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Comparison of Canny's and Snakes' Algorithm as Applied to Diabetic Retinopathy

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Authors' contributions

This work was carried out in collaboration between both authors. Author MA formulated the original research proposal. Author FJ contributed to the research proposal, and organized the procurement of the images. Author MA developed the computer algorithms, and wrote the programs. Both authors helped in analyzing the results. Both authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: To ascertain the effectiveness of edge detection and contour detection algorithms to identify hard exudates and hemorrhage region in fundus images of diabetic patients.
Study Design: Canny's algorithm was selected as the edge detection algorithm, and Snakes' algorithm was selected as the contour detection algorithm.
Place and Duration of Study: A total of 212 fundus images were procured from the Department of Ophthalmology of Bangladesh Institute of Research and Rehabilitation for Diabetes, Endocrine and Metabolic Disorders for this study. The images were captured between 2010 and 2013.
Methodology: Noise was removed from the images using successive Gaussian and median filtering. Green component of the image was used for detection of hard exudates, and red component was used for detection of hemorrhage. To apply Canny's algorithm, color gradient was calculated, and a threshold was applied to the gradient to select a candidate region. Snakes' algorithm was applied by scaling the color intensity from 0 to 1, and a threshold color value was chosen to draw the contours. Several filters were applied to the selected region to detect and discard the false-positives. A total of 32 images were

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used for training purpose. The algorithm was later applied to the rest of the 180 images.
Results: For Canny's algorithm, a threshold color gradient value of 0.30 was chosen to identify the hard exudates, and a value of 0.28 was chosen to identify the hemorrhage regions. For Snakes' algorithm, a color intensity value of 0.7 was chosen for detection of hard exudates, and 0.83 was chosen for detection of hemorrhage regions. Both Canny's algorithm and Snakes' algorithm performed similarly in detection of hard exudates. For detection of hemorrhage regions, generally Canny's algorithm performed better compared to Snakes' algorithm. Even in situations where there was poor color contrast, Canny's algorithm was able to suggest a candidate region, whereas Snakes' algorithm completely failed to suggest a region.
Conclusion: Both Canny's algorithm and Snakes' algorithm performs equally effectively in detecting hard exudates. But in detection of hemorrhage regions, generally Canny's algorithm performs better compared to Snakes' algorithm.

Keywords: Diabetic retinopathy; color image processing; canny algorithm; snakes' algorithm; color funduscopy.

1. INTRODUCTION

Diabetes is rapidly becoming a major metabolic disorder globally. It is estimated that 2.8% of world population has this metabolic disorder [1]. This is expected to rise to 4.4% by 2030. Though the estimates for Bangladesh vary, there are reports that anywhere from 4.8% to 6.6% of the population of the country have Type 2 diabetes [2]. Type 2 diabetes is a hereditary disorder, and is also known to result from limited physical activities and lifestyle.

One of the ramifications of Type 2 diabetes is abnormalities in the eyes known as diabetic retinopathy (DR). Diabetic retinopathy causes abnormalities in the retina, and in worst case, blindness. The visual features of DR include, among others, retinal hemorrhage, micro aneurysm, hard and soft exudates. As shown in Fig. 1, in color retinal images, retinal hemorrhage appear as dark brown regions; hard exudates appear as bright yellow regions with sharp boundaries; and soft exudates appear as light yellow regions with blur boundaries. The amount of these features increase with the advancement of diabetes. Therefore, their early detection is paramount importance in treatment, control and monitoring of diabetes. As a result, substantial amount of effort has been devoted towards detection of these regions by processing their images.

All features of detection algorithms normally have two steps: image enhancement and candidate selection. In image enhancement, some kind of filters are used to enhance the regions under consideration; and in candidate selection, normally some statistical measure is used to identify the region. For detection of retinal hemorrhage, some enhancement techniques include median filtering [3,4], histogram specification [5,6] and contrast enhancement [7] and candidate selection methods include assignment of posterior probability [3], morphological thresholding [4], principal component analysis [5,6,7].

