An Analysis Of Segmentation And Glaucoma Diagnosis By Deep Learning Technique Via Retinal Fundus Images

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Abstract: A leading retinal disease was Glaucoma. It damages the eye due to the intraocular pressure on the eye. When glaucoma was untreated left, it would lead to the loss of vision by affecting the ONH (optic nerve head). The glaucoma progression was investigated on the retina of eye through ophthalmologist. This method was very boring and it enhances more time to do by human beings. Therefore, this issue was the right problem which may be solved by diagnosing automatically with the support of the approach of deep learning process. CNNs are suitable to identify the solution for this problem. It may extract different stages of information from the input picture and motivates to variate among glaucomatic and non-glaucomatic pictures. This examined paper presents an effective glaucoma structure to fragment the optic disc and cup to identify the CDR value. The glaucoma was achieved by deep learning process along with the novel Convolutional Neural Network. An examined method uses 2 similar Convolutional neural network architecture to extract the optic disc and optic cup to get perfect output. This design was tested and trained on DRISHRI-GS data base, that was available publicly and an exact value of 97% for OC and 98% for OD segmentation was investigated.

Keywords: Deep learning, OC, OD, CDR, Convolutional neural network, nerve, pressure.

1. Introduction

Glaucoma was the 2nd important reason for blindness. It was caused by the intraocular pressure that causes mechanical breakage to the optic nerve, which consists of nerve fibre in retina. A retinal fundus was used commonly to track or monitor the glaucoma progress. It was like a laser beam of the fundus, permitting the evaluation of framework connections of the OC, retina and OD. The CDR correlates the OC diameter to the OD and halfly denotes the status of disease. Previous researches reveals that a high vertical cup to disc ratio was linked with the progression of glaucoma. Though the cup to disc ratio was not diagnostic, it was helpful in the medical practice for the valuation of glaucoma. The manual consideration of cup to disc ration was time consuming, subjective, dependent on operator and poor reproducible. Because of these reasons, there are great interest regarding this topic.

A method of traditional division was depend upon thee super pixels, shape, graph cut models trust on hand crafted characteristics and an exact knowledge of the customer who purifies the division. These approaches usually based on the low level characteristics like local quality which do not seize the variations in the picture. Likewise, the process of methods trust on correctly converting a more parameters which block broad applications.

Some of the main structural suggestions of glaucoma are PPA, ISNT rule, Cup to disc ration, proportion of Neuroretinal, Rim in superior and inferior. These things are concentrated usually around and in optic disc. Then the division of this ROI was monitoring the contour of optic disc. It was not only helpful for a highlighted clinical valuation by Ophthalmologists but also useful in training a computer depend division discs which are sensitive to the perfection of division and even a little mistake in delimitation of optic disc and also influence the diagnosis. An automatic process for glaucoma detection depend on this method of ROI removal are hardy to localization mistakes.

An automatic finding technique consists of 5 things. They are classification, selection (feature), pre-processing, extraction and segmentation. The 1st step was the processing before where outliers and noise are neglected for the image improvement. It was a basic method in which the picture consumption would do by neglecting all insufficient parts on the retina. So the accuracy of the eye will be improved. For this step many filters was appeared suchas Gaussian, mean and median. Few morphological methods are used for extracting and selecting the feature. And at last, various algorithms are used for classification and segmentation.
2. Literature Survey

A diagnosis of glaucoma was important for patients during treatment. Doctors have examined various criteria for beginning diagnosis and these measures highlight around or on optic disc region. When the size, position and centre of optic disc was measured perfectly, it may support in automatic analysis of the picture.

