieved.

Step 9: present search results.

3.2 CALCULATION OF IMAGE COLOUR RATIO VALUE

Objective brightness of a point should be independent from its surroundings, but the actually perceived colour depends more on its relationship with adjacent points rather than its own amount of light reflection. Therefore, the colour perception amount is subject to the overall situation. That has to say, the adjacent spatial area of the object will be taken into account by human visual system when calculating its colour. Therefore, the invariant colour characteristics may be based on operations to adjacent points; that's, the relationship between a point and its adjacent points should be considered. The following common assumptions are made to image environment: the surface is not smooth, only diffuse reflection exists, and there is no shade on the surface. These assumptions may not always be reached, but it renders analysis to the colour ratio model operative. In computer calculations, these are some typical assumptions. [6] Set αβξ as the conversion factor and make the following assumptions: illumination function may be expressed using the following linear function:

$$E(\lambda) = \sum_{i=1}^{N} \alpha_i E_i(\lambda)\,. \quad (3)$$

Surface reflection function may be expressed as follows:

$$S(\lambda) = \sum_{j=1}^{M} \beta_j S_j(\lambda)\,. \quad (4)$$

Illumination may be described using an expression merely relying on conversion ratio, so may similar reflection functions. Equation (2) can be approximated as:

$$\phi_k = \sum_{\lambda}\sum_{i=1}^{N}\sum_{j=1}^{M}\alpha_i\beta_i E(\lambda)S(\lambda)R_k(\lambda) = \sum\xi_{ijk}(\lambda)\cdot S(\lambda)\,. \quad (5)$$

Despite of illumination changes, adjacent points will receive the same amount of light simultaneously.

For the two different points of (x_1, y_1), (x_2, y_2) on the surface, simple expressions for colour responsively at Channel k may be given separately: $\phi_k^1 = k\xi^1 S^1$; $\phi_k^2 = k\xi^2 S^2$. The parameter ξ is used to capture changes in illumination and surface reflection function. Illuminations for the small adjacent areas are the same. At this time, ξ depends only on surface reflection, thereby substantially dependent on physical properties of the image surface. Based on the same assumptions, k is also same for the two points. Thus, k may be removed in obtaining the colour ratio.

These assumptions are relatively weak and are easy to be satisfied in practice. For small adjacent spatial areas, the fourth assumption is obviously correct. When N and M is relatively small, such as 3, most changes in ambient light or reflection coefficient can be calculated using the linear function. As mentioned above, even if the illumination is changed, colour responsivities of the adjacent points are the same, unless colour borders exist. Therefore, to obtain the unchanged colour characteristics, we only need to detect how the colour value of a point varies as that of its adjacent point varies. The ratio is obtained using the following formula:

$$\Phi_{x,y} = \frac{\varphi_{x,y} - \frac{1}{m}\sum_{i=1}^{m}(\varphi_{x,y} - \varphi_{x,y}^{i})}{\varphi_{x,y}}\,, \quad (6)$$

where in: $\varphi_{x,y}$ means the colour value of the point (x, y), $0 \le \phi \le L$ and L is the colour grade, $\varphi_{x,y}^{i}$ means the colour value 0 the i^{th} adjacent point near to the point (x, y).

The colour ratio Φ of the aforesaid result is a constant physical quantity of adjacent points on the surface. The ratio is invariable compared to the illumination changes. It is essentially a description of the spatial context information of a small area in the image. It is independent from external factors, such as external light. For the three colour channels, three colour ratio figures for the original image are drawn.

Algorithm is designed to obtain colour ratio of the image. First of all, the formula suitable for colour ratio calculation should be located. Φ obtained from Equation (6) is the desired colour ratio. But obviously the equation is relatively complicated. To simplify the colour ratio calculation, the colour ratio model is further standardized.

In Equation (6), the colour model is formulated to emphasize the relationship between its spatial adjacent points. The equation can be simplified as follows:

$$\Phi_{x,y} = \frac{\frac{1}{m}\sum_{i=1}^{m}\varphi_{x,y}}{\varphi_{x,y}}\,. \quad (7)$$

Thus, for a given colour channel, colour ratio of a designated point is the average of colour values of its adjacent points. The colour ratio model can be expressed using the following simpler one:

$$\Phi_{x,y} = \sum_{i=1}^{m}\psi^{i}(x,y)\,, \quad (8)$$

where: $\psi^{i}(x,y)$ is the colour value of the i^{th} adjacent point of the specified point. If $\psi^{i}(x,y) = \varphi_{x,y}^{i} / m\varphi_{x,y}$, Equations (6) and (7) will be used to obtain the colour ratio characteristics. If $\psi^{i}(x,y) = \log(\varphi_{x,y}^{i} / \varphi_{x,y})$, the method proposed first by Land and McCann and then used by Funt and Finlayson will be adopted to obtain the colour ratio characteristics. This is more in line with the multiplication of adjacent ratios rather than addition. A standard calculation formula for colour ratio model is presented in Equation (8), which is helpful to analyse colour ratio distribution. To facilitate the analysis, only direct colour value is considered; that's, $\psi^{i}(x,y) = \varphi_{x,y}^{i} / m\varphi_{x,y}$.

First of all, the colour value for each pixel is extracted from the image and stored in a matrix. Then the colour ratio value is calculated as per Equation (6) and stored in another matrix with the same size. The ratio between the differences of each pixel and its neighbouring 8 points and the sum are calculated. During this process, some particular points need to be treated differently, namely, the pixels at the image edge, separately the matrix middle row, the 1st column or the maximum. These pixels can be divided into several categories; and the colour ratio calculation of each category of pixels needs to be treated differently instead of only substituting the pixel value into the formula. The colour ratio calculated in this way is closer to the actual value. Only in this way, can this indexing mechanism have obvious advantages in effect.

