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RESEARCH ARTICLE

OPTIC CUP SEGMENTATION USING MANUAL THRESHOLDING LEVEL TECHNIQUE

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ABSTRACT

Optic cup segmentation is a very important step in glaucoma detection, where untreated glaucoma leads to irreversible optic nerve head (ONH) damage and loss of vision. Thus, it is the second cause of blindness around the world. In this paper, manual thresholding level technique in optic cup segmentation is applied, evaluated, and compared with other segmentation techniques. The optic cup segmented by thresholding level 240 from the optic disc partas a region of interest (ROI), after vessel removal by the morphological operation to improve segmentation process, filtering, contrast equalization and finally boundary smoothed by dilating and eroding operation and border clearing. The algorithm was evaluated on DRISHTI-GS database, which has anoptic cup segmentation ground truth. The proposed cup segmentation method evaluate by 3 parameters, which are Dice coefficient (DSC), Jaccard coefficient and structural similarity (SSIM) and achieved best Dice coefficient 73%, Jaccard coefficient 60%, and structural similarity 93%. Because the human visual system is good at perceiving structure, the SSIM quality metric agrees more closely with the subjective quality score, therefore, the obtained results so near to the ophthalmologist segmentation judgment. It was concluded that an optic cup (OC) segmentation algorithm via manual thresholding technique is easy, fast, and inexpensive computationally and obtained good segmentation results and would help in early detection of glaucoma by the ophthalmologist.

Key words: Glaucoma, Optic cup, Thresholding, Morphological operation, Dice coefficient, Structural similarity coefficient.

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INTRODUCTION

Image segmentation is the process of dividing an image into multiple parts, which used to identify information from the digital image as in optic cup segmentation used for glaucoma detection. There are many different methods for image segmentation, like thresholding methods such as Otsu's method, color-based segmentation such as K-means clustering, transform methods such as watershed segmentation, and Texture methods such as texture filters (Math Works, 2018). The main goal of optic cup segmentation is to extract the cup region which is important in glaucoma detection. There are two main features can used to identify glaucoma by an ophthalmologist from the digital fundus images, which morphological features and non-morphological features, the morphological features depend on features extracted from the segmented disc and cup like CDR, ISNT rule and PPA. The non-morphological features depend on whole image features like color, shape and texture features. The CDR can calculate by the diameter and the area of the optic disc (OD) and optic cup (OC).

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The accurate OC segmentation is an essential step to develop computer diagnostic system for Glaucoma detection (Muhammad, 2018). The inferior > superior > nasal > temporal (ISNT rule) in rim area which is the area between the OD and OC to detect accurate ISNT rule need accurate segmentation (Chan *et al.,* 2013), Figure (1) illustrate the retina structure in optic disc, cup, rim, and ISNT value.

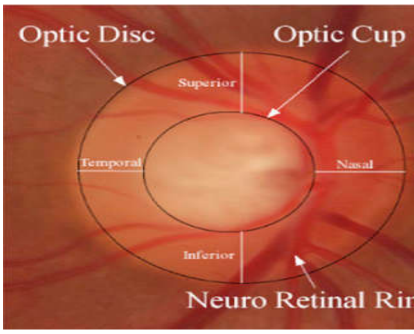

Figure 1. Retina structure

For early and accurate glaucoma diagnosing an algorithm to optic cupsegmentation is needed and proposed.

The paper is organized as follows. A review of OC detection and segmentation methodologies are presented in the related work section. The proposed materials and methodology explained in the material and method section. The evaluation metrics used and evaluation results and comparative analysis with other methods are presented in result section. Final section concludes the paper.