Eswaran et al. [12] proposed such strength difference depend upon this method. He applied a 35 x45 minimum filter with correct weights of one on the picture to soft it and get rid of variations, intensity and protect ROI. Chrástek et al. [13] used 32x32 minimum filter and the ROI was expected to be 135x135 pixels. He used Canny Side analyser to mark the sides in the picture. He used only green approach of RGB picture to confine the OD region. Abràmoff et al. [15] examined that the OD may be choosen by picking only top five percentage of bright pixels and heu range in the yellow color. The pixels are grouped to establish a user region. The groups are below a threshold which was unwanted. Liu et al. [16] analysed a same method. He 1st classified the picture into 9x9 pixels and choosen the brick with high number of top five percentage bright pixels as the middle of the disc. Nyúl [17] used a correct thersholding along with a window. It size was considered to match the vessel size. An observation was exploited and made through many experts like Siddalingaswamy and Prabhu [18]. He also recorded that the green channel of retina which has the highest contrast correlated to blue and red channels. Hence, a channel red was used because of the fact which it has low blood vessels that may confuse the principle depend localizaitn algorithm. A theershold of optimal was selected depend on the picture histogram. The picture histogram was scanned gradually from a high value I1, gradually low the intensity till it reaches a low value I2 which generates at least thousand pixels with the same intensity. It finshed in a histogram subset. A threshold optimal was taken as the 2 intensities mean value I1 and I2. Dashtbozorg et al. [23] analysed SBF on sample version of resolution pictures ti ll sliding band filter was very cost computationally. The place of this hard ROI was used to provide a low ROI on normal size for a 2nd process of sliding band filter. Zhang et al. [25] examined a fastest process to find OD. 3 vessel features are used to measure the horizontal joining of the disc. These characteristics are uniformity, local density of vessel and compactness of the vessels. The vertical joints of the disc are measured by Hough Transform.

Classification of Glaucoma:

A glaucoma classification and automatic identification are studied widely by exper. An outline of this work was presented under briefly.

Fuente-Arriaga et al. [33] examined the displacement of blood vessels inside the disc for glaucoma identification. At first, extract vascular in optic disc to place a analysed point in the ISNT of the cup. Important positions of nasal, inferior and superior bundles are considered and used to calculate L1 displacemtn between the ordinal position and centroid of vascular groups. It was applied on a group of 68 pictures safely and chosen for quality and clarity of retina from the private reports and dataset 92.56% accuracy. Ahmad et al. [34] and Khan et al. [35] are used same techniques to find glaucoma. It measured ISNT and CDR quadrants and divide a picture as glaucomatous. When the cup to disc ratio was greter than 0.6 and it damages the ISNT rule. Ahmad et al. applied procedure on 90 pictures taken from the dataset of DMED.

3. Influence

Important contribution of the paper
a The deep learning increased convulational neural network design was separately modelled for both the OC and OD to measure the Cup to Disc Ratio.
b These two desing modelled for OC and OD that are composed of 40 layers. Enhancing the no. of layers supports to extract many no. of features and supports to reduce the mistakes.
c Down and up sampling layers in the design supports to retain identical input picture in the result image.
d An examined design existed outputs correlated with the obtained method which used to divide the OC and OD.
Figure 1. The representation shows the normal healthy eye and glaucoma suspicious eye. The outer dotted lines represent the optic disc, and the inner line represents the optic cup (image is taken from Drive database)

Description of dataset:
The database of DRISHTI-GS contains 102 fundus pictures that are gathered from the Aravind Eye Hospital. The pictures are classified into 56 testing and 51 training pictures. An image is gathered equally as female and male inside all the range of 41 to 84 year people picture samples. The database mainly contains all the related topic about nerve and calculated manually by 4 clinical experts. The truth value of pictures are determined by developing OD as middle with 35° view in the 2987x1987 pixel dimension. The plotings for the OD including minimum boundary of OC and OC. A value of soft map and cup to disc ratio are existed by well-experienced medical experts.