Different enhancement techniques have been proposed for exudates also. Some of these techniques include homographic surface fitting to compensate the non-uniform illumination [8], histogram specification [9,10] and gamma correction [11]. Procedures for candidate selection include dynamic clustering [12], morphological closing and thresholding [13,14], edge detection [15,16,17], fuzzy c-means clustering [9,10] and recursive region growth [3].

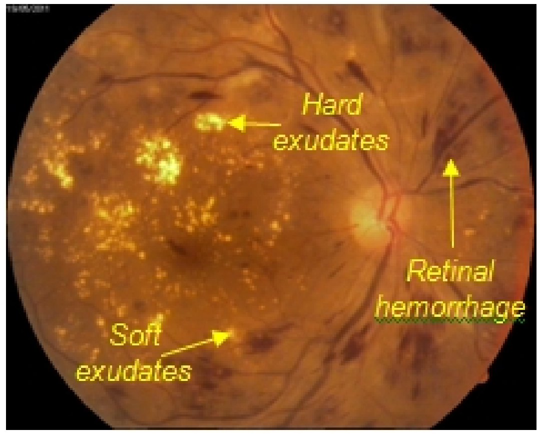

Fig. 1. Color fundus image with different features identified

It is quite clear from the brief review above that the topic of color fundus image processing to detect diabetic retinopathy is fairly new, and is still in its exploratory stage. No standard detection technique has yet been developed for selection of candidate regions. Nevertheless, because of its immense medical and social importance, there is tremendous interest in this subject.

This research looks at the effectiveness of two popular algorithms those are used for feature detection - edge detection using Canny's algorithm, and contour detection using Snakes' algorithm. The study was undertaken to enhance the understanding of retinal feature detection in terms of hard exudates and retinal hemorrhage; hence to facilitate the treatment, control and monitoring of diabetes in Bangladesh.

2. MATERIALS AND METHODS

This study was started as an initial exploratory study. Therefore, of the retinal features discussed earlier in this paper, it was decided that detection of retinal hemorrhage and hard exudates would be attempted. Detection of soft exudates was not among the primary objectives in this study.

The identification algorithm started with the fact that color images are a combination of red, green and blue components. The intensity of the three components of colors of each pixel are arranged in blue, green and red sequence, each sequence being one byte long. As a first step of this study, the color image was separated into its components colors. Fig. 2 shows the three components colors of an example color fundus image. We can clearly observe that certain features of the fundus are more prominent in particular color components. To obtain a better understanding of the color variations in each image, each color component of a pixel was used to construct the gray scale of the pixel for that color. To obtain the gray scale of a particular color component of a pixel, the other two color components were manually replaced with the particular component. For example, for a particular pixel, to obtain the gray scale of the red component, the intensity of the red component was manually substituted in the blue and green components of the color. The results are shown in Fig. 3. We notice from Figs. 3(*b*)–(*d*) that the contrast difference between exudates and the background is more prominent in Fig. 3(*c*), i.e. the green component. On the other hand, the contrast difference between retinal hemorrhage and the background is more prominent in Fig. 3(*b*), i.e. the red component. Therefore, as done in earlier studies, the green component of the color image was used to identify the hard exudates. But, because of better contrast, the red component was used to identify the retinal hemorrhage.

