Contour Detection of Gradient Images Using Morphological Operator and Transform Domain Filtering

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***Abstract*— In this work, an improved computational approach based on gradient image and transform domain filtering has been proposed. The proposed technique effectively detects contours of objects while suppressing the low frequency edges in natural scene images. To accomplish this, a novel morphological operator has been designed which generates the gradient image. This image is filtered using transform domain filtering by spectrum distribution of low frequency edges and contours. The proposed approach can effectively detect contours of objects and able to reduce irrelevant information generated from background with textures. The results of qualitative evaluation clearly validate the efficiency of the proposed method.**

Keywords- Contour detection; Edge detection; Gradient image; Transform filtering

I. INTRODUCTION

Edge detection is amongst the most commonly used areas in image processing and computer vision. Several authors have presented the reviews and comparisons of various techniques used for edge detection like Prewitt, Roberts, Sobel and Canny [1-5]. These operators use optimal threshold values to detect the most prominent edges in gradient images. However, many of these edge detection operators are sensitive to noise. In addition, these methods may fail in situations when the components with low frequency are stronger than the components with high frequency. The low frequency components generally refer to the textured edges in which the gray level of pixels changes very slowly. On the other hand, the high frequency components refer to contour edges in which the changes in gray level of pixels are very fast.

Natural images contain both textured and contour edges. The presence of prominent textures like grass and water in natural images sometimes cause the traditional edge detection operators to fail. Therefore, it is desirable to remove the most of the texture edges in these images in order to effectively detect the contour edges [6]. The main purpose of detecting contour edges is to capture the meaningful information and changes in the images. The detection of edges can be done with the morphological operators which give more superior gradient image than other differential edge detection operator and also help to remove noise. Image gradients extract both texture and contour edges in different directions.

Filtering process is used to enhance certain features and to enhance the visual representation of an image. There are two main approaches to filtering, namely, spatial filtering and transform domain filtering [7]. Spatial filtering directly deals with image pixels and changes the gray level values of the image. This enhances the whole image and it is not possible to selectively enhance the desirable information or edges in an image. On the other hand, transform domain filtering works according to the frequency contents of the image and can selectively enhance the frequency components or edges of image.

In this paper, an improved computational approach for detection of contours in natural images is proposed which is based on gradient computation and transform domain filtering. The gradient is computed using novel morphological operator and then, the transform domain filtering is applied on gradient image which is followed by the suppression and thresholding techniques to get the final edge image.

II. RELATED WORK

Significant research work has been done on the detection of contour edges in the images. Some of these are discussed in this section. Perona and Malik [8] proposed an approach based on scale space and diffusion process to detect edges. Diffusion coefficients were chosen to vary in spatial domain for inter-region smoothing. This technique obtained high quality edge detector with sharp region boundaries. Non-classical receptive field inhibitation technique was proposed by Grigorescu et al. [9] using Gabor energy operator to clearly detect edges, contours and isolated lines. Further improvements were done by Grigorescu et al. [10] using suppression of texture edges to clearly detect contours of objects and area boundaries in natural images. In order to eliminate the need for explicit scale selection, an improved approach was presented by Sumengen and Manjunath [11] which used multi scale edge detection and segmentation.

A unified approach to contour detection and image segmentation was proposed by Arbelaez et al. [12] which resulted in high performance contour detection. A robust solution for edge detection has been presented by Roque et al. [13]. The proposed method examined canny and sobel

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detectors for developing optimized edge detection strategies which can be used in augmented reality applications. There were some extensions to edge detection using morphological operators. A morphological approach by Bai et al. [14] was proposed to remove noise and edge detection and overcome the deficiency of conventional methods.

To improve the edge detection methods, one combined method using fuzzy rules was presented by Dowlatabadi and Shirazi [15] to overcome the limitations of edge detection based on wavelet transform and mathematical morphology in noisy images. In further improvements, mathematical edge detection method was introduced by NagaRaju [16], which used multi-structure elements in different directions and significantly reduced the less relevant information.

It is concluded from the literature that there is not any method which combines the morphological operator and transform domain filtering for contour detection.

III. Proposed Work

In this work, firstly the novel morphological operator has been designed. This operator is applied on input image $I(x,y)$ to get the gradient image $G(x,y)$. This is followed by the application of transform domain filtering. Finally, the suppression and thresholding of edge image is done.