Fig. 2. System Work Flow

A measurement of cup to disc ratio plays an important role in having perfect outputs in the identification of glaucoma and also based upon the correct division of OD and OC in this examined work. Figure 2 shows the entire system work flow. The size of fundus picture 2987x1987 pixel was given as an input value. The morphology process such as CLAHE, erosion and dilation was taken in the first step to increase the contrast and quality of a picture. The characteristics of pre-processing picture are removed by relating the Watershed algorithm and Sobel Edge detection method to place the optic nerve region. After placing the wanted area where the glaucoma was found, then the area was cropped in the size of 516x516. Two different Convolutional Neural Networks designs with 40 layers was developed for the division of OD and OC. The edited image was given as an input for 2 designs. It give the judged mask from the edges of both designs. An explanation of block was given below.
3.1. Pre-Processing:
This step was a crucial process for the diagnosis of fundus pictures. The fundus pictures are influenced by the gaussian white noise, salt and pepper noise. Eliminating noise from these pictures was an important aspect of the diagnosis by the ophthalmologist. A filter like Gaussian was used to eradicate the Gaussian noise in fundus pictures. Here the component of blue, green and red are not isolated into various channels. This was forwarded into other process.

3.1.1. Erosion and dilation:
Erosion and dilation are the essential math morphological process used for the improvement of the picture. The blood vessels in the picture fundus will become light weight and it includes pixels to the boundaries of the input pictures using the process of dilation. It fills the inside gaps in the pixels: therefore by increasing the dilation method in the picture improvement. Same constructing components are used in the dilation method which will be used for the process of erosion. Erosion supports to have soft picture and to contrast the borders of the picture when the dilation was applied 2 times, then the erosion was doubly applied.

3.1.2. Contrast Limited Adaptive Histogram Equalization (CLAHE) technique:
The CLAHE provides perfect outputs in increasing the picture by correlating normal HE and AHE. This supports to develop the contrast in very low contrast pictures especially in clinical pictures. An image contrast was static by contrast limiting. If it applies to normal HE to noise amplification, everyone can limit the contrast if the noise was prominent one. Therefore the outputs will be analysed after appearing CLAHE to the histogram equalization. It was calculated by correlating the slp with inner intensity value of picture. An output will be shown in the shape of histograms. The histogram level reveals the contrast level in the picture. To manage the image contrast, the limit clip and slope method will be applied. In normal HE, the picture was classified into various sub levels and interpolation bilinear which was separately applied for the sub section.

3.1.3. Shape detection
EHD was applicable mainly for detecting the shape of a picture. The picture area was represented basically with 5 various kinds of shapes. These 5 shapes analyze all occurrence of a picture. Here, the provided picture was segmented into 5x5 divisions known as sub image. This sub image again classified into sixteen blocks that produce a histogram for every block. The sides in every division are clustered into 5 kinds. The sides are non-directional, 136° diagonal, vertical, 45° diagonal edges and horizontal.

3.2. Feature extraction
The characteristics of contour shape and edges are removed with the support of the watershed algorithm and sobel edge identification in the proposed procedure. By eliminating the characteristics of contour shapes and edges, supports to confine the Optic cup and optic disc. Then the placed area will be cropped and provided an input to the examined design to divide the OC and OD regions.

3.2.1. Sobel edge detection
Edge identification was the important technique in picture processing to identify the borders of the provided input image. This method was applied for the removal of information and the division of the needed area. The correct localization of optic cup and optic disc borders will be identified in the diagnosis of glaucoma. The sides data will be removed by applying the procedure of sobel edge identification. There are some edge identification methods such as logic, prewitt, Roberts, canny and so on, but the side data was extracted mainly by the technique of sobel edge detection. It reveals how the pixel on the picture denote on the sides. The pixels on the sides from light to bright along with the vector values are applied.

