Comparative Analysis on Optic Cup and Optic Disc Segmentation for Glaucoma Diagnosis

Niharika Thakur and Mamta Juneja

Abstract Glaucoma is an eye disease which causes continuous increase in size of optic cup and finally the permanent vision loss due to damage to the optic nerve. It is the second most prevailing disease all over the world which causes irreversible vision loss or blindness. It is caused due to increased pressure in the eyes which enlarges size of optic cup and further blocks flow of fluid to the optic nerve and deteriorates the vision. Cup to disc ratio is the measure indicator used to detect glaucoma. It is the ratio of sizes of optic cup to disc. The aim of this analysis is to study the performance of various segmentation approaches used for optic cup and optic disc so far by different researchers for detection of glaucoma in time.

Keywords Segmentation · Cup to disc ratio (CDR) · Optic disc · Optic cup · Glaucoma

1 Introduction

Glaucoma is a primary cause of permanent blindness all over the world. It occurs due to compression and/or deteriorating blood flow through the nerves of the eyes. It is caused due to increase in optic cup size present on the optic disc. Optic disc is the location from where major blood vessels enter to supply the blood to retina. Optic cup is the central depth of variable size present on optic disc. A disc with disease condition varies in color from a pink or orange to white. In a survey conducted by World Health Organization (WHO) it has been ranked as the second major cause of blindness across the world. It influenced nearly 5.2 million population across the world i.e. 15 % of the total world population and is expected to

N. Thakur (✉) · M. Juneja
Computer Science and Engineering UIET, Panjab University, Chandigarh, India
e-mail: niharikathakur04@gmail.com

M. Juneja
e-mail: mamtajuneja@pu.ac.in

A. Nagar et al. (eds.), *Proceedings of 3rd International Conference on Advanced Computing, Networking and Informatics*, Smart Innovation, Systems and Technologies 43, DOI 10.1007/978-81-322-2538-6_23

increase by 11.2 million population by 2020 [1]. In country like Thailand, it affected 2.5–3.8 % of the total population of the country or approximately 1.7–2.4 million population over the country [2]. Currently, Cup to disc ratio (CDR) is a measure indicator of glaucoma. It is calculated as the ratio of the vertical diameters of optic cup to optic disc. CDR can be determined by analyzing the sizes of optic cup and optic disc [3]. As a researcher we can diagnose the glaucoma by segmenting the optic cup and optic disc and then calculating the ratio's of their vertical diameter for diagnosis of glaucoma. According to survey conducted this can be said that CDR for person with normal eye is less than 0.5 and that for eyes with disease Glaucoma is more than 0.5.

2 Methodologies Used with Performance Evaluation

In 2008, Liu et al. [4] gave thresholding followed by variational level-set approach for segmentation of optic cup and optic disc. This improved the performance of segmentation in comparison to color intensity based method but had a drawback that cup segmentation was not accurate.

In 2008, previous approach was further improved by Wong et al. [5] by adding ellipse fitting to the previous method in post processing which increased the accuracy of the segmentation.

In 2009, Wong et al. [6] further added support vector machine (SVM) for classification, neural network for training and testing. This further improved the accuracy and increased the acceptability of glaucoma diagnosis.

Evaluation criteria used for comparing these approaches were acceptability which is calculated as difference between some standard clinical CDR and calculated CDR. CDR values with a difference of less than 0.2 units are considered appropriate [4].

Table 1 below shows the comparison of above techniques on the basis of Acceptability.

In 2010, Joshi et al. [7] used bottom-hat transform, morphological closing operation, region-based active contour and thresholding to detect optic disc and optic cup boundary. This approach was good at handling gradient distortion due to the vessels. Evaluation criteria used for this approach was Mean CDR error calculated as mean of differences of CDR values .

In 2013, this approach was further improved by Cheng et al. [8] that used simple linear iterative clustering, contrast enhanced histogram, color maps, center surround statistics and support vector machines for classification. This approach improved the [7] by reducing the value of Mean CDR error.

