Glaucoma detection and its classification using image processing and fuzzy classification

GOLI HAVEESH¹, GOVARDHAN HEGDE K², BHARGAV J BHATKALKAR², SRIKANTH PRABHU², SULATHA BHANDARY³

¹Department of Computer Science, Mahindra École Centrale College of Engineering, Hyderabad, India
²Department of Computer Science, Manipal Institute of Technology, Manipal University, Manipal India
³Department of Ophthalmology, K.M.C, Manipal University, Manipal

Email: govardhanhegde@gmail.com, haveeshgoli4@gmail.com

Abstract: Manual diagnosis needs a great deal of time for ophthalmologists to analyse and review retinal images of the eye obtained by fundus camera. Digital image processing techniques enable ophthalmologists to detect and treat several eye diseases like diabetic retinopathy and glaucoma. Glaucoma, the most common cause of blindness is the disease of the optic nerve of the eye and can lead to ultimate blindness if not treated at an early stage. Raised intraocular pressure, increase in cup to disk ratio and visual field test are some of the measures for such a disease. The main objective of this paper is to find an automated tool to detect glaucoma at an early stage and to classify this disease based on its severity and damage of the optic fibre. The objective of this study is pre-processing of retinal fundus image for enhancing the quality which is required for further processing and to design a novel algorithm to measure the cup to disc ratio of retinal fundus image from the online database and classify the disease according to its severity using fuzzy classification toolbox in MATLAB. We use the method of principle component analysis wherein we extract the dominant Eigen values and Eigen vectors to classify the images into various stages of glaucoma with high accuracy.

Keywords: Glaucoma, Cup-Disc Ratio , Image Processing, Glaucoma Stages

Introduction:
Diabetic Retinopathy (DR) and Glaucoma are the two major causes for retinal disorder which leads to vision loss if not treated at an early stage. Early screening is very essential so that the patient is out of danger. The ophthalmologists are going to either take fundus images or OCT images for detection and diagnosis of the disease. The detection of glaucoma from a fundus photograph is much easier than that from an OCT image. In our paper we have concentrated mainly on fundus image of the retina. We have detected the cup-to-disc ratio (CDR) to identify the disease at the early stage and used fuzzy classification to classify the severity of the disease. The measure of Intra ocular pressure is also equally important in detecting glaucoma at an early stage. Other methods to detect glaucoma are finding the ratio of the distance between optic disc centre and optic nerve head to optic disc diameter [1]. Typical fundus photo of given retina looks as shown in Fig.1

Figure 1 Normal Fundus Image

Histogram Equalization:
There is a need to enhance the image for getting a better quality of the image. There are many enhancement schemes used for image enhancement which basically include gray scale handling, image filtering and image histogram equalization. Histogram equalization is very commonly used image enhancement technique and is easy to apply. It also helps in retaining the input brightness and generating a quality output image.[2]. The main reason behind using this technique is to enhance the contrast by re-mapping the grey levels in the input image. We use this technique on the retinal fundus image captured by ophthalmologist. In order to enhance the fundus image captured by ophthalmologist, we must first extract the green channel of the fundus image. In the second step, we are interested in its histogram equalization. [3] shown in fig.2
The formula that we are applying is

\[ h(v) = \text{round} \left( \frac{\text{cdf}(v) - \text{cdf}_{\text{min}}}{(M \times N) - \text{cdf}_{\text{min}}} \times (L - 1) \right) \]

Where, \( \text{cdf}_{\text{min}} \) calculates the minimum value of the cumulative distribution function, \( M \times N \) gives the number of pixels in the image, \( L \) is the count of grey levels. After the histogram equalization, we can enhance the fundus image and extract the optic disc, optic cup and calculate the CDR ratio.

**Optic Disc and Optic Cup Extraction:**
In order to calculate Cup-Disc Ratio (CDR), we first need to extract the optic disc and optic cup. Typical steps involved in finding CDR is shown in Fig 4.