3.2.2. Watershed algorithm
An algorithm of watershed was applicable mainly for image division and also for the extraction of feature. This algorithm was used for the extraction of contour shape in this paper. The optic cup and optic disc object lines and boundaries are extracted easily depend on this output. At first, in this division technique, the whole picture was divided into a various set of areas with the help of the contour shapes. Then each pixel region clustered are known as super pixels. The entire picture was analysed as a surface and it identifies th catchmet basins and water shed lines on the picture. It develops the regions by determining lights high and dark as low. This technique workd mainly under 3 various algorithms. They ar marker controlled approach, gradient method and distance transform approach. Here the cropped picture was provided as an input to appear the log for the border removal of the OC and OD.
3.3. Cropping
The remaining part of the picture will be cropped into the needed size after placing the disc on the picture. The size of input picture was 2788x1978 pixel will be cropped to 513x513 dimension. Only cropped pictures will be provided as an input picture for further process. This leads to data loss with the extract of region which was not needed for the diagnosis of glaucoma that will guide to decrease computation time.

3.4. Proposed segmentation methodology using modified CNN
The changed version of CNN was used to divide the optic cup and optic disc for detecting glaucoma in the examined procedure. The 2 separate convolutional neural network design was used to improve the perfection of the division process. An identical layers applied for optic cup and optic disc in the division process. The size of the whole fundus picture 2100x1400 was not provided as an input for the model of convolutional neural network for image training. The cropped picuter size 130x130 pixel in the nerve region was provided as an input for the model of convolutional neural network to decrease the implementation time. The layers in the model of convolutional neural network increased to 40 layers contains merge layer, upsampling, convolutional, drop out and max pooling. The channel was not isolated into blue, red and green channels; the whole RGB pictures was determined for the division process. The layer of convolution was used to join the 2 sets of information and to give a map by analysing various filters. The image size may be decreased by choosing the high values from the groups in the layer of max-pooling. Down sampling in convolutional neural network analyses the network to highlight on the some activation marks, that are efficient to decrease the dismissal in the map. Up sampling supports to give the information which was lost.

The layer of dropout was applied after each layer of convolution to fall out the chosen information to eliminate the over fitting in CNN. The function of ReLu activation was used in each layer and it supports to train the desing and provides best process correleated to the other process. A result was the binary mask of the optic disc by showing the values of pixel in the shape of 0 and 1. When the given value of pixel was similar as the original picture, it shows in the form of black pixel and white pixel. The judged mask of the optic disc was provided to other design to analyze the mask of optic cup.

The border of optic cup will not be judged perfectly in the obtained technique for this reason. The issue will be analyzed by having perfect output in the analysis of thee optic disc mask. The size of picture used to judge the optic cup which based upon the size of the image for the optic disc in the 1st design. The OC was the result from the 2nd design which was saved. The cup to disc raio was measured to analysis whether is is glaucoma or not. The whole architecture of the given process was shown in the figure 3.

![Fig. 3. Architecture used to identify CDR](image)

3.4.1. Training and Modelling
The 2 different modified layer of convolutional neural network design was used in the division process. This supports in improving the perfection in the layer. Th eTensor Flow nad kEra are used in the growth of the convolutional neural network model. The 40 layers contains of dropout, convolutional, merge layer, down and up sampling are used in the 1st model to divide OD. The size of cropping image 130x130 was provided as an input for the 1st design. The size of same layer 513x513 provided as input to the 2nd convolutional neural network model for the OC prediction. The whole parameters are 650,238, parameters for training aree 650,238 and not trainable are zero.
3.4.2. Prediction

An important aim of this paper was to identify the value of cup to disc ratio to judge the glaucoma progression. The value of cup to disc ratio was measured by taking the result from these designs. The proportion of the disc regions square root was calculated to measure the value of CDR. The white pixels provides OC and OD fields.

3. Results and discussion

The structure with NVIDIA Ge force was used to train the design. Many metrics are proposed to analyze the outputs and the outputs are correlated with the obtained system. The output existed after the stage of pre-processing that was shown in the figure 4 to 7. It shows the outputs of optic cup division, optic disc division, preprocessing and feature extraction.

