Color Edge Detection based on Bhattacharyya Distance

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Abstract: In this paper, we propose to apply the multi-dimensional edge detection algorithm developed for hyperspectral images to colour image edge detection. The multi-dimensional edge detection algorithm utilizes the Bhattacharyya distance and considers the statistical difference between two neighbouring blocks. In order to apply the algorithm to colour images, we need to take into account the singularity problem of the covariance matrices. In the algorithm, we first apply the Wiener filter to supress noise and select four block pairs including up-down, left-right, diagonal-left-down and diagonal-right-down. The experimental results show that the colour edge detection method based on the Bhattacharyya distance shows promising results compared to the results obtained by the Sobel and Canny-edge edge detection algorithms.

1 INTRODUCTION

Edge detection is a basic operation in pattern recognition and image processing. Although many researchers have proposed numerous algorithms, edge detection is still a challenging problem. Due to the complexity of typical images, current edge detection algorithms fail to produce satisfactory edges in some cases. Most images are available in colour. In general, colour image edge detection should provide better performance compared to grey scale images, though the difference may not be significant in some cases. Among various edge detection algorithms, the Sobel and Canny edge detection algorithms are still widely used.

Recently, the Bhattacharyya distance was used to detect edges in multispectral images. By utilizing second order statistics, it can better utilize the information of multispectral images. In this paper, we explore the edge detection algorithm based on the Bhattacharyya distance for colour image edge detection.

The rest of this paper is organized as follows: Section 2 summarizes the edge detection algorithm based on the Bhattacharyya distance along with some modifications to solve the singularity problem of colour images. Section 3 presents experimental results and conclusions are provided in section 4.

2 THE METHOD

Fig. 1 is a block diagram of edge detection using the Bhattacharyya Distance. We used several colour images to test the performance. First, we apply the Wiener filter to RGB images to supress noise. Then, four block pairs are selected and the Bhattacharyya distances of the four pairs are computed. Finally, the maximum value is selected as an edge value.

2.1 Pixel-wise Wiener Filter

Most images often contain artefacts that may adversely affect edge detection. To avoid this problem, a pixel-wise adaptive Wiener filter based on statistical characteristic estimation from the local neighbourhood of each pixel was used.
The Wiener filter is commonly used in image processing applications to remove additive noise from degraded images. The local mean (μ) and variance (σ^2) are computed as follows:

$$\mu = \frac{1}{N \bullet M} \sum_{i=1}^{N} \sum_{j=1}^{M} L(i, j) \quad (1)$$

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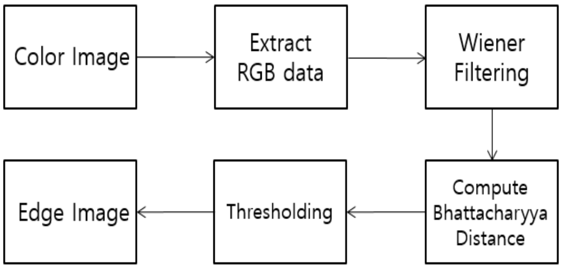

Figure 1: Block diagram of the proposed method.

$$\sigma^2 = \frac{1}{N \bullet M} \sum_{i=1}^{N} \sum_{j=1}^{M} L^2(i,j) - \mu^2 \tag{2}$$

where L(i,j) represents a block image in the N-by-M local neighbourhood of each pixel. Then, the Wiener filter is given as follows:

$$W(i,j) = \mu + \frac{\sigma^2 - \upsilon^2}{\sigma^2}[L(i,j) - \mu]. \tag{3}$$

2.2 Bhattacharyya Distance

For each pixel, four pairs of blocks were chosen: up-down, left-right, diagonal-left-down and diagonal-right-down pairs. Fig. 2 illustrates the four pairs of blocks.