RELATED WORK

Rafael *et al.* (2017), Present an algorithm for cup segmentation using an Ant Colony Optimization-based method. The artificial agents will construct their solutions influenced by a heuristic that combines the intensity gradient of the OD area and the curvature of the vessels. To improve their segmentation algorithm sharing the experience of the entire colony are capable of obtaining accurate cup segmentations, even in images with a weak or non-obvious pallor. This method has been appliedin the RIM-ONE database, the result obtained an average overlapping error of 24.3% of the cup segmentation and an area under the curve (AUC) of 0.7957 using the cup to disc ratio (CDR) for glaucoma assessment. Jun Cheng *et al.* (2013) propose a superpixel classification method for optic cup segmentation. In the proposed method, the first step was each optic disc image is over-segmented into superpixels, then mean intensities, center surround statistics and the location features are extracted from each superpixel to classify it as cup or non-cup. The proposed method has been tested in 650 images with manual OCsegmentation marked by trained professionals and one database of 1676 images with the diagnostic outcome. The final results showed average overlapping error around 26.0% compared with manual cup region and area under the curve of the receiver operating characteristic curve (ROC) in glaucoma detection at 0.811 and 0.813 in the two databases, which are much better compared with other methods. Chunlan *et al.* (2018) presentedan optic cup segmentation method using an improved Bertalmio–Sapiro–Caselles–Ballester (BSCB) model to eliminate the noising induced by the blood vessel. First, enhanced green channel image extracted by morphologicaloperations. Then blood vessels were segmented and filled by improved BSCB model. At the end, Local Chart-Vest model was applied to segment the optic cup. The method tested at 94 samples which included32 glaucoma fundus images and 62 normal fundus images. The evaluation results of F-score and the boundary distance achieved by the proposed method were 0.7955 ± 0.0724 and 11.42 ± 3.61, respectively. Average CDRValues of the normal and glaucoma images achieved by the proposed method were 0.4369 ± 0.1193 and 0.7156 ± 0.0698. In addition, 39 glaucoma images from the public dataset RIM-ONE were also used for methodology validation.

In conclusion, the proposed method could overcome the influence of blood vessels to some degree and be good compared to other current optic cup segmentation algorithms. This novel methodology can beused in a clinic in the field of glaucoma screening. Suman *et al.* (Sedai, 2016), proposed a fully automatic regression based method for an optic cup and disc segmentationfrom retinal fundus image. The first step was roughly to segment optic disc using Circular Hough Transform, then the approximated optic disc is used to compute the initial optic disc and cup shapes. A robust and efficient cascaded shape regression method has been proposed which iteratively learns the final shape of the optic cup and disc from a given initial shape, using the gradient boosted regression trees to learn each regressor. To improve the regressors performance a novel data augmentation designed by synthetic training data. The proposed optic cup and disc segmentation method aretested on 50 patients' images and obtained high segmentation accuracy for an optic cup and disc with dice metric of 0.95 and 0.85 respectively. Comparative study shows that the proposed method outperforms of the current methods. Ingle and Mishra (Ingle, 2003), present the cup segmentation based on the gradient method, the gradient images were obtained from an original image convolved with a filter. Two methods were used to find the gradient: Linear gradient and Radial gradient. At first, the contrast was improved for all image components (red, blue, and green) by Contrast Limited Adaptive Histogram Equalization then,the initial threshold was set for red (R), blue (B), and G (green) components after many iterations to detect the region found the R channel pixel value is less than 60 and B and G pixel values are greater than 100. Subsequently. Then the radial gradient was obtained in the images in all directions and intensities were computed and linearly transformed to the range of (0-1). The G and B channels were founded more effective for OC segmentation. Finally, the circular structural elements were used to fill the blood vessels region in order to blood vessel remove. The algorithm was evaluated based on the accuracy of the cup and disc area in all directions as well as CDR, instead of relying on the accuracy only in one direction.

MATERIALS AND METHODS

The algorithm developed and tested in DRISHTI-GS public database, which contain 101 images, 70 glaucoma and 31 healthy (Sivaswamy, Jayanthi, 2014). The optic cup segmentation method proposed, depend on optic disc thresholding at level 240, which is the best level differentiate between the disc and cup parts then clear border, smoothing boundary and binaries the final image,Fixed thresholding is of the form:

$$\mathrm{OC}(x,y) = \sum_{1\ \ f(x,y) >= t}^{0\ \ f(x,y) < t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where t is thresholding level= 240, the proposed method illustrate in Figure (2).

