

# Automatic Detection of Optic Disc from Fundus Images of ROP Infant Using 2D Circular Hough Transform

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## Abstract

*In this paper, a method of automatic detection of an Optic Disc (OD) in low-contrast infant's digital fundus images based on circular Hough transform is proposed. Number of dimensions of normal circular Hough Transforms histogram is reduced from 3 to 2 dimensions based on an approximation of OD radius. First few circles are approximated by using maximum points from Hough space. A circle with the best fit to OD edge image is chosen. The results are validated with ophthalmologists' hand-drawn ground truth. This algorithm produces 81.7% accuracy with simpler computational complexity.*

## 1. Introduction

An optic disc (OD) or optic nerve head is the point in the eye where the optic nerve enters the retina. It is not sensitive to light and is formed by the meeting of all the retinal ganglion cell axons as they enter the optic nerve. Precise localization of optic disc boundary is an important sub problem of higher level problems in ophthalmic image processing. Specifically this will be very useful in Retinopathy of Prematurity (ROP), a common retinal vascular disorder of premature infants, or a diabetic retinopathy proliferate where fragile vessels develop in the retina, largely in the OD region, in response to circulation problems created during earlier stages of the disease.

If the optic disc is identified, the position of areas of clinical importance such as the fovea may be determined. Moreover, OD detection is fundamental for establishing a frame of reference within the retinal image and is, thus, important for any image analysis application.

Many techniques have been purposed including detection of the OD regions by clustering the brightest pixels in retinal image and locating potential OD area [1], [2]. Other techniques have been recently proposed, based on a model of vascular structure by M. Foracchia

et al. [3]. They use a geometrical parametric model locating at the center point of OD. Akita et al. [4], trace the parent-child relationship between blood vessels segments, tracking back to the center of the optic disc. This also proposed robust detection of the blood vessels, which is difficult in images of diseased retina where even quite sophisticated algorithms detect false positives along the edges of white lesions and along the optic disc. Lalonde [5] used pyramidal decomposition and Hausdorff-based template matching that is guided by scale tracking of large objects using multi-resolution image decomposition. This method is effective, but rather complex. In three dimensional reconstructions of conventional stereo optic disc image procedures [6], the resulting 3 dimensional contour images show optic disc structure clearly and intuitively, helping physicians in understanding the stereo disc photograph. Cox and Wood [7] presented a semi-automated method to indicate external points on the boundary which were automatically connected by tracing along the boundary. Morris and Cox [8] initially presented a completely automatic method which traced between points on the boundary identified automatically by their grey level gradient properties. Sinthanayothin [9] used the rapid intensity variation between the dark vessels and the bright nerve fibers to locate the optic disc. However, we found that this algorithm often failed for fundus images with a large number of white lesions. Lee [10] also applied an active contour model to high resolution images centered on the optic nerve head and his problem caused by the boundary of the pallor and by very faint or missing edges. Most of techniques reviewed in this section were used to identify adult's well-form optic disc. Only a few papers described techniques used to detect OD in usually low-contrast infant images. We have tried a few techniques but it did not effectively detect the OD from fundus image of an infant with ROP where the vessel and OD are not very well developed.

## 2. Overview of the Hough Transform

The Hough transform is a technique to identify the locations and orientations of certain types of features in a digital image. The transform consists of parameterized description of a feature at any given location in the original image space. A multi-dimensional array in the space defined by these parameters is then generated. At each point, a value is accumulated; indicating probability of an object generated by the parameters defined at that point fits the given image. Any points in the array that have relatively higher values are used to describe features that may be projected back onto the image. The higher to value, the bigger possibility that the features actually present in the image.

The Hough transform can be used for representing objects that can be parameterized mathematically. For example, in our case, a circle, can be parameterized by an equation (1),

$$(x - a)^2 + (y - b)^2 = r^2 \quad \dots\dots\dots (1)$$

Where  $(a,b)$  is the coordinate of the center of the circle that passes through  $(x,y)$  and  $r$  is its radius. From this equation, it can be seen that three parameters are used to formalize a circle which means that Hough space will be a three-dimensional space for this case.