The Bhattacharyya distance takes into account the mean and covariance differences. Therefore, it can better utilize multispectral images, including colour images. The Bhattacharyya distance can be defined as follows:

$$d = \frac{1}{8}(\vec{\mu}_1 - \vec{\mu}_2)^T \sum (\vec{\mu}_1 - \vec{\mu}_2) + \frac{1}{2}\ln\left(\frac{\det \boldsymbol{\Sigma}}{\sqrt{\det \boldsymbol{\Sigma}_1 \det \boldsymbol{\Sigma}_2}}\right) \tag{4}$$

where $\vec{\mu_i}$ and $\sum_i$ are the mean vector and covariance matrix of the i_{th} block, and $\sum = \frac{\Sigma_1 + \Sigma_2}{2}$.

The up-down blocks are used to find vertical edges whereas the left-right blocks are used to find horizontal edges. The diagonal-left-down blocks and diagonal-right-down blocks are used to detect diagonal edges. We compute four Bhattacharyya distances and choose the maximum value, which represents the edge strength as follows:

$$Edgeimage(i) = Max(UD(i), LR(i), DLD(i), DRD(i)). \tag{5}$$

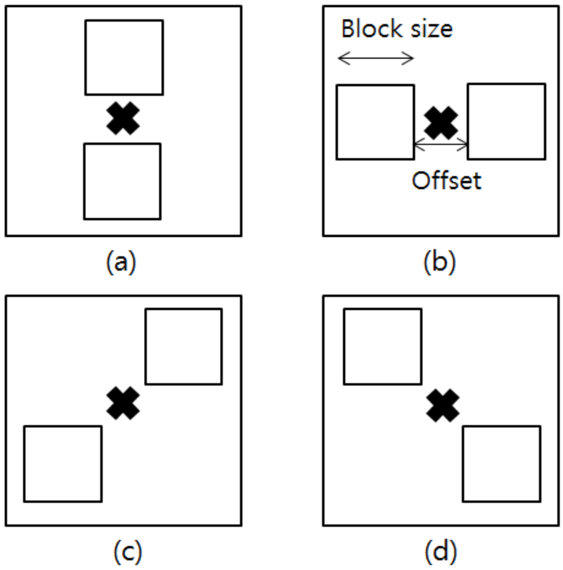

Figure 2: Four pairs of neighbourhood blocks. (a) Up-down (UD), (b) Left-right (LR), (c) Diagonal-left-down, (d) Diagonal-right-down.

2.3 Outliers and Singularity Problem

There is a possibility that a block may contain outlier pixels, which cause a large variance. Such outlier pixels may generate erroneous edge pixels. To address this problem, outliers are removed before computing the mean vector and covariance matrix.

Unlike multi-spectral images, a small block can be very homogeneous in colour images. It is also possible that a block may have the same RGB values if it represents constant regions. In such cases, the covariance matrix is singular and the Bhattacharyya distance cannot be computed since the determinant is zero. To solve this problem, we add a very small value (ε) to the diagonal terms of the covariance matrix. Table. 1 illustrates this procedure.

Table 1: Covariance Matrix.

$C_1 + \varepsilon$	C_2	C_3
C_4	$C_5 + \varepsilon$	C_6
C_7	C_8	$C_9 + \varepsilon$

3 EXPERIMENTAL RESULTS

In the experiments, we set the block size to 3x3 pixels and the offset to one pixel to compute the Bhattacharyya distance. Along with the colour edge detection method based on the Bhattacharyya distance (BD method), we tested the Sobel and Canny edge detection algorithms.

Figs. 3-6 show performance comparisons of the three methods. In Fig. 3, the Sobel and Canny edge detection algorithms failed to detect the weak edges between the top of the box and the white wall, whereas the BD method successfully recovered the edges. In Fig. 4, the Sobel and Canny edge detection algorithms failed to detect the boundary between the wheel and the shadow background, whereas the BD method better recovered the missing edges. In Fig. 6, the Sobel and Canny edge detection algorithms completely failed to detect the dark building, whereas the BD method detected the building structure.

4 CONCLUSIONS

In this paper, we applied the edge detection algorithm based on the Bhattacharyya distance for colour image edge detection. In order to solve the covariance singularity problem, we added a very small value to the diagonal terms of the covariance matrix. Experimental results show that the edge detection algorithm based on the Bhattacharyya distance can detect some edges missed by the Sobel and Canny-edge detection algorithms.