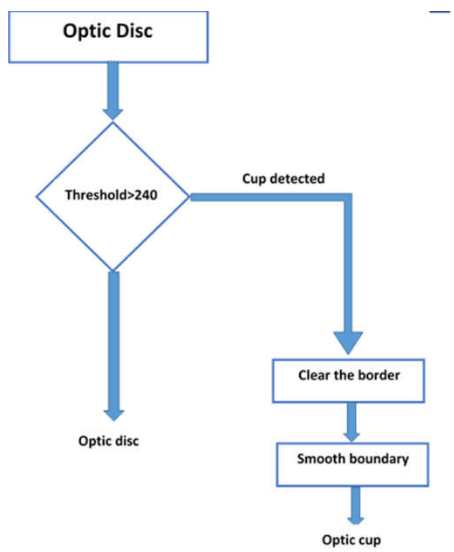

Figure 2. Cup segmentation proposed algorithm based on thresholding technique from optic disc region

First the optic disc was segmented using the same method in several steps, which are:

Vessel removed by opening morphological operation, where for an image f by a structuring element s (denoted by $f \circ s$) the opening morphological operation defined:

$$f \circ s = (f \ominus s) \oplus s \qquad \text{.................(2)}$$

It used to open up a gap between objects connected by a thin bridge of pixels. Any regions that have survived the erosion are restored to their original size by the dilation, and that makes the blood vessel dilated with it is surrounded pixel and disappeared. Opening morphological techniques probe an image with a small shape or template called a structuring element it is positioned at all possible locations in the image and it is compared with the corresponding neighborhood of pixels, because the optic disc is a circle shape the structuring element chosen was a disk with corresponding neighborhood of pixels 8 to get good and fast result in vessel removing (Auckland University, 2018).

The median filter is a nonlinear digital filtering technique used to remove noise from an image. As the pre-processing step to improve the results of later processing in edge detection on an image. Median filtering used here for it preserves edges while removing noise.

The thresholding segmentation assumes that the intensity values are different in different regions, and similar to represents the corresponding object. In fixed (or manual) thresholding, the threshold value is held constant throughout the image and treating each pixel independently of its neighborhood.

- Fixed Thresholding is of the form:

$$g(x, y) = \sum \begin{matrix} 0 & f(x, y) < T \\ 1 & f(x, y) >= T \end{matrix} \qquad \text{... ... ... (3)}$$

The threshold level is chosen manually. Which done by trial and error, using a histogram as a guide to get more accurate segmentation (National Instruments, 2016).

To smooth the boundary erosion and dilation operation, where it is operation expands or thickens foreground objects in an image are applied to segmented disc and border cleared to suppresses structures that are lighter than their surroundings and that are connected to the disc border. For segmented disc the function tends to reduce the overall intensity level in addition to suppressing border structures (Soille, 1999). binarization image that to convert an intensity image to a binary image with global threshold level, function uses Otsu's method, which chooses the threshold to minimize the interclass variance of the black and white pixels (Otsu, 1979). To obtain more accurate segmentation and based on the truth of the optic disc and optic cup are a circular shape, logical circle image was constructed using the center point and the axis from the segmented object by the equation:

$$(x - h)^2 + (y - k)^2 = r^2 \qquad \text{...................(4)}$$

Wherer= the radius from the segmented object, k = the center from the segmented object.

Finally, the segmented disc act as ROI for cup segmentation, using thresholding level 240 to differentiate the region to cup or non-cup, then the boundary was smoothed by the morphological operation.

RESULTS

The proposed algorithm evaluated based on many parameters:

The Dice similarity coefficient (DSC) was used as a statistical validation metric to evaluate the segmentations and the spatial overlap accuracy, A and B target regions, and is defined as DSC.

$$DSC = 2(A \cap B) / (A+B) \qquad \text{....................(5)}$$

Where∩ is the intersection

Jaccard similarity coefficient is the Intersection over Union and is a statistic used for comparing the similarity and diversity of images sets with a range of 0% to 100%. The higher the percentage, the more similar in the two image sets, its formula is:

$$J(A, B) = |A \cap B| / |A \cup B| \qquad \text{..........................(6)}$$

Structural Similarity (SSIM) Index. The SSIM parameter combines image structure, luminance, and contrast features into a single quality parameter. In this metric, the structures representthe pixel intensities pattern, after normalizethe luminance and contrast features. Thus the human visual system is good at perceiving structure, the SSIM quality metric agrees more closely with the subjective quality score and obtained evaluation near to the human eye.

