**Progress Towards Automated Detection and Characterisation of the Optic Disk in Glaucoma and Diabetic Retinopathy**

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## Abstract

The shape and appearance of the optic nerve head is sensitive to changes associated with glaucoma and diabetes that may or may not be asymptomatic. The changes can be diagnostic of the diseases and tracking of the changes in sequential images can be used to assess treatment or the progress of the illness. We are concerned with developing automated techniques of generating quantitative descriptions of the nerve head that might be used in diagnosis and assessment using images that have been collected and stored remotely.

Normal and abnormal images were collected from a range of sources, to simulate the mass screening process. They were processed using methods described in this paper. Using a chi-squared test, the separation of normal and abnormal images using this test was found to be highly significant ($p < 0.05$, $n = 60$).

## Introduction

The optic nerve head is that area of the retina where nerve fibres and blood vessels pass through the sclera. It is sensitive to changes in intraocular pressure associated with glaucoma that may occur asymptomatically, which can be diagnostic and must be tracked to monitor the progress of treatment. Likewise, there are changes in the appearance of the retinal surface that are associated with diabetic retinopathy that are also diagnostic and should also be tracked to allow the progress of the disease and treatment to be assessed. Currently, a clinician, or clinicians, performs the diagnosis and uniform standards of assessment cannot be guaranteed. Likewise, a clinician or clinicians perform the tracking at repeat examinations and the repeatability of the assessments cannot be guaranteed. We are seeking methods of quantifying the optic disk objectively: firstly to identify groups of patients who have abnormal ocular appearances and should be further investigated; and secondly to track changes in the appearance of the retina. In this paper we report on an investigation into methods of solving the former problem. We shall provide a brief overview of previous attempts at quantifying the optic nerve head, we shall describe the data capture process that simulates a mass

screening process, we shall describe the algorithms used to analyse the images and present sample results.

**Review**

One of the symptoms of glaucoma is an increase in pressure within the eye as a result of blockage of the flow of aqueous humour, a watery fluid produced by the ciliary body. The increase in pressure damages the optic nerve that carries information from the retina to the brain. In most cases the damage occurs asymptomatically, i.e. before the patient notices any changes to his or her vision. The damage is irreversible; treatment can only reduce or prevent further damage. Visually, the damage is observed as a change in the relative areas of the optic disk and the cup within the disk, figure 1.

Diabetes mellitus is a disorder of carbohydrate metabolism characterised by dysfunctional production of insulin, and thereby elevated blood sugar levels. This leads to problems with different organs such as the eyes, kidneys, heart and cardiovascular system and nerves. Diabetes mellitus has two side effects on the blood vessels: leaking and clogging that can lead to degradation of the retina (retinopathy). This is observed as the proliferation of new vasculature and clotting, figure 2. Retinopathy is one of the main causes of blindness in the working age population [1].

To characterise the optic disk (and retina) the optic disk and retinal vasculature must be identified. The disk has previously been identified using the maximum variance as an indication for the location of the disk [2]; template matching followed by principal component analysis (PCA) [3]; by measuring the strength of vessels and the attributes of the bright areas of the image [4] or by identifying the origin of the vessel tree [5]. Colour morphology and dynamic contours (snake) in different colour spaces [6, 7] and wavelet segmentation [8] have been used. Edge detection followed by curve fitting has also been used [9, 10, 10].

Manual screening is reported to detect diabetic retinopathy and glaucoma with sensitivities and specificities of 76% and 95% [11] and 71% and 94% [12].