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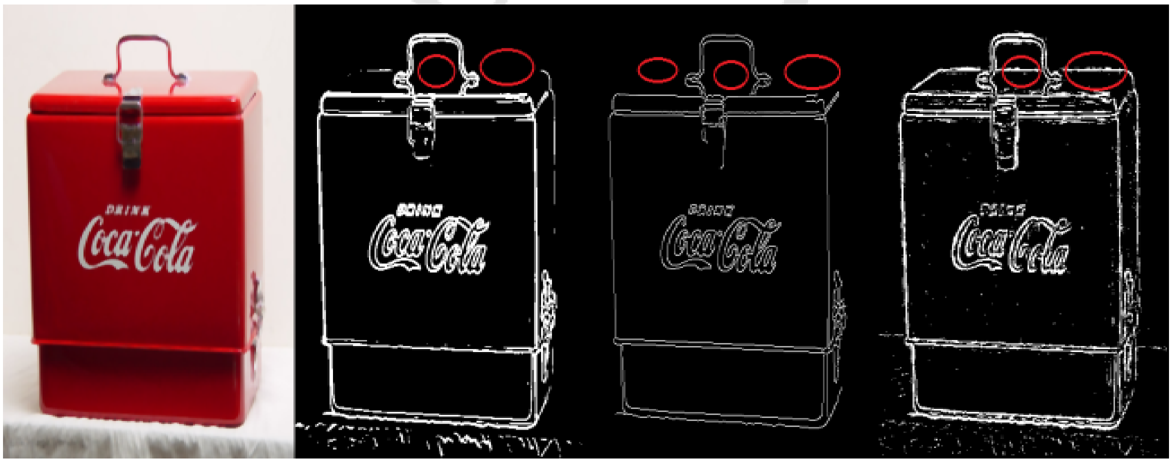
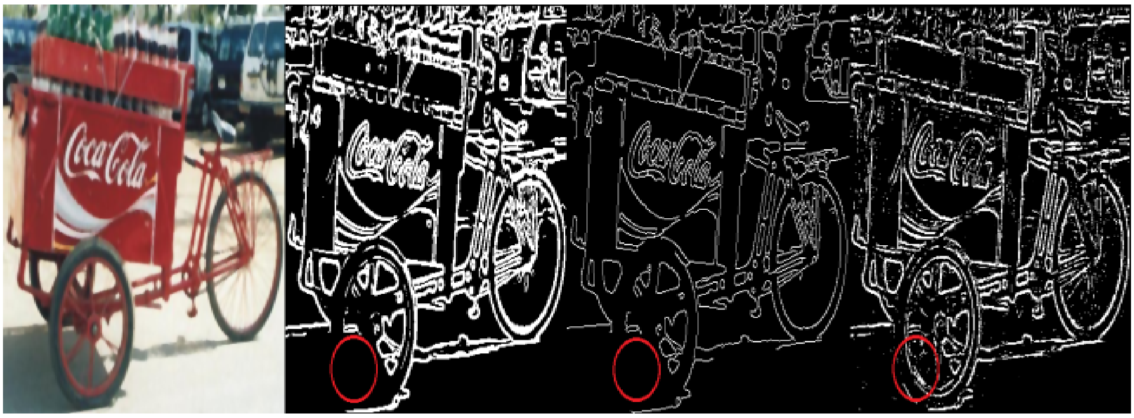


(a) (b) (c) (d)

Figure 3: Performance comparison. (a) Original image, (b) Sobel filtering, (c) Canny edge detection, (d) the colour edge detection based on the Bhattacharyya Distance.



(a) (b) (c) (d)

Figure 4: Performance comparison. (a) Original image, (b) Sobel filtering, (c) Canny edge detection, (d) the colour edge detection based on the Bhattacharyya Distance.

(a) (b) (c) (d)

Figure 5: Performance comparison. (a) Original image, (b) Sobel filtering, (c) Canny edge detection, (d) the colour edge detection based on the Bhattacharyya Distance.

(a) (b) (c) (d)

Figure 6: Performance comparison. (a) Original image, (b) Sobel filtering, (c) Canny edge detection, (d) the colour edge detection based on the Bhattacharyya Distance.