$$SSIM(x, y) = [l(x, y)]^{\alpha} . [c(x, y)]^{\beta} . [s(x, y)]^{\gamma} \qquad \text{..............(7)}$$

$$l(x, y) = \frac{2\mu x \mu y + c_1}{\mu 2_x + \mu 2_y + c_1} \qquad \text{...........(8)}$$

$$c(x,) = \frac{2\sigma_x \sigma_y + c_2}{\sigma_x^2 + \sigma_y^2 + c_2} \qquad \text{..............(9)}$$

$$s(x, y) = \frac{2\sigma_{xy} + c_3}{\sigma_x \sigma_y + c_3} \qquad \text{...........(10)}$$

Where $\mu x, \mu y, \sigma x, \sigma y, and\ \sigma xy$ are the local means, standard deviations, and cross-covariance for images *x, y*. If $\alpha = \beta = \gamma = 1$ (the default for Exponents), and $C_3 = C_2/2$ (default selection of C_3.

The results were compared with other methods like super pixel segmentation method, super pixel combined with circle reconstruction, modified thresholding and the best results obtained by global thresholding technique as shown in Figure (3). The cup segmentation using manual thresholding level technique applied and compared with other segmentation techniques, the results evaluated based on standard parameters and shown in Figure (4).

DISCUSSION

In this section, a cup boundary detection algorithm presented and the segmentation results from the digital fundus images evaluated in Drishti _GS database an example of the segmentations shown in Figure (6).

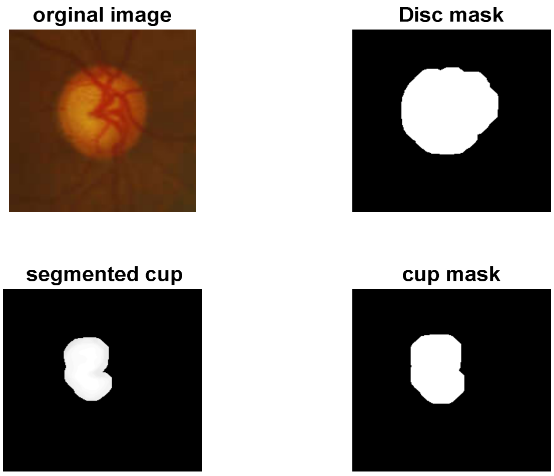

Figure 3. Shows a cup segmentation and binarization from the disc part for glaucoma image using manual thresholding level technique

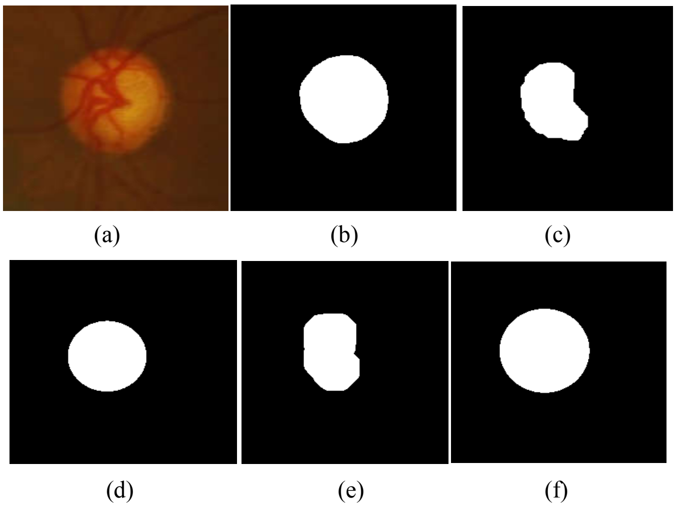

Figure 4. Shows (a) the original image (b) ground truth image (c) super pixel segmentation (d) super pixel segmentation with circle construction (e) manual thresholding level (f) global Thresholding segmentation with circle construction

Table 1. Comparison of the proposed method against other segmentation methods by same database and same evaluation parameters

Segmentation Method	DSC %	Jaccard coefficient%	SSIM %
Super pixel segmentation	66	52	90
Super pixel with circle construction	58	45	83
manual thresholding level (proposed)	73	60	93
Global with circle construction	53	39	80