4.1. Dice similarity coefficient

The dice metric for set A and B will be measured as

\[ DSC = \frac{2|A \cap B|}{|A| + |B|} \]  

The set A and B are shown as |A| and |B|, the equation one and two provides the equation for dice metric. It can be shown in terms of TN, FN, TP and FP.

\[ DSC = \frac{2TP}{2TP + FP + FN} \]  

4.2. Intersection over union (IOU)

It is used commonly metric in the division process. It was the proportion area through the union of area and also it was shown in the shape of sets to calculate the variation between these sets. It was known as Jaccard Index. It was measured as

\[ IOU(A, B) = \frac{|A \cap B|}{|A| + |B| - |A \cap B|} \]  

4.3. F1 score

To calculate the output accuracy, the score of F1 was used. It will also verified the classification of binary value. it was in the form of recall and precision. It was measured by equation 4

\[ F1 = \frac{2 \cdot P \cdot R}{P + R} \]  

\[ \text{Fig. 4. The result screen of Pre-processing level} \]

\[ \text{Fig. 5. Output of feature Extraction Process.} \]

\[ \text{Fig. 6. Output existed after OD division} \]
Here p was the output of TP from the classifier and R was the count of TP outputs by the count of all samples. Here the recall was known as sensitivity.

4.4. Structural similarity Index (SSIM)
Structural Similarity Index was used to judge the image quality and also for videos. The equation was shown below

$$SSIM(x, y) = \frac{(2\mu_x\mu_y + c_1)(\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)}$$

where, $\mu_x$ was the average value of $x$, $\mu_y$ was an average value of y, $\sigma_x$ was the variance of $x$, $\sigma_y$ was the variance of y, $\sigma_{xy}$ was the covariance of $x$ and y, $c_1$ and $c_2$ are the variables.

4.5. Accuracy
The % of pixels in the picture are classified correctly that was measured by pixel value through equation 6.

$$Accuracy = \frac{TP}{TP+TN+FP+FN}$$

4.6. Mathews correlation coefficient (MCC)
The Mathews correlation coefficient was used to calculate the quality of binary division.

$$MCC = \frac{TP\times TP - FP \times FN}{\sqrt{(TP+FP)(TP+FN)(TN+FP)(TN+FN)}}$$

The entire metrics are measured for optic cup and optic disc measurement. The parameters are measured to value the performance of the design when the examined design was tested and trained for many times. Table 1 reveals the accuracy with various metrics for OC and OD in the Red Green Blue image

The examined procedure tested and trained for five hundred epochs with the metrics performance. But the metric dice was the basic metric that was used to correlate with the obtained techniques. This was shown in the tab.2. The layers in the design are improved still the mistake got decreased. Figure 8 and 9 reveals the graph of training information existed for 500 repetitions for dice metric versus loss in OD division. Figure 10 and 11 reveals the graph existed for 500 repetitions for dice metric Versus loss in OC division and dicee metric. And at last the existed result of 97.9% and 97.6% for OC and OD division for trained information. Figure 12 and 13 reveals the graph of test information existed for 500 repetitions for Dice metric Versus OD division and Dice metric Versus OC division. Figure 14 explains about the given methodology provided the perfect output while comparing to other obtained techniques. The design was evaluated with a different rate of learning like 0.01, 0.001, 0.0001, 0.00001. The design takes much time to test and train the design, when the rate of learning was slow. Table 3 shows the evaluation of the design with different rate of learning.

