

Using computers on the Eye to monitor Diabetes

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Abstract

The appearance, shape, and colouration of the retina, and in particular the head of the Optic Nerve are all sensitive to diseases of the eye and will change in line with the type and severity of the disease. But often changes can be noted before any symptoms of the disease become obvious. Changes that take place in the Nerve Head and the Optical Disc can be correlated with changes in the body's physiology, eg Blood Pressure and diseases such as Diabetes. The purpose of this Paper is to describe automated techniques for analysing the image of the optical disc using computer techniques. Studies have been carried out which show that the detection rate for abnormal changes when using these techniques, ie the accuracy, is statistically significant, so much so that the technique is worthy of consideration for introduction into routine use as a screening tool.

Introduction

The optic nerve head is that area of the retina where nerve fibres and blood vessels pass through the Sclera (the 'white of the eye' the surface of the sphere which constitutes the eye-ball). Changes in intra-ocular pressure, such as occur in Glaucoma, will affect the appearance of the Nerve Head. Hence tracking changes in the Nerve Head presents a means of monitoring the progress of the disease, especially in diseases like Hypertension and Diabetes, both of which can be debilitating. Also there are changes in the surface of the retina which are associated with Diabetic Retinopathy which can be used as a diagnostic tool, and then used subsequently to monitor the success or otherwise of the treatment.

Present practice is that the clinicians, or team of clinicians, will achieve the diagnosis by examining the retina, but this can produce a variability, and non-uniformity, in the diagnosis and hence in the treatment. What is sought is an automated system for diagnosis which will thereby produce consistent results. What follows will describe attempts at quantifying changes in the optical

disc, and a data-capture and analysis system using new algorithms to analyse the image. Previous attempts at producing such a system will be mentioned and details of the new proposed system will be described.

Physiology

When Glaucoma occurs there is an increase in pressure within the eyeball as a result of blockages in the flow of aqueous humour, a water-like fluid which is produced by the ciliary body. This increase in pressure damages the optic nerve that carries information to the brain. Generally the damage occurs un-noticed, ie the patient does not notice any change in their vision. Sadly the damage is irreversible: treatment can only prevent further damage. Visually, the damage is observed as a change in the relative areas of the optical disc and of the cup within the disc. Figure 1 shows a normal disc and an abnormal one in which the disc is enlarged and the arteries damaged.

Diabetes Mellitus is a disorder of the body's carbohydrate mechanism whereby the production of insulin is reduced leading to elevated blood-sugar levels. This in turn gives rise to problems in various organs such as the eyes, the kidneys, the heart and cardiovascular system, and the nervous system. Diabetes Mellitus has side effects on the blood vessels, namely a leaking and a clogging that can lead to a degradation of the retina, Retinopathy. Retinopathy is observed as a proliferation of new vasculature and clotting. See Figure 2. Retinopathy is one of the main causes of blindness in the working 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].

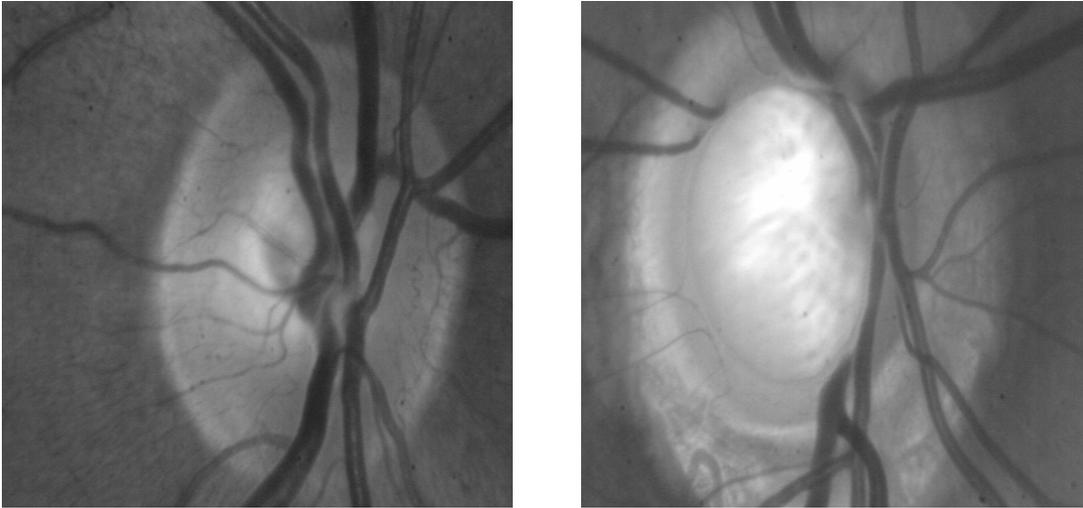


Figure 1. (a) A normal optic discs, (b) the optic disc in a severe case of Glaucoma.

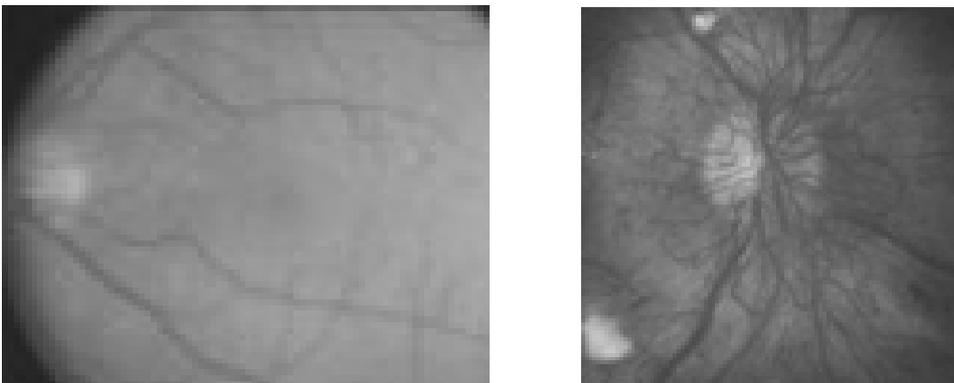


Figure 2 (a) A normal Retina, (b) the Retina in Diabetes Mellitus.