## 3. Methodology

### 3.1 Edge detection

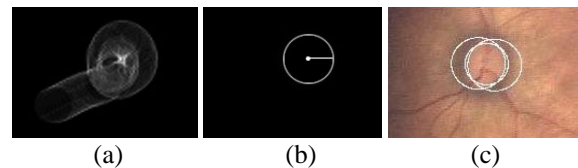
Some specific properties of the infant's fundus images are that they are low contrast and very noisy. However, only the edge of the OD's circular shape is needed to calculate the Hough Transform. In order to get rid of noisy and unwanted information, Canny Edge operator was experimentally chosen and applied to the image as the first step in this process. This technique removes most of the noise due to the fine texture leaving only the required edges of the OD. Experimentally, we found that the Canny Operator with the following parameters gives the best result:  $\sigma = 1$  and the window size is  $5 \times 5$ .

### 3.2 First approximation of Optic Disc

Normal circular Hough transform requires very high computational power because it is needed to form a 3D histogram. We tried to reduce dimensions of the histogram to two dimensions, based on an

approximation of the first known OD radius. From our test set of images, statistically, we found that size of most of the OD radii are between 20 pixels and 25 pixels. This prior information can be used to reduce dimensionality of the Circular Hough histogram from 3D to 2D for better accuracy and faster calculation. During the calculation process, the accumulator parameter array are filled according to each of the above radii, where each array composed of cells for the  $(x,y)$  coordinates of the center of the potential circle. The edge image is scanned and all the points in this space are mapped to Hough space using an equation (1). A value in particular point in Hough space is accumulated if there is a corresponding point in the image space. The process is repeated until all the points in the image space are processed. The resulting Hough transform image was scaled so all the values lie between 0 and 1. Then it was threshold to leave only those points with high probability of being the centers. The resulting point-sets are then labeled with different numbers. Then the different regions were matched by different circles. The output image is computed by drawing circle with these points and adding this to the input image as shown in Figure 1.

In order to reduce the chance that there is more than one threshold points staying closed together. The resulting 2D histogram will be sent to dilation and erosion functions, so these points will be combined as one final point.



**Figure 1.** (a) A part of an resulting image after applying 2D circular Hough transform (b) Result of matching the circle to the high probability point with 20-pixel radius (c) First few approximation of circle.

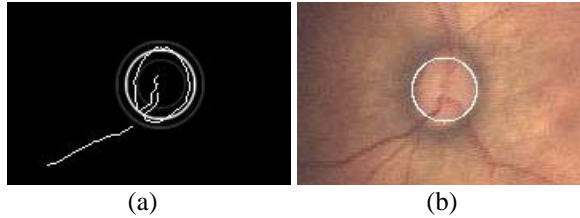
### 3.3 Finding Best Circle

A set of approximated circles from the previous step will be compared in this step. The best circles of this set would be the circle that fits most of the OD edges. In this step we counted the number of pixel which is in the vicinity of the detected circle's edge. A mask in a shape of a donut is put on the binary edge image on the same location of each of the detected circle. From the statistical experiment, the best width of the donut ring is 5 pixels.

Number of edge pixels under this mask will be counted and compared for all the detected circles.

The pixel counting is normalized by this formula,  $X = \text{detected pixels} / 2\pi r$ , a number of detected pixels divided by the total curriculum of a approximated circle as shown in Figure 2.

The value shows the percentage of edge pixel being detected. The highest percentage means that the circle is best to use to locate the optic disc.