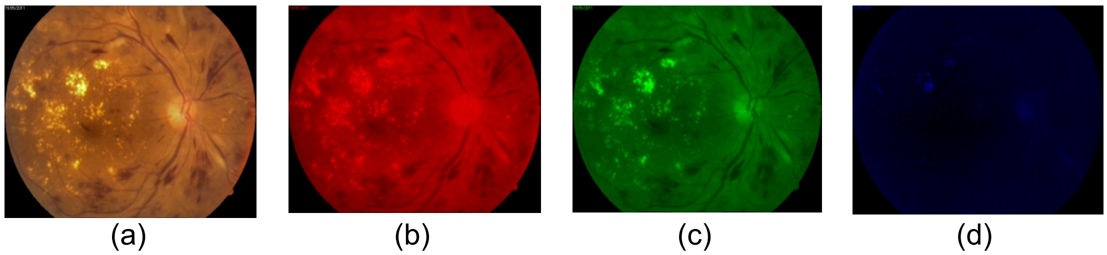

Fig. 2. Color fundus image with component images. (a) original color image. (b) red component. (*c*) green component. (d) blue component

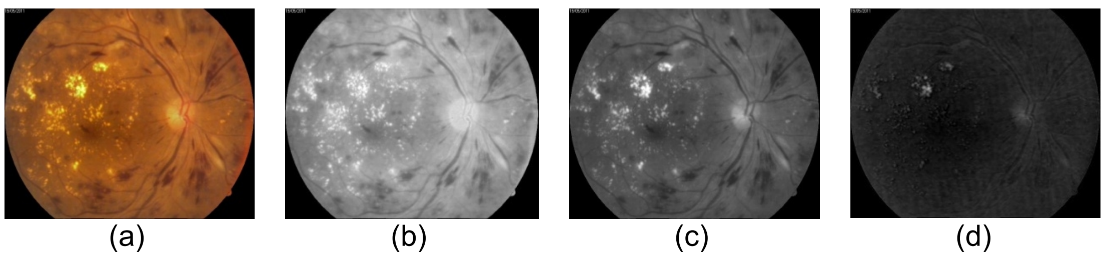

Fig. 3. Grayscale components of the color fundus image. (a) original color image. (b) grayscale of the red component. (c) grayscale of the green component. (d) grayscale of the blue component

Though there was very little noise in most of the fundus images; nevertheless, noise reduction was achieved using both Gaussian filter and median filter. The kernel of the Gaussian filter was

$$K = \frac{1}{159}\begin{bmatrix} 2 & 4 & 5 & 4 & 2 \\ 4 & 9 & 12 & 9 & 4 \\ 5 & 12 & 15 & 12 & 5 \\ 4 & 9 & 12 & 9 & 4 \\ 2 & 4 & 5 & 4 & 2 \end{bmatrix}$$

It was observed that using the two filters give a better result than using either of the two filters individually.

For edge detection, traditional Canny's algorithm was used [18,19]. The green component of the color image was used for exudates detection, and the red component was used for hemorrhage detection. Earlier work has already applied Canny's algorithm for diabetic retinopathy [20].

The details of Canny's algorithm for edge detection can be obtained elsewhere [18], but briefly, the idea of this algorithm is that for an edge pixel, the gradient of the gray-scale intensity between the edge and its neighbor pixel would be high. Therefore, for each pixel, the gradient of gray-scale component, *D*, is calculated as

$$D = \sqrt{D_x^2 + D_y^2}$$

where D_x is the gradient in *x*-direction, and D_y is the gradient in *y*-direction obtained from the Sobel-operator [21] using the following kernel matrix.

$$D_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \qquad D_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

If the calculated gradient is greater than a preset threshold value the pixel is then identified as an edge pixel. After the pixel is identified, it is tested to filter out false positive. This is achieved by checking the neighboring pixels. If none of the neighboring pixel has been detected as an edge, then the particular pixel is considered to be a false-positive, and discarded. Finally, the identified pixels are then marked on the color image.

Though several algorithms are available for contour detection, Snakes' algorithm is used most widely. Briefly, Snakes' are active contour models that are guided by energy minimizing external constraint forces that pull it towards features such as lines edges, or function values. The details of Snakes' algorithm has been described well in literature [22,23]. Contour detection has extensive application in medical imaging also. It is used widely in CAT scanning and MRI [24,25]. Snakes' algorithm has been used in this study also. The color component value of edge pixel was chosen as the function value, and the algorithm was used to draw a contour of that color component value. Once again, the green component was used for exudates detection, and the red component was used for hemorrhage detection. Before the algorithm was used, the color components were normalized from 0 to 1.