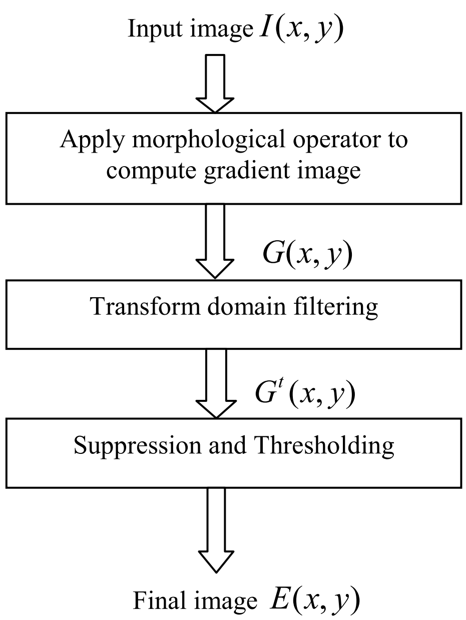


Figure 1. Flow chart of proposed work

A. Morphological Operator

Mathematical morphology uses four basic operations to process a binary image. These operations are described as follows:

a) Dilation: Dilation operator expands the image by changing pixels values 0 to 1. Dilation of A and B is denoted as : $A \oplus B$.

b) Erosion: Erosion operator shrinks the image by changing pixels values 1 to 0. Erosion of A and B is denoted as: $A \Theta B$.

c) Opening: Opening operator tends to smooth the object contours. Opening of A and B is denoted as: $A \circ B$.

d) Closing: Closing operator also tends to smooth the contours of object but in addition, the small holes are eliminated and gaps are filled in object contours. Closing of A and B is denoted as: $A \bullet B$.

B. Proposed Algorithm for Morphological Gradient Computation

In this work, five directional structuring elements, each of size 3×3, are applied to the input image. The fundamental operations of morphology which include erosion, dilation, closing, opening, top hat transform and bottom hat transform are applied to input image $I(x,y)$ to get gradient image $G(x,y)$. Two edge maps denoted by and are computed in horizontal and vertical directions by applying structuring elements denoted as S_1, S_2, S_3, S_4 and S_5.

$$S_1 = [1,1,1;0,0,0;1,1,1] \tag{1}$$

$$S_2 = [1,0,1;1,0,1;1,0,1] \tag{2}$$

$$S_3 = [0,1,1;1,0,1;1,1,0] \tag{3}$$

$$S_4 = [1,1,0;1,0,1;0,1,1] \tag{4}$$

$$S_5 = [0,1,0;1,0,1;0,1,0] \tag{5}$$

$$B_1 = \sum_{i=5}^{5} \left\{ \begin{matrix} (((I \bullet S_i) \circ S_i) \oplus S_i) - \\ (((I \bullet S_i) \circ S_i) \Theta S_i) \end{matrix} \right\} \tag{6}$$

$$B_2 = \sum_{i=5}^{5} \left\{ \begin{matrix} (((I \bullet S_i) \circ S_i) \oplus S_i) - \\ ((((I \bullet S_i) \circ S_i) \bullet S_i) \Theta S_i) \end{matrix} \right\} \tag{7}$$

Resultant edge map $B_f(x,y)$ is computed by adding both the edge maps. Bottom hat transform is applied on $B_f(x,y)$ using diamond shape structuring element of radius unity and then, the top hat transform is applied by using same structuring element. The bottom hat transform is symbolized as B_h whereas the top hat transform is symbolized as T_h. The gradient image is computed as shown in Eq. 8.

$$G(x,y) = B_f(x,y) + T_h - B_h \qquad (8)$$

C. *Transform Domain Filtering*

Fourier transform is applied on gradient image $G(x,y)$ to get its transform domain filtering $F(u,v)$:

$$F(u,v) = \Im[G(x,y)] = Amp(u,v)\exp(j\phi(u,v)) \qquad (9)$$

Here $\Im$ represents the gradient image's fourier transform, $A(u,v)$ is amplitude spectrum and $\phi(u,v)$ is gradient image's phase spectrum.

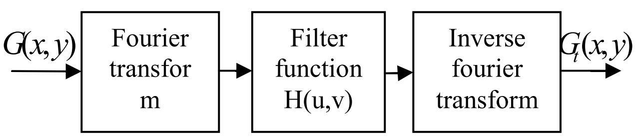


Figure 2. Transform domain filtering

To detect edges with high frequency and to suppress edges generated by texture, the amplitude spectrum of gradient image is multiplied with filter function as shown in Eq. 10.