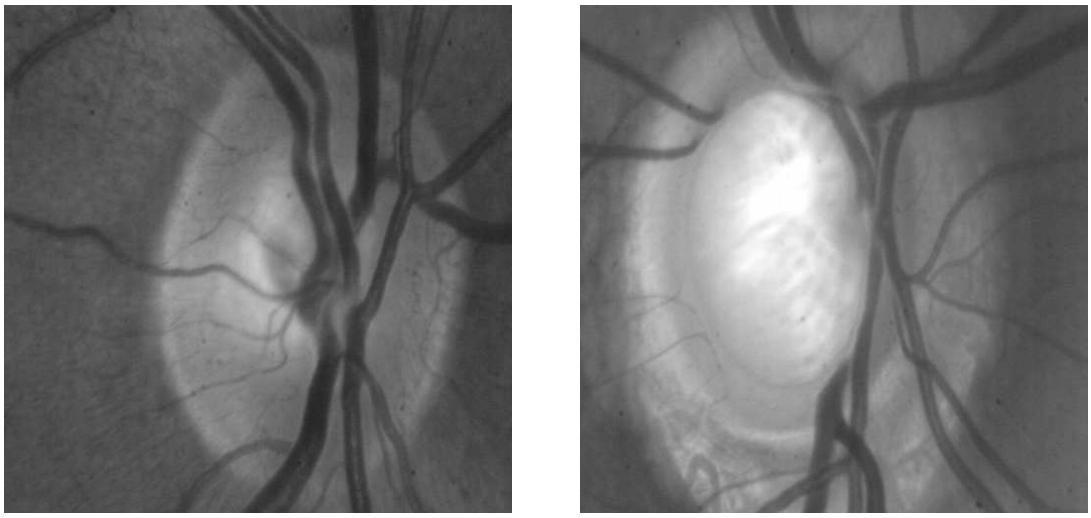


**Figure 1.** Normal and glaucomatous optic disks.

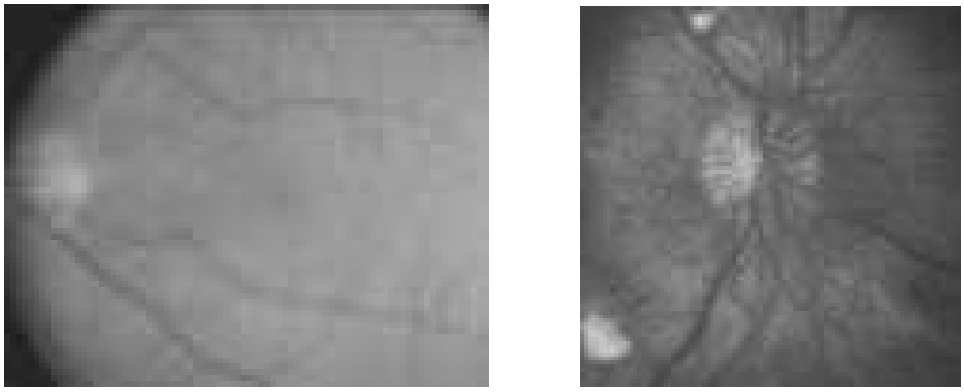


**Figure 2.** Retina in diabetes mellitus.

## Materials

The tools to be developed will be used in multiple clinics that are unlikely to have the same image capture devices. To simulate this, our data was gathered from a range of sources. Diabetic

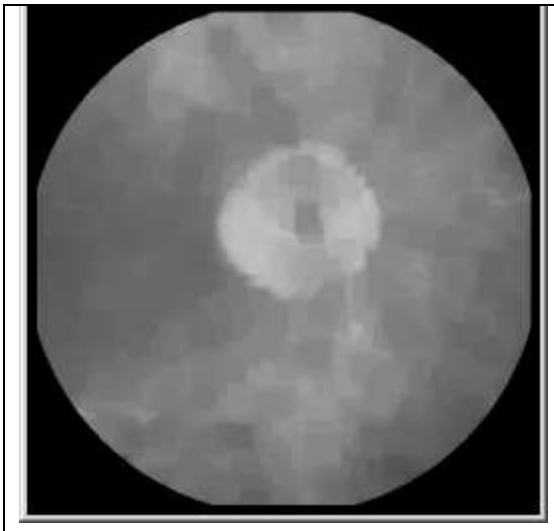
retinopathy images were obtained at the Department of Optometry at UMIST, using a Topcon NW6S Non-Mydriatic Retinal Camera. These images were saved as 24-bit true colour JPEG files. Images were taken with a field view of 45 degrees. Glaucoma images were collected from Manchester Royal Eye Hospital; these images were also in the JPEG format. Normal images and a second set of diabetic retinopathy images were downloaded from the STARE (STructured Analysis of the Retina) website [13].

All images were converted to a similar size, as close as possible to 512 by 512 pixels: given the constraints of scaling by an integral factor and retaining the images' aspect ratios. Pixels were represented as 24 bit values. The scaled images were stored in the JPEG format using the best quality settings i.e. near lossless.

Although approximately 90 images were gathered, 16 normal, 31 glaucoma and 13 diabetic retinopathy images were suitable for processing. Of the other 30, some were blurred and others did not contain the whole optic disk. Although full colour images were captured, only the green channel was processed as it was found to have the greatest contrast for these studies.