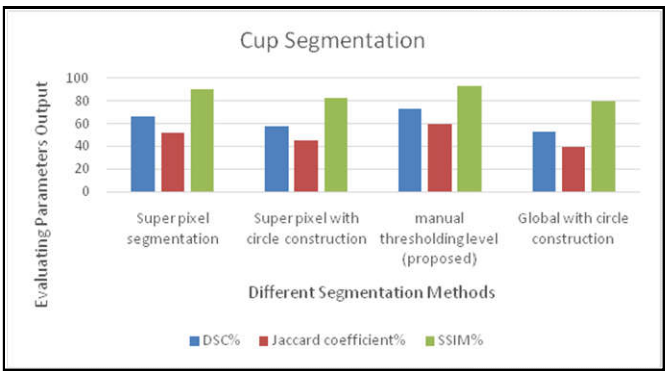

Figure 5. Bar chart illustrates the comparison between different segmentation techniques

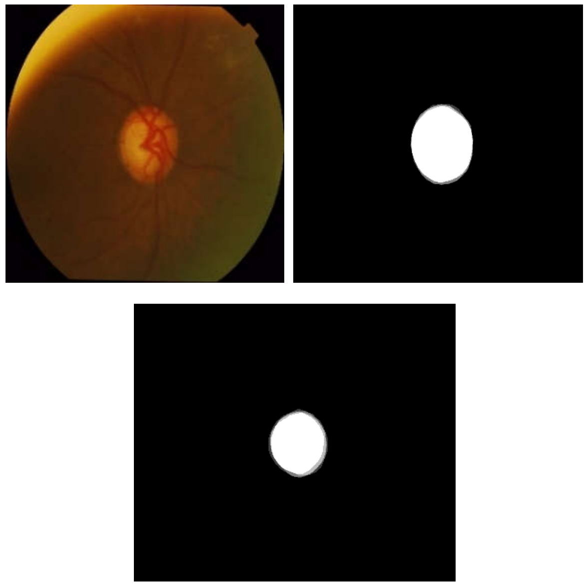

Figure 6. Sample Image and Ground-Truth in Drishti_GS dataset - (From Left to Right) Original image (2047x1751) in the dataset, Ground-truth Optic cup Mask, proposed segmented Optic Cup Mask

The ROI was selected to be the optic disc because the optic cup is a circular yellowish part inside the disc, and this minimizes segmentation error can happened due to papillary atrophy (PPA) , Blood vessels and disc boundary itself. Where thresholding is the most common method of segmenting images into particle regions and background regions. A typical segmentation method would start with filtering or other enhancements to sharpen the boundaries. Then, the objects are separated from the background using thresholding here the ROI was already filtered and blood vessel removed in optic disc segmentation step. Although experimentally, it was demonstrated that the use of manual thresholding level can help improve the optic cup detection, however, it should be noted that there are some limitations and considerations for the effective use this method for cup boundary detection. Like the thresholding level differentiate from one database to another. Figure (7) is an example of un-segmented images due to a bad localization of the ROI region.

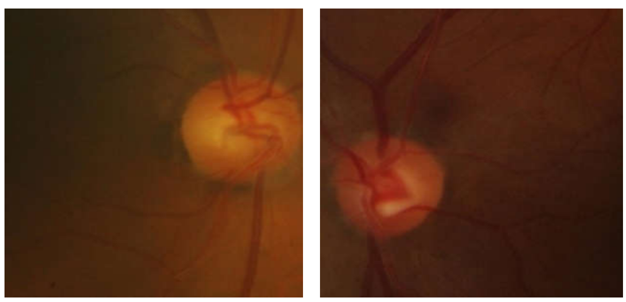

Figure 7. An examples of un-segmented image due to ROI bad localization

CONCLUSION

Optic cup segmentation algorithm for digital fundus image has been proposedusingmanual thresholding level technique with intensity level=240. The ground truth was considered to evaluate the new algorithm obtained from DRISTHI-GS database. The DSC, Jaccard coefficient and SSIM parameters were chosen to evaluate the new system in this paper and founded that the DSC was 73 %, Jaccard coefficient 60 %, and SSIM 93%. In conclusion, this paper has presented a method to localize the optic cup in digital fundus images. The framework provides two major contributions. Firstly, a robust and stable optic cup localization is presented. Secondly, the accuracy, simplicity and inexpensive computation method proposed. Experimentally, it was demonstrated that this method is able to produce optic cup can use in glaucoma detection.

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