<table>
<thead>
<tr>
<th>Table 1 Performance metrics measurement for disc and cup segmentation</th>
</tr>
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<tbody>
<tr>
<td>Accuracy Metrics</td>
</tr>
<tr>
<td>Dice Metric</td>
</tr>
<tr>
<td>IOU</td>
</tr>
<tr>
<td>F1 Score</td>
</tr>
<tr>
<td>SSIM</td>
</tr>
<tr>
<td>Accuracy</td>
</tr>
<tr>
<td>MCC</td>
</tr>
</tbody>
</table>
Table 2 Comparison of dice metrics obtained in the proposed method with existing approaches

<table>
<thead>
<tr>
<th>Learning rate</th>
<th>OD accuracy</th>
<th>OC accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>0.9611</td>
<td>0.9578</td>
</tr>
<tr>
<td>0.01</td>
<td>0.9668</td>
<td>0.9599</td>
</tr>
<tr>
<td>0.001</td>
<td>0.9839</td>
<td>0.9722</td>
</tr>
<tr>
<td>0.0001</td>
<td>0.9451</td>
<td>0.9320</td>
</tr>
</tbody>
</table>

Figure 8 and 9. The scatter plot between dice metric of OD and the 500 epochs for trained data

Figure 10 and 11. The comparison graph for optic disc of dice metric versus loss obtained from trained data

The rate of learning at 0.001 gains more perfection for both OC and OD division. The two convolutational neural network designs for glaucoma detection with down and up sampling layer gained a perfect accuracy in the proposed method. The U-net design with normal design needs ten hours to train the design by NVIDIA in the obtained model. Sevastopolosky (Sevastopolsky, 2017) examined a glaucoma design with 453 epochs by u neet design and it needs around 2.34 hours to test and train the design. Shuang (Yu et al., 2019) examined a RESNET design for detecting the glaucoma. The method utilizes pre-trained of picutree and uses two hours to train the design. Therefore the design was compared better to all obtained designs for the glaucoma detection.
Fig. 14. Comparison of dice metrics obtained in the proposed method with existing approaches.

Table 3 The result of the proposed model with various learning rate.

<table>
<thead>
<tr>
<th>Approach</th>
<th>Epoch</th>
<th>Dice Metric</th>
<th>Dice Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zilly et al(b) (Zilly et al, 2018)</td>
<td>1000</td>
<td>0.85</td>
<td>0.83</td>
</tr>
<tr>
<td>Zilly et al(a) (Zilly et al, 2015)</td>
<td>1000</td>
<td>0.90</td>
<td>0.87</td>
</tr>
<tr>
<td>U Raghavendra (Raghavendra et al., 2018)</td>
<td>500</td>
<td>0.96</td>
<td>0.95</td>
</tr>
<tr>
<td>Juneja et al. (Juneja et al., 2019)</td>
<td>500</td>
<td>0.93</td>
<td>0.92</td>
</tr>
<tr>
<td>Jiang et al. (Jiang, 2019)</td>
<td>500</td>
<td>0.97</td>
<td>0.95</td>
</tr>
<tr>
<td>Proposed approach</td>
<td>500</td>
<td>0.9875</td>
<td>0.9711</td>
</tr>
</tbody>
</table>

5. Conclusion

A leading retinal disease was Glaucoma. It damages the eye due to the intraocular pressure on the eye. When glaucoma was untreated left, it would lead to the loss of vision by affecting the ONH. (optic nerve head) The glaucoma progression was investigated on the retina of eye through ophthalmologist. This method was very boring and it enhance more time to do by human beings. Therefore, this tiuuse was the right problem which may be solved by diagnosing automatically with the support of the approach of deep learning process. CNNs are suitable to identify the solution for this problem. It may extract different stages of information from the input picture and motivates to variate among glaucomica and non-glaucomic pictures. A method of traditional division was depend upon the super pixels, shape, graph cut models trust on hand crafted characteristics and an exact knowledge of the customer who purifies the division. These approaches usually based on the low level characteristics like local quality which do not seize the variations in the picture. Likewise, the process of methods trusts on correctly converting a more parameters which block broad applications. This examined paper presents an effective glaucoma structure to fragment the optic disc and cup to identify the CDR value. The glaucoma was achieved by deep learning process along with the novel Convolutional Neural Network.

Reference


N. Gillies, R.J., Kinahan, P.E., Hricak, H., 2016. Radiomics: images are more than pictures. They Are Data 25, 563–577.