Filter function $H(x,y)$, represents the Gaussian high pass filter and is shown in Eq. 11.

$$A_f(u,v) = Amp(u,v) \cdot H(u,v) \qquad (10)$$

$$H(u,v) = \exp\left[-\frac{D^2(u,v)}{2D_{\circ}^2}\right] \qquad (11)$$

Where $D(u,v)$ is cut-off frequency and is computed as:

$$D(u,v) = \left[\left(\frac{u-N}{2}\right)^2 + \left(\frac{v-N}{2}\right)^2\right]^{1/2} \qquad (12)$$

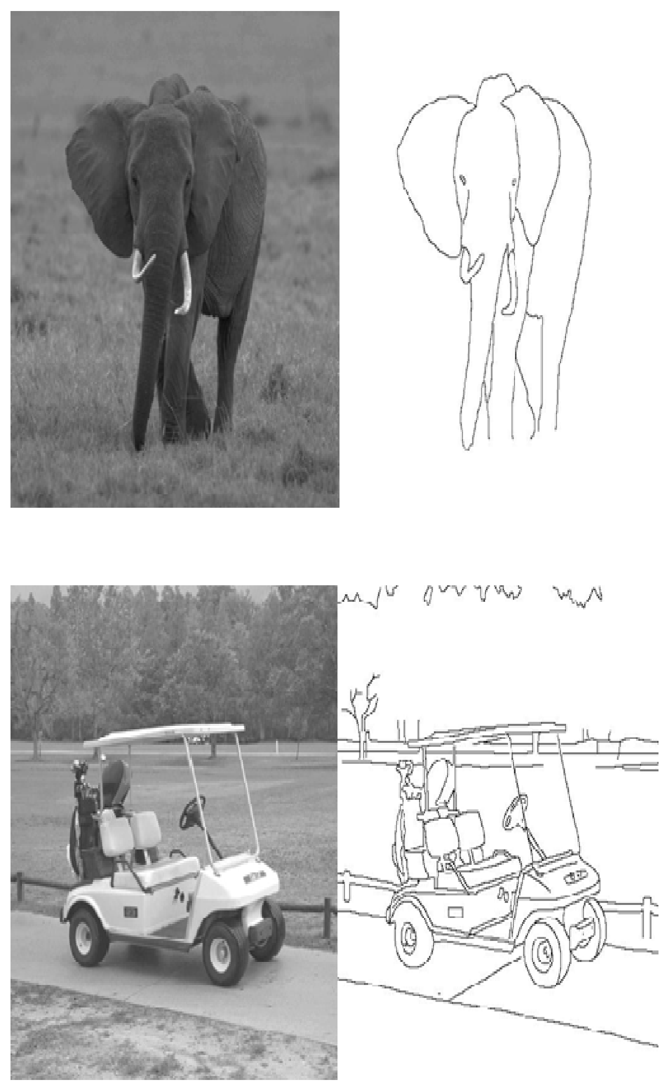
D is cut off frequency used to increase the variance of contour edges over the edges with texture. Selection of appropriate value of D helps to control the high frequency edges. The filtered image $G^t(x,y)$ is obtained in spatial domain by implementing the inverse fourier transform as follows:

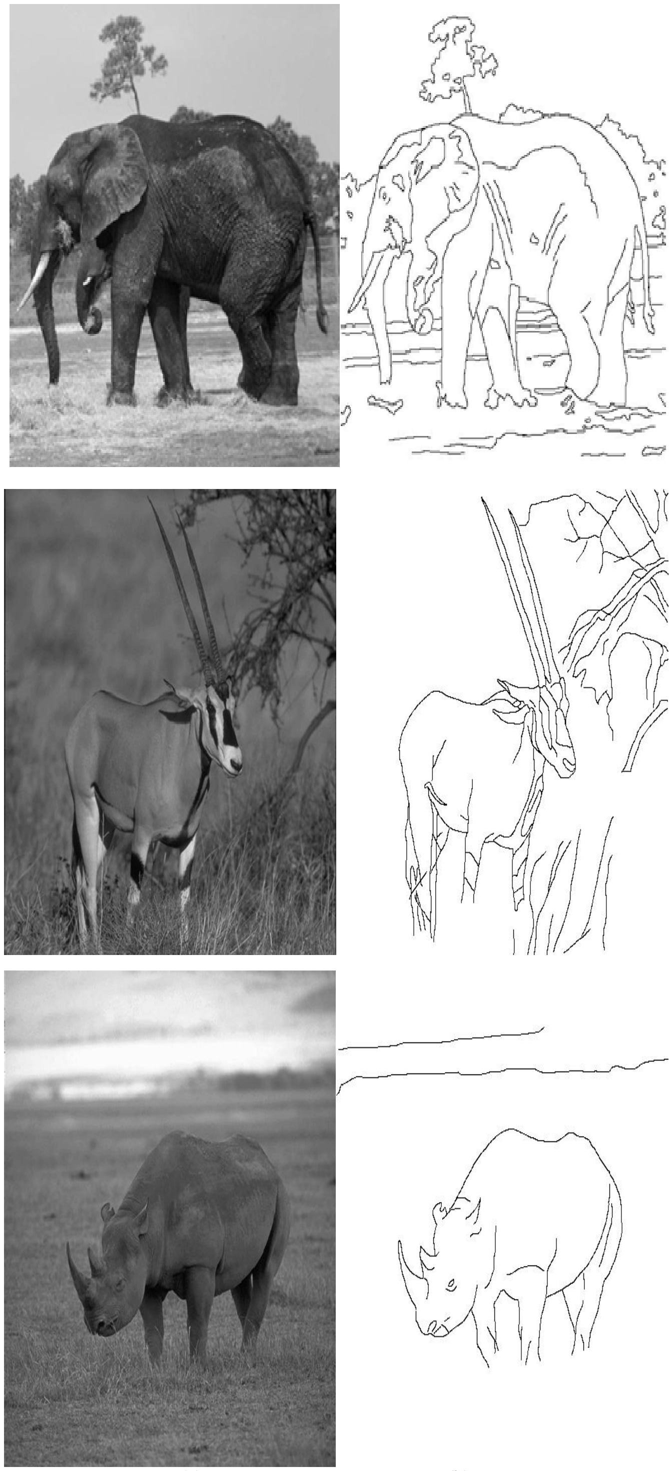
$$G^t(x,y) = \Im^{-1}[Amp(u,v)\exp(j\phi(u,v))] \qquad (13)$$

Inverse fourier transform is denoted as $\Im^{-1}$. The resultant final edge image $E(x,y)$ is produced by applying suppression and thresholding. The suppression process has been used to perform edge thinning. To get final binary contour image, the thresholding technique has been used.

IV. RESULTS AND DISCUSSION

In order to validate the performance of the proposed algorithm, the visual appearance method is used. Five test images namely elephant_3.jpg, golfcart.jpg, elephant.jpg, gazelle.jpg and rino.jpg have been used for performance evaluation. These gray scale test images and their corresponding ground truth images are shown in Fig. 3. All the images are of size 512×512 and these have been taken from online databases [17].