4 Experiments

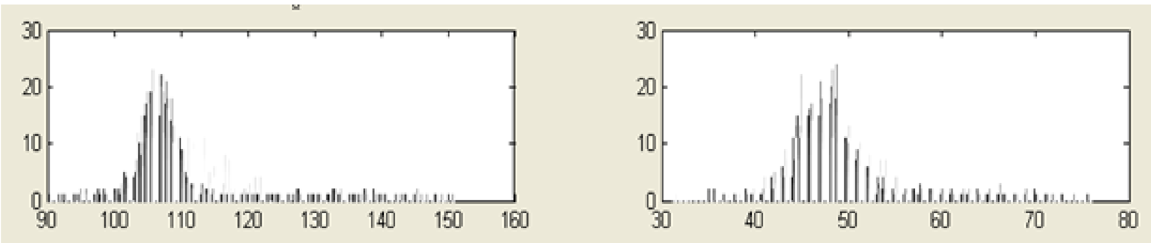
Two images photographed are loaded under different illuminations. Here are two images with the same scene separately photographed at daytime and night-time by the monitoring system, used for experimental purpose. This is one of the practical areas for this technology application.

(a) At daytime (b) At nighttime

FIGURE 1 Two images with the same scene photographed at daytime and nighttime by the monitoring system

Obviously, the two images have the same scene. However, when performing matching retrieval using traditional colour histograms, they will deemed to be completely different by computers since their colour histograms vary greatly.

Perform statistics of and draw colour histograms as shown in Figure 2. Through intuitive comparison of the two colour histograms, it can be seen that the two images are greatly different. Calculate colour ratio values and obtain colour ratio images as shown in Figure 3. Calculate and obtain colour ratio histograms as shown in Figure 4. It can be seen from the two images that they are quite similar.

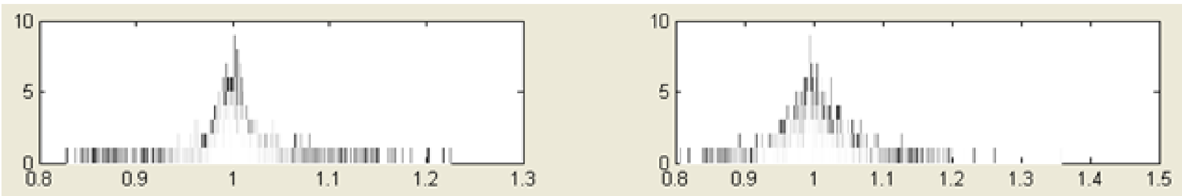


(a) Daytime histogram (b) Nighttime histogram

FIGURE 2 Colour histograms

(a) Daytime colour ratio image (b) Night-time colour ratio image

FIGURE 3 Colour ratio images



(a) Daytime colour ratio histogram (b) Night-time colour ratio histogram

FIGURE 4 Colour ratio histograms

Another method may be used to display the colour ratio histogram as shown in Figure 5. It can be seen that the two colour ratio histograms are similar in a more intuitive and obvious manner.

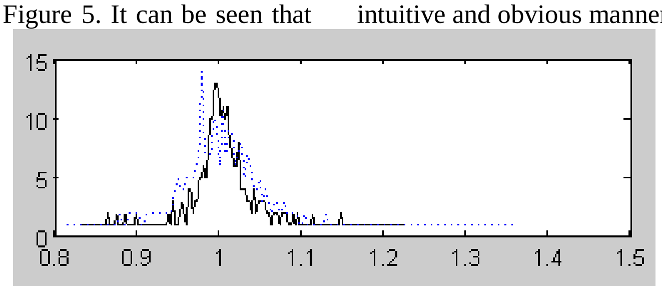


FIGURE 5 Colour ratio histogram

The distribution status of the colour ratio histogram of the image at daytime is drawn by solid black line while that at night-time is drawn by the blue dotted line. In this way, it can be seen that they are substantially the same in a more intuitive manner. When it is used as an index in a retrieval system, correct matching may be achieved with only one threshold value set.

5 Conclusions

How to extract effective colour characteristics from the image and remove the illumination effect are mainly studied in the paper. This algorithm can be used for effective computer recognition of target object in the image. This algorithm is relied by target recognition of modern intelligent traffic monitoring system.

Through analysis of current status of computer image processing, such as image retrieval, the application and development status of colour characteristics in image retrieval field, technologies for effective characteristic extract, application of colour indexing in image retrieval and illumination problems, as well as analysis and research on colour processing technologies, one illumination invariance indexing algorithm is proposed and described accordingly; besides, experimental results, specific requirements for the experimental platform, presentation of experimental results, as well as histograms and colours are detailed.

The algorithm is studied and achieved for the final purpose of applying it in target recognition of traffic monitoring system. After the algorithm is achieved, we should move to target object recognition. One background image and one target image under the same ground are given, just like frame images extracted from the traffic monitoring system. Since images photographed within one day may be subject to illumination differently, the algorithm achieved in this paper instead of traditional colour information is to be used in target recognition.

Acknowledgements

This work was supported by the National Science-technology Support Plan Project of China (No.2012BAK03B06, No.2013BAK02B06, No. 2012BA K03B00), the National Natural Science Foundation of China (No. 91224009), special funds of marine public welfare industry scientific research projects (201305033), Tianjin informatization project, MOHURD program of China (No.2011-K9-21), Housing and Urban-rural Development project of Shandong Province (Grant No.2011YK026), Soft science research project of Shandong province (No.2013RKB01284).

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