Table 2 below shows the comparison of techniques [7] and [8] on the basis of Mean CDR error.

In 2011, Joshi et al. [9] used gradient vector flow (GVF), chan-vese (C-V) model, optic disc localization, Contour Initialization, and Segmentation in Multi-Dimensional Feature Space for optic disc detection. It used vessels r-bends information and 2D spline interpolation for optic cup detection. Proposed method

Table 1 Comparison on the basis of acceptability

Authors	Acceptability
Liu et al. [4]	62.5 %
Wong et al. [5]	75 %
Wong et al. [6]	87.5 %

Table 2 Comparison on the basis of Mean CDR error

Authors	Mean CDR error
Joshi et al. [7]	0.121
Cheng et al. [8]	0.107

Table 3 Comparison on the basis of Recall, Precision F-score, Accuracy

Authors		Recall	Precision	F-score	Accuracy
Joshi et al. [9]	Optic cup	–	–	0.84	–
	Optic disc	–	–	0.97	–
Rama Krishnan et al. [10]	Optic disc	0.91	0.93	0.92	93.4 %
Noor et al. [11]	Optic cup	0.35	1	0.51	67.25 %
	Optic disc	0.42	1	0.59	70.90 %
Vimala et al. [12]	Optic disc	–	–	–	90 %
Noor et al. [11]	Optic cup	0.806	0.999	0.82	90.26 %
	Optic disc	0.876	0.997	0.93	93.70 %

of optic disc segmentation performed better than GVF and C-V model and that of cup was better than threshold and ellipse fitting. It used F-score for evaluating its result and found that F-score for this approach was higher than other approaches and hence was considered better than other approaches.

In 2012, Rama Krishnan et al. [10] used intuitionistic fuzzy histon for optic disc segmentation, adaptive histogram equalization for pre-processing for disc and gabor response filter for retinal classification. This approach improved the accuracy of this method as compared to other by increasing value of F-score.

In 2013, Noor et al. [11] used region of interest analysis followed by color channel analysis and color multithresholding for segmentation. It also evaluated various parameters such as Precision, recall, F-score, accuracy and calculated the CDR value. With this approach 88 % of the CDR results agreed with those of ophthalmologists.

In 2013, Vimala et al. [12] used line operator and fuzzy c means clustering for optic disc segmentation. This approach detected the optic disc better than other by achieving the accuracy of 90 %.

In 2014, Noor et al. [11] used region of interest extraction, morphological operation and fuzzy c mean segmentation to detect optic cup and optic disc. With this approach accuracy achieved for optic cup and optic disc was increased. 88 % of CDR results agreed with that from standard CDR achieved by ophthalmologist.

Parameters such as Precision, recall, F-score and accuracy are calculated as given below [13]

$$\text{Precision} = \frac{\text{tp}}{\text{tp} + \text{fp}} \times 100 \tag{1}$$

$$\text{Recall} = \frac{\text{tp}}{\text{tp} + \text{fn}} \times 100 \tag{2}$$

$$\text{F score} = 2 \times \frac{\text{Precision} \cdot \text{Recall}}{\text{Precision} + \text{Recall}} \tag{3}$$

$$\text{Accuracy} = \frac{\text{tp} + \text{tn}}{\text{tp} + \text{fp} + \text{fn} + \text{tn}} \times 100 \tag{4}$$

where,

tp is the region segmented as Disk/Cup that proved to be Disk/Cup
tn is the region segmented as non Disk/Cup that proved to be non Disk/Cup
fp is the region segmented as Disk/Cup that proved to be non Disk/Cup
fn is the region segmented as non Disk/Cup that proved to be Disk/Cup

Table 3 below shows the comparison on the basis of Precision, Recall, F-Score and Accuracy.