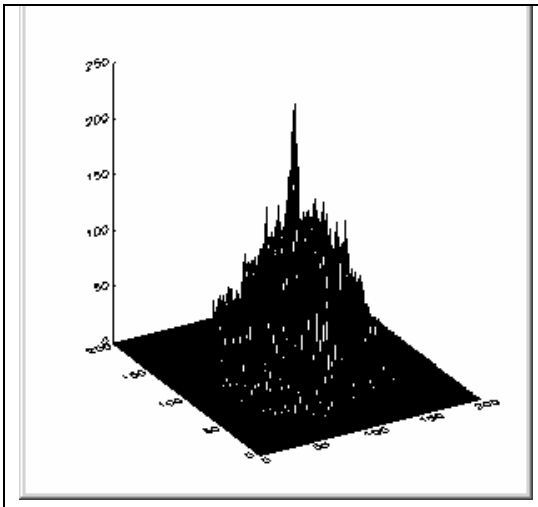
**Methods**

The green band of the images was processed as it was found that these images had the greatest contrast between the optic disk and the retinal tissue. Firstly, the blood vessels in the image were suppressed by morphological methods (closing). We then defined 24 radial vectors using the approximate centre of the optic disk as the origin. The image was resampled along these vectors to form a representation that was subsequently processed.

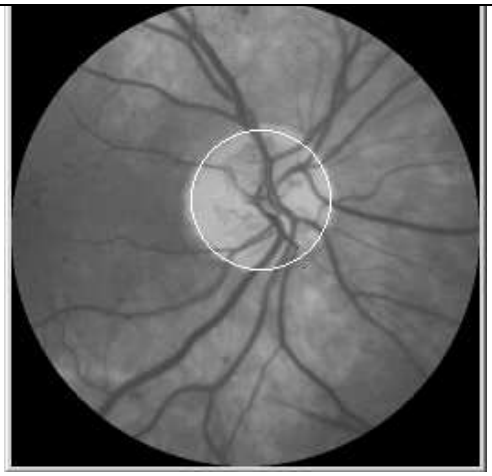


Colour image after deleting vessels

Edge points detected by Sobel filter




Circular Hough Transform space



OD by applying CHT on edge points

**Figure 3.** Location of the optic disk using the Circular Hough Transform.

*Optic disk location and image resampling*

An approximate location of the centre of the optic disk is required. The image was firstly enhanced using the Sobel operator, and then thresholded using the local mean and variance to compute the threshold value. The remaining points were input to a circular Hough Transform, the largest circle was found consistently to correspond to the optic disk, figure 3. The origin of the circle was used for the resampling vectors.

Twenty four uniformly distributed vectors were defined, starting at the optic disk centre. The image was resampled at regular intervals along these using nearest neighbour interpolation.

*Processing resampled images*

The resampled images were processed using the Lee filter [14] which suppresses small scale variations whilst retaining significant features. An 11 by 11 pixel kernel was used.

It was found that in many images of normal retinas (set A), the cup region was transformed into a region of maximum intensity spanning the width of the image, but not extending the image's height. This image was also thresholded, at a value of mean + 0.5*standard deviation. It was found that a set of normal images (set B) also had a region of maximum intensity spanning the width of the image, but not extending the image's height. The union of the two sets includes virtually all of the normal images.

**Results**

Sixty images, including 15 normal and 45 abnormals were processed as described above. If the resultant images were members of set A or set B they were classified as normals. The results are summarised in the contingency table, table 1.

| | | Hypothesis | |
|---|---|---|---|
| | | Normal | Abnormal |
| Result | Positive | 9 | 6 |
| | Negative | 7 | 38 |

**Table 1.** Contingency table.

A chi-squared test gave a significant result ($p < 0.05$), indicating that the test is able to separate normal from abnormal (glaucoma or diabetic retinopathy) images. A success rate of 65% was obtained, with sensitivity and specificity rates of 60% and 84% respectively.

**Conclusions**

In this study we set out to develop methods of separating normal from abnormal images (cases of glaucoma or diabetic retinopathy). These would be used in a screening clinic to identify at-risk patients.

Images were collected from various sources to mimic the data collected at a range of sites. Methods were developed to separate the normal from the abnormal images; this was done with reasonable success. Whilst the modest success could be attributed to the insensitivity of our analysis, it can also be attributed to the nature of the diagnosis: we are labelling images as being abnormal or not, without recognising that there is a spectrum of appearances.

The tests indicate that the optic disc's appearance is more uniform in the normals and becomes progressively less so as the diseases progress.

Future work is directed in two directions: accumulating further data and developing more robust and accurate methods of processing this highly variable data.

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