**Figure 2** Fundus image and its Histogram equalization

**Figure 3** Green channel fundus image and its Histogram equalization

**Figure 4** Typical steps involved in Glaucoma

**Figure 5** CDR calculation after Optic Disc Extraction

**Figure 6** Optic cup and disk boundary

Ophthalmologist can manually detect optic disc boundary and optic cup boundary. Typical disk boundary is shown above. But it becomes cumbersome if there are thousands of images. The boundary selection implementation results as shown below in Fig 7.
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**Cup Disc Ratio:**
Then optic cup and disk are extracted as shown in figure 8. Once the optic cup and optic disc are extracted, then comes the measurements of the Cup Disc ratio (CDR). It is calculated as shown in Fig 8

$$\text{CDR} = \frac{\text{Area of the Cup}}{\text{Area of the Disc}}$$

Typical optical cup region and optical disk region is shown in Fig 9. Once the cup and disc boundaries are obtained, we will follow clinical method of detecting Cup-Disc Ratio which is an indicator for the detection of the presence of glaucoma disease in the patient.

When the cup-disc ratio increases over a threshold value, we consider that the patient is suffering from glaucoma or we can say that the patient is glaucomatous.

A tool used for screen automates measuring cup-to-disc ratios to provide earlier intervention and treatment.

**Classification of Glaucoma:**
It is very important to know whether the input image is glaucomatous or not. Once we identify that the fundus image is glaucomatous based on the CDR, we further classify for its severity like mild, moderate and severe.

Glaucoma can be classified as either Open Angle Glaucoma or Closed Angle Closure.

- **Primary Open Angle Glaucoma**
  Primary open angle glaucoma is affected mainly due to clogging of eye’s drainage canals [5] where the inner IOP raises, as proper amount of fluid inside the eye cannot drain. It is very important to diagnose such patients at an early stage as it can affect the vision of patient.

- **Closed angle Glaucoma**
  This type of glaucoma is also called as acute glaucoma or narrow angle glaucoma. It happens due to continual production of fluid within the eye and drains out of, the normal eye. This causes blockage of the drainage angle of the eye. The major difference in primary glaucoma and secondary glaucoma is shown in fig.11. (a) and (b).

Typical classification of glaucoma disease in any patient can be broadly classified as shown in Fig.10.
Fuzzy Classification:
Grouping elements into a set which are operated by a function or a set of functions defined is called ‘classification’ and if the elements are grouped into a fuzzy set with the membership function defined by the truth value of a fuzzy propositional function , the process is called as ‘fuzzy classification’.

The goal is to classify the image using fuzzy logic and hence the input data must be same. Fuzzy logic is the superset of the standard Boolean logic. In other sense, in fuzzy logic if the fuzzy values take 1 and 0 for completely true and completely false respectively, the logic converges to Boolean logic. That is for example X AND Y operator in Boolean logic is replaced with min (X, Y) operator; X OR Y with max (X, Y) and NOT X with 1 - X.

Matlab’s Fuzzy Logic Toolbox:
Matlab’s Fuzzy Logic Toolbox is a good alternative to solve the problem. It allows using logic if-then rules to describe the system’s behavior. This Toolbox is a compilation of functions built on the MATLAB numeric computing environment and provides tools for creating and editing fuzzy inference systems within the framework of MATLAB. Three categories of tools are provided by this toolbox.
• command line functions,
• graphical interactive tools and
• Simulink blocks and examples.

This Toolbox provides a number of interactive tools that allows access to many functions through a graphical user interface (GUI)

Conclusion:
Glaucoma, being the second major cause of blindness can be effectively predicted using the basic fundus photographs which are used for prediction of symptoms of glaucoma at an early stage for the better good of the patient.

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[10] Caesar Iyakaremye, Lappeenranta University of Technology , Faculty of Technology , Dept. of Mathematics and physics , Lappeenranta, Finland ,cesar.Iyakaremye@lut.fi