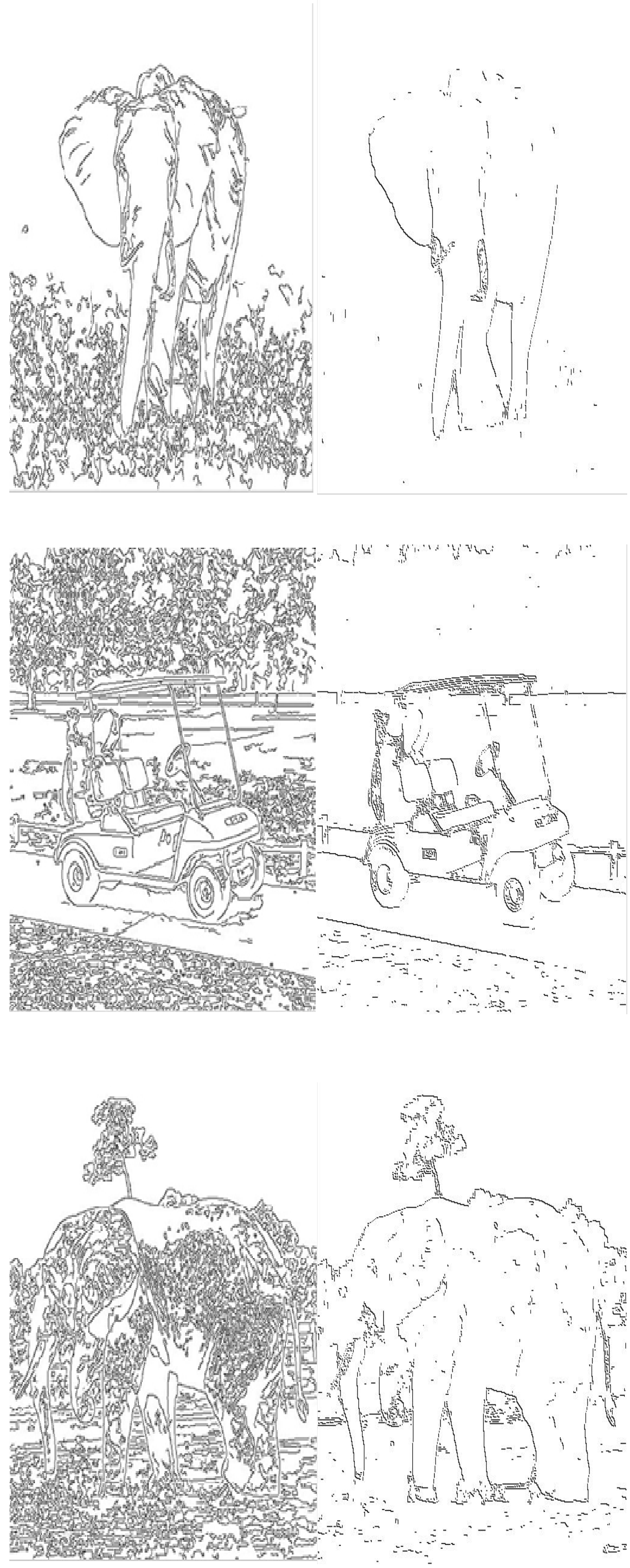




(a) (b)

Figure 3. (a) The original images (b) Desired output contour maps.

The binary contour maps are obtained by applying suppression and thresholding steps on the gradient image. Fig. 4 shows the binary contour maps of standard canny edge detector and proposed method.



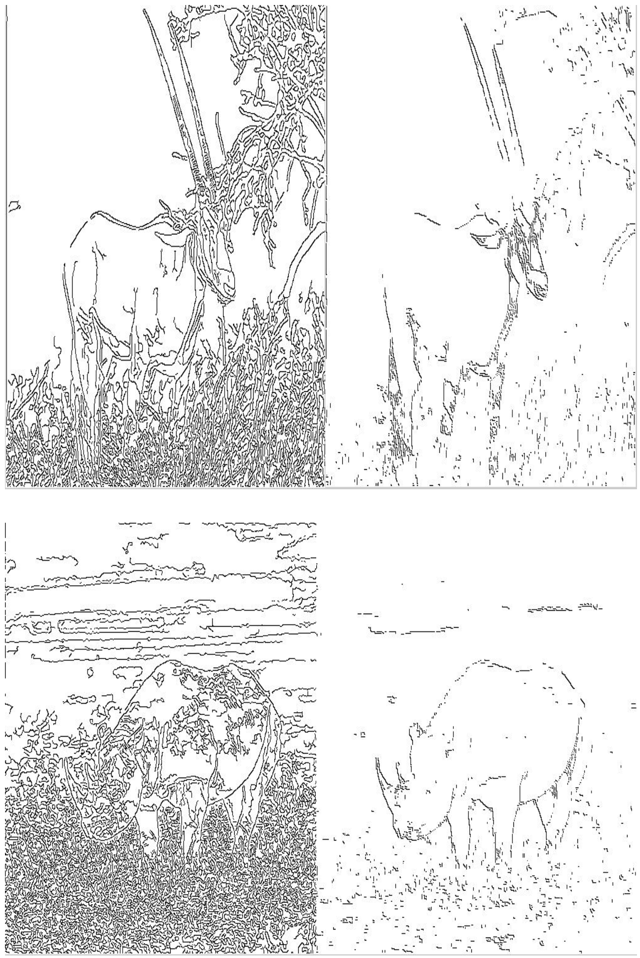

(a) (b)

Figure 4. A comparison of the proposed operator generated contours with the results for canny edge detector. (a) Standard canny edge detector (b) Contour detection by proposed method.

According to the results shown in Fig. 4, the standard canny edge detector detects more texture edges while proposed method is able to remove most of the texture edges generated by texture background and to retain contour edges. Hence, proposed method gives better results than standard canny edge detector.

V. Conclusion and Future Scope

In this paper, an improved approach to effectively detect the contour edges in natural images has been proposed. The gradient image is computed using novel morphological operator. To produce a more pinpointed and integral gradient image, the transform domain filtering is done on gradient image. The purpose to apply the transform domain filtering on gradient image is to decrease the amount of texture edges and to filter out contour edges in natural images with texture background. In future, the proposed method can be extended to detect contour maps of colored images and three dimensional images.

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