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

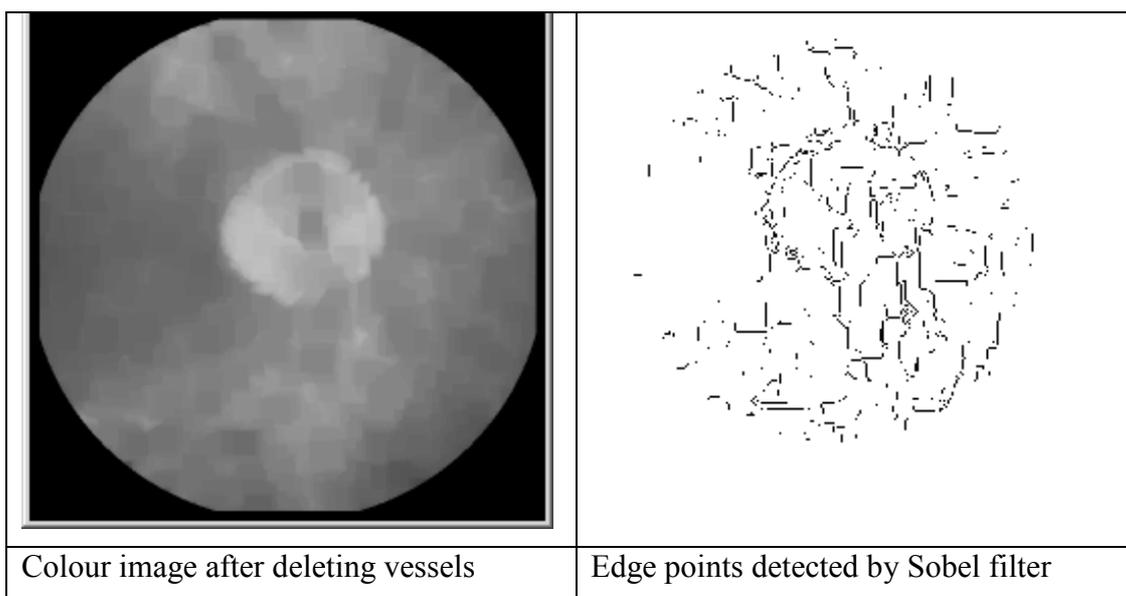
second set of diabetic retinopathy images were downloaded from the STARE (Structured Analysis of the Retina) website [13].

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.



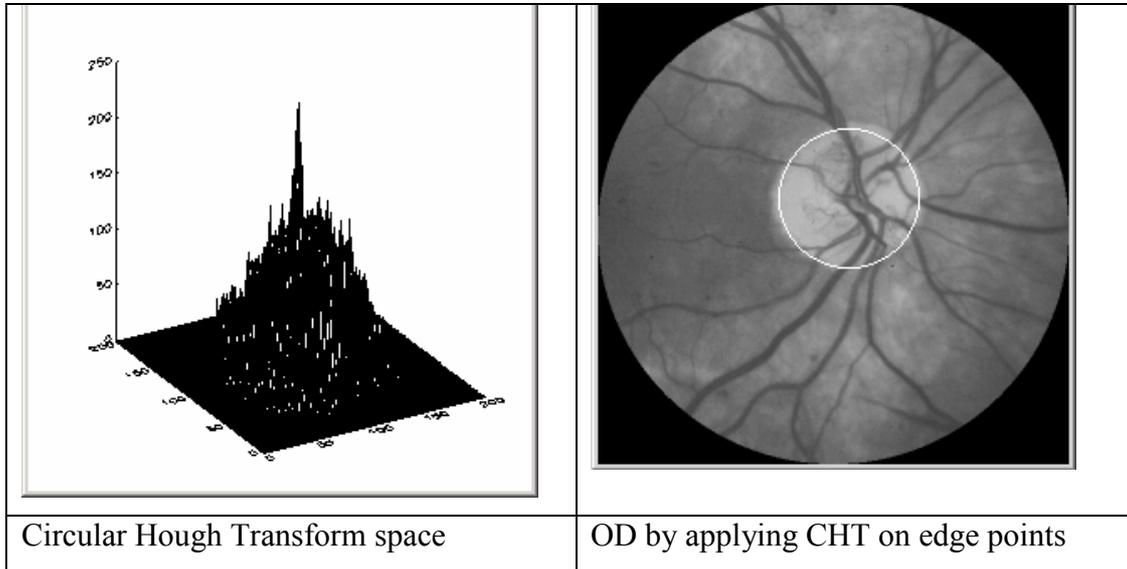


Figure 3. Location of the optic disk using the Circular Hough Transform.

Optic disk location and image re-sampling

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 re-sampling 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 re-sampled 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 x 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 abnormal 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.

		Computer	
		Normal	Abnormal
Truth	Positive	9	6
	Negative	7	38

Table 1. Contingency Table showing what the computer found vis-a-vis the true diagnosis

A chi-squared test, $\chi^2 = 11.36$, gave a significant result ($p < 0.01$), 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.

Finally, it has just been announced in the UK (October 2006) that the new drug "Lucentis" has been shown to halt Age-related Macular Degeneration (AMD), a disease in which the growth of new blood vessels behind the retina causes bleeding and scarring and hence damage to the retina, and in many cases even improves existing AMD. Again, the computer-analysis system described above will be a useful tool in monitoring this condition.

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