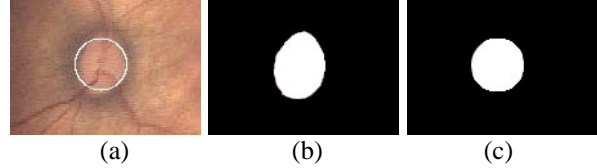
**Figure 2.** (a) Using a mask shape of donut (b) The best detected circle

#### 4. Verification

The results were clinically validated in this step. All images in our test set are sent to ophthalmologist to identify the OD manually. All the OD's which are automatically detected by our system are then compared with clinician's hand-drawn ground truth. Figure 3 shows an example of both ground truth image and our detection result. The hand-drawn and detected optic disc images are represented in white. Number of pixels of the detected image that intersected with pixels of the hand-drawn image will be summed and compared with the number of pixels on the hand-drawn ground truth as demonstrated in table 1.

**Table 1.** Some examples of comparison result of intersected pixels on some selected images.

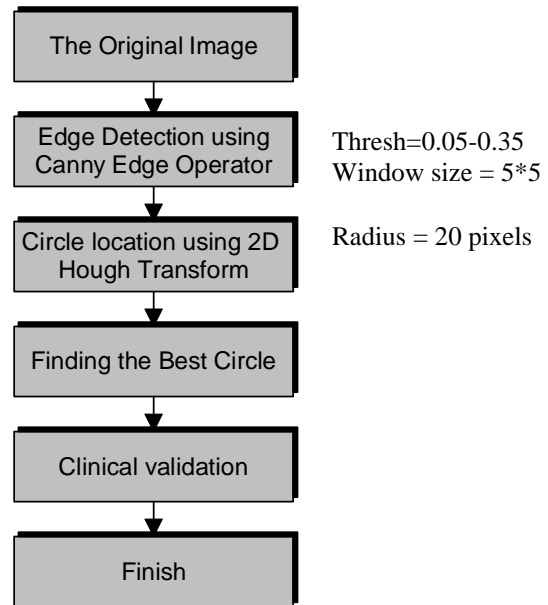
Image ID	Image Name	Detected pixels	Ground truth pixels	Accuracy (%)
1	A1	1152	1175	98.5
2	A2	1215	1332	95.1
3	A3	1047	1177	89.0
4	A5	1325	1530	86.6
5	A7	1291	1470	87.8
6	A8	1248	1538	81.1
7	A11	1236	1312	94.2
8	A12	1295	1401	92.4
9	A13	1261	1416	89.1
10	A14	1125	1470	76.5



**Figure 3.** (a) OD automatically detected by our system (b) Clinician's hand-drawn ground truth (c) Detected pixels.

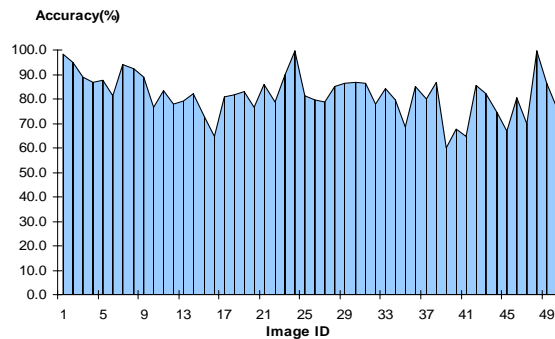
All of the processes are concluded with a flow chart in a Diagram 1.

**Diagram 1.** Showing a flowchart of our process



#### 5. Results

The method is tested using a randomly selected set of 50 images. The accuracy result is demonstrated by a graph in Figure 4. The chart represents the OD performance evaluation for each image. We found that the average of the accuracy by this method is 81.7 %.



**Figure 4.** Showing the accuracy result.

## 6. Conclusion

This method is based on Canny edge detection and circular Hough transform technique. A prototype has been implemented in MATLAB on a 3.00 GHz PC under Windows XP. It was tested using a data set of 50 infant fundus images. The OD position was considered correctly detected if the pixels in the detected image present in the clinician's hand-drawn ground truth. This method was able to locate the position of OD with a high 81.7% accuracy. This technique works pretty well even though the input image is in a low-contrast condition.

## 7. References

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