A total of 212 color fundus images were procured from Bangladesh Institute of Research and Rehabilitation for Diabetes, Endocrine and Metabolic Disorders (BIRDEM). The images were captured using a Zeiss Visucam Fundus Camera. The images had a resolution of 720 × 576 pixels. Of these 212 images, 32 – about 15% – images were used as reference for training of the algorithms. The algorithms were then applied to the other 180 images for feature identification.

All image processing was accomplished using custom written computer programs.

3. RESULTS AND DISCUSSION

Canny's algorithm and Snakes' algorithm were used to detect hard exudates and retinal hemorrhage from color fundus images. Both these algorithms have been explained briefly in the previous section. As stated earlier, 212 color fundus images were available, of which 32 images were used to decide upon the threshold values to detect the candidate regions.

In order to detect the hard exudates using Canny's algorithm, the green component of the color image was separated. The first derivatives were calculated, and was checked and filtered as suggested by the algorithm. The corrected derivatives were scaled from 0 to 1. A threshold value of 0.3 was set to choose the borders of the hard exudates.

The detection of retinal hemorrhage using Canny's algorithm started with the selection of the red component of the color image. The first derivatives were calculated and filtered as stated earlier. Finally a threshold value of 0.28 was set to choose the hemorrhage region.

To detect the hard exudates using Snakes' algorithm, once again the green component was chosen. The color values were scaled from 0 to 1, and a threshold value 0.7 was set to identify the candidate region. The detection of retinal hemorrhage using Snakes' algorithm was achieved using the red component, and a threshold value of 0.83.

After the threshold values were decided using 32 images, the algorithms were used to process the other 180 images. Some of the results are shown in Fig. 4. Eight examples are shown in the figure. The regions marked with blue are the candidate regions for exudates; whereas the regions marked with red are the candidate regions for retinal hemorrhage. The figures marked with (*i*) are the color images with the candidate regions as detected by Canny's algorithm, and the figures marked with (*ii*) shows the candidate regions as detected by snakes' algorithm.