3 Conclusion

In this study, we analysed various existing methods used for optic cup and optic disc segmentation for glaucoma detection used by different researcher from time to time based on their performance. Most of these techniques used methods such as region of interest extraction, histogram equalization and morphological operations for pre-processing to overcome the problems of segmentation due to presence of vessels, noise etc. The performance of all these methods varies depending upon the segmentation techniques used by different researchers. All these methods have their own importance depending upon the types of images taken. It has gained a great attention in recent years due to the growth of glaucoma rapidly and commonly. Glaucoma is detected by calculating the CDR values which is the ratio of optic cup to optic disc vertical diameter. This ratio is achieved by segmenting optic disc and optic cup. Segmentation is done only in retinal fundus images captured by fundus cameras. From this comparative study, we analysed that clustering techniques are more appropriate for segmenting optic cup and optic disc due to improved accuracy as compared to others techniques and hence can be modified and improved further to increase the accuracy. Region of interest extraction makes the segmentation fast. It can be seen that optic cup segmentation is more appropriate in green channel and that of optic disc in red channel due to clear visibility of cup and disc in these channels.

Acknowledgments I sincerely thank all those people who helped me in completing this comparative analysis.

References

1. World Health Organisation Media centre (April, 2011). Magnitude and Causes of Visual Impairment [Online] Available: http://www.who.int/mediacentre/factsheets/
2. Rojpongpan, P.: Glaucoma is second leading cause of blindness [Online]. March (2009) Available: http://www.manager.co.th/QOL/ViewNews/
3. Burana-Anusorn, C. et al.: Image processing techniques for glaucoma detection using the cup-to-disc ratio. Thammasat Int. J. Sci. Technol. **18**(1), 22–34 January-March (2013)
4. Liu et al.: Optic cup and disc extraction from retinal fundus images for determination of cup-to-disc ratio. IEEE, 1828–1832, (2008)
5. Wong et al.: Level-set based automatic cup-to-disc ratio determination using retinal fundus images in ARGALI. In: 30th Annual International IEEE EMBS Conference Vancouver, British Columbia, Canada, August 20–24, pp. 2266–2269 (2008)
6. Wong et al.: Intelligent Fusion of Cup-to-Disc Ratio Determination Methods for Glaucoma Detection in ARGALI. In: 31st Annual International Conference of the IEEE EMBS Minneapolis, Minnesota, USA, September 2–6, pp. 5777–5780 (2009)
7. Joshi et al.: Optic disc and cup boundary detection using regional information, IEEE, ISBI, 948–951 (2010)
8. Cheng et al.: Super pixel classification based optic disc and optic cup segmentation for glaucoma screening. IEEE Trans. Med. Imaging. **32**(6), 1019–1032 (2013)
9. Joshi, G.D. et al.: Optic disc and optic cup segmentation for monocular colour retinal images for glaucoma detection. IEEE Trans. Med. Imaging. **30**(6), 1192–1205 (2011)
10. Rama Krishnan et al., Application of Intuitionistic Fuzzy Histon Segmentation for the Automated Detection of Optic Disc in Digital Fundus Images, In: Proceedings of the IEEE-EMBS International Conference on Biomedical and Health Informatics (BHI), Hong Kong and Shenzhen, China, pp. 444–447, 2–7 Jan (2012)
11. Noor et al.: Optic Cup and Disc Colour Channel Multithresholding Segmentation. In: IEEE International Conference on Control System, Computing and Engineering, Penang, Malaysia, pp. 530–534, 29 November–1 Dececmber (2013)
12. Annie Grace Vimala, G. S., Kaja Mohideen, S.: Automatic Detection of Optic Disk and Exudate from Retinal Images Using Clustering Algorithm. In: Proceedings of the 7th International Conference on Intelligent Systems and Control (ISCO), pp. 280–284 (2013)
13. Khalid, N.E.A., et al.: Fuzzy C-Means (FCM) for optic cup and disc segmentation with morphological operation, Procedia Computer Science. In: International Conference on Robot PRIDE 2013–2014 Medical and Rehabilitation Robotics and Instrumentation, ConfPRIDE 2013–2014. Elsevier, vol. 42, pp. 255–262, Dec 2014