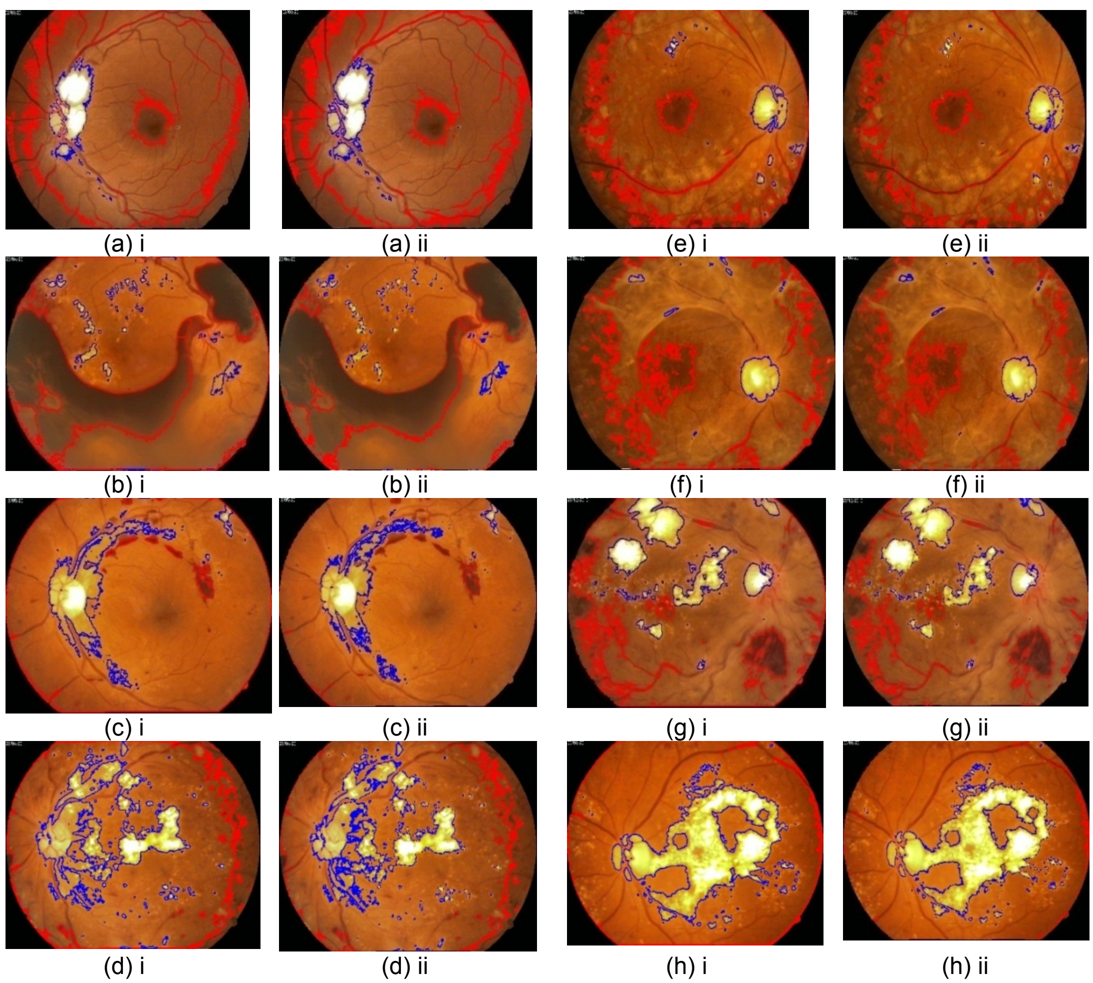

Fig. 4. Eight examples of color fundus images with the hard exudates and retinal hemorrhage detected.

In almost all cases, the optic disk was also identified with the hard exudates as a candidate region. Since the algorithm for the detection of optic disk is quite routine and no attempt was made in this study to remove the disk. Moreover, as the objective of this study was to evaluate the effectiveness of two detection algorithms, ignoring the optic disk does not make any effect in evaluation of the algorithms.

It is quite clear from the images that there is quite a bit of subjectivity in the selection of the candidate regions. Though, of the images shown, it can be seen that Canny's algorithm performs better, but this cannot be made as a general statement. There are images where Snakes' algorithm performs better. In general, it can be said that both the methods performs equivalently while detecting hard exudates, but in detection of the retinal hemorrhage, in most cases Canny's algorithm performs better. In images where there was very poor contrast of the retinal hemorrhage, Canny's algorithm was observed to indicate a specific region that was highly subjective, but in most cases, the Snakes' algorithm completely failed to identify any region as a candidate region. Furthermore, in Snakes' algorithm, as the selection criteria was a color value, and the values of color components range from 0 to 255; therefore, it was quite common that the program would attempt to draw a contour through a range of points – hence failing to draw a contour. This raised lots of ambiguity in the resulting contour.

4. CONCLUSION

The subject of analyzing color fundus image for diabetic retinopathy is fairly new. The comparison of the two algorithms shows that Canny's algorithm is more robust than contouring algorithm in detecting hard exudates and retinal hemorrhages. Because of the nature of contouring algorithm, lots of ambiguities develop while attempting to find a candidate region. Furthermore, it was observed that the threshold level of both these algorithms can be adjusted to obtain any candidate region. So, it is difficult to decide upon a 'global' threshold level that can be used everywhere. Therefore, further research is needed in this area is needed to decide upon a robust algorithm for diabetic